

Buller Plateaux Continuation Project: Water quality protection guidelines

Prepared for

Bathurst Resources Limited, including its subsidiary companies Bathurst Coal Ltd and Buller Coal Ltd, and joint venture company BT Mining Ltd ("Bathurst")

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Executive summary

Bathurst Resources Limited (including its subsidiary companies Bathurst Coal Ltd and Buller Coal Ltd, and joint venture company BT Mining Ltd (“Bathurst”)) is seeking to obtain authorisation through the Fast Track Approvals Act (FTAA) to progress development and mining of the coal resources across the wider Buller Plateaux. This project is referred to as the Buller Plateaux Continuation Project (BPCP or Project).

The purpose of the BPCP is to re-consent the existing infrastructure and mining operations associated with the existing Stockton Mine and provide access to additional coal mining areas across the Buller Plateaux, as the coal resource in the current Stockton mine is close to depletion, and further coal resources for blending are required. There are five key Project sub-areas:

- Stockton mining area (Stockton)
- Mount Frederick South (MFS)
- Escarpment Extended (ESE)
- Upper Waimangaroa Haul Road (UWHR) Transport Corridor
- Cypress mining area (Cypress)

This report uses a combination of guidance documents/standards, the nature of the existing receiving environment and historic activities (both water quality and ecology), and the anticipated effects of future activities, to recommend compliance limits for relevant contaminant discharges, from MFS, ESE and UWHR and assesses why those limits are appropriate to manage/improve water quality and ecological outcomes.

Specifically, this report develops:

- Guidelines for bioavailable metals incorporating Toxicity Modifying Factors (TMFs = pH, hardness, dissolved organic carbon (DOC)) and potentially toxic nitrogenous compounds (nitrate-N and ammoniacal-N: TMFs = hardness & pH, temperature respectively). These guidelines are designed to be protective of macroinvertebrate and fish communities in these naturally acidic streams on the Buller Plateaux and provide a range of Levels of Protection (LoP).
- A classification scheme using chemistry and biological measures to identify streams with differing levels of existing acid and metalliferous drainage (AMD) impact across the Buller Plateaux. Reduced LoPs are recommended for AMD-affected streams.
- Site-specific sediment (turbidity) guidelines for macroinvertebrate and fish protection.

Receiving waters are characterised for the background water quality of the naturally acidic streams, the nature of hydrological flows and the durations of flood events, together with the characteristics of flow-related variability of metals and TMFs in mine-influenced receiving waters.

Toxicity assessment results for acute and chronic exposures of freshwater crayfish (kōura) to different pH/hardness modified mine water and mayfly (*Deleatidium* sp.) and green algal sensitivity to nickel and cobalt at different pHs, and hardness-modified Buller Plateaux waters, are provided and discussed.

Compliance monitoring conditions for sediments (turbidity and clarity), nutrients and TMF-modified metals are recommended. Monitoring is also recommended for Reference, Compliance and Performance sites using continuous, discrete and flood samplers.

1 Introduction

1.1 Description of project footprint

The Buller Plateaux Continuation Project (BPCP or “Project”) will expand the existing mining activities on the Buller Plateaux (including Stockton Plateau and Denniston Plateau, collectively referred to as “Buller Plateaux”¹) with a water permit term sought for 35 years (BRL, 2026a). It will utilise existing infrastructure facilities at Stockton Mine to support and extend the mine life of the current Stockton Operations on the West Coast. The Project will comprise site preparation and construction of transportation infrastructure and ancillary buildings; water diversion, management and treatment facilities; mining operations; vegetation clearance, overburden disposal, and rehabilitation activities; and historic acid mine drainage rehabilitation. For the purpose of this report the Project will be described with respect to five main Project sub-areas as shown in Table 1-1 and Figure 1-1.

The Project sub-areas of ESE, MFS and UWHR contain historic mining activity which results in variable levels of AMD input to streams and rivers (Figure 1-1–1-3). The acid and metalliferous drainage (AMD) inputs primarily affect stream pH and metal concentrations – especially aluminium – with many receiving waters exceeding the toxicological and physiological tolerance range for aquatic species at many sites in these areas. Establishing the background water quality conditions and guidelines and compliance monitoring locations for ecological protection in the ESE, MFS and UWHR mining areas is a priority for this report.

Table 1-1: BPCP sub-area and scope

PROJECT SUB-AREA	SCOPE
Stockton Mine (STO)	Completion of mining of existing pits and remaining coal resources. Ongoing utilisation of existing infrastructure. Includes Stockton and Millerton mining areas. Activities lie within the Ngākawau, Twins, Rudolph, Waimangaroa and Granity catchments.
Mount Frederick South (MFS)	Development of an access road from the Waimangaroa Valley into the Mount Frederick South mine area, initial mining through old underground workings, and extension into unmined areas to the northwest.
Escarpment Extended (ESE)	Mining of an existing pit at the Escarpment Mine, underground workings (Whareatea), and an extension into unworked areas (West Whareatea)
Upper Waimangaroa Haul Road (UWHR)	Road connecting Stockton with Mount Frederick South and Escarpment Extended. Combination of upgrades to existing roads and development of new section through the Waimangaroa Valley.
Cypress Mine	Included because of the need for variation of some consent conditions to align with the Project; and the need for a wildlife permit but outside the ambit of this report.

¹ This report uses the term “Buller Plateaux” to describe the proposed Escarpment Extended (ESE) mine on the Denniston Plateau, the proposed Mount Frederick South (MFS) mine and most of the Upper Waimangaroa Haul Road (UWHR) which are located on the Stockton Plateau. The streams associated with the Stockton Mine are not considered in this report and are addressed elsewhere (PDP 2026; GHD 2026).

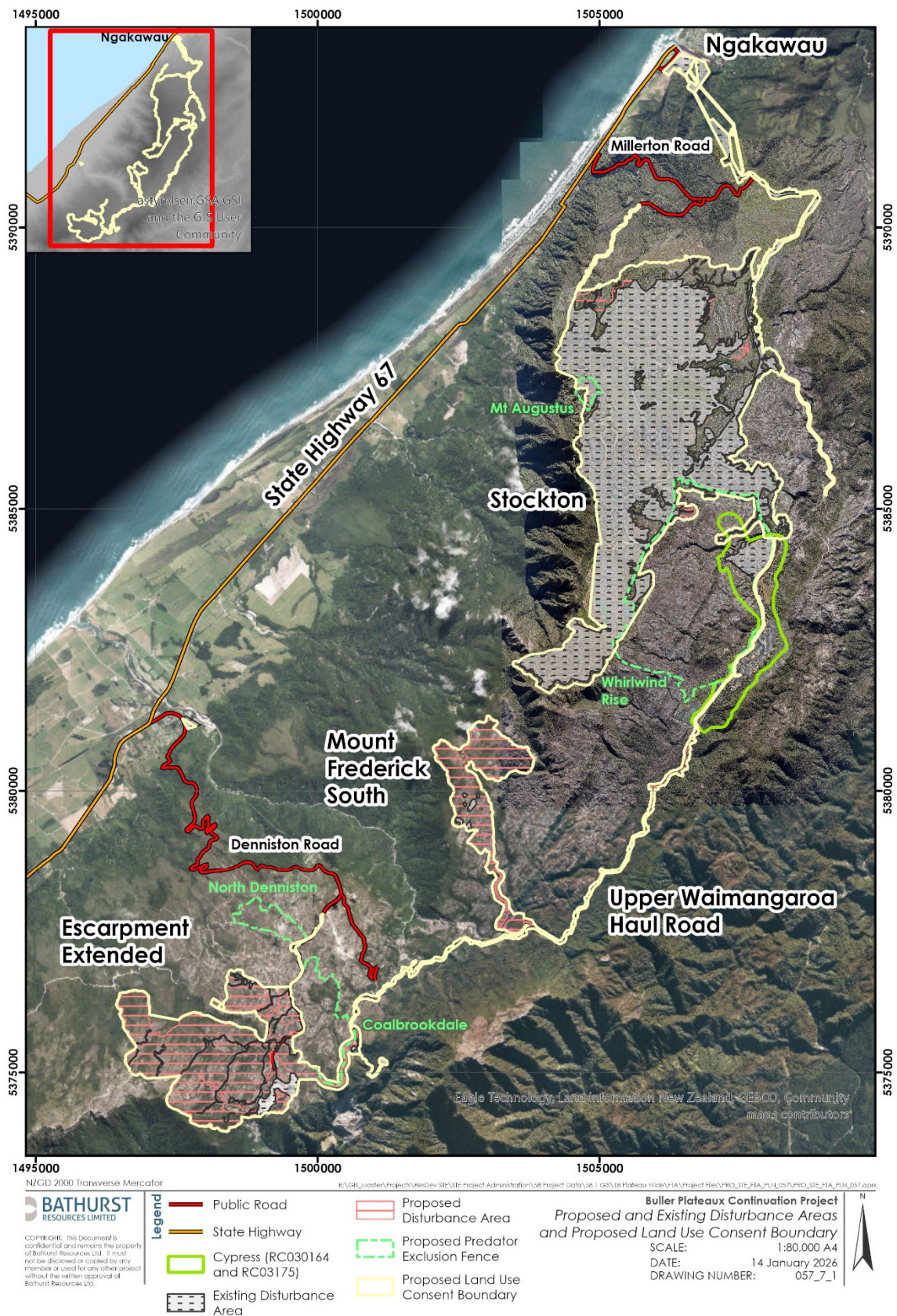


Figure 1-1: Location of Stockton Mine, Mount Frederick South (MFS), Cypress Mine, Escarpment Extended (ESE), and Upper Waimangaroa Haul Road (UWHR) sub-areas.

The Buller Plateaux area has a long history of mining activity and AMD discharges resulting in significant effects in receiving waters. The streams draining historically mined areas generally have very low pH and elevated aluminium concentrations. In more recent times, the emphasis for Stockton AMD management is for increasing treatment and restoration of receiving waters (Instream, 2026b). The planned restoration will need to occur over a long time (nominally 80-years), because of the complexity of the historic mining areas (including over 130 years of mining induced AMD impacts) and the level of treatment required (Instream, 2026b).

Ecological recovery targets and progressive improvement guidelines for Stockton Plateau streams and the existing Stockton Mine are provided in Instream (2026b). Water quality for Stockton Plateau streams is described in Instream (2026b) and GHD (2026). This report is defining protection guidelines for the proposed mine sites in the Project sub-areas of ESE, MFS and UWHR on the Denniston Plateau.

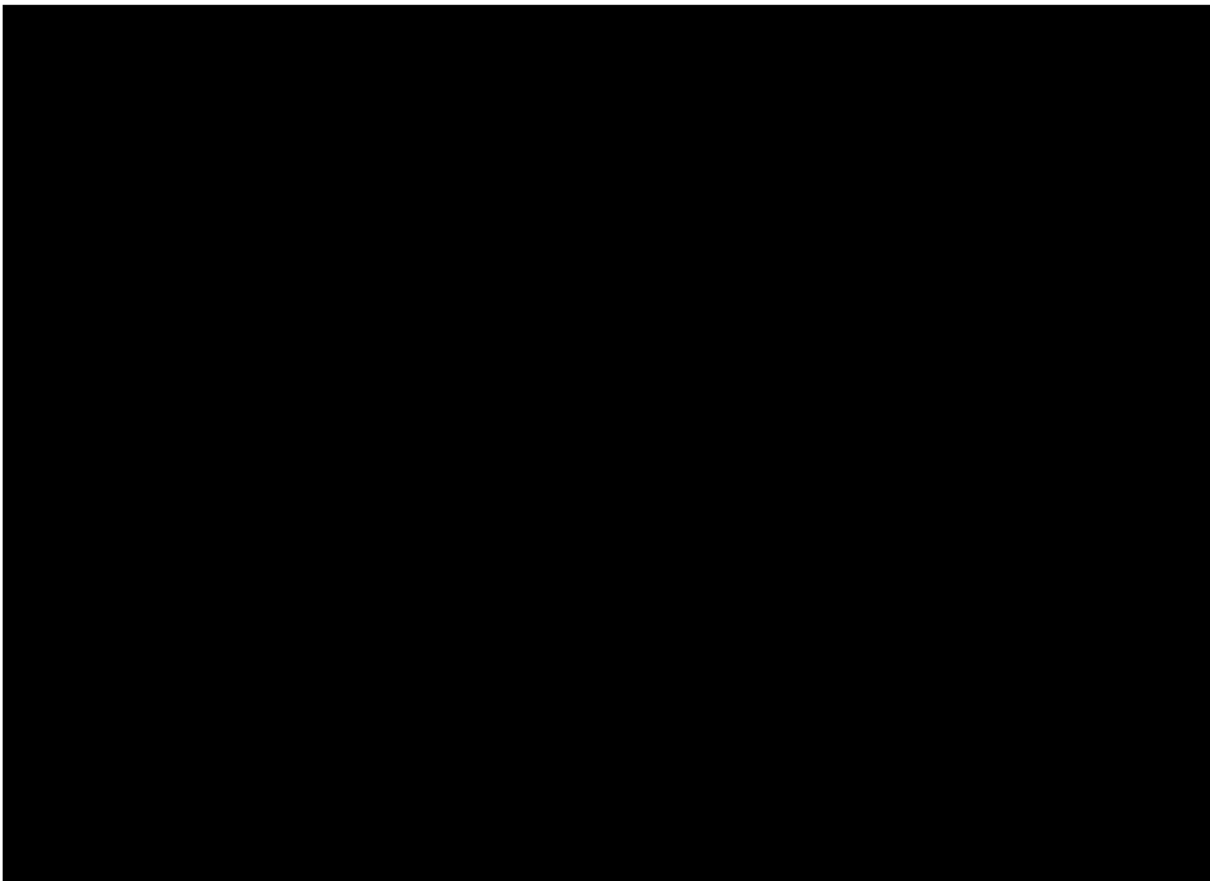


Figure 1-2: Map showing historic workings and location of monitoring sites used for LoP classification (Hickey, 2026b) for proposed MFS and ESE mining sub-areas.

1.2 Guideline development for Buller Plateaux streams

Guidelines have been developed for bioavailable metals incorporating Toxicity Modifying Factors (TMFs = pH, hardness, dissolved organic carbon (DOC); temperature for ammoniacal-N) (presented in Sections 6 and 7). These guidelines are designed to be protective of macroinvertebrate and fish communities in streams draining the Buller Plateaux and provide a range of Levels of Protection (LoP). This approach differs from that used for the Escarpment Mine consented in 2012 which use a Biotic Ligand Model (BLM) approach based on rainbow trout protection. Since 2012, there has been

the development and regulatory adoption of bioavailability guidelines which use multiple linear regressions (MLR) relationships to quantitatively modify guideline values (GVs) for TMFs. These GV include toxicity data for fish, macroinvertebrates and plants as the basis of the derivation. The Australian and New Zealand Guidelines (ANZG) provide GV with differing LoPs for different receiving water applications. The background and approach for guideline development for Buller Plateaux streams are described in Section 5.1.5.

A classification scheme was developed using chemistry and biological measures to identify Buller Plateaux streams with differing levels of AMD impact. This identified stream categories as Excellent, Good, Fair and Severely Impacted relative to the suite of AMD-related chemistry and biological 'health' measures. This analysis facilitated the ANZG approach with differing LoPs to be appropriately applied to proposed Compliance and Performance monitoring locations. Reduced LoPs are recommended for some AMD-affected streams. The background and approach for classification development for Denniston Plateau streams is described in Section 5.1.1.

Site-specific sediment (turbidity) guidelines are developed for macroinvertebrate and fish protection. The background and approach for site-specific turbidity guidelines development are described in Section 5.1.9.

1.3 Guidelines for lowland streams

Guidelines for the Buller Plateaux streams are also applicable to the lowland stream sites for ecological protection. The two streams relevant for ecological and drinking water protection are Whareatea and Waimangaroa rivers (Appendix A, Figure A-1). Some lowland streams draining the Buller Plateaux have significant AMD inputs (e.g., Rapid Stream at State Highway 67 (SH67)) from historic mining activities (NIWA, 2020).

Proposed compliance sites are located on the Buller Plateaux at multiple locations designed to assess the effects of Bathurst mining-related discharges – including the Water Treatment Plant (WTP) discharges. Compliance with the ecological guidelines at the proposed compliance monitoring sites at Buller Plateaux locations will ensure protection of downstream ecology at SH67.

Specific assessments are undertaken for human and stock drinking water consumption at Buller Plateaux sites discharging to the coast with background monitoring assessments at multiple SH67 locations (Section 8.3.2). Future Performance monitoring is proposed for these SH67 sites with specific drinking water consumption assessment based on the upstream Compliance sites and adjustment for catchment dilution (Section 9.2).

2 Conceptual overview of assessment approach

2.1 Introduction

This report uses a combination of guidance documents/standards, the nature of the existing receiving environment and historic activities (both water quality and ecology), and the anticipated effects of future activities, to recommend compliance limits for relevant contaminant discharges, and assesses why those limits are appropriate to manage/improve water quality and ecological outcomes.

Key characteristics of the Buller Plateaux environment include: naturally acidic stream water with very low ionic strength and hardness; elevated DOC in many streams from organic matter input –

resulting in natural brown-water streams; abundant bryophyte (i.e., moss, liverwort and lichen) communities; the absence of fish on the Buller Plateaux; and abundant freshwater crayfish (kōura) at many sites. Many of the streams are affected to varying degrees by AMD inputs from historic mining activity (see Figure 1-2), with some having large inflows of AMD from adits. These AMD discharges result in a further reduction in pH and elevation of metal concentrations – particularly aluminium, iron, manganese and zinc (Hogsden and Jellyman, 2026).

The background water quality characteristics of these streams (i.e., low pH and very low hardness) are outside of the normal range of water quality guideline derivations. Additional toxicity testing has been undertaken to support the adequacy of the GV prediction for key species protection both for the naturally low water quality and for elevated pH and hardness associated with mine water treatment.

2.2 Weight-of-evidence (WOE) approach

The conceptual approach for the development of the water quality guidelines for ecological protection follows the general Australian and New Zealand Guidelines (ANZG) framework. That framework uses a weight-of-evidence (WOE), risk-based approach supported by ecotoxicological data.

The WOE framework integrates:

- Field monitoring
- Toxicity data
- Chemical measurements
- Biological assessments (macroinvertebrates, fish, algae)

A WOE approach is used for stream classification incorporating chemical and biological monitoring data to establish LoPs appropriate for the Buller Plateaux streams (Hickey, 2026b). This classification established categories of: Excellent, Good, Fair, Poor and Severely Impaired based on increasing levels of AMD influence and its adverse biological effects on streams.

Field monitoring and chemical measurements from baseline assessments were used to characterise the Buller Plateaux stream water quality and the hydrological nature of the streams. The Buller Plateaux streams are characterised by naturally low pH (4.5-5.5), low hardness (<10 mg CaCO₃/L) and often DOC. The DOC input comes from leaching of dissolved organic matter from vegetation leaf litter and generating “brown water” streams which have very low turbidity at base flow (typically < 2 NTU). The fulvic and humic acids from plant material may further reduce the pH in the brown water streams to pH 4 to 4.5.

The low pH of rainfall is attributed to absorbed carbon dioxide (CO₂) and the CO₂/bicarbonate equilibrium. Long-term monitoring of rainfall chemistry at three New Zealand locations has identified a variable marine component of the ionic composition (60-90%) and similar mean pH ranges for each of the sites (means 5.3-5.4; range 4.73-6.54 at Kelburn (highest marine influence), 4.20-6.82 at Lauder (inland Otago)) (Nichol et al., 1997). The electrical conductivity (EC) of the Kelburn site was 37.7 µS/cm (range 11.0-132.0 µS/cm) and the Lauder site 7.14 µS/cm (range 2.2-24.7 µS/cm). The hard rock composition of the Buller Plateaux results in minimal mineral addition to the rainfall chemistry.

The naturally low pH and hardness for the Buller Plateaux streams were generally outside of the range applicable to all internationally derived water quality guidelines, requiring site-specific considerations (Section 5.1.5). The hydrological nature of the Buller Plateaux is for high rainfall and flow variability – with a rapid return to baseflow conditions (generally <48-hours). This rainfall and flow variability have site-specific implications for the application of water quality guidelines (Sections 5.1.3 for hydrological flow variability; Section 6.2 for background TMF and metals variability; Section 8.1.3 for time-response sensitivity for mayflies).

Toxicity guidelines (Section 6.1) used incorporated bioavailability adjustment using site-specific TMFs, which included pH, hardness and DOC for various contaminants. Water quality monitoring for a range of stream flows was used to establish the background variability of TMFs and turbidity in relation to rainfall/flood events (Section 6.2). This background monitoring established the importance of the TMFs for toxicity assessment, with a combination of continuous and discrete monitoring used for pH, EC and turbidity at some sites (Section 7.1 for turbidity assessment). The background water quality data provided input parameterisation for predictive modelling for mining, active water treatment, post-mining active and passive water treatment stages for the BPCP assessments (MWM, 2026i; 2026k; 2026o). The active water treatment significantly increases the pH and hardness concentrations. The post mining passive treatment is proposed to utilise mussel shell reactors (MSRs) which will also markedly increase the pH and hardness compared with the natural streams (MWM, 2026f; 2026i). Ecotoxicity testing was undertaken for potential for acute and chronic effects on key species (kōura and mayflies) for pH and hardness changes (Section 8.1).

Biological assessments included macroinvertebrate, periphyton, fish and bryophyte communities. There are no fish present on the Buller Plateaux, though they are present in the lowland coastal stream reaches (Hogsden and Jellyman, 2026). Freshwater crayfish (kōura) are an important macroinvertebrate component of the Buller Plateaux stream communities. The EPT² macroinvertebrate species richness was used as the primary measure of AMD effects for classification, together with the abundance of kōura. The EPT species abundance was generally dominated by the mayfly *Deleatidium* spp. in these naturally acidic waters. Bryophyte communities – comprising liverworts, hornworts and mosses – are common in the acidic waters of Buller Plateaux streams (Hogsden and Hickey, 2025; NIWA, 2025c). A study of the diverse bryophyte communities across a pH gradient of Buller Plateaux streams provided the site-specific basis for establishing the pH limits for proposed discharges (NIWA, 2025e).

Ecotoxicity testing was undertaken using juvenile kōura testing chronic survival for a range of pH exposure conditions (pH 5.5, 6.5 and 7.5) in reference Whareatea River water and a representative treated mine water (Untreated Inflow (Barren Valley Engineered Land Form "BV ELF" MSR Inflow) and Partially Treated Inflow (BV ELF MSR Inflow – CaO Treated))(NIWA, 2025f) (see Section 8.1.1, Appendix H). The BV ELF mine water provided a well characterised drainage water which would be expected from Buller Plateaux mining operations. The untreated water (pH 2.95, hardness 97 mgCaCO₃/L) was pH modified (i.e., no hardness adjustment) and partially treated (pH 6.04 with CaO, hardness 176 mgCaCO₃/L), with all treatments diluted with the pH adjusted river water (unmodified pH 5.7, hardness 2.1 mgCaCO₃/L). Additional mayfly acute and chronic testing was also undertaken to establish trace element sensitivity for cobalt and nickel in reference Whareatea River water for a range of exposure pH conditions (ESNZ, 2025b)(see Section 8.1.2, Appendix I). Toxicity measures

² E = Ephemeroptera, mayflies; P = Plecoptera, stoneflies; T = Trichoptera, caddisflies.

from time-response data are used to establish no-effect thresholds³ for application to compliance monitoring. This risk-based approach is dependent on both the site hydrographs – establishing exposure duration – and the TMF levels – establishing bioavailability.

Sites with existing AMD inputs occur on the Buller Plateaux associated with the historic mining activity (as there is for multiple stream sites draining the Stockton Plateau). The level of AMD input to these streams results in highly acidic conditions (i.e., often pH <3) and elevated dissolved aluminium concentrations (>1 mg/L). Macroinvertebrate life in these streams is very limited with sites downstream of abandoned adit discharges often characterised by only tolerant macroinvertebrates (e.g., chironomids) and extensive filamentous algal proliferations (Hogsden and Jellyman, 2026; NIWA, 2020). Remediation works are planned for adit discharges associated with the ESE mining activities. A “Betterment” assessment approach⁴ is proposed for these sites with assessment of long-term improvement in key water quality measures (i.e., pH, aluminium, turbidity).

The sites recommended for receiving water monitoring include Reference, Compliance (with differing levels of protection) and Performance. The Reference sites are all Excellent or Good classification – except for the upstream reference site on the Waimangaroa River, which receives AMD inputs from historic mining disturbance– with these sites providing an upstream or local reference for water chemistry and biological monitoring (Sections 5.1.1 and 6.3). The Compliance sites have numeric compliance limits for water chemistry and requirements for biological monitoring linked with a Reference site. The Performance sites target operational management and off-site validation that water management controls are operating effectively measuring downstream effects measured at Compliance sites. Performance sites will have a targeted suite of measures and different sampling frequencies from Compliance sites.

Together, these components have been used to provide the WOE assessment to establish compliance levels for ecological protection for Buller Plateaux streams and monitoring requirements associated with discharges from the ESE, MFS and UWHR sub-areas.

Additional assessments are included for aesthetic and recreational effects on water clarity and drinking water for human and stock consumption at lowland (SH67) sites.

2.3 Terminology and Guidelines

An important note on terminology

Buller Plateaux Continuation Project (BPCP)

The BPCP encompasses new proposed coal mining operations on the Denniston Plateau within the **Escarpment Extended (ESE)** sub-area (including the existing Escarpment Mine which was originally consented in 2013) and Stockton Plateau including **Mount Frederick South (MFS)** and most of the **Upper Waimangaroa Haul Road (UWHR)** sub-areas. Collectively, in this document, these two mining areas and the UWHR are referred to as discharging to ‘**Buller Plateaux streams**’ because of the broad similarities in the nature of the stream receiving environments.

The Buller Plateaux streams are characterised by a naturally low pH, low ionic strength and often elevated organic matter inputs from native vegetation resulting in “brown water” – with this organic matter further

³ No-effect concentration (NEC) = The maximum concentration of a toxicant that causes no adverse effect in a target organism, based on a threshold parameter in a concentration–response model (Warne et al. 2025). Operationally for the chronic values used for guidelines derivation are the negligible effect threshold such as the EC_x/IC_x where x ≤10 (EC = exposure concentration, IC = inhibiting concentration – where 10 indicates a 10% effect. (see Glossary).

⁴ Betterment = Improving water quality overtime through both water management activities and natural processes to a point where waterways will support aquatic life (see Glossary).

reducing the natural pH. [REDACTED]
[REDACTED]. Historic mining results in AMD affecting many streams and rivers on the Buller Plateaux.

The BPCP also includes mining activities that discharge water to the Ngakawau River (Stockton sub-area), and the Cascade Creek (ESE sub-area). Discharges to Cascade Creek occur from the Buller Plateaux and will be affected by ESE operations and are considered in this report. Streams draining the Buller Plateaux from the ESE and MFS sub-areas mainly discharge in a westerly direction towards the coast. A state highway (SH67) runs along the base of the Buller Plateaux and provides monitoring access. [REDACTED]

[REDACTED]. Assessments for background condition and potential effects at SH67 sites are collectively referred to as '**lowland streams**' because of the broad similarities in the nature of the stream receiving environments.

Guidelines and standards

The ANZECC & ARMCANZ (2000)⁵ Australian and New Zealand guidelines for fresh and marine water quality were replaced in 2018 (ANZG 2018)⁶. The new guidelines can be referred to as the ANZG guidelines, while the website is referred to as ANZG (2018). ANZG is an abbreviation for Australian and New Zealand Governments and Australian state and territory governments.

While ANZECC & ARMCANZ (2000) referred to "trigger values" which would "trigger" some action if exceeded, the ANZG guidelines now refer to "guideline values" or **GVs**. This is more consistent with international terminology. There are two types of GV: **site-specific GVs** and **default GVs (DGVs)**. Site-specific GVs are relevant to local conditions or situations and may have been developed by local authorities. These are not provided on the ANZG (2018) website.

DGVs, where they have been developed, are provided on the ANZG (2018) website and are chronic (long-term) protection guidelines. They are recommended for generic application in the absence of site-specific GVs. In some cases, DGVs are developed to be more relevant to local conditions (such as the DGVs for physico-chemical stressors which are specific to River Environment Classification (REC) classes) or can be subsequently tailored to local conditions (e.g., by adjusting for local water chemistry). Many DGVs have been carried across from ANZECC & ARMCANZ (2000) into the new ANZG (2018) website with no updates, such as DGVs for cadmium and lead. These should also be referred to as DGVs (rather than trigger values), but to reflect their origins, are referenced as ANZECC & ARMCANZ (2000).

ANZG have narrative descriptors and associated numeric values for differing **levels of protection (LoP)**. A statistical model is fitted to the **species sensitivity distribution (SSD)** for the species is used to derive a toxicant GV to provide a range of protection levels (nominally 99%, 95%, 90% and 80%). Overseas jurisdictions only provide GVs equivalent to the 95% protection level. Statistical models were fitted to overseas data – where used – to derive differing LoPs for application to Buller Plateaux sites.

There are draft updates for copper and zinc **DGVs** for fresh waters. These updates are **bioavailability-based guidelines** which include **toxicity modifying factor (TMF)** relationships to adjust the guidelines for water quality (TMFs include pH, hardness, dissolved organic carbon (DOC) and temperature). These DGVs can be tailored to specific local water quality conditions. As these DGVs have not yet been published by the Australian and New Zealand governments as finalised DGVs, they are referred to as **draft DGVs**. When guideline values from other countries, developed using different methods (e.g., for short-term exposures), or site-specific guideline values are discussed in this document, these are referred to as **GVs**. Short-term guidelines for copper and zinc have recently been derived for New Zealand following the ANZG methodology for bioavailability guidelines (Gadd et al., 2024). These are termed '**acute GVs**' – which are of short duration relative to organism's life-span (generally hours to days). The acute GVs are derived from acute EC₅₀ data (i.e., median effective concentration causing a 50% effect in a species) by application of a **conversion factor (CF-acute)** to derive EC₁₀ data which are used for **acute GV** derivation. When acute and chronic GVs are modified for TMF levels a **metal ecotoxicity quotient (MEQ)** is calculated (i.e., measured or predicted concentration/TMF-modified GV). MEQ values

⁵ ANZECC/ARMCANZ (2000) Australian and New Zealand guidelines for fresh and marine water quality, National Water Quality Management Strategy Paper No. 4, Australian and New Zealand Environment and Conservation Council and Agriculture and Resource Management Council of Australia and New Zealand, Canberra, Australia.

⁶ ANZG 2018 Australian and New Zealand guidelines for fresh and marine water quality, Australian and New Zealand Governments.

greater than 1 indicate parameters exceed the relevant WQ GV. Conversely, MEQ values less than 1 are below the relevant WQ Ref GV.

Both nitrate-N and ammoniacal-N toxicity guidelines incorporate TMFs – hardness for nitrate-N and pH and temperature for ammoniacal-N. The TMF-modified nutrient GVs provide the basis for calculation of the **nutrient ecotoxicity quotient (NEQ)** values, comparable with the MEQ values.

Site-specific guidelines are derived for a specific location. The Buller Plateaux streams are characterised by a naturally acidic freshwater, a high flow variability ('flashy' hydrographs) and sometimes elevated DOC associated with humic organic matter from natural leaf litter decay. Thus, the assessment of water quality guidelines for the receiving waters represents a unique suite of conditions which require **site-specific GVs** applicable to downstream compliance sites. Both **acute (short-term) no effect guidelines (acute GVs)** and **chronic (long-term) guidelines (GV)** are proposed for application to the Buller Plateaux streams.

Standards are when guidelines are incorporated into a consent condition or enacted as part of a legislated requirement (such as the **National Objectives Framework (NOF)** standards as part of the **National Policy Statement for Freshwater Management (NPS-FM)**) (MfE, 2020c). The NPS-FM standards are generally applied at catchment nodes – termed **Freshwater Management Units (FMUs)**. There are standards for nitrate-nitrogen (N) and ammoniacal-N in rivers which are relevant to this effects assessment.

Predictive modelling

Predictive modelling of **water load balance models (WLBMs)** has been undertaken by **Mine Waste Management (MWM)** for the proposed ESE and MFS mine areas. These models predict receiving water concentrations at proposed compliance locations for range of **potential constituents of concern (PCOC)** and TMFs.

3 Existing characteristics of Buller Plateaux and lowland sites receiving future ESE and MFS mine water discharges

3.1 Description of receiving environment

The Buller Plateaux streams have a range of bare rock to vegetated catchments – with many being brown water streams associated with humic acid inputs. Key biological characteristics include the absence of fish on Denniston Plateau (ESE sub-area) and Stockton Plateau (MFS and UWHR sub-areas); bryophyte dominance in naturally acidic streams and freshwater crayfish (kōura) abundance in acid streams (Hogsden and Jellyman, 2026).

Water quality and biological measures are used for classification of streams for the LoP relative to the background historic AMD inputs (Hickey, 2026b). Classification approaches have also been developed for habitat, species conservation status and ecological values for Buller Plateaux streams (Hogsden and Jellyman, 2026).

3.2 Hydrology

The high and variable rainfall of the Buller Plateaux generates “flashy” nature stream hydrology. Additionally, most of the streams are steep, with large cobble, boulder or a hard rock bed (NIWA, 2020).

A hydrological assessment of the Buller Plateaux streams is provided in MWM (2026g). Section 5.1.2 describes the nature and duration of flood events in Buller Plateaux streams. The flood event duration is of relevance to the contaminant exposure period for organisms which might occur during high rainfall events – with associated bypass discharges – and for upstream AMD inputs.

3.3 Water quality of reference and AMD-affected streams

3.3.1 Reference stream pH and electrical conductivity response to rainfall

Background water quality conditions in the Buller Plateaux streams are highly variable for pH and ionic strength (measured by electrical conductivity (EC)) during rainfall events.

Figure 3-1 shows the fall in pH and EC after the onset of a rainfall event at monitoring site WM-2, not impacted by AMD, within the Whareatea River. The pH decreases from around pH 5 to about pH 4.4 and then slowly recovers – together with EC. This response is caused by the combination of the naturally low rainfall pH (pH 5-5.5 because of high carbon dioxide, (Nichol et al., 1997)) and the catchment runoff of humic acids – generating brown water streams from catchment vegetation.

A key observation for these sites is that the pH only decreases to pH 4.25 and then progressively increases after the rain event ceases.

This natural variability in rainfall (flow), pH and EC means that the organisms present in these streams are adapted to this rapid change in physico-chemical conditions in their environment.

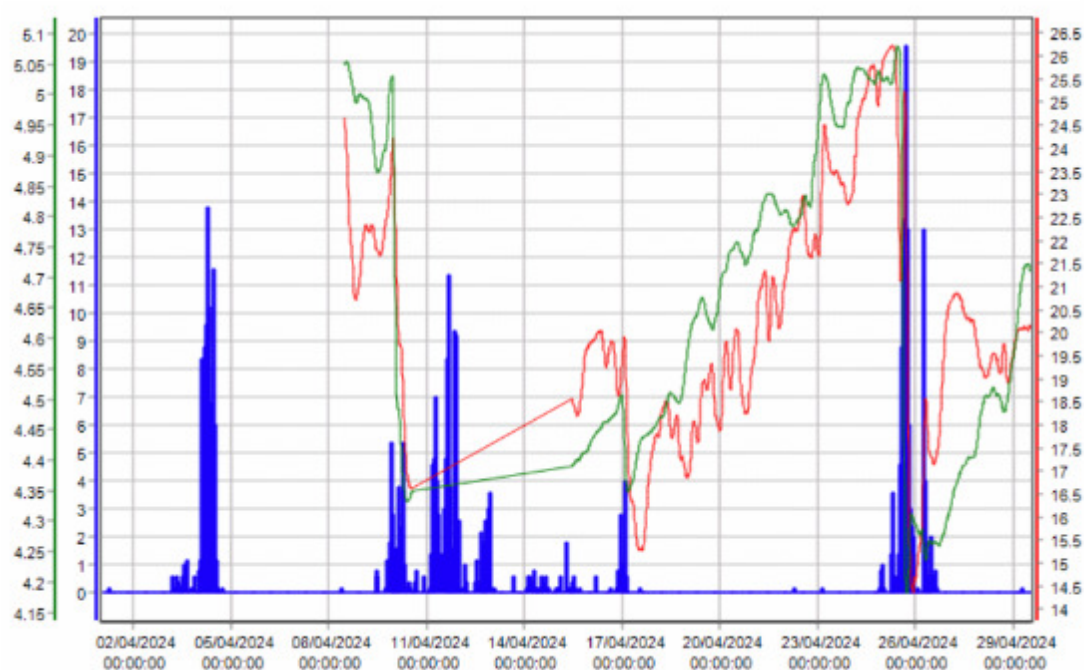


Figure 3-1: Response of continuous pH (green line and bar on y-axis) and electrical conductivity (micro siemens per centimetre, $\mu\text{S}/\text{cm}$; red line and bar on y-axis) in relation to hourly rainfall (millimetres, mm; blue bars and bar on y-axis) for Whareatea River at site WM-2. (BRL monitoring data).

3.3.2 Acid and metalliferous drainage (AMD) influenced streams: pH and electrical conductivity response to rainfall

The response of an AMD-influenced stream to a rainfall event differs markedly from that of a natural reference stream. Figure 3-2 shows the pH of Rapid Stream downstream of an adit discharge containing AMD over a rainfall event. The monitoring shows that the initial pH was around 2.9 and initially increases with the flow dilution – maximum about pH 4.1 – then decreases to pH 2.8 and remains very low for an extended period.

Jewiss et al. (2020) provides monitoring data for an AMD-influenced site on Cascade Creek (Figure 3-3). At this site, the initial rainfall increases the pH, followed by an AMD flush. The AMD input then dominates resulting in a prolonged period of very low pH (pH <3.3). The EC (termed specific conductance in plot) is diagnostic for the AMD influence – showing a reduced EC with rainfall dilution and an increased EC when the AMD is flushed from the catchment.

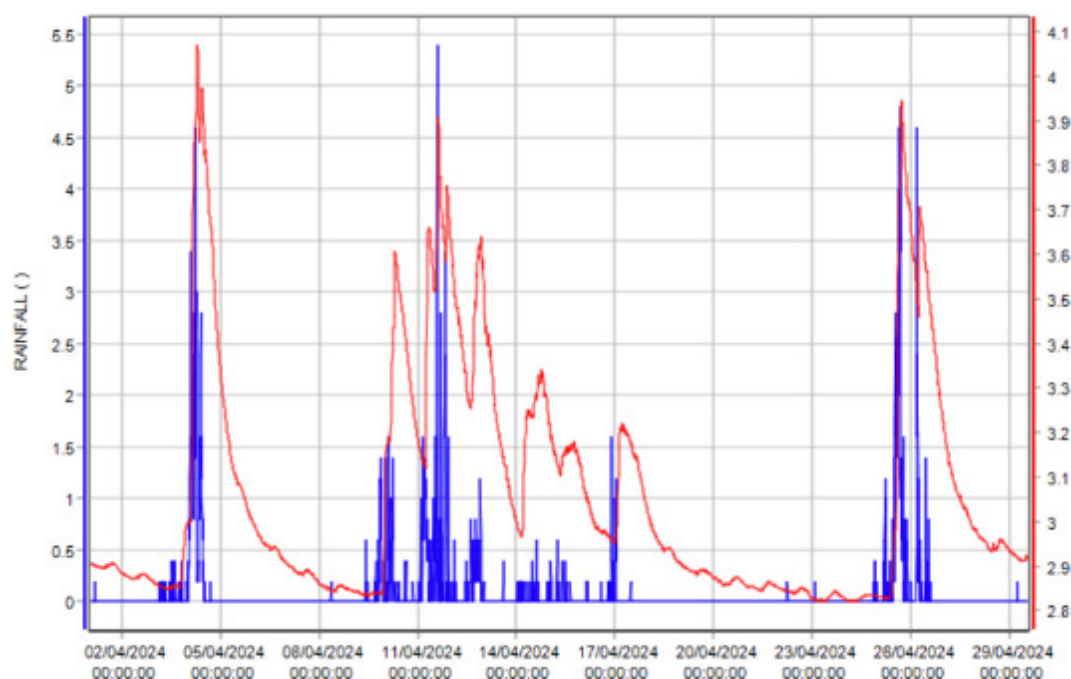


Figure 3-2: Response of continuous pH (red line and bar on y-axis) in relation to hourly rainfall (millimetres, mm; blue bars and bar on y-axis) for Rapid Stream downstream of adit. Major AMD input above this site. (site W8, BRL monitoring data).

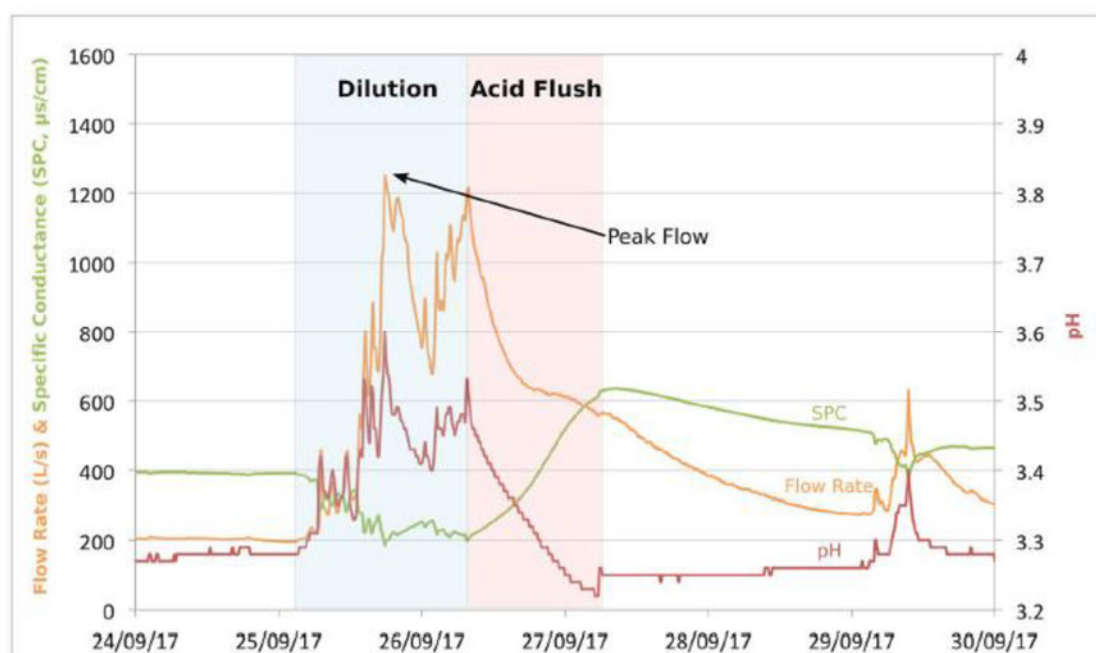


Figure 3-3: Relationship between pH, specific conductance (SPC), and flow rate during a high rainfall event at Cascade site 1 from Jewiss et al. (2020).

3.3.3 Water quality for reference and acid and metalliferous drainage (AMD) influenced streams

The background water quality in reference and AMD-influenced streams responds significantly to flow – particularly for pH and ionic strength (measured as EC). The hydrology of Buller Plateaux streams is described in section 5.1.3 and water quality for metals and TMFs in section 6.1. The background turbidity monitoring data is described in Hickey (2026c), with the site-specific guidelines presented in section 7.1.

The broad extent of historical mining on the Buller Plateaux results in multiple streams being influenced to varying degrees by AMD discharges. The level of AMD input affects both the water chemistry and the aquatic communities present. Together the water quality and ecological measures are used to generate a classification approach for the Buller Plateaux streams. This classification is the basis for the LoP to be applied to the different streams. This classification scheme is detailed in Hickey (2026b) and a summary provided in section 5.1.1.

4 Characterisation of mine water treatment systems

A water treatment summary report has been prepared by MWM (2026o). This report describes AMD and sediment treatment/management through the different operational phases at ESE and MFS.

4.1 Mine water treatment

Extensive trials have been undertaken to optimise the treatment systems to be used in the water treatment plants (WTPs) (Process Flow, 2025).

The WTPs use calcium oxide for pH management and to increase hardness. Flocculent (polyacrylamide; Rheomax 1030 – a high molecular weight anionic polyacrylamide) is used for reducing suspended solids concentrations. A metal-chelating agent (Metalzorb FZ) has been trialled for use to further reduce the concentrations of trace metals (MWM, 2026o; Process Flow, 2025).

The WTP designs have a fixed treatment capacity. At MFS, once that capacity, and the upstream sumps holding capacity, is exceeded then a pumped bypass flow will be discharged at Smokestack to Waimangaroa River. The two upstream sumps at MFS would discharge untreated mine water to Deep Stream, on infrequent occasions once all of the holding capacity is exceeded. At ESE, once the WTP capacity, and the upstream sumps holding capacity, is exceeded the sumps would spill to either the Whareatea catchment or the Cascade catchment.

The upstream sumps do not have any active treatment for TSS removal or pH control. The size of the sumps is expected to allow settling of coarse solids while elevated turbidity will discharge, once the holding capacity is exceeded, during the bypass/spill events.

The location of the proposed WTPs and discharges are shown in the Process Flow diagrams (Appendix B).

4.2 Construction treatment

Sediment control measures and retention ponds are proposed for the construction phase of the BPCP, including the construction of the Upper Waimangaroa Haul Road (UWHR). A monitoring and management plan has been developed for sediment control associated with land disturbance (SLR Consulting, 2026). Proposed water management and treatment during the construction phase of the BPCP is discussed in detail in MWM (2026q).

The location of the proposed construction phase sediment retention ponds and their discharges are shown in the Process Flow diagrams (Appendix B).

4.3 Closure treatment systems

The proposed passive treatment option for water management is to use mussel shell reactors (MSRs) for metals removal (Crombie et al., 2011; DiLoreto et al., 2016; MWM, 2026o). The treatment system increases the ELF seepage pH to 7.5-8 and increases hardness because of calcium carbonate dissolution from the mussel shells. There will be a degree of mixing of the MSR discharge with the receiving water, based on the relative flows of each, which will reduce this pH – however this pH is markedly higher than the natural low pH found in both the low ionic strength and brown-water Buller Plateaux streams. It is noted that there is the option to implement pH trimming of MSR discharge, if needed – this is discussed further by MWM (2026p) and Hogsden and Jellyman (2026).

Studies of the BV ELF MSR have provided site-specific information on the performance of the MSRs under local conditions (MWM, 2026f). The MSRs will treat the ELF seepage, with the rainfall runoff from rehabilitated ELF surfaces being diverted around the MSRs.

The location of the proposed MSRs is shown in the Process Flow diagrams (Appendix B).

5 Approach for Conducting the Aquatic Effects Assessment

5.1 Receiving Environment Characterisation

5.1.1 Overview

Characterisation of Buller Plateaux streams is required to provide the basis for establishing water quality protection guidelines. The basis for these guidelines requires the LoP to be linked to biological and water quality, hydrological characteristics, and linkages between background water quality and contaminants – including metals, suspended solids/turbidity, acidity – and TMFs that affect bioavailability. Specific issues addressed include the natural pH range and the upper limit associated with maintaining bryophyte communities. The water quality guidelines are based on published ANZG and recently updated international guidelines – many incorporating TMF modifiers. Laboratory toxicity testing with key native species was undertaken to determine effect thresholds in relation to background TMF conditions and for representative post-treatment mine water. The assessment was informed for Potential Constituents of Concern (PCOCs) by summarised background water quality (MWM, 2026j), mine water treatment studies (MWM, 2026o; Process Flow, 2025), mine water characterisation from the BV ELF (MWM, 2026f), an AMD review (MWM, 2026p) and predictive modelling for ESE (MWM, 2026k) and MFS (MWM, 2026i).

Biological monitoring of Buller Plateaux streams – together with site chemistry from water monitoring on the sampling occasions – was summarised in NIWA (2020). Additional studies have subsequently been undertaken as part of the baseline investigations, such as the bryophyte studies (Hogsden and Hickey, 2025; NIWA, 2025c). The bryophyte species distributions provide the basis for establishing the pH maximum (Hogsden and Hickey, 2025), while natural background minima at reference sites together with species tolerance for low pH (Greig et al., 2010; Jellyman and Harding, 2014; West et al., 1997) informed the minimum pH. A summary report supporting the biological aquatic effects assessment, based on available baseline data for ESE, MFS and UWHR sub-areas has been produced by Hogsden and Jellyman (2026).

A narrative classification system was developed to include the effects of historic and contemporary inputs of AMD to provide the basis for the differing LoPs in the Buller Plateaux receiving water environment (Hickey, 2026b). This assessment was required to link the narrative descriptors in the ANZG with the LoPs for compliance monitoring locations. The classification approach for LoPs is described in Section 5.1.2 and summarised in Section 6.3.

Fluvial geomorphology and hydrology of the Buller Plateaux streams have been summarised (MWM, 2026g; NIWA, 2024c). Those assessments described the stream flows, bed characteristics and slope from the Buller Plateaux to the lowland reach (SH67). An analysis of flood frequency and flood event duration is provided in this report (Section 5.1.3). This characterisation was required to support the proposed GVs for ecosystem protection.

The receiving environment characterisation also includes rainfall and flow-related changes in pH, EC and turbidity in reference streams and examples of AMD input with continuous monitoring. Continuous monitoring data for pH and EC in relation to rainfall/flood events for AMD and reference streams are shown in Section 3.3, with continuous turbidity monitoring data shown in Hickey (2026c). The approach is summarised in Section 5.1.4, with future exposure assessment addressed in Section 5.2 and the site-specific guideline derivation for turbidity provided in Section 7.1 and metals in Section 6.1 with TMF relationships provided in Table 6-2. Discrete monitoring data for flow-related changes in metal and TMF concentrations at Smokestack (2W) have been analysed to provide characterisation of the historic and contemporary AMD inputs to the upper Waimangaroa River to establish the LoP – which will be reflected in future monitoring at the upstream local reference site (16W) for the WTP at MFS. The monitoring approach is described in Section 5.1.4 and data is presented and discussed in Section 6.2.

Mine Waste Management (MWM) have summarised the background discrete water quality data for ESE and MFS streams and sites monitored in the greater catchments (MWM, 2026j; 2026l). The site summary data was compared to screening criteria (the RC10193 compliance limits for the Whareatea River granted for the existing Escarpment Mine in 2013, (MWM (2026j), Appendix C). The PCOCs are addressed in Section 5.1.5. Additional background water quality data are provided in MWM (2026j) for lowland river sites adjacent to SH67 (Waimangaroa, Whareatea, Rapid) and presented here for Waimangaroa and Whareatea rivers at SH67 for comparison with standards and guidelines for drinking water and stock water use in Section 8.3.2 (Table 8-7). Rapid Stream receives AMD inputs from an historic adit in the mid-catchment – with associated elevation of metal concentrations and reduced pH – with some downstream dilution prior to the Rapid Stream confluence with Whareatea River. The biological resources at these sites is described by Hogsden and Jellyman (2026).

The derivation of guidelines for metals is described in Section 5.1.6 with exposure assessment addressed in Section 5.2.1 and the guideline derivations presented in Section 6.1.

Increased stream nitrogen concentrations are possible because of the use of nitrogen-containing explosives (MWM, 2026f). Guidelines for nitrogen-containing compounds for ecological (toxicity) protection and human health (drinking water) are described in Section 5.1.7, and the exposure assessment basis is provided in Section 5.2.4, with the environmental assessment provided in Section 7.2.

An overview of laboratory toxicity testing with kōura and mayflies is provided in Section 5.3 with results for mine water and metal (cobalt and nickel) testing summarised in Section 8.1, together with time-response data for metals and data from other toxicity studies on AMD affected waters.

Recommendations for management and monitoring are provided in Section 9.

5.1.2 Classification of streams for water quality levels of protection (LoP)

The objectives of this classification assessment were to:

1. Summarise water quality and associated macroinvertebrate and kōura data covering a range of existing water quality conditions from pristine/uncontaminated to very poor water quality associated with historic and contemporary AMD discharges.
2. Determine which combination of water quality and biological parameters provides the best characterisation of AMD to derive a weight-of-evidence approach for classification categories.
3. Establish defensible levels of protection for compliance sites and identify suitable reference sites based on the Australian and New Zealand Guidelines (ANZG) classification narratives (primary objective).
4. Establish category ranges for predictive chemical parameters which could readily be applied to other monitoring sites.

A classification system linking biological condition with water quality in the ESE and MFS sub-area streams for BPCP was developed (Hickey, 2026b).

Historic and contemporary mining disturbance exists (to varying degrees) in both the ESE and MFS sub-areas. A classification system is needed to identify streams which have background levels of AMD which degrades water quality. A “weight-of-evidence” approach that follows recognised international guidance (ANZG, 2018a; Suter and Cormier, 2011) has been taken in developing this classification system. The AMD causes both physical and chemical changes in the receiving environment which can adversely affect biological communities (Hogsden and Harding, 2012). These changes include;

- acidity (i.e., low pH),
- elevated metal concentrations,
- elevated sulphate concentration from oxidation of sulphide minerals,
- precipitation of iron and aluminium flocs and
- high time-variability (i.e., a combination of point source adit discharges and diffuse runoff from mine-affected acid-forming rock deposits) of these inputs associated with the Buller Plateaux rainfall patterns.

Establishing the key causation in AMD-affected environments is challenging, requiring pressure-stressor-ecosystem response relationships to be established. Causal relationships are best developed for stressor gradients to establish the level of tolerance and adverse effect thresholds for ecological communities. Such an approach has been used here to develop the classification system using baseline chemical and biological monitoring data for streams draining the ESE, MFS and UWHR sub-areas.

Many of the Buller Plateaux streams are naturally acidic from rainfall with a low mineral input from the rocky catchments. Additional natural acidity input to streams comes from the dissolved organic matter (DOM) production of humic and fulvic acids derived from plant leaf-litter in the catchment. The composition and concentration of the humic and fulvic acids will differ with vegetation type (Holland et al., 2018), with the nature of this DOM affecting the binding of metals and potential

toxicity reduction. The level of DOM input will establish the natural pH minimum of the stream below the rainfall pH. The catchments with native bush cover have “brown water” streams with a level of organic enrichment which is operationally measured as DOC concentrations.⁷

Additional acidity input to streams is generated from AMD inputs from historic and contemporary mining areas (see Appendix A maps for locations). The oxidation of sulphide minerals (exposed to weathering processes as a consequence of mineral excavation processes) results in additional acidity with increasing sulphate concentrations in the AMD-affected streams. The AMD also adds metal contaminants to the streams with elevated concentrations resulting in adverse toxicity effects to aquatic species.

The variable rainfall patterns across the Buller Plateaux lead to highly time variable inputs of AMD from historic mine areas with point and diffuse sources and associated receiving water concentrations, combined with catchment DOM input from leaf-litter decay. The acidity of the rain (normally about pH 5.5, Nichol et al. (1997)) is further increased by the AMD and/or DOM flows into the receiving waters – resulting in a further reduction in pH. The ecology of the Buller Plateaux streams is adapted to the naturally acidic background conditions with associated episodic variability. However, AMD can result in extremely low pH conditions (at times, pH <3) which exceed the physiological tolerance of most aquatic species.

Low pH conditions (<pH 4.5) naturally result in elevated aluminium (Al) concentrations due to solubilisation from aluminosilicates and other minerals. The concentration of ionic aluminium (Al³⁺) is considered the primary ecotoxic form of aluminium. Elevated DOC in brown water streams can reduce the toxicity of the Al³⁺ through binding to the humic and fulvic acid compounds. Both pH and hardness are also TMF which affect Al toxicity (Section 6.1.3).

The biological communities in streams on the Buller Plateaux areas of the proposed ESE, MFS and UWHR sub-areas do not have fish communities due to physical barriers (ESNZ, 2025a). [REDACTED]

[REDACTED]

[REDACTED]

Water quality data and associated macroinvertebrate and kōura data for Buller Plateaux streams is limited. A suite of chemical and biological measures is needed for a gradient of sites covering non-AMD affected reference sites and those with differing levels of existing AMD effects to provide the basis of characterisation of the Buller Plateaux sites for LoP assessment. A limitation for water quality and biological data used for LoP classification is the need for a representative number of samples collected over an extended multi-year period to characterise a site for rainfall/flow and seasonal biological variability. The need for high flow sampling was addressed by use of Storm Water Samplers and associated pressure transducers for stream depth/collection time (Section 6.2.1). Water quality data was limited at some Buller Plateaux sites where a comprehensive range of parameters had not been measured and/or associated biological sampling where sample counts were low at the time of analysis for this LoP classification (Hickey, 2026b) (see Section 6.3). Additional more recent sampling data has been included for background metal concentrations and TMF levels in relation to flow for Waimangaroa River to establish an appropriate LoP classification for that site (see Section 6.2).

⁷ The DOC measurement involves acidification to remove carbonate and bicarbonate and the oxidation of carbon. Low levels of organic carbon should be analysed by dissolved non-purgeable organic carbon (DNPOC) to provide improved analysis of organic carbon.

Many recently derived water quality guidelines incorporate TMFs to derive bioavailability-based thresholds for ecological protection for metals and for some other contaminants. The primary TMFs are:

- pH – which affects the toxicity of metals and ammoniacal-N
- hardness – composed of the concentration of calcium and magnesium ions which competitively interact with biological receptors to reduce toxicity
- DOC – which binds to some metal ions to reduce toxicity – and
- temperature – which affects the toxicity of ammoniacal-N.

The Buller Plateaux waters have naturally very low hardness, effectively increasing receptor susceptibility to metals. Conversely, waters often have elevated DOC, which can reduce metal toxicity. The naturally low pH of Buller Plateaux streams has a variable effect on metal toxicity, with low pH reducing the toxicity of ammoniacal-N to aquatic organisms. Therefore, the interactions with TMFs are a major consideration for Buller Plateaux streams which affect their susceptibility to metal contaminant effects.

5.1.3 Hydrology

River hydrology and discharges

The general hydrology for streams draining the Buller Plateaux is described elsewhere (MWM, 2026g; NIWA, 2024c). Those documents provide stream flows and catchment yields for mine-impacted and reference streams.

Process flow diagrams are provided in Appendix B. These show the configuration of bypass/spill discharges from sumps to receiving waters (dashed lines) – which will occur intermittently, clean water diversions, WTP discharges, inputs from historic underground mine workings (adits) and infrastructure discharge locations for the BPCP stages. Separate process flow diagrams are provided for ESE and MFS with the Compliance and Performance monitoring locations identified.

Specific process flow diagrams are also provided in Appendix B for the post-mining passive treatment stage. Multiple MSRs are proposed over the mine life as water treatment requirements transition from active (using WTP) to passive (using MSR) based on rehabilitation status and water treatment requirements. The receiving waters for the MSRs are shown in Appendix B.

The various clean water diversions, bypass events, and treated water discharges will result in significant differences in median and low flows in some streams during the operational and post-mining periods. These changes in baseflow have been modelled as part of the water load balance model (WLBm) modelling for MFS (MWM, 2026i) and ESE (MWM, 2026k). Modelled receiving water pH and concentrations of hardness and metals are compared with site-specific water quality guidelines (this report, Section 6.1) for an effects assessment.

The predicted proportional changes in flow for compliance sites for baseline and operational stages from the predictive modelling and the hydrological record (MWM, 2026g) are used for risk assessment calculations for contaminant loads for nitrogen (this report, Section 7.2).

Hydrology and flood frequency characteristics

The baseflow and flood-flow characteristics of a receiving water establishes the dilution available for a discharge. The ‘flashy’ nature of Buller Plateaux stream flows with frequent rainfall events are important site-specific characteristics, with the short duration of flood-flow peaks and a rapid flow recession being a basis for using a two-number standards applying to the median and 95th percentile concentrations (Hickey, 2012). A median standard for chronic GV protection applies with a short-term (acute) toxicological no-effect threshold⁸ GV applying to the short-duration peak flow period. The two-number standards approach is comparable with the NPS-FM standards for toxicants (i.e., nitrate-N and ammoniacal-N) (MfE, 2020c). While the NPS-FM standards are generally associated with a monthly monitoring frequency, discrete weekly sampling is proposed for most Buller Plateaux compliance sites for metals, nutrients and TMs, with continuous turbidity monitoring at key sites. This higher frequency of sampling will provide better characterisation of the Buller Plateaux streams for compliance assessment. The rising stage and peak flow condition is when the most elevated concentration of contaminants is expected from catchment runoff and bypass flows associated with sumps but are of short duration in Buller Plateaux streams.

The flow hydrograph for Whareatea River at site WM-2 is shown in Figure 5-1 for a 3.6-year period. This site is located on the Buller Plateaux in the central area of the proposed ESE sub-area (Appendix A, Figure A-1). The cumulative flow duration curve for WM-2 is shown in Figure 5-2 with selected flow statistics summarised in Table 5-1. The median flow for this site is 0.055 m³/s. Hydrographs for the individual years show summer low flows in most years with highest flood events in winter/spring periods (Appendix D).

An analysis was undertaken to characterise the duration of a flood event relative to a range of flow exceedance thresholds. This calculation measures the duration of a flood event – in hours – calculated from the time that the flood exceeds the flow exceedance threshold until the flow recedes through that threshold. The resolution of this duration calculation is limited by the 10-minute logging frequency of the stage height recorder. These data are summarised in Table 5-2 for an annual basis and for the number of events over the 3.6-year period. The analysis showed that most events are of short duration (8- to 12-hours). No events exceeded 48-h for event thresholds >90th percentile (i.e., 1.4 m³/s), with 5 events annually exceeding for the 80th percentile (i.e., 0.42 m³/s) and 17 events annually exceeding for the 70th percentile (i.e., 0.17 m³/s).

The 90th percentile flow exceedance threshold of 1.4 m³/s is shown on the annual flow hydrographs in Appendix C. The hydrographs show that the significant flood events show a rapid onset for this Buller Plateaux stream with a rise from the low flow to the 90th percentile threshold generally in less than 30-minutes. As measured by the analysis, most events are of short duration (Table 5-2), with the rapid rise and fall of the hydrograph evident from the annual plots (Appendix D).

Together these analyses characterise the flashy nature of Buller Plateaux streams, with the short duration of flood events. Runoff of contaminants from catchments and potential bypass / spill events from sumps during high rainfall will result in short-duration exposure periods for receiving water biota. The proposed site-specific receiving water guidelines for contaminants include both chronic (long-term) and acute (short-term, no effect) numeric GV for differing levels of protection. The site-specific guidelines are designed to provide ecological protection for both long-term and short-term

⁸ No-effect threshold-acute = Corresponding to an estimated no-effect or acceptable-effect level; negligible-effect concentrations for acute (short-term) duration tests.

exposures, which is considered to be the appropriate approach based on the local hydrology and the proposed activities. The guidelines are provided in Section 6.1 of this report.

Understanding the flow variability for toxicity modifiers (i.e., DOC, pH and hardness) in receiving waters is also important for site-specific guideline application as marked variation in the modifier concentrations can significantly affect site-specific GVs in a receiving water for many elements. This information is particularly important when high flow discharges of untreated mine influenced water need to be discharged during flood-flow conditions. The effects of toxicity modifiers for background conditions are provided in Section 6.2 of this report.

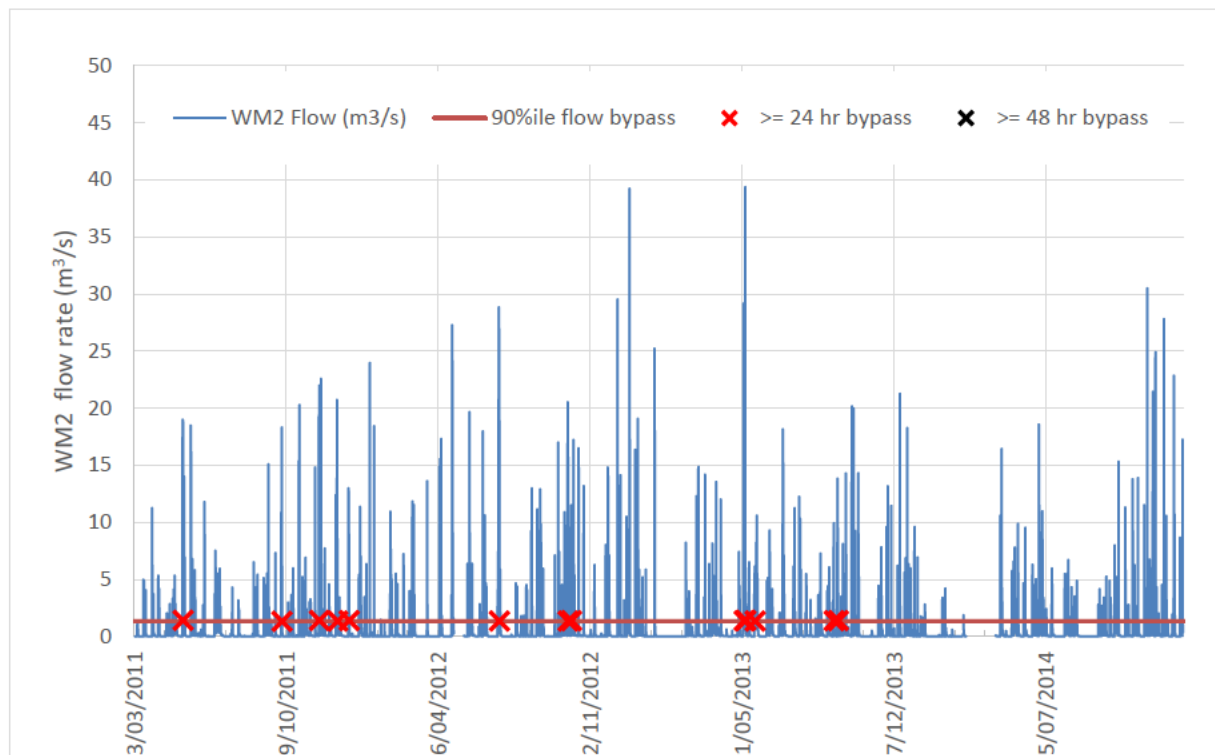


Figure 5-1: Flow hydrograph for Whareatea at site WM-2 for period March 2011 to December 2014 (3.6-years, stage height logged every 10 min). The horizontal line indicates where bypass discharges of mine-impacted water might occur at the 90th percentile flow (i.e., 1.4 m³/s, the flow exceeded 10% of the time), with red x indicating events where flood duration exceeds 24-h, and black x indicating events exceeding 48-h duration (none for this event threshold). The flow duration curve for this site is shown in Figure 5-2 and summarised in Table 5-1. See Appendix A, Figure A-1 for site location.

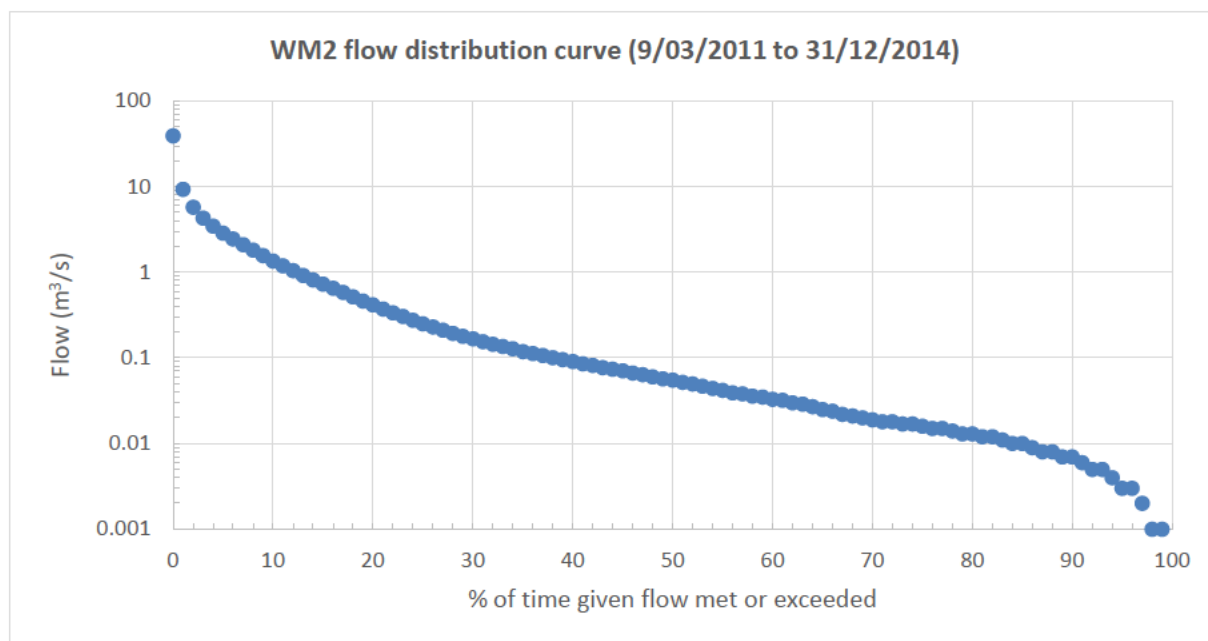


Figure 5-2: Flow duration curve for Whareatea River at WM-2 (ESE sub-project area). Selected flow statistics for this site are provided in Table 5-1. See Appendix A, Figure A-1 for site location.

Table 5-1: Whareatea River at site WM-2 (ESE sub-project area) percentage of time flow met or exceeded (Figure 5-2) and flow non-exceedance thresholds (grey shaded) for calculation of flood event durations (Table 5-2). See Appendix A, Figure A-1 for site location.

	Percentage of time flow met or exceeded (%)					
	2	5	10	20	30	50
Flow non-exceedance threshold (%)	98	95	90	80	70	50
Flow (m ³ s)	5.8	2.9	1.4	0.42	0.17	0.055

Table 5-2: Event durations for different percentile flow non-exceedance thresholds (Table 5-1) on an annual basis and for the 3.6-year analysis period for Whareatea River at site WM-2 (ESE sub-project area). Conditional colour coding indicates lowest events/year as green with gradation to greatest events/year as red. See Appendix A, Figure A-1 for site location.

Period (Hours)	98th %ile Events/Year	95th %ile Events/Year	90th %ile Events/Year	80th %ile Events/Year	70th %ile Events/Year
8	3.1	12	34	71	68
12	1.4	5.6	16	56	61
16	0.6	3.1	10	41	52
20	0.6	2.5	6.1	28	45
24	0.3	1.1	3.6	23	38
36	0	0.3	1.1	11	26
48	0	0	0	5	17
Period (Hours)	98th %ile Total Events	95th %ile Total Events	90th %ile Total Events	80th %ile Total Events	70th %ile Total Events
8	11	44	123	256	245
12	5	20	59	201	220
16	2	11	36	149	186
20	2	9	22	101	163
24	1	4	13	84	137
36	0	1	4	39	94
48	0	0	0	17	60

5.1.4 Continuous monitoring and stormflow sampling

Continuous monitoring data is available for pH, EC and turbidity at a range of sites. The spatial extent and monitoring duration of the continuous instrumentation deployment differs across the Buller Plateaux streams. The limited deployment period for most sites restricts the extent of the flood flow range characterised, with most sites not having data for very high or extreme events. Thus, representative data is unavailable for flood events at many sites and discrete sampling was required to characterise for a larger flow range. Collection of water samples from many Buller Plateaux streams is hazardous for staff access during high rainfall and flood events.

Natural low-flow conditions in the Buller Plateaux streams are characterised by low pH, EC and hardness (Appendix C – from 2012 hearing, Hickey (2012)), which results in significant changes in water chemistry during rainfall events – with pH and EC decreasing during the flood-flow period (see Section 3.3).

Streams receiving AMD inputs also show marked changes in chemistry during rainfall events – with different responses from the non-AMD influenced streams.

Continuous turbidity monitoring has been undertaken historically on some Buller Plateaux streams and was supplemented with more recent deployments in 2024/25 at key sites. The available turbidity monitoring data and derivation of site-specific turbidity guidelines is described elsewhere (Hickey, 2026c) (Appendix C).

Quality control (QC) procedures were applied to the continuous monitoring data. This involved comparison with discrete monitoring data, examination of the background behaviour and peak behaviour over time. The procedures for turbidity and example plots with continuous and discrete data are provided in Hickey (2026c).

Nalgene Storm Water Samplers⁹ were used to supplement routine stream water quality monitoring at key sites (e.g., upper Waimangaroa River) to characterise water chemistry variability (i.e., metal concentrations and TMs) during flood events (see Section 6.2.1). The Storm Water Samplers were deployed at gauging sites at a surveyed height, together with a logging pressure transducer at each site. The time of filling of the Storm Water Sampler was determined from the stage height logger and the stream flow calculated. Multiple Storm Water Samplers were deployed at each site to collect samples over the flood height range.

The Storm Water Samplers bottles are deployed above the water level prior to a storm event, fill with rising stage water once water either flows over them or reaches the intake level when deployed into a stream. They close off by means of a float valve or ball cock, preventing any further water from mixing with the sample. The stoppering system maintains the integrity of the water sample from atmospheric exchange after collection – which could significantly alter pH. The Storm Water samples were analysed for a limited number of constituents: pH, hardness, DOC, sulphate, aluminium, iron (Fe) and manganese (Mn). Trace elements were not analysed in the routine deployments because adequate cleaning procedures and field preservation procedures were not available or practical (i.e., acid preservation would have compromised pH and speciation of Al, Fe and Mn). All results from the Storm Water Samplers are identified in the plots against flow at the monitoring sites (Section 6.2.1).

5.1.5 Potential Constituents of Concern (PCOC)

PCOCs overview

PCOCs are relevant to the changes in concentration/levels which occur in the receiving environment and the duration of the events. The constituents include physico-chemical changes – such as pH and hardness – and chemical contaminants (e.g., metals, nitrate-N, ammoniacal-N) which may result in toxicity to aquatic organisms. Total suspended solid (TSS) include relatively coarse material (e.g., sand/silt) – which may scour the stream bed and very fine non-settling material (silts and clays) which do not settle and are measured as turbidity or as visual clarity (black disk measurements). Increased turbidity can reduce light penetration and hence the photosynthetic production of plants (i.e., bryophytes and filamentous algae) living on the bed of Buller Plateaux streams. This primary production decrease can affect the food chain comprising macroinvertebrate grazers and secondary consumers (e.g., kōura, fish).

⁹ <https://envcoglobal.com/catalog/water/water-quality-sampling/surface-water-sampling/specialty-samplers/i-chem-storm-water/>. See Appendix E (Figure E-1) for Storm Water Sampler photo and see Gadd and Milne (2019) for deployment guidance.

Metal concentration changes become relevant when they result in direct toxicity to aquatic organisms, bioaccumulate in tissue and affect consumers or affect downstream drinking water quality for stock or human consumers. The natural low pH of Buller Plateaux streams results from rainfall and fulvic/humic acids from plant material and causes elevated concentrations of Al, Fe and Mn in streams unaffected by AMD discharges. The local geology also results in elevated concentrations of some trace metals (e.g., zinc (Zn)).

The historic and contemporary AMD discharges result in varying levels of enrichment of metals – including Al, Fe and Mn – together with trace elements. Some adit discharges result in highly acidic (pH <3) waters and major concentration increases for metals.

This assessment specifically covers five scenarios: (i) untreated bypass water; (ii) discharges during construction phase; (iii) treated mine water from WTP; (iv) operational mining and rehabilitation contaminant discharges; and (v) passive treatment MSR discharge water on closure.

5.1.6 Approach used for the existing Escarpment Mine, 2012-2013

The PCOCs were determined in the 2012 hearing by comparing the water quality measured in an uncontaminated reference stream (Conglomerate Stream) with water quality in an Escarpment drainage stream (██████████1) which received very low pH (3.2) from an adit drainage (Hickey (2012), see Appendix C, Table C-2). The major metals increasing >50-times in concentration compared to the reference site were Al, Fe, Mn, nickel (Ni) and Zn. Cadmium (Cd) and cobalt (Co) concentrations increased 24-times and 27-times. Notably, arsenic, boron, chromium, copper, mercury and lead showed minimal concentration increases, or were at analytical levels of detection, and would not be considered contaminants of potential concern based on the composition of the AMD from the existing adit discharge.¹⁰ Leaching trials were also undertaken with overburden from various areas representative of the mine overburden have shown differing mineralogy, which could potentially affect the AMD composition. Those results indicated that dissolved chromium (Cr), copper (Cu) and lead (Pb) may also be elevated in AMD from some areas, and each of these metals can be successfully treated using the proposed treatment system. On that basis I also included Cr, Cu and Pb as potential constituents of concern.¹¹ That assessment process established the PCOCs for the 2013 consent (Appendix C).

The 2012 assessment identified five trace metals from the Escarpment drainage adit discharge (site WQGS1 to V37 Creek) which were markedly elevated compared with the analytical detection limit values in the reference stream (i.e., Cd, Co, Ni, Mn and Zn), in addition to Al and Fe which are present at high concentrations. Four of these are essential elements for biological growth (i.e., Co, Ni, Mn and Zn) and are vital components in many metalloenzymes, with only Cd a non-essential element. While essential for biological growth at low concentrations these metals may cause adverse effects at high concentrations. The PCOCs assessment process for the 2012 hearing did not determine receiving water concentrations from treated mine water. As such, the PCOCs assessment did not identify the ecosystem risk based on the element concentrations in the receiving water. Additionally, while the Conglomerate Stream has a natural mean pH of 4.9 (range 4.7-5.2) the adit affected Escarpment drainage stream had a significantly lower mean pH of 3.0. This acidifying of the stream by the adit would have resulted in dissolution of minerals from the stream bed – as evidenced by the

¹⁰ Hickey (2012) EIC paragraph 35.

¹¹ Hickey (2012) EIC paragraph 36.

100-times increase in the calcium concentration – and would not be considered a reliable indicator of treated mine water.

The 2013 Escarpment Mine consent conditions and the supporting evidential PCOCs analysis summary tables are provided in Appendix C.

5.1.7 Approach for Buller Plateaux streams, 2025-2026

The Buller Plateaux streams for this assessment now include a larger spatial area which includes different geologies in the MFS and UWHR sub-areas. The existing Escarpment Mine monitoring has provided site-specific data for rehabilitated ELFs and other contaminant risks associated with the uses of ammonium-nitrate fuel oil (ANFO) explosives for overburden removal and mining (MWM, 2026f). Based on this assessment there are guidelines and monitoring recommendations for nitrogen which includes potential nitrogen inputs from ANFO, fertiliser and treated discharge water (Hickey, 2026e) (see Section 5.1.7).

Additionally, a site-wide review of the water quality monitoring data provides a broad spatial background for existing water quality conditions (MWM, 2026j). That assessment covered the monitoring sites shown in Appendix A (Figure A-1) and calculated metal ecotoxicity quotients (MEQs)¹² were used in this report to identify PCOC that may be elevated with respect to water quality guidelines, compliance limits, or trigger values¹³.

Mine Waste Management (MWM 2025c) compared maximum measured concentrations with screening criteria, including the existing Escarpment Mine Project water quality limits for the Whareatea River (RC10193), ANZG (2018) 95% protection default guideline values (DGVs) and NPS-FM standards for nitrate-N and ammoniacal-N (MfE, 2020c). No hardness modifications were applied to collected data as this was conducted as a screening assessment to determine PCOC in the existing background water quality.

MWM (2026j) identified elevated zinc concentrations in the proposed MFS sub-area because of different geology. The locations of historic mining areas are broadly known (see Appendix A, Figure A-3) together with major discharges from underground mine adits. Some sites, like the Waimangaroa River at Smokestack site and upstream, have relatively low levels of historic AMD inputs. However, some sites in smaller streams downstream of adits are highly acidic and have high metal concentrations (e.g., Cascade Stream, Rapid Stream). Such sites are not amenable to implementing protective water quality guidelines because of the existing severity of ecological impacts – with their management being based on a “Betterment” approach to measure improvement trends over time.

The WLBM provide the primary approach for predicting contaminants concentrations in receiving waters. These models utilise GoldSim to provide predictions of receiving water concentrations of contaminants and TMs (i.e., pH, hardness, DOC). Their input data (source terms) includes monitoring data from Stockton monitoring of sumps (MWM, 2026c), treatment trial WTPs (Process Flow, 2025) and intensive process monitoring of BV ELF seepage and MSR discharges from the existing Escarpment Mine (MWM, 2026f). WLBM have been developed for ESE (MWM, 2026k) and

¹² The MEQ value for a PCOC is determined by dividing the measured maximum concentration by the WQ GV. MEQ values greater than 1 indicate parameters that exceed the relevant WQ GV. Conversely, MEQ values less than 1 are below the relevant WQ GV. If any PCOC are within 50% of the WQ GV (i.e., MEQ ≥ 0.5) they are considered elevated (and are noted as being elevated) and ongoing monitoring is recommended to confirm trends and/or potential hazards. This approach is similar to using 50% of maximum acceptable value (MAV) for drinking water standards where it is used as a screening level for follow up action.

¹³ “Trigger values” was a term applied to water quality guidelines in ANZECC (2000). The term has now been replaced by guideline values (GV) in ANZG (2018).

MFS (MWM, 2026i) with hydrological modelling based on a “typical” rainfall year (2019), a “wet year” (2022) and using stochastic rainfall – a synthetic long term record that includes more multi-year cycles / variability. The WLBM integrates the complex hydrological transfers of sump and clean water, bypass discharge from sumps and WTP discharges to multiple streams. The WLBM calculates concentrations of contaminants in the receiving waters and MEQ values for the bioavailability guidelines incorporating the TMF levels (Section 6.1). The MEQ values are also calculated as cumulative frequency distributions for each compliance site so that the contaminant exposure risk can be assessed.

The Process Flow diagrams in Appendix B show the water transfers, bypass discharge and WTP locations together with the receiving water reference sites and compliance locations.

A classification scheme was developed using chemical and biological monitoring data to categorise the ranges of effect measures for the streams to establish appropriate LoPs. The approach used a weight-of-evidence (WOE) approach to integrate the environmental measures. That approach was used to determine the appropriate narrative and numeric classification for the level of protection (Hickey, 2026b). Most compliance sites which will receive mine discharges have a “Good” classification and are recommended for 95th percentile levels of protection (LoP). The upper Waimangaroa River with historic AMD inputs has a “Fair” classification and is recommended for an 80th percentile LoP for compliance associated with MFS discharges, with one site receiving ESE discharges on MM1 on V8 Creek also recommended for 80th percentile protection because of the high AMD input. Those with very high AMD are depauperate and classified as “Severely Impacted” are not considered suitable for ecological protection guidelines and are proposed for “Betterment”. This classification approach is addressed in Section 6.3.

5.1.8 Guidelines for metals

Bioavailability guidelines - background

The suite of guidelines as consented for the existing Escarpment Mine relating to discharges to the Whareatea River (RC10193) were from Hickey (2012) evidence and are provided in Appendix C.

The Whareatea River conditions were based on a two-number system for proposed compliance. The median GVs were for long-term (chronic) protection and 95th percentile values were for short-term (acute) low/no-effect exposures. The basis for this derivation was the high flow variability of the Whareatea River – with peak flow events of short duration. The hydrological flow data was presented in evidence at the hearings (Hickey, 2012). As discussed in Section 5.1.3, above, this local hydrological regime remains relevant and has been applied in the current assessment for the BPCP.

The ANZG derives only chronic (long-term) protection guidelines (called “trigger values” in ANZECC (2000) and now termed Default Guideline Values (DGV)). Those values provided the median compliance values for the Whareatea River (RC10193), with hardness standardised to 50 mg CaCO₃/L. The 95th percentile compliance values for the Whareatea River (RC10193) came from the contemporary US EPA criterion maximum concentration (CMC) values – with hardness adjustment where appropriate.

All the GVs for the Whareatea River (RC10193) were to provide a 95% protection threshold considered appropriate for that river. This is considered appropriate for ANZG narrative descriptor of ‘slightly to moderately disturbed’ systems and is the usual GV applied to waterways with some level of human and catchment disturbance.

Two sets of compliance limits were proposed and consented based on median pH, with category limits for pH >5.5 and pH <5.5 to account for receiving water pH differences. The pH dependent limits were based on Biotic Ligand Model (BLM) predictions for a pH value of 5 for the pH <5.5 category and a pH value of 6.5 for the pH >5.5 category (Hickey, 2012).

Overall, there was a pH range limitation for the receiving water of 4.5-6.5 for the clear-water (i.e., low humic content) associated with the Whareatea River. The upper bound for the pH in the naturally acidic Whareatea River was recommended (and consented RC10193) to provide conditions suitable for continued growth of mosses (bryophytes) in the receiving water downstream of the existing Escarpment Mine treated mine water discharge.

The standards incorporated a hardness adjustment guideline for metals which have modified toxicity with hardness. This was for a single nominal hardness level of 50 mg CaCO₃/L. The routine treatment for AMD is to increase the pH with lime addition which increases both the pH and the hardness. The degree to which this treatment can be implemented is limited by the upper pH bound of 6.5. The pH of many West Coast streams is influenced by DOM leaching from leaf litter and reducing the pH below 4.5. These acidic brown water streams have naturally different water quality characteristics, with the elevated DOM concentrations providing protection from potential toxicological effects of metals and supporting diverse macroinvertebrate (Collier and Winterbourn, 1987; Winterbourn and Collier, 1987) and fish (Greig et al., 2010) communities. Thus, brown water streams with elevated DOM require different water quality guidelines than clear water streams.

Bioavailability guidelines – approach, BPCP

Chronic guidelines

The most recently derived WQGs were used from ANZG or Environment Canada, where an appropriate ANZG WQG is currently unavailable (e.g. cobalt (Co)) to provide site-specific chronic guidelines. Many metals (Al, Cu, Co, Mn, Zn) include one or more TMFs (pH, hardness, DOC) with multiple linear regression (MLR) equations providing toxicity relationships with the modifiers.

Most of the new bioavailability guidelines for metals incorporate one or more TMFs which affect the sensitivity of freshwater organisms to the dissolved metal. The advantage of incorporating TMF relationships are that they provide for changes in toxicity associated with TMFs for upstream conditions and for treatment modifications. A MLR-relationship limitation for pH and hardness are that these do not extend down to the low pH and hardness levels¹⁴ found in the natural Buller Plateaux waters (Hickey et al., 2017). The guidance for application of the GVs is that the lowest TMF range values are used as the site-specific GV. Laboratory toxicity testing has been undertaken with key native invertebrate species to test sensitivity to metals and treated mine water at a range of pH levels and using natural Whareatea River dilution water (Section 5.3).

A chronic cobalt guideline from Environment Canada (CCME, 2017) has been used and should be considered an interim guideline. This Canadian derivation incorporates chronic sensitivity data for 13 species and a hardness modifier. The ANZECC (2000) guidelines provided only an interim “low reliability” guideline.¹⁵ A comprehensive review of Co toxicity has recently been undertaken (Stubblefield et al., 2020) and revised guidelines are being developed following US EPA and

¹⁴ Range (10th and 90th percentiles) for New Zealand freshwaters: pH, 7.2-8.2; Ca, 4.2-17.4 mg/L; Mg, 0.7-3.6 mg/L; hardness 16-56 mg CaCO₃/L; DOC 0.35-10.5 mg/L (Table 2-1 from Hickey et al. 2017).

¹⁵ A “low reliability” freshwater trigger value was derived by dividing the lowest chronic figure (2.8 µg/L) by an AF of 2 (cobalt is an essential element)” (section 8.3.7, ANZECC 2000).

international methodologies. These updated guidelines will include MLR relationships for bioavailability toxicity prediction (W. Stubblefield, Oregon State University, pers comm).

ANZG is in the review process for updated Ni and Zn guidelines for freshwater, but the numeric thresholds have not been finalised. The Ni and Zn ANZG guidelines and the forthcoming Co guidelines – each with TMF relationships – are recommended to be reviewed as a part of the 6-year review of compliance chemistry and biological monitoring data for ecological protection for this the BPCP.

An index condition is calculated for guideline equations to provide a benchmark for comparing numeric values from predictive equations. The normal suite of TMFs for the index condition are pH 7.5, hardness 50 mg CaCO₃/L and DOC of 0.5 mg/L. A site-adapted index condition using TMFs pH 7.0, hardness 50 mg CaCO₃/L and DOC of 3.5 mg/L (the average for Whareatea River at WM-2 (Appendix C), are used for the summary table to provide a representative suite of potential post-treatment GVs with the differing LoPs (Table 6.3).

Differing levels of protection

Effect thresholds for ANZG have a range of LoPs which correspond to narrative protection levels and calculated numeric thresholds. This approach is designed to provide protection levels suitable for application to environments with differing levels of anthropogenic influence.

The numeric thresholds are statistically calculated from the species sensitivity distribution (SSD) for each contaminant. The range of protection levels calculated are: High, 99% protection; Slightly to moderately disturbed, 95% protection; Highly disturbed, 90% and 80% protection. These differing LoPs are not calculated in other international jurisdictions who only provide the equivalent of 95% protection.

The chronic sensitivity data from Environment Canada were uploaded and used to recalculate thresholds for differing LoPs for four metals (Al, Cd, Co and Mn) following the most recent guidance for model averaging SSDs (Warne et al., 2025).¹⁶ An adjustment ratio of the model-calculated 95% protection threshold to 90% and 80% protection thresholds was used to generate modified equations for the TMF relationships. This approach maintained the original Environment Canada 95% protection and the predictive MLR relationships.

Acute guidelines

Guidelines for protection from short-term (acute) exposures to toxicants are only provided by two jurisdictions. The US EPA calculates the Criterion Maximum Concentration (CMC) values from acute toxicity data (e.g., EC/LC50 concentrations) based on the 5% effect value from the SSD and application of an assessment factor of 2 to convert acute toxicity values to chronic “no effect” toxicity values for all metals. Environment Canada calculates “short-term” benchmark values from the acute toxicity data (e.g., EC/LC50 concentrations) for defined short-term exposure periods (e.g., for Zn, CCME 2018a,b). These benchmarks are estimators of severe effects to the aquatic ecosystem and are intended to give guidance on the impacts of severe but transient situations, such as spill events and infrequent releases of short-lived or non-persistent substances. Short-term benchmark concentrations do not provide guidance for protective levels of a substance in the aquatic environment, as they are levels that do not protect against adverse effects. ANZG does not provide acute GVs for ecosystem protection for any toxicants.

¹⁶ <https://bcgov-env.shinyapps.io/ssdtools/>

Short-term GVs for Cu and Zn have recently been derived for New Zealand freshwaters following the ANZG procedures (Gadd et al., 2024). As Cu and Zn bioavailability and toxicity to aquatic organisms is influenced by water chemistry (e.g., pH), these acute GVs must incorporate the use of models that consider the difference in metal bioavailability under different water chemistry conditions. Use of a single GV for each metal could result in GVs that are under-protective in some locations, but overly conservative in others. These “no-effect” acute GVs include sensitivity data for a range of native New Zealand species. These acute GVs are normalised to an index condition (pH 7.5, hardness 50 mgCaCO₃/L, DOC 0.5 mg/L) and both Cu and Zn acute GVs have TMF relationships with pH, hardness and DOC. These acute GVs provide thresholds for short-term peak concentration exposures for protection of native species.

Acute no-effect thresholds are not available for other metals. The ratio of the acute no-effect threshold to the chronic value for the index condition in the derivations for Zn was used to estimate the acute thresholds for other metals (Section 6.1, Appendix F).

There was no acute sensitivity data available for Al. Given the complex speciation behaviour of Al in relation to pH, and other toxicity modifiers, the use of just chronic compliance thresholds for pH ≤6.5 and TMF relationships for pH >6.5 is considered appropriate as a site-specific approach. The natural flow variability during rainfall events generates short-term low pH events (see Section 3.3) and dissolved Al concentration increases during these events, together with marked changes in TMF concentrations (i.e., DOC, see Section 6.2.1). Thus, the natural background in these streams results in short-term exposures to high dissolved Al concentrations – to which the local species are adapted. The level to which the local species are tolerant of short-term elevation of dissolved Al concentrations – particularly if co-associated with increased hardness and/or DOC concentrations – is not known.

Alumnion™ is a proprietary measure of bioavailable Al which has been shown to relate well to change in EPT taxa richness¹⁷ in acidic/high Al streams around the Stockton Mine (Waters and Webster-Brown, 2013). Further use of the Alumnion™ test in conjunction with chemical and biological monitoring is recommended to assess the utility of the test for improved bioavailable Al measurement. Validation of the Alumnion™ chemical measurement method is required for a range of Buller Plateaux waters with elevated Al concentrations and differing TMF levels together with site macroinvertebrate community monitoring. The use of the Alumnion™ test could provide an improved site-specific method for establishing chronic limits for Al in these waters.

The approach used for deriving GVs for each metal is summarised in Section 6.1 with details provided in Appendix F. The chronic GVs are proposed for application to median monitoring data and the acute GVs for application to the 95th percentile of monitoring data (Section 9).

5.1.9 Guidelines for nitrogen

The nitrogen effects assessment considered three potential sources of dissolved nitrogen which may be elevated in Buller Plateaux receiving waters because of BPCP activities (Hickey, 2026e).

These include:

1. Runoff from nitrogen-based explosives used for mining.
2. Nutrients from treated sewage discharge disposal areas.
3. Nutrients from fertiliser applied as part of the remediation and revegetation.

¹⁷ E = Ephemeroptera, mayflies; P = Plecoptera, stoneflies; T = Trichoptera, caddisflies.

Nitrate-N

The assessment is based on nitrate-N toxicity for potential adverse ecological effects and for stock and human drinking water consumption. The assessment does not consider potential downstream eutrophication effects because those effects are assessed by Hogsden and Jellyman (2026).

The concentration of nitrate-N has not been measured routinely. A limited number of measurements in the Whareatea River (site WM-2) have shown consistently low concentrations (average 0.054 mg/L, range 0.005-0.20 mg/L, n=4) for pH 4.9 water (Bathurst database). The total nitrogen concentration measured for two occasions was 0.19 mg/L and 0.071 mg/L with the nitrate-N accounting for 3% and 7% of the TN, with ammoniacal-N accounting for 16% and 28% (see below) for those occasions. This large difference is likely to be dissolved organic nitrogen associated with leaf-litter decay from catchment vegetation (McGroddy et al., 2008).

For the assessment, predicted concentrations from catchment mine discharges (MWM, 2026f) are compared with the recently updated Australian and New Zealand Guidelines (ANZG) for nitrate-N ($\text{NO}_3\text{-N}$) – which are hardness-dependent (ANZG, 2025a), and the NPS-FM standards for nitrate (MfE, 2020c) after receiving water dilution (Hickey, 2026e).

The ANZG (2025a) guideline values are: (i) for 95% protection in low hardness waters are 1.1 mg/L for hardness <30 mg/L as CaCO_3 , 2.6 mg/L for 30-150 mg/L hardness and 29 mg/L for >150 mg/L hardness; and (ii) for 90% protection in low hardness waters are 1.5 mg/L for hardness <30 mg/L as CaCO_3 , 4.2 mg/L for 30-150 mg/L hardness and 38 mg/L for >150 mg/L hardness.

The 95th percentile LoP is proposed for Whareatea River (at KEL), Deep Stream (at SW01 and SW03) and Rapid Stream (at W07), with an 80% LoP proposed for Waimangaroa River (at Smokestack, 2W and downstream of Deep Stream, 17W).

The NPS-FM has “bottom line” standards for nitrate-N of an annual median of 2.4 mg/L and an annual 95th percentile of 3.5 mg/L (MfE, 2020c). The more sensitive of these standards represents the controlling statistic.

Drinking water standards also include nitrate as a PCOC (NZ Government, 2022). The drinking water standard (11.3 mg/L nitrate-N maximum concentration) would be applicable to any downstream take from surface waters. There have been no authorised drinking water takes identified from the Waimangaroa River, Whareatea River, Rapid Stream, V62 Stream, or Cascade Creek (MWM, 2026g).

Ammoniacal-N

The concentration of ammoniacal-N has not been measured routinely. A limited number of measurements in the Whareatea River (site WM-2) have shown consistently low concentrations (average 0.018 mg/L, range 0.005-0.030 mg/L, n=3) for pH 4.9 water (Bathurst database). The total nitrogen concentration measured for two occasions was 0.19 mg/L and 0.071 mg/L with the ammoniacal-N accounting for 16% and 28% of the TN, with dissolved inorganic N (i.e., ammoniacal-N + nitrate-N) accounting for 18% and 35% of the TN.

The ANZG have recently been updated for ammoniacal-N ($\text{NH}_4\text{-N}$) – which are pH- and temperature-dependent (ANZG, 2026c), and the NPS-FM standards for ammoniacal-N which are pH-dependent (MfE, 2020c). The toxicity of ammoniacal-N increases as pH increases.

The ANZG (2026c) guideline values for pH 7 and 15°C: (i) for 95% protection 1.2 mg/L; (ii) 90% protection 2.0 mg/L and (iii) 80% protection 3.6 mg/L. The GV tables for TMF adjustment for pH and temperature are provided in Appendix F (Tables F-30 to F-32). The index condition used above is the maximum pH and approximate average temperature for Buller Plateaux streams.

The NPS-FM has “bottom line” standards for total ammoniacal-N of an annual median of 0.24 mg/L and an annual 95th percentile of 0.40 mg/L (at pH 8 and 20°C) (MfE, 2020c). The more sensitive of these standards represents the controlling statistic for the freshwater management unit (FMU). The NPS-FM standards are pH-dependent with adjustment factors (AF-TMF) provided in Appendix F (Table F-33) (MfE, 2018).

There are no stock water guidelines or human drinking water standards for ammoniacal -N (Section 8.3.2), so no assessments are required from monitoring data from Buller Plateaux compliance sites or SH67 monitoring.

MWM (2026f) concluded that while nitrate concentrations from BV ELF were low, that there is a risk that construction of the ELFs may generate sub-oxic conditions that may convert nitrate to ammoniacal nitrogen. Based on this assessment, future compliance monitoring should also include ammoniacal-N and the associated TMFs (i.e., temperature and pH) because of the potential increase in stream concentrations from future mine-related discharges.

5.1.10 Guidelines for turbidity and suspended solids

Site-specific water quality protection levels for turbidity linking biological condition with water quality were developed for streams draining the ESE, MFS and UWHR sub-areas (Hickey, 2026c). The site-specific guidelines require both acute guidelines – to cover short-term bypass events and construction activities – and chronic guidelines for longer duration WTP discharges and mining activities. Guidelines for limits derivation are based on ecological effects on fish and macroinvertebrate protection.

Additionally, an assessment is required for visual aesthetic effects for amenity values in the vicinity of the SH67 where most human interaction occurs. This assessment is based on the change in visual clarity of the waters from the background condition. This assessment either requires site-specific clarity measurements or use of conversion factors (termed CF-clarity) from other measures of total suspended solids (TSS) or turbidity. The aesthetic effect thresholds are based on an add-to-background for a site. A swimming suitability assessment is also potentially relevant for all SH67 sites, with the threshold based on a single visual clarity range threshold.¹⁸

The species sensitivity review and development of guidelines for turbidity is provided in Hickey (2026c) and receiving water guidelines presented in Section 7.1.

5.2 Exposure assessment for potential constituents of concern (PCOC)

5.2.1 Metals

A cumulative assessment is required of potential ecological effects in Buller Plateaux streams with integration of three metal concentration and mass load components: (i) background; (ii) sump bypass

¹⁸ ANZECC (2000) guidelines for Recreational Water Quality and Aesthetics recommend: ““To protect the visual clarity of waters used for swimming, the horizontal sighting of a 200 mm diameter black disc should exceed 1.6 m”. This is to ensure swimmers can see hazards and estimate depths and is based on the earlier MfE (1994) publication.

discharges; and (iii) WTP discharges. In addition to the metal concentrations the TMF levels are needed for the receiving water.

For most sites the 95% LoP is recommended for compliance for chronic and acute no-effect guidelines. However, an 80% LoP is recommended for the upper Waimangaroa River (Section 9.2) because historical mine discharges elevate upstream background concentrations, precluding the practical application of a 90% or 95% LoP at this site. The compliance with the acute and chronic GVs will be assessed based on differing sampling frequencies on an annual basis with TMF adjustment for each sampling occasion (Section 9.2.2).

The WLBM for ESE and MFS predict the integrated metal and TMF levels in the receiving waters and provide cumulative exceedance predictions for various mining stages with MEQ calculation for likelihood of toxic effects (MWM, 2026i; 2026k).

5.2.2 pH

The previous pH range for the existing Escarpment Mine discharge to the Whareatea River (RC10193) was 4.5-6.5, based on maintaining bryophyte communities (Hickey 2012).

A recent survey of the distribution of bryophyte species in Buller Plateaux streams (NIWA, 2025c) was used to refine tolerance limits for these plants (Hogsden and Hickey, 2025). A pH range of 4.5-7.0 – for compliance 95% of the time – is recommended based on those studies for all Buller Plateaux sites except for site MM1 on V37 Creek.

The WLBM for ESE and MFS predict the pH downstream of the mining activities.

5.2.3 Suspended sediment and turbidity

Site-specific protection thresholds for acute and chronic exposures to turbidity were derived by Hickey (2026c), and use an add to background calculation.

The WLBM for ESE and MFS predict the total suspended solids (TSS) concentrations downstream of the mining activities. A conversion factor (CF-clarity) for TSS to turbidity was applied, based on a site-specific relationship between TSS and turbidity developed from local monitoring data from Stockton Mine (MWM, 2026c). The WLBM predict turbidity at compliance locations (see Appendix A, Figure A-3).

5.2.4 Nitrogen

The combined effects of runoff from nitrogen-based explosives used for mining, nutrients from treated sewage discharge disposal areas and nutrients from fertiliser applied as part of the remediation and revegetation process was calculated for potential concentration increases in streams and for toxicity thresholds (Hickey, 2026e).

That assessment showed that the nitrogen-based explosives used for mining were likely to be the strongest contributor to nitrogen concentrations, based on the BV ELF load model (MWM, 2026f).

The summary of findings from that assessment are integrated into the overall effects assessment (Section 7.2).

5.3 Toxicity Assessment

5.3.1 Laboratory toxicity testing methods

Toxicity testing was conducted by the National Institute of Water and Atmospheric Research (NIWA, now Earth Science New Zealand, ESNZ) in Hamilton. This section describes the test design and methods with the results presented in Section 8.1.

Kōura sensitivity testing

Testing was undertaken with freshwater crayfish (kōura, *Paranephrops planifrons*) measuring acute and chronic endpoints with juvenile kōura (NIWA, 2025f). Kōura were chosen for this testing as they are key species in Buller Plateaux streams where fish are absent because of physical access barriers (Hogsden and Jellyman, 2026).

The objectives of the study were:

1. Measure acute and chronic toxicity of a representative mine water sample to a key native freshwater invertebrate species – crayfish, kōura.
2. Measure the survival and growth of juvenile kōura in the low pH (~pH 5.5) and low hardness Whareatea River water from upstream of the proposed ESE water discharge.
3. Determine the effect of different pHs – which affect the chemical characteristics and biological availability of metals – in mine water diluted with Whareatea River water.
4. Compare the toxicity of a treated mine water sample (i.e., high hardness, elevated pH) with a range of pH buffered mine waters.

The testing was undertaken in March/April 2025 using juvenile kōura laboratory hatched from adult females sourced from Lake Tarawera.¹⁹

The dilution water used was from Whareatea River (site WM-1) with test samples comprising Untreated Inflow (BV (Barren Valley) ELF MSR Inflow) and Partially Treated Inflow (BV ELF MSR Inflow – CaO Treated to pH 6.5). This is AMD seepage from an ELF already in place at ESE and is considered to be representative of future mine water seepage for the project.

The pH of test waters was adjusted to three buffered pH levels (pH 7.5, 6.5 and 5.5) and to unmodified partially CaO Treated Inflow water. The buffer strength was 500 mg/L using HEPES for pH 7.5, PIPES for pH 6.5 and MES for pH 5.5 (Good et al., 1966).²⁰ Additional controls were dechlorinated tap water (source Hamilton City Council – NIWA control water) and the test water used to prepare the dilutions (WM-1 Whareatea River (buffered and unmodified)). For the unmodified testing, no buffer was added to the CaO Treated MSR Inflow sample or WM1 Whareatea River dilution water.

Four days prior to test initiation kōura were gradually acclimated from laboratory water to the test dilution water (buffered HEPES, PIPES, and MES or unmodified). This was achieved by sequentially

¹⁹ Juveniles were required for testing. Multiple egg-bearing females are collected maintained in laboratory conditions for hatching and initial rearing of juveniles. These juveniles were adapted to the reference dilution water prior to test initiation. It is not practical to collect gravid females from plateaux streams to provide sufficient numbers of juveniles needed for testing.

²⁰ MES (2-(N-morpholino) ethanesulfonic acid), *pKa* 6.1, buffer range pH 5.5–6.7; PIPES (Piperazine-1,4-bis(2-ethanesulfonic acid)), *pKa* 6.8, pH range 6.1 – 7.5; HEPES (4-(2-Hydroxyethyl)piperazine-1-ethanesulfonic acid, N-(2-Hydroxyethyl)piperazine-N'-(2-ethanesulfonic acid)), *pKa* 7.5, pH range of 6.8 to 8.2.

exposing the kōura to a higher concentration of test dilution water e.g., day 1, 25%; day 2, 50%; day 3, 75%; and day 4, 100% test dilution water.

Details of the test method and results are provided in NIWA (2025f).

Mayfly and alga sensitivity testing

ESNZ undertook chronic ecotoxicity testing to two freshwater species, a green alga (*Raphidocelis subcapitata*²¹ 72-hour growth test) and a mayfly nymph (*Deleatidium* sp., 14-day survival test)(ESNZ, 2025b) (Appendix I). The testing was undertaken for two metals (Co and Ni) because they had been highlighted as particular PCOCs from the WLBM and/or initial screening assessment of background monitoring data and sensitivity information was absent for these native species. The study design used natural Whareatea River water (i.e., low pH) and both pH and pH and hardness-modified mine water. This testing provided sensitivity site-specific information for low pH and hardness outside of the range normally used for standard laboratory testing.

Toxicity testing was undertaken with two chemicals, Co and Ni, using supplied Whareatea River water (site WM-1), both ‘unmodified’ (buffered and pH adjusted) and ‘modified’ (hardness and pH adjusted) for the chemical dilutions and as controls. The ‘unmodified’ Whareatea River water was buffered with MES to ensure maintenance of target pH (pH 5.5) throughout the testing duration. The ‘modified’ Whareatea River water was hardness adjusted with CaO and adjusted to pH 7.5 as required for testing. In addition to the chronic 14-day endpoint, mayfly nymph survival was also evaluated at two acute endpoints, 48 and 96 hours (2- and 4-days respectively), throughout the chronic mayfly tests.

For the “unmodified” tests, buffered Whareatea River water was used as the diluent (hardness 3.9 mg/L CaCO₃; DOC 2.6 mg/L). Buffer was added to maintain the pH, as algal metabolism and aeration within the mayfly test were likely to cause an increase in pH. MES buffer (Sigma M8250), which has a useful buffering range of pH 5.5-6.7 and does not form complexes with most metals,²² was added at 0.5 mM (97 mg/L) to half of the supplied Whareatea River water and the pH adjusted to the target level, 5.5 ± 0.1 units.

For the “modified” tests, the remainder of the supplied Whareatea River water was hardness and pH modified prior to use. The hardness was adjusted to a target 66 mg/L as Ca (as for a preceding toxicity study with kōura²³; 158 mg/L required – see results) using supplied CaO as used for mine treatment. The pH was adjusted to the target pH level, 7.5 ± 0.1 units.

²¹ Formerly known as *Selenastrum capricornutum* and *Pseudokirchneriella subcapitata* (Nygaard et al. 1987). Nygaard, G., Komárek, J., Kristiansen, J., Skulberg, O.M. (1987 '1986') Taxonomic designations of the bioassay alga NIVA-CHL 1 ("*Selenastrum capricornutum*") and some related strains. Opera Botanica, 90: 1-46, 35 figs, 9 tables.

²² Cardwell, A.S., Rodriguez, P.H., Stubblefield, W.A., DeForest, D.K. and Adams, W.J. (2023), Chronic Toxicity of Iron to Aquatic Organisms under Variable pH, Hardness, and Dissolved Organic Carbon Conditions. Environ Toxicol Chem, 42: 1371-1385. <https://doi.org/10.1002/etc.5627>

Stauber, J., Golding, L., Peters, A., Merrington, G., Adams, M., Binet, M., Batley, G., Gissi, F., McKnight, K., Garman, E., Middleton, E., Gadd, J. & Schlekert, C. (2021) Application of Bioavailability Models to Derive Chronic Guideline Values for Nickel in Freshwaters of Australia and New Zealand. Environmental Toxicology and Chemistry, 40, 100-112.

²³ Thompson, K., Shepherd, A. (2025) Kōura ecotoxicity testing for mine wastewater samples at various pH levels. NIWA Client Report, 2025202HN: 80

5.4 Characterisation of Potential Adverse Effects

5.4.1 Discharge points and receiving water prediction and compliance

Locations for sump bypass and WTP discharges and proposed compliance sites are shown in the process flow diagrams (Appendix B), with stream and discharge locations in maps in Appendix A.

For most Buller Plateaux sites a 95% LoP is recommended for metals with incorporation of TMFs, with specified exceptions for Al and Fe. However, for the Waimangaroa River, with upstream AMD inputs an 80% LoP is recommended for downstream sites. The monitoring data shows high background variability of metals (mainly Al and Zn) and TMFs with MEQs sometimes exceeding the 90% LoP for multiple metals (see Section 6.2.1). Background chronic MEQ/flow relationships for Waimangaroa River show frequent low flow exceedances of the 90th percentile LoP for Zn, Cd and Co (by up to 2.2-fold) – occasionally Al – with only Al exceeding the 80th percentile LoP (Figure 6-5). Those Al exceedance events generally occur at low flows. The proposed compliance for downstream discharge to Waimangaroa River is 80th percentile LoP. Details of the LoP classification for compliance are provided in Section 6.3.

There is currently a limited understanding of the flow variability of metals and TMFs in the Waimangaroa River. Thus, no predictive quantitative flow relationships with TMFs have been developed for use in WLBM as upstream input conditions. The WLBM provide predicted concentrations and calculated MEQs for contaminants at the compliance sites using constant concentration terms and mass loads of constituents which allows pH and hardness calculation for discharges (MWM, 2026i; 2026k). The TMF variability is marked in the upper Waimangaroa River associated with historic and contemporary AMD inputs. This data is presented in Section 6.2.1. The relationships for the receiving water guidelines are provided in Section 6.1 and examples of WLBM predictions provided in Section 8.2.

For turbidity the models predict downstream levels on an add-to-background approach relative to the upstream or reference site condition for median and 95th percentile and/or continuous monitoring statistics (Hickey, 2026c). The turbidity assessment and site-specific guidelines are presented in Section 7.1.

5.4.2 Mining stages

The WLBM calculate modelled stream flow distributions for compliance sites for baseline, operations and post-closure periods. These flow distributions, together with mass load and process information, form the basis of the predictive relationships for receiving water contaminant concentrations and TMF levels (pH, hardness, DOC) together with the MEQ calculations.

These calculations were done for a representative rainfall year (2019), a wet year (2022) and stochastic long term rain record – including multiyear climate trends/cycles with a climate change factor included, which together form the basis for their predictions.

The MWM WLBM for ESE and MFS are presented in (MWM, 2026i; 2026k), with effects assessment summarised in (MWM, 2026o; 2026p).

The MWM TMF predictions for ESE and MFS are presented in Section 8.2. These are included here because of their importance for site-specific guideline calculations (Table 6-2). The background variability of the TMFs is presented in section 8.1.3.

6 Receiving water guidelines

6.1 Bioavailable guidelines for metals

6.1.1 Guideline development

Many water quality guidelines have been updated internationally and for the suite of Australian and New Zealand Guidelines (ANZG) since previous assessment for the Escarpment Mine Project in 2013. While the ANZECC/ARMCANZ (2000) and other international jurisdictions (e.g., US EPA, Environment Canada and EU) at that time used only water hardness as a TMFs for metals, the updated guidelines now incorporate additional TMF factors (including pH, hardness and DOC). The updated guidelines with TMF modifiers are termed a “bioavailability” approach in that the guidelines incorporate changes in both metal speciation and organism binding and uptake of metals – which together affect the toxicity of metals in the receiving environment.

The derivation of the bioavailable guidelines involves standardising the toxicity data to an index condition of water quality (i.e., adjusting the reported species sensitivity to an index condition for pH, hardness and DOC). The more complex approach involves using a biotic ligand model (BLM) for this adjustment – which requires a large suite of water quality parameters as inputs to the model. An alternative approach is to use MLR equations to adjust the toxicity data to an index condition based on pH, hardness and DOC. Guideline values (GVs) for effects protection are then based on a generated SSD generated from the index-normalised toxicity data, with look-up tables (or statistical software) used to generate GV for the range of TMFs used for the derivation. The GV predictions are limited to the ranges of the TMF water quality modifiers of the species toxicity data – with only a limited extrapolation of the bounds permitted without test species validation. The robustness of the permissible extrapolation for TMF modifiers is dependent on the goodness of fit of the relationships and whether they are applicable to all species or limited to a species group (e.g., fish).

Almost all international jurisdictions use a 95% protection threshold generated from an SSD (or other statistical fitting technique) to generate the guidelines for long-term (i.e., chronic) ecological protection. Only the ANZG guidelines provide a range of chronic protection levels (i.e., 99%, 95%, 90% and 80%) which can be applied to receiving environments requiring differing levels of protection. The US EPA and Environment Canada provide some short-term guidelines (i.e., using acute data in some form) for managing peak concentration exposures.

Implementing bioavailable guidelines necessarily involves having information on the TMFs after mixing with the receiving waters, in addition to the concentration of the element of potential concern. This information requirement is now increased from the hardness only modifier which applied to some metals in the ANZECC (2000) guidelines, and which have currently been carried into the ANZG guidelines.

Several updated metals guidelines have been drafted for updating the freshwater ANZG guidelines (i.e., chronic, long-term, guidelines) and are in various stages of review or approval. These include nickel, copper and zinc (Table 6-1). There is currently uncertainty with these guideline derivations in that the final numeric values have not been set by ANZG. There is no updating of the ANZG freshwater aluminium guidelines planned.

Short-term GV for copper and zinc have recently been derived for New Zealand freshwaters following the ANZG procedures (Gadd et al., 2024). These no-effect acute GV include sensitivity data for a range of native New Zealand species. These acute GV are normalised to an index condition and

both copper and zinc have TMF relationships with pH, hardness and DOC. These acute GVs can provide thresholds for short-term peak concentration exposures for protection of native species.

Using the most up to date international guideline for a revised assessment is the most pragmatic approach for a rapid assessment, given the draft state of several of the ANZG revisions. However, this approach needs to consider some key methodology differences between jurisdictions. For example, two key components of the US EPA guidelines are that they do not include data for any aquatic plant species (e.g., bryophytes), nor do they include any data for species not resident in North America. Both methodological conditions are not present for the ANZG derivations, which include a global assessment of all chronic toxicity tests which satisfy the quality control procedures. The Environment Canada guideline derivation procedure is most like the ANZG method.

Table 6-1: Summary of sources for guidelines used in this assessment.

Toxicant	Test type	Status	Reference
Aluminium (Al)	Long-term (chronic)	CCME used for pH>6.5 with TMFs	US EPA (2018); CCME (2021)
Cadmium (Cd)	Short-term; Long-term	CCME acute and chronic guidelines used with TMFs.	CCME (2014)
Chromium (Cr(III))	Long-term	Screening guideline ^a	(ANZG, 2026b)
Cobalt (Co)	Short-term; Long-term	CCME used with TMFs	CCME (2017) ^b
Copper (Cu)	Short-term; Long-term	NZ (acute) with TMFs; ANZG (chronic) with TMFs	Gadd et al. (2024) (NZ acute); ANZG (2026a) ^c
Iron (Fe)	Long-term	US EPA used	Brix et al. (2023); ANZG (2025b); CCME (2024); (US EPA, 1986)
Lead (Pb)	Short-term; Long-term	Screening guideline with TMFs	CCME (2020)
Manganese (Mn)	Short-term; Long-term	CCME used with TMFs	CCME (2019)
Nickel (Ni)	Short-term; Long-term	ANZG used with TMFs	ANZG (2018a); Stauber et al. (2021) ^d
Zinc (Zn)	Short-term; Long-term	NZ (acute) used with TMFs; CCME (chronic) used with TMFs	Gadd et al. (2024) (NZ acute); ANZG (2026d) ^d ; CCME (2018a); CCME (2018b)

^a Guideline used for screening for PCOCs in WLBMs with TMFs (if appropriate).

^b Guideline in process of revision for international application.

^c Updated ANZG used as in final review.

^d ANZG guideline in process of revision but not completed. Draft guideline not used.

6.1.2 Guideline derivation for metal in the Buller Plateaux streams

A range of metal guidelines have been used for assessment and/or for site-specific guideline development (Table 6-1). The guideline equations for different LoPs for metal, nitrate-N and ammoniacal-N are summarised in Table 6-2. The GVs are calculated for the site-specific index condition in Table 6-3. Appendix J provides an index condition calculation for the lowest applicable MLR pH and hardness values (from Table 6-2; Note that some GVs show minimal difference from the Index Condition values in Table 6-3 because of the minimum applicable hardness values for the equation). These will be the default minimum GVs that would apply for that LoP.

The metal index condition used for the ANZG DGVs and Environment Canada (CCME) is pH 7.5, hardness 50 mgCaCO₃/L and 0.5 mg/L DOC. The site-specific index condition modifies this to the maximum pH of 7.0 – based on the acceptable maximum for bryophyte species (Hogsden and Hickey, 2025), hardness 50 mgCaCO₃/L and a DOC of 3.5 mg/L – being the average measured in the Whareatea River at site WM-2. The site-specific index condition retains the DGV hardness value of 50 mgCaCO₃/L, though this is likely to be more elevated in WTP discharges because of the hardness-modifying treatment. The predicted changes in pH, hardness and DOC from background conditions will differ markedly between the compliance sites depending on the nature and magnitude of the

discharge(s), the available receiving water dilution and the upstream water quality. Model predictions of TMFs and key metal concentrations at compliance sites are presented in Section 8.2.

Table 6-3 also summarises the trace level limit of quantitation (LOQ) for the analytes and calculates ability for that level of analysis to resolve the GV for the site-specific index condition TMF levels. The index example shown indicates that the 95% protection GV for cadmium would not be resolved (shown in red) due to the LOQ.

Guideline derivation details for the metals are presented in the following section (6.1.3) with SSD plots provided in Appendix F showing the species distributions for the various metals.

Table 6-2: Bioavailability guideline value (GV) equations for chronic GVs and acute GVs for differing levels of protection (LoP). Toxicity modifier factor (TMF) range indicated for metals pH, hardness (as CaCO₃) and DOC; index condition values for nitrate-N and ammoniacal-N indicated.

Application (Note 1)	Guideline Value (µg/L) (Note 2)	TMF range (Note 3).	Reference
Dissolved Aluminium Guideline Values (µg/L)			
	Chronic Aluminium GV		
95% LoP. pH ≤ 6.5	500	pH: ≤ 6.5 (Note 4 for basis of change of pH threshold)	a
95% LoP. pH > 6.5	exp(0.645×ln(DOC) + 2.255×ln(Hardness) + 1.995×pH + (-0.284×ln(Hardness)×pH) -9.898) *Note if algorithm is ≤ pH 6.5 use 500.	pH: 6.5-8.7 Hardness: 10-430 mg/L DOC: 0.08-12.3 mg/L	b
90% LoP	95% LoP / 0.79		b
80% LoP	95% LoP / 0.58		b
Dissolved Copper Guideline Values (µg/L)			
	Chronic Cu GV		
95% LoP	DGV _{0.5} x (DOC/0.5)^0.70 where DGV _{0.5} = 0.73	pH: 6.0-8.5 Hardness: 35-400 mg/L DOC: 0.1-20 mg/L	c
90% LoP	DGV _{0.5} x (DOC/0.5)^ 0.70 where DGV _{0.5} = 0.89		
80% LoP	DGV _{0.5} x (DOC/0.5)^ 0.70 where DGV _{0.5} = 1.4		
	Acute Cu GV		
95% LoP	exp (-6.6 + 0.78xpH + 0.58×ln(Hardness) + 0.70×ln(DOC)	pH: 6.0-8.8 Hardness: 35-898 mg/L DOC: 0.1-30 mg/L	d
90% LoP	exp (-6.3 + 0.78xpH + 0.58×ln(Hardness) + 0.70×ln(DOC)		
80% LoP	exp (-5.8 + 0.78xpH + 0.58×ln(Hardness) + 0.70×ln(DOC)		
Dissolved Iron Guideline Values (µg/L)			
All LoP	500	All conditions	e
Dissolved Zinc Guideline values (µg/L)			
	Chronic Zn GV		
95% LoP	exp(0.947xln(Hardness) - 0.815xpH + 0.398xln(DOC) + 4.63)	pH: 5.7-8.1 Hardness: 15-399 mg/L DOC: 0.3-22.9 mg/L	f
90% LoP	95% LoP / 0.62		
80% LoP	95% LoP / 0.35		
	Acute Zn GV		
95% LoP	exp (2.5 - 0.12×pH + 0.6×ln(Hardness) + 0.13×ln (DOC)	pH: 5.4-8.5 Hardness: 14-826 mg/L DOC: 0.1-22 mg/L	g
90% LoP	exp (2.9 - 0.12×pH + 0.6×ln(Hardness) + 0.13×ln (DOC)		
80% LoP	exp (3.4 - 0.12×pH + 0.6×ln(Hardness) + 0.13×ln (DOC)		
Dissolved Cobalt Guideline values (µg/L)			
	Chronic Co GV		
95% LoP	Exp((0.414xLn(hardness)-1.285)	Hardness range: 52-396 mg/L	h
90% LoP	Exp((0.414xLn(hardness)-0.427)		
80% LoP	Exp((0.414xLn(hardness)+0.557)		
	Acute Co GV		
95% LoP	95%Chronic CoGV/0.16	Hardness range: 52-396 mg/L	i
90% LoP	95%Chronic CoGV/0.11		
80% LoP	95%Chronic CoGV/0.062		

Application (Note 1)	Guideline Value (µg/L) (Note 2)	TMF range (Note 3).	Reference
	Dissolved Nickel Guideline values (µg/L)		
	Chronic Ni GV		
95% LoP	$11 \times (\text{Hardness}/30)^{0.85}$	Hardness range: 30-400 mg/L. No guidance for pH application range. Normally taken as physiological pH range as used for testing (pH 6.5-8.5).	j
90% LoP	$13 \times (\text{Hardness}/30)^{0.85}$		
80% LoP	$17 \times (\text{Hardness}/30)^{0.85}$		
	Acute Ni GV		
95% LoP	$95\% \text{Chronic NiGV}/0.16$	Hardness range: 30-400 mg/L	k
90% LoP	$95\% \text{Chronic NiGV}/0.11$		
80% LoP	$95\% \text{Chronic NiGV}/0.062$		
	Dissolved Manganese Guideline values (µg/L)		
	Chronic Mn GV		
95% LoP	$\text{Exp}((0.411 \times \ln(\text{hardness}) + 4.46))$	Hardness range: 25-670 mg/L Simplified equation for hardness only calculated at pH 7.5. Look-up tables provided for pH 5.8 to 8.4.	l
90% LoP	$\text{Exp}((0.411 \times \ln(\text{hardness}) + 4.89))$		
80% LoP	$\text{Exp}((0.411 \times \ln(\text{hardness}) + 5.38))$		
	Acute Mn GV		
95% LoP	$(\text{Exp}((0.878 \times \ln(\text{hardness}) + 4.84)))/2.13$	Hardness range: 25-250 mg/L	m
90% LoP	$(\text{Exp}((0.878 \times \ln(\text{hardness}) + 6.90)))/2.13$		
80% LoP	$(\text{Exp}((0.878 \times \ln(\text{hardness}) + 7.20)))/2.13$		
	Dissolved Cadmium Guideline values (GVs, µg/L)		
	Chronic Cd GV		
95% LoP	$10^{(0.83 \times \text{LOG}_{10}(\text{Hardness}) - 2.46)}$	Hardness range: 17-280 mg/L	n
90% LoP	$(10^{(0.83 \times \text{LOG}_{10}(\text{Hardness}) - 2.46)}) \times 1.84$		
80% LoP	$(10^{(0.83 \times \text{LOG}_{10}(\text{Hardness}) - 2.46)}) \times 4.15$		
	Acute Cd GV		
95% LoP	$(10^{(1.016 \times \text{LOG}_{10}(\text{Hardness}) - 1.71)}) \times 0.47$	Hardness range: 5.3-360 mg/L	o
90% LoP	$(10^{(1.016 \times \text{LOG}_{10}(\text{Hardness}) - 1.71)}) \times 0.61$		
80% LoP	$(10^{(1.016 \times \text{LOG}_{10}(\text{Hardness}) - 1.71)}) \times 2.1$		
	Nitrate-N (ANZG – hardness (H)-dependent; guideline)		
	Chronic Nitrate-N GV		
95% LoP	1100 (H<30); 2600 (H30-150); 29,000 (H >150)	Hardness dependent	p
90% LoP	1500 (H<30); 4200 (H30-150); 38,000 (H >150)		
80% LoP	2300 (H<30); 7100 (H30-150); 56,000 (H >150)		
	Acute Nitrate-NGV		
	Not available		
	Nitrate-N (NPS-FM; standard)		
	Chronic Nitrate-N Standard (median standard)		
95% LoP	2400		q
90% LoP	Below “bottom line”		
80% LoP	Below “bottom line”		
	Acute Nitrate-N Standard (95th percentile standard)		
95% LoP	3500		q
90% LoP	Below “bottom line”		
80% LoP	Below “bottom line”		
	Chronic ammoniacal-N (ANZG guideline)		
95% LoP	1200	pH and temperature dependent. Values at pH 7 and 15°C.	r
90% LoP	2000		
80% LoP	3600		
	Acute ammoniacal-N (ANZG guideline)		
	Not available		

Application (Note 1)	Guideline Value (µg/L) (Note 2)	TMF range (Note 3).	Reference
Chronic ammoniacal-N (NPS-FM median standard)			
95% LoP	580	pH dependent. Values at pH 7.	s
90% LoP	Below “bottom line”		
80% LoP	Below “bottom line”		
Acute ammoniacal-N (NPS-FM 95th percentile standard)			
95% LoP	968	pH dependent. Values at pH 7.	s
90% LoP	Below “bottom line”		
80% LoP	Below “bottom line”		
pH			
	Maintain in range 4.5-7.0 for WTP discharge		t

Note 1: The level of protection (LoP) values are species protection levels based on narrative descriptors from ANZG (2018). Site-specific classification levels for ESE and MFS streams have been developed (Hickey, 2026b).

Note 2: The compliance range for pH at Smokestack is 4.5 to 7.0. The equations vary in their calibrated TMF ranges. For monitored water quality values less than the lowest calibrated TMF value the calculated guideline value (GV) will apply to that monitoring occasion.

Note 3: Toxicity modifying factors (TMFs) are pH, hardness (calcium and magnesium concentrations), dissolved organic carbon (DOC, measured as dissolved non-purgeable organic carbon (DNPOC) in natural waters) and temperature. Copper calibration range minimums are: chronic – hardness 2.0 mg CaCO₃/L; pH 6.0; acute – hardness 3.9 mg CaCO₃/L; pH 5.0; Harmonised for chronic and acute to hardness 35 mg CaCO₃/L; pH 6.0.

For pH, hardness and DOC values exceeding the TMF range use the lowest or highest calculated LoP value (except for dissolved aluminum where a 500 µg/L LoP applies to waters below pH 6.5 for all hardness and DOC concentrations).

Note 4: pH minimum for aluminum is based on the pH transition for Al³⁺ and Al-DOM (dissolved organic matter) binding which have elevated concentrations at lower pH levels. This pH threshold also corresponds to that used in the ANZG (2018) and ANZECC (2000) guidelines for Australia and New Zealand.

References: (a) Chronic GV for pH ≤6.5 from Hickey (2012) derivation using BLM approach; (b) Chronic GV for 95% LoP from CCME (2021) for pH >6.5. Reduced LoPs calculated from CCME chronic dataset. No acute sensitivity data in CCME dataset so no acute GVs calculated; (c) Chronic GVs for copper from ANZG (2026a); (d) Acute GVs for copper from Gadd et al. (2024); (e) Iron GV is half the value originating from US EPA (1976) to prevent floc on bed; (f) Chronic GV for zinc from CCME (2018b). Reduced LoPs calculated from CCME chronic dataset; (g) Acute GVs for zinc from Gadd et al. (2024); (h) Chronic GVs for cobalt from CCME (2017). Reduced LoPs calculated from CCME chronic dataset; (i) Acute GVs for cobalt based on CCME (2017) chronic dataset with acute no effect thresholds from acute/chronic ratio from zinc sensitivity Gadd et al. (2024). These Canadian GVs are considered interim with updated GVs being derived with MLR and BLM approaches by Stubblefield based on their earlier publication (Stubblefield et al., 2020); (j) Chronic nickel GVs from ANZG (2018a); (k) Acute GVs for nickel from ANZG (2018a) acute no effect thresholds from acute/chronic ratio from zinc sensitivity Gadd et al. (2024); (l) Chronic manganese GVs from CCME (2019). Reduced LoPs calculated from CCME chronic dataset; (m) Acute manganese GVs calculated from CCME (2019) chronic data adjusted from 95% protection. Conversion factor (CF-acute) of 2.13 converts the acute EC50 to acute no effect based on the zinc ratio (from Gadd et al., 2024); (n) Chronic cadmium GVs from CCME (2014). Reduced LoPs calculated from CCME chronic dataset; (o) Acute GVs for cadmium based on CCME (2014) dataset. Conversion factor (CF-acute) of 2.13 converts the acute EC50 to acute no effect based on the zinc ratio (from Gadd et al 2024); (p) Chronic GVs for nitrate from ANZG (2025a); (q) Nitrate standards (chronic and acute for median and 95th percentile compliance, respectively) from MfE (2020c); (r) Chronic ammoniacal-N guidelines from ANZG (2026c), based on ANZECC/ARMCANZ (2000); (s) Ammoniacal-N standards (chronic and acute for median and 95th percentile compliance, respectively) from MfE (2020c). pH adjustment to pH 7 (2.42-times increase from pH 8 default) from MfE (2018); (t) Upper and lower pH range from bryophyte species distribution range for Buller Plateaux streams from Hogsden and Hickey (2025).

Table 6-3: Guideline values (GVs) calculated for differing levels of protection (LoP) for a **Site-specific Index Condition** for toxicity modifying factors (TMFs = pH 7.0, hardness 50 g CaCO₃/m³, DOC 3.5 g/m³) using equations provided in Table 6-2. Analytical detection limit for trace analysis limit of quantitation (LOQ) with chronic GV/LOQ ratio calculated (RED if chronic GV < LOQ).^a

Element	LoP	Chronic GV		Acute GV	Analytical detection limit (Trace level)	
		g/m ³	mg/m ³		LOQ g/m ³	Chronic GV/LOQ
Dissolved Aluminium	95%	0.37	372	No GV	0.003	124
Dissolved Aluminium	90%	0.47	471	No GV	0.003	157
Dissolved Aluminium	80%	0.64	642	No GV	0.003	214
Dissolved Cobalt	95%	0.0014	1.4	8.7	0.0002	7
Dissolved Cobalt	90%	0.0033	3.3	13	0.0002	16
Dissolved Cobalt	80%	0.0088	8.8	23	0.0002	44
Dissolved Copper	95%	0.0029	2.9	7.4	0.0005	6
Dissolved Copper	90%	0.0035	3.5	10	0.0005	7
Dissolved Copper	80%	0.0055	5.5	17	0.0005	11
Dissolved Iron	All	1.0	1000	No GV	0.02	50
Dissolved Manganese	95%	0.43	432	1,842	0.0005	863
Dissolved Manganese	90%	0.66	664	14,453	0.0005	1327
Dissolved Manganese	80%	1.08	1083	19,509	0.0005	2167
Dissolved Nickel	95%	0.017	17	106	0.0005	34
Dissolved Nickel	90%	0.020	20	154	0.0005	40
Dissolved Nickel	80%	0.026	26	274	0.0005	52
Dissolved Zinc	95%	0.023	23	65	0.0010	23
Dissolved Zinc	90%	0.037	37	97	0.0010	34
Dissolved Zinc	80%	0.065	65	159	0.0010	58
Dissolved Cadmium	95%	0.00009	0.09	0.49	0.0001	0.9 ^a
Dissolved Cadmium	90%	0.00016	0.16	0.63	0.0001	1.6
Dissolved Cadmium	80%	0.00037	0.37	2.2	0.0001	3.7

^a Half detection limit is used for MEQ calculation for compliance assessment and to provide statistical analysis (see section 9.2.2).

6.1.3 Guideline details for metals

Aluminium

Aluminium toxicity guidelines are not being updated by ANZG. The most recent (and still current) ANZG GV for aluminium date from the 1998 derivations in the ANZECC (2000) guidelines. The most recent jurisdictional adoption of updated guidelines for aluminium are Environment Canada (CCME, 2017), USEPA (US EPA, 2018) and B.C. Government (B.C. Ministry of Water Land and Resources Stewardship, 2023). Each of these derivations incorporate TMFs for pH, hardness and DOC.

Site-specific studies were previously undertaken on selected streams on the Stockton Plateau with Al concentrations ranging from 0.034 to 27 mg/L by Waters and Webster-Brown (2013). Their modelling

using PHREEQC²⁴ indicated that between 0.2 and 85% of the dissolved Al was present as the free ion Al^{3+} , the most toxic Al species, which dominated in waters of pH = 3.8–4.8. Al-sulphate complexation reduced the Al^{3+} concentration at lower pH, while Al-organic and – hydroxide complexes dominated at higher pH. Macroinvertebrate richness in the streams identified an indicative Al^{3+} ‘threshold’ of approximately 0.42 mg/L, above which taxa declined rapidly.

Waters and Webster-Brown (2013) found that colorimetric ‘Aluminon™’ analysis²⁵ on unpreserved, unfiltered waters provided a better estimation of Al^{3+} concentrations than inductively couple plasma–mass spectrometry (ICP-MS) on filtered, acidified waters. The chemical analysis of dissolved Al potentially has colloidal clays passing through the 0.45 µm (or smaller pore size) filters, hence the Aluminon™ provides a potentially more relevant measurement to show monomeric toxic concentrations of free Al^{3+} .

The existing Escarpment Mine compliance limits for the Whareatea River (RC10193) incorporated a chronic aluminium value of 0.5 mg/L based on the BLM method for pH <5.5 (Hickey, 2012). That standard was to be applied as a median compliance limit (Appendix C). This threshold was retained for pH ≤6.5 with transition to calculations based on the CCME (2017) MLR relationships for pH, hardness and DOC above this pH. This has potential to create a step change in compliance concentration for small changes in pH at this threshold, but Table 6.3 suggests that the effect is relatively small. The retention of this threshold is supported by the Waters and Webster-Brown (2013) Aluminon™ measurements and the breakpoint observed for EPT species around their threshold of 0.42 mg/L.

The CCME (2017) guideline derivation methodology uses an approach most similar to the ANZG approach. The CCME data was used to calculate LoP values for 90% and 80% to adjust the CCME 95% value LoP.

The use of the Aluminon™ test as well as dissolved aluminium measurements is recommended for all annual biological monitoring sites and for proposed 6-yearly longitudinal surveys (e.g., Cascade Creek (NIWA, 2025d)). The additional surveys can be used to further evaluate the utility of the Aluminon™ test for assessment of species and EPT richness.

Recovery target concentrations for Al have been established for Stockton streams which are severely impacted from AMD. A threshold for dissolved Al of 1 mg/L has been proposed based on being protective of fish (Greig et al., 2010) and for median macroinvertebrate species diversity recovery based on the AMDI (Instream, 2026b). A dissolved Al threshold value of 1 mg/L equates to a chronic GV LoP of 70% for some level of chronic effect (see Appendix F for SSD). The recovery target of 1 mg/L does not incorporate TMFs of pH, hardness and DOC – with both pH and hardness levels increasing markedly because of AMD treatment – thus, the target will be conservative in application. Guidance for application is that once 75% of the Al recovery target is reached then biological monitoring should be increased and ecologically protective guidelines implemented (Instream, 2026b).

²⁴ PHREEQC is a U.S. Geological Survey (USGS) open-source computer program (written in C/C++) designed to simulate aqueous geochemical reactions, including speciation, batch-reaction, and 1D transport calculations. It models water-rock interactions—mineral, gas, and surface equilibrium or kinetics—and is used for analysing natural or polluted water. Definition: The name stands for PH-REdox-EQuilibrium in C.

²⁵ The HACH Aluminon Method 8012 was used for dissolved Al using a HACH DR/890 colorimeter, with samples diluted as necessary to be within the analytical range of the method (0.008–0.800 mg/L) ([Hach Aluminon link](#)).

AMD impacted sites in the vicinity of the ESE sub-area of the BPCP (Rapid Stream, Cascade Stream) which currently exceed the recovery targets for Al (1 mg/L) and pH (<4.5) are proposed for “Betterment”, in the same manner as the significantly AMD-impacted Stockton waterways (PDP, 2026). Betterment requires that activities have a positive contribution to ongoing river health rather than merely avoiding or mitigating adverse effects. Betterment requires active improvement of river health over the long-term.

The chronic aluminium GV would be applied to receiving waters downstream of a mine water discharge as a median concentration after incorporation of TMF adjustment. For pH <6.5 a single compliance value of 0.5 mg/L dissolved Al would apply. Above pH 6.5 the compliance limit incorporates multiple TMFs (i.e., pH, hardness and DOC). The applicable TMF ranges are provided in Table 6-2, with the maximum or minimum GV applicable for TMF levels outside of this range.

There are no acute aluminium GVs.

Cobalt

There is no cobalt moderate- or high-quality guidelines for freshwater in ANZECC (2000)²⁶ and no updated guidelines are in progress for the ANZG. Environment Canada updated their chronic freshwater guideline for cobalt in 2017 (CCME, 2017). The updated CCME guideline is hardness dependent.

The ecotoxicity testing with native mayflies indicated that there is a low acute or chronic toxicity risk for adverse effects on this key inhabitant of Buller Plateaux streams (see Section 5.3). The absence of fish on the Buller Plateaux would provide an option for developing site-specific guidelines based only on macroinvertebrate and plant species.

The CCME chronic data was used to calculate LoP values for 90% and 80% to adjust the CCME 95% value LoP. Acute GVs for cobalt were estimated from the acute no effect to chronic GV ratio from the New Zealand zinc data (Gadd et al., 2024).

Stubblefield et al. (2020) have reviewed acute and chronic cobalt toxicity and SSDs for standards derivation. A revised cobalt guideline is currently being developed using MLR approaches (W. Stubblefield, Oregon State University, pers comm).

The CCME (2017) cobalt bioavailability guidelines are recommended for the current application and should be reviewed after 6-years of chemical monitoring and biological assessments, with critical consideration of implementing the revised guidelines with associated TMFs or deriving site-specific guidelines (i.e., species modified) from those generic guidelines should the level of biological protection be identified as being inadequate.

The chronic cobalt GV would be applied to receiving waters downstream of a mine water discharge as a median concentration after incorporation of TMF levels (i.e., hardness) (Table 6-2).

The acute cobalt GVs would apply to the receiving water condition downstream of mine water discharges. The acute cobalt GV values would be for compliance 95% of the time after incorporation of TMF levels (i.e., hardness) (Table 6-2).

²⁶ “A “low reliability” freshwater trigger value was derived by dividing the lowest chronic figure (2.8 µg/L) by an AF of 2 (cobalt is an essential element)” (section 8.3.7, ANZECC 2000)

Copper

Chronic copper

The chronic copper guideline is being updated by ANZG and is currently in the final stages of review (ANZG, 2026a). At this near-final stage of the derivation process it is considered unlikely that the final GVs will change markedly from the draft values. The draft updated copper chronic guideline only has DOC as a TMF affecting the GVs. The draft ANZG chronic copper guideline has been applied to this assessment.

The chronic copper GVs for differing levels of protection in relation to a range of DOC concentrations are provided in Appendix F. These show a marked increase of the chronic copper GV as the DOC increases. The DOC covers a wide range as a toxicity modifier (0.1-30 mg/L). The pH and hardness ranges for the toxicity data are included in the derivation but are not incorporated in the GV calculations (Table 6-2).

The SSD plot for the normalised chronic copper GV is shown in Appendix F and is based on 51 chronic species data for freshwater. The equation for conversion of the DGV to differing levels of protection is provided in Table 6-2.

The chronic copper GV would be applied to receiving waters downstream of mine water discharges as a median concentration after incorporation of TMF concentration (i.e., DOC).

Acute copper

The acute copper GVs were calculated for no effect (EC10) toxicity thresholds to provide a range of protection levels (Gadd et al., 2024). This derivation equation incorporate TMFs for pH, hardness and DOC (Table 6-2).

The acute copper GVs covering a representative range of TMFs is shown in Appendix F. The range of TMFs applicable to the acute copper GVs are shown in Table 6-2. Appendix F shows plots of how the TMFs affect the GVs. These cover a wide range of low pH, hardness and DOC values applicable to the Buller Plateaux streams.

The normalised SSD for acute copper GV derivation is shown in Appendix F with data for 90 species, including seven native species, covering seven taxonomic groups. The equations to calculate GVs for different protection levels and TMF levels are provided in Table 6-2 with index condition values in Table 6-3.

The acute copper GVs would apply to the receiving water condition downstream of mine water discharges. The acute copper GV values would be for compliance 95% of the time after incorporation of TMF concentration (i.e., DOC).

Cadmium

Cadmium toxicity guidelines are not being updated by ANZG. The most recent (and still current) ANZG GVs for cadmium date from the 1998 derivations in the ANZECC (2000) guidelines. The Environment Canada acute and chronic guidelines for cadmium have been updated with incorporation of recent species sensitivity data and incorporating hardness modifiers (CCME, 2014). The chronic data from that guideline were used to calculate 90% and 80% LoPs and the values adjusted relative to the 95% CCME protection guideline.

CCME (2014) provides an acute dataset for 50% effect endpoints. That dataset was used to calculate 95%, 90% and 80% protection thresholds. These thresholds were converted to no effect acute GVs based on the zinc relationship of Gadd et al. (2024).

The chronic and acute SSDs are shown in Appendix F with the predictive equations in Table 6-2.

Cadmium was identified as a constituent which is predicted to occasionally exceed the chronic guidelines in the MFS sub-area at sites SW01 and SW03 (exceedance frequencies <3%) in the active mining phase (MWM, 2026i) and is recommended for implementation in the consent standards (Table 6-2).

The chronic cadmium GV would be applied to receiving waters downstream of mine water discharges as a median concentration after incorporation of TMF levels (i.e., hardness). Cadmium concentrations below the trace detection limit should use half the detection limit for MEQ calculation and compliance analysis (see Section 9).

The acute cadmium GVs would apply to the receiving water condition downstream of mine water discharges. The acute cadmium GV values would be for compliance 95% of the time after incorporation of TMF levels (i.e., hardness).

Iron

Research work is underway to assess iron toxicity and the interaction with pH and DOC TMFs in freshwaters with GVs calculated following the European Union approach (similar to the ANZG method) (Brix et al., 2023).²⁷ CCME (2024) released an iron guideline with pH and DOC as TMF variables with 95% protection values.²⁸ The CCME guideline derivation is based on the SSD and MLR relationships published by Brix et al. (2023). There are no predictive equations provided for the TMF relationships provided by Brix et al. (2023) or CCME (2024) because of differences between the TMFs affecting the representative macroinvertebrate and fish species. Both publications provide a spreadsheet calculator and a look-up table for GVs with different pH and DOC. The GVs for total iron decrease with both reducing pH and DOC. An updated ANZG iron guideline has recently been released with no TMF modifiers (ANZG, 2025b).²⁹ An overview of these guideline derivations is provided in Appendix F.

The ANZECC 2000 iron guideline and US EPA criteria for freshwaters are based on the concentration of iron which results in the formation of precipitated flocs on the bed of streams. The original iron criteria comes from the 'Red book' from 1976 with a value of 1.0 mg/L *"based on field observations principally,...is believed to be adequately protective"* (US EPA, 1976), which has been adopted for all subsequent US EPA guideline updates (e.g., US EPA (2009)). This criteria value provided the basis for the existing Escarpment Project in 2012 (Hickey, 2012).

The recently promulgated iron GVs are not considered suitable for the naturally acidic and elevated dissolved organic matter (measured as DOC) conditions with associated elevated dissolved iron concentrations (commonly 0.2-0.3 mg/L dissolved Fe, for pH 4.5-5.5 and DOC up to 10 mg/L conditions, Appendix D). The Buller Plateaux streams show maximum dissolved Fe concentrations at

²⁷ WQG (95% protection, total iron) = 0.11 mg/L at pH 7.5 and 0.5 mg/L DOC; 0.40 mg/L at pH 7.0 and DOC 3.5 mg/L. TMF modifiers pH and DOC. TMF applicability range pH 6.0-8.4; DOC 0.5-10 mg/L. Spreadsheet calculator provided.

²⁸ FWQG (95% protection, total iron) = 0.11 mg/L at pH 7.5 and 0.5 mg/L DOC. TMF modifiers: pH and DOC. TMF applicability range: pH 6-8.5; DOC 0.3-10.9 mg/L. Index condition value = 0.4 mg Fe/L for pH 7.1 and 3.5 mg/L DOC. Look-up tables and spreadsheet calculator provided.

²⁹ DGVs (acid soluble iron) = 95%, 0.28 mg/L; 90%, 0.43 mg/L; 80% 0.73 mg/L. No TMF modifiers. Applicability range: pH 6-8; hardness 8-252 mg CaCO₃/L; DOC 0-4 mg/L.

low EC values – which would correspond to high rainfall conditions – and a marked reduction at high EC values and strong positive relationships with DOC (e.g., Deep Stream sites, Figure 6-1; Waimangaroa River sites, Figure 6-3; Whareatea River sites, Figures D-3 to D-5, Appendix D). These background conditions have dissolved Fe concentration which exceed the ANZG (2025f) GV for 95% protection (0.28 mg/L) and the Environment Canada default GV for a relevant reference water condition (i.e., 0.30 mg/L at pH 6 and DOC 3.5 mg/L, CCME (2024)). Currently, there is a lack of consistency in GV derivations from different jurisdictions in relation to the base derivation data and incorporation of TMF relationships (i.e., pH and DOC for CCME (2024); pH and DOC as species-specific MLRs for Brix et al. (2023)³⁰; no TMFs for ANZG (2025)), together with the limited pH range and variable chronic toxicity data incorporated in these derivations. All toxicity tests for these derivations are based on addition of pH adjusted ferric hydroxide to the test organisms – with most concentrations exceeding the solubility for the test conditions (i.e., a predominance of ferric hydroxide particulates) with mostly minimal DOC in test solutions. Brix et al. (2023) states that “*An important uncertainty in these derivations is the applicability of the C. dubia [a cladoceran] MLR model (no pH parameter) to aquatic insects, and understanding the pH sensitivity of aquatic insects to Fe toxicity is a research priority.*” This research needs to extend to the importance of DOC in modifying Fe solubility, together with other TMFs (i.e., hardness and pH) and potential toxicity to native species in order to validate MLRs (ANZG (2025f)). An overview of these guideline derivations is provided in Appendix F.

Biota in the Buller Plateaux streams are adapted to experiencing the elevated intermittent dissolved Fe exposures to about 0.3 mg/L coincident with elevated DOC concentrations (Figures 6-1, 6-3, Appendix D). Prevention of adverse ecological effects caused by excessive precipitation of iron flocs as a result of pH increase to pH >6-7 with associated elevated DOC conditions³¹ in the high flow and pH variable stream flows after proposed WTP discharges where pH will increase to 7 – together with background DOC and hardness as a result of CaO treatment – is considered the priority for the Fe management guideline.

A guideline value of 1.0 mg/L for dissolved iron was recommended and consented for application to Whareatea River receiving waters (regardless of pH) for the existing Escarpment Mine (RC10193) (Hickey 2012, Appendix C). A more conservative guideline value of 0.5 mg/L is recommended for the BPCP as a dissolved iron standard and would be applicable to all receiving waters downstream of mine water discharges from ESE and MFS (Table 6-2). The compliance for this guideline would be based on a median concentration with an expectation (and acceptance) of an existing background of intermittent short-term elevated concentrations from natural acid and/or legacy AMD runoff events.

The WLBM model predictions of dissolved Fe concentrations show a mean exceedance of 0.8% for the Base Case – maximum 1.4% for Scenario 1 (high rainfall) – and a maximum annual Base Case exceedance of 7.7% and 13% for Scenario 1 – of the time for the various rainfall scenarios (ESE, KEL site). The highest mean exceedance for MFS occurred at SW01 and SW03 for Scenario 2 (Stochastic rainfall) at 0.3%, with the highest annual maximum at these sites occurring and <2.7% of the time, with other sites 0.3-0.8% in the active treatment phase (Section 8.2.2). The proposed passive

³⁰ Brix et al. (2023) state: “*An important uncertainty in these derivations is the applicability of the C. dubia MLR model (no pH parameter) to aquatic insects, and understanding the pH sensitivity of aquatic insects to Fe toxicity is a research priority.*” This consideration adds to the model derivation uncertainties relating to the plateau sites where macroinvertebrates dominate and fish species are absent.

³¹ pH 3.5 – 4.0: Ferric iron (Fe³⁺) begins to become insoluble and can form precipitates. Higher pH near circum-neutral generates precipitation in freshwaters. The solubility of ferric hydroxide is markedly increased by the presence of humic acids (HA) – a major component of the DOC measured in plateau streams – with a greater HA affect as pH increases (Liu and Millero 1999). Overview presented in Appendix D.

treatment systems (MSRs) and polishing ponds are not predicted to generate any Fe concentrations above 0.5 mg/L.

Implication of using total Fe measurements for water quality criteria

Although the use of total Fe as an indicator of toxicity was appropriate for laboratory waters devoid of suspended solids, use of the total or total recoverable analytical methods for Fe may result in elevated concentrations in effluents or receiving waters with high suspended mineral solids. Inorganic suspended solids principally consist of soil particles that are rich in Fe and Al. Iron associated with suspended solids is assumed to be non-bioavailable and therefore an appropriate method for measuring bioavailable Fe is needed. The analytical method for measuring total (or total recoverable) Fe by aggressive analytical digestion (such as acidification using strong acids and/or refluxing by heating) may liberate organic, inorganic, polymeric, colloidal, and particulate forms of Fe. Because natural waters contain forms of Fe that are not bioavailable, aggressive digestion methods will likely lead to overestimation of bioavailable Fe in natural waters, and this in turn may lead to exceedances of Fe guidelines even though there is no potential for aquatic toxicity (Cardwell et al., 2023).

Standard procedures recommending acidification of field-collected freshwater samples prior to filtration may result in the liberation of Fe from non-bioavailable mineralogical phases (minerals, suspended solids, or sediments) resulting in elevated Fe concentrations.

The ANZG (2025f) for total iron recommends using a weak acid digest – to better assess ‘bioavailable’ Fe – based on Balsamo Crespo et al. (2023). The non-inclusion of TMFs – particularly DOC – in the present ANZG guideline is considered to make this guideline inappropriate for this site-specific application (see Appendix F discussion).

The use of dissolved Fe for compliance monitoring is considered appropriate for this site-specific application given the natural acidic and elevated DOC and dissolved Fe background conditions (see Appendix D). Inorganic suspended solids with elevated Fe content will frequently occur in Buller Plateaux streams during high rainfall events and would result in exceedance of compliance conditions if total Fe were used.

Manganese

Chronic manganese

Manganese toxicity guidelines are not being updated by ANZG. The most recent (and still current) ANZG GVs for manganese date from the 1998 derivations in the ANZECC (2000) guidelines and do not include TMFs.³² The Environment Canada acute and chronic guidelines for manganese have been updated with incorporation of recent species sensitivity data and incorporating TMFs (CCME, 2019). The chronic data from that guideline were used to calculate 90% and 80% LoPs and the values adjusted relative to the 95% CCME protection guideline.

Updated chronic manganese guidelines have been derived by Environment Canada (CCME, 2019). These derivations provide both chronic (long-term) and acute (short-term) GVs. The TMFs values for pH and hardness for the chronic GVs and only hardness for the short-term GVs. Environment Canada provide a spreadsheet calculator for the chronic guidelines as a single equation which is not

³² ANZG manganese = 95%, 1.9 mg/L; 90% 2.5 mg/L; 80% 3.5 mg/L.

applicable to all species groups in the derivation. A single equation is provided for the short-term hardness-related GV calculations.

A range of chronic GV calculations for manganese are shown in Appendix F (Table F-17). These GVs would be equivalent to the 95% protection thresholds for ANZG. The TMF ranges applicable to the chronic GVs are provided in Appendix F (s 14.7.3).

The SSD for chronic manganese was derived for 14 species covering fish, invertebrates and plants and standardised to 50 mg/L hardness and pH 7.5 (Appendix F, Figure F14). The spreadsheet calculator uses 132 unique combinations of pH and hardness and to derive the look-up table. The regression equation provided in Table 6-2 is a predictor for hardness – as the major TMF – at pH 7.5. A look-up database should be used for compliance assessment for restricted pH (5.8-8.4) and hardness (255-670 mgCaCO₃/L) ranges from this data for site-specific application.

Guideline values for lower species protection levels of 90% and 80% were calculated from the SSD for the chronic dataset. The AF LoP compared to the 95%ile normalised GV were a 1.6-times increase for the 90th percentile and a 2.5-times increase for the 80th percentile (Appendix F, Table F-19).

The chronic manganese GVs would apply to receiving water median concentrations downstream of a mine water discharge after TMF adjustment.

Acute manganese

Environment Canada short-term GVs are calculated from the acute 50% effect values and normalised for water hardness (CCME, 2019). A TMF adjustment for hardness was used to normalise the data and calculate freshwater GVs.

The short-term TMF for manganese is only hardness for values over the range 25-250 mgCaCO₃/L (Appendix F, Table F-20).

The normalised SSD for acute manganese data for 17 species including a range of fish, invertebrate and an amphibian is shown in Appendix F (Figure F-17). This dataset was used to calculate the short-term 90% and 80% GVs and the AF-LoP relative to the 95% GV (Appendix F, Table Mn_acute_2).

The acute Mn GVs are only dependent on hardness while the chronic GVs are dependent on both hardness and pH. Thus, the difference between these acute and chronic GVs will depend on the TMFs of the receiving waters.

The acute manganese GVs would apply to the receiving water downstream of mine water discharges after TMF adjustment with compliance based on monitored 95th percentile concentrations.

Nickel

Nickel chronic toxicity guidelines are currently being updated by ANZG with the incorporation of recent species sensitivity data and TMFs. Those updated guidelines are currently (2025) in review so remain in draft. The most recent (and still current) ANZG GVs for nickel date from the 1998 derivations in the ANZECC (2000) guidelines and only include hardness TMFs.³³ The Environment Canada acute and chronic guidelines for nickel have been updated with incorporation of recent species sensitivity data and incorporating TMFs. The chronic data from that guideline were used to calculate 90% and 80% LoPs and the values adjusted relative to the 95% CCME protection guideline.

³³ ANZG = 95%, 0.011 mg/L; 90%, 0.013 mg/L; 80% 0.017 mg/L at 30 mgCaCO₃/L hardness. Hardness slope 0.85. (ANZG 2018).

The chronic nickel guidelines for freshwater have been updated following the ANZG process (Stauber et al., 2021), however these have not yet been reviewed for incorporation into ANZG. The British Columbia Government published guidelines for acute and chronic nickel in 2024 (B.C. Ministry of Water Land and Resources Stewardship, 2024). Both of these recently updated guidelines have TMFs for pH, hardness and DOC. The B.C. guidelines include a spreadsheet calculator and a simplified biotic ligand model for calculation of GVs to provide 95% species protection.

The TMF ranges for the Stauber et al. (2021) have different ranges for the different species groups (Appendix F, Table F-21). The invertebrate and fish MLRs have TMF ranges which cover the range for Buller Plateaux streams. Look-up tables and a shiny app³⁴ provide guideline calculation for GVs. Site-specific guidelines could be developed for more limited ranges of TMFs and limited to macroinvertebrates and plants as representative of Buller Plateaux streams.

The ecotoxicity testing with native mayflies indicated that there is a low acute or chronic toxicity risk for adverse effects on this key inhabitant of Buller Plateaux streams (see Section 5.3). The absence of fish on the Buller Plateaux would provide an option for developing site-specific guidelines based only on macroinvertebrate and plant species.

The current ANZG (2018a) are recommended for the current application for consent compliance with the hardness correction relationships provided in Table 6-2. The compliance criteria should be critically reviewed after 6-years chemical monitoring and biological assessments. That review should evaluate the nickel DGV guidelines – with associated TMFs – for calculation of site-specific guidelines based on macroinvertebrates and plants – with incorporation of native mayfly sensitivity data – should the level of biological protection be identified as being inadequate. That review should consider exclusion of fish data from the site-specific nickel guidelines for Buller Plateaux sites. The estimated acute no effect thresholds in Table 6-2 are calculated from the acute no effect to chronic GV ratio from the New Zealand zinc data (Gadd et al., 2024).

The chronic nickel GV would be applied to receiving waters downstream of a mine water discharge as a median concentration after incorporation of TMF levels (i.e., hardness) (Table 6-2).

The acute nickel GVs would apply to the receiving water condition downstream of mine water discharges. The acute nickel GV values would be for compliance 95% of the time after incorporation of TMF levels (i.e., hardness) (Table 6-2).

Zinc

Chronic zinc

Zinc chronic toxicity guidelines are currently being updated by ANZG with the incorporation of recent species sensitivity data and pH, hardness and DOC TMFs. The ANZG guidelines for chronic zinc have been updated to include recent international and NZ data, together a bioavailability approach with the same suite of TMFs incorporated as into the Canadian guidelines (ANZG, 2026d). This updated ANZG guideline is in the final review and revision process and would not be considered suitable for implementation at this time. The most recent (and still current) ANZG GVs for zinc date from the 1998 derivations in the ANZECC (2000) guidelines and only include hardness TMF.³⁵ The Environment Canada acute and chronic guidelines for zinc have been updated with incorporation of recent species

³⁴ This app fits species sensitivity distributions to concentration data. The app is built from the R package ssdtools and shares the same functionality. Seb Dalgarno (2018) ssdtools: A shiny web app to analyse species sensitivity distributions. Prepared by Poisson Consulting for the Ministry of the Environment, British Columbia. <https://bcgov-env.shinyapps.io/ssdtools/>

³⁵ ANZG = 95%, 0.008 mg/L; 90%, 0.015 mg/L; 80% 0.031 mg/L at 30 mgCaCO₃/L hardness. Hardness slope 0.85. (ANZG 2018).

sensitivity data and incorporating TMFs. The chronic data from that guideline were used to calculate 90% and 80% LoPs and the values adjusted relative to the 95% CCME protection guideline.

The chronic zinc guidelines from Environment Canada are the most recently updated international derivation with updated data and incorporating TMF variation for pH, hardness and DOC for a bioavailability approach (CCME, 2018a; 2018b). This has been applied to the BPCP, rather than the current/outdated ANZG guideline because the bioavailability guidelines with multiple TMFs will provide better ecological protection for Buller Plateaux streams where background TMFs are variable (see Section 6.2) and proposed water treatment will markedly alter the TMFs (see Section 8.2).

The equation for calculating the Canadian Water Quality Guideline (CWQG) is shown in Appendix F. The TMF modifying equations are applied to the normalised SSD for the 29 freshwater species (Appendix F, Figure F-19). The range of TMFs are summarised in Table 6-2, with the pH range of 6.5-8.13 limiting application for the naturally acidic Buller Plateaux streams. The site-specific compliance criteria would be the GV calculated for the minimum (or maximum) TMF value. Appendix F provides plots of the GVs for the range of TMF values applicable to the derivation.

The TMF-modified chronic GVs correspond to an ANZG 95% protection level. These GVs would apply to the median concentration in the receiving water downstream of a mine water discharge. Where the receiving water pH, hardness or DOC values exceed the valid calculation range the closest applicable GV would apply.

GVs for protection levels of 90% and 80% are calculated from the statistical model fitted to the normalised SSD from CCME (2018) and normalised to the 95% protection level (Tables 6-2, 6-3).

Acute zinc

Neither ANZECC (2000) nor ANZG (2018) provide acute (short-term) GVs for freshwaters. Acute GVs for no-effect toxicity thresholds (i.e., EC10 effect levels) were derived following ANZG procedures (Gadd et al., 2024). These bioavailability guidelines incorporate TMFs for pH, hardness and DOC.

A representative table of acute Zn GVs is shown in Appendix F and TMF ranges in Table F-27, with plots of the acute Zn GV response to TMFs provided in Appendix F (Figure F-25).

The acute zinc GV was based on normalised toxicity for 69 species, including 11 native species, from 8 taxonomic groups. The SSD for the normalised data is shown in Appendix F (Figure F-23). The SSD provides the basis for fitting the statistical model for the different protection level GVs. The equations for the calculation of the 95%, 90% and 80% protection level GVs are provided in Appendix F. These equations are valid for the TMF ranges shown in Table 6-2.

The TMF ranges for the chronic zinc Environment Canada's WQGs and the acute zinc GVs differ, with the latter being validated over a larger range – including for pH ranging from 5.4 to 8.5 and a minimum hardness value of 14 mg CaCO₃/L. The low pH and hardness values validation provides a more robust basis for GV calculation in the Buller Plateaux streams.

The acute zinc GVs would apply to the receiving water condition downstream of mine water discharges. The acute zinc GV values would be for compliance 95% of the time.

6.2 Flow effects on toxicity modifiers and background contaminants

6.2.1 Flow effects on water quality

Background water quality relationships with flow were developed for monitoring sites in the vicinity of the BPCP activities to provide an understanding of how existing local water quality varies with flow – this is fundamental for the BPCP water quality assessment because flow rate (driven by rainfall) is considered to be the primary driver of water quality variation in West Coast waterways, rather than the seasonal variation that is more typically found in other regions of New Zealand. The monitoring sites selected for this analysis were based on the availability of extended concurrent periods of flow and water quality monitoring and included: (i) [REDACTED]

The plots below show selected metal concentrations and TMF concentrations in relation to flow and a time series comparison with TMF-modified GVs.

Deep Stream sites show a general increase in dissolved Al with decreasing pH, with a marked increase at SW05 below the AMD influence (Figure 6-1). The dissolved Fe concentrations are maximal at the reference site (Billo Stream) with elevated concentrations around pH 4.5-5.5, with high values comprising a concentration band above the SW01 and SW03 sites. The SW01 and SW03 compliance sites show no clear trends for Al, Fe, Zn or Ni in relation to flow – though there is a general trend for Al and Fe concentrations to decrease at low flows. Notably, the dissolved Fe concentrations at the reference site are markedly elevated on occasions at all flows compared with the other Deep Stream sites.

TMFs show a marked response for pH, hardness and DOC at the SW01 and SW03 compliance sites in relation to flow (Figure 6-2). The pH and hardness increase at low flow with DOC increasing during flood events. These variable TMF levels will significantly affect the bioavailability guidelines.

The AMD-influenced Waimangaroa River has existing elevated dissolved Al concentrations, but these show little variation with flow, while the Zn concentration increases markedly at low flow and Fe concentration increases markedly at high lows (Figure 6-3). The contrasting relationships between dissolved Al and EC – positive slope – and dissolved Fe and EC – negative (non-linear) slope – highlights the different geochemical processes operating on Al and Fe in this river.

The TMFs for Waimangaroa River show variable pH (4.8-6.6), with hardness increasing markedly at low flows and DOC increasing at high flows (Figure 6-4). These variable TMF levels will markedly affect the bioavailability guidelines – particularly the high hardness at low flows. The WTP which discharges upstream of Smokestack – together with intermittent untreated bypass discharges – will markedly change the TMFs, as simulated in the WLBMs (MWM, 2026i; 2026k).

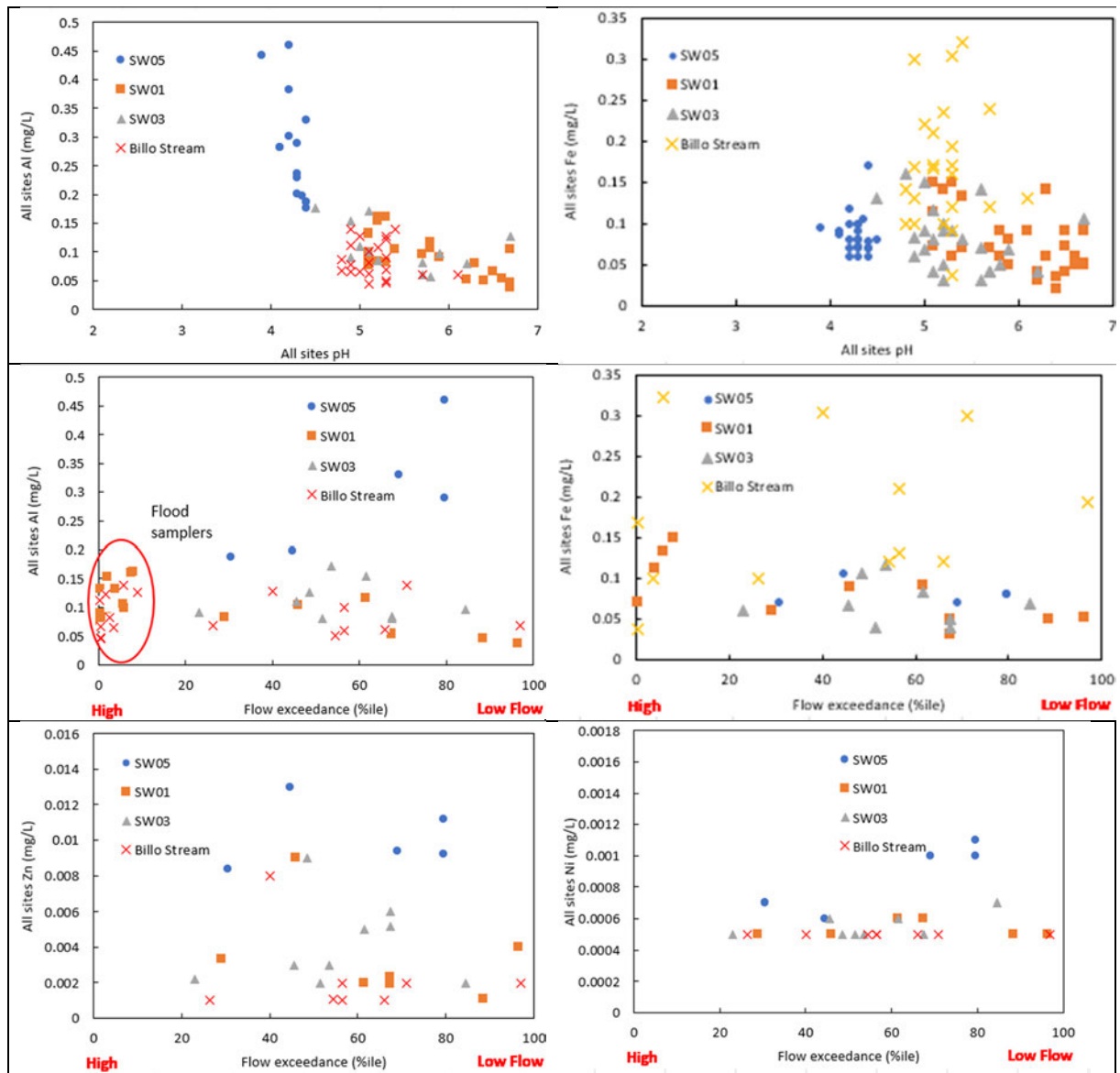


Figure 6-1: Deep Stream aluminium and iron concentrations in relation to pH and flow exceedance relationships with aluminium, zinc, nickel and iron for dissolved metals. Monitoring period June 2024 to May 2026.

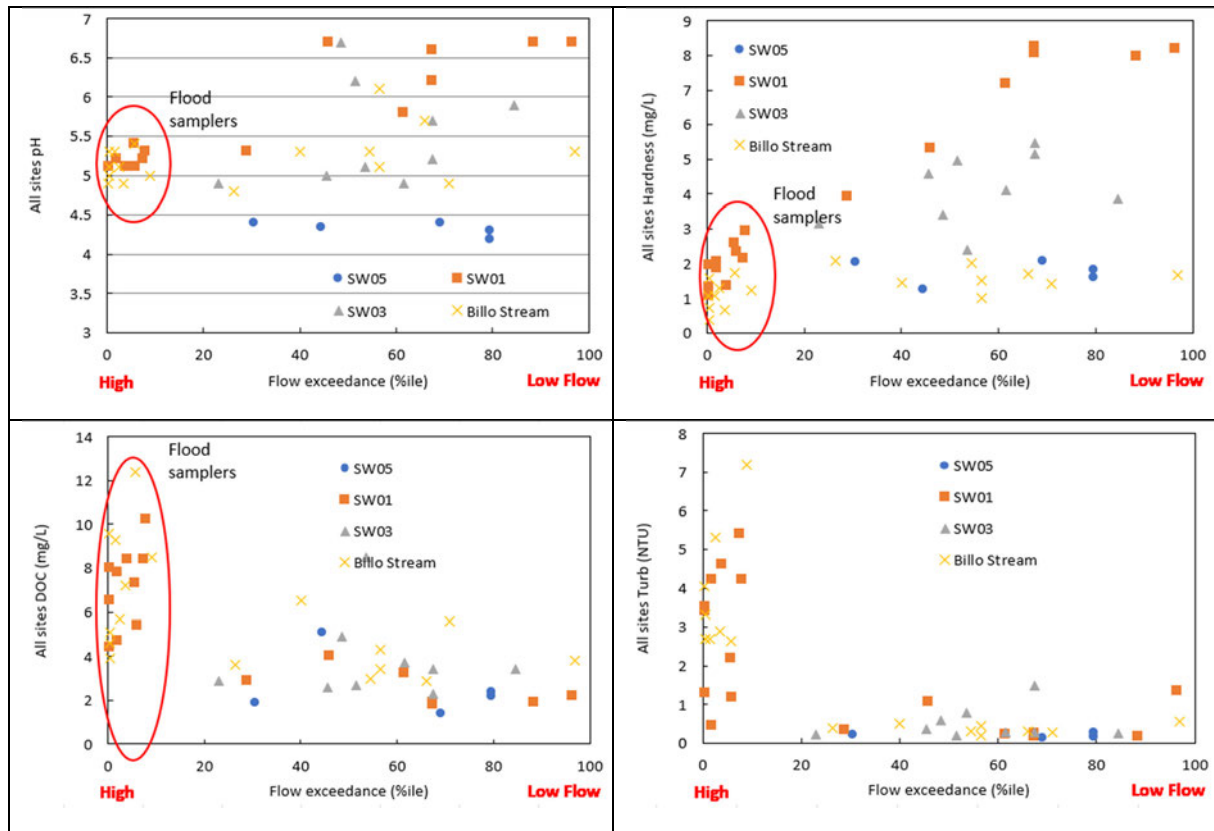


Figure 6-2: Deep Stream toxicity modifiers (pH, hardness and DOC) and turbidity in relation to flow exceedance. Monitoring period June 2024 to May 2026.

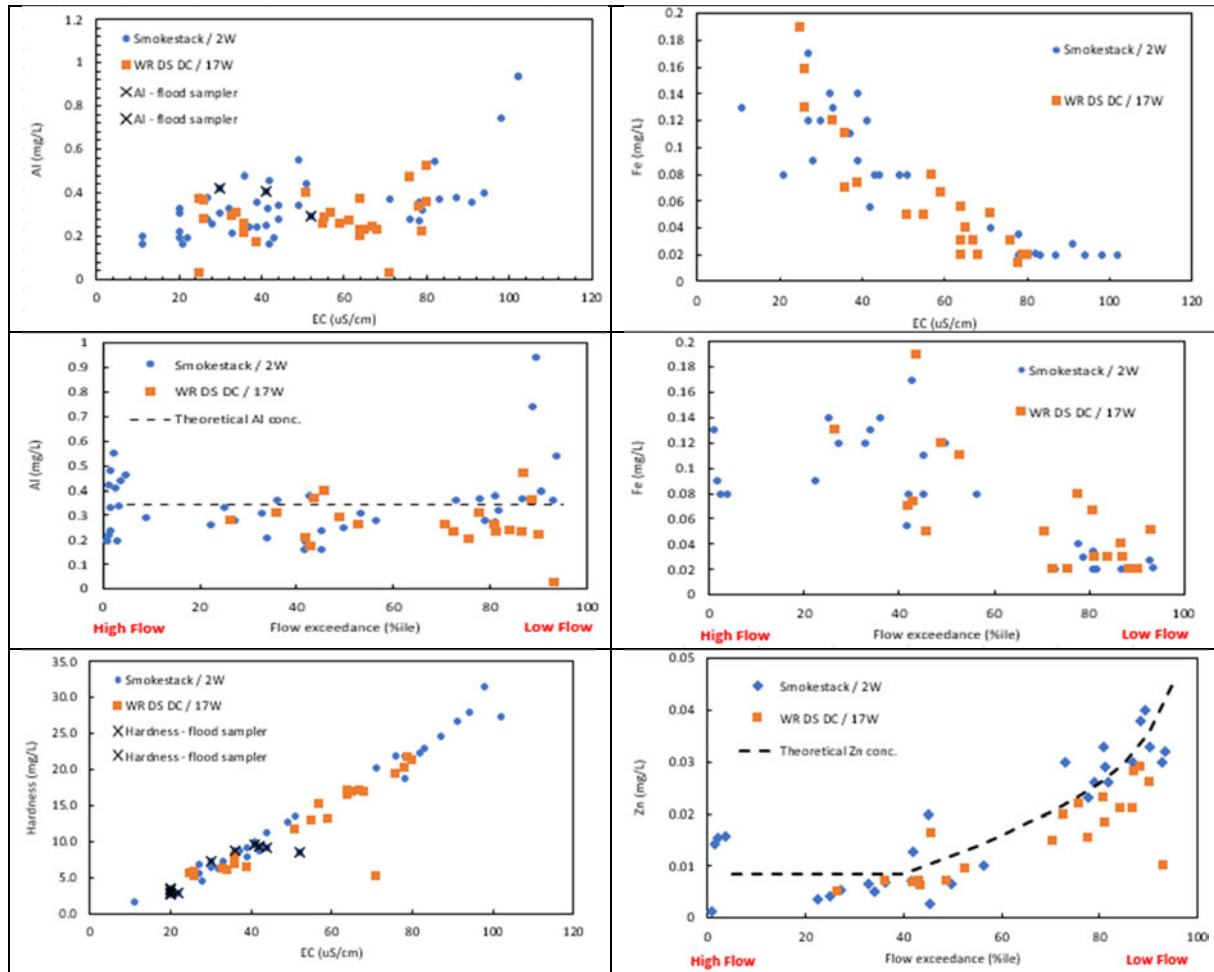


Figure 6-3: Waimangaroa River aluminium and iron concentrations in relation to EC; hardness and EC relationship and flow exceedance relationships for iron, aluminium and zinc for dissolved metals. Monitoring period June 2024 to May 2026.

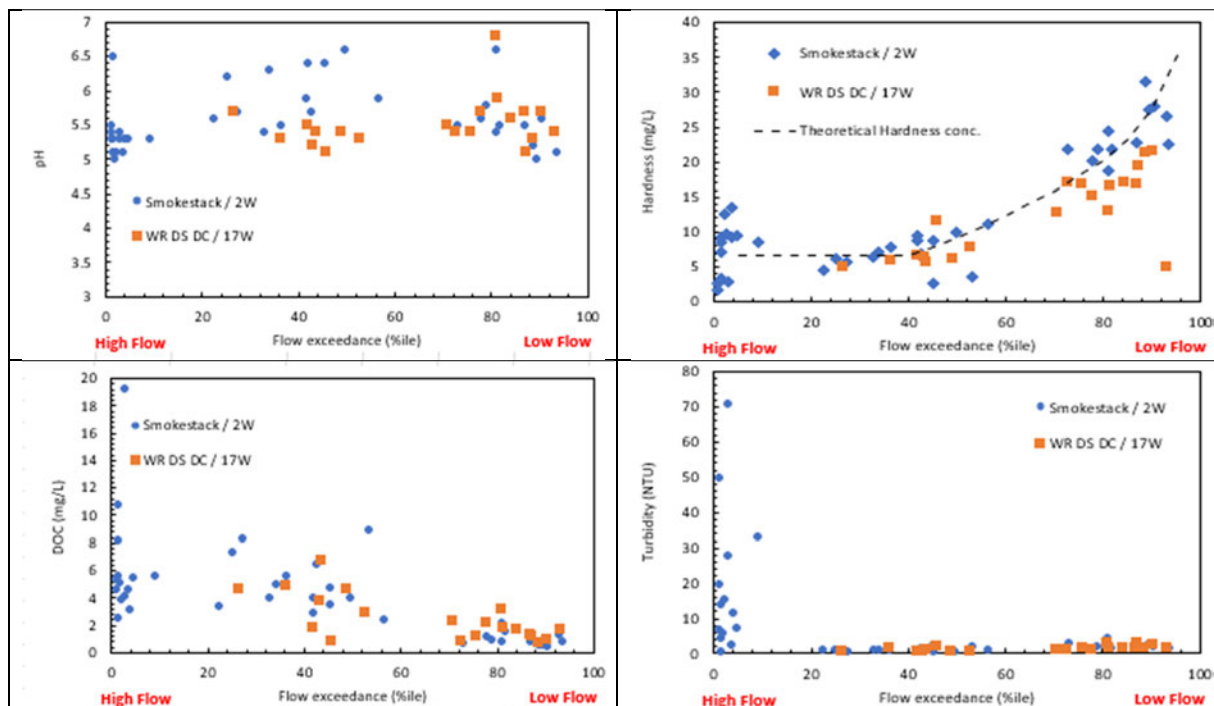


Figure 6-4: Waimangaroa River toxicity modifiers (pH, hardness and DOC) and turbidity in relation to flow exceedance. Monitoring period June 2024 to May 2026.

6.2.2 Background metals comparison with guidelines

Background metals monitoring data for Waimangaroa River calculated relative to flow for MEQ values are shown in Figure 6-5 for Al, Zn, Ni and Co for both 90% and 80% LoPs. The guideline exceedances for Al, Zn and Co occur for low flow conditions, with only Al showing a slight exceedance at high flow. The elevated metal concentrations at low flow indicate that the AMD inputs are predominantly point sources with flows (from historic mining activities) minimally affected by rainfall and increased flows. The compliance criteria recommended for Waimangaroa River is an 80% LoP (Section 6.3) to accommodate the variable upstream AMD metal and TMF inputs.

The time series for dissolved Al and Zn protection at the SW01 and SW03 proposed BPCP compliance site on Deep Stream are shown in relation to proposed water quality guidelines for 95%, 90% and 80% LoPs in Figure 6-6. This shows that for all occasions the background metal concentrations are below the 95% compliance level proposed for Deep Stream sites, supporting the application of the 95% LoP for these sites.

The time series for dissolved Al, Co, Cd, Ni and Zn at the Smokestack (2W) proposed compliance site on Waimangaroa River are shown in Figure 6-7 in relation to proposed water quality guidelines for 95%, 90% and 80% LoPs. These data show the variable background river metal concentrations with multiple metals exceeding the 90% LoP GV's but generally below the 80% LoP GV's. As shown in Figure 6-5 the exceedances are predominantly at low flow (as discussed above).

An 80% LoP is proposed for metals at the Waimangaroa River proposed BPCP compliance sites: Smokestack (2W) and downstream of Deep Stream confluence (17W). The basis for this proposed LoP is both the elevated metal concentrations and the highly variable background AMD inputs upstream, together with the TMF variability present at this site (see Section 6.3). Site 16W (~400

metres upstream of Smokestack) is proposed as the local reference site for Smokestack and 16W compliance assessment.

The resident macroinvertebrates and bryophyte communities are adapted to this current AMD background variability. The classification of the Waimangaroa River is “Fair” for the WOE assessment of water quality and biotic communities (see Section 6.3).

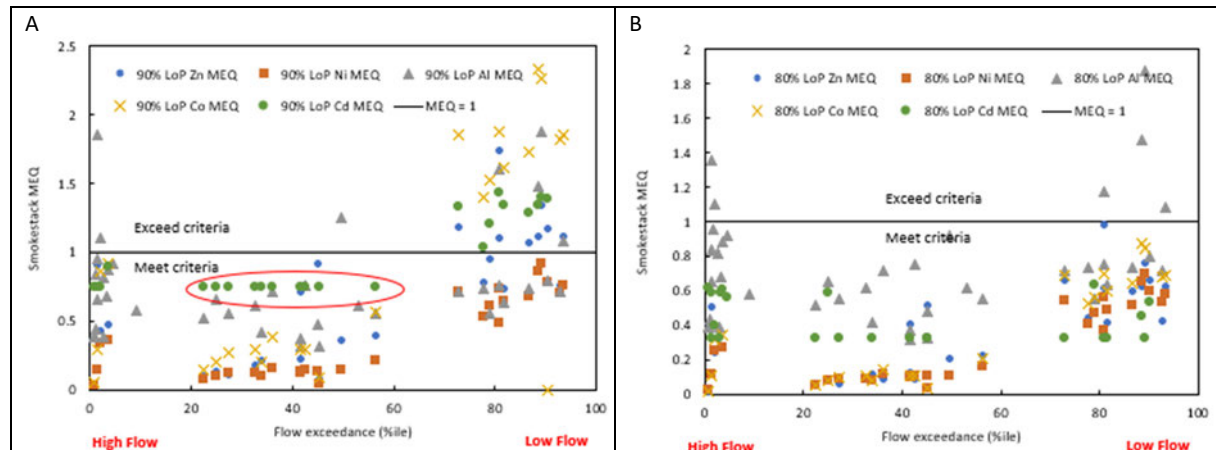


Figure 6-5: Waimangaroa River chronic MEQ values at Smokestack (2W) for dissolved metal concentrations in relation to flow for 90% LoP (A) and 80% LoP (B). Circled Cd values are analytical detection limit values. Monitoring period February 2025 to May 2026. MEQs calculated using equations in Table 6-2 from concurrent TMF sampling.

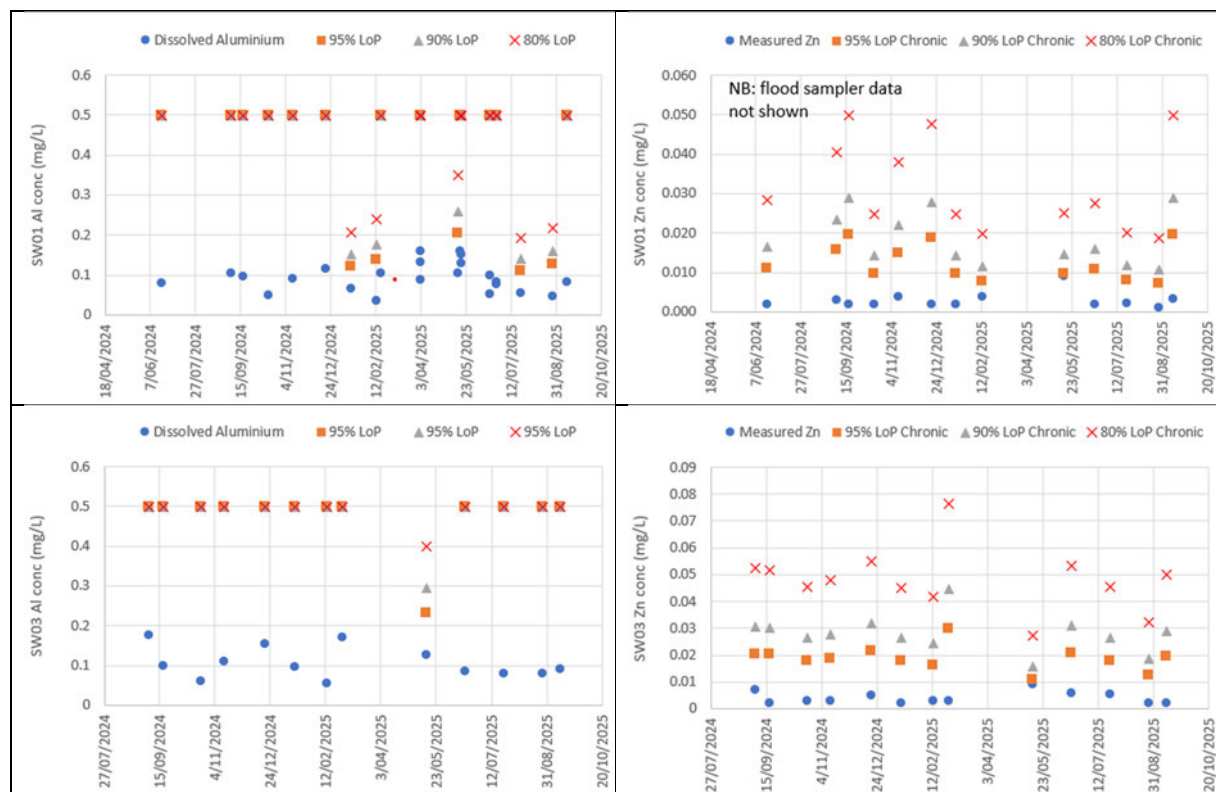


Figure 6-6: Deep Stream dissolved aluminium and zinc concentrations at SW01 and SW03 compared to TMF-modified GV (from Table 6-2). Aluminium GV for 95% and 90% protection are shown where pH >6.5 (brown boxes).

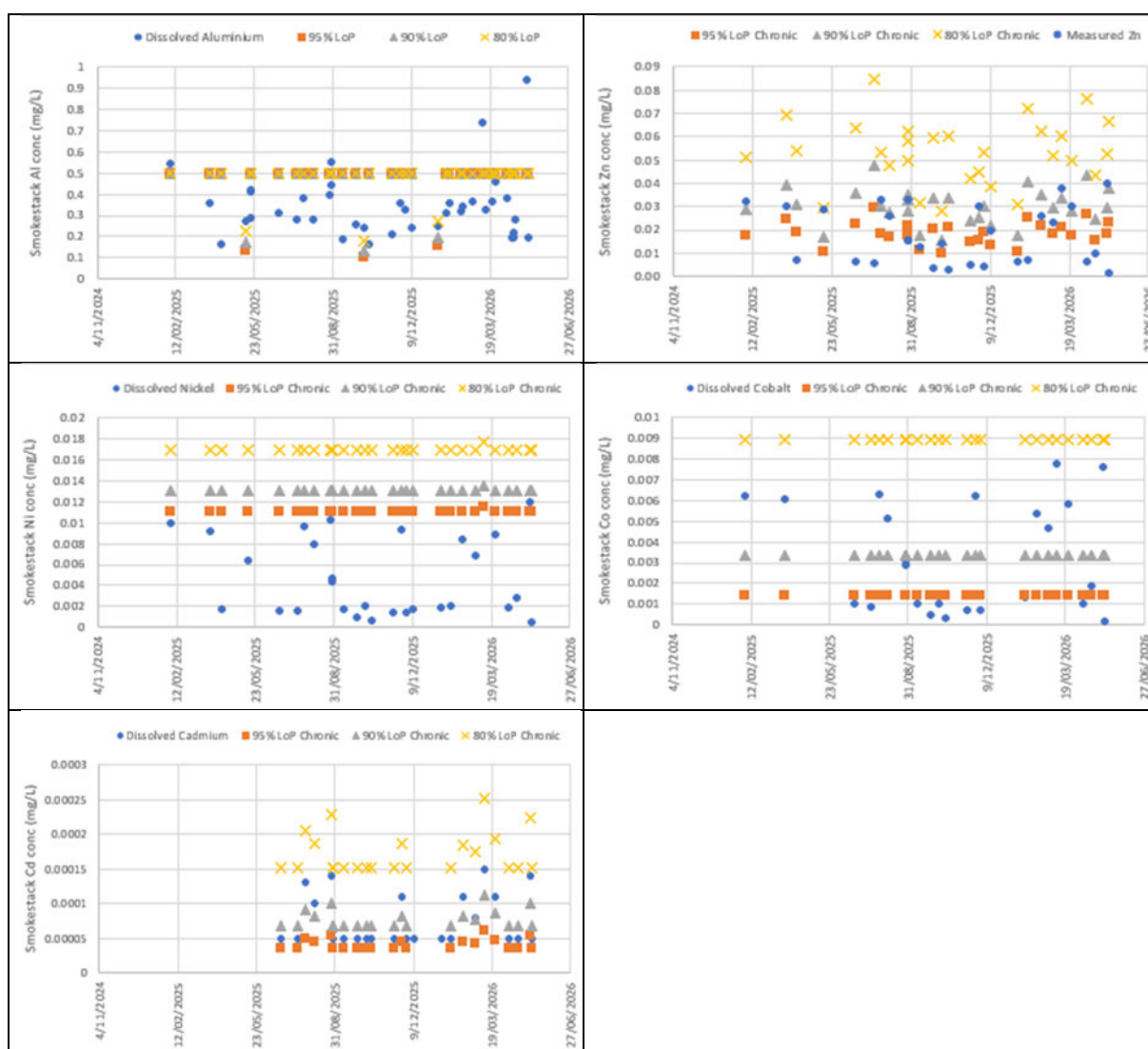


Figure 6-7: Waimangaroa River dissolved aluminium, zinc, nickel, cobalt and cadmium concentrations at Smokestack compared to TMF-modified GV (from Table 6-2). Aluminium GV for 95% and 90% protection are shown where pH >6.5 (brown boxes). Monitoring period February 2025 to May 2026.

6.3 Classification of Streams for Levels of Protection (LoP) Assessment

A stream classification for LoP assessment was developed using a “weight of evidence (WOE)” approach for the Buller Plateaux streams using chemical and biological monitoring data (Hickey, 2026b). Classifications for LoP assessment, narrative descriptors and attribute descriptors are provided in Table 6-7. The summary of gradient sites for the chemical and biological measures are shown in Table 6-8. A statistical summary of the available chemical monitoring data used, together with sample numbers and the time period, are summarised in Table 6-9. This analysis identified reference sites for future monitoring and the LoP for streams with different levels of existing AMD influence.

Box plots of selected chemical and biological measures in relation to LoP classification categories are shown in Figure 6-8 for the Buller Plateaux streams. Both chemical and biological measures show minimal difference between Excellent and Good categories, with kōura numbers having the highest values in some Excellent streams. The Fair category is characterised by elevated EC, sulphate, Al, Ni and Zn concentrations relative to the Good and Excellent streams. Notably, the flow-dependent AMD

results in a high variability in metal concentrations – notably Al and Zn at low flows (Figure 6-3) – together with TMF variability – high hardness at low flow and high DOC at high flows (Figure 6-4). The upstream AMD inputs result in frequent exceedance of the 90% LoP for multiple metals (Cd, Co, Ni and Zn) at low flows, with only occasional exceedance of Al for the 80% LoP (Figure 6-5). The marked exceedance of the 90% LoP at low flows for multiple metals justifies the 80% LoP compliance level for the Waimangaroa River receiving waters.

There is no reduction in EPT species richness or the AMDI in the Fair category compared with Good and Excellent category streams, however kōura were essentially absent from the two Fair sites (Figure 6-8). While the median bryophyte species richness was reduced compared with Good category streams the species diversity was comparable with data from the for streams in the Excellent category.

All biological measures in the Poor/SI category (i.e., EPT taxa richness, koura numbers, bryophyte species richness) and the AMDI index were markedly lower than the other LoP categories (Figure 6-8). The Poor/SI category had marked pH reduction at some sites, high and variable EC and sulphates and highly elevated and variable metals (Al, Zn and Ni) concentrations (Figure 6-8 Table 6-9). This baseline chemical and biological data indicate that the effects of AMD inputs are likely to be associated with both the average water quality conditions and also the intermittent shorter-term flow-dependent concentration peaks. The use of the combine acute and chronic TMF-modified GVs for compliance assessment are proposed to address the site-specific water quality conditions in Buller Plateaux streams.

One site proposed for Compliance monitoring in the ESE sub-area in the Poor/SI category is MM-1 on V8 Creek. This is proposed for an 80% protection level for compliance criteria. Other sites in the Poor/Si classification category all receive very high AMD inputs, are biologically depauperate and classified as “Severely Impacted”. These sites are not considered suitable for ecological protection guidelines and are proposed for “Betterment”.

This classification analysis for LoP is limited in robustness by the number of chemical and biological sampling occasions for most of the stream sites. The biological sampling (kick net for macroinvertebrates)³⁶ [REDACTED]

[REDACTED]). Additional sampling is planned in the period before mining commences which will be expected to refine the LoP classifications as well as providing additional [REDACTED]. This additional data is not expected to affect the Fair classification and the proposed 80% protection recommendation; however, it will provide biological variability information and a pre-commencement baseline for ongoing biological monitoring, as described by Hogsden & Jellyman (2026).

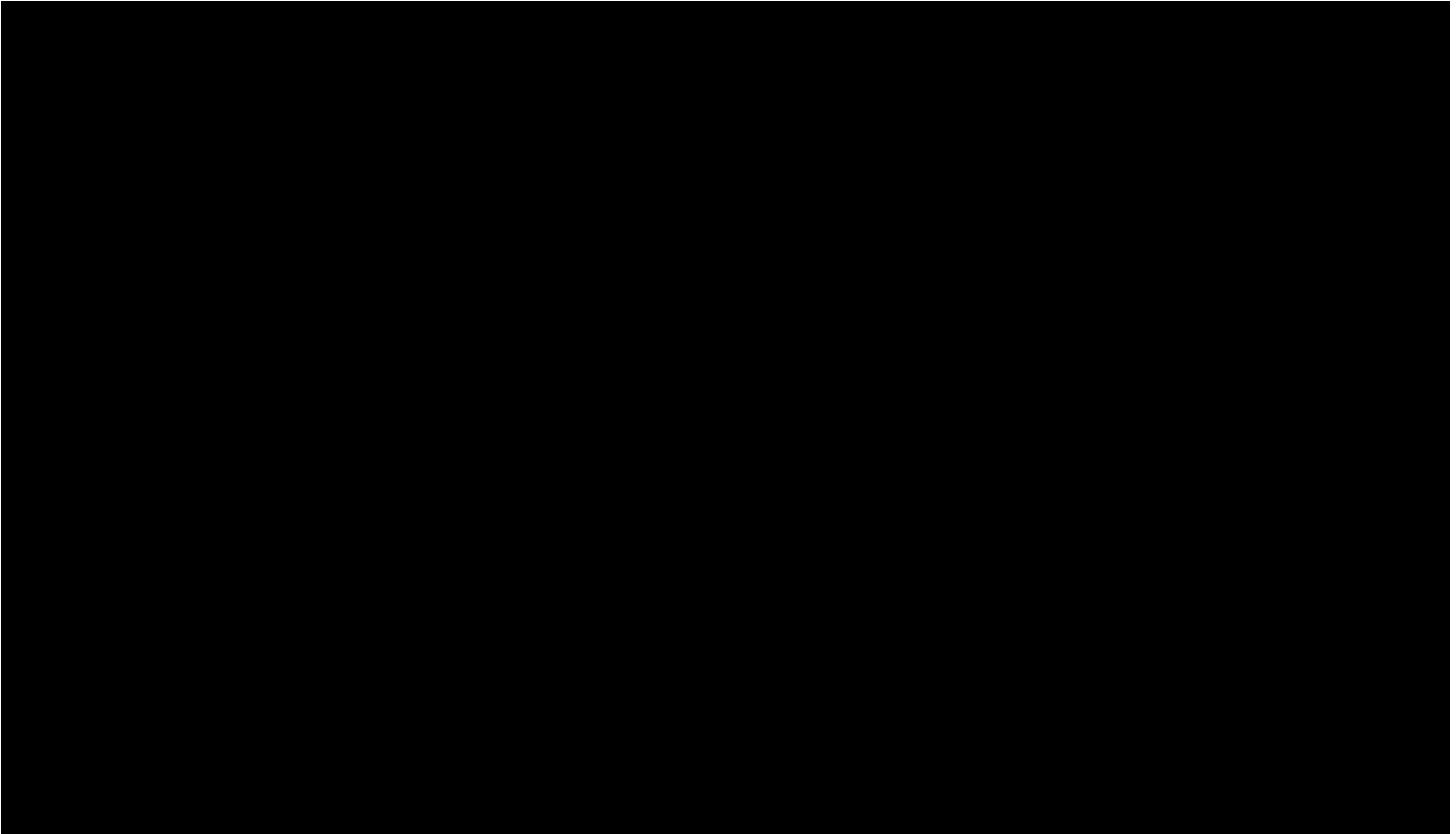
A summary of proposed reference and compliance sites is provided in Appendix G. This identifies the LoP and the monitoring parameter with the type of monitoring (e.g., continuous turbidity, discrete samples). Background data for turbidity monitoring and proposed compliance values are provided in Appendix D of Hickey (2026c), with compliance, performance and reference sites and monitoring frequency provided in Appendix E (Table E1).

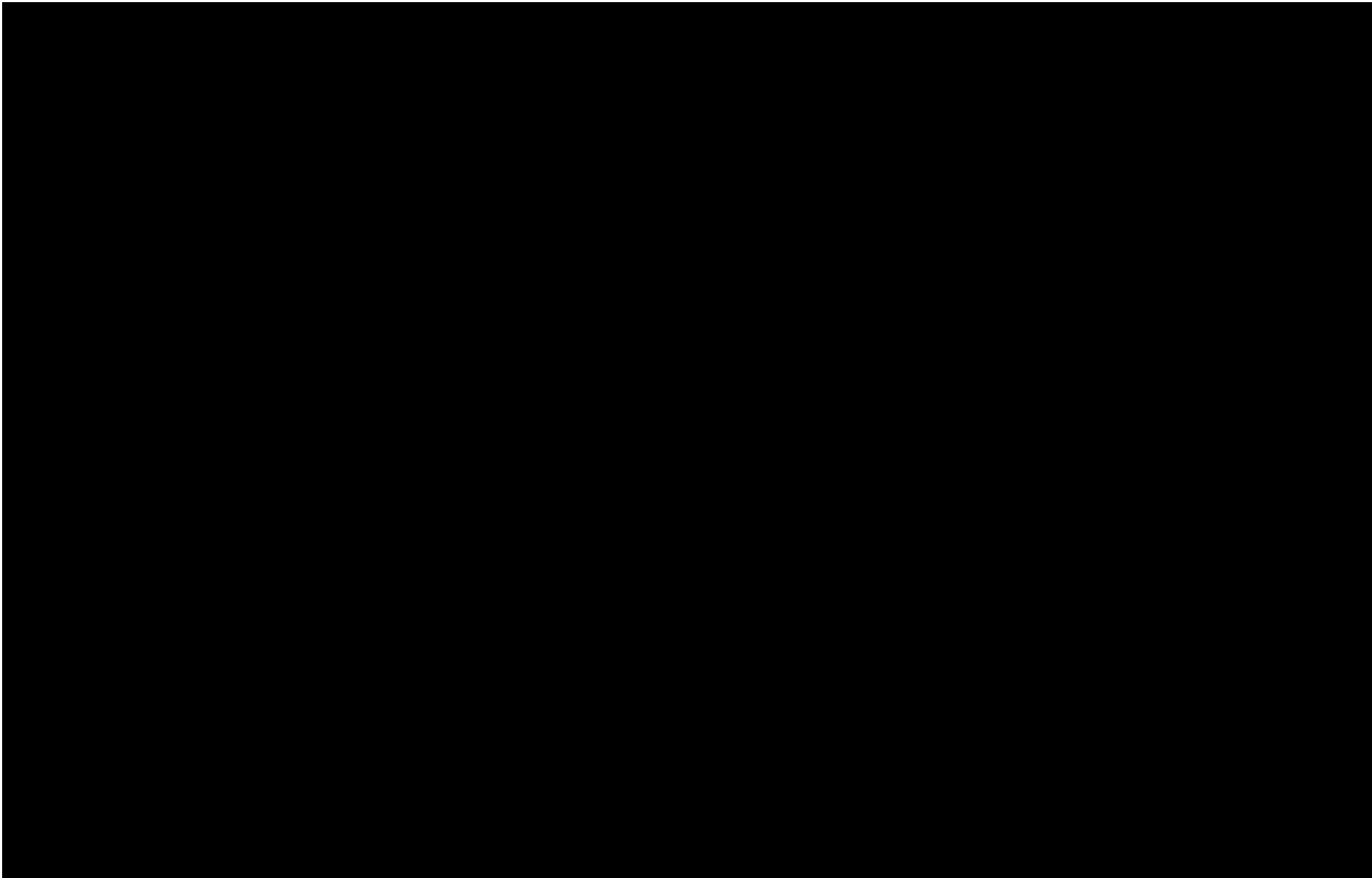
³⁶ eDNA sampling has also been undertaken on selected streams (Hogsden and Jellyman 2026). The eDNA technique focused on identifying the presence of species classified as “threatened”. The semi-quantitative eDNA method is not suitable for classification of specific sites because of the multiple potential upstream sources of eDNA from both AMD-affected and reference streams.

Table 6-7: Narrative descriptors for ecosystem and toxicant attributes for different toxicant protection levels (ANZG, 2018a). Narrative classification for protection classes adapted from MfE (2020c).

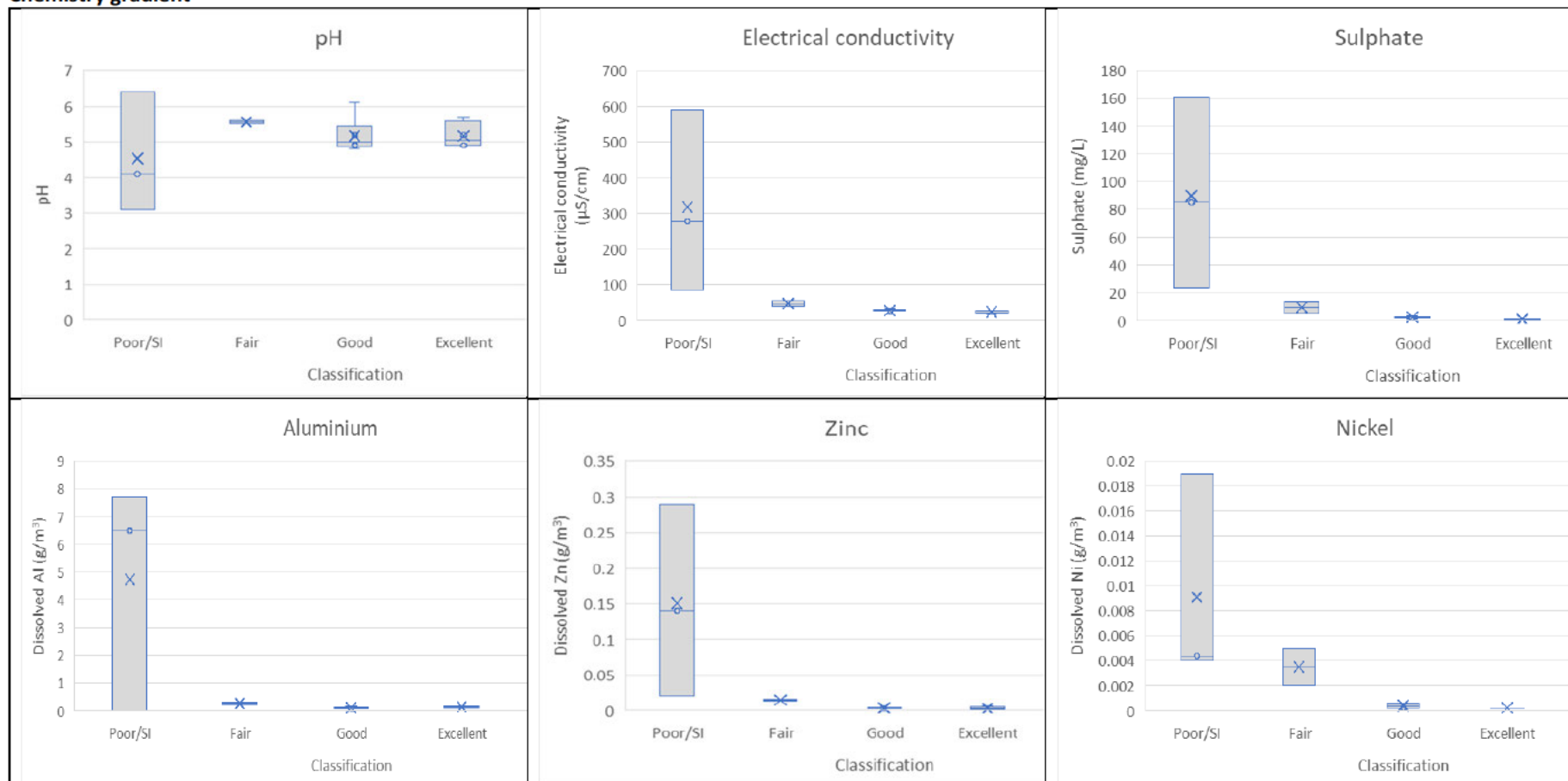
Narrative classification (this analysis) ¹	Narrative descriptor	Toxicant protection percentage	Attribute descriptor: Ecosystem	Attribute descriptor: Toxicants
Excellent	High conservation or ecological value systems	99%	For ecosystems highly valued for their unmodified state and outstanding natural and conservation values, there should typically be no change in biodiversity beyond natural variability. You should only relax the chemical and physical guideline values for these ecosystems if it is known that such a degradation in water/sediment quality will not compromise the objective to maintain biological diversity in the system.	For toxicants generated by human activities, detection at any concentration could be grounds for investigating their source and for management intervention. For globally distributed chemicals, it may be necessary to apply representative background concentrations — as for naturally occurring toxicants.
Good	Slightly to moderately disturbed systems	95%	Ecosystem in which aquatic biological diversity may have been adversely affected to a relatively small but measurable degree by human activity. The biological communities remain in a healthy condition and ecosystem integrity is largely retained. Freshwater systems would typically have slightly to moderately cleared catchments or reasonably intact riparian vegetation.	For toxicants in water, apply 95% species protection DGVs, or 99% species protection for highly bioaccumulating toxicants, if local biological-effects data are unavailable.
Fair/Poor	Highly disturbed systems	90%, 80%	Measurably degraded ecosystems of lower ecological value. Sites with known historic mining activity and ongoing adit discharges within the catchments.	Lower protection levels may be accepted by stakeholders if water quality for slightly to moderately disturbed systems cannot yet be met.

¹ Narrative descriptor for condition from MfE (2020c) as used for microbiological attribute classes.

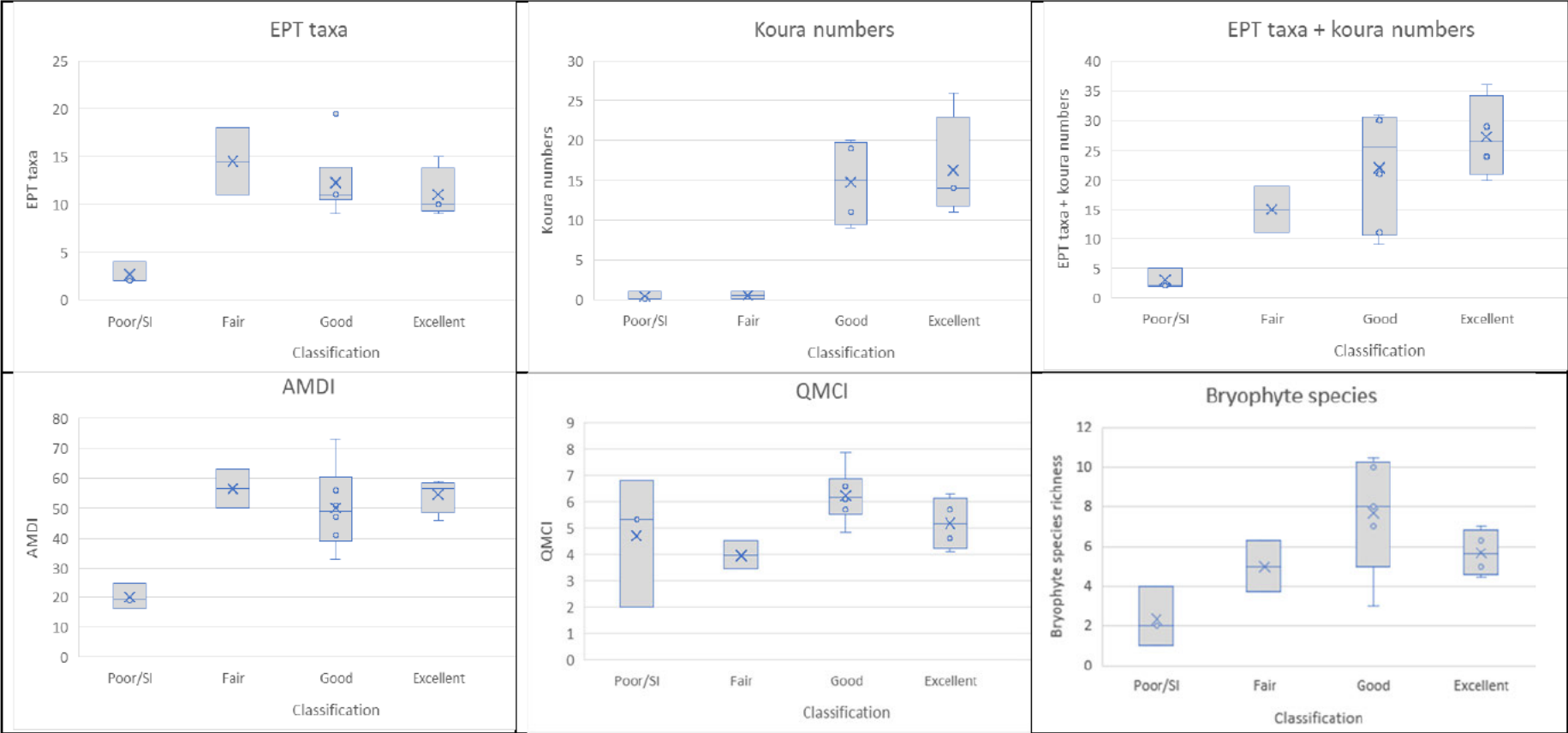




Chemistry gradient



Biological gradient



[REDACTED]

[REDACTED]

[REDACTED]

[REDACTED]

[REDACTED]

7 Other contaminants

7.1 Turbidity

7.1.1 Background

Site-specific water quality protection levels for turbidity linking biological condition with water quality in streams draining ESE, MFS and UWHR sub-areas have been developed (Hickey, 2026c). The site-specific guidelines require both acute guidelines – to cover short-term bypass events and construction activities – and chronic guidelines for longer duration mine water discharges. Guidelines for turbidity limits derivation are based on ecological effects.

Additionally, an assessment has been undertaken for visual aesthetic effects for amenity values for lowland areas along the coastal strip where most human interaction occurs. This assessment is based on the change in median visual clarity of the waters from the background condition. This assessment either requires clarity measurements or use of site-specific conversion factors (CF_clarity) from other measures of total suspended solids (TSS) or turbidity. The aesthetic effect thresholds are based on background conditions for a site. A swimming suitability assessment has also been undertaken for all SH67 sites due to advice that occasional recreational contact for swimming could occur at these sites (Greenaway, 2026), with the threshold based on a single visual clarity range threshold.¹⁸ Recreational and drinking water guidelines for background water quality are addressed in Section 8.3.2.

An assessment of the potential for adverse effects on fish is also required for the lowland stream reaches and estuarine areas. This assessment is most relevant to migratory whitebait (inanga) runs which seasonally occur in the potentially affected streams but also for a range of fish species which inhabit the lower reaches. The distribution of fish species in the upper reaches of rivers which drain the Buller Plateaux are generally limited by physical barriers to migration to the upper Buller Plateaux (Harding et al., 2006), though fish species distribution in some rivers is limited by existing legacy AMD (e.g., Rapid Stream, Cascade Creek) (NIWA, 2020).

Over 100 years of mining activities across the Buller Plateaux have resulted in legacy AMD which results in reduced pH in streams and the discharge of elevated concentrations of metals – particularly aluminium and iron. Discharge of high concentrations of aluminium and/or iron into oxygenated and circum-neutral pH streams results in the precipitation of elevated turbidity flocs in the water column and deposition of these flocs onto the stream bed. These AMD-affected streams have depauperate macroinvertebrate and fish communities because of the low pH and elevated metals, with some sites having metal flocs (iron, aluminium and manganese; e.g., NIWA (2025d)) that can result in physical loss of habitat. For these receiving waters a “Betterment” classification is proposed where monitoring is designed to track management measures in these waters with the ultimate objective of restoring the ecological communities.

7.1.2 Assessment

The assessment included data on the sensitivity of fish and macroinvertebrates to turbidity for acute and chronic exposure durations (Hickey, 2026c). Available continuous and discrete monitoring of turbidity is summarised for the Buller Plateaux streams and the lowland SH67 sites.

Relationships between TSS and turbidity from Stockton monitoring is the basis for the WLBM predictions for effects (MWM, 2026i; 2026k). Stockton monitoring also developed relationships between TSS/turbidity/visual clarity – with the range of those relationships limited by use of a 1 m black disk tube for clarity measurements. Published data from West Coast placer mine studies of TSS/turbidity/clarity (Davies-Colley et al., 1992a) were used to estimate background visual clarity in the Buller Plateaux streams based on turbidity monitoring data.

The Buller Plateaux streams are characterised by low turbidity and high visual clarity, with the clarity range limited by the naturally humic brown water at some sites. Streams receiving high AMD inputs may have turbidity associated with precipitated metal flocs (e.g., iron and aluminium flocs in Cascade Creek (NIWA, 2025d)).

Extreme rainfall and flood events are relevant to the generation of naturally elevated suspended solids concentrations and turbidity from catchment runoff and instream processes (i.e., bed scour, bank erosion). The recurrence interval for an extreme event is not a standardised value and will be dependent on the natural rainfall patterns and catchment characteristics. For areas such as the West Coast, the high and variable natural rainfall with bed-rock and bolder streams are resilient to high turbidity generation.

The long-term flow record for Waimangaroa River at Smokestack was used as the basis for extreme event analysis based on mean annual flood and return interval analysis (Hickey, 2026c). These data show that the Waimangaroa River (median flow (0.7 m³/s) is well adapted to the high flow associated with the mean annual flood, with its marked increase above the median flow. The 10-year return interval is an increase of 1.2-times for mean annual flood (138 m³/s) and 1.4-times for 24-h rainfall and a 9.3% increase in rating stage height (i.e., 5400 mm to 5900 mm). A 10-year return period rainfall is recommended as a basis for an extreme event when compliance with the turbidity limits should not be expected. For the BPCP, a 10-year event is 374 mm over 24-h, with 16 mm in 10-min or 34 mm in 30 min (M. Chater, Bathurst) based on analysis of a comprehensive local rainfall dataset, collected over the period 2008-2025 at the Stockton Meteorological Station.

An add-to-background approach is recommended for guideline compliance.

7.1.3 Site-specific turbidity guidelines

The proposed site-specific turbidity guidelines are provided in Table 7-1. Background turbidity monitoring data and indicative GVs calculated on the basis of available monitoring data provided in (Appendix E, Table E-2 from Appendix D of Hickey (2026c)). Annual compliance assessment is proposed for compliance sites using comparisons with local reference sites for the assessment period (see Section 9). The recommended reference and compliance site locations are shown in Appendix E (Table E-1).

The continued use of Storm Water samplers for both background monitoring and for event-related compliance assessment is recommended. These discrete sampling devices are well suited to collection of samples from short-term bypass discharge events and upstream reference samples for the same event. Their implementation is recommended for all compliance and associated reference sites where mine water bypass discharges may occur.

Assessment of compliance with the proposed turbidity guidelines would exclude data from “extreme events” where high catchment turbidity may be expected to occur naturally. A 10-year return period rainfall event (or greater) is proposed as an extreme event for Buller Plateaux streams.

Table 7-1: Summary of site-specific turbidity guideline values for short- and long-term protection of ecological communities, aesthetic and performance. Proposed compliance locations for Escarpment and Mount Frederick South mine water discharges shown in Appendix E. Allowable compliance assessment exceedance frequencies shown in Appendix K. (from Hickey 2026c).

Classification/Nominal protection level	Short-term (acute) turbidity (NTU) maximum/limit, exposure period	Long-term (chronic) turbidity (NTU) median/95 th percentile/exposure reporting period ^{f, g}
Ecological – continuous ^{a, e}	550 max ^a /100, 7-d rolling median	+5 NTU median above background/+20 NTU 95 th percentile/annual
Ecological – discrete ^{b, e}	550 max ^a	As above
Aesthetic ^{c, e}	n/a	+50% change from background for median; [>1.6 m median clarity (bathing)/annual] ^h
Performance ^{d, e}	n/a	25 NTU 15-sample rolling median

^a Continuous monitoring with 10-min logging frequency and targeting >90% data capture after quality control and clean up procedures for reporting period – to exclude potential spurious instrumental values or debris contacting probe. The 7-d rolling median assessed weekly based on telemetered data. Discrete daily sampling should be used for easily accessible sites upstream and downstream of a WTP. Sites must have reliable access for sample collection during high flow events.

^b Discrete compliance assessment will differ with monitoring frequency (see Appendix E, Table E-2).

^c Aesthetic compliance assessment for mine-related effects based on continuous monitoring at Buller Plateaux compliance sites and calculated flow adjustment.⁵⁰ Weekly or monthly discrete sampling at SH67 to validate upstream monitoring adjustments. Annual compliance period for aesthetic assessment. (Indicative Compliance assessment for discrete monitoring sample numbers provided in Appendix E, Table E-2).

^d Proposed limit for “Performance” assumed to be based on weekly or monthly discrete sampling (see Appendix E). Key sites could be assessed based on continuous or discrete monitoring. Trend assessments for Performance sites may be based on annual or 6-yearly monitoring data depending on significance of site. Site MM1 is a Compliance assessment for this turbidity threshold (see Appendix E).

^e All measurements to exclude “extreme event” flood conditions. A proposed 1 in 10-year rainfall event is proposed as an extreme event (see Section 7.1.2).

^f Compliance assessment for ecological protection to be based on annual median and 95th percentile for site compared with background from upstream or reference site.

^g Indicative values shown in Appendix E (Table E-2) based on monitoring data for median and 95th percentile (n>8) or mean and maximum values. Visual clarity reduction estimate is for 50% clarity reduction with calculated turbidity (from Davies-Colley et al. 1992) with assessment based on annual median of monitoring data. A site-specific relationship between turbidity and black disk visual clarity should be developed from representative stream samples for Performance assessment sites.

^h Indicative bathing threshold is “suitable” classification from consensus curves for suitability for bathing, with >1.1 m being “marginally suitable” Smith and Davies-Colley (1992). The aesthetic median clarity for bathing would only be applicable to rivers with recreational bathing activity and may only be applicable to summer periods.

7.1.4 Recommendations

Turbidity monitoring data for background characterisation for some compliance, reference and performance monitoring sites is limited either for duration or by the type of monitoring undertaken. Additionally, there are limitations for deployment periods for continuous monitoring instruments for turbidity to include a representative range of rainfall events and hydrological flows for the sites. A 2–3-year period is typically required to obtain a representative range of rainfall/flood events. This background information is primarily required to determine the level of treatment required for mine water discharges under average and high rainfall conditions, however BPCP treatment requirements have been modelled through varying rainfall conditions within the WLBM by MWM (MWM, 2026i; 2026k) which included source terms and receiving water concentrations for sediment, as TSS. Having a minimum of one year of high-quality data from these sites will provide the pre-mining background and also establish target water quality for streams post-remediation.

The continued use of Storm Water samplers³⁷ for discrete event sampling should be used to obtain turbidity samples for a range of flood events and used to supplement the manual grab sample collection for compliance assessment. These samplers have the advantage that they can collect high flow samples when the stream/river access is unsafe for personnel.

³⁷e.g., Nalgene Storm [Water](#) sampler (see Appendix E for photo).

[REDACTED]

- [REDACTED]
- [REDACTED]
- [REDACTED]
- [REDACTED]
- [REDACTED]
- [REDACTED]
- [REDACTED]

7.2 Nitrogen – ammonia, nitrate – potential for ecotoxicity

7.2.1 Background

The measured background nitrogen (N) concentrations (nitrate-N, ammoniacal-N and total N) in Buller Plateaux streams are low (Section 5.1.7) so it is important to understand if there are any N additions from the BPCP.

The nitrogen assessment considers three potential sources of dissolved nitrogen which may be elevated in Buller Plateaux receiving waters because of BPCP activities at ESE and MFS (Hickey, 2026e).

These include:

1. Runoff from nitrogen-based explosives used for mining.
2. Nutrients from treated sewage discharge disposal areas.
3. Nutrients from fertiliser applied as part of the remediation and revegetation.

This is a screening level assessment for potential concentration increases for nitrogen and for cumulative assessment of the multiple sources. The assumptions included in this assessment are designed to make the assessment conservative for receiving water effects. Recommended environmental monitoring programmes will include nitrogen measurements and adaptive management thresholds will be implemented to trigger operation changes should receiving water thresholds be exceeded (MWM, 2026f).

This assessment is based on predicted nitrate-N concentration increase in the receiving waters and toxicity effect thresholds. The assessment assumes that the form of nitrogen entering the streams will all be nitrate-N and that other forms of N, such as ammoniacal-N, are minimal. It does not consider potential eutrophication effects of the predicted nutrient enrichment which is addressed elsewhere (Hogsden and Jellyman, 2026).

7.2.2 Assessment

[REDACTED]

[REDACTED]

[REDACTED]

[REDACTED]

[REDACTED]

[REDACTED]

[REDACTED]

[REDACTED]

The ESE catchments were considered the worst case for this analysis because of the higher ANFO usage and the lower receiving water stream flows (compared with MFS). The mining area in ESE has ~83% of the area draining to the Whareatea River and ~16% draining to V8 Creek (MM1 compliance site) which flows into the upper Cascade Creek.

Water quality data from Stockton and the existing Escarpment Mine indicates that nitrate nitrogen and ammoniacal nitrogen concentrations are low in recently blasted pit water, seepage to pits from backfill, and in seepage from ELF's (MWM, 2026f).

Mine Waste Management (MWM) developed a model, based on empirical data from the BV ELF and the ELF Seepage Water Quality Model suggested that nitrogenous compounds will be relatively low in BPCP ELF seepage waters. These data suggest that the risk of elevated nitrate is low for the BPCP (i.e., all nitrate-N data are <1 mg/L for ELF seepage and within active pits (blasting and backfill), which is likely associated with two key drivers (MWM, 2026f):

- High rainfall environment leading to considerable flushing and dilution of any blasting residues.
- Nitrate reduction due to pyrite oxidation (biogeochemical processes), where often higher sulfur environments have a lower risk of elevated nitrogenous compounds.

The results for six sub-catchments draining to the Whareatea River predicted a cumulative mean maximum concentration of 0.45 mg/L (range 0.23-0.89 mg/L) (Table 15, MWM (2026f)).

The predicted concentration range for ELF seepage is below the NPS-FM standards with the average at 19% (maximally 37%) of the annual median (2.4 mg/L) and 13% (maximally 25%) of the 95th percentile limit (3.5 mg/L). The predicted concentrations would also be below the ANZG (2025a) guideline values for 95% species protection for all hardness levels.

Based on this assessment there would not be any toxicity issues associated with elevated NO₃-N concentrations from the proposed ESE sub-area discharging to the Whareatea River at the KEL compliance location.

Treated sewage discharge to ESE sub-area.

The four proposed treatment systems in the ESE sub-area are summarised (see Table 3-1, Hickey (2026e)) together with the predicted total nitrogen (TN) and NO₃-N annual discharge loads (CEC, 2026). The most ecologically sensitive Whareatea River with minimal flows is used for this effects assessment. No sewage discharges are proposed for the MFS sub- area.

The calculated increases in NO₃-N concentration showed that the greatest predicted NO₃-N concentration increase is 0.33 mg/L from the combined treatment systems discharges to the Whareatea River at the KEL compliance site (Table 3-2, Hickey (2026e)).

Assuming low hardness receiving water the predicted median flow nitrate-N increase would be 2.6% for construction and 0.65% of the ANZG GV (ANZG, 2025a) for operations, with a low flow nitrate-N increasing to 30% for construction and 11% of the GV for operations.

Compared with the NPS-FM standards (MfE, 2020c), the construction stage is the worst case for the Whareatea River at KEL with a median of 1.1% of the standard (2.4 mg/L) and the 95th percentile value at 9.5% of the standard (3.5 mg/L).

Thus, the toxicity risk for sewage discharges to the Whareatea River at KEL is considered low. The assessment for the 95th percentile low flow is considered an unlikely scenario as that low flow river condition would not persist for an annual discharge period.

Fertiliser nitrogen sources

An application rate of 90 kg/ha of slow-release fertiliser is proposed for use in the rehabilitation areas at the time of tree planting. The fertiliser has a 20% N content by weight.³⁸

The assessment assumptions were:

1. All fertiliser nutrients applied to the remediation area each year are solubilized and available for export.
2. Thirty percent of the applied fertiliser is taken up by the plants (i.e., 70% exported) (MWM, 2026h).
3. The receiving water flows for the operational period provide the most appropriate basis for the assessment. The planned remediation is progressive with areas being remediated as the mining progresses, so the operational flows are appropriate. The modelled flows for baseline, operational and post-closure are shown in Hickey (2025e, Appendix A).
4. Median flow provides an appropriate flow measure for stream dilution. The assumptions of this assessment are that the applied fertiliser is lost over the application year. The flow path from the catchment will result in a prolonged input to receiving waters. Thus, the median flow provides an appropriate metric for the concentration increase.
5. That the fertiliser will all enter the streams as nitrate-N.

For ESE the proposed total rehabilitation areas over the mining period average 24.3 ha/yr, ranging from 7.5 to 41 ha/yr (i.e., a range of areas rehabilitated in any one year). The average fertiliser N used is 437 kg (range 135-743 kg) with 306 kg of N (range 95-520 kg) exported to the stream over the 14-year operational period. The average increase in stream nitrate-N is predicted to be 0.029 mg/L (range 0.009-0.050 mg/L).

For MFS the proposed total rehabilitation areas over the mining period average 7.9 ha/yr, ranging from 1.0 to 20 ha/yr. The average fertiliser N used is 142 kg (range 18-360 kg) with 100 kg of N (range 13-252 kg) exported to the stream over the 14-year operational period. The average increase in stream nitrate-N is predicted to be 0.044 mg/L (range 0.006-0.11 mg/L).

Conclusions for fertiliser nutrients:

Fertiliser nutrients - ESE:

1. The calculated maximum increase in NO₃-N for Whareatea River at KEL for the operational period is 0.050 mg/L. This increase is 2% of the NPS-FM median standard and 4.6% of the low hardness ANZG GV for 95% protection.
2. Based on this assessment the potential for nutrient increase from fertiliser run-off in the Whareatea River would represent a minimal risk for exceedance of the proposed toxicity limit.

³⁸ Stockton fertiliser use in rehabilitation areas is 1 kg bags of 100 tabs so 90 kg/ha at 9000 plants/ha and nitrogen component is 20% (P. Lindsay, Bathurst)

Fertiliser – MFS:

1. The calculated maximum increase in NO₃-N for Deep Stream for the operational period is 0.11 mg/L. This increase is 4.6% of the NPS-FM median standard and 10% of the low hardness ANZG GV for 95% protection.
2. Based on this assessment the potential for nutrient increase from fertiliser run-off in Deep Stream would represent a minimal risk for exceedance of the proposed toxicity limit. This risk is further minimised by the operational transfer of most of the sump water to the WTP for discharge to Waimangaroa River.

7.2.3 Summary for nitrogen addition assessment

The ESE sub-area was identified as likely the most susceptible receiving water for nutrients (N) concentration increases for potential toxicity effects, with the Whareatea River and the KEL compliance location providing the basis for this assessment.

The screening assessment for potential ecotoxic effects of N has found that the predominant driver of N addition to Buller Plateaux streams from BPCP activities is expected to be from ANFO/blasting, and that the cumulative assessment identified no additional concerns with respect to addition of N from proposed treated sewage discharges or N leached from proposed fertiliser additions for rehabilitation.

The assessments of increased concentrations were made in comparison to the ANZG (2025a) GVs for nitrate-N and the NPS-FM standards. This assessment did not consider potential eutrophication which is addressed elsewhere (Hogsden and Jellyman, 2026).

7.2.4 Recommendations

[REDACTED]

[REDACTED]

[REDACTED].

Compliance monitoring

Compliance monitoring for nitrate-N and ammoniacal-N is proposed for all compliance sites.

8 Assessment of effects

8.1 Ecotoxicity

8.1.1 Introduction

Laboratory toxicity testing was conducted with two key native invertebrate species inhabiting Buller Plateaux streams: kōura (freshwater crayfish) and mayflies (*Deleatidium* sp.).

The primary objectives of these tests were to quantitatively assess the sensitivity of the species at differing pHs and in the low ionic strength Whareatea River water and with representative treated mine water – which increases both the hardness and pH – to establish Co and Ni sensitivity testing for the mayflies. Additional quantitative testing was also undertaken with a green alga (*Raphidocelis subcapitata*) for Ni and Co sensitivity in waters of differing pHs.

The testing was undertaken in two independent trials: (i) the kōura testing measured acute and chronic survival at three pHs (5.5, 6.5 and 7.5) for mine water diluted with Whareatea River water; and (ii) the mayfly testing measured acute and chronic survival of mayflies, and chronic survival of an algal species for Co and Ni at two pHs (5.5 and 7.5) with hardness adjustment (using CaO to simulate treatment).

A summary of results is presented below.

8.1.2 Kōura testing

This study used a novel method for kōura, which was pioneered for this assessment to provide chronic measurements for a range of pH levels to provide sensitivity data beyond the physiological pH range normally used for standard testing (i.e., pH 6.5-8.5). The kōura were first gradually physiologically acclimated to the naturally low pH and low ionic strength Buller Plateaux dilution water (pH 5.5 [redacted] water). The study used pH buffers to maintain the target testing pH at three levels (pH 5.5, 6.5 and 7.5). The testing also measured survival in a representative treatment water (i.e., BV ELF discharge) at these pH values and hardness-modified to pH 6.0 as an analogue for BPCP treated mine water discharge.

The toxicity test results are provided in NIWA (2025f) with results summarised below. Additional analysis of kōura survival in relation to chemistry is provided in Appendix I of this report. A summary of the survival and growth results are provided in Table 8-1. The study design was to use 21-day survival and growth measurements as chronic endpoints. However, the control performance of the juvenile kōura survival was unacceptable and the 14-d survival was used, with control growth for this reduced exposure period being less than the detection limit for effects assessment.

Chemistry data for control and 100% treatments are shown in Table 8-2 with chronic survival plots in Figure 8-1. There was no concentration-response shown for the kōura for any of the key metals (i.e., Al, Fe, Co, Ni, Mn, Zn or Fe) with markedly elevated metal concentrations compared to the Whareatea River (WM-1) dilution water. Though the chronic control and 100% treatment survivals were reduced (60-80%)³⁹ compared to the standard dilution water (pH 7.5, 100%) the absence of a reducing concentration/response survival trend indicates species tolerance. Longer equilibration

³⁹ The reduced survival in the buffered treatments compared with the standard dilution water may be attributable to an effect of the buffer relatively high concentrations used (i.e., 500 mg/L). This level was used to counter the buffer capacity of the CaO treatments and atmospheric carbon dioxide adsorption.

times to low pH/low ionic strength water and potentially lower pH buffer concentrations may be required to provide definitive survival thresholds for kōura for chronic exposure periods.

The results of site-specific GV calculations for Ni, Co and Zn for all of the pH/hardness treatments are shown in Appendix H. The dilution requirements for 95% protection for each of these metals are also calculated. For Ni and Co, the GV is only dependent on the hardness, while the Zn GV is dependent on hardness, pH and DOC. These results indicate that the BV ELF CaO treated (as supplied) would require dilutions of 1.8-times based on Ni, 9.7-times based on Co and 3.8-times based on Zn. Use of these numeric site-specific GVs will be conservative and protective of juvenile kōura populations based on sufficient dilution of discharges being available.

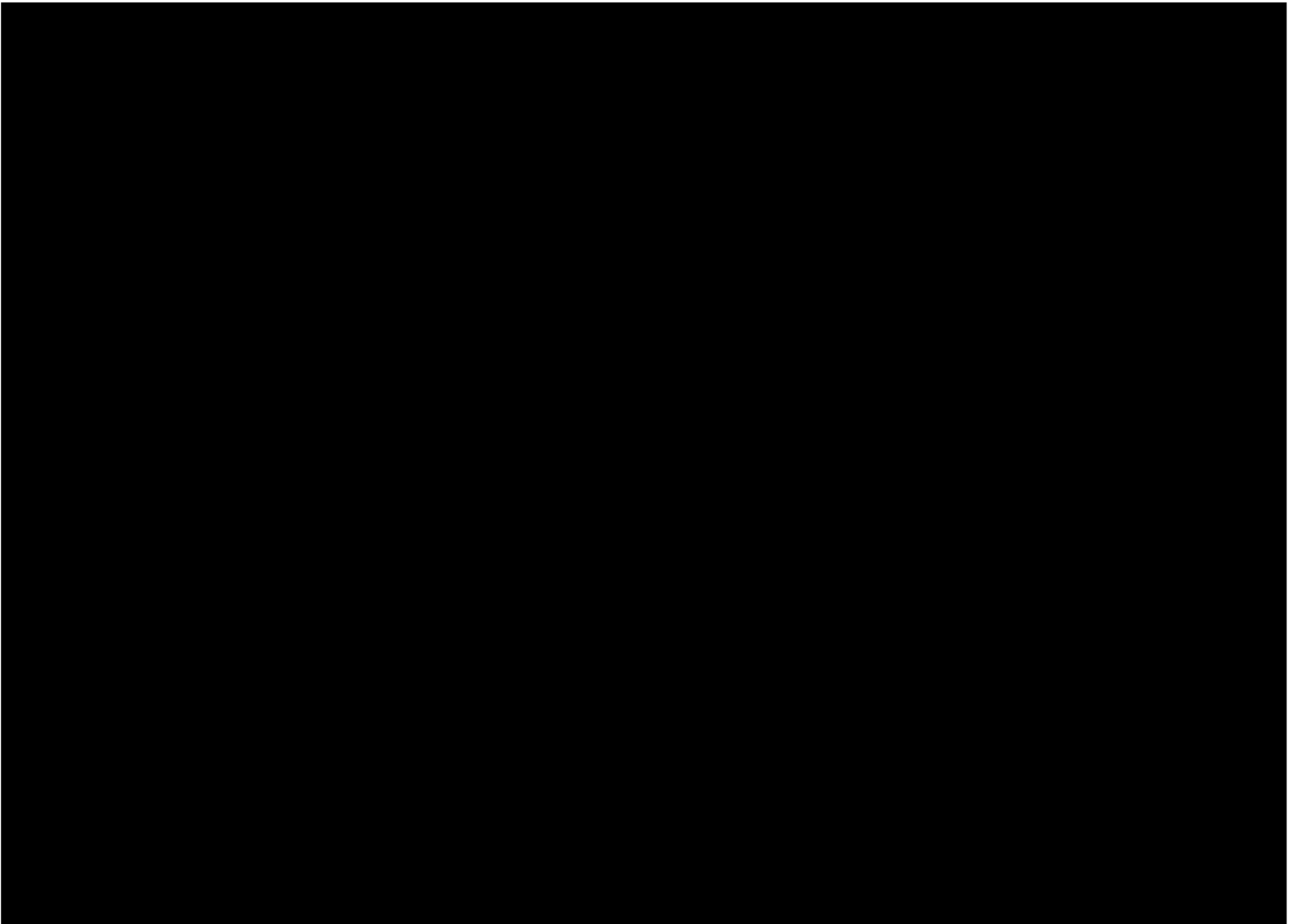
The key conclusions from this study were:

1. The 96-h acute kōura survival rates in all test treatments were consistently high, with $\geq 80\%$ survival observed even under conditions of high hardness and maximum contaminant concentrations.
2. The 14-d chronic kōura survival rates in all test treatments were $\geq 60\%$ to 80% survival and showed no concentration-response trend with increasing metal concentrations.
3. The calculated site-specific GVs for the BV ELF CaO treated (as supplied) would require dilutions of 1.8-times based on Ni, 9.7-times based on Co and 3.8-times based on Zn.
4. Use of these site-specific GVs will be conservative and protective of juvenile kōura populations.

Table 8-1: Summary of juvenile kōura (*Paranephrops planifrons*) toxicity test results for mine discharge water samples. Bold indicates toxicity values used for calculating the no toxicity dilution. Length endpoint results are excluded due to their low reliability, stemming from minimal observed growth (OCL length) in the NIWA test controls. (Table 1-2 from NIWA (2025f)).

Endpoint	NOEC ^a (%)	LOEC ^a (%)	TEC ^a (%)	No Toxicity Dilution ^b
21-d Survival	100 ^c	>100 ^c	>100 ^c	<1 [5.6x ^c]
21-d Growth - Biomass	3.2 ^d	10 ^d	5.7 ^d	18x ^d
14-d Survival	100 ^c	>100 ^c	>100 ^c	<1 [5.6x ^c]
96-h Survival	100	>100	>100	<1
21-d Survival	100	>100	>100	<1
21-d Growth - Biomass	100	>100	>100	<1
14-d Survival	100	>100	>100	<1
96-h Survival	100	>100	>100	<1
21-d Survival	100	>100	>100	<1
21-d Growth - Biomass	100	>100	>100	<1
14-d Survival	100	>100	>100	<1
96-h Survival	100	>100	>100	<1
21-d Survival	100	>100	>100	<1
21-d Growth - Biomass	100	>100	>100	<1
14-d Survival	100	>100	>100	<1
96-h Survival	100	>100	>100	<1

^a NOEC = No observed effect concentration; LOEC = Lowest observed effect concentration; TEC = threshold effect concentration (Geometric mean of NOEC and LOEC); ^b No toxicity dilution calculated as follows: chronic test = (1/TEC) * 100. ^c Statistically significant effects measured for comparison with NIWA control water (pH 7.8, comparable with HEPES buffer). Values reduced to: NOEC 10%, LOEC 32%, TEC 18% and No toxicity dilution 5.6-fold. ^d Low reliability values due to low 21-d control survival (40% and 60% control survival for HEPES and WM1; PIPES and MES are 80% control survival).



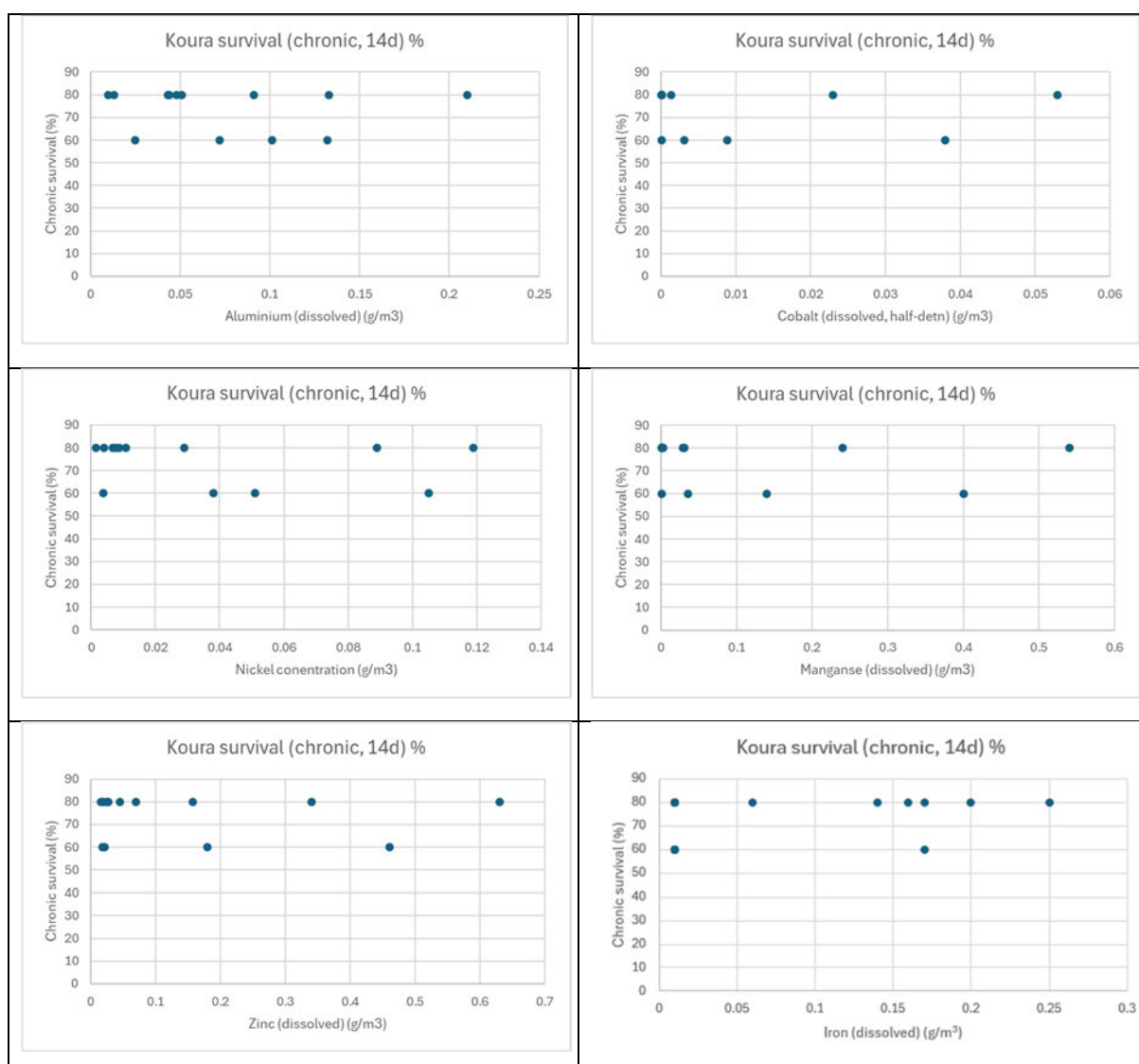


Figure 8-1: Plots of kōura chronic survival in relation to dissolved metal (aluminium, cobalt, nickel, manganese, zinc and iron) concentrations. Data from Table 8-2.

8.1.3 Mayfly and algal sensitivity testing

Mayfly and algal toxicity testing were conducted by Earth Sciences New Zealand (ESNZ, 2025b). The full results of this testing are provided in Appendix I.

The results of mayfly nymph (*Deleatidium* sp.) and green algal (*Raphidocelis subcapitata*) sensitivity testing to elevated Co and Ni concentrations in the natural water (██████████, pH 5.5) and modified (hardness treated to pH 7.5) are shown in Table 8-3. The results show that algae are markedly more sensitive than mayflies to cobalt (ca. >18-times) with minimal difference in sensitivity between pH 5.5 and 7.5. However, for Ni the mayflies are only slightly less sensitive at pH 5.5 (1.3-times), but markedly less sensitive at pH 7.5 (>4.5-times).

The threshold toxicity values (EC_{10S}) are compared with site-specific guidelines in Table 8-4. The calculated “Safety Factor” indicates the acute or chronic toxicity risk with values >1 indicating no toxicity. The Safety Factor values are highest for Co for both algae and mayflies (>42-times). Algal sensitivity at pH 7.5 has the lowest Safety Factor (2), with mayflies higher (7-times). The short-term

acute exposure for mayflies at pH 5.5 has a Safety Factor of 3 relative to the site-specific acute GV (Table 6-2).

In conclusion, the proposed site-specific GVs will be protective of algal and mayfly nymph toxicity (survival) from Ni or Co at the ambient pH 5.5 or for hardness-modified receiving water at pH 7.5.

Dilution water	Treatment	Control performance	EC ₁₀ ^a (95% CL) µg L ⁻¹	EC ₅₀ ^a (95% CL) µg L ⁻¹	NOEC ^b µg L ⁻¹	LOEC ^c µg L ⁻¹	TEC ^d µg L ⁻¹
		Density increase					
Laboratory water	Nil	25 x (CV 4.6%)					
Unmodified pH 5.5	Cobalt	4.3 x (CV 16%)	72 (31-117)	591 (370-943)	107	210	150
Modified pH 7.5	Cobalt	11 x (CV 8.9%)	92 (68-112)	247 (222-274)	110	215	154
Unmodified pH 5.5	Nickel	3.9 x (CV 17%)	171 (74-235)	457 (371-564)	125	240	173
Modified pH 7.5	Nickel	12 x (CV 7.9%)	68 (52-81)	148 (134-163)	55	108	77
		Mean survival %					
Laboratory water	Nil	88					
Unmodified pH 5.5	Cobalt	84	>1230 ^f	>1230	1230	>1230	>1230
Modified pH 7.5	Cobalt	88	>1685	>1685	1685	>1685	>1685
Unmodified pH 5.5	Nickel	84	226 ^f (124-N/A)	>307	138	307	206
Unmodified pH 5.5	Nickel	84	223 (N/A-348)	>307	138	307	206
Modified pH 7.5	Nickel	88	>308	>308	308	>308	>308

^a Statistically determined test Concentration causing a X% Effect on the endpoint after the specified exposure period. ^b NOEC: The highest concentration causing No Observed Effect relative to the controls. ^c LOEC: The Lowest tested Concentration causing an Observed Effect relative to the controls. ^d TEC: Threshold Effect Concentration, the geometric mean of NOEC and LOEC. ^e Low reliability values due to low control value as EC₁₀ not available with the linear interpolation analysis used.

Test organism	Dilution water	Treatment	EC ₁₀ (µg/L)	Hardness (mg/L CaCO ₃)	DOC (mg/L)	Calculated chronic [acute] GV (95%) (µg/L)	Safety Factor (SF) EC ₁₀ /GV
Alga 72 h ^c	Unmodified pH 5.5	Cobalt	72	3.8	2.6	1.4	51
Alga 72 h ^c	Modified pH 7.5	Cobalt	92	158	2.6	2.2	42
Alga 72 h ^c	Unmodified pH 5.5	Nickel	171	3.8	2.6	11	16
Alga 72 h ^c	Modified pH 7.5	Nickel	68	158	2.6	45	2
Mayfly nymph 14 d	Unmodified pH 5.5	Cobalt	>1230	3.8	2.6	1.4	879
Mayfly nymph 14 d	Modified pH 7.5	Cobalt	>1685	158	2.6	2.2	766
Mayfly nymph 96 h	Unmodified pH 5.5	Nickel	226	3.8	2.6	[69]	3
Mayfly nymph 14 d	Unmodified pH 5.5	Nickel	223	3.8	2.6	11	20
Mayfly nymph 14 d	Modified pH 7.5	Nickel	>308	158	2.6	45	7

8.1.4 Time-response for metal exposure to mayflies

Time-response toxicity data is available for mayflies exposed to metals (Hickey and Vickers, 1992) and for exposure to AMD (Bradley, 2003).

The metal data for Zn, Cu, Cd, Co and Ni is summarised in Table 8-5 and shown in Figure 8-2. The mayfly *Deleatidium* is highly insensitive to Zn (24-h EC₅₀ >25,000 µg/L = >25 mg/L) and Cd (24-h EC₅₀ >1,000 µg/L = >1 mg/L) (Table 8-5). The mayfly sensitivity is markedly lower for 24-h exposure than for the standard 96-h acute exposure test time - >3-times for Zn; 8.8-times for Cu and >7.4-times for Cd (48-h c.f. 96-h: >3-times, 2.2-times and 1.5-times respectively; Table 8-5, Figure 8-2).

Bradley (2003) measured the response of mayflies placed in AMD water at pH 3.5 with and without the metals present (Figure 8-3). The mayflies showed a progressive time-response to this multi-stressor AMD exposure with the presence of metals increasing the mortality response. That study did show that the physiological tolerance to prolonged low pH at 3.5 results in very low survival (<50%) even without the metals present.

The environmental implications of this toxic sensitivity time response relationship are that mayflies can tolerate short-term exposures to elevated contaminant concentrations far better than suggested by conventional 96-hour acute toxicity thresholds. This indicates that standard acute tests may overestimate the sensitivity of mayflies to brief contaminant pulses in natural systems.

Gadd et al. (2024) have developed water quality guideline values for acute no effect thresholds (termed GV-acute) for Cu and Zn for freshwaters. Those derivations follow the ANZG methodology

and include New Zealand species data for developing the SSD and the protection thresholds. Those GV-acute thresholds and the TMF equations have been used in this study to provide predictive levels for Cu and Zn (see Table 6-2).

Table 8-5: Time-response data for mayfly (*Deleatidium* sp.) exposure to metals at circum-neutral pH. Chronic data (14-d, 336-h) shown for comparison. Higher EC₅₀ values indicate lower toxicity.

Toxicant	EC ₅₀ concentration (µg/L)				
	Time (h)	Zinc ^a	Copper ^a	Nickel ^b	Cadmium ^a
	24	>25,000	325		>1,000
	48	>25,000	86		199
	96	9,036	39	307	135
	336			308	>1,685

^a Hickey and Vickers (1992); ^b ESNZ (2025b)

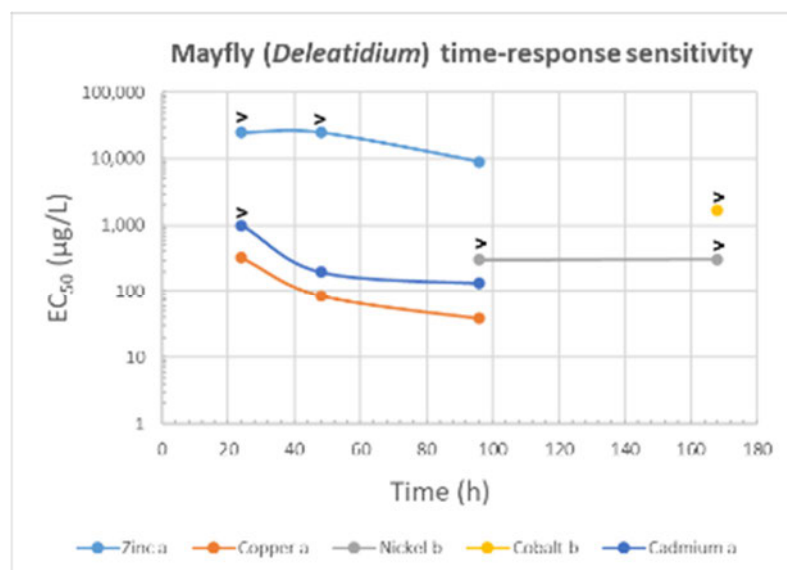


Figure 8-2: Time-response data for mayfly (*Deleatidium* sp.) exposure to metals at circum-neutral pH. Chronic data (14-d exposure, plotted at 168-h) shown for comparison. ">" indicates EC₅₀ greater than indicated. EC₅₀ = concentration causing a 50% survival reduction after that exposure time. Higher EC₅₀ values indicate lower toxicity.

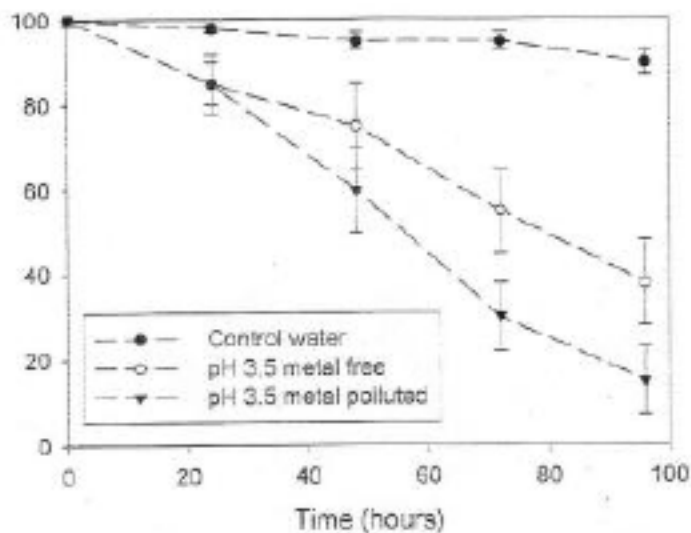


Figure 8-3: Mayfly (*Deleatidium* sp.) survival in control water (circum-neutral pH), AMD influenced Rapid Stream water (pH 3.5) and treated (metal free) Rapid Stream water (pH 3.5) (Bradley, 2003).

8.1.5 Other mayfly toxicity studies

A suite of chronic tests (14-d exposures) in acidic St Patrick Stream water (pH 5.4, Stockton Plateau) were undertaken for five metals (cadmium, nickel, lead, aluminium, cadmium and zinc) with a mayfly (*Deleatidium* spp.; measuring effects on growth (moulting), feeding behaviour and motility) and an alga (*Klebsormidium dissectum*; measuring effect on growth) in 2010. (Champeau and Cavanagh, 2010).

Their experiments were undertaken in St Patrick Stream water with mayflies collected from Carlton Creek (pH 5.4). St Patrick DOC was 3.1 mg/L, pH 6.3 and hardness 2.4 mg CaCO₃/L, with an elevated Zn concentration of 7.9 µg/L at the time of sampling (Appendix 2, Table 10 data from Champeau and Cavanagh, 2010). The toxicity results are shown in Table 8-6.

The site-specific GVs for St Patrick Stream water quality are (from Table 6-2): Cd 0.04 µg/L; Ni 11 µg/L; Pb – no GV; and Zn 26 µg/L. The Cd thresholds are all above the site-specific GV, with the Ni No Observed Effect Concentration (NOEC) below the site-specific GV by 27%, with the Lowest Observed Effect Concentrations (LOEC) higher (by 46%) for motility. The EC₁₀ threshold values are the preferred statistical measure for the updated ANZG derivations but regression thresholds are not provided by Champeau and Cavanagh (2010). Moulting and feeding endpoints are generally not included in the GV derivations, with motility being a preferred measure (Warne et al., 2025).

Table 8-6: No Observed Effect Concentration (NOEC) and Lowest Observed Effect Concentrations (LOEC) values (µg/L) for the mayfly *Deleatidium* sp. endpoints.

Endpoints		Cadmium (µg/L)	Nickel (µg/L)	Lead (µg/L)	
Moulting	NOEC	1.6	16	64	
	LOEC	0.8 (2 nd feeding)	16 (2 nd feeding)	4 (1 st feeding)	-
Feeding	NOEC	1.6 (2 nd feeding)	-	8 (1 st feeding)	4 (2 nd feeding)
	LOEC	0.2	8	8	
Motility	NOEC	0.4	16	16	
	LOEC				

Their conclusions were:

Exposure to Cd²⁺, Ni²⁺ and Zn²⁺ for 14 days resulted in significant effects on feeding and motility in the mayfly (Deleatidium spp.). These effects were observed at concentrations higher than the consent criteria and the ANZECC guidelines. The concentrations used in this study are lower than those typically used in similar toxicity studies. No effects on moulting behaviour were observed at the concentrations tested.

Algal biomass production was not affected by Ni (23 µg/L), Cd (0.31 µg/L), Zn (74 µg/L), Pb (4 µg/L), or Al (140 µg/L) at the concentrations tested. [measured concentrations added from Table 12].

Generally, the mayfly sensitivity thresholds measured in the acidic St Patrick Stream water (pH 5.4) by Champeau and Cavanagh (2010) will be protected by the site-specific GV for chronic exposure.

8.1.6 Summary: kōura and mayfly and green alga toxicity studies

The kōura and mayfly toxicity studies measured acute and chronic sensitivity across a range of pH levels and at high hardness – simulating the WTP treatment – bypass flows diluted into the naturally low-pH Whareatea River water (and other Buller Plateaux streams).

The kōura chronic studies showed no concentration-response reduction in survival for a wide range of metal concentration in the pH and hardness modified treatments. The proposed site-specific GV would be protective of kōura based on Ni, Co and Zn assessments.

The mayfly chronic toxicity studies showed that the proposed site-specific GV will be protective of algal (growth) and mayfly nymph (survival) toxicity from Ni or Co at either the ambient pH 5.5 or for hardness-modified receiving water at pH 7.5.

A review of time-response toxicity studies for the mayfly (*Deleatidium* sp.) data showed Zn sensitivity was 3-times less sensitive for 24-h or 48-h exposures than for the standard 96-h acute measurement period. This time-response sensitivity data supports the use of acute no effect threshold data for compliance assessment relative to the short-duration flood-flow bypass events experienced on the Buller Plateaux .

8.2 Predicted receiving water quality in ESE and MFS sub-areas

8.2.1 Results of WLBM predictions for TMFs in receiving waters

Mine Waste Management have undertaken WLBM for ESE (MWM, 2026k) and MFS (MWM, 2026i) with the effects assessment summarised in MWM (2026o). Their effects assessments have used the proposed site-specific guidelines (Table 6-2) and incorporate predicted changes in TMF levels in the receiving waters after mixing.

The MWM models predict the contaminant concentrations at compliance locations downstream of discharges during the active and post-closure (passive) water treatment phases. These discharges include intermittent sump bypass/spill discharges and WTP discharges during the active treatment phase and continuous MSR discharges during the passive treatment phase. The discharge and MSR locations are shown in the Process Flow diagrams (Appendix B) and site maps (Appendix A).

The models use a 24-h time step for predictions so can provide output calculations for concentrations and durations which are appropriate for the high intensity rainfall events and the associated discharge variability. The models used were dynamic and incorporated TMFs (i.e., pH, hardness and DOC) at each time step.

The prediction of changes in TMF levels are an important component of the site-specific GV calculations. Cumulative exceedance plots are presented to show the percentage of time the levels are equalled or exceeded. Figure 8-4 shows the data for Whareatea River at KEL for pH, DOC and hardness. Both the pH and hardness increase markedly from the current background of pH around 5.5 and hardness <5 mg CaCO₃/L. These changes in TMF will markedly affect the potential toxicity of most metals at the KEL compliance site.

The cumulative exceedance plots for hardness on Waimangaroa River at Smokestack (2W) are shown in Figure 8-6. These show that hardness will also increase markedly at these sites during active and the passive water treatment phases from the current background hardness <10 mg CaCO₃/L.

Significantly, the MWM models do not incorporate the flow variability of TMFs at compliance sites. The flow effects are shown in Section 6.2.1 with upstream hardness varying significantly with flow at Smokestack together with background metal concentrations. Thus, the individual sampling occasions will need to be assessed as MEQs at this compliance site for each sampling occasion to allow for the upstream variability in water quality from the historic AMD inputs.

In conclusion, these model simulation results indicate that both the active and passive phases will markedly increase hardness – but to a varying degree – which will reduce potential toxicity of the discharges. The predicted changes in pH and DOC in the receiving waters will also affect the potential toxicity of the discharges.

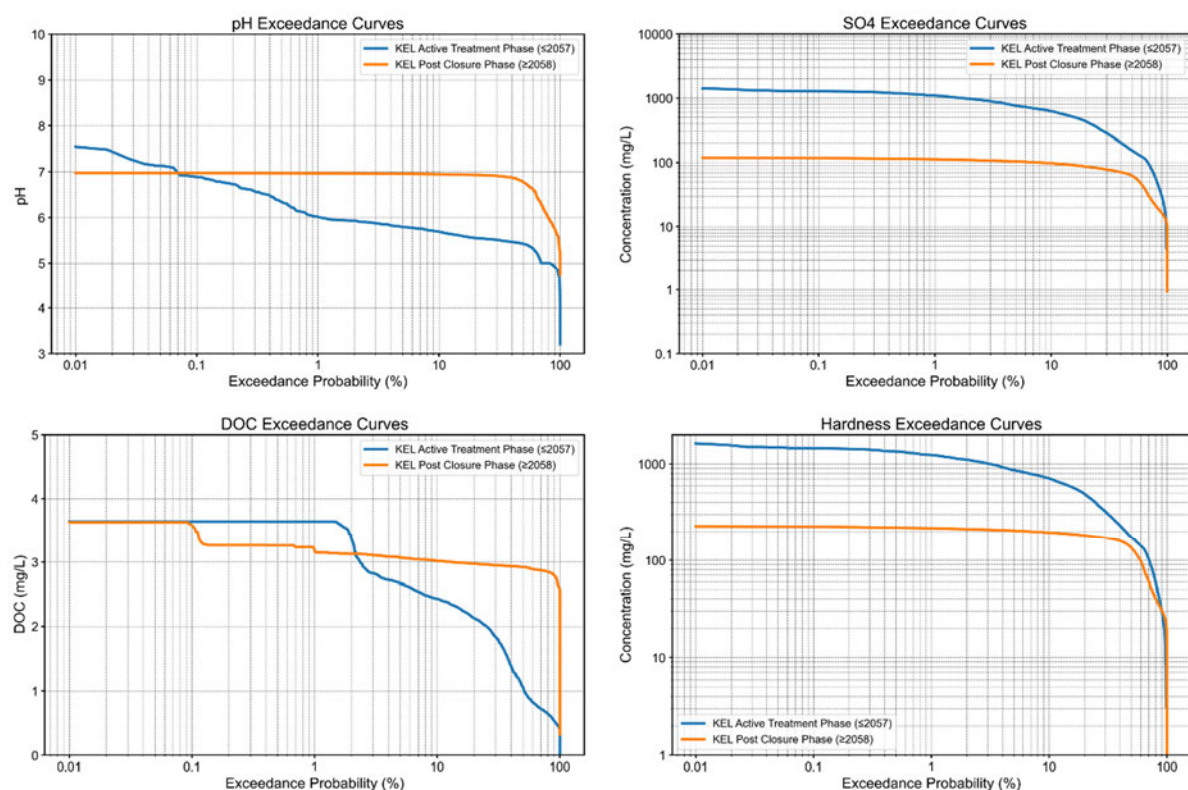


Figure 8-4: KEL - exceedance plots (pH, SO₄, DOC, hardness) (Figure 38 from MWM (2026k)). Sulphate (SO₄) concentration exceedance probabilities are included as these indicate the quantity of AMD neutralised. The model calculations for constituent concentrations are based on correlations with sulphate (MWM, 2026e).

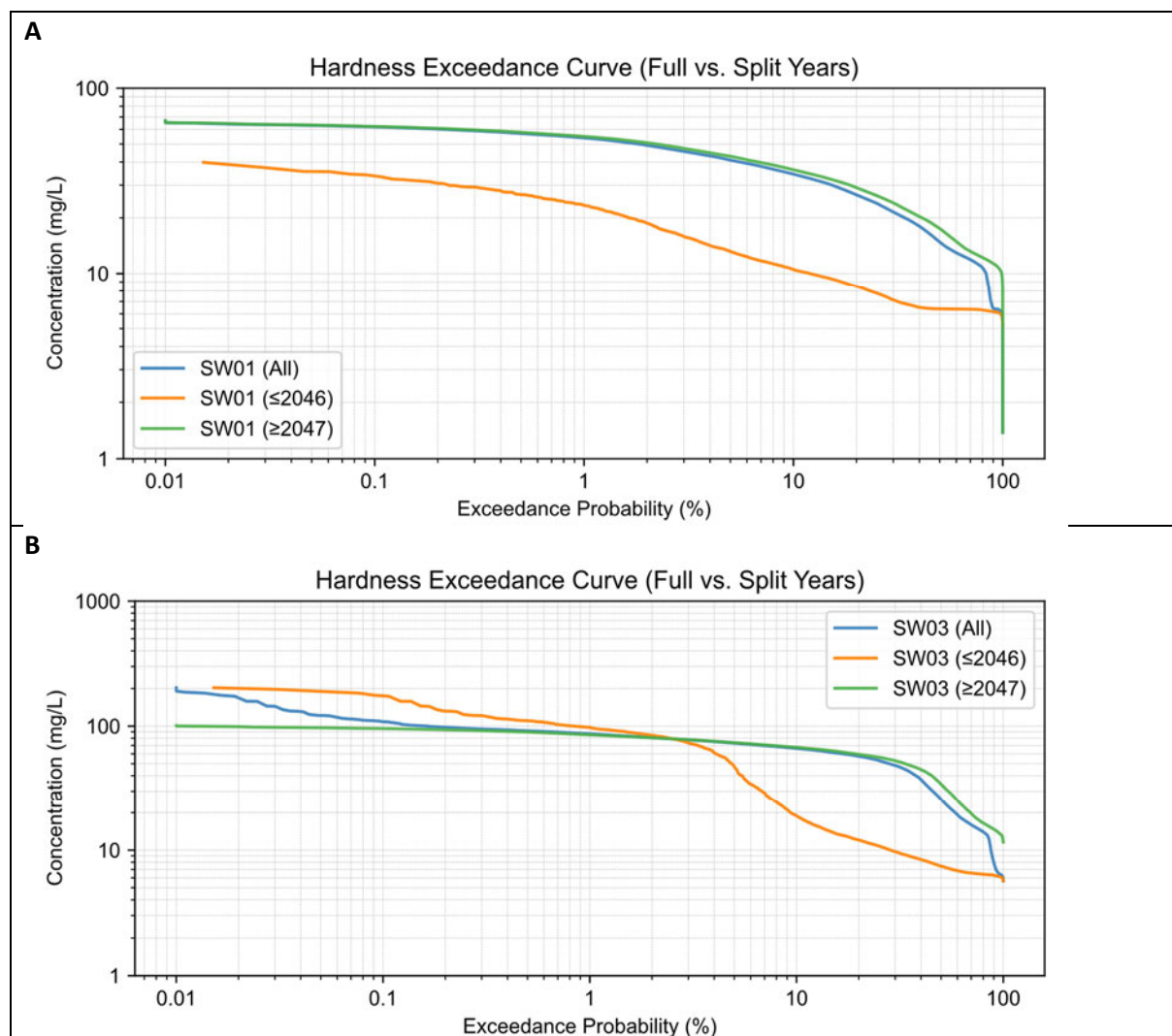


Figure 8-5: Exceedance probability of daily results for hardness at (A) SW01 (Figure 40) and (B) SW03 (Figure 52) for the 'Active Phase' (≤ 2046) and 'Passive Phase' (≥ 2047), and the overall data (MWM, 2026i).

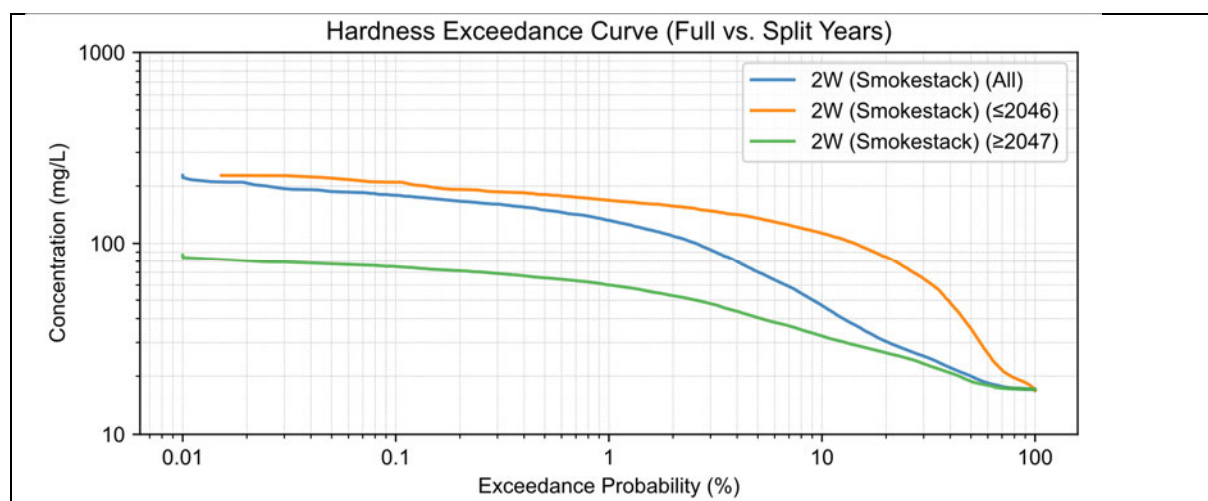


Figure 8-6: Exceedance probability of daily results for hardness at 2W (Smokestack) for the 'Active Phase' (≤ 2046) and 'Passive Phase' (≥ 2047), and the overall data (Figure 64 from MWM (2026i)).

8.2.2 WLBm predictions of exceedance frequency of metal chronic limits for ESE and MFS sub-areas

The WLBm results for mean and maximum exceedance frequency for chronic and acute limits – with TMFs – for five rainfall scenarios are shown for the ESE sub-area in Figure 8-7 and the MFS sub-area in Figure 8-8 for the active treatment phase, with numeric values provided in Appendix M. The ten metals assessed are based on the chronic and acute compliance relationships shown in Table 6-2, with screening for trivalent chromium (Cr(III)) and lead (Pb) – which are not included in the proposed compliance suite – using the GVs from Table 6-1. The “active phase” includes discharges from both mine sumps and WTPs in each sub-area.

For both sub-areas, the WLBm did not predict exceedances of the Cr(III) or Pb site-specific mean chronic guideline values – with only KEL site showing predicted low maximum values (generally <0.5% chronic maxima for the various scenarios). This supports their exclusion from the proposed compliance limits (Table 6-2). All other metals show mean chronic exceedances less than 5% of the time for ESE and MFS for all scenarios at all sites for the active treatment phase.

The maximum annual chronic exceedances for the operational periods in the ESE sub-area occurred on at site KEL (~6–<15% for Al, Fe & Zn; <5% for Co, Cu, Cd, Ni & Mn). The highest maximum chronic exceedance frequency for ESE occurs for the high rainfall scenarios (Scenarios 1 & 3 respectively) for Al, Fe and Zn at KEL, with V62 having chronic exceedance maxima for multiple metals (<5% of the time) (Figure 8-7). The mean acute exceedance values are highest for Zn at KEL and V62 (<1.5% for all scenarios) with the predicted acute maximum exceedance <5% for all scenarios (Figure 8-7).

The maximum annual chronic exceedances for the MFS sub-area were all <10% and occur for Cd and Zn (each about <7% of the time for the various scenarios) for SW01 and SW03 sites on Deep Stream. The chronic exceedance was maximally <~3% of the time for various scenarios for other metals at sites SW01 and SW03. The Cd exceedance at SW01 and SW03 likely attributable in part to the low GV⁴⁰, high protection level (95%) and likely low hardness for these sites during sump bypass discharge events and the trace analytical detection limit (identified for the site-specific index condition in Table 6-3).

The maximum chronic exceedances at 2W and 17W on Waimangaroa River was for Cu (<0.5%) with all other metals showing negligible exceedance. All acute exceedance frequencies were <0.5% with the highest values at 17W for Cu (0.3%). All other metals at these sites showed negligible exceedance (Figure 8-8, Appendix M).

⁴⁰ MEQ and compliance calculations are recommended to use half detection limit for trace analyses for assessments because of the low GV and likely less than detection for many analyses (see Section 9.2.2).

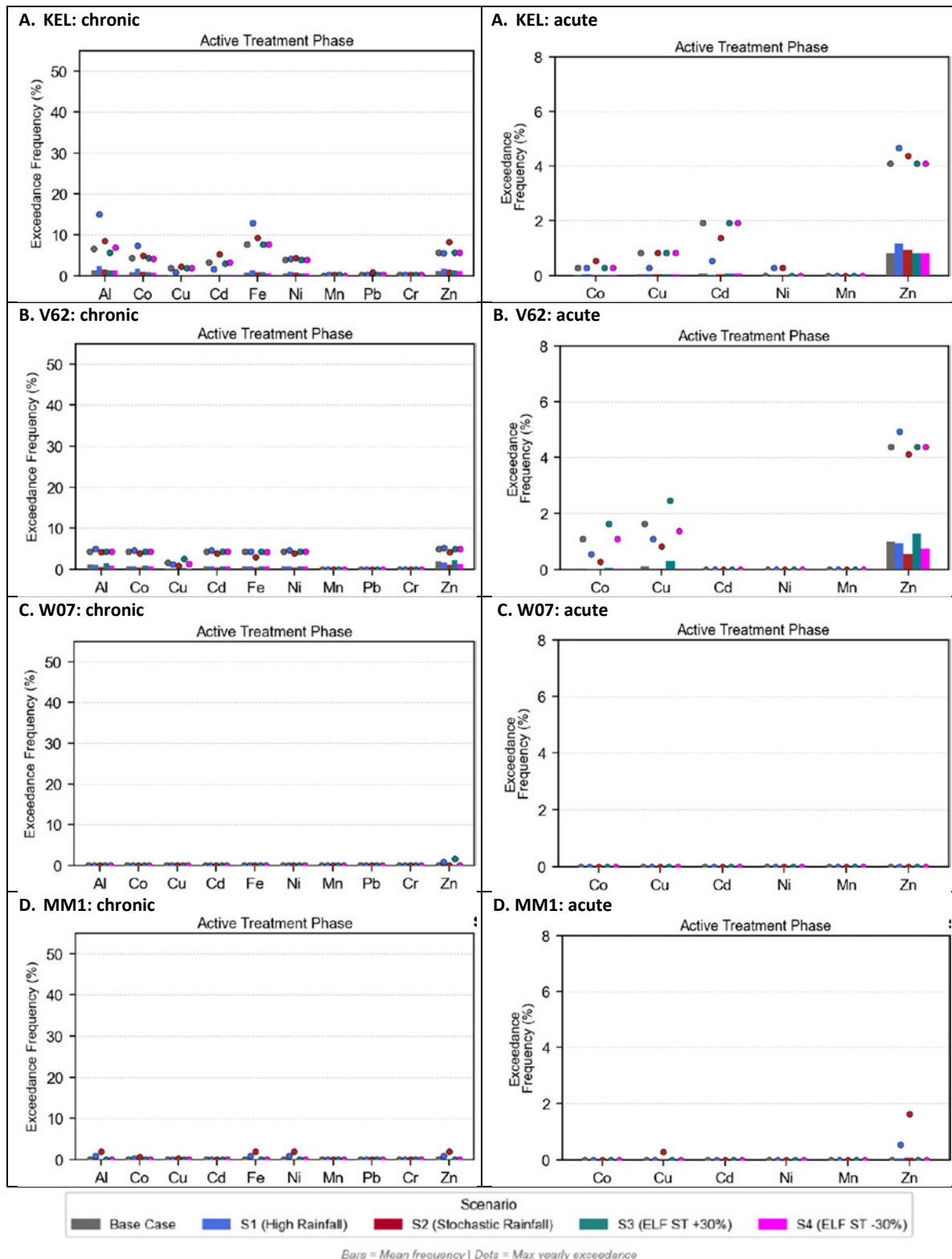


Figure 8-7: WLBW results for ESE sub-area sites for mean and maximum exceedance frequency (chronic and acute limits; Note: no acute GV for Al, Pb, Fe or Cr) per station, scenario for active treatment operational phase (Appendix C from MWM (2026k)). LoPs are: A. 95% for KEL; B. V62 and C. W07; D. 80% for M-M1. Scenarios labelled in Figure 8-7 and described in Table 7 of MWM report. “ELF ST +30%” evaluates higher loading rates to base case and “ELF ST -30%” evaluates a 30% reduction in loading to the base case. See Appendix A for site locations and Appendix M for numeric frequency values.

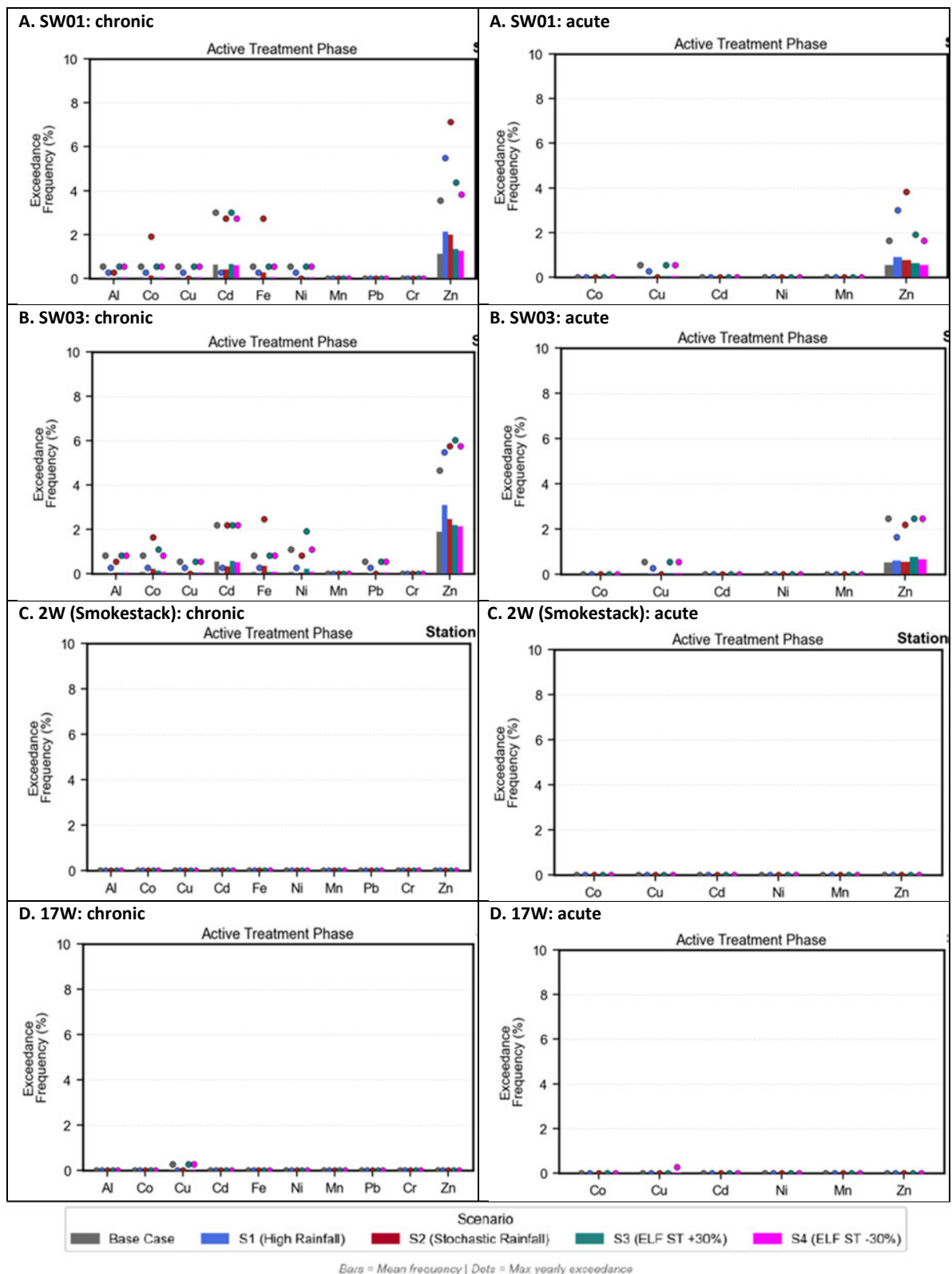


Figure 8-8: WLBm results for MFS sub-area for mean and maximum exceedance frequency (chronic and acute limits; Note: no acute GV for Al, Pb, Fe or Cr) per station, scenario for active treatment operational phase (Appendix E from MWM (2026i)). LoPs are: 95% for SW01 (A) and SW03 (B); 90% for 2W (C) and 17W (D – downstream of Deep Stream confluence). Scenarios provided in Table 6 of MWM report. “ELF ST +30%” evaluates higher loading rates to base case and “ELF ST -30%” evaluates a 30% reduction in loading to the base case. See Appendix A for site locations and Appendix M for numeric frequency values.

8.3 Lowland streams and estuaries

8.3.1 Ecological protection of lowland streams

The lowland coastal reaches of streams draining the Buller Plateaux have diverse ecological communities comprising both macroinvertebrates and native fish species (Hogsden and Jellyman, 2026; NIWA, 2020), with some limited recreational fishing for whitebait and brown trout (Greenaway, 2026).

Water quality (Section 6.1.2; including nitrate-N and ammoniacal-N for toxicity protection; pH) and sediment (turbidity) (Section 7.1.3) guidelines are proposed for compliance locations which are located on the Buller Plateaux. The site-specific guidelines are for protection of fish, invertebrate and plant communities. Additional downstream dilution will occur downstream in the proposed mining catchments which will further reduce the potential risk for contaminant exposures of downstream ecological communities.

The proposed sediment (turbidity) guidelines include values for protection of aesthetic impacts on the downstream recreational users. There is comprehensive upstream compliance monitoring and performance monitoring at SH67 to ensure that water clarity is maintained through mining operations at the BPCP.

Consideration of the PCOCs present in the pH neutralised mine sumps – primarily elevated dissolved Al, Mn, Fe and Zn concentrations – does not raise concerns for potential significant tissue bioaccumulation and any exceedance of human consumption guidelines.⁴² Migrating whitebait are sea-run and are resident in the freshwater environment for such a short time before potential harvest that no significant bioaccumulation of metal contaminants – if elevated – would occur. Eels (tuna) would likely be the major resident mahinga kai with small ‘estuarine trout’ considered of local significance for angling (Greenaway, 2026).⁴³

8.3.2 Drinking water and stock water use

There are no identified drinking water takes from the Whareatea River downstream of the proposed ESE sub-area or the Waimangaroa River downstream of the proposed MFS sub-area and UWHR (MWM, 2026g).

Taumata Arowai administers New Zealand’s drinking water standards (NZ Govt, 2022)⁴⁴ and aesthetic values for drinking water (Taumata Arowai, 2022).⁴⁵ The ANZG provide stock drinking water

⁴¹ Sampling kōura and fish species (including eels) for tissue analysis. Species collection from a range of reference, plateaux and AMD-affected sites (including Stockton). Analysis for: lipid content; iron, aluminium, antimony, arsenic, bismuth, cadmium, cobalt, copper, lead, manganese, mercury, nickel, silver, thallium, tin and zinc.

⁴² The concentrations of Mn, Fe and Zn are essential elements and thus regulated in biological organisms. Aluminium has a low bioaccumulation factor in aquatic organisms – though some level of tissue elevation will be expected for waters with elevated dissolved Al concentrations.

⁴³ “The Fish and Game Council Sports Fish and Game Management Plan for West Coast Region (2024) notes the presence of brown trout in the Ngakawau, Whareatea and Waimangaroa Rivers and classes them as of local significance for angling. This reflects the presence of relatively small (under 3 lb) ‘estuarine trout’ in the lowest reaches of the three rivers. These are mostly vagrant fish which follow smelt entering from the sea late in year, targeted by the occasional local angler.” (s3.5, Greenaway 2025).

⁴⁴ <https://www.legislation.govt.nz/regulation/public/2022/0168/latest/whole.html>

⁴⁵ <https://www.taumataarowai.govt.nz/assets/Uploads/Rules-and-standards/Taumata-Arowai-Aesthetic-Values-for-Drinking-Water-2022.pdf>

guidelines – which are currently in revision⁴⁶ from the ANZECC 2000 guidelines. The ANZECC guidelines for stock water were used for this assessment. The ANZECC 2000 guidelines included chemical thresholds for recreational exposure. These have been discontinued in ANZG which now links to the National Health and Medical Research Council (NHMRC) Australian Recreational Water Quality Guidelines – which are currently draft and out for public consultation.⁴⁷ This draft document focuses on providing guidance for a risk assessment such as identifying potential sources of chemical (and microbial) contamination in recreational waters. Assessing chemical quality associated with pH measurement as an indicator of recreational water quality is potentially relevant to this assessment.⁴⁸ No specific chemical thresholds for recreational use were identified in this document relative to these sites – other than the pH range of 5.0-9.0 for low buffering capacity waters. The WHO guidelines for drinking water quality assume an individual drinks 2 litres of water per day. During swimming or recreational activities, an individual is assumed to inadvertently swallow roughly 100 mL of water per day (WHO, 2024). To assess the chemical safety for recreational activity, the provisional recreational screening threshold is set at 20 times higher than the standard drinking water guideline values (i.e., 2 L/0.1 L = 20). Based on this WHO assessment basis there are no exceedances of recreational guidelines for chemicals at SH67 sites for Whareatea or Waimangaroa river (Table 8-7).

The drinking water standards, stock and recreational guidelines are compared with the maximum contaminant concentrations measured at the SH67 sites in Table 8-7. There are no exceedances of the drinking water Maximum Acceptable Values (MAVs) for either of the river sites. Aesthetic values for drinking water are exceeded for aluminium, iron and turbidity. These parameters would be readily removed with basic drinking water treatment should downstream surface water be used as a drinking supply in the future.

There is no monitoring data for the SH67 sites for nitrate-N and ammoniacal-N. Background monitoring information is needed for these sites because of the potential for increased nitrogen from mining activities (Section 7.2). This background information for SH67 sites is proposed for collection with monthly pre-commencement monitoring in the coming 1-year period.

⁴⁶ <https://www.waterquality.gov.au/anz-guidelines/guideline-values/default/primary-industries/stock-water-guidance>

⁴⁷ <https://www.nhmrc.gov.au/about-us/publications/guidelines-managing-risks-recreational-water#block-views-block-file-attachments-content-block-1>

⁴⁸ Guidance: “Low pH increases the probability that inorganic substances will occur naturally. Whenever the pH is less than 5.5 (e.g., water influenced by acid mine drainage), any water in contact with mineral deposits will require investigation. Both alkaline and acidic waters may cause eye and skin irritation and may affect the taste of water. Waters used for primary recreation should be in the pH range 6.5–8.5. If the water has a very low buffering capacity, the pH range may be extended to 5.0–9.0.” (Table 9.4, NHMRC 2026).

Table 8-7: Comparisons of stock drinking water guideline values (ANZG 2018), drinking water (Maximum acceptable value, MAVs; NZ Govt (2022)) and aesthetic values for drinking water (Taumata Arowai, 2022) with maximum contaminant concentrations measured in Whareatea River (SH67, site WM-3; n = 38-70 occasions) and Waimangaroa River (SH67, n = 1-7 occasions). Bold italics indicates exceedance of the drinking water MAV (none identified) and aesthetic values for drinking water are bold/grey background for any exceedances. NG = no guideline; NS = no standard; ND = no data.

Name	Stock drinking water guideline values (mg/L)	Drinking water (MAV, mg/L)	Aesthetic values for drinking water (mg/L)	Whareatea (WM-3, mg/L)	Waimangaroa (SH67, mg/L)
Aluminium	5	1	≤0.1	0.86	0.29
Antimony	NG	0.02		ND	ND
Arsenic	0.5	0.01		<0.01	ND
Barium	1	1.5		ND	ND
Boron	5	2.4		ND	ND
Cadmium	0.01	0.004		0.001	<0.00005
Chromium	1	0.05		0.0053	ND
Copper	0.4	2	≤1	0.0053	<0.0005
Fluoride	2	1.5		ND	ND
Iron	NG	NS	≤0.3	0.56	0.13
Lead	0.1	0.01		0.0006	<0.0005
Manganese	NG	0.4	≤0.04	0.013	0.0082
Mercury	0.002	0.007		ND	ND
Nickel	1	0.08		0.0015	0.0025
Nitrate-N	92	11.5		ND	ND
Selenium	0.02	0.04		ND	ND
Sodium	NG	NG	≤200	ND	ND
Sulfate	1000	NG	≤250	2.1	11.8
Zinc	20	NG	≤1.5	0.035	0.0094
Other				ND	ND
Ammonia (as N)	NG	NS	≤1.5	ND	ND
Oxygen	NG	NS		ND	ND
pH	NG	NS	7.0-8.5	8.0	6.8
Turbidity	NG	NS	≤5	344	54
Total dissolved solids (TDS)	NG	NS	≤1000	ND	ND

8.4 Hazardous chemicals

A comprehensive review of potentially hazardous chemicals stored and used on the Buller Plateaux for current and future proposed mining has been undertaken (T&T, 2026).

The T&T (2026) report concluded that: *“Provided the controls and mitigations are in place as outlined above, the effects on the environment are expected to be low and do not require further consideration as part of the BPCP ecotoxicity effects assessment.”* (section 10.2.2).

Based on that assessment, no specific risk assessments for other potential chemical contaminant effects have been undertaken other than those covered in this report.

9 Management and monitoring

Planned monitoring includes continued background monitoring associated with pre-commencement, and future compliance monitoring associated with the construction phase, operational mining and post-closure when the passive treatment systems will be operational. Progressive rehabilitation and installation of some passive treatment will occur during the operational mining stage.

The proposed monitoring sites include local reference sites and compliance sites for compliance assessment. These sites are shown in the Process Flow diagrams (Appendix B) and the Buller Plateaux site maps (Appendix A).

Additional targeted monitoring is to be undertaken at “Performance” sites. These sites are located relative to existing AMD inputs and downstream adjacent to SH67.

9.1 Background

Continued pre-commencement collection of background monitoring data collection is proposed for both sediment (turbidity), chemical and biological characterisation as well as additional monitoring.

This additional data will include continuous turbidity monitoring at a number of sites, continued deployment of Storm Water Samplers to characterise high flow events and discrete chemical sampling. Additionally, repeat biological sampling (periphyton, bryophytes, macroinvertebrates and kōura) will be undertaken to provide a minimum of three sampling occasions at key sites (Hogsden and Jellyman, 2026).

The reference and compliance site sampling for continued background information is summarised in Appendix L.

9.2 Compliance limits

9.2.1 Suspended sediments (turbidity)

Suspended sediment compliance conditions are provided in Table 7-1 with locations for reference, compliance and performance sites provided in Appendix E (Table E-1) with indicative compliance limits based on existing background monitoring data in Table E-2.

All the compliance and reference sites have proposed continuous turbidity monitoring with additional weekly discrete turbidity monitoring. The weekly monitoring would be used to check calibration of the continuous turbidity sensors (rather than for compliance assessment).

The proposed compliance assessment would be based on an add-to-background calculation for compliance site relative to the associated reference site for the annual median and annual 95th percentile limits. Additionally, there are 7-d rolling median and a maximum limit condition that would apply at the downstream compliance sites. Performance sites with a lower frequency of sampling would apply a 15-sample rolling median for comparison with the long-term limit.

Key Performance monitoring assessments are for SH67 sites where aesthetic conditions are relevant. Monthly discrete monitoring of turbidity at these sites is proposed for the construction phase and operational mining period (Appendix L). A proposed assessment threshold of <50% change in clarity at SH67.

The background clarity measurements from continuous turbidity and discrete clarity measurements (black disc) monitoring at SH67 sites during the pre-commencement phase would establish the basis for turbidity/clarity conversion relationships⁴⁹. Continuous monitoring at the upstream compliance sites, with a flow adjustment factor (AF-flow) (Appendix E), could be used to calculate the median turbidity at the SH67 sites to determine mine-related turbidity contribution. This calculated value compared with the pre-commencement ‘background’ median turbidity (clarity) at SH67 would provide a calibration of potential catchment effects for the future assessment of aesthetic effects.

An “Extreme event” threshold of a 10-year return interval rainfall event is proposed as a natural high turbidity event (Section 7.1.2, from Hickey (2026c). The measured turbidity data for these periods would be excluded from both the determination of the basis of assessment (background) and from the compliance assessment.

Quality control - turbidity

All measurements should be taken with a temperature compensated meter calibrated to 25°C. The reported sensor accuracy for turbidity-field measurements is ± 0.3 FNU (Formazan Nephelometric Units) from 0 to 999 FNU and 5% for 1000 to 4000 FNU (NEMS, 2019), so a non-compliance assessment should incorporate this measurement resolution. Performance of field and laboratory turbidity instruments can vary significantly (Davies-Colley et al., 2021). Thus, standardisation of field turbidity instrumentation is desirable and regular calibration using a range of standards relevant to the field measurement range. Continuous turbidity monitors should also be standardised and regularly calibrated with comparison to portable field instruments. Self-cleaning probes and a regular maintenance programme should be in place to ensure reliable measurements.

An accuracy assessment for continuous turbidity monitoring equipment should be undertaken and incorporated into the consent non-compliance assessment conditions.

Field measurements of black disk clarity should follow standard protocols (Davies-Colley, 1988; MfE, 1994).

9.2.2 Chemistry

Metals and TMFs

The proposed metals compliance limits are based on dissolved metal concentrations and incorporate TMF (pH, hardness and DOC – differing between metals) relationships to derive bioavailable metal guidelines.

The compliance equations for chronic and acute GVs for differing LoPs are provided in Table 6-2. Calculated Index Condition (pH 7.0, hardness 50 mg CaCO₃/L, DOC 3.5 mg/L) are provided in Table 6-3. The metals have differing minimum and maximum pH, hardness and DOC range for calculation of the GVs. The GV calculated for the maximum or minimum TMF value applies for any level of TMF above or below that limit.

Index Condition-Low values for minimum pH and hardness values are shown in Appendix J (Table J-1). For most metals, hardness is the key modifier, and minimum values are about 50 mg CaCO₃/L.

⁴⁹ Special site visits to SH67 sites will probably be necessary to obtain representative turbidity and black disk measurements (either in river or using bankside channels) covering a representative range of low and high flow conditions.

Thus, “true” site-specific GVs cannot be calculated for the naturally very low hardness Buller Plateaux streams (background hardness <5 mg CaCO₃/L).

Compliance assessment is based on a 95% LoP for most sites. The compliance sites are shown in the Process Flow diagrams (Appendix B) and listed in Appendix L for differing LoPs. These sites are assessed relative to the TMF-adjusted guideline value.

Sites on the Waimangaroa River (MFS sub-area) have an 80% LoP (Appendix G) based on historic and ongoing upstream AMD inputs. The downstream compliance sites are assessed relative to the TMF-adjusted guideline value for those sites conservatively including the elevated upstream constituent concentration at the downstream compliance site. For this assessment the compliance site constituent concentration on the monitoring occasion is compared with the TMF-adjusted GV appropriate for the downstream compliance site. This approach is considered appropriate for the time-variable upstream AMD inputs with high associated TMF variability (Section 6.2.2).

One compliance site in ESE sub-area (MM1, V8 Creek) has an existing AMD input and receives some WTP discharge, is also considered appropriate for 80% LoP compliance limits for metals and nutrients (Appendix G, Table G-1) and Performance for turbidity for with a compliance limit (Table 7-1; Appendix E, Table E-1). The proposed frequency of monitoring at this site is weekly and a Betterment (i.e., improving trend) assessment is also recommended for turbidity because of proposed improvements to manage adit AMD inflows.

Monitoring data collected when no mine discharges are occurring should not be included for the annual compliance assessment or for betterment trend analysis.

Quality control – chemistry sampling and analysis

Water sampling for chemical analysis should follow documented clean sampling techniques (NEMS, 2019).

Chemical analyses should be performed at an IANZ or equivalent analytical laboratory to “trace” level of quantitation (LOQ) (e.g., values in Table 6-3). Analytical results database should record data as reported by analytical laboratory (i.e., with “<” or “>” values) together with the LOQ for the reporting period. Half detection limit values should be used for consent compliance assessment.

The key TMFs – pH, hardness (i.e., Ca & Mg concentrations), DOC – should be collected for each monitoring occasion. The DOC analytical method used should be specified as “dissolved non-purgeable organic carbon (DNPOC)” to provide improved analysis of organic carbon. Field temperature measurement is also required for ammoniacal-N toxicity assessment (following section).

Nitrogen

Nitrate-N and ammoniacal-N could potentially be elevated in receiving waters – primarily from explosives and to a much lesser extent from proposed treated sewage discharge (Hickey, 2026e).

Nitrate-N

The measured concentrations are compared with the recently updated ANZG for nitrate-N (NO₃-N) – which are hardness-dependent (ANZG, 2025a), and the NPS-FM standards for nitrate (MfE, 2020c).

The ANZG (2025a) **guideline values**: (i) for 95% protection in low hardness waters are 1.1 mg/L for hardness <30 mg/L as CaCO₃, 2.6 mg/L for 30-150 mg/L hardness and 29 mg/L for >150 mg/L

hardness; and (ii) for 90% protection in low hardness waters are 1.5 mg/L for hardness <30 mg/L as CaCO₃, 4.2 mg/L for 30-150 mg/L hardness and 38 mg/L for >150 mg/L hardness.

The NPS-FM has “**bottom line**” standards for nitrate-N of an annual median of 2.4 mg/L and an annual 95th percentile of 3.5 mg/L (MfE, 2020c). The more sensitive of these standards represents the controlling statistic.

Drinking water standards also include nitrate as a contaminant of potential concern (NZ Government, 2022). The drinking water standard (11.3 mg/L nitrate-N maximum acceptable value (MAV) concentration) would be applicable to any future downstream drinking water take from surface waters. All the receiving waters downstream of the proposed discharges from the ESE, MFS and UWHR sub-areas currently have no identified takes for drinking water supply (MWM, 2026g).

The compliance sites should be assessed against the appropriate hardness-band GV for the LoP (Appendix G, Table G-1, GVs in Table 6-2) and all sites assessed against the NPS-FM bottom line standards values.

If nitrate is elevated at compliance sites, a dilution adjustment should be applied for SH67 concentration (Appendix E) based on the maximum concentration. The maximum SH67 concentration should not exceed the MAV of 11.3 mg/L. A precautionary compliance limit of 11.3 mg/L of nitrate-N maximum concentration should be placed on Buller Plateaux compliance sites on Whareatea River (site KEL) and Waimangaroa River (site 17W).

Ammoniacal-N

The measured concentrations are compared with the recently updated ANZG for ammoniacal-N (NH₄-N) – which are pH- and temperature-dependent (ANZG, 2026c), and the NPS-FM standards for ammoniacal-N which are pH-dependent (MfE, 2020c). The toxicity of ammoniacal-N increases as pH increases.

The ANZG (2026c) **guideline values** for pH 7 and 15°C: (i) for 95% protection 1.2 mg/L; 90% protection 2.0 mg/L and (iii) 80% protection 3.6 mg/L. The GV tables for TMF adjustment for pH and temperature are provided in Appendix F (Tables F-30 to F-32). The index condition used above is the maximum pH and approximate average temperature for Buller Plateaux streams.

The ANZG (2026c) ammoniacal-N guidance states that they should not be applied to low ionic strength waters (EC <50 µS/cm). The Buller Plateaux waters have naturally low ionic strength but the ELF drainage water and WTP discharges will have markedly higher ionic strength. Thus, the ANZG ammoniacal-N guidelines would be expected to be applicable to mine-affected receiving waters.

The NPS-FM has “**bottom line**” standards for total ammoniacal-N of an annual median of 0.24 mg/L and an annual 95th percentile of 0.40 mg/L (at pH 8 and 20°C) (MfE, 2020c). The more sensitive of these standards represents the controlling statistic for the freshwater management unit (FMU). The NPS-FM standards are pH-dependent with adjustment factors (AF-TMF) provided in Appendix F (Table F-33) (MfE, 2018).

There are no stock water guidelines or human drinking water standards for ammoniacal-N (Section 8.3.2), so no assessments are required from monitoring data from Buller Plateaux compliance sites of SH67 monitoring.

pH

The pH range for 95th and 90th percentile LoP sites is pH 4.5-7.0 for sites requiring ecological species protection (Hogsden and Hickey, 2025). Compliance sites with historic AMD input (e.g., MM1 on V8 Creek) should have pH as a performance measure until remediation measures are completed.

There is potential for natural short-term reductions in pH below 4.5 in reference streams in response to humic/fulvic acid inflow during rain events. The compliance site assessment for grab samples and Storm Water samplers at compliance sites should consider the reference site pH for the concordant monitoring occasion. If reference site pH is below 4.5 then the compliance site should be considered compliant.

All measurements should be taken with a temperature compensated meter calibrated to 25°C. The reported sensor accuracy for pH field measurements is ± 0.2 pH units (NEMS, 2019), so a non-compliance assessment should incorporate this measurement resolution.

Monitoring parameters and frequency for physico-chemical measurements

The compliance sites and associated monitoring frequencies for the operational mining period are given in Appendix L. The standard compliance parameters are listed in Table 9-1.

The routine compliance frequency is weekly for the Table 9-1 parameters. This will result in 52 samples per year for statistical compliance analysis.

A comprehensive 6-yearly biological and chemical monitoring assessment is proposed which will include longitudinal river surveys (see Hogsden & Jellyman, 2026). It is recommended that a consent condition be that the AluminonTM test be included with that monitoring. Developing relationships between dissolved aluminium, the AluminonTM test and biological measures (i.e., EPT taxa richness, AMDI and fish species) will be beneficial to refining chemical monitoring in acidic/low pH waters. Additional AluminonTM testing should be undertaken in conjunction with proposed Buller Plateaux monitoring at Stockton Mine-associated sites with elevated dissolved Al concentrations (PDP 2026), to provide a larger dataset for site-specific evaluations for a range of water quality conditions.

Table 9-1: Default Compliance suite for site monitoring. DOC should be measured as DNPOC.

Physico/chem	Dissolved metals	Nutrients
pH ^a	Aluminium (Al)	nitrate-N
Temperature ^a	Cadmium (Cd)	nitrite-N ^b
Electrical conductivity (EC) ^a	Calcium (Ca)	ammoniacal-N
Turbidity ^a	Cobalt (Co)	
DOC (DNPOC)	Copper (Cu)	
Sulphate	Iron (Fe)	
	Magnesium (Mg)	
	Manganese (Mn)	
	Nickel (Ni)	
	Zinc (Zn)	

Abbreviations: DOC = dissolved organic carbon; DNPOC = dissolved non-purgeable organic carbon.

^a Field measurements. pH, EC and turbidity should also be included in laboratory suite of measurements.

^b Nitrite-N is standardly reported with nitrate-N laboratory measurements.

9.3 Compliance assessment

9.3.1 Assessment period

Compliance assessment is recommended to be on an annual basis for the hydrological year (i.e., 1 July – 30 June). This will provide a 12-month period for sampling.

9.3.2 Metals

The suite of parameters for comprehensive compliance monitoring is provided in Table 9-1. Monitoring for dissolved metals requires concurrent monitoring of appropriate TMF concentrations (Table 6-2).

Most sites have a recommended 95% LoP – except for Waimangaroa River which has an 80% protection compliance assessment (i.e., compliance incorporates the upstream metal concentration) and V8 Creek (site MM1) which also has an 80% protection level (Appendix G).

The chronic metals guidelines should be TMF adjusted for each monitoring occasion and the fraction of the site-specific GV (Table 6-2) calculated to provide the MEQ value.⁵⁰ MEQ values greater than 1 indicate parameters that exceed the relevant WQ GV. Conversely, MEQ values less than 1 are below the relevant WQ GV. For compliance, the annual median of the TMF-modified chronic GV should be no greater than 1. Half detection limit values should be used for MEQ calculation and compliance limit assessment.

The acute metal guidelines should be TMF adjusted for each monitoring occasion and the fraction of the site-specific acute GV calculated (Table 6-2). For compliance, the annual 95th percentile of the TMF-modified acute GV should be no greater than 1. Half detection limit values should be used for MEQ calculation and compliance limit assessment (95%, i.e., less than 5% of the acute MEQ values exceed the TMF-modified acute GV).

Any lower frequency (e.g., monthly) monitoring data for compliance assessment (i.e., 12 monitoring occasions annually) should use the look-up tables for permissible number of exceedances (Appendix K) and Hazen percentile calculation of numeric values for the TMF-adjusted median and 95th percentile permissible exceedances for metals, nitrate-N and ammoniacal-N and for turbidity guideline comparisons.

Storm Water samplers

Storm Water samplers (termed “High flow samplers” in Appendix L, see Appendix E for photo) are recommended for use at sites which will experience intermittent bypass flows from sumps (Appendix E and Appendix L).

They are deployed at a fixed surveyed location together with a pressure (depth) transducer which logs the time and flow (from the site flow rating) when the sample is collected. This information, together with the sump bypass flow monitoring data, facilitates sample identification for bypass discharge events from background conditions.

A “basic” chemistry suite of analyses (Appendix L, Table L-4) is proposed for the Storm Water sampler samples. Routinely, this analysis suite would not include dissolved Zn as the Storm Water sampler cleaning procedures are not suitable for trace metals analysis and sample preservative (acid) is not

⁵⁰ Metal Ecotoxicity Quotient = measured concentration/TMF-modified GV

present in the samplers. Addition of acid preservative would preclude measurement of pH for the high flow event and would modify the chemical speciation of the aluminium.

The analysis and reporting of Storm Water sampler results should be undertaken in conjunction with sump constituent monitoring, bypass frequency and discharge volume reporting. The percentage contribution of Al and turbidity to the receiving water levels should be calculated for these bypass events.

9.3.3 pH

The compliance pH range of 4.5-7.0 should be assessed based on the annual 95th percentile of the weekly monitoring dataset for sites with 95th and 90th percentile LoPs.

There is potential for natural short-term reductions in pH below 4.5 in reference streams in response to humic/fulvic acid inflow during rain events. The compliance site assessment for grab samples and Storm Water samplers should consider the reference site pH for the concordant monitoring occasion. If reference site pH is below 4.5 then the compliance site should be considered compliant.

Rainfall events result in a marked change in pH with the direction and magnitude of change differing between natural and AMD-affected streams (Section 3.3). The pH of the sump bypass waters and WTP discharges would be expected to dominate low strength buffering of the Buller Plateaux receiving waters (see Section 8.2 for model results). Together, the combined upstream and downstream of mine water discharges are likely to be variable but dominated by the operational monitored intermittent sump and WTP discharges.

The potential for reduced pH mine discharge water will be monitored from operational monitoring of sumps and in receiving waters from the Storm Water samplers (Section 9.3.2). Should these samplers identify low non-compliant pH conditions beyond the limits during bypass events then either pH treatment will need to be implemented for sumps or further investigations undertaken with upstream Storm Water samplers to measure background water quality during events.

Continuous pH/EC/temperature monitoring is proposed for performance monitoring at five sites (Waimangaroa River, 2W; Deep Stream, SW01, SW03; Whareatea River, KEL; V8 Creek, MM1; Appendix L). This continuous data should be used to establish the adequacy of the weekly discrete monitoring data for pH and validate the WLBM predictions for ESE and MFS compliance sites.

The pH range would not apply to the highly AMD-affected V8 Creek (MM1 site) with weekly compliance monitoring for other parameters.

9.3.4 Nutrients: nitrogen toxicity

The nitrate-N and ammoniacal-N guidelines and standards are for toxicity protection in receiving waters.

The suite of parameters for comprehensive compliance monitoring is provided in Table 9-1. Monitoring for dissolved nutrient requires concurrent monitoring of appropriate TMF concentrations of hardness for nitrate-N and pH and temperature for ammoniacal-N (Table 6-2).

The proposed compliance limits for both nitrate-N and ammoniacal-N include both ANZG guidelines and NPS-FM standards. The ANZG guidelines would require concurrent TMF measurement on each

sampling occasion. As for the metals, the Nutrient Ecotoxicity Quotient (NEQ)⁵¹ should be calculated for the chronic TMF-adjusted GV. Compliance is assessed based on the annual median value of the NEQ being less than 1.

The NPS-FM standards provide “bottom line” nitrate-N and ammoniacal-N standards annual compliance for median and 95th percentile concentrations. The ammoniacal-N concentrations are pH adjusted. The NPS-FM standards apply to Freshwater Management Unit (FMU) nodes in catchments. To our knowledge, the West Coast Regional Council has not developed FMU nodes in catchments for regional rivers and streams. The NPS-FM bottom line values would not be expected to be compliance values applicable at the Buller Plateaux compliance sites, rather they might be expected to be applicable at the SH67 as FMU nodes.

Adjustment factors for flows (AF-flow) at the Buller Plateaux compliance sites to SH67 are provided in Appendix E. The Buller Plateaux concentrations should be adjusted (i.e., measured concentration/AF-flow) for each river catchment and compared with the NPS-FM bottom line values. The annual median NEQ should be less than the applicable median standard and the 95th percentile NEQ less than the applicable 95th percentile NEQ.

Compliance would be assessed for the suite of ANZG toxicity measures for Buller Plateaux compliance sites and the NPS-FM standard assessed for the SH67 sites (i.e., incorporating the river-specific AF-flow values). Exceedance of any of these limits would constitute a non-compliance for nutrients.

9.3.5 Suspended sediments

The basis for the proposed site-specific suspended sediments guidelines for turbidity for short- and long-term protection of ecological communities are discussed in Section 7.1 with guidelines provided in Table 7-1. The recommended compliance sites and frequency of monitoring are provided in Appendix E (Table E-1). A 95% LoP applies to all compliance sites using an add-to-background approach measured relative to the associated reference sites for the annual compliance assessment. A mix of continuous and discrete monitoring is recommended.

Continuous monitoring is recommended for key compliance and associated reference sites, with 10-min logging frequency and targeting >90% data capture after quality control and clean up procedures – to exclude potential spurious instrumental values or debris contacting probe. The maximum turbidity limit of 550 NTU with a 100 NTU 7-d rolling median to be assessed on a weekly basis on telemetered data is proposed for assessment of potential short-term effects.

Monitoring of sites for “Performance” limit is recommended to be based on 25 NTU with a 15-sample rolling median based on either continuous or discrete monitoring (weekly frequency). Site MM1 on V8 Creek receives significant AMD inputs and is proposed for 80% LoP for metals and nutrients (Appendix G, Table G-1).

Aesthetic guidelines are proposed to protect recreational users of rivers at SH67. The guidelines proposed are for no more than a 50% change in background for median clarity and >1.6 m median clarity (Table 7-1). These clarity changes would apply to SH67 sites on the Whareatea River (site WM-3), Rapid Stream (site W09) and Waimangaroa River (site 18W). The available turbidity monitoring data at these sites is summarised in Appendix E (Table E-2). A relationship between turbidity and black disk clarity will need to be developed for the background water quality in these streams.

⁵¹ NEQ = measured N concentration/TMF-modified chronic guideline N concentration

Compliance assessment for aesthetic guidelines at SH67 is proposed to be based on turbidity measurements at Buller Plateaux compliance sites and application of river-specific AF-flow values (Appendix E) to predict SH67 clarity related to mining activity. These AF-flow values allow for additional catchment dilution but not downstream turbidity inputs. Monthly performance monitoring at SH67 sites will provide an assessment of turbidity changes in the catchment.

Extreme events

Extreme rainfall and flood events are relevant for natural suspended solids and turbidity generation from catchment runoff and instream processes (i.e., bed scour, bank erosion).

A 10-year return period rainfall is recommended as a basis for an extreme event when compliance with the turbidity limits should not be expected. For the BPCP, a 10-year event is 374 mm over 24-h, with 16 mm in 10-min or 34 mm in 30 min based on analysis of a comprehensive local rainfall dataset, collected over the period 2008-2025 at the Stockton Meteorological Station.

9.3.6 Drinking water

There are no identified drinking water takes from the Whareatea River downstream of the proposed ESE mine or the Waimangaroa River downstream of the proposed MFS mine and UWHR.

The Buller Plateaux compliance sites on Whareatea River (site KEL) and Waimangaroa River (site 17W) should have a maximum compliance limit of 11.3 mg/L nitrate-N to ensure that any future drinking water takes are less than the maximum permissible MAV. This assessment will be conservative as there is additional catchment dilution downstream of these Buller Plateaux sites before the lowland coastal area is reached where potential drinking water takes would occur.

This drinking water assessment does not include Rapid Stream because of the significant AMD input from an adit in the upper reaches of the stream. This adit discharges to the stream downstream of the Rapid Stream compliance site (W07) proposed for assessment of potential BPCP mine water inputs.

10 Summary and Recommendations

10.1 Summary

10.1.1 Bioavailability guidelines for ecological protection

Site-specific bioavailable guidelines for metals and other contaminants were developed for application to the Buller Plateaux receiving waters. These GVs incorporate toxicity-modifying factors (TMFs) (e.g., pH, hardness, DOC, temperature) where appropriate and are used for chronic and acute (no-effect) assessments. Equations are provided for differing levels of protection (LoP) – appropriate for application to receiving waters with differing levels of AMD influence. A weight of evidence (WoE) classification was developed to assess Buller Plateaux streams for AMD influence and the appropriate LoP (see Section 10.1.3).

The bioavailability equations are summarised in Table 10-1.

Compliance assessment is based on a 95% LoP for most sites. The compliance sites are shown in the Process Flow diagrams (Appendix B) and listed in Appendix L for differing LoPs. These sites are assessed relative to the TMF-adjusted guideline value.

Sites on the Waimangaroa River have an 80% LoP (Appendix B) based on historic and ongoing AMD inputs. These sites are assessed relative to the TMF-adjusted guideline value for the compliance site (see Section 9.2.2).

One compliance site (MM1, V8 Creek) has an existing AMD input and receives some WTP discharge, is considered appropriate for 80% LoP compliance limits for metals and nutrients.

A hydrological assessment was conducted to characterise the duration of flood events on Buller Plateaux streams – establishing the floods were of short duration (generally <48 h, see Section 10.1.2). The short duration of the flood events supports application of the chronic guideline values for a median concentration compliance assessment and the acute GVs for a 95th percentile concentration compliance assessment.

Table 10-1: Bioavailability guideline value (GV) equations for chronic GVs and acute GVs for differing levels of protection (LoP). Toxicity modifier factor (TMF) range for pH, hardness (as CaCO₃) and dissolved organic carbon (DOC) indicated. See Table 6-2 for Notes and reference footnotes.

Application (Note 1)	Guideline Value (µg/L) (Note 2)	TMF range (Note 3).	Reference
Dissolved Aluminium Guideline Values (µg/L)			
Chronic Aluminium GV			
95% LoP. pH ≤ 6.5	500	pH: ≤ 6.5 (Note 4 for basis of change of pH threshold)	a
95% LoP. pH > 6.5	$\exp(0.645 \times \ln(\text{DOC}) + 2.255 \times \ln(\text{Hardness}) + 1.995 \times \text{pH} + (-0.284 \times \ln(\text{Hardness}) \times \text{pH}) - 9.898)$ *Note if algorithm is ≤ pH 6.5 use 500.	pH: 6.5-8.7 Hardness: 10-430 mg/L DOC: 0.08-12.3 mg/L	b
90% LoP	95% LoP / 0.79		b
80% LoP	95% LoP / 0.58		b
Dissolved Copper Guideline Values (µg/L)			
Chronic Cu GV			
95% LoP	$\text{DGV}_{0.5} \times (\text{DOC}/0.5)^{0.70}$ where $\text{DGV}_{0.5} = 0.73$	pH: 6.0-8.5 Hardness: 35-400 mg/L DOC: 0.1-20 mg/L	c
90% LoP	$\text{DGV}_{0.5} \times (\text{DOC}/0.5)^{0.70}$ where $\text{DGV}_{0.5} = 0.89$		
80% LoP	$\text{DGV}_{0.5} \times (\text{DOC}/0.5)^{0.70}$ where $\text{DGV}_{0.5} = 1.4$		

Application (Note 1)	Guideline Value (µg/L) (Note 2)	TMF range (Note 3).	Reference
	Acute Cu GV		
95% LoP	$\exp(-6.6 + 0.78 \times \text{pH} + 0.58 \times \ln(\text{Hardness}) + 0.70 \times \ln(\text{DOC}))$	pH: 6.0-8.8	d
90% LoP	$\exp(-6.3 + 0.78 \times \text{pH} + 0.58 \times \ln(\text{Hardness}) + 0.70 \times \ln(\text{DOC}))$	Hardness: 35-898 mg/L	
80% LoP	$\exp(-5.8 + 0.78 \times \text{pH} + 0.58 \times \ln(\text{Hardness}) + 0.70 \times \ln(\text{DOC}))$	DOC: 0.1-30 mg/L	
	Dissolved Iron Guideline Values (µg/L)		
All LoP	500	All conditions	e
	Dissolved Zinc Guideline values (µg/L)		
	Chronic Zn GV		
95% LoP	$\exp(0.947 \times \ln(\text{Hardness}) - 0.815 \times \text{pH} + 0.398 \times \ln(\text{DOC}) + 4.63)$	pH: 5.7-8.1	f
90% LoP	95% LoP / 0.62	Hardness: 15-399 mg/L	
80% LoP	95% LoP / 0.35	DOC: 0.3-22.9 mg/L	
	Acute Zn GV		
95% LoP	$\exp(2.5 - 0.12 \times \text{pH} + 0.6 \times \ln(\text{Hardness}) + 0.13 \times \ln(\text{DOC}))$	pH: 5.4-8.5	g
90% LoP	$\exp(2.9 - 0.12 \times \text{pH} + 0.6 \times \ln(\text{Hardness}) + 0.13 \times \ln(\text{DOC}))$	Hardness: 14-826 mg/L	
80% LoP	$\exp(3.4 - 0.12 \times \text{pH} + 0.6 \times \ln(\text{Hardness}) + 0.13 \times \ln(\text{DOC}))$	DOC: 0.1-22 mg/L	
	Dissolved Cobalt Guideline values (µg/L)		
	Chronic Co GV		
95% LoP	$\text{Exp}((0.414 \times \ln(\text{hardness}) - 1.285))$	Hardness range: 52-396 mg/L	h
90% LoP	$\text{Exp}((0.414 \times \ln(\text{hardness}) - 0.427))$		
80% LoP	$\text{Exp}((0.414 \times \ln(\text{hardness}) + 0.557))$		
	Acute Co GV		
95% LoP	95%Chronic CoGV/0.16	Hardness range: 52-396 mg/L	i
90% LoP	95%Chronic CoGV/0.11		
80% LoP	95%Chronic CoGV/0.062		
	Dissolved Nickel Guideline values (µg/L)		
	Chronic Ni GV		
95% LoP	$11 \times (\text{Hardness}/30)^{0.85}$	Hardness range: 30-400 mg/L. No guidance for pH application range. Normally taken as physiological pH range as used for testing (pH 6.5-8.5).	j
90% LoP	$13 \times (\text{Hardness}/30)^{0.85}$		
80% LoP	$17 \times (\text{Hardness}/30)^{0.85}$		
	Acute Ni GV		
95% LoP	95%Chronic NiGV/0.16	Hardness range: 30-400 mg/L	k
90% LoP	95%Chronic NiGV/0.11		
80% LoP	95%Chronic NiGV/0.062		
	Dissolved Manganese Guideline values (µg/L)		
	Chronic Mn GV		
95% LoP	$\text{Exp}((0.411 \times \ln(\text{hardness}) + 4.46))$	Hardness range: 25-670 mg/L	l
90% LoP	$\text{Exp}((0.411 \times \ln(\text{hardness}) + 4.89))$	Simplified equation for hardness only calculated at pH 7.5. Look-up tables provided for pH 5.8 to 8.4.	
80% LoP	$\text{Exp}((0.411 \times \ln(\text{hardness}) + 5.38))$		
	Acute Mn GV		
95% LoP	$(\text{Exp}((0.878 \times \ln(\text{hardness}) + 4.84)))/2.13$	Hardness range: 25-250 mg/L	m
90% LoP	$(\text{Exp}((0.878 \times \ln(\text{hardness}) + 6.90)))/2.13$		
80% LoP	$(\text{Exp}((0.878 \times \ln(\text{hardness}) + 7.20)))/2.13$		
	Dissolved Cadmium Guideline values (GVs, µg/L)		
	Chronic Cd GV		
95% LoP	$10^{(0.83 \times \text{LOG}_{10}(\text{Hardness}) - 2.46)}$	Hardness range: 17-280 mg/L	n
90% LoP	$(10^{(0.83 \times \text{LOG}_{10}(\text{Hardness}) - 2.46)})^{*1.84}$		
80% LoP	$(10^{(0.83 \times \text{LOG}_{10}(\text{Hardness}) - 2.46)})^{*4.15}$		
	Acute Cd GV		
95% LoP	$(10^{(1.016 \times \text{LOG}_{10}(\text{Hardness}) - 1.71)})^{*0.47}$	Hardness range: 5.3-360 mg/L	o
90% LoP	$(10^{(1.016 \times \text{LOG}_{10}(\text{Hardness}) - 1.71)})^{*0.61}$		
80% LoP	$(10^{(1.016 \times \text{LOG}_{10}(\text{Hardness}) - 1.71)})^{*2.1}$		

Application (Note 1)	Guideline Value (µg/L) (Note 2)	TMF range (Note 3).	Reference
	Nitrate-N (ANZG – hardness (H)-dependent; guideline)		
	Chronic Nitrate-N GV		
95% LoP	1100 (H<30); 2600 (H30-150); 29,000 (H >150)	Hardness dependent	p
90% LoP	1500 (H<30); 4200 (H30-150); 38,000 (H >150)		
80% LoP	2300 (H<30); 7100 (H30-150); 56,000 (H >150)		
	Acute Nitrate-NGV		
	Not available		
	Nitrate-N (NPS-FM; standard)		
	Chronic Nitrate-N Standard (median standard)		
95% LoP	2400		q
90% LoP	Below “bottom line”		
80% LoP	Below “bottom line”		
	Acute Nitrate-N Standard (95th percentile standard)		
95% LoP	3500		q
90% LoP	Below “bottom line”		
80% LoP	Below “bottom line”		
	Chronic ammoniacal-N (ANZG guideline)		
95% LoP	1200	pH and temperature dependent. Values at pH 7 and 15°C.	r
90% LoP	2000		
80% LoP	3600		
	Acute ammoniacal-N (ANZG guideline)		
	Not available		
	Chronic ammoniacal-N (NPS-FM median standard)		
95% LoP	580	pH dependent. Values at pH 7.	s
90% LoP	Below “bottom line”		
80% LoP	Below “bottom line”		
	Acute ammoniacal-N (NPS-FM 95th percentile standard)		
95% LoP	968	pH dependent. Values at pH 7.	s
90% LoP	Below “bottom line”		
80% LoP	Below “bottom line”		
	pH		
	Maintain in range 4.5-7.0 for WTP discharge		t

10.1.2 Hydrological assessment

The hydrological assessment covered the duration of flood events and the changes in background contaminant concentrations and TMF levels during flood events.

Those analyses showed:

- Flood events on Buller Plateaux streams are generally of short duration (<48-h) – with a rapid return to near base flow conditions. This supports the application of chronic GVs for median conditions and acute (no effect) GVs for 95th percentile conditions.
- Background contaminant concentrations can increase markedly in AMD influenced streams. For these sites a reduced LoP is recommended for guideline compliance.
- The Buller Plateaux streams are naturally of low pH (4.5-5.5) and show a marked response of reducing pH during rainfall events.
- The Buller Plateaux streams are naturally very low hardness.

- The Buller Plateaux streams can show a marked variability in hardness, DOC and pH during rainfall events.
- The high variability in TMFs with rainfall necessitates measuring of TMF variables and bioavailability adjustment for each sampling occasion.

10.1.3 Classification scheme for determining LoPs for AMD-affected streams

A classification scheme for determining LoPs was developed using a WoE approach to incorporate biological and chemical measures to assess the level of AMD effects. This classification established categories of: Excellent, Good, Fair and Poor based on increasing levels of AMD influence and adverse biological effects on streams.

This classification scheme identified most of the Buller Plateaux streams to be “Good” and applicable for 95th percentile GVs. However, the Waimangaroa River was classified as “Fair” and considered suitable for 80th percentile GVs.

10.1.4 Site-specific turbidity guidelines

Site-specific water quality protection levels for turbidity linking biological condition with water quality in Escarpment Extended (ESE) and Mount Frederick South (MFS) streams have been developed.

The assessment included data on the sensitivity of fish and macroinvertebrates to turbidity for acute and chronic exposure durations. Available continuous and discrete monitoring of turbidity is summarised for the ESE and MFS streams and the SH67 sites.

The proposed site-specific turbidity guidelines are summarised in Table 10-2. The monitoring of compliance sites for continuous and discrete turbidity measurements is also recommended.

Table 10-2: Summary of site-specific turbidity guideline values for short- and long-term protection of ecological communities, aesthetic and performance. Proposed compliance locations for Escarpment Extension and Mount Frederick South mine water discharges shown in Appendix E (see Table 7-1 for footnotes and additional details).

Classification/Nominal protection level	Short-term (acute) turbidity (NTU) maximum/limit, exposure period	Long-term (chronic) turbidity (NTU) median/95 th percentile/exposure reporting period ^{f, g}
Ecological – continuous ^{a, e}	550 max ^a /100, 7-d rolling median	+5 NTU median above background/+20 NTU 95 th percentile/annual
Ecological – discrete ^{b, e}	550 max ^a	As above
Aesthetic ^{c, e}	n/a	+50% change from background for median [>1.6 m median clarity/annual] ^h
Performance ^{d, e}	n/a	25 NTU 15-sample rolling median

10.1.5 Drinking water protection

There are no identified drinking water takes from the Whareatea River downstream of the proposed ESE mine or the Waimangaroa River downstream of the proposed MFS mine and UWHR.

The Buller Plateaux compliance sites on Whareatea River (site KEL) and Waimangaroa River (site 17W) should have a maximum compliance limit of 11.3 mg/L nitrate-N to ensure that any future drinking water takes are less than the maximum permissible MAV.

10.2 Recommendations

Ongoing background monitoring is recommended for turbidity, metals and nitrogen for the compliance suite of analyses for discrete sampling (see Section 9.1, Table 9-1).

10.2.1 Turbidity

Background monitoring to characterise turbidity should be undertaken prior to BPCP commencement in the relevant catchments. The additional turbidity monitoring should include discrete and continuous monitoring at the following sites (all with weekly inspection and 3-monthly instrument calibration):

■	[REDACTED]
■	[REDACTED]
■	[REDACTED]
■	[REDACTED]
■	[REDACTED]
■	[REDACTED]
■	[REDACTED]
■	[REDACTED]

Storm Water Samplers

The continued use of Storm Water samplers for both background monitoring and for event-related compliance assessment is recommended. These discrete sampling devices are well suited to collection of samples from short-term bypass discharge events and upstream reference samples for the same event.

Their implementation is recommended for all compliance and associated reference sites where mine water bypass discharges may occur.

Turbidity and visual clarity relationships

A site-specific relationship between turbidity and black disk visual clarity should be developed from representative samples from Whareatea and Waimangaroa rivers covering a range of low and high flow conditions.

10.2.2 Metals

Continued collection of background dissolved metals and TMFs (i.e., temperature, pH, hardness, DOC) at compliance and reference sites is recommended.

The metals should be analysed to trace level and TMFs collected on each monitoring occasion. The comprehensive suite of parameters is provided in Table 9-1.

Aluminon™

The use of the Aluminon™ test as well as dissolved aluminium measurements is recommended for all annual biological monitoring sites and for proposed 6-yearly longitudinal surveys (e.g., Cascade Creek). The additional surveys can be used to further evaluate the utility of the Aluminon™ test for assessment of macroinvertebrate species sensitivity, EPT taxa richness and AMDI.

Additional Aluminon™ testing should also be undertaken in conjunction with proposed Buller Plateaux monitoring at Stockton Mine-associated sites with elevated dissolved Al concentrations to provide a larger dataset for site-specific evaluations for a range of water quality conditions.

Iron

The iron GV is based on half the US EPA guideline for minimising iron floc precipitation in waters. The Buller Plateaux streams naturally variable dissolved iron concentrations associated with transient elevated DOC concentrations associated with rainfall events. The recently released ANZG (2025) guidelines for iron do not incorporate a TMF relationship with DOC and are lacking in Australian and New Zealand native species. These guidelines were not considered suitable for this site-specific application.

While chemical speciation modelling can be undertaken to predict iron floc formation (e.g., using Humic Ion Binding Model (HIBM) VII (a component of WHAM (Windermere Humic Aqueous Model) – a mechanistic chemical process model used to calculate equilibrium chemical speciation in natural environments like surface waters, soils, and sediments), the modelled results are only for equilibrium conditions (e.g., (Catrouillet et al., 2014; Tipping et al., 2002)) and not well suited to the highly variable geochemical conditions existing in Buller Plateaux streams.

A tiered evaluation approach is recommended for assessing receiving water iron toxicity risks should predicted or observed iron concentrations approach the proposed iron GV. These should include:

1. Continued collection of water quality data for dissolved Fe, DOC, pH, temperature and hardness in reference and compliance sites.
2. Incorporation of this background data into WLBM runs to improve simulations for Scenarios predicting receiving water concentrations. Provide semi-dynamic predictions of receiving water concentrations for time-concentration duration during representative events.
3. Investigate if ANZG (2025) guidelines for iron can be upgraded to incorporate DOC as a TMF for site-specific application to Buller Plateaux streams.

Should significant Fe issues arise then possible additional work could include:

1. Undertake a literature review of HIBM model development to establish whether non-equilibrium models are available for site-specific Buller Plateaux applications.
2. Undertake bench tests to determine iron floc formation thresholds in Buller Plateaux waters for a range of pH, DOC, hardness and temperature conditions. The time-response of iron floc formation is an important component of these bench test to ensure applicability to transient events.
3. Native species testing (e.g., mayfly, *Deleatidium* sp.) to establish toxicity thresholds for iron under representative receiving water exposure conditions.

The order and prioritising of the above suite of recommended approaches needs to be determined based on concentration-exposure information for key receiving water sites. Not all evaluations may necessarily be undertaken.

Metals guideline review

A critical review of compliance criteria for trace metals should be undertaken after 6-years of chemical and biological monitoring. This review should focus on the adequacy of protection for trace metals in relation to TMF levels in the receiving waters. Continued development of metal guidelines with inclusion of TMF relationships are expected to be published and implemented by various international jurisdictions in this period. These updated guidelines may be applicable to the MFS and ESE receiving to provide an improved risk assessment for biological effects protection for different LoPs.

The guideline review should also evaluate the utility of Aluminon™ testing for bioavailable aluminium measurement compared with the dissolved Al and TMF assessment. This evaluation to compare Aluminon™ and bioavailable Al measurements with biological assessment measures.

10.2.3 Nitrogen

A range of adaptive management approaches are recommended by MWM (2026f) to minimise the loss of nitrogen compounds from ANFO use and for methods to treat nitrogenous compounds.

Compliance monitoring for nitrate-N and ammoniacal-N and associated TMFs (pH, hardness, temperature) is proposed for all compliance sites for ecological protection from potential toxicity.

Monitoring for nitrate-N and ammoniacal-N should also be undertaken at SH67 sites to provide background information pre-commencement for a 1-year period because of the potential for increased nitrogen from mining activities. Monthly performance monitoring nitrate-N and ammoniacal-N and associated TMFs (pH, hardness, temperature) is proposed for SH67 sites for the duration of mining.

10.2.4 pH monitoring and management

The potential for reduced pH mine discharge water will be monitored from operational monitoring of sumps and in receiving waters at compliance sites using grab samples and Storm Water samplers (Section 9.3.2). There is potential for natural short-term reductions in pH below 4.5 in reference streams in response to humic/fulvic acid inflow during rain events. The compliance site assessment for grab samples and Storm Water samplers should consider the reference site pH for the concordant monitoring occasion. If reference site pH is below 4.5 then the compliance site should be considered compliant.

██
██
████████████████████ This continuous data should be used to establish the adequacy of the weekly discrete monitoring data for pH and validate the WLBM predictions for ESE and MFS compliance sites.

The pH range would not apply to the highly AMD-affected V8 Creek (MM1 site) with weekly compliance monitoring for other parameters.

10.2.5 Quality control procedures

Quality control (QC) procedures for sample collection, physico/chemical analysis, database management, data analysis and reporting and continuous instrument calibration and management are recommended (Section 9.1). Guidance for many of these QC procedures are provided in (NEMS,

2019). Additionally, standard operating procedures (SOPs) should be produced by Bathurst to cover field sampling procedures for water sampling, discrete field monitoring (e.g., pH, temperature, EC, turbidity) equipment calibration and use together with deployment, calibration and maintenance of continuous monitoring instrumentation.

11 Acknowledgements

[REDACTED]

12 Glossary of abbreviations and terms

Word/acronym/abbreviation/	Description
adverse effect	A harmful result of some activity. In the RMA, adverse effects may include temporary or permanent effects and cumulative effects that arise over time or in combination with other effects.
ACR	Acute-to-Chronic Ratio. Calculated using the EC ₅₀ (or LC ₅₀) / Chronic NOEC (or EC _{10/20}) values. Note that the ACR differs between jurisdictions.
Acute GV	An acute (short-term) guideline value, developed to assist in managing effects of short-term exposures to toxicants. Acute GVs are derived from standard acute EC ₅₀ data – standardised for exposure durations used by species group – to after application of a conversion factor (CF) to provide EC ₁₀ data (see Gadd et al. (2024) for details of acute GV derivation for copper and zinc. Table 7.1 provides standard exposure durations for acute GV derivation).
Add-to-background	Turbidity: Turbidity compliance is based on a level of increase (NTU) from the measured median and 95th percentile at the upstream or reference site for the annual compliance period. Metals: Upstream background concentrations included in the measured concentrations at the downstream compliance location for an annual compliance measurement period. Sites with significant background AMD and elevated metal concentrations would normally have a reduced LoP (i.e., 90% or 80%). For metals the downstream TMF-modified metal GV is the basis for the compliance assessment. Calculation based on calculated MEQ values for chronic and acute GVs.
acute toxicity	A lethal or adverse sub-lethal effect that occurs as the result of a short exposure period to a chemical relative to the organism's life span (e.g., generally hours to days). Refer to Warne et al. (2025) for examples of acute exposures.
Aluminium (Al)	Dissolved aluminium measured in waters. Increased concentration of Al is a major contaminant associated with acid and metalliferous drainage (AMD). The chemical form (speciation) of Al differs with pH, hardness and DOC. The concentration increases markedly when pH is below 5. The toxicity of Al is largely attributable to free Al ³⁺ ions.
Aluminon™	HACH Aluminon™ Method 8012 for dissolved aluminium using a HACH DR/890 colorimeter. Analytical range of the method 0.008–0.800 mg/L.

Adjustment factors (AF-x)	Multiple adjustment factors used: (i) Adjustment factor for flow (AF-flow) = Conversion factor for catchment flow (dilution) adjustment from Buller Plateaux compliance sites to lowland (SH67) performance monitoring sites. (ii) Adjustment factor for levels of protection (AF-LoP) = adjustment factor for calculation of different LoPs from SSD relationship. (iii) Adjustment factor for TMFs (AF-TMF) = Adjustment factor applied to GVs for TMF values (i.e., different hardness, pH, DOC or temperature) in either index water or site-specific water. Adjustment applied prior to MEQ calculation.
Assessment factor	Arbitrary factor used by US EPA and in EU to convert an acute criteria value to a “no effect” guideline value. Not used in this report.
Acid and metalliferous drainage (AMD)	Condition where high acid conditions (i.e., low pH) are generated in mine discharge waters. The acidity is generated from the oxidation of metal sulphides present in the rock and minerals which is oxidised to generate sulphuric acid on exposure to air (oxygen). The oxidation process generates elevated sulphate concentrations in the AMD water. The abbreviation AMD refers to acid mine drainage in some documents.
ANZECC	Australian and New Zealand Environment and Conservation Council. Water quality guidelines derived using the Australian and New Zealand Environment and Conservation Council risk-based methodology. The last revision of the guidelines was in 2000 but updates (including copper and zinc for freshwaters) are presently being undertaken.
ANZG	Australia and New Zealand Governments, publishers of water quality guidelines for fresh and marine waters used in New Zealand.
ARMCANZ	Agricultural and Resource Management Council of Australia and New Zealand
Attribute band	A classification band used by MfE for the NPS-FM to define the water quality state (see Numeric attribute state).
average	Arithmetic mean value calculated for a measured (or modelled) variable or parameter.
Bioavailability	A measure of the rate and extent to which a substance (such as a metal) is taken up by an organism and reaches the site of action where toxicity can occur.
Bioavailability guidelines	A term applied to water quality guidelines which incorporate toxicity modifiers (e.g., pH, hardness, dissolved organic carbon (DOC); see TMF).
Betterment	Improving water quality overtime through both water management activities and natural processes to a point where waterways will support aquatic life. Performance monitoring with analysis of improving trends in water quality and biological measures. “Target” values for some parameters established as management measures for remediation.

bioavailable Cu or bioavailable Zn	The measured concentration of copper (Cu) or zinc (Zn) adjusted based on the appropriate TMF concentrations and response slopes. The bioavailable Cu or Zn concentration is compared directly with the copper and zinc tier 1 DGV.
BLM	Biotic ligand model, a model or set of models for metal toxicity in aquatic organisms, that account for differing bioavailability of individual metals in waters with differing chemistry (particularly DOC, pH, calcium and magnesium).
bottom line	a term used in the NPS-FM to indicate a level at which sites would be considered degraded, and above which target attribute states must be set.
catchment	The land area providing surface water hydraulic inputs to streams and rivers.
CCC	Criterion Continuous Concentration. Term used by the US EPA for acute guideline values.
CCME	Canadian Council of Ministers for the Environment, publishers of water quality guidelines for fresh and marine waters used across Canada.
chronic toxicity	A lethal or sublethal adverse effect that occurs after exposure to a chemical for a period of time that is a substantial portion of the organism's life span. Long-term, e.g., several days to weeks or months. In addition, chronic toxicity includes adverse effects on a sensitive early life stage – these may occur after exposure for a short-time, hours to days.
Clarity	Visual clarity in waters is measured with a black disk with metres (m) as the unit of measurement (Davies-Colley, 1988). Site-specific relationships can be developed between visual clarity and turbidity (NTU). Turbidity is often used as the preferred routine monitoring method because of ease of measurement with portable and continuous monitoring instrumentation.
CMC	Criterion Maximum Concentration. Term used by the US EPA for acute guideline values.
Concentration units	µg/L = micrograms per litre, parts per billion; mg/L = milligrams per litre, parts per million
Conversion factors (CF-x)	Multiple conversion factors used: (i) CF-acute = A conversion factor is used to derive an acute (short-term) GV from acute EC ₅₀ data to EC ₁₀ data (see Gadd et al. (2024) for acute GV derivations for copper and zinc). (ii) CF-clarity = A conversion factor to calculate visual clarity (horizontal black disk, m) from turbidity (NTU).
Conversion ratio (CR)	A ratio used to calculate ammoniacal-N toxicity for different pH values from the standard pH 8 value (MfE 2020c, 2018; Appendix F).
criteria	Term used by the US EPA for their guideline derivations.
Cu	Copper

default guideline value (DGV)	A guideline value recommended for generic application in the absence of a more specific guideline value (e.g., site-specific) in the Australian and New Zealand Guidelines for Fresh and Marine Water Quality. Formerly known as 'trigger values'.
dissolved metal concentration	Operationally defined as the concentration remaining after filtration through a 0.45 µm pore filter.
DNPOC	Dissolved non-purgeable organic carbon – preferred measurement for dissolved organic carbon in natural waters.
DOC	Dissolved organic carbon – a measurement of organic matter in solution, based on the carbon content (using a carbon analyser), after passing through a 0.45 µm filter.
DoC	Department of Conservation (used in this document to distinguish from dissolved organic carbon (DOC).
DOM	Dissolved organic matter – a generic term for all forms of organic material in a filtered water sample.
EC	Electrical Conductivity (units µS/cm or mS/m).
ECx	The concentration of a substance in water or sediment that is estimated to produce an x% change in the response being measured or a certain effect in x% of the test organisms, under specified conditions.
EC50 (median effective concentration)	The concentration of a substance in water or sediment that is estimated to produce a 50% change in the response being measured or a certain effect in 50% of the test organisms relative to the control response, under specified conditions.
endemic	Species native to a particular area; originating where it occurs.
endpoint	The specific response of an organism that is measured in a toxicity test (e.g., mortality, growth, reproduction, a particular biomarker).
EPT	Macroinvertebrate species in the orders Ephemeroptera (mayflies), Plecoptera (stoneflies) and Trichoptera (caddisflies).
fDOM	Fluorescence measurement of DOC
FMU	Freshwater Management Unit. Term used in relation to application of NPS-FM water quality standards (MfE 2020c). Generally taken to be a node in catchment in the absence of a formally designated regional FMU classification.
guideline value (GV)	The concentration of an indicator for a specific community value (such as aquatic ecosystem health) below which there is considered to be a low risk of unacceptable effects. The ANZG framework recommends that GVs for more than one indicator should be used simultaneously in multiple lines of evidence approach. (Also refer to default guideline value (DGV) and site-specific guideline value).

hardness	The sum of the measured concentrations of dissolved calcium and magnesium. Units of mg CaCO ₃ /L.
humic	Humic acids are natural organic material which result in brown colouration and reduced pH in natural waters. They derive from leaf-litter breakdown and leaching from soils.
index condition	a) A suite of toxicity modifying factors (TMFs) used to normalise toxicity data and for DGV calculation. The index condition (IC_{GV}) parameters differ depending on the metal: Copper – DOC 0.5 mg/L; Zinc pH 7.5, hardness 30 mg/L and DOC 0.5 mg/L. b) A nominal site-specific index condition (IC_{ss}) calculated GVs at a standardised water quality to allow numeric comparisons (pH 7.0, hardness 50 mg/L and DOC 3.5 mg/L).
ICx	The concentration of a substance in water or sediment that is estimated to produce an x% inhibition of the response being measured in test organisms relative to the control response, under specified conditions.
LCx	The concentration of a substance in water or sediment that is estimated to be lethal to x% of a group of test organisms under specified conditions.
LC50 (median lethal concentration)	The concentration of a substance in water or sediment that is estimated to be lethal to 50% of a group of test organisms, relative to the control response, under specified conditions.
Level of protection (LoP)	LoPs are calculated for DGVs from statistical fitting to the SSD to provide a range of protection levels (e.g., 95%, 90%, 80%) for a specific element. Numeric GVs for a contaminant calculated for the site-specific water quality TMF modifiers based on dissolved concentrations. LoP values may be for chronic guideline values (LoP-chronic, annual median) or acute no-effect guideline values (LoP-acute, annual 95 th percentile).
lowest observed effect concentration (LOEC)	The lowest concentration of a material used in a toxicity test that has a statistically significant adverse effect on the exposed population of test organisms as compared with the controls.
Median	The statistically calculated middle value of a numeric dataset.
Metal Ecotoxicity Quotient (MEQ)	The MEQ value for a PCOC is determined by dividing the measured concentration by the WQ GV (TMF-modified chronic GVs or acute GVs). MEQ values greater than 1 indicate parameters that exceed the relevant WQ GV. Conversely, MEQ values less than 1 are below the relevant WQ GV. For compliance, the annual median of the TMF-modified chronic GV should be no greater than 1 and the annual 95 th percentile of the TMF-modified acute GV should be no greater than 1. Half detection limit values should be used for MEQ calculation and compliance limit assessment.
MfE	Ministry for the Environment, New Zealand
MLR	Multiple linear regression – a type of model increasingly used to assess metal bioavailability.

Monitoring frequency	The monitoring frequency is prescribed for compliance assessment. The discrete monitoring frequency for most parameters and sites is weekly. Turbidity monitoring has recommended continuous monitoring for key sites with weekly discrete sampling for calibration checking. Note: the frequency of sampling affects the calculated median and 95 th percentile compliance calculation for the highly flow variable Buller Plateaux stream sites.
Negligible effect	Corresponding to an estimated no-effect or acceptable-effect level; negligible-effect concentrations typically include the NEC, NSEC, BEC10, ECx/ICx where $x \leq 10$, and NOEC, but if necessary, can also include the ECx/ICx where $x > 10$ and ≤ 20 (Warne et al., 2025).
NEMS	National Environmental Monitoring Standards (https://www.nems.org.nz/).
Nutrient Ecotoxicity Quotient (NEQ)	The NEQ value for a potential nitrogenous toxicant (nitrate-N or ammoniacal-N) is determined by dividing the measured concentration by the WQ GV (adjusted for the appropriate TMF: hardness for nitrate-N; pH and temperature for ammoniacal-N). NEQ values greater than 1 indicate parameters that exceed the relevant WQ GV. Conversely, MEQ values less than 1 are below the relevant WQ GV. For compliance, the annual median of the TMF-modified chronic GV should be no greater than 1 and the annual 95 th percentile of the TMF-modified acute GV should be no greater than 1.
Ni	Nickel
Ninety fifth percentile (95 th ile)	The statistically calculated 95 th percentile value of a numeric dataset.
No-effect threshold-acute	Corresponding to an estimated no-effect or acceptable-effect level; negligible-effect concentrations for acute (short-term) duration tests (see Negligible effect definition which applies to chronic (long-term) endpoints used for ANZG GV derivations).
no observed effect concentration (NOEC)	The highest concentration of a material used in a toxicity test that has no statistically significant ($p \leq 0.05$) adverse effect on the exposed population of test organisms as compared with the controls (Warne et al., 2025).
NOF	National Objectives Framework
No-effect concentration (NEC)	The maximum concentration of a toxicant that causes no adverse effect in a target organism, based on a threshold parameter in a concentration–response model (Warne et al., 2025).
NPS-FM	National Policy Statement for Freshwater Management. New Zealand legislation which requires regional councils to establish objectives and set limits in their regional plans to manage fresh water.
NTU	Nephelometric turbidity units is an index of light scattering by suspended particles. It is widely used as an instrumental surrogate for suspended sediment and also relates more directly than mass concentration to optical effects of suspended matter. Different turbidity sensors are known to respond differently to the same suspensions (Davies-Colley et al., 2021).

Nutrient Ecotoxicity Quotient (NEQ)	The NEQ value for a potential nitrogenous toxicant (nitrate-N or ammoniacal-N) is determined by dividing the measured concentration by the WQ GV (adjusted for the appropriate TMF: hardness for nitrate-N; pH and temperature for ammoniacal-N). NEQ values greater than 1 indicate parameters that exceed the relevant WQ GV. Conversely, MEQ values less than 1 are below the relevant WQ GV.
NZ	New Zealand
Numeric attribute state	Numeric threshold values describing the bounds of attribute bands in the NPS-FM (MfE 2020c). For metals, nitrate-N and ammoniacal-N there are median and 95 th percentile values for each attribute band.
pH	A measure of acid or alkaline balance in water.
PCOC	Potential Constituents of Concern are chemical contaminants which are sufficiently elevated in concentration in the AMD – or other water discharges – that they may result in adverse effects in the receiving environment.
ppt	Parts per thousand (i.e., g/L). Measure of concentration used for salinity.
Safety factor	Measured concentration/TMF-adjusted GV or EC ₅₀ /GV. Values >1 indicate no toxicity.
site-adapted guideline value	A DGV that has been adapted, based on existing knowledge, to make it more relevant to a site of interest (modified from van Dam et al. 2019)
site-specific guideline value	A GV that has been specifically developed to account for relevant chemical, physical and/or ecological conditions that occur at a site of interest (modified from van Dam et al. (2019)).
Species (biological)	A group of organisms that resemble each other to a greater degree than members of other groups and that form a reproductively isolated group that will not produce viable offspring if bred with members of another group.
Speciation – chemical	Chemical nature of an element changed by water chemistry. Component of TMFs (e.g., pH, DOC) affecting bioavailability guidelines.
Species sensitivity distribution (SSD)	A method that plots the cumulative frequency of species' sensitivities to a toxicant and fits a statistical distribution to the data. From the distribution, the concentration that should theoretically protect a selected percentage of species can be determined. Provides levels of protection (LoP) values – nominally 99%, 95%, 90% or 80%.
standard	A water quality guideline which has a statutory promulgation (e.g., NPS-FM compliance conditions, regional plans).
Target	A numeric water quality concentration of physico-chemical level (e.g., pH) relating to a restoration objective. A site-specific target may be set from statistical analysis of treatment system performance either based on end-of-pipe or receiving water monitoring locations. See also Betterment.
toxicity	The inherent potential or capacity of a material to cause adverse effects in a living organism.

TMFs, Toxicity modifying factor(s)	The aspects of water chemistry that influence bioavailability. In this guidance use of the term TMF generally refers only to pH, hardness and DOC, though there are other variables that may influence bioavailability such as water temperature and alkalinity.
toxicity test	The means by which the toxicity of a chemical or other test material is determined. A toxicity test is used to measure the degree of response produced by exposure to a specific level of stimulus (or concentration of chemical) for a specified test period.
US EPA	United States Environmental Protection Agency
Weight-of-evidence (WOE)	Weight of evidence describes the process to collect, analyse and evaluate a combination of different qualitative, semi-quantitative or quantitative lines of evidence to make an overall assessment of water/sediment quality and its associated management (ANZG 2018a). Applying a weight-of-evidence process incorporates judgements about the quality, quantity, relevance and congruence of the data contained in the different lines of evidence (Warne et al., 2025).
WTP	Water Treatment Plant
Zn	Zinc

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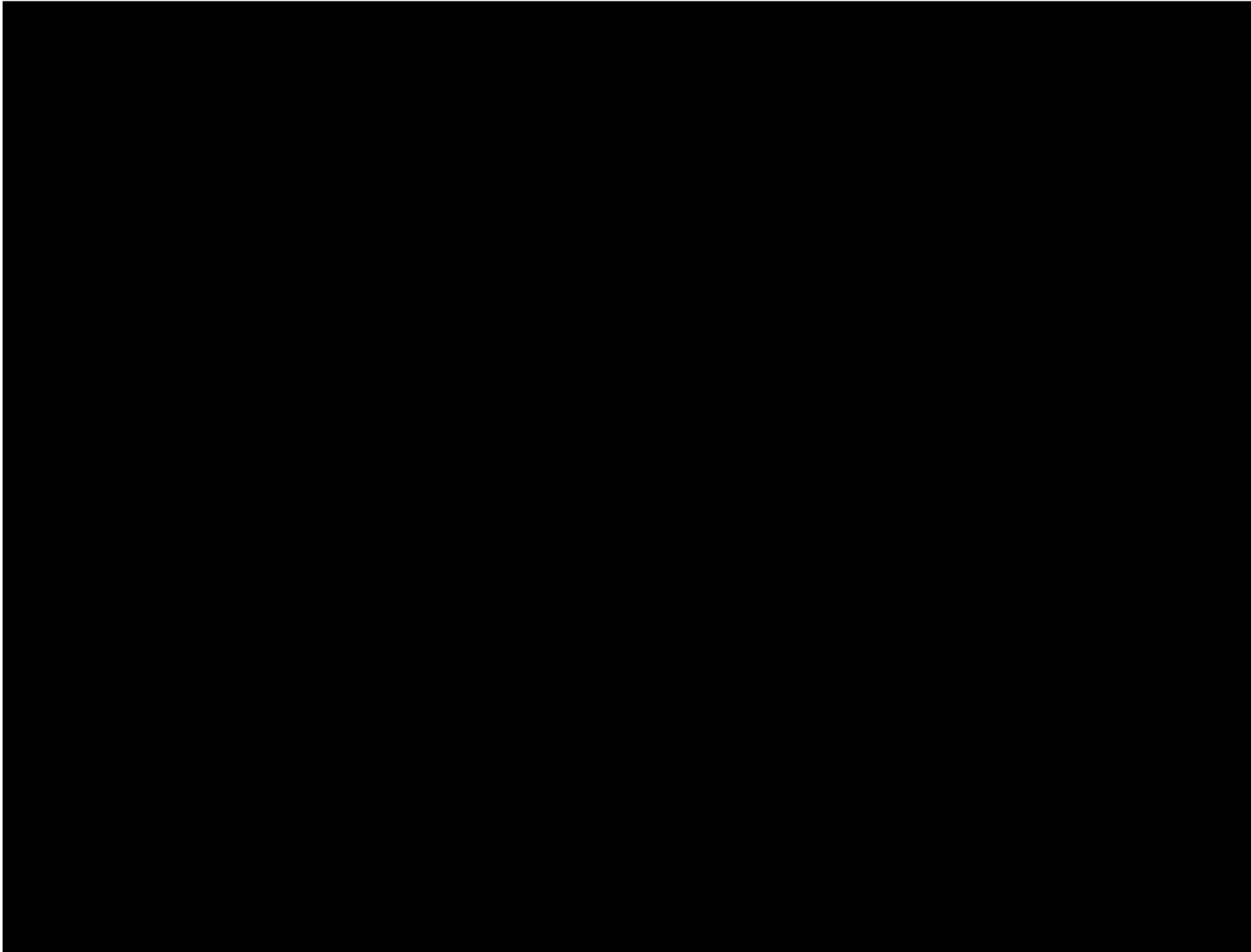
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14 Appendices



Appendix B Process flow diagrams for MFS and ESE

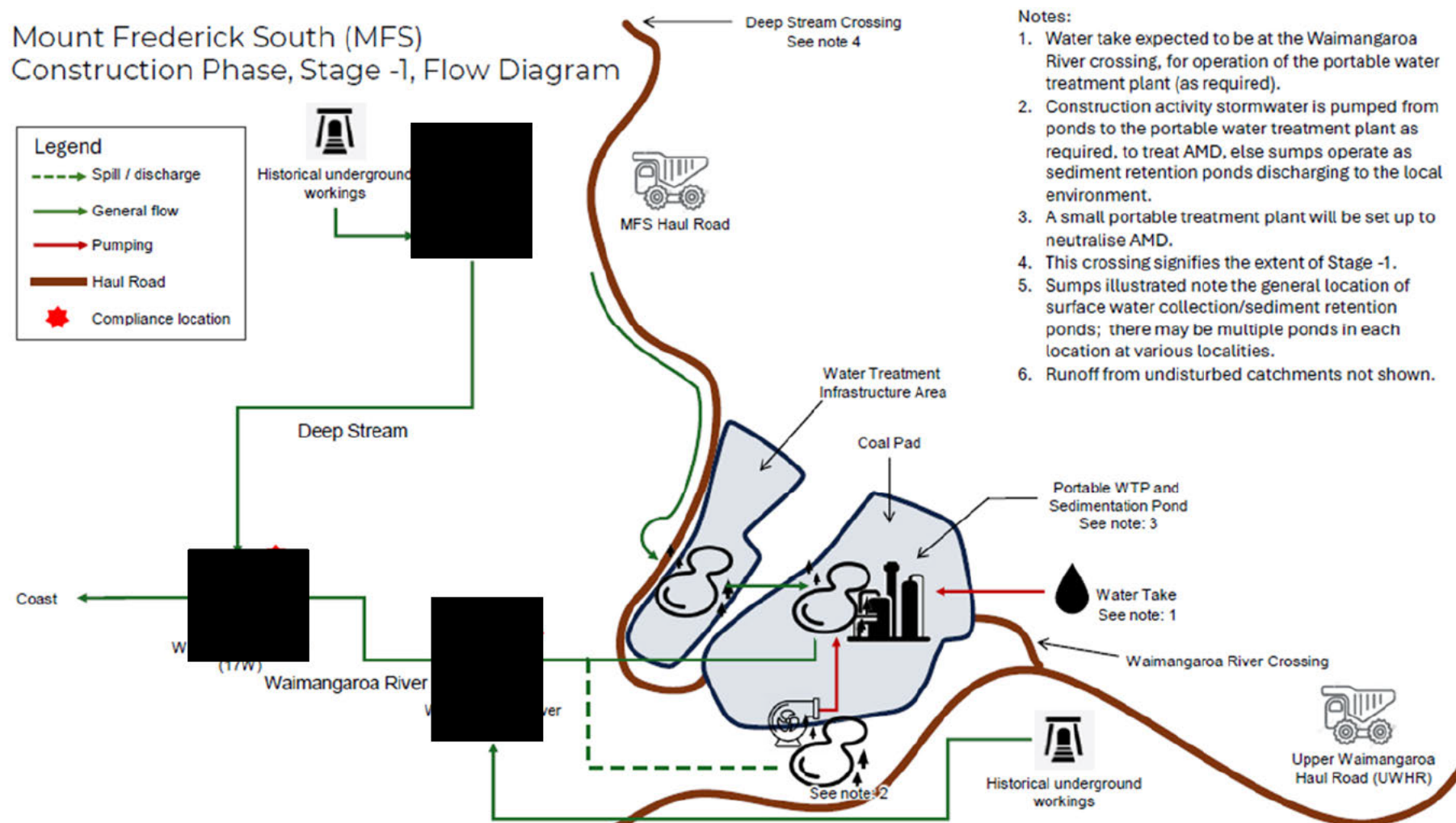


Figure B-1: Mount Frederick South (MFS) construction phase, Stage-1, flow diagram.

Mount Frederick South (MFS) Construction Phase, Stage 0, Flow Diagram

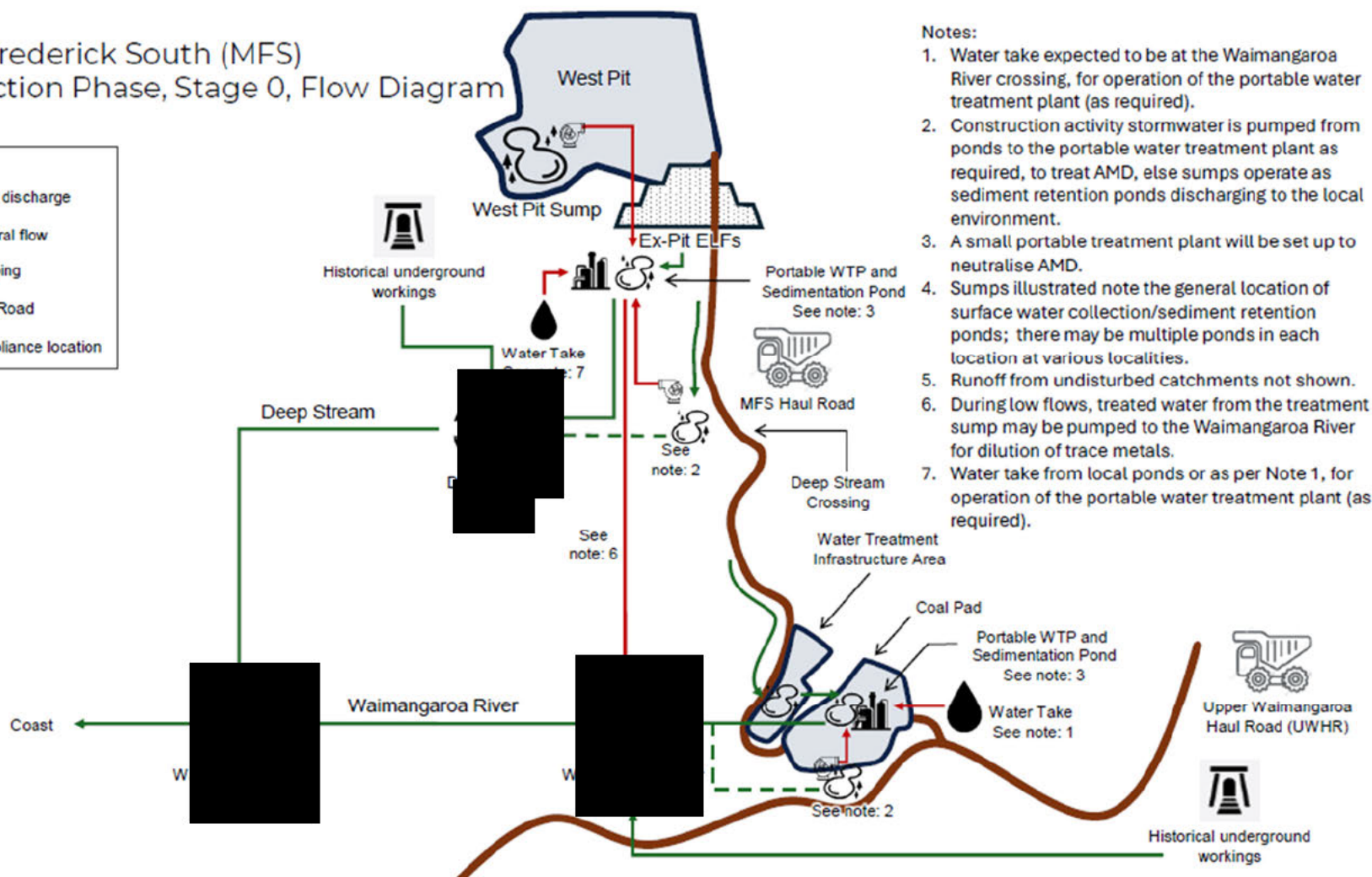
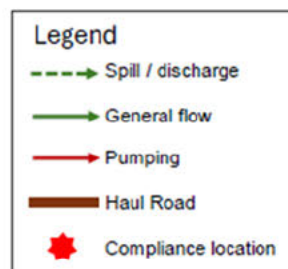


Figure B-2: Mount Frederick South (MFS) construction phase, Stage-0, flow diagram.

Mount Frederick South (MFS) Active Water Treatment Flow Diagram

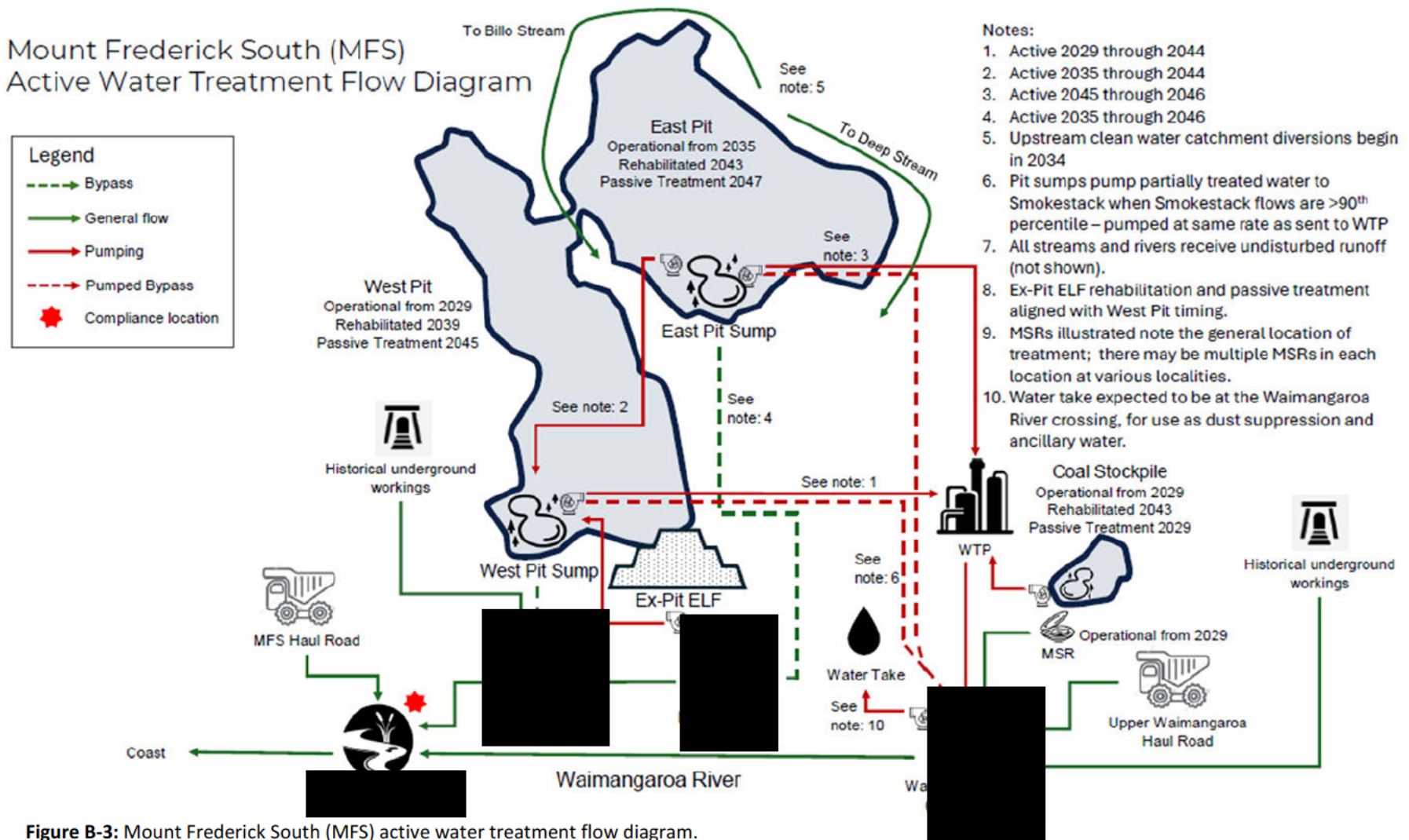


Figure B-3: Mount Frederick South (MFS) active water treatment flow diagram.

Mount Frederick South (MFS) Post-Closure Flow Diagram

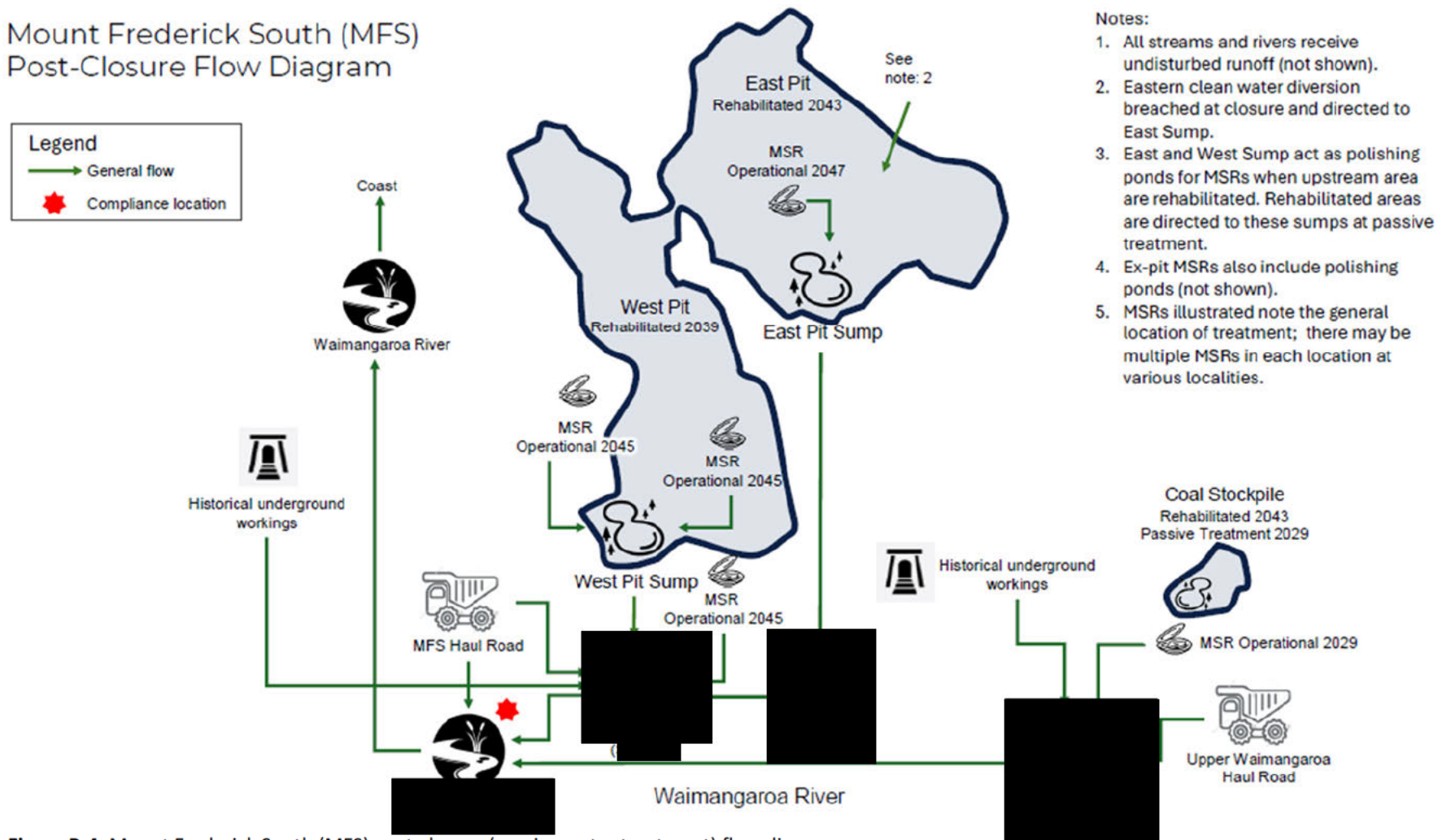


Figure B-4: Mount Frederick South (MFS) post-closure (passive water treatment) flow diagram.

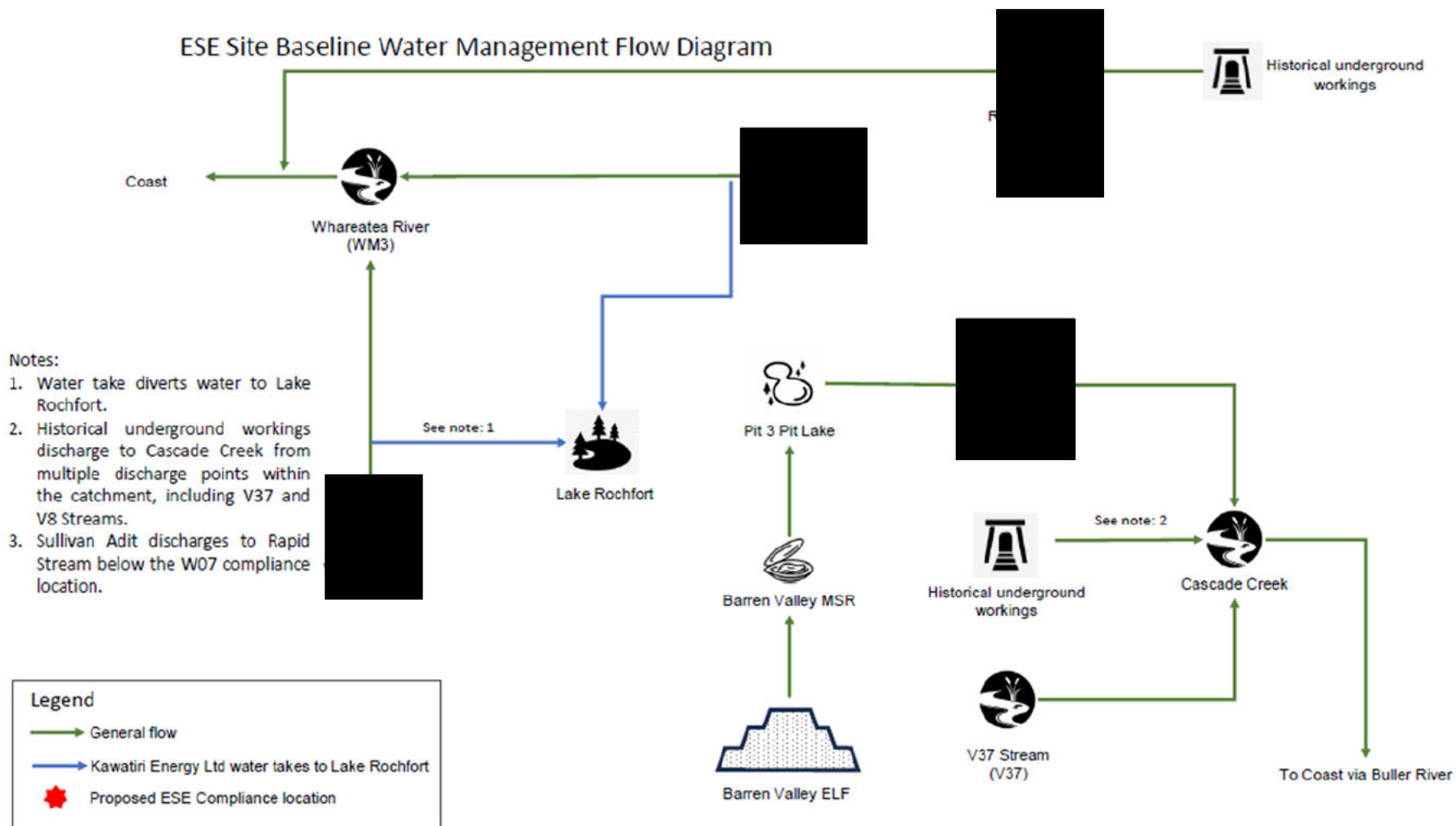


Figure B-5: Escarpment Extended (ESE) baseline water management flow diagram.

ESE Construction Phase, Stage -1, Flow Diagram

Notes:

1. All pond water is pumped to Pit 3 Pit Lake. A pond here will later be used as the WTP Polishing Pond.
2. Water take from Pit 3/Lake Brazil for operation of the portable water treatment plant (as required).
3. ESE Pit extent illustrated for reference.
4. Runoff from undisturbed catchments not shown.
5. Sediment retention ponds will be located at various localities. A single pond is shown for simplicity.
6. Construction activity stormwater may be pumped from sediment retention ponds to the Pit 3 Pit Lake for AMD treatment as required.
7. These waterways may receive impacted waters for a limited period during the construction of water infrastructure controls (e.g., channels, sumps and pumping stations) prior to the waters being directed to Pit 3 Pit Lake. Monitoring of any discharges will undertaken.
8. A sediment retention pond will be located within the footprint of the borrow pit. Should waters be impacted by AMD this will be pumped to Pit 3 for treatment.

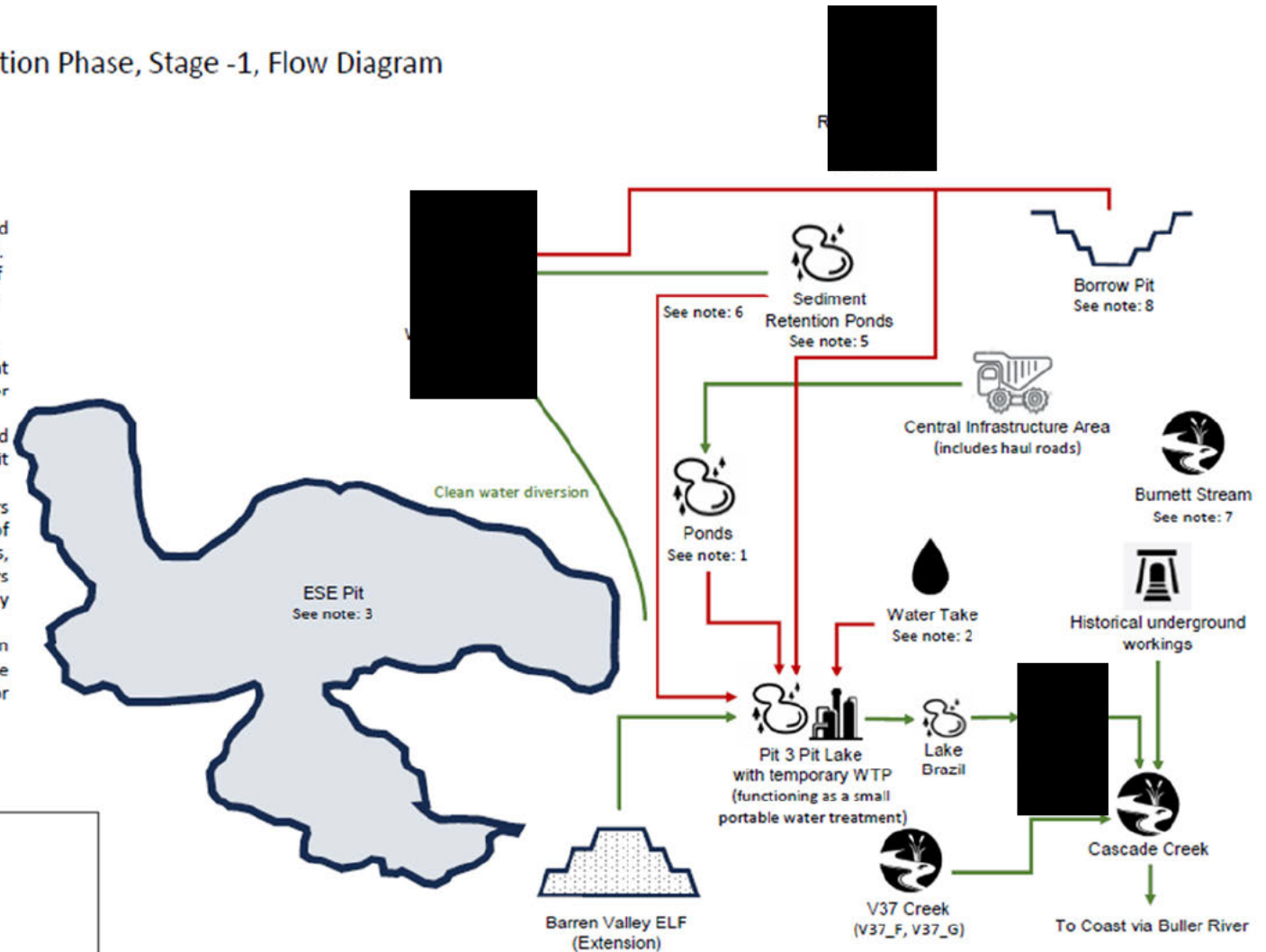
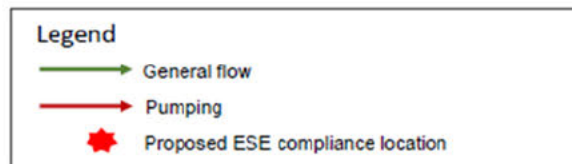


Figure B-6: Escarpment Extended (ESE) construction phase, Stage-1, flow diagram. (Note: "Borrow Pit" shown is no longer included. WLBm outputs included in report are calculated with this change.)

ESE Construction Phase, Stage 0, Flow Diagram

Notes:

1. The Ex-Pit Seal is used as the Surge Pond for the full scale WTP.
2. Water take from local ponds for operation of the portable water treatment plant (as required).
3. ESE Pit extent illustrated for reference.
4. Runoff from undisturbed catchments not shown.
5. Sediment retention ponds will be located at various localities. A single pond is shown for simplicity.
6. Construction activity stormwater may be pumped from sediment retention ponds to the Ex-Pit Seal for AMD treatment as required.
7. These catchments will be impacted during the construction phase. The waterways may receive impacted waters for a limited period during the construction of water infrastructure controls (e.g., channels, sumps and pumping stations) prior to the waters being directed to the Ex-Pit Seal. Monitoring of any discharges will undertaken.
8. A sediment retention pond will be located within the footprint of the borrow pit. Should waters be impacted by AMD this will be pumped to the Ex-Pit Seal for treatment.

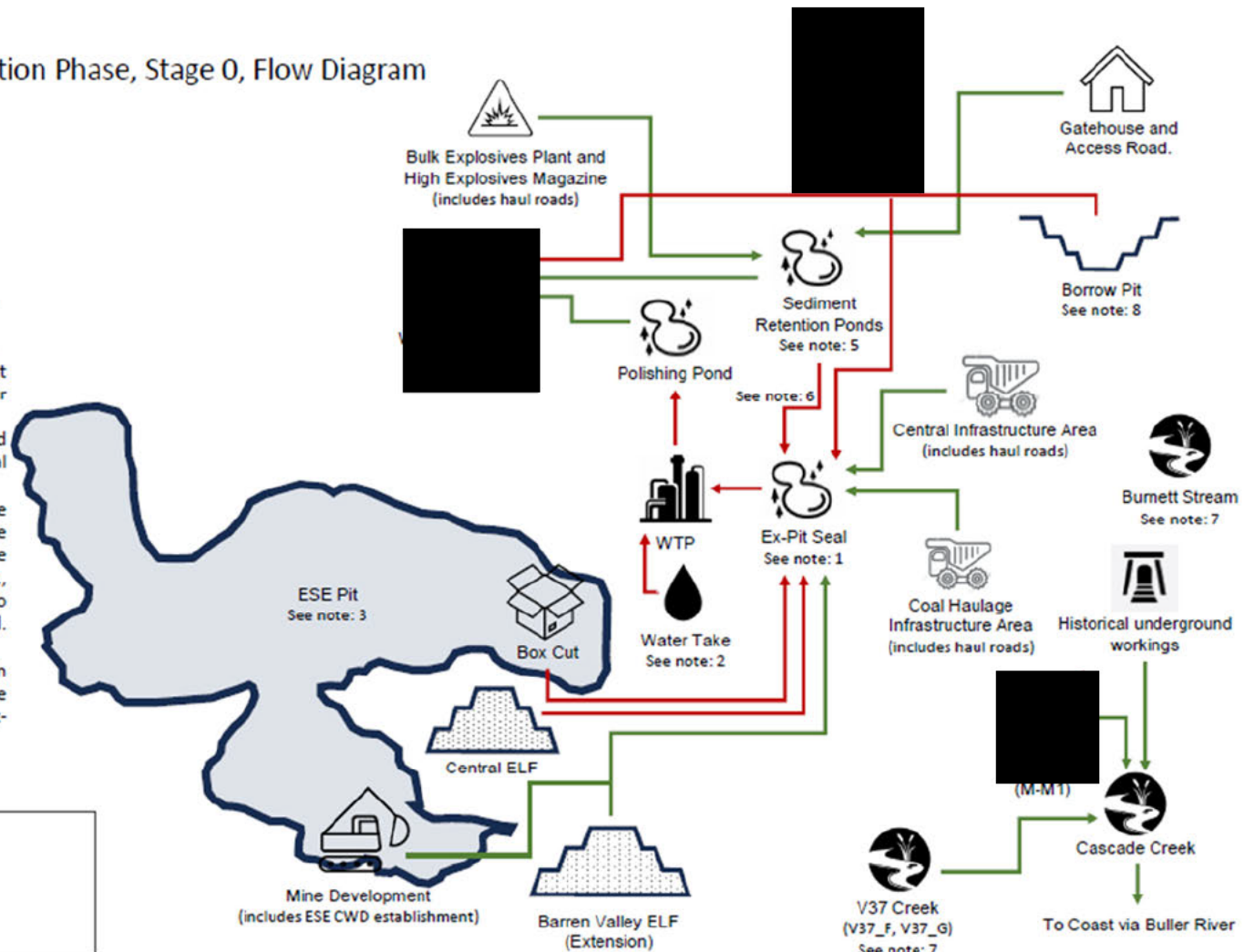
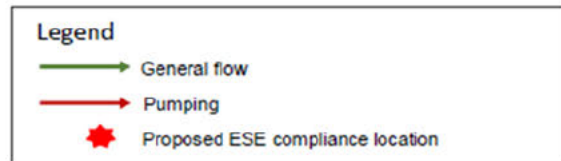


Figure B-7: Escarpment Extended (ESE) construction phase, Stage-0, flow diagram. (Note: "Borrow Pit" shown is no longer included. WLBM outputs included in report are calculated with this change.)

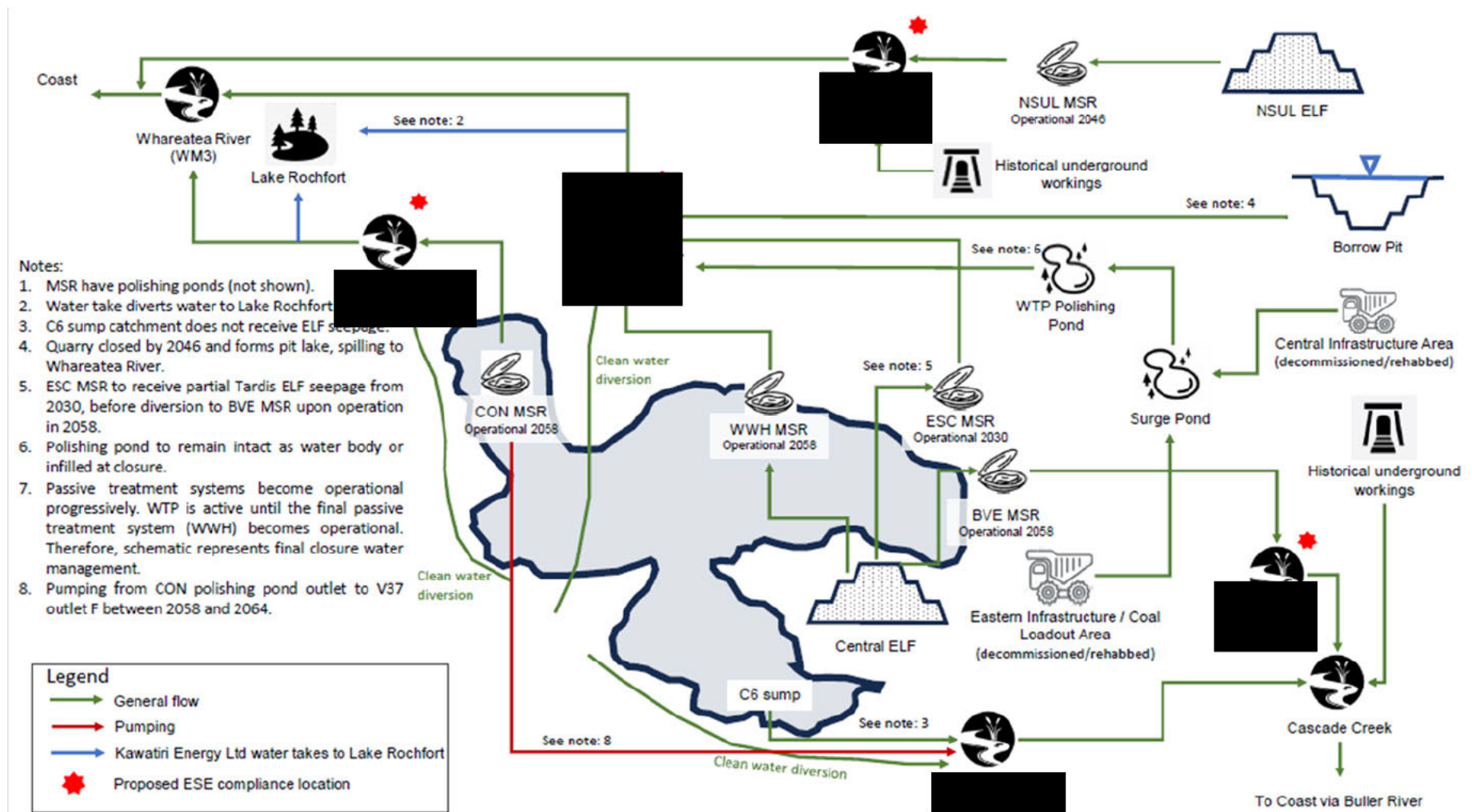


Figure B-9: Escarpment Extended (ESE) post-closure flow diagram. (Note: “Borrow Pit” shown is no longer included. WLBm outputs included in report are calculated with this change.)

Appendix C Escarpment Mine consent (R10193) and background data used for derivation

Table C-1: Whareatea River Escarpment Mine consent limits (R10193) for receiving water monitoring at site WM-2. (from (Hickey, 2012)). Basis for background MEQ screening assessment of monitoring data undertaken by MWM (2025j)

255. The discharge to Whareatea River during mining operations shall meet the compliance limits listed in Table 3 at monitoring point W-M2. Compliance at W-M2 shall be based on a percentile compliance.

Table 3: Receiving Waters Compliance Limits at monitoring Site W-M2

	Compliance Limits	
pH	Shall not fall outside a range of 4.5 – 6.5	
	Median concentrations, g/m³ unless stated	
Total suspended solids	15	
Turbidity	15 NTU	
Iron + manganese	1.1	
Aluminium	0.5	
Median pH	pH >5.5	pH <5.5
Cadmium	0.0003	0.0012
Chromium	0.05	0.20
Cobalt	0.044	0.18
Copper	0.002	0.0013
Lead	0.0065	0.026
Nickel	0.017	0.068
Zinc	0.012	0.054
	95th percentile concentrations, g/m³ unless stated	
Total suspended solids	30	
Turbidity	30 NTU	
Iron + manganese	2.2	
Aluminium	1.0	
Median pH	pH >5.5	pH <5.5
Cadmium	0.0011	0.004
Chromium	1.0	4.0
Cobalt	0.17	0.63
Copper	0.007	0.004
Lead	0.03	0.14
Nickel	0.26	1.0
Zinc	0.067	0.29
Notes:		
a) All compliance limits are based on dissolved metal concentrations;		
b) Limits for cadmium, copper, chromium, lead, nickel and zinc are based on a median water hardness of 50g CaCO ₃ /m ³ .		
c) pH dependent limits based on biotic ligand model (BLM predictions)		
d) Chromium limit is based on Crill and uses U>S, EPA criteria values.		
e) See Condition 218 for method of compliance assessment with monitoring data.		

Table C-2: Background Whareatea River, Conglomerate Stream (reference) and Escarpment adit drainage (WQGS1) data used for the 2012 guideline derivations (using BLM) and for establishing PCOC (EIC from Hickey (2012))

Attachment 7: Escarpment legacy drainage and adit water quality compared to Conglomerate (reference) Stream (data are means with ranges in brackets)

A. Physico-chemical parameters	Units	Conglomerate Stream (reference)	Escarpment drainage (WQGS1)	Adit	Escarpment increase c.f. reference
Flow	m ³ /s	0.022 (0.008-0.053)	0.003 (0-0.018)	,ND	0.14
Temperature	°C	12.6 (9.4-15.1)	10.1 (8.3-11.9)	10.2 (8.3-11.9)	0.80
Dissolved oxygen	% saturation	97 (92-106)	22 (18-73)	79 (74-99)	75% reduction
pH		4.9 (4.7-5.2)	3.0 (3.0-3.1)	3.4 (3.2-3.9)	-1.9 units
Conductivity	mS/m	2.2 (2.0-4.3)	71 (64-77)	27 (10-33)	32
Turbidity	NTU	0.6 (0.3-2.90)	5.2 (2.1-51)	0.65 (0.2-6.0)	8.7
Total suspended solids	g/m ³	4.0	10 (2.0-19)	4.0 (2.0-4.0)	2.5
Dissolved organic carbon (DOC)	g/m ³	ND	ND	ND	
Hardness	g/m ³ as CaCO ₃	2.0 (1.0-3.0)	42 (34-49)	14 (5.0-19)	21
Calcium	g/m ³	0.13 (0.11-0.27)	13 (10-14)	3.6 (1.3-6.1)	100
Sulphate	g/m ³	0.95 (0.5-2.1)	230 (49-250)	50 (17-240)	242

Attachment 7: continued

B. Metal and metalloids	Units	Conglomerate Stream (reference)	Escarpment drainage (WQGS1)	Adit	Escarpment increase c.f. reference
Aluminium	g/m ³	0.13 (0.097-0.15)	11 (8.3-12)	1.3 (0.38-1.7)	85
Arsenic	g/m ³	<0.01	0.015 (<0.01-0.02)	<0.01	1.5
Boron	g/m ³	<0.02	<0.02	<0.02	
Cadmium	g/m ³	<0.0005	0.012 (0.0005-0.0032)	<0.0005	24
Chromium	g/m ³	<0.001	0.002 (0.002-0.003)	<0.001	2
Cobalt	g/m ³	<0.001	0.027 (0.023-0.029)	0.005 (0.002-0.008)	27
Copper	g/m ³	<0.001	0.0045 (0.001-0.012)	0.002 (<0.001-0.002)	4.5
Iron	g/m ³	0.16 (0.12-0.24)	33 (10-52)	3.1 (1.0-5.1)	206
Lead	g/m ³	<0.003	<0.003	0.0035 (<0.003-0.004)	
Manganese	g/m ³	0.0035 (0.002-0.005)	0.32 (0.24-0.38)	0.14 (0.037-0.2)	91
Nickel	g/m ³	<0.0005	0.061 (0.051-0.064)	0.011 (0.003-0.016)	122
Zinc	g/m ³	0.005 (<0.005-0.005)	0.41 (0.35-0.43)	0.061 (0.019-0.094)	82

Table C-3: Background data summary statistics for flow, physico/chemical measures, and dissolved metals/metaloids in Conglomerate Stream (reference) and longitudinal sites in Whareatea River used for the 2012 guideline derivations (using BLM) (EIC from Hickey (2012)). See Appendix A for site locations.

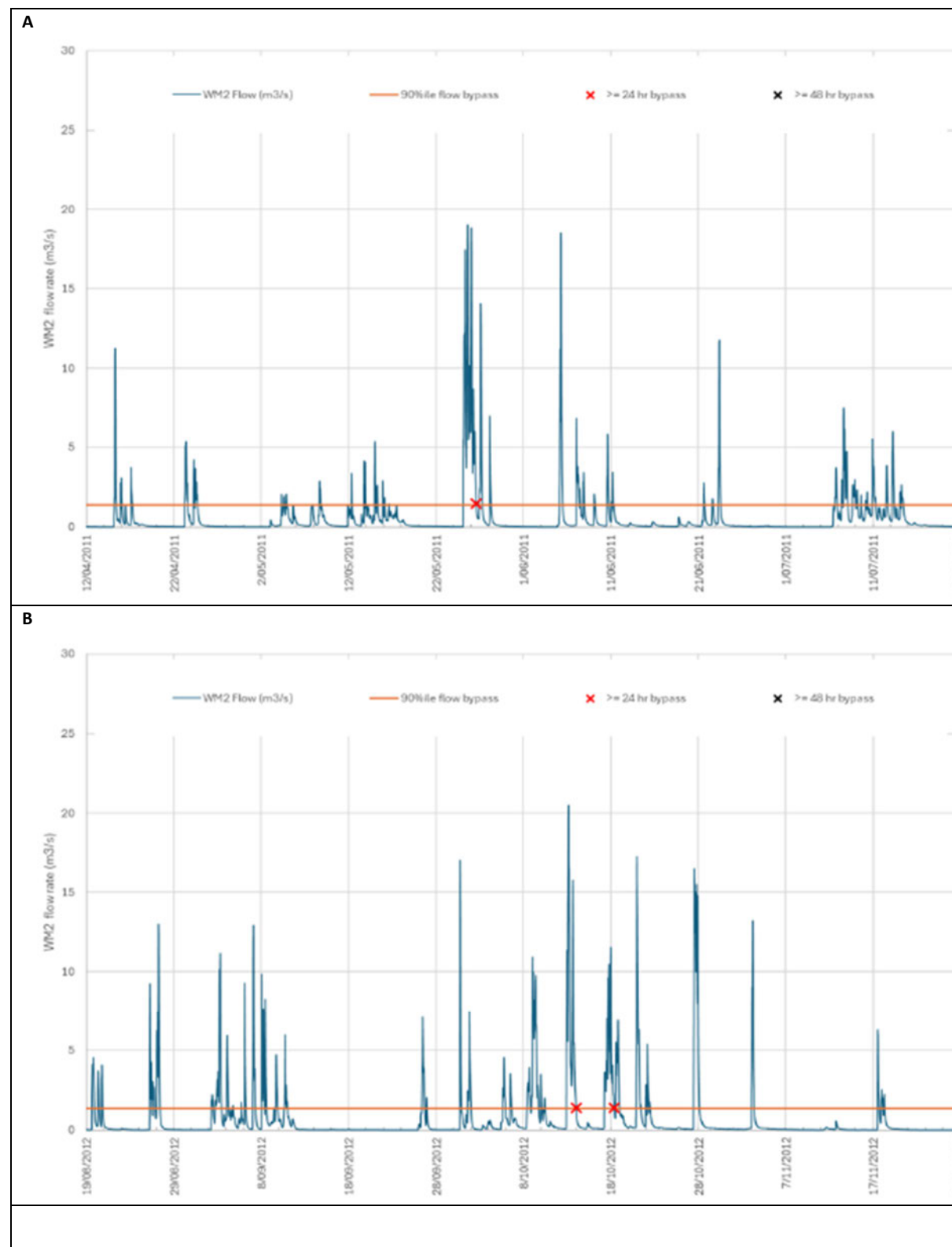
Attachment 8: Whareatea River water quality compared to Conglomerate (reference) Stream (data are means with ranges in brackets)					
A. Physico-chemical parameters	Units	Conglomerate Stream (reference)	Whareatea River (W-M1)	Whareatea River (W-M2)	Whareatea River (W-M3)
Flow	m ³ /s	0.022 (0.008-0.053)	0.022 (0.001-0.12)	0.055 (0.004-0.48)	0.54 (0.12--12.7)
Temperature	°C	12.6 (9.4-15.1)	13.7 (10.2-18.5)	12.9 (9.7-14.8)	14.8
Dissolved oxygen	% saturation	97 (92-106)	99 (89-108)	100 (91-107)	89
pH		4.9 (4.7-5.2)	4.6 (4.3-4.7)	4.8 (4.7-4.9)	6.4 (6.1-6.6)
Conductivity @ 25 °C	mS/m	2.2 (2.0-4.3)	4.2 (2.4-5.1)	2.9 (2.5-4.0)	1.7
Turbidity	NTU	0.6 (0.3-2.90)	1.3 (0.5-23)	0.9 (0.3-3.3)	2.8 (0.5-38)
Total suspended solids	g/m ³	4	2 (1-26)	2 (1-5)	4 (1-52)
Dissolved organic carbon (DOC)	g/m ³	ND	1.7 (0.5-5.2)	3.6 (1.2-8.3)	4.6 (1.5-10)
Hardness	g/m ³ as CaCO ₃	2.0 (1.0-3.0)	3.0 (1.0-7.0)	3.0 (1.0-7.0)	7.0 (4.0-16)
Calcium	g/m ³	0.13 (0.11-0.27)	0.48 (0.14-1.5)	0.33 (0.12-1.4)	1.5 (0.67-3.9)
Sulphate	g/m ³	0.95 (0.5-2.1)	4.7 (1.7-6.9)	3.8 (2.2-4.6)	2.3

Attachment 8: ...continued.

B. Metal and metalloids	Units	Conglomerate Stream (reference)	Whareatea River (W-M1)	Whareatea River (W-M2)	Whareatea River (W-M3)
Aluminium	g/m ³	0.13 (0.097-0.15)	0.16 (0.063-0.27)	0.11 (0.057-0.18)	0.11 (0.03-0.2)
Arsenic	g/m ³	<0.01	<0.01	<0.01	<0.01
Boron	g/m ³	<0.02	<0.02	<0.02	<0.02
Cadmium	g/m ³	<0.0005	<0.0005	<0.0005	<0.0005
Chromium	g/m ³	<0.001	<0.001	<0.001	<0.001
Cobalt	g/m ³	<0.001	<0.001	<0.001	<0.001
Copper	g/m ³	<0.001	0.001 (<0.001-0.001)	0.002 (<0.001-0.002)	<0.001
Iron	g/m ³	0.16 (0.12-0.24)	0.21 (0.03-0.35)	0.14 (0.049-0.27)	0.094 (0.008-0.21)
Lead	g/m ³	<0.003	<0.003	<0.003	<0.003
Manganese	g/m ³	0.0035 (0.002-0.005)	0.011 (0.003-0.026)	0.007 (0.003-0.026)	0.003 (0.002-0.005)
Nickel	g/m ³	<0.0005	0.0008 (0.0005-0.007)	0.0006 (0.0005-0.001)	<0.0005
Zinc	g/m ³	0.005 (<0.005-0.005)	0.009 (<0.005-0.041)	0.008 (<0.005-0.043)	0.005 (<0.005-0.005)

Appendix D Hydrographs flood event durations and dissolved iron relationships for Whareatea River; dissolved iron relationships for Waimangaroa River

Annual Whareatea River at site WM-2 hydrographs



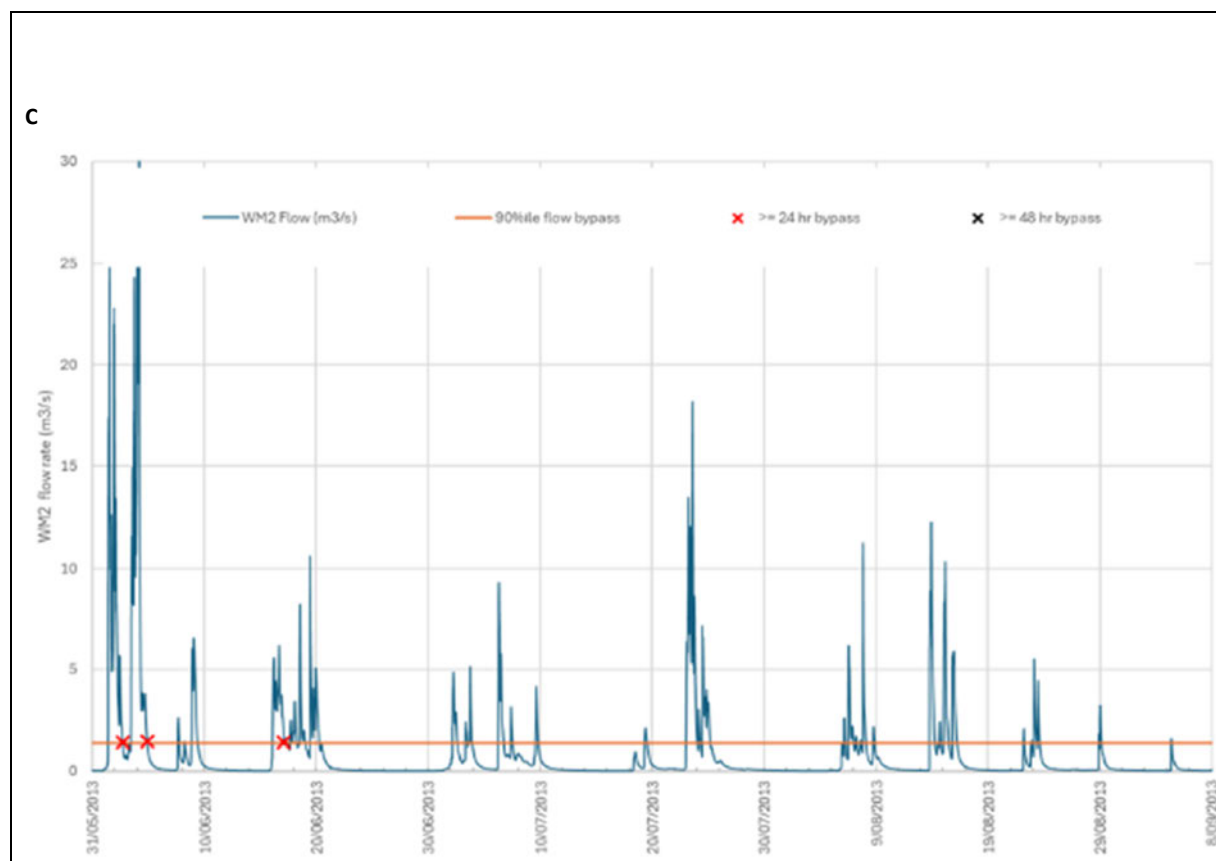


Figure D-1: Annual flow hydrographs for Whareatea River at site WM-2: A 2011; B 2012; C 2013.

Background water quality monitoring for dissolved iron
Whareatea River

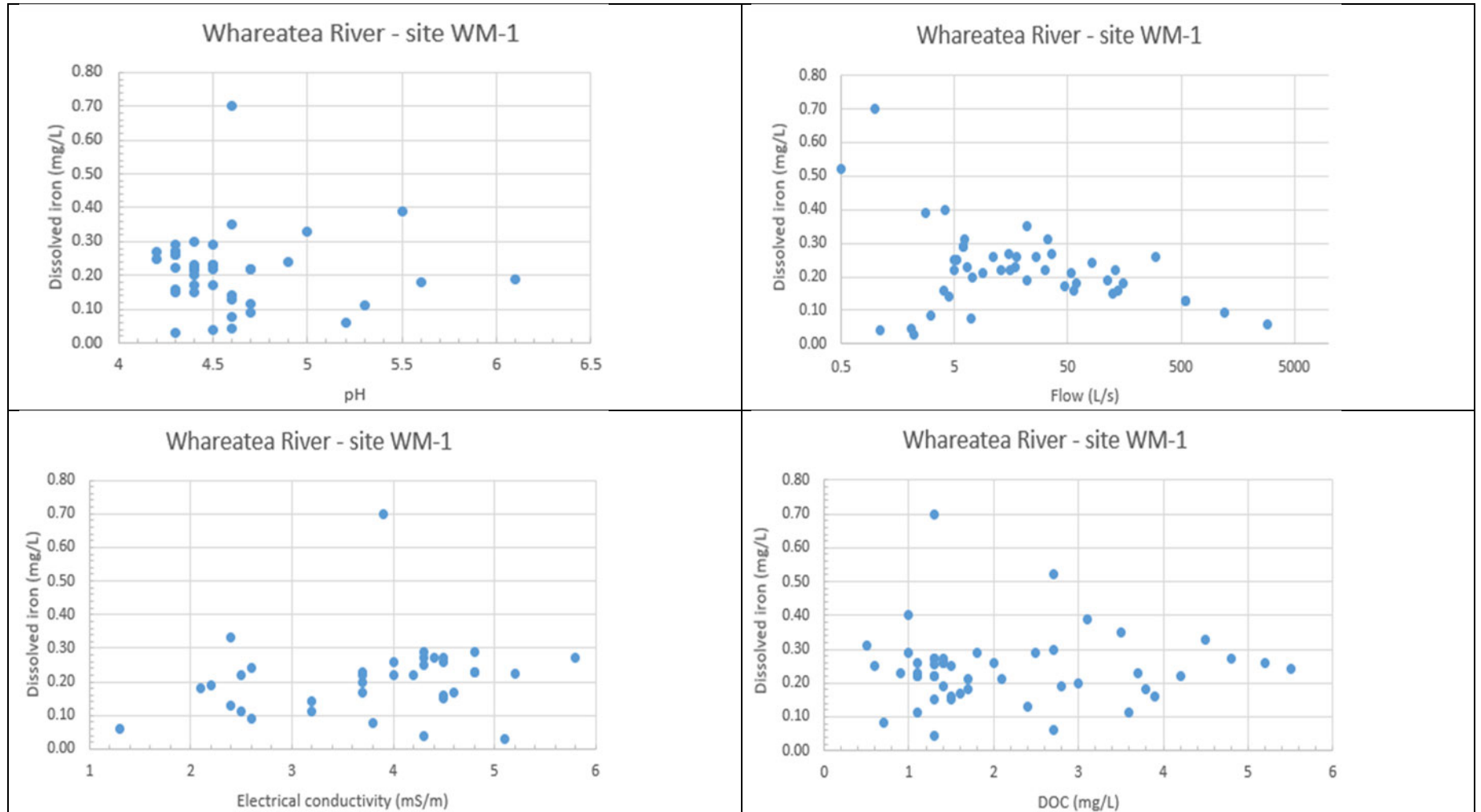


Figure D-2: Dissolved iron relationships for Whareatea River at Buller Plateaux site WM-1 – background water quality site. Monitoring period November 2010-August 2014.

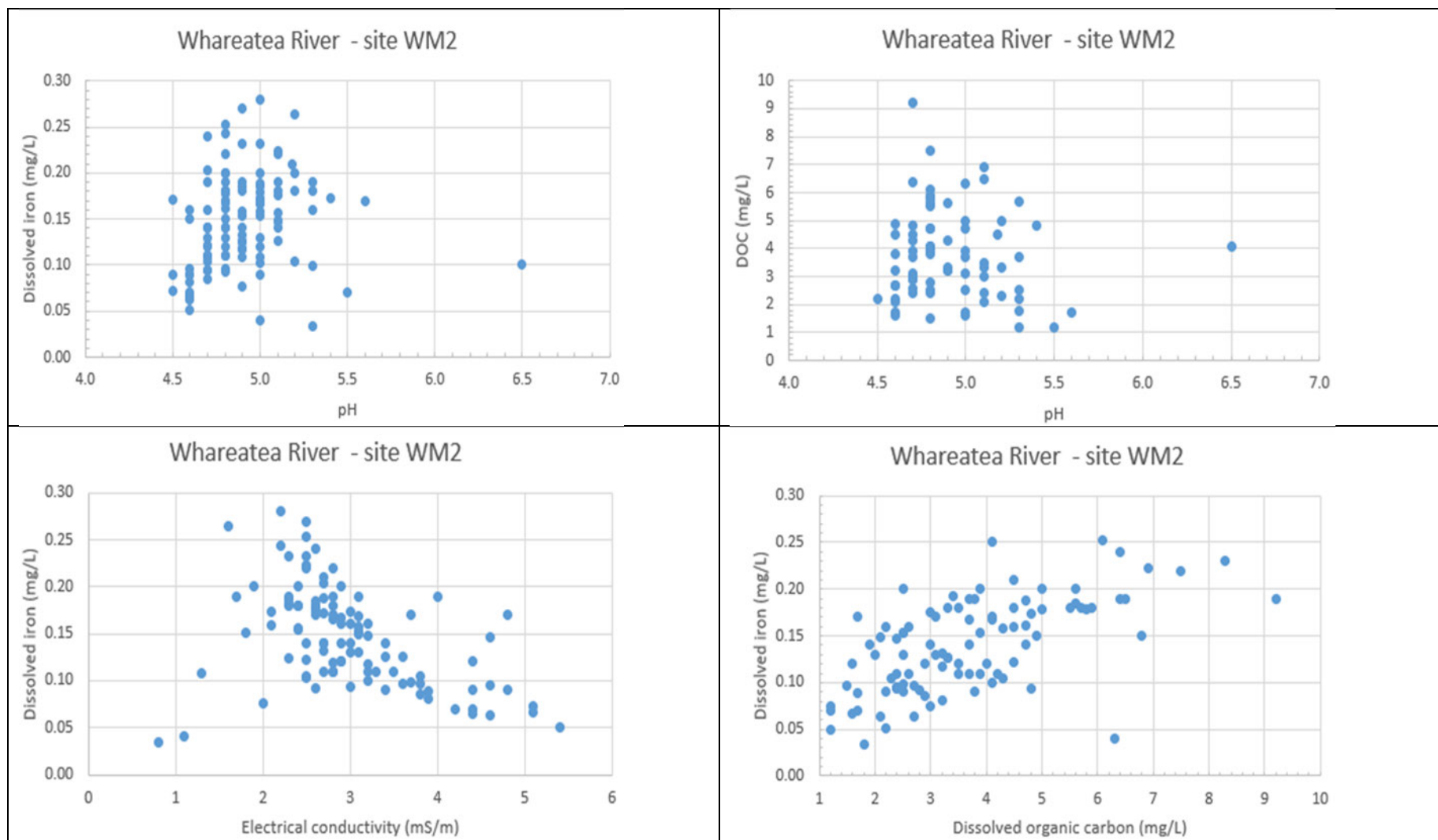


Figure D-3: Dissolved iron relationships for Whareatea River at Buller Plateaux site WM-2 – background water quality site. Monitoring period December 2010 to June 2024.

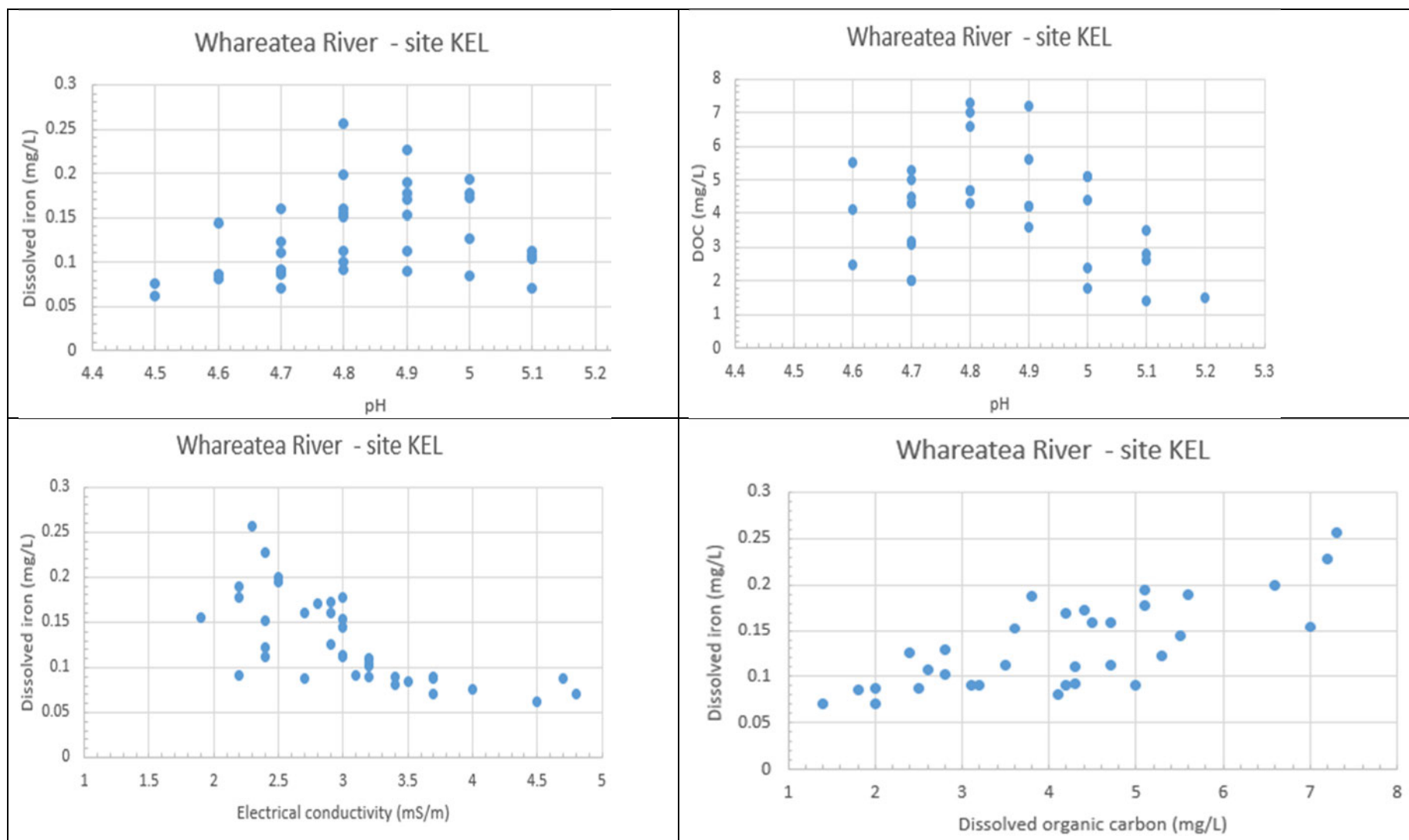


Figure D-4: Dissolved iron relationships for Whareatea River at site KEL – background water quality site. Monitoring period July 2014 to September 2015.

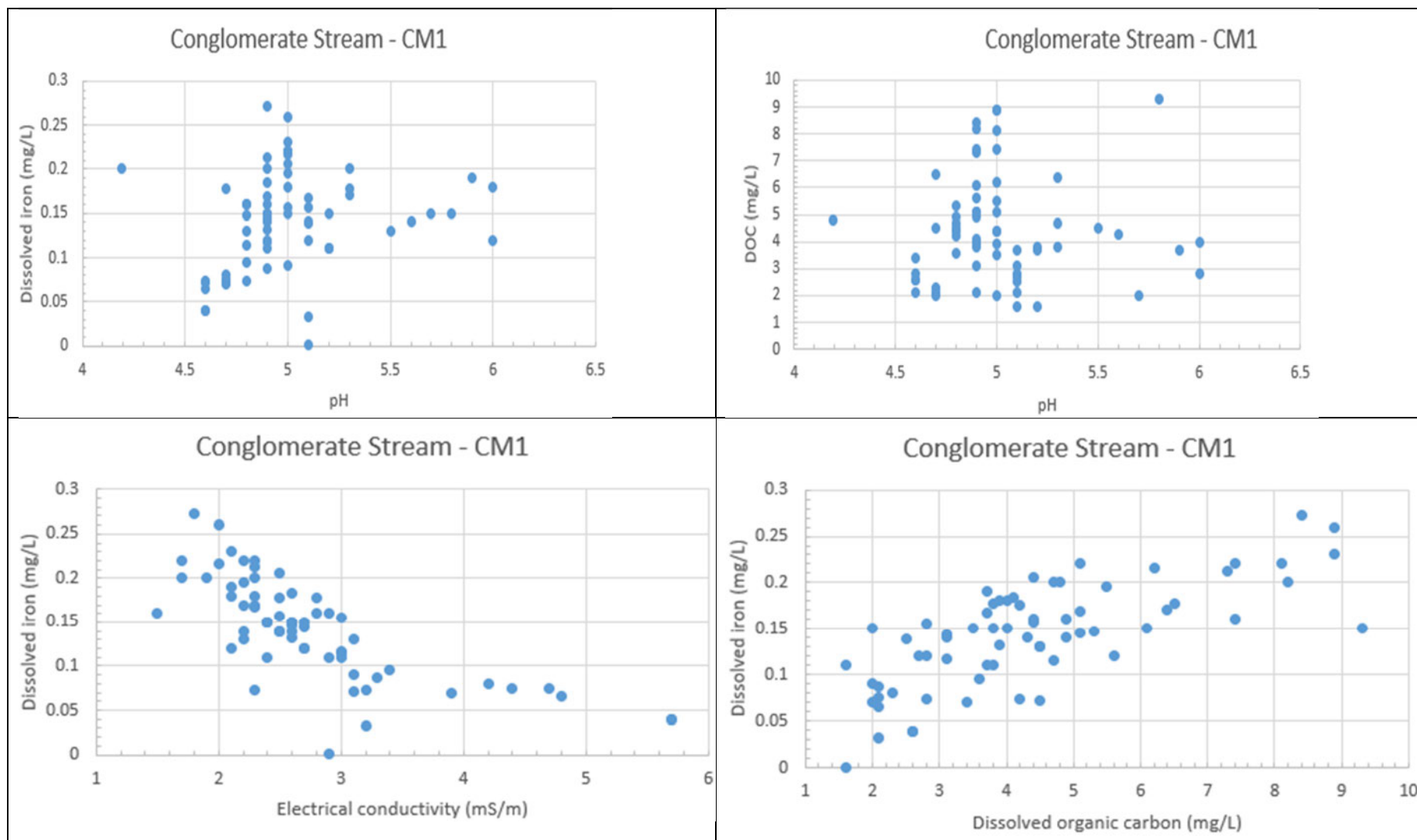


Figure D-5: Dissolved iron relationships for Conglomerate Stream at Buller Plateaux site CM-1 – background water quality site. Monitoring period May 2012 to June 2024.

Waimangaroa River at Smokestack

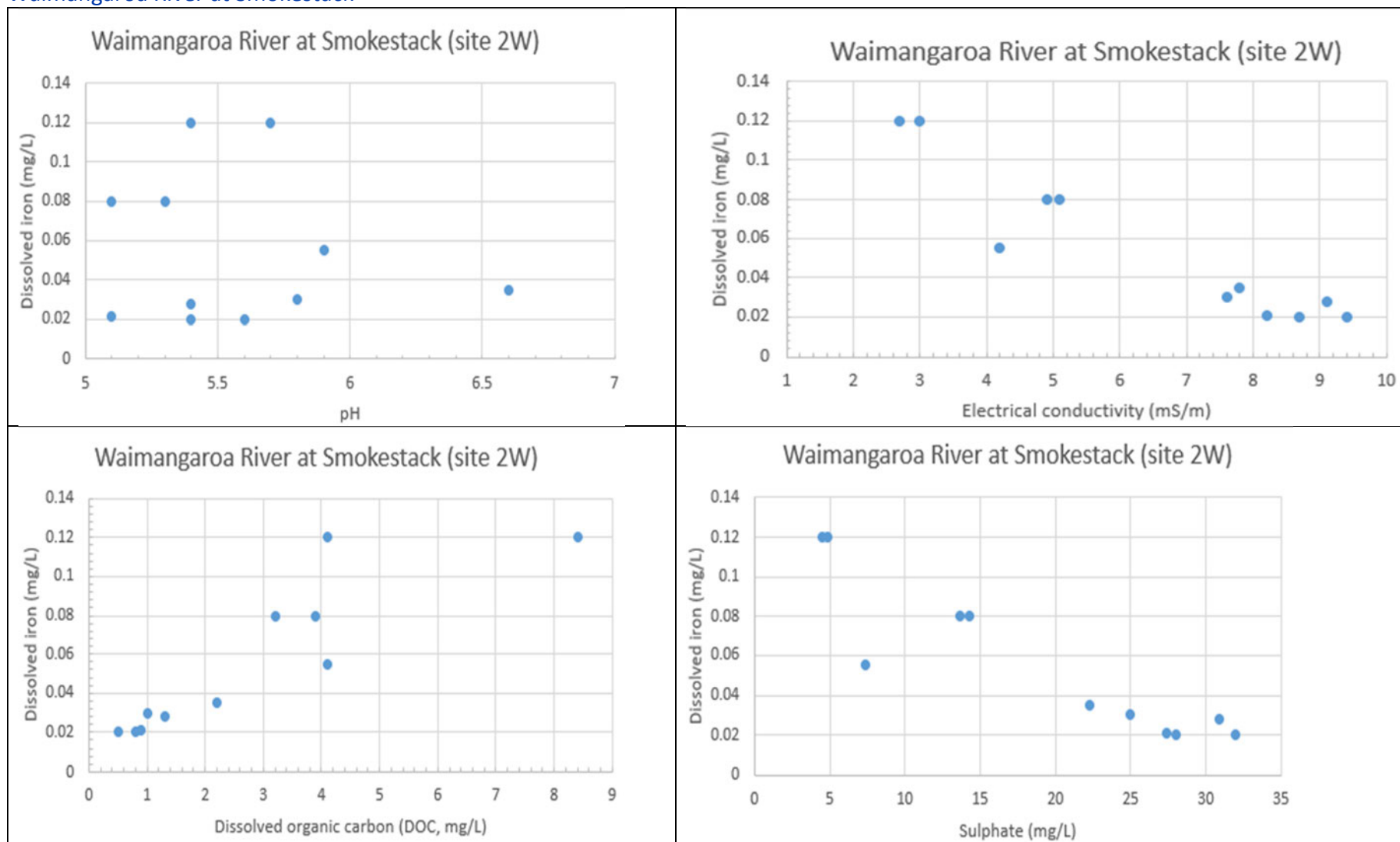


Figure D-6: Dissolved iron relationships for Waimangaroa River at Buller Plateaux site Smokestack (site 2W) – background water quality site with AMD upstream. Monitoring period February to August 2025.

Dissolved iron relationships with pH and effect of dissolved organic carbon

The solubility of ferric hydroxide in pure water is strongly dependent on pH, reducing from about 7.8×10^{-5} mol/L (8.4 mg/L) at pH 3 to 2.6×10^{-9} mol/L (0.0003 mg/L) at pH 7 (Figure D-7, after Liu and Millero (1999)).

The Buller Plateaux streams are naturally acidic – generally in the range 4.5-5.5 – showing a maximum dissolved Fe concentration around pH 5 and consistently lower concentrations as pH reduces to 4.5 (Figures D-3 to D-5). The maximum dissolved Fe concentration at about pH 5 is common with the DOC maxima. Together, these observations indicate that it is not the reduced pH that is resulting in elevated dissolved Fe concentrations but rather the increased DOC levels.

The addition of humic acid (HA) – a primary component of the DOC present in the Buller Plateaux streams – significantly increases the total dissolved iron content at pH 4-8 by forming soluble organic complexes, effectively preventing the iron from precipitating as solid hydroxide (Liu and Millero, 1999). The studies of Liu and Millero (1999) showed that the solubility increase from HA addition was pH dependent – increasing at higher pH – and showed a saturation response with increasing HA concentration (about 90% saturation at 4 mg/L HA). At pH 8 the solubility increase of ferric hydroxide is about 1000-times (i.e., 0.00013 mg/L to 0.13 mg/L) about while at pH 5 the solubility increase is about 10-times (i.e., 0.019 mg/L to 0.19 mg/L).

The concentration increases measured by Liu and Millero (1999) for pure ferric hydroxide with HA addition are in the range of dissolved Fe concentrations measured in the Buller Plateaux streams (i.e., 0.2-0.3 mg/L, previous section) and markedly higher than the solubility of pure ferric hydroxide. This supports the importance of HA in modifying the dissolved Fe in the Buller Plateaux streams.

Additionally, the natural Buller Plateaux streams show strong positive linear relationships between dissolved iron and DOC concentrations (e.g., Whareatea River at WM-2 and KEL, Figures D-3 and D-4; Conglomerate Stream at CM1, Figure D-5) with maximum Fe concentration occurring with the highest DOC. This shows the importance of the natural DOC in modifying dissolved Fe in these streams. The AMD-affected Waimangaroa River at Smokestack also shows a positive linear relationship between dissolved Fe and DOC (Figure D-6). The maximum concentrations of Fe and DOC occur at the lowest EC and sulphate concentrations indicating that high rainfall is associated with the maximum instream concentrations.

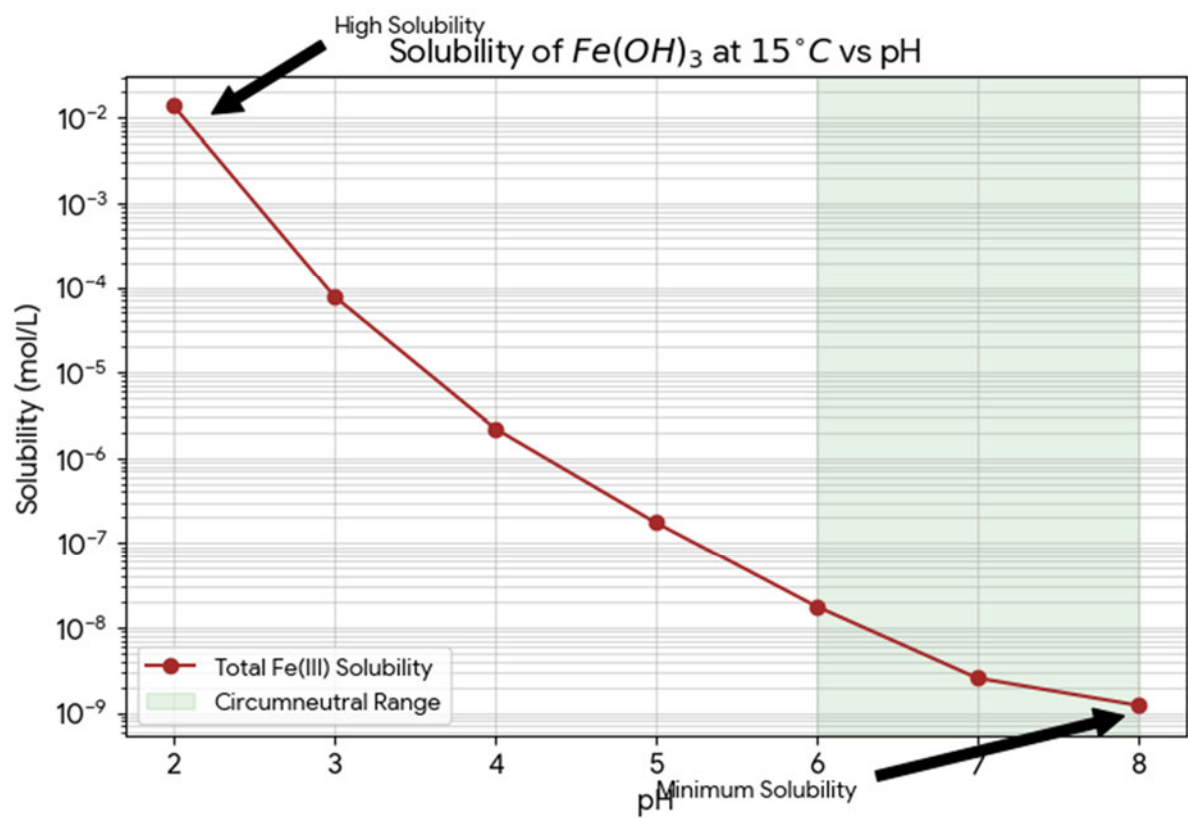


Figure D-7: Solubility of ferric hydroxide in water at 15°C at a range of pH values (Liu and Millero, 1999)

Appendix E Turbidity monitoring compliance and reference sites

Table E-1: Proposed compliance, performance and reference monitoring sites for turbidity. Site locations shown on Appendix A. Annual compliance assessment proposed based on limits in Table 7-1. LoPs and indicative limits provided in Table E-2.

No.	Mine catchment	River/stream	Site name/code	Compliance/performance	Justification	Monitoring type/frequency	Note
1	Escarpment	Whareatea R.	KEL	Compliance	Downstream WM-2. Will receive mine discharges. No upstream reference site on Whareatea – V70 to be used.	Continuous turbidity/discrete weekly turbidity	1
2	Escarpment	Whareatea R.	WM-3	Performance	Aesthetic effects.	Discrete monthly turbidity	1,2
3	Escarpment	Cascade Creek trib. (V8 Creek)	MM1	Compliance (metals & nutrients)/ Performance (turbidity)	Impacted by underground AMD and receives WTP discharge.	Discrete weekly turbidity. Turbidity limit applies.	1,3
4	Escarpment	Whareatea R. trib	V62	Compliance	Drains mining area. Receives bypass discharges. Reference site on V70 to be used.	Continuous turbidity/discrete weekly turbidity	4
5	Escarpment	Whareatea trib	V70	Performance & reference	Reference site for Whareatea R. monitoring (KEL & WM-3).	Continuous turbidity/discrete weekly turbidity	1,5
6	Escarpment	Rapid Stm	W07	Compliance	Mining in upper catchment.	Continuous turbidity/discrete weekly turbidity	4
7	Escarpment	Rapid Stm	W09 (@SH67)	Performance	Aesthetic effects	Discrete monthly turbidity	1,2
8	Mount Frederick South	Deep Stream	SW01	Compliance	D/s East Mine sump	Continuous turbidity/discrete weekly turbidity	1
9	Mount Frederick South	Deep Stream	SW03	Compliance	D/s West Mine sump	Continuous turbidity/discrete weekly turbidity	1
10	Mount Frederick South	Waimangaroa R.	Smokestack (SS) (2W)	Compliance	D/s WTP	Continuous turbidity/discrete weekly turbidity	1
11	Mount Frederick South	Waimangaroa R.	WR d/s Deep Stream (17W)	Compliance	D/s WTP and Deep Stm inflow (East and West sump bypass flows).	Continuous turbidity/discrete weekly turbidity	1
12	Mount Frederick South	Waimangaroa R.	u/s Deep Stream & Smokestack (16W)	Performance & reference	Reference site for Waimangaroa R. monitoring (Smokestack (2W), d/s Deep Stream (17W) and @SH67 (18W)).	Continuous turbidity/discrete monthly turbidity	1
13	Mount Frederick South	Waimangaroa R.	Billo Stream tributary (site BIL.L1)	Performance & reference	Reference site for SW01 and SW03 monitoring	Continuous turbidity/discrete weekly turbidity	1,6

No.	Mine catchment	River/stream	Site name/code	Compliance/performance	Justification	Monitoring type/frequency	Note
14	Mount Frederick South	Waimangaroa R.	@SH67 (18W)	Performance	Aesthetic effects	Discrete monthly turbidity	1,2

Notes:

1. Maintained for duration of active mining in catchment. Annual compliance assessment for median and maximum limits. (Note: this applies to all sites as no lower LoP GV's available for turbidity. Except for the Performance classification for MM1 with Compliance limit of 25 NTU based on a 15-sample rolling median). Trend assessments for Performance sites may be based on annual or 6-yearly monitoring data depending on significance of site.
2. Performance for turbidity and clarity (converted from turbidity – indicative values provided in Table E-2). Monitoring frequency may need to be increased to weekly for initial overburden removal and mining period. Mining-related turbidity/clarity measured at Buller Plateaux compliance sites could be translated to SH67 sites using flow relationships.⁵² Annual assessment and reporting.
3. Improvement trend monitoring based on implementation of AMD treatment. Note: This AMD treatment not expected to markedly improve variable turbidity in this stream (Table E-2).
4. Background water quality and baseline biological sampling required. Maintained for duration of active mining in catchment – may have delayed start for compliance monitoring as catchment mining planned for late stage. Annual compliance assessment for median and maximum limits.
5. Maintained for duration of active mining in catchment. Continuous monitoring to provide reference turbidity condition for inter-annual variability.
6. Maintained for duration of active mining in catchment. Continuous monitoring to provide reference turbidity condition for inter-annual variability. Note: Billo Stream site (BS01) which has background data will be mined out after 5-years.

⁵² Median flows (L/s): WM-2+CM1 = KEL = 84 L/s; WM-3 = 271 L/s; a 3.5-times adjustment factor; Rapid W07 = 12 L/s, Rapid at SH67 = 189 L/s a 15.7-times adjustment factor; Waimangaroa @ Smokestack = 704 L/s; Waimangaroa @ SH67 = 1389 L/s (calculated) a 1.2-times adjustment factor.

Table E-2: Turbidity monitoring data and ecological level of protection (LoP) classification for compliance, performance and reference sites with proposed compliance limits (Appendix D, Table D-1 from Hickey 2026c). Compliance limits (indicative) based on Table 7-1. N/A = not applicable. See Appendix A for site locations.

Mine catchment	River/stream	Site name/code	Compliance/ Performance/ Reference	Turbidity ^a (NTU, mean, <i>median</i> , range, 95 th percentile) [visual clarity (m)] ^b	Level of Protection (LoP)	Compliance limits ^c (median/95 th /7-d rolling median/ maximum) (NTU) (unless otherwise stated)	Continuous (C) or Discrete (D) compliance monitoring	Note
Escarpment	Whareatea R.	KEL	Compliance	2.1, 0.63 (0.2-39, 4.8); n=36 [4.6 m]	95%	5.6/25/100/550	C	Limits estimate based on discrete monitoring data.
Escarpment	Whareatea R.	WM-3	Performance	10.7, 2.9 (0.4-344); n=98 [1.3 m]	N/A	50% clarity change (aesthetic) [estimate: 0.65 m; 6.8 NTU]	C&D	Clarity change estimated from KEL continuous with supplemented discrete monitoring.
Escarpment	Cascade Creek trib. (V8 Creek)	MM1	Performance	6.2, 1.3 (0.17-118); n = 135 [2.5 m]	80%	25 NTU 15-sample rolling median	D	Intermittent turbidity elevation associated with AMD inputs.
Escarpment	Whareatea trib	V62	Compliance	0.57 (0.25-0.75); n = 3 [5.0 m]	95%	5.6/21/100/550	D	
Escarpment	Whareatea trib	V70	Reference	0.70 (0.26-1.1); n = 3 [4.2 m]	N/A	N/A	C&D	Continuous turbidity monitor needed to provide basis for KEL compliance.
Escarpment	Rapid Stream	W07	Compliance	0.68 (0.15-1.1); n = 6 [4.4 m]	95%	5.7/21/100/550	D	Compliance limits calculated from mean and maximum baseline.
Escarpment	Rapid Stream	W09 (@SH67)	Performance	11.7, 7.7 (0.12-90); (continuous Jan2020-Apr2022) [0.58 m]	N/A	50% clarity change (aesthetic) [estimate: 0.29 m; 12 NTU]	D	Background for performance to be established from monitoring before mining commencement.
Mt Frederick South	Deep Stream	SW01	Compliance	1.6, 0.58 (0.16-5.4, 4.6); n=23 0.57, 0.47 (0.09-17), (continuous) [5.9 m]	95%	5.5/25/100/550	C&D	Limits calculated on basis of continuous monitoring Nov 2024-Sept 2025.
Mt Frederick South	Deep Stream	SW03	Compliance	0.52, 0.35 (0.20-1.5, 1.2); n=13 [7.6 m]	95%	5.5/21/100/550	C&D	Limits calculated on basis of continuous monitoring at SW01.

Mine catchment	River/stream	Site name/code	Compliance/ Performance/ Reference	Turbidity ^a (NTU, mean, <i>median</i> , range, 95 th percentile) [visual clarity (m)] ^b	Level of Protection (LoP)	Compliance limits ^c (median/95 th /7-d rolling median/ maximum) (NTU) (unless otherwise stated)	Continuous (C) or Discrete (D) compliance monitoring	Note
Mt Frederick South	Waimangaroa R.	Smokestack (SS) (2W)	Compliance	7.9 2.0 (0.66-71, 34); n=40 2.4. 2.1 (1.3-53.5), (continuous) [1.7 m]	80%	7.0/54/100/550	C&D	Limits calculated on basis of discrete monitoring Feb 2025 – May 2026.
Mt Frederick South	Waimangaroa R.	D/s Deep Stream (17W)	Compliance	1.6, 1.6 (0.64-3.2, 3.0); n=24 [1.8 m]	80%	7.0/23/100/550	C&D	Limits calculated on basis of basis of discrete monitoring Feb 2025 – May 2026.
Mt Frederick South	Waimangaroa R.	U/s Deep Stream & SS (16W)	Performance & Reference	1.0 (0.45-2.1); n=4 (site K monitoring) [3.2 m]	N/A	N/A	C&D	Continuous turbidity monitor needed to provide basis for Smokestack compliance.
Mt Frederick South	Waimangaroa R.	Billo Stream (BS01) tributary (BIL.L1)	Performance & Reference	3.9 (2.7-7.2); n=8 (flood samples) Continuous (BS1) 0.68, 0.34 (0.1-21.3) [7.7 m]	N/A	N/A	C&D	BS1 continuous from Nov 2024-Sept 2025. Continuous turbidity monitor needed to provide basis for SW01 and SW03 compliance.
Mt Frederick South	Waimangaroa R.	18W (@SH67)	Performance	2.6, 2.5 (0.5-5.9, 4.3); n=59 [1.5 m]	N/A	50% clarity change (aesthetic) [estimate: 0.75 m; 5.7 NTU]	D	Baseline for performance to be established from monitoring before mining commencement.

^a Note: sample numbers vary between sites. Larger numbers include data from 2009 for some sites with low sample numbers from recent (2024/ February 2025).

^b Visual clarity calculated from median turbidity (n >8) or mean turbidity using regression equation (Regression equation for turbidity vs black disk (BD): $\log_{10}(\text{Turbidity}) = -0.833 \times \log_{10}(\text{BD}) + 0.499$; turbidity in NTU, BD in m) for instream measurements (from Davies-Colley et al. 1992, data shown in Hickey (2026c; Figure 3-1)).

^c Compliance assessment for ecological protection to be based on annual median and 95th percentile for site compared with background from upstream or reference site. **Indicative values shown here** based on monitoring data for median and 95th percentile (n>8) or mean and maximum values. Visual clarity reduction estimate is for 50% clarity reduction with calculated turbidity (from Davies-Colley et al. 1992) with assessment based on annual median of monitoring data.

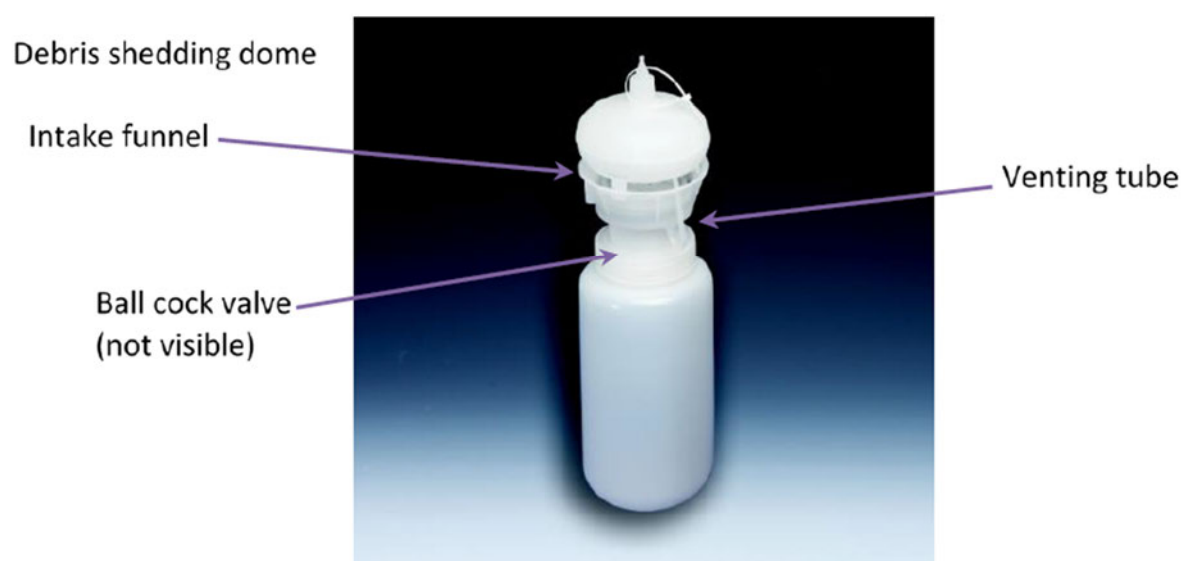


Figure E-1: Nalgene[®] Storm Water Sampler bottles. Image from Thermoscientific. See Gadd and Milne (2019) for guidance for deployment.

Appendix F Guideline species sensitivity distributions and sensitivity data tables

The primary datasets used for the guideline value (GV) derivations are summarised in Table F-1.

Most of the international jurisdiction datasets used do not contain GVs for a range of levels of protection (LOP). The original data from these publications were modelled in an SSD tools shiny app⁵³ to derive differing LoPs for the metals. This is the approach recommended for the ANZG derivations (Warne et al., 2025).

The Cu and Zn guidelines for freshwaters have been updated following the revised procedures for chronic guideline derivation. The chronic Cu guidelines are largely finalised and have been used (ANZG, 2026a), while the Zn guidelines (ANZG, 2026d) are still in the review process and have not been used. Acute guidelines for both Cu and Zn have been completed following the ANZG methodology (Gadd et al., 2024). Those GV_acute values are used in this site-specific derivation.

The freshwater guidelines for Ni are in the process of updating and incorporation of new species sensitivity material (Peters et al., 2018; Peters et al., 2021; Stauber et al., 2021). However, the finalised guideline derivation has not been undertaken at the time of writing.

For some metals the derivations included “short-term” datasets for acute LC/EC50 values. These short-term values were adjusted to acute no effect values based on the Zn relationships in (Gadd et al., 2024). The acute/chronic ratio (ACR) from the zinc derivations following the ANZG methodology (Gadd et al., 2024) was used to estimate the acute no effect GVs (i.e., LC/EC10 estimates) from the chronic data where no acute datasets were available.

The recent Canadian guideline derivations (i.e., Al, Cd, Co, Mn and Zn; Table F-1) are preferred compared with the ANZECC (2000) guidelines (incorporated into the ANZG 2018) for two primary reasons: (i) the updated Canadian guidelines incorporate toxicity modifiers using the multiple linear regression (MLR) approach – which is being adopted from the updated ANZG derivations (Warne et al., 2025); and (ii) the Canadian methodology is most similar to the Australian and New Zealand approach which incorporates all freshwater species – notably the US EPA methodology excludes algae and plants.

The following sections include SSDs to show the distribution and sensitivity of species tested and the more sensitive species leveraging the distributions.

Summary tables are included showing the normalising calculations for the chronic and acute LoPs relative to the referenced derivation dataset.

⁵³ <https://bcgov-env.shinyapps.io/ssdtools/>

Table F-1: Overview of metal toxicants and data sources (see Section 6.1 text for details).

Toxicant	Test type	Status	Reference
Aluminium (Al)	Long-term (chronic)	CCME used for pH>6.5 with TMFs	US EPA (2018); CCME (2021)
Cadmium (Cd)	Short-term; Long-term	CCME acute and chronic guidelines used with TMFs.	CCME (2014)
Chromium (Cr(III))	Long-term	Screening guideline ^a	(ANZG, 2026b)
Cobalt (Co)	Short-term; Long-term	CCME used with TMFs	CCME (2017) ^b
Copper (Cu)	Short-term; Long-term	NZ (acute) with TMFs; ANZG (chronic) with TMFs	Gadd et al. (2024) (NZ acute); ANZG (2026a) ^c
Iron (Fe)	Long-term	US EPA used	Brix et al. (2023); ANZG (2025b); CCME (2024); (US EPA, 1986)
Lead (Pb)	Short-term; Long-term	Screening guideline with TMFs	CCME (2020)
Manganese (Mn)	Short-term; Long-term	CCME used with TMFs	CCME (2019)
Nickel (Ni)	Short-term; Long-term	ANZG used with TMFs	ANZG (2018a); Stauber et al. (2021) ^d
Zinc (Zn)	Short-term; Long-term	NZ (acute) used with TMFs; CCME (chronic) used with TMFs	Gadd et al. (2024) (NZ acute); ANZG (2026d) ^d ; CCME (2018a); CCME (2018b)

^a Guideline used for screening for PCOCs in WLBMs with TMFs (if appropriate).

^b Guideline in process of revision for international application.

^c Updated ANZG used as in final review.

^d ANZG guideline in process of revision but not completed. Draft guideline not used.

Table F-2: Summary of data availability from Table F-1 references. LoPs either available or calculated from chronic or acute SSDs. 'X' indicated no acute data available for calculation. n/a = not applicable.

Toxicant	Chronic			Acute		
	SSD	LoPs - available	LoPs calculated	SSD	LoPs - available	LoPs calculated
Aluminium (Al)	✓		✓	X	X	X
Cadmium (Cd)	✓		✓	✓		✓
Cobalt (Co)	✓		✓	✓		✓
Copper (Cu)	✓	✓			✓	✓
Iron (Fe)	n/a	n/a	n/a	n/a	n/a	n/a
Lead (Pb)	✓		✓	X	X	X
Manganese (Mn)	✓		✓	✓		✓
Nickel (Ni)	✓	✓		X		✓
Zinc (Zn)	✓		✓	✓	✓	

Aluminium

Chronic – aluminium

The chronic dataset is from CCME (2021) with the normalised SSD shown in Figure F-1 and equation in Table F-3. Figure F-2 shows the model average SSD with the differing LoPs shown in Table F-4.

Plots of the effect of toxicity modifiers in aluminum toxicity are shown in Figure F-3. These show the ranges when the TMF provide the greatest reduction in toxicity.

A summary of the aluminium site-specific guideline derivation is provided in Section 14.1.3

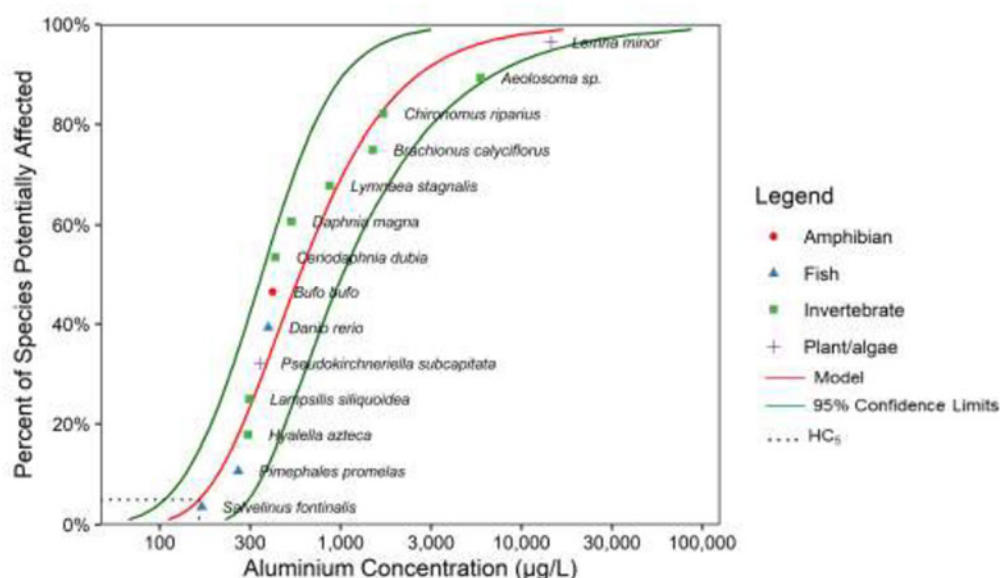


Figure F-1: FWQG model averaged species sensitivity distribution (SSD) for aluminium in freshwater for example site (pH 7.5, DOC 0.5 mg/L, hardness 50 mg/L). The 5th percentile is 170 µg Al/L. (Figure 2 from CCME (2021))

Table F-3: CCME Federal water quality guideline for total aluminium (µg/L). (Table 1 from CCME (2021)).

Aquatic Life	Guideline ^a
FWQG Equation	$\text{FWQG } (\mu\text{g/L}) = \exp([0.645 \times \ln(\text{DOC})] + [2.255 \times \ln(\text{hardness})] + [1.995 \times \text{pH}] + [-0.284 \times (\ln(\text{hardness}) \times \text{pH})] - 9.898)$
Example FWQG ^b	170 µg/L

^a The FWQG is expressed as an equation in order to calculate a site-specific FWQG. The FWQG is for total aluminium in fresh waters and is calculated using the equation above or using the FWQG calculator (Appendix B). The FWQG equation is valid between hardness 10 and 430 mg/L, pH 6 and 8.7, and dissolved organic carbon (DOC) 0.08 and 12.3 mg/L.

^b As an example, the FWQG at a hardness of 50 mg/L, pH 7.5, and DOC concentration of 0.5 mg/L is 170 µg/L.

Derivation of different LoPs for aluminium from CCME (2021) dataset

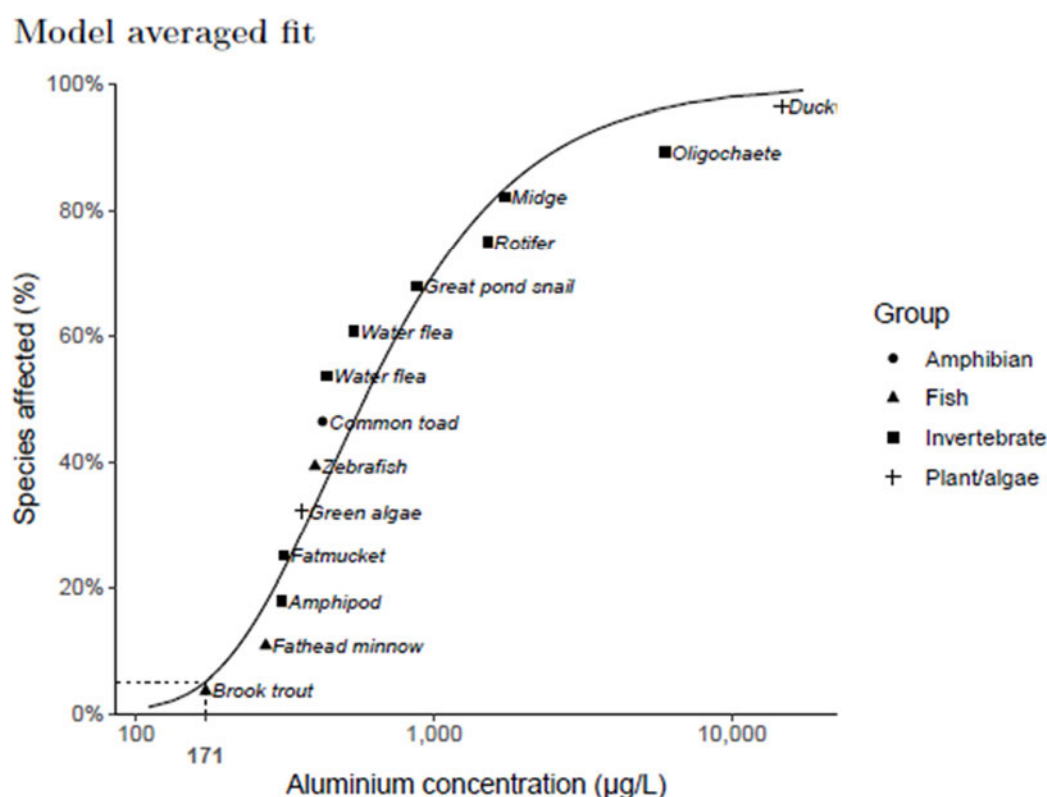


Figure F-2: SSD for calculation of differing LoPs from CCME (2021)

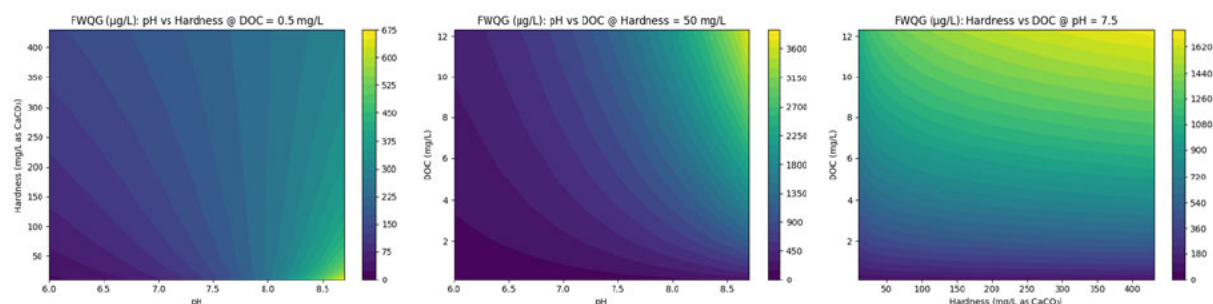
Table F-4: The estimated hazardous/protective concentrations for aluminium. ‘HCx’ is the % species affected; ‘PCx’ is the % species protected; ‘est’ is the model-averaged estimate of the concentration; ‘se’ is the bootstrap based standard error of the estimate; ‘lcl’ and ‘ucl’ are the bootstrapped based lower and upper 95% confidence limits; ‘nboot’ is the number of bootstrap samples; ‘pboot’ is the proportion of bootstrap samples that converged. The model-averaged estimate(s) is calculated by treating the distribution as a single weighted mixture distribution. Distributions with an absolute AIC difference greater than a default delta of 9.21 (corresponding to a weight of no more than 0.01) are excluded prior to bootstrapping (data from Figure F-2).

Estimated hazardous/protective concentration

HCx	PCx	est	se	lcl	ucl	nboot	pboot
1	99	109.766	51.300	20.421	240.056	1000	1
5	95	170.525	57.399	70.269	318.415	1000	1
10	90	214.882	62.340	124.085	378.786	1000	1
20	80	291.105	73.956	187.149	484.831	1000	1

Toxicity modifiers for aluminium

Figure F-3: Plots showing the effects of toxicity modifiers (pH, hardness, DOC) on chronic aluminium toxicity.



Calculator

A toxicity calculator is provided by CCME (2021) for 95th percentile protection calculation.⁵⁴

Acute-aluminium

There is no short-term GV or normalised acute dataset provided in CCME (2021).

Aluminium summary

The chronic GVs for aluminium for differing LoPs are summarised in Table F-5. The 90% and 80% LoPs adjustment factors are incorporated into the equations in Table 6-2.

Table F-5: Aluminium summary for chronic GVs at differing LoPs. The 'Normalising factor' adjusts the 'GV_{calc}' (Table F-4) to the CCME GV.

Chronic LoP (%)	GV _{calc} (µg/L)	Ratio to Chronic GV 95% ^a	CCME _{GV} (µg/L) ^b	Normalising factor ^c	GV _{LoPs} (µg/L)
95	170.5	1	170	1.00	170
90	214.9	1.3		1.00	214
80	291.1	1.7		1.00	290

^a CCME equation divided by the reciprocal of these ratios to derive 90% and 80% LoPs

^b CCME (2021) FWQG (chronic) for aluminium at pH 7.5, DOC 0.5 mg/L and hardness 50 mg/L CaCO₃

^c Normalising factor to adjust 'GV_{calc}' value to 'CCME_{GV}' for differing LoPs (i.e., 'GV_{calc}' / Normalising factor)

⁵⁴ <https://www.canada.ca/content/dam/eccc/documents/xlsx/pded/feqg/Appendix%20B-FWQG%20Calculator.xlsx>

Cadmium

Data for long-term and short-term sensitivity for cadmium was from CCME (2014).

Chronic – cadmium

The chronic SSD for cadmium is shown in Figure F-4 with the calculated LoPs in Table F-6.

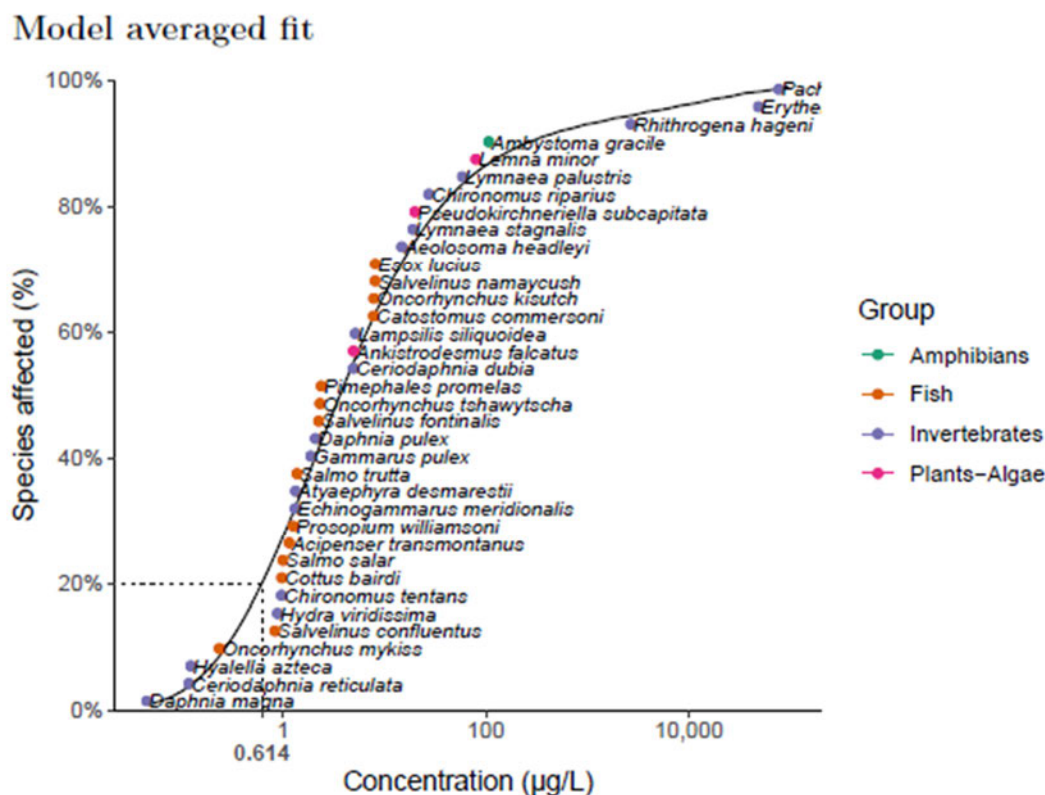


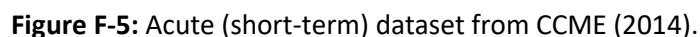
Figure F-4: Chronic dataset from CCME (2014)

Table F-6: The estimated hazardous/protective concentrations for cadmium (chronic). ‘HCx’ is the % species affected; ‘PCx’ is the % species protected; ‘est’ is the model-averaged estimate of the concentration; ‘se’ is the bootstrap based standard error of the estimate; ‘lcl’ and ‘ucl’ are the bootstrapped based lower and upper 95% confidence limits; ‘nboot’ is the number of bootstrap samples; ‘pboot’ is the proportion of bootstrap samples that converged. The model-averaged estimate(s) is calculated by treating the distribution as a single weighted mixture distribution. Distributions with an absolute AIC difference greater than a default delta of 9.21 (corresponding to a weight of no more than 0.01) are excluded prior to bootstrapping.

Estimated hazardous/protective concentration

HCx	PCx	est	se	lcl	ucl	nboot	pboot
1	99	0.051	0.043	0.007	0.170	1000	1
5	95	0.148	0.095	0.067	0.432	1000	1
10	90	0.273	0.159	0.140	0.771	1000	1
20	80	0.614	0.307	0.316	1.506	1000	1

The acute (short-term) SSD for cadmium is shown in Figure F-5 with the calculated LoPs in Table F-7.



Estimated hazardous/protective concentration

HCx	PCx	est	se	lcl	ucl	nboot	pboot
1	99	0.212	0.321	0.001	1.185	1000	1
5	95	1.235	0.987	0.186	3.918	1000	1
10	90	3.158	2.550	1.206	9.449	1000	1
20	80	11.222	13.288	4.531	52.306	1000	1

CCME (2014) equations: summary tables

Table 1. Canadian Water Quality Guidelines (CWQG) for the protection of aquatic life for cadmium.

	Long-term Exposure ($\mu\text{g}\cdot\text{L}^{-1}$)	Short-term Exposure ($\mu\text{g}\cdot\text{L}^{-1}$)
Freshwater	0.09 ^a	1.0 ^b
Marine	0.12 ^c	NRG

NRG = no recommended guideline

^a The long-term CWQG of $0.09 \mu\text{g}\cdot\text{L}^{-1}$ is for waters of $50 \text{ mg CaCO}_3\cdot\text{L}^{-1}$ hardness. At other hardness values, the CWQG can be calculated with the equation $\text{CWQG} = 10^{(0.83(\log[\text{hardness}]) - 2.46)}$, valid for hardness between 17 and $280 \text{ mg CaCO}_3\cdot\text{L}^{-1}$.

^b The short-term benchmark concentration of $1.0 \mu\text{g}\cdot\text{L}^{-1}$ is for waters of $50 \text{ mg CaCO}_3\cdot\text{L}^{-1}$ hardness. At other hardness values, the benchmark can be calculated with the equation $\text{Benchmark} = 10^{(1.016(\log[\text{hardness}]) - 1.71)}$, valid for hardness between 5.3 and $360 \text{ mg CaCO}_3\cdot\text{L}^{-1}$.

^c This value was not assessed as part of the present update; value is from CCME (1996).

Table 8. CWQGs for cadmium in fresh water at various levels of water hardness.

Hardness ($\text{mg}\cdot\text{L}^{-1} \text{ CaCO}_3$)	Guideline value ($\mu\text{g Cd}\cdot\text{L}^{-1}$)	
	Short-term	Long-term
Lower limit*	0.11	0.04
Soft (60)	1.2	0.10
Medium (120)	2.5	0.18
Hard (180)	3.8	0.26
Upper limit**	7.7	0.37

Lower and upper limits for hardness reflect the minimum and maximum hardness values, respectively, that were used in the derivation of hardness slopes, beyond which values should not be extrapolated.

*A lower limit of $0.11 \mu\text{g}\cdot\text{L}^{-1}$ is the short-term benchmark that applies to all waters of hardness below $5.3 \text{ mg CaCO}_3\cdot\text{L}^{-1}$. A lower limit of $0.04 \mu\text{g}\cdot\text{L}^{-1}$ is the long-term guideline value that applies to all waters of hardness below $17 \text{ mg CaCO}_3\cdot\text{L}^{-1}$.

**An upper limit of $7.7 \mu\text{g}\cdot\text{L}^{-1}$ is the short-term benchmark that applies to all waters of hardness above $360 \text{ mg CaCO}_3\cdot\text{L}^{-1}$. An upper limit of $0.37 \mu\text{g}\cdot\text{L}^{-1}$ is the long-term guideline that applies to all waters of hardness above $280 \text{ mg CaCO}_3\cdot\text{L}^{-1}$.

Normalising calculations - cadmium

Chronic and acute normalised adjustment calculations are shown in Tables F-8 and F-9 respectively. These are used to provide GVs for different LoPs in Table 6-2.

The SSDs for both chronic and acute datasets were used to provide the basis for the protection ratios (see above).

Table F-8: Chronic GV for cadmium for various LoPs from CCME (2014). The ratio to chronic GV is used to adjust the CCME long-term exposure equation (Section 4.2.3) to other LoPs.

Chronic LoP (%)	GV_calc (µg/L)	Ratio to Chronic GV 95% ^a	CCME_GV (µg/L)	GV_LoPs ^b (µg/L)
95	0.148	1	0.09	0.09
90	0.273	1.84		0.17
80	0.614	4.15		0.37

^a AF-LoP

^b 'GV_LoPs' = 'CCME_GV' x 'Ratio to chronic GV 95%'

Table F-9: Acute GV for cadmium for various LoPs from CCME (2014). The ratio to acute GV x No effect conversion factor are used to adjust the CCME short-term exposure equation (Section 4.2.3) to other LoPs.

Acute LoP (%)	Acute_GV_calc (µg/L)	Ratio to Acute_GV 95% ^a	CCME_Short-term_GV (µg/L)	No effect conversion factor ^b	GV_acute ^c (µg/L)
95	1.24	1	1	2.13	0.47
90	3.16	2.55		2.13	1.2
80	11.2	9.03		2.13	4.2

^a AF-LoP

^b CV_acute = No effect conversion factor from EC/LC50 to EC/LC10 ratio for zinc from Gadd et al. (2024)

^c 'GV_acute' = 'CCME_Short-term_GV' x AF-LoP x CV_acute

Cobalt

The chronic cobalt dataset was available from (CCME, 2017). There were no acute normalised data available.

Chronic – cobalt

The chronic SSD for cobalt is shown in Figure F-6 with the calculated LoPs in Table F-10.

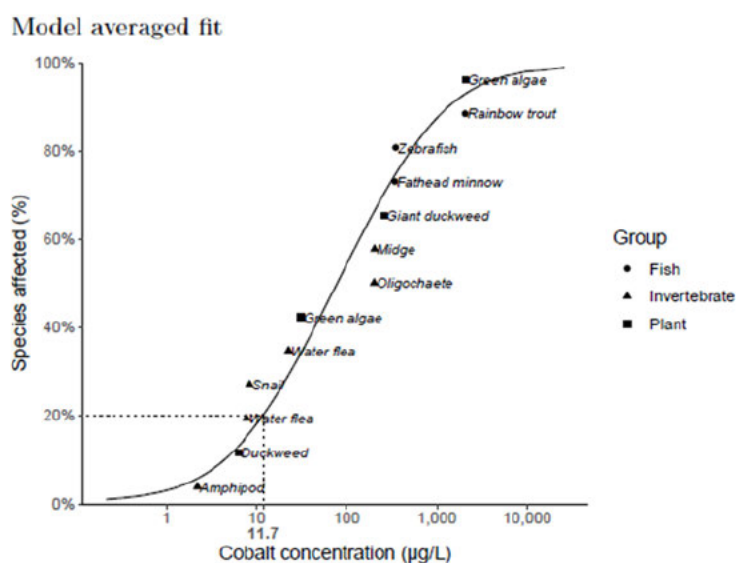


Figure F-6: Chronic cobalt data from CCME (2017). Data normalised to 100 mg/L CaCO₃.

Table F-10: The estimated hazardous/protective concentrations for cobalt (chronic). ‘HCx’ is the % species affected; ‘PCx’ is the % species protected; ‘est’ is the model-averaged estimate of the concentration; ‘se’ is the bootstrap based standard error of the estimate; ‘lcl’ and ‘ucl’ are the bootstrapped based lower and upper 95% confidence limits; ‘nboot’ is the number of bootstrap samples; ‘pboot’ is the proportion of bootstrap samples that converged. The model-averaged estimate(s) is calculated by treating the distribution as a single weighted mixture distribution. Distributions with an absolute AIC difference greater than a default delta of 9.21 (corresponding to a weight of no more than 0.01) are excluded prior to bootstrapping.

Estimated hazardous/protective concentration

HCx	PCx	est	se	lcl	ucl	nboot	pboot
1	99	0.212	1.503	0.003	5.261	1000	1
5	95	1.862	3.849	0.127	13.605	1000	1
10	90	4.391	6.982	0.580	25.482	1000	1
20	80	11.749	14.829	2.730	54.394	1000	1

Acute – cobalt

There was no normalised acute (short-term) data in CCME (2017).

Cobalt data for acute and chronic guideline derivation has recently been reviewed (Stubblefield et al., 2020). Updated guidelines following US EPA and international methodologies are currently being developed (B. Stubblefield, Oregon State University, pers comm).

CCME (2017) summary tables

Table 3. FWQGs (µg/L) for the protection of aquatic life for selected water hardness values

hardness (mg/L)	FWQG (µg/L)
52	0.78
100	1.0
150	1.2
200	1.4
250	1.5
300	1.6
350	1.7
396	1.8

Because hardness was a significant toxicity modifying factor, the FWQG is expressed as an equation where the site-specific hardness must be entered in order to calculate a site-specific FWQG. The equation is based on the toxicity-hardness slope value of 0.414 and the 5th percentile value of 1.0 µg/L is derived from the SSD when hardness is 100 mg/L.

Based on the toxicity-hardness slope value and the SSD, the equation to derive FWQG for Co is:

$$y\text{-intercept} = \ln(5^{\text{th}} \text{ percentile}) - [\text{hardness slope} \times \ln(\text{hardness})]$$

$$= \ln(1.02) - [0.414 \times \ln(100)]$$

$$= -1.887$$

$$\text{FWQG } (\mu\text{g/L}) = e^{\{(0.414[\ln(\text{hardness})] - 1.887)\}}$$

Site-specific FWQGs for cobalt at discrete water hardness concentrations are provided in Table 3. Since the slope relating hardness to toxicity was based on a study conducted over hardness levels from 52-396 mg/L, the FWQG should not be extrapolated beyond this hardness range. Accordingly, the minimum and maximum FWQG for cobalt at water hardness levels of 52 and 396 mg/L are 0.78 and 1.80 µg/L, respectively.

Normalising calculations – cobalt

Chronic and acute normalised adjustment calculations are shown in Tables F-11 and F-12 respectively. These are used to provide GV values for different LoPs in Table 6-2.

The SSD for the chronic dataset was used to provide the basis for the protection ratios (see above).

Table F-11: Derivation of site-specific chronic GV values for cobalt for differing LoPs.

Chronic LoP (%)	GV _{calc} (µg/L)	Ratio to Chronic GV 95%	CCME_GV (µg/L) ^a	Hardness slope coefficient ^b	Normalising factor ^c	GV _{LoPs} (µg/L)
95	1.86	1	1.0	-1.2850	1.86	1.0
90	4.39	2.36		-0.4270	1.86	2.4
80	11.75	6.32		0.5572	1.86	6.3

^a CCME (2017) FWQG for cobalt at 100 mg/L CaCO₃

^b For use in CCME (2017) hardness adjustment equation (CCME 2017, Table 3 equation)

^c Normalising factor to adjust 'GV_{calc}' value to 'CCME_GV' for differing LoPs

Table F-12: Derivation of site-specific acute GVs for cobalt for differing LoPs.

Acute LoP (%)	GV_LoPs ^a (µg/L)	ACR factor ^a	GV_acute ^c (µg/L)
95	1.0	0.16	6.3
90	2.4	0.11	21
80	6.3	0.062	102

^a CCME (2017) FWQG (chronic) for cobalt at 100 mg/L CaCO₃

^b No effect acute/chronic ratio (ACR) from GV_acute:GV_chronic ratio for zinc from Gadd et al. (2024)

^c 'GV_acute_LoPs' calculated as 'GV_LoPs' / 'ACR factor'

Copper

The chronic copper guidelines are from ANZG (2026a) and the acute guidelines from Gadd et al. (2024).

Chronic – copper

The chronic SSD for copper is shown in Figure F-7 with the relative species group sensitivities in Figure F-8. The chronic guidelines are provided in Table F-13.

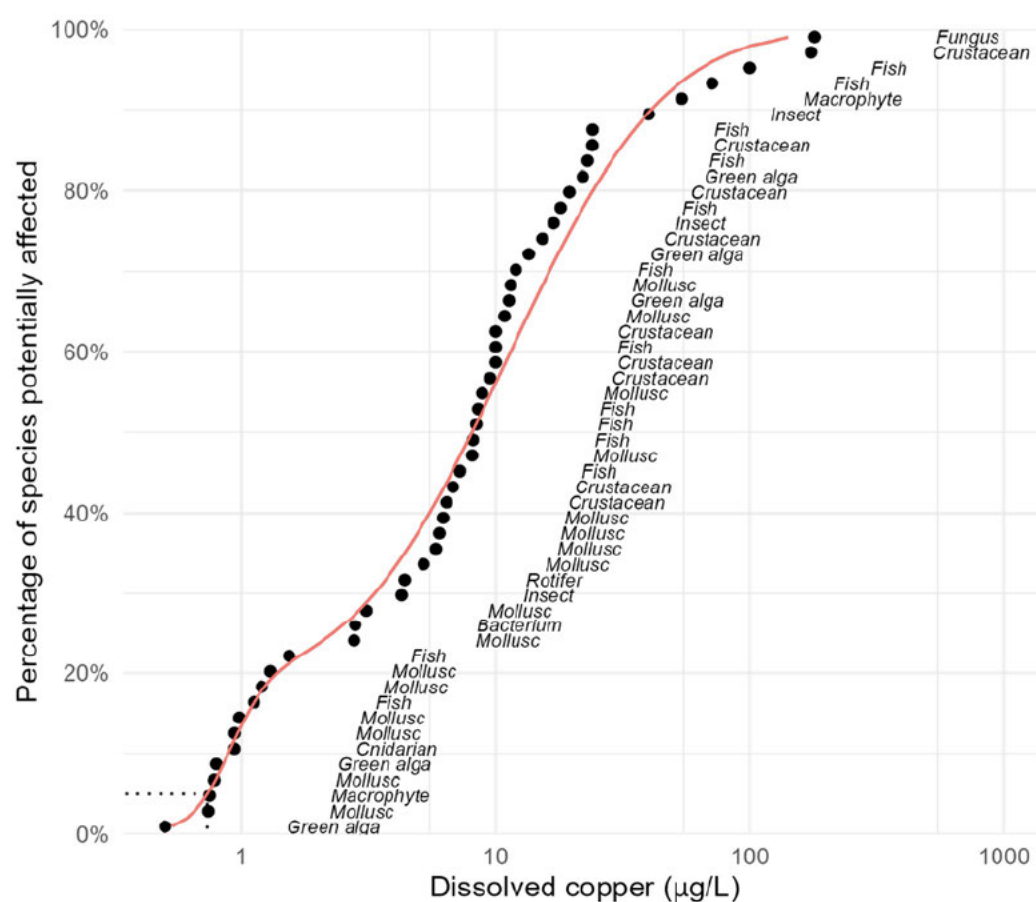


Figure F-7: Species sensitivity distribution, dissolved copper in freshwater (at the reference condition of ≤0.5 mg/L dissolved organic carbon). (Figure 3 from ANZG (2026a)).

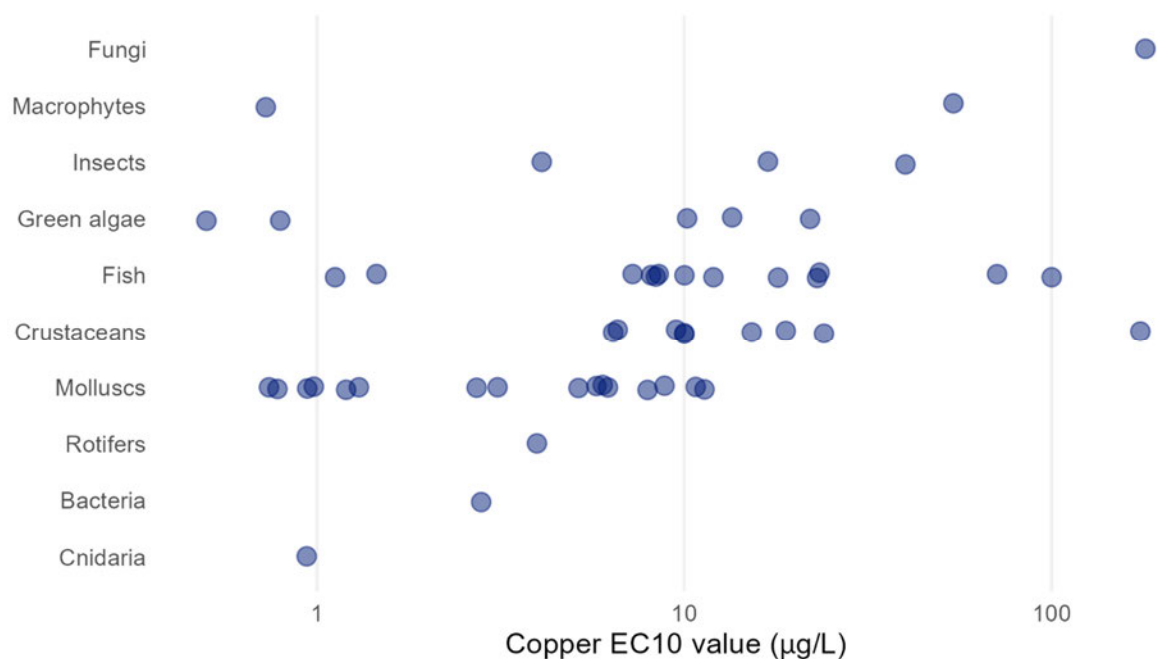


Figure F-8: Comparison of dissolved copper toxicity between taxonomic groups. (Figure 2 from ANZG (2026a)).

Table F-13: Toxicant default guideline values, dissolved copper in freshwater at ≤ 0.5 mg/L dissolved organic carbon, very high reliability. (Table 3 from ANZG (2026a)).

Level of species protection (%)	DGV for dissolved copper in freshwater (µg/L) ^a
99	0.53
95	0.73
90	0.89
80	1.4

^a DGVs were derived using the ssdtools package in R (Thorley et al. 2024) and apply to water with a DOC of ≤ 0.5 mg/L, a pH range of 6–8.5 and range of 2–400 mg CaCO₃/L. DGVs have been rounded to two significant figures. DGVs can be adjusted for different DOC concentrations.

Acute – copper

The acute copper SSD is shown in Figure F-9 with the relative contributions for international and NZ species in Figure F-10 for copper and zinc. The relative sensitivity of species groups are shown in Figure F-11.

Figure F-12 shows the response of acute copper sensitivity to toxicity modifiers.

Table F-14 provides GVs for a range of TMF levels.

The equations for calculating the acute copper GVs are provided below and in Table 6-2.

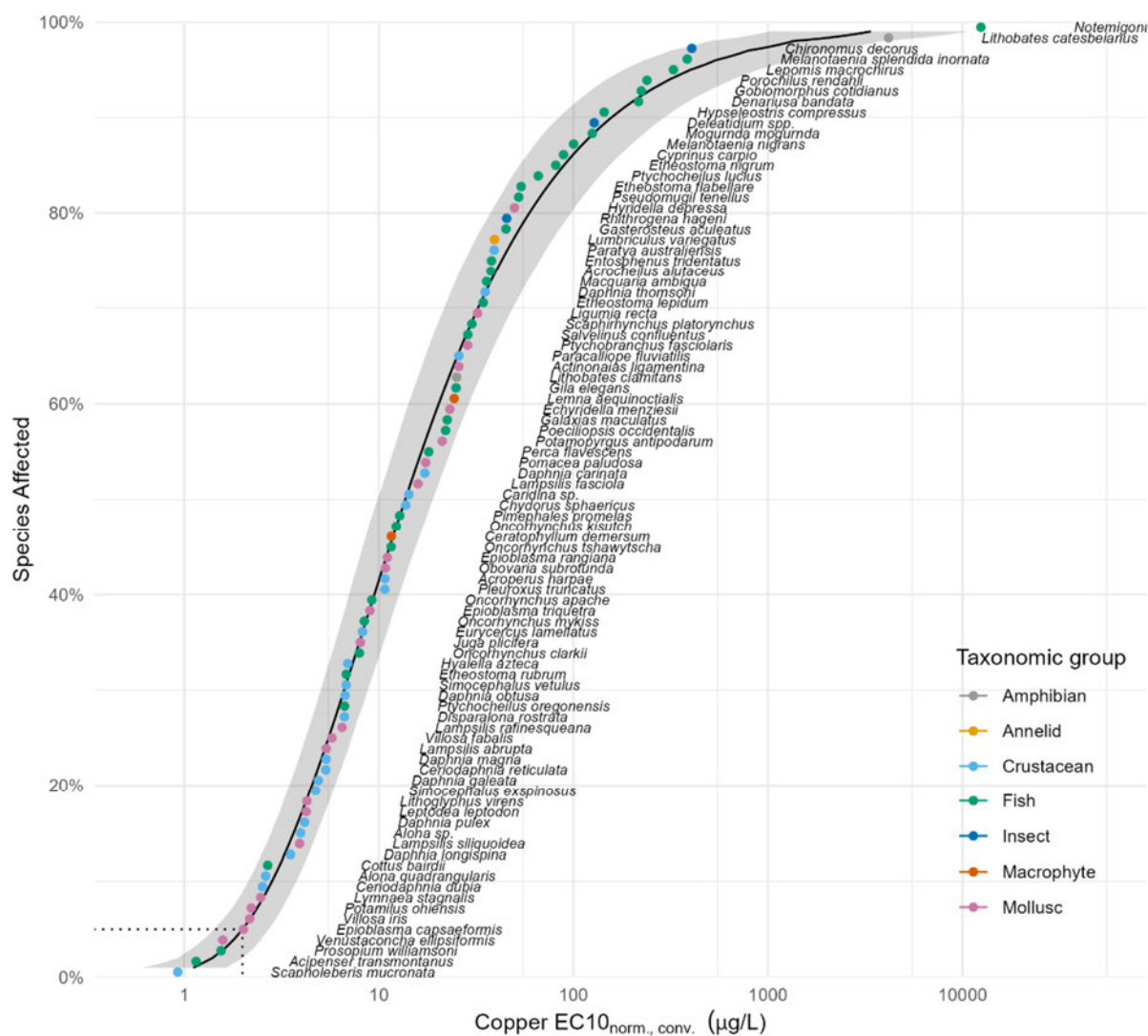


Figure F-9: Copper species sensitivity distribution based on normalised and converted EC10 values. Toxicity data normalised to index condition (pH 7.5, hardness 30 mg/L and DOC 0.5 mg/L). Colour of points indicates taxonomic grouping of that species. Black line indicates model average fitted line, shaded area indicates the 95% confidence interval, dotted line indicates the model-averaged concentration for 95% species protection (5% species affected). (Figure 8.9 from Gadd et al. (2024)).

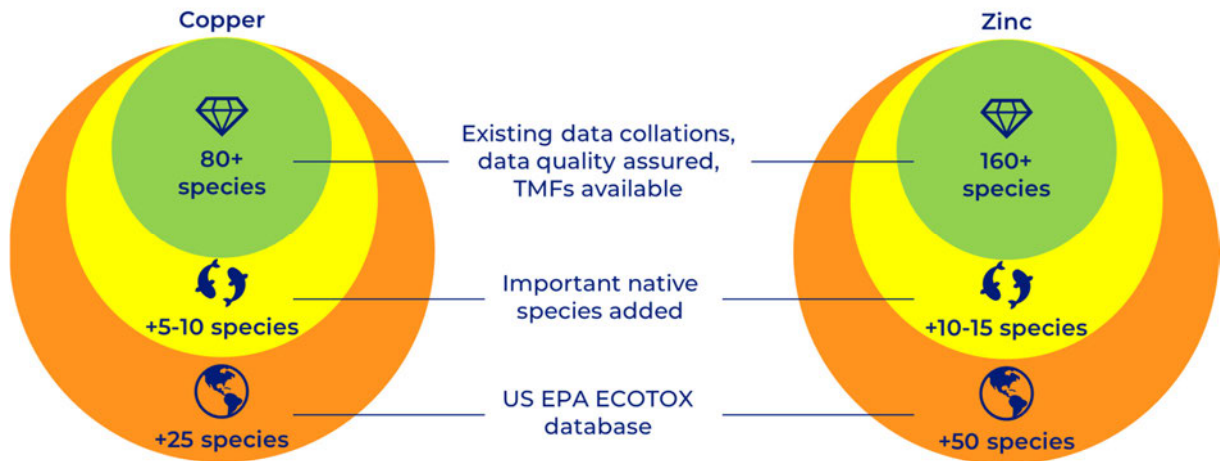


Figure F-10: Indication of number of species with acute **copper** and **zinc** toxicity data based on different data sources. (Figure 7.1 from Gadd et al. (2024)).

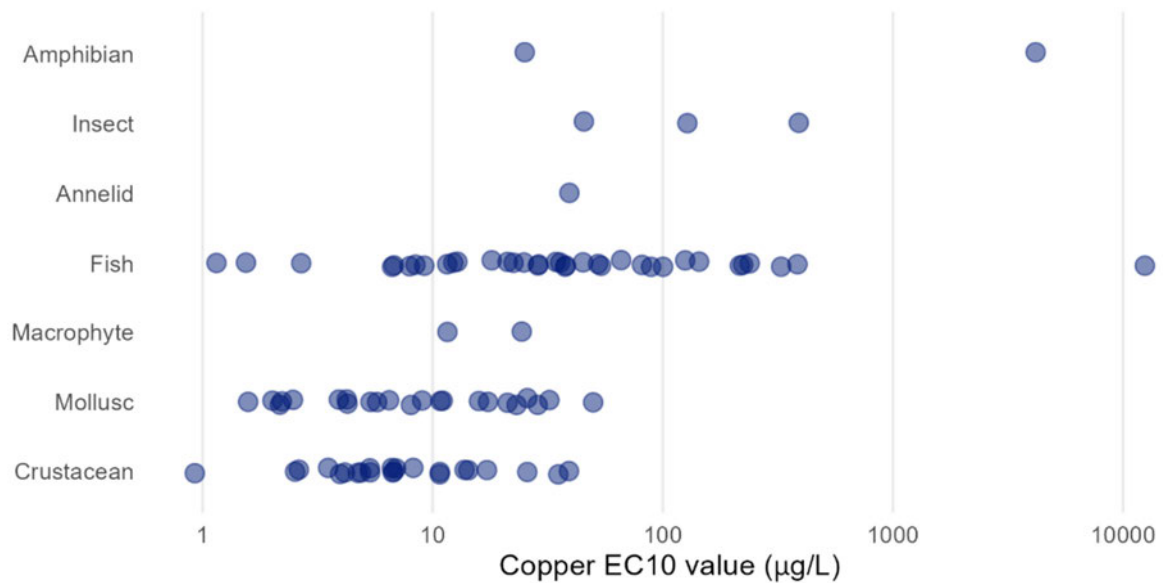


Figure F-11: Comparison between taxonomic groups of normalised converted acute **copper** EC10 values. (Figure 8.5 from Gadd et al. (2024)).

Equations for copper GV_{acute} calculation for different LoPs:

$$Copper\ acute\ GV_{99} = [exp]^{(-7.2 + 0.78\ pH + 0.58 \times \log(hardness) + 0.70 \times \log(DOC))} \quad \text{Equation 8.1}$$

$$Copper\ acute\ GV_{95} = [exp]^{(-6.6 + 0.78\ pH + 0.58 \times \log(hardness) + 0.70 \times \log(DOC))} \quad \text{Equation 8.2}$$

$$Copper\ acute\ GV_{90} = [exp]^{(-6.3 + 0.78\ pH + 0.58 \times \log(hardness) + 0.70 \times \log(DOC))} \quad \text{Equation 8.3}$$

$$Copper\ acute\ GV_{80} = [exp]^{(-5.8 + 0.78\ pH + 0.58 \times \log(hardness) + 0.70 \times \log(DOC))} \quad \text{Equation 8.4}$$

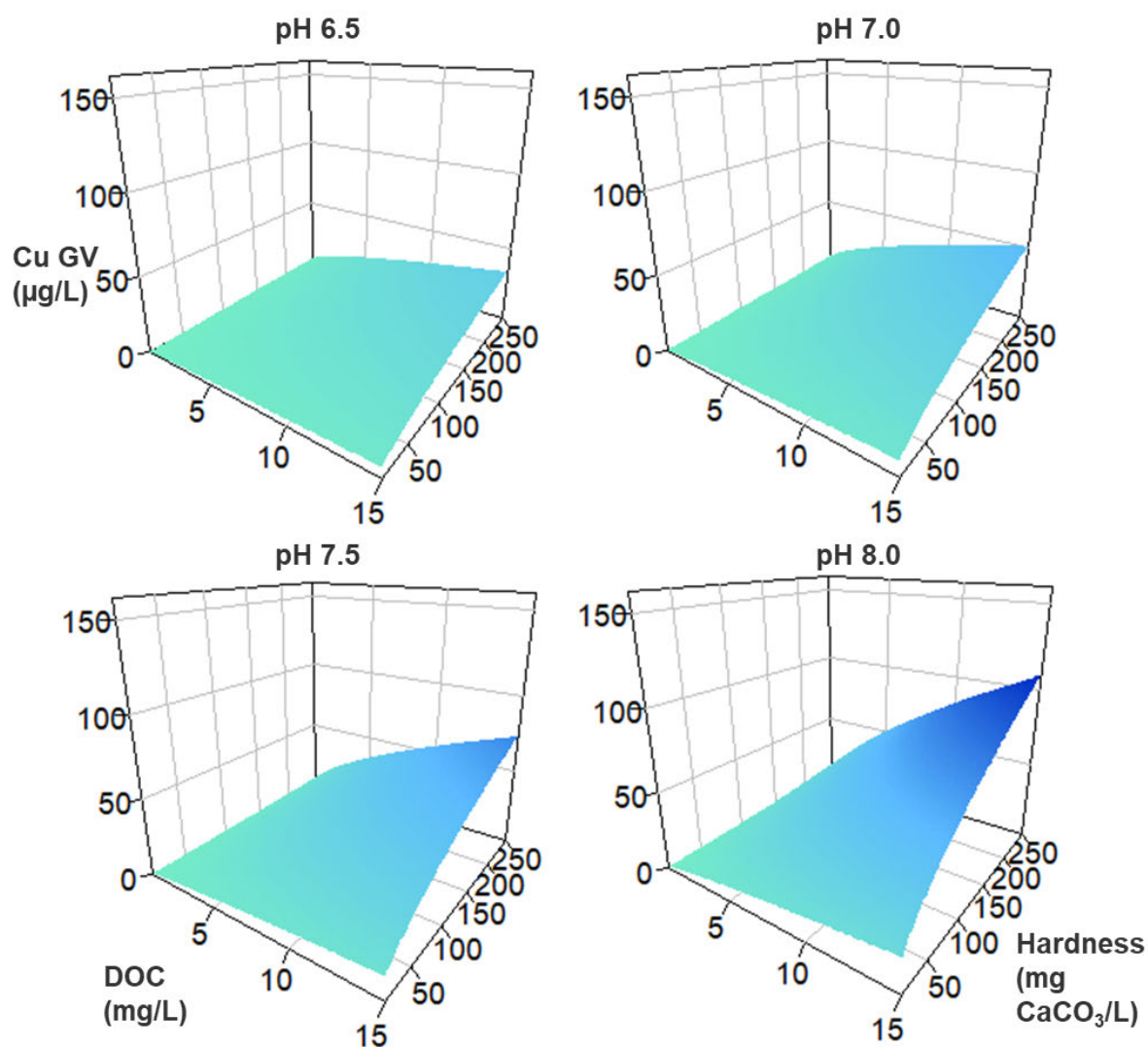


Figure F-12: Copper acute GV (for 95% species protection) at different pH values and as a function of hardness and DOC. (Figure 8.11 from Gadd et al. (2024)).

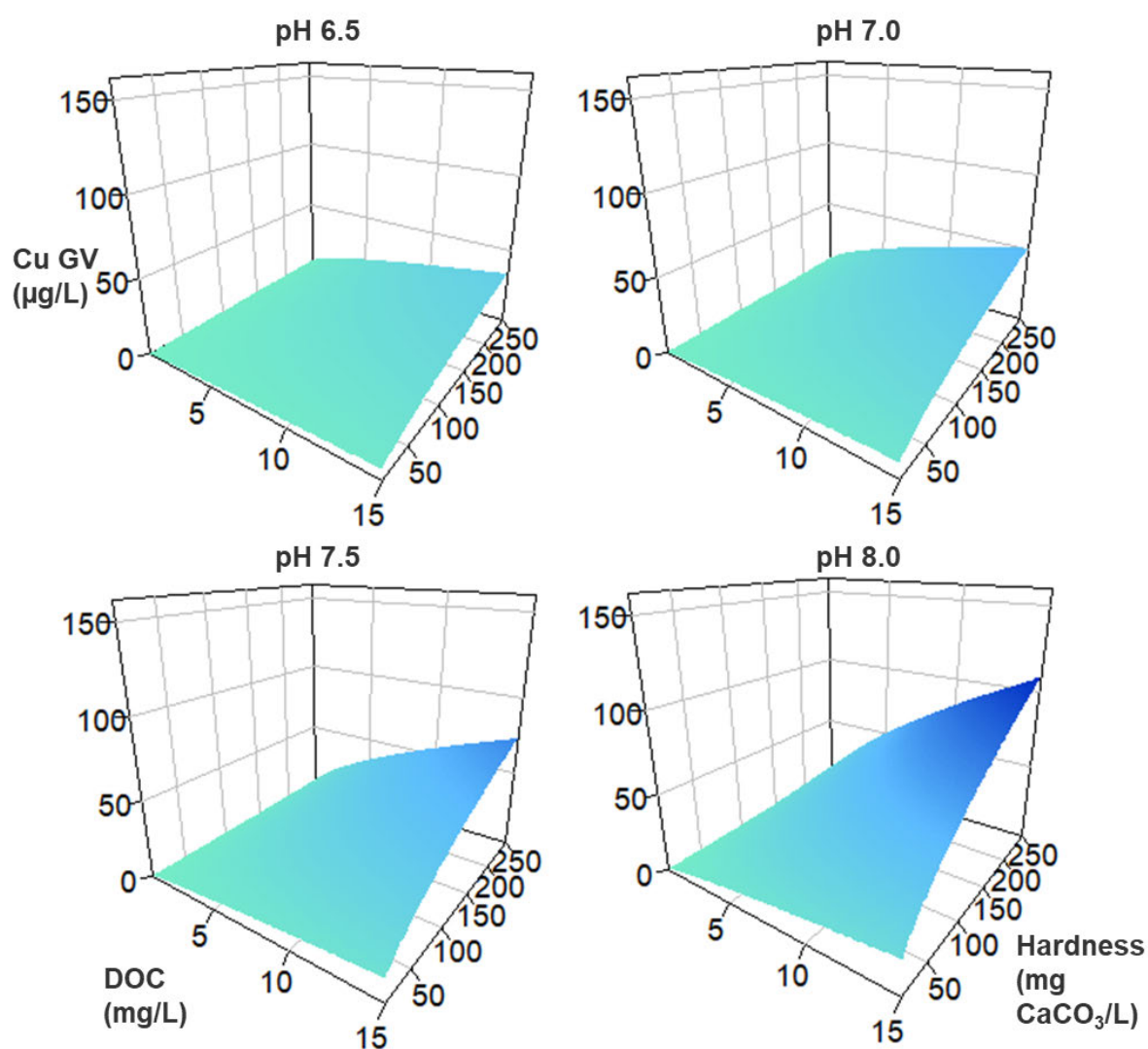


Table F-14: Copper acute GVs (µg/L) for 95% species protection at different pH, hardness and DOC concentrations. Interim Tier 1 acute GV for 95% species protection is 1.3 µg/L. (Table 10.2 from Gadd et al. (2024)).

pH	DOC (mg/L)	Hardness (mg CaCO ₃ /L)				
		15	30	60	120	240
6.5	0.3	0.4	0.6	1.0	1.4	2.1
7.5	0.3	0.9	1.4	2.1	3.1	4.6
8.5	0.3	2.0	3.0	4.5	6.8	10
6.5	1.5	1.3	2.0	2.9	4.4	6.6
7.5	1.5	2.9	4.3	6.4	9.6	14
8.5	1.5	6.3	9.3	14	21	31
6.5	6	3.5	5.2	7.8	11.6	17
7.5	6	7.6	11	17	25	38
8.5	6	17	25	37	55	82

Iron

The recommended iron guideline is based on protection from iron precipitation. The basis for this recommendation is discussed in section 6.1.3. Background Buller Plateaux stream monitoring data for dissolved Fe and relationships with DOC and EC are provided in Appendix D, together with review information on dissolved iron relationships with pH and DOC.

Chronic – iron

Brix et al. (2023)

Brix et al. (2023) developed MLR relationships for total iron in freshwaters and derived GVs following the EU approach (EC₁₀ values) and the US EPA approach (using EC₂₀ values). Both datasets were normalised to a standard TMF conditions (pH 6 and 8; DOC 2 mg/L; hardness 100 mg/L) prior to derivation. The studies incorporated all measured toxicity effects based on ferric hydroxide effects – with most exposure concentrations exceeding the freshwater solubility of ferric hydroxide for the pH and DOC conditions (i.e., predominantly insoluble ferric hydroxides present).

The representative DOC and pH relationships for macroinvertebrates came from chronic 7-day survival/reproduction tests with a cladoceran (*Ceriodaphnia dubia*) from Cardwell et al. (2023). Those tests included DOCs from 0.3-12 mg/L (Suwannee natural organic matter) and pHs from 6.3 to 8.0 (pH buffered with MES, MOPES and HEPES buffers). The testing was limited in the number of pH, hardness and DOC combinations. This limited the ability to develop robust MLR relationships for macroinvertebrates. The largest number of tests were conducted at a hardness of 84 mg/L, with the pH 6.3 results showing a chronic EC₁₀ values for total Fe of 1.0 mg/L for 0.3 mg/L DOC, increasing to 6.3 mg/L at 4 mg/L DOC (i.e., 6.1-times), and 11 mg/L at 10 mg/L DOC (i.e., 11-times). There was no detectable dissolved (<0.22-µm) iron present in the absence of DOC regardless of the hardness concentration. When DOC was added, dissolved iron ranged from 2% to 14%, 0.005% to 6%, and 0% of total iron at 25 mg/L CaCO₃, 84 mg/L CaCO₃ and 252 mg/L CaCO₃ hardness, respectively. This suggests that the precipitated form of iron (III) was chronically toxic to *C. dubia* reproduction and this was primarily mitigated by DOC and secondarily through interactions with hardness. The authors note that: “Precipitation/flocculant was observed in the higher concentrations in all the pH 7.2–8.5 toxicity tests, whereas the pH 6.3 tests only had visible precipitation in a small number of tests. This is indicative of the insoluble nature of Fe hydroxides at circumneutral pHs, in addition to the higher total Fe concentrations (exceeding solubility) necessary to illicit biological effects in the higher pH tests.”

Data from multispecies macroinvertebrate mesocosm tests exposed for 10-days and measuring organism abundance from Cadmus et al. (2018a) were also included in the GV derivation. Those tests added ferric chloride to generate ferric hydroxide after pH neutralisation (to pH 7.2) for a range of concentrations (nominally: 0, 464, 944, 2425, 5238, and 14,073 µg/L total Fe; measured control was 110 µg/L). No DOC information was provided for these tests.

Cadmus et al. (2018a) noted that: “Despite the high-flow, turbulent environment produced in the experimental streams, we observed Fe precipitates clogging interstitial space and covering substrate and organisms.”

The short (10-day) duration of these mesocosm tests and multispecies exposure would not qualify these data for inclusion in the ANZG derivation procedure (Warne et al. 2025).

A pooled MLR model was not possible because of differences between species, so the *R. subcapitata* model was applied to plants, the *P. promelas* model was applied to fish, and the *C. dubia* model was

applied to all invertebrates, including insects. There was uncertainty about the applicability of the *C. dubia* model to insects because of a lack of knowledge regarding the pH dependence of insect responses and a lack of validation for molluscs and other crustaceans (e.g. *Daphnia magna*).

The DOC-dependent 95% protection GVs calculated for pH 7.5 and hardness 100 mg/L ranged from 0.1 mg/L total iron at 0.5 mg/L DOC to 0.7 mg/L total iron for 10 mg/L DOC.

CCME (2024)

CCME (2024) use the Brix et al. (2023) MLRs and database to derive GVs for 95% protection in freshwaters. They provide a look-up table and spreadsheet calculator for pH and DOC covering the applicable range.

ANZG (2025b)

ANZG (2025b) have recently published GVs for total iron in freshwater following the recent guidance (Warne et al. 2025). The derivation was based on chronic toxicity data for 20 species from 10 taxonomic groups, comprising 3 fungi, one microalga, one macrophyte, one rotifer, one annelid, one planarian, 2 insects, 3 crustaceans, one amphibian and 6 fish. Chronic toxicity values ranged from 192 µg/L to 50,000 µg/L total iron across a range of different endpoints and exposure durations. The DGVs for 99%, 95%, 90% and 80% species protection are 140 µg/L, 280 µg/L, 430 µg/L and 730 µg/L, respectively. When comparing iron concentrations in water samples to the DGVs, the iron concentration should be based on either total iron or, preferably, the potentially bioavailable fraction (i.e. pH 2 extractable) of iron (III). No TMFs were included in the derivation.

The non-incorporation of TMFs and associated MLRs in the ANZG derivation means that the reported chronic toxicity results are not normalised to a standard index condition (Brix et al, (2023) use pH 7.5, hardness 100 mg/L and 2 mg/L DOC; CCME (2024) use pH 7.5 and 0.5 mg/L DOC) prior to generating the SSD for GV calculation. This results in differing species rankings in the SSD than Brix et al. (2023) or CCME (2024) and associated GVs – even if the same base chronic toxicity data was incorporated into each of the derivations.

The ANZG authors stated that: “Although the Brix et al. (2023) MLR models were recently used by Canada to develop bioavailability-based guideline values for iron in freshwater (CCME 2024), these models have not been adopted in the current version of the iron DGVs for Australia and New Zealand. This is because the models are yet to be validated for local species and water-quality conditions. As noted, there is still considerable uncertainty surrounding the applicability of the *C. dubia* MLR model for other invertebrates (Brix et al. 2023), and none of the existing models have been validated for very soft, acidic waters (Kevin Brix, EcoTox, pers comm, 28 March 2024), which are not uncommon in Australia.”

The Buller Plateaux streams with their natural acidic conditions and elevated DOC and associated dissolved iron concentrations (Appendix D) would not be considered suitable for the application of the ANZG (2025f) iron guidelines without TMF incorporation. The marked reduction in chronic toxicity of Fe measured for a cladoceran species (*C. dubia*) by Cardwell et al. (2023, detailed above) as DOC increases shows no toxicity at 11 mg/L Fe for 10 mg/L DOC (approximately the maximum measured in the Buller Plateaux streams, Appendix D). This highlights the importance of understanding the role of elevated DOC in reducing Fe toxicity. As noted by ANZG (2025f), validation of the role of elevated DOC for toxicity reduction of Fe is required for native species under low hardness and pH conditions.

Lead

Chronic lead guidelines have recently been updated by CCME (2020) with DOC and hardness as toxicity modifiers.

Guideline information is included below for screening assessment of Buller Plateaux sites.

Chronic – lead

The chronic SSD for lead is shown in Figure F-13 and the GV equation in Table F-15. A summary look-up table is provided in Table F-16.

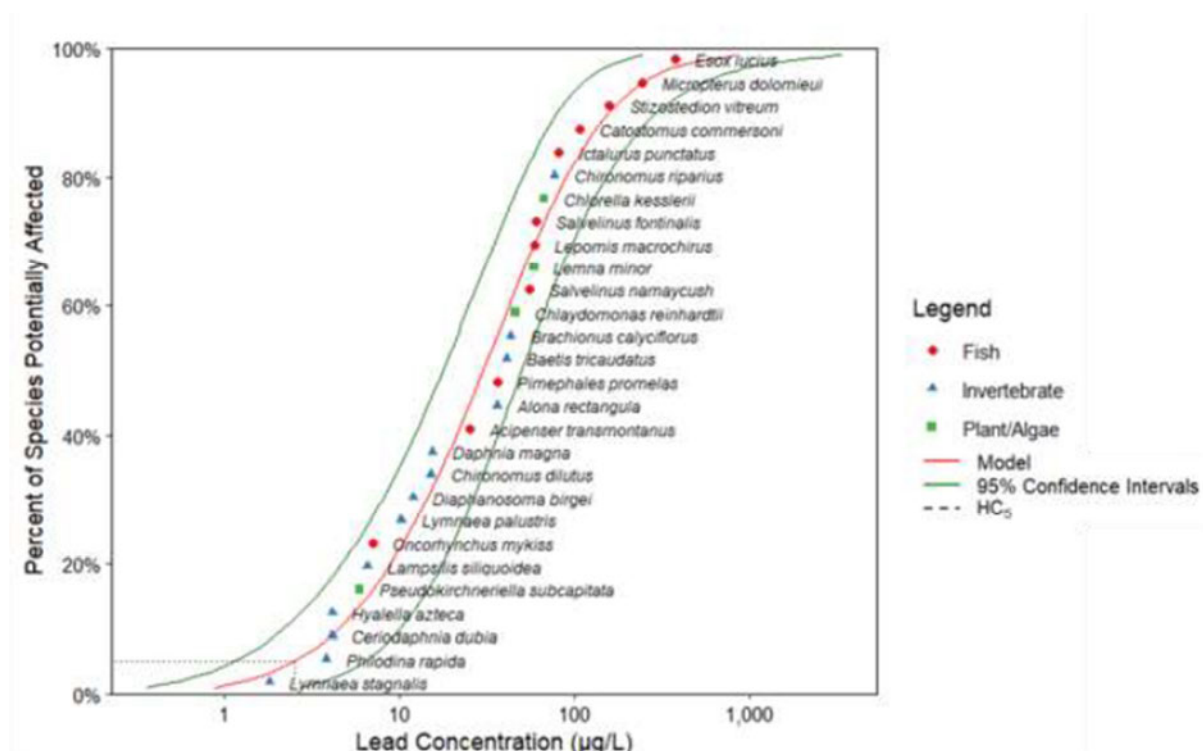


Figure F-13: Species sensitivity distribution (SSD) for the chronic toxicity of lead at DOC of 0.5 mg/L and hardness of 50 mg/L. The HC5 is 2.5 µg/L. (Figure 1 from CCME (2020)).

Table F-15: Federal Freshwater Quality Guideline for Lead (dissolved). (Table 1 from CCME (2020)).

Freshwater Aquatic Life	Guideline Value (µg/L) ^a
FWQG Equation	$FWQG = \exp(0.514[\ln(DOC)] + 0.214[\ln(Hardness)] + 0.4354)$
Example FWQG	2.5

^aFWQG is for dissolved lead for waters and is calculated using the equation above. As an example, the FWQG at a DOC concentration of 0.5 mg/L and hardness of 50 mg/L is 2.5 µg/L. The FWQG equation is valid for DOC 0.5-31.5 mg/L and hardness 4.7-511 mg/L.

Table F-16: FWQGs (µg/L) for lead for the protection of aquatic life for selected DOC and hardness values. (Table 6 from CCME (2020)).

DOC (mg/L)	Hardness (mg/L)					
	50	100	200	300	400	500
0.5	2.5	2.9	3.4	3.7	3.9	4.1
2	5.1	5.9	6.9	7.5	8.0	8.3
5	8.2	9.5	11.0	12.0	12.7	13.4
10	11.7	13.5	15.7	17.1	18.2	19.1
20	16.6	19.3	22.4	24.4	26.0	27.3
30	20.5	23.8	27.6	30.1	32.0	33.6

Manganese

Chronic and acute (short-term) data was obtained from CCME (2019). Both the chronic and acute GV's are hardness dependent.

Chronic – manganese

The chronic manganese SSD is shown in Figure F-14 and the calculated LoPs in Table F-17. A plot of the TMF response is shown in Figure F-15.

Section 4.7.2 provides the CCME (2019) equations and a look-up table.

Model averaged fit

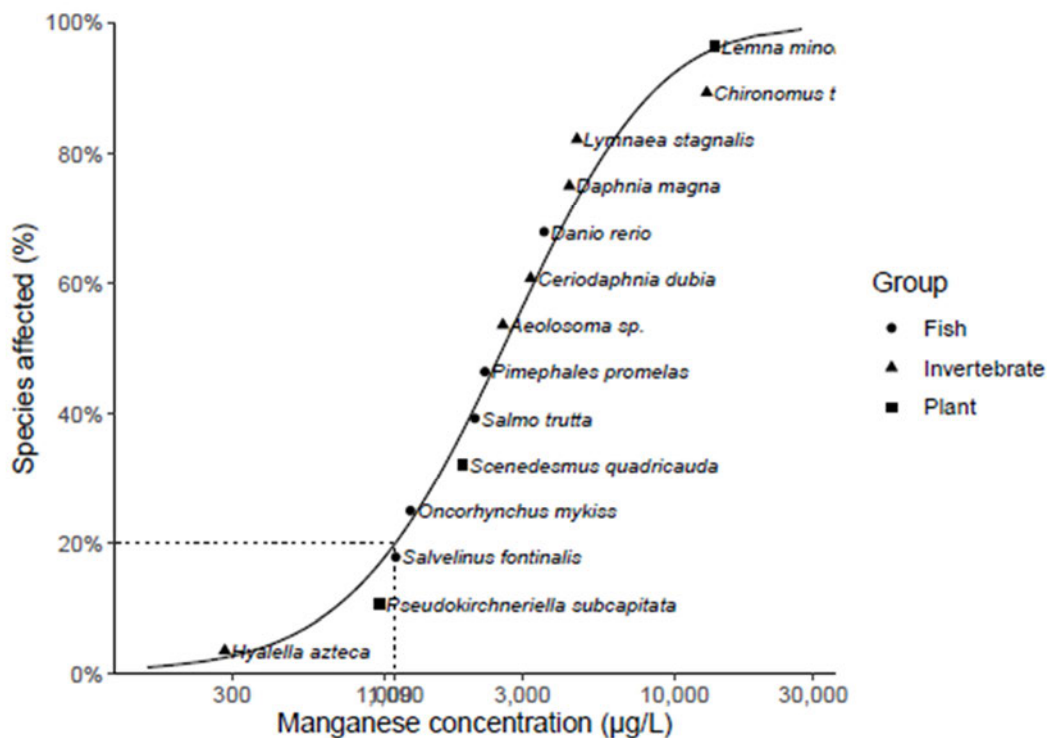


Figure F-14: Chronic manganese data used for calculation of LoPs (from CCME (2019)).

Table F-17: The estimated hazardous/protective concentrations for manganese (chronic). ‘HCx’ is the % species affected; ‘PCx’ is the % species protected; ‘est’ is the model-averaged estimate of the concentration; ‘se’ is the bootstrap based standard error of the estimate; ‘lcl’ and ‘ucl’ are the bootstrapped based lower and upper 95% confidence limits; ‘nboot’ is the number of bootstrap samples; ‘pboot’ is the proportion of bootstrap samples that converged. The model-averaged estimate(s) is calculated by treating the distribution as a single weighted mixture distribution. Distributions with an absolute AIC difference greater than a default delta of 9.21 (corresponding to a weight of no more than 0.01) are excluded prior to bootstrapping.

Estimated hazardous/protective concentration

HCx	PCx	est	se	lcl	ucl	nboot	pboot
1	99	153.326	178.011	17.846	691.771	1000	0.999
5	95	435.141	257.013	120.896	1097.935	1000	0.999
10	90	673.489	310.717	277.659	1448.910	1000	0.999
20	80	1094.012	394.365	561.610	2070.100	1000	0.999

Manganese GV calculation equations and look-up table from CCME (2019)

CWQG and short-term benchmark for the protection of aquatic life for manganese

	Short-term benchmark (µg/L)	Long-term guideline (µg/L)
Fresh Water	3,600	430
Marine	Not assessed	Not assessed

Notes: These values are for a water hardness of 50 mg/L as CaCO₃ and pH 7.5. The freshwater benchmark equation and the CWQG table found below must be used in order to obtain a site-specific benchmark and CWQG, respectively, based on the hardness and pH of the water body of interest. Note that it is not appropriate to apply the manganese freshwater guidelines to marine or estuarine environments.

The short-term benchmark is for **dissolved** manganese and is calculated using the equation:

$$\text{Benchmark} = \exp^{(0.878[\ln(\text{hardness})] + 4.76)}$$

Water hardness (mg/L as CaCO ₃)	Long-term CWQG values for dissolved manganese (µg/L)										
	pH 5.8	pH 6.0	pH 6.3	pH 6.5	pH 6.7	pH 7.0	pH 7.2	pH 7.5	pH 7.7	pH 8.0	pH 8.4
25–49	290	290	310	330	350	380	380	350	320	270	200
50–74	390	400	430	460	490	500	490	430	390	320	220
75–99	470	480	530	560	590	590	560	490	440	350	240
100–124	530	550	610	640	670	650	610	530	470	370	250
125–149	590	620	670	710	730	710	660	570	500	390	260
150–174	640	670	740	770	790	750	700	600	520	400	260
175–199	690	720	790	830	840	790	730	620	540	420	270
200–299	730	770	840	880	890	830	760	640	560	430	270
300–399	880	940	1,000	1,000	1,000	940	860	710	610	460	290
400–669	1,000	1,100	1,200	1,200	1,200	1,000	930	770	650	480	300
≥670	1,300	1,400	1,500	1,400	1,400	1,200	1,100	860	720	520	320

*If pH is in between column values, round to the pH that would give you the most conservative (lower) CWQG value. Guideline values are rounded to two significant figures.

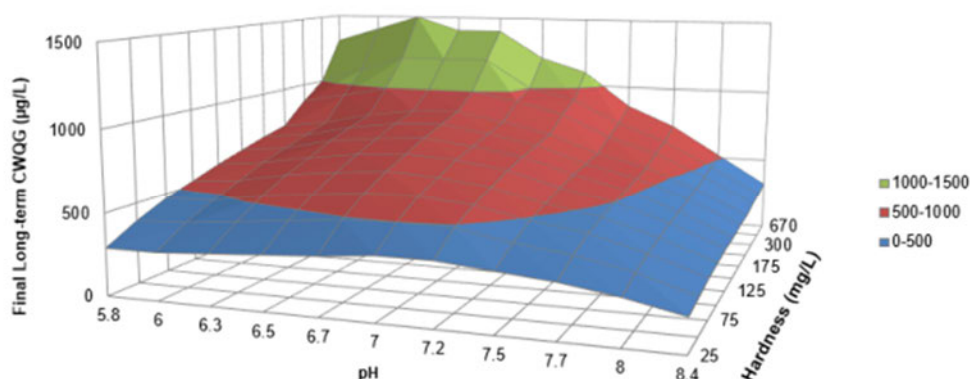


Figure F-15: CCME CWQG values for dissolved manganese as a function of hardness and pH (CCME, 2019).

Acute – manganese

The CCME (2019) SSD is shown in Figure F-16 with the SSD for the LoPs in Figure F-17. The differing LoPs are provided in Table F-18.

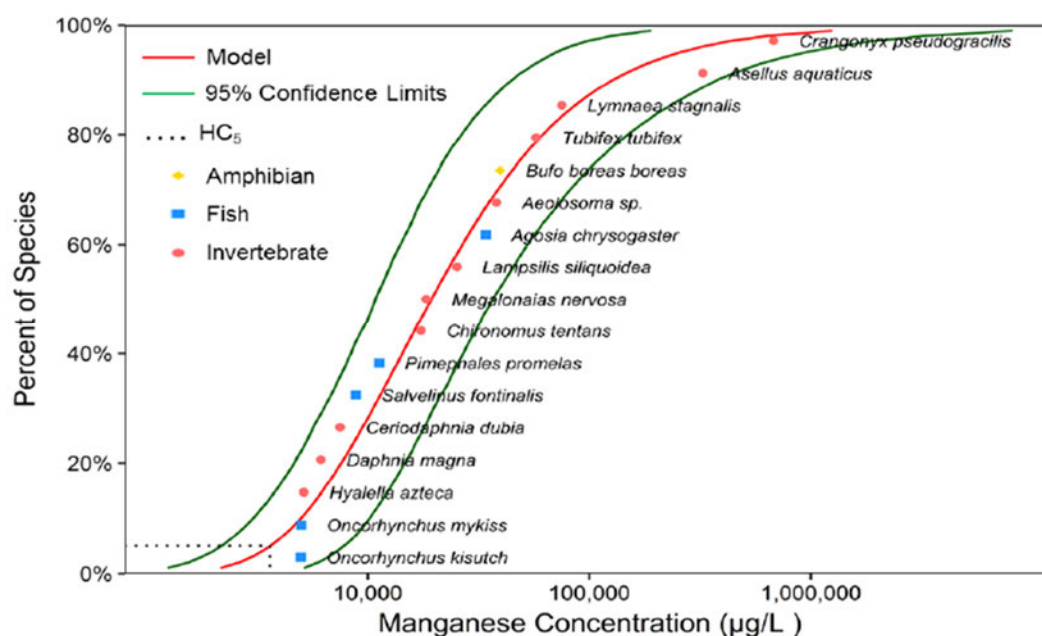


Figure F-16: Short-term SSD data from (CCME, 2019). Normalised to 50 mg/L hardness.

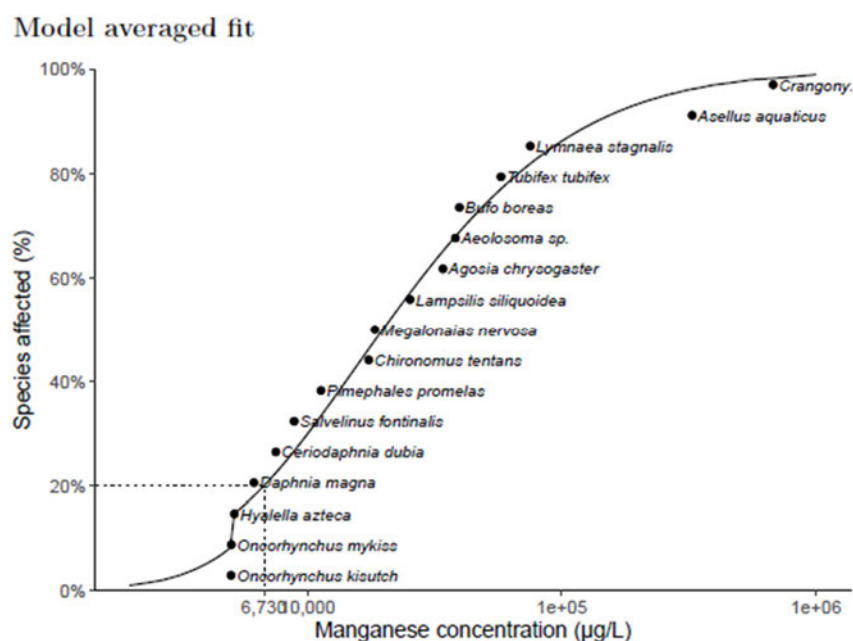


Figure F-17: Short-term SSD for derivation of LoPs.

Table F-18: The estimated hazardous/protective concentrations for manganese (acute). 'HCx' is the % species affected; 'PCx' is the % species protected; 'est' is the model-averaged estimate of the concentration; 'se' is the bootstrap based standard error of the estimate; 'lcl' and 'ucl' are the bootstrapped based lower and upper 95% confidence limits; 'nboot' is the number of bootstrap samples; 'pboot' is the proportion of bootstrap samples that converged. The model-averaged estimate(s) is calculated by treating the distribution as a single weighted mixture distribution. Distributions with an absolute AIC difference greater than a default delta of 9.21 (corresponding to a weight of no more than 0.01) are excluded prior to bootstrapping.

Estimated hazardous/protective concentration

HCx	PCx	est	se	lcl	ucl	nboot	pboot
1	99	1989.984	1205.216	429.875	5006.789	1000	0.998
5	95	3942.394	1383.409	1574.709	7106.394	1000	0.998
10	90	5010.377	1651.341	2663.607	9326.601	1000	0.998
20	80	6731.987	2553.185	4203.464	13680.778	1000	0.998

Normalising calculations - manganese

Chronic and acute normalised adjustment calculations are shown in Tables F-19 and F-20 respectively. These are used to provide GVs for different LoPs in Table 6-2.

The SSDs for both chronic and acute datasets were used to provide the basis for the protection ratios (see above).

Table F-19: Manganese chronic GVs calculated for pH 7.5 and 50 mg/L CaCO₃ hardness.

Chronic LoP (%)	GV_calc (µg/L)	Ratio to Chronic GV 95% ^a	CCME_GV (µg/L)	Eqn intercept for LoPs ^b	GV_LoPs (µg/L) ^c
95	0.435	1	0.43	4.46	0.43
90	0.674	1.55		4.89	0.67
80	1.094	2.51		5.38	1.1

^a AF-LoP

^b Intercept calculated for chronic GV hardness adjustment equation

^c 'GV_LoP' calculated as 'GV_calc' (normalised to 'CCME_GV' for 95th %ile) x AF-LoP

Table F-20: Manganese acute GVs calculated for pH 7.5 and 50 mg/L CaCO₃ hardness.

Acute LoP (%)	Acute_GV_calc (µg/L)	Ratio to Acute_GV 95% ^a	CCME_Short-term_GV (µg/L)	Eqn intercept for LoPs ^b	No effect conversion factor ^c	GV_acute_LoPs (µg/L) ^d
95	3.942	1	3.6	4.84	2.13	1.7
90	5.01	1.27		6.90	2.13	2.7
80	6.731	1.71		7.20	2.13	4.9

^a AF-LoP

^b Intercept calculated for acute GV hardness adjustment equation

^c CV_acute = No effect conversion factor from EC/LC50 to EC/LC10 ratio for zinc from Gadd et al. (2024)

^d 'GV_acute_LoPs' calculated as 'Acute_GV_calc' (normalised to 'CCME_Short-term_GV' for 95th %ile) x AF-LoP

Nickel

The interim site-specific GVs for nickel are based on (ANZG, 2018a) which have not been updated since ANZECC (2000).

ANZG chronic nickel guideline

The ANZG (2018) GVs for nickel are based on:

“There are 18 data points covering 7 species and 4 taxonomic groups. The lowest experimental chronic figure, (after hardness correction) was a 28-d LC50 of 18.5 $\mu\text{g/L}$ for *O. mykiss*.

Amphibian: 1 sp, *Ambystoma opacum*, 31 $\mu\text{g/L}$, from 8-d LC50 Crustacean: 1 sp, *D. magna*, 13.5 $\mu\text{g/L}$, from 5–30 d EC50. Lowest experimental chronic figure (after hardness correction) was 67 $\mu\text{g/L}$ Mollusc: 1 sp, *Juga plicifera*, 39.5 $\mu\text{g/L}$. An experimental NOEC of 69 $\mu\text{g/L}$ was reported.

A freshwater high reliability trigger value of 11 $\mu\text{g/L}$ was calculated for nickel using the statistical distribution method at 95% protection. This applies to low hardness waters, 30 mg/L as CaCO_3 .”

The hardness slope is 0.85. The site-specific GVs are adjusted to a hardness of 50 mg/L for normalised comparison with other GVs.

Chronic nickel guideline for Australia and New Zealand in development

The following is the SSDs and MLR equations for nickel guideline development (Stauber et al., 2021). The updated ANZG is currently not finalised.

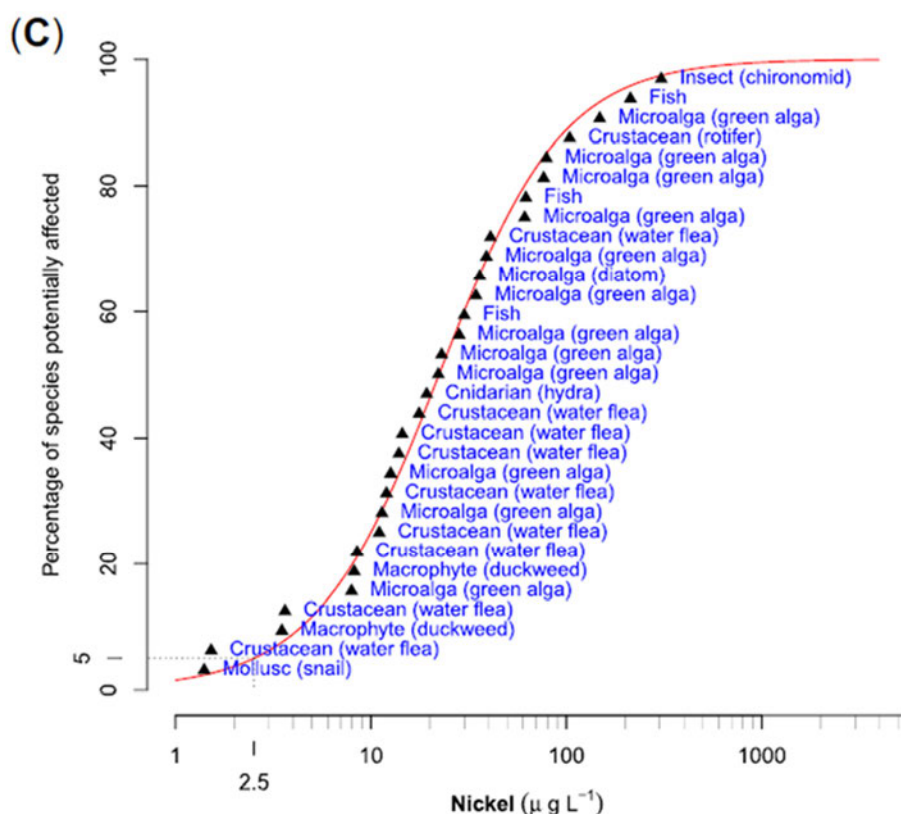


Figure F-18: SSD for nickel for tropical and temperate data from Stauber et al. (2021).

Table F-21: MLR equations for nickel GV calculation for various species groups (from Stauber et al. (2021)).

Trophic level	MLR
Algae	$\text{Log}_e(\text{EC10}) = \text{sensitivity} + 0.28.\text{log}_e(\text{DOC}) + 0.50.\text{log}_e(\text{Mg}) - 0.20.\text{pH}$
Aquatic plants	$\text{Log}_e(\text{EC10}) = \text{sensitivity} + 0.96.\text{log}_e(\text{DOC}) - 1.44.\text{pH}$
Invertebrates	$\text{Log}_e(\text{EC10}) = \text{sensitivity} + 2.09.\text{log}_e(\text{DOC}) + 0.19.\text{log}_e(\text{Ca}) + 0.40.\text{log}_e(\text{Mg}) - 0.40.\text{pH} - 0.24.\text{log}_e(\text{DOC}).\text{pH}$
Fish	$\text{Log}_e(\text{EC10}) = \text{sensitivity} - 1.05.\text{log}_e(\text{DOC}) + 3.55.\text{log}_e(\text{Mg}) - 0.07.\text{pH} + 0.19.\text{log}_e(\text{DOC}).\text{pH} - 0.42.\text{log}_e(\text{Mg}).\text{pH}$
Pooled	$\text{Log}_e(\text{EC10}) = \text{sensitivity} + 2.81.\text{log}_e(\text{DOC}) - 0.16.\text{log}_e(\text{Ca}) + 0.81.\text{log}_e(\text{Mg}) - 0.57.\text{pH} - 0.43.\text{log}_e(\text{DOC}).\text{pH} + 0.27.\text{log}_e(\text{DOC}).\text{log}_e(\text{Mg})$

^aFrom Peters et al. 2021. Note that the parameters in the MLR equations have been rounded to 2 decimal places.
EC10 = 10% effect concentration; DOC = dissolved organic carbon.

Table F-22: TMF boundary ranges for MLR equations (Table F-21) for nickel (from Stauber et al. (2021)).

TABLE 2: Water chemistry boundaries for each model^a

Model	pH	DOC (mg/L)	Ca (mg/L)	Mg (mg/L)	Calculated Hardness (mg CaCO ₃ /L)
Algal MLR	6.0–8.0	0.3–26	3–144	3–115	20–481
Plant MLR	6.9–8.3	0.7–7.1	3–72	0.8–21	12–250
Invertebrate MLR	5.9–8.2	0.3–17	0.1–88	0.2–72	1–316
Fish MLR	5.5–8.5	0.5–18	3.7–110	1.1–286	14–1450
Trophic level-specific MLR	5.5–8.5	0.3–26	0.1–144	0.2–286	1–1450
Pooled MLR	6.0–8.0 ^b	0.3–26	0.1–110	0.2–286	1–1450
European Union BLM	6.5–8.7	<0.5–26 ^c	2–88	— ^d	8–250
Softwater BLM	5.5–8.7	<0.5–26 ^c	0.1–10	—	1–50

^aFrom Peters et al. 2021.

^bNote that this was the approximate pH range for the algal and plant data, with a larger pH range for invertebrates and fish.

^cBLMs do not have boundary conditions for DOC, rather, this is the range of DOC in the tests used to derive and validate the BLMs.

^dBoundaries for Mg in BLMs are implied, although not specified, by the boundaries for Ca, and because both Ca and Mg have the same effect on nickel toxicity (including identical log *K* values for binding to the biotic ligand).

DOC = dissolved organic carbon; MLR = multiple linear regression; BLM = biotic ligand model.

Summary tables for nickel chronic and acute GVs

Chronic and acute normalised adjustment calculations are shown in Tables F-23 and F-24 respectively. These are used to provide GVs for different LoPs in Table 6-2.

Table F-23: Chronic GVs for nickel for various LoPs from ANZG (2018).

Chronic LoP (%)	GV _{calc} ^a (µg/L)	Ratio to Chronic GV 95% ^b	GV _{LoPs} (µg/L)
95	0.017	1	0.017
90	0.020	1.2	0.020
80	0.026	1.5	0.026

^a ANZG (2018) chronic GV hardness adjusted to 50 mg/L CaCO₃ (hardness slope 0.85)

^b AF-LoP

Table F-24: Acute GVs for nickel (estimated) for various LoPs based on chronic ANZG (2018) (Table F-23).

Acute LoP (%)	GV _{LoPs} ^a (µg/L)	ACR ^b	GV _{acute_LoPs} (µg/L) ^c
95	0.017	0.16	0.11
90	0.020	0.11	0.18
80	0.026	0.062	0.42

^a ANZG (2018) chronic GV hardness adjusted to 50 mg/L CaCO₃ (hardness slope 0.85)

^b No effect acute/chronic ratio (ACR) from GV_{acute}:GV_{chronic} ratio for zinc from Gadd et al. (2024) for different LoPs

^c 'GV_{acute_LoPs}' calculated as 'GV_{LoPs}' / 'ACR factor'

Zinc

The chronic zinc guidelines are from CCME (2018a) and the acute guidelines from Gadd et al. (2024). Chronic and acute site-specific zinc GVs are hardness, pH and DOC modified.

Chronic – zinc

The chronic zinc SSD from CCME (2018a) is shown in Figure F-19 with the equation in Table F-25.

Figure F-20 shows the model averaged equation SSD used for the different LoPs calculation (Table F-26).

The chronic zinc response to TMFs is shown in Figure F-21.

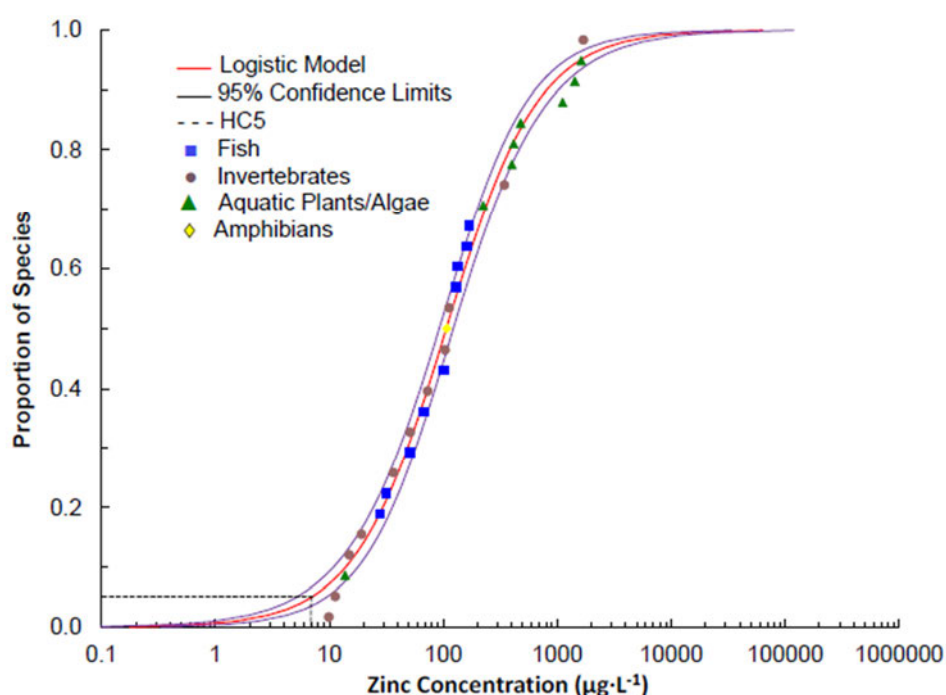


Figure F-19: SSD for zinc from CCME (2018a)

Table F-25: Short-term and long-term GVs from CCME (2018a)

Table 1. Canadian Water Quality Guidelines (CWQGs) for the Protection of Aquatic Life for Dissolved Zinc for Specified Water Quality Conditions

	Short-term exposure ($\mu\text{g}\cdot\text{L}^{-1}$)	Long-term exposure ($\mu\text{g}\cdot\text{L}^{-1}$)
Fresh water	37 ^a	7.0 ^b
Marine	Not assessed	Not assessed

^a The short-term benchmark is for dissolved zinc and is calculated using the following equation: **Benchmark** = $\exp(0.833[\ln(\text{hardness } \text{mg}\cdot\text{L}^{-1})] + 0.240[\ln(\text{DOC } \text{mg}\cdot\text{L}^{-1})] + 0.526)$. The value in the table is for surface water of 50 $\text{mg CaCO}_3\cdot\text{L}^{-1}$ hardness and 0.5 $\text{mg}\cdot\text{L}^{-1}$ dissolved organic carbon (DOC). The benchmark equation is valid between hardness 13.8 and 250.5 $\text{mg CaCO}_3\cdot\text{L}^{-1}$ and DOC 0.3 and 17.3 $\text{mg}\cdot\text{L}^{-1}$.

^b The long-term CWQG is for dissolved zinc and is calculated using the following equation: **CWQG** = $\exp(0.947[\ln(\text{hardness } \text{mg}\cdot\text{L}^{-1})] - 0.815[\text{pH}] + 0.398[\ln(\text{DOC } \text{mg}\cdot\text{L}^{-1})] + 4.625)$. The value in the table is for surface water of 50 $\text{mg CaCO}_3\cdot\text{L}^{-1}$ hardness, pH of 7.5 and 0.5 $\text{mg}\cdot\text{L}^{-1}$ DOC. The CWQG equation is valid between hardness 23.4 and 399 $\text{mg CaCO}_3\cdot\text{L}^{-1}$, pH 6.5 and 8.13 and DOC 0.3 to 22.9 $\text{mg}\cdot\text{L}^{-1}$.

Model averaged fit

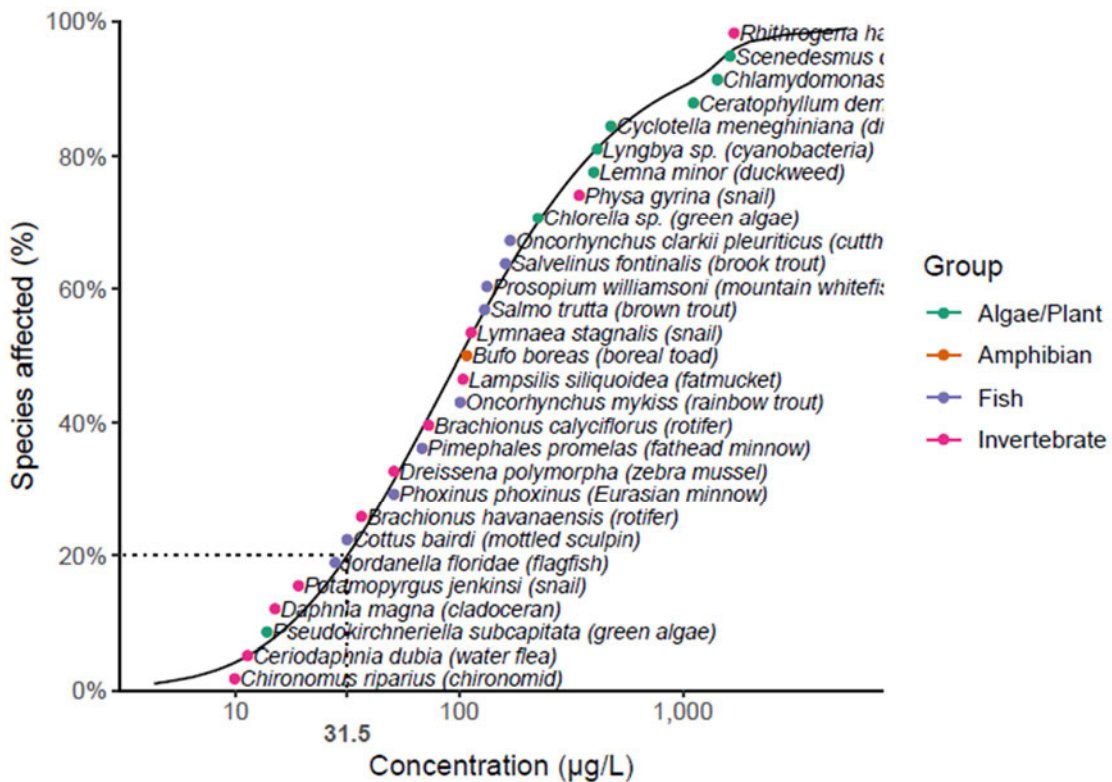


Figure F-20: Chronic zinc SSD for calculation of different LoPs (from CCME (2018a)).

Table F-26: The estimated hazardous/protective concentrations for zinc (chronic). ‘HCx’ is the % species affected; ‘PCx’ is the % species protected; ‘est’ is the model-averaged estimate of the concentration; ‘se’ is the bootstrap based standard error of the estimate; ‘lcl’ and ‘ucl’ are the bootstrapped based lower and upper 95% confidence limits; ‘nboot’ is the number of bootstrap samples; ‘pboot’ is the proportion of bootstrap samples that converged. The model-averaged estimate(s) is calculated by treating the distribution as a single weighted mixture distribution. Distributions with an absolute AIC difference greater than a default delta of 9.21 (corresponding to a weight of no more than 0.01) are excluded prior to bootstrapping.

Estimated hazardous/protective concentration

HCx	PCx	est	se	lcl	ucl	nboot	pboot
1	99	4.305	3.509	1.098	13.583	1000	1
5	95	11.146	5.184	4.691	24.141	1000	1
10	90	17.775	6.896	8.702	35.532	1000	1
20	80	31.522	10.751	18.021	58.621	1000	1

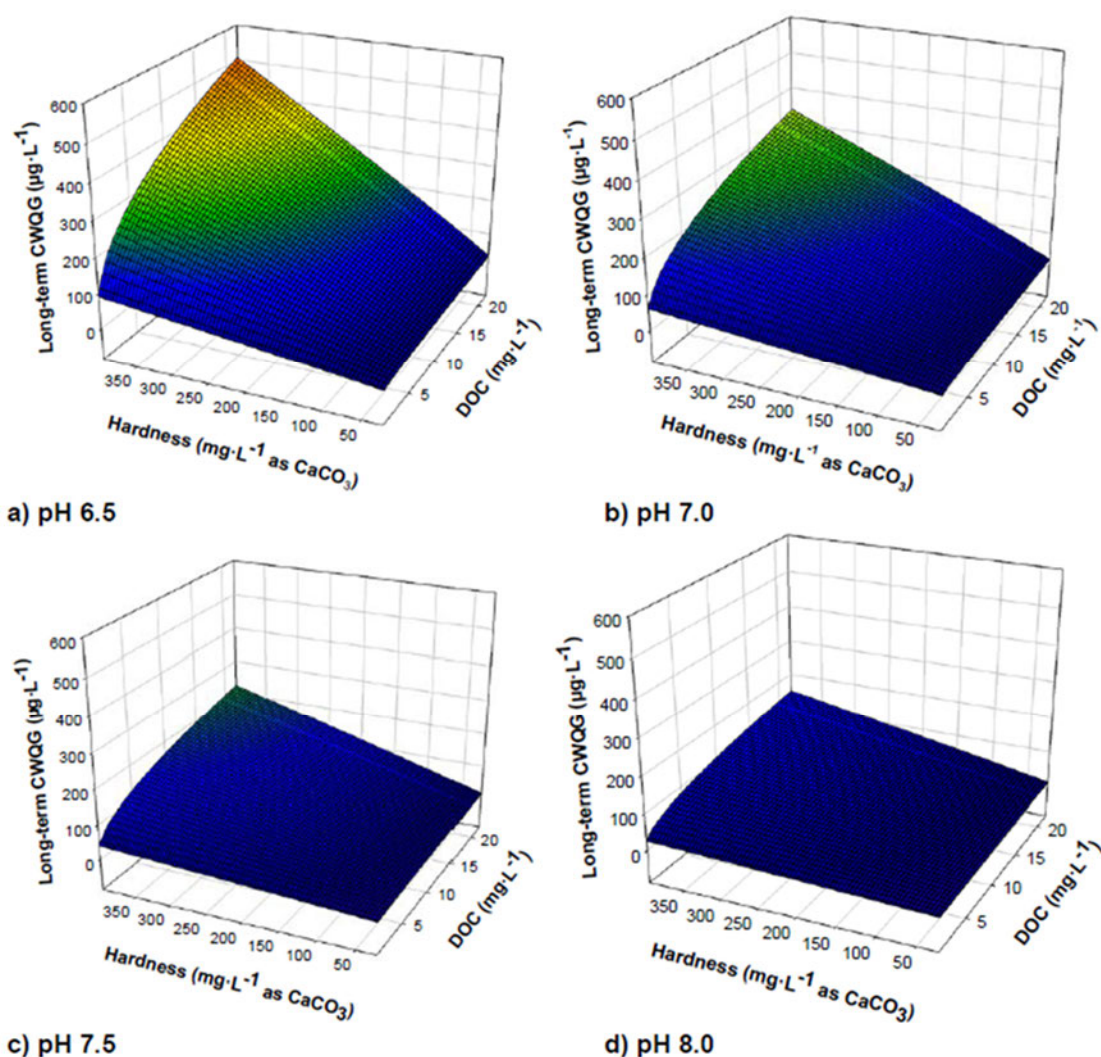


Figure F-21: Long-term CWQGs for dissolved zinc as a function of hardness, pH and DOC based on the rainbow trout (*Oncorhynchus mykiss*) MLR modelling approach (Figure 10.4 from CCME (2018b)).

Chronic zinc guideline for Australia and New Zealand in development

The SSD for the ANZG draft zinc guideline is shown in Figure F-22 (ANZG, 2026d).

This SSD is provided to show the differences from the CCME (2018a) SSD (Figure F-19) (e.g., the low green algal data). Notably the ANZG chronic SSD does contain additional NZ species (Figure F-10). However, at the time of writing this chronic zinc GV has not been finalised.

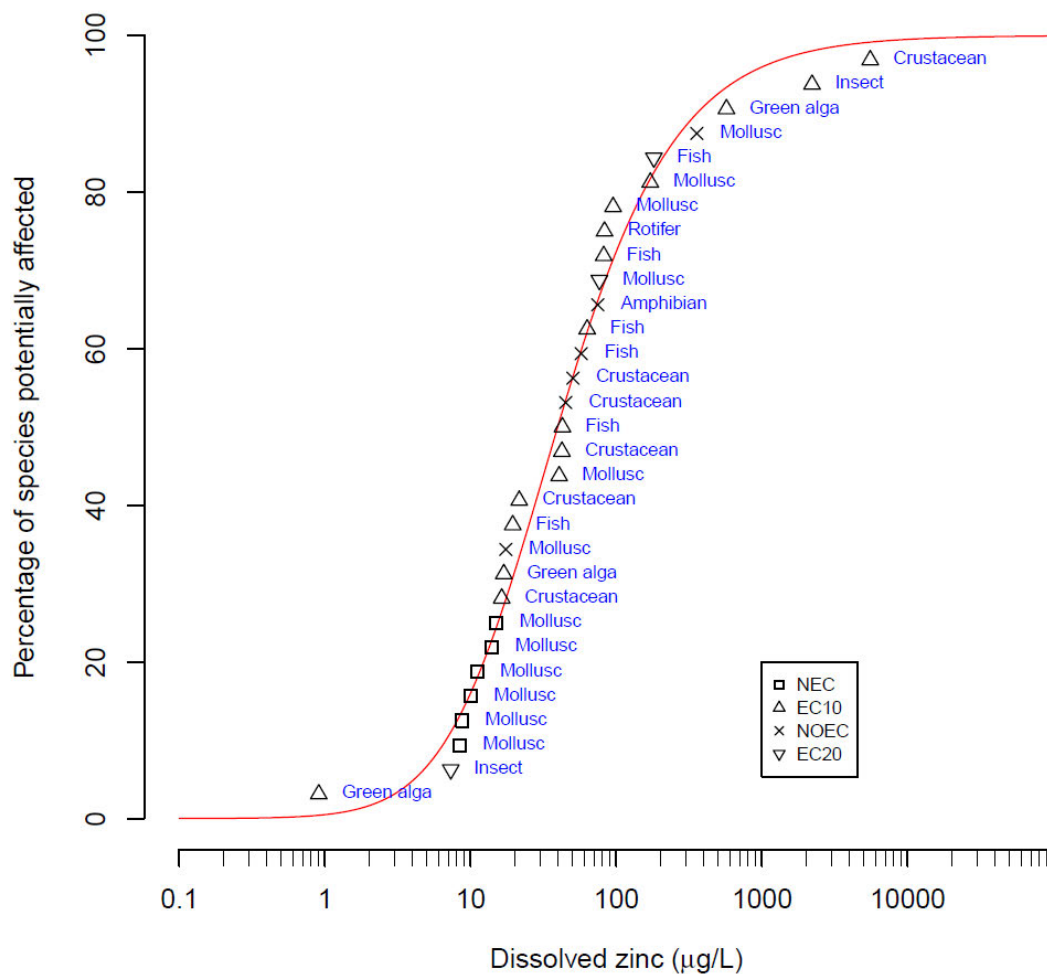


Figure F-22: Species sensitivity distribution for zinc in freshwater, normalised to the index condition of pH 7.5, hardness 30 mg/L CaCO₃ and 0.5 mg/L DOC (Figure 1 from ANZG (2026d)).

Acute – zinc

The acute species SSD is shown in Figure F-23 with the relative sensitivity of species groups in Figure F-24. Plots showing the relationship with TMFs are shown in Figure F-25.

A look-up table with acute zinc GVs in relation to TMFs is provided in Table 27.

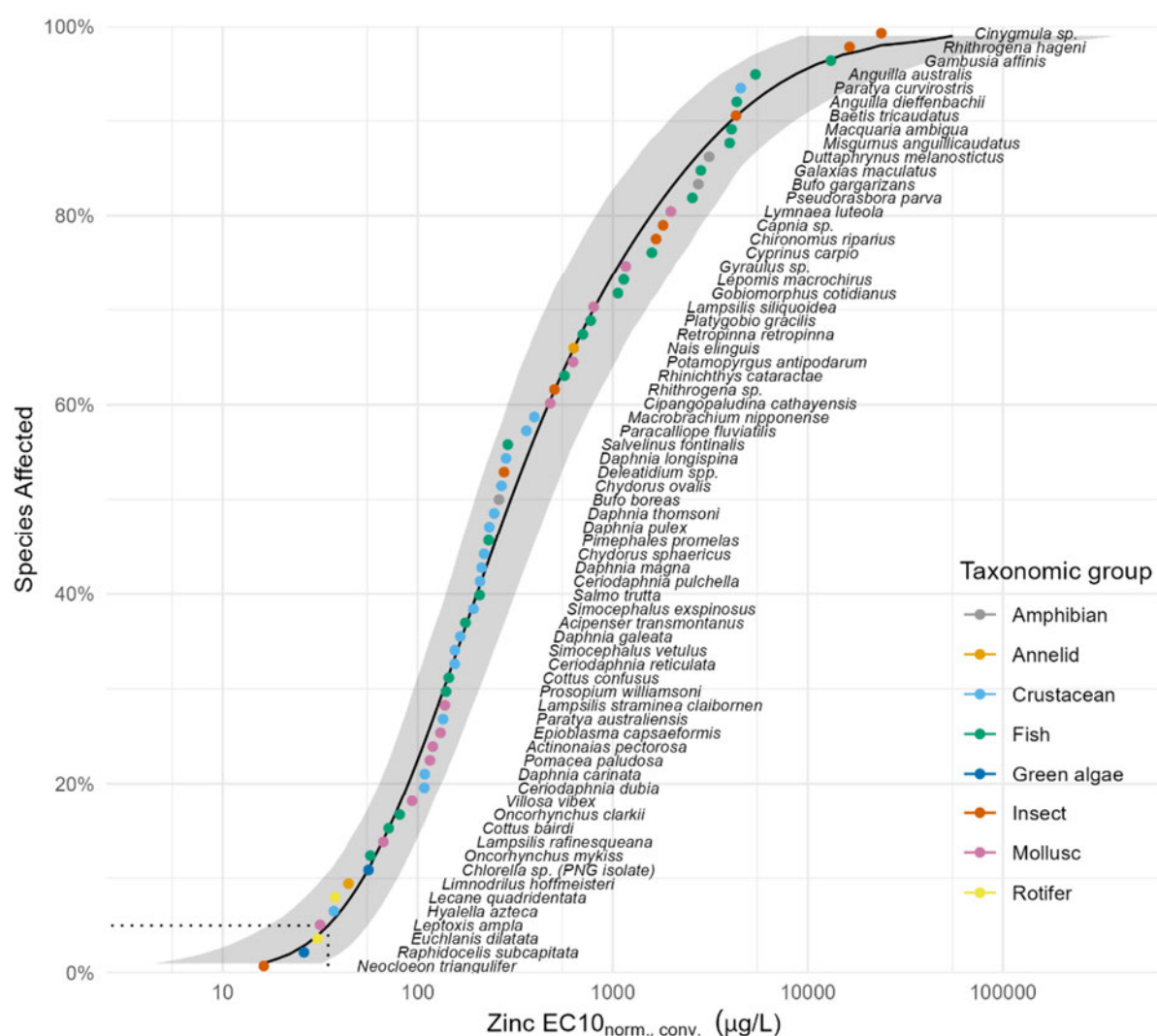


Figure F-23: Zinc species sensitivity distribution based on normalised and converted EC10 values. Toxicity data normalised to index condition (pH 7.5, hardness 30 mg/L and DOC 0.5 mg/L). Colour of points indicates taxonomic grouping of that species. Black line indicates model average fitted line, shaded area indicates the 95% confidence interval, dotted line indicates the model-averaged concentration for 95% species protection (5% species affected). (Figure 8.10 from Gadd et al. (2024)).

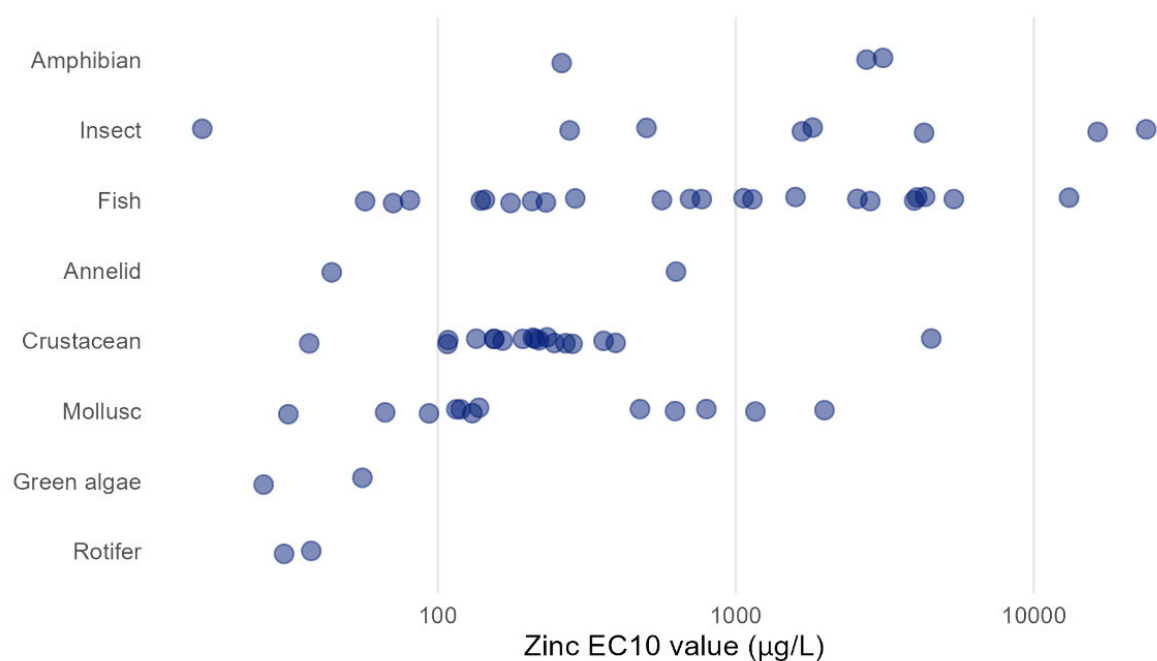


Figure F-24: Comparison between taxonomic groups of normalised converted acute **zinc** EC10 values. (Figure 8.6 from Gadd et al. (2024)).

Acute zinc GV equations for different LoPs (from Gadd et al. (2024)):

$$\text{Zinc acute } GV_{99} = [\exp]^{(1.75 - 0.12 \times pH + 0.6 \times \log(\text{hardness}) + 0.13 \times \log(DOC))} \quad \text{Equation 8.5}$$

$$\text{Zinc acute } GV_{95} = [\exp]^{(2.5 - 0.12 \times pH + 0.6 \times \log(\text{hardness}) + 0.13 \times \log(DOC))} \quad \text{Equation 8.6}$$

$$\text{Zinc acute } GV_{90} = [\exp]^{(2.9 - 0.12 \times pH + 0.6 \times \log(\text{hardness}) + 0.13 \times \log(DOC))} \quad \text{Equation 8.7}$$

$$\text{Zinc acute } GV_{80} = [\exp]^{(3.4 - 0.12 \times pH + 0.6 \times \log(\text{hardness}) + 0.13 \times \log(DOC))} \quad \text{Equation 8.8}$$

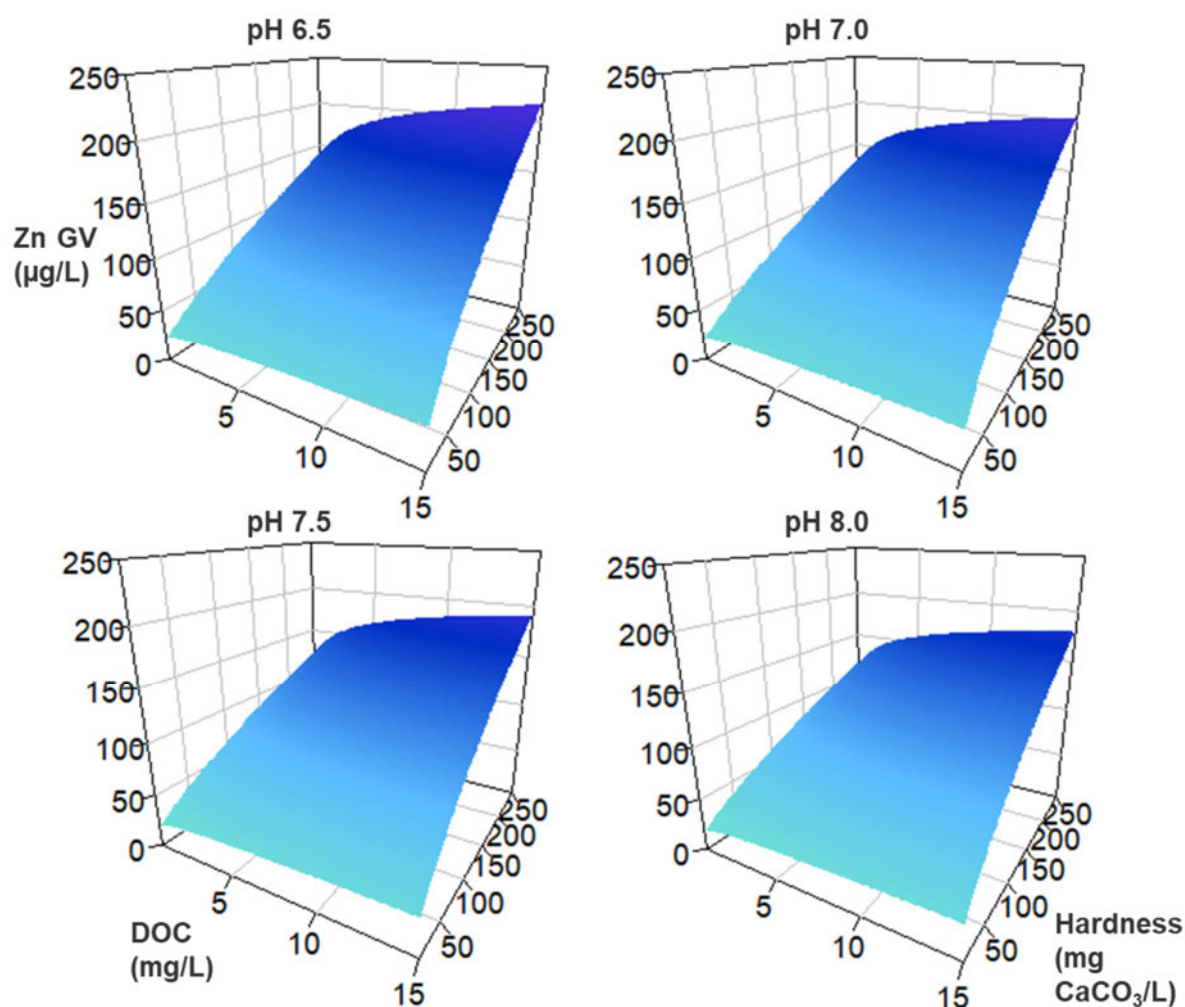


Figure F-25: Zinc acute GV (for 95% species protection) at different pH values and as a function of hardness and DOC. (Figure 8.12 from Gadd et al. (2024)).

Table F-27: Zinc acute GV (µg/L) for 95% species protection at different pH, hardness and DOC concentrations. Interim Tier 1 acute GV for 95% species protection is 24 µg/L. (from Gadd et al. (2024)).

pH	DOC (mg/L)	Hardness (mg CaCO ₃ /L)				
		15	30	60	120	240
6.5	0.3	24	37	56	84	128
7.5	0.3	21	33	49	75	113
8.5	0.3	19	29	44	66	100
6.5	1.5	30	45	68	103	157
7.5	1.5	26	40	60	92	139
8.5	1.5	23	35	54	81	123
6.5	6	35	54	81	123	187
7.5	6	31	48	72	109	166
8.5	6	28	42	64	97	147

Summary tables for zinc chronic and acute GVs

Chronic and acute normalised adjustment calculations are shown in Tables F-28 and F-29 respectively. These are used to provide GVs for different LoPs in Table 6-2.

The SSDs for the chronic and acute datasets were used to provide the basis for the protection ratios (see above).

Table F-28: Derivation of site-specific chronic GVs for cobalt for differing LoPs.

Chronic LoP (%)	GV_calc (µg/L)	Ratio to Chronic GV 95%	CCME_GV (µg/L) ^a	Normalising factor ^b	GV_LoPs (µg/L)
95	11.1	1	7.0	1.59	7.0
90	17.8	1.6		1.59	11
80	31.5	2.8		1.59	20

^a CCME (2018) FWQG (chronic) for zinc at pH 7.5, DOC 0.5 mg/L and hardness 50 mg/L CaCO₃

^b Normalising factor to adjust 'GV_calc' value to 'CCME_GV' for differing LoPs (i.e., 'GV_calc' / Normalising factor')

Table F-29: Derivation of site-specific acute GVs for zinc for differing LoPs (from Gadd et al. (2024)).

Acute LoP (%)	GV_acute_LoPs ^a (µg/L)	GV_acute (µg/L)
95	47.0	47
90	71.0	71
80	116.0	116

^a GV_acute values for zinc from Gadd et al. (2024) at pH 7.5, DOC 0.5 mg/L and hardness 50 mg/L CaCO₃

Ammoniacal-N

ANZG (2026) – ammoniacal-N pH and temperature correction

The ANZG ammoniacal-N guidelines have recently been updated and include both pH and temperature TMFs (ANZG, 2026c). The DGVs are shown in Table F-29 with pH and temperature look-up tables for 95%, 90% and 80% protection shown in Tables F-30-F-32.

Table F-29: DGV values for total ammoniacal-N in freshwater (Table 4 from ANZG 2026c).

Level of species protection (%)	Default guideline value (mg/L) at pH 7, temperature 20°C	Default guideline value (mg/L) at pH 7.5, temperature 20°C	Default guideline value (mg/L) at pH 8, temperature 20°C
99	0.32	0.24	0.13
95	0.97	0.72	0.40
90	1.6	1.2	0.68
80	3.0	2.3	1.3

^a See Appendix E for ammonia default guideline values applicable to a range of pH and temperatures.

^b The default guideline values were derived using the shinyssdtools (version 0.2.0) software and are reported to 2 significant figures. They are not applicable to waters of low ionic strength (e.g. < 50 µS/cm).

Table F-30: Freshwater 95% LoP values for ammoniacal-N at different pH and temperature values (Table E2 – pH range reduced – from ANZG 2026c).

Table E.2 Freshwater 95% species-protection guideline values for total ammonia (mg/L N) at different pH and temperature

Temp. (°C)	pH															
	6.0	6.1	6.2	6.3	6.4	6.5	6.6	6.7	6.8	6.9	7.0	7.1	7.2	7.3	7.4	7.5
10	1.8	1.8	1.8	1.8	1.8	1.8	1.7	1.7	1.7	1.6	1.6	1.5	1.4	1.3	1.2	1.2
11	1.8	1.7	1.7	1.7	1.7	1.7	1.7	1.6	1.6	1.5	1.5	1.4	1.4	1.3	1.2	1.1
12	1.7	1.6	1.6	1.6	1.6	1.6	1.6	1.5	1.5	1.5	1.4	1.4	1.3	1.2	1.1	1.0
13	1.6	1.6	1.6	1.5	1.5	1.5	1.5	1.5	1.4	1.4	1.3	1.3	1.2	1.1	1.1	0.99
14	1.5	1.5	1.5	1.5	1.4	1.4	1.4	1.4	1.4	1.3	1.3	1.2	1.2	1.1	1.0	0.94
15	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.3	1.3	1.3	1.2	1.2	1.1	1.0	0.98	0.90
16	1.4	1.4	1.3	1.3	1.3	1.3	1.3	1.3	1.2	1.2	1.2	1.1	1.1	1.0	0.93	0.86
17	1.3	1.3	1.3	1.3	1.3	1.2	1.2	1.2	1.2	1.1	1.1	1.1	1.0	0.95	0.89	0.82
18	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.13	1.10	1.1	1.0	0.97	0.91	0.85	0.78
19	1.2	1.2	1.2	1.2	1.2	1.15	1.13	1.11	1.09	1.06	1.0	0.98	0.93	0.88	0.82	0.75
20	1.1	1.1	1.1	1.1	1.1	1.09	1.08	1.06	1.03	1.00	0.97	0.93	0.88	0.83	0.78	0.72
21	1.1	1.1	1.1	1.0	1.0	1.03	1.01	0.99	0.97	0.94	0.91	0.87	0.83	0.78	0.73	0.67
22	1.0	1.0	1.0	1.0	1.0	0.99	0.98	0.96	0.94	0.91	0.88	0.84	0.80	0.76	0.71	0.65
23	0.98	0.98	0.97	0.96	0.95	0.94	0.93	0.91	0.89	0.87	0.84	0.80	0.76	0.72	0.67	0.62
24	0.93	0.92	0.92	0.91	0.90	0.89	0.88	0.86	0.84	0.82	0.79	0.76	0.72	0.68	0.63	0.58
25	0.88	0.88	0.87	0.87	0.86	0.85	0.83	0.82	0.80	0.78	0.75	0.72	0.68	0.65	0.60	0.55
26	0.84	0.83	0.83	0.82	0.81	0.80	0.79	0.78	0.76	0.74	0.71	0.68	0.65	0.61	0.57	0.53
27	0.79	0.79	0.78	0.78	0.77	0.76	0.75	0.74	0.72	0.70	0.68	0.65	0.62	0.58	0.54	0.50
28	0.75	0.75	0.74	0.74	0.73	0.72	0.71	0.70	0.68	0.66	0.64	0.61	0.58	0.55	0.51	0.47
29	0.71	0.71	0.70	0.70	0.69	0.68	0.67	0.66	0.64	0.62	0.60	0.58	0.55	0.52	0.48	0.45
30	0.66	0.66	0.66	0.65	0.65	0.64	0.63	0.62	0.60	0.58	0.57	0.54	0.52	0.49	0.45	0.42

Table F-31: Freshwater 90% LoP values for ammoniacal-N at different pH and temperature values (Table E3 – pH range reduced – from ANZG 2026c).

Table E.3 Freshwater 90% species-protection guideline values for total ammonia (mg/L N) at different pH and temperature

Temp. (°C)	pH															
	6.0	6.1	6.2	6.3	6.4	6.5	6.6	6.7	6.8	6.9	7.0	7.1	7.2	7.3	7.4	7.5
10	2.9	2.8	2.8	2.8	2.8	2.7	2.7	2.7	2.6	2.5	2.4	2.3	2.2	2.1	1.9	1.8
11	2.8	2.7	2.7	2.7	2.7	2.6	2.6	2.6	2.5	2.4	2.3	2.2	2.1	2.0	1.9	1.7
12	2.6	2.6	2.6	2.6	2.6	2.5	2.5	2.4	2.4	2.3	2.2	2.2	2.0	1.9	1.8	1.7
13	2.5	2.5	2.5	2.5	2.5	2.4	2.4	2.3	2.3	2.2	2.2	2.1	2.0	1.8	1.7	1.6
14	2.4	2.4	2.4	2.4	2.4	2.3	2.3	2.3	2.2	2.1	2.1	2.0	1.9	1.8	1.7	1.5
15	2.3	2.3	2.3	2.3	2.3	2.3	2.2	2.2	2.1	2.1	2.0	1.9	1.8	1.7	1.6	1.5
16	2.3	2.2	2.2	2.2	2.2	2.2	2.1	2.1	2.0	2.0	1.9	1.8	1.7	1.6	1.5	1.4
17	2.2	2.2	2.1	2.1	2.1	2.1	2.1	2.0	2.0	1.9	1.8	1.8	1.7	1.6	1.5	1.4
18	2.1	2.1	2.1	2.1	2.0	2.0	2.0	1.9	1.9	1.8	1.8	1.7	1.6	1.5	1.4	1.3
19	2.0	2.0	2.0	2.0	2.0	1.9	1.9	1.9	1.8	1.8	1.7	1.7	1.6	1.5	1.4	1.3
20	1.9	1.9	1.9	1.9	1.9	1.9	1.8	1.8	1.8	1.7	1.6	1.6	1.5	1.4	1.3	1.2
21	1.8	1.8	1.8	1.8	1.8	1.8	1.7	1.7	1.7	1.6	1.6	1.5	1.4	1.3	1.3	1.2
22	1.8	1.8	1.8	1.8	1.7	1.7	1.7	1.7	1.6	1.6	1.5	1.5	1.4	1.3	1.2	1.1
23	1.7	1.7	1.7	1.7	1.7	1.6	1.6	1.6	1.5	1.5	1.5	1.4	1.3	1.2	1.2	1.1
24	1.6	1.6	1.6	1.6	1.6	1.6	1.5	1.5	1.5	1.4	1.4	1.3	1.3	1.2	1.1	1.0
25	1.6	1.6	1.5	1.5	1.5	1.5	1.5	1.4	1.4	1.4	1.3	1.3	1.2	1.1	1.1	0.98
26	1.5	1.5	1.5	1.5	1.4	1.4	1.4	1.4	1.3	1.3	1.3	1.2	1.2	1.1	1.0	0.93
27	1.4	1.4	1.4	1.4	1.4	1.4	1.3	1.3	1.3	1.3	1.2	1.2	1.1	1.0	0.97	0.89
28	1.4	1.4	1.3	1.3	1.3	1.3	1.3	1.3	1.2	1.2	1.2	1.1	1.1	0.99	0.92	0.85
29	1.3	1.3	1.3	1.3	1.3	1.2	1.2	1.2	1.2	1.1	1.1	1.1	1.0	0.95	0.88	0.81
30	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.1	1.1	1.1	1.0	1.0	0.95	0.90	0.84	0.77

Table F-32: Freshwater 80% LoP values for ammoniacal-N at different pH and temperature values (Table E4 – pH range reduced – from ANZG 2026c).

Table E.4 Freshwater 80% species-protection guideline values for total ammonia (mg/L N) at different pH and temperature

Temp. (°C)	pH															
	6.0	6.1	6.2	6.3	6.4	6.5	6.6	6.7	6.8	6.9	7.0	7.1	7.2	7.3	7.4	7.5
10	4.9	4.9	4.8	4.8	4.8	4.7	4.6	4.5	4.4	4.3	4.2	4.0	3.8	3.6	3.3	3.1
11	4.8	4.7	4.7	4.7	4.6	4.6	4.5	4.4	4.3	4.2	4.1	3.9	3.7	3.5	3.2	3.0
12	4.6	4.6	4.6	4.5	4.5	4.4	4.4	4.3	4.2	4.1	3.9	3.8	3.6	3.4	3.1	2.9
13	4.5	4.5	4.4	4.4	4.3	4.3	4.2	4.1	4.1	3.9	3.8	3.6	3.5	3.3	3.0	2.8
14	4.3	4.3	4.3	4.2	4.2	4.2	4.1	4.0	3.9	3.8	3.7	3.5	3.4	3.2	2.9	2.7
15	4.2	4.2	4.2	4.1	4.1	4.0	4.0	3.9	3.8	3.7	3.6	3.4	3.3	3.1	2.9	2.6
16	4.1	4.0	4.0	4.0	4.0	3.9	3.8	3.8	3.7	3.6	3.5	3.3	3.2	3.0	2.8	2.6
17	3.9	3.9	3.9	3.9	3.8	3.8	3.7	3.7	3.6	3.5	3.4	3.2	3.1	2.9	2.7	2.5
18	3.8	3.8	3.8	3.8	3.7	3.7	3.6	3.5	3.5	3.4	3.3	3.1	3.0	2.8	2.6	2.4
19	3.7	3.7	3.7	3.6	3.6	3.6	3.5	3.4	3.4	3.3	3.2	3.0	2.9	2.7	2.5	2.3
20	3.6	3.6	3.5	3.5	3.5	3.4	3.4	3.3	3.2	3.2	3.0	2.9	2.8	2.6	2.4	2.3
21	3.4	3.4	3.4	3.4	3.3	3.3	3.3	3.2	3.1	3.0	2.9	2.8	2.7	2.5	2.3	2.2
22	3.3	3.3	3.3	3.3	3.3	3.2	3.2	3.1	3.0	2.9	2.8	2.7	2.6	2.4	2.3	2.1
23	3.2	3.2	3.2	3.2	3.1	3.1	3.1	3.0	2.9	2.8	2.7	2.6	2.5	2.4	2.2	2.0
24	3.1	3.1	3.1	3.0	3.0	3.0	2.9	2.9	2.8	2.7	2.6	2.5	2.4	2.3	2.1	1.9
25	3.0	3.0	3.0	2.9	2.9	2.9	2.8	2.8	2.7	2.6	2.5	2.4	2.3	2.2	2.0	1.9
26	2.9	2.9	2.8	2.8	2.8	2.8	2.7	2.7	2.6	2.5	2.4	2.3	2.2	2.1	2.0	1.8
27	2.8	2.8	2.7	2.7	2.7	2.7	2.6	2.6	2.5	2.4	2.4	2.3	2.2	2.0	1.9	1.7
28	2.7	2.7	2.6	2.6	2.6	2.6	2.5	2.5	2.4	2.3	2.3	2.2	2.1	1.9	1.8	1.7
29	2.6	2.6	2.5	2.5	2.5	2.5	2.4	2.4	2.3	2.3	2.2	2.1	2.0	1.9	1.8	1.6
30	2.5	2.5	2.4	2.4	2.4	2.4	2.3	2.3	2.2	2.2	2.1	2.0	1.9	1.8	1.7	1.5

NPS-FM – ammoniacal-N pH correction

The NPS-FM standards are provided at pH 8 – a conservative value as ammoniacal-N toxicity increases as pH increases. The guidance for pH adjustment calculations from (MfE, 2018) is below with conversion ratios provided in Table F-33.

Appendix – Ammonia adjustment calculations

ANZECC (2000, Section 8.3.7.2) observes that total ammoniacal nitrogen, $\text{NH}_4\text{-N}$ (often referred to as 'total ammonia'), 'refers to two chemical species that are in equilibrium in water: the un-ionised ammonia, NH_3 , and the ionised ammonium ion, NH_4^+ .' And, 'The proportion of the two chemical forms varies with the physico-chemical properties of the water, particularly pH and temperature.'

However, as the name 'total ammonia' implies, the combined amount of these two chemical species is constant, and it does not vary with the physico-chemical properties of the water. That is, 'adjusting' the ammonia concentration for pH does not mean that the amount of total ammonia present changes (and in fact the standard laboratory analysis for $\text{NH}_4\text{-N}$ is successfully carried out at a high pH, e.g. pH 11).

Instead, pH adjustment means calculating the amount of $\text{NH}_4\text{-N}$ at pH 8 that would have the equivalent toxicity to the amount of $\text{NH}_4\text{-N}$ measured in the sample at the pH of the sample – whatever that may have been. That is, the calculation produces the concentration of $\text{NH}_4\text{-N}$ which at pH 8 would have the same toxicity as the observed (ie, unadjusted) $\text{NH}_4\text{-N}$ concentration would have at the observed pH.

The information in table 10 allows the ammonia concentration of a sample to be converted to an equivalent concentration at pH 8 using the following equation:

$$\text{Conc}_{\text{pH } 8} = \frac{\text{Conc}_{\text{pH sample}}}{\text{Ratio}} \quad \text{Equation (1)}$$

Where $\text{Conc}_{\text{pH sample}}$ is the concentration of the sample and Ratio is read from table 10 for the given sample pH.

For example, if a sample was observed with 1.12 mg $\text{NH}_4\text{-N/L}$ at pH 7.5, the adjusted concentration to use in calculating sample statistics would be 0.63 mg $\text{NH}_4\text{-N/L}$ at pH 8. This is derived as follows:

Using equation (1) and table 10:

$$\text{Conc}_{\text{pH } 8} = 0.63 = \frac{1.12}{1.79}$$

Where the numerator (1.12) is the observed sample concentration and the denominator (1.79) is the Ratio from table 10 at pH of 7.5.

That is, although there is still 1.12 mg/L of $\text{NH}_4\text{-N}$ present in the sample, the adjustment process has identified that the toxicity of this sample at pH 7.5 is equivalent to the toxicity associated with a $\text{NH}_4\text{-N}$ concentration of 0.63 mg/L at pH 8. It's the equivalent toxicity that has been adjusted, and not the amount of $\text{NH}_4\text{-N}$ present in the sample (which remains unchanged).

Note that a method for converting to standard temperature is not currently available.

Table F-33: Conversion ratios for pH adjustment of NPS-FM standards (Table 10 from MfE 2018)

Table 10: Conversion ratios for pH adjustment of ammonia concentrations

Sample pH	Ratio	Sample pH	Ratio	Sample pH	Ratio
6	2.86	7	2.42	8.1	0.87
6.1	2.84	7.1	2.32	8.2	0.73
6.2	2.82	7.2	2.21	8.3	0.62
6.3	2.80	7.3	2.09	8.4	0.53
6.4	2.77	7.4	1.94	8.5	0.44
6.5	2.73	7.5	1.79	8.6	0.38
6.6	2.70	7.6	1.63	8.7	0.32
6.7	2.64	7.7	1.47	8.8	0.27
6.8	2.59	7.8	1.31	8.9	0.23
6.9	2.51	7.9	1.14	9	0.20
		8	1.00	>9	0.20

Source: Adapted from ANZECC (2000) and Hickey (2014).

Appendix G Proposed compliance and reference site and monitoring parameters

Table G-1: Reference and compliance monitoring sites for MFS and ESE mining areas. Shading indicates reference sites. See Appendix A for maps with site locations and historic mining areas.

Project sub-area	Location / catchment	Stream/ River	Compliance/ Reference	Included in LoP classification assessment	Level of protection (%)	Monitoring parameters					Notes
						pH	Metals	Hardness/ DOC	Nutrients	Turbidity	
MFS	Waimangaroa	Waimangaroa River	Reference		n/a	✓	✓	✓	✓	c,d	1
MFS / UWHR	Waimangaroa	Waimangaroa River	Compliance	✓	80	✓	✓	✓	✓	c,d,s	2,3
MFS / UWHR	Waimangaroa	Waimangaroa River	Compliance	✓	80	✓	✓	✓	✓	c,d	2,3,4
MFS / UWHR	Waimangaroa	Waimangaroa River trib	Reference		n/a	✓				d,s	5
MFS / UWHR	Waimangaroa	Waimangaroa River trib	Reference		n/a	✓				d,s	5
MFS	Deep	Billo Stream trib	Reference	✓	n/a	✓	✓	✓	✓	c,d,s	6
MFS	Deep	Deep Stream	Compliance	✓	95	✓	✓	✓	✓	c,d,s	7
MFS	Deep	Deep Stream	Compliance	✓	95	✓	✓	✓	✓	c,d,s	7
ESE	Whareatea	Whareatea River trib	Reference	✓	n/a	✓	✓	✓	✓	c,d	8
ESE	Rapid	Rapid Stream trib	Reference		n/a	✓	✓	✓	✓	d	9
ESE	Rapid	Rapid Stream	Compliance	✓	95	✓	✓	✓	✓	d	10
ESE	Whareatea	Whareatea River	Compliance	✓	95	✓	✓	✓	✓	d	11
ESE	Cascade	Cascade Creek trib (V8)	Compliance	✓	80	✓	✓	✓	✓	d	12
ESE	Whareatea	Whareatea River trib	Compliance	✓	95	✓	✓	✓	✓	d	13

Abbreviations: Proposed sampling regime for turbidity: c = continuous, d = discrete, s = storm water sampler. LoP = Level of Protection.

Notes:

- Reference site upstream of WTP discharge to Waimangaroa River.
- Downstream of WTP discharge. Compliance based on reduced LoP for these sites because of significant upstream AMD input of trace metals.
- Compliance site integrates WTP and occasional bypass discharges. Potential Upper Waimangaroa Haul Road (UWHR) influence with Storm Water samplers for events.
- Compliance site integrates WTP, Deep Stream intermittent sump bypass discharges (above SW01 & SW03) and historic mining inputs. Metal and nutrient monitored concentrations at this site used to calculate SH67 concentrations.
- Reference sites for UWHR discharges from treatment sumps - turbidity and limited acid drainage. Discrete sampling and Storm Water samplers.
- Reference site upstream of SW01 and SW03 Deep Stream sites.
- Compliance sites located downstream of East and West sump intermittent discharges.
- Reference site for Whareatea River compliance monitoring at KEL.
- Reference site for compliance assessment at W07 on Rapid Stream.
- Compliance site for ELF seepage discharge to Rapid Stream.
- Compliance location on Whareatea River. Receives WTP, WTP polishing pond, sump/surge pond and clean water discharges from the ESE pit. Metal and nutrient monitored concentrations at this site used to calculate SH67 concentrations.
- Sites discharging to Cascade Creek which currently receive historic AMD discharges. Some WTP polishing pond, stormwater and clean water diversion during operational period. Remediation of some of the AMD discharge to occur. Proposed for 80% level of protection for metals and nutrients for MM1; Compliance/Performance LoP for turbidity is 25 NTU rolling 15-sample median (Table 7-1) - based on intermittent elevated turbidity associated with AMD inputs.
- Compliance site receives clean diversion water and ESE pit water. Enters Whareatea River downstream of KEL. Metal and nutrient monitored concentrations at this site can be used to calculate SH67 concentrations (see footnote ⁵⁰).

