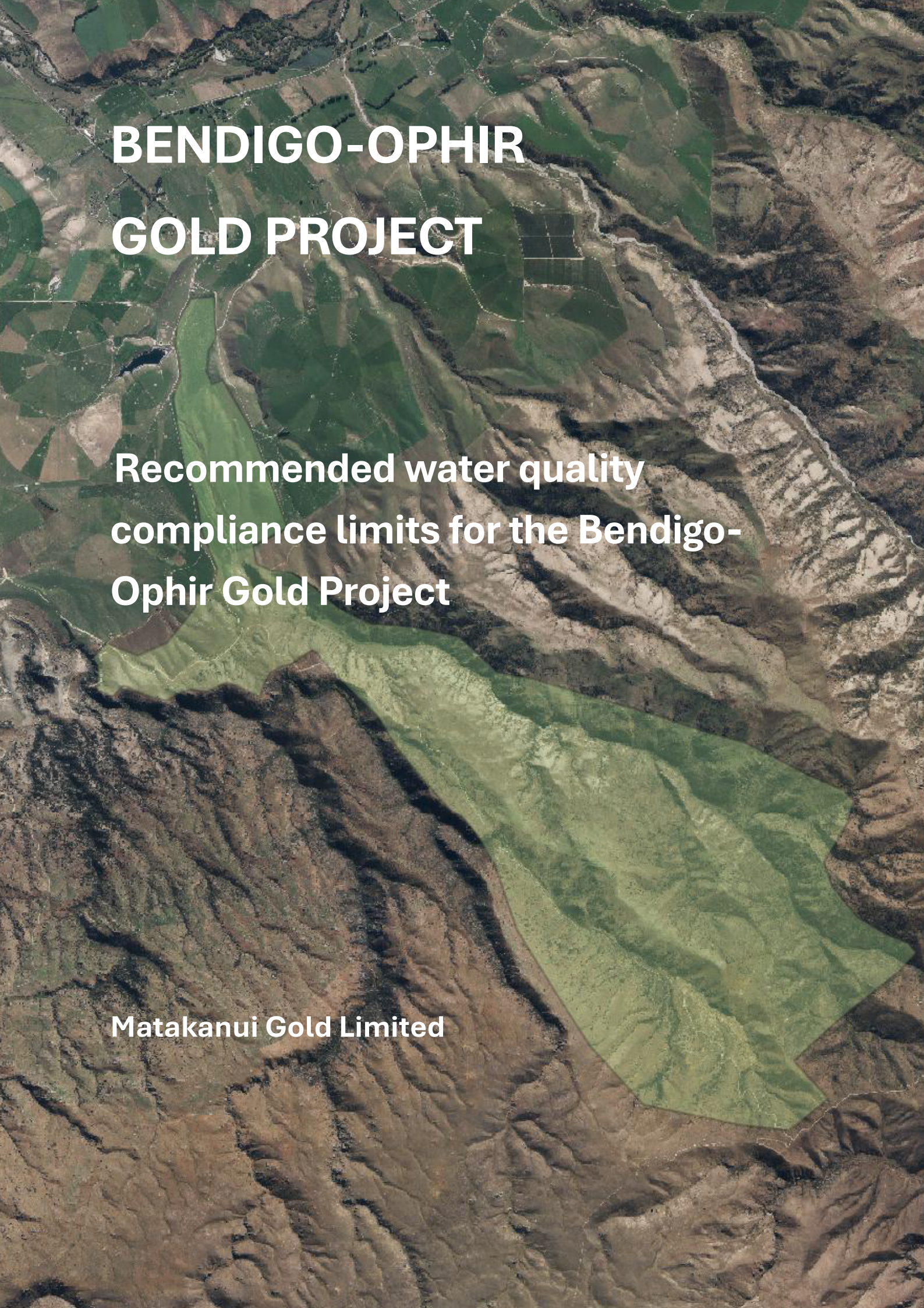


An aerial photograph of a rugged, mountainous landscape. The terrain is characterized by steep, brownish-grey slopes and deep, winding valleys. A large, irregularly shaped area in the center-left of the image is highlighted in a vibrant green color, indicating the project area. The surrounding landscape is a mix of green vegetation and exposed rock faces.

BENDIGO-OPHIR GOLD PROJECT

**Recommended water quality
compliance limits for the Bendigo-
Ophir Gold Project**

Matakanui Gold Limited

BENDIGO-OPHIR GOLD PROJECT

Recommended water quality compliance limits for the Bendigo-Ophir Gold Project

Prepared for Matakanui Gold Limited
by Greg Ryder Consulting

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Executive Summary

Water quality compliance limits are recommended in order to establish acceptable quantifiable thresholds for various chemical indicators of water quality. They are essential tools for managing human impacts and ensuring freshwater ecosystems, stock water and drinking water remain safe.

Catchments within the Project footprint have relatively small surface water features, which drain to either Bendigo Creek or the Lindis River. In both cases, surface flow typically does not make it all the way to surface waters further downstream. For example, once Shepherds Creek reaches the floodplain associated with the Lindis River catchment, the watercourse is typically dry and there is usually no surface discharge from it into the Lindis River. It is at best an ephemeral water course and in the very lower reaches there is no evidence that a water course even exists. Bendigo Creek drains into the gravels of the Bendigo aquifer, except during periods of high rainfall, and only occasionally discharges directly into Lake Dunstan.

Surface waters within the Bendigo-Ophir Gold Project (BOGP) footprint include sections that are either ephemeral, intermittent or perennial, supporting varying ecological values. Significant sections of these streams are degraded due to current and historic land use practices (agricultural and mining practices), along with the spread of undesirable species such as crack willow and Lagarosiphon, and mammalian pests.

Ecological surveys of these streams found no benthic invertebrate species that are classified as threatened under the Department of Conservation threat ranking classification for aquatic macroinvertebrates. No kōura (freshwater crayfish) or kākahi (freshwater mussel) were detected through the various survey methods.

Fish populations are limited to introduced brown trout in a short perennial reach of Bendigo Creek (~ 1.5 km reach immediately below of the Dunstan Mountains) and an eDNA signal for native kōaro (*Galaxias brevipinnis*) in Bendigo Creek upstream of the brown trout population, although the presence of kōaro does not appear to be that far upstream based on the results of electric fishing and eDNA sampling further upstream. Surveys of Rise and Shine Creek and Clearwater Creek did not detect any fish. Electric fishing and eDNA sampling in Shepherds Creek also did not detect the presence of any fish species.

Overall, the freshwater environment and freshwater ecological values within the mine BOGP are considered to be relatively low, given:

- the absence of fish communities;
- relatively poor invertebrate community composition in many locations and no rare or endangered freshwater invertebrate species present;

- surface water quality, physical habitat and riparian habitat that have been impacted by historic mining activities, stock grazing and invasive species.

Water from the Shepherds Creek catchment ultimately discharges into the Ardour Alluvial Aquifer, some of which is drawn into a small number of nearby private water bores. This aquifer water ultimately discharges to the Lindis River and/or flows parallel to the Lindis River and discharges into the Clutha River / Mata-Au.

A number of watercourses within the Project area appear to be more than 'slightly to moderately' disturbed, as defined under the ANZG (2018) water quality guidelines. Therefore, with respect to Potential Contaminants of Concern (PCOC) in water, such as dissolved metals, ammonia and nitrate, 90% species protection is considered an acceptable level of protection for these freshwater ecosystems given their historic and current level of disturbance.

Some contaminants, such as sulphate, have no recognised ecological guidelines or water quality criteria in New Zealand and there is no ANZG default guideline value. Therefore, bespoke compliance limits have been developed based on local and international information.

Groundwater may be abstracted for pasture irrigation, and human and livestock drinking water. Some local groundwater will also find its way back to surface waters (Lindis River and Clutha River / Mata-Au).

Draft livestock drinking water guidelines have recently been published by ANZG (ANZG 2023). The New Zealand Drinking Water Standards were recently updated (2022) along with the 2022 Aesthetic Values for Drinking Water Notice. All of these documents have been consulted when considering appropriate compliance limits for groundwater.

Proposed surface water and groundwater quality compliance limits for the BOGP are summarised in the tables below and compliance limits for individual contaminants are discussed in subsequent sections of this report.

Summary of recommended water quality compliance limits for BOGP surface water

PARAMETER (units are mg/L unless stated otherwise)	SURFACE WATER Recommended compliance limit(s)
pH (unitless)	6.5-9.0
Turbidity (NTU)	5 (over a 5-year rolling period, 80% of samples, when flows are at or below median flow, are to meet the limit)
Ammoniacal-nitrogen (NH ₃ -N)	≤0.24 (annual median) <0.4 (annual 95 th %) See Appendix A for adjustments
Nitrate-nitrogen (NO ₃ -N)	<2.4 (annual median) <3.5 (annual 95 th %)
Cyanide (CN ⁻)	0.011 (un-ionised HCN, measured as [CN], ANZG 2018) See Appendix A for adjustments
Sulphate (SO ₄ ²⁻)	A. If hardness is <100 mg/L (CaCO₃), the sulphate compliance limit = 500 mg/L. B. If chloride is <5 mg/L, the sulphate compliance limit = 500 mg/L C. If the hardness is 100–500 mg/L AND if chloride is 5–<25 mg/L, the sulphate compliance limit is (in mg/L): $[-57.478 + 5.79 * (\text{hardness mg/L CaCO}_3) + 54.163 * (\text{chloride mg/L})] * 0.65$ D. If hardness is between 100 and 500 mg/L AND if chloride is between ≥25 and ≤500 mg/L, the sulphate limit is (in mg/L): $[1276.7 + 5.508 * (\text{hardness mg/L CaCO}_3) + 1.457 * (\text{chloride mg/L})] * 0.65$ A minimum of 12 samples must be collected over any rolling 12-month period. For compliance limits in A to D, no more than 20% of samples collected over a rolling 12-month period may exceed the relevant compliance limit. E. An acute compliance limit = 1,000 mg/L averaged over 4 days and not to be exceeded more than once in a one-year period, OR in more than 10% of samples over a one-year period.
Aluminium (Al) (dissolved)	≤0.08
Antimony (Sb) (total)	0.074 (chronic) 0.250 (acute)

PARAMETER (units are mg/L unless stated otherwise)	SURFACE WATER Recommended compliance limit(s)
	See below
Arsenic (As(V)) (dissolved)	≤0.042
Cadmium (Cd) (dissolved)	≤0.0004 See below for adjustment algorithm
Chromium (Cr) (dissolved)	≤0.0033 (CrIII) ≤0.006 (CrVI) See below for adjustment algorithm
Cobalt (Co) (dissolved)	0.001 (chronic) 0.11 (acute, not to exceed) See below for adjustment algorithm
Copper (Cu) (dissolved)	≤0.0018
Molybdenum (dissolved)	≤0.034
Zinc (Zn) (dissolved)	0.015 See below for adjustment algorithm
Cd (dissolved)	HMTV = TV (H/30) ^{0.89} , where hardness-modified trigger value (HMTV) = (µg/L), trigger value (TV) (µg/L) at a hardness of 30 mg/L as CaCO ₃ ; H, measured hardness (mg/L as CaCO ₃) of a fresh surface water.
Cr (dissolved)	HMTV = TV (H/30) ^{0.82} , where hardness-modified trigger value (HMTV) = (µg/L), trigger value (TV) (µg/L) at a hardness of 30 mg/L as CaCO ₃ ; H, measured hardness (mg/L as CaCO ₃) of a fresh surface water.
Co (dissolved)	Cobalt (µg/L) = exp{[0.414[ln(hardness CaCO ₃ mg/L)] – 1.887}
Sb (total)	(chronic) the average of 5 (monthly) samples over a 5-month period (acute) not to be exceeded at any time
Zn (dissolved)	HMTV = TV (H/30) ^{0.85} , where hardness-modified trigger value (HMTV) = (µg/L), trigger value (TV) (µg/L) at a hardness of 30 mg/L as CaCO ₃ ; H, measured hardness (mg/L as CaCO ₃) of a fresh surface water.

Summary of recommended water quality compliance limits for BOGP ground water

PARAMETER (units are mg/L unless stated otherwise)	GROUNDWATER Recommended compliance limit(s)
Nitrate-nitrogen (NO ₃ -N)	11.3 (MAV)*
Cyanide (CN ⁻)	0.6 (MAV)
Sulphate (SO ₄ ²⁻)	≤250 (taste threshold)
Aluminium (Al)	1 (MAV)
Antimony (Sb)	0.02 (MAV)
Arsenic (As(V))	0.01 (MAV)
Cadmium (Cd)	0.004 (MAV)
Chromium (Cr)	≤0.05(MAV)
Cobalt (Co)	<1 (livestock drinking water)
Copper (Cu)	≤0.5
Iron (Fe)	≤0.3
Lead (Pb)	0.01 (MAV)
Manganese (Mn)	0.4 (MAV)
Molybdenum (Mo)	<0.01
Strontium (Sr)	4
Uranium (U)	0.03 (MAV)
Zinc (Zn)	≤1.5
* MAV = Maximum acceptable value – From NZ drinking water standards	

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1. Introduction

Matakanui Gold Limited (“**MGL**”) is proposing to establish within the Bendigo-Ophir Gold Project (“**BOGP**”), a new gold mine, ancillary facilities and environmental mitigation measures on Bendigo and Ardgour Stations in the Dunstan Mountains of Central Otago. The project site is located approximately 20 km north of Cromwell.

The BOGP is located within the footprint of Minerals Exploration Permit 60311, which overlays several pastoral stations that have grazed sheep and cattle in the area for over 100 years. MEP60311 is held by MGL under the Crown Minerals Act 1991. MGL has land access agreements with Bendigo and Ardgour Stations. The BOGP is located adjacent to land administered by the Department of Conservation (“**DOC**”), including the Bendigo Historic Reserve, the Bendigo Conservation Area and the Ardgour Conservation Area. The BOGP planned operations do not directly impact these areas.

The BOGP’s exploration has discovered numerous soil geochemical anomalies and extensive drill evaluation has defined four (4) gold deposits worthy of economic extraction. The most significant is the Rise and Shine (“**RAS**”) discovery which is the most significant gold discovery in New Zealand in the past four decades. The other discoveries at Come in Time (“**CIT**”), Srex (“**SRX**”) and Srex East (“**SRE**”) are smaller in size and tenor.

The defined orebodies are planned to be mined by open pit methods. Underground mining is planned for the deeper parts of the RAS orebody in the later years of development.

The majority of the mining activities, ancillary facilities and associated infrastructure will be located in the Shepherds Valley somewhat hidden from the view of the public. Access, and service and administration offices are planned to be located on the adjoining Ardgour Terrace.

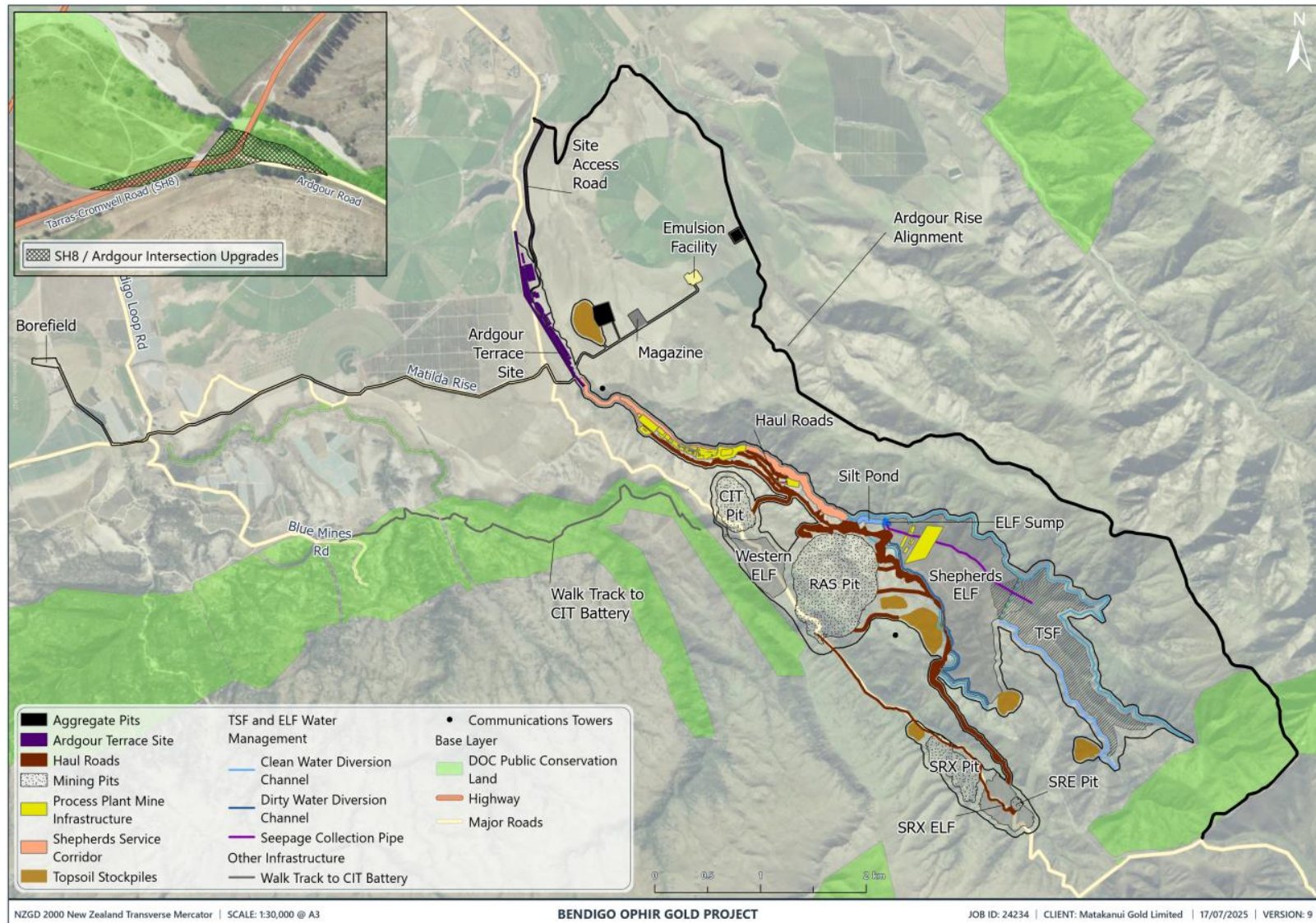


Figure 1. Overview site layout of the Bendigo-Ophir Gold Project.

Figure 1 above provides an overview of the footprint associated with the establishment, operation and rehabilitation within the BOGP. Direct disturbance in the pastoral area will be approximately 380 hectares (ha). A disturbance contingency has been allowed around the mine and infrastructure for footprint adjustments during detailed design. A further 18 ha (approximately) of disturbance will be needed to establish the Thomson Gorge Road alternative alignment (Ardgour Rise). Maximum potential disturbance in the pastoral area, including contingency and Ardgour Rise, is 568 ha.

Additional disturbance of approximately 52 ha will be required in the agricultural area on Ardgour Terrace. This area will be used for offices, security, medical, laboratory, laydown, storage, contractor areas, topsoil storage, emulsion manufacture and magazine facilities, plus quarries and roading.

Ecological work will include rehabilitation on direct disturbed areas, ecological uplift activities and pest exclusion area(s) adjacent to the footprint on nearby areas such as Ardgour and Bendigo Stations. A full description of the various activities comprising the establishment, operation and rehabilitation within the BOGP is provided in the Assessment of Environmental Effects (“**AEE**”) prepared by Mitchell Daysh Limited. However, by way of summary, the BOGP includes the following components:

- The establishment of the RAS Open Pit and SRX Open Pit, which are planned to form partial pit lakes at closure.
- The establishment of RAS Underground which is planned to be backfilled with cement paste.
- The establishment of the CIT Open Pit, which is the smallest of footprints and is planned to be progressively backfilled with waste rock from the RAS Open Pit and profiled to integrate with the surrounding terrain. Rehabilitation will enable nearby native herb fields to be re-established at the completion of mining activities.
- The establishment of the small SRE Open Pit, which will be partially backfilled with waste rock before being covered with overburden to form the engineered landform for the adjoining SRX Open Pit (“**SRX ELF**”).
- A conventional hard rock gold processing plant (1.2 million tonnes per annum expandable to 1.8Mtpa) applying modern Carbon-in-Leach (“**CIL**”) technology constructed in the lower reach of Shepherds Valley. The plant will operate in a closed water circuit with the TSF. Residual chemicals in the tailings slurry will be detoxified and/or precipitated with specialist plant.
- The operation of the process plant will be supported by ancillary facilities such as maintenance workshops, raw material and process chemical storage, fuel depot, laboratory and warehousing. Mine offices, carparking and security services will also be established.

- The construction of the plant in the lower reaches of the Shepherds valley will include the realignment of Shepherds Creek.
- The establishment of water storage dams and tankage for use in the process plant, dust suppression and drinking water supply.
- The establishment of a Tailings Storage Facility (“**TSF**”) in the upper reach of Shepherds Valley (including clean water diversion drains), which will utilise waste rock from mining activities within the project site.
- The establishment of permanent engineered landforms in the Shepherds Valley (“**Shepherds ELF**”) and an unnamed creek west of RAS pit (“**WELF**”).
- The establishment of temporary topsoil, vegetation and brown rock stockpiles around the project site.
- The extraction of groundwater from the Bendigo Aquifer for use in mining-related activities as well as supplying BOGP drinking water and replacing small irrigation water takes from Shepherds Creek. Bore water will be pumped to the processing plant via a pipeline over a distance of approximately 7 km.
- The establishment of supporting infrastructure / activities for the project, such as the upgrade of Ardgour Road and parts of Thomson Gorge Road to provide improved access to the BOGP, internal mine access and haul roads, water pipelines and underground utilities, and electricity supply to the project site from Lindis Crossing via a new 66kV overhead powerline that will follow the existing road reserve corridor.
- A realignment of part of Thomson Gorge Road, via Ardgour Station (Ardgour Rise) is planned to provide public access through to the Manuherikia Valley.
- Main explosives magazines and emulsion mixing facilities (located outside the project site on Ardgour Terrace).
- The establishment of non-operational infrastructure associated with the BOGP on the Ardgour Terrace, including security, first aid and administrative offices, geology facilities, high voltage substation and temporary construction workers accommodation.
- The establishment of pest exclusion area(s) for ecological enhancement activities.

Resource consents required for the Project will include conditions pertaining to water quality compliance limits for receiving water environments (surface and groundwater). This report presents recommended water quality compliance limits that are considered appropriate and defensible for the local receiving environment (surface and ground water).

2. Receiving environments

2.1. Surface waters

2.1.1. Physical

There are several catchments within the Project footprint, and these have associated surface water features, some sections of which have been identified as being ephemeral, intermittent, perennial or spring (Figure 2). Physical descriptions of these surface water features are described in the report by Water Ways Consulting (2025¹). The primary streams within the Project footprint are Shepherds Creek, which drains into the outwash gravels to the west of the Dunstan Mountains and into the groundwater of the Ardgour aquifer adjacent to the Lindis River, and Rise and Shine Creek, which drains to Bendigo Creek which in turn drains into the gravels of the Bendigo aquifer except during periods of high rainfall. The Lindis River discharges into the Clutha River/Mata-Au not far upstream of the head of Lake Dunstan (formed by the construction of the Clyde Dam), and Bendigo Creek occasionally discharges directly into Lake Dunstan (Figure 3).

Water Ways Consulting (2025) undertook watercourse mapping over January-April 2024. A total watercourse length of 57.5 km was mapped within the Project area and in adjacent water courses. The mapping exercise found that ephemeral and intermittent reaches occurred in smaller tributaries and in the lower reaches of Bendigo Creek, Shepherds Creek and in two adjacent un-named Lindis River tributaries when flow paths left the Dunstan Range to flow across the Clutha and Lindis terraces (Figure 2). The downstream dry reaches were the result of water abstraction and/or the loss of surface water to groundwater as the streams flowed across porous alluvial deposits (Water Ways Consulting 2025).

¹ Water Ways Consulting. 2025. *Bendigo Ophir Gold Mine: Aquatic Assessment of Effects (draft report)*. Prepared for Santana Minerals Limited. Report Number 38-2024A.

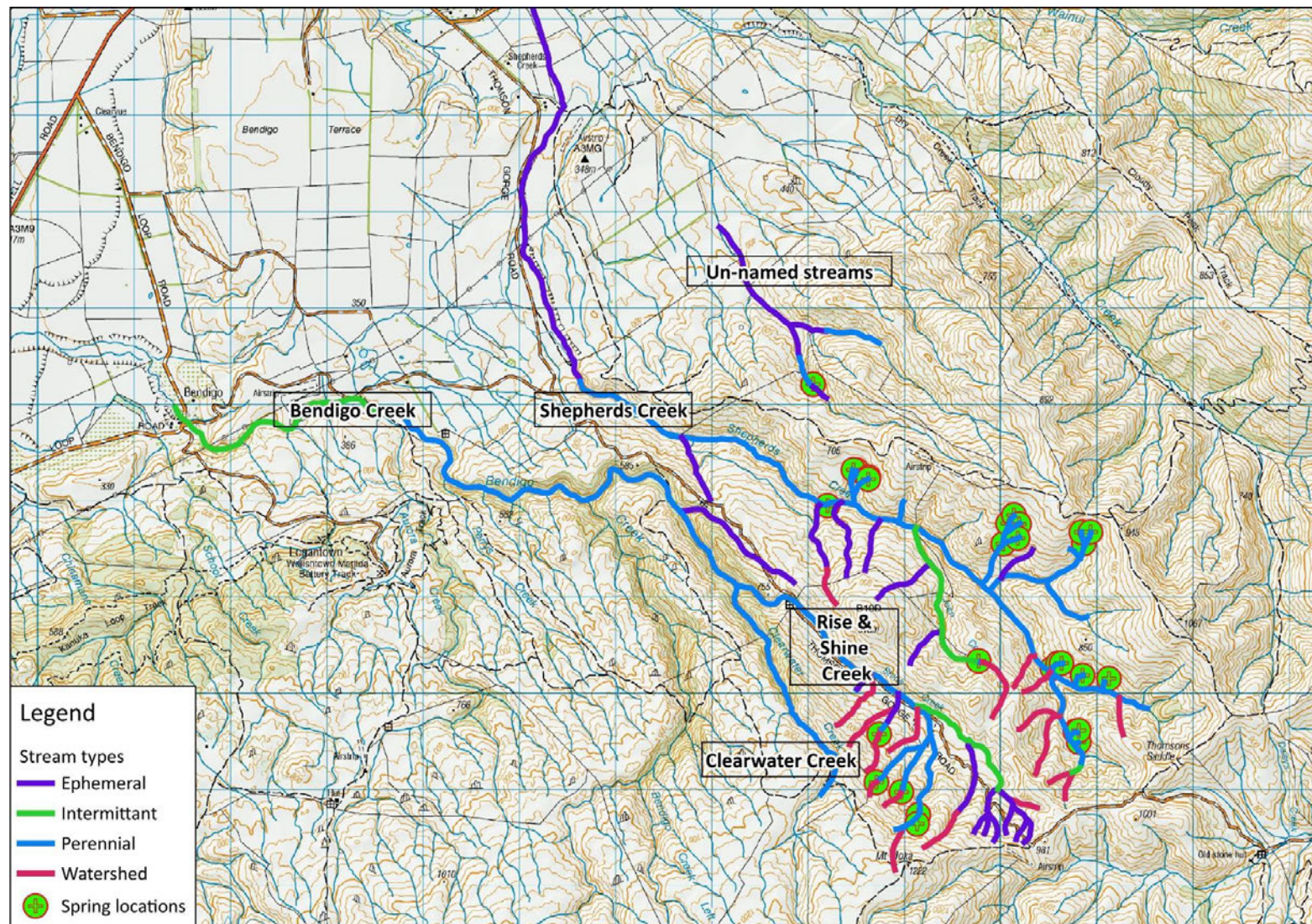


Figure 2. Mapped watercourses. (source: Water Ways Consulting 2025)

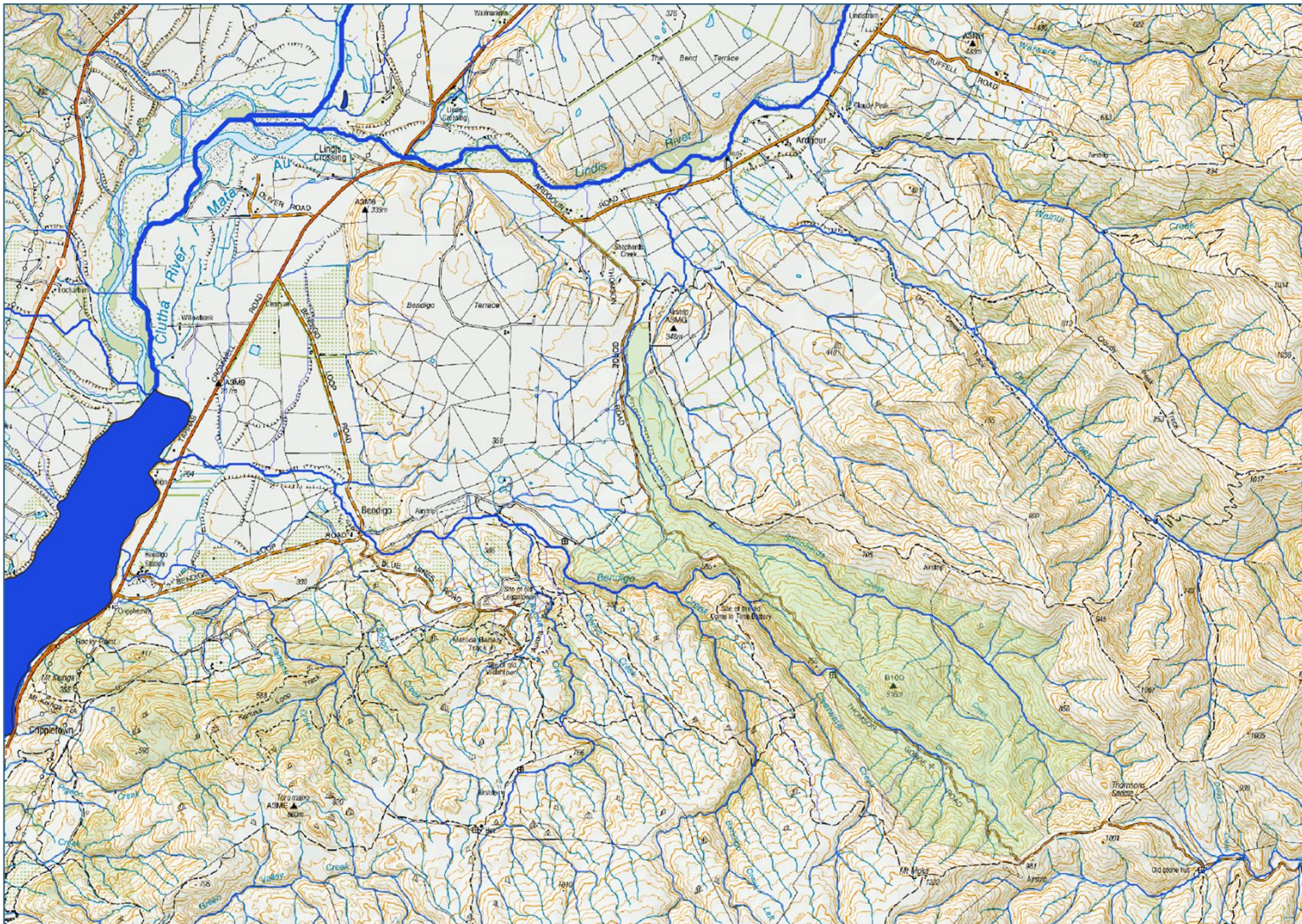


Figure 3. Map showing the BOGP boundary (shaded) and local surface water environments (some sections of which are ephemeral, intermittent or perennial – see Figure 2).

The upper section of Shepherds Creek is relatively unmodified with respect to hydrology. The mid-section reach has permanent flow, although this is low in the summer (<5 L/sec). The lower 4.8 km section has a highly modified flow regime due to abstraction for agriculture. Shepherds Creek flows through a narrow gorge onto a floodplain associated with the Lindis River Catchment. Prior to reaching the floodplain, there is an irrigation intake downstream of the BOGP SC01 monitoring site, which diverts water into an irrigation dam located further down the catchment. This water irrigates about 48 hectares of farmland. Surface flow beyond the irrigation intake largely enters the Ardour Alluvial Aquifer. Shepherds Creek not far downstream of the gorge is typically dry and there is usually no surface discharge from it into the Lindis River. It is at best an ephemeral water course and in the very lower reaches there is no evidence that a watercourse even exists.

2.1.2. Ecological values

Water Ways Consulting (2025) has estimated the loss of stream habitat as a result of the development of the BOGP. This includes intermittent, ephemeral, and perennial watercourses and watershed environments (i.e., the upper reaches of water courses that consist of terrestrial vegetation across the valley floor and no obvious channel features) (Table 1).

Table 1. Summary of the estimated length of stream lost in the BOGP footprint. (source: Water Ways Consulting 2025)

Effect	Stream type lost (m)				
	Ephemeral	Intermittent	Minor perennial order	Perennial 2 nd order +	Watershed
Stream length lost Shepherds Creek	4,474	1,631	1,236	5,903	1,4378
Stream length realigned Shepherds Creek	0	0	0	2,960	0
Stream length lost Rise and Shine Creek	700	0	305	1,092	0
Non-permanent stream length loss at soil storage areas	672	97	19	0	312

Significant sections of Shepherds Creek, Rise and Shine Creek, and Bendigo Creek, downstream of the confluence with Rise and Shine Creek, are degraded due to current and historic land use practices, along with the spread of undesirable species such as crack willow and *Lagarosiphon*. These ongoing impacts can be summarised as arising from:

- Past mining (largely pre-1900) altering watercourse physical character (channel straightening, sediment deposition, water races diverting water, small dams) and affecting water quality (discharges from workings, such as tailings and adits, including elevated metal concentrations).

- Past and current farming practices (general loss of natural freshwater habitat through water abstraction, pond creation, physical alteration of springheads for stock water access, general stock access to riparian margins creating bank erosion, pugging and direct nutrient inputs to water through defecation).
- Introduction of exotic species such as crack willow (binding bed gravels, etc), *Lagarosiphon* in the lower sections (choking waterways and outcompeting native aquatic plant species, also potentially affecting water quality such as dissolved oxygen and pH), introduced brown trout (potentially outcompeting native fish species) and rabbits (browsing riparian plants).

A total of 28 aquatic macroinvertebrate taxa were identified to species level in the eDNA sampling of sites throughout the Shepherds Creek and Bendigo Creek catchments (Water Ways Consulting 2025). Many sites surveyed had relatively low taxonomic richness, except in Bendigo Creek and upper Clearwater Creek. All species detected are classed as ‘not threatened’ under the Department of Conservation threat ranking classification for aquatic macroinvertebrates (Grainger *et al.* 2018²). Further, electric fishing, eDNA sampling and the stream walks all failed to detect any kōura (freshwater crayfish) and kākahi (freshwater mussel).

Fish populations are limited to brown trout in a short perennial reach of Bendigo Creek (in a ~ 1.5 km long reach immediately below of the Dunstan Mountains) and an eDNA signal for kōaro in Bendigo Creek upstream of the brown trout population, although the presence of kōaro does not appear to be that far upstream based on the results of electric fishing and eDNA sampling further upstream. Surveys of Rise and Shine Creek and Clearwater Creek did not detect any fish. Electric fishing and eDNA sampling in Shepherds Creek also did not detect the presence of any fish species.

Some natural fish barriers (which may be partial barriers only some native species that can climb, e.g., kōaro) are also a feature restricting fish species diversity in the mid to upper reaches of these watercourses. Further, loss of surface flow, either naturally (this is a low rainfall area with very warm summer temperatures) or exacerbated by human activities as described above, acts to limit stream habitat availability for many species. These are small creek environments.

Overall, the freshwater environment and freshwater ecological values within the mine BOGP are considered to be relatively low. This finding is based on:

- absence of fish communities;
- no rare or endangered freshwater invertebrate species present and some

² Grainger, N., Harding, J., Drinan, T., Collier, K., Smith, B., Death, R., Makan, T., Rolfe, J. 2018. *Conservation Status of New Zealand freshwater invertebrates, 2018*. New Zealand threat classification series 28. Department of Conservation, Wellington.

sections of watercourse having poor invertebrate community composition;

- surface water quality and physical habitat, including riparian habitat, that has been impacted by historic mining activities, stock grazing and invasive species.

2.2. Aquifer

Shepherds Creek does not make a surface (wet) connection with the downstream Lindis River, which is a tributary of the Clutha River / Mata Au. Instead, Shepherds Creek infiltrates into its bed and into the downstream Ardgour Valley Aquifer (i.e., a dry subsurface connection). The Shepherds Creek catchment contribution ultimately discharges into the Lindis River, via seepage, or is drawn into a small number of nearby private water bores.

The Ardgour Alluvial Aquifer is located in the Lindis River Valley between the Clutha River / Mata-Au and the small town of Tarras. The aquifer is bounded on the west by high glacial / post glacial terraces and on the east by the Dunstan Mountains.

KSL (2025³) report that an estimated 522,000 m³/yr of water enters the Ardgour Alluvial Aquifer from Shepherds Creek. This water then co-mingles with water from the Lindis River, and water from other Dunstan Mountain catchments, before discharging into the Lindis River and/or flowing parallel to the Lindis River and discharging into the Clutha River / Mata-Au.

Preliminary modelling of the aquifer by KSL (2025) suggests that there is limited dilution in the aquifer for any contaminants derived from the Shepherds Creek catchment.

³ KSL. 2025. *Post Closure Impacts of Bendigo Ophir Gold Deposit on the Ardgour Aquifer*. Report: Z24002.2 prepared by Kōmanawa Solutions Ltd for Matakānui Gold Ltd.

3. Receiving water quality consent compliance targets

3.1. Background

Potential sources of mine contaminants and Potential Constituents of Concern (“**PCOC**”) are detailed in reports prepared by MWM. MWM (2025a⁴) report that these effects will include:

- Elevated total suspended solids (“**TSS**”) in surface waters.
- Neutral metalliferous drainage (“**NMD**”) that may have elevated PCOC such as arsenic (As), sulphate (SO₄) and potentially lesser amounts of trace metals.
- Nitrate-rich (NO₃-N) drainage due to the use of Ammonium-Nitrate Fuel Oil (“**ANFO**”) explosives and cyanide (due to gold recovery) that may also include ammoniacal nitrogen.

3.2. Surface waters

There is a range of water quality guidelines and criteria that can assist to determine appropriate surface (receiving) water quality compliance limits for the BOGP.

Monitoring to date, as summarised in the MWM 2025 report⁵, indicates that some surface waters are already elevated in PCOC relative to some commonly adopted water quality guidelines/criteria, probably as a result of historic mining. MWM assessed surface and groundwater against the 95% ANZG (2018) default guideline values (DGVs) for the Project area sites, and for ammonia and nitrate toxicity, the 2020 National Policy Statement for Freshwater Management attribute states (2020 NPS-FM). This approach is sound and typically adopted in New Zealand when there are no alternative, commonly accepted, guideline values available, where no site-specific guidelines/criteria have been developed, or where there are no limits specified in regional water plans.

The ‘95%’ is a reference to the level of species protection, and this is often applied to ‘slightly to moderately disturbed ecosystems’. ANZG describe the attributes (ecosystem condition) of slightly to moderately disturbed freshwater ecosystems as:

Ecosystems 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 example, rural streams

⁴ MWM. 2025a. *Engineered Landform Water Quality Forecast Report*. Prepared for Matakanui Gold Limited. Document Number: J-NZ0457-002-Rev0

⁵ MWM. 2024a. *Baseline Water Quality Report*. Prepared for Matakanui Gold Limited. Document J-NZ0233-006-R-RevB

receiving runoff from land disturbed to varying degrees by grazing or pastoralism.

Arguably, the surface waters potentially affected by the Project are, currently, more adversely affected by human activities than that defined above under the ANZG 95% guidelines. However, the ANZG's next (degraded) level of ecosystem condition (90%) is 'highly disturbed systems', described as:

Measurably degraded ecosystems of lower ecological value. For example, shipping ports and sections of harbours serving coastal cities, urban streams receiving road and stormwater runoff, or rural streams receiving runoff from intensive horticulture.

While the Project area watercourses do not fit either of the examples cited in the ANZG examples above, they appear to be more than 'slightly to moderately' disturbed given the historic and current modifications and associated impacts on stream ecology described previously.

With respect to PCOC in water, such as dissolved metals, ammonia and nitrate, 90% species protection is considered an acceptable level of protection for these freshwater ecosystems given their historic and current level of disturbance. Some contaminants, such as sulphate, have no recognised ecological guidelines or water quality criteria in New Zealand and there is no ANZG default guideline value. Therefore, bespoke compliance limits have been developed based on local and international information.

3.3. Groundwater

Groundwater may be abstracted for pasture irrigation, and human and livestock drinking water. Some local groundwater will also find its way back to surface waters (Lindis River and Clutha River / Mata-Au).

Draft livestock drinking water guidelines were recently published by ANZG (ANZG 2023). The New Zealand Drinking Water Standards were recently updated (2022) along with the 2022 Aesthetic Values for Drinking Water Notice. All of these documents have been consulted when considering appropriate compliance limits for groundwater.

3.4. Recommended Surface and Groundwater compliance limits

Proposed surface water and groundwater quality compliance limits for the BOGP are summarised in Table 2 and Table 3 and compliance limits for individual contaminants are discussed below.

Table 2. Summary of recommended water quality compliance limits for BOGP surface water

PARAMETER (units are mg/L unless stated otherwise)	SURFACE WATER Recommended compliance limit(s)
pH (unitless)	6.5-9.0
Turbidity (NTU)	5 (over a 5-year rolling period, 80% of samples, when flows are at or below median flow, are to meet the limit)
Ammoniacal-nitrogen (NH ₃ -N)	≤0.24 (annual median) <0.4 (annual 95 th %) See Appendix A for adjustments
Nitrate-nitrogen (NO ₃ -N)	<2.4 (annual median) <3.5 (annual 95 th %)
Cyanide (CN ⁻)	0.011 (un-ionised HCN, measured as [CN], ANZG 2018) See Appendix A for adjustments
Sulphate (SO ₄ ²⁻)	A. If hardness is <100 mg/L (CaCO₃), the sulphate compliance limit = 500 mg/L. B. If chloride is <5 mg/L, the sulphate compliance limit = 500 mg/L C. If the hardness is 100–500 mg/L AND if chloride is 5–<25 mg/L, the sulphate compliance limit is (in mg/L): $[-57.478 + 5.79 * (\text{hardness mg/L CaCO}_3) + 54.163 * (\text{chloride mg/L})] * 0.65$ D. If hardness is between 100 and 500 mg/L AND if chloride is between ≥25 and ≤500 mg/L, the sulphate limit is (in mg/L): $[1276.7 + 5.508 * (\text{hardness mg/L CaCO}_3) + 1.457 * (\text{chloride mg/L})] * 0.65$ A minimum of 12 samples must be collected over any rolling 12-month period. For compliance limits in A to D, no more than 20% of samples collected over a rolling 12-month period may exceed the relevant compliance limit. E. An acute compliance limit = 1,000 mg/L averaged over 4 days and not to be exceeded more than once in a one-year period, OR in more than 10% of samples over a one-year period.
Aluminium (Al) (dissolved)	≤0.08
Antimony (Sb) (total)	0.074 (chronic) 0.250 (acute)

PARAMETER (units are mg/L unless stated otherwise)	SURFACE WATER Recommended compliance limit(s)
	See below
Arsenic (As(V)) (dissolved)	≤0.042
Cadmium (Cd) (dissolved)	≤0.0004 See below for adjustment algorithm
Chromium (Cr) (dissolved)	≤0.0033 (CrIII) ≤0.006 (CrVI) See below for adjustment algorithm
Cobalt (Co) (dissolved)	0.001 (chronic) 0.11 (acute, not to exceed) See below for adjustment algorithm
Copper (Cu) (dissolved)	≤0.0018
Molybdenum (dissolved)	≤0.034
Zinc (Zn) (dissolved)	0.015 See below for adjustment algorithm
Cd (dissolved)	HMTV = TV (H/30) ^{0.89} , where hardness-modified trigger value (HMTV) = (µg/L), trigger value (TV) (µg/L) at a hardness of 30 mg/L as CaCO ₃ ; H, measured hardness (mg/L as CaCO ₃) of a fresh surface water.
Cr (dissolved)	HMTV = TV (H/30) ^{0.82} , where hardness-modified trigger value (HMTV) = (µg/L), trigger value (TV) (µg/L) at a hardness of 30 mg/L as CaCO ₃ ; H, measured hardness (mg/L as CaCO ₃) of a fresh surface water.
Co (dissolved)	Cobalt (µg/L) = exp{[0.414[ln(hardness CaCO ₃ mg/L)] – 1.887}
Sb (total)	(chronic) the average of 5 (monthly) samples over a 5-month period (acute) not to be exceeded at any time
Zn (dissolved)	HMTV = TV (H/30) ^{0.85} , where hardness-modified trigger value (HMTV) = (µg/L), trigger value (TV) (µg/L) at a hardness of 30 mg/L as CaCO ₃ ; H, measured hardness (mg/L as CaCO ₃) of a fresh surface water.

Table 3. Summary of recommended water quality compliance limits for BOGP groundwater

PARAMETER (units are mg/L unless stated otherwise)	GROUNDWATER Recommended compliance limit(s)
Nitrate-nitrogen (NO ₃ -N)	11.3 (MAV)*
Cyanide (CN ⁻)	0.6 (MAV)
Sulphate (SO ₄ ²⁻)	≤250 (taste threshold)
Aluminium (Al)	1 (MAV)
Antimony (Sb)	0.02 (MAV)
Arsenic (As(V))	0.01 (MAV)
Cadmium (Cd)	0.004 (MAV)
Chromium (Cr)	≤0.05(MAV)
Cobalt (Co)	<1 (livestock drinking water)
Copper (Cu)	≤0.5
Iron (Fe)	≤0.3
Lead (Pb)	0.01 (MAV)
Manganese (Mn)	0.4 (MAV)
Molybdenum (Mo)	<0.01
Strontium (Sr)	4
Uranium (U)	0.03 (MAV)
Zinc (Zn)	≤1.5
* MAV = Maximum acceptable value – From NZ drinking water standards	

3.4.1. pH

During periods of active plant photosynthesis, dissolved carbon dioxide is taken up by aquatic plants and algae, and converted into organic matter, producing oxygen and consuming acid (H⁺). This causes the pH and dissolved oxygen to rise. The reverse happens at night when plants respire the oxygen produced during the day. These processes result in diurnal (daily) swings in pH and dissolved oxygen that can be quite significant depending on the amount of algae and plant biomass present.

The US EPA pH criteria for freshwater aquatic life of 6.5 to 9.0 is recommended as a consent compliance (pH as measured in the laboratory).

pH can also influence the toxicity of other compounds (e.g., ammonia) and so it is important that it is monitored at the same time other water quality parameters are monitored.

3.4.2. Water clarity and turbidity

Water clarity (as affected by suspended fine sediment) and fine sediment deposition on the creek bed can adversely affect stream ecosystem health through a variety of

mechanisms (Ryder 1989⁶).

Schedule 15⁷ of the Regional Plan: Water for Otago sets out the numerical limits and targets for achieving acceptable water quality for all catchments in the Otago region and includes limits for turbidity. The receiving water limits and targets are applied as five-year, 80th percentiles, when flows are at or below median flow.

The turbidity limit for the receiving water group that includes streams draining the BOGP footprint is 5 NTU and it is recommended that this is adopted as a consent compliance limit.

3.4.3. Ammonia (NH₄-N) and nitrate (NO₃-N) as toxic compounds

(i) Surface water

Currently, concentrations of ammoniacal nitrogen and nitrate nitrogen in surface waters associated with the Project area are relatively low or slightly elevated possibly due to stock access to creeks, but at much higher concentrations they can become toxic to aquatic life. Ammonia and nitrate compounds can be generated from mining operations through the use of explosives, and it is appropriate that consent compliance limits are set for both compounds.

The 2020 NPS-FM attribute states include national bottom lines for ammonia and nitrate toxicity to aquatic life, and it is appropriate that consent compliance limits are not set at concentrations below the national bottom line. **Therefore, the bottom of band B is the recommended compliance limit for ammonia and nitrate. In numerical terms these are:**

Compound	Annual median (mg/L)	Annual 95 th percentile (mg/L)
Ammoniacal-N ⁸	≤0.24	<0.40
Nitrate-N	<2.4	<3.5

Compliance limits for ammonia are based on pH 8 and temperature of 20°C. Assessments against the compliance limits above should be undertaken after pH adjustment, as Detailed in Appendix A, and Table A1.

The freshwater aquatic life compliance limit for nitrate is much lower than the compliance limit for livestock drinking water (see below) and should provide adequate

⁶ Ryder, G.I. 1989. *Experimental studies on the effects of fine sediments on lotic invertebrates*. PhD thesis, University of Otago, Dunedin, New Zealand.

⁷ Schedule of characteristics and numerical limits and targets for good quality water in Otago lakes and rivers.

⁸ Numeric attribute state is based on pH 8 and temperature of 20°C. Compliance with the numeric attribute states should be undertaken after pH adjustment.

protection for livestock that drink water from the affected creeks.

(ii) Groundwater

Nitrate can also be an issue in groundwater used for human and stock consumption.

The draft ANZG (2023) livestock drinking water guidelines state that, except for poultry, nitrate concentrations <100 mg/L in livestock drinking water should not be harmful to animal health⁹. This is equivalent to 22.6 mg/L of nitrate-N and is the recommended compliance limit for livestock, except for groundwater, where the human drinking water standard would apply (see below). Note that 1 mg/L nitrate-N = 4.43 mg/L nitrate.

The 2022 New Zealand Drinking Water Standard¹⁰ for nitrate-N is 11.3 mg/L and is the recommended consent compliance limit for groundwater monitoring sites associated with the BOGP. Note that the New Zealand drinking water limits for determinands¹¹ are referred to as maximum acceptable values (MAV) and should not be exceeded at any time.

3.4.4. Cyanide (CN)

(i) General

Cyanides are organic and/or inorganic compounds which contain the cyano group CN. The toxicity of cyanides is mainly through the inhibition of cellular respiration. The molecular HCN and ionic CN⁻ present or derived from dissociation of complexed or bound cyanides are the principal toxic forms to aquatic life. The binding of cyanide to haeme iron(III) of enzymes such as cytochrome oxidase, prevents electron transfer to molecular oxygen (ANZG 2018).

(ii) Surface water

Currently, the proposed surface water compliance sites SC01 and RS03 have had no samples exceeding the lab detection limits for total cyanide of <0.001 and <0.005 mg/L (the lab detection limit changed from <0.005 to <0.001 mg/L in May 2024). This means that the ANZG (2018) cyanide guideline for 90% species protection (0.011 mg/L for un-ionised HCN) is not threatened. Cyanide will be used to extract gold in the process circuit, which will be a closed loop, but at mine closure, a discharge will present to

⁹ ANZG. 2023. *Livestock drinking water guidelines (draft)*. Australian and New Zealand Guidelines for Fresh and Marine Water Quality. Australian and New Zealand Governments and Australian state and territory governments, Canberra.

¹⁰ Ministry of Health. 2008. *Drinking-water Standards for New Zealand 2005 (Revised 2008)*. Wellington: Ministry of Health. ISBN 978-0-478-31810-4

¹¹ A substance or characteristic that is measured or estimated in drinking water. These determinands are often related to chemical and physical properties, and their values must meet certain standards to ensure drinking water quality.

surface waters after drain down of the TSF.

It is recommended that testing for free cyanide is undertaken to assess against a recommended surface water compliance limit of 0.011 mg/L un-ionised HCN. pH and temperature would also need to be recorded to calculate the proportion of un-ionised HCN to free cyanide ($\text{HCN} + \text{CN}^-$) at ranges of 6.5 to 9.0 for pH and 10 to 30°C for temperature using the data in Appendix A, Table A2.

(iii) Groundwater

The 2022 New Zealand Drinking Water Standard for cyanide is 0.6 mg/L (MAV) and is the recommended consent compliance limit for groundwater monitoring sites associated with the BOGP.

3.4.5. Sulphate (SO_4^{2-})

(i) General

Sulphate is primarily generated in hard rock mining through the oxidation of sulphide minerals, especially pyrite (FeS_2) and other metal sulphides, which are commonly associated with gold deposits. When these sulphide minerals are exposed to oxygen and water, they undergo a chemical reaction that produces acid and dissolved sulphate. At the BOGP, it is expected the acidity is neutralised by carbonate minerals within the rock such that the pH of drainage is circum-neutral (MWM 2024b¹²).

(ii) Freshwater biota

There are no recognised freshwater aquatic life guidelines or criteria for sulphate in New Zealand, therefore overseas guidelines and standards have been considered, along with some local Otago ecotoxicology studies, both described below.

Sulphate toxicity is chloride and hardness dependent, becoming increasingly less toxic with increasing chloride and hardness (Elphick *et al.* 2011¹³). The State of Iowa undertook a review of sulphate in freshwater in 2009 (Iowa DNR¹⁴). Prior to then, the state had no water quality criteria for the protection of freshwater aquatic life for sulphate. However, the state did have a water quality guideline for livestock watering of 1,000 mg/L for sulphate. The state's revised guidelines included raising the guideline for livestock watering to 2,000 mg/L and a set of sulphate criteria for freshwater aquatic life

¹² MWM. 2024b. *Factual Report: Geoenvironmental Hazards – Bendigo-Ophir Gold Project*. MWM Report J-NZ0233-008-R-Rev0.

¹³ Elphick, JR., Davies, M., Gilron, G., Canaria, EC., Lo, BC., and Bailey, HC. 2011. *An aquatic toxicological evaluation of sulfate: the case for considering hardness as a modifying factor in setting water quality guidelines*. Environmental Toxicology and Chemistry, Vol. 30, No. 1, pp. 247–253.

¹⁴ Iowa DNR. 2009. *Water Quality Standards Review: Chloride, Sulfate and Total Dissolved Solids*. Iowa Department of Natural Resources

that accounted for chloride and hardness (Table 3). These were approved by the US EPA, and can be summarised as follows:

- the following sulphate standards must be met at all times when hardness (in mg/L as CaCO₃) and chloride (in mg/L) concentrations other than specified are present:
 - If the hardness concentration of water is less than 100 mg/L, or chloride concentration of water is less than 5 mg/L, the sulphate water quality standard is 500 mg/L.
 - If hardness concentration of water is greater than 500 mg/L, and the chloride concentration of water is equal to or greater than 5 mg/L, the sulphate standard is 2,000 mg/L.
- If the hardness concentration of water is between 100 mg/L and 500 mg/L, and if the chloride concentration of water ranges between 5 mg/L and less than 25 mg/L, the sulphate water quality standard is:

$$[-57.478 + 5.79 (\text{hardness}) + 54.163 (\text{chloride})] * 0.65$$

- If the hardness concentration (in mg/L as CaCO₃) of water is between 100 mg/L and 500 mg/L, and if the chloride concentration of water is between 25 mg/L and 500 mg/L, the sulphate water quality standard is:

$$[1276.7 + 5.508 (\text{hardness}) - 1.457 (\text{chloride})] * 0.65$$

Table 3. Sulphate criteria for Iowa waters (Iowa DNR 2009).

Water hardness (mg/L)	Chloride (mg/L)		
	Cl ⁻ < 5	5 ≤ Cl ⁻ < 25	25 ≤ Cl ⁻ ≤ 500
H < 100	500	500	500
100 ≤ H ≤ 500	500	$[-57.478 + 5.79 (\text{hardness}) + 54.163 (\text{chloride})] * 0.65$	$[1276.7 + 5.508 (\text{hardness}) - 1.457 (\text{chloride})] * 0.65$
H > 500	500	2,000	2,000

Iowa's sulphate criteria was also adopted by the state of Montana (Steinmetz 2014¹⁵). That state also added a chronic sulphate target of 129 mg/L. However, this is only applied when hardness is less than 50 mg/L.

An upper sulphate compliance limit of 2,000 mg/L appears to be too high for New

¹⁵ Steinmetz, A. 2014. *Translation and Guidance on Application of the Montana Narrative Water Quality Criterion for Sulfate*. Helena, MT: Montana Department of Environmental Quality.

Zealand streams based on local assessments described further below.

Concerned about the lack of water quality guidelines for sulphate, and the lack of data on chronic toxicity, Elphick *et al.* (2011) conducted chronic toxicity tests with sulphate using a variety of freshwater test organisms including algae, invertebrates and fish in British Columbia. Using a species sensitivity distribution (“**SSD**”) approach, they calculated suitable levels of protection of 644 mg/L and 725 mg/L for moderately hard water (80–100 mg/L) and hard water (160–250 mg/L), respectively.

Surface waters in the Shepherds Creek catchment have hardness that is currently well in excess of 100 mg/L. Hardness in Clearwater Creek is typically less than 20 mg/L, whereas in Rise and Shine Creek it typically ranges between 50 and 100 mg/L, although at some sites it is less than 50 mg/L (MWM data).

OceanaGold (NZ) Limited commissioned the University of Otago to undertake sulphate toxicity testing using sensitive life stages (eggs and larvae) of the local native flathead galaxias fish (*Galaxias depressiceps*), which is the dominant fish species in the small streams of the Macraes Gold Mine area in North Otago, and has a threat classification of ‘Threatened – Nationally Vulnerable’¹⁶. Testing ran for 50 days and showed no effects on growth or mortality at a sulphate concentration equivalent to the existing Macraes Gold Mine compliance limit for Deepdell Creek of 1,000 mg/L¹⁷. No fish have been recorded in streams within the BOGP footprint. Trout have been recorded downstream of the footprint in Bendigo Creek. Fish are present in Lake Dunstan, the Clutha River / Mata-Au and Lindis River (approximately 10 km and 5 km respectively from the BOGP footprint). However, there is no wet/surface connection between Bendigo Creek and the Clutha River / Mata-Au nor Shepherds Creek and the Lindis River under normal flow conditions.

MGL commissioned NIWA to assess the toxicity of sulphate to the ubiquitous New Zealand mayfly *Deleatidium* spp., a freshwater invertebrate taxa which is present in surface waters of the Bendigo-Ophir Gold Project area (Appendix B). *Deleatidium* is frequently used in toxicity testing for New Zealand freshwaters. It is an important bioindicator and regarded as a taxa relatively sensitive to poor water quality and physical habitat conditions. It is found throughout most streams and rivers in the country, is an important component of benthic communities and an important food source for freshwater fish.

The NIWA testing involved exposing mayfly larvae to a range of sulphate concentrations,

¹⁶ Dunn, NR., Allibone, RM., Closs, GP., Crow, SK., David, BO., Goodman, JM., Griffiths, M., Jack, DC., Ling, N., Waters, JM. and Rolfe, JR. 2018. *Conservation status of New Zealand freshwater fishes, 2017*. New Zealand Threat Classification Series 24. Department of Conservation, Wellington, New Zealand.

¹⁷ OceanaGold (NZ) Ltd. 2018. *Assessment of the potential impact of waste rock stack leachate on the early life cycle stages of the Taieri Flathead Galaxiid (Galaxias depressiceps)*.

along with control water, over a 96-hour exposure period (i.e., an acute toxicity test). The 96-hour survival test showed no progressive concentration-response relationship until greater than 775 mg/L¹⁸ sulphate concentration. Exposure to 2,435 mg/L sulphate at a hardness of 14 mg/L CaCO₃ significantly decreased *Deleatidium* survival. The test resulted in an EC₁₅ and EC₅₀ of 963 (854-966 95% confidence intervals) mg/L and 1,597 (1,506-1,614 95% confidence intervals) mg/L sulphate, respectively.

It is recommended that parts of the Iowa water quality criteria be modified as compliance limits for surface waters of the BOGP, with some additional limits to reflect conditions in New Zealand streams, as follows:

Chronic compliance limits:

A. If the hardness concentration (in mg/L as CaCO₃) of water is less than 100 mg/L, or chloride concentration of water is less than 5 mg/L, the sulphate water quality standard is 500 mg/L.

B. If the hardness concentration of water is between 100 mg/L and 500 mg/L and if the chloride concentration of water ranges between 5 mg/L and less than 25 mg/L the sulphate surface water quality compliance limit is:

$$\text{Sulphate (mg/L)} = [-57.478 + 5.79 (\text{hardness mg/L CaCO}_3) + 54.163 (\text{chloride mg/L})] * 0.65$$

C. If the hardness concentration of water is between 100 mg/L and 500 mg/L, and if the chloride concentration of water is between 25 mg/L and 500 mg/L, the sulphate water quality standard is:

$$\text{Sulphate (mg/L)} = [1276.7 + 5.508 (\text{hardness}) - 1.457 (\text{chloride})] * 0.65$$

A minimum of 12 samples must be collected over any rolling 12-month period. For compliance limits in A to C, no more than 20% of samples may exceed the relevant compliance limit.

Acute compliance limit:

D. The sulphate concentration shall not exceed 1,000 mg/L, averaged over 4 days and not to be exceeded more than once in a one year period, or in more than 10% of samples collected monthly over a 12 month period.

The acute compliance limit reflects the results of the *Deleatidium* mayfly toxicity testing results for sulphate. The adoption of a one year period (rather than three year as often

¹⁸ This concentration is the NOEC: the highest tested concentration causing 'No Observed Effect' relative to the controls.

used by the US EPA) for exceedances reflects the lack of fish populations in the immediate area (fish populations can take several years to recover from a significant decline in abundance) and that stream invertebrate communities can rapidly repopulate streams following physical or water quality disturbance, typically within one month or less (Ryder 1989).

With respect to the proposed acute compliance limit, averaged over 4 days, it is not practical to sample daily for sulphate. However, it has been demonstrated at the Macraes Gold Mine that there is very strong correlation in surface waters between electrical conductivity and sulphate concentration (i.e., r^2 values >0.98). This strong relationship opens the possibility of continuous monitoring of conductivity in receiving water using conductivity loggers and using conductivity readings as a surrogate for determining real-time sulphate concentration.

(iii) Stock drinking water

The draft ANZG (2023) livestock drinking water guidelines state that, except for poultry, sulphate concentrations <500 mg/L in livestock drinking water should not be harmful to animal health. These guidelines note that chronic exposure effects seem to start at sulphate concentrations of 1,000 mg/L and that chronic or acute health problems are expected at concentrations of 1,500–2,000 mg/L. **The recommend acute and chronic compliance limits for freshwater biota set out above will provide adequate protection for livestock that drink water from the affected creeks.**

(iv) Groundwater

Shepherds Creek does not make a surface connection with the downstream Lindis River, which is a tributary to the Clutha River/Mata-Au. Instead of a surface connection, Shepherds Creek infiltrates into its bed and into the downstream Ardgour Valley Aquifer (i.e., a dry subsurface connection). The Shepherds Creek catchment contribution ultimately discharges into the Lindis River via seepage or is drawn into a small number of nearby private water bores (KSL 2024¹⁹).

The 2022 NZ Drinking Water Standard for sulphate is 250 mg/L. **The recommended aquifer compliance limit for sulphate is 250 mg/L.** This is the taste threshold presented in the schedule of the New Zealand Aesthetic Values for Drinking Water Notice 2022 (issued under the Water Services Act 2021).

¹⁹ KSL. 2024. *Dry-Connection of Mine catchments to downstream alluvial aquifers*. Memo to Mary Asky, BOGP Water Management Group.

3.4.6. Metals and metalloids

(i) Aluminium (Al)

Elevated levels of aluminium can affect some species' ability to regulate ions, like salts, and inhibit respiratory functions, like breathing. Aluminium can accumulate on the surface of a fish's gill, leading to respiratory dysfunction, and possibly death. Aquatic plants are generally less sensitive to aluminium than fish and other aquatic life.

Monitoring has shown that dissolved aluminium concentrations are already relatively elevated and highest in the Rise and Shine catchment but less so in the Shepherds Creek catchment (the maximum recorded concentration at all surface water monitoring sites is 0.049 mg/L). Modelling of the ELF indicates aluminium may become elevated. Although this is likely to reprecipitate once it equilibrates in the sediment pond, a conservative approach has been adopted and a compliance limit for aluminium has been proposed.

The ANZG (2018) DGV for 95% freshwater species protection for dissolved aluminium (at pH >6.5) is 0.055 mg/L and the 90% species protection is 0.08 mg/L for Al with pH >6.5.

The recommended surface water compliance limit for dissolved aluminium is 0.08 mg/L.

The draft ANZG 2023 livestock drinking water guidelines state aluminium concentrations <5 mg/L in livestock drinking water should not be harmful to animal health. The 2022 NZ Drinking Water Standard for aluminium is 1 mg/L.

The recommended aquifer compliance limit for aluminium is 1 mg/L.

(ii) Antimony (Sb)

ANZG (2018) has a default freshwater guideline for antimony (Sb(III)) of 0.009 mg/L, based on one fish species tested, and that result (a 96-hour LC₅₀ of 9 – 12 mg/L) was applied with an assessment (safety) factor of 1000. There are no fish species present in surface waters of the BOGP area and the ANZG default guideline has an unknown level of species protection.

The British Columbia (BC) Ministry of Water, Land and Resource previously adopted the Australia and New Zealand's Sb guideline as a working water quality guideline ("WWQG") for the protection of freshwater aquatic life and natural ecosystem functions (ANZECC, 2000). However, since that time, additional studies have improved the understanding of Sb toxicity.

The BC 2023 guidelines²⁰ updated chronic long-term and acute short-term water quality guidelines (WQGs) for total Sb for the protection of freshwater aquatic life, are 0.074 and 0.250 mg/L, respectively. These are the recommended compliance limits for the surface waters compliance sites of the BOGP. The long-term chronic WQG represents a level which is predicted to protect all aquatic species from negative sub-lethal effects of Sb over indefinite exposures. The short-term acute guideline is designed to protect aquatic species from severe effects, such as lethality, and represents a level that should not be exceeded at any given time. **Note that the recommended compliance limits are based on total Sb concentration²¹.**

The 2022 Drinking Water standards for New Zealand has a MAV for antimony of 0.02 mg/L and this is the recommended compliance limit for groundwater at BOGP aquifer monitoring sites.

(iii) Arsenic (As)

Results from Rise and Shine Creek water quality monitoring indicated elevated arsenic concentrations, which may be due to historic gold mining activities or enhanced arsenic export due to local geology. Arsenic (III) and arsenic (V) are the most common forms of arsenic.

ANZG (2018) water quality guidelines for 90% species protection are 0.094 mg/L for As(III) and 0.042 mg/L for As(V). **The recommended compliance limit for BOGP surface water monitoring sites is 0.042 for dissolved As(V) and, if this is exceeded, test again for both As(V) and As(III).** The 90% level of species protection recognises the already elevated As level in local surface waters.

The 2022 Drinking Water standards for New Zealand has a MAV for arsenic of 0.01 mg/L and this is the recommended compliance limit for groundwater at BOGP aquifer monitoring sites.

(iv) Boron (B)

MWM report that boron could potentially be elevated in the ELF seepage water. It is proposed that performance monitoring is undertaken at locations where boron could be elevated (e.g., ELF and TSF seepage). If boron is identified as requiring management, then it is recommended that compliance limits should be set during the operational phase of the BOGP.

²⁰ B.C. Ministry of Water, Land and Resource Stewardship 2023. *Antimony water quality guidelines for the protection of freshwater aquatic life*. Water Quality Guideline Series, WQG-21. Prov. B.C., Victoria B.C.

²¹ Generally, for metals, the dissolved fraction is shown to cause adverse effects and be a better representative of toxicity compared total concentration, however, this phenomenon is not demonstrated for Sb (BC 2023 guidelines).

(v) Cadmium (Cd)

Water quality monitoring has shown that cadmium concentrations are generally low in surface waters associated with the BOGP, however it was elevated in the Lower Bendigo Adit. **The ANZG (2018) water quality guideline water quality guideline for 90% species protection is 0.0004 mg/L and is the recommended compliance limit for BOGP surface water monitoring sites.** The trigger has been calculated using a hardness of 30 mg/L CaCO₃, and should be adjusted to the site-specific hardness using the following algorithm²²:

Cadmium HMTV = Cadmium TV (H/30)^{0.89} where:

HMTV is the hardness-modified trigger value in µg/L;

TV is the trigger value (in µg/L) at a hardness of 30 mg/L as CaCO₃;

H is the measured hardness (mg/L as CaCO₃) of the surface water sample.

The Drinking Water standards for New Zealand has a MAV for cadmium of 0.004 mg/L and this is the recommended cadmium compliance limit for groundwater at BOGP aquifer monitoring sites.

(vi) Chromium (Cr)

Water quality monitoring has shown that chromium concentrations were elevated at some surface waters monitoring sites and the Lower Bendigo Adit relative to default ANZG values. ANZG (2018) water quality guidelines for 90% species protection are 0.0033 mg/L for dissolved Cr(III) and 0.006 mg/L for dissolved Cr(VI). **The ANZG (2018) water quality guideline for 90% species protection are the recommended compliance limit for BOGP surface water monitoring sites.**

Hardness correction algorithms²³ used to convert chronic toxicity data for chromium(III) at a given test water hardness to a hardness (H) of 30 mg CaCO₃/L are recommended as follows:

Chromium HMTV (µg/L) = Chromium TV (µg/L) / (H (mg/L)/30)^{0.82}

The Drinking Water standards for New Zealand has a provisional MAV for total chromium of 0.05 mg/L and this is the recommended chromium compliance limit

²² ANZECC & ARMCANZ. 2000. Australian and New Zealand Guidelines for Fresh and Marine Water Quality. Volume 1: The Guidelines.

²³ Warne, MStJ., Batley, GE., van Dam, RA., Chapman, JC., Fox, DR., Hickey, CW., & Stauber, JL. 2018. *Revised method for deriving Australian and New Zealand water quality guideline values for toxicants - update of 2015 version*. Prepared for the Australian and NZ Guidelines for Fresh and Marine Water Quality.

for groundwater at BOGP aquifer monitoring sites.

(vii) Cobalt (Co)

SEM-EDS mineralogy reports identify cobaltite a (As, Co) sulfide mineral as being present. Cobalt was elevated at one groundwater monitoring site on one occasion, which aligns with the elevated Co in the geohazard testing. Elsewhere, cobalt was well below relevant guidelines by at least one order of magnitude. However, a compliance limit is recommended for cobalt in receiving surface and ground waters based on the potential for it to become present in water.

(i) Surface water

The ANZG (2018) guidelines recommend a trigger level of 0.0014 mg/L (1.4 µg/L), however the level of species protection is unknown.

The Canadian Federal Environmental Quality Guidelines (FWQG) (2017) for cobalt recommend a freshwater aquatic life guideline value (for chronic toxicity) of 0.001 mg/L (1µg/L) for waters that have hardness of 100 mg/L, and this is recommended as a consent compliance limit for surface waters. For other hardness values between 52-396 mg/L, the guideline can be calculated with the following algorithm:

$$\text{FWQG for Cobalt} = \text{EXP}((0.414 * \text{LN}(\text{Hardness})) - 1.887)$$

where: FWQG for Cobalt is in µg/L and Hardness in in mg/L CaCO₃

The FWQG for Cobalt (chronic toxicity) aligns reasonably well with the ANZG (2018) DVG. I note that Nagpal (2004) also recommends an interim acute (maximum, or not to exceed concentration) guideline of 110 µg/L (0.11 mg/L). **It is recommended that this be included as a compliance limit for surface waters.**

(ii) Groundwater

A recommended compliance limit for cobalt with respect to livestock comes from the draft 2023 livestock drinking water guidelines. **The recommended compliance limit is <1 mg/L for total cobalt and this would also apply to groundwater used for livestock drinking water.** The guidelines state that the limit should not be harmful to animal health, however, if livestock diets are high in cobalt, the concentration in drinking water should be reduced.

(viii) Copper (Cu)

Water quality monitoring has shown that copper concentrations were elevated at some surface and groundwater monitoring sites on some occasions relative to ANZG default

(95%) values. **The ANZG (2018) water quality guideline for 90% species protection 0.0018 mg/L are the recommended compliance limit for BOGP surface water monitoring sites.**

The 2022 Drinking Water standards for New Zealand has a MAV for dissolved copper of 2 mg/L, while the ANZG draft 2023 livestock drinking water guidelines state that the following copper concentrations should not be harmful to animal health:

- <0.5 mg/L for sheep
- <1 mg/L for cattle
- <5 mg/L for pigs and poultry.

These guidelines also advise that if livestock diets are high in copper, the concentration in stock drinking water should be reduced.

It is recommended that a dissolved copper compliance limit of <0.5 mg/L, being the most conservative limit, is used for groundwater at BOGP aquifer monitoring sites.

(ix) Iron (Fe)

Iron precipitates can affect stream communities in a number of ways including by smothering bed substrate and reducing light penetration.

ANZG (2018) state that there is insufficient data to derive a reliable freshwater trigger for iron, but suggests the current Canadian freshwater guideline level of 0.3 mg/L (total iron) could be used as an interim indicative working level, although further data are required to establish a figure appropriate for New Zealand waters. This guideline level is recommended in other North American states. Total iron concentrations are already higher than this interim guideline level at a number of BOGP surface and ground water monitoring sites. **It is recommended that iron be monitored at surface water compliance monitoring sites, and if a 20% increase in average concentration is detected, a review of the most recent water quality international guidelines is undertaken. This review would inform whether there have been any revisions of guidelines relevant to iron that indicate that adverse effects on surface water biota is occurring.**

The draft ANZG 2023 livestock drinking water guidelines state there is no guideline value for iron in livestock drinking water because it poses a very low risk to animal health. Similarly, there is no New Zealand drinking water standard. **The US EPA has a ‘Secondary Drinking Water Regulation’ (non-enforceable Federal guidelines regarding cosmetic effects, such as tooth or skin discoloration, or aesthetic**

effects, such as taste, odour, or colour of drinking water) for iron of 0.3 mg/L²⁴, and this is recommended for groundwater at BOGP aquifer monitoring sites.

(x) Lead (Pb)

Lead concentrations are low at all BOGP surface and groundwater monitoring sites and are at least one order of magnitude lower than the ANZG (2018) DGV for freshwater of 0.0034 mg/L for 95% species protection. There does not appear to be any proposed mining activity that would significantly elevate lead concentrations in receiving waters higher than current levels, **therefore no consent compliance limit is recommended for lead in surface waters with respect to freshwater ecology.**

The draft ANZG 2023 livestock drinking water guidelines state that lead concentrations >0.1 mg/L in livestock drinking water may be hazardous to animal health. However, they go on to state that lead is accumulative, and problems may begin at concentrations of 0.05 mg/L. ANZG (2023) recommend that the ANZECC (1992) guideline value of 0.1 mg/L for lead is retained in the absence of contradicting information, and this is recommended for stock drinking water (surface or ground water).

The 2022 Drinking Water standards for New Zealand has a provisional MAV for dissolved lead of 0.01 mg/L and this is the recommended lead compliance limit for groundwater at BOGP aquifer monitoring sites. This limit would override the livestock human drinking water compliance limit if both forms of consumption were utilised.

(xi) Manganese (Mn)

Manganese is widely distributed in the earth's crust and is an essential trace element for microorganisms, plants and animals (ANZG 2018). Its toxicity is low compared to other trace metals and toxicity to brown trout decreased significantly with increasing hardness (Stubblefield *et al.* 1997²⁵).

Manganese was elevated in only one sample collected as part of the BOGP monitoring programme. All other samples were below the ANZG (2018) water quality guideline for 90% species protection of 2.5 mg/L, typically by several orders of magnitude. There is no indication that the mining activities will elevate manganese concentrations beyond their current levels, **therefore it is recommended that a compliance limit for manganese in surface water is not required. The 2022 New Zealand Drinking Water Standard for manganese is 0.4 mg/L and is the recommended consent compliance**

²⁴ US EPA. 2012. *2012 Edition of the Drinking Water Standards and Health Advisories*. EPA 822-S-12-001.

²⁵ Stubblefield, WA., Brinkman, SE., Davies, PH., Garrison, TD., Hockett, JR., & McIntyre, MW. 1997. *Effects of water hardness on the toxicity of manganese to developing brown trout (Salmo trutta)*. Environmental Toxicology and Chemistry 16, 2082–2089.

limit for groundwater monitoring sites associated with the BOGP.**(xii) Molybdenum (Mo)**

Molybdenum is a heavy metal. Its concentrations are low at all BOGP surface and groundwater monitoring sites. However, modelling by MWM determined that it is likely to become elevated in seepage water from ELFs and therefore a PCOC (MWM 2025).

ANZG (2018) states there were not sufficient freshwater data for molybdenum to derive either a high or moderate reliability guideline trigger value, hence a freshwater low reliability trigger value of 0.034 mg/L (34 µg/L) was determined for molybdenum using an assessment factor (AF) of 20, **and this is the recommended compliance limit for the surface waters compliance sites of the BOGP.**

The 2022 Drinking Water standards for New Zealand has no recommended value for molybdenum.

The draft ANZG 2023 livestock drinking water guidelines state that molybdenum concentrations <0.01 mg/L in livestock drinking water should not be harmful to animal health, depending on total dietary intake of molybdenum, copper, iron and sulfur. **It is recommended that a molybdenum compliance limit of <0.01 mg/L is used for groundwater at BOGP aquifer monitoring sites to protect livestock drinking water.**

(xiii) Selenium (Se)

A major source of selenium in the environment is weathering of rocks and soils, and this can be exacerbated through mining. ANZG (2018) default guidelines are available for selenium. ANZG presents a freshwater high reliability trigger value of 0.011 mg/L for Se (total) using the statistical distribution method at 95% protection, and a 90% protection level of 0.018 mg/L.

The 2022 Drinking Water standards for New Zealand has a MAV of 0.04 mg/L for selenium.

The draft ANZG 2023 livestock drinking water guidelines recommend a guideline value of 0.02 mg/L for total selenium in livestock drinking water.

Total selenium concentrations at all BOGP surface and groundwater monitoring sites are below the laboratory detection limit of 0.001 mg/L (which was the detection limit used in the most recent lab testing). The laboratory detection limit of 0.001 mg/L is an order of magnitude lower than the ANZG (2018) water quality guideline for 90% species protection (0.018 mg/L), the NZ MAV drinking water standard (0.04 mg/L) and the draft ANZG 2023 livestock drinking water guideline (0.02 mg/L).

There is no indication that proposed mining activities will increase selenium concentrations in surface and ground waters, therefore **no consent compliance limit is recommended for selenium in surface or ground waters.**

(xiv) Strontium (Sr)

Strontium is rarely analysed in New Zealand waters and is typically regarded as a trace element, however it has been found to be elevated in some groundwater samples collected from the BOGP area, although not in surface waters. There is a risk that, with dewatering of the mine pits and underground seepage, the flow to groundwater could increase.

There are no recognised New Zealand guidelines for strontium. **The US EPA (2012²⁶) has a lifetime health advisory of 4 mg/L for strontium in drinking water and this is the recommended compliance limit for the Ardour Aquifer BOGP compliance monitoring sites.**

(xv) Thallium (Tl)

Historically, thallium has not been an issue in NZ, however the concentration exceeded the ANZG (2018) DGV of 0.00003 mg/L (level of species protection unknown) at groundwater monitoring site MDD015 when sampled in April 2024. This DGV is regarded as a low reliability trigger value. Surface water monitoring sites recorded thallium concentrations of 0.00005 mg/L, however the laboratory detection limit (reporting limit) was 0.0001 mg/L and so, presumably, the results were reported as half the lab detection limit (0.00005 mg/L), which is greater than the DGV of 0.00003 mg/L.

The USEPA (1980) report that data for thallium indicate that acute and chronic toxicity to freshwater aquatic life occurs at concentrations as low as 1.4 and 0.04 mg/L, respectively (at a hardness of 100 mg/L CaCO₃). These concentrations are much higher than the ANZ DGV.

The draft ANZG 2023 livestock drinking water guidelines has no guideline value for thallium, and similarly there is no New Zealand drinking water standard for thallium.

It seems that thallium is unlikely to be a water quality issue with respect to the surface and ground waters affected by the BOGP. However, it is recommended that it be monitored as a part of the performance monitoring programme.

²⁶ US EPA. 2012. *2012 Edition of the Drinking Water Standards and Health Advisories*. EPA 822-S-12-001 Office of Water U.S. Environmental Protection Agency Washington, DC.

(xvi) Uranium (U)

Water quality monitoring has shown that uranium is naturally elevated in some waters within the mine footprint. There are no recommended New Zealand freshwater guidelines for uranium. ANZG (2018) DGV provides a freshwater low reliability trigger value of 0.5 µg/L, which was calculated using an AF of 20 on limited chronic data. This guideline is much lower than the chronic limit from the Canadian Council of Ministers of the Environment (2011²⁷) of 0.015 mg/L (15 µg/L).

The concentrations of uranium found in surface waters within the mine footprint are slightly elevated relative to the ANZG default guideline, but much lower than the Canadian guideline. **There is no indication that the mining activities will elevate uranium concentrations beyond their current levels, therefore it is recommended that a compliance limit for uranium in surface water is not required but be included in the performance monitoring programme. The 2022 New Zealand Drinking Water Standard for uranium is 0.03 mg/L and is the recommended consent compliance limit for groundwater monitoring sites associated with the BOGP.**

(xvii) Vanadium (V)

MWM report that vanadium could potentially be elevated in the ELF seepage water. It is proposed that performance monitoring is undertaken at locations where vanadium could be elevated (e.g., ELF and TSF seepage). If vanadium is identified as requiring management, then it is recommended that compliance limits should be set during the operational phase of the BOGP.

(xviii) Zinc (Zn)

Water quality monitoring has shown that dissolved zinc concentrations were elevated at some surface and groundwater monitoring sites on some occasions relative to ANZG default (95%) values.

The ANZG (2018) water quality guideline for 90% species protection 0.015 mg/L is the recommended compliance limit for BOGP surface water monitoring sites.

The draft ANZG 2023 livestock drinking water guidelines state that a zinc concentration of <20 mg/L should not be harmful to animal health. **The New Zealand Water Services Authority (Taumata Arowai) has a drinking water aesthetic value for zinc of ≤1.5 mg/L (taste threshold)²⁸ and this is the recommended compliance limit for**

²⁷ Canadian Council of Ministers of the Environment, 2011. *Canadian water quality guidelines for the protection of aquatic life: Uranium*. In: *Canadian environmental quality guidelines, 1999*. Canadian Council of Ministers of the Environment, Winnipeg.

²⁸ <https://www.taumataarowai.govt.nz/assets/Uploads/Acceptable-Solutions-etc/Drinking-Water-Aesthetic-Values.pdf>

groundwater at BOGP aquifer monitoring sites.

3.5. Proposed compliance monitoring sites

Proposed surface water and groundwater monitoring sites are shown in Figure 4. Monthly monitoring is recommended.

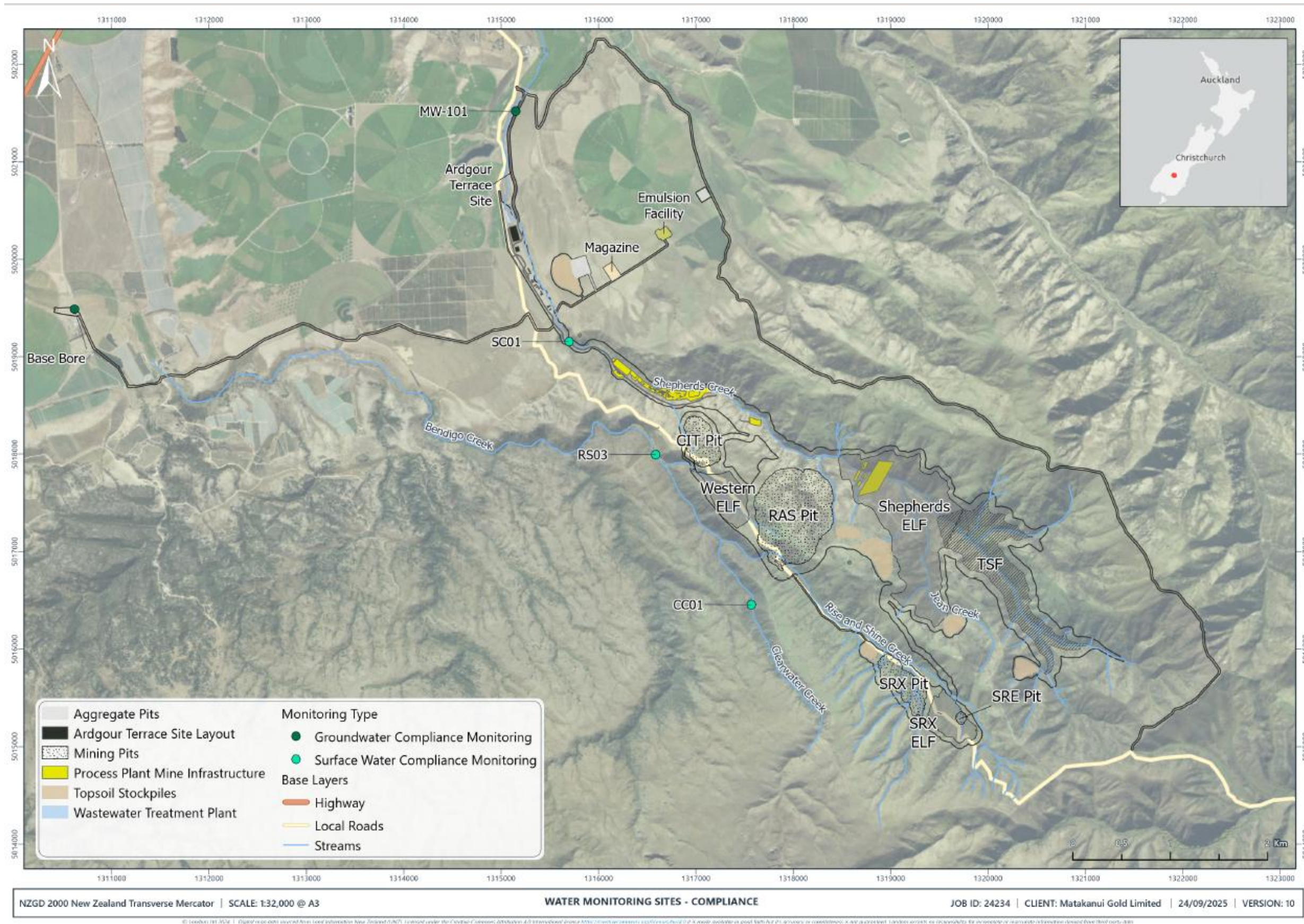


Figure 4. BOGP proposed compliance sites for surface water and groundwater.

4. Conclusion

Water quality compliance limits are recommended to establish acceptable quantifiable thresholds for various chemical indicators of water quality. They are essential tools for managing human impacts and ensuring freshwater ecosystems, stock water and drinking water remain safe.

Catchments within the Project footprint have relatively small surface water features, which drain to either Bendigo Creek or the Lindis River. In both cases, surface flow typically does not make it all the way to surface waters further downstream. For example, once Shepherds Creek reaches the floodplain associated with the Lindis River catchment, the watercourse is typically dry and there is usually no surface discharge from it into the Lindis River. It is at best an ephemeral water course and in the very lower reaches there is no evidence that a water course even exists. Bendigo Creek drains into the gravels of the Bendigo aquifer, except during periods of high rainfall, and only occasionally discharges directly into Lake Dunstan.

Surface waters within the BOGP footprint include sections that are ephemeral, intermittent and perennial, supporting varying ecological values. Significant sections of these streams are degraded due to current and historic land use practices (agricultural and historic mining practices), along with the spread of undesirable species such as crack willow and *Lagarosiphon*, and mammalian pests.

Overall, the freshwater environment and freshwater ecological values within the mine BOGP are considered to be relatively low.

A number of watercourses within the Project area appear to be more than 'slightly to moderately' disturbed, as defined under the ANZG (2018) water quality guidelines. Therefore, with respect to COPC in water, such as dissolved metals, ammonia and nitrate, 90% species protection is considered an acceptable level of protection for these freshwater ecosystems given their historic and current level of disturbance.

Some contaminants, such as sulphate, have no recognised ecological guidelines or water quality criteria in New Zealand and there is no ANZG default guideline value. Therefore, bespoke compliance limits have been developed based on local and international information.

Compliance limits for groundwater reflect the potential use for pasture irrigation, and human and livestock drinking water.

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APPENDIX A

Ammonia adjustment calculations

(adapted from: MfE 2018²⁹)

pH adjustment means calculating the amount of NH₄-N at pH 8 that would have the equivalent toxicity to the amount of NH₄-N measured in the sample at the pH of the sample –whatever that may have been. That is, the calculation produces the concentration of NH₄-N which at pH 8 would have the same toxicity as the observed (i.e., unadjusted) NH₄-N concentration would have at the observed pH.

The information in Table A3 allows the ammonia concentration of a sample to be converted to an equivalent concentration at pH 8 using the following equation:

$$Conc_{pH8} = Conc_{pH\ sample} / Ratio \quad \text{Equation (1)}$$

Where $Conc_{pH\ sample}$ is the concentration of the sample and $Ratio$ is read from Table A3 for the given sample pH.

For example, if a sample was observed with 1.12 mg NH₄-N/L at pH 7.5, the adjusted concentration to use in calculating sample statistics would be 0.63 mg NH₄-N/L at pH 8. This is derived as follows:

Using equation (1) and Table A3:

$$Conc_{pH8} = 0.63 = 1.12 / 1.79$$

Where the numerator (1.12) is the observed sample concentration, and the denominator (1.79) is the Ratio from Table A3 at pH of 7.5.

That is, although there is still 1.12 mg/L of NH₄-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 NH₄-N concentration of 0.63 mg/L at pH 8. It is the **equivalent toxicity** that has been adjusted, and not the amount of NH₄-N present in the sample (which remains unchanged). Note that a method for converting to standard temperature is not currently available.

²⁹ Ministry for the Environment. 2018. A Guide to Attributes in Appendix 2 of the National Policy Statement for Freshwater Management (as amended 2017). Wellington: Ministry for the Environment. Publication number: ME 1346

Table A1. Conversion ratios for pH adjustment of ammonia concentrations.

Sample pH	Ratio
6.0	2.86
6.1	2.84
6.2	2.82
6.3	2.80
6.4	2.77
6.5	2.73
6.6	2.70
6.7	2.64
6.8	2.59
6.9	2.51
7.0	2.42
7.1	2.32
7.2	2.21
7.3	2.09
7.4	1.94
7.5	1.79
7.6	1.63
7.7	1.47
7.8	1.31
7.9	1.14
8.0	1.00
8.1	0.87
8.2	0.73
8.3	0.62
8.4	0.53
8.5	0.44
8.6	0.38
8.7	0.32
8.8	0.27
8.9	0.23
9.0	0.20
>9	0.20

Cyanide - calculated percentages of un-ionised hydrogen cyanide in aqueous cyanide solutions

Table A2. Calculated percentages of un-ionised hydrogen cyanide in aqueous cyanide solutions [HCN + CN⁻]. (source: ANZG 2018)

Temp. (°C)	pH																									
	6.5	6.6	6.7	6.8	6.9	7.0	7.1	7.2	7.3	7.4	7.5	7.6	7.7	7.8	7.9	8.0	8.1	8.2	8.3	8.4	8.5	8.6	8.7	8.8	8.9	9.0
10.0	99.9	99.9	99.9	99.8	99.8	99.7	99.6	99.5	99.41	99.3	99.1	98.8	98.5	98.2	97.7	97.1	96.4	95.5	94.4	93.1	91.4	89.4	87.0	84.2	80.9	77.1
12.5	99.9	99.9	99.8	99.8	99.7	99.7	99.6	99.5	99.3	99.2	99.0	98.7	98.4	97.9	97.4	97.8	96.0	95.0	93.8	92.3	90.4	88.3	85.7	82.6	79.0	75.0
15.0	99.9	99.9	99.8	99.8	99.7	99.6	99.5	99.4	99.3	99.1	98.8	98.5	98.2	97.7	97.1	96.4	96.5	94.4	93.0	91.4	89.4	87.0	84.2	80.9	77.0	72.7
17.5	99.9	99.8	99.8	99.7	99.7	99.6	99.5	99.3	99.2	99.0	98.7	98.4	97.9	97.4	96.8	96.0	95.0	93.7	92.3	90.4	88.3	85.7	82.6	79.0	75.0	70.4
20.0	99.9	99.8	99.8	99.7	99.6	99.5	99.4	99.3	99.1	98.8	98.5	98.2	97.7	97.1	96.4	95.5	94.4	93.1	91.4	89.4	87.0	84.2	80.9	77.1	72.8	68.0
22.5	99.8	99.8	99.7	99.7	99.6	99.5	99.3	99.2	99.0	98.7	98.4	98.0	97.4	96.8	96.0	95.0	93.8	92.3	90.5	88.3	85.7	82.7	79.1	75.1	70.5	65.5
25.0	99.8	99.8	99.7	99.6	99.5	99.4	99.3	99.1	98.8	98.5	98.2	97.7	97.1	96.4	95.6	94.5	93.1	91.5	89.5	87.2	84.4	81.1	77.3	73.0	68.2	63.1
27.5	99.8	99.7	99.7	99.6	99.5	99.4	99.2	99.0	98.7	98.4	98.0	97.5	96.8	96.0	95.1	93.9	92.4	90.6	88.5	85.9	82.9	79.4	75.4	70.9	65.9	60.5
30.0	99.8	99.7	99.6	99.5	99.4	99.3	99.1	98.9	98.6	98.2	97.8	97.2	96.5	95.6	94.6	93.2	91.6	89.7	87.4	84.6	81.4	77.6	73.4	68.6	63.5	58.0

Sulphide - calculated percentages of un-ionised hydrogen sulphide in total aqueous sulphide solutions

Table A3. Calculated percentages of un-ionised hydrogen sulphide in total aqueous sulphide solutions. (source: ANZG 2018)

Temp (°C)	pH																				
	6.5	6.6	6.7	6.8	6.9	7.0	7.1	7.2	7.3	7.4	7.5	7.6	7.7	7.8	7.9	8.0	8.1	8.2	8.3	8.4	8.5
10.0	82.4	78.8	74.7	70.1	65.0	59.6	54.0	48.2	42.5	37.0	31.8	27.1	22.8	19.0	15.7	12.9	10.5	8.52	6.89	5.55	4.46
12.5	81.0	77.2	72.9	68.2	63.0	57.5	51.8	46.0	40.4	35.0	29.9	25.3	21.2	17.6	14.5	11.9	9.69	7.85	6.34	5.10	4.10
15.0	79.7	75.7	71.2	66.3	60.9	55.3	49.6	43.9	38.3	33.0	28.1	23.7	19.8	16.4	13.5	11.0	8.96	7.25	5.84	4.70	3.77
17.5	78.3	74.1	69.5	64.4	58.9	53.3	47.5	41.8	36.4	31.2	26.5	22.3	18.5	15.3	12.5	10.2	8.30	6.71	5.40	4.34	3.48
20.0	76.9	72.5	67.7	62.5	57.0	51.3	45.5	39.9	34.5	29.5	25.0	20.9	17.3	14.3	11.7	9.51	7.71	6.22	5.01	4.02	3.22
22.5	75.5	71.0	66.0	60.7	55.1	49.3	43.6	38.0	32.8	27.9	23.5	19.6	16.3	13.4	10.9	8.87	7.13	5.78	4.65	3.73	2.98
25.0	74.1	69.4	64.3	58.9	53.2	47.4	41.8	36.3	31.2	26.4	22.2	18.5	15.3	12.5	10.2	8.28	6.69	5.39	4.33	3.47	2.78
27.5	72.7	67.8	62.6	57.1	51.4	45.7	40.0	34.6	29.6	25.1	21.0	17.4	14.4	11.8	9.56	7.75	6.26	5.03	4.04	3.24	2.59
30.0	71.3	66.3	61.0	55.4	49.7	43.9	38.4	33.1	28.2	23.8	19.9	16.5	13.5	11.1	8.98	7.27	5.86	4.71	3.78	3.03	2.42

APPENDIX B

Sulfate toxicity to *Deleatidium* sp. mayfly nymph

Prepared for Santana Minerals Ltd

November 2024



Prepared by:
Karen Thompspon

For any information regarding this report please contact:

Karen Thompson
Aquatic Ecology and Ecotoxicology Technician
Chemistry and Ecotoxicology



National Institute of Water & Atmospheric Research Ltd
PO Box 11115
Hamilton 3251

Phone +64 7 856 7026

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Quality Assurance Statement

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	Formatting checked by:	Carole Evans
	Approved for release by:	Michael Bruce

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Executive summary

Santana Minerals is an exploration and development company specialising in precious metals, particularly gold and silver. One of their key projects is the Bendigo-Ophir Project, located in the South Island of New Zealand. Baseline geochemical studies at this site have revealed sulfate concentrations of approximately 0.1% in the waste rock.

Santana Minerals engaged NIWA to conduct laboratory testing to assess the toxicity of sulfate to the mayfly species *Deleatidium* sp., supporting the resource consent application for the Bendigo-Ophir Gold Project. *Deleatidium* sp. are among the most abundant invertebrates in fast-flowing, cool, well-aerated, stony-bottom streams, particularly in the South Island. They feed by scraping diatom algae and other organic matter from stone surfaces, and their high numbers, often alongside other mayfly or stonefly species, are indicators of good habitat and water quality. This testing will help establish appropriate consent conditions for the project to support the protection of site catchment ecosystems.

The acute *Deleatidium* sp., mayfly nymph test showed that a 96-hour exposure to 2,435 mg/L sulfate at a hardness of 14 mg L⁻¹ CaCO₃ significantly decreased *Deleatidium* sp. survival. The test resulted in an EC₁₅ and EC₅₀ (95% confidence interval) of 963 (854-966) mg L⁻¹ and 1,597 (1,506-1,614) mg L⁻¹ sulfate, respectively.

These results should be interpreted with caution regarding attributing the toxicity effects observed solely to the sulfate ion (SO₄). The concentration of sodium ions is highly elevated in the maximum exposure concentration where the only toxicity effects were observed. High sodium ion concentrations can cause physiological toxicity attributable to the sodium/potassium (Na/K) balance in the organism. The K concentration in the dilution water was 4.4 mg L⁻¹ and rivers with higher K concentrations may be expected to reduce toxicity related to the elevated Na ion concentration.

1 Introduction

Santana Minerals is an exploration and development company primarily focused on precious metals, particularly gold and silver. Santana Minerals operates in various regions, including New Zealand. One of their notable projects includes the Bendigo-Ophir Project in the South Island of New Zealand, where they focus on the exploration of gold deposits in a historically significant gold-mining region.

Santana Minerals engaged NIWA to undertake laboratory testing to determine the toxicity of sulfate to a mayfly species, *Deleatidium* sp. The ecotoxicology testing will support the resource consent application for the Bendigo Ophir Gold Project, where baseline geochemical studies have identified sulfate concentrations of approximately 0.1% in the waste rock. This testing will aid in establishing suitable consent conditions for the project.

Deleatidium sp. mayfly nymphs are characterized by their flattened bodies, single leaf-like gills, and broad labrum (upper "lip"). These larvae are typically very abundant invertebrates in many fast-flowing, cool, well-aerated, stony-bottom streams, particularly in the South Island. They feed by scraping diatom algae and other organic matter from stone surfaces. High numbers of *Deleatidium* sp. indicate good habitat and water quality, especially when accompanied by other mayfly or stonefly species.

Mayfly nymphs undergo several developmental stages known as instars, shedding their exoskeleton at each stage to grow. The number of moults varies among species and can range from a few to over 20 before reaching the final nymphal stage, at which point they emerge as adults.

2 Methods

2.1 Test Item

Sodium sulfate (CAS 7757-82-6) was sourced from Merck Life Science Ltd. A Certificate of Analysis (CoA) was obtained and is available in Appendix A.

2.2 Toxicity testing

2.2.1 Mayfly collection and laboratory maintenance

Deleatidium sp. nymphs were collected via kick netting in areas with rocky substrate on 12th September 2024 from a known population in the Waimakariri Stream (-38.009710, 175.848982) and transported to the NIWA Ecotoxicology Laboratory. Upon arrival the nymphs were maintained in aerated aquaria with small cobbles collected from the source site as substrate and a natural biofilm food source until testing commenced. Acclimation to the test water, upper Waihou River water, was carried out in four steps:

- Day 0: 25% Waihou River water and 75% source water.
- Day 1: 50% Waihou River water and 50% source water.
- Day 2: 75% Waihou River water and 25% source water.
- Day 3: 100% Waihou River water.

2.2.2 Toxicity testing

Testing was completed according to NIWAs Standard Operating Procedure (SOP):

- SOP 61.0 – Mayfly nymph (*Deleatidium* sp.) acute toxicity test (NIWA 2024).

A summary of test conditions and test acceptability information specified in the SOP document is provided in Appendix B.

2.3 Sample dilutions

Prior to the initiation of the toxicity test, a 3,000 mg L⁻¹ stock solution of sodium sulfate was prepared volumetrically using test dilution water. A magnetic stirrer and bar were used to achieve dissolution of the chemical. Immediately prior (<2 h) to the initiation of the toxicity test the stock solution was further diluted to make a total of 5 treatment concentrations. Test concentrations were determined based on the outcomes of preliminary rangefinder experiments in which 0% survival was observed at 3,000 mg L⁻¹ sulfate (data not shown). The test utilised upper Waihou River water (hardness 14.0 mg L⁻¹ CaCO₃) as per SOP 61.0 (NIWA 2024) for dilution and the additional control treatment ('Concentration 0'). The pH for the test should range from 6.0 to 9.0, and the test should be conducted without adjusting the pH. If the pH falls outside this range, a second test may be performed, adjusting the pH of the stock solution to match that of the dilution water before adding the test substance (OECD 2004).

A summary of the nominal test treatment concentrations is provided in Table 3-1.

2.4 Reference toxicant

Reference toxicant testing was undertaken concurrently to measure the sensitivity and condition of the test organisms using the standard test procedures (NIWA 2024). Zinc sulfate is used as the reference toxicant and results from this test were compared to the long-term data set (NIWA, unpublished). This is part of the quality control procedures and enables comparability between laboratory test results in standard dilution water at different times. The zinc sulfate stock concentration was validated by chemical analysis (Hill Labs, data not shown).

2.5 Chemical analysis

Hill Laboratories analysed subsamples from each test treatment, including the dilution water, for sulfate and chloride levels. Additionally, total hardness (measured as dissolved calcium and magnesium) and dissolved organic carbon (DOC) were measured in the dilution water, as well as in the lowest and highest test treatments (nominally 22 mg L⁻¹ and 2,040 mg L⁻¹ sulfate, respectively) (Appendix C).

2.6 Test acceptability criteria

The test was deemed acceptable if control organisms had greater than or equal to 90% mean survival (NIWA 2024) (Appendix B).

2.7 Statistical analysis

The sulfate concentrations used in the statistical analyses were a mean of the concentrations measured at the test start (T₀) and end (T₉₆).

The test results were statistically analysed using CETIS™ v2.1.4.5 (Comprehensive Environmental Toxicity Information System) software and corresponding user manual by Tidepool Scientific (2001-2022). CETIS™ is a statistical application designed for analysing and reporting dose-response results from aquatic, terrestrial and sediment toxicity tests. All statistical analyses follow US EPA standard guidelines for toxicity data analysis.

Initial analysis determined if there was a survival concentration relationship and if so, an ANOVA compared the survival at each concentration to determine the no observed effect concentration (NOEC) and the lowest observed effect concentration (LOEC). A linear interpolation was conducted to calculate point estimates (LC₅₀ and LC₁₅) with associated 95% confidence intervals ($\alpha=0.05$) (Appendix D).

3 Results and discussion

A summary of the data observations, physico-chemical analyses, and statistical analyses for the mayfly test is provided in Table 3-2, Appendix E and Appendix D.

The air temperature of the controlled temperature room which held the test vessels was $15 \pm 1.0^{\circ}\text{C}$ throughout the duration of the test. The solution temperatures at test initiation were $15.3\text{--}15.7^{\circ}\text{C}$ and the DO concentration $8.7\text{--}8.8\text{ mg/L O}_2$. At the test termination the DO was $8.1\text{--}8.7\text{ mg/L O}_2$, and the solution temperatures ranged from $15.5\text{--}15.8^{\circ}\text{C}$. The pH of the test solutions measured at the start and end of the exposure ranged from $7.8\text{--}8.0$ pH units for sulfate treatment and was 8.2 pH units for the negative control (Appendix E).

After 96 hours the average survival in the control treatments was 94% and all replicates had greater than 80% survival. Therefore, the test met the criterion for validity (Appendix B). The reference toxicant 96 h survival EC_{50} for zinc was $14.5 (14.5\text{--}14.5)\text{ mg L}^{-1} \text{Zn}^{2+} (\pm 95\% \text{CL})$. The reference toxicant testing criterion is that the EC_{50} falls within 2 standard deviations of the long-term average, however NIWA has very limited data for this species (Appendix B).

The mean sulfate concentrations measured by Hill Laboratories (Appendix C) were all within 18% of the nominal concentrations, the largest discrepancy was measured in the 'Concentration 5' treatment (nominally $2,040\text{ mg L}^{-1}$ sulfate). Larger differences in sulfate concentrations were measured between the test solutions at the initiation of the exposure period (T_0) and at the end of the exposure period (T_{96}), indicating that although the stock solution appeared to dissolve completely further dissolution occurred throughout the test period (Table 3-1).

Table 3-1: Nominal and measured sulfate concentrations at the start (T_0) and end (T_{96}) of the 96-h mayfly survival toxicity test. Measured by Hill Laboratories. Percentage differences calculated for nominal and mean measured concentrations, and initial and final measured test concentrations. Shaded cells indicate concentrations used in statistical analyses.

Treatment	Nominal concentration (mg L^{-1})	Measured T_0 concentration (mg L^{-1})	Measured T_{96} concentration (mg L^{-1})	Mean measured concentration (mg L^{-1})	Difference between nominal and mean measured concentrations %	Difference between T_0 and T_{96} measured concentrations %
Concentration 0 - Control	0	2.03	2.35	2.2	200	14
Concentration 1	22	22.1	22.4	22	0	0
Concentration 2	68	65.7	70.8	69	1	7
Concentration 3	218	214	231	220	1	9
Concentration 4	680	680	868	775	13	25
Concentration 5	2,040	1,970	2,880	2,435	18	38

The 96-h survival test showed no progressive concentration-response relationship until greater than 775 mg L^{-1} sulfate concentration when a marked reduction in survival in response to increased sulfate concentration occurred. The $2,435\text{ mg L}^{-1}$ sulfate treatment had a statistically significant negative effect on mayfly survival with a 79% reduction compared to the negative control treatment. The acute toxicity test for *Deleatidium* sp. resulted in an EC_{15} of 963 mg L^{-1} sulfate (by linear

interpolation), with a 95% confidence interval of 854-966 mg L⁻¹ sulfate and an EC₅₀ of 1,597 mg L⁻¹ sulfate, with a 95% confidence interval of 1,506-1,614 mg L⁻¹ sulfate (Table 3-3 and Appendix D).

These results should be interpreted with caution regarding attributing the toxicity effects observed solely to the sulfate ion (SO₄). The concentration of sodium ions is highly elevated in the maximum exposure concentration where the only toxicity effects were observed (EC 4,300 µS/cm, equivalent to a salinity of 2.8 ‰). High sodium ion concentrations can cause physiological toxicity attributable to the sodium/potassium (Na/K) balance in the organism. The K concentration in the Waihou River dilution water was 4.4 mg L⁻¹ (Appendix C and Smith and Maasdam (1994)) and rivers with higher K concentrations may be expected to reduce toxicity related to the elevated Na ion concentration (Wang et al. (2020)).

Table 3-2: Average mayfly survival percentage every 24 h for each sulfate treatment.

Treatment	Concentration	%			
	mg L ⁻¹	24 h survival	48 h survival	72 h survival	96 h survival
Concentration 0 - Control	2.2	97	97	94	94
Concentration 1	22	96	96	90	90
Concentration 2	69	100	100	96	96
Concentration 3	220	100	100	100	100
Concentration 4	775	100	100	100	100
Concentration 5	2,435	100	100	94	7

Table 3-3: Toxicity statistics as derived by CETIS™ (mg L⁻¹ sulfate) for *Deleatidium* sp. 96-hour survival in upper Waihou River water. Values in parentheses are the EC₅₀ value 95% confidence intervals.

Treatment	EC ₁₅ ^a (95% CL) mg L ⁻¹	EC ₅₀ ^a (95% CL) mg L ⁻¹	NOEC ^b mg L ⁻¹	LOEC ^c mg L ⁻¹	TEC ^d mg L ⁻¹
Sulfate	963 (854-966)	1,597 (1,506-1,614)	775	2435	1374

^a EC_x: The statistically determined test Concentration causing a X% Effect on the endpoint after the specified exposure period. ^b NOEC: The highest tested 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.

4 Acknowledgements

I thank Mary Askey of Santana Minerals for project liaison. I also thank NIWA Principal Technician, Brian Smith for assisting with field work and conducting the test.

5 References

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- NIWA (2024) Mayfly Nymph (*Deleatidium* sp.) Acute Toxicity Test, Ecotoxicology Standard Operating Procedure 61.0. Version 1.0. March 2024. Prepared for Internal Use Only, National Institute of Water and Atmospheric Research Ltd. (NIWA) Ecotoxicology Laboratory, Hamilton, New Zealand.
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- USEPA. (2002). Methods for measuring the acute toxicity of effluents and receiving waters to freshwater and marine organisms. Fifth edition. EPA-821-R-02-012. [Methods for Measuring the Acute Toxicity of Effluents and Receiving Waters to Freshwater and Marine Organisms; 5th ed.](#)

Appendix A Certificate of Analysis

Sigma-Aldrich.

3050 Spruce Street, Saint Louis, MO 63103, USA

Website: www.sigmaaldrich.com

Email USA: techserv@sial.com

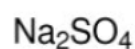
Outside USA: eurtechserv@sial.com

Certificate of Analysis

Product Name:

Sodium sulfate - ACS reagent, ≥99.0%, anhydrous, powder

Product Number: 238597
Batch Number: MKCS7461
Brand: SIGALD
CAS Number: 7757-82-6
MDL Number: MFCD00003504
Formula: SO₄.2Na
Formula Weight: 142.04 g/mol
Quality Release Date: 19 DEC 2022



Test	Specification	Result
Appearance (Color)	White	White
Appearance (Form)	Powder	Powder
X-Ray Diffraction	Conforms to Structure	Conforms
Purity (Titration by NaOH)	≥ 99.0 %	100.0 %
Loss on Ignition	≤ 0.5 %	0.2 %
Insoluble Matter	≤ 0.01 %	< 0.01 %
Chloride Content	≤ 0.001 %	< 0.001 %
Iron (Fe)	≤ 0.001 %	< 0.001 %
Heavy Metals	≤ 5 ppm	< 5 ppm
Miscellaneous Assay	≤ 5 ppm	< 5 ppm
Nitrogen Compounds		
pH	5.2 - 9.2	6.0
At 25 Degrees Celsius, c = 5%; Water		
Phosphate (PO ₄)	≤ 0.001 %	< 0.001 %
Calcium (Ca)	≤ 0.01 %	< 0.01 %
Magnesium (Mg)	≤ 0.005 %	< 0.001 %
Potassium (K)	≤ 0.01 %	< 0.01 %
Meets ACS Requirements	Current ACS Specification	Conforms

Larry Coers, Director
Quality Control

Sigma-Aldrich warrants, that at the time of the quality release or subsequent retest date this product conformed to the information contained in this publication. The current Specification sheet may be available at Sigma-Aldrich.com. For further inquiries, please contact Technical Service. Purchaser must determine the suitability of the product for its particular use. See reverse side of invoice or packing slip for additional terms and conditions of sale.



Version Number: 1

Page 1 of 2

Certificate of Analysis

Product Number: 238597
Batch Number: MKCS7461

Milwaukee, WI US

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Version Number: 1

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Appendix B Summary of test conditions

Parameter	Condition
Reference Method	ASTM (2014) and USEPA (2002)
Test Protocol	NIWA SOP 61.0 (2024)
Test Species	<i>Deleatidium</i> sp.
Organism size	Early instar <5 mm
Source	Waimakariri Stream, Waikato
Dilution Water	Upper Waihou River
Test type	Static, non-renewal
Organisms/Container	7
Test Concentrations	Nominally 0 (control), 32, 100, 320, 1000, 3000 mg L ⁻¹ sodium sulfate
Test Duration	96 hours
Replicates	5 for control; 3 for treatment dilutions
Sample pre-treatment	Nil
Test Chambers	250 mL polystyrene beakers
Test volume	200 mL
Lighting	16:8h light:dark, low light
Temperature	15 ± 1°C
Aeration	Moderate aeration at >100 bubbles/min
Feeding	Nil
Chemical Data	Initial and final temperature, conductivity, dissolved oxygen, pH
Reference Toxicant	Zinc sulphate
Effect Measured	Survival
Zn sensitivity current test; long term mean (EC ₅₀ ±2sd)	14.5 mg L ⁻¹ Zn ²⁺ ; 14.5 (N/A) mg L ⁻¹ Zn ²⁺ , n=1 at hardness 14 mg L ⁻¹ and 63 (0–132) mg L ⁻¹ Zn ²⁺ , n=3 at hardness 61 mg L ⁻¹ (Note: Zn toxicity is water hardness dependent so these natural water tests would not be expected to be directly comparable).
Test Acceptability	Mean control survival ≥ 90% Survival in each control replicate must be ≥ 80%

Appendix C Hill Laboratories results

Certificate of Analysis

Page 1 of 2

Client:	NIWA Corporate	Lab No:	3675699	SUPV2
Contact:	K Thompson	Date Received:	19-Sep-2024	
	C/- NIWA Corporate	Date Reported:	06-Nov-2024	(Amended)
	PO Box 11115	Quote No:	132853	
	Hillcrest	Order No:	U337609	
	Hamilton 3251	Client Reference:	SML25201 Test TO	
		Submitted By:	K Thompson	

Sample Type: Aqueous				
Sample Name:	Control 0 mg/L 19-Sep-2024	Sulfate 32 mg/L 19-Sep-2024	Sulfate 100 mg/L 19-Sep-2024	Sulfate 320 mg/L 19-Sep-2024
Lab Number:	3675699.1	3675699.2	3675699.3	3675699.4
Total Hardness	g/m ³ as CaCO ₃	14.87 ± 0.69	14.92 ± 0.70	-
Dissolved Calcium	g/m ³	3.07 ± 0.20	3.05 ± 0.20	-
Dissolved Magnesium	g/m ³	1.75 ± 0.12	1.78 ± 0.12	-
Dissolved Potassium	g/m ³	4.42 ± 0.33	-	-
Chloride	g/m ³	6.48 ± 0.52	6.63 ± 0.53	6.41 ± 0.52
Sulphate	g/m ³	2.03 ± 0.37	22.1 ± 1.4	65.7 ± 4.0
Dissolved Organic Carbon (DOC)	g/m ³	< 0.5 ± 1.5	< 0.5 ± 1.5	-

Sample Name:	Sulfate 1000 mg/L 19-Sep-2024	Sulfate 3000 mg/L 19-Sep-2024
Lab Number:	3675699.5	3675699.6
Total Hardness	g/m ³ as CaCO ₃	15.41 ± 0.72
Dissolved Calcium	g/m ³	3.17 ± 0.21
Dissolved Magnesium	g/m ³	1.82 ± 0.13
Chloride	g/m ³	6.39 ± 0.52
Sulphate	g/m ³	6.42 ± 0.52
Dissolved Organic Carbon (DOC)	g/m ³	1,970 ± 120
		< 0.5 ± 1.5

The reported uncertainty is an expanded uncertainty with a level of confidence of approximately 95 percent (i.e. two standard deviations, calculated using a coverage factor of 2). Reported uncertainties are calculated from the performance of typical matrices, and do not include variation due to sampling.

For further information on uncertainty of measurement at Hill Laboratories, refer to the technical note on our website: www.hill-laboratories.com/files/Intro_To_UOM.pdf, or contact the laboratory.

Analyst's Comments

Amended Report: This certificate of analysis replaces report '3675699-SUPv1' issued on 27-Sep-2024 at 1:12 pm.
Reason for amendment: Additional testing added.

Summary of Methods

The following table(s) gives a brief description of the methods used to conduct the analyses for this job. The detection limits given below are those attainable in a relatively simple matrix. Detection limits may be higher for individual samples should insufficient sample be available, or if the matrix requires that dilutions be performed during analysis. A detection limit range indicates the lowest and highest detection limits in the associated suite of analytes. A full listing of compounds and detection limits are available from the laboratory upon request. Unless otherwise indicated, analyses were performed at Hill Labs, 28 Duke Street, Frankton, Hamilton 3204.

Sample Type: Aqueous			
Test	Method Description	Default Detection Limit	Sample No
Filtration, Unpreserved	Sample filtration through 0.45µm membrane filter.	-	1-6
Total Hardness	Calculation from Calcium and Magnesium. APHA 2340 B : Online Edition.	1.0 g/m ³ as CaCO ₃	1-2, 6
Filtration for dissolved metals analysis	Sample filtration through 0.45µm membrane filter and preservation with nitric acid. APHA 3030 B : Online Edition.	-	1-2, 6
Dissolved Calcium	Filtered sample, ICP-MS, trace level. APHA 3125 B : Online Edition.	0.05 g/m ³	1-2, 6



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Sample Type: Aqueous			
Test	Method Description	Default Detection Limit	Sample No
Dissolved Magnesium	Filtered sample, ICP-MS, trace level. APHA 3125 B : Online Edition.	0.02 g/m ³	1-2, 6
Dissolved Potassium	Filtered sample, ICP-MS, trace level. APHA 3125 B : Online Edition.	0.05 g/m ³	1
Chloride	Filtered sample. Ion Chromatography. APHA 4110 B (modified) : Online Edition.	0.5 g/m ³	1-6
Sulphate	Filtered sample. Ion Chromatography. APHA 4110 B (modified) : Online Edition.	0.5 g/m ³	1-6
Dissolved Organic Carbon (DOC)	Filtered sample, Supercritical persulphate oxidation, IR detection, for Total C. Acidification, purging for Total Inorganic C. TOC = TC -TIC. APHA 5310 C (modified) : Online Edition.	0.5 g/m ³	1-2, 6

These samples were collected by yourselves (or your agent) and analysed as received at the laboratory.

Testing was completed between 20-Sep-2024 and 06-Nov-2024. For completion dates of individual analyses please contact the laboratory.

Samples are held at the laboratory after reporting for a length of time based on the stability of the samples and analytes being tested (considering any preservation used), and the storage space available. Once the storage period is completed, the samples are discarded unless otherwise agreed with the customer. Extended storage times may incur additional charges.

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Ara Heron BSc (Tech)
Client Services Manager - Environmental

Certificate of Analysis

Page 1 of 1

Client:	NIWA Corporate	Lab No:	3681276	SUPv1
Contact:	K Thompson	Date Received:	27-Sep-2024	
	C/- NIWA Corporate	Date Reported:	03-Oct-2024	
	PO Box 11115	Quote No:	132853	
	Hillcrest	Order No:	U337583	
	Hamilton 3251	Client Reference:	SML 25201 Test	
		Submitted By:	K Thompson	

Sample Type: Aqueous					
Sample Name:		0 mg/L 23-Sep-2024	32 mg/L 23-Sep-2024	100 mg/L 23-Sep-2024	320 mg/L 23-Sep-2024
Lab Number:		3681276.1	3681276.2	3681276.3	3681276.4
Chloride	g/m ³	6.84 ± 0.54	6.54 ± 0.52	6.91 ± 0.54	7.13 ± 0.55
Sulphate	g/m ³	2.35 ± 0.37	22.4 ± 1.4	70.8 ± 4.3	231 ± 14

Sample Name:		1000 mg/L 23-Sep-2024	3000 mg/L 23-Sep-2024
Lab Number:		3681276.5	3681276.6
Chloride	g/m ³	7.18 ± 0.55	6.97 ± 0.54
Sulphate	g/m ³	868 ± 53	2,880 ± 180

The reported uncertainty is an expanded uncertainty with a level of confidence of approximately 95 percent (i.e. two standard deviations, calculated using a coverage factor of 2). Reported uncertainties are calculated from the performance of typical matrices, and do not include variation due to sampling.

For further information on uncertainty of measurement at Hill Laboratories, refer to the technical note on our website: www.hill-laboratories.com/files/Intro_To_UOM.pdf, or contact the laboratory.

Summary of Methods

The following table(s) gives a brief description of the methods used to conduct the analyses for this job. The detection limits given below are those attainable in a relatively simple matrix. Detection limits may be higher for individual samples should insufficient sample be available, or if the matrix requires that dilutions be performed during analysis. A detection limit range indicates the lowest and highest detection limits in the associated suite of analytes. A full listing of compounds and detection limits are available from the laboratory upon request. Unless otherwise indicated, analyses were performed at Hill Labs, 28 Duke Street, Frankton, Hamilton 3204.

Sample Type: Aqueous			
Test	Method Description	Default Detection Limit	Sample No
Filtration, Unpreserved	Sample filtration through 0.45µm membrane filter.	-	1-6
Chloride	Filtered sample. Ion Chromatography. APHA 4110 B (modified) : Online Edition.	0.5 g/m ³	1-6
Sulphate	Filtered sample. Ion Chromatography. APHA 4110 B (modified) : Online Edition.	0.5 g/m ³	1-6

These samples were collected by yourselves (or your agent) and analysed as received at the laboratory.

Testing was completed between 30-Sep-2024 and 03-Oct-2024. For completion dates of individual analyses please contact the laboratory.

Samples are held at the laboratory after reporting for a length of time based on the stability of the samples and analytes being tested (considering any preservation used), and the storage space available. Once the storage period is completed, the samples are discarded unless otherwise agreed with the customer. Extended storage times may incur additional charges.

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Ara Heron BSc (Tech)
Client Services Manager - Environmental



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Appendix D CETIS™ data analysis reports

CETIS Analytical Report

Report Date: 28 Oct-24 10:35 (p 1 of 3)

Test Code/ID: SML25201 MAS / 00-4152-7360

Mayfly Acute Survival

NIWA Ecotoxicology

Analysis ID: 14-1580-7559	Endpoint: 96h Survival Rate	CETIS Version: CETISv2.1.4
Analyzed: 28 Oct-24 9:57	Analysis: Parametric-Multiple Comparison	Status Level: 1
Edit Date:	MD5 Hash: 740090A11DC975ED4D8150464C18C033	Editor ID:
Batch ID: 12-1954-6276	Test Type: Survival (96h)	Analyst: Ecotox Team
Start Date: 19 Sep-24	Protocol: NIWA (2024)	Diluent: Upper Waihou River
Ending Date: 23 Sep-24	Species: <i>Deleatidium</i> sp	Brine: Not Applicable
Test Length: 96h	Taxon:	Source: Waimakariri Stream Age:
Sample ID: 06-3241-6058	Code: SML25201 MAS	Project: Toxicity Screening
Sample Date: 19 Sep-24	Material: Sodium sulfate	Source: Collected by NIWA
Receipt Date: 19 Sep-24	CAS (PC):	Station: Merck
Sample Age: ---	Client:	

Comments: Hardness 14mg/L CaCO₃

Data Transform	Alt Hyp	NOEL	LOEL	TOEL	Tox Units	MSDu	PMSD
Angular (Corrected)	C > T	775	2435	1374	---	0.1233	13.08%

Bonferroni Adj t Test

Control	vs	Conc-mg/L	df	Test Stat	Critical	MSD	P-Type	P-Value	Decision(α:5%)
Dilution Water		22	6	0.7947	2.56	0.1696	CDF	0.8844	Non-Significant Effect
		69	6	-0.1987	2.56	0.1696	CDF	1.0000	Non-Significant Effect
		220	6	-1.192	2.56	0.1696	CDF	1.0000	Non-Significant Effect
		775	6	-1.192	2.56	0.1696	CDF	1.0000	Non-Significant Effect

Auxiliary Tests

Attribute	Test	Test Stat	Critical	P-Value	Decision(α:5%)
Control Trend	Mann-Kendall Trend Test	0.7983	0.05	0.7983	Non-Significant Control Trend

ANOVA Table

Source	Sum Squares	Mean Square	DF	F Stat	P-Value	Decision(α:5%)
Between	0.0388419	0.0097105	4	1.18	0.3683	Non-Significant Effect
Error	0.0987869	0.0082322	12			
Total	0.137629		16			

ANOVA Assumptions Tests

Attribute	Test	Test Stat	Critical	P-Value	Decision(α:1%)
Variance	Bartlett Equality of Variance Test				Indeterminate
	Levene Equality of Variance Test	12.65	5.412	0.0003	Unequal Variances
	Mod Levene Equality of Variance Test	0.5833	7.847	0.6850	Equal Variances
Distribution	Anderson-Darling A2 Test	0.7011	3.878	0.0671	Normal Distribution
	D'Agostino Skewness Test	0.518	2.576	0.6045	Normal Distribution
	Kolmogorov-Smirnov D Test	0.2059	0.2405	0.0538	Normal Distribution
	Shapiro-Wilk W Normality Test	0.9214	0.848	0.1557	Normal Distribution

96h Survival Rate Summary

Conc-mg/L	Code	Count	Mean	95% LCL	95% UCL	Median	Min	Max	Std Err	CV%	%Effect
2.2	D	5	0.9429	0.8457	1.0000	1.0000	0.8571	1.0000	0.0350	8.30%	0.00%
22		3	0.9048	0.6999	1.0000	0.8571	0.8571	1.0000	0.0476	9.12%	4.04%
69		3	0.9524	0.7475	1.0000	1.0000	0.8571	1.0000	0.0476	8.66%	-1.01%
220		3	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	0.0000	0.00%	-6.06%
775		3	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	0.0000	0.00%	-6.06%
2435		1	0.2000			0.2000	0.2000	0.2000	---	---	78.79%

Convergent Rounding (4 sf)

CETIS™ v2.1.4.5 (008-408-407-6)

CETIS Analytical Report

Report Date: 28 Oct-24 10:36 (p 2 of 3)
Test Code/ID: SML25201 MAS / 00-4152-7360

Mayfly Acute Survival

NIWA Ecotoxicology

Analysis ID: 14-1580-7559 Endpoint: 96h Survival Rate CETIS Version: CETISv2.1.4
Analyzed: 28 Oct-24 9:57 Analysis: Parametric-Multiple Comparison Status Level: 1
Edit Date: MD5 Hash: 740090A11DC975ED4D8150464C18C033 Editor ID:

Angular (Corrected) Transformed Summary

Conc-mg/L	Code	Count	Mean	95% LCL	95% UCL	Median	Min	Max	Std Err	CV%	%Effect
2.2	D	5	1.3020	1.1670	1.4360	1.3810	1.1830	1.3810	0.0484	8.31%	0.00%
22		3	1.2490	0.9658	1.5320	1.1830	1.1830	1.3810	0.0658	9.13%	4.05%
69		3	1.3150	1.0320	1.5980	1.3810	1.1830	1.3810	0.0658	8.67%	-1.01%
220		3	1.3810	1.3800	1.3810	1.3810	1.3810	1.3810	0.0000	0.00%	-6.07%
775		3	1.3810	1.3800	1.3810	1.3810	1.3810	1.3810	0.0000	0.00%	-6.07%
2435		1	0.4636			0.4636	0.4636	0.4636	---	---	64.38%

96h Survival Rate Detail

Conc-mg/L	Code	Rep 1	Rep 2	Rep 3	Rep 4	Rep 5
2.2	D	0.8571	1.0000	1.0000	0.8571	1.0000
22		0.8571	1.0000	0.8571		
69		0.8571	1.0000	1.0000		
220		1.0000	1.0000	1.0000		
775		1.0000	1.0000	1.0000		
2435		0.2000				

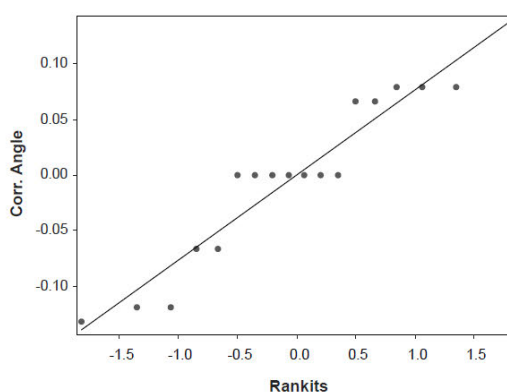
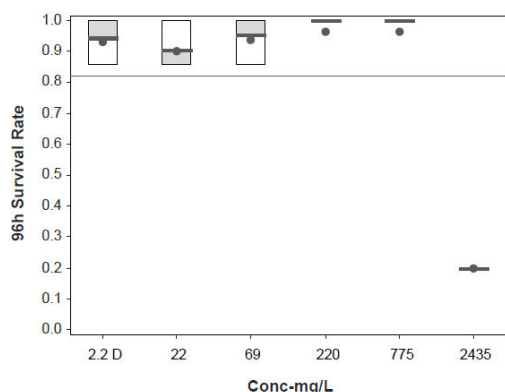
Angular (Corrected) Transformed Detail

Conc-mg/L	Code	Rep 1	Rep 2	Rep 3	Rep 4	Rep 5
2.2	D	1.1830	1.3810	1.3810	1.1830	1.3810
22		1.1830	1.3810	1.1830		
69		1.1830	1.3810	1.3810		
220		1.3810	1.3810	1.3810		
775		1.3810	1.3810	1.3810		
2435		0.4636				

96h Survival Rate Binomials

Conc-mg/L	Code	Rep 1	Rep 2	Rep 3	Rep 4	Rep 5
2.2	D	6/7	7/7	7/7	6/7	7/7
22		6/7	7/7	6/7		
69		6/7	7/7	7/7		
220		7/7	7/7	7/7		
775		7/7	7/7	7/7		
2435		1/5				

Graphics



Convergent Rounding (4 sf)

CETIS™ v2.1.4.5 (008-408-407-6)

CETIS Analytical Report

Report Date: 28 Oct-24 10:41 (p 1 of 2)

Test Code/ID: SML25201 MAS / 00-4152-7360

Mayfly Acute Survival

NIWA Ecotoxicology

Analysis ID: 04-4077-7529	Endpoint: 96h Survival Rate	CETIS Version: CETISv2.1.4
Analyzed: 28 Oct-24 9:59	Analysis: Linear Interpolation (ICPIN)	Status Level: 1
Edit Date:	MD5 Hash: 740090A11DC975ED4D8150464C18C033	Editor ID:
Batch ID: 12-1954-6276	Test Type: Survival (96h)	Analyst: Ecotox Team
Start Date: 19 Sep-24	Protocol: NIWA (2024)	Diluent: Upper Waihou River
Ending Date: 23 Sep-24	Species: Deleatidium sp	Brine: Not Applicable
Test Length: 96h	Taxon:	Source: Waimakariri Stream Age:
Sample ID: 06-3241-6058	Code: SML25201 MAS	Project: Toxicity Screening
Sample Date: 19 Sep-24	Material: Sodium sulfate	Source: Collected by NIWA
Receipt Date: 19 Sep-24	CAS (PC):	Station: Merck
Sample Age: ---	Client:	

Comments: Hardness 14mg/L CaCO3

Linear Interpolation Options

X Transform	Y Transform	Seed	Resamples	Exp 95% CL	Method
Log(X+1)	Linear	421272	200	Yes	Two-Point Interpolation

Point Estimates

Level	mg/L	95% LCL	95% UCL
LC15	962.8	854	965.9
LC20	1035	926.4	1039
LC25	1113	1005	1119
LC40	1382	1282	1394
LC50	1597	1506	1614

96h Survival Rate Summary

Conc-mg/L	Code	Count	Calculated Variate(A/B)						Isotonic Variate		
			Mean	Median	Min	Max	CV%	%Effect	ΣA/ΣB	Mean	%Effect
2.2	D	5	0.9429	1.0000	0.8571	1.0000	8.30%	0.00%	33/35	0.9600	0.00%
22		3	0.9048	0.8571	0.8571	1.0000	9.12%	4.04%	19/21	0.9600	0.00%
69		3	0.9524	1.0000	0.8571	1.0000	8.66%	-1.01%	20/21	0.9600	0.00%
220		3	1.0000	1.0000	1.0000	1.0000	0.00%	-6.06%	21/21	0.9600	0.00%
775		3	1.0000	1.0000	1.0000	1.0000	0.00%	-6.06%	21/21	0.9600	0.00%
2435		1	0.2000	0.2000	0.2000	0.2000	---	78.79%	1/5	0.2000	79.17%

96h Survival Rate Detail

Conc-mg/L	Code	Rep 1	Rep 2	Rep 3	Rep 4	Rep 5
2.2	D	0.8571	1.0000	1.0000	0.8571	1.0000
22		0.8571	1.0000	0.8571		
69		0.8571	1.0000	1.0000		
220		1.0000	1.0000	1.0000		
775		1.0000	1.0000	1.0000		
2435		0.2000				

96h Survival Rate Binomials

Conc-mg/L	Code	Rep 1	Rep 2	Rep 3	Rep 4	Rep 5
2.2	D	6/7	7/7	7/7	6/7	7/7
22		6/7	7/7	6/7		
69		6/7	7/7	7/7		
220		7/7	7/7	7/7		
775		7/7	7/7	7/7		
2435		1/5				

Convergent Rounding (4 sf)

CETIS™ v2.1.4.5 (008-408-407-6)

CETIS Analytical Report

Report Date: 28 Oct-24 10:41 (p 2 of 2)
Test Code/ID: SML25201 MAS / 00-4152-7360

Mayfly Acute Survival

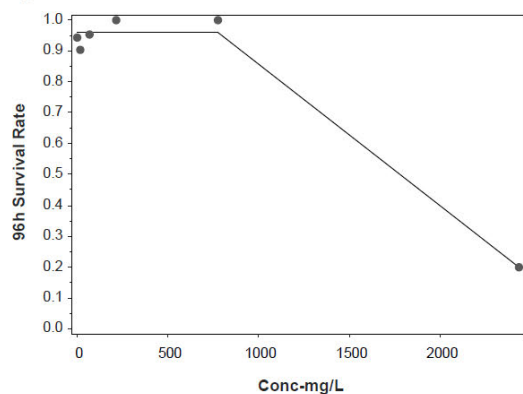
NIWA Ecotoxicology

Analysis ID: 04-4077-7529
Analyzed: 28 Oct-24 9:59
Edit Date:

Endpoint: 96h Survival Rate
Analysis: Linear Interpolation (ICPIN)
MD5 Hash: 740090A11DC975ED4D8150464C18C033

CETIS Version: CETISv2.1.4
Status Level: 1
Editor ID:

Graphics



Convergent Rounding (4 sf)

CETIS™ v2.1.4.5 (008-408-407-6)

Appendix E Physico-chemical data

Table E-1: Summary of physico-chemical measures from acute *Deleatidium* sp. toxicity testing with sulfate. Values shown are the measurements taken at test initiation (T₀) and test termination (T₉₆).

Nominal concentration (mg L ⁻¹ sulfate)	pH		Dissolved Oxygen (mg L ⁻¹)		Conductivity (μS/cm)		Temperature (°C)	
	T ₀	T ₉₆	T ₀	T ₉₆	T ₀	T ₉₆	T ₀	T ₉₆
0 Control	8.2	8.2	8.8	8.7	124	128	15	16
22	7.9	7.9	8.8	8.6	150	154	15	16
68	7.9	7.8	8.8	8.5	267	268	15	16
218	7.8	7.8	8.8	8.1	640	642	16	16
680	7.9	8.0	8.8	8.7	1,720	1,724	16	16
2,040	7.8	7.8	8.7	8.4	4,343	4,353	16	16