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

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

Statement of Evidence in Reply of **Christopher Wayne Hickey (Ecotoxicology)** for Bathurst Coal Limited

Dated: 25 February 2022

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INTRODUCTION

Qualifications and Experience

1. My full name is Dr Christopher Wayne Hickey.

2. I have the qualifications and experience set out at paragraphs 1 – 9 of my Statement of Evidence dated 1 October 2021 (**EIC**).

Code of Conduct

3. 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 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 that I express.

SCOPE OF EVIDENCE

4. My evidence will address the following matters that were raised at the hearing on 26 to 29 October 2021 and raised at post hearing conferencing on 23 and 24 November 2021:

   (a) ongoing contaminant monitoring and compliance limits;

   (b) operation of the Mussel Shell Reactor (MSR);

   (c) operation of the N02 Pit Pond for the dilution of boron in the Tara catchment; contaminant risks in relation to existing sediments in ponds at the Canterbury Coal Mine (CCM) site; and

   (d) response to comments from other experts.

5. In preparing this response, I have read and reviewed the following evidence and documents:

   (a) Summary evidence statement of Dr Michael Massey (dated 29 October 2021);

   (b) Summary evidence statement of Dr Adrian Meredith (dated 29 October 2021);

(c) Memorandum regarding post hearing conferencing outcomes from Bathurst Coal Limited (BCL) to the Commissioners (dated 20 December 2021) referred to in this evidence as Markup Document;

(d) The updated Trigger Action Response Plan Rev4 (TARPS) for water quality prepared to include amendments for sites, monitoring parameters and frequency, and decision-making criteria appended to the Conferencing memorandum (termed Markup TARPS).

6. I participated in the post-hearing caucusing conferencing with Dr Michael Massey, Dr Adrian Meredith and Mr Ian Jenkins for Canterbury Regional Council (**ECan**) on 23 and 24 November 2021. That caucusing addressed the proposed consent conditions and TARPS.

7. I address specific issues raised at the hearing and in conferencing in relation to water quality monitoring and ecological risk relating to contaminants of potential concern in the CCM discharges.

EXECUTIVE SUMMARY

8. I have reviewed Potential Contaminants of Concern (**PCOC**) and summarised recent monitoring information for the BCL Canterbury Coal Mine (**CCM**) site for these contaminants. I have reviewed the final proposed consent conditions

9. Overall, I agree with the approach proposed by way of conditions that water quality monitoring for sites be split into:

(a) Compliance monitoring – with associated compliance limits recorded within the conditions of consent;

(b) Performance monitoring – frequent multiparameter monitoring for operational monitoring, some of which support the TARP implementation.

10. I have provided further recommendations on this monitoring (frequency and parameters) in my evidence, with these updated into the revised Tables 1 and 2 in Appendix 1 of **Eden Sinclair's** reply evidence.

(a) I support the additional performance monitoring for other limited additional PCOCs at Compliance sites on an annual basis. I support the recommended sites, parameters and monitoring frequencies as

proposed in the revised TARP tables 1 and 2 in Appendix 1 of Eden Sinclair's reply evidence.

(b) I recommend that dissolved oxygen (DO) monitoring is required for the discharge from the MSR below the Tara spillway mixing structure (site code CC02_TSMS in summary tables). I consider that the proposed flow pathway of about 20 m through corrugated pipe prior to the Tara spillway mixing structure will reliably generate a well oxygenated discharge. I recommend a DO target for the monthly monitoring of 50% saturation.

(c) I support a Mussel Shell Reactor (MSR) commissioning period to establish inflow and outflow concentrations and loads prior to permanently discharging diluted MSR effluent. Measurements of total and dissolved concentrations of iron, manganese and aluminium are proposed for the CC02_TSMS site for the Active Closure Phase.

11. I agree with the reply evidence of **Dr Weber** and recommend that a critical review of the monitoring programme and TARPs be undertaken in March 2024:

(a) I support moving the compliance point to the bottom of the Tara Pond spillway, downstream of the mixing structure, as soon as pumped discharges cease. The proposed condition 31 reflect this move.

(b) I support the draft compliance limits as proposed in Conditions 22 and 25.

12. I support the retention of the North ELF[2] ponds (Pond 1 and Pond 2) and the Tara Pond. These are essential closure infrastructure. I do not recommend that the sediment is removed from these structures as this may introduce new environmental risks for the management of these materials.

13. I understand that a buried decant pipe will transfer water from the N02 pond to the Tara spillway mixing structure for dilution of the MSR effluent. I am confident that this will ensure that the decant flow rate and water quality from the N02 pond is maintained for use as a diluent.

[1] CRC [Tara Stream Discharge].
[2] ELF = Engineered Landform

14. I have reviewed the proposed Consent Conditions and support them as set out in this statement of evidence.

CONTAMINANT MONITORING AND LIMITS

Compliance monitoring and limits

15. Compliance monitoring have been updated for the Active Management and Post Closure phases following the hearing and conferencing. These are contained in Table 1 of the reply evidence of **Dr Weber** and TARP Tables 1 and 2 in Appendix 1 of the reply evidence of **Eden Sinclair** and conditions 20 to 24 of the proposed revised conditions of consent appended to the evidence of Ms Hunter.

16. I make the following comments with respect to the limits and monitoring of Aluminium, Boron and Iron.

Aluminium

17. Aluminium is the third most abundant element and the most common metal in the Earth's crust,[3] with a high concentration present in clay minerals. On the CCM site, poly-aluminium chloride (PAC) has been used as a coagulant treatment agent to floc and assist in precipitation of suspended sediments, thus reducing the turbidity and sediment load of the mine water discharges.

18. PAC will be used on site in the active closure phase to manage turbidity in the N02 Pit Pond for short-term applications.[4]

19. Total aluminium measurements were elevated for TCLP data generated from two Coal Combustion Residuals (**CCR**) samples, with values of 2.9 and 10 mg/L (reply evidence of **Dr Weber, Appendix 3**).[5] This indicates that either water neutralisation, which would precipitate the aluminium as hydroxides, or

[3] United States Environmental Protection Agency "Aquatic Life Ambient Water Quality Criteria for Aluminum No. EPA-822-R-18-001" (United States Environmental Protection Agency, Office of Water, Washington D.C. 2018) at 329.
[4] Section 2.4 of appendix 4 of the Mine Closure Management Plan (**MCMP**).
[5] Appendix 3 of the Statement of Reply Evidence of Paul Weber dated 25 February 2022 presents data for the Synthetic Precipitation Leaching Procedure (**SPLP**) which is similar to the Toxicity Characteristic Leaching Procedure (**TCLP**) but uses inorganic acid as an extractant. For convenience, the abbreviation TCLP will be used in this evidence for this type of extraction data.

dilution in the receiving water would be required for CCR materials exposed to acidic groundwaters.

20. Dissolved aluminium is routinely monitored at monthly intervals for all compliance sites. Currently, there is a compliance limit of 0.055 mg/L which is applied when pH values were less than 5.5, or greater than 7.5 (CRC170541). The proposed dissolved aluminium limit is 0.055 mg/L and would apply for all pH conditions.[6]

21. The current monitoring for aluminium has a LOQ of 0.005 mg/L, which is 11-fold lower than the ANZG GV for 95% protection of 0.055 mg/L in waters of pH >5.5. Thus, the current method provides sufficient sensitivity for monitoring relevant to the ANZG GV.

22. In waters with a circum-neutral pH the dissolved aluminium forms colloidal flocs of predominantly hydroxide complexes in the water. The chemical measurement of a "dissolved" chemical fraction in water is operationally defined for filtration through a standard filter with a nominal pore size (normally 0.45 µm). The filtration of this floc material through the standard filter may result in some fine flocs being forced though the filter and thus measured as part of the "dissolved" fraction. Reducing the floc transferred though the filter by using a finer pore size (e.g., 0.2 µm or ultrafilters) may be used to obtain a better measure of the true dissolved aluminium faction.

23. **Dr Weber** addresses issues with dissolved aluminium measurement in acid mine drainage (AMD) waters in his reply evidence (paragraph 23). I agree with his recommendation that the consent conditions be drafted in a manner to allow additional if colloidal aluminium is present.

24. The ANZECC (2000) guidelines for aluminium have not been updated for the ANZGs. Other international jurisdictions have recently updated their aluminium guidelines for freshwaters, with Environment Canada publishing theirs in 2021[7] and the US EPA in 2018[8]. Each of these new guidelines for aluminium include water quality modifiers of pH, hardness and dissolved organic carbon (**DOC**). It is likely that these modifiers will be included in any

[6] Marked up document page 65.
[7] Canadian Environmental Protection Act 1999, *Federal Environmental Quality Guidelines Aluminum* (2021).
[8] United States Environmental Protection Agency "Aquatic Life Ambient Water Quality Criteria for Aluminum No. EPA-822-R-18-001" (United States Environmental Protection Agency, Office of Water, Washington D.C. 2018) at 329.

future guideline revision for ANZG. The Environment Canada guideline process is most similar to the ANZG method and would be a useful template for assessment of CCM monitoring data for potential adverse environmental effects. The Environment Canada guideline value for 95% protection for their base water quality condition (pH 7.5, DOC 0.5 mg/L, hardness 50 mg/L) is 0.17 mg Al/L. The GV increases with increasing pH, DOC and hardness.

25. The recent monitoring data for the CCM site showed less than detection for the one monitoring occasion at CC02 underdrain and exceedance of the limit on two of the monitoring occasions for CC02_tele (by about 2x, with both exceedances less than the ANZG 80% GV of 0.15 mg/L), despite pH being within the 5.5-7.5 range where no analysis for Al is required by CRC170541.

26. I recommend that continued routine monitoring of dissolved aluminium at the compliance sites should be undertaken with associated compliance limits imposed as per the conditions of consent. Care needs to be taken with filtration to get the dissolved fraction of aluminium and use of a 0.2 µm should be considered to reduce transfer of colloidal material. Additional monitoring should include DOC to better facilitate implementation of future water quality guidelines for the site.

27. I recommend that the conditional pH range for reporting of dissolved aluminium data be deleted from Condition 20 (condition 25 from the markup document has been removed)[9] The water quality guideline for aluminium in freshwater applies for all pH values >5.5.

28. For aluminium I have raised potential issues in relation to compliance with this limit due to fine clay particles affecting the “dissolved” filtration method (at paragraph 41 below). I also recommend adding DOC measurements as part of a characterisation to provide data for critical review of the aluminium data and for potential implementation of future revised guidelines.

29. Post closure limits should have footnote added stating that metals compliance is based on dissolved fraction.[10]

[9] Revised condition numbers refer to those attached to Claire Hunter’s evidence, unless referenced to the markup document.
[10] Marked up doucment on page 75.

Boron

30. Boron has been identified as a contaminant of potential concern at the CCM site because of elevated concentrations leaching from coal measures and CCR.

31. Routine monthly monitoring at compliance sites and other performance monitoring sites includes dissolved boron measurements. The analytical LOQ for boron is 0.005 mg/L, which is 300x lower than the proposed compliance limit of 1.5 mg/L. This LOQ provides a good ability to monitor discharge concentrations of boron relative to the compliance limit.

32. I have described the basis for the boron guideline derivation in my EIC. I noted that at the consented standard of 1.5 mg/L there is potential sub-lethal effects for macroalgal (diatom) species and a macrophyte (duck weed, *Lemna* sp.), should the long-term concentration of the discharge be maintained at that level (paragraph 41). The consent limit of 1.5 mg/L is the 90% protection GV from ANZG. The 95% protection GV from ANZG 0.94 mg/L.[11]

33. I also described in my EIC the relative sensitivity of juvenile Canterbury mudfish to long-term boron exposure having a chronic sensitivity of 10.2 mg/L based on the measured toxicity endpoints of survival, growth (length and weight) and condition (paragraph 39), noting that all fish survived at the highest test exposure concentration of 55 mg boron/L (paragraph 44).

34. I addressed the possible species which may be chronically affected should long-term discharge of the undiluted CC02 underdrain, at 3.7 mg/L, occur to the receiving environment (paragraph 42). However, I consider that the proposed approach of using dilution water from either an existing (limited) potable water supply and ultimately the N02 pit-pond water to achieve compliance with the current limit is a pragmatic approach to managing the water quality, and reducing the potential environmental risk associated with elevated boron concentrations. I also note that greatly reduced flows which will be discharged at the CC02 mixing structure under low-flow conditions.

35. I presented monitoring data in my EIC,[12] showing that while the concentration of boron is increasing in the CC02 underdrain water the total volume of

[11] Statement of Evidence of Christopher Hickey dated 1 October 2021 at Appendix 6.
[12] At Appendix 4.

discharge is decreasing, resulting in a marked reduction in the mass load of boron emanating from the underdrain.

36. The reduction in mass load of a contaminant is important for two reasons: (i) receiving environment concentrations are reduced after dilution with downstream waters; and (ii) tends to increase naturally occurring removal processes, such as those associated with uptake or metabolism by plants.

37. I concluded in the EIC in relation to my ecotoxicological risk assessment for boron, that compliance with the proposed limit of 1.5 mg/L would be highly unlikely to result in any mortality or reductions in growth for juvenile mudfish.[13] The wetland in Tara Stream downstream of the discharge is likely to provide efficient removal of boron by plant uptake, further reducing the exposure to downstream aquatic species.

38. Recent monitoring has been undertaken for boron on one occasion on the CC02 underdrain since the monitoring data was presented to the hearing, with a flow of 0.06 L/s and a concentration of 3.9 mg/L on the day of sampling (**Appendix 1**), this boron and underdrain flow data is comparable with that presented in my EIC at the hearing. Recent monitoring at CC02_tele for flows ranging from 2-70 L/s had boron concentrations ranging 0.67-1.0 mg/L (mean 0.81 mg/L), with all values less than the proposed compliance limit of 1.5 mg/L. Monitoring at CC24 and CC20 for flows of 20 L/s, including 6 L/s of pond outflow (i.e., CC20 data), had boron concentrations of 0.028 and 0.37 mg/L respectively.

39. The proposed compliance limit for boron is 1.5 mg/L (i.e., the 90th percentile ANZ GV), which I consider is appropriate for this site and receiving environment. I note that the proposed boron compliance has removed the "three month rolling median" condition of the previous consent which I raised as an issue in my EIC. I support the removal of the rolling median calculation because the averaging obscures high concentrations peaks which, for toxic components, might otherwise result in adverse ecological effects in the receiving water.

[13] At [44].

Iron

40. Long-term monitoring of dissolved iron concentrations has been undertaken at most environmental monitoring sites.

41. Iron is an essential element for all living organisms and low concentrations are naturally present in freshwaters.

42. Elevated dissolved iron concentrations are generated from sediments and minerals under acidic and/or anoxic conditions.

43. I summarised recent monitoring of dissolved iron concentrations at CC02_tele and CC02 (underdrain) in my EIC,[14] which showed that the median underdrain concentration was greater than 250x higher than the CC02_tele discharge. I consider that this large difference would likely be attributable to anoxic conditions in the groundwater.

44. **Dr Weber** presented evidence showing a decreasing trend in both concentration and mass load of iron from the CC02 underdrain.[15] He also presented data from MSR trial reactors showing a 98% median removal of iron, and predicted the MSR would efficiently remove iron from the CC02 groundwater for the predicted flow rates, with a final concentration of 0.4 mg/L.[16]

45. I recommend that the conditional pH range for reporting of dissolved iron data be deleted from Condition 20 (condition 25 from the markup document has been removed). The water quality guideline for iron in freshwater applies for all pH values.

46. I support the proposed monthly monitoring of both total and dissolved iron from CC02_TSMS site to characterise the concentrations and mass loads discharged to the Tara Stream.[17]

[14] Above n 11 at Appendix 4 table.
[15] Above n 11 at Appendix 1 figure.
[16] Summary Statement of Paul Weber dated 26 October 2021 at Appendix 4
[17] Statement of Reply Evidence of Eden Sinclair dated 25 February 2022 at Appendix 1, Table 1.

Conclusion on compliance limits

47. For the above reasons and those set out in my EIC, I support the monitoring frequency and compliance limits for CC02_tele and CC02_TSMS as shown in Table 1 of the reply evidence of **Dr Weber**.

PERFORMANCE MONITORING

48. This section of my evidence addresses the proposed performance monitoring. The reply evidence of **Dr Weber** contains a summary table of proposed additional monitoring parameters, frequency and locations for the Active Closure Phase and the Post Closure Phase (**Table 2**). The TARPs include tables summarising the parameters to be monitored and the designated purpose, being for "Compliance" or "Performance/Receiving environment" monitoring. Table 1 summarises for the Active Closure Phase Monitoring and Table 2 the Post Closure Monitoring. These tables have been updated for additional parameters and frequencies at some locations and are provided in Appendix 1 in the reply evidence of **Eden Sinclair**.

49. I support the contaminants proposed, the monitoring sites and frequency of measurement.

50. I agree with the approach to separate Compliance and Performance/Receiving environment /Receiving environment/trend monitoring for the CCM site. I support this distinction for many of the sites as they are strongly influenced by other external factors (e.g., forestry, in-stream processes) and are thus for most of the parameters being monitored are not directly causatively linked to the CCM-site management. This is particularly the case as the flow volumes and mass loads of contaminants discharged to the Tara Stream will decrease markedly.

51. Operational monitoring of the N02 pit-pond is essential to provide baseline water quality information on the suitability of this water for future dilution of the MSR effluent water prior to discharge.

52. I understand that the N02 pond will only fill with water late in the Active Closure Phase, therefore the monitoring for stratification will largely be undertaken in the Post Closure Phase. I have reviewed the proposed surface water and deep

water (at 2.5 m depth)[18] and consider that the monthly monitoring frequency and parameters measured will provide a robust basis for stratification assessment and establishing whether significant geochemical differences are present between surface and deep waters.

53. Below I provide comment on parameters/contaminants for which I support performance monitoring.

Hardness

54. Concentrations of calcium and magnesium are required for calculation of water hardness.

55. Hardness is a water quality modifier which is used to adjust the GV of certain metals which have reduced toxicity as the hardness increases.

56. The hardness-modified metals are: cadmium, chromium(III), copper, lead, nickel and zinc.

57. Samples for water hardness are required for all monitoring occasions when comparisons with water quality guidelines are to be undertaken.

Dissolved organic carbon (DOC)

58. The concentration of DOC is an important water quality modifier for the toxicity of several metals.

59. Recently updated international guidelines for aluminium in freshwaters incorporate DOC, pH and hardness for the GV calculation.

60. I recommend that DOC be measured at monitoring sites where aluminium compliance monitoring is undertaken. This will enable assessment of water quality compared with future updated guidelines.

BOD/COD and alkalinity

61. I note that biochemical oxygen demand (BOD), and chemical oxygen demand (COD) and alkalinity measurements have been removed from the list for the monitoring of the N02 pit-pond.[19] I do not consider that these parameters will usefully add information relevant to the management of the pond or water discharged and support their removal. These modifications are highlighted

[18] Marked up document page 130.
[19] Revised Table 1, page 109 of markup document.

(green/strikethrough) in the TARP Tables 1 and 2 in Appendix 1 of **Eden Sinclair's** reply evidence.

Polycyclic Aromatic Hydrocarbons (PAHs)

62. Polycyclic aromatic hydrocarbons are a natural component of plants, coals and oils and are composed of a wide range of chemical structures built on cyclic carbon frameworks built on a hexagonal base. Chemical analysis for 'total PAH' measurement is based on the summed concentrations of 26 "priority PAHs" as established by the US EPA. These priority PAHs range from low molecular weight compounds, such as the volatile naphthalene, to complex high molecular weight molecules. All PAHs are termed "hydrophobic", meaning that they have a low solubility in water. Their hydrophobic nature means that PAHs preferentially bind to organic matter on solids and sediments, which further reduces their tendency to transfer to the water phase.

63. The background concentration of total PAHs in coal is about 0.1% on a dry weight basis but would be expected to vary depending on the type and source of coal.[20] I am not aware of any analytical data for total PAHs for the CCM coal deposits.

64. Reviews of the environmental relevance of PAHs have found that the environmental impact of hard coal/ bituminous coal particles and coal fines in soils and sediments is unavailable for uptake by organisms.[21]

65. Low levels of PAH compounds which may leach from coal fines or Coal Combustion Residuals (**CCR**) material will be strongly bound to organic matter in soils[22], thus are unlikely to be elevated to concentrations which exceed ecological effect thresholds in groundwaters discharging from the CCM site.

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[20] MJ Ahrens and DJ Morrisey (2005). "Biological effects of unburnt coal in the marine environment" (2005) 43 Oceanography and Marine Biology: An Annual Review at 69-122; see review of C Achten and T Hofmann, "Native polycyclic aromatic hydrocarbons (PAH) in coals–a hardly recognized source of environmental contamination" (2009) 407 Science of the total Environment at 2461-2473.

[21] Above n 20 at 69-122; ME Bender, MH Roberts Jr and PO deFur (1987). "Unavailability of polynuclear aromatic hydrocarbons from coal particles to the eastern oyster" (1987) 44(4) Environmental Pollution at 243 – 260.

[22] RM Burgess, MJ Ahrens, CW Hickey (2003). "Geochemistry of PAHs in aquatic environments: Source, persistence and distribution". In *PAHs: an ecotoxicological perspective*" (PET. Douben, ed. Wiley, Chichester, 2003) at 35-46.; RM Burgess, MJ Ahrens, CW Hickey, PJ den Besten, D ten Hulscher, B van Hattum, JP Meador, PET Douben, "An overview of the partitioning and bioavailability of PAHs in sediments and soils." In: *PAHs: An Ecotoxicological Perspective*. (PET Douben, ed. Wiley, Chichester, 2003). at 99-126.

66. The high temperatures present in boilers which generated the CCR material will combust most if not all the PAHs present in the parent coal material, particularly the volatile low molecular weight compounds, such as naphthalene, which might cause ecotoxic effects. The TCMP data, as presented by **Dr Weber's** reply evidence (**Appendix 3**),[23] showed all chemical measurements undertaken on two CCR samples were limited to metals.

67. The limited supplementary monitoring for analysis of PCOCs in water samples from two sites (CC02_tele and CC24) was undertaken on 15 and 21 December 2021 indicated all 15 PAHs were at the analytical method analytical detection limit (termed Limit of Quantification, LOQ) (**Appendix 1**). The ANZGs only provide a guideline value (GV) for naphthalene, as one of the more water soluble and ecotoxic PAHs, with a 95% protection value of 0.016 mg/L. The LOQ for the Eurofins Laboratory method is 0.0001 mg/L for naphthalene, which is 160x lower than the GV (i.e. a safety factor of 160x for this compound).

68. I agree that the proposed monitoring programme for the active closure phase should include annual performance monitoring of PAHs from the compliance sites.[24] The summary of new performance monitoring parameters for the compliance sites is provided in **Table 2** of **Dr Weber's** reply evidence, which I support.

69. I do not support compliance monitoring for PAHs because I consider that the likelihood of CCM site-derived PAHs being discharged at concentrations which result in adverse ecological effects in the receiving environment is very low.

Mercury

70. Background mercury concentrations are naturally present in the New Zealand environment, including coals, with a range of geochemical factors affecting bioavailability.

71. Mercury has been monitored on four recent occasions for the CC02_tele, when discharge was occurring, and the CC20 and CC24 sites on one occasion. On all recent monitoring occasions, the dissolved mercury concentrations were less than the analytical LOQ of 0.0005 mg/L (**Appendix**

[23] Above n 5 Appendix 3 presents data for the Synthetic Precipitation Leaching Procedure (SPLP) which is similar to the TCLP but uses inorganic acid as an extractant. For convenience, the abbreviation TCLP will be used in this evidence for this type of extraction data.
[24] Above n 5 Table 1.

1), as was the case for all monitoring with measurements on 37 occasions for surface water discharges and 13 occasions for CC02 underdrain groundwater.[25]

72. The LOQ of analytical laboratory is less than the ANZG 95th percentile GV of 0.0006 mg/L, so provides a suitable analytical ability to measure mercury concentrations at levels below the long-term environmental effect threshold.

73. Once operational, the mussel shell reactor (**MSR**) will generate anoxic conditions in the bed of the reactor with production of free sulphides likely. Passage of groundwater through the MSR will result in precipitation of highly insoluble mercury sulphides, should any dissolved mercury be present.

74. I support the proposed performance monitoring programme for the active closure phase including annual dissolved mercury monitoring at the compliance sites. This monitoring will provide additional data for the proposed March 2024 water quality review.

75. I do not support compliance monitoring for mercury because I consider that the likelihood of CCM site-derived mercury being discharged at concentrations which result in adverse ecological effects in the receiving environment is very low.

Arsenic

76. Arsenic is elevated in many New Zealand regions because of the volcanic, geothermal and marine influences on local geologies.

77. Arsenic occurs in two oxidation states in the aquatic environment, arsenic III (AsIII) and arsenic V (AsV). Arsenic III is the more toxic form and occurs under reducing (anoxic) conditions. When the water is oxygenated the AsIII oxidises to the less toxic AsV form.

78. Arsenic has been monitored on four recent occasions for CC02_tele, when discharge was occurring, and the CC02 and CC24 sites on one occasion. On all recent monitoring occasions the dissolved arsenic concentrations were less than the analytical LOQ of 0.001 mg/L (**Appendix 1**), as was the case for most

[25] Above n 5 at Appendix 2.

historic monitoring with measurements on 37 occasions for surface water discharges and 12 occasions for CC02 underdrain groundwater.[26]

79. The ANZECC (2000) guidelines had low reliability derivations for AsIII and AsV of 0.024 mg/L and 0.013 mg/L respectively. The LOQ of analytical laboratory is less than these 95th percentile GVs, so provides a suitable analytical ability to measure arsenic concentrations at levels below the long-term environmental effect threshold.

80. I am not aware of any revised arsenic guidelines submitted for the ANZG updating of guidelines. I have recently completed a revision of the AsV guideline, which includes data for 25 long-term (chronic) species tests, giving a GV for 95% protection of 0.050 mg/L.[27] This indicates the likely GV for an updated arsenic guideline which would be appropriate for receiving water applications.

81. Data for TCLP for two CCR samples showed leachates for both were less than the analytical detection limit of 0.021 mg/L (reply evidence of **Dr Weber, Appendix 2**). Notably, the analytical detection limit for those tests was greater than the current ANZG GVs for AsIII or AsV.

82. I support performance monitoring for the active closure phase including annual dissolved arsenic monitoring at the compliance sites during the active closure phase (reply evidence of **Dr Weber, Table 2**). This monitoring will provide additional data for the March 2024 water quality review.

83. I do not support compliance monitoring for arsenic because I consider that the likelihood of CCM site-derived arsenic being discharged at concentrations which result in adverse ecological effects in the receiving environment is very low.

Dissolved Oxygen

84. Dr Massey commented regarding dissolved oxygen (**DO**) compliance that "*A dissolved oxygen concentration minima should be in this table (at least 5 mg/L or 50% saturation*."[28] I consider that the very low flow discharges from the CC02_TSMS site after mixing across the mixing structure are likely to have

[26] Above n 5 Appendix 2.
[27] C. Hickey, unpublished report.
[28] Markup Document Note "DM" on page 70. A DO concentration of 5 mg/L is 50% saturation in freshwater at 15°C.

elevated water temperatures during summer, potentially up to 25°C which has a 50% DO saturation of 4.1 mg/L.

85. Two processes with oxygenate the discharge:

    (i) passage of the MSR discharge down the corrugate pipe prior to mixing; and

    (ii) mixing with the oxygenated N02 pond water, or the potable water, prior to final discharge.

86. I recommend a DO target of 50% saturation rather than an absolute concentration target. The use of percentage saturation provides a practical means of monitoring for a range of expected discharge temperatures, with a portable DO meter set to percentage mode to provide the saturation measurement.

87. I agree that oxygenation of the initially anoxic MSR discharge is essential prior to final discharge from the compliance point. I understand that the MSR effluent oxygenation will occur while flowing through approximately 20 m of 110 mm corrugated pipe prior to entering the mixing structure.[29] I consider that this will be a highly efficient aeration process. Secondary oxygenation will come from mixing with the potable water or N02 pond water diluent prior to discharge. Additional modification to DO is likely to come from attached filamentous algae which may grow on the diffuser structure at times, with oxygenation/deoxygenation occurring when the mixed water flows over the outlet structure.

88. Overall, I consider that performance reporting for DO measurements should be included for these sites for the discharge water. The water should always be oxygenated with a DO saturation of 50%. I do not consider this should be a fixed compliance limit for the site discharge because of the likely variability of factors affecting the final discharge concentration, as discussed in paragraph 87. Rather, I consider that the 50% DO saturation at the CC02_TSMS site and the N02 inflow (decant) water should be considered “targets” to ensure that oxygenated conditions always exist at the discharge compliance site.

[29] Personal communication with Eden Sinclair.

89. I expect that there will be further oxygenation of the CC02_TSMS discharge under low-flow conditions after passage through the sonde monitoring vessel and before entering the Tara Stream.[30] However, the level of oxygenation in the overflow from the Tara weir structure is unknown.

90. The suite of monitoring parameters and frequencies, compliance limits and the DO monitoring target are presented in Tables 1 and 2 in the reply evidence of **Dr Weber**. I consider that the monitoring results should be critically reviewed at the proposed March 2024 water quality review.

91. Discrete monitoring of DO at monthly intervals are included for sites CC02_tele, CC02 and N02 pit pond for the Active Closure Phase and CC02_TSMS and N02 pit pond (surface and basal water) for the Post Closure Phase. These modifications are highlighted (green/strikethrough) in the TARP Tables 1 and 2 in Appendix 1 of **Eden Sinclair's** reply evidence.

Compliance location

92. I support moving the compliance point to the bottom of the Tara Pond spillway mixing structure, new site CC02_TSMS (Appendix 1 in reply evidence of **Eden Sinclair**), as soon as pumped discharges cease as reflected in Condition 3.[31] The CC02_tele site is influenced by wetland processes affecting multiple compliance parameters and sampling from that site will not provide useful data once the diluted MSR effluent becomes the most common discharge.

Oyster Gully

93. Dr Meredith proposed ongoing monitoring of Oyster Gully Stream at the CC12 site.[32]

94. I support the inclusion of this site for multiparameter Performance/Trend monitoring to observe water quality trends within the catchment. The CC12 site has a high proportion of forestry in the catchment so the monitoring data will not be expected to solely represent restoration changes attributable to the CCM management (paragraph 93).

[30] Above n 17 at Figure 1.
[31] CRC [Tara Stream Discharge].
[32] Section 42A Council Officer's Report Summary Statement of Dr Adrian Meredith dated 29 October 2021 at [9].

95. I do not consider that compliance limits should apply to the Oyster Gully (CC12) monitoring site. This site has only a partial fraction of its catchment (about 18%,)[33] with the bulk of the remaining catchment being forested. I consider that the data from this site will be useful for monitoring water quality trends, in that it has a long-term record of multiparameter monitoring, with the time-series data providing a useful assessment for both remediation success and the effects of climatic factors on water quality. A potential step-change in some parameters may occur for this site when the small sump is remediated and pumped transfer from the West pit ceases as the site transitions to the Post Closure Phase.

Proposed Review

96. I acknowledge the comments of Dr Massey in relation to the likely need for a longer duration monitoring programme to characterise the chemistry and mass loads for contaminant discharge for some sites.[34]

97. The chemistry of the N02 pit-pond will require more than one calendar year to characterise after filling. This time will be required for stabilisation of groundwater and surface-water inflows, sediment-water interactions (e.g., oxygen demand, geochemical processes) and the development of biological communities in the ponds (e.g., algae). The dissolved oxygen content of the pond waters is a balance between removal processes, such as sediment oxygen demand, and oxygenation processes from the atmosphere and algal production during daytime.

98. The development of thermal stratification in the ponds could potentially occur during periods of warm calm weather when wind mixing of the pond is absent. Should stable thermal stratification occur then the transfer of oxygen from the atmosphere to bottom waters does not occur and reduced conditions may result as sediment oxygen demand removes the dissolved oxygen.

99. Operationally, changes in water quality of the bottom waters should not be an issue for use of the N02 pit pond water for use as a diluent for the MSR effluent discharge to Tara Stream. The primary water quality factor is the boron concentration, which will not be affected by changes in pond DO. The use of

[33] Above n 17 at [16(c)].
[34] Section 42A Council Officer's Report Summary Statement of Michael Massey dated 28 October 2021 at [24], [26], [29] and [79].

the decant structure for offtake of surface water for use as diluent will maintain a generally consistent water quality for the N02 decant flow.

100. The water quality of the N02 pond bottom waters only becomes a potential issue for use as a diluent should the surface-water decant exhaust the supply of surface water at times when the pond is stratified. The development and calibration of the hydrological model[35] for the pond will provide increased certainty for the long-term availability of dilution water supply from the N02 pond for use for the MSR effluent discharge to Tara Stream.

101. There is a planned one-year period of post closure phase where the pond will be full prior to the planned March 2024 water quality review. Data available at that time should enable an initial baseline characterisation of water quality and its suitability for dilution of the CC02 underdrain water.

102. Dr Meredith would also like to see a strategy in place for destratification of the N02 pond before the stratification occurs.[36] I do not consider that this contingency needs to be addressed at this early stage. Should stable and prolonged stratification occur, with associated marked chemical changes to the bottom waters, this may not constitute a problem for the quality of the decant (surface) water. A decision point at this time could involve destratification, which in the short-term could be undertaken with a portable air compressor and diffuser hoses extending across the bed of the pond. I am confident that such a system could be installed in a short time frame (weeks) as an interim measure prior to establishing a long-term destratification system for the site.

Resampling approach proposed

103. Proposed revised Conditions 23 as attached to the evidence of Ms Hunter prescribes a duplicate (a "b" sample) and a resampling approach.

104. The TARP recommends an increase in sampling frequency of water sampling for several of the response phases (e.g., TARP 1.5 for N02 pit pond boron: Orange – Level 3. "*Increase frequency of water sampling to weekly until boron concentrations decrease to <1.5 mg/L*."). This increase in sampling frequency

[35] Condition 13(a) CRC[Tara Stream Discharge] requires the consent holder to develop, calibrate and validate a water balance model for the dilution of the CC02 underdrain/MSR discharge with N02 pond water.
[36] Above n 32 at [16].

can be considered a “resampling” which is targeted at the triggering parameter.

105. For the reasons below, I support the above approach.

106. I consider that a pragmatic approach is required for the validation of water quality measurements which might otherwise trigger extensive management actions. Sample handling for filtration and laboratory analysis procedures may be a source of contamination or outlier results which can adversely affect a monitoring programme.

Compliance monitoring

107. To manage this non-compliance risk, I recommend that BCL take a duplicate reserve sample (a “b” sample) for compliance monitoring sites, which is chemically preserved or frozen, for potential use for reanalysis should an uncertainty in the analytical results.

108. Further, I support a subsequent sample (“resampling”) being taken and exceedance being confirmed after analysis of this second sample for all compliance limits except for Boron as outlined in condition 23. For pond water samples from the N02 pond the subsequent sample will likely be comparably representative of the earlier sample, unless a major hydrological event has occurred in the interim.

109. For Boron I do not support the subsequent sample (“resampling”) being the trigger for the initial exceedance but support reviewing a duplicate reserve sample (a “b” sample) to validate the analytical result. This process could be expedited rapidly by submission of the duplicate samples to the analytical laboratory with the b sample held for an exceedance triggering of the need for boron analysis.

110. Should the b sample analysis confirm non-compliance for boron then urgent management actions should be undertaken to mitigate the elevated boron concentration in the discharge. The management actions should be accompanied by resampling of the discharge consistent with condition 23.

Performance monitoring

111. BCL may also consider collection of b samples for some selected parameters for performance monitoring as this may reduce the frequency of triggering higher frequency sampling for TARP Orange or Red actions.

112. I support the concept of a higher frequency sampling as proposed for the Orange threshold exceedance. I consider this response appropriate to determine the persistence of the event and to provide a robust measure of level of exceedance.

113. Dr Massey raised concern about the resampling approach proposed by BCL to confirm an exceedance of a TARP threshold might not be appropriate for surface waters.[37] For the reasons above, I support the proposed approach.

Response to ECan's comments on monitoring

114. I address further the relevant issues arising from the conferencing session and the evidence of Drs Adrian Meredith and Michael Massey on monitoring in this section of my evidence.

Broader suite of contaminants

115. Dr Massey recommends inclusion of a "*broader suite of contaminants*", including PAHs.[38] In his conclusions, he supports Mr Gardner's s42A report and recommends: "…*monitoring a wider suite of contaminants, including trace metals such as arsenic, cadmium, chromium, copper, nickel, lead, and polycyclic aromatic hydrocarbons*…"[39], in order to assess "*potential water quality impacts*".[40] He added also mercury to his list of monitoring parameters.[41]

116. Furthermore, he recommended that BCL should undertake "…*frequent long-term monitoring at all existing monitoring points be codified as a condition of the consent*."[42]

[37] Above n 34 at [32].
[38] at [45].
[39] at [76].
[40] at [12].
[41] at [77].
[42] at [29].

117. In the post-conference caucusing relating to condition 20, he stated that: (i) "*Add additional contaminants as per s42A report*." and (ii) "*Asking for confirmation that the additional metal contaminants are not there. See it as part of the routine monitoring – all monitoring events*."

118. Dr Meredith also raises concerns about the CCR (Coal Combustion Residues (coal ash)) contaminants, and particularly potential PAHs in the ash.

119. I have addressed PAHs and presented recent monitoring earlier in my evidence (paragraphs 62-69). I consider that there is a low likelihood for PAH concentrations reaching environmental effects thresholds for this site.

120. **Dr Weber** presents water quality monitoring data for the CCM site CPOCs for surface water discharges on 37 occasions from 2004 to December 2021 and CC02-underdrain groundwater/seepage water for 12 occasions from 2016 to January 2022.[43] This data summary for arsenic (As), mercury (Hg), cadmium (Cd), chromium (Cr), copper (Cu) and lead (Pb) includes relevant default guidelines, with hardness-adjusted guidelines for the relevant elements (Cd, CrIII, Cu and Pb).[44] Arsenic, mercury and lead have the largest number of samples, with many collected under acidic conditions when the potential leaching would have been enhanced.

121. Notably, all of these elements were either at the LOQ or just above detection, with all detected concentrations markedly below the guideline values. Arsenic was only detected on six of the 37 surface water and 12 underdrain monitoring occasions (16% of samples), with all values close to the LOQ. Mercury was less than the detection limit on all 37 surface water and 12 underdrain monitoring occasions. Cadmium was less than the LOQ on all monitoring occasions for surface waters and maximally 31% and 44% of the HMTV on two of the seven recent occasions for the groundwater. Chromium was less than the LOQ for surface and groundwaters on all occasions. Copper was detected at a trace level for most occasions, with a maximum of 25% of the HMTV in the underdrain on one occasion. Lead was largely at the LOQ for all recent samples, with trace levels detected in 2015/16. I consider that all of these PCOC analyses have been undertaken using LOQs which were suitable sensitive for guideline comparison and the detection of potential receiving water effects.

[43] Above n 20 at Appendix 2.
[44] Termed HMTV = Hardness Modified Trigger Value

122. Based on my review of the monitoring data presented by **Dr Weber** in his Appendix 2 and the analysis provided by **Dr Weber** in relation to these PCOCs (paragraphs 28-38), I consider that there is a low environment risk for all the elements recommended by ECan staff for additional monitoring.

123. There is annual monitoring proposed for a larger suite of contaminants (arsenic, cadmium, chromium, copper, lead and mercury), including PAHs at sites CC02_tele, CC02_TSMS and CC20[45] in the Active Closure Phase and sites CC02_TSMS and CC20 for Performance monitoring, as presented in the evidence of **Dr Weber** (**Table 1**). The updated TARP tables 1 and 2 which include this additional PCOC monitoring, together with cost implications for more extensive multisite monitoring scenarios are addressed in the evidence of **Eden Sinclair**.[46]

124. I consider that the proposed annual monitoring at compliance sites supports Dr Meredith's monitoring suggestion that a "*core suite of mine parameters should be monitored regularly*" and that a greater suite be monitored annually, or if underdrain flows deviate from steady flow rates.[47]

125. Overall, I consider that the monitoring information provided on PCOCs presented in Appendix 2 in the evidence of **Dr Weber**, together with the proposed annual multisite monitoring at compliance sites for six additional elements and PAHs, constitutes a suitable frequency and selection of locations for these parameters.

Comparison of the CCM site to a petrol station/ municipal landfills

126. In his supplementary evidence, Dr Massey supported his monitoring arguments in relation to groundwater contamination from petrol stations and municipal landfills.[48] I consider that the chemical nature of contaminants from these sources differs widely from that which will be potentially affecting the groundwater for this coal mine remediation and therefore they do not provide an informative basis for design of the CCM monitoring programme.

Total contaminant vs dissolved fraction

[45] Site CC20 is recommended for this PCOC monitoring as the pond discharge has potential for higher concentrations than the downstream compliance site at CC24.
[46] Above n 17at [46-52].
[47] Above n 34 at [47].
[48] At [20]-[21].

127. Dr Massey stated that: "…*measurement of total contaminant concentration in water, rather than "dissolved" concentrations (which are measured after filtration) should be specified in the monitoring program*. *This because the contaminant load to surface waters consists of dissolved, colloidal and solid particles*."[49]

128. I disagree with Dr Massey. In my expert opinion, the dissolved fraction of metals is widely accepted as the toxicologically relevant fraction, so this is the most appropriate measure for ecotoxicological effects assessment.

129. I also note that the Active Closure Phase of the MSR monitoring will include monitoring of total and dissolved iron, aluminium and manganese at monthly intervals at CC02_TSMS (Table 1 of **Dr Weber's** reply evidence) and updated in TARP Table 1 in Appendix 1 in the reply evidence of **Eden Sinclair**. This data will establish the proportion of the dissolved fraction, which is expected to be a high percentage based on previous monitoring of the CC02 underdrain without MSR treatment.

MUSSEL SHELL REACTOR

130. I support the use of the mussel shell reactor (MSR) for treatment and removal of metal contaminants and pH neutralisation of the CC02 underdrain groundwater prior to discharge to Tara Stream.

131. Dr Massey and Dr Meredith have raised concerns about the reliance on the MSR. I respond to these comments below.

132. I agree that oxygenation of the anoxic discharge from the MSR will be required, as raised by Dr Meredith.[50] I consider that the proposed flow path for the MSR discharge down 20 m of corrugated pipe will efficiently aerate the discharge (paragraph 87). The configuration of the MSR and the associated Tara Pond discharge structure is shown in **Eden Sinclair's** reply evidence. [51]

133. Dr Massey raises concerns about DO depletion in relation to the MSR and recommends continuous water quality monitoring.[52] I have addressed earlier in my evidence the issues in relation to oxygenation of the initially anoxic MSR

[49] At [47].
[50] At [11].
[51] Above n 17 at Figures 1 and 2.
[52] Above n 34 paragraph [60].

effluent (paragraphs 84 - 87). I consider that the physical characteristics of the discharge structures will result in efficient aeration and that the proposed discrete monthly monitoring of DO will be sufficient to verify performance of the mixed discharge. Regular monthly monitoring of DO in the CC02_TSMS discharge will be undertaken in the Active Closure Phase and the Post Closure Phase as shown in Tables 1 and 2 of Appendix 1 in the reply evidence of **Eden Sinclair**.

134. Dr Massey recommends that additional monitoring be undertaken of the MSR before and after replenishment.[53] I understand that intensive inflow and outflow monitoring will be undertaken of the MSR to characterise performance during the expected 4-12 week commissioning phase prior to commencement of the mixed discharge (TARP 1.3). This monitoring will also include total and dissolved measurements for a suite of metals, together with flows, to characterise mass loads in the MSR effluent. I support the proposed intensive monitoring and characterisation of the MSR prior to initiation of the discharge to Tara Stream.

135. I support the regular monthly monitoring of both total and dissolved iron, aluminium and manganese will be undertaken in the Active Closure Phase once the in the CC02_TSMS discharge is initiated, as shown in Table 1 of Appendix 1 in the reply evidence of **Eden Sinclair**. This monitoring will establish the mass loads and chemical form of these elements in the final discharge.

OPERATION OF THE N02 PIT POND

136. There was significant discussion at the hearing about the reliability of the operation of the N02 pit-pond as a diluent source.

137. I am confident that the proposed surface and deep-water monitoring programme, together with the continuous water quality monitoring and local weather station data, will provide the information needed to critically evaluate the suitability of the pond decant water for boron dilution of the MSR discharge to Tara Stream.

138. I understand that the decant flow from the N02 pond to the Tara Pond mixing structure for use in diluting the MSR effluent will be transferred in buried poly

[53] Above n 34 at [26].

pipes.[54] The use of the piped water will maintain water quality and reduce evaporative loss of the water, which may otherwise occur with flow in the open concrete channel. Burial of the pipes will limit any temperature increase which would otherwise occur in summer and potential icing during very cold winter conditions.

139. I am confident that metered flows from the N02 pond using the pipes will provide the most reliable way to manage low-flow dilution of the MSR effluent.

140. Information on the water quality and quantity of water available from the N02 pit-pond will only become available when the pond fills near the end of Active Closure Phase.

141. The TARP contains multiparameter thresholds for triggering action in relation to water quality changes in relation the development of thermal stratification in the pond.[55] I would reemphasis at this point that having thermal stratification occur is not an issue per se, rather it is the potential chemical changes that may occur post-stratification which may degrade water quality in the pond outflow.

142. It is acknowledged that there is some risk in terms of the level of information held. Some information required on the ability of the N02 pit-pond to supply sufficient volume of water with low boron concentration will only become available once the pond is full and seasonal variation in water flow and quality can be quantified.[56]

143. My understanding is that a limited off-site supply of potable water is available for use as a MSR effluent diluent. This will reduce the non-compliance risk for the site discharge for periods when N02 pond water volume is limited, or water quality is unsuitable.

144. Dr Meredith has raised his concerns regarding the management of the N02 pond, stating: "*I recommend that N02 pit pond should be actively monitored for stratification and an agreed strategy put in place for managing stratification as/ or before it happens*.".[57]

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[54] Personal Communication with Eden Sinclair.
[55] TARP "N02 Pit Pond Stratification", Post Closure Phase. Page 131 of markup document.
[56] Condition 13a requires development and calibration of a water balance model as part of the Post Closure Phase (Page 57 of markup document). This model and initial monitoring results will be reviewed 2024.
[57] Above n 32 at [16].

145. A condition (35a) has been introduced to specify that: "*Monitoring of the N02 Pit Pond for potential stratification effects and mitigative actions included as part of the TARPs should any stratification effects be detected*."

146. I consider that the proposed surface and deep-water sampling programme of the N02 pond will adequately trigger responses to significant stratification-related water quality which may ultimately affect outflow water quality in the decant.[58]

147. There will be at least one year of post closure phase monthly monitoring data available prior to the proposed March 2024 water quality review, and I expect that a longer monitoring period will be required to establish the likely frequency of stratification and the associated water quality changes (paragraph 52). I consider that this adaptive management approach proposed is appropriate and that the mitigations would effectively manage stratification-related changes in water quality in a timely manner.[59]

CONTAMINANT RISKS IN EXISTING POND SEDIMENTS

148. At the hearing questions were raised about the contaminant risk of existing sediment in the ponds that are proposed to remain at the CCM after closure. To my knowledge, the sediment contaminants present in the North ELF ponds or the Tara Pond have not been characterised and for these on-site treatment ponds I do not consider that these sediment chemistry analyses are warranted.

149. Two potential processes may result in release of chemical contaminants from pond sediments into environments downstream. However, I do not consider either of these likely.

    (a) scour of sediments as a result of high hydraulic inflows. In evidence in relation to the North ELF Ponds, Sioban Hartwell's view in her EIC that the sediment will not be disturbed and that disturbing the sediment by removing it would have greater adverse outcomes. She adds in her reply evidence that she considers that the 2 m water depth above the sediment will make it unlikely that wind disturbance will occur, with the planned fencing and native vegetation planting of the pond riparian

[58] Markup document pages 131-133.
[59] TARP "N02 Pit Pond Stratification", Post Closure Phase. Page 131 of markup document.

areas as a means of excluding stock and creating habitat.[60] I agree with these opinions based on my knowledge of the North ELF Ponds; and

(b) chemical processes within the ponds which result in release of otherwise bound chemical contaminants. The two primary water quality factors may result in release of bound chemical contaminants from sediments: acidity and deoxygenation. The management of the restored site should prevent acidic conditions (i.e., pH <4) which might result in significant release of metals. Deoxygenation of pond waters (i.e., DO <1-2 mg/L) will result in release of manganese and iron from the sediments, and arsenic (if present). Some level of deoxygenation is likely to be currently occurring for the North Elf Ponds based on the variable and sometimes elevated concentration of dissolved manganese, however the dissolved iron data is generally low (CC20 data). This difference in dissolved manganese and iron concentrations indicates that the DO in the ponds is reduced at times, which releases the manganese, but does not near anoxic conditions, which would release the iron. No recent dissolved arsenic data is available for CC20, but monthly measurements in 2017 from March to December gave all arsenic measurements less than the LOQ (i.e., <0.001 mg/L), indicating no potential risk for downstream for arsenic exposure.

150. Based on the available data I do not consider that the sediment contaminants present in the ponds on the CCM site represent an inappropriate risk for adverse effects on downstream ecology caused by the release of chemical contaminants.

COMMENTS ON OTHER EXPERTS' EVIDENCE

151. In this section of my evidence, I provide specific comment on the evidence of Drs Massey and Meredith where I have not already addressed their evidence above.

Comments specific to Michael Massey evidence

152. I refer to Dr Michael Massey's summary evidence dated 28 October 2021.

[60] Statement of Reply Evidence of Sioban Hartwell dated 25 February 2022 at [13]-[16].

Monitoring sites.

153. Dr Massey recommends "…*frequent long-term monitoring at all existing monitoring points be codified as a condition of the consent*."[61]

154. As discussed above (at paragraph 15) I support the proposed distinction between Compliance and Performance/Receiving water monitoring sites, with the inclusion of Oyster Gully (CC12) as a monitoring site for continued discrete water quality monitoring as documented in the revised TARP Table 1, and 2. [62] All these sites have ongoing regular multiparameter monitoring. The discharge Compliance sites also have flow or water level monitoring so that load reductions from the site can be characterised.

155. I do not consider that any additional sites warrant continuous or discrete monitoring for additional parameters.

156. The monitoring data from this programme can be critically reviewed in March 2024 to evaluate performance and further optimise monitoring sites, parameters and frequency for long-term monitoring.

Toxic characteristic leaching procedure (TCLP)

157. Dr Massey raises concerns regarding the extent of TCLP testing and the appropriateness of the analytical detection limits used.

158. The TCLP procedure uses weak acid in a standard laboratory procedure to assess metal leaching potential from soils and sediments. He raises concerns that the analytical method used for the assessments had a low method detection limit and has been assessed against high class B landfill leachate limits, citing data for arsenic as an example.[63]

159. The TCLP is a standard procedure, with an arbitrary ratio of sediment: water (or weak acid), used for assessing potential for release of metals, with general application in relation to landfill disposal assessment criteria. It is not a definitive procedure for prediction of concentrations which might occur in sediment or soil pore waters, nor in groundwater flows, but rather to provide indicative levels of releasable metals. It is also useful to identify metals which

[61] Above n 34 at [29].
[62] Above n 17 Tables 1 and 2 at Appendix 1.
[63] Above n 34 at [42].

do not leach, particularly in relation to total metals analyses undertaken on the soil or sediment sample.

160. I consider that the chemical analyses on groundwater flows are the most relevant for this site for assessment of potential environmental effects in receiving waters. I consider that the chemical methods being used for these analyse are sufficiently sensitive for effects assessment relative to water quality guidelines, as discussed in paragraphs 62 - 22**.**

161. I support the proposed annual monitoring for potential PCOCs, arsenic, cadmium, chromium, copper, lead, mercury and PAHs, at the Compliance sites.[64]

Comments specific to Adrian Meredith evidence

162. I refer to Dr Adrian Meredith's evidence dated 29 October 2021. A number of the issues raised in his evidence were raised in the subsequent caucusing and have been incorporated into the revised consent conditions or into the marked up TARPs.

Boron limits and effects

163. Dr Meredith addresses his concerns regarding boron toxicity and the potential for adverse effects on the Canterbury mudfish.[65]

164. The research studies undertaken to establish the sensitivity of juvenile Canterbury mudfish to boron exposure were agreed with Environment Canterbury, with Dr Meredith present at the study design meeting, and followed internationally recognised standard procedures for fish toxicity testing. The basis for proposing this approach was that chronic testing had been successfully undertaken in New Zealand using juvenile whitebait (inanga) with a successful testing protocol developed for that species.

165. A standard method for embryo-larval development for Canterbury mudfish was not used in testing as no standard method was available. With many fish species there may be a high egg or larval mortality under laboratory conditions, which would then render the test results unsuitable for establishing effects thresholds for the contaminant being tested. Both embryo-larval and juvenile

[64] Above n 17 Tables 1 and 2 at Appendix 1. Note that site CC20 is recommended for this monitoring as it has a lower dilution than the downstream CC24 compliance site.
[65] Above n 32 at [23]-[26].

fish toxicity data are acceptable for guideline development, providing they meet the appropriate quality control procedures.[66]

166. I provided benchmark sensitivity data for rainbow trout embryo-larval testing in my EIC as they are widely acknowledged as being sensitive to chemical contaminants. They are considered ecologically important in many freshwater environments (though not present in the Waianiwaniwa catchment) and there is a robust range of chronic testing data included in the boron derivation database. Dr Meredith has suggested that: "*It would be more appropriate to compare mudfish with the zebra fish results*."[67] The Zebrafish (*Dania rerio*) is a tropical fish species and data comes from a single Dutch study for embryo development over a 34-d period.[68] A no observed effect concentration (**NOEC**) value of 1.8 mg/L for growth (weight) was used in the boron guideline derivations, while the other toxicity endpoints had NOEC values of 5.6 mg/L for mortality and growth (length). A statistically significant effect measure of the lowest observed effect concentration (**LOEC**) for growth (weight) was 5.6 mg/L. If, as suggested by Dr Meredith, the toxicity results for zebrafish are more applicable to the Canterbury mudfish then the significant effect on growth is likely to be between the NOEC and LOEC values (i.e., 1.8-5.6 mg/L) and for mortality something greater than the NOEC value (i.e., >5.6 mg/L). Thus, the use of boron limit of 1.5 mg/L for the discharge would be protective of all of these effect thresholds.

167. I recommend that compliance with the boron limit for all monitoring occasions at the Compliance sites would provide the greatest certainty for protection of environmental species.[69]

168. Earlier in my evidence (paragraph 109), I suggest that a second water sample (a "b" sample) should be taken at Compliance sites for each sampling occasion and suitably preserved for boron analysis should the initial test fail. Should the "b" sample analysis also fail for that boron, then urgent mitigation should be

[66] MS Warne, GE Batley, RA van Dam, JC Chapman, DR Fox, CW Hickey, JL Stauber, (2018). "A revised method for deriving Australian and New Zealand water quality guideline values for toxicants" (2018) Prepared for the revision of the Australian and New Zealand Guidelines for Fresh and Marine Water Quality, (Australian and New Zealand Governments and Australian state and territory governments, Canberra) pp 48.
[67] Above n 32 at [24].
[68] RN Hooftman, D van Drongelen-Sevenhuijsen, HPM de Haan, 2000a. Early life stage test under semi-static conditions with boric acid, manufacturing grade and the zebrafish *Brachydanio rerio*. TNO Report V99.168. TNO Nutrition and Food, Research Institute Netherlands, 35.
[69] 1.5 mg/L as specified in Conditions 22 and 27 of the markup document.

implemented, together with a timely resampling programme undertaken, with investigations into the cause of the non-compliance.

169. I consider that my suggested modifications to Condition 28 will address the concern raised by Dr Meredith who considers that: "…*I consider that it is not appropriate to allow boron concentrations beyond trigger levels to be discharged for periods beyond the compliance point through the natural waterway reaches (CC02 to CC03 and to CC09)*." [70]

170. In my EIC I concluded that, based on my analysis of the water quality monitoring of the Tara Stream that the wetland has been providing consistent removal of boron, likely by uptake by vegetation, seen for the long-term monitoring. I was not, in my conclusions, advocating this as a necessary component of the treatment system, but rather as an additional process which reduces boron exposure to downstream ecological communities. I disagree with Dr Meredith's statement that: "*This is not a sustainable strategy, particularly when previous years mining activities will have already loaded the system up with boron*."[71] With my extensive experience my understanding is that there is not a cumulative and ever accumulating concentration of boron in the downstream wetland environment of Tara Stream as boron does not accumulate in depositional sediments. Rather, the monitoring data indicates that the mechanism of removal has been occurring for a long period and would constitute a sustainable process.

DRAFT RESOURCE CONSENT CONDITIONS

171. In this section of my evidence I discuss the proposed conditions for CRC for Tara Stream discharges.

172. Consent conditions 20 relates to water quality monitoring requirements (parameters and frequency) for the Operational/Active Closure Phase and the Post Closure Phase respectively. The compliance limits for the water quality monitoring parameters are provided in condition 22 respectively. These consent conditions apply to discharges to the Tara Stream as monitored at sites CC02_tele or "Tara spillway mixing structure" (site code CC02_TSMS) as specified in Condition 3.

[70] Above n 32 at [25].
[71] At [26].

173. The conditions specifying actions for non-compliance of any parameters are specified in Condition 23 for the Operational/Active Closure Phase and the Post Closure Phase respectively.

174. I address below the specific components of these consent conditions which I have addressed in my evidence:

(a) I support moving the compliance site from CC02_tele to the Tara Pond spillway mixing structure (site code CC02_TSMS) as required by condition 3.

(b) I support removal of the pH conditions for iron and aluminium from compliance assessment in Condition 20, noting further steps may need to be taken to remove colloidal elements from the sample.

(c) I support the removal of “three month rolling median” from the boron limit for the reasons discussed in paragraph 39.

(d) I support the proposed boron limit of 1.5 mg/L in Condition 22 as discussed in paragraphs 30-39.

(e) I recommend that the boron limit be considered as a maximum concentration which should not be exceeded in the discharges, as discussed in paragraphs 107, 167 and 168 in relation to Condition 23.

(f) I recommend taking a duplicate “b” sample for each monitoring occasion for confirmatory reanalysis should a non-compliance for boron occur, and timely resampling should non-compliance be confirmed, as discussed in paragraphs 108-112 in relation to Conditions 23 and 28.

(g) Continuous dissolved oxygen monitoring was requested by Dr Massey. I recommend that discrete monitoring would be sufficient with a target minimum DO of 50% saturation as discussed in paragraphs 84-91.

(h) It was noted in the conferencing material circulated that there was general agreement to measure total and dissolved metals for some contaminants. I support the inclusion of both total and dissolved measurements of iron, aluminium and manganese for the Active Closure Phase monitoring at the CC02_TSMS site.

(i) An advice note should be added in relation to dissolved aluminium measurement as discussed in paragraph 22.

TRIGGER ACTION MANAGEMENT PLANS

175. I support the use of an adaptive management approach for monitoring the CCM site and consider that the TARPs, with their various triggers and associated management actions, provide a good risk assessment tool for assessment and interpretation of monitoring data.

176. I support an annual monitoring frequency for arsenic, cadmium, chromium, copper, lead, mercury and PAH concentrations at Compliance sites, as discussed in paragraphs 114-124.

177. Dr Meredith raised specific concerns regarding the management of the N02 pit pond with regard to stratification and the associated TARP framework.[72]

178. As discussed in my evidence, I consider that the proposed monthly surface and deep monitoring data from the initial monitoring period of about a year after the pond fills will provide indicative data for consideration in the March 2024 review. I consider that a longer monitoring time frame will be required to establish chemical changes and stratification (paragraphs 97-100). The need for longer-term monitoring is one of the concerns raised by Dr Meredith.

179. I recommend that a critical review of the TARPs be undertaken in the proposed March 2024 water quality review.

Christopher Wayne Hickey
25 February 2022

[72] Above n 32 [16].

Appendix 1

Recent BCL Monitoring Data (December 2021-January 2022) which includes Potential Contaminants of Concern (PCOC)

	CC02 underdrain*							CC02-tele							CC24 (CC20 data)							Notes
Date	Flow (L/s)	pH	PAHs	Boron (mg/L)	Mercury (mg/L)	Arsenic (mg/L)	Aluminium (mg/L)	Flow (L/s)	pH	PAHs	Boron (mg/L)	Mercury (mg/L)	Arsenic (mg/L)	Aluminium (mg/L)	Flow (L/s)	pH	PAHs	Boron (mg/L)	Mercury (mg/L)	Arsenic (mg/L)	Aluminium (mg/L)	
13/12/2021								70	7.5		1.04	<0.00050	<0.001	0.114								
15/12/2021	0.06	6	<0.001-<0.0001	3.9	<0.00050	<0.001	<0.005	2	6.7		0.76	<0.00050	<0.001	0.008	20 (6)	6.7	<0.001-<0.0001	0.028 (0.37)	<0.00050	ND	ND	
22/12/2021								70	7.4	<0.001-<0.0001	0.67	<0.00050	<0.001	0.108								
7/01/2022								40	7.1		0.76	<0.00050	<0.001	0.005								
Maximum			<0.0001	3.9	<0.00050	<0.001	<0.005			<0.0001	1.0	<0.00050	<0.001	0.11			<0.0001	0.028 (0.37)	<0.00050	ND	ND	
LOQ			0.0001	0.005	0.0005	0.001	0.005															a
Limit/Guideline			**0.0001**	**1.5**	**0.0006**	**0.024**	**0.055**			**0.0001**	**1.5**	**0.0006**	**0.024**	**0.055**			**0.0001**	**1.5**	**0.0006**	**0.024**	**0.055**	b
Safety factor			*1*	**0.4**	*1.2*	*24*	*11*			*1*	1.4	*1.2*	*24*	**0.5**			*1*	4.1	*1.2*			c

Note: *CC02 underdrain is a groundwater sample and will be treated through the MSR and diluted prior to future discharge from CC02_TSMS (Tara Pond spillway mixing structure). Abbreviations = Polycyclic aromatic hydrocarbons (PAHs).

a LOQ = Limit of Quantification for the analytical laboratory and current test. PAH range is for the 15 priority PAHs analysed, value specified is for napthalene which is the only PAH with an ANZG GV.

b ANZG GVs for 95% protection for PAH: napthalene; mercury; arsenic (AsIII); aluminium (pH >5.5). Boron limit is ANZG GV for 90% protection.

c Safety factor = Maximum value / Limit (or GV); Detection limit used if no measured data (in italics). SF values greater than 1 do not require receiving water dilution. SF values less than 1 require dilution or treatment. Bold (whiteface) indicates parameters where dilution/treatment required for compliance.