Macraes Phase Four Project (MP4)

Active Water Treatment Study

Prepared For:	OceanaGold (New Zealand) Limited
Prepared By:	Process Flow
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NAME	TITLE	SIGNATURE	DATE
Gary Smith	Engineering Manager	[redacted]	21 August 2026

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EXECUTIVE SUMMARY

To support the development of the substantive application for the Macraes Phase Four (MP4) Project, OceanaGold New Zealand Limited (OGNZL) has engaged Process Flow Limited to provide an assessment on applicable active water treatment technologies to treat mine influenced water as part of the MP4 project.

The objective for Process Flow Ltd was to examine available technologies that could be used to treat the mine influenced water (MIW) prior to discharge from the site to water qualities at or better than the compliance criteria discussed in section 2.4.

A range of Active Treatment technologies for sulphate and metals removal exist, including ettringite precipitation, reverse osmosis, biological sulphate removal, ion exchange and electrocoagulation treatment. Several of these technologies were selected for further assessment due to the availability of process information, and the likelihood of achieving treatment targets.

The processes considered in this study are:

- Lime dosing and settling (as a pre-treatment option)
- Ferric Chloride dosing (as a pretreatment option)
- Reverse Osmosis (RO)
- Chemical (Ettringite) Precipitation

All processes will produce a waste stream, which will require managing. For lime dosing, ferric chloride dosing and ettringite precipitation a settled or filtered sludge will require dewatering and disposal and for reverse osmosis a brine will need concentrating and disposal.

As a preliminary recommendation, reverse osmosis technology should be considered the base case treatment system for MP4. This may or may not include pre-treatment with lime or ferric chloride dosing as discussed in section 4.2. The primary reason for selecting this technology over others is:

- Excellent performance of reverse osmosis technology when treating high sulphate waters;
- Ability to remove key metals such as arsenic;
- Good performance for nitrate removal;
- Availability of technology, experienced suppliers and support; and
- Pilot scale systems readily available for testing on site.

To further enhance metals removal, pre-treatment may be installed prior to the RO process. Lime dosing using Calcium Oxide (CaO) was trialled. Results are discussed in detail in the laboratory scale test report attached as appendix A (Wildy,J. 2026), however as a summary the following key test outcomes were achieved:

- Most metals concentrations (As, Co, Ni, Zn) drop dramatically; and
- TSS remained low (20–66 g/m³), no major suspended solids carry-over.

Lime dosing is a commonly used method for removal of dissolved metals from mine influenced water. Typically, one of the following lime reagents is used, where pH is adjusted:

- Hydrated Lime - $Ca(OH)_2$ (Hydrated Lime)
- Calcium Oxide – CaO (Quicklime)

Expected theoretical performance of RO with pre-treatment on typical Macraes water are shown in table 1. These results were calculated by applying pre-treatment test work efficiencies with theoretical RO membrane removal efficiencies, as discussed in section 3.0 of this report.

Table 1: RO + Pre-treatment Water Quality

Head Concentration		Raw	Pretreatment + RO		Compliance	Comment
			Expected removal %	Predicted WQ		
pH	pH Units	7.4		7.5	6.5-9.0	Will require pH trimming
Total Hardness	g/m3 as CaCO3	3400	99.4%	22		
Total Suspended Solids	g/m3	4		<0.1	< 5 NTU	Units TSS (Not NTU)
Dissolved Arsenic	g/m3	0.199	99.7%	0.0007**	0.013	** Textbook - As^{3+} as H_3AsO_3 ~75%, As^{5+} as $H_2AsO_4^-/HAsO_4^{2-}$ ~96%
Dissolved Boron	g/m3	0.24	37.5%	0.15	0.94	Some Boron removal
Dissolved Cobalt	g/m3	0.092	*	<0.0001		* Result below detection
Dissolved Copper	g/m3	<0.0005		<0.0005	0.004	Raw below detection
Dissolved Iron	g/m3	<0.02		<0.02	0.1	Raw below detection
Dissolved Lead	g/m3	<0.0001		<0.0001	0.045	Raw below detection
Dissolved Nickel	g/m3	0.077	*	<0.0001	0.016	* Result below detection
Dissolved Zinc	g/m3	0.0091	*	<0.0001	0.002	* Result below detection
Chloride	g/m3	16.9	97.4%	0.38		
Total Ammoniacal-N	g/m3	2.2	79.8%	0.44	0.52	Good Ammoniacal-N removal
Nitrate-N	g/m3	3.1	88.5%	0.33	1.1	Good Nitrate-N removal
Sulphate	g/m3	3400	99.2%	27	<500	Excellent sulphate removal
Dissolved Organic Carbon (DOC)	g/m3	<0.5		-		

As representative water is already available at site, it is strongly recommended that pilot scale trials to verify theoretical performance be commenced as soon as possible and these trials should include:

- Sourcing a pilot RO plant to carry out site specific trials on water quality;
- Investigate brine disposal options both pre and post closure;
- Establish areas within the mine site where active treatment can be installed;
- Further refine flow rates, water qualities and site factors that may affect the plant performance;
- Establish feed water requirements for surge mitigation including feed sump/pond size; and
- Establish treated water requirements, treated water ponds, discharge locations and retention times.

Pre-treatment will potentially be required prior to the RO process if higher metals concentrations from some sources occur. This step will reduce metals at the feed to the reverse osmosis system and enhance removal. The following pilot trials and further investigations should be considered alongside the reverse osmosis pilot trials:

- Trial both lime and ferric chloride
- Source a pilot lamella plant (with chemical mixing and dosing) to carry out site specific trials on water quality;
- Carry out sludge dewatering trials on the lamella underflow;
- Investigate sludge disposal options both pre and post closure;
- Establish areas within the mine site where active treatment can be installed;
- Determine flow rates, water qualities and site factors that may affect the plant performance;
- Establish feed water requirements for surge mitigation including feed sump/pond size;
- Establish treated water requirements, treated water ponds, discharge locations and retention times; and
- Revisit active water treatment options as more is learned during water treatment trials

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1 INTRODUCTION

1.1 Background

OceanaGold (New Zealand) Limited ("**OGNZL**") currently undertakes open pit and underground gold mining operations at the Macraes Operation located at Golden Point Road, Macraes Flat, East Otago. As part of their ongoing operations, OGNZL continually review the remaining life of the Macraes Operation in light of updated knowledge of the gold resource and the economics of mining.

Reflecting recent exploration success and optimisation work, together with higher gold prices, the Macraes Phase Four Project ("**MP4**" or "**the Project**") seeks to extend the life of mining at the Macraes Operation until at least 2039. The Project, which will enable ongoing gold production at a rate of approximately 130,000 ounces per annum, is identified as a Listed Project in Schedule 2 of the Fast-track Approvals Act 2024 ("**FTAA**") as a project providing significant national or regional benefits.

To support the development of the substantive application for the Project, OGNZL has engaged **Process Flow Limited** to provide an assessment of the Project's effects on **Active Water Treatment** and, to the extent required, identify any necessary management and operation measures to address any such effects.

This scope of this report is to:

- Test representative mine influenced water to confirm an effective active treatment process;
- Investigate alternate treatment system(s);
- Compare the expected performance of the active treatment system with project water quality compliance limits;
- Provide advice and a recommendation on a suitable active treatment process, and any alternative options available; and
- Provide a report suitable to support the FTA application.

OGNZL owns and operates the Macraes Operation at Macraes, approximately 30 km northwest of Palmerston in the Otago Region. The Macraes Operation is the largest gold mine in New Zealand and, since commissioning in 1990, has produced more than 6 million ounces of gold.

Macraes Flat is situated on an elevated plateau at approximately 500 m above sea level. The plateau is flanked by the Taieri Ridge to the northwest, Shag Valley and Horse Range to the east, and the coastal hills and extinct volcanic cones of Palmerston and Waikouaiti to the southeast. Macraes Road provides access to Macraes Flat and the Macraes Operation, connecting to State Highway 85 to the east and State Highway 87 (SH87, the Middlemarch–Hyde Road) to the west.

The environment within and surrounding the Macraes Operation has been shaped by historic and current mining activities. Figure 1 shows the arrangement of the major mine features at the Macraes Operation. In summary, the current components of the Macraes Operation include:

- Numerous open pits (both operational and non-operational);
- Two underground mines (Frasers, now closed, and Golden Point, which is actively mined);
- Waste rock stacks at various stages of operation and rehabilitation;
- A network of haul roads and general mine service tracks;
- A Processing Plant;
- Five tailings storage facilities (three inactive, one active but nearing capacity, and one under construction and currently receiving tailings);
- An extensive network of water management infrastructure, including diversion drains, silt ponds, sumps, pit lakes, and freshwater storage reservoirs;
- Two consented but not yet constructed water storage reservoirs (Camp Creek Dam and Coal Creek Dam); and

- Associated infrastructure supporting ongoing operations, including district roads, powerlines, workshops, offices, and associated water and amenity facilities.

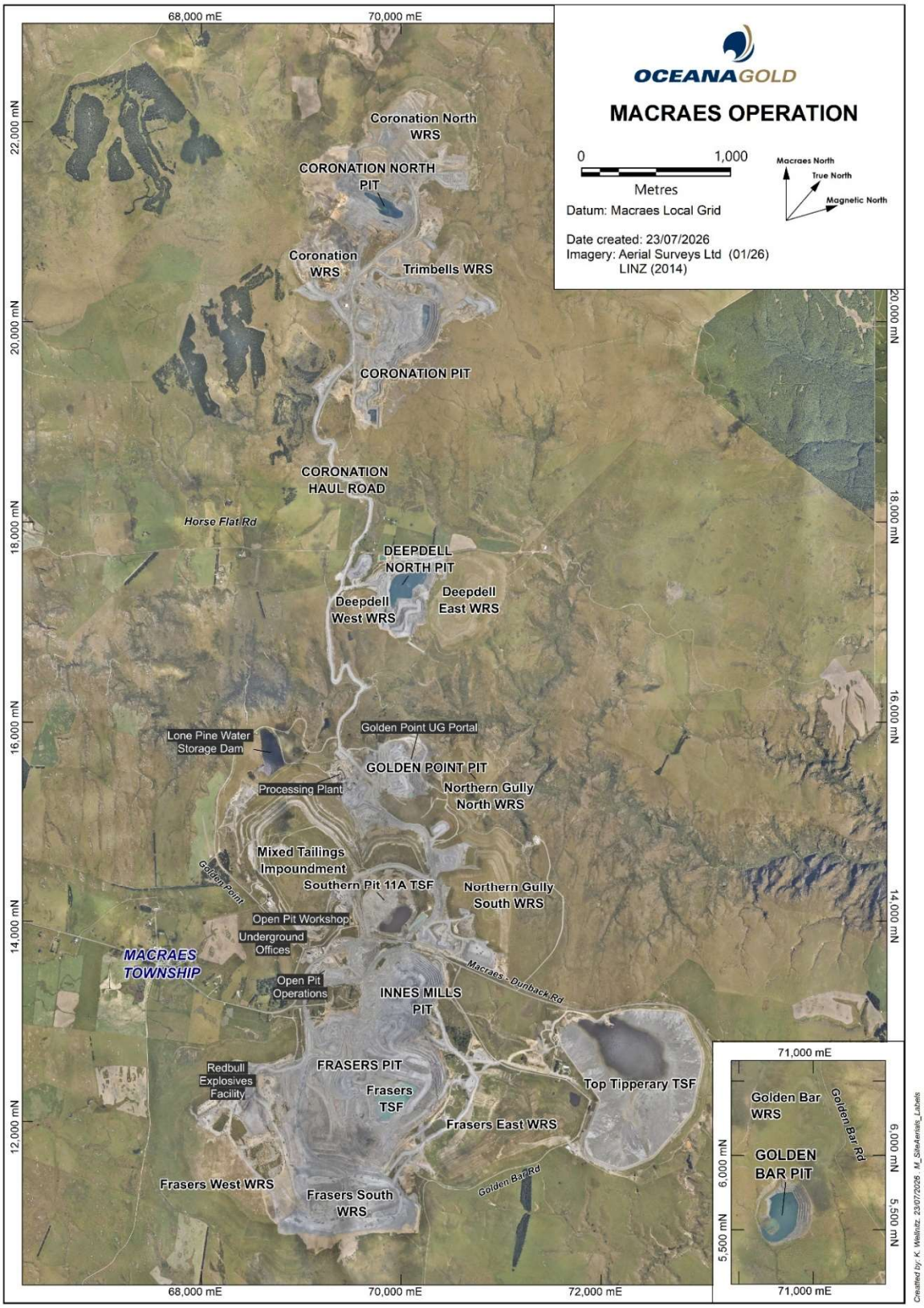


Figure 1: Existing site layout at the Macraes Operation (as of July 2026)

1.2 Project Overview

The Project is made up of the following proposed key activities:

- **Open pit extensions** at Coronation, Coronation North, Innes Mills, and Golden Bar.
- **Underground mine expansion** through further development of the Golden Point Underground mine ("**GPUG**").
- **Tailings management**, including:
  - Construction of the Frasers Tailings Storage Facility ("**FTSF**") Stage 3 to accommodate a total tailings storage of up to 153 Mt; and
  - Hydraulic mining and relocation of tailings from the Mixed Tailings Impoundment ("**MTI**"), Southern Pit Option 10 TSF ("**SP10**"), and Southern Pit Option 11A TSF ("**SP11**") to FTSF.
- **Waste rock disposal**, including increased storage capacity within open pits and at existing waste rock stacks at Coronation, Coronation North, Innes Mills, Golden Bar, Golden Point, and Frasers.
- **Water management infrastructure and operations**, including:
  - Construction of Camp Creek and Coal Creek water storage dams for flow and water quality management;
  - Construction, operation and maintenance of a Water Treatment Plant; and
  - Ongoing operation and maintenance of the Mine Water Management System ("**MWMS**").
- **Infrastructure and roading works**, including:
  - Realignment of Macraes Road in two stages; and
  - Relocation of the Open Pit Mining Workshop.
- **Ecological enhancements**, including establishment of:
  - Murphys Ecological Enhancement Area ("**MEEA**") near Murphys Creek, including predator fencing, access tracks, and site facilities;
  - Mt Highlay restoration area;
  - Cranky Jims Link shrubland enhancement area;
  - Murphys Link tussock protection area; and
  - Additional compensation measures for residual ecological impacts.
- **Mine closure and rehabilitation activities**, including rehabilitation of mining landforms, creation of pit lakes, dry capping of tailings storage facilities, and revegetation in accordance with closure objectives.

An overview of the proposed activities which make up the Project is shown in Figure 2 below.

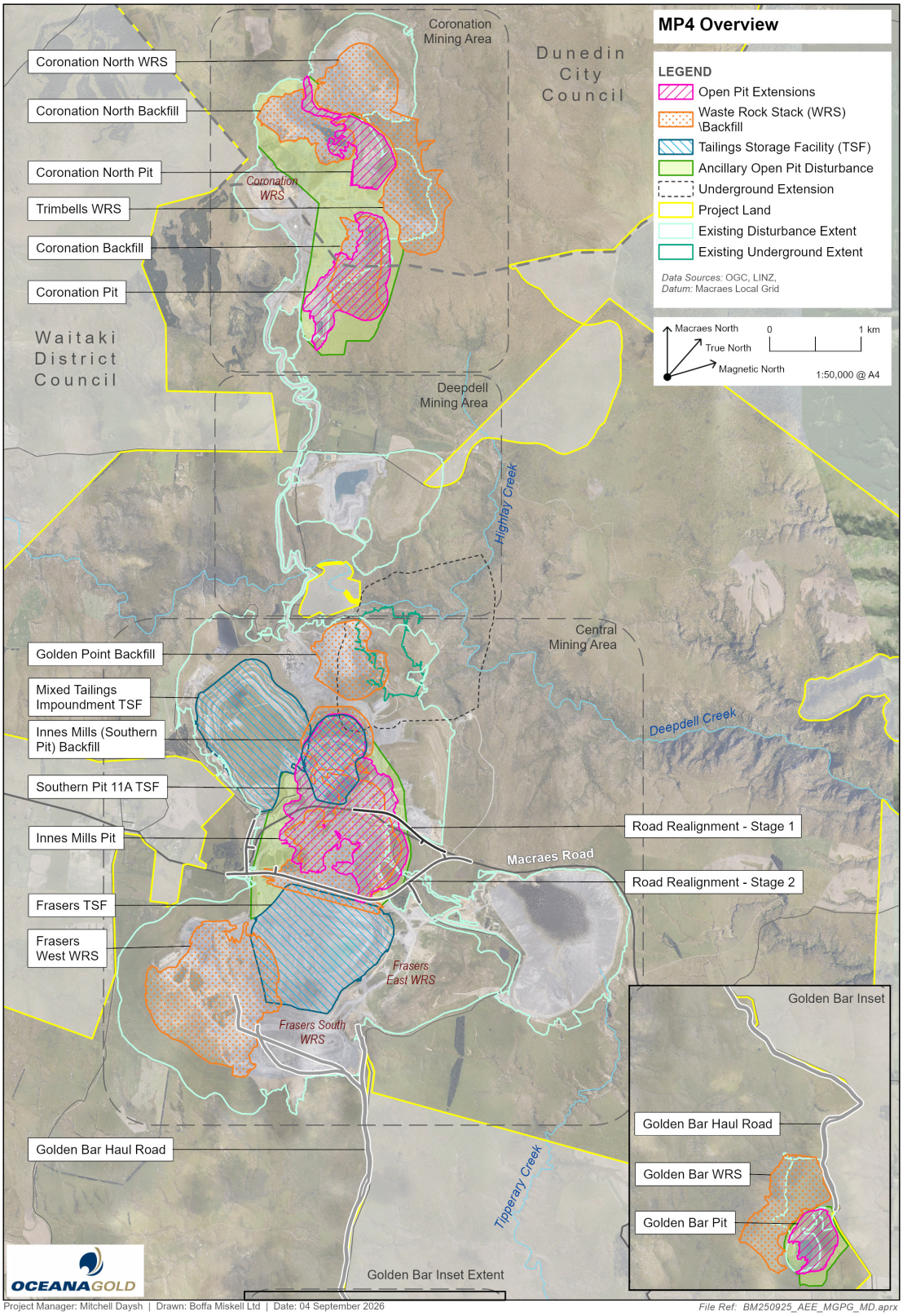


Figure 2: MP4 Overview Plan

The Active Water Treatment plant (as described in this report) has been located as shown in figure 3.

Figure 3: Proposed Active Water Treatment Plant Location

2 STUDY OBJECTIVES AND ASSUMPTIONS

2.1 Reference Information

- Viridis Report, Macraes Phase 4 Project – Recommended Surface Water Quality Triggers, Document No. 10023-010-0
- Wildy, J. (2026) Macraes Mine Water Treatability Study, Evaluation of Sulphate Reduction from Mine-Impacted Water Using Two-Stage Ettringite Precipitation, Final Report 01 September 2026
- GHD MP4 Surface and Groundwater Assessment – 12682240-REP-Rev0
- MWM Report J-NZ0498-025-M-Rev0 – Adaptive Management of Elevated Nitrate in WRS

2.2 Study Objectives

As part of MP4, OGNZL has engaged Process Flow Limited to provide an assessment on applicable active water treatment technologies to treat mine influenced water on site.
The objective for Process Flow Ltd was to examine available technologies that could be used to treat the mine influenced water (MIW) prior to discharge from the site in accordance with the compliance criteria discussed in section 2.4.

2.3 Definition of Mine Water Quality (Plant Feed Envelope)

To determine the type(s) of water typically encountered at the Macraes operation (and likely to require active treatment) two existing mine influenced water sources were chosen by OGNZL and sampled as follows. The samples are representative of the water quality likely to require treatment by an active water treatment plant.

- Northern Gully Silt Pond (NGSP) – high sulphate water ~3,500[1] g/m^3
- Top Tipperary Tailings Storage Facility (TTTSF) – high sulphate water ~3,000 g/m^3

These water samples were collected from the Macraes operation site by OGNZL staff and transported to Process Flow on the 24th of February 2026. Once at Process Flow the water samples were analysed for raw water quality, including a 50:50 blend of the two water samples, which was used for subsequent test work, and definition of treatment systems

These water samples were chosen to represent a typical water requiring treatment from site, it should be noted that multiple other sources of water (as detailed in the WBM) are present on site and may require treatment. Table 2 summarises the Raw Water Quality Analysis carried out by Hill Laboratories.

[1] The units g/m^3 and mg/L are used interchangeably in this report, these units are technically equivalent.

Table 2: Raw Water Quality Data

PARAMETER	UNITS	RAW WATER QUALITY NGSP 24/02/2026 4111117.1	RAW WATER QUALITY 50:50 24/02/2026 4111117.2	RAW WATER QUALITY TTTSF 24/02/2026 4111117.3
pH	pH Units	7.9	7.2	7
Total Alkalinity	g/m3 as CaCO3	380	370	370
Carbonate	g/m3 at 25°C	1.7	< 1.0	< 1.0
Bicarbonate	g/m3 at 25°C	460	460	450
Total Hardness	g/m3 as CaCO3	3,700	3,100	2,500
Electrical Conductivity (EC)	mS/m	477	482	481
Total Suspended Solids	g/m3	22	16	6
Total Solids (TS)	g/m3	5,900	5,400	5,000
Dissolved Aluminium	g/m3	< 0.003	< 0.003	< 0.003
Total Aluminium	g/m3	< 0.0032	0.023	0.045
Dissolved Antimony	g/m3	0.0037	0.002	0.0008
Total Arsenic	g/m3	0.0065	0.87	1.87
Dissolved Boron	g/m3	< 0.05	0.22	0.4
Dissolved Calcium	g/m3	310	390	460
Dissolved Cobalt	g/m3	< 0.0002	0.114	0.22
Dissolved Iron	g/m3	< 0.02	< 0.02	< 0.02
Total Iron	g/m3	< 0.021	2.5	5.5
Dissolved Magnesium	g/m3	710	510	330
Dissolved Manganese	g/m3	< 0.003	4	7.7
Dissolved Molybdenum	g/m3	0.0007	0.0034	0.0055
Dissolved Potassium	g/m3	14.6	36	58
Dissolved Selenium	g/m3	0.034	0.0171	< 0.003
Dissolved Sodium	g/m3	73	240	380
Dissolved Sulphur	g/m3	1,160	1,080	1,000
Dissolved Thallium	g/m3	< 0.00005	< 0.00005	0.00007
Total Cyanide	g/m3	< 0.002	< 0.002	< 0.002
Chloride	g/m3	11.8	18.8	24
Fluoride	g/m3	< 0.05	0.13	0.2
Total Nitrogen	g/m3	6.7	8.5	10.2
Total Ammoniacal-N	g/m3	< 0.010	3.1	6
Nitrite-N	g/m3	0.061	0.31	0.52
Nitrate-N	g/m3	5.2	2.9	0.81
Nitrate-N + Nitrite-N	g/m3	5.2	3.2	1.33
Total Kjeldahl Nitrogen (TKN)	g/m3	1.49	5.4	8.9
Sulphate	g/m3	3,500	3,200	3,000
Dissolved Organic Carbon (DOC)	g/m3	< 0.5	4.8	3.9
Heavy metals, dissolved, trace As,Cd,Cr,Cu,Ni,Pb,Zn				
Dissolved Arsenic	g/m3	0.0061	0.24	0.42
Dissolved Cadmium	g/m3	< 0.00005	0.00006	0.00012
Dissolved Chromium	g/m3	< 0.0005	< 0.0005	< 0.0005
Dissolved Copper	g/m3	< 0.0005	< 0.0005	< 0.0005
Dissolved Lead	g/m3	< 0.00010	< 0.00010	< 0.00010
Dissolved Nickel	g/m3	0.0131	0.085	0.148
Dissolved Zinc	g/m3	< 0.0010	0.0101	0.0198

2.4 Discharge Water Requirements

Refer Viridis Report *"10023-010-0 Recommended Surface Water Quality Triggers – July 2026*

OGNZL has engaged Viridis Limited (Viridis) to develop a compliance framework for assessing surface water quality at key receiving environments. While compliance limits already apply at various downstream surface water sites under existing consents, these have been developed over time through multiple approval processes and reflect differing methodologies. As such, they do not constitute a single, consistent approach. The proposed MP4 development provides an opportunity to implement a more coherent and up-to-date framework for assessing and managing surface water quality effects across the site.

The framework is intended to provide a more integrated and transparent approach to compliance assessment, aligned with current guidelines and best practice and tailored to site-specific conditions at the Macraes Operation. It will enable the identification of potential water quality issues and facilitate timely management responses to avoid adverse effects.

Viridis' report on surface water quality triggers outlines the proposed framework, its application at the Macraes Operation, and the rationale for the development of site-specific trigger values. The derivation of these values draws on relevant national and international guidance and, where appropriate, considers site-specific water chemistry, monitoring data, and ecological information, including factors relevant to both contaminant toxicity and nutrient enrichment.

As part of the test work and preliminary design of an active water treatment process it is important to know what water quality targets need to be achieved. The compliance framework provides trigger values for water quality within the various receiving environments at Macraes, therefore when considering the output required for active treatment these values provide a minimum treatment target for water quality exiting the proposed active treatment system, in some cases treatment outputs may exceed these numbers and provide dilution to the downstream environment; this is detailed in the WBM.

In section 3.0 of this report, the water quality achieved in testing is compared against the compliance trigger limits presented in Viridis' Table 3, which provides trigger values for the following parameters:

- pH
- Turbidity (NTU)
- Sulphate
- Ammoniacal nitrogen
- Nitrate nitrogen
- Soluble inorganic nitrogen
- Arsenic
- Boron
- Copper
- Iron
- Lead
- Nickel
- Zinc
- Cyanide

2.5 Active WTP – Treatment Flowrate Requirements

Refer report: *GHD MP4 Surface and Groundwater Assessment – 12682240-REP-Rev0*

Water Load Balance Modelling (WBM) predicts that active treatment will be required during the following stages of the MP4 mining cycle.

- **Stage 1** – A reduced size WTP managing an average inflow of about 5 L/s treating WRS seepage water from November 2029 to January 2032. Modelling represents influent water quality as a combination of all captured WRS seepage waters.
- **Stage 2** – A full scale WTP treating all captured waters prior to discharge within the mining phases:
    - Mining – Treating all captured WRS seepage water and returning treated water to receiving catchments.
    - Closure - Treating all captured WRS seepage water and captured TSF underdrain water. The treated water is discharged back to the source catchments in a manner that achieves compliance with water quality conditions.

A summary of the mean inflow rates to the WTP estimated by the WBM are outlined in Table 3 with the following key transitions: *(Table 26. from the WBM Report)*

Table 3: Summary of WTP mean inflow rates by mining phase (L/sec)

PHASE	MINING STG.1 WTP (2030)[1]	MINING STG.2 WTP (2032)[2]	CLOSURE (~2040)[3]	POST CLOSURE (~2050)[3]
WRS Seepage Combined (L/sec)	5	18.2	18.2	7
TSF Underdrains Combined (L/sec)	-	-	26.9	15.9
Total Mean Inflow (L/sec)	5	18.2	45.1	22.9

[1] Stage 1 WTP at peak flow of 5 L/sec assumed
[2] Stage 2 WTP with current WRS infiltration rates
[3] Stage 2 WTP with reduced WRS infiltration rates recognised

GHD recommend that for application of these modelling outcomes, it is suggested that a variability of ±30% is applied to the annualised flow rates and an additional +25% contingency on flow rates representing uncertainty in seepage flow capture rates. Table 4 summarises the required WTP flow rates with contingencies applied.

Table 4: WTP design flow rates (L/sec)

DESCRIPTION	STAGE1	STAGE 2	CLOSURE	POST CLOSURE
Total (mean annualised) Inflow Rates (L/sec)	5	18.2	45.1	22.9
+ 30% variability (L/sec)	6.5	23.6	58.6	29.8
+ 25% Contingency (L/sec)	8.1	29.5	73.3	37.2
WTP Design Max Flow (L/sec)	**8.1**	**29.5**	**73.3**	**37.2**

These flow rates should be used in preliminary design of the active water treatment plant and updated as flow measurements from the seepage water capture system and other mine influenced water sources are collected.

3 ACTIVE WATER TREATMENT PROCESSES

3.1 Summary of treatment options

A range of Active Treatment technologies for sulphate and metals removal exist, including ettringite precipitation, reverse osmosis, biological sulphate removal, ion exchange and electrocoagulation treatment. Several of these technologies were selected for further assessment due to the availability of process information, and the likelihood of achieving treatment targets.

The processes considered in this study are:

- Lime dosing and settling (as a pre-treatment option)
- Ferric chloride dosing (as a pre-treatment option)
- Reverse Osmosis
- Chemical (Ettringite) Precipitation

All processes will produce a waste stream, which will require management. For lime dosing, ferric chloride dosing and ettringite precipitation a settled or filtered sludge will require dewatering and disposal, and for reverse osmosis a brine will need concentrating and disposal.

While the above processes when combined can effectively remove sulphates and metals, depending on process selection other treatment methods may be investigated as more is learned for example passive treatment to reduce nitrate concentrations in the discharge water might be considered (Refer MWM Report J-NZ0498-025-M-Rev0 – Adaptive Management of Elevated Nitrate in WRS).

3.2 Lime Dosing and Settling (as a Pre-treatment option)

Lime dosing is a commonly used method for removal of dissolved metals from mine influenced water. Typically using one of the following lime reagents, where pH is adjusted:

- Hydrated Lime - $Ca(OH)_2$ (Hydrated Lime)
- Calcium Oxide – CaO (Quicklime)

Lime dosing using CaO was trialled using the 50:50 blend water detailed in Table 5. Results are documented in detail in the laboratory scale test report attached as appendix A (Wildy,J. 2026), which achieved the following key test outcomes.

- Most metals concentrations (As, Co, Ni, Zn) drop dramatically.
- TSS remains low (20–66 g/m^3), no major suspended solids carry-over.

The water quality achieved in testing is summarised in table 2 and compared to the proposed ecological trigger values and compliance criteria as shown in the Viridis report (“Viridis 2026” - 10023-010-0 Table 3.).

Table 5: CaO Dosing - Water Quality

Parameter (g/m3)	Units	Raw Concentration	Lime Dosing (CaO)	Lime Dosing (Cao) Efficiency %	Target Treatment Limit	Comment
pH	pH Units	7.4	11.8		6.5-9.0	Will need pH trimming
Total Hardness	g/m3 as CaCO3	3400	3325		<500	
Total Suspended Solids	g/m3	4	35		< 5 NTU	
Dissolved Arsenic	g/m3	0.199	0.0029	98.5%	0.013	Excellent metals removal
Dissolved Boron	g/m3	0.24	0.2	16.7%	0.94	Poor removal - Depends on raw conc
Dissolved Cobalt	g/m3	0.092	0.0011	98.8%		Excellent metals removal
Dissolved Copper	g/m3	<0.0005	<0.0005		0.004	Starting Concentrations below detection
Dissolved Iron	g/m3	<0.02	<0.02		0.1	Starting Concentrations below detection
Dissolved Lead	g/m3	<0.0001	0.0024		0.045	Starting Concentrations below detection
Dissolved Nickel	g/m3	0.077	0.0006	99.2%	0.016	Excellent metals removal
Dissolved Zinc	g/m3	0.0091	0.0005	94.5%	0.002	Excellent metals removal
Chloride	g/m3	16.9	16.3	3.6%		
Total Ammoniacal-N	g/m3	2.2	2.7	-22.7%	0.52	Poor Nitrate removal
Nitrate-N	g/m3	3.1	3.1	0.0%	1.1	Poor Nitrate removal
Sulphate	g/m3	3400	2888	15.1%	<500	Some Sulphate Reduction
Dissolved Organic Carbon (DOC)	g/m3	<0.5	-			

3.2.1 Considerations for Lime Dosing

- Sulphate removal was limited with only a small reduction in sulphate concentration;
- Metals precipitation was excellent with good reduction in concentrations for key parameters, such as arsenic, nickel and zinc;
- pH was not adjusted (trimmed) to compliance levels; however, this can be carried out by pH trimming post settlement;
- Nitrate removal was poor with little to no removal for both Nitrate N, and Ammoniacal-N; and
- Total sludge production expected from the lime dosing process would be ~1-3% by volume of the influent water[2]. This can be reduced by dewatering and recycling of filtrate.
- There is potential for downstream scaling of reverse osmosis equipment from Calcium Sulphate and this should be considered, when selecting the pre-treatment reagents. This should be confirmed by pilot trials.
- LSI needs to stay low (~2.5 or below) or RO recovery will fall. Lime treated supernatant will likely need acid or CO2 trimming to control LSI before the membranes.

When comparing water quality results achieved in testing in Table 5, the tests demonstrated that lime dosing is very effective in removal of metals. However, it did not perform well in reduction of sulphate or nitrates, meaning that this process would only be suitable as a pre-treatment step for a multi-stage water treatment plant and not as a standalone process for the site.

3.3 Reverse Osmosis

Reverse osmosis (RO) is a water treatment process that works by forcing contaminated water through semi-permeable membranes and retaining the clean/filtered water on the other side of the membrane. It can strip out up to 99% of dissolved solids, including minerals, salts, heavy metals, fluoride, and most bacteria.

Due to the documented performance of reverse osmosis technology when treating high sulphate waters, as well as its ability to remove key metals such as arsenic, RO has been considered suitable as a treatment system for the project.

[2] Full-scale estimate of sludge volume after thickening, not a jar test result

To get specific engineering input regarding expected performance of an RO treatment system Process Flow contacted Osmoflo Water Management Pty Ltd (Osmoflo) (a company Process Flow has worked with before on installation of RO technology) to provide engineering advice on the suitability of the process for treating Macraes MP4 mine influenced water. Osmoflo is a leading supplier of RO technology in Australia with extensive experience in the mining sector.

Osmoflo reviewed the raw water quality presented in Table 2 and provided advice on the expected performance (removal efficiencies) of an RO system should it be adopted for the MP4 project.
Table 6 is a list of expected treated water concentrations (treated water quality) that Osmoflo have indicated could be achieved with an RO system treatment solution. Noting that these efficiencies should be proven by pilot scale test work.

Table 6: Expected RO Performance

Parameter (g/m3)	Units	Raw Concentration	RO Performance	RO Efficiency %	Maximum Limit	Comment
pH	pH Units	7.4	6.1		6.5-9.0	Will need pH adjustment
Total Hardness	g/m3 as CaCO3	3400	23	99.3%	<500	
Total Suspended Solids	g/m3	4	<0.1		< 5 NTU	< 5NTU Turbidity
Dissolved Arsenic	g/m3	0.199	0.0498 0.008	See comment	0.013	Textbook - As^{3+} as H_2AsO_3 ~75%, As^{5+} as $H_2AsO_4^-$/$HAsO_4^{2-}$~96%
Dissolved Boron	g/m3	0.24	0.18	25.0%	0.94	Limited removal - Depends on raw conc
Dissolved Cobalt	g/m3	0.092	0.006	>=96%		Excellent Metals Removal
Dissolved Copper	g/m3	<0.0005	<0.0005	>=96%	0.004	Raw below detection limit
Dissolved Iron	g/m3	<0.02	<0.02	>=96%	0.1	Raw below detection limit
Dissolved Lead	g/m3	<0.0001	<0.0001	>=96%	0.045	Raw below detection limit
Dissolved Nickel	g/m3	0.077	0.005	>=96%	0.016	Excellent Metals Removal
Dissolved Zinc	g/m3	0.0091	0.0005	>=96%	0.002	Excellent Metals Removal
Chloride	g/m3	16.9	0.44	97.7%		
Total Ammoniacal-N	g/m3	2.2	0.36	83.6%	0.52	Good Nitrate removal performance
Nitrate-N	g/m3	3.1	0.3	89.5%	1.1	Good Nitrate removal performance
Sulphate	g/m3	3400	32	99.1%	<100	Excellent Sulphate removal performance
Dissolved Organic Carbon (DOC)	g/m3	<0.5		>=96%		

The RO efficiencies provided in Table 6 indicate the expected removal rates. Where raw concentrations that are reported at less than the laboratory detection limits, the efficiencies shown in table 6 would apply for higher raw water concentrations should they become elevated.

3.3.1 Considerations for RO Technology

- RO technology performance would be well suited to treat the Macraes water with excellent removal of sulphate. (99% removal).
- Excellent metals and suspended solids removal could also be expected from the RO process (in most cases > 95%).
- Good removal of nitrates (>80%) which depending on inflow concentration should achieve water quality compliance limits in the discharge water.
- RO system recovery is a consideration as overall >15% of the feed water would report as brine for further treatment or disposal. There are options available for brine concentration processes that could be investigated on site to improve recovery.
- Brine density will be elevated, with initial projections approximately 1,032g/L at 25 degC. This may help when considering disposal options.

3.4 Chemical (Ettringite) Precipitation

Ettringite precipitation is an advanced chemical treatment process used to remove high concentrations of dissolved sulphate, heavy metals, and other scaling compounds (like calcium) from industrial and mining mine influenced water.

Some available ettringite precipitation processes are:

- SAVMIN Process – developed by Mintek (South Africa)
- CESR Process – (Cost Effective Sulphate Removal)
- Outotec (Metso) Ettringite Process

To determine whether a two-stage chemical (Ettringite) precipitation process was suitable for active treatment of the mine influenced water from Macraes, test work was carried out during March and April 2026. This test work was carried out by Dr Joe Wildy (JBH Environmental) and reported in a separate report attached as Appendix A. Evaluation of Sulphate Reduction from Mine Impacted Water using Two Stage Ettringite Precipitation (Wildy,J. 2026) Noting that "Phase 1" mentioned below is lime dosing already described in section 3.2.

The objective was to see if the two-stage process could reduce sulphate concentrations to a target range of 250 to500 mg/L as well as achieve co-precipitation of metals to levels that allow the treated mine influenced water to meet acceptable standards for discharge into the environment. The process used in testing is shown in figure 4.

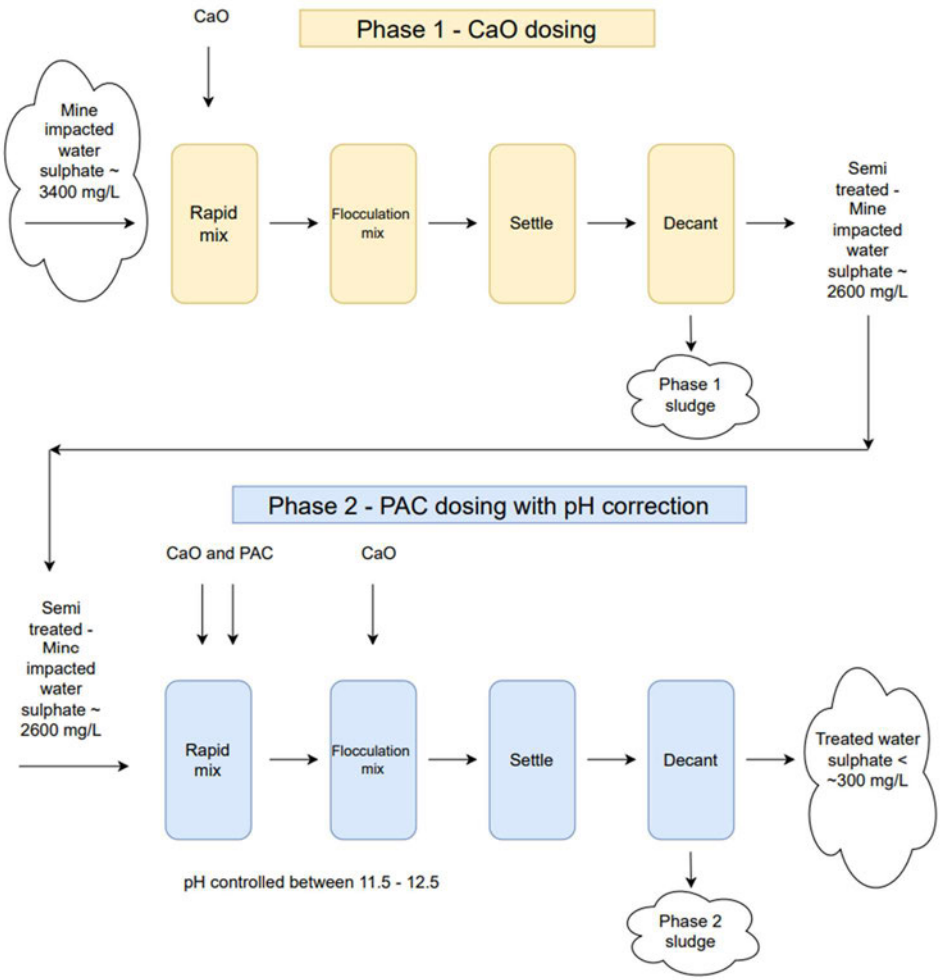


Figure 4: Schematic of Test Process

As shown in figure 4, there were two stages of testing carried out, phase one where raw water was dosed with CaO (Calcium Oxide) to elevate the pH and precipitate out metals, phase two where the supernatant was dosed with PAC (Poly Aluminium Chloride) and CaO for pH control to precipitate out sulphate.

The laboratory jar testing program has successfully demonstrated that a two-stage ettringite precipitation process can effectively reduce sulphate concentrations in impacted water from 3400 mg/L to well below the target discharge range. Additionally, the process achieved excellent co-precipitation of metals.

The water quality achieved in testing is summarised in table 7 and compared to the proposed ecological trigger values and compliance criteria as shown the Viridis report ("Viridis 2026" - 10023-010-0 Table 3.).

Table 7: Ettringite Precipitation Performance

Parameter (g/m3)	Units	Raw Concentration	Ettringite Precipitation)	Ettringite Efficiency %	Maximum Limit	Comment
pH	pH Units	7.4	12.4		6.5-9.0	Will need pH trimming
Total Hardness	g/m3 as CaCO3	3400	3000		<500	Likely will reduce with reagent swap and pH Trim
Total Suspended Solids	g/m3	4	116		< 5 NTU	Will need polishing prior to discharge
Dissolved Arsenic	g/m3	0.199	0.0048	97.6%	0.013	Excellent metals removal
Dissolved Boron	g/m3	0.24	<0.05	79.2%	0.94	Good removal - Below detection limit
Dissolved Cobalt	g/m3	0.092	0.0003	99.7%		Excellent metals removal
Dissolved Copper	g/m3	<0.0005	0.0023		0.004	Raw concentration below detection limits
Dissolved Iron	g/m3	<0.02	<0.02		0.1	Raw concentration below detection limits
Dissolved Lead	g/m3	<0.0001	<0.0001		0.045	Raw concentration below detection limits
Dissolved Nickel	g/m3	0.077	0.0010	98.7%	0.016	Excellent metals removal
Dissolved Zinc	g/m3	0.0091	0.0020	78.0%	0.002	Excellent metals removal
Chloride	g/m3	16.9	1473			Likely PAC Issue (Poly Aluminium Chloride)
Total Ammoniacal-N	g/m3	2.2	1.8	18.2%	0.52	Low Nitrate removal
Nitrate-N	g/m3	3.1	2.3	26.8%	1.1	Low Nitrate removal
Sulphate	g/m3	3400	7	99.8%	<100	Excellent Sulphate Reduction
Dissolved Organic Carbon (DOC)	g/m3	<0.5	-			

3.4.1 Considerations for Ettringite Precipitation

- Sulphate removal performed exceptionally well, with concentrations reducing from 3,400 g/m^3 to less than 10 g/m^3.
- Metals precipitation was excellent with good reduction in concentrations for key parameters, such as arsenic, nickel and zinc.
- pH was not adjusted (trimmed) to compliance levels; however, this work would be included in another round of process optimisation testing
- Ammoniacal nitrogen, although reduced through the process, is still elevated above the compliance limit, likely meaning a secondary treatment system may be required.
- Chloride and hardness results are elevated; these will need to be revisited during the optimisation testing and will likely be reduced by pH trimming and alternative aluminium reagents.
- Total sludge production expected from the 2-stage precipitation process would be ~5-10 % by volume. Further work defining sludge production, dewatering and disposal options is discussed below in section 4.

While test results indicated that the process is viable to treat the water, further scaled up testing should be conducted prior to considering adopting this process for site.

3.5 Other Treatment Processes

Other processes that may be needed as an add on to the active WTP depending on the selected option are:

- Potential additional nitrate removal after WTP via biological processes.

3.5.1 Nitrate Removal

Nitrate removal may be required, however nitrite/nitrate levels in the Macraes raw water were reduced by the two-stage precipitation process, additionally reverse osmosis can remove nitrates from wastewater, as well as other technologies. Confirmation from the outputs of water load balance modelling will determine whether the active treatment plant requires additional nitrate removal.

If required following modelling and pilot scale test work, additional nitrate treatment systems can be added as a bolt on to the back end of the plant, depending on the amount of removal required. Options include the following:

- Fluidised bed reactors (FBR);
- Dissolved organic carbon dosed passive treatment systems
- Ion Exchange;
- Wetland (if polishing required);

4 PROCESS RECOMMENDATION

A review of the treatment options discussed in section 3.0 was carried out, and the following recommendations should be considered when selecting a treatment process for the MP4 project:

- Reverse Osmosis – This should be the primary treatment system considered due to performance, availability of equipment and robustness of technology – further recommended work required for reverse osmosis is discussed further below in section 4.1.
- If required as a pre-treatment to reverse osmosis, lime dosing or ferric chloride dosing could be implemented to give greater removal of metals. Further work is required for the assessment of lime or ferric chloride dosing as a pre-treatment step, as discussed below in section 4.2.
- Ettringite Process – Although test work indicates that this option performs well for sulphate and metals removal, it achieves limited nitrate removal. This should be considered a secondary option that requires further work to give confidence of process and to develop sludge disposal options. This further work for the Ettringite process is discussed further below in section 4.3.

4.1 Reverse Osmosis – Recommendations

At the time of writing this report reverse osmosis technology should be considered the base case treatment system for MP4. This may or may not require pre-treatment as discussed in section 3.2. The Ettringite precipitation process may prove viable for the intended purpose. However, until such a time that the ettringite precipitation process trials are complete, reverse osmosis is considered to be the most robust of the treatment systems being considered. The following pilot scale trials should be carried out to understand performance with actual site water to inform detailed design of a water treatment plant.

4.1.1 Pilot Scale Trials

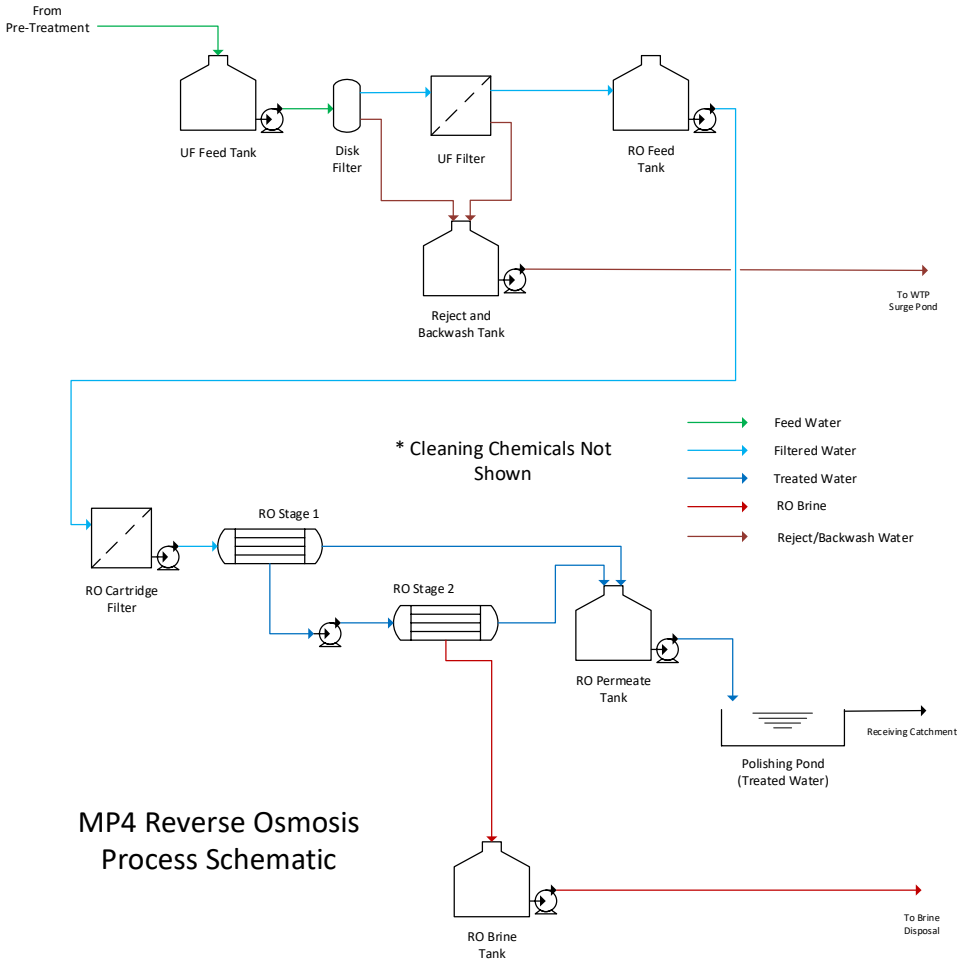
As representative water is already available at site, pilot scale trials should be commenced as soon as possible and should include:

- Sourcing a pilot RO plant to carry out site specific trials on water quality;
- Investigate brine disposal options both pre and post closure;
- Establish areas within the mine site where an active treatment plant can be installed;
- Determine flow rates, water qualities and site factors that may affect the plant performance;
- Establish feed water requirements for surge mitigation, including feed sump/pond size; and
- Establish treated water requirements, treated water ponds, discharge locations and retention times.

4.1.2 Preliminary Process Schematic

Figure 5 is a preliminary process schematic showing the likely key steps required in implementing a reverse osmosis process on site.

Figure 5: RO Process Schematic



4.1.3 Preliminary Site Layout

Figure 6, is a preliminary site layout showing the following key items,

- The plant area of 70m x 50m has been sized on a typical water treatment plant incorporating pre-treatment and reverse osmosis, noting this is preliminary only.
- A Surge Sump of 25,000m^3 has been sized based approximately on 7 days storage at mean flow.
- A treated water sump of 5000m^3 has been sized based greater than 24 hours storage at mean flow
- An access road for delivery of chemicals and reagents has been provided

The indicative water treatment plant location is shown in figure 3 (section 1 of the report)

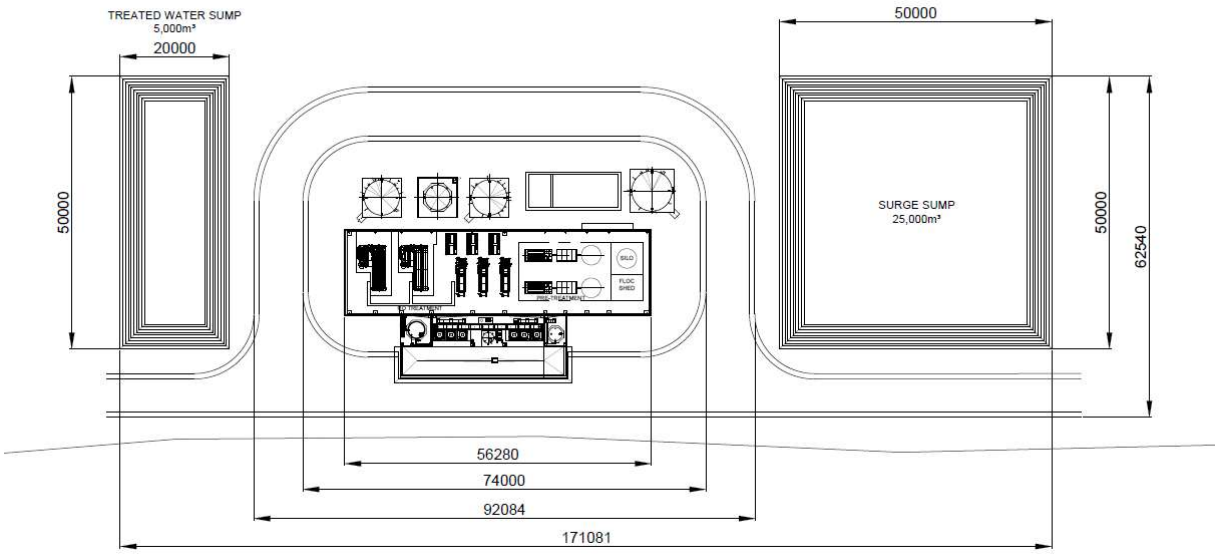


Figure 6: Preliminary WTP Layout

4.2 Pre-treatment – Recommendations

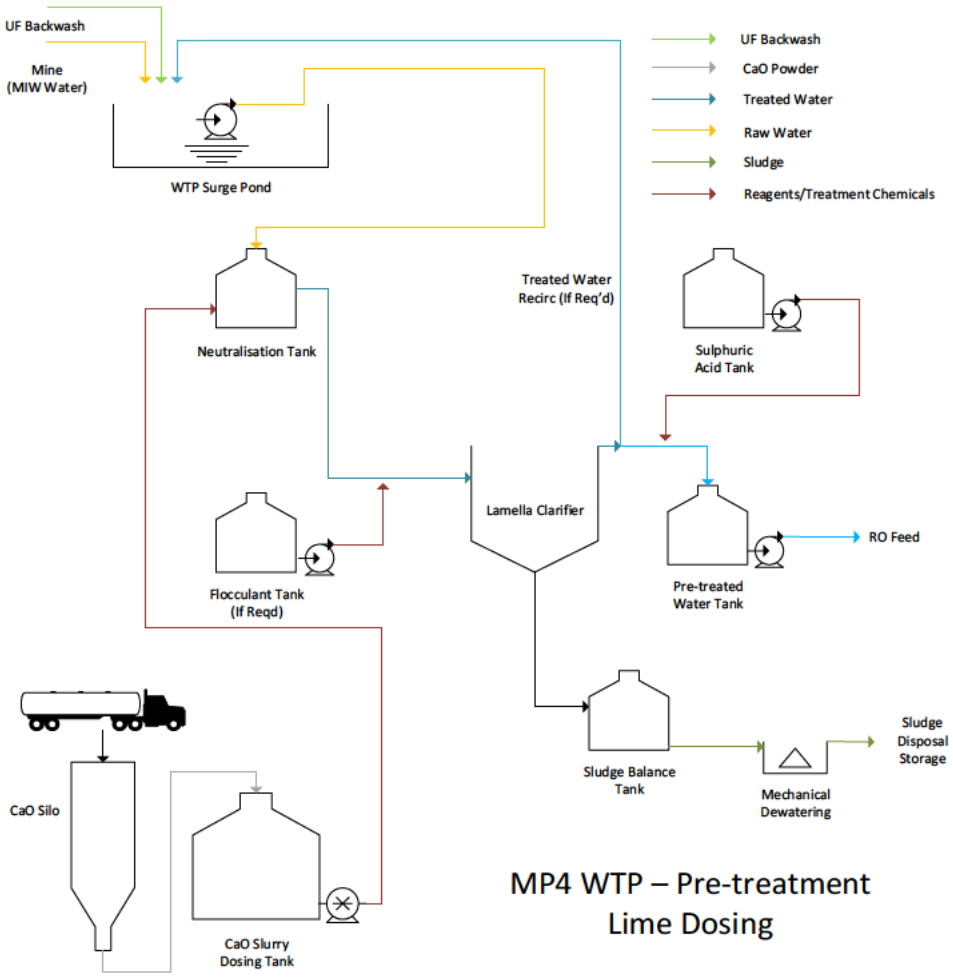
Pre-treatment will potentially be required prior to the RO process if greater reductions in metals concentrations are predicted to be necessary by the site wide water load balance model (WLBM). This step will reduce metals at the feed to the reverse osmosis system and enhance removal. The following pilot trials should be considered alongside the reverse osmosis pilot trials:

- Sourcing a pilot lamella plant (with chemical mixing and dosing) to carry out site specific trials on water quality;
- Carry out sludge dewatering trials on the Lamella underflow;
- Investigate sludge disposal options both pre and post closure;
- Establish areas within the mine site where an active treatment can be installed;
- Determine flow rates, water qualities and site factors that may affect the plant performance;
- Establish feed water requirements for surge mitigation including feed sump/pond size;
- Establish treated water requirements, treated water ponds, discharge locations and retention times;
- Trial the system using Lime, CaO and Ferric Chloride $FeCl_3$

4.2.1 Preliminary Process Schematic

Figure 7 is a preliminary process schematic showing the likely key steps required in implementing a lime dosing pre-treatment system. (Note Ferric Chloride dosing will also be trialled and may be used for pretreatment as an alternative to lime dosing)

Figure 7: Pre-treatment Process Schematic



4.3 Ettringite Precipitation – Recommendations

To test that this process is robust and will achieve consistently acceptable water quality in the discharge water the following additional work should be carried out prior to consideration of implementing this technology.

4.3.1 Optimisation Testing

The following optimisation tests are planned and underway. However, the results may not be available to include in this study before the submission date for the consent application.

- Trials using Sodium aluminate as a reagent in place of PAC are being carried out. The objectives of these trials are to eliminate the need for pH control during PAC dosing and reduce the elevated chloride concentration in the treated water.
- pH trimming trials of the treated water are planned, to reduce pH to within compliance limits. This will also potentially reduce the elevated hardness concentration. Methods of pH trimming trialled will be acid dosing, and CO_2 dosing.

- Characterisation of generated sludge samples is underway[3], including XRF, XRD and TCLP analysis (this may need repeating once optimisation testing is complete).

4.3.2 Recommended further work (following optimisation testing)

After the optimisation testing it is recommended that the following further work be carried out as part of the design development:

- Sludge dewatering test work;
- Investigate sludge disposal options both pre and post closure;
- Establish areas within the mine site where active treatment can be installed;
- Determine flow rates, water qualities and site factors that may affect the plant performance;
- Establish feed water requirements for surge mitigation including feed sump/pond size;
- Establish treated water requirements, treated water ponds, discharge locations and retention times; and
- Proceed to pilot-scale testing prior to detailed design to validate performance under continuous flow conditions, optimise reagent dosing, and refine sludge handling requirements.

[3] SpectraChem SA26170 and Sietronics LS3663 results landed June 2026

5 DISCLAIMER

This report provides information that is preliminary in nature and has been prepared to provide the client with water treatment information suitable for a "concept level" assessment for the overall project. The information provided is not suitable for detailed design or construction purposes and the information should not be used as a specification for tendering or any other construction related purpose.

This report has been prepared solely for the benefit of OceanaGold (New Zealand) Limited ("OGNZL"). No liability is accepted by this company or any employee or sub-consultant of this company with respect to its use by any other person/parties.

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Process Flow acknowledges that this report will be relied on by a Panel appointed under the Fast Track Approvals Act 2024 and these disclaimers do not prevent that reliance.

The information presented in this report is based on laboratory scale test work and review of known water treatment process technologies for primarily sulphate and metals removal. The information presented is preliminary, and pilot scale test-work should be carried out to confirm design assumptions and prove final water qualities can be achieved for the flows required.

APPENDIX A – MINE WATER TREATABILITY – TEST WORK REPORT

- Evaluation of Sulphate Reduction of Mine-Impacted Water Using Two-Stage Ettringite Precipitation

Macraes Mine Water Treatability Study

Evaluation of Sulphate Reduction from Mine-Impacted Water Using Two-Stage Ettringite Precipitation

Final Report – 01 September 2026

Macraes Mine Water Treatability Study

Evaluation of Sulphate Reduction from Mine-Impacted Water Using Two-Stage Ettringite Precipitation

Prepared by:
Dr Joe Wildy
Civil/Environmental Engineer
CPEng, CMEngNZ, PhD, ME, BE (Hons), NZCE, Dip Eng, (all Civil Engineering)

Prepared for:
Gary Smith Process Flow Water Infrastructure Ltd

Final Report – 01 September 2026

Disclaimer

This report presents the results and interpretation of initial laboratory-scale jar testing conducted on a 50:50 blend of mine impacted water[1] to evaluate the performance of a two-stage ettringite precipitation process (CaO gypsum pre-treatment followed by PAC polishing).

The findings are based on controlled, short-duration batch jar tests performed under specific laboratory conditions and are intended only as a preliminary proof-of-concept evaluation. They reflect the behaviour of spot samples taken at the time of testing and do not constitute a comprehensive or definitive characterisation of long-term treatment performance under full-scale, variable field conditions.

The results should not be relied upon as the sole basis for detailed design, operational, or environmental management decisions. Site-specific factors (including seasonal variations in water chemistry, scaling effects, and long-term sludge stability) have not been fully assessed in this study.

It is recommended that the outcomes of this work be validated through additional testing, including pilot-scale trials, before proceeding to full-scale implementation. Further work may also include XRD and XRF confirmation of ettringite formation, polymer optimisation for settling, sludge characterisation, and economic/cost modelling.

No liability is accepted for any decisions, actions, or omissions made on the basis of this preliminary analysis. Clients are advised to undertake appropriate additional sampling, detailed technical review, pilot testing, and risk assessment prior to making any design, operational, or environmental management decisions. All interpretations remain subject to the limitations of the laboratory-scale experimental setup and the data available at the time of reporting.

[1] Mine impacted water was sourced from tailings underdrain and waste rock seepage

Contents

1.0 Executive Summary

- Mine impacted water at Macraes Mine in East Otago can contain sulphate concentrations of up to ~3500 mg/L.
- The primary objective of this laboratory testing was to evaluate and optimise a dosing strategy for calcium oxide (CaO, quicklime) and polyaluminium chloride (PAC) to achieve effective sulphate (SO_4^{2-}) removal from the mine-impacted water via a two-stage ettringite precipitation process prior to discharging from the site.
- Figure 1 illustrates a schematic of the process used in this study.

Primary objectives of this work:

- Reduce sulphate from ~3400 mg/L (actual 50:50 blend) to nominal targets of between 200 to 500 mg/L.
- Determine minimum effective dose rates of CaO and PAC while minimising sludge volume and residual metals.
- Evaluate pH, mixing, settling, and decanting for scalability.
- Confirm ettringite as the primary Phase 2 mechanism.

Secondary objectives of this work:

- Identify site-specific interferences.
- Generate baseline data for future lab work and pilot scale work enhancements (e.g., polymer, sodium aluminate, Al recycling).

Key outcomes:

- Phase 1 (CaO optimisation):
    - Optimum dose of 5.6 g/L CaO reduced sulphate to 2600 mg/L (23.5 % removal) while quantitatively removing magnesium as brucite and achieving excellent co-precipitation of metals (As, Co, Mn, Ni, Fe).
    - High magnesium in the raw water (570 mg/L) limited gypsum-stage performance.
- Phase 2A (PAC without pH control):
    - Sulphate reduced to a minimum of 1400 mg/L (46 % removal of remaining fraction). However, the acidic PAC caused rapid pH collapse (down to 4.0), preventing ettringite formation and producing fluffy $Al(OH)_3$ sludge with high residual dissolved aluminium.
- Phase 2B (PAC with active pH control):

- Four jars were tested at moderate to very-high PAC doses while maintaining pH 11.5-12.5 (via dosing of CaO). Sludge was finer, off-white, and settled to ~5-10 % by volume after 24 h (improved over Phase 2A).
- The objective was to see if the two-stage process could reduce sulphate concentrations to a target concentration of 200-500 mg/L.

- Key conclusions:
  - Two-stage process is confirmed as viable with the lab work successfully achieving/exceeding treatment targets.
  - Continuous pH control between 11.5 and 12.5 is critical for ettringite formation.
  - Polymer is recommended to accelerate Phase 2 settling.
  - Sludge production ~5-10 % by volume.
  - This proof-of-concept has successfully identified and resolved the key site-specific interference (high Mg + PAC acidity).

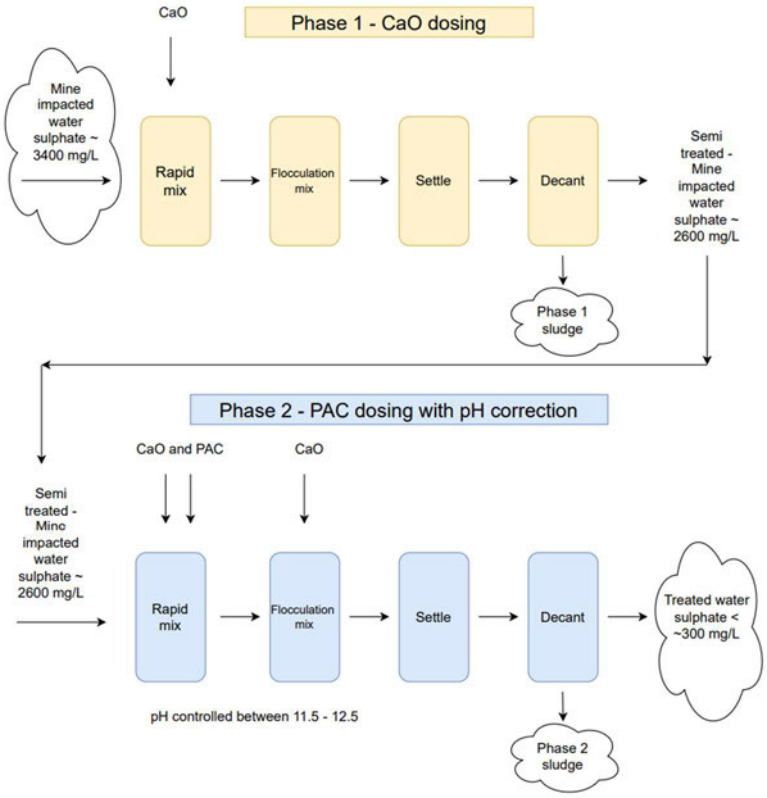

Figure 1: Schematic of the process used in this study.

2.0 Background

- Mine-impacted water can contain elevated sulphate levels (up to ~3500 mg/L in this case) from pyrite oxidation and other mineral weathering processes.

- Conventional treatment with lime (CaO or $Ca(OH)_2$) precipitates sulphate as gypsum ($CaSO_4 \cdot 2H_2O$).
- Gypsum is a hydrated calcium sulphate mineral with moderate solubility (~2.1 g/L at 20°C), limiting residual sulphate to 1400–2000 mg/L.
- For lower concentrations like 200-500 mg/L, advanced methods like ettringite precipitation will also be required.
- Ettringite is a low-solubility mineral with the formula $Ca_6Al_2(SO_4)_3(OH)_{12} \cdot 26H_2O$, formed at high pH (11.5–12.5) by combining calcium (from CaO), aluminium (i.e. from PAC, which hydrolyses to $Al(OH)_3$ equivalents), and sulphate from the water.
- The stoichiometric ratio is approximately 1:2:0.67 (SO_4:Ca:Al molar), but practical doses include 10–30% excess to account for inefficiencies.
- The process can achieve 85–99% sulphate removal, as demonstrated in commercial systems like SAVMIN or Outotec Ettringite Process.
- A two-stage approach, gypsum precipitation with CaO (Stage 1), followed by settling/decanting and ettringite formation with PAC (Stage 2) is likely to be effective for high-sulphate waters (>2000–2500 mg/L), as it separates bulk removal from polishing, reduces interferences, and improves sludge handling.
- A Jar testing apparatus can usually simulate and replicate mixing conditions (rapid mixing, flocculation mixing) along with settling in a controlled lab environment.
- This research has simulated the 2-stage treatment process under laboratory conditions to demonstrate if and how the Macraes Mine water can be treated to successfully reduce the concentration of sulphate.

3.0 Materials and Equipment

3.1 Reagents

- Mine-impacted water sample:
    - Freshly collected and stored under conditions to preserve composition (e.g., refrigerated at 4°C, analysed for initial SO_4 ~3500 mg/L, pH, metals, and other ions like Mg^{2+}).
    - Calcium Oxide (CaO, quicklime): Sourced from Taylors Lime at Dunback (just down the road from Macraes).
    - Polyaluminium chloride (PAC) commercial grade (e.g., 10–18% Al_2O_3 content).
- Deionized water:
    - For reagent slurries or dilutions.
- pH adjustment aids:

- Small amounts of acid (e.g., HCl) or additional CaO can be used if pH adjustment is required.

3.2 Equipment

- Phipps and Bird jar mixer: 4-bay unit for simultaneous testing of multiple doses.
- Beakers/jars: 2L capacity (but use 1 L), graduated square jars with extras for supernatant transfer.
- Analytical balance: For precise reagent weighing (5dp)
- pH meter: RE357 lab grade pH meter.
- Pipettes.
- Imhoff cone for sludge volume measurement.
- Timer: For controlled mixing and settling phases.
- Decanting tools.
- Analysis of supernatant via R J Hills Laboratory.
- Optional: XRD/XRF for sludge characterization.

4.0 Experimental Methodology

- The experimental methodology was broken down into two separate phases.
  - Phase 1 related to the dosing of CaO to determine the optimum dose rate and performance of CaO dosing.
  - Phase 2, with the results from Phase 1, a second series of tests were developed to determine the optimum PAC dose rate and optimum conditions for PAC dosing.

4.1 Experimental Methodology Phase 1

- The raw water characteristics are illustrated in Section 5.0.
- This test work was undertaken on a 50:50 blend which had the following characteristics:
  - Sulphate: 3200 g/m³ (mg/L), starting concentration.
  - pH: 7.2.
  - Total hardness: 3100 g/m³ as $CaCO_3$.
  - Dissolved Mg: 510 mg/L (moderate, may form minor brucite in Stage 2)
  - Dissolved Ca: 390 mg/L.
  - Total Fe: 2.5 mg/L, Dissolved Mn: 4.0 mg/L, As: 0.87 mg/L (all expected to co-precipitate).
  - Other: low DOC (4.8 mg/L), moderate TSS (16 mg/L).

Calculations:

- Calcium oxide (CaO) Dose for 1 L of 50:50 Blend to achieve the lowest possible residual SO_4 (Stage 1, gypsum precipitation).
- Step 1: Confirm starting concentration SO_4 (50:50 blend) = 3200 mg/L = 3.2 g/L.
- Step 2: Stoichiometric (theoretical) CaO requirement reaction:
    - $CaO + SO_4^{2-} + 2H_2O \rightarrow CaSO_4 \cdot 2H_2O$ (gypsum)
    - Molar mass CaO = 56.08 g/mol
    - Molar mass SO_4 = 96.06 g/mol
    - Mass ratio = 56.08 / 96.06 = 0.5833 g CaO per g SO_4
    - Theoretical CaO = 3.2 g/L × 0.5833 = 1.8666 g/L ≈ 1.87 g per litre (This would theoretically remove every gram of SO_4 if gypsum had zero solubility, which it does not.)
- Step 3: Gypsum solubility at 20–25 °C limits residual SO_4 to ~1,400–2,000 mg/L.
    - Typical achievable target after good mixing/settling = ~1,400–1,800 mg/L.
    - Step 4: Practical dosing range (includes excess for pH, kinetics & common-ion effect) 0.75–1.5 mg CaO per mg initial SO_4 (~30 % to 160 % excess).
    - This is standard practice for high-sulphate water to reach the gypsum solubility limit quickly and raise pH to 9.5–11.
- Table 1 illustrates the jar testing dosing matrix.

Methodology Phase 1:

1. Add ~1000 mL of mine-impacted water to each jar.
2. Record initial pH, temperature.
3. Accurately weigh out the mass of CaO to be dosed on a five dp analytical balance.
4. Dose CaO variably across jars targeting pH 9.5–11 for gypsum formation.
5. Rapid mix at 200 rpm for 30 seconds to disperse CaO and initiate pH rise/gypsum precipitation.
6. Slow mix at 30 rpm for 30 minutes to allow initial precipitation and crystal growth.
7. Allow settling for 60 minutes (extend if flocs are slow).
8. Carefully decant or siphon supernatant from each jar into clean beakers or new jars, minimizing disturbance of settled solids to avoid carryover.
9. Analyse the decanted supernatant for: SO_4 (expect ~1400–2000 mg/L), pH, turbidity, and metals.
10. Measure sludge volume and note settling characteristics.
11. Filter and vacuum pack a sample of the sludge for potential XRD and XRF analysis.

Table 1: Phase 1 testing matrix.

Jar	Ratio (mg CaO per mg SO_4)	CaO Dose (grams per 1 L jar)	Purpose / Behaviour
1	0.5	1.6 g	Severe under-dose
2	0.75	2.4 g	Low dose
3	1	3.2 g	Near-stoichiometric
4	1.25	4.0 g	Moderate excess
5	1.5	4.8 g	Strong excess
6	1.75	5.6 g	High excess
7	2	6.4 g	Very high excess
8	2.5	8.0 g	Extreme overdose (test limit)

4.2 Experimental Methodology Phase 2A

- The Phase 2 testing was initially undertaken without pH control during PAC addition.
- It was found the lack of pH control resulted in reduced SO_4 removal.
- The test work was subsequently repeated with pH correction.
- The results for Phase 2 have been presented as follows:
    - Phase 2A no pH correction (results in appendix).
    - Phase 2B with pH correction.
- The optimum CaO dose rate from Phase 1 is identified and the supernatant from that dose rate is collected for use in Phase 2.
- The characteristics of this supernatant are then used to calculate the PAC dosing matrix for Phase 2 as follows.

Comments:

- The material is PAC, but the supplier (Chemiplas) and the entire water-treatment industry report its strength as % Al_2O_3 (aluminium oxide equivalent).
- This is not elemental aluminium or $AlCl_3$ (it is a standardised convention).
- Al_2O_3 is used on the spec sheet and in calculations
- On the Chemiplas AC100S specification sheet the very first parameter is: 'Aluminium as Al_2O_3, percent by mass, Min 9.50' (This is the official, guaranteed strength of the product.)
- Every commercial PAC supplier worldwide (including Chemiplas, Ixom, Kemira, etc.) quotes the active aluminium content this way because:
    - It is the international standard for comparing PAC products regardless of their exact structure.
    - It allows direct conversion to the $Al(OH)_3$ equivalent needed for ettringite precipitation dosing (the calculation we use in Stage 2).

- Chemically, PAC is a mixture of polymeric aluminium species (e.g. $[Al_2(OH)_nCl_{6-n}]_m$). When it hydrolyses at high pH it behaves as if it were providing $Al(OH)_3$. The % Al_2O_3 figure is simply the manufacturer's way of expressing how much 'aluminium oxide equivalent' is present in the liquid.

PAC dosing calculations, worked example (0.75 Ratio)

- The PAC dosing in Phase 2 is based on the actual residual sulphate measured after Phase 1 (2600 mg/L).
- Then use a simple 'ratio' to decide how much aluminium to add.
- Below is a full worked example for the 0.75 ratio (the jar we expect to be close to optimum).
- What the 'ratio' means.
    - The ratio is simply: mg $Al(OH)_3$ equivalent per mg of remaining SO_4
    - A ratio of 0.75 means we are adding 0.75 mg of aluminium (expressed as $Al(OH)_3$) for every 1 mg of sulphate still left in the water after Stage 1.
    - This is a practical dosing rule based on ettringite chemistry.
    - The theoretical stoichiometric ratio is ~0.54, but we use higher values (0.75–1.05) to give some excess and ensure good removal in real water.
- Calculate the $Al(OH)_3$ equivalent dose residual SO_4 after Phase 1 = 2600 mg/L = 2.6 g/L

$$\text{Al(OH)}_3 \text{ equivalent dose (g/L)} = \text{Ratio} \times 2.6$$

For the 0.75 ratio:

$$0.75 \times 2.6 = \mathbf{1.95\ g/L\ Al(OH)_3\ equivalent}$$

- This is the amount of aluminium (expressed as $Al(OH)_3$) we need to add per litre of supernatant.
- Convert to actual volume of Chemiplas PAC liquid the Chemiplas PAC spec sheet tells us the product contains 10 % Al_2O_3 by mass and has a density of 1.2 g/mL.
- First, convert the 10 % Al_2O_3 into an $Al(OH)_3$ equivalent content:

$$1\ \text{g}\ Al_2O_3 \equiv 1.53\ \text{g}\ Al(OH)_3$$

So 10 % Al_2O_3 = **15.3 % $Al(OH)_3$ equivalent** by mass.

Then we calculate how much liquid PAC is needed:

$$\text{Mass of PAC required (g/L)} = \frac{1.95\ \text{g Al(OH)}_3}{0.153} \approx 12.75\ \text{g/L}$$

- Finally convert mass to volume using the density:

$$\text{Volume of PAC (mL/L)} = \frac{12.75\ \text{g/L}}{1.2\ \text{g/mL}} = \mathbf{10.63\ mL/L}$$

- Result for the 0.75 ratio jar: Add 10.63 mL of Chemiplas PAC liquid per litre of Phase 1 supernatant.
- Summary of the full 8-jar series (for easy reference).
    - The same method was used for all jars:
    - Ratio 0.30 → 4.25 mL/L.
    - Ratio 0.45 → 6.38 mL/L.
    - Ratio 0.60 → 8.50 mL/L.
    - Ratio 0.75 → 10.63 mL/L (example above).
    - Ratio 0.90 → 12.75 mL/L.
    - Ratio 1.05 → 14.88 mL/L.
    - Ratio 1.20 → 17.00 mL/L.
    - Ratio 1.50 → 21.26 mL/L.
- These volumes are specific to the Chemiplas AC100S product (10 % Al_2O_3, density 1.2 g/mL).
- If the actual batch assay is slightly different (e.g. 9.5 % or 12 %), the volumes can be scaled by the factor 10 / actual % Al_2O_3.
- This method ensures we dose the correct amount of aluminium while keeping the calculations transparent and reproducible.
- Table 2 illustrates the jar testing dosing matrix (developed on the basis of the Phase 1 supernatant characteristics and the methodology described above).

Table 2: Phase 2 testing matrix.

Jar	Ratio	$Al(OH)_3$ Equiv. (g/L)	PAC Liquid Volume (mL per 1 L jar)	Purpose
1	0.3	0.78	4.25 mL	Under-dose
2	0.45	1.17	6.38 mL	Low dose
3	0.6	1.56	8.50 mL	Moderate
4	0.75	1.95	10.63 mL	Likely optimum
5	0.9	2.34	12.75 mL	Strong excess
6	1.05	2.73	14.88 mL	High excess
7	1.2	3.12	17.00 mL	Very high
8	1.5	3.9	21.26 mL	Maximum test

Methodology Phase 2A:

1. Add ~1000 mL of supernatant from the optimum CaO dose rate in Phase 1.
2. Check pH; if <11.5, if not then add small additional CaO (e.g., 0.2–0.5 g/L) to reach 11.5–12.5 for ettringite stability.
3. Add fixed PAC dose
4. Rapid mix at 200 rpm for 30 seconds.
5. Slow mix at 20–30 rpm for 30 minutes to promote ettringite formation and flocculation.
6. Allow settling for 60 minutes.
7. Decant supernatant from each jar.
8. Analyse supernatant for: SO_4
9. Measure sludge volume and note settling characteristics.
10. Vacuum pack a sample of the sludge for potential XRD and XRF analysis.

4.3 Experimental Methodology Phase 2B

- Phase 2 testing needs to be repeated with pH control to ensure the water stays between pH 11.5 to pH 12.5 for optimum sulphate removal via ettringite formation.
- The methodology for Phase 2B is the same as Phase 2A but with improved pH control during the process.

1. Add ~1000 mL of supernatant from the optimum CaO dose rate in Phase 1.
2. Check pH; if <11.5, if not then add CaO to reach 11.5–12.5 for ettringite stability.
3. Continuously monitor pH and dose CaO to maintain pH between 11.5 and 12.5 while slowly adding PAC dose.
4. pH control using CaO must be maintained continuously until the end of the slow mix phase.

5. Rapid mix at 200 rpm for 30 seconds.
6. Slow mix at 20–30 rpm for 30 minutes to promote ettringite formation and flocculation.
7. Allow settling for 60 minutes.
8. Decant supernatant from each jar.
9. Analyse supernatant for: SO_4
10. Measure sludge volume and note settling characteristics.
11. Vacuum pack a sample of the sludge for potential XRD and XRF analysis.

4.4 Experimental Methodology – Additional Filtration Stage.

- With respect to Phase 1, Phase 2A and Phase 2B.
    - Where settling rates are insufficient to produce a clear decantable supernatant within the nominated 60-minute period (or where residual floc carry-over was observed), the supernatant was filtered.
    - In practice:
        - It was not necessary to filter Phase 1 supernatant.
        - Phase 2A was vacuum filtered through a Whatman GF/C under vacuum.
        - Phase 2B was pressure filtered through a dual filter Advantec 5A under pressure (larger capacity device and process).
- Filtering was implemented in accordance with the contingency described in the original project methodology and mirrors the standard laboratory practice employed by R J Hill Laboratories for all 'dissolved' parameters, including sulphate (APHA 4110 B), metals (APHA 3125 B), and dissolved organic carbon.
- Filtration isolates the truly soluble fraction that would be representative of the final treated water quality after full-scale clarification and/or filtration.
- In practice (as the test work was completed):
    - Phase 1, the suspended solids settled within a reasonable time to produce a clear supernatant. Therefore, no filtering was required on the Phase 1 supernatant. The supernatant was decanted for R J Hills analysis.
    - Phase 2A and Phase 2B, the suspended solids did settle to produce a clear supernatant but the settling rates were slow and in practice it is likely an additional polymer would be used to flocculate the fine suspended solids and accelerate the sedimentation rates. Therefore, filtration was undertaken to separate the suspended solids so R J Hills could be given a sample of the supernatant for analysis.

- The Phase 2A sample was vacuum filtered through a Whatman GF/C (1.2 µm nominal pore size glass-fibre filter), which is the standard filter for Total Suspended Solids (TSS) analysis (APHA 2540 D).
- The Phase 2B sample was pressure filtered through dual Advantec Quantitative Ashless Filter Paper with the following specifications:
  - Grade 5A (Medium Retention).
  - Brand / Grade: Advantec (Japan) No. 5A
  - Type: Quantitative ashless filter paper.
  - Diameter: 110 mm circles
  - Quantity: 100 circles per box
  - Pore size / Particle retention: 7 µm (medium filtration speed)
  - Ash content: ≤ 0.01 % (ashless grade)
  - Flow rate: Medium
  - Application: General quantitative analysis, filtration of precipitates, and gravimetric determinations where low ash residue is required.
- Grade 5A is comparable to Whatman Grade 40/41 in performance, it retains particles larger than ~7 µm while allowing reasonably fast filtration. It is the standard "medium" ashless paper in the Advantec range and is ideal for vacuum (or pressure) filtration step after jar testing (removing fine flocs while providing clear supernatant for Hill Labs analysis).

- The analysis work by R J Hill Laboratories required ~ 3 L of sample.
- In Phase 2B the decision was made to switch from vacuum filtration to a larger capacity pressure filtration system.
- The benefit of these systems is they can be filled with bulk sample and left for an extended period to slowly produce filtrate. They take a larger diameter filter, have a ~10 L reservoir capacity and operate on adjustable air pressure in the head space as opposed to a vacuum system which requires a vacuum pump.
- Vacuum pump systems are ideal for separating small samples, i.e. for TSS analysis or analysis of dissolved fractions, however they only do ~ 100 mL at a time.
- Figure 2 illustrates the filtration system used for Phase 2B.
- Towards the end of the experimental work, it was also necessary to collect sludge samples from Phase 1 and Phase 2B for XRF and XRD analysis, the hardware used in Figure 2 was used to pressure filter both respective samples.

Figure 2: Filtration hardware used on Phase 2B. Filter papers are held on a stainless-steel support base and are clamped into the bottom. Sample is introduced into the top. Air pressure is then set and maintained in the headspace to enhance filtration rates. In this instance dual filters were used.

5.0 Raw Water Characteristics

- Surface water samples were collected from two sources at Macraes Mine:
  - NGSP (Northern Gully Silt Pond) and,
  - TTTSF (Top Tipperary Tailings Storage Facility) taken from the seepage collection sump.
- The samples were collected in late January 2026 by staff from Mine Waste Management.
- Samples were provided to the laboratory in sealed 20 L jerry cans.
- The samples were analysed independently and a 50:50 blend was also produced and used for the analysis work in this report. Table 3 illustrates a summary of the respective water characteristics.

Table 3: Characteristics of raw NGSP and TTTSF surface water along with a 50:50 blend of each sample. The 50:50 blend was used in subsequent testing in this water treatability study.

Parameter	Unit	NGSP	50:50	TTTSF
pH	pH Units	7.9	7.2	7
Total Alkalinity	g/m³ as $CaCO_3$	380	370	370
Carbonate	g/m³ at 25°C	1.7	< 1.0	< 1.0
Bicarbonate	g/m³ at 25°C	460	460	450
Total Hardness	g/m³ as $CaCO_3$	3,700	3,100	2,500
Electrical Conductivity (EC)	mS/m	477	482	481
Total Suspended Solids	g/m³	22	16	6
Total Solids (TS)	g/m³	5,900	5,400 *1	5,000
Dissolved Aluminium	g/m³	< 0.003	< 0.003	< 0.003
Total Aluminium	g/m³	< 0.0032	0.023	0.045
Dissolved Antimony	g/m³	0.0037	0.002	0.0008
Total Arsenic	g/m³	0.0065	0.87	1.87
Dissolved Boron	g/m³	< 0.05	0.22	0.4
Dissolved Calcium	g/m³	310	390	460
Dissolved Cobalt	g/m³	< 0.0002	0.114	0.22
Dissolved Iron	g/m³	< 0.02	< 0.02	< 0.02
Total Iron	g/m³	< 0.021	2.5	5.5
Dissolved Magnesium	g/m³	710	510	330
Dissolved Manganese	g/m³	< 0.003	4	7.7
Dissolved Molybdenum	g/m³	0.0007	0.0034	0.0055
Dissolved Potassium	g/m³	14.6	36	58
Dissolved Selenium	g/m³	0.034	0.0171	< 0.003
Dissolved Sodium	g/m³	73	240	380
Dissolved Sulphur	g/m³	1,160	1,080	1,000
Dissolved Thallium	g/m³	< 0.00005	< 0.00005	0.00007
Total Cyanide	g/m³	< 0.002	< 0.002	< 0.002
Chloride	g/m³	11.8	18.8	24
Fluoride	g/m³	< 0.05	0.13	0.2

Table 3: Continued.

Parameter	Unit	NGSP	50:50	TTTSF
Total Nitrogen	g/m³	6.7	8.5	10.2
Total Ammoniacal-N	g/m³	< 0.010	3.1	6
Nitrite-N	g/m³	0.061	0.31	0.52
Nitrate-N	g/m³	5.2	2.9	0.81
Nitrate-N + Nitrite-N	g/m³	5.2	3.2	1.33
Total Kjeldahl Nitrogen (TKN)	g/m³	1.49	5.4	8.9
Sulphate	g/m³	3,500	3,200	3,000
Dissolved Organic Carbon (DOC)	g/m³	< 0.5	4.8	3.9
Dissolved Arsenic	g/m³	0.0061	0.24	0.42
Dissolved Cadmium	g/m³	< 0.00005	0.00006	0.00012
Dissolved Chromium	g/m³	< 0.0005	< 0.0005	< 0.0005
Dissolved Copper	g/m³	< 0.0005	< 0.0005	< 0.0005
Dissolved Lead	g/m³	< 0.00010	< 0.00010	< 0.00010
Dissolved Nickel	g/m³	0.0131	0.085	0.148
Dissolved Zinc	g/m³	< 0.0010	0.0101	0.0198

6.0 Results (Jar Testing)

- The results are presented in two stages:
  - Jar testing results (Section 6.0).
  - Sedimentation, sludge characteristics (Section 7.0).

6.1 Results Phase 1

Table 4 illustrates the analysis results of the supernatant following the Phase 1 (CaO dosing).

Table 4: Phase 1 supernatant characteristics (post CaO dosing).

Parameter	Units	Control 50:50	J1	J2	J3
pH	pH Units	7.4	9.8	10.6	11.9
Total Alkalinity	g/m3 as CaCO3	380	53	101	510
Carbonate	g/m3 at 25°C	< 1.0	11.1	38	86
Bicarbonate	g/m3 at 25°C	460	38	22	2.6
Total Hardness	g/m3 as CaCO3	3,400	2,800	2,800	2,900
Electrical Conductivity (EC)	mS/m	499	443	440	590
Total Suspended Solids	g/m3	4	37	34	27
Total Solids (TS)	g/m3	5,200	4,600	4,500	4,600
Dissolved Aluminium	g/m3	< 0.003	< 0.003	< 0.003	< 0.003
Total Aluminium	g/m3	0.0049	< 0.0032	0.0145	0.0181
Dissolved Antimony	g/m3	0.0022	0.0017	0.0011	0.0008
Dissolved Arsenic	g/m3	0.199	0.0052	0.0025	0.0025
Total Arsenic	g/m3	0.3	0.0081	0.0082	0.0052
Dissolved Boron	g/m3	0.24	0.16	0.15	0.21
Dissolved Cadmium	g/m3	0.00007	< 0.00005	< 0.00005	< 0.00005
Dissolved Calcium	g/m3	410	590	1,100	1,170
Dissolved Chromium	g/m3	< 0.0005	0.0023	0.0055	0.0069
Dissolved Cobalt	g/m3	0.092	0.0017	0.001	0.001
Dissolved Copper	g/m3	< 0.0005	0.0006	0.0007	0.0008
Dissolved Iron	g/m3	< 0.02	< 0.02	< 0.02	< 0.02
Total Iron	g/m3	0.39	< 0.021	< 0.021	< 0.021
Dissolved Lead	g/m3	< 0.00010	< 0.00010	< 0.00010	0.00063
Dissolved Magnesium	g/m3	570	330	16.9	0.04
Dissolved Manganese	g/m3	3.9	0.023	< 0.0005	0.001
Dissolved Molybdenum	g/m3	0.0024	0.0024	0.002	0.0021
Dissolved Nickel	g/m3	0.077	0.0022	0.0008	0.0006
Dissolved Potassium	g/m3	37	36	38	37
Dissolved Selenium	g/m3	0.0174	0.0166	0.0165	0.0172
Dissolved Sodium	g/m3	240	230	240	240
Dissolved Thallium	g/m3	< 0.00005	< 0.00005	< 0.00005	< 0.00005
Dissolved Vanadium	g/m3	< 0.0010	< 0.0010	< 0.0010	< 0.0010
Dissolved Zinc	g/m3	0.0091	< 0.0010	< 0.0010	0.0012
Total Cyanide	g/m3	< 0.002	< 0.002	< 0.002	< 0.002
Chloride	g/m3	16.9	16.9	16.6	16.8
Fluoride	g/m3	0.12	< 0.05	< 0.05	< 0.05
Total Nitrogen	g/m3	7.8	7.8	7.3	7.3
Total Ammoniacal-N	g/m3	2.2	2.8	2.7	2.8
Nitrite-N	g/m3	0.78	0.76	0.77	0.79
Nitrate-N	g/m3	3.1	3.3	3.1	3.1
Nitrate-N + Nitrite-N	g/m3	3.9	4.1	3.8	3.9
TKN	g/m3	3.9	3.7	3.5	3.4
Sulphate	g/m3	3,400	3,200	3,000	3,100
DOC	g/m3	< 0.5	3.8	4.1	5.2

Table 4: Continued.

Parameter	Units	J4	J5	J6	J7	J8
pH	pH Units	12.2	12.4	12.5	12.6	12.6
Total Alkalinity	g/m3 as CaCO3	890	1,590	1,940	2,200	2,400
Carbonate	g/m3 at 25°C	72	127	172	198	230
Bicarbonate	g/m3 at 25°C	< 1.0	< 1.0	1.1	1.1	1.3
Total Hardness	g/m3 as CaCO3	2,800	3,200	4,000	3,900	4,200
Electrical Conductivity (EC)	mS/m	683	916	1,022	1,133	1,189
Total Suspended Solids	g/m3	54	16	66	26	20
Total Solids (TS)	g/m3	4,200	4,600	5,000	5,200	5,400
Dissolved Aluminium	g/m3	< 0.003	< 0.003	< 0.003	< 0.003	< 0.003
Total Aluminium	g/m3	0.0052	< 0.0032	< 0.0032	< 0.0032	< 0.0032
Dissolved Antimony	g/m3	0.0006	0.0004	0.0002	< 0.0002	< 0.0002
Dissolved Arsenic	g/m3	0.0027	0.0027	0.0028	0.0025	0.0025
Total Arsenic	g/m3	0.0076	0.0027	0.0042	0.0029	0.0032
Dissolved Boron	g/m3	0.21	0.21	0.2	0.21	0.21
Dissolved Cadmium	g/m3	< 0.00005	< 0.00005	< 0.00005	< 0.00005	< 0.00005
Dissolved Calcium	g/m3	1,140	1,290	1,610	1,550	1,670
Dissolved Chromium	g/m3	0.0071	0.0083	0.01	0.0096	0.0109
Dissolved Cobalt	g/m3	0.001	0.001	0.001	0.0009	0.0009
Dissolved Copper	g/m3	< 0.0005	< 0.0005	< 0.0005	< 0.0005	< 0.0005
Dissolved Iron	g/m3	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02
Total Iron	g/m3	< 0.021	< 0.021	< 0.021	< 0.021	< 0.021
Dissolved Lead	g/m3	0.00013	0.00025	0.00017	0.00062	0.00013
Dissolved Magnesium	g/m3	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02
Dissolved Manganese	g/m3	< 0.0005	< 0.0005	< 0.0005	< 0.0005	< 0.0005
Dissolved Molybdenum	g/m3	0.002	0.0032	0.0034	0.0032	0.0031
Dissolved Nickel	g/m3	< 0.0005	0.0005	0.0006	< 0.0005	< 0.0005
Dissolved Potassium	g/m3	38	37	38	38	37
Dissolved Selenium	g/m3	0.0172	0.0175	0.0177	0.0178	0.018
Dissolved Sodium	g/m3	240	240	240	240	230
Dissolved Thallium	g/m3	< 0.00005	< 0.00005	< 0.00005	< 0.00005	< 0.00005
Dissolved Vanadium	g/m3	< 0.0010	< 0.0010	< 0.0010	< 0.0010	< 0.0010
Dissolved Zinc	g/m3	< 0.0010	0.0028	< 0.0010	< 0.0010	< 0.0010
Total Cyanide	g/m3	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002
Chloride	g/m3	16.3	16.1	16	15.3	16.2
Fluoride	g/m3	0.05	0.06	0.05	< 0.05	< 0.05
Total Nitrogen	g/m3	7.2	7.2	7.2	7.6	7.3
Total Ammoniacal-N	g/m3	2.6	2.7	2.6	2.8	2.7
Nitrite-N	g/m3	0.78	0.8	0.79	0.79	0.78
Nitrate-N	g/m3	3.1	3.2	3.1	3.1	3.1
Nitrate-N + Nitrite-N	g/m3	3.9	4	3.9	3.9	3.9
TKN	g/m3	3.3	3.2	3.3	3.7	3.4
Sulphate	g/m3	2,800	2,700	2,600	2,800	2,900
DOC	g/m3	5.3	3.9	3.8	3	3.2

Phase 1- Results analysis:

- The data shows clear trends in pH, metals removal, magnesium behaviour, and hardness, however no jar reached the predicted sulphate 1400–1600 mg/L range.
- Table 5 illustrates a summary of the key data.
- With reference to Table 5, sulphate removal peaks at only 23.5% (2600 mg/L) in Jar 6 and then plateaus or slightly rebounds at higher doses.
- pH behaves as expected with rapid rise above 11.5 once Mg starts precipitating.
- Magnesium is quantitatively removed (>99%) once CaO exceeds ~3.2 g/L (brucite formation).
- Most metals (As, Co, Mn, Ni, total Fe, total As) drop dramatically, excellent co-precipitation.
- Aluminium stays very low (<0.018 mg/L total).
- Hardness and dissolved Ca increase with dose (excess Ca^{2+}), as expected.
- EC rises sharply at higher doses (expected from added ions and pH shift).
- TSS remains low (20–66 g/m^3), no major suspended solids carry-over.

Table 5: Summary of key Phase 1 supernatant characteristics.

Jar	CaO Dose (g/L)	pH	Sulphate (mg/L)	% SO_4 Removal from Control	Dissolved Mg (mg/L)	Total Hardness (g/m^3)	Dissolved Ca (g/m^3)	Total Al (g/m^3)	Notes
Control	0	7.4	3400	—	570	3400	410	0.0049	Baseline
1	1.6	9.8	3200	5.90%	330	2800	590	<0.0032	Minor removal
2	2.4	10.6	3000	11.80%	16.9	2800	1100	0.0145	Mg starts dropping
3	3.2	11.9	3100	8.80%	0.04	2900	1170	0.0181	Mg fully removed
4	4	12.2	2800	17.60%	<0.02	2800	1140	0.0052	—
5	4.8	12.4	2700	20.60%	<0.02	3200	1290	<0.0032	—
6	5.6	12.5	2600	23.50%	<0.02	4000	1610	<0.0032	Lowest SO_4
7	6.4	12.6	2800	17.60%	<0.02	3900	1550	<0.0032	Slight rebound
8	8	12.6	2900	14.70%	<0.02	4200	1670	<0.0032	Plateau

Why sulphate did not drop to the predicted 1400–1600 mg/L:

- The initial modelling (and standard literature for gypsum precipitation) assumed typical high-sulphate mine water where lime dosing easily reaches the gypsum solubility limit of ~1400–2000 mg/L residual SO_4.
- The Macraes Mine samples provided have unusually high magnesium (570 mg/L dissolved Mg in the control).

Full explanation:

1. Magnesium consumes a large fraction of the added CaO. Brucite precipitation reaction: $Mg^{2+} + CaO + H_2O \rightarrow Mg(OH)_2\downarrow + Ca^{2+}$ Stoichiometric requirement: ~2.3 g CaO per g Mg. For 570 mg/L Mg this alone demands ~1.31 g/L CaO just to remove magnesium before any sulphate is touched. Once pH exceeds ~11 (Jars 3+), virtually all Mg is removed as brucite. The CaO that would otherwise be available for gypsum formation is partly diverted to supplying the OH^- for brucite. This reduces the effective excess Ca^{2+} available for common-ion suppression of gypsum.
2. Competing precipitates and high-pH effects at the doses needed for full Mg removal (≥4 g/L CaO), pH is already 12.2–12.6. In this regime:
    - Gypsum solubility is slightly higher than at pH 9–11 (the classic 'sweet spot').
    - Minor calcium carbonate formation occurs (carbonate rises to 230 g/m³ in Jar 8), which competes for Ca^{2+}.
    - The system is approaching conditions where ettringite-like phases could start forming (but without Al added yet, this doesn't help SO_4 removal).
3. Matrix-specific solubility, the water had high ionic strength (EC up to 1189 mS/m at high doses). Activity coefficients change, and the effective gypsum solubility product increases. Combined with the high background ions (Na 240 mg/L, K 37–38 mg/L, Cl ~16 mg/L), the practical residual SO_4 floor for this specific water is likely ~2600 mg/L after lime treatment, not the 1400–1600 mg/L seen in lower Mg waters.
4. Kinetics and jar-test realities, even with our improved 200 rpm rapid mix and 30 rpm slow mix, full gypsum crystal growth and equilibrium may not have been reached in the 60-minute settling time, especially with the competing brucite flocs.

Bottom line: The prediction was based on general literature for 'typical' gypsum-limited waters. The Macraes Mine water's high magnesium (570 mg/L) creates a competing lime demand that limits Stage 1 SO_4 removal to ~23–24% maximum. Site specific sample collection and test work proved important for this study.

Positive outcomes and recommendation for Phase 2:

- Excellent metal co-removal (As down to ~0.0025–0.008 mg/L, Mn/Co/Ni/Fe near detection limits).
- Magnesium is completely removed at ≥4 g/L CaO.
- Aluminium remains negligible, perfect for Stage 2 PAC addition.

Recommended optimal CaO dose for Phase 2:

- Jar 6 (5.6 g/L) gives the lowest supernatant SO_4 (2600 mg/L), full Mg removal, good pH (12.5), and low residual metals/Al.
- Moving forward, the work for Phase 2 needs to replicate the supernatant from the 5.6 g/L CaO dose for the PAC optimisation runs.
- We now have data showing that Stage 1 alone cannot reach the target, which is why the ettringite polishing step will be essential.

Phase 2 (PAC optimisation), Predicted outcomes for Phase 2 (estimate only)

- The following is an estimate for the likely final sulphate concentrations after optimised PAC dosing in Phase 2.
- Estimates and reasoning:
    - Considering our actual Phase 1 sulphate residual is ~2,600 mg/L SO_4 (Jar 6, 5.6 g/L CaO), the ettringite precipitation stoichiometry, real-world performance data from commercial ettringite processes, and our high-pH supernatant (pH 12.5) with complete Mg removal (both ideal conditions for ettringite).
- Theoretical minimum (100 % efficient ettringite):
    - From the ettringite formula $Ca_6Al_2(SO_4)_3(OH)_{12}\cdot 26H_2O$: 3 moles SO_4 require 2 moles $Al(OH)_3$. Mass ratio = 0.541 g $Al(OH)_3$ per g SO_4.
    - For 2.6 g/L SO_4 → theoretical $Al(OH)_3$ needed = 1.41 g/L.
    - If 100 % efficient → residual SO_4 could theoretically drop to <100 mg/L.
- Overall project removal: 92–94 % from the original 3,400 mg/L (control).

6.2 Results Phase 2B

- A four jar PAC sequence on the optimal Phase 1 supernatant (5.6 g/L CaO, 2 600 mg/L residual SO_4, starting pH 12.5) has been completed.
- pH control was maintained through the entire process (until the end of the slow mixing phase).
- Table 6 illustrates the testing matrix.
- Table 7 illustrates the Phase 2B supernatant results.
- Table 8 illustrates a summary of the key Phase 2B parameters.

Table 6: Phase 2B testing matrix.

Jar	Ratio	$Al(OH)_3$ Equiv. (g/L)	PAC Liquid Volume (mL per 1 L)	Purpose
1	0.6	1.56	8.50 mL	Moderate
2	0.75	1.95	10.63 mL	Likely optimum
3	0.9	2.34	12.75 mL	Strong excess
4	1.2	3.12	17.00 mL	Very high

Table 7: Phase 2B supernatant characteristics (post CaO and PAC dosing).

Parameter	Units	J1	J2	J3	J4
pH		11.9	12.3	12.4	12.4
Total Alkalinity	g/m^3 as $CaCO_3$	460	1,340	1,820	1,790
Carbonate	g/m^3 at 25°C	41	163	280	250
Bicarbonate	g/m^3 at 25°C	1.1	1.7	2.3	1.9
Total Hardness	g/m^3 as $CaCO_3$	1,880	2,400	3,200	3,400
Electrical Conductivity (EC)	mS/m	565	873	1,067	1,126
Total Suspended Solids	g/m^3	65	74	138	135
Total Solids (TS)	g/m^3	3,300	3,800	4,600	4,900
Dissolved Aluminium	g/m^3	0.006	0.037	0.009	0.022
Total Aluminium	g/m^3	0.098	1.05	0.66	1.2
Dissolved Antimony	g/m^3	0.0002	< 0.0002	< 0.0002	< 0.0002
Total Arsenic	g/m^3	0.0061	0.0053	0.0046 #1	0.0048
Dissolved Boron	g/m^3	< 0.05	< 0.05	< 0.05	< 0.05
Dissolved Calcium	g/m^3	750	980	1,290	1,350
Dissolved Cobalt	g/m^3	0.0008	0.0003	0.0003	< 0.0002
Dissolved Iron	g/m^3	< 0.02	< 0.02	< 0.02	< 0.02
Total Iron	g/m^3	< 0.021	< 0.021	0.175	0.024
Dissolved Magnesium	g/m^3	0.06	< 0.02	< 0.02	< 0.02
Dissolved Manganese	g/m^3	< 0.0005	< 0.0005	< 0.0005	< 0.0005
Dissolved Molybdenum	g/m^3	0.0034	0.004	0.005	0.0014
Dissolved Potassium	g/m^3	35	36	35	37
Dissolved Selenium	g/m^3	0.0123	0.0012	0.0014	< 0.0010
Dissolved Sodium	g/m^3	230	230	230	230
Dissolved Sulphur	g/m^3	156	2.1	3.8	1.2
Total Sulphur	g/m^3	160	5.7	4.8	2.5
Dissolved Thallium	g/m^3	< 0.00005	< 0.00005	< 0.00005	< 0.00005
Total Cyanide	g/m^3	< 0.002	< 0.002	< 0.002	< 0.002
Chloride	g/m^3	1,070	1,290	1,480	1,650
Fluoride	g/m^3	< 0.05	< 0.05	< 0.05	< 0.10 #3

Table 7: Continued.

Parameter	Units	J1	J2	J3	J4
Total Nitrogen	g/m³	5.1	4.8	5.4	5.4
Total Ammoniacal-N	g/m³	1.78	2.0 #2	1.59	1.9
Nitrite-N	g/m³	0.65	0.64	0.64	0.62
Nitrate-N	g/m³	2.2	2.2	2.3	2.3
Nitrate-N + Nitrite-N	g/m³	2.8	2.9	2.9	2.9
Total Kjeldahl Nitrogen (TKN)	g/m³	2.3	1.94 #2	2.5	2.5
Sulphate	g/m³	470	6	11	3
Dissolved Organic Carbon (DOC)	g/m³	4.1	2.6	4.5	2.8
Heavy metals, dissolved, trace As,Cd,Cr,Cu,Ni,Pb,Zn					
Dissolved Arsenic	g/m³	0.0054	0.0051	0.0048 #1	0.0045
Dissolved Cadmium	g/m³	< 0.00005	< 0.00005	< 0.00005	< 0.00005
Dissolved Chromium	g/m³	0.0146	0.004	0.0038	0.0011
Dissolved Copper	g/m³	0.0024	0.0015	0.0034	0.0021
Dissolved Lead	g/m³	< 0.00010	< 0.00010	0.00016	< 0.00010
Dissolved Nickel	g/m³	0.0022	0.0006	0.0016	0.0007
Dissolved Zinc	g/m³	0.0012	0.001	0.0044	0.0012

Key Observations & Comments

- With pH control maintained at 11.9–12.4, sulphate was reduced to < 10 mg/L in the best jars, well below the 200–500 mg/L target.
- J4 achieved 99.9 % overall removal from the raw 3400 mg/L.
- pH control was the decisive factor, in Phase 2B the pH stayed firmly in the ettringite stability window (11.5–12.5), enabling true ettringite precipitation.
- Residual aluminium is very low: 0.006–0.009 mg/L in the best jars.

Other parameters:

- Metals are extremely low.
- Sludge was finer and settled better.

Why this likely worked so well:

- Maintaining pH 11.5–12.5 allowed the aluminium from PAC to combine with residual Ca^{2+} and SO_4^{2-} to form the low-solubility ettringite mineral.
- The CaO top-ups compensated for the acidity of the PAC and kept the system in the correct chemical window.
- High magnesium was already removed in Phase 1, removing the main interference.

Bottom line:

- Phase 2B with active pH control delivered the performance we were hoping for and in some jars even better than predicted.
- This confirms the two-stage ettringite process is likely viable for Macraes Mine water.
- Table 8 illustrates a summary of the results.

Table 8: Summary of supernatant characteristics.

Stage	SO_4 (mg/L)	% Removal of remaining SO_4	Overall removal from raw (3400 mg/L)	Final pH	Dissolved Al (mg/L)
Raw 50:50 blend (control)	3400	—	—	7.2	<0.003
Phase 1 optimum (5.6 g/L CaO)	2600	23.5%	23.5%	12.5	<0.0032
Phase 2A (no pH control)	1400 (best jar)	46.0%	59.0%	4	200
Phase 2B (pH controlled)					
J1 (moderate PAC)	460	82.0%	86.0%	11.9	0.006
J2	4.6	99.8%	99.9%	12.3	0.009
J3	10	99.6%	99.7%	12.4	0.006
J4 (very high PAC)	2.1	99.9%	99.9%	12.4	0.008

7.0 Results (Sedimentation)

- The jar testing work also provided an opportunity to observe the following:
    - Characteristics of suspended solids.
    - Settling rates under these specific lab conditions.
    - Sludge production rates versus unit volume of water treated versus time (as sludge consolidates).
- Time lapse cameras were used during the laboratory test work to document the settling characteristics of treated Phase 1 and Phase 2 water in the following environments:
    - Treated sample within jar tester using the 2L square Phipps and Bird beakers.
    - Treated sample within jar tester using traditional 2L glass beakers.
    - Treated sample transferred to a 1L glass volumetric cylinder (used as a settling cylinder).
    - Treated sample transferred to a 1L volumetric SVI cone (typically used for Sludge Volume Index (SVI) measurements in biological wastewater treatment plants).
- The time lapse cameras produced video with a date and time water mark.
- Height measurements on the containment vessel allowed measurement of the interface height to the nearest mm (and linked to a time accurate to 1 second).
- For example, a settling test could be undertaken in the 2L beaker in the jar tester and the time lapse video contained the real date and time to the nearest second coded onto the video and a measurement device against the beaker could record the sludge interface height at anytime as the sludge settled.
- By taking multiple readings over time and plotting sludge height versus time a curve can be produced to illustrate the different stages of sludge settling
- Sludge settling behaviour
    - Sludge settling was observed and quantified. Three distinct stages were identified.
    - Stage 1 (Rapid free settling): Large, well-formed flocs settled rapidly under gravity, producing a clear supernatant zone above a distinct interface.
    - Stage 2 (Hindered / zone settling): Floc concentration increased, causing hindered settling where particles interfered with one another, resulting in a slower but still well-defined interface descent.
    - Stage 3 (Compression / consolidation): The settled sludge layer compacted under its own weight, expelling interstitial water and reducing sludge volume to a stable final height.

7.1 Results Phase 1

- Once the optimum dose rate of CaO was determined a series of 2L and 1L settling assessments were undertaken.
- This data should be considered as indicative only (further test work is required to provide data for detailed design and decision making).
- At the completion of CaO dosing and a 30-minute low shear flocculation phase each sample was put into a sedimentation phase.
- Subsequent analysis of the sludge interface height versus time was able to produce a settling curve as illustrated in Figure 3.
- Three distinct stages were identified, rapid free settling, hindered, and compression.
- With respect to clarifier considerations.
    - Table 9 illustrates the settling data collected from four typical assessments.
    - The settling velocities range from 0.22 m/h to 0.33 m/h.
    - For a first pass assessment of clarifier surface area, we would usually use the most conservative value (0.22 m/h) with a safety factor of 1.5–2.0.
    - This gives a recommended design overflow rate (surface loading rate) of approximately 0.11–0.15 m/h.
    - This range remains typical for lime-treated mine sludge and confirms that Phase 1 sludge settles reasonably well (polymer addition would likely help).
    - Using flow rates m^3/hour the area m^2 can be estimated.
    - The following links illustrate videos of various settling assessments:
        - Video link (unlisted) Test 03 click here. https://youtu.be/NFlkrNXAoi8
        - Video link (unlisted) Test 04 click here. https://youtu.be/5U-SBC3ddR4
        - Video link (unlisted) Test 05 click here. https://youtu.be/rCDQWr2TUus
        - Video link (unlisted) Test 06 click here. https://youtu.be/DzYGXtPN100
        - Video link (unlisted) Test 10 click here. https://youtu.be/Q9DLMJHwp9M
        - Video link (unlisted) Test 11 click here. https://youtu.be/oXex7DtVxns
    - The videos are unlisted so can only be viewed by clicking on the secure link.
    - The videos links above only work in the PDF copy of this report (they may not work in the Word copy).
    - Hard copies of the videos have been provided via USB stick to Process Flow.

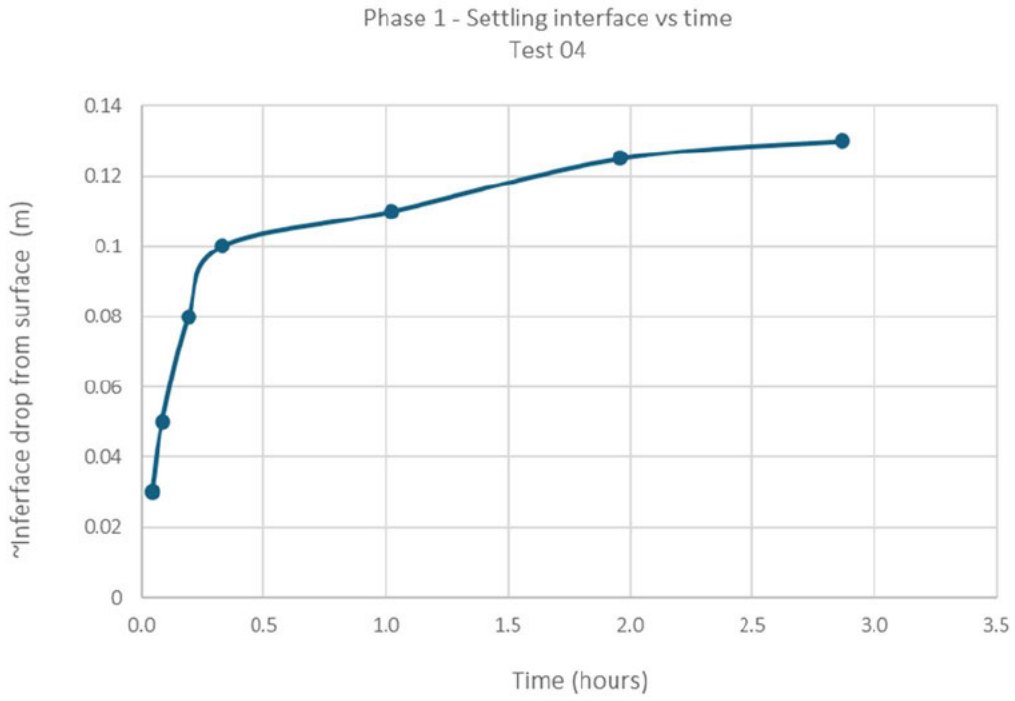

Figure 3: Plot of cumulative interface drop versus time (Test 04).

Table 9: Settling characteristics of 2L Phase 1 samples.

Test	Linear Phase (hours)	Δh (m)	Δt (h)	Zone settling velocity (m/h)	Design Overflow Rate (with 1.5–2.0 safety factor)
3	0.092 – 0.497	0.09	0.41	0.22	0.11 – 0.15 m/h
4	0.042 – 0.329	0.07	0.29	0.24	0.12 – 0.16 m/h
5	0.082 – 0.378	0.085	0.30	0.29	0.15 – 0.19 m/h
6	0.160 – 0.371	0.07	0.21	0.33	0.17 – 0.22 m/h

- Figure 4 and Figure 5 illustrate some Phase 1 samples during jar testing.
- Figure 6 and Figure 7 illustrates the Phase 1 sludge.

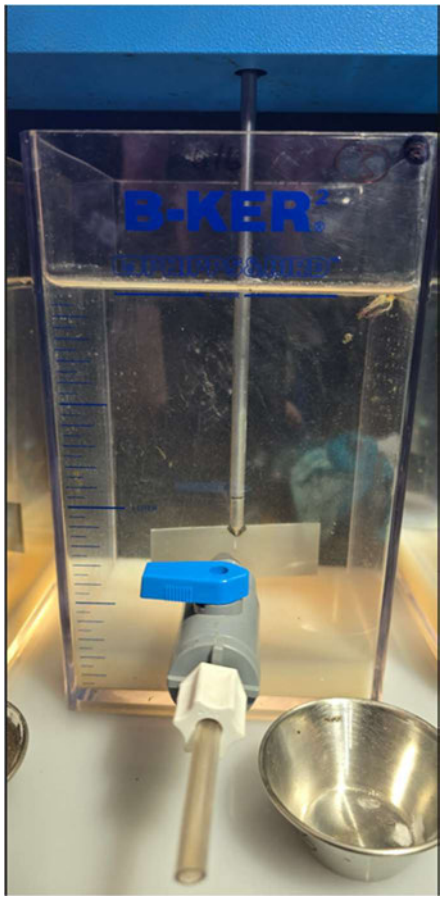

Figure 4: 2L beaker in jar testing apparatus (Phase 1 sludge in base).

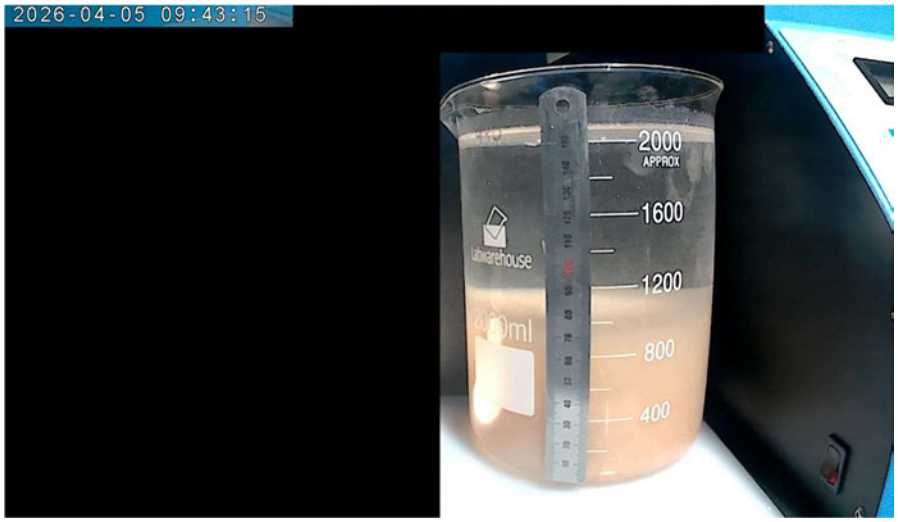

Figure 5: Better view of what Phase 1 sludge looks like (during settle phase). What appears to be iron hydroxide precipitates gives the sludge a light orange, brown colour.

Figure 6: Illustration of Phase 1 sludge (this has been dewatered via pressure filtration). The circular marks are from the sludge pressing against the filter and filter support.

Figure 7: Illustration of Phase 1 sludge - cross section through the material.

A sample of the Phase 1 sludge has been dewatered and then oven dried at 105 ^{o}C before being vacuum sealed in a plastic bag for storage and subsequent analysis (outside the scope of this work).

7.2 Results Phase 2B

- The supernatant at the start of Phase 2B was crystal clear with negligible suspended solids.
- When the PAC was dosed, the resulting precipitates were white and appeared fine structured.
- CaO was also dosed to maintain the pH within the pH 11.5-12.5 range.
- The settling characteristics of the Phase 2B suspended solids were slower than Phase 1.
- Further work is recommended to elucidate the merits of additional polymer dosing to enhance the settling characteristics.
- In the interim the following video link illustrates Phase 2B settling characteristics https://youtu.be/QbTWe0xO0g0
- Figure 8 illustrates Phase 2B sample during flocculation mixing.
- Figure 9 illustrates Phase 2B sludge.

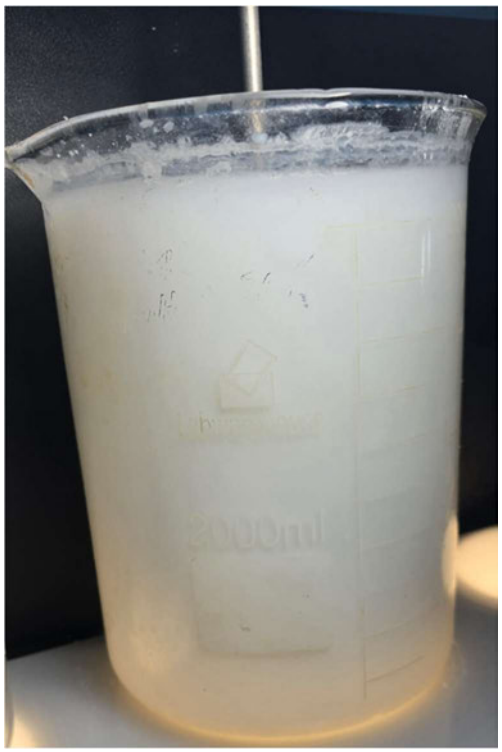

Figure 8: Illustration of Phase 2B sample during flocculation mixing (bright white appearance).

Figure 9: Illustration of Phase 2B sludge – bright white and fine-grained material.

A sample of the Phase 2B sludge has been dewatered and then oven dried at 105 ^{o}C before being vacuum sealed in a plastic bag for storage and subsequent analysis (outside the scope of this work).

8.0 Conclusions and Recommendations

- The laboratory jar testing program has successfully demonstrated that a two-stage ettringite precipitation process can effectively reduce sulphate concentrations in Macraes Mine 50:50 blended impacted water from 3400 mg/L to the target concentration range of 200–500 mg/L.
- **Phase 1 (CaO optimisation)** identified an optimum dose of 5.6 g/L CaO, achieving 23.5 % sulphate removal (residual 2600 mg/L). High magnesium content in the raw water (570 mg/L) was the primary limiting factor in the gypsum stage, causing significant CaO demand for brucite formation and restricting further sulphate reduction.
- **Phase 2B (PAC dosing with active pH control)** Phase 2B (PAC dosing with active pH control) maintained pH between 11.5 and 12.5 throughout the reaction and enabled stable ettringite formation. Sulphate was reduced to low levels of 460 mg/L, 4.6 mg/L, 10.0 mg/L and 2.1 mg/L across the four jars tested, representing greater than 99.9 % overall removal in the best-performing jars. Residual aluminium remained very low (< 0.01 mg/L).
- These findings suggest the two-stage process is technically viable and effective once pH is properly managed. The work identified and resolved the key site-specific interferences (high magnesium in Phase 1 and PAC acidity in Phase 2).

- The Macraes Mine water will likely require final pH adjustment to pH ~ 7.0 prior to release to the environment (outside the scope of this preliminary assessment).

Suggestions for further work

- Proceed to pilot-scale testing prior to detailed design to validate performance under continuous flow conditions, optimise polymer dosing, and refine sludge handling requirements.
- Considerations for further lab/pilot scale work:
    - Adopt the optimised two-stage process:
    - Stage 1: 5.6 g/L CaO
    - Stage 2: PAC dosed at approximately 0.75–1.05 $Al(OH)_3$ equivalent ratio, with continuous real-time pH control using small additional CaO additions to maintain pH 11.5–12.5 throughout mixing and settling.
    - Add anionic polymer flocculant (0.5–2 mg/L) in Stage 2 to improve floc formation and accelerate settling rates.
    - Characterise sludge via XRD and XRF to confirm ettringite content and evaluate potential reuse or recycling options (completed by Process Flow in August 2026).
    - Consider sodium aluminate as an alternative aluminium source in future optimisation work to reduce lime demand for pH control.

9.0 Appendix

- The Phase 2 testing was initially undertaken without pH control during PAC addition.
- It was found the lack of pH control resulted in reduced SO_4 removal.
- The test work was subsequently repeated with pH correction.
- The results for Phase 2 have been presented as follows:
    - Phase 2A no pH correction.
    - Phase 2B with pH correction.
- The lessons from Phase 2A were used to develop the Phase 2B work.
- As future work will include pH correction in Phase 2 the results from Phase 2A are not considered relevant to any future scenario.
- Therefore, the Phase 2A (no pH correction) results have been included in this appendix.

9.1 Results (Jar Testing) Phase 2A

- Full 8-jar PAC sequence on the optimal Phase 1 supernatant (5.6 g/L CaO, 2 600 mg/L residual SO_4, starting pH 12.5).
- Table 10 and Table 11 provides a summary of key Phase 2A supernatant characteristics.

Phase 2A- Results analysis:

Overall performance:

- The sulphate removal fell well short of the predicted 220–320 mg/L target.
- In Phase 2A (no pH control) the pH collapsed to 4.0, preventing ettringite formation and producing only fluffy $Al(OH)_3$.
- Maximum SO_4 removal of the remaining fraction, only 46 % (J8).
- Final SO_4 range: 1400–2300 mg/L (nowhere near the predicted 220–320 mg/L).
- Overall project removal from raw 3400 mg/L: ~59 % (still above nominal targets).

Why sulphate removal was lower than predicted:

- The root cause is pH collapse caused by the acidic nature of the Chemiplas PAC liquid.
- Ettringite formation (the mechanism that gives low residual SO_4) only occurs stably above pH 11.5–12.5.
- Our Phase 1 supernatant started at pH 12.5.
- PAC is acidic (pH of 5 % solution = 1.8–4.5).
- Each incremental dose neutralised alkalinity and dropped the pH rapidly.
- By Jar 4 the pH had already fallen to 7.8, by Jar 8 it was 4.0. At these pH levels ettringite cannot form.
- Instead, we get simple aluminium hydroxide ($Al(OH)_3$) precipitation. $Al(OH)_3$ removes almost no sulphate.

Supporting evidence in the data:

- Dissolved Al skyrockets at the higher doses (84 mg/L in J7, 200 mg/L in J8) because the pH is too low for the aluminium to stay precipitated as ettringite, it remains dissolved or as fine $Al(OH)_3$ flocs.
- Total Alkalinity collapses from ~100 g/m³ down to < 1.0 g/m³.
- In practice, the PAC acidity was far stronger than anticipated.
- This was further demonstrated by subsequent pH-controlled testing in Phase 2B.

Note on the analyst comments:

- The lab flagged high Al interference on fluoride and noted that some dissolved fractions were close to total fractions, all consistent with massive excess aluminium carry-over due to the pH crash.

Positive outcomes:

- Some sulphate removal still occurred (down to 1400 mg/L at highest dose), better than Phase 1 alone.
- The test clearly identified the need for pH control which is valuable data for full-scale design.
- This highlights the potential merits of sodium aluminate ($Na_2Al_2O_4$) for Phase 2 in a future run; it is alkaline rather than acidic and maintains high pH without extra lime.
- If lime is used for pH control the process will require online real-time continuous lime dosing through the full mix phase.

Analysis of other parameters:

- Sulphate (SO_4)
    - Maximum removal only 46 % of the remaining fraction (down to 1 400 mg/L).
    - Removal peaks at the highest PAC dose but is still far below the predicted 85–95 % (220–350 mg/L).
    - The curve is not smooth, removal dips in mid-doses then rises again at very high PAC, consistent with pH-driven chemistry rather than stoichiometric ettringite formation.
- pH and alkalinity
    - pH starts at ~12.5 (Phase 1 supernatant) and collapses rapidly.
    - By Jar 4 it is already below 8, and by Jar 8 it reaches 4.0.
    - Total alkalinity drops from ~100 g/m³ to <1.0 g/m³.

    - This is the primary failure mode: ettringite ($Ca_6Al_2(SO_4)_3(OH)_{12}\cdot 26H_2O$) requires pH 11.5–12.5 to be stable.
- Aluminium
    - Dissolved Al is extremely high at low and high doses (30 mg/L in J1, 200 mg/L in J8).
    - This matches the lab's analyst comment #1 (dissolved > total in some cases due to analytical variation) and comment #2/#3 (high Al interference on fluoride).
    - At mid-doses Al is lower but still indicates incomplete precipitation because pH is too low for ettringite.
- Hardness, calcium, magnesium
    - Total hardness rises steadily (2,200 – 4,200 g/m³) due to excess Ca from Phase 1 plus any minor CaO carry-over.
    - Dissolved Mg remains very low (<1.1 mg/L), confirming Phase 1 success.
- Other metals and parameters
    - Excellent control of As, Sb, Cd, Pb, etc. (all very low).
    - Chloride rises sharply with PAC dose (as expected from the PAC chemistry).
    - DOC stable ~2–3 g/m³.
    - Cyanide and other anions remain low.

- Sludge behaviour
    - Fluffy white sludge with slow settling.
    - This reflects $Al(OH)_3$ precipitation at low pH.

Table 10: Phase 2A supernatant characteristics (post CaO and PAC dosing).

Parameter	Units	J1	J2	J3	J4	J5	J6	J7	J8
pH	pH Units	9.1	8.9	9.4	7.8	6.8	5.6	4.2	4
Total Alkalinity	g/m³ as $CaCO_3$	103	69	63	16.9	8.8	3.4	< 1.0	< 1.0
Carbonate	g/m³ at 25°C	6.1	2.7	6.6	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0
Bicarbonate	g/m³ at 25°C	112	78	63	20	10.7	4.2	< 1.0	< 1.0
Total Hardness	g/m³ as $CaCO_3$	2,200	2,700	3,400	3,600	3,900	3,900	4,100	4,200
Electrical Conductivity (EC)	mS/m	422	511	606	675	723	771	879	973
Total Solids (TS)	g/m³	3,800	4,700	5,600	5,800	5,800	6,600	7,100	7,600
Dissolved Aluminium	g/m³	30 #1	19.7 #1	14.3	1.87	0.62 #1	1.34	84	200
Total Aluminium	g/m³	30 #1	19.3 #1	23	2.5	0.51 #1	2.7	92	220
Dissolved Antimony	g/m³	< 0.0002	< 0.0002	< 0.0002	< 0.0002	< 0.0002	< 0.0002	< 0.0002	< 0.0002
Dissolved Arsenic	g/m³	0.004	0.0038	0.0038 #1	0.0031	0.0013	0.0012	0.0021	0.0023
Total Arsenic	g/m³	0.0039	0.0039	0.0037 #1	0.0037	0.0017	0.0013	0.0024	0.0026
Dissolved Boron	g/m³	< 0.05	< 0.05	0.09	0.13	0.18	0.24	0.25	0.27
Dissolved Cadmium	g/m³	< 0.00005	< 0.00005	< 0.00005	< 0.00005	< 0.00005	< 0.00005	< 0.00005	0.00009
Dissolved Calcium	g/m³	870	1,100	1,350	1,450	1,560	1,570	1,650	1,680
Dissolved Chromium	g/m³	0.0074	0.0072	0.0071	0.0065	0.0052	0.0057	0.0063	0.006
Dissolved Cobalt	g/m³	0.0008	0.0007	0.0007	0.0008	0.001	0.0012	0.0012	0.0014
Dissolved Copper	g/m³	0.0017	0.0011	0.001	0.0007	0.0008	0.0031	0.0151	0.0193
Dissolved Iron	g/m³	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	0.03	0.07
Total Iron	g/m³	< 0.021	< 0.021	< 0.021	< 0.021	< 0.021	< 0.021	0.121	0.102
Dissolved Lead	g/m³	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	0.00048	0.00178	0.0025
Dissolved Magnesium	g/m³	0.26	0.14	0.09	0.22	0.46	0.57	0.81	1.11
Dissolved Manganese	g/m³	< 0.0005	< 0.0005	< 0.0005	0.0005	0.0031	0.0057	0.0129	0.0169

Table 10: Continued.

Parameter	Units	J1	J2	J3	J4	J5	J6	J7	J8
Dissolved Molybdenum	g/m³	0.0024	0.0025	0.0026	0.0023	0.0009	0.0002	0.0003	0.0004
Dissolved Nickel	g/m³	0.0008	0.0006	0.0005	0.0007	0.0033	0.0054	0.0077	0.0091
Dissolved Potassium	g/m³	35	35	35	35	40	34	36	35
Dissolved Selenium	g/m³	0.014	0.0146	0.0149	0.0147	0.0144	0.0128	0.0114	0.0104
Dissolved Sodium	g/m³	230	240	240	240	240	240	240	240
Dissolved Thallium	g/m³	< 0.00005	< 0.00005	< 0.00005	< 0.00005	< 0.00005	< 0.00005	< 0.00005	< 0.00005
Dissolved Vanadium	g/m³	< 0.0010	< 0.0010	< 0.0010	< 0.0010	< 0.0010	< 0.0010	< 0.0010	< 0.0010
Dissolved Zinc	g/m³	< 0.0010	< 0.0010	< 0.0010	0.0067	0.055	0.119	0.175	0.26
Total Cyanide	g/m³	< 0.002	< 0.002	0.005	0.003	< 0.002	< 0.002	< 0.002	< 0.02 #4
Chloride	g/m³	560	800	1,080	1,350	1,670	1,900	2,500	2,900
Fluoride	g/m³	< 5 #2	< 5 #2	< 5 #2	< 0.5 #3	< 0.05	< 3 #3	< 10 #2	< 5 #2
Total Nitrogen	g/m³	5.7	5.8	6.2	6.4	6.5	6.5	6.6	6.6
Total Ammoniacal-N	g/m³	1.9	1.81	1.87	1.94	2.1	2.1	2.1	2.1
Nitrite-N	g/m³	0.89	0.91	0.9	0.89	0.9	0.92	0.86	0.84
Nitrate-N	g/m³	2.4	2.7	3	3.2	3.2	3.2	3.1	3.2
Nitrate-N + Nitrite-N	g/m³	3.3	3.6	3.9	4.1	4.1	4.1	4	4
Total Kjeldahl Nitrogen (TKN)	g/m³	2.3	2.2	2.3	2.4	2.4	2.4	2.6	2.6
Sulphate	g/m³	1,760	2,000	2,300	2,300	1,950	1,740	1,520	1,400
Dissolved Organic Carbon (DOC)	g/m³	3.2	3.1	3	2.1	2.6	2.2	3	2.6

Table 11: Summary of key Phase 2A supernatant characteristics.

Jar	PAC (mL/L)	$Al(OH)_3$ equiv. (g/L)	Final pH	Final sulphate (mg/L)	% Removal of remaining SO_4	Dissolved Al (mg/L)	Total Hardness (g/m³)	Notes
J1	4.25	0.78	9.1	1 760	32%	30	2 200	Moderate removal
J2	6.38	1.17	8.9	2 000	23%	19.7	2 700	Removal decreases
J3	8.5	1.56	9.4	2 300	12%	14.3	3 400	Poor
J4	10.63	1.95	7.8	2 300	12%	1.87	3 600	Poor
J5	12.75	2.34	6.8	1 950	25%	0.62	3 900	—
J6	14.88	2.73	5.6	1 740	33%	1.34	3 900	—
J7	17	3.12	4.2	1 520	42%	84	4 100	High Al
J8	21.26	3.9	4	1 400	46%	200	4 200	Best SO_4 removal but extreme Al

9.2 Results (Sedimentation) Phase 2A

- If continuous pH correction is not employed during PAC dosing the pH decline results in the formation of light fluffy white aluminium hydroxide flocs.
- These are 'bulky flocs' with a high surface area (they look like cotton wool under a microscope).
- The formation of these flocs inhibits the settling characteristics of the sludge.
- Keeping the pH within the range pH 11.5-12.5 is important not only for sulphate removal but also for the subsequent settling characteristics.

9.3 Hills Laboratory results

- Hills Laboratory results attached.

R J Hill Laboratories Limited
28 Duke Street Frankton 3204
Private Bag 3205
Hamilton 3240 New Zealand

0508 HILL LAB (44 555 22)
+64 7 858 2000
mail@hill-labs.co.nz
www.hill-labs.co.nz

Certificate of Analysis

Client:	Process Flow Limited	**Lab No:**	4111117	SPv2
Contact:	Gary Smith	**Date Received:**	25-Feb-2026	
	C/- Process Flow Limited	**Date Reported:**	04-Mar-2026	
	4/38 Estuary Place	**Quote No:**	143624	
	Richmond 7020	**Order No:**		
		Client Reference:		
		Submitted By:	Gary Smith	

Sample Type: Potable Water

		Sample Name:	NGSP 24-Feb-2026 4:00 pm	50:50 24-Feb-2026 4:15 pm	TTISF 24-Feb-2026 4:15 pm
		Lab Number:	4111117.1	4111117.2	4111117.3
Individual Tests					
pH	pH Units		7.9	7.2	7.0
Total Alkalinity	g/m³ as $CaCO_3$		380	370	370
Carbonate	g/m³ at 25°C		1.7	< 1.0	< 1.0
Bicarbonate	g/m³ at 25°C		460	460	450
Total Hardness	g/m³ as $CaCO_3$		3,700	3,100	2,500
Electrical Conductivity (EC)	mS/m		477	482	481
Total Suspended Solids	g/m³		22	16	6
Total Solids (TS)	g/m³		5,900	5,400 #1	5,000
Dissolved Aluminium	g/m³		< 0.003	< 0.003	< 0.003
Total Aluminium	g/m³		< 0.0032	0.023	0.045
Dissolved Antimony	g/m³		0.0037	0.0020	0.0008
Total Arsenic	g/m³		0.0065	0.87	1.87
Dissolved Boron	g/m³		< 0.05	0.22	0.40
Dissolved Calcium	g/m³		310	390	460
Dissolved Cobalt	g/m³		< 0.0002	0.114	0.22
Dissolved Iron	g/m³		< 0.02	< 0.02	< 0.02
Total Iron	g/m³		< 0.021	2.5	5.5
Dissolved Magnesium	g/m³		710	510	330
Dissolved Manganese	g/m³		< 0.003	4.0	7.7
Dissolved Molybdenum	g/m³		0.0007	0.0034	0.0055
Dissolved Potassium	g/m³		14.6	36	58
Dissolved Selenium	g/m³		0.034	0.0171	< 0.003
Dissolved Sodium	g/m³		73	240	380
Dissolved Sulphur	g/m³		1,160	1,080	1,000
Dissolved Thallium	g/m³		< 0.00005	< 0.00005	0.00007
Total Cyanide	g/m³		< 0.002	< 0.002	< 0.002
Chloride	g/m³		11.8	18.8	24
Fluoride	g/m³		< 0.05	0.13	0.20
Total Nitrogen	g/m³		6.7	8.5	10.2
Total Ammoniacal-N	g/m³		< 0.010	3.1	6.0
Nitrite-N	g/m³		0.061	0.31	0.52
Nitrate-N	g/m³		5.2	2.9	0.81
Nitrate-N + Nitrite-N	g/m³		5.2	3.2	1.33
Total Kjeldahl Nitrogen (TKN)	g/m³		1.49	5.4	8.9
Sulphate	g/m³		3,500	3,200	3,000
Dissolved Organic Carbon (DOC)	g/m³		< 0.5	4.8	3.9

Sample Type: Potable Water				
Sample Name:		NGSP 24-Feb-2026 4:00 pm	50:50 24-Feb-2026 4:15 pm	TTISF 24-Feb-2026 4:15 pm
Lab Number:		4111117.1	4111117.2	4111117.3
Heavy metals, dissolved, trace As,Cd,Cr,Cu,Ni,Pb,Zn				
Dissolved Arsenic	g/m³	0.0061	0.24	0.42
Dissolved Cadmium	g/m³	< 0.00005	0.00006	0.00012
Dissolved Chromium	g/m³	< 0.0005	< 0.0005	< 0.0005
Dissolved Copper	g/m³	< 0.0005	< 0.0005	< 0.0005
Dissolved Lead	g/m³	< 0.00010	< 0.00010	< 0.00010
Dissolved Nickel	g/m³	0.0131	0.085	0.148
Dissolved Zinc	g/m³	< 0.0010	0.0101	0.0198

Analyst's Comments

#1 It should be noted that the result for Total Solids was above the upper limit of the method. As the sample dried ok the upper limit was extended to allow a numeric result to be reported.

Samples 2-3 Comment:
Please note that the level of Uncertainty of Measurement (UOM) for the DOC result is significantly greater than that usually reported for this analyte (>300% at the 95% confidence level).

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: Potable Water			
Test	**Method Description**	**Default Detection Limit**	**Sample No**
Heavy metals, dissolved, trace As,Cd,Cr,Cu,Ni,Pb,Zn	0.45µm Filtration, ICP-MS, trace level. APHA 3125 B : Online Edition.	0.00005 - 0.0010 g/m³	1-3
Total Digestion	Nitric acid digestion. APHA 3030 E (modified) : Online Edition.	-	1-3
pH	pH meter. APHA 4500-H^+ B (modified) : Online Edition. Note: It is not possible to achieve the APHA Maximum Storage Recommendation for this test (15 min) when samples are analysed upon receipt at the laboratory, and not in the field. Samples and Standards are analysed at an equivalent laboratory temperature (typically 18 to 22 °C). Temperature compensation is used.	0.1 pH Units	1-3
Total Alkalinity	Titration to pH 4.5 (M-alkalinity), autotitrator. APHA 2320 B (modified for Alkalinity <20) : Online Edition.	1.0 g/m³ as $CaCO_3$	1-3
Carbonate	Calculation: from alkalinity and pH, valid where TDS is not >500 mg/L and alkalinity is almost entirely due to hydroxides, carbonates or bicarbonates. APHA 4500-CO_2 D : Online Edition.	1.0 g/m³ at 25°C	1-3
Bicarbonate	Calculation: from alkalinity and pH, valid where TDS is not >500 mg/L and alkalinity is almost entirely due to hydroxides, carbonates or bicarbonates. APHA 4500-CO_2 D : Online Edition.	1.0 g/m³ at 25°C	1-3
Total Hardness	Calculation from Dissolved Calcium and Dissolved Magnesium. APHA 2340 B : Online Edition.	1.0 g/m³ as $CaCO_3$	1-3
Electrical Conductivity (EC)	Conductivity meter, 25°C. APHA 2510 B : Online Edition.	0.1 mS/m	1-3
Total Suspended Solids	Filtration using Whatman 934 AH, Advantec GC-50 or equivalent filters (nominal pore size 1.2 - 1.5µm), gravimetric determination. APHA 2540 D (modified) : Online Edition.	3 g/m³	1-3
Total Solids (TS)	Gravimetric. APHA 2540 B (modified) : Online Edition.	10 g/m³	1-3
Filtration for dissolved metals analysis	Sample filtration through 0.45µm membrane filter and preservation with nitric acid. APHA 3030 B : Online Edition.	-	1-3
Filtration for dissolved metals analysis - Misc	Sample filtration through 0.45µm membrane filter and preservation with nitric acid. APHA 3030 B : Online Edition.	-	1-3
Dissolved Aluminium	Filtered sample, ICP-MS, trace level. APHA 3125 B : Online Edition.	0.003 g/m³	1-3
Total Aluminium	Nitric acid digestion, ICP-MS, trace level. APHA 3125 B : Online Edition.	0.0032 g/m³	1-3
Dissolved Antimony	Filtered sample, ICP-MS, trace level. APHA 3125 B : Online Edition.	0.0002 g/m³	1-3
Total Arsenic	Nitric acid digestion, ICP-MS, trace level. APHA 3125 B : Online Edition.	0.0011 g/m³	1-3
Dissolved Boron	Filtered sample, ICP-MS, trace level. APHA 3125 B : Online Edition.	0.05 g/m³	1-3

Sample Type: Potable Water			
Test	**Method Description**	**Default Detection Limit**	**Sample No**
Dissolved Calcium	Filtered sample, ICP-MS, trace level. APHA 3125 B : Online Edition.	0.05 g/m³	1-3
Dissolved Cobalt	Filtered sample, ICP-MS, trace level. APHA 3125 B : Online Edition.	0.0002 g/m³	1-3
Dissolved Iron	Filtered sample, ICP-MS, trace level. APHA 3125 B : Online Edition.	0.02 g/m³	1-3
Total Iron	Nitric acid digestion, ICP-MS, trace level. APHA 3125 B : Online Edition.	0.021 g/m³	1-3
Dissolved Magnesium	Filtered sample, ICP-MS, trace level. APHA 3125 B : Online Edition.	0.02 g/m³	1-3
Dissolved Manganese	Filtered sample, ICP-MS, trace level. APHA 3125 B : Online Edition.	0.0005 g/m³	1-3
Dissolved Molybdenum	Filtered sample, ICP-MS, trace level. APHA 3125 B : Online Edition.	0.0002 g/m³	1-3
Dissolved Potassium	Filtered sample, ICP-MS, trace level. APHA 3125 B : Online Edition.	0.05 g/m³	1-3
Dissolved Selenium	Filtered sample, ICP-MS, trace level. APHA 3125 B : Online Edition.	0.0010 g/m³	1-3
Dissolved Sodium	Filtered sample, ICP-MS, trace level. APHA 3125 B : Online Edition.	0.02 g/m³	1-3
Dissolved Sulphur	Filtered sample, ICP-OES. APHA 3120 B : Online Edition.	0.10 g/m³	1-3
Dissolved Thallium	Filtered sample, ICP-MS, trace level. APHA 3125 B : Online Edition.	0.00005 g/m³	1-3
Total Cyanide Trace	On-line distillation, colorimetry, trace level. ISO 14403:2012(E) (modified).	0.002 g/m³	1-3
Chloride	Filtered sample. Ion Chromatography. APHA 4110 B (modified) : Online Edition.	0.5 g/m³	1-3
Fluoride	Direct measurement, ion selective electrode. APHA 4500-F^- C : Online Edition.	0.05 g/m³	1-3
Total Nitrogen	Calculation: TKN + Nitrate-N + Nitrite-N. Please note: The Default Detection Limit of 0.05 g/m³ is only attainable when the TKN has been determined using a trace method utilising duplicate analyses. In cases where the Detection Limit for TKN is 0.10 g/m³, the Default Detection Limit for Total Nitrogen will be 0.11 g/m³. In-house calculation.	0.05 g/m³	1-3
Total Ammoniacal-N	Phenol/hypochlorite colourimetry. Flow injection analyser. (NH_4-N = NH_4^+-N + NH_3-N). APHA 4500-NH_3 H (modified) : Online Edition.	0.010 g/m³	1-3
Nitrite-N	Automated Azo dye colorimetry, Flow injection analyser. APHA 4500-NO_3^- I (modified) : Online Edition.	0.002 g/m³	1-3
Nitrate-N	Calculation: (Nitrate-N + Nitrite-N) - Nitrite-N. In-House.	0.0010 g/m³	1-3
Nitrate-N + Nitrite-N	Total oxidised nitrogen. Automated cadmium reduction, flow injection analyser. APHA 4500-NO_3^- I (modified) : Online Edition.	0.002 g/m³	1-3
Total Kjeldahl Nitrogen (TKN)	Total Kjeldahl digestion, automated phenol/hypochlorite colorimetry. APHA 4500-N_{org} D (modified): Online Edition.	0.10 g/m³	1-3
Sulphate	Filtered sample. Ion Chromatography. APHA 4110 B (modified) : Online Edition.	0.5 g/m³	1-3
Soluble Sulphate*	Calculation: from dissolved sulphur.	2 g/m³	1-3
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/m³	1-3

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

Testing was completed between 26-Feb-2026 and 04-Mar-2026. 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.

Yu-Hsuan (Coco) Hsueh BSc (Tech)
Client Services Manager - Environmental

R J Hill Laboratories Limited
28 Duke Street Frankton 3204
Private Bag 3205
Hamilton 3240 New Zealand

0508 HILL LAB (44 555 22)
+64 7 858 2000
mail@hill-labs.co.nz
www.hill-labs.co.nz

Certificate of Analysis

Client:	JBH Environmental Engineering Limited	**Lab No:**	4125105	SPv1
Contact:	Joe Wildy	**Date Received:**	09-Mar-2026	
	C/- JBH Environmental Engineering Limited	**Date Reported:**	16-Mar-2026	
	48 Early Valley Road	**Quote No:**	143911	
	RD 2	**Order No:**		
	Christchurch 7672	**Client Reference:**	Mine Water	
		Submitted By:	Joe Wildy	

Sample Type: Aqueous

	Sample Name:	Control 50:50 08-Mar-2026	J1 08-Mar-2026	J2 08-Mar-2026	J3 08-Mar-2026	J4 08-Mar-2026
	Lab Number:	4125105.1	4125105.2	4125105.3	4125105.4	4125105.5
pH	pH Units	7.4	9.8	10.6	11.9	12.2
Total Alkalinity	g/m³ as $CaCO_3$	380	53	101	510	890
Carbonate	g/m³ at 25°C	< 1.0	11.1	38	86	72
Bicarbonate	g/m³ at 25°C	460	38	22	2.6	< 1.0
Total Hardness	g/m³ as $CaCO_3$	3,400	2,800	2,800	2,900	2,800
Electrical Conductivity (EC)	mS/m	499	443	440	590	683
Total Suspended Solids	g/m³	4	37	34	27	54
Total Solids (TS)	g/m³	5,200	4,600	4,500	4,600	4,200
Dissolved Aluminium	g/m³	< 0.003	< 0.003	< 0.003	< 0.003	< 0.003
Total Aluminium	g/m³	0.0049	< 0.0032	0.0145	0.0181	0.0052
Dissolved Antimony	g/m³	0.0022	0.0017	0.0011	0.0008	0.0006
Dissolved Arsenic	g/m³	0.199	0.0052	0.0025	0.0025	0.0027
Total Arsenic	g/m³	0.30	0.0081	0.0082	0.0052	0.0076
Dissolved Boron	g/m³	0.24	0.16	0.15	0.21	0.21
Dissolved Cadmium	g/m³	0.00007	< 0.00005	< 0.00005	< 0.00005	< 0.00005
Dissolved Calcium	g/m³	410	590	1,100	1,170	1,140
Dissolved Chromium	g/m³	< 0.0005	0.0023	0.0055	0.0069	0.0071
Dissolved Cobalt	g/m³	0.092	0.0017	0.0010	0.0010	0.0010
Dissolved Copper	g/m³	< 0.0005	0.0006	0.0007	0.0008	< 0.0005
Dissolved Iron	g/m³	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02
Total Iron	g/m³	0.39	< 0.021	< 0.021	< 0.021	< 0.021
Dissolved Lead	g/m³	< 0.00010	< 0.00010	< 0.00010	0.00063	0.00013
Dissolved Magnesium	g/m³	570	330	16.9	0.04	< 0.02
Dissolved Manganese	g/m³	3.9	0.023	< 0.0005	0.0010	< 0.0005
Dissolved Molybdenum	g/m³	0.0024	0.0024	0.0020	0.0021	0.0020
Dissolved Nickel	g/m³	0.077	0.0022	0.0008	0.0006	< 0.0005
Dissolved Potassium	g/m³	37	36	38	37	38
Dissolved Selenium	g/m³	0.0174	0.0166	0.0165	0.0172	0.0172
Dissolved Sodium	g/m³	240	230	240	240	240
Dissolved Thallium	g/m³	< 0.00005	< 0.00005	< 0.00005	< 0.00005	< 0.00005
Dissolved Vanadium	g/m³	< 0.0010	< 0.0010	< 0.0010	< 0.0010	< 0.0010
Dissolved Zinc	g/m³	0.0091	< 0.0010	< 0.0010	0.0012	< 0.0010
Total Cyanide	g/m³	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002
Chloride	g/m³	16.9	16.9	16.6	16.8	16.3
Fluoride	g/m³	0.12	< 0.05	< 0.05	< 0.05	0.05
Total Nitrogen	g/m³	7.8	7.8	7.3	7.3	7.2
Total Ammoniacal-N	g/m³	2.2	2.8	2.7	2.8	2.6
Nitrite-N	g/m³	0.78	0.76	0.77	0.79	0.78
Nitrate-N	g/m³	3.1	3.3	3.1	3.1	3.1

Sample Type: Aqueous						
Sample Name:		Control 50:50 08-Mar-2026	J1 08-Mar-2026	J2 08-Mar-2026	J3 08-Mar-2026	J4 08-Mar-2026
Lab Number:		4125105.1	4125105.2	4125105.3	4125105.4	4125105.5
Nitrate-N + Nitrite-N	g/m³	3.9	4.1	3.8	3.9	3.9
Total Kjeldahl Nitrogen (TKN)	g/m³	3.9	3.7	3.5	3.4	3.3
Sulphate	g/m³	3,400	3,200	3,000	3,100	2,800
Dissolved Organic Carbon (DOC)	g/m³	< 0.5	3.8	4.1	5.2	5.3

	Sample Name:	J5 08-Mar-2026	J6 08-Mar-2026	J7 08-Mar-2026	J8 08-Mar-2026
	Lab Number:	4125105.6	4125105.7	4125105.8	4125105.9
pH	pH Units	12.4	12.5	12.6	12.6
Total Alkalinity	g/m³ as $CaCO_3$	1,590	1,940	2,200	2,400
Carbonate	g/m³ at 25°C	127	172	198	230
Bicarbonate	g/m³ at 25°C	< 1.0	1.1	1.1	1.3
Total Hardness	g/m³ as $CaCO_3$	3,200	4,000	3,900	4,200
Electrical Conductivity (EC)	mS/m	916	1,022	1,133	1,189
Total Suspended Solids	g/m³	16	66	26	20
Total Solids (TS)	g/m³	4,600	5,000	5,200	5,400
Dissolved Aluminium	g/m³	< 0.003	< 0.003	< 0.003	< 0.003
Total Aluminium	g/m³	< 0.0032	< 0.0032	< 0.0032	< 0.0032
Dissolved Antimony	g/m³	0.0004	0.0002	< 0.0002	< 0.0002
Dissolved Arsenic	g/m³	0.0027	0.0028	0.0025	0.0025
Total Arsenic	g/m³	0.0027	0.0042	0.0029	0.0032
Dissolved Boron	g/m³	0.21	0.20	0.21	0.21
Dissolved Cadmium	g/m³	< 0.00005	< 0.00005	< 0.00005	< 0.00005
Dissolved Calcium	g/m³	1,290	1,610	1,550	1,670
Dissolved Chromium	g/m³	0.0083	0.0100	0.0096	0.0109
Dissolved Cobalt	g/m³	0.0010	0.0010	0.0009	0.0009
Dissolved Copper	g/m³	< 0.0005	< 0.0005	< 0.0005	< 0.0005
Dissolved Iron	g/m³	< 0.02	< 0.02	< 0.02	< 0.02
Total Iron	g/m³	< 0.021	< 0.021	< 0.021	< 0.021
Dissolved Lead	g/m³	0.00025	0.00017	0.00062	0.00013
Dissolved Magnesium	g/m³	< 0.02	< 0.02	< 0.02	< 0.02
Dissolved Manganese	g/m³	< 0.0005	< 0.0005	< 0.0005	< 0.0005
Dissolved Molybdenum	g/m³	0.0032	0.0034	0.0032	0.0031
Dissolved Nickel	g/m³	0.0005	0.0006	< 0.0005	< 0.0005
Dissolved Potassium	g/m³	37	38	38	37
Dissolved Selenium	g/m³	0.0175	0.0177	0.0178	0.0180
Dissolved Sodium	g/m³	240	240	240	230
Dissolved Thallium	g/m³	< 0.00005	< 0.00005	< 0.00005	< 0.00005
Dissolved Vanadium	g/m³	< 0.0010	< 0.0010	< 0.0010	< 0.0010
Dissolved Zinc	g/m³	0.0028	< 0.0010	< 0.0010	< 0.0010
Total Cyanide	g/m³	< 0.002	< 0.002	< 0.002	< 0.002
Chloride	g/m³	16.1	16.0	15.3	16.2
Fluoride	g/m³	0.06	0.05	< 0.05	< 0.05
Total Nitrogen	g/m³	7.2	7.2	7.6	7.3
Total Ammoniacal-N	g/m³	2.7	2.6	2.8	2.7
Nitrite-N	g/m³	0.80	0.79	0.79	0.78
Nitrate-N	g/m³	3.2	3.1	3.1	3.1
Nitrate-N + Nitrite-N	g/m³	4.0	3.9	3.9	3.9
Total Kjeldahl Nitrogen (TKN)	g/m³	3.2	3.3	3.7	3.4
Sulphate	g/m³	2,700	2,600	2,800	2,900
Dissolved Organic Carbon (DOC)	g/m³	3.9	3.8	3.0	3.2

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 0.45 µm membrane filter. Analysed at Hill Laboratories - Chemistry; Unit 1, 17 Print Place, Middleton, Christchurch.	-	1-9
Total Digestion	Nitric acid digestion. APHA 3030 E (modified) : Online Edition.	-	1-9
pH	pH meter. Analysed at Hill Laboratories - Chemistry; Unit 1, 17 Print Place, Middleton, Christchurch. APHA 4500-H^+ B (modified) : Online Edition. Note: It is not possible to achieve the APHA Maximum Storage Recommendation for this test (15 min) when samples are analysed upon receipt at the laboratory, and not in the field. Samples and Standards are analysed at an equivalent laboratory temperature (typically 18 to 22 °C). Temperature compensation is used.	0.1 pH Units	1-9
Total Alkalinity	Titration to pH 4.5 (M-alkalinity), autotitrator. Analysed at Hill Laboratories - Chemistry; Unit 1, 17 Print Place, Middleton, Christchurch. APHA 2320 B (modified for Alkalinity <20) : Online Edition.	1.0 g/m^3 as $CaCO_3$	1-9
Carbonate	Calculation: from alkalinity and pH, valid where TDS is not >500 mg/L and alkalinity is almost entirely due to hydroxides, carbonates or bicarbonates. APHA 4500-CO_2 D : Online Edition.	1.0 g/m^3 at 25°C	1-9
Bicarbonate	Calculation: from alkalinity and pH, valid where TDS is not >500 mg/L and alkalinity is almost entirely due to hydroxides, carbonates or bicarbonates. APHA 4500-CO_2 D : Online Edition.	1.0 g/m^3 at 25°C	1-9
Total Hardness	Calculation from Dissolved Calcium and Dissolved Magnesium. APHA 2340 B : Online Edition.	1.0 g/m^3 as $CaCO_3$	1-9
Electrical Conductivity (EC)	Conductivity meter, 25°C. Analysed at Hill Laboratories - Chemistry; Unit 1, 17 Print Place, Middleton, Christchurch. APHA 2510 B : Online Edition.	0.1 mS/m	1-9
Total Suspended Solids	Filtration using Whatman 934 AH, Advantec GC-50 or equivalent filters (nominal pore size 1.2 - 1.5 µm), gravimetric determination. Analysed at Hill Laboratories - Chemistry; Unit 1, 17 Print Place, Middleton, Christchurch. APHA 2540 D (modified) : Online Edition.	3 g/m^3	1-9
Total Solids (TS)	Gravimetric. Analysed at Hill Laboratories - Chemistry; Unit 1, 17 Print Place, Middleton, Christchurch. APHA 2540 B (modified) : Online Edition.	10 g/m^3	1-9
Filtration for dissolved metals analysis	Sample filtration through 0.45µm membrane filter and preservation with nitric acid. APHA 3030 B : Online Edition.	-	1-9
Dissolved Aluminium	Filtered sample, ICP-MS, trace level. APHA 3125 B : Online Edition.	0.003 g/m^3	1-9
Total Aluminium	Nitric acid digestion, ICP-MS, trace level. APHA 3125 B : Online Edition.	0.0032 g/m^3	1-9
Dissolved Antimony	Filtered sample, ICP-MS, trace level. APHA 3125 B : Online Edition.	0.0002 g/m^3	1-9
Dissolved Arsenic	Filtered sample, ICP-MS, trace level. APHA 3125 B : Online Edition.	0.0010 g/m^3	1-9
Total Arsenic	Nitric acid digestion, ICP-MS, trace level. APHA 3125 B : Online Edition.	0.0011 g/m^3	1-9
Dissolved Boron	Filtered sample, ICP-MS, trace level. APHA 3125 B : Online Edition.	0.05 g/m^3	1-9
Dissolved Cadmium	Filtered sample, ICP-MS, trace level. APHA 3125 B : Online Edition.	0.00005 g/m^3	1-9
Dissolved Calcium	Filtered sample, ICP-MS, trace level. APHA 3125 B : Online Edition.	0.05 g/m^3	1-9
Dissolved Chromium	Filtered sample, ICP-MS, trace level. APHA 3125 B : Online Edition.	0.0005 g/m^3	1-9
Dissolved Cobalt	Filtered sample, ICP-MS, trace level. APHA 3125 B : Online Edition.	0.0002 g/m^3	1-9
Dissolved Copper	Filtered sample, ICP-MS, trace level. APHA 3125 B : Online Edition.	0.0005 g/m^3	1-9
Dissolved Iron	Filtered sample, ICP-MS, trace level. APHA 3125 B : Online Edition.	0.02 g/m^3	1-9
Total Iron	Nitric acid digestion, ICP-MS, trace level. APHA 3125 B : Online Edition.	0.021 g/m^3	1-9

Sample Type: Aqueous			
Test	**Method Description**	**Default Detection Limit**	**Sample No**
Dissolved Lead	Filtered sample, ICP-MS, trace level. APHA 3125 B : Online Edition.	0.00010 g/m³	1-9
Dissolved Magnesium	Filtered sample, ICP-MS, trace level. APHA 3125 B : Online Edition.	0.02 g/m³	1-9
Dissolved Manganese	Filtered sample, ICP-MS, trace level. APHA 3125 B : Online Edition.	0.0005 g/m³	1-9
Dissolved Molybdenum	Filtered sample, ICP-MS, trace level. APHA 3125 B : Online Edition.	0.0002 g/m³	1-9
Dissolved Nickel	Filtered sample, ICP-MS, trace level. APHA 3125 B : Online Edition.	0.0005 g/m³	1-9
Dissolved Potassium	Filtered sample, ICP-MS, trace level. APHA 3125 B : Online Edition.	0.05 g/m³	1-9
Dissolved Selenium	Filtered sample, ICP-MS, trace level. APHA 3125 B : Online Edition.	0.0010 g/m³	1-9
Dissolved Sodium	Filtered sample, ICP-MS, trace level. APHA 3125 B : Online Edition.	0.02 g/m³	1-9
Dissolved Thallium	Filtered sample, ICP-MS, trace level. APHA 3125 B : Online Edition.	0.00005 g/m³	1-9
Dissolved Vanadium	Filtered sample, ICP-MS, trace level. APHA 3125 B : Online Edition.	0.0010 g/m³	1-9
Dissolved Zinc	Filtered sample, ICP-MS, trace level. APHA 3125 B : Online Edition.	0.0010 g/m³	1-9
Total Cyanide Trace	On-line distillation, colorimetry, trace level. ISO 14403:2012(E) (modified).	0.002 g/m³	1-9
Chloride	Filtered sample from Christchurch. Ion Chromatography. APHA 4110 B (modified) : Online Edition.	0.5 g/m³	1-9
Fluoride	Direct measurement, ion selective electrode. APHA 4500-F^- C : Online Edition.	0.05 g/m³	1-9
Total Nitrogen	Calculation: TKN + Nitrate-N + Nitrite-N. Please note: The Default Detection Limit of 0.05 g/m³ is only attainable when the TKN has been determined using a trace method utilising duplicate analyses. In cases where the Detection Limit for TKN is 0.10 g/m³, the Default Detection Limit for Total Nitrogen will be 0.11 g/m³. In-house calculation.	0.05 g/m³	1-9
Total Ammoniacal-N	Filtered Sample from Christchurch. Phenol/hypochlorite colourimetry. Flow injection analyser. (NH_4-N = NH_4^+-N + NH_3-N). APHA 4500-NH_3 H (modified) : Online Edition.	0.010 g/m³	1-9
Nitrite-N	Filtered sample from Christchurch. Automated Azo dye colorimetry, Flow injection analyser. APHA 4500-NO_3^- I (modified) : Online Edition.	0.002 g/m³	1-9
Nitrate-N	Calculation: (Nitrate-N + Nitrite-N) - Nitrite-N. In-House.	0.0010 g/m³	1-9
Nitrate-N + Nitrite-N	Filtered sample from Christchurch. Total oxidised nitrogen. Automated cadmium reduction, flow injection analyser. APHA 4500-NO_3^- I (modified) : Online Edition.	0.002 g/m³	1-9
Total Kjeldahl Nitrogen (TKN)	Total Kjeldahl digestion, automated phenol/hypochlorite colorimetry. APHA 4500-N_{org} D (modified): Online Edition.	0.10 g/m³	1-9
Sulphate	Filtered sample from Christchurch. Ion Chromatography. APHA 4110 B (modified) : Online Edition.	0.5 g/m³	1-9
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/m³	1-9

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

Testing was completed between 09-Mar-2026 and 16-Mar-2026. 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.

Ara Heron BSc (Tech)
Client Services Manager - Environmental

R J Hill Laboratories Limited
28 Duke Street Frankton 3204
Private Bag 3205
Hamilton 3240 New Zealand

0508 HILL LAB (44 555 22)
+64 7 858 2000
mail@hill-labs.co.nz
www.hill-labs.co.nz

Certificate of Analysis

Client:	Process Flow Limited	**Lab No:**	4167322	SPv1
Contact:	Gary Smith	**Date Received:**	07-Apr-2026	
	C/- Process Flow Limited	**Date Reported:**	15-Apr-2026	
	4/38 Estuary Place	**Quote No:**	143624	
	Richmond 7020	**Order No:**		
		Client Reference:		
		Submitted By:	Gary Smith	

Sample Type: Potable Water

		Sample Name:	J1 05-Apr-2026	J2 05-Apr-2026	J3 05-Apr-2026	J4 05-Apr-2026
		Lab Number:	4167322.1	4167322.2	4167322.3	4167322.4
Individual Tests						
pH	pH Units		11.9	12.3	12.4	12.4
Total Alkalinity	g/m³ as $CaCO_3$		460	1,340	1,820	1,790
Carbonate	g/m³ at 25°C		41	163	280	250
Bicarbonate	g/m³ at 25°C		1.1	1.7	2.3	1.9
Total Hardness	g/m³ as $CaCO_3$		1,880	2,400	3,200	3,400
Electrical Conductivity (EC)	mS/m		565	873	1,067	1,126
Total Suspended Solids	g/m³		65	74	138	135
Total Solids (TS)	g/m³		3,300	3,800	4,600	4,900
Dissolved Aluminium	g/m³		0.006	0.037	0.009	0.022
Total Aluminium	g/m³		0.098	1.05	0.66	1.20
Dissolved Antimony	g/m³		0.0002	< 0.0002	< 0.0002	< 0.0002
Total Arsenic	g/m³		0.0061	0.0053	0.0046 #1	0.0048
Dissolved Boron	g/m³		< 0.05	< 0.05	< 0.05	< 0.05
Dissolved Calcium	g/m³		750	980	1,290	1,350
Dissolved Cobalt	g/m³		0.0008	0.0003	0.0003	< 0.0002
Dissolved Iron	g/m³		< 0.02	< 0.02	< 0.02	< 0.02
Total Iron	g/m³		< 0.021	< 0.021	0.175	0.024
Dissolved Magnesium	g/m³		0.06	< 0.02	< 0.02	< 0.02
Dissolved Manganese	g/m³		< 0.0005	< 0.0005	< 0.0005	< 0.0005
Dissolved Molybdenum	g/m³		0.0034	0.0040	0.0050	0.0014
Dissolved Potassium	g/m³		35	36	35	37
Dissolved Selenium	g/m³		0.0123	0.0012	0.0014	< 0.0010
Dissolved Sodium	g/m³		230	230	230	230
Dissolved Sulphur	g/m³		156	2.1	3.8	1.2
Total Sulphur	g/m³		160	5.7	4.8	2.5
Dissolved Thallium	g/m³		< 0.00005	< 0.00005	< 0.00005	< 0.00005
Total Cyanide	g/m³		< 0.002	< 0.002	< 0.002	< 0.002
Chloride	g/m³		1,070	1,290	1,480	1,650
Fluoride	g/m³		< 0.05	< 0.05	< 0.05	< 0.10 #3
Total Nitrogen	g/m³		5.1	4.8	5.4	5.4
Total Ammoniacal-N	g/m³		1.78	2.0 #2	1.59	1.90
Nitrite-N	g/m³		0.65	0.64	0.64	0.62
Nitrate-N	g/m³		2.2	2.2	2.3	2.3
Nitrate-N + Nitrite-N	g/m³		2.8	2.9	2.9	2.9
Total Kjeldahl Nitrogen (TKN)	g/m³		2.3	1.94 #2	2.5	2.5
Sulphate*	g/m³		470	6	11	3
Dissolved Organic Carbon (DOC)	g/m³		4.1	2.6	4.5	2.8

Sample Type: Potable Water					
Sample Name:		J1 05-Apr-2026	J2 05-Apr-2026	J3 05-Apr-2026	J4 05-Apr-2026
Lab Number:		4167322.1	4167322.2	4167322.3	4167322.4
Heavy metals, dissolved, trace As,Cd,Cr,Cu,Ni,Pb,Zn					
Dissolved Arsenic	g/m³	0.0054	0.0051	0.0048 #1	0.0045
Dissolved Cadmium	g/m³	< 0.00005	< 0.00005	< 0.00005	< 0.00005
Dissolved Chromium	g/m³	0.0146	0.0040	0.0038	0.0011
Dissolved Copper	g/m³	0.0024	0.0015	0.0034	0.0021
Dissolved Lead	g/m³	< 0.00010	< 0.00010	0.00016	< 0.00010
Dissolved Nickel	g/m³	0.0022	0.0006	0.0016	0.0007
Dissolved Zinc	g/m³	0.0012	0.0010	0.0044	0.0012

Analyst's Comments

#1 It has been noted that the result for the dissolved fraction was greater than that for the total fraction, but within analytical variation of the methods.

#2 It has been noted that the result for Total Ammoniacal-N was greater than that for Total Kjeldahl Nitrogen, but within the analytical variation of these methods.

#3 Due to the nature of the sample a dilution was required prior to analysis, resulting in a detection limit higher than that normally achieved for the Fluoride analysis.

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: Potable Water			
Test	**Method Description**	**Default Detection Limit**	**Sample No**
Heavy metals, dissolved, trace As,Cd,Cr,Cu,Ni,Pb,Zn	0.45µm Filtration, ICP-MS, trace level. APHA 3125 B : Online Edition.	0.00005 - 0.0010 g/m³	1-4
Total Digestion	Nitric acid digestion. APHA 3030 E (modified) : Online Edition.	-	1-4
Total Digestion	Boiling nitric acid digestion. APHA 3030 E (modified) : Online Edition.	-	1-4
pH	pH meter. Analysed at Hill Laboratories - Chemistry; Unit 1, 17 Print Place, Middleton, Christchurch. APHA 4500-H^+ B (modified) : Online Edition. Note: It is not possible to achieve the APHA Maximum Storage Recommendation for this test (15 min) when samples are analysed upon receipt at the laboratory, and not in the field. Samples and Standards are analysed at an equivalent laboratory temperature (typically 18 to 22 °C). Temperature compensation is used.	0.1 pH Units	1-4
Total Alkalinity	Titration to pH 4.5 (M-alkalinity), autotitrator. Analysed at Hill Laboratories - Chemistry; Unit 1, 17 Print Place, Middleton, Christchurch. APHA 2320 B (modified for Alkalinity <20) : Online Edition.	1.0 g/m³ as $CaCO_3$	1-4
Carbonate	Calculation: from alkalinity and pH, valid where TDS is not >500 mg/L and alkalinity is almost entirely due to hydroxides, carbonates or bicarbonates. APHA 4500-CO_2 D : Online Edition.	1.0 g/m³ at 25°C	1-4
Bicarbonate	Calculation: from alkalinity and pH, valid where TDS is not >500 mg/L and alkalinity is almost entirely due to hydroxides, carbonates or bicarbonates. APHA 4500-CO_2 D : Online Edition.	1.0 g/m³ at 25°C	1-4
Total Hardness	Calculation from Dissolved Calcium and Dissolved Magnesium. APHA 2340 B : Online Edition.	1.0 g/m³ as $CaCO_3$	1-4
Electrical Conductivity (EC)	Conductivity meter, 25°C. Analysed at Hill Laboratories - Chemistry; Unit 1, 17 Print Place, Middleton, Christchurch. APHA 2510 B : Online Edition.	0.1 mS/m	1-4
Total Suspended Solids	Filtration using Whatman 934 AH, Advantec GC-50 or equivalent filters (nominal pore size 1.2 - 1.5 µm), gravimetric determination. Analysed at Hill Laboratories - Chemistry; Unit 1, 17 Print Place, Middleton, Christchurch. APHA 2540 D (modified) : Online Edition.	3 g/m³	1-4
Total Solids (TS)	Gravimetric. Analysed at Hill Laboratories - Chemistry; Unit 1, 17 Print Place, Middleton, Christchurch. APHA 2540 B (modified) : Online Edition.	10 g/m³	1-4
Filtration for dissolved metals analysis	Sample filtration through 0.45µm membrane filter and preservation with nitric acid. APHA 3030 B : Online Edition.	-	1-4

Sample Type: Potable Water			
Test	**Method Description**	**Default Detection Limit**	**Sample No**
Filtration for dissolved metals analysis - Misc	Sample filtration through 0.45µm membrane filter and preservation with nitric acid. APHA 3030 B : Online Edition.	-	1-4
Dissolved Aluminium	Filtered sample, ICP-MS, trace level. APHA 3125 B : Online Edition.	0.003 g/m³	1-4
Total Aluminium	Nitric acid digestion, ICP-MS, trace level. APHA 3125 B : Online Edition.	0.0032 g/m³	1-4
Dissolved Antimony	Filtered sample, ICP-MS, trace level. APHA 3125 B : Online Edition.	0.0002 g/m³	1-4
Total Arsenic	Nitric acid digestion, ICP-MS, trace level. APHA 3125 B : Online Edition.	0.0011 g/m³	1-4
Dissolved Boron	Filtered sample, ICP-MS, trace level. APHA 3125 B : Online Edition.	0.05 g/m³	1-4
Dissolved Calcium	Filtered sample, ICP-MS, trace level. APHA 3125 B : Online Edition.	0.05 g/m³	1-4
Dissolved Cobalt	Filtered sample, ICP-MS, trace level. APHA 3125 B : Online Edition.	0.0002 g/m³	1-4
Dissolved Iron	Filtered sample, ICP-MS, trace level. APHA 3125 B : Online Edition.	0.02 g/m³	1-4
Total Iron	Nitric acid digestion, ICP-MS, trace level. APHA 3125 B : Online Edition.	0.021 g/m³	1-4
Dissolved Magnesium	Filtered sample, ICP-MS, trace level. APHA 3125 B : Online Edition.	0.02 g/m³	1-4
Dissolved Manganese	Filtered sample, ICP-MS, trace level. APHA 3125 B : Online Edition.	0.0005 g/m³	1-4
Dissolved Molybdenum	Filtered sample, ICP-MS, trace level. APHA 3125 B : Online Edition.	0.0002 g/m³	1-4
Dissolved Potassium	Filtered sample, ICP-MS, trace level. APHA 3125 B : Online Edition.	0.05 g/m³	1-4
Dissolved Selenium	Filtered sample, ICP-MS, trace level. APHA 3125 B : Online Edition.	0.0010 g/m³	1-4
Dissolved Sodium	Filtered sample, ICP-MS, trace level. APHA 3125 B : Online Edition.	0.02 g/m³	1-4
Dissolved Sulphur	Filtered sample, ICP-OES. APHA 3120 B : Online Edition.	0.10 g/m³	1-4
Total Sulphur	Nitric acid digestion, ICP-OES (method may not fully account for H_2S due to volatilisation during digestion). All forms of oxidised and organic sulphur will be determined by this method. APHA 3120 B : Online Edition.	0.5 g/m³	1-4
Dissolved Thallium	Filtered sample, ICP-MS, trace level. APHA 3125 B : Online Edition.	0.00005 g/m³	1-4
Total Cyanide Trace	On-line distillation, colorimetry, trace level. ISO 14403:2012(E) (modified).	0.002 g/m³	1-4
Chloride	Filtered sample from Christchurch. Ion Chromatography. APHA 4110 B (modified) : Online Edition.	0.5 g/m³	1-4
Fluoride	Direct measurement, ion selective electrode. APHA 4500-F^- C : Online Edition.	0.05 g/m³	1-4
Total Nitrogen	Calculation: TKN + Nitrate-N + Nitrite-N. Please note: The Default Detection Limit of 0.05 g/m³ is only attainable when the TKN has been determined using a trace method utilising duplicate analyses. In cases where the Detection Limit for TKN is 0.10 g/m³, the Default Detection Limit for Total Nitrogen will be 0.11 g/m³. In-house calculation.	0.05 g/m³	1-4
Total Ammoniacal-N	Filtered Sample from Christchurch. Phenol/hypochlorite colourimetry. Flow injection analyser. (NH_4-N = NH_4^+-N + NH_3-N). APHA 4500-NH_3 H (modified) : Online Edition.	0.010 g/m³	1-4
Nitrite-N	Filtered sample from Christchurch. Automated Azo dye colorimetry, Flow injection analyser. APHA 4500-NO_3^- I (modified) : Online Edition.	0.002 g/m³	1-4
Nitrate-N	Calculation: (Nitrate-N + Nitrite-N) - Nitrite-N. In-House.	0.0010 g/m³	1-4
Nitrate-N + Nitrite-N	Filtered sample from Christchurch. Total oxidised nitrogen. Automated cadmium reduction, flow injection analyser. APHA 4500-NO_3^- I (modified) : Online Edition.	0.002 g/m³	1-4
Total Kjeldahl Nitrogen (TKN)	Total Kjeldahl digestion, automated phenol/hypochlorite colorimetry. APHA 4500-N_{org} D (modified): Online Edition.	0.10 g/m³	1-4
Soluble Sulphate*	Calculation: from dissolved sulphur.	2 g/m³	1-4
Total Sulphate*	Calculation: from total sulphur.	2 g/m³	1-4
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/m³	1-4

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

Testing was completed between 08-Apr-2026 and 15-Apr-2026. 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.

This certificate of analysis must not be reproduced, except in full, without the written consent of the signatory.

Graham Corban MSc Tech (Hons)
Client Services Manager - Environmental