September 2016

CORONATION NORTH PROJECT

Water Quality Effects, Management and Mitigation

Submitted to:
Oceana Gold (New Zealand) Ltd

REPORT

Report Number: 1545831-010-Rev3

Distribution:

Jackie St John, Oceana Gold (New Zealand) Ltd

Golder Associates

Table of Contents

TABLES

FIGURES

APPENDICES

1.0 INTRODUCTION

1.1 Background

Oceana Gold (New Zealand) Limited (OceanaGold) has applied to Otago Regional Council (ORC) for consents authorising the construction of the Coronation North Project. The Project generally consists of:

- Construction, operation and closure of the planned Coronation North Pit, together with an associated haul road connecting to the ore processing plant at the Macraes Gold Project (MGP).
- Extension of the existing Coronation Pit beyond its currently consented area to what has been termed the Coronation Stage 5 (CS5) pit shell.
- Construction and rehabilitation of the planned Coronation North waste rock stack (WRS).

Golder Associates (NZ) Limited (Golder) provided technical support to OceanaGold with respect to assessing the effects of the Project on groundwater (Golder 2016a), surface water (Golder 2016b) and water quality (Golder 2016b).

The work documented in the above reports indicated OceanaGold would need to instigate mitigation measures in order to enable ongoing compliance with water quality criteria proposed by OceanaGold. The proposed water quality criteria would be applicable at the proposed MB02 compliance monitoring point (Table 1). These criteria are the same as existing criteria applicable at the existing Coronation Project compliance monitoring point MB01 in Mare Burn, and the most up-stream surface compliance monitoring points on other catchments already affected by the MGP.

Table 1: Compliance criteria proposed by OceanaGold for MB02.

Parameter (1)	Existing at MB01 and proposed for MB02	ANZECC 2000 (stock water)	NZDWS 2008 (2)
pH (unitless)	6.0 – 9.5	-	7.0 – 8.5
Sulfate	1,000	1,000	250
$Cyanide_{WAD}$	0.1	-	0.08
Arsenic	0.15	0.5	0.01
Copper (3)	0.009	0.5	2
Iron	1.0	N/A	0.2
Lead (3)	0.0025	0.1	0.01
Zinc (3)	0.12	20	-

Notes:
1) All units g/m^3 unless stated.
2) Some of these values are maximum acceptable values while others are guideline values for aesthetic determinands.
3) Copper, lead and zinc compliance criteria for MB01 are hardness related.

Surface water flow and quality modelling (Golder 2016b) indicated that that the primary contaminant requiring mitigation in order to meet the proposed compliance criteria at MB02 would be sulfate, which is also the case for most of the catchments affected by the MGP (Golder 2011a, 2011b). The modelled water quality compliance issues for sulfate were primarily associated with periods of low flow in Mare Burn. Environmental monitoring data from the MGP indicates waste rock stack (WRS) leachate is characterised by high sulfate concentrations (Golder 2016b). During periods of low flow in Mare Burn there is insufficient in-stream dilution available for the WRS discharges to enable OceanaGold to comply with the proposed limit for sulfate (Table 1). The model outcomes also indicated elevated concentrations of dissolved iron and arsenic may require localised mitigation measures to be implemented to enable compliance with the proposed water quality criteria.

Construction and operation of a freshwater dam on Coal Creek (Figure 1), a tributary of Mare Burn upstream from the proposed MB02 compliance point, was proposed. The objective of the freshwater dam was to provide a reliable base flow at MB02 sufficient to enable ongoing compliance with the proposed sulfate limit. Water balance modelling of the dam indicated that a 680 ML freshwater reservoir in the Coal Creek sub-catchment would be sufficient to provide a reliable constant discharge of up to 7 L/s. Ongoing compliance with the proposed sulfate limit at MB02 could be achieved if a constant discharge rate of 5 L/s from the fresh water dam is achieved (Golder 2016c).

Hydrogeochemical modelling of the surface water system in the Mare Burn catchment was undertaken separately using the PHREEQC software package to evaluate natural attenuation of dissolved iron and arsenic. This modelling indicated that natural attenuation of iron and arsenic upstream from MB02 would enable OceanaGold to comply with the water quality limits for both iron and arsenic (Golder 2016d).

1.2 Scope of Work

This report provides additional information related to the work undertaken by Golder to support OceanaGold in applying for the necessary resource consents for the Coronation North Project.

ORC and independent consultants undertook reviews of the application for resource consents authorising the Coronation North Project. A number of issues were raised which are specifically addressed in this report:

- The potential for WRS discharges to be reduced through capping or other management measures.
- The potential for the WRS discharges to be diverted through a water race or other means to a downstream discharge point or an area where the water could be discharged to land.
- The quality of water in and discharging from the proposed freshwater dam, taking into account the likelihood of reservoir stratification.
- The applicability of the proposed criteria with respect to ecological protection of the Mare Burn catchment.
- The future compliance of the Coronation North Project with nitrate-nitrogen (NO_3-N) criteria introduced by ORC through the Regional Plan Change 6a.

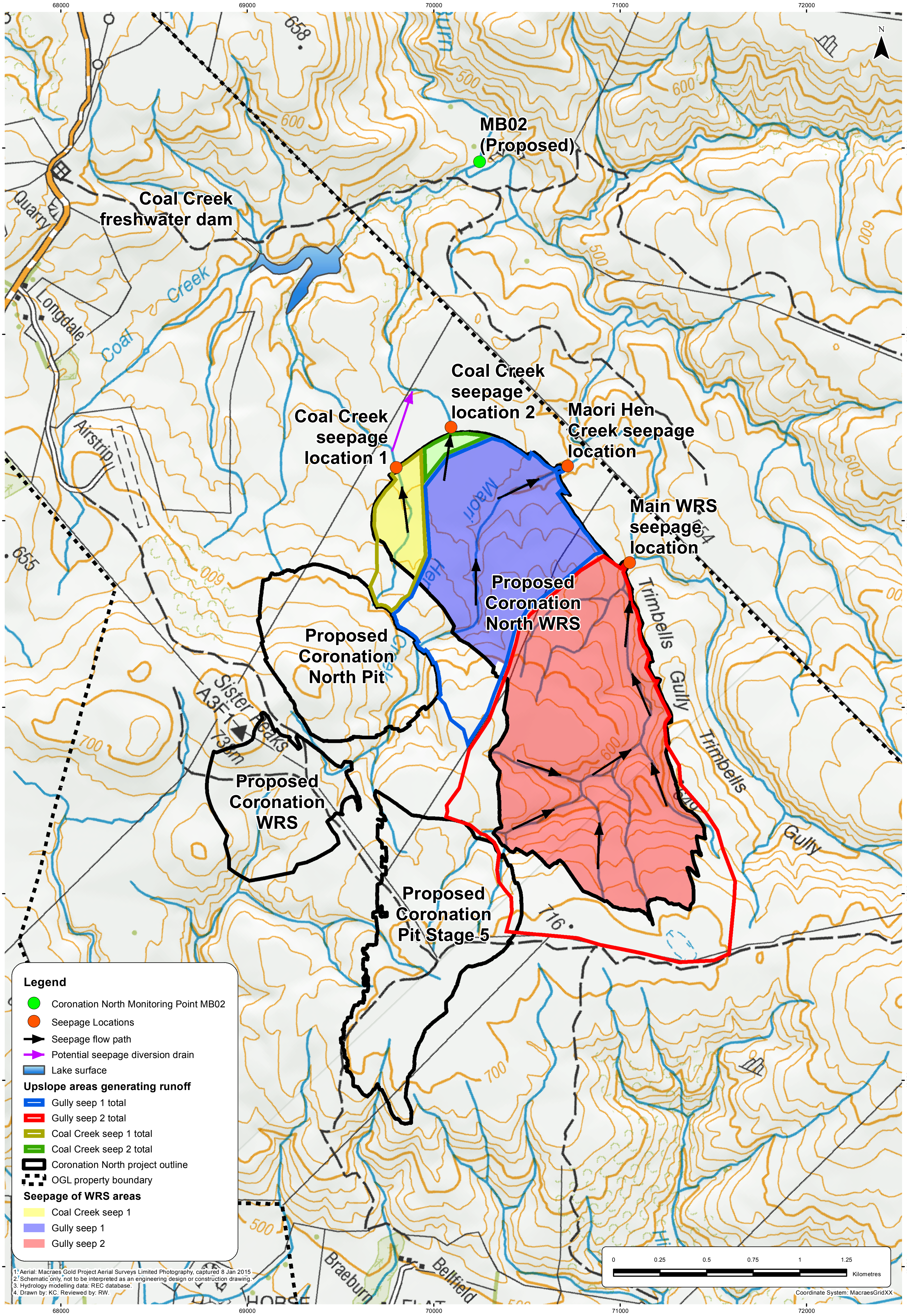
The information presented in this report should be considered in conjunction with:

- The surface water modelling assessment for the Coronation North Project (Golder 2016b).
- The water quality effects mitigation report documenting the proposed Coal Creek freshwater dam (Golder 2016c).
- The assessment of the natural attenuation of iron and arsenic within the surface water system of Mare Burn upstream from MB02 (Golder 2016d).

1.3 Report Structure

In addition to this introductory section, this report contains the following sections:

- Section 2.0 summarises options for managing WRS leachate through seepage control or options for improving seepage water quality.
- Section 3.0 provides information on the stratification of the proposed Coal Creek freshwater dam and measures proposed to manage the quality of the discharge water from the dam.



Golder Associates

TITLE CORONATION NORTH WRS
PRIMARY SEEPAGE DISCHARGE LOCATIONS

SEPTEMBER 2016

PROJECT 1545831-010

1

S:\GIS\Projects-Dynamics\2015\7410\1545831_OceanaGold(NZ)Ltd_CoronationNorthPitWaterAssessment\MapDocuments\010\Fig01_SeepageLocation_A3P_GIS.mxd

- Section 4.0 compares contaminant concentrations, either modelled for the proposed Mare Burn compliance monitoring point MB02 or observed at MGP environmental monitoring sites, with water quality guidelines based on the protection of freshwater aquatic species.
- Section 5.0 summarises the contents of the report and presents the conclusions.
- A statement of limitations and the list of referenced documents are presented in Sections 6.0 and 7.0.

2.0 WRS LEACHATE MANAGEMENT

2.1 Leachate Volume Reduction

2.1.1 Introduction

OceanaGold is considering several options that may enable a reduction in leachate volumes derived from infiltration of rainwater to the Coronation North WRS. The options primarily relate to reducing the amount of rainfall entering the body of the WRS through:

1) Reducing the area of the Coronation North WRS and therefore the amount of rainfall incipient to the WRS.
2) Reducing the rate at which incipient rainfall infiltrates through the rehabilitated WRS cover to the body of the stored wastes.
3) Reducing run-on to the WRS from adjacent undisturbed catchment areas.

2.1.2 WRS area reduction

Reducing the area of the WRS would reduce the amount of rainfall intercepted by the stored wastes and therefore the amount of infiltration and consequent leachate. Reducing the WRS footprint however requires the height of the WRS to be increased, involving additional haulage costs. Golder has been advised by OceanaGold (J. St John, pers comm) that there is very limited scope for increasing the height of the WRS while retaining an economically viable project.

OceanaGold has considered the possibility of storing wastes from Coronation North Pit in Coronation Pit after ore recovery operations from the latter pit have been completed. Ideally the waste rock would be stored beneath the final water level of the Coronation Pit lake. Golder has been advised by OceanaGold (J. Bywater, pers comm) that the operational schedules of the two pits do not offer opportunity for significant quantities of waste rock to be stored in Coronation Pit.

OceanaGold has also considered the possibility of storing waste rock from Coronation North Pit in the Deepdell Creek catchment. Golder has been advised by OceanaGold (J. Bywater, pers comm) that the haulage costs of doing so are prohibitive.

2.1.3 WRS capping

Reducing the rate at which incipient rainfall infiltrates through the rehabilitated cover of the WRS can potentially be done through:

- Designing the WRS upper surface to enhance stormwater run-off.
- Installing a layered WRS cap designed to reduce the rate at which incipient rainfall seeps through the cap into the body of the stored wastes.

Further work can be undertaken with respect to both of the above measures. It is however important to recognise that the infiltration rate incorporated into the catchment water model for the WRS areas is equivalent to the groundwater recharge rate for the wider undisturbed catchments. This rate of 32 mm/year is already very low, due primarily to evapotranspiration at the site exceeding rainfall for most of the year.

Significant reductions in this infiltration rate are likely to be difficult to achieve without compromising other rehabilitation objectives for the WRS, including the establishment of a significant topsoil horizon to support revegetation.

OceanaGold is reviewing the upper surface design of the Coronation WRS, with the objective of enhancing run-off. At this stage it is unclear if a significant reduction in infiltration, and therefore leachate discharge flows, can be achieved.

2.1.4 Run-on diversion drains

Diversion drains have been incorporated in the Coronation North WRS design by Engineering Geology Limited, to minimise surface water run-on from the up-gradient catchment. These drains were not taken into account when developing the catchment water model for the Coronation North Project (Golder 2016b).

The effect of installing these diversion drains on run-on volumes to the WRS has been reviewed. For three of the seepage discharge points the installation of these drains would make no difference to the discharge flow rates, as the catchment areas would not be affected. For the main WRS discharge point to Trimbells Gully the installation of one diversion drain removes a small component of the contributing catchment. The gain is however very small with respect to contaminant mass loads and improvements in downstream water quality.

2.2 Leachate Diversion

2.2.1 Discharges to land

OceanaGold has reviewed options for the capture of Coronation North WRS leachate and diversion of the leachate to either discharge points further downstream on Mare Burn or to an area where the water can be discharged to land. The basic assumption incorporated in the review is that the eventual discharge point(s) would need to be down-gradient from the leachate collection points, to enable gravitational water flows. It is important to recognise that OceanaGold's current land holdings in the Mare Burn catchment limit the potential mitigation options available.

Two primary factors have been taken into account in assessing the irrigation area required for land disposal:

1) Complete loss of the irrigated water through evaporation during dry summer periods when the Mare Burn is likely to be dry.

2) A nitrate loading limit to land based on the ORG Regional Plan Change 6a objective of 30 kgN/ha/year.

The two WRS seepage discharge points within the Coal Creek catchment (Figure 1) are calculated to generate minimal flows due to the small size of these contributing catchment areas (Table 2). These discharge points are located at relatively high elevations, in gullies that are not deeply incised. The discharge from the Coal Creek 2 seepage point is unlikely to reach Coal Creek during dry summer periods. The discharge from Coal Creek 1 seepage point may reach the proposed Coal Creek reservoir during dry summers although the flow would be reduced due to evaporative losses.

If necessary, short diversion channels could be constructed to distribute the discharge flows from Coal Creek seepage points 1 and 2 across hillsides to the north of the WRS. There are sufficient areas of hillside accessible for water distributed by gravity flow to enable the seepage to generally evaporate during dry summer periods and therefore not influence water quality at Mare Burn during these periods. Sulfate compounds precipitated during dry periods are however likely to remobilise during wetter periods, either through dissolution or through physical transport to Coal Creek and thence to Mare Burn.

Under the ORC Regional Plan Change 6a several criteria have been identified to nitrogen loading to land, with the objective of improving or maintaining in-stream water quality. In the area of the MGP, the criterion applicable will be 30 kgN/ha/year. There are sufficient areas of hillside accessible for water distributed from Coal Creek seepage points 1 and 2 by gravity flow to enable this criterion to be met (Table 3). Compliance with the nitrogen loading criterion from the Plan Change 6a would however require larger irrigation areas than those indicated for evaporative management of water from these two discharge points.

Table 2: Coronation North WRS seepage points and indicative evaporation areas required.

WRS seepage discharge point	Elevation	Flow		Evaporation area required over summer
	(mRL)	(m^3/day)	(L/s) [1]	(ha) [1]
Main WRS seepage location	507	258.6	3.0	19
Maori Hen Gully	485	111.0	1.3	8
Coal Creek seepage location 1	525	3.2	0.04	0.2
Coal Creek seepage location 2	530	24.2	0.3	2
Total		397	4.6	30

Note: 1) Values rounded.

Table 3: Coronation North WRS seepage points, nitrate loads and indicative irrigation areas required.

WRS seepage discharge point	Flow	Nitrate mass loads [1]		Irrigation area required [2]
	(m^3/day)	(kg/day)	(kg/year)	(ha)
Main WRS seepage location	258.6	2.9	1,076	36
Maori Hen Gully	111	1.3	462	15
Coal Creek seepage location 1	3.2	0.04	13	0.4
Coal Creek seepage location 2	24.2	0.3	101	3.4
Total	397	4.5	1,652	55

Note: 1) Loads are based on a median NO_3-N concentration in WRS seepage water of 11.4 g/m^3.
2) Based on nitrate loading rate of 30 kgN/ha/year. Values rounded.

The main Coronation North WRS discharge to Trimbells Creek and the discharge location in Maori Hen Gully are both located in more deeply incised gullies. There are no areas currently owned by OceanaGold downslope from these two sites that are sufficiently large to serve the purpose of land based disposal. These flows could potentially be pumped to an appropriate disposal area at a higher elevation. This option is however not considered to be an appropriate long term solution to reducing projected sulfate concentrations at MB02 or to meeting the Plan Change 6a nitrate loading criterion for irrigation to land.

2.2.2 Coal Creek Dam bypass

Under the current Coronation North WRS design, Coal Creek seepage location 1 will contribute flows and contaminant loads to the proposed Coal Creek freshwater dam (Figure 1). This contribution would constitute the largest single source of sulfate being introduced to the Coal Creek dam and would influence the sulfate concentration in the dam water (Table 4).

The Coal Creek Dam reservoir is expected to stratify on a seasonal basis (refer Section 3.2). Sulfide accumulation in the deeper water within the lake has the potential to have a transient seasonal influence on shallow water quality in the reservoir. The potential for sulphide production from the underlying soils following inundation has not been quantified and has therefore not been incorporated in the mass balance. A simple sulfate mass balance summary of the flows contributing to the reservoir however indicates flow from the Coal Creek seepage location 1 is potentially a substantial contributor to the reservoir (Table 4). In order to reduce the sulfate mass load to the lake, flows from Coal Creek seepage location 1 can be diverted past the reservoir to Coal Creek downstream from the dam (Figure 1). Modelling indicates that this would have no effect on the sulfate projections documented for MB02 in the surface water mitigation report (Golder 2016c) but would lead to improved water quality in the reservoir (Table 4).

Table 4: Coal Creek Dam sulfate mass balance summary.

Parameters [1,2]	Units	Coal Creek seepage 1	Coronation North Pit overflow	Remainder inflows	Combined in Coal Creek Dam [1]
Sulfate mass load to Coal Creek dam with Coal Creek 1 seepage included					
SO_4 concentration	g/m^3	2,900	350	6	59
Average flow	m^3/day	24.2	18	1,400	1,442
Mass load	kg/day	70.2	6.3	8.4	83
Sulfate mass load to Coal Creek dam with Coal Creek 1 seepage excluded					
SO_4 concentration	g/m^3	0	350	6	10
Average flow	m^3/day	0	18	1,400	1,418
Mass load	kg/day	0	6.3	8.4	13

Note: 1) The concentrations presented in this column assume full and ongoing mixing of the reservoir.
2) Sulfate derived from inundated soils is not included in mass balance calculation.

2.3 Leachate Quality Improvement

Improvements in leachate water quality are being investigated by OceanaGold with two specific areas of focus:

1) Reducing sulfate concentrations in the WRS discharge water.

2) Reducing nitrate concentrations in the WRS discharge water.

Some of the mitigation options identified to reduce sulfate concentrations in the discharge water may also result in reduced nitrate concentrations. At this stage however, this possibility has not been investigated in detail.

Sulfate

Preliminary options for the reduction of sulfate concentrations in leachate seepage and discharge water have been presented to OceanaGold (O'Kane 2016) for further investigation. These options include:

- Separation of higher sulphide wastes from wastes with lower sulphide concentrations. Encapsulation of the higher sulphide wastes within layers of low permeability compacted weathered rock within the WRS. The objective of the encapsulation is to reduce oxygen access to the higher sulphide waste and reduce seepage flows through the higher sulphide wastes.
- Reduction of oxygen ingress to the WRS, thereby reducing the rate of metal sulphide conversion from the waste rock to sulfates.
- Increasing the availability of Ca^{2+} ions to leachate within the WRS through the addition of limestone or lime to the stored wastes. Increasing the concentration of Ca in the leachate water would encourage the precipitation of gypsum ($CaSO_4$) and thereby reduce the concentration of sulfate in the discharge water.
- Treatment of the WRS discharge water through:
  - Dosing the water with lime to encourage the precipitation of gypsum and reduce the concentration of sulfate in the discharge water.

- Installing bioreactors at the leachate discharge points from the WRS, to convert the sulfate in solution into an insoluble metal sulphide and capture the precipitate.

All of the options presented above have been demonstrated successfully overseas (INAP 2003). At this stage none of these options have been reviewed to a pre-feasibility level for application at the MGP. As such, OceanaGold has not taken into account the potential benefits from instigating any of the above measures when developing mitigation options for the Coronation North Project. Golder has however been advised that OceanaGold is investigating the most prospective of the options for sulfate management (O'Kane 2016). Should any of these options prove economically viable at reducing sulfate concentrations in leachate discharges from the Coronation North WRS leachate discharge points, and subsequently be installed, this could be expected to reduce the required discharge flow rate from the proposed Coal Creek freshwater dam.

Nitrate

One of the primary constituents of the explosives used at the MGP, and at mine sites worldwide, is ammonium nitrate. Under ideal blast conditions, the ammonium nitrate from the explosives would be fully converted to reaction gases, principally consisting of CO_2, N_2 and H_2O. Most detonations do not however occur under ideal conditions. International research has shown that ammonium nitrate explosives often fail to ignite or burn completely in shot holes.

Nitrate concentrations detected in seepage water discharging from exiting WRS areas at the MGP (Appendix A) are elevated but decrease over approximately the first three years following closure of the WRS. An initial interpretation of this short-term trend is that it represents the leaching of explosive residues from the WRS. OceanaGold has been investigating the possibility of reducing explosive residues (J St John, pers comm).

The source of nitrates detected in leachate water over the longer term from WRS areas at the MGP is less clear. The most likely scenario appears to be that the nitrates derive from weathering of the waste rock (Appendix A). Further investigations will be needed to verify this scenario. If correct, this situation has not been widely documented with respect to mine wastes internationally and further work would be required to identify possible mitigation options that may be applied.

2.4 Summary

The proposed Coal Creek freshwater dam with an associated continuous release of 5 L/s has been demonstrated to be an effective mitigation measure enabling OceanaGold to comply with the proposed water quality criteria for sulfate at MB02 (Golder 2016c).

Coronation North WRS options identified to reduce infiltration rates may achieve small reductions in the volumes of leachate requiring management, however these reductions are unlikely to achieve significant improvements in water quality at MB02.

A diversion drain should be installed to divert WRS leachate discharging at the Coal Creek seepage location 1 downstream past the Coal Creek freshwater dam. This diversion drain would result in reduced sulfate concentrations in the freshwater reservoir but would not affect previous water quality modelling outcomes at MB02.

Irrigation of leachate from Coal Creek seepage locations 1 and 2 to hillside pastures down-slope from Coronation North WRS should enable summer discharges of water from these sites to Mare Burn to be eliminated. OceanaGold does not own sufficient land within the Mare Burn catchment down-slope from the other WRS discharge points to enable management of the leachate through passive irrigation of the leachate to land.

Pumping of WRS leachate water to appropriate irrigation areas at higher elevations could be used over the short term to manage contaminants within the Mare Burn catchment. This option is however not considered to be an appropriate long term solution to reducing projected sulfate concentrations at MB02 or to meeting the ORC Regional Plan Change 6a nitrate loading criterion for irrigation to land.

None of the leachate management and mitigation options identified in this section offer a reliable, sustainable and economically viable solution to enable OceanaGold to achieve long term compliance with water quality criteria proposed for MB02. They may however contribute to an overall contaminant management plan for the catchment.

3.0 COAL CREEK FRESHWATER DAM

3.1 Introduction

Coal Creek freshwater dam has been proposed by OceanaGold to provide a reliable and continuous discharge of water to dilute contaminants derived from the Coronation North WRS at the MB02 compliance point. OceanaGold recognises the construction of a large freshwater reservoir would generate environmental issues that also require mitigation. It is for this reason that OceanaGold plans to undertake a best practice options assessment seeking other leachate management and mitigation options that would reduce or negate the need for the dam (OceanaGold 2016).

3.2 Reservoir Stratification

The freshwater reservoir retained behind the proposed Coal Creek dam is deep enough to stratify seasonally. Water in deeper sections of the reservoir close to the dam may become permanently deoxygenated and characterised by reducing conditions. Shallow reservoir water would generally tend to be well oxygenated. The epilimnion is the shallow warmer and usually well oxygenated layer within a thermally stratified lake. The seasonal development and subsequent disappearance of an epilimnion may result in chemically reduced contaminants being mixed throughout the lake on a transient basis. Chemically reduced metal compounds, sulphides and ammonium are more toxic to aquatic life than oxidised metal compounds, sulfates and nitrates.

A continuous discharge of water from the Coal Creek reservoir is proposed as a mitigating measure to enable OceanaGold to maintain compliance with the proposed water quality criteria at MB02. Releasing chemically reduced compounds from the reservoir into Mare Burn could however potentially affect the downstream ecology.

A preliminary assessment of the potential depth of the thermocline within the reservoir during the summer (Table 5) has been based on historical observations from natural New Zealand lakes (Davies-Colley 1988). The depth of the thermocline is partially dependent on wind disturbance of the lake surface and the consequent wave and current motions. The degree of wind disturbance of the lake is dependent on the surface fetch. As there are two main branches of the reservoir, both have been considered. The fetch has been calculated using the equation:

$$\text{Fetch} = (\text{Length} + \text{Width})/2 \qquad \text{(Davies-Colley 1988)}$$

A preliminary estimate of the depth of the thermocline (Table 5) has been calculated using the equation:

$$\text{Thermocline depth} = 8.58 \times \text{Fetch}^{0.408} \qquad \text{(Davies-Colley 1988)}$$

Table 5: Coal Creek freshwater dam indicative depth of epilimnion.

Parameter	Western branch	Southern branch
Length (m)	660	500
Width (m)	80	90
Fetch (km)	0.37	0.30
Thermocline depth (m) (1)	5.7	5.2

Note: 1) Depth to steepest vertical temperature gradient below lake surface.

A substantial reduction in the depth and volume of the Coal Creek dam reservoir would be needed to ensure the deeper layers of stored water remain in an oxygenated state throughout the year. Other mitigation measures have been identified that may reduce the required size of the reservoir (Section 2.0). These measures are however collectively either insufficient to replace the need for the freshwater reservoir or need further work to validate their efficiency. The potential reduction in required reservoir size through applying other mitigation measures collectively through a catchment contaminant management plan has not yet been quantified.

3.3 Coal Creek Dam discharge water treatment

The risk of deoxygenated water and possibly iron and manganese in reduced forms being seasonally discharged in solution from the Coal Creek reservoir can be mitigated through an appropriately engineered design for the discharge system. This design incorporates a floating decant from the reservoir, an oxygenation stage, a settling pond stage and potentially a small wetland polishing stage. The concept is based on the need to manage a relatively small and constant flow of water with no active intervention. System monitoring and maintenance would however be required to ensure the discharge water continues to be adequately oxygenated and carries acceptably low concentrations of contaminants in the reduced form.

A conceptual design of the discharge system incorporates:

- A floating decant syphon from the reservoir, to ensure water is discharged from the most highly oxygenated zone of the reservoir.
- An outlet pipe through the toe of the embankment to avoid the need for a pumped discharge.
- An outflow cascade to increase the level of oxygenation in the discharged water.
- A settling pond to provide time for contaminants in the water to oxidise, precipitate and subsequently settle out of the water column.
- A small wetland to help filter out any remaining precipitated contaminants before the water is discharged to the bed of Coal Creek downstream from the dam.

In addition to the above engineered features, the dam design report (EGL 2016) also incorporates:

- A primary piped spillway discharging close to the downstream toe of the dam. This spillway would need to discharge downstream from any water treatment system installed to reduce the risk of damage to the treatment system through erosion.
- An auxiliary spillway designed to accommodate major storm flows and discharge these flows to Coal Creek further downstream from the embankment.

The discharge points for these spillways would be designed to take into account and protect any water treatment structures installed close to the toe of the embankment.

4.0 CONTAMINANT TOXICITY

4.1 Sulfates

The British Columbia guidelines for sulfate have been identified by the ORC reviewer as potentially appropriate for ecological protection at the Coronation North Project. An initial indication as to whether OceanaGold can meet these guidelines can be gained be reviewing water quality data obtained from existing environmental monitoring data from the MGP. Specifically:

- Water quality from monitoring points in Deepdell Creek upstream (DC01 and DC02) and downstream (DC07 and DC08) from the MGP.
- Water quality from silt dams downstream from the Clydesdale, Murphys Creek, Northern Gully and Deepdell North WRSs.
- Water quality in Golden Bar pit lake and Deepdell South pit lake.

The British Colombia guidelines link sulfate toxicity to the hardness of the water, with the guideline value increasing stepwise as the hardness increases Figure 2). Above a hardness of 250 g/m^3 the guidelines indicate site specific testing should be undertaken.

OceanaGold has monitored both sulfate concentrations and total hardness in Deepdell Creek since 1990, when MGP operations started in the catchment. Measured sulfate concentrations in the stream have increased over time, from baseline concentrations of less than 10 g/m^3 to currently observed concentrations of generally between 100 g/m^3 and 300 g/m^3. Higher concentrations have also been measured during dry summer periods. A strong relationship between sulfate concentration and total hardness has been recorded from the downstream compliance points in Deepdell Creek. For sulfate concentrations up to 200 g/m^3 the data consistently plotted below the British Colombia guideline values (Figure 2).

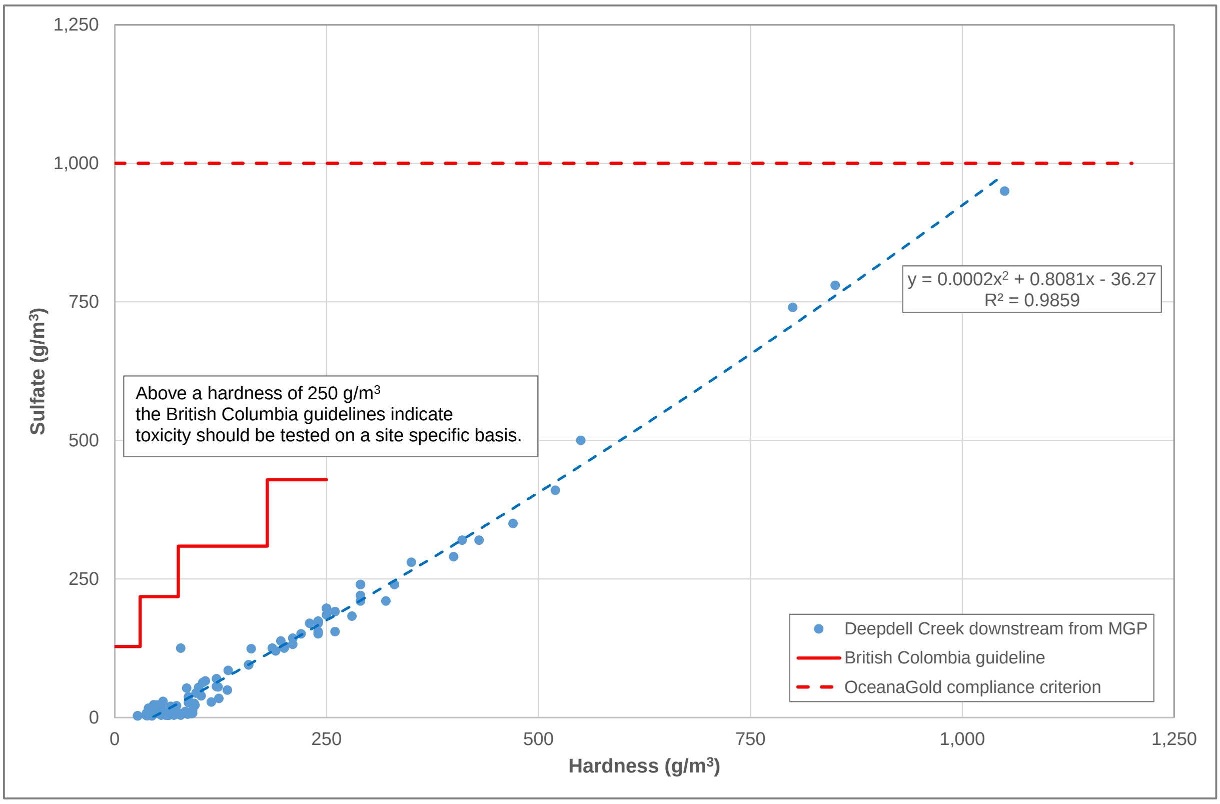


Figure 2: Sulfate to hardness relationship in Deepdell Creek at downstream compliance point, 1990 to 2015.

4.2 Nitrates

4.2.1 Nitrate Environmental Objective Guidance

Otago Regional Council Plan Change 6a

Plan Change 6a to the Otago Regional Plan, Schedule 16, identifies permitted activity discharge thresholds for water quality, including for nitrate-nitrite nitrogen and ammoniacal nitrogen. In summary, discharges of contaminants to water within the Taieri River catchment are restricted discretionary activities requiring resource consents if:

- Nitrate nitrogen at an appropriate compliance point exceeds a concentration of 1 g/m^3 (mg/L).
- Ammoniacal nitrogen at an appropriate compliance point exceeds a concentration of 0.2 g/m^3

These thresholds are linked to low flow criteria in the Taieri River, however for the purpose of this report they are accepted as applying continuously.

National Policy Statement for Freshwater Management 2014

The National Policy Statement for Freshwater Management 2014 (MfE 2014) provides nitrate-N and ammoniacal-N toxicity guidance to protect ecosystem health. Sections of the appropriate tables from the NPS 2014 are presented in Table 6, with attribute state C and the national bottom line concentrations omitted from the table.

Table 6: Nitrate-N and ammoniacal-N NPS attributes for toxicity (MfE 2014).

Parameter	Attribute state	Annual median	Annual 95th percentile	Narrative attribute
Nitrate-N ($g\ NO_3\text{-}N/m^3$)	A	≤ 1.0	≤ 1.5	High conservation value system. Unlikely to be effects even on sensitive species.
	B	> 1.0 and ≤ 2.4	> 1.5 and ≤ 3.5	Some growth effect on up to 5 % of species.
Ammoniacal-N ($g\ NH_4\text{-}N/m^3$) (1)	A	≤ 0.03	≤ 0.05	99 % species protection level: no observed effect on any species tested.
	B	> 0.03 and ≤ 0.24	> 0.05 and ≤ 0.4	95 % species protection level: starts impacting occasionally on the 5 % most sensitive species.

Note: 1) Based on pH 8 and temperature of 20 °C.

4.2.2 Catchment Water and Contaminant Mass Balance Modelling

Flow and contaminant mass balance modelling has been undertaken for the Mare Burn catchment using the GoldSim modelling package, with the outcomes for various contaminants documented in a separate report (Golder 2016a). Additional modelling was undertaken to evaluate the effects of constructing a freshwater reservoir within the catchment, and releasing a constant flow of 5 L/s to the stream, on water quality at MB02 (Golder 2016b). Two of the models developed for the above purposes have been used for the assessment of potential nitrate nitrogen concentrations in Mare Burn following closure of the Coronation North Project. These models are:

- Stage 3 base case, which simulates the Mare Burn catchment incorporating the structures and waste storage associated with both the fully developed Coronation Stage 5 Pit and Coronation North Pit post closure. It is assumed the WRSs have been rehabilitated prior to the start of this stage.
- Stage 3 freshwater dam mitigation option, which also includes the structures and waste storage associated with both the fully developed Coronation Stage 5 Pit and Coronation North Pit post closure.

These two models have been used to simulate potential nitrate nitrogen concentrations in Mare Burn following closure of the Coronation North Project, as described in the following sections. The water balance components of the models have not been changed from those documented in the respective reports identified above.

The management of nitrates during the operational period of the Coronation North Project has not been simulated using the catchment water balance models because short to medium term active management options are available to OceanaGold.

4.2.3 Input Nitrate-N Concentrations

Indicative modelling of nitrate-N concentrations in Mare Burn at MB02 has been based on input concentrations presented in Table 7. The derivation of these input concentrations is summarised in Appendix A.

Table 7: Nitrate-N concentrations applied to Mare Burn catchment GoldSim model.

Model version (1)	Undisturbed catchment run-off and groundwater discharges (2)	WRS leachate	Pit lake (3)
Stage 3 (post-closure) unmitigated with 95 % WRS leachate concentration	0.03	17 (4)	0.5
Stage 3 (post closure) with freshwater dam and 95 % WRS leachate concentration	0.03	17 (4)	0.5
Stage 3 (post closure) with freshwater dam and median WRS leachate concentration	0.03	11.4 (5)	0.5

Notes:
1) All concentrations in g/m^3 NO_3-N.
2) Median up-stream total nitrogen concentration from Deepdell Creek used in lieu of adequate nitrate data from Mare Burn.
3) 95th percentile pit lake water quality from January 2009 to 2016 (Figure A2).
4) 95th percentile WRS seepage water quality from January 2009 to 2016 (Figure A1).
5) Median WRS seepage water quality from January 2009 to 2016 (Figure A1).

4.2.4 Nitrate-N modelling results

At this stage mitigation options to geochemically reduce nitrate generation within the WRS have not been identified or tested. The only mitigation option reviewed is the construction of the Coal Creek freshwater dam, with an associated continuous release of 5 L/s from the reservoir.

The model results for different scenarios are summarised as figures within this section of the report. In each case, the nitrate-N exceedance curves are compared to:

- NPS Attribute B 50th percentile concentration of 2.4 g/m^3 NO_3-N.
- NPS Attribute B 95th percentile concentration of 3.5 g/m^3 NO_3-N.

In order for the model outcome, as presented in each of the following figures, to meet the Attribute B requirements from the NPS:

1) The percentage of time indicated for the green 50th percentile line must exceed 50 %, and
2) The percentage of time indicated for the orange 95th percentile line must exceed 95 %.

A conservative simulation of nitrate-N concentrations at the proposed MB02 Mare Burn compliance point, without incorporating the Coal Creek freshwater dam, indicates the stream would not meet the NPS Attribute B criteria for toxicity (Figure 3). Applying the more realistic median WRS leachate nitrate-N concentration of 11.4 g/m^3 also does not generate a result that meets the Attribute B criteria.

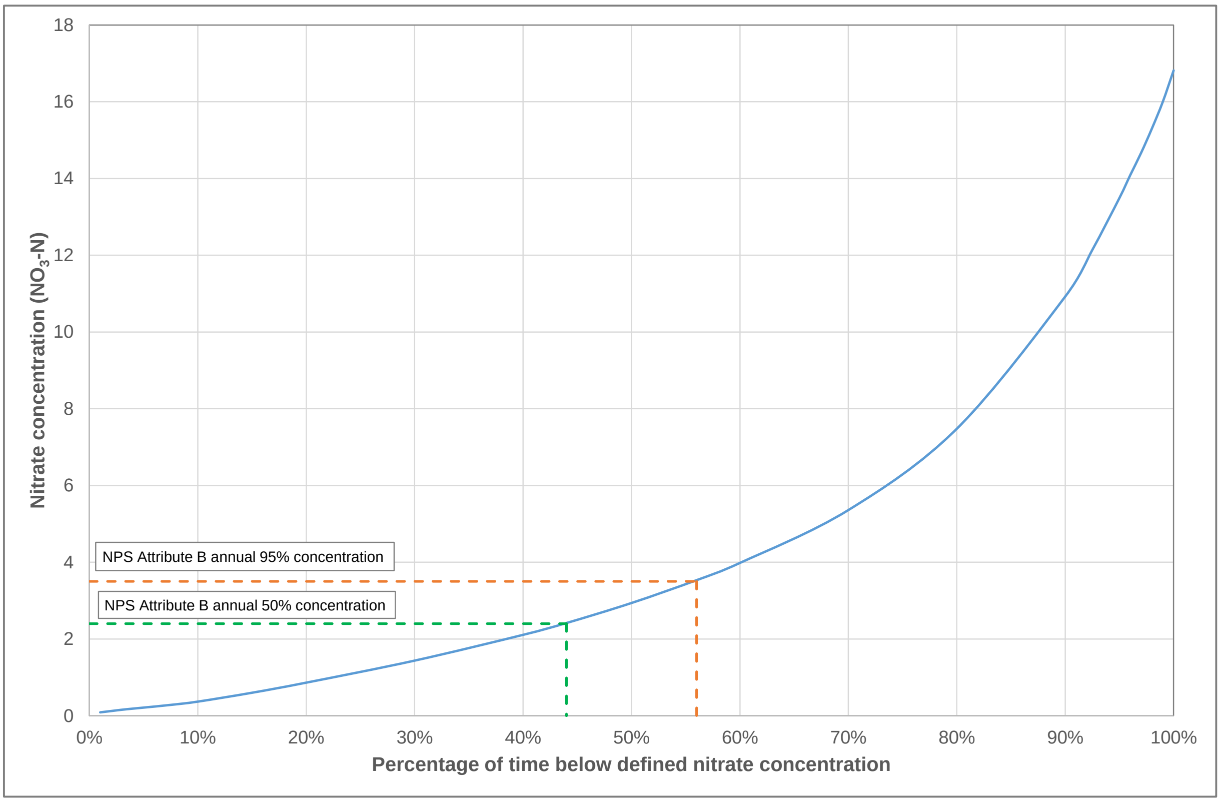


Figure 3: Nitrate-N unmitigated exceedance frequency based on WRS leachate 95 % concentration of 17 g/m^3.

The results of the simulation applying the 95th percentile nitrate-N concentration for WRS leachate, taking into account the planned installation and operation of the Coal Creek freshwater dam, also indicated the Attribute B criterion would not be achieved Figure 4). This is however an overly conservative simulation as it assumes the nitrate-N concentration in WRS leachate is consistently at the 95th percentile of the concentrations observed to date.

The outcomes from the more realistic simulation incorporating the median nitrate-N concentration for the WRS leachate concentration and the effects of the Coal Creek freshwater dam indicated the NPS Attribute B criteria for nitrate toxicity could be met at MB02 (Figure 5). This outcome is considered to be a reasonable reflection of the likely outcome with respect to nitrate-N concentrations at MB02 from constructing and operating the freshwater dam.

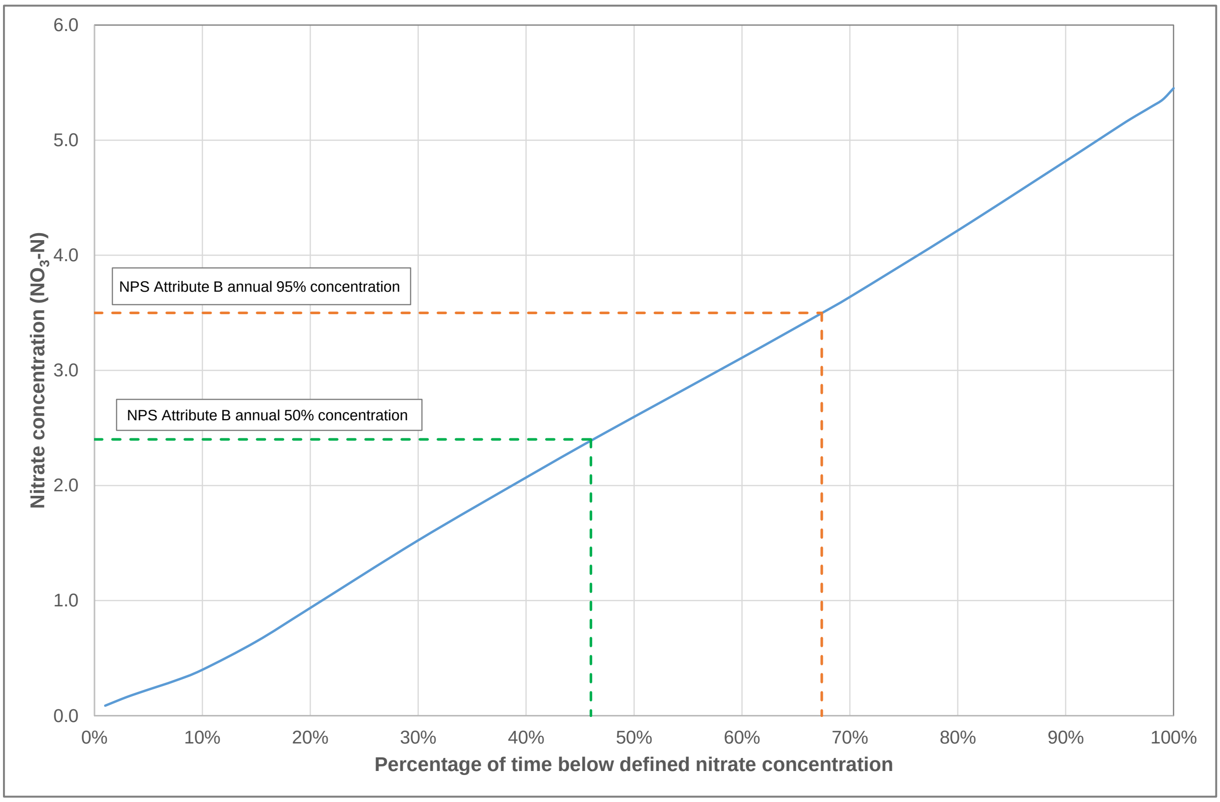


Figure 4: Nitrate-N mitigated exceedance frequency based on 95 % WRS leachate concentration of 17 g/m^3.

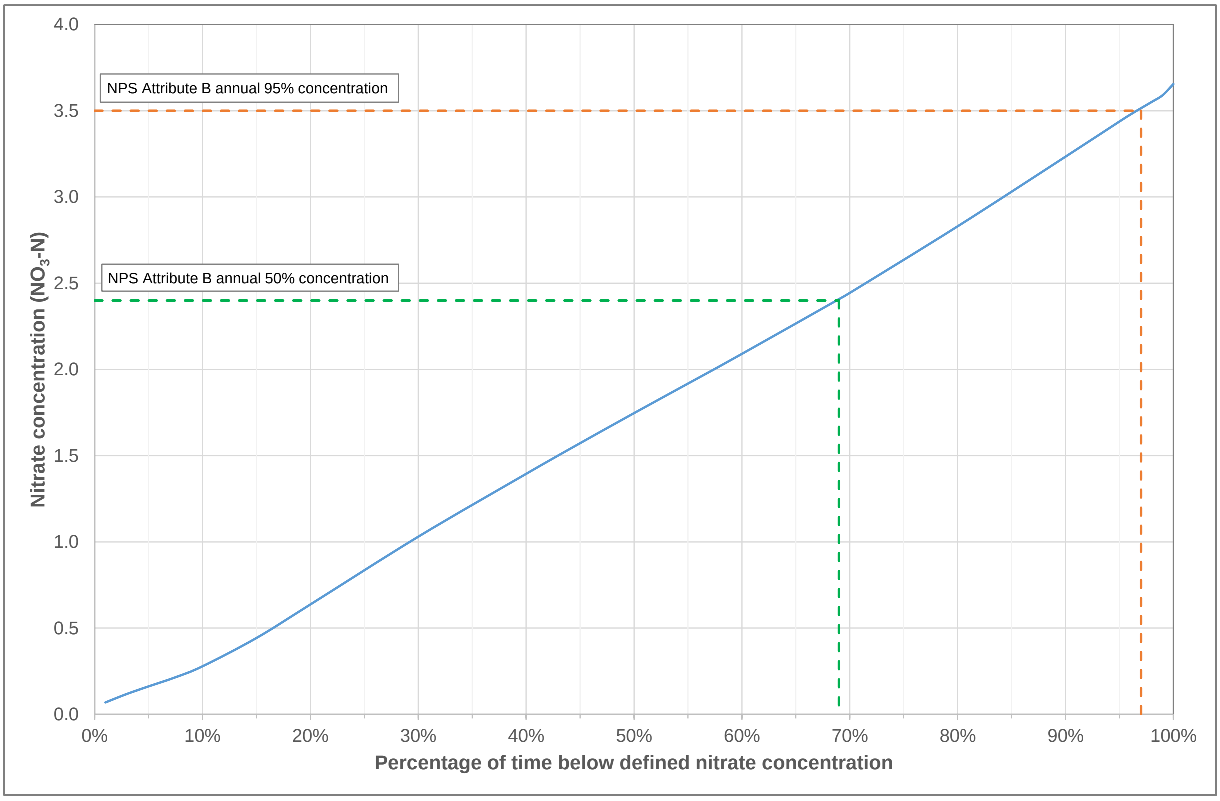


Figure 5: Nitrate-N mitigated exceedance frequency based on median WRS leachate concentration of 11.4 g/m^3.

Other mitigation measures may be required to manage nitrate-N mass loads to Mare Burn for the first three years following construction of the Coronation North WRS. Initially high nitrate levels in the leachate observed at other WRS monitoring points (Appendix A) may be repeated at the Coronation North WRS if explosive residues are the cause. Monitoring of water quality at the site dams in the gullies downstream from Coronation North WRS should be designed to verify if past nitrate-N trends are repeated. If observed concentrations at MB02 start to exceed the Attribute B 95th percentile of 3.5 g/m^3 NO_3-N then further short to medium term mitigation measures could be instigated. These measures include:

- Pumping of the leachate to either Coronation North or Coronation Pits, to be managed together with the pit water.
- Pumping of the leachate to appropriate land irrigation areas.

The ammoniacal-N and nitrate-N concentrations observed in operational pits at the MGP, such as Frasers Pit (Figure 6) and at Coronation North Pit have proven to be highly variable. This variability reflects the explosive residues as the primary source of these contaminants in pit sumps (Appendix A). Due to the elevated concentrations observed in the past, OceanaGold has advised Golder that pit sump water from both Coronation and Coronation North pits will not be discharged to Mare Burn. At this stage investigations are ongoing with respect to several options, including pumping the pit sump water back to the MGP mine water management system or irrigating to land.

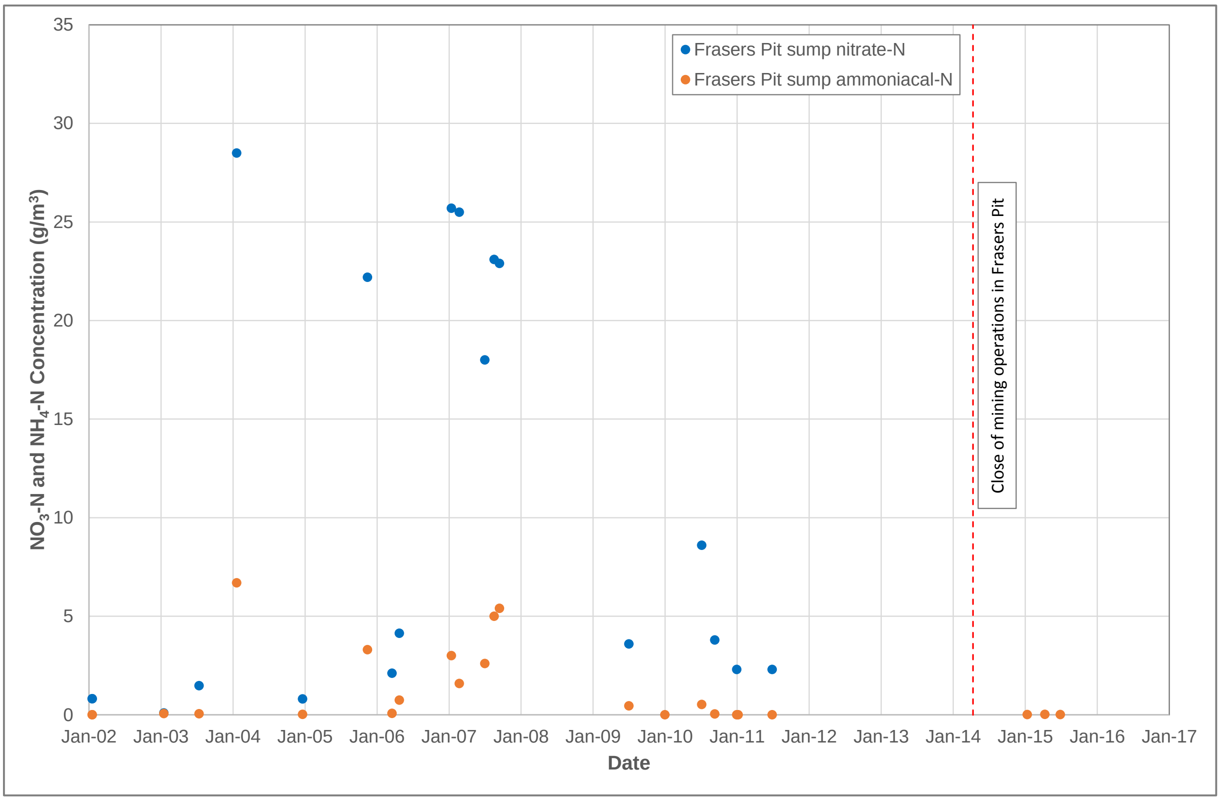


Figure 6: Nitrate-N and ammoniacal-N concentrations in Frasers Pit sump during pit operational period.

4.3 Other Contaminants

During the review of the consent application, the ORC reviewer identified:

- A set of additional water quality parameters outside the existing MGP compliance parameters that are applied in compliance monitoring elsewhere.
- Water quality criteria sources from the Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZECC 2000).

Projective modelling of the potential concentrations of these contaminants for Mare Burn has not been undertaken for reasons including:

- Insufficient or no baseline or mining influenced water quality data.
- Insufficient or no baseline or mining influenced water quality data linked to hardness, for the parameters that have hardness related criteria.
- Insufficient or no data that can be related directly to WRS seepage, which in the case of Mare Burn is the primary area of contaminant concern.

For these reasons a more general review of water quality data available from OceanaGold's environmental database has been undertaken. This review provides an indication as to whether mining influenced water from the MGP would be likely to meet the guideline values identified by the reviewer. The review has focused on water quality monitoring points from the MGP that are considered most relevant to the effects of the Coronation North Project.

The outcomes of the review of water quality data from compliance and baseline monitoring in Deepdell Creek are summarised in Table 8. The outcomes of the review of water quality data from WRS discharges and developing pit lakes at the MGP are summarised in Table 9.

Based on the monitoring data that is available from the MGP, OceanaGold could be expected to meet ecological based guidelines for most of the parameters for which data is available. OceanaGold has no available monitoring data for manganese, silver or nickel. OceanaGold also has no monitoring data available at this stage to support an assessment of the effects of mining on downstream turbidity, suspended solids or dissolved oxygen.

Of the other contaminants reviewed:

- Sulfate remains the primary contaminant of issue requiring management, with documentation related to sulfate management provided elsewhere in this report.
- Arsenic is also identified as a contaminant that may require management. This has been recognised by OceanaGold in the past related to the planning requirements for closure of the MGP, with the focus on water quality in the pit lakes and pit lake discharges following closure. There are however no compliance limits applicable at the MGP for water quality in the pit lakes. OceanaGold's consenting emphasis has been focused on not generating downstream effects off-site as a result of mining related changes to in-stream water quality.

  An assessment of iron and arsenic mobility in surface water at the Coronation North Project (Golder 2016d) has been undertaken. This assessment indicated that natural attenuation downstream from the eventual pit lake overflow points, through precipitation of iron and arsenic compounds or sorption processes, would occur to the extent that both elements would meet the proposed compliance criteria at MB02 without further management. However, in order to avoid arsenic and iron compounds precipitating onto the stream beds downstream from the pit lake overflows, management at the point of overflow is recommended. This can be achieved through passive treatment of the discharge, with a range of options available, including the installation of small wetlands.

Table 8: Comparison of measured data from Deepdell Creek and Mare Burn with potential ecologically relevant guidelines.

Parameter [1]	Existing compliance criteria at MB01	Reviewer identified environmental protection guidelines	DC01 & DC02 [2,3] Deepdell Upstream	DC07 & DC08 [2,3] Deepdell Downstream	Mare Burn MB01 & MB02 [2,3]
pH (unitless)	6.0 – 9.5	6.5 – 9.0	6.5 – 8.47	7.0 – 8.81	7.2 – 8.1
Dissolved copper	0.009	0.0014	<0.0005 – 0.002	<0.0005 – 0.0031	<0.0005 – 0.0016
Dissolved zinc	0.12	0.008	ND	<0.001 – 0.006	<0.001 – 0.0011
Dissolved nickel		0.011	ND	ND	ND
Dissolved lead	0.0025	0.0034	<0.0001 – 0.001	<0.0001 – 0.00178	<0.0001 – 0.00181
Dissolved silver		0.00005	ND	ND	ND
Arsenic	0.15	0.013, 0.024	<0.001 – 0.005	0.0015 – 0.03 [4]	<0.001 – 0.0082
Iron	1	1	0.08 – 0.58	0.02 – 0.38	0.2 – 0.84
Manganese		0.5	ND	ND	ND
Cyanide	0.1	0.007	NA	NA	NA [5]
Sulphate	1,000	128 (429)	1.3 – 29	9.9 – 1,020	1.3 – 78
Dissolved oxygen	~-	>7.0 (>5.0)	ND	ND	ND
Nitrate		2.4 (3.5) [6]	Refer Section 4.1 and Appendix A.		
Ammonia		0.24 (0.40) [6]	Refer Section 4.1 and Appendix A.		
Turbidity		30 % – 50 % change in clarity	ND	ND	ND
Suspended solids		30 % – 50 % change in clarity	ND	ND	ND

Notes:
1) All units in g/m^3 except pH. Number of samples analysed varies with site and parameter.
2) Colour definitions. Compared to potential ecological protection criteria indicated by reviewer. Green = meets criterion; Blue = likely meets criterion but hardness dependent; Orange = possibly meets criterion but hardness dependent; Grey = contaminant probably not sourced from MGP operations; Red = does not meet criterion.
3) ND = no data; NA = not applicable as no cyanide or cyanide bearing wastes are being used or stored in Mare Burn catchment.
4) Only two samples out of 67 obtained since start of 2005 exceeded 0.024 g/m^3. Downstream arsenic concentrations have not increased since the start of MGP operations in 1990.
5) Anomalous CN was detected in catchment during mining but traced by OceanaGold to pipeline section from process plant being used for water management at Coronation Pit.
6) Attribute B criteria from NPS (MfE 2014). First value is the median criterion and the value in brackets is the 95th percentile criterion.

Table 9: Comparison of measured data from silt dams below WRS discharges and in existing pit lakes at site with potential ecologically relevant guidelines.

Parameter [1]	Existing compliance criteria at MB01	Reviewer identified environmental protection guidelines	WRS discharges [2,3]	Golden Bar pit lake [2,3]	Deepdell South pit lake [2,3]
pH (unitless)	6.0 – 9.5	6.5 – 9.0	6.4 – 8.64	7.0 – 8.41	7.8 – 8.45
Dissolved copper	0.009	0.0014	<0.001 – 0.004 [4]	<0.0005 – 0.059 [4,5]	<0.0005 – 0.001
Dissolved zinc	0.12	0.008	<0.005 – 0.04	0.002 – 0.0093	0.0012 – 0.0038
Dissolved nickel		0.011	<0.005 – <0.01	ND	ND
Dissolved lead	0.0025	0.0034	<0.0001 – 0.00031 [4]	<0.0001 – 0.0042 [4,6]	<0.0001 – 0.00012
Dissolved silver		0.00005	ND	ND	ND
Arsenic	0.15	0.013, 0.024	<0.005 – 0.024 [4]	0.01 – 0.599	0.128 – 0.497
Iron	1	1	<0.04 – 0.39	<0.02 – 0.58	<0.02 – 0.16
Manganese		0.5	ND	ND	ND
Cyanide	0.1	0.007	NA	NA	NA
Sulphate	1,000	128 (429)	Up to 2,900	50 – 320 [7]	43.7 – 410
Dissolved oxygen	~-	>7.0 (>5.0)	ND	ND	ND
Nitrate (NO_2-N)		<2.4 (<3.5)	Refer Section 4.1 and Appendix A.		
Ammonia (NH_4-N)		<0.24 (<0.40)	Refer Section 4.1 and Appendix A.		
Turbidity		30 % – 50 % change in clarity	ND	ND	ND
Suspended solids		30 % – 50 % change in clarity	ND	ND	ND

Notes:
1) All units in g/m^3 except pH. Number of samples analysed varies with site and parameter.
2) Colour definitions. Compared to potential ecological protection criteria indicated by reviewer. Green = meets criterion; Blue = likely meets criterion but hardness dependent; Orange = possibly meets criterion but hardness dependent; Red = does not meet criterion.
3) ND = no data; NA = not applicable as no cyanide or cyanide bearing wastes are being used or stored in Mare Burn catchment.
4) High end of range defined as 95th percentile to exclude individual anomalous results.
5) 95th percentile still strongly influenced by one high value of 0.074 g/m^3. Would otherwise be 0.012 g/m^3?
6) 95th percentile still strongly influenced by one high value of 0.005 g/m^3. Would otherwise be 0.001 g/m^3?
7) Single highly anomalous value of 2,100 g/m^3 removed from dataset.

- It is likely dissolved copper and zinc would generally meet the suggested guideline values. Any dilution provided if the Coal Creek freshwater dam was constructed, and the proposed dilution water made available at MB02, would reduce the risk of exceedance during periods of no natural flow in Mare Burn and increase the margin for compliance. The water quality in the pit lakes, at the WRS discharge monitoring points and in Deepdell Creek is already close to meeting the guidelines for these metals without taking into account the proposed mitigation measures for the Coronation North Project.

OceanaGold is planning to instigate targeted monitoring programs for dissolved oxygen, turbidity and suspended solids to provide data to support an improved assessment of the environmental performance of the MGP with respect to these parameters (D Clarke, pers comm). For each of these parameters there are also well known and commonly applied engineered measures that can be used to manage water quality at the proposed MB02 compliance point if required. These measures include the use of silt ponds, constructed wetlands and passive aeration systems.

5.0 CONCLUSIONS

There are two primary water quality parameters identified in this report that would require mitigation measures to be instigated in order to enable OceanaGold to meet either the proposed compliance criteria at MB02 or NPS Attribute B guideline values. These parameters are sulfate and nitrate-N.

If the proposed Coal Creek freshwater dam is constructed and operated to release a continuous flow of 5 L/s:

- The modelled concentrations for sulfate do not exceed the proposed compliance limit of 1,000 g/m^3.
- The modelled water quality at MB02 would comply with the Attribute B guidelines for nitrate-N as summarised in Table 6.

Secondary water quality mitigation measures will be required to ensure that the water discharging from the Coal Creek freshwater dam is adequately oxygenated and carries only low concentrations of reduced form metal compounds and ammonium. These measures can be addressed through the construction of an engineered passive water treatment system in the Coal Creek gully immediately downstream from the proposed dam.

The application of additional water quality management and mitigation measures is being investigated by OceanaGold. Combining a selection of additional measures into a catchment contaminant management plan should enable the eventual size of the proposed Coal Creek dam and reservoir to be reduced, while still enabling OceanaGold to comply with the water quality criteria proposed for downstream compliance point MB02.

6.0 LIMITATIONS

Your attention is drawn to the document, “Report Limitations”, as attached in Appendix B. The statements presented in that document are intended to advise you of what your realistic expectations of this report should be, and to present you with recommendations on how to minimise the risks to which this report relates which are associated with this project. The document is not intended to exclude or otherwise limit the obligations necessarily imposed by law on Golder Associates (NZ) Limited, but rather to ensure that all parties who may rely on this report are aware of the responsibilities each assumes in so doing.

7.0 REFERENCES

Bailey B, Smith L J D, Blowes D, Ptacek C, Smith L, Sego D 2013. The Diavik waste rock project: persistence of contaminants from blasting agents in waste rock effluent. Applied Geochemistry 36: 256-270.

Brochu S 2010. Assessment of ANFO on the environment. Defence R&D Canada – Valcartier Technical Memorandum 2009-195.

Davies-Colley RJ 1988. Mixing depths in New Zealand lakes. New Zealand Journal for Freshwater Research 22 (4) 517-528.

EGL 2016. Oceana Gold (New Zealand) Ltd, Macraes Gold Project, Coronation North Project, Coal Creek Freshwater Dam, technical report. Report prepared for OceanaGold (New Zealand) Ltd by Engineering Geology Limited. EGL report reference 8122.

Golder 2011a. Macraes Phase III Project. Water management summary report. Report prepared for Oceana Gold (New Zealand) Ltd by Golder Associates (NZ) Limited, 0978110562-002.

Golder 2011b. Macraes Phase III Project. Water quality effects mitigation options. Report prepared for Oceana Gold (New Zealand) Ltd by Golder Associates (NZ) Limited. 0978110562-009.

Golder 2016a. Coronation North Project. Groundwater assessment. Report prepared for Oceana Gold (New Zealand) Ltd by Golder Associates (NZ) Limited. Golder report number 1545831-002.

Golder 2016b. Coronation North Project. Surface water modelling. Report prepared for Oceana Gold (New Zealand) Ltd by Golder Associates (NZ) Limited. Golder report number 1545831-003.

Golder 2016c. Coronation North Project. Water quality mitigation – freshwater dam scenario. Report prepared for Oceana Gold (New Zealand) Ltd by Golder Associates (NZ) Limited. Golder report number 1545831-004.

Golder 2016d. Arsenic and iron mobility in Coronation North Project surface water. Letter to Jackie St John, Oceana Gold (New Zealand) Ltd from Golder Associates (NZ) Limited. 23 May 2016. Golder reference number 1545831_7410-005.

Holloway J M, Dahlgren RA 1999. Geologic nitrogen in terrestrial biogeochemical cycling. Geology 27 (6) 567–570.

Holloway J M, Dahlgren RA 2002. Nitrogen in rock: occurrences and biogeochemical implications. Global Biogeochemical Cycles 16 (4) 65-1 – 65-17.

INAP 2003. Treatment of sulphate in mine effluents. Report produced by the International Network for Acid Prevention. October 2003.

Magesan G N, Wang H, Clinton PW 2012. Nitrogen cycling in gorse-dominated ecosystems in New Zealand. New Zealand Journal of Ecology 36 (1) 21-28.

Morin K, Hutt N 2009. Mine-water leaching of nitrogen species from explosive residues. Proceedings of GeoHalifax 2009. The 62nd Canadian Geotechnical Conference and 10th Joint CGS/IAH-CNC Groundwater Conference, Halifax, Nova Scotia, Canada. September 20-24. pp 1549-1553.

OceanaGold 2016. Coronation North Project application for resource consents and assessment of environmental effects.

O’Kane 2016. Coronation North waste rock dump design considerations. Draft report prepared for Oceana Gold (New Zealand) Ltd by O'Kane Consultants (NZ) Ltd. O’Kane reference number 913-14-1.

Pitcairn I K, Teagle D A H, Kerrich R, Craw D, Brewer TS 2005. The behaviour of nitrogen and nitrogen isotopes during metamorphism and mineralization: Evidence from the Otago and Alpine Schists, New Zealand. Earth and Planetary Science Letters 233: 229–246.

APPENDIX A

MGP Nitrate Leaching Data

1.0 BACKGROUND

1.1 Potential Nitrogen Sources

Review of the operations and rehabilitation practices at the MGP indicates there are four potential sources of nitrogen to mine water at the site. These sources are:

- Residues from the use of ammonium nitrate explosives.
- The use of fertiliser for rehabilitation purposes.
- The weathering of freshly exposed rock.
- Nitrogen fixed in the soils through plant growth.

Of the above potential sources, introductory information on the first three sources is provided in following sections. This does not, however, imply that nitrogen fixation to soils followed by leaching from the soils is not occurring at the site.

1.2 Ammonium Nitrate Explosive Residues

One of the primary constituents of the explosives used at the MGP, and at mine sites worldwide, is ammonium nitrate. Under ideal blast conditions, the ammonium nitrate from the explosives would be fully converted to reaction gases, principally consisting of CO_2, N_2 and H_2O. Most detonations do not however occur under ideal conditions (Brochu 2010). Explosives are one of the main sources of nitrogen emissions in the mining industry (Morin & Hutt 2009).

International research has shown that ammonium nitrate explosives often fail to ignite or burn completely in shot holes. Ammonium nitrate is highly soluble in water, rapidly dissociating into NO_3^- and ammonium ($NH4^+$). The concentration of explosive-derived ammoniacal-nitrogen (NH_4-N) and nitrate-nitrogen (NO_3-N) in mine water varies widely from site to site. In addition, estimates for the percentage loss of nitrogen from explosives to groundwater also varies greatly from site to site (Brochu 2010).

Following a blast the concentrations of both NO_3-N and NH_4-N in pit sump water can be expected to increase substantially over the short term. As the residue leaching process in a wet environment, as is found beneath the floor of an opencast pit, is rapid, the concentrations of both NO_3-N and NH_4-N decrease again as water from the pit sump is pumped away. Concentrations in the remaining water decrease as:

- The NH_4-N becomes oxidised to NO_3-N.
- Both become diluted through inflows of fresh groundwater and surface water run-off.

Blasting occurs frequently throughout the life of a mine. The concentrations of both NO_3-N and NH_4-N in mine water pumped from an opencast mine can therefore be expected to vary greatly over time. Following closure of the mine, and development of a pit lake, oxidation and dilution processes generally lead to substantial decreases in pit lake nitrate concentrations. Following the close and rehabilitation of a WRS, the concentrations of both NO_3-N and NH_4-N derived from explosives residues tend to decrease within periods of months (Bailey et al 2013) to a few years as there is no renewal of the source.

1.3 Fertiliser use

Nitrogenous fertilisers are used at the MGP in very limited amounts to support the site rehabilitation program. These fertilisers are only applied in small amounts immediately following the initial seeding of capped WRS areas. Subsequent fertiliser use is limited to superphosphates and lime (D. Clarke, OceanaGold, pers comm). On this basis Golder does not expect nitrogenous fertilisers to contribute significantly to NO_3-N discharges in WRS leachate water. Although there are some rehabilitated areas within the run-off catchments of Golden Bar Pit, these do not appear to have contributed detectably to nitrate concentrations in the pit lake.

1.4 Waste Rock Weathering

Schists of the Otago Region contain low but potentially significant concentrations of nitrogen, primarily associated with ammonium bound up in the micas within the rock mass. Limited sampling from the Macraes Flat area suggests the schist in this area is enriched in nitrogen compared to schist from the wider Otago region (Pitcairn et al 2005). Concentrations of up to 1,350 g/t have been detected in rocks from Macraes Flat.

Micas weather relatively rapidly compared to other minerals in the schist rock mass. This process would lead to the release of ammonium, followed by its oxidation to nitrate. Compared to the release of nitrates from explosives residues or fertilisers, the initial rate of release from the rock mass would be expected to be slow. Over time however the NO_3-N contribution from weathering of schist at the scale of the WRS areas at the MGP could potentially become significant.

2.0 PIT LAKES

Monitoring of NO_3-N and NH_4-N has been undertaken in the Frasers Pit sump water since 2002 (Figure A1). Mining operations in the pit ceased in 2014. The concentrations recorded prior to that date are indicative of concentrations to be expected in water from any sump in an operational pit at the MGP. On that basis concentrations of NO_3-N exceeding 20 g/m^3 are expected to occur in sump water discharges from the Coronation North and Coronation Pit Stage 5 sumps. Similarly, concentrations of NH_4-N are also expected to occur in the water in both of these pit sumps. Following the closure of Frasers Pit, insufficient sampling and analysis for NO_3-N and NH_4-N has been undertaken to provide definitive information on the water quality trends.

Monitoring of water quality in the Deepdell South and Golden Bar pit lakes has been undertaken since 2004. Following the close of mining and dewatering operations in these pits in 2004, nitrate concentrations decreased substantially (Figure A2). This change is most clearly seen in the data from Golden Bar pit lake, where NO_3-N concentrations decreased by approximately three orders of magnitude over a period of nine years. The initial decrease in the NO_3-N concentrations in Deepdell South pit lake was more rapid, with a change of over two orders of magnitude being recorded during a three year period.

For long term modelling of NO_3-N concentrations in the Mare Burn catchment, a pit lake water concentration of 0.5 g/m^3 has been applied. This is the 95th percentile concentration derived from the combined data from Deepdell South and Golden Bar pit lakes for the period from January 2009 to July 2016. Based on the water quality trend observed in the Golden Bar pit lake data, this estimate for NO_3-N concentrations in the future Coronation and Coronation North pit lakes may be conservatively high by between one and two orders of magnitude (Figure A2). The total flows from the Coronation and Coronation North pit lakes to Mare Burn following their eventual overflows are however small compared to other water sources. As such, the use of a conservative concentration applied to the pit lake water does not have a major influence on the outcomes of the modelling documented in the body of this report.

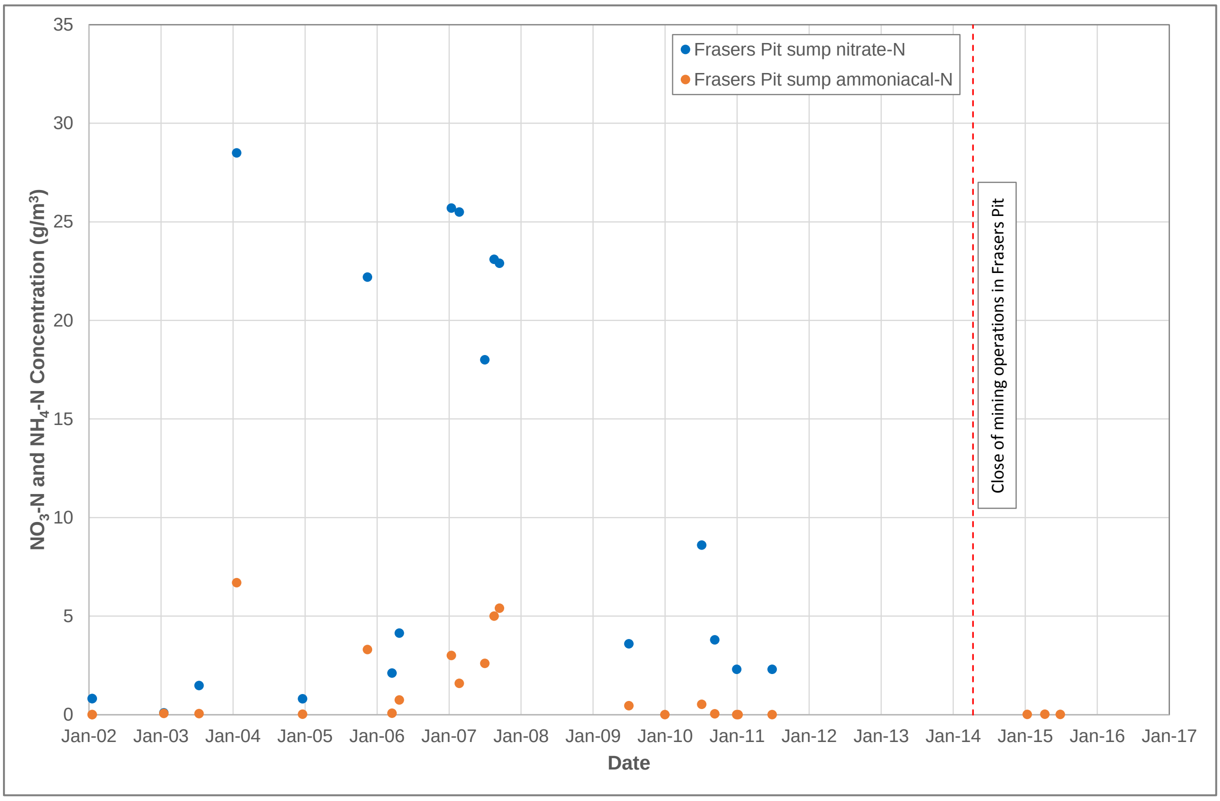


Figure A1: Frasers Pit sump nitrate-N and ammoniacal-N concentrations.

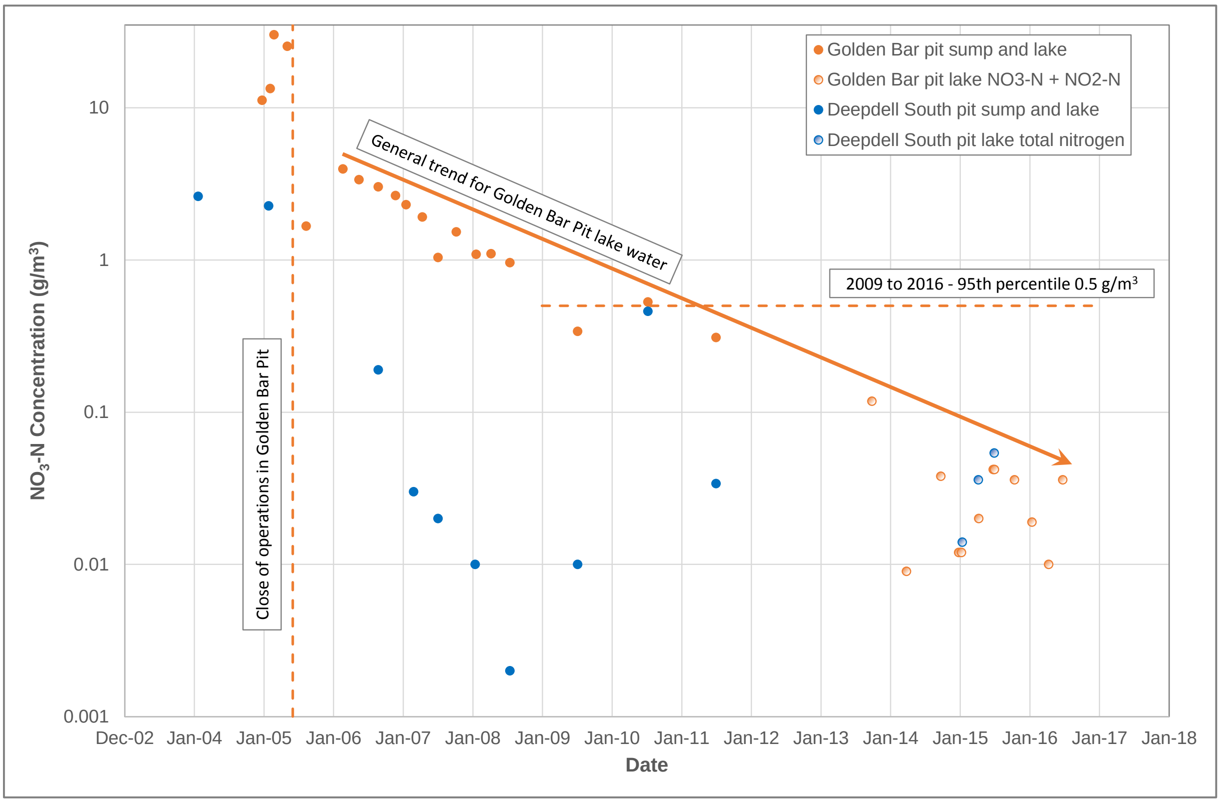


Figure A2: Golden Bar and Deepdell South pit lakes nitrate concentrations.

3.0 WRS LEACHATE

WRS seepage discharge points at the MGP have been monitored for NH_4-N and NO_3-N since 2000. During that time the general trend in NH_4-N concentrations detected has been downward, although a set of anomalous results were recorded in April 2015 (Figure A3). Many of the samples analysed have also returned results below the laboratory detection limit of 0,01 g/m^3 although they have been represented at that concentration in Figure A3.

As described in Section 1.2, the leaching of NH_4-N from explosives residues should decrease over time, which appears to be reflected in the overall trend represented in Figure A3. Some areas within each WRS are however characterised by reducing geochemical conditions. The leaching of nitrogen from the rock mass and its transport in seepage through a WRS is therefore likely to continue to generate detectable concentrations of NH_4-N at the discharge points into the future. As ammonium rapidly converts to nitrate on exposure to oxygen in the silt ponds and in stream beds immediately downstream from the discharge points, the downstream concentrations of NH_4-N derived from Coronation North WRS are likely to be close to or below the detection limit.

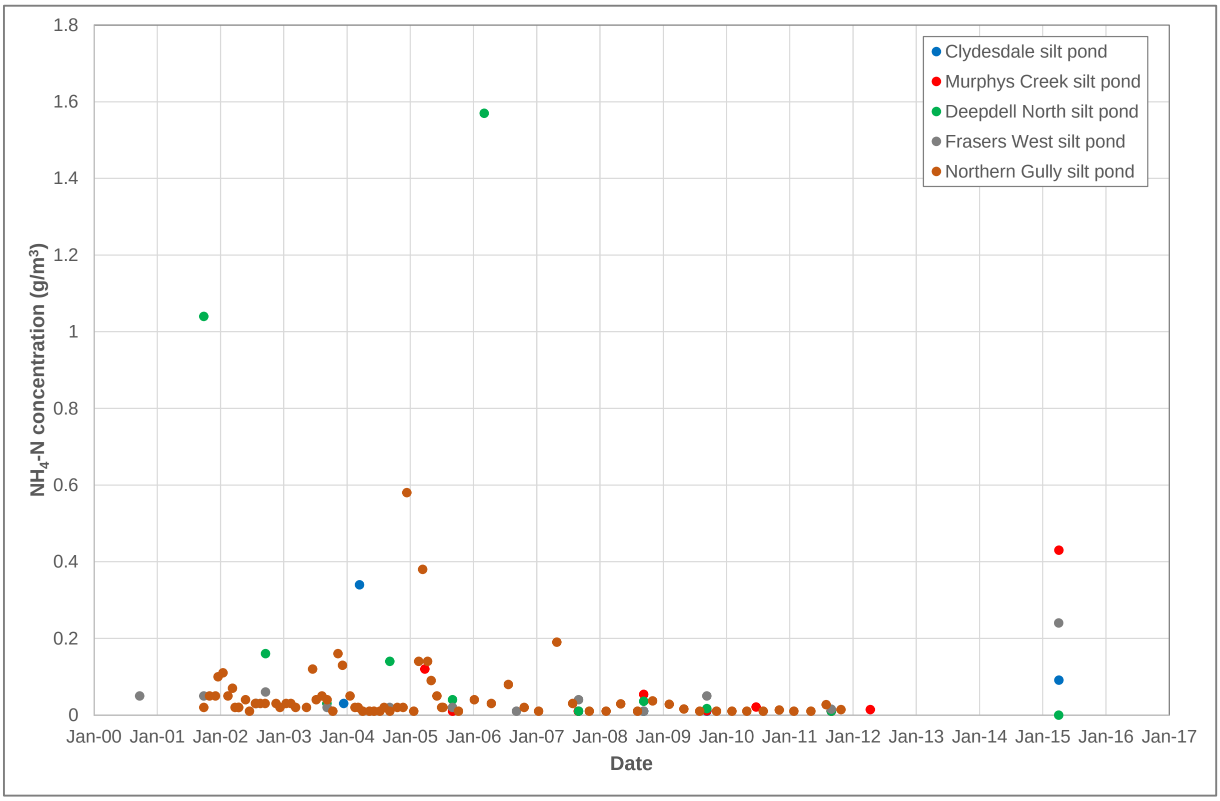


Figure A3: Waste rock stack seepage NH_4-N concentrations.

Nitrate concentrations measured in leachate water from five WRSs at the MGP are summarised in Figure A4. Detailed investigations of the sources of the nitrate in the seepage water have not been undertaken to date. The interpretation of the data trends presented in Figure A4 is therefore preliminary at this stage.

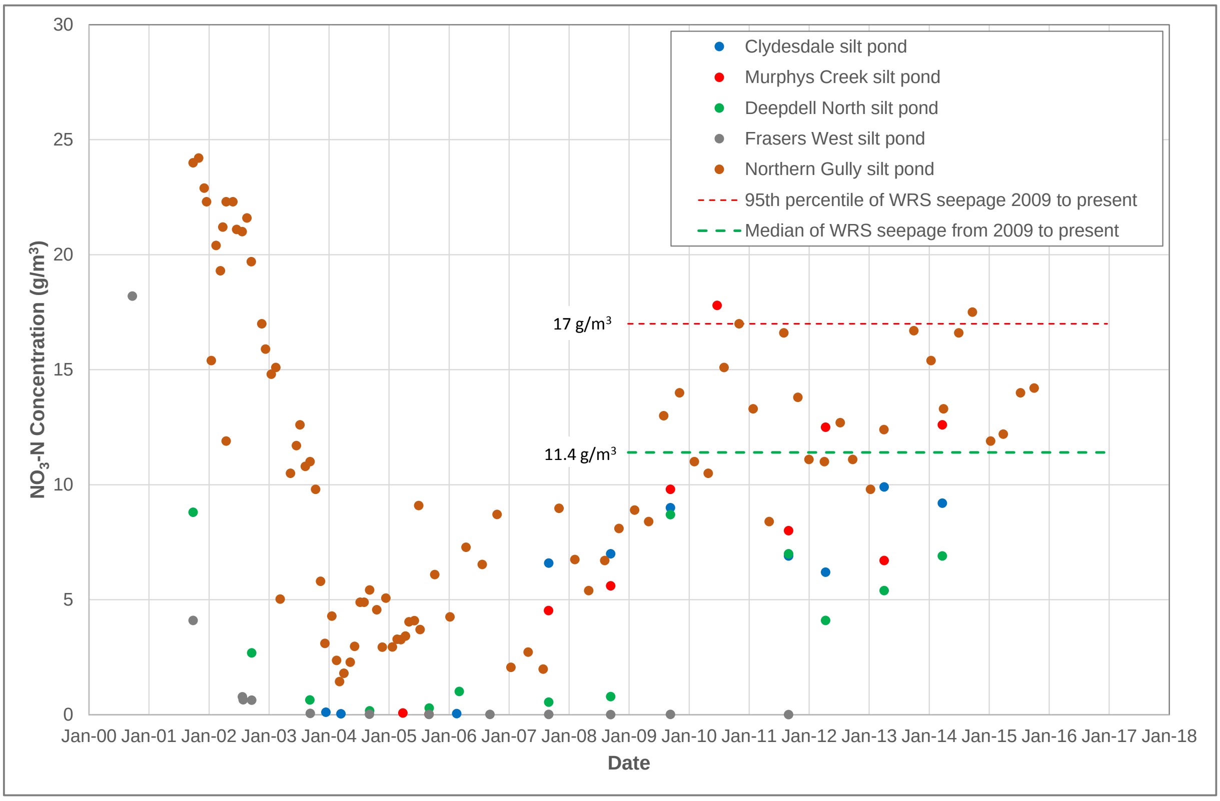


Figure A4: Waste rock stack seepage NO_3-N concentrations.

Prior to 2004, NO_3-N concentrations in the three WRS areas being monitored at that time were decreasing rapidly. This decrease is interpreted to reflect the removal of explosive residues from each WRS through leaching. It would be expected that leachate discharging from the Coronation North WRS is likely to be in the 20 g/m^3 to 30 g/m^3 range at and immediately following close of waste storage operations. This range also reflects the water quality in the pit sump water presented in Figure A1. Provided Coronation North WRS follows the trends identified in the other WRS areas on site, the NO_3-N concentrations could be expected to decrease below 5 g/m^3 within approximately 3 years.

The subsequent increase in NO_3-N concentrations observed at each of the WRS discharge monitoring points after 2005 cannot be clearly explained through the leaching patterns of explosive residues, or the use of fertilisers for rehabilitation purposes by OceanaGold. It also seems unlikely that nitrate fixation in the rehabilitated soil horizon capping the WRS, followed by leaching of this nitrate, would generate concentrations in the discharge water at the levels observed. As described in Section 1.4, the leaching of ammonium through weathering of micas in the freshly exposed surfaces of the rock wastes, followed by the oxidation to nitrate, could potentially explain this trend. Examples have been documented of soils enriched in nitrogen derived from the weathering of nitrogen rich parent rocks (Holloway & Dahlgren 1999) and acidification of soils due to the release of ammonium from underlying parent schists (Holloway & Dahlgren 2002).

Modelling of the potential nitrate concentrations in Mare Burn at MB02 has been based on two leachate water quality scenarios:

1) A conservative scenario where the 95th percentile of the accumulated NO_3-N data from January 2009 onward, 17 g/m^3, is applied to WRS seepage.

2) A more realistic scenario where the mean NO_3-N concentration from the same period, 11.4 g/m^3, is applied to WRS seepage.

The use of the 95th percentile for simulating nitrate concentrations in Mare Burn at MB02 is expected to be overly conservative for three reasons:

1) The water balance model provides for a statistical outcome based on rainfall and run-off patterns. Applying the 95th percentile concentration results in a reasonable interpretation of the overall range of concentrations but significantly overestimates the percentile concentrations.

2) The NO^3-N concentrations measured in leachate from the Northern Gully WRS since 2010 show seasonal variation as well as varying between years. The summer concentrations have consistently been 2 g/m^3 to 3 g/m^3 NO_3-N less than the winter and spring concentrations. There is insufficient data from the other WRS monitoring points to confirm this trend applies universally at the MGP.

3) The concentrations measured in the Northern Gully silt pond, which collects water from the Northern Gully WRS, have also been consistently higher than the concentrations measured in the water derived from other WRS silt ponds.

4.0 SUMMARY

In modelling of nitrate loads and concentrations in the Mare Burn derived from the Coronation North Project, the following input parameters have been applied, as described in this appendix:

1) A conservatively high NO_3-N concentration for pit lake water following overflow of 0.5 g/m^3.

4) A conservative scenario for WRS seepage where the 95th percentile of the accumulated NO_3-N data from January 2009 onward, 17 g/m^3, is applied to WRS seepage.

5) A more realistic scenario for WRS seepage where the mean NO_3-N concentration from the same period, 11.4 g/m^3, is applied to WRS seepage.

APPENDIX B

Report Limitations

Report Limitations

This Report/Document has been provided by Golder Associates (NZ) Limited ("Golder") subject to the following limitations:

i) This Report/Document has been prepared for the particular purpose outlined in Golder's proposal and no responsibility is accepted for the use of this Report/Document, in whole or in part, in other contexts or for any other purpose.

ii) The scope and the period of Golder's Services are as described in Golder's proposal, and are subject to restrictions and limitations. Golder did not perform a complete assessment of all possible conditions or circumstances that may exist at the site referenced in the Report/Document. If a service is not expressly indicated, do not assume it has been provided. If a matter is not addressed, do not assume that any determination has been made by Golder in regards to it.

iii) Conditions may exist which were undetectable given the limited nature of the enquiry Golder was retained to undertake with respect to the site. Variations in conditions may occur between investigatory locations, and there may be special conditions pertaining to the site which have not been revealed by the investigation and which have not therefore been taken into account in the Report/Document. Accordingly, if information in addition to that contained in this report is sought, additional studies and actions may be required.

iv) The passage of time affects the information and assessment provided in this Report/Document. Golder's opinions are based upon information that existed at the time of the production of the Report/Document. The Services provided allowed Golder to form no more than an opinion of the actual conditions of the site at the time the site was visited and cannot be used to assess the effect of any subsequent changes in the quality of the site, or its surroundings, or any laws or regulations.

v) Any assessments, designs and advice made in this Report/Document are based on the conditions indicated from published sources and the investigation described. No warranty is included, either express or implied, that the actual conditions will conform exactly to the assessments contained in this Report/Document.

vi) Where data supplied by the client or other external sources, including previous site investigation data, have been used, it has been assumed that the information is correct unless otherwise stated. No responsibility is accepted by Golder for incomplete or inaccurate data supplied by others.

vii) The Client acknowledges that Golder may have retained subconsultants affiliated with Golder to provide Services for the benefit of Golder. Golder will be fully responsible to the Client for the Services and work done by all of its subconsultants and subcontractors. The Client agrees that it will only assert claims against and seek to recover losses, damages or other liabilities from Golder and not Golder's affiliated companies. To the maximum extent allowed by law, the Client acknowledges and agrees it will not have any legal recourse, and waives any expense, loss, claim, demand, or cause of action, against Golder's affiliated companies, and their employees, officers and directors.

viii) This Report/Document is provided for sole use by the Client and is confidential to it. No responsibility whatsoever for the contents of this Report/Document will be accepted to any person other than the Client. Any use which a third party makes of this Report/Document, or any reliance on or decisions to be made based on it, is the responsibility of such third parties. Golder accepts no responsibility for damages, if any, suffered by any third party as a result of decisions made or actions based on this Report/Document.

At Golder Associates we strive to be the most respected global company providing consulting, design, and construction services in earth, environment, and related areas of energy. Employee owned since our formation in 1960, our focus, unique culture and operating environment offer opportunities and the freedom to excel, which attracts the leading specialists in our fields. Golder professionals take the time to build an understanding of client needs and of the specific environments in which they operate. We continue to expand our technical capabilities and have experienced steady growth with employees who operate from offices located throughout Africa, Asia, Australasia, Europe, North America, and South America.

Africa	+ 27 11 254 4800
Asia	+ 86 21 6258 5522
Australia & NZ	+ 61 3 8862 3500
Europe	+ 356 21 42 30 20
North America	+ 1 800 275 3281
South America	+ 55 21 3095 9500

solutions@golder.com
www.golder.com

AUCKLAND

Tel +64 9 486 8068
Fax +64 9 486 8072

Level 2
Nielsen Centre
129 Hurstmere Road
Takapuna
Auckland 0622

PO Box 33-849
Takapuna 0740

WELLINGTON

Tel +64 3 377 5696

Level 1
93 The Terrace
Wellington 6011

PO Box 5234
Wellington 6145

HAMILTON

Tel +64 7 859 2356
Fax +64 9 486 8072

Room 31 in the Homestead
Ruakura Research Centre
10 Bisley Road
Hamilton 3214

PO Box 19-479
Hamilton 3244

NELSON

Tel +64 3 548 1707
Fax +64 3 548 1727

Level 3
295 Trafalgar Street
Nelson 7010

PO Box 1724
Nelson 7040

CHRISTCHURCH

Tel +64 3 377 5696
Fax +64 3 377 9944

Level 1
214 Durham Street
Christchurch 8011

PO Box 2281
Christchurch 8140

DUNEDIN

Tel +64 3 479 0390
Fax +64 3 474 9642

Level 7B
John Wickliffe House
265 Princes Street
Dunedin 9016

PO Box 1087
Dunedin 9054

Golder Associates