April 2011

MACRAES PHASE III PROJECT

Site Wide Surface Water Model

Submitted to:
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REPORT

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Executive Summary

Oceana Gold (New Zealand) Limited (OceanaGold) is proposing to undertake a substantial expansion to the Macraes Gold project, including the storage of tailings and waste rock in areas previously not influenced by the mining operation. This expansion is termed the Macraes Phase III Project. OceanaGold is seeking to obtain resource consents authorising the operations which form the Macraes Phase III.

Macraes Phase III Project

The main features of the Macraes Phase III project are:

- A new tailings storage facility, labelled the Top Tipperary Tailings Storage Facility, which is to be constructed in the upper Tipperary Creek catchment.
- Reclamation of tailings from within the current Southern Pit 11 Impoundment. The tailings are to be relocated to stacks within the footprints of the existing Mixed Tailings Impoundment. Any overflow from the stacks within the Mixed Tailings Impoundment will be incorporated into the dam impoundment of the new Top Tipperary Tailings Storage Facility.
- A new waste rock stack and extensions to existing waste rock stacks are to be constructed, increasing the total consented tonnage from 850 Mt to 1,180 Mt. A new waste rock stack is planned, substantially extending the existing Back Road Waste Rock Stack, to the east of the Round Hill/Southern Pit locations. Frasers East and Frasers West WRS are to be expanded and a new linking WRS between these two, called Frasers South Waste Rock Stack, is to be constructed.
- Expansion of existing pits to include the Frasers Stage VI, Round Hill Southern Pit Extension and Innes Mills Stage V.
- Diversions and new silt control dams to manage surface water run-off from the expanded mining infrastructure.
- A revised closure plan, comprising two lakes formed within the opencast pit excavations.

The ore processing rate is to be similar to current operations and the intensity of operations on site would be similar to present.

Environmental monitoring records from the Macraes Gold Project indicate a very high degree of compliance with resource consent water quality conditions at the site. During the operational phase of the mine, discharges from the tailings storage facility drainage systems are pumped back to the process water system for reuse. This water recovery process reduces the requirement for make-up water from the Taieri River and minimises water loss to the surrounding environment.

Construction of the Macraes Phase III Project would require an extension of the environmental compliance monitoring program. The proposed compliance monitoring regime includes:

- New compliance monitoring points downstream from the Back Road WRS (DC08) and the Top Tipperary Tailings Storage Facility (TC01, CJ01 and the Shag at McCormicks).
- Removal of unnecessary compliance monitoring points on Deepdell Creek (DC07) and the North Branch Waikouaiti River (NBWR).
- Shifting of one compliance monitoring point on Murphys Creek (MC100 to MC01).

The water quality compliance limits are proposed to be standardised across the site. No water quality parameters have been removed from the list of compliance parameters, however at some sites new parameters have been added as part of the standardisation.

As part of the environmental assessment of the Macraes Phase III Project, a mine water management model has been constructed to simulate dissolved contaminant transport in surface water from the Macraes Gold Project site. One set of input parameters for this mine water modelling is derived from groundwater contaminant transport modelling undertaken as part of the same project.

Planned operations at the Macraes Gold Project involve mining based on the following extraction schedule:

- Continuation of mining in Frasers Pit though until December 2015.
- In Round Hill Pit from January 2015 to December 2017.
- In Innes Mills Pit from January 2018 to January 2019.
- Mine closure at the end of 2019.

The average annual rate of waste rock deposition is to be approximately 55 Mt, based on the following likely sequence of waste rock stack construction:

- Within the existing consented WRS footprints until mid-late 2012.
- Back Road Waste Rock Stack from early-mid 2012 till 2015-16.
- Return to the Frasers South, East and West Extension Waste Rock Stacks.
- In-pit backfill within Frasers pit.

OceanaGold needs capacity to store an additional 43.5 Mt of tailings to take the Macraes Gold Project from mid 2012 through until early 2020 at current processing rates. A review of OceanaGold's new mining schedule showed switching to a new facility to be a more economic alternative for tailings storage through to the end of mine life than continuing construction on the existing tailings storage facilities.

OceanaGold is planning to decommission both of the current TSFs by mid 2012 and commence using the new Top Tipperary Tailings Storage Facility at this time. The final Top Tipperary Tailings Storage Facility footprint is to be 184 ha with a capacity of 38,744,000 m^3. The embankment crest elevation is planned to be 560 mRL and the operating height would be 70 m above natural topography at its highest point.

Mine Water Management Model

A mine water management model has been constructed using the GoldSim modelling platform. The model simulates water flows across the Macraes Gold Project site and in downstream catchments, taking into account the planned sequential mining operations at the site. Runoff and surface flows, based on rainfall records from the site, have been calibrated against flow records from monitoring stations on Deepdell Creek and the Shag River.

Rainfall projections have been developed using a stochastic rainfall generator and converted into run-off projections using the Australian water balance model. The outcomes of these rainfall and run-off projections have been compared to the historical records. The comparison indicates the projections are very similar to observed hydrological patterns, although minor anomalies are present relating to the exaggeration of rare extreme rainfall events.

Water quality data from OceanaGold's environmental monitoring database have been evaluated. Representative water quality characteristics for tailings storage facility decant water and drainage water, WRS drainage water and run-off water from disturbed surfaces, rehabilitated surfaces and undisturbed surfaces have been produced. Dissolved parameter concentrations for water quality modelling have been defined as being toward the upper end of the observed range for each parameter, in order to ensure model outcomes for contaminant transport are conservative.

All simulated run-off and tailings storage facility discharges have been allocated appropriate water quality characteristics within the model. Groundwater seepage quality has been derived from the groundwater models developed for this project. The model generates a water balance for the MGP site, with an associated mass load related to each receiving water catchment. Dilution water together with the appropriate water quality is modelled as being available from the surrounding catchments upstream from each simulated compliance point.

Water Model Results

Modelling indicates that without management the proposed water quality limits are likely to be exceeded at most compliance monitoring sites, either during the operational period of the mine or following mine closure. The modelled exceedances are mainly for sulphate, arsenic and iron, although the simulations also indicate copper and cyanide$_{WAD}$ may also exceed the compliance limits at individual sites.

As the surface water models used for this project incorporate an assumption of conservative contaminant transport within surface water bodies, the modelled exceedances for arsenic and cyanide$_{WAD}$ are unlikely to occur. Both are subject to geochemical reactions, precipitation, adsorption or breakdown in the natural environment. Dissolved iron is also unlikely to present an issue at the compliance points, due to its capacity to rapidly oxidise and subsequently precipitate. Mitigation measures may however be required to minimise any possible issues of iron flocculants and discolouration of stream beds close to the tailings storage facilities.

The primary water quality issue identified is the need to manage sulphate concentrations in receiving surface water bodies. As sulphate is conservatively transported in water, it does not become naturally attenuated except through dilution. Without management, sulphate concentrations at all of the proposed compliance monitoring sites, except the site on Cranky Jims Creek, are likely to eventually exceed the relevant compliance limits on a seasonal basis. Mitigation measures are therefore considered to be necessary to ensure water quality on all of the creeks intersecting the MGP site and in the Shag River continues to comply with the existing and proposed consent compliance limits. This site water modelling report does not take into account the possible application of mitigation measures.

A variety of appropriate water management options are available to minimise or mitigate for potential effects on water quality downstream from the MGP. Mitigation options are presented and the effectiveness of several options summarised in a separate report by Golder (2011a).

Reductions in Surface Water Flows

During the operational period of the MGP, run-off from much of the mine site is captured and diverted to the process plant, rather than discharging to the natural receiving water bodies. Following closure of the mine run-off from the rehabilitated mine surfaces including the TSFs will be allowed to discharge back to natural receiving water bodies. The exception would be water that discharges to the opencast pit lakes.

The reductions in catchment areas due to the MGP operations result in reduced flows downstream from the mine site. As you move down the catchment the respective changes in flow are reduced. At the water quality compliance points of NB03, Loop Road and McCormicks, which are located upstream from consented water takes, the changes in flows are very modest. At these monitoring points the reductions in flows are expected to be within the error associated with the current estimated flows.

ABBREVIATIONS

ANZECC	Australian and New Zealand Environment and Conservation Council
AWBM	Australian Water Balance Model
CIL	Cyanide in Leach
CRC	Cooperative Research Centre
CTI	Concentrate Tailings Impoundment
EGL	Engineering Geology Limited
FTI	Flotation Tailings Impoundment
GIS	Geographic Information System
GPP	Golden Point Pit
MGP	Macraes Gold Project
MoH	New Zealand Ministry of Health
MTG	Maori Tommy Gully
MTI	Mixed Tailings Impoundment
NBWR	North Branch Waikouaiti River
NZDWS	New Zealand Drinking Water Standard
ORC	Otago Regional Council
RGP	Reefton Gold Project
RHP	Round Hill Pit
RL	relative level, in this case metres above mean sea level
RRL	Rainfall Run-off Library
SPI	Southern Pit Tailings Impoundment
SP10	Southern Pit Tailings Impoundment SP10, currently incorporated in SP11
SP11	Southern Pit Tailings Impoundment SP11
TPM	Transition Probability Matrix
TSF	Tailings storage facility
TTTSF	Top Tipperary Tailings Storage Facility
WAD	Weak acid dissociable
WRS	Waste rock stack

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1.0 INTRODUCTION

1.1 Background

Oceana Gold (New Zealand) Limited (OceanaGold) operates the Macraes Gold Project (MGP) located in East Otago, approximately 25 km west of Palmerston (Figure 1). The MGP consists of a series of opencast pits and an underground mine supported by ore processing facilities, waste storage areas and water management systems (Figure 2).

OceanaGold is now seeking to obtain resource consents for Macraes Phase III which involves further expansion of the site including new waste rock stacks (WRS), a new tailings storage facility (TSF) and expansion of existing pits.

Golder Associates (NZ) Limited (Golder) has been engaged by OceanaGold to undertake technical assessments for mine water management that are to support the resource consent application. This report documents development of the site wide surface water model and the outcomes from the modelling program.[1]

The main purpose of this site wide surface water model report is to produce water quality projections for receiving environment waterways and compare these projections to existing or proposed receiving environment water quality criteria. This comparison is used to assess likely compliance with the criteria and to identify the need for specific mitigation measures.

The scope of the modelling program and this report does not include assessment of potential mitigation measures and their performance. The modelling and performance of mitigation measures are documented in a separate report (Golder 2011a).

1.2 Existing Models

A number of surface water models have been prepared by Kingett Mitchell Limited (Kingett Mitchell) (now Golder), for the site. The purpose of these models ranged from evaluating the site wide water balance and process water demand, to assessing effects from site activities (including pit lake formation and site discharges).

The existing models were developed using a mining industry specific model developed by Kingett Mitchell, which utilises a spreadsheet platform to model hydrology and water quality for the site and receiving environments. The model includes a calibration process that matches projected and actual hydrographs and flow duration curves by varying a number of coefficients for rapid run-off and antecedent flows including a base flow yield factor.

Following the merger of Kingett Mitchell and Golder, the Kingett Mitchell model has been integrated into a different modelling platform known as GoldSim (http://www.goldsim.com/Home/#). The model has been further developed to provide improved calibrations and allow more probabilistic analysis for projected outcomes.

1.3 Project Description

1.3.1 Main features

The main features of the Macraes Phase III project are:

- A new TSF, labelled the Top Tipperary Tailings Storage Facility (TTTSF), which is to be constructed in the upper Tipperary Creek catchment. Construction of the TTTSF would result in an increase of 51 Mt in the total consented tailings storage capacity (from 81 Mt currently to 132 Mt).

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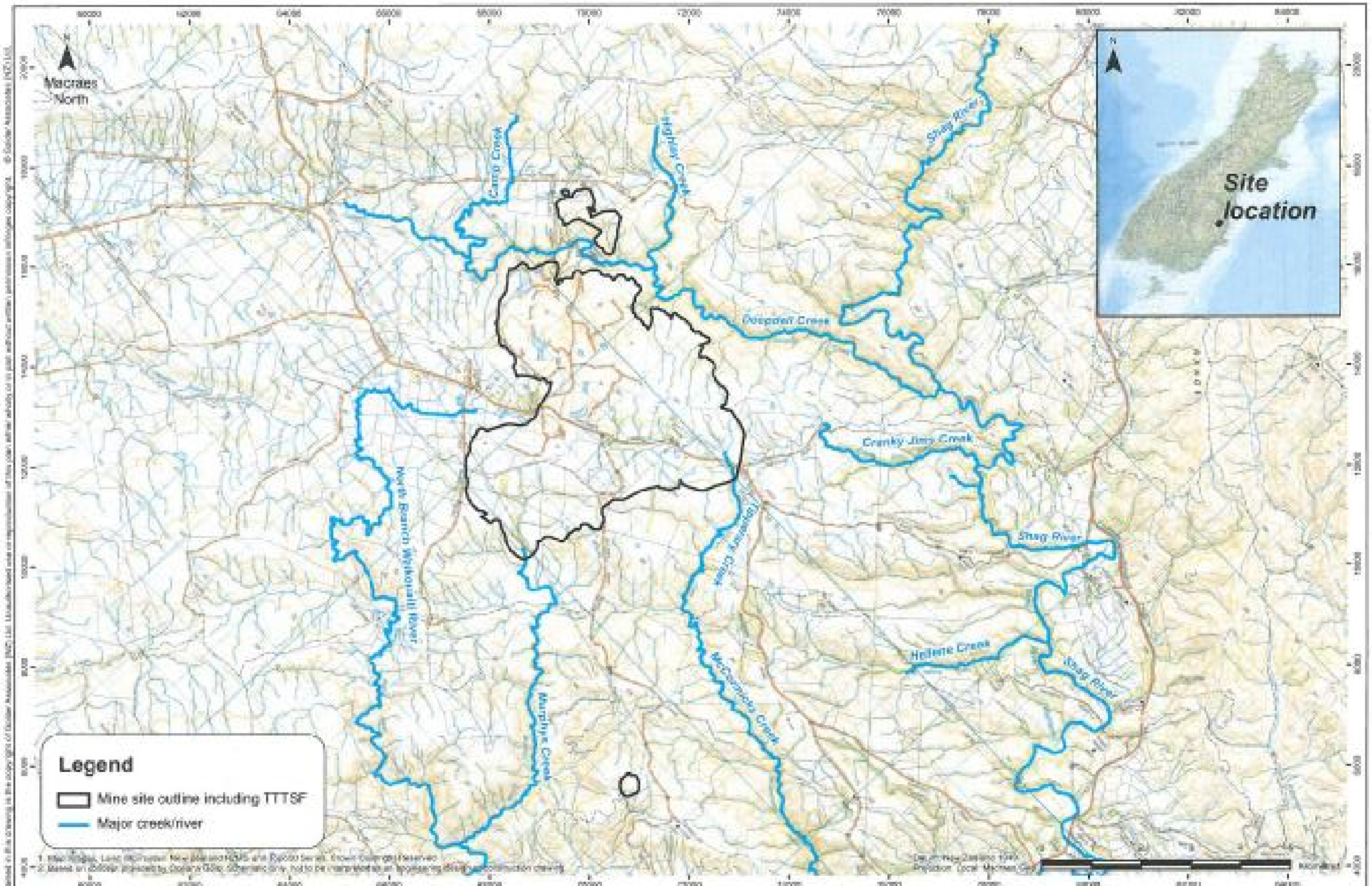
[1] This report is subject to the limitations in Appendix A.

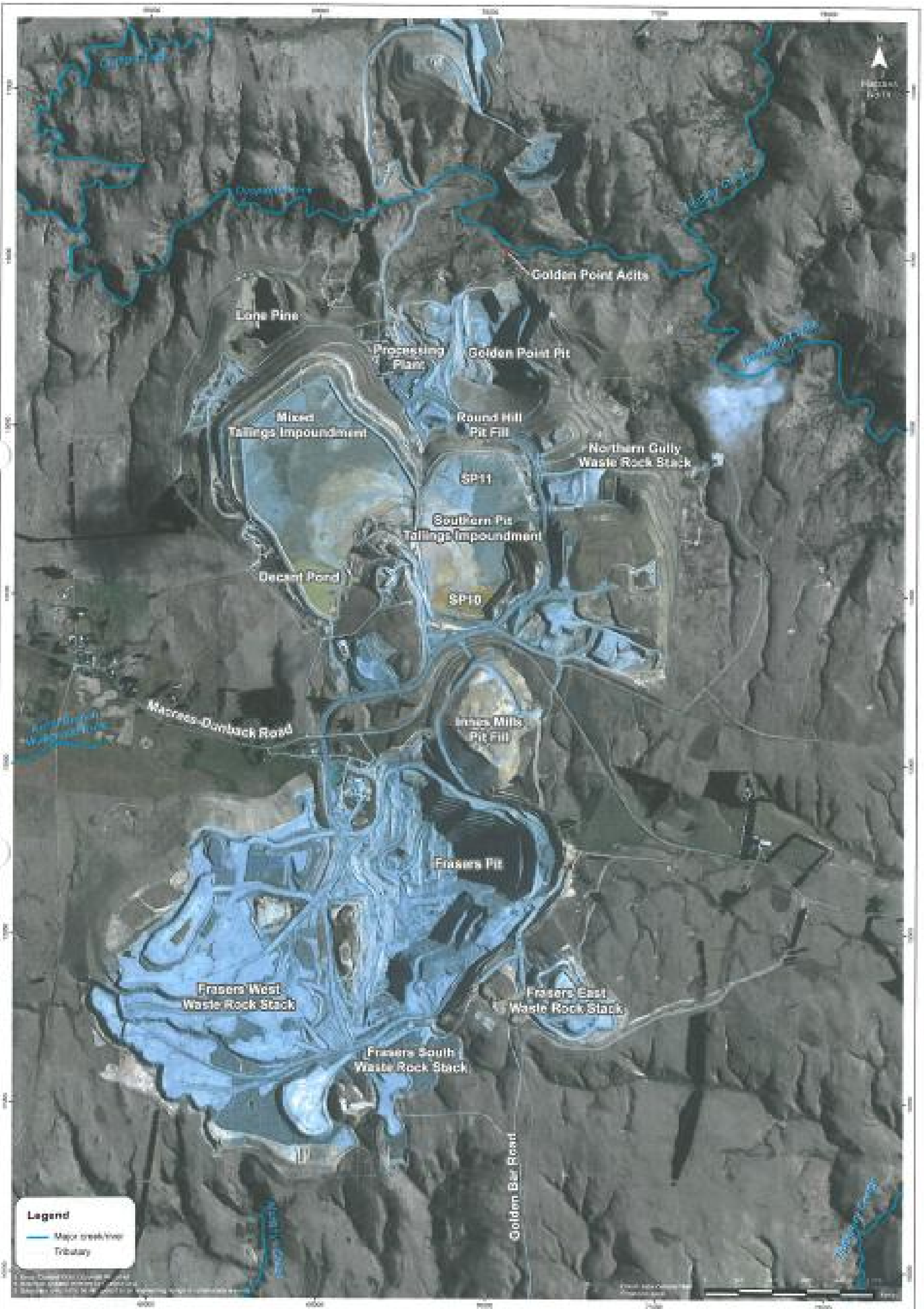


SITE LOCATION PLAN

MARCH 2011

PROJECT 0978110562

1



CURRENT SITE LAYOUT PLAN,
LATE 2010

MARCH 2011

2

- Reclamation of tailings from within the current Southern Pit 11 (SP11) TSF. The tailings are to be relocated to stacks within the footprints of the existing Mixed Tailings Impoundment (MTI). Any overflow from the stacks within the MTI will be incorporated into the dam impoundment of the new TTTSF.
- A new WRS and extensions to existing WRS are to be constructed, increasing the total consented tonnage from 850 Mt to 1,180 Mt. A new WRS is planned, substantially extending the existing Back Road WRS, to the east of the Round Hill/Southern Pit locations. Frasers East and Frasers West WRS are to be expanded and a new linking WRS between these two, called Frasers South WRS is to be constructed.
- Expansion of existing pits to include the Frasers Stage VI, Round Hill Southern Pit Extension and Innes Mills Stage V.
- Diversions and new silt control systems to manage surface water run-off from the expanded mining infrastructure.
- A revised closure plan, comprising two lakes formed within the opencast pit excavations.

The ore processing rate is to be similar to current operations and the intensity of operations on site would be similar to present.

1.3.2 Tailings storage

At the MGP, there are currently two active TSFs. These are the Mixed Tailings Impoundment (MTI) and the Southern Pit 11 (SP11) tailings impoundment. A previous tailings storage facility, SP10, sits within the footprint of SP11 and is completely buried by tailings stored in the larger impoundment.

OceanaGold needs capacity to store an additional 43.5 Mt of tailings to take the MGP from mid 2012 through until early 2020 at current processing rates. At this point, it is likely that both existing TSFs will have remaining resource consent life. A review of OceanaGold's new mining schedule showed switching to a new facility to be a more economic alternative for tailings storage through to the end of mine life.

It is envisaged there will be one final deposition phase into the consented rear compartment of SP11, from circa January 2011 until June 2011, whilst a final upstream lift on the MTI is constructed. Deposition is currently occurring in the MTI and a final tailings deposition period in this impoundment is planned to occur from circa June 2011 to May 2012.

OceanaGold is planning to decommission both of the current TSF by mid 2012 and commence using the new TTTSF at this time. The final TTTSF footprint is to be 184 ha with a capacity of 38,744,000 m^3. The embankment crest elevation is planned to be 560 mRL and the operating height would be 70 m above natural topography at its highest point.

The TTTSF is planned to be located in the headwaters of Tipperary Creek outside the catchments of the North Branch of the Waikouaiti River (NBWR) and Deepdell Creek. It is proposed to pump tailings to the TTTSF via a pipeline from the processing plant and deposit the tailings sub-aerially by spiggoting from the TTTSF embankment. This tailings deposition strategy is the same as that employed for the existing TSF. The footprint of the TTTSF is to gradually expand, reaching its maximum extent by about 2017.

Following decommissioning a process of closure and rehabilitation would commence on each TSF. In the case of the SP11 TSF, the outer compartment (north of the internal SP10 wall), will be mechanically re-handled once dry enough. The re-handled tailings are to be placed as a reclaimed tailings stack (RTS) on top of the MTI and/or into the new TTTSF. The tailings stored in SP10 above the level of the SP10 embankment are also to be removed, so that SP10 is effectively reinstated as an existing, decommissioned TSF.

The MTI and SP10 embankments are to remain in place following site closure. The SP11 embankment is to be removed as the tailings are stripped down.

The rehabilitation plan at closure calls for each TSF to be fully capped with brown rock (highly weathered schist) and topsoil and for pasture to be re-established. Each TSF is expected to quickly revert to farm land that can be readily grazed as per current rehabilitated areas at the MGP.

During the operational phase of the mine, discharges from the TSF drainage systems are pumped back to the process water system for reuse. This water recovery process reduces the requirement for make-up water from the Taieri River and minimises water loss to the surrounding environment.

1.3.3 Waste rock storage

There are currently two main WRS under construction at the MGP, the Frasers West WRS and Frasers East WRS. Other WRS's already present at MGP include Deepdell North, Western, Northern Gully South, Northern Gully North and Back Road.

At present, there remains 149 Mt of consented capacity in the current WRS's. Macraes Phase III requires an increased WRS capacity of 311 Mt.

Three new WRS's are planned to be constructed, in addition to those already under construction or consented.

- The existing Back Road WRS is to be expanded (additional capacity of 228 Mt), with the expansion to be wholly contained within the present Deepdell catchment. When completed the Back Road WRS is to abut the northern boundary of the Tipperary Creek catchment.
- The Frasers East WRS, which is currently under construction, is to be expanded to include a northern addition to the currently consented WRS (additional capacity of 26 Mt).
- The Frasers South WRS is planned to link the Frasers West and East WRS's, with a capacity of 50 Mt.

The construction of the two WRS described above has the potential to affect the location of the existing groundwater divides separating the Tipperary Creek catchment from the Deepdell Creek and (NBWR) catchments. Accumulation of groundwater within the two WRS could result in the Tipperary Creek groundwater catchment expanding slightly at the expense of the other two catchments.

In summary the WRS storage capacity required in addition to currently consented capacity is:

i) Back-Road 228 Mt

ii) Frasers West 27 Mt

iii) Frasers South 50 Mt

iv) Frasers East Extension 26 Mt

The planned Back Road WRS is to comprise material removed from Southern and Round Hill Pits along with some material from Innes Mills Pit. The total footprint of this WRS is 234 ha and it is to reach an elevation of 650 mRL at its highest point. This would result in a maximum WRS height of 65 m above natural topography.

The Frasers South WRS is to be located on the southern edge of the Frasers Pit, connecting the current Frasers East WRS with the Frasers West WRS. It is to be located straddling the catchment divide of Murphys Creek and the NBWR. This WRS is to reach a maximum height of 590 mRL, 45 m above natural topography.

The expanded Frasers East WRS is to include a northern addition to the current consented WRS, termed the Frasers North WRS. Construction of the Frasers North WRS and the TTTSF would necessitate the realignment of a 4.5 km stretch of the Macraes-Dunback road.

The average annual rate of waste rock deposition is to be approximately 55 Mt, based on the following likely sequence of WRS construction:

- Within the existing consented WRS footprints until mid-late 2012.
- Back Road WRS from early-mid 2012 till 2015-16.
- Return to the Frasers South, East and West extension WRS.
- In-pit backfill within Frasers pit.

Rehabilitation of the completed WRS's is to be undertaken on a progressive basis. Once final profiles are achieved then a 300 mm layer of brown rock is to be placed over the fresh waste rock and track rolled. Over this is placed a 150 mm layer of topsoil. Fertilising and seeding of grasses shall then be undertaken to return the ground to pasture similar to that present prior to mining.

1.4 Macraes Phase III Schedule

A schedule of mining operations has been developed by OceanaGold which has been divided into four phases for the purposes of mine water management modelling. These phases have not been specifically incorporated into the groundwater models (Golder 2011b,c), as it was not considered necessary to simulate each stage of the proposed mine development in detail for groundwater contaminant transport assessment purposes. The outcomes of the groundwater model are however applied to the mine water management model.

There are no operations currently planned for the Deepdell North or South pits during the Macraes Phase III Project. Deepdell North pit has been backfilled and rehabilitated. Deepdell South pit is inactive and a lake is developing in this pit.

Stage -1: January 2000 to December 2010 – calibration period

- Stage -1 represents site conditions during the past 10 years of operation. Frasers Pit is operational. Golden Point and Round Hill pits are inactive. Water levels in Golden Point pit are being actively managed. Water from pit dewatering is either utilised in the processing plant or for dust suppression.
- Round Hill and Innes Mills pits are being backfilled with waste rock. Waste rock placement is also to Frasers West WRS.
- Tailings from the process plant are alternately placed in the MTI and SP11. Seepages from both TSFs are collected by the impoundment drainage systems and returned to the process plant. Process plant water requirements exceed the volume of return water available. Make-up water is pumped from the Taieri River.
- Surface water run-off and groundwater seepage collecting in the Northern Gully Silt Pond is pumped back to the process plant. Water collecting in Maori Tommy Silt Pond is pumped to the Lone Pine Reservoir (Lone Pine). Water collecting in the Battery Creek, Frasers West and Murphys Creek Silt Ponds discharges via the decant system in each pond to the respective water course.

Stage 0: January 2011 to February 2012

- Stage 0 is representative of site conditions up until the commencement of the Macraes Phase III development at the end of February 2012. Frasers Pit is operational. Golden Point, Round Hill and Innes Mills pits are inactive. Round Hill and Innes Mills pits are backfilled with waste rock. Frasers pit is being actively dewatered. Water levels in Golden Point pit are being actively managed. Water from pit dewatering is either utilised in the processing plant or for dust suppression.
- Waste rock placement is to Frasers West and Frasers East WRS's.
- Tailings from the process plant are alternately placed in the MTI and SP11. Seepages from both TSFs are collected by the impoundment drainage systems and returned to the process plant. Process plant water requirements exceed the volume of return water available. Make-up water is pumped from the Taieri River.
- Surface water run-off and groundwater seepage collecting in the Northern Gully Silt Pond is pumped back to the process plant. Water collecting in Maori Tommy Silt Pond is pumped to the Lone Pine Reservoir (Lone Pine). Water collecting in the Battery Creek, Frasers West and Murphys Creek Silt Ponds discharges via the decant system in each pond to the respective water course.

Stage 1: March 2012 to December 2015

- Stage 1 incorporates most of the Frasers Stage 6 pit expansion. Golden Point, Round Hill and Innes Mills pits are inactive. Round Hill and Innes Mills pits are full of waste rock with possible movement of waste rock from the Round Hill pit to the Back Road WRS. Frasers pit is being actively dewatered. Water levels in Golden Point pit are being actively managed. Water from pit dewatering is either utilised in the processing plant or for dust suppression.
- Waste rock placement is to Frasers East, Frasers North and Frasers South WRS. Frasers West WRS is being rehabilitated.
- Tailings from the process plant are stored in the TTTSF. The MTI, SP10 and SP11 are inactive, are becoming dewatered and seepage drain discharges are declining. Tailings from SP11 are being recovered and dry stacked on the MTI or in the TTTSF. Seepages from the TSF are collected by the impoundment drainage systems and returned to the process plant. Process plant water requirements exceed the volume of return water available. Make-up water is pumped from the Taieri River.

Surface water run-off and groundwater seepage collecting in the Northern Gully Silt Pond is pumped back to the process plant and water collecting in Maori Tommy Silt Pond is pumped to Lone Pine. Water collecting in the Battery Creek, Frasers West and Murphys Creek Silt Ponds discharges via the decant system in each pond to the respective water course.

Stage 2: January 2016 to December 2017

- Stage 2 incorporates the period of mining in Round Hill pit and the conclusion of mining in Frasers Pit. Innes Mills pit is inactive and full of waste rock. Round Hill pit is being actively dewatered. Water from pit dewatering is either utilised in the processing plant or for dust suppression. Water management for Frasers pit has ceased and a pit lake is starting to develop.
- Back Road WRS has become the active waste rock storage area. Frasers East, Frasers North and Frasers South WRS are being rehabilitated.
- Tailings from the process plant are stored in the TTTSF. The MTI and SP10 are being rehabilitated and drain discharges are declining. The SP11 embankment has been removed. Seepages from the TSF are collected by the impoundment drainage systems and returned to the process plant. Process plant water requirements exceed the volume of return water available. Make-up water is pumped from the Taieri River.

Surface water run-off and groundwater seepage collecting in the Northern Gully Silt Pond is pumped back to the process plant and water collecting in Maori Tommy Silt Pond is pumped to Lone Pine. Water collecting in the Battery Creek, Frasers West and Murphys Creek Silt Ponds discharges via the decant system in each pond to the respective water course.

Stage 3: January 2018 to December 2018

- Stage 3 incorporates the period of mining in Innes Mills pit. The existing waste rock fill is removed as part of this operation. It is assumed that water inflows to Innes Mills Pit would flow out into Frasers Pit and not require active management.
- Waste rock placement is to Back Road WRS and to the relatively small Frasers South in-pit stack.
- Tailings from the process plant are stored in the TTTSF. The MTI and SP10 are being rehabilitated and drain discharges are declining. Seepages from the TSFs are collected by the impoundment drainage systems and returned to the process plant. Process plant water requirements exceed the volume of return water available. Make-up water is pumped from the Taieri River.
- Water management for Round Hill pit has ceased and pit lakes are developing in both Round Hill and Frasers pits.
- Surface water run-off and groundwater seepage collecting in the Northern Gully Silt Pond is pumped back to the process plant and water collecting in Maori Tommy Silt Pond is pumped to Lone Pine. Water collecting in the Battery Creek, Frasers West and Murphys Creek Silt Ponds discharges via the decant system in each pond to the respective water course.

Stage 4: January 2019 to December 2168

- Stage 4 represents long term closure of the Macraes Phase III site.
- All mining operations have ceased. Pit lakes are developing in Frasers, Round Hill and Innes Mills pits.
- Rehabilitation of all WRS's is completed.
- Site management is undertaken to minimise and mitigate environmental effects. For an initial period following mine closure, tailings seepage collected by impoundment drainage systems will be of high quantity and poor quality. Over time the quantity declines and the quality improves (Golder 2011d). Collected tailings drain discharges are to be initially pumped to Frasers Pit until they can be either passively managed or released to the environment without exceeding consent conditions.
- Seepage water collecting in the Northern Gully and Maori Tommy Gully silt ponds is released to the downstream receiving waters. Seepage water collected in a sump downstream from the TTTSF is to be initially pumped to Frasers Pit until this water can be either passively managed or released to the environment without exceeding consent conditions.

1.5 Scope

OceanaGold has requested that Golder develop a site wide water quantity and quality model for the MGP. The 'model' is to be constructed using the GoldSim software package.

This report provides an overview of how the site wide water model was developed. The key limitations of the model, and the assumptions that it is based on are outlined. This report also provides the model specification which provides details on the purpose, objectives, content and outputs that are to be provided by the model.

The model is to be used to assess how mining processes, including: the placement of mine waste in WRS's, the decommissioning of existing TSFs, the development of open pits and the construction and operation of the TTTSF, may affect surface water quality within the boundary of the mining lease and in receiving waters at specified water quality compliance points.

The outputs of the model may be used to:

- Inform project stakeholders on the potential effect that the operation and closure of the mine is likely to have on surface water flow and quality.
- Support identification of the scale and nature of mitigation measures appropriate to offset potential adverse effects of mine drainage on the receiving environment.

The model was not developed for pre-feasibility level engineering design analyses.

The model is to simulate water flow, and water quality with respect to electrical conductivity, dissolved calcium, magnesium, sodium, potassium, chloride, sulphate, arsenic, copper, iron, lead, zinc and weak acid-dissociable cyanide (cyanide$_{WAD}$) from the mining impacted and non-impacted areas within the mine lease and in receiving waters at specified water quality compliance points.

The limitations and assumptions detailed in this section are such that the model should not be used for operational water and mine waste management and engineering design without further development, testing and verification.

The key elements of the scope of this report are to:

- Describe the modelling approach adopted.
- Define the scope of the model.
- Define the model boundaries and points for which water quality projections are calculated.
- Develop the model logic.
- Describe and justify model assumption and inputs, including:
    - Define the catchments and mining elements for hydrological modelling;
    - Define the catchments in terms of water quality (i.e., for WRS's, undisturbed catchments and pits etc.);
    - Rainfall and evaporation data;
    - Flow data used for calibration and verification; and
    - Groundwater and seepage inputs (quantity and quality) including drains and seepages from TSFs.
- Describe the modelling process.
- Summarise the modelling results.
- Compare receiving environment water quality to existing (or proposed) water quality criteria.
- Summarise projected site performance with respect to compliance with consent conditions.
- Recommend scope of mitigation required.

1.6 Report Structure

Following this introductory section, this surface water management technical report has the following structure:

- Section 2 summarises the water balance modelling approach including assumptions, model structure, projection points, model limits and boundaries. In addition, this section describes the stochastic rainfall data generation.
- Section 3 summarises the model inputs, including rainfall, evaporation, catchment areas, process water system, water quality and groundwater seepage.
- Section 4 summarises the model calibration and verification process.
- Section 5 provides a summary of the site wide water balance projections.
- Section 6 describes the stream water quality projections and a summary of the scope of mitigation work potentially necessary to ensure compliance with existing and proposed water quality consent conditions.
- Section 7 presents conclusions reached from the modelling.
- Section 8 contains a list of documents referenced in this report.

2.0 WATER BALANCE MODEL

2.1 Model Approach

2.1.1 Initial assumptions

A range of assumptions with regard input parameters have been incorporated in the surface water model. Most of these assumptions relate to water quality values applied to the modelling and are documented in the appropriate sections. Two assumptions have, however, been incorporated that fundamentally affect the model outcomes and how these outcomes are to be understood.

The surface water model incorporates the assumption that all contaminants are transported in the surface water systems without attenuation, except what may be provided through dilution. In the case of the major ions, this is generally expected to be correct. In the case of most metals and cyanide$_{\text{WAD}}$ however, this assumption is conservative. Metals are subject to geochemical reactions leading to adsorption or precipitation while cyanide$_{\text{WAD}}$ breaks down on exposure to ultraviolet light. The water quality projections documented in this report are therefore mostly conservative with respect to dissolved metals and cyanide$_{\text{WAD}}$. The degree of conservatism introduced by this assumption is discussed in Section 6.9.1.

The model also assumes that no specific water quality management measures have been instigated by OceanaGold with respect to soluble contaminants, with one exception. The existing water management plan for the site requires the pumping of TSF drain discharge water to Frasers Pit for a period of time following closure of MGP operations. This measure has been incorporated in the site water management model, with the initial assumption that the period of pumping would be 20 years. It is expected that 20 years is overly conservative estimate and other mitigation measures may be instigated to substantially shorten this pumping period. For the purposes of this unmitigated water management model, the assumed pumping period is appropriate.

Water management measures that may be appropriate to mitigate for possible water quality effects identified in this report are not documented in this report. A review of potential mitigation measures is presented in a separate report (Golder 2011a).

2.1.2 GoldSim

The model has been developed using GoldSim Pro (Vers.10.11) software. GoldSim is a graphical object-oriented modelling environment with the capacity to carry out dynamic probabilistic simulations. Originally developed by Golder in the early 1990s, GoldSim is now a separate entity to Golder. GoldSim has been applied successfully in a decision support role to a range of water balance, water chemistry and water resource projects and is used by companies such as RioTinto, BHP and AngloAmerican.

GoldSim models are composed of containers and functional elements – such as inputs, expressions, allocators, stocks, events, delays and results. Each functional element forms part of the model structure which is developed specifically for a particular modelled system.

Model simulations are run on daily time steps over a period of up to 150 years, with one or multiple realisations. A realisation is defined as a single model run within a simulation. The benefit of running multiple realisations of the model is to provide results based on probability. The model will operate in a deterministic mode for all input parameters other than rainfall, which is simulated on a probabilistic basis.

A GoldSim water balance and water quality model is a computer-based representation of the essential features of a natural hydrological and biogeochemical system that uses the laws of science, engineering and mathematics. The basis of model development includes two key components: a conceptual model and a numerical model.

The conceptual model is an idealised representation (i.e., a picture) of our understanding of the key processes of the system. The numerical model is a set of equations, which, subject to certain assumptions, quantifies the physical processes active in the system(s) being modelled. While the model itself lacks the detailed reality of the environmental system, the behaviour of a valid model approximates that of the environmental system.

The model provides a scientific means to draw together the currently available data into a numerical characterisation of the environmental system. The model represents the environmental system to an adequate level of detail, and provides a predictive scientific tool to quantify the impacts of the proposed activity on the receiving system and enables the assessment of potential environmental effects.

2.1.3 Site wide model

A site wide model has been developed for the entire MGP, (including the Golden Bar operations). The model calculates flow and water quality on a daily time interval for all mine site catchments and natural waterway catchments. Catchment contributions are combined to produce projections for site discharges to receiving environment waterways and flows and water quality in the receiving environment waterways. The conceptual model logic is presented in Appendix B.

This above approach enables site discharges to be characterised and the consequent effects on receiving environment water quantity and quality to be assessed.

The model integrates results from numerical groundwater modelling as inputs for groundwater and other seepages such as: groundwater seepage to waterways; WRS and TSF seepages; and Pits and Pit Lake groundwater inflows. The process water system is included in the model to provide a holistic site wide modelling approach. Modelling the process water system allows demonstration that a water balance can be achieved by recycling process water, using pit and other water collection around the site and using the Taieri River abstraction to provide top up and security of supply.

Run-off in the model is calculated in several ways depending on the catchment type. Mine site catchments are calculated using a look up table with run-off coefficients for various rainfall depths. This approach allows modification of coefficients during a calibration process to match observed water volumes stored in pits and silt dams. Run-off from natural catchments is calculated using the Australian Water Balance Model (AWBM) and is calibrated against site rainfall and flow records.

Generic model development included several steps, undertaken in the following order:

- Define the purpose of the model and the required model projections.
- Define the stages of mine development.
- Create the conceptual model, including defining the:
  - Model limits;
  - Mine-site features (WRS's, TSFs, pits, pit lakes and silt dams);
  - Process water system elements;
  - Catchments and water quality classifications;
  - Site receiving environment waterways;
  - Discharge locations; and
  - Receiving environment water quality and quantity projection points.
- Define the model inputs for each stage of mining, including:
  - Catchment areas;
  - Rainfall and evaporation;
  - Groundwater inflows and other seepage rates;
  - Water quality for all groundwater and seepage inputs;
  - Runoff water quality for each catchment classification;
  - Pumping rates;
  - Storage volumes for pits, pit lakes, TSFs and Lone Pine; and
  - Silt dam assumptions.
- Construct the numerical model.
- Calibrate model by adjusting parameters until simulation results acceptably match measured data.
- Complete model verification, sensitivity and uncertainty analysis.
- Carry out predictive analyses and document results.

2.1.4 Stochastic rainfall generator

The current mine development schedule provided by OceanaGold (Section 1.4) indicates the MGP is to be operational up until early 2019 at which point the mine would close. For the purposes of estimating long term compliance with water quality consent conditions, modelling has been completed for 150 years post closure to evaluate long term effects.

As a rainfall record for the site covering an equivalent period does not exist, a synthetic long term rainfall dataset was constructed using a stochastic rainfall generator that is based on the Transition Probability Matrix (TPM) method (Srikanthan & McMahon, 2000; Srikanthan et al. 2002). The method divides rainfall into daily states based on the daily rainfall depth (Table 1). The probabilities for a day of rain from one state to be followed the next day by rain in the same or another state are derived from existing rainfall record and collated into a matrix.

This matrix is developed using as many complete years of rainfall record as possible. Seasonality of rainfall is modelled by using different TPMs for each month of the year. An example of the TPM for January is presented in Table 2, which shows the probability of a certain rain state following the rain state for the previous day. For example, if 10 mm of rain fell the previous day (rain state 5), the probability of another 10 mm rainfall event (i.e., another rain state 5) occurring today is 0.095 or 9.5%.

Table 1: Daily rainfall states used in the stochastic rainfall generator.

State	Daily rainfall depth (mm)		
1		zero	
2	zero<	rain	<=0.9
3	0.9<	rain	<=2.9
4	2.9<	rain	<=6.9
5	6.9<	rain	<=14.9
6	14.9<	rain	no upper limit

Table 2: Example of the transition probability matrix for January.

		Today					
	State	1	2	3	4	5	6
Yesterday	1	0.694	0.035	0.112	0.084	0.054	0.021
	2	0.647	0.074	0.147	0.044	0.029	0.059
	3	0.570	0.089	0.158	0.070	0.057	0.057
	4	0.573	0.052	0.146	0.063	0.083	0.083
	5	0.527	0.135	0.095	0.108	0.095	0.041
	6	0.391	0.109	0.239	0.065	0.109	0.087

The overall method relies on future rainfall having the same statistical distribution as historic recorded rainfall. The method allows for extreme events but does not allow for changing weather patterns which could alter the statistical distribution of rainfall at the site. Similarly, the rainfall generator does not consider the decreasing probability of high rainfall occurring on multiple days. New Zealand's weather patterns fluctuate rapidly and rainfall patterns are very dependent on generally short (hours or days rather than weeks) duration storm events. By only considering the previous days rainfall the generator will tend to over predict long duration high rainfall events.

The Glendale Station (NIWA site number I50341) rainfall gauge is situated adjacent to the mine (approximately 1 km north east of Frasers pit). Glendale is the longest historical rainfall record in the vicinity of the mine with daily rainfall records available since January 1959. The record is almost complete with very limited missing data. The small amount of missing data from the Glendale Station record was in-filled using correlated data from the Palmerston (NIWA site number I50471) rainfall gauge. More information on site rainfall can be found in the water management report by Golder (2011e).

Daily rainfall from the filled Glendale Station rainfall record for the forty year period from 2nd May 1969 to 1st May 2009 was used as input to the stochastic rainfall generator to develop the required 170 years (20 years operational and 150 years post closure) of rainfall record required for the GoldSim model. A set of one hundred separate artificial rainfall records of the same length were generated, based on the same TPM. All 100 artificial rainfall records were used as inputs to the model when assessing the 10 year operational period of the Macraes Phase III project. The 50th percentile record (calculated from the cumulative rainfall volume over the 170 year period) was used as input to the model when assessing the 150 year post-closure phase.

A statistical analysis was used to compare the rainfall data from Glendale Station (40 year record) with the 170 years of generated stochastic rainfall. As shown in Table 3, the standard deviation and average annual rainfall for the two rainfall data sets are very similar.

Table 3: Statistical comparison between observed and stochastic rainfall.

	Data period (years)	Standard deviation of daily rainfall values (mm)	Average annual[2] rainfall (mm)	Minimum annual[2] rainfall (mm)	Maximum annual[2] rainfall (mm)
Stochastic rainfall	170	5.23	659	393	1025
Glendale Station rainfall (1)	40	5.28	649	395	1046

Notes: (1) Rainfall record gaps filled with correlated data from Palmerston; and (2) annual refers to calendar years.

2.1.5 Australian water balance model (AWBM)

Run-off from areas either not affected by mining or rehabilitated areas has been calculated by the AWBM rainfall run-off module within GoldSim. The AWBM used site rainfall and run-off records to generate a calibrated run-off model. For the purposes of this project, two separate run-off models were developed and calibrated for catchments simulated in the model.

One run-off model was calibrated based on the Deepdell Creek flow record from the Golden Point flow monitoring station. This run-off calibration was applied to the mine site receiving environment waterways, including Cranky Jims Creek, Tipperary Creek, Murphys Creek, NBWR and Deepdell Creek.

A second run-off model was calibrated against flows in the Shag River recorded from the Craig Road flow monitoring station. This separate calibration was undertaken because the flow regime in the Shag River differs substantially from that of Deepdell Creek, especially under low flow conditions when Deepdell Creek can become dry. This calibration was utilized for simulating the Shag River and the lower portion of McCormicks Creek.

A flow monitoring station has recently been established on Tipperary Creek (Golder 2011). The length of the flow record is however too short to be used for flow calibration purposes.

The AWBM generates run-off projections based on a rainfall time series, by developing a relationship of run-off to rainfall. The relationship takes into account soil and groundwater storage and release, antecedent wetness, infiltration, vegetation and evapotranspiration (Boughton 2005). This relationship can be effectively developed through calibration of the model, using available rainfall and run-off data for catchments in the area. The AWBM has been calibrated using the Rainfall Run-off Library (RRL), software developed by the eWater Cooperative Research Centre (eWater CRC) (refer Section 4.0).

2.1.6 Run-off from mining affected areas

Run-off from mining affected areas is based on the rational method using a number of different run-off assumptions which are linked to catchment land use. The run-off flow characteristics for these areas vary depending on the land use. The land uses present at the site have been separated into two categories.

- Impacted catchments within the mining area – pit areas, haul roads and other mining impacted areas.
- WRSs.

A distinction has been made between the separate land use units because the amount of rainfall which becomes run-off will vary between the surfaces. The amount of rainfall which becomes run-off on any given day depends upon a number of factors including the intensity of the rain, the amount of vegetated surface, the degree of compaction of the soil surface, the soil type, the slope and the antecedent rainfall conditions. In impacted catchments where land has been cleared and the ground surface has often been subjected to a degree of compaction, the surface run-off is greater than for natural catchments.

Run-off factors for mining affected catchment surfaces have been established based on known site conditions and from run-off coefficients calculated for the catchment above the Deepdell Creek flow monitoring site. Due to high evaporation/evapotranspiration rates, storage within sumps, pit benches, diversion drains and channels, on-site run-off coefficients are expected to be relatively low.

2.2 Model Limits

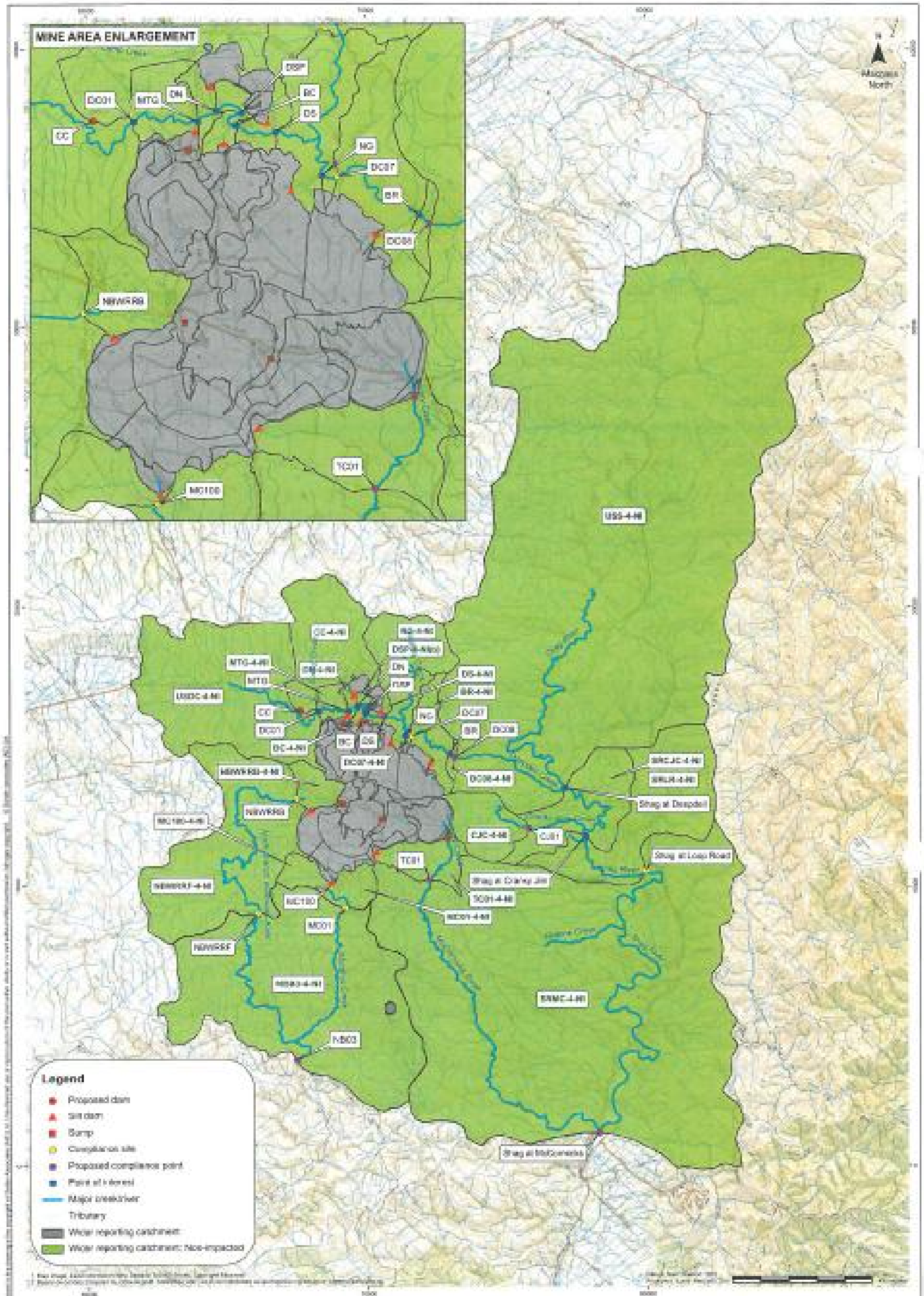
2.2.1 Model extent

All major mining infrastructure features within the mine site are incorporated within the model. Where a catchment contributing to the water flow within the mine site extends beyond the site boundary, that catchment area is also included in the model. The model boundaries are presented in (Figure 3). The model extends to the existing and proposed compliance points within the following receiving environment waterways:

- Deepdell Creek – full catchment to confluence with Shag River (including DC07 and proposed DC08).
- Tipperary Creek – full catchment to confluence with McCormicks Creek (including proposed TC01).
- McCormicks Creek – full catchment to confluence with Shag River.
- Cranky Jims Creek – full catchment to confluence with Shag River.
- Shag River – limited to water quality projections at the existing compliance monitoring point at Loop Road and the proposed compliance monitoring point downstream from the McCormicks Creek confluence with the Shag River. The model does not simulate the hydrology of the Shag River to the same level of detail as for the other waterways due to the large size of the Shag River catchment and the presence of water abstractions.
- Murphys Creek – full catchment to compliance point MC01.
- North Branch Waikouaiti River – full catchment to compliance point NB03.

2.2.2 Model projection points

The primary water quality projection points for the model include existing and proposed receiving water compliance sites (Table 4). The catchment areas for each waterway at the compliance points are also summarised in Table 4 and are shown in Figure 3.



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The site wide water balance and water quality model simulates water flow, dissolved arsenic, sulphate, $\text{cyanide}_{\text{WAD}}$, copper, iron, lead, sodium, potassium, calcium, magnesium, zinc and chloride inputs from the impacted and non-impacted areas within the mine site within receiving environment waterways at existing and proposed environmental compliance points.

Table 4: Model water quality projection points.

Watercourse	Site	Catchment area (km^2)
Deepdell Creek	DC07	51.6
	DC08	56.8
Tipperary Creek	TC01	6
Cranky Jims Creek	CJ01	5.1
Shag River	Shag at Loop Road	263
	Shag at McCormicks Creek	345
NBWR	NBWRRB	3.4
	NBWRRF	27
	NB03	75.7
Murphys Creek	MC100	2.6
	MC01	4.9

2.2.3 Model limitations

The limitations associated with the model specification described in this document include the following.

- The numerical modelling approach is designed to be used for surface water flow and quality evaluations for the purposes of assessing potential adverse environmental effects and supporting an application for resource consents. The model incorporates simplifications to the internal mine water management system as additional detail was not considered necessary for these purposes. At this stage of development, the model is not considered to be of sufficient detail to be used for feasibility level engineering designs or detailed mine water management.
- Assumptions built into this model include water management objectives that are not necessarily valid under all and operational conditions and scenarios. For this reason, the model is not considered to be suitable for detailed mine water management design purposes.
- OceanaGold has been granted consent to discharge mine water at up to 100 L/s from Frasers Pit directly to the NBWR under certain conditions. This discharge is not considered to be a standard operational procedure. Due to difficulties in incorporating this aspect of mine water management in the model, no allowance for this discharge has been simulated.
- The water quality database for the MGP site includes over 12,000 individual water quality samples. However, there are a number of limitations with the dataset and these are summarised and reviewed in Golder (2011d). In summary these limitations include a low number of samples analysed for metals and metalloids. Water quality input values used in the model are in some cases based on a very small number of analysis results. As analysis results reported as being below detection limits have not been taken into account, model outcomes are expected to overstate the concentrations of some parameters in the receiving waters.

- There is limited geochemical data to define the static bulk chemistry or kinetic reactivity of the primary lithological units within the waste zones of the pits that have been or are planned to be mined.

2.2.4 Availability of water quality data

There is limited hydrochemical data in the water quality database for some parameters, specifically: cadmium, copper, lead, and zinc (Golder 2011d). Table 5 presents the average percentage of samples within the surface water database for the listed parameters. The limited number of data for some sites will have an effect on water quality projections.

Table 5: Water quality data availability.

	Water quality data availability			Water quality data availability	
Parameter	**Number of samples were parameter tested**	**% of total samples**	**Parameter**	**Number of samples were parameter tested**	**% of total samples**
Arsenic	6,853	57.0	Sulphate	10,703	89.0
Cadmium	1,072	8.9	Chloride	10,125	84.2
Copper	3,443	28.6	Potassium	10,042	83.5
Iron	6,497	54.0	Calcium	10,057	83.6
Lead	2,925	24.3	Magnesium	10,056	83.6
Zinc	570	4.7	Sodium	10,113	84.1
Cyanide$_{WAD}$	5,134	42.7			

2.2.5 Operational mining procedures

Over the duration of the project there have been a large number of operational water management changes. It is expected that there will be a similar frequency of changes in operational procedure as the project moves forward, i.e., minor changes to the mine development schedule outlined in Section 1.4. These changes affect the mine water balance and therefore modelled water quality projections. In many cases, the timing or magnitude of these changes cannot be accurately predicted. This uncertainty introduces a similar uncertainty to the outcomes of model projections.

Potential changes to future operations may include:

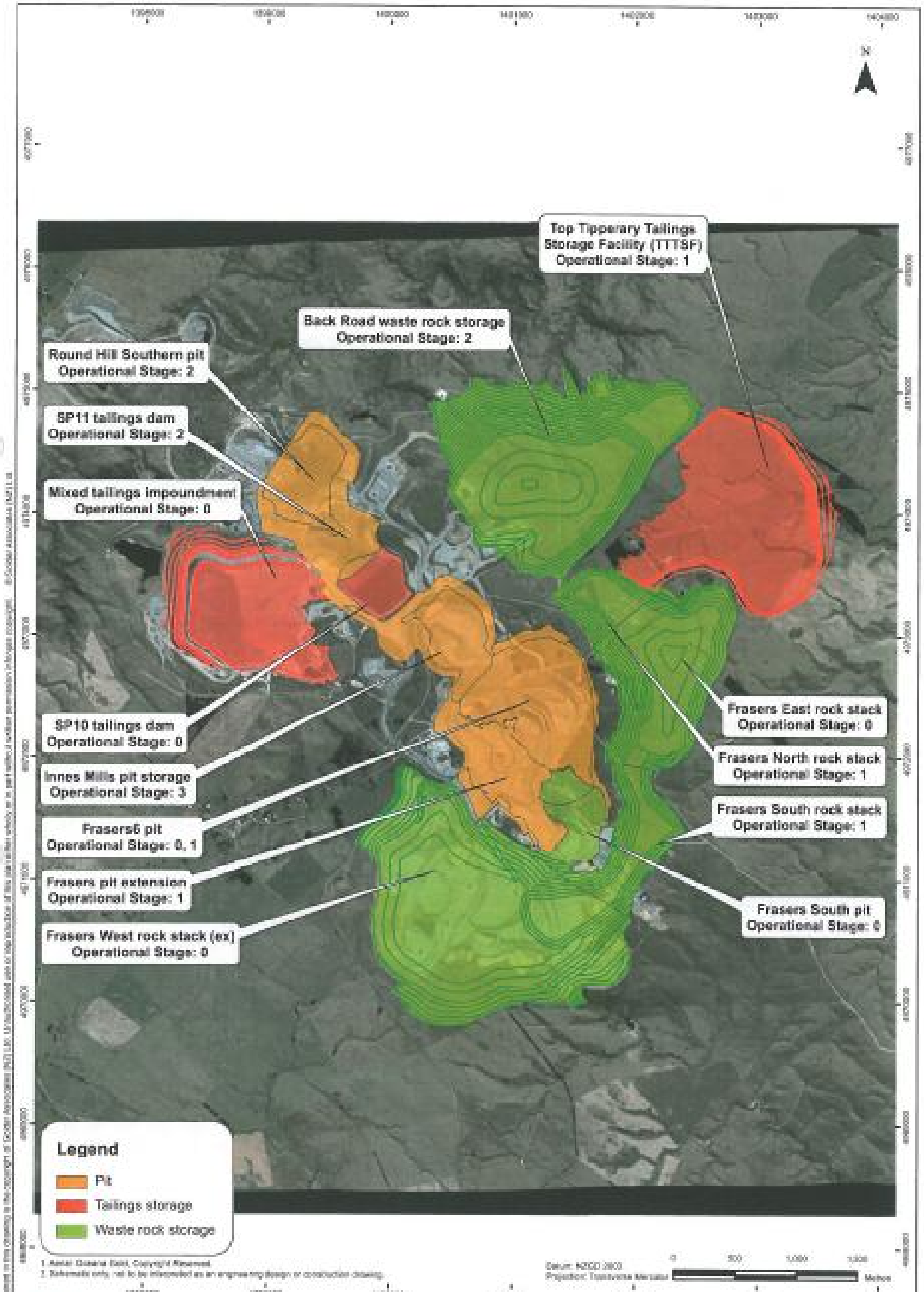
- Processing of different ratios of ore from MGP and the Reefton Gold Project (RGP).
- Changes to the processing method.
- Changes to the way in which water is reused and recycled.

Specifically, no attempt has been made to reproduce the variability associated with water quality measurements from the past 20 years of the mine life. Rather, it is the broader trends that are the objectives for this modelling project.

2.2.6 Temporal duration

The Macraes Phase III model runs on a daily time step according to a staged approach based on projected mine development (Figure 4). The entire model covers a 170 year period which includes:

- A 10 year calibration phase.



1. Aerial: Oceana Gold, Copyright Reserved.
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- The Phase III Project of approximately 10 years.
- A 150 year post-closure phase.

The temporal duration with the stage of key elements of the mining operation shown is summarised in **Error! Not a valid bookmark self-reference.**.

Table 6: Model temporal duration.

Mine stage	Description	Duration
-1	Calibration	1 January 2000 to 31 December 2010
0	Current situation – Stage 0	1 January 2011 to 29 February 2012
1	Phase III Start Stage 1	1 March 2012 to 31 December 2015
2	Phase III Start Stage 2	1 January 2016 to 31 December 2017
3	Phase III Start Stage 3	1 January 2018 to 31 December 2018
4	End of Phase III i.e., closure date	1 January 2019
5	Post closure Stage 4	1 January 2019 to 31 December 2168

The variability in water quality measurements seen over the duration of the mine life is not evident in the model outputs as detailed operational changes during that period have not been simulated. Rather, it is the broader trends that have been incorporated in the model.

2.3 GoldSim Model Structure

2.3.1 Site wide model structure

Fundamentally there are two main components to the site wide model (Figure 5). There is a hydrological component and an associated water quality component. The water quality component follows and utilises the water quantity component for mass balance calculations. Components of the model are referred to as 'containers' and 'modules'.

The water quantity component of the model represents the combination of site run-off and site seepages from the MGP site. The run-off generating calculator is located within the Climate and AWBM containers of the model. The AWBM container links to the Climate container and run-off (mm/day) is generated based on rainfall, evaporation and soil storage, infiltration, antecedent rainfall and antecedent wetness.

Catchment areas and stage area storage curves assumptions are located within the Areas and Stage Storage container. The content of this container is linked across to the Pits, Silt Ponds, TSFs, Process Plant and the Receiving Environment containers for use in mass balance calculations.

The run-off coefficient container contains run-off coefficients for WRS's, impacted pit areas and rehabilitated tailings areas.

The containers for Pits, Silt Ponds, TSFs, Process Plant and the Receiving Environment all contain model logic components for the generation of run-off and seepage for the site. The Pit container contains the logic for the Frasers/Innes Mills, Round Hill/Golden Point/Southern Pit and the Deepdell Pit. The Silt Pond container contains the logic for the 10 silt ponds/sumps. The TSF container contains the logic for the MTI, SPI (SP10 and SP11) and TTTSF. The Receiving Environment container contains the run-off generation logic for the Shag River catchment to the McCormicks Creek confluence model boundary (including the tributary catchments of Deepdell Creek, Cranky Jims Creek and Tipperary/McCormicks Creek) and the NBWR to the NB03 model boundary (including the tributary catchment of Murphys Creek).

The Chemistry container is where the water quality calculations are computed. Components within this container are linked to the corresponding components of the hydrological system. Within this container is a sub container (Chemistry Assumptions) where the water quality assumptions for land use areas and seepage water quality are located. Chemical species concentrations are associated with the particular land uses such as impacted pit areas, WRS areas, TSFs, Process Plant and the non-impacted areas. Assumptions of seepage water quality generated from WRS and TSF are also contained within the Chemistry Assumptions container.

An overall Mine Stage element allocates a mine stage based on projected life of mine time periods supplied by OceanaGold (see Section 1.4). The entire model is dynamic in the sense that as the model progresses through the various mine development stages, all elements linked to the Mine Stage element will change. For example, the Mine Stage element is linked to all catchment areas, stage storage curves, pump rates and pumping locations. This allows for the changes in the size of catchments, the amount of storage in pits, the pumping rates and the location of pumping within pit sumps, tailings decants and silt ponds.

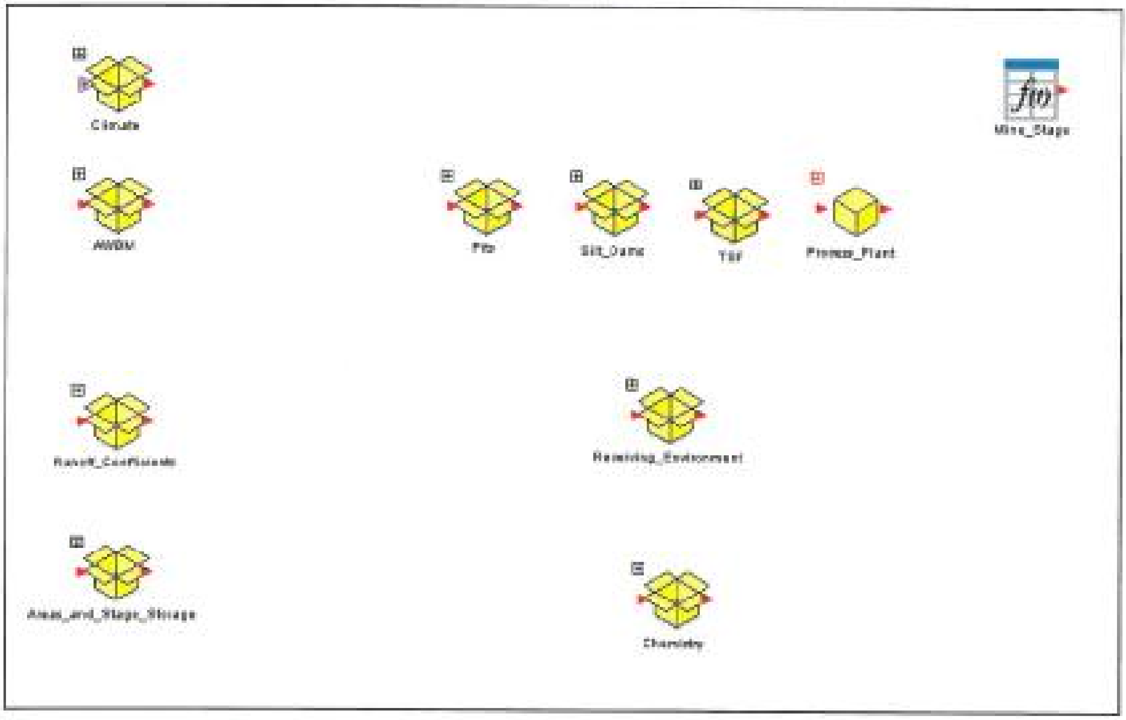


Figure 5: GoldSim site wide model structure.

2.3.2 Pit lake module

The pit lake module consists of a reservoir element (Pit Sump) and two containers housing the inflow elements and the outflow elements. The pit sump actually forms a pit lake on closure of the mine. The inflow elements include direct rainfall to the pit sump/lake, run-off from impacted, non-impacted and WRS land use areas and groundwater seepage to the pit. On closure, there is also some tailings run-off to some of the pits and tailings seepage drains are also directed to the Frasers Pit on closure for a number of years.

The pit lake outflow elements include evaporation from the sump or pit lake surface and also the pumping rate for the particular pit. Seepage losses from the pits to surrounding groundwater have not been simulated as the pit lake levels are assumed to be below the surrounding groundwater levels for most of the modelled post-closure period. The exception to this assumption is the Golden Point/Round Hill Pit, in which the lake level reaches the level of historical underground workings prior to the close of the simulation. The implications for this situation are discussed later in this report. Pumping is dependent on the mine stage for the particular pit.

Stage storage area curve assumptions within the Areas and Stage Storage container dictate the pit lake relative level (RL) and surface area based on the stored sump/lake volume. Sump/lake overflows are triggered when the maximum storage volumes are reached. These volumes are calculated from pit geometry and likely overflow points from site contour data. Figure 6 presents the pit lake module.

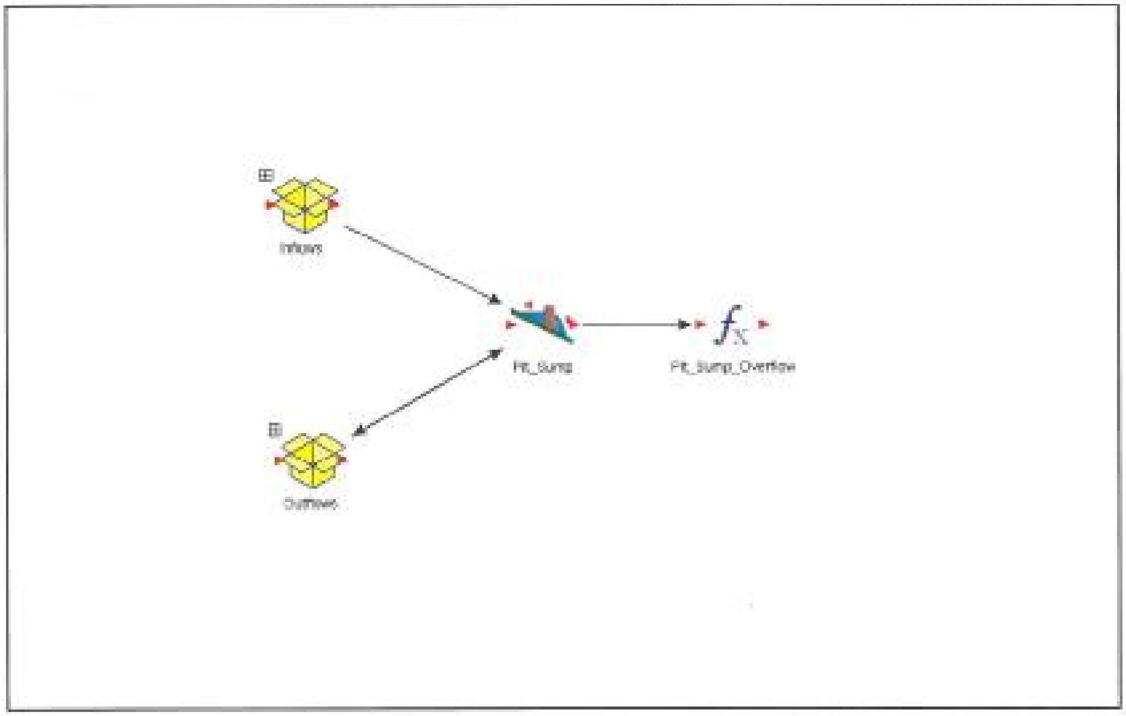


Figure 6: GoldSim pit lake module.

The Frasers Pit catchment includes all catchment areas that report to the pit void. These include WRS, impacted areas and non impacted areas. The Frasers Pit sump collects the run-off and groundwater seepage generated from the Frasers Pit catchments. There are also two additional sumps within the Frasers Pit catchment; these are the Frasers East and Frasers West sumps. The Frasers East sump is located on the eastern side of the pit void and collects non-impacted run-off from the dissected (NBWR). The Frasers Pit was developed within the headwaters of the NBWR. A small stream section still exists, effectively cut off from the lower portion of the NBWR by the Frasers Pit void. Water from this stream section is collected in the Frasers East sump, pumped around the pit and discharged back into the NBWR.

The Frasers West sump is located on the western side of the pit void. This sump collects water from a small catchment and also receives water from the underground operations in Frasers Pit. A small amount of this water is used for dust suppression and the rest is pumped to the MTI and is either evaporated or pumped back to the process plant.

The Round Hill/Golden Point and Southern Pit catchment represents the combined catchment associated with three pits which will be used as the mine is developed. A small sump is assumed to be operating within this combined catchment and run-off and groundwater seepage to the pit is collected in the sump and pumped back to the process plant for reuse. This pit also currently has an overflow through old mining adits. When the pit is dewatered these adits cease to discharge, however if the pit is allowed to fill, seepage through these adits will occur. The adits are planned to be sealed for the Phase III expansion. For the purposes of this model, seepage through these adits (Golder 2011h) is not included in the model.

There will be no active mining within the Deepdell South catchment during the Macraes Phase III expansion project. However, this catchment was modelled and consists of an historical pit void collecting run-off and groundwater seepage from a small non-impacted catchment. When operational, water from this pit was pumped back to the process plant. However, the pit was decommissioned in October 2003 and has been filling as a pit lake since then. Modelling assumes that this pit lake remains empty until October 2003 whereby it then starts filling.

2.3.3 Silt pond modules

The silt pond module is fundamentally the same as the pit lake module in the sense that it is made up of a reservoir element (Silt Pond) and two containers housing the inflow and outflow elements. The inflow elements include direct rainfall to the silt pond, run-off from non-impacted and WRS land use areas and groundwater seepage to the pond.

The pond outflow elements include evaporation from the pond surface and also the pumping rate for the particular pond. The majority of the silt ponds do not have a pumped outflow and only lose water through evaporative losses and overflows during particularly heavy rain.

Stage storage area curve assumptions within the Areas and Stage Storage container dictate the pond RL and surface area based on the stored pond volume. Pond overflow volumes are calculated from silt pond geometry and likely overflow points from site contour data. Figure 7 presents the silt pond module.

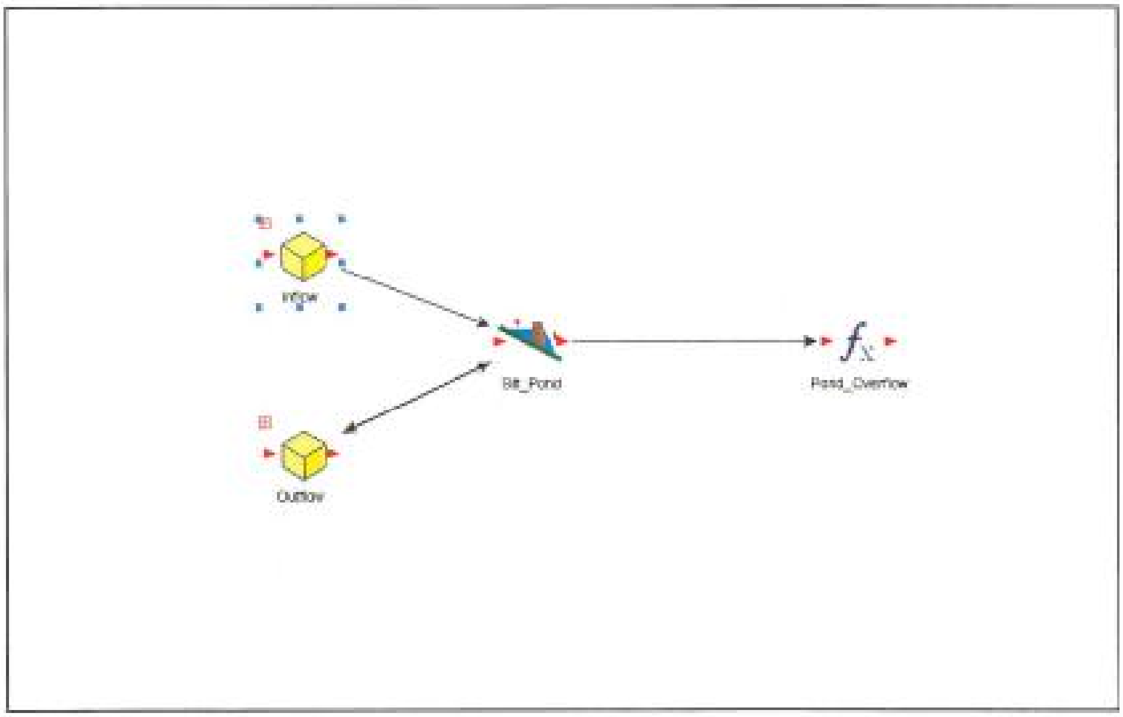


Figure 7: GoldSim silt pond module.

2.3.4 Tailings storage module

The tailings storage module is fundamentally the same as the pit lake and silt pond modules in the sense that it is made up of a reservoir element (the decant pond) and two containers housing the inflow and outflow elements.

The inflow elements include direct rainfall to the tailings decant surface, run-off from the tailings beach surface (both wet and dry surface) and direct tailings transfer from the process. This tailings transfer is located in a separate container where calculations of daily tailings mass transfer and tailings slurry density coupled with assumptions of void ratio and a number of other assumptions produce an estimate of supernatant, or tailings seepage water and a volume of dried tailings entering the facility.

The decant outflow elements include evaporation from the decant surface and also the return water pumping rate for the particular TSF.

Stage storage area curve assumptions within the Areas and Stage Storage container dictate the decant RL and surface area based on the stored decant volume. An overflow element has been included in the model, however, TSF are not designed to overflow and this element is only included as a safety check. Figure 8 presents the tailings storage module.

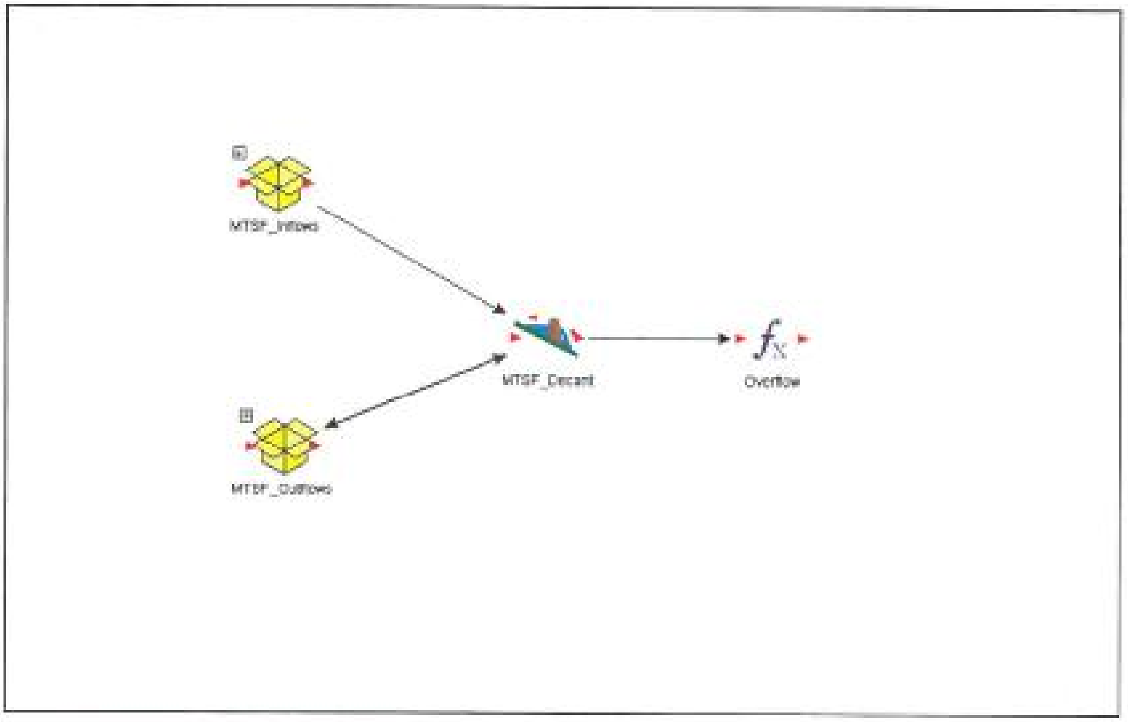


Figure 8: GoldSim tailings storage module.

2.3.5 Process water system module

The Process catchment includes the processing plant, process reservoirs, Lone Pine and the catchment areas reporting to these areas. Lone Pine is a large (approximately 600,000 m^3) freshwater reservoir that supplements the process with fresh water. Water is pumped from the Taieri River some 30 km away and also from the Maori Tommy Gully silt pond to the reservoir. The reservoir also receives run-off from a small non-impacted catchment and also run-off generated from sections of the MTI embankment. A process sump also exists within this catchment and the sump collects process return water from TSFs and also non-process water such as that in the Northern Gully silt pond, Frasers pit sump water and Round Hill/Golden Point pit sump water.

Conceptual models for each stage in the mining and decommissioning phase, including the site components, are provided in Appendix B. The numerical model was structured according to these conceptual modelling schematics, with details of water flow and water quality, at the compliance points located downstream from the mine site.

2.3.6 Receiving environment

The receiving environment module models the natural receiving catchments surrounding the MGP. Specifically the module provides calculation nodes at compliance points and other points of interest within the catchments of Deepdell Creek, Shag River, NBWR and their tributaries. Figure 9 below presents the Deepdell Creek container of the receiving environment module. A data element with a catchment area is linked to the AWBM container to produce a flow rate at each node along the Deepdell Creek. The flow rates along the Deepdell Creek are produced by the accumulation of each node downstream. Lookup tables are used to change data elements to account for different stages in mine development. In the Deepdell Creek example shown in Figure 9, BC_NI represents a lookup table which allows changes in catchment area as the mine site encroaches on non-impacted receiving environment catchment areas. The catchment area lookup tables are linked to the Mine Stage element.

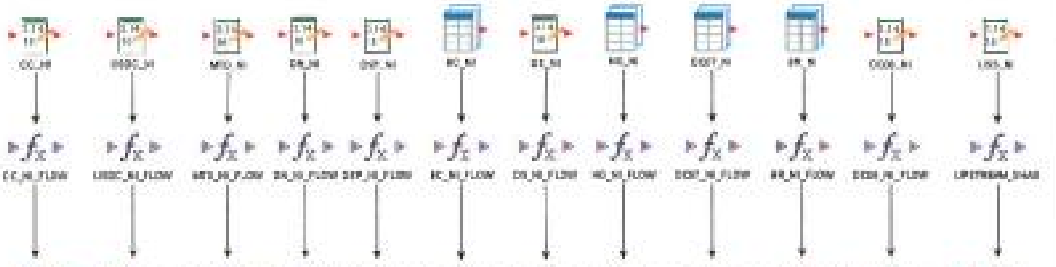


Figure 9: Receiving environment water quantity module (Deepdell Creek).

2.3.7 Water quality module

The water quality module (Material) contains a number of sub-containers that separate components of the water quality system. Figure 10 represents the site wide water quality module container layout.

The Chemistry Assumptions container holds the chemical species and water quality assumptions for run-off for differing land uses (e.g., non-impacted, WRS, impacted, tailings surfaces, rehabilitated WRS), groundwater seepage and TSF drain quality. These data elements are linked throughout the water quality module so that changes can be made in the Chemistry Assumptions container and are automatically updated throughout the model.

The Pits, Silt ponds, TSFs, Process Plant and the Receiving Environment containers hold the chemistry logic for the respective model components and these logics follow the structure of the water quantity component. Within each water quality 'cell', species (chemical) masses contained in the inflows and outflows are combined along with corresponding flow rates generated in the water quantity component of the model. The result is water quality projection of both total mass and concentration at selected reporting points within the model. Figure 11 presents the receiving environment water quality module. The module is set up with a number of 'cells' which generate water quality projections at differing points along Deepdell Creek.

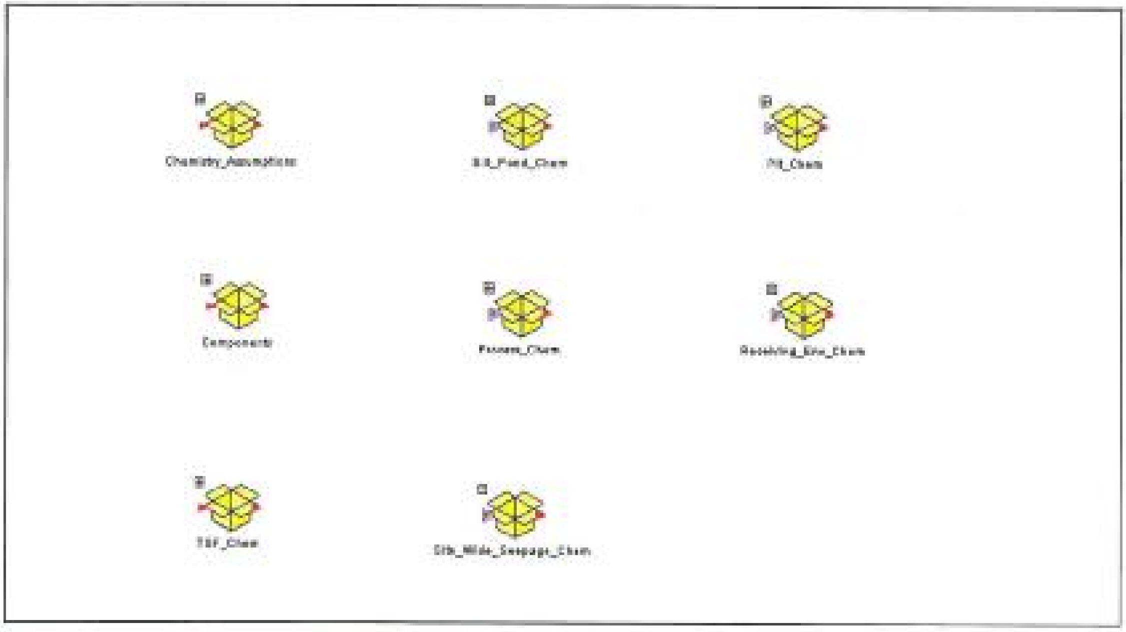


Figure 10: Site wide water quality module overview.

3.0 MODEL INPUTS

3.1 Meteorological Inputs

3.1.1 Rainfall

The model rainfall input data were derived from data recorded at the Glendale Station rainfall gauge (NIWA site # I50341) using a stochastic rainfall generator based on the TPM method (see Section 2.1.4).

Daily rainfall for a 170 year period was required to run the model for the 10 year calibration period (2000 – 2010), the 10 year operational period (2010 - 2020) and 150 year post closure period. To keep the model run time short, 100 realisations of the rainfall generator were run to produce a range of possible site specific rainfall records. The statistics for the 100 realisations are summarised in Table 7. The 50th percentile rainfall record was utilised for the subsequent site water management modelling.

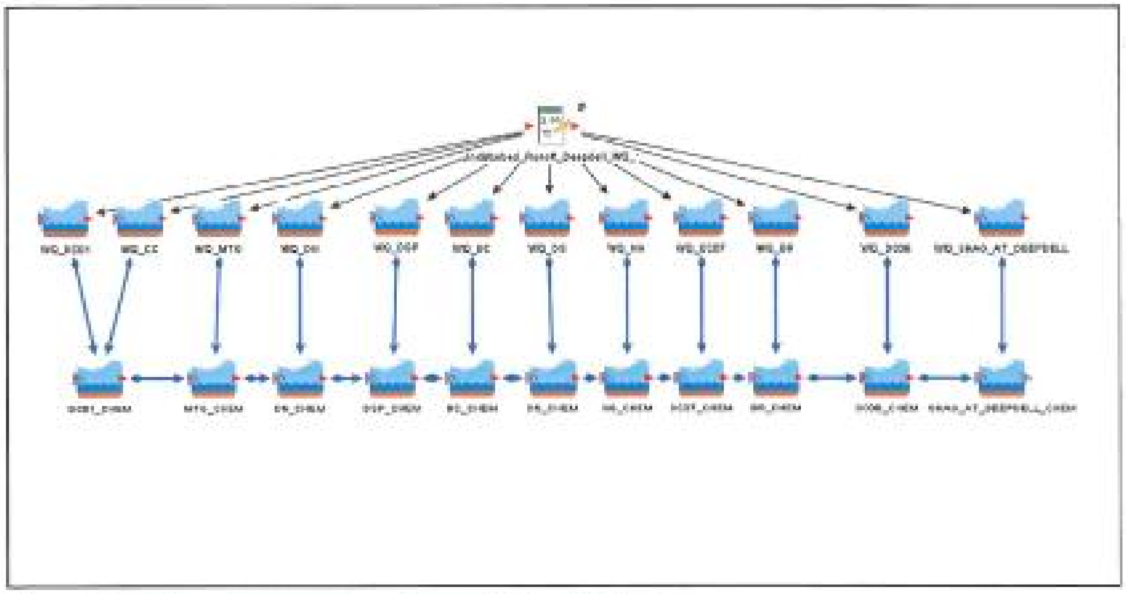


Figure 11: Receiving environment water quality module (Deepdell Creek).

Table 7: Rainfall statistics.

Month	2000-2010				2011-2020				2021-2170			
	Min	Percentile		Max	Min	Percentile		Max	Min	Percentile		Max
		50th	95th			50th	95th			50th	95th	
Jan	15.7	42.6	131.4	138.3	33.2	68.7	99.8	103.5	5.6	63.9	136.2	222.8
Feb	16.0	64.7	110.1	125.8	22.5	41.6	100.4	126.7	4.1	45.2	105.3	207.8
Mar	18.4	46.9	80.5	82.7	13.9	35.3	91.5	124.7	4.7	42.7	120.0	209.8
Apr	6.8	34.8	74.4	85.2	10.6	32.4	95.7	132.4	3.2	43.3	97.5	163.0
May	9.2	34.9	71.9	76.0	12.9	42.1	81.3	84.1	5.9	39.7	105.5	178.8
Jun	8.4	38.8	85.6	105.6	6.9	32.5	114.8	117.3	0.0	37.3	103.7	315.4
Jul	4.3	40.7	126.5	133.3	16.7	50.7	236.0	369.9	2.2	43.0	172.6	307.2
Aug	7.9	34.2	157.3	225.6	10.6	38.6	68.3	76.1	1.4	41.8	115.4	144.7
Sep	22.2	36.7	91.7	104.7	4.7	52.6	84.0	92.9	2.6	47.8	104.0	146.9
Oct	10.3	52.0	86.8	100.4	19.7	56.1	93.6	102.5	9.4	54.8	119.2	221.1
Nov	32.1	41.0	78.3	79.8	33.6	54.3	87.1	89.4	5.3	41.1	87.9	119.0
Dec	47.5	111.7	180.7	201.1	36.9	84.0	117.5	122.8	13.1	75.1	171.8	221.6

Note: All values in units of mm.

3.1.2 Evaporation

Monthly evaporation data is available on-site for the period 1992 to 2008. Daily evaporation data is also available for Palmerston (site I50471) for the period 1986 to present. Palmerston is approximately 25 km distant from the mine site.

Evaporation data utilised in the model (Table 7) represents daily average evaporation based on the particular month of the year. This data has been produced from an evaporation series based on OceanaGold evaporation data collected on-site and also the Palmerston dataset. More detailed information on evaporation data and the relationship between the two datasets is presented in the MGP water management overview report (Golder 2011e).

Evaporation rates from pit lakes are known to be less than standard pan evaporation rates: some pit lakes have less than 80% of standard daily evaporation. Evaporation has, however, been applied to the model based on the pan evaporation data. The calibration process results in setting run-off coefficients that result in predicted run-off rates approximately equal to actual measured flows which means uncertainty in the actual evaporation rates is addressed and is no longer important provided a good calibration is achieved.

The evaporative losses from the surface of the pit lakes as they have evolved have not been adapted for changing lake area on a daily basis. The effect of not incorporating the changing evaporative area on a daily basis is not considered to be substantial, either in terms of eventual water quality or in water levels in the lakes.

Table 8: Daily pan evaporation rates averaged on a monthly basis used in the GoldSim model.

Month	Evaporation (mm)
January	4.3
February	3.7
March	2.9
April	1.9
May	1.3
June	1.1
July	1.1
August	1.6
September	2.3
October	3.2
November	3.8
December	4.2

3.2 Catchment Areas and Mining Elements

As mining develops, mining areas expand and non-impacted areas reduce. For this reason, catchment areas within the model are also dynamic. Catchments have been defined for each major mining element within the mine site including:

- TSFs – Mixed Tailings, Top Tipperary, SP10 and SP11.
- Water Reservoirs and Silt Ponds – e.g., Lone Pine.
- Open Pits – e.g., Frasers, Round Hill, Golden Point, Innes Mill.
- WRS's (e.g., Frasers East, Frasers West, Back Road).

As the mine develops, the mining elements change with corresponding changes to the catchment areas. The catchments associated with the five stages of mine development (Section 1.4) are shown in Figure 13 (Stage 0) to Figure 16 (Stage 4).

Catchment areas have also been defined for major areas outside of the mine site and will cover all non-mined land and catchments which contribute to flow at the various compliance points.

As shown in Table 9 the mine site constitutes 4.9% of the total combined catchment areas of the Shag and NBWR upstream of the existing compliance points. Table 10 presents a breakdown of the catchment areas for the different stages of the mine life.

Table 9: Catchment areas of the mine site.

Catchments	Area (km^2)
Total catchment area upstream of the Shag River and NBWR compliance points	470
Area of mine site	21

Table 10: Comparison of contributing areas upstream of the Shag River and NBWR compliance points.

Contributing areas (ha)	Stages				
	0	1	2	3	4
Percentage of impacted mine site to total mine area	59	72	82	83	16
Percentage of non-impacted mine site to total mine area	41	28	18	17	19
Percentage of rehabilitated mine site to total mine area	0	0	0	0	67
Percentage of impacted mine site to total catchment area	2.9	3.5	4.0	4.0	0.76
Percentage of non-impacted land to total catchment area	97	96	96	96	96
Percentage of rehabilitated mine site to total catchment area	0	0	0	0	3.2

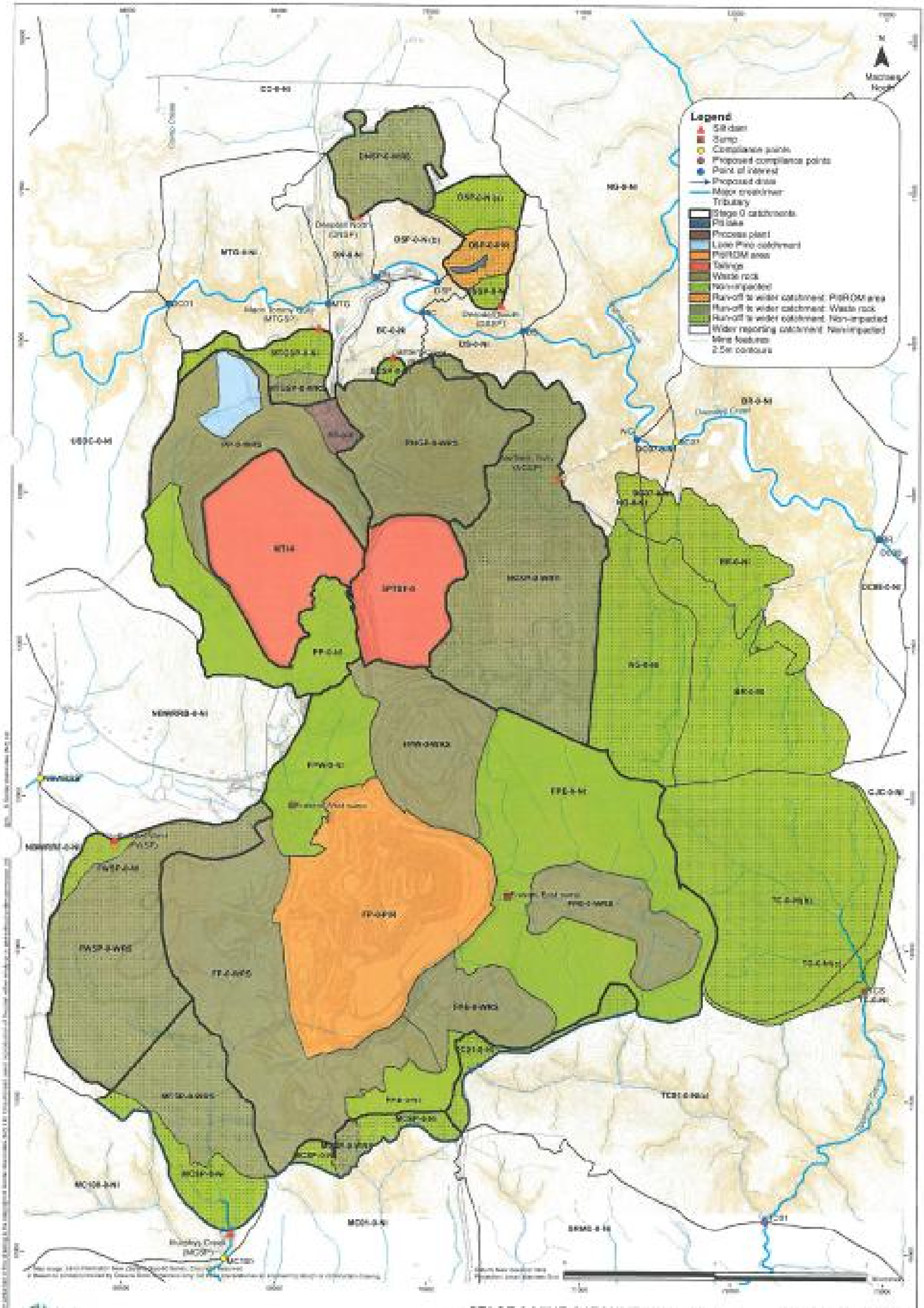
Catchments for each mining stage have been delineated based on run-off quantity and run-off quality. Stage 0 represents the existing situation at the end of 2010 (Figure 12). The first stage of Macraes Phase III is Stage 1 (Figure 13) where Frasers Pit is extended (and assumed to be at its maximum extent for this stage) and Frasers South and North WRS are constructed (assumed to be at their maximum extent). Stage 2 (Figure 14) represents the completion of Frasers Pit and commencement of mining within the Round Hill-Southern Pit and the Back Road WRS. The final stage of mining is Stage 3 (Figure 15) represents mining within the Innes Mills Pit while Stage 4 (Figure 16) represents the site at closure. The catchment areas used in the model for each stage of modelling are provided in Appendix C.

3.3 Catchment Run-off

Catchment run-off coefficients

Catchment run-off within the model is calculated as outlined in Section 2. For natural undisturbed catchments the AWBM run-off calculator is used to convert catchment rainfall to run-off. For non-impacted mining areas and rehabilitated WRS surfaces the AWBM is also used. The AWBM on average yields around 12% of rainfall reporting as run-off.

Run-off from mining surfaces is based on the rational method using a number of different run-off assumptions and these are based around catchment land use. Depending on the land use type, the rainfall reporting from these surfaces vary. Table 11 outlines the run-off coefficients used for impacted mining areas. Rainfall events were analysed for likely return period and an appropriate coefficient assigned to each event.



Golder Associates

STAGE 0 MINE CATCHMENT LAYOUT

MARCH 2011

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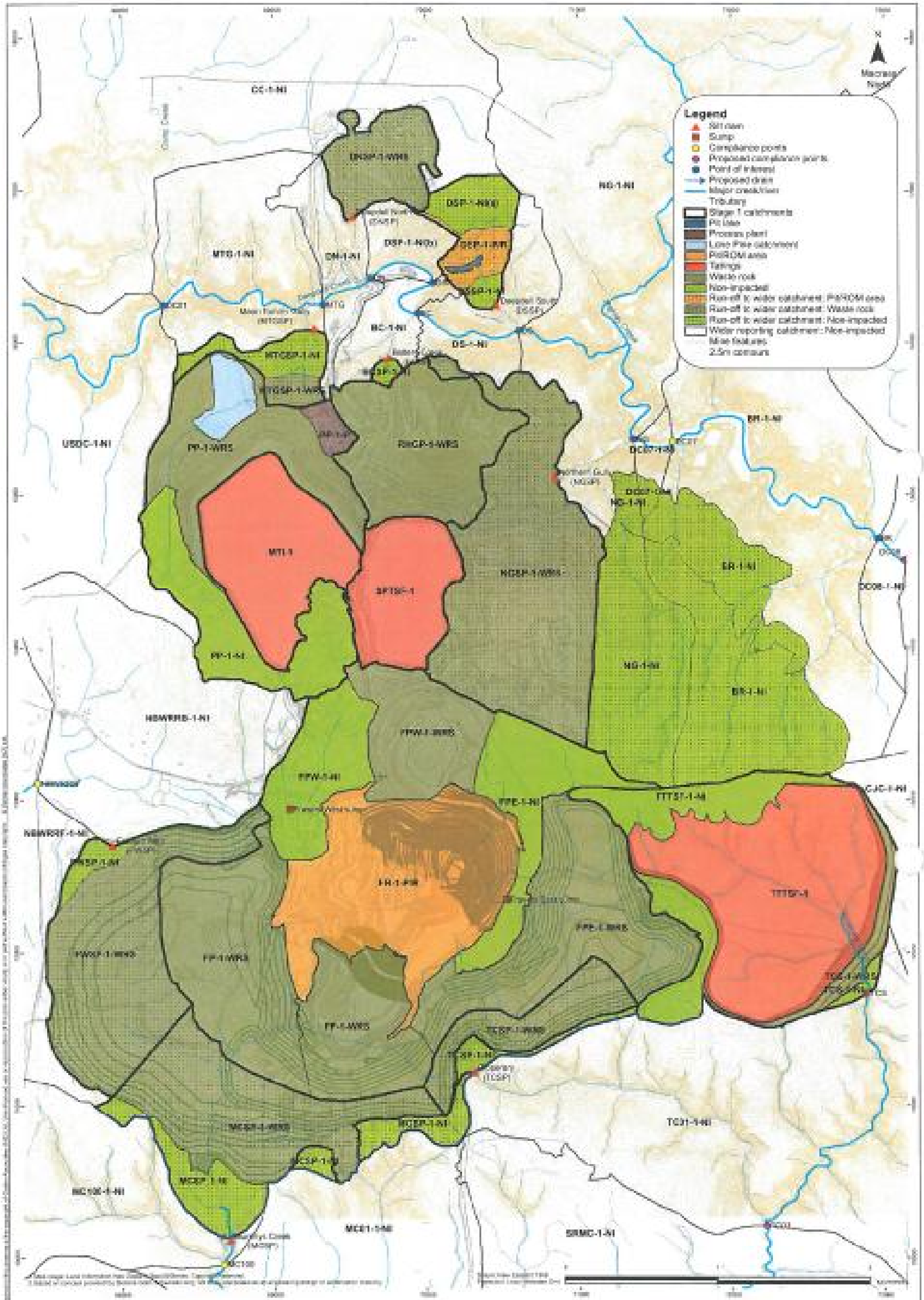
12



STAGE 1 MINE CATCHMENT LAYOUT

MARCH 2011

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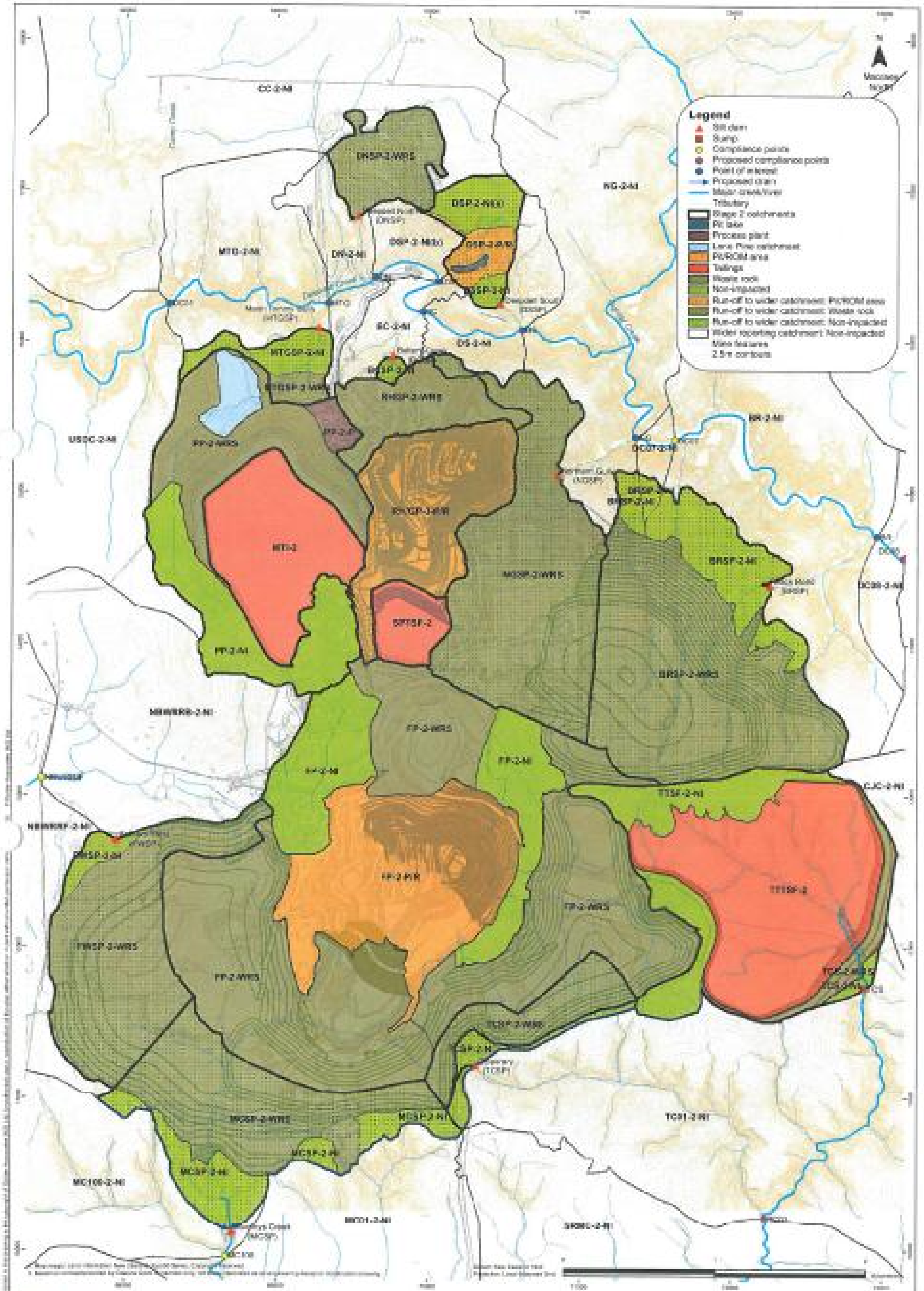
Golder Associates



Golder Associates

STAGE 2 MINE CATCHMENT LAYOUT

MARCH 2011

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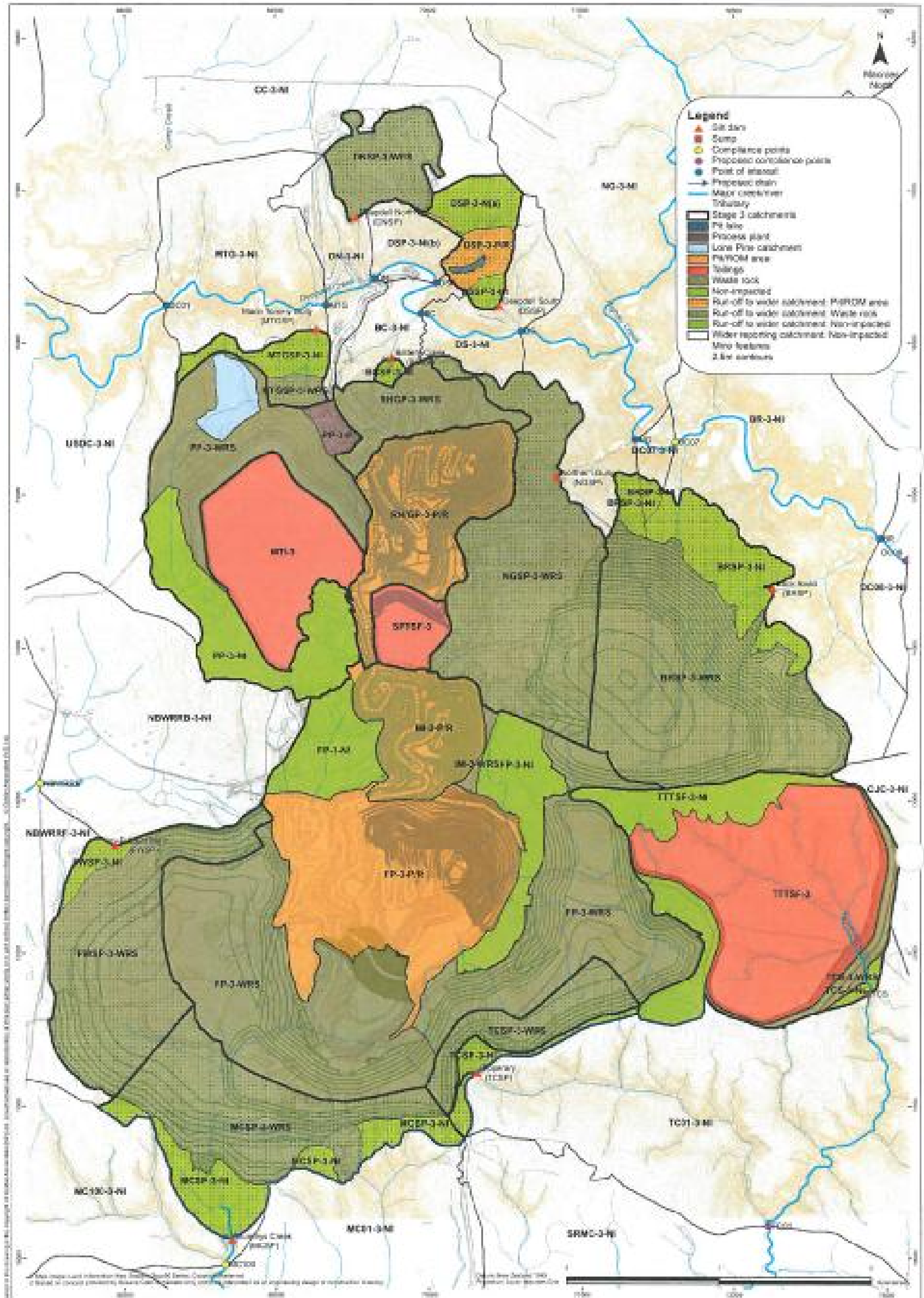
14



STAGE 3 MINE CATCHMENT LAYOUT

MARCH 2011

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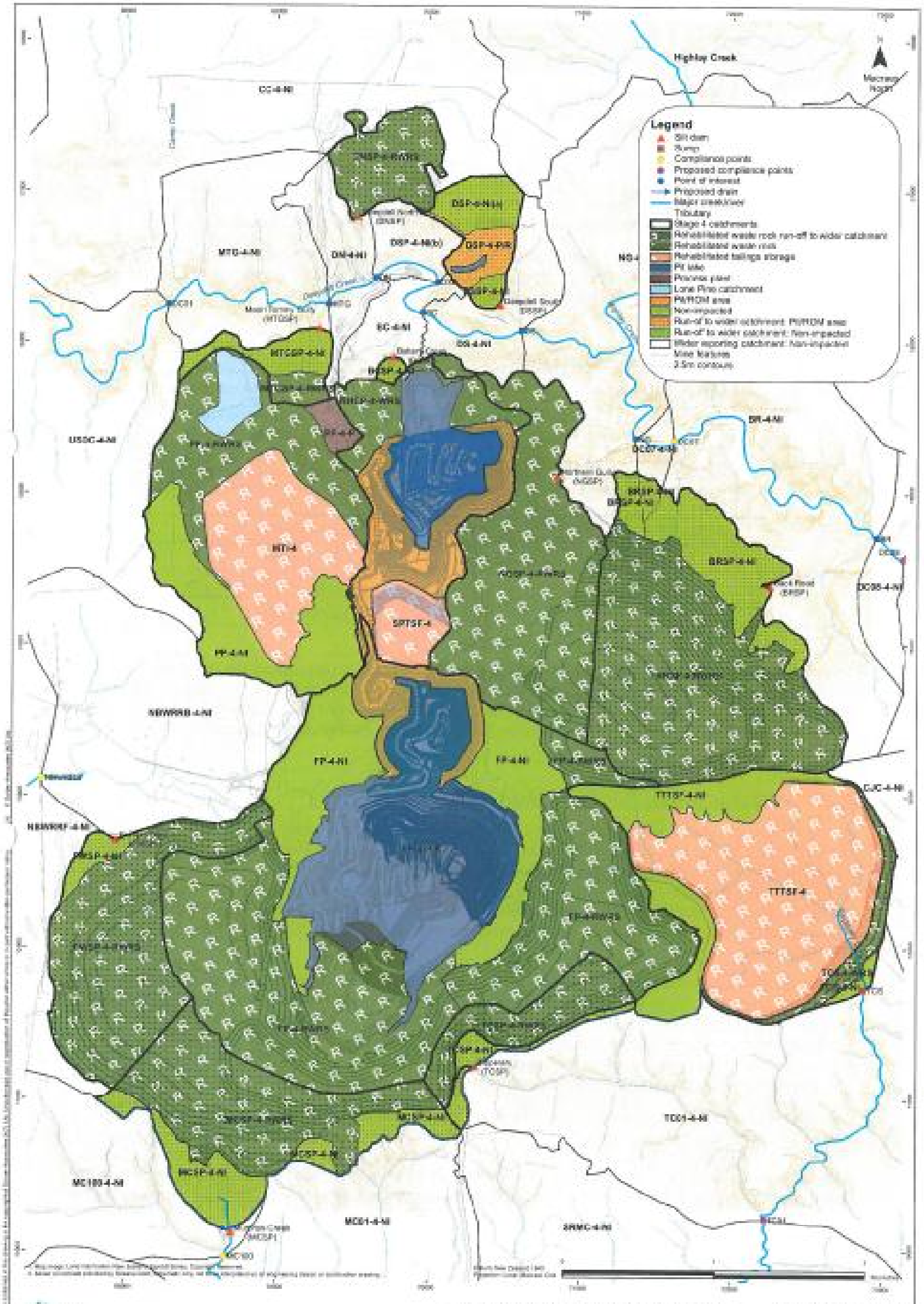
15



Golder Associates

STAGE 4 MINE CATCHMENT LAYOUT

MARCH 2011

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16

Anecdotal evidence suggests that minimal run-off occurs from WRS and the porous nature of the waste rock results in water percolating through and either entering the groundwater system or eventually evaporating. For the purposes of modelling the run-off coefficients in Table 11 have been adopted. Rainfall events were analysed for likely return period and an appropriate coefficient assigned to each event.

For impacted mining areas and WRS's a run-off coefficient is assigned to the catchment rainfall based on the daily rainfall total. For impacted areas, model projections indicate around 14% of rainfall reports as run-off. For WRSs, the model predicts around 3.5% rainfall reporting as run-off.

Table 11: Impacted area run-off coefficients.

	Daily rainfall (mm)	Run-off coefficients	Return period of rainfall event
Pit Areas	0 - 10	0.05	<1 year
	10 - 50	0.2	1- 5 year
	50 - 90	0.4	>5 year but <20 year
	>90	0.7	>20 year
WRS Areas	0 - 10	0	<1 year
	10 - 50	0.05	1- 5 year
	50 - 90	0.15	>5year but <20 year
	>90	0.4	>20 year

The majority of the Deepdell Creek catchment (upstream of the DC08 site) utilises the Deepdell Creek AWBM run-off calculator. The lower Deepdell Creek and upper, middle and lower Shag River catchments utilise the Shag River AWBM run-off calculator. The upper Cranky Jims Creek, Tipperary Creek, Murphys Creek and the NBWR catchments also utilise the Deepdell Creek AWBM run-off calculator.

3.4 Water level, Surface Area, Volume Inputs

As the standard model outputs are volumetric, simple relationships have been developed and included in the model for each sump, silt pond or decant pond which relate volume to both water level and surface area. These relationships allow evaporation losses to be assessed and key deliverables such as decommissioned pit filling rates, silt pond overflow volumes and maximum pond volumes to be calculated. For existing silt ponds the volume/water level and volume/surface area relationships were provided by OceanaGold. For proposed silt ponds, the relationships were developed using GIS analysis of contours at their proposed locations.

Similar volume/water level and volume/surface area relationships are required for the various pits on the mine site. To ensure run times for the model are acceptable the model has be simplified by combining the various pits on the mine site into three separate pit areas Frasers/Innes Mills, Golden Point/Round Hill/Southern and Deepdell South, Relationships for each of the three pit areas were developed using assigned pit geometries which represent the combined geometry of the relevant individual pits. The pit geometries were developed using GIS analysis of proposed mining contours provided by OceanaGold.

As each stage of mining commences, the individual mining areas will converge to form the combined pit areas. The volume/water level and volume/surface area relationships for the pits evolve over time as the pits are worked, where in-pit tailings are mined and removed in the case of SP11 and where pits are backfilled with waste rock. At closure, two pit lakes will develop, as run-off and groundwater seepages are allowed to fill the pits. Lookup tables are used within the model to account for changes in pit geometry and catchment areas associated with the different stages in mine development. It should be noted that the Deepdell South pit is not proposed to change during the Macraes Phase III project as no mining is scheduled to occur in that pit.

Volume/water level and volume/surface area relationships for Lone Pine were provided by OceanaGold.

TSFs do not have volume/water level and volume/surface area relationships as TSFs are usually large and relatively shallow with a large sloping beach. OceanaGold provided information on the surface area of the existing and proposed impoundments. The maximum surface area supplied for each TSF has been used in the model and an unlimited maximum volume has been assumed which allows the model to output potential volumes within each TSF.

Table 12 below outlines the maximum volumes for each pit, sump or pond as well as the overflow RL.

Table 12: Pit, reservoir/sump and silt pond maximum capacity and overflow RL.

Pit, Reservoir/Sump and Silt Pond	Maximum volume (m^3)	Water elevation at overflow [1] (mRL)
Frasers/Innes Mills Pit	222,000,000	503
Golden Point/Round Hill/Southern Pit	25,600,000	405
Deepdell South Pit	126,000	380
Frasers East Pond	10 000	N/A
Frasers West Pond	10 000	N/A
Deepdell North Silt Pond	29,000	427
Deepdell South Silt Pond	9,300	373
Maori Tommy Gully Silt Pond	91,000	373
Battery Creek Silt Pond	7,900	366
Northern Gully Silt Pond	41,000	406
Back Road Silt Pond [2]	49,000	408
Fraser's West Silt Pond	46,000	498
Murphy's Creek Silt Pond	47,000	435
Tipperary Creek Sump	7,900	N/A
Lone Pine	610,000	444

Notes: [1] mRL = metres above mean sea level; [2] Back Road silt pond may not be constructed as other silt management measures are likely to be applied. This change would have no water quality implications for the mine water management model as the model is not simulating total suspended solids.

Appendix D presents all the volume/water level and volume/surface area relationship curves that were used in the model.

3.5 Run-off Water Quality

3.5.1 Introduction

Surface water geochemistry is broken down into three situations:

- Undisturbed surface water geochemistry, namely surface water which drains from natural areas not affected by mining.

- Non impacted surface water geochemistry, namely surface water which drains from either natural areas or rehabilitated WRS which are not directly affected by mining activities (i.e., natural areas within the mine site which are affected by dust).
- Impacted surface water geochemistry, namely surface water which drains from areas within the mine site which are directly affected by mining activities.

The following sections outline the geochemistry assumptions for each of the three situations. The water quality input values presented in the following sections have been derived from MGP environmental monitoring records as summarised in Appendix E. Where input values are based on monitoring records or modelling projections where water quality parameters were below laboratory method detection limits, the detection limit was used for the geochemistry input assumption.

3.5.2 Undisturbed surface water geochemistry

The geochemistry of surface water run-off which drains from natural areas not affected by mining is presented in Table 13. Undisturbed or background geochemistry was assigned for each catchment based on baseline water quality data contained in the water quality database for the MGP (Golder 2011d). Baseline water quality varies slightly across the site due to localised conditions and particularly catchment geology. Run-off from the Deepdell Creek and Shag River catchments tends to have the lowest concentrations of the key geochemical parameters. Run-off from the NBWR and Murphys Creek catchments tend to have the highest concentrations of the key geochemical parameters. Run-off from the catchments of Tipperary Creek, McCormicks Creek, and Cranky Jims Creek tends to have concentrations, of the key geochemical parameters, which are between the other two groups.

Table 13: Undisturbed surface water geochemistry assumptions (all mining stages).

Parameter (1)	Catchments			
	Deepdell/Shag	**Tipperary/McCormicks/ Cranky Jims**	**NBWR/Murphys**	**NBWR downstream (2)**
Arsenic	0.0015	0.005	0.007	0.0058
Sulphate	4	4	47	58
Cyanide $_{WAD}$	0.003	0.005	0.005	0.002
Copper	0.0011	0.002	0.001	0.002
Iron	0.2	0.5	0.1	0.18
Lead	0.0001	0.001	0.001	0.001
Sodium	11	11	13	12
Potassium	1	2	2	1.6
Calcium	13	10	36	24
Magnesium	4	4	12	11
Zinc	0.005	0.005	0.005	0.004
Chloride	11	11	10	12

Notes: (1) All concentrations presented in units of g/m^3; and (2) area downstream from Ross Ford.

These apply for all mining phases throughout the modelling period.

3.5.3 Non-impacted surface water geochemistry

Non-impacted geochemistry includes all the run-off generated from surfaces which are indirectly affected by mining activities. These areas include:

- Areas within the mine site that are still in a natural state but are impacted by mining (i.e., natural areas which are affected by mine dust).
- Rehabilitated WRS.

The geochemistry of surface water run-off from surfaces which are indirectly affected by mining activities is presented in Golder (2011d). The geochemistry is assumed to be the same for all mining stages. The non-impacted surface water geochemistry was based on water quality data contained in the water quality database for the MGP (Golder 2011d).

3.5.4 Impacted surface water geochemistry

Impacted geochemistry includes all the run-off generated from surfaces which are directly affected by mining activities. These include:

- Pit walls.
- Processing areas.
- WRS (unrehabilitated).
- Rehabilitated tailings surfaces.

The geochemistry of surface water run-off from surfaces which are directly affected by mining activities is presented in Table 14. The geochemistry is assumed to be the same for all mining stages. The impacted surface water geochemistry was based on water quality data contained in the water quality database for the MGP (Golder 2011d).

Table 14: Non-impacted and impacted surface water geochemistry assumptions (all mining stages).

	Non-impacted areas	Impacted areas
Arsenic	0.021	0.1
Sulphate	125	201
Cyanide $_{WAD}$	0.001	0.001
Copper	0.001	0.002
Iron	0.05	0.135
Lead	0.0001	0.001
Sodium	15	28
Potassium	3	4
Calcium	46	63
Magnesium	26	34
Zinc	0.005	0.005
Chloride	6	13

Note: All data g/m^3.

3.6 Hydrogeological Inputs

3.6.1 Seepage and drainage flows

3.6.1.1 Introduction

Groundwater inflows have been calculated in a separate groundwater model and were inputted into the surface water model. Detailed information on the groundwater assumptions and calculations can be found in groundwater modelling reports by Golder (2011b,c). Groundwater inflows are generally fixed inflows that vary with mine stage. Generally mine elements have a groundwater inflow rather than a groundwater outflow. For example, a WRS does not have a groundwater outflow or seepage, rather, the silt pond down slope of the WRS has a groundwater inflow or seepage that accounts for the WRS. The exception to this rule is TSF under-drains. These do generate a seepage that is routed according to the model logic.

3.6.1.2 TSF groundwater assumptions

Groundwater seepages from the tailings body are assumed to exit the facilities and these are incorporated into seepage inflows to other mine elements. TSF under-drains intercept seepage from the tailings body and the chimney drains intercept seepage from the TSF impoundment bund. Together these form the TSF drain seepage and these assumptions are routed as per the model logic for differing stages. Table 15 below presents the groundwater seepage assumptions generated within the TSF drains.

Table 15: TSF drainage systems discharge rates.

TSF Drainage Systems	Operational stage [1,2]					
	0	1	2	3	4	Closure + 150 years
MTI [3]	1,500	800	640	480	240	300
SPI [3]	1,000	200	160	120	60	26
TTTSF [4]	0 [5]	1,800	1,800	1,800	260	260

Notes: [1] All values presented in units of m^3/day; [2] the rates at which tailings discharges to the TSF drain systems decline have been calculated based on observed rates of decline (Golder 2011g) rather than from the rates of decline simulated in the groundwater models; [3] assumes tailings deposition primarily in MTI through until close of both impoundments and takes into account removal of SP11; [4] the seepage water discharge rates to the TTTSF drain systems has been sourced from Golder 2011c; and [5] TTTSF not yet constructed.

3.6.1.3 Pits and pit lakes groundwater assumptions

Pit groundwater inflow rates are dependent on two factors: the mining stage and the pit reduced level (RL). As the mine is developed groundwater inflow rates may change depending on the degree of development. Additionally, as the pit lake starts to fill at closure, the groundwater inflow rates are dependent on the pit lake level.

Table 16 and Table 17 below present the groundwater inflow matrix used to assign groundwater inflow rates in the model. Groundwater inflow rates are interpolated between stages and between RLs in the model.

3.6.1.4 Silt Pond groundwater assumptions

Silt pond inflow rates are dependent on mine staging. Groundwater inflows are fixed assumptions based on the groundwater models (Golder 2011 b, c). Table 18 below presents the groundwater seepage assumptions that report to silt ponds.

Table 16: Round Hill/Golden Point/Southern Pit groundwater inflow matrix.

Pit Water Elevation (mRL)	Operational stage (1)						
	-1	0	1	2	3	4	Closure + 150 years
220	160	160	178	178	178	178	178
340	160	160	156	156	156	156	156
400	160	160	134	134	134	134	134
430	160	160	90	90	90	90	90
530	160	160	90	90	90	90	90
580	160	160	90	90	90	90	90

Note: All values presented in units of m^3/day.

Table 17: Frasers/Innes Mills Pit groundwater inflow matrix.

Pit water elevation (mRL)	Operational stage (1)						
	-1	0	1	2	3	4	Closure + 150 years
190	290[1]	685	685	685	1,275	1,275	1,275
250	290	685	685	685	318	318	318
430	290	685	685	685	248	248	248
480	290	685	685	685	NA (2)	52	52
520	290	685	685	685	NA (2)	52	52

Notes: (1) All values presented in units of m^3/day; and (2) water level managed due to need to operate in Innes Mills pit.

Table 18: Silt pond groundwater inflow assumptions.

Silt pond/sump	Operational stage (1)						
	-1	0	1	2	3	4	Closure + 150 years
Deepdell North Silt Pond (2)	0	0	0	0	0	0	0
Deepdell South Silt Pond (2)	0	0	0	0	0	0	0
Maori Tommy Gully Silt Pond	70	70	70	70	70	70	70
Battery Creek Silt Pond (2)	0	0	0	0	0	0	0
Northern Gully Silt Pond	70	70	70	70	70	40	40
Frasers West Silt Pond	150	150	150	150	150	54	54
Murphys Creek Silt Pond	24	24	24	24	24	122	122
Back Road Silt Pond (3)	0 (4)	0 (4)	0 (4)	65	65	65	65
Tipperary Sump (5)	0 (4)	0 (4)	140	140	140	30	30

Notes: (1) All values presented in units of m^3/day; (2) simulated silt ponds do not receive groundwater seepage (this is supported by observations at Deepdell South and Battery Creek however may not be the case for Deepdell North); (3) Back Road silt pond may not be constructed as other silt management measures are likely to be applied (this change would have no water quality implications for the mine water management model as the model is not simulating total suspended solids); (4) silt pond not yet constructed; and (5) the groundwater seepage rates to silt ponds in the Tipperary Creek catchment has been sourced from the Golder 2011c report and included here for completeness sake.

3.6.1.5 Receiving waterways groundwater assumptions

Each receiving waterway has an assigned site wide groundwater seepage assumption. This groundwater seepage is calculated within the separate groundwater model and is simply a fixed input at certain points along the stream. It is treated like a small point source inflow but actually represents seepage that naturally accumulates along the stream. Modelling assumes:

- Groundwater seepage enters Deepdell Creek at DC07 and DC08.
- Groundwater seepage enters the Cranky Jims Creek at CJ01.
- Groundwater seepage enters the Tipperary Creek at TC01.
- Groundwater seepage enters Murphys Creek at MC100 .
- Groundwater seepage enters NBWR at NBWRRB.

The assumptions are fixed groundwater seepages and the flow rates are provided in Table 19.

Table 19: Receiving water groundwater inflow assumptions.

Receiving water	Operational stage (1,2)						
	-1	0	1	2	3	4	Closure + 150 years
Deepdell Creek at DC07	660[1]	730	730	730	730	730	660
Deepdell Creek at DC08	N/A	BG (2)	BG (2)	350	350	350	350
Cranky Jims Creek at CJ01 (3)	N/A	BG (4)	54	54	54	54	54
Tipperary Creek at TC01 (3)	N/A	BG (4)	440	440	440	660	660
Murphys Creek at MC100	180	180	180	180	180	180	180
North Branch Waikouaiti River at NBWRRB	100	100	100	100	100	100	100

Notes: (1) All values presented in units of m^3/day; (2) background water quality in catchment area as construction on Back Road WRS not yet initiated; (3) the groundwater rates to receiving waters in the Tipperary Creek catchment has been sourced from Golder 2011c; (4) background water quality in catchment area as construction on TTTSF not yet initiated; and N/A – not available.

3.6.2 Groundwater seepage and TSF drainage water quality

3.6.2.1 Tailings storage facilities

TSF seepage drain flow water quality assumptions are presented in Table 20 below. During operation, seepage from the TSFs follows the operational assumptions below. Following closure the TSF assumptions change as outlined in the last column of Table 20.

3.6.2.2 Pits and pit lakes

Pit lake groundwater seepage inflow quality derived from the site wide groundwater model (Golder 2011b) is presented in Table 21. These assumptions remain unchanged throughout the mine staging.

3.6.2.3 Silt ponds/sumps

Silt pond groundwater inflow chemistry is presented in Table 22 for all silt ponds where chemistry inputs do not change with mine stages. Maori Tommy Gully and Tipperary Sump assumptions vary throughout mine stages. For Maori Tommy Gully Silt Pond and Tipperary Sump, Stages -1 to 3 remain the same but following closure in Stage 4 the chemistry assumptions change due to operational changes. The chemistry changes due to the fact that tailings seepages are now not actively pumped back to the process.

Table 20: TSF drain discharge water quality.

Parameter [1, 2]	Operational seepage water quality			Tailings seepage water quality following TSF closure.
	TTTSF	MTI	SPI	
Arsenic	2.7	4.15	4.15	0.58
Sulphate	2,756	2,750	2,763	2,300
Cyanide $_{WAD}$	0.036	0.051	0.022	0.08
Copper	0.011	0.003	0.02	0.003
Iron	7.1	13	0.71	19
Lead	0.0006	0.0005	0.0008	0.001
Sodium	377	435	318	404
Potassium	40	43	36	16
Calcium	473	445	500	410
Magnesium	263	260	266	200
Zinc	0.022	0.017	0.028	0.022
Chloride	33	37	30	47

Notes: [1] All values presented in units of g/m^3; and [2] TSF drainage discharge water quality has been sourced from Golder (2011d) and included here for completeness sake.

Table 21: Pit and pit lake water quality assumptions.

Parameter [1]	Frasers Pit/Innes Mills	Round Hill/Golden Point/ Southern Pit	Deepdell South Pit
Arsenic	0.057	0.43	0.00001
Sulphate	450	900	5
Cyanide $_{WAD}$	0.4	1.18	0.00001
Copper	0.001	0.003	0.00001
Iron	2.4	8.06	0.002
Lead	0.00001	0.001	0.00001
Sodium	18.7	51.7	0.13
Potassium	1.8	4.09	0.027
Calcium	83	220	0.99
Magnesium	40	118	0.61
Zinc	0.004	0.009	0.00001
Chloride	13.8	40.8	0.023

Note: All values presented in units of g/m^3.

Table 22: Silt pond seepage water quality assumptions for all mining stages.

Parameter[1]	Deepdell North	Deepdell South	Battery Creek	Northern Gully	Frasers West (NBWR)	Murphys Creek	Back Road	Tipperary Creek
Arsenic	0.011	0.00001	0.00001	0.001	0.001	0.00001	0.00001	0.00001
Sulphate	38.6	15.4	1,200	2,300	1,500	1,320	2,200	100
Cyanide $_{WAD}$	0.00001	0.00001	0.00001	0.013	0.00001	0.00001	0.00001	0.00001
Copper	0.001	0.00001	0.00001	0.003	0.001	0.001	0.002	0.00001
Iron	0.170	0.00001	0.00001	0.93	0.42	0.52	0.91	0.037
Lead	0.001	0.00001	0.00001	0.00001	0.00001	0.00001	0.00001	0.00001
Sodium	16	10.8	36	57.7	26.2	33	56.4	2.34
Potassium	5.5	1.89	10	12	5.47	6.69	11.7	0.49
Calcium	68.5	40.2	290	434	199	250	425	17.6
Magnesium	14.5	7.7	200	360	165	204	352	14.7
Zinc	0.00001	0.00001	0.00001	0.032	0.015	0.018	0.032	0.00001
Chloride	11.5	7.1	10	10.2	4.69	6.03	9.99	0.42

Notes: [1] All values presented in units of g/m^3; and [2] the quality of groundwater discharging to silt ponds in the Tipperary Creek catchment has been sourced from the Golder 2011b report and included here for completeness sake.

Table 23 presents the water quality assumptions used for groundwater inflows to the Tipperary Sump. The simulated water quality outcomes from the groundwater model (Golder 2011c) for discharges to the Tipperary Sump do not change during the operational period of the mine (Table 23). This lack of change is due to the time delay between the start of tailings disposal in the TTTSF and the down-gradient response of water quality in the groundwater system.

Table 23: Tipperary Sump seepage water quality assumptions for mine stages.

Parameter (1,2)	Operational Stage						
	-1	0	1	2	3	4	Closure +150 years
Arsenic	0.00001	0.00001	0.00001	0.00001	0.00001	0.00001	0.00001
Sulphate	100	100	100	100	100	1,500	1,500
Cyanide $_{WAD}$	0.00001	0.00001	0.00001	0.00001	0.00001	0.00001	0.00001
Copper	0.00001	0.00001	0.00001	0.00001	0.00001	0.00001	0.00001
Iron	0.035	0.035	0.035	0.035	0.035	0.035	0.035
Lead	0.00001	0.00001	0.00001	0.00001	0.00001	0.00001	0.00001
Sodium	2.3	2.3	2.3	2.3	2.3	2.3	2.3
Potassium	0.45	0.45	0.45	0.45	0.45	0.45	0.45
Calcium	19.8	19.8	19.8	19.8	19.8	19.8	19.8
Magnesium	15.4	15.4	15.4	15.4	15.4	15.4	15.4
Zinc	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Chloride	0.50	0.50	0.50	0.50	0.50	0.50	0.50

Notes: [1] All values presented in units of g/m^3; and [2] the quality of groundwater discharging to silt ponds in the Tipperary Creek catchment has been sourced from Golder (2011c) report and included here for completeness sake.

This is a simplification of the actual situation; however groundwater discharges to the creek upstream from the sump are to be managed by pumping during the operational period of the mine. The practical effect of this simplification is therefore expected to be minimal.

Table 24 presents the water quality assumptions used for groundwater inflows to the Maori Tommy Gully silt pond.

Table 24: Maori Tommy Gully silt pond seepage water quality assumptions for mine stages.

Parameter	Operational stage						
	-1	0	1	2	3	4	Closure +150 years
Arsenic	0.6	0.6	0.6	0.6	0.6	0.6	0.6
Sulphate	1,270	1,270	1,270	1,270	1,270	600	600
Cyanide $_{WAD}$	1.14	1.14	1.14	1.14	1.14	1.14	1.14
Copper	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Iron	6.92	6.92	6.92	6.92	6.92	6.92	6.92
Lead	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Sodium	22.5	22.5	22.5	22.5	22.5	22.5	22.5
Potassium	1.04	1.04	1.04	1.04	1.04	1.04	1.04
Calcium	238	238	238	238	238	238	238
Magnesium	110	110	110	110	110	110	110
Zinc	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Chloride	71	71	71	71	71	71	71

Note: All values presented in units of g/m^3.

3.6.2.4 Receiving waterways

The receiving water seepages quality assumptions follow the seepage rates and apply to the receiving environment nodes as discussed in Section 2.3.6. These are for the site wide ground water seepages associated with:

- Groundwater seepage entering Deepdell Creek at DC07 and DC08.
- Groundwater seepage entering Cranky Jims Creek at CJ01.
- Groundwater seepage entering Tipperary Creek at TC01.
- Groundwater seepage entering Murphys Creek at MC100.
- Groundwater seepage entering NBWR at NBWRRB.

Table 25 presents the water quality assumptions for the receiving waterways groundwater seepage.

Table 25: Receiving waterways groundwater seepage water quality.

Parameter [1]	Deepdell Creek		Cranky Jims Creek [2]	Tipperary/ McCormicks Creek [2]	Murphys Creek	North Branch Waikouaiti River
	DC07	DC08	CJ01	TC01	MC100	NBWRRB
Arsenic	0.057	0.0001	0.000	0.0001	0.0001	0.00003
Sulphate	590	1,050	580	530	380	1,090
Cyanide $_{WAD}$	0.06	0.0001	0.000	0.01	0.0001	0.00007
Copper	0.001	0.0012	0.000	0.0001	0.0001	0.0012
Iron	0.47	0.44	3.0	3.28	0.15	0.44
Lead	0.001	0.0001	0.000	0.0001	0.0001	0.00009
Sodium	15	28	54	54	10	27
Potassium	3	6	3	3.3	2	6
Calcium	110	203	94	94	72	206
Magnesium	90	167	70	70	59	170
Zinc	0.008	0.015	0.000	0.01	0.005	0.008
Chloride	9	5	9	9	2	5

Notes: [1] All values presented in units of g/m^3; and [2] the quality of groundwater discharging to receiving waters in the Tipperary Creek catchment has been sourced from the Golder (2011c) and included here for completeness sake.

3.7 Process Water System Inputs

3.7.1 Introduction

The Process Plant and associated systems have a number of sumps and reservoirs that collect process type water from the TSFs and also non-process water from some silt dams during the operational stage. A number of pumps are required to move water throughout the site. The water returned to the process plant is used in the processing of ore and reduces the need for additional water. Additional water is pumped from the Taieri River to supplement the process. The following section describes the key assumption made in the processing system. Where available, pump capacities and demands were calculated based on measured flow meter data for sump, pond and reservoir pumps supplied by OceanaGold. Where no data is available, the pump rates are assumed based on pumping data for similar ponds/sumps.

3.7.2 Plant demand

The process plant water demand is approximately 43,200 m^3/day for operational purposes. This water is made up of recycled process water, non-process water and "top up" water from Lone Pine. Process and non-process water includes returned from the active TSFs (decant water and seepage), water generated in the dewatering process of the actively mined pits and some water pumped from the Maori Tommy Gully and Northern Gully silt ponds.

3.7.3 Tailings return water pump capacity

Tailings return water pump capacities for each corresponding mine stage are presented in Table 26.

Table 26: Tailings return water pump capacities.

TSF [1]	Stage				
	0	1	2	3	4
TTTSF	N/A	10,368	10,368	10,368	0
MTI	17,280	17,280	17,280	17,280	0
SPI	16,416	16,416	16,416	16,416	0

Note: [1] All values m^3/day

3.7.4 Water abstraction from Taieri River

OceanaGold has been granted resource consents authorising water abstraction of up to 200 L/s (17,280 m^3/day) from the Taieri River. The existing pump and pipeline is however not capable of transmitting this flow rate. It is estimated that 5,000 m^3/d is the maximum capacity of the existing infrastructure.

Water from the Taieri River is utilised as "make up" water for process requirements. Generally, this water is required as the climate at Macraes Flat is water deficient.

3.7.5 Tailings placement schedule

OceanaGold propose to commence placing tailings within TTTSF at the beginning of Stage 1. Two separate types of tailings are produced by differing ore processing and these comprise of flotation tailings and cyanide in leach tailings. Table 27 and Table 28 below outline the proposed tailings placement schedule for the current and future operation. For the simplicity of the model, the average placement of tailings for both flotation and CIL tailings are utilised for the model. For the CIL tailings the average annual mass of tailings placed is 89,300 tonnes/year and for flotation tailings the annual average mass of tailings placed is assumed to be 5,943,057 tonnes/year.

Table 27: Flotation tailings placement schedule.

Year	Deposited mass [1] (tonne/year)
1/1/2000-1/1/2006	6,578,760
1/1/2007	6,578,760
1/1/2008	6,578,760
1/1/2009	6,578,760
1/1/2010	6,578,760
1/1/2011	5,637,000
1/1/2012	5,711,000
1/1/2013	5,663,000
1/1/2014	5,654,000
1/1/2015	5,644,000
1/1/2016	5,672,000
1/1/2017	5,635,000
1/1/2018	5,643,000
1/1/2019	5,050,000

Note: [1] Tailings placement represents tailings mass placed within the impoundment and includes the slurry water.

Table 28: CIL tailings placement schedule.

Year	Deposited mass [1] (tonne/year)
1/1/2000	8,000
1/1/2011	88,000
1/1/2012	94,000
1/1/2013	93,000
1/1/2014	101,000
1/1/2015	111,000
1/1/2016	101,000
1/1/2017	119,000
1/1/2018	112,000
1/1/2019	66,000

Note: [1] Tailings placement represents tailings mass placed within the impoundment and includes the slurry water.

Within the GoldSim tailings module, tailings supernatant water, or seepage from the processed tails, is calculated. This tailings inflow water is described as tailings seepage or supernatant and is calculated on a daily average basis. The daily average seepage volume is based on the following assumptions:

- Daily tailings slurry mass inflow (tonne/day).
- Slurry density (29%).
- Tailings dry density (1.1 tonne/m^3).
- Density of water (1 tonne/m^3).
- Specific gravity of tailings (2.85) (g/cm^3).

From these assumptions, the volume of dry tailings retained within the impoundment is calculated using the daily slurry inflow and tailings dry density. The volume of slurry water is also calculated using the density of water. A certain volume of water is also retained within the pore spaces of the tailing body. To calculate the pore space, a void ratio is calculated based on the specific gravity of the tailings, density of the water and the tailings dry density. This void ratio of the tailings body holds a portion of slurry water that is retained within the tailings and is effectively lost to the system. The balance is the seepage or supernatant volume that reports to the TSF decant structure.

3.7.6 Lone Pine pump capacity and management

Lone Pine is a freshwater dam utilised for additional top up water to supplement the process. When the process sump water availability cannot meet the plant demand requirement of 43,200 m^3/day, the additional water is abstracted from Lone Pine. For modelling purposes, the maximum pump capacity of Lone Pine is assumed to be that of the maximum demand of the plant or 43,200 m^3/day.

3.7.7 Pit water

Water generated in the Frasers Pit/Innes Mills sump and the Round Hill/Golden Point/Southern Pit during the operational period is pumped out of the pits to be used for dust suppression or in the processing plant. Table 29 below presents the maximum pit sump pumping rates.

Table 29: Pump capacities for opencast pit sumps.

Opencast pits	Stage				
	0	1	2	3	4
Frasers Pit/Innes Mills	10 368	10 368	10 368	10 368	N/A
Round Hill/Golden Point / Southern	4 320	4 320	4 320	N/A	N/A

Notes: N/A denotes no pumping; and all values m^3/day.

Table 30 below outlines the locations that the pits pump to for each model stage.

Table 30: Pit Pumping Locations.

	Stage				
	0	1	2	3	4
Frasers Pit	Process sump	TTTSF	TTTSF	TTTSF	N/A
Round Hill	Process sump	Process sump	Process sump	Process sump	N/A

Note: N/A denotes no pumping.

3.7.8 Tailings storage facilities

The TSF impoundments are modelled assuming an endless storage capacity to allow modelling projections for the maximum volume of storage required. For this reason, the only inputs to the model for the TSFs are assumptions of tailings wet and dry beach run-off and a maximum surface area of the tailings facility to calculate run-off and evaporation volumes. All TSFs assume a wet beach run-off coefficient of around 0.9 and a dry beach run-off coefficient of around 0.7. Around 70% of the TSF area is assumed to be dry beach and the remaining 30% is assumed to be wet beach. The MTI, TTTSF and SPI (SP11 and SP10) surface areas are presented in Table 31 below.

Table 31: TSF surface area assumptions.

	Stage				
	0	1	2	3	4
MTI	799,815	799,815	799,815	799,815	799,815
SPI	576,386	576,386	576,386	576,386	576,386
TTTSF	1,605,632	1,605,632	1,605,632	1,605,632	1,605,632

Note: All values presented in units of m^2.

3.7.9 Lone Pine reservoir

Lone Pine is a fresh water reservoir located to the northwest of the MTI. This reservoir is utilised as a water source for the process plant. Lone Pine provides supplementary flows to the process plant when demand exceeds the water available through the process sump. Lone Pine has an assumed maximum storage capacity of approximately around 611,000 m^3 and, when full, a surface area of approximately 87,900 m^2.

The model assumes that the reservoir has an operational volume of approximately 400,000 m^3. If stored water in the reservoir drops below this volume "make up" water is pumped into the reservoir from the Taieri River. It is estimated that 5,000 m^3/d is the maximum "make up" capacity of the existing infrastructure.

During the operational phases, Lone Pine inflows include the Lone Pine catchment (MTI embankment, some non-impacted catchment, direct rainfall), water pumped from the MTG silt pond, and "make up" water sourced from the Taieri River and pumped into Lone Pine.

Post closure, the reservoir will receive inflows from the MTI embankment, non impacted catchment surrounding the reservoir as well as run-off from the rehabilitated MTI surface.

During operational phases, Lone Pine outflows include evaporation from the reservoir surface, water pumped to the process (maximum pump rate assumed to be the same as the process demand) and any overflow of the reservoir reports to the MTG via a spillway.

4.0 CALIBRATION AND VERIFICATION

4.1 Calibration

4.1.1 Natural catchments

Natural catchments have been modeled using the AWBM. The conceptual logic of the AWBM is presented in Figure 17. To calibrate an AWBM rainfall, evaporation and run-off data are required. The total area of the catchment affecting the compliance points is large and variation in the run-off coefficients can be expected. In response to this variation, two AWBMs have been calibrated to be used in the GoldSim model. Both AWBM's use the same rainfall and evaporation data, with run-off data from either Deepdell Creek or the Shag River used.

The AWBM has been calibrated using the Rainfall Run-off Library (RRL), software developed by the eWater CRC. The data used for these calibrations is summarized below (Table 32 and Table 33).

Table 32: Data used in the Deepdell Creek AWBM calibration.

Data type	Dataset	Source	Data period
Rainfall	Glendale Station	OceanaGold	20 April 1997 to 27 March 2001
Evaporation	Palmerston Pan Evaporation Data calibrated with Site Pan Evaporation Data	Palmerston (site I50471) and OceanaGold	20 April 1997 to 27 March 2001
Run-off – for Deepdell Ck Calibration	Run-off - Deepdell Creek at Golden Point Weir	Scott Tech	20 April 1997 to 27 March 2001

The RRL is used to calibrate the AWBM by calculating the parameters used in the AWBM to produce a run-off data set that matches as closely as possible to the observed data set (Deepdell Creek or Shag River). The stream flow data available for the Deepdell calibration was from 20 April 1997 to 27 March 2001 and from 24 Dec 1993 to 28 April 2009 for the Shag River calibration. The rainfall and evapotranspiration data corresponding to these dates was also used in the calibration.

Table 33: Data used in the Shag River AWBM calibration.

Data Type	Dataset	Source	Data period
Rainfall	Glendale Station	OceanaGold	24 Dec 1993 to 28 April 2009
Evaporation	Palmerston Pan Evaporation Data calibrated with Site Pan Evaporation Data	Palmerston (site I50471) and OceanaGold	24 Dec 1993 to 28 April 2009
Run-off for Shag River calibration	Run-off, Shag River at Craig Road	Otago Regional Council	24 Dec 1993 to 28 April 2009

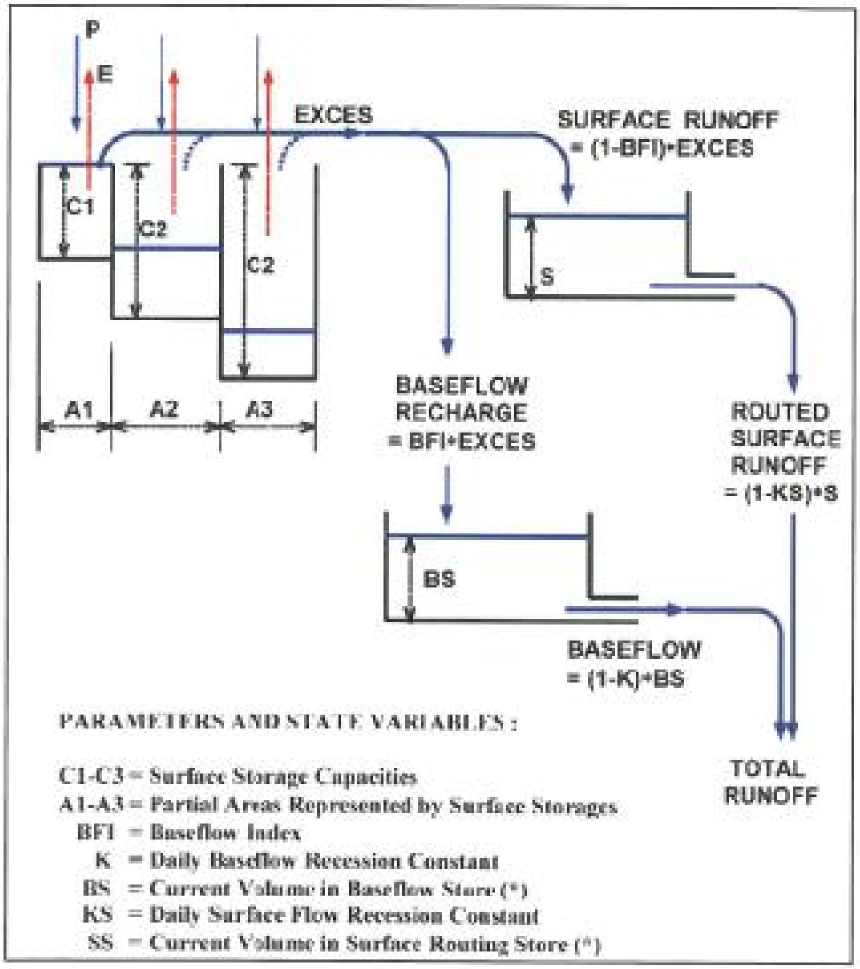


Figure 17: Australian Water Balance Model (CRC 2004).

A section of the data was selected for use as warm-up data in RRL to allow for the program to assess the rainfall conditions prior to the start of the model and make an estimate of the contents of each of the soil moisture stores (Podger 2004). The warm-up period for the Deepdell Creek calibration was set from 20 April 1997 to 8 August 1997. This meant that the period of calibration was from 8 August 1997 to 27 March 2001. The warm-up period for the Shag River calibration was set from 24 December 1993 to 24 September 1994. The period of calibration was from 27 September 1994 to 28 April 2009.

The available data for both calibrations were relatively short periods, so it was decided to calibrate over the entire period (rather than use some of the data for calibration, some for verification) to achieve the most optimum calibration for the available data (Podger 2004).

A good calibration was achieved for the Deepdell calibration. Figure 18 shows the run-off calculated by AWBM based on the Glendale rainfall, compared to the real set of stream flow data from Deepdell Creek corresponding with the Glendale rainfall. In Figure 18, it can be seen that there is a good relationship between the calculated and observed run-off. The R^2 value for the Deepdell AWBM is 0.869.

The modeling of concentrations at the compliance points has been to determine whether compliance levels can be achieved during periods of low flow. For this reason the Shag River calibration was optimized to achieve the low flows in the creek. The accuracy of the high flows is less precise; however for the purpose of the calibration this is acceptable. Figure 19 shows the run-off calculated by AWBM on the Glendale rainfall and is compared to the real set of stream flow data from the Shag River corresponding to the Glendale Station rainfall.

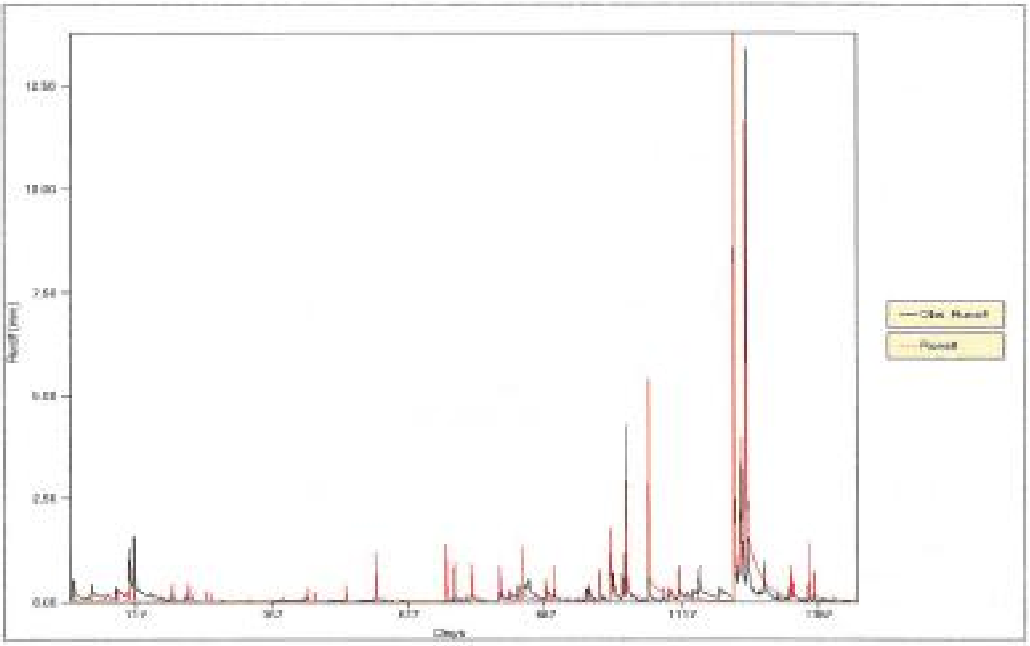


Figure 18: Calibration graph showing calculated run-off plotted against recorded run-off from Deepdell Creek.

Table 34 shows the calculated and recorded run-off volumes and confirms a good calibration. The AWBM parameters optimised through this calibration are presented in Table 35.

Table 34: AWBM calibration results.

Totals	Deepdell Creek run-off depth (mm)	Shag River run-off volume (ML)
Recorded run-off	186	1,571
Calculated run-off	184	1,376

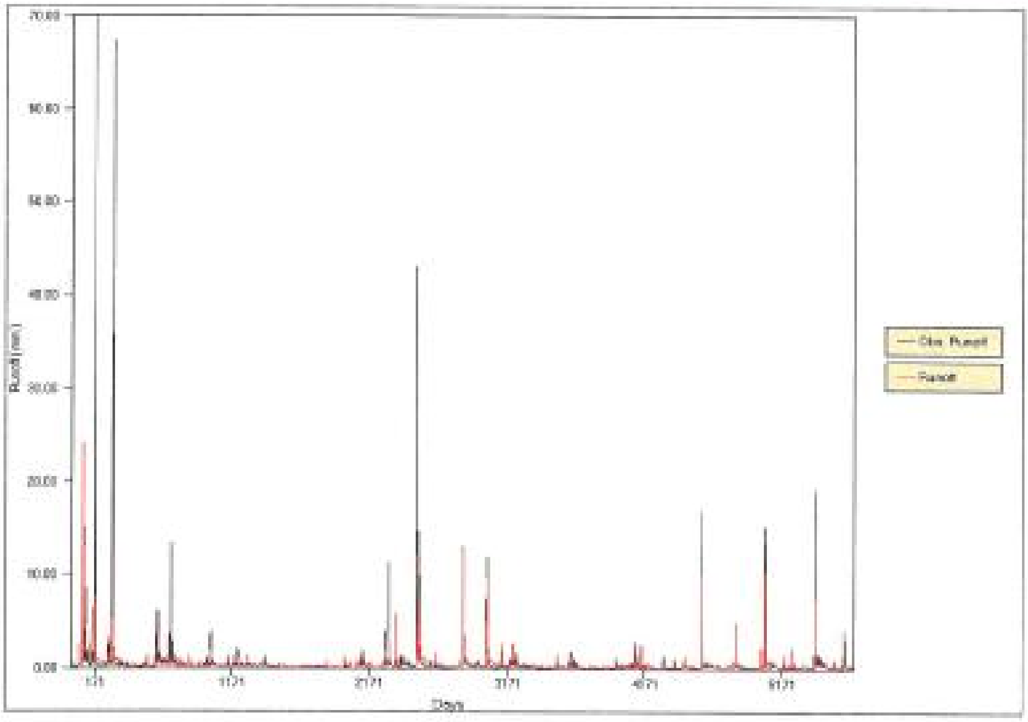


Figure 19: Calibration graph showing calculated run-off plotted against recorded run-off from Shag Creek.

Table 35: Calibrated AWBM parameters.

Parameter		Deepdell Creek calibration values	Shag River calibration values
Partial Area 1	A1	0.134	0.134
Partial Area 2	A2	0.433	0.433
Partial Area 3	A3	0.433	0.433
Base Flow Index	BFI	0.6	0.008
Surface Storage Capacity 1	C1	8.5	7
Surface Storage Capacity 2	C2	47.5	7
Surface Storage Capacity 3	C3	145	8
Base Flow Recession Constant	KBase	0.96	0.3
Surface Flow Recession Constant	KSurf	0.06	0.1

4.2 Verification

4.2.1 Pit lake formation rates

A simple model verification was undertaken to assess the run-off generated from impacted areas (pit walls and mining areas). The model was set up to model the pit lake recovery in the decommissioned Deepdell South Pit. The Deepdell South pit has two contributing catchment types (impacted and undisturbed) and the model was set up to generate projections for the volumes of water within this decommissioned pit from the date of decommissioning to mid 2009. The Deepdell South pit was decommissioned in Late October 2003. The final pit shell and profile has been analysed by GIS and a volume, area and RL curve was constructed.

OceanaGold has a number of observed water level readings from site surveys undertaken since October 2003. The modelled pit volumes were then converted to pit lake water level and thus directly comparable with the observed measurements. The run-off coefficients were then varied for the impacted portion of the catchment until the model projected actual pit volumes in an acceptable manner. The non impacted portion of run-off was generated from actual Deepdell Creek rainfall run-off calibration and therefore acceptable.

Inputs to the model included:

Pit inflows:

- Impacted catchment of 140,472 m^2.
- Non-impacted catchment of 175,462 m^2.
- Groundwater inflow rate estimated from previous groundwater modelling of around 16 m^3/d.
- Direct rainfall to the pit lake.

Pit Outflows:

- Evaporation from the pit lake surface
- Pit lake overflow to Deepdell Creek (although currently the pit lake does not overflow)

A comparison of the model outputs with measured lake levels (Figure 20) indicates that the simple model slightly overestimates the rate at which the lake level rises. The results are however considered to be reasonable for the purposes of this project. This outcome indicates the impacted run-off coefficients are acceptable for the conservative modelling approach.

4.2.2 Process verification

To verify the process water model actual water required from Lone Pine (sourced from OceanaGold) to meet process demand was compared to the model projected volumes. Daily or monthly pumping data was deemed inappropriate due to the functionality of the model and the fact that the model utilizes randomly generated rainfall data. For this reason annual records were compared.

The comparison was primarily to determine if the model grossly overestimates or underestimates the additional volume of water required for the process. Some variation would be expected as climate for the particular year would drive the demand for additional water. Only data for the complete years 2005 – 2009 was available for the comparison and these are presented in Table 36. The full modelled data has been presented for the calibration period.

The average additional water required during the calibration period was estimated by the model to be approximately 3,530 m^3/d. The short measured dataset suggests that around 4,400 m^3/d is required. The difference is the result of several factors relating to assumptions and modelling approaches. These include uncertainties over the water balance within the TSF between:

- Evaporation of water from the tailings surface and decant pond.
- Seepage rates through tailings impoundment.
- The rate of tailings bleed water to the decant pond.
- The total volume of water stored within the tailings mass.

The calibration could be improved by adjusting the factors and assumptions that result in less tailings water returning to the process system so that an additional 870 m^3/day of water is required from non-site derived water. However there is not sufficient data to identify which factor needs to be modified to justify modification of individual assumptions. An error of approximately 20% in make-up water required is considered acceptable for the purpose of the process water system modelling.

The purpose of the process water system modelling is to demonstrate no process water system discharges are required during the operation phase. The calibration is therefore conservative as it assumes more water is required to be stored on-site each day than the actual data suggests. It should also be noted that the process water system calibration does not affect the water quality predictions from the site wide discharge assessment.

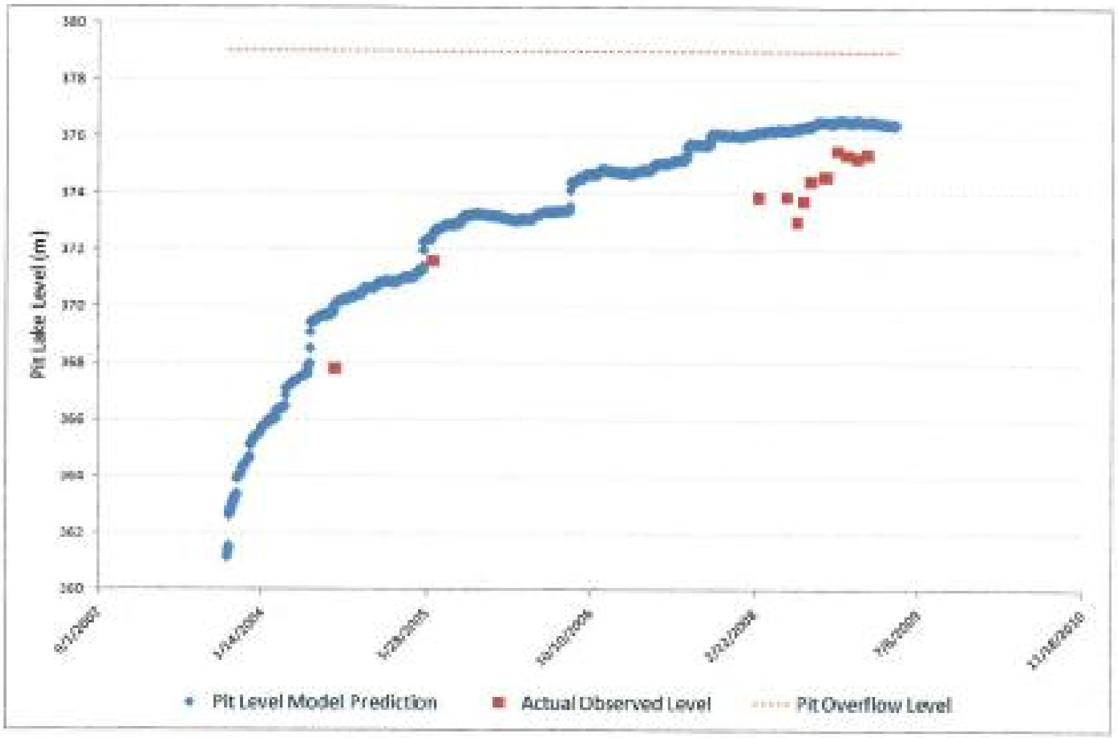


Figure 20: Deepdell South Pit projected and observed volumes.

Table 36: Modelled and observed additional water requirements for the operational process.

Year	**Daily average water required**	
	Modelled	**Measured**
2000	6,435	N/A
2001	3,824	N/A
2002	3,185	N/A
2003	3,018	N/A
2004	3,132	N/A
2005	4,481	3,870
2006	3,514	4,346
2007	1,866	4,327
2008	1,949	4,956
2009	3,797	4,533
2010	3,434	N/A
2011	3,719	N/A
Average	**3,530**	**4,406**

4.2.3 Model sensitivity

The sources of simulated contaminant discharges to Deepdell Creek following closure of the mining operation have been investigated in a short sensitivity analysis. The process followed was to define the contaminant concentrations from various sources in the surface water model as zero, with the exception of the source being assessed. In effect, the sensitivity analysis assumes that all contaminants from other sources can be caught and fully treated before the water is released. The analysis was undertaken on this basis to support an evaluation of the most effective options for potential mitigation measures.

The outcomes from the sensitivity analysis (Table 37) indicate the two crucial sources of modelled contaminant discharges to Deepdell Creek are the TSF drainage systems and the wider groundwater seepage which is dominated by infiltration through the WRS's. The seepage through the wider groundwater system to Deepdell Creek appears to be of greater significance than groundwater seepage discharging to MTG. When the timing of the discharges is taken into account, the latter is more important during the first few decades following closure of operations at the site. The load of contaminants transported from the WRS's would require this period to reach a maximum, whereas the discharges to MTG would start to decline after the groundwater system in the tailings mass reaches a steady state.

Table 37: Model sensitivity at DC08 with respect to varying geochemical inputs.

Model run (1)	**Arsenic** (2,3)	**Sulphate** (2,3)
Unmitigated run with all assumed chemistry inputs	0.41	1,400
All chemistry inputs zero except **MTI/SPI drains**	0.23	930
All chemistry inputs zero except **MTI/SPI groundwater seepage**	0.19	190
All chemistry inputs zero except general **groundwater seepage** to Deepdell Creek not including MTI/SPI groundwater seepage (represents seepage from waste rock stacks)	0.04	890
All chemistry inputs zero except **impacted runoff**	0.05	110
All chemistry inputs zero except **non-impacted runoff**	0.005	30

Notes: (1) Maximum concentrations from model runs presented; (2) all concentrations presented in units of g/m^3; and (3) totals to not add up to t he un-mitigated run result due to varying degrees of dilution from other water sources.

5.0 WATER BALANCE PROJECTIONS

5.1 Process Water Projections

5.1.1 Introduction

The modelling of the site process water system was undertaken to evaluate whether the simulated rainfall patterns could result in water management issues during the operational period of the mine. As the model is a simplified representation of the mine water management system, this approach is purely taken to verify that mine water at the MGP can be managed with minimal risk of unplanned discharges.

As discussed previously, the modelling utilises a probabilistic approach to rainfall simulation. Reservoir and TSF inflows, decant volumes and outflows are partially based on one hundred randomly generated rainfall scenarios (refer Section 2.1.4).

During the verification process for the rainfall simulator it was identified that cumulative rainfall from large multi-day events are exaggerated in the simulation. Consequently, the worst case scenarios derived from the model are considered to be extremely low probability and do not provide a reasonable test of the mine waste management system. It was concluded that the 95th percentile outcomes for water volumes potentially accumulating in the pits, TSFs and Lone Pine are an acceptably conservative test of the risk of unplanned discharge.

5.1.2 TTTSF

The TTTSF receives inflows from rainfall falling on the tailings beach and decant pond, non-process water from the Frasers pit underground operation and the Frasers pit sump during operations. In addition, the TTTSF receives tailings solids and water in the form of a tailings slurry inflow.

Outflows from the TTTSF include evaporative losses from the tailings beach and decant pond, return water pumped to the process system and seepage to the tailings drain system. The maximum return water pump rate is set at 43,200 m^3/d. The pumped return water system is planned to be operational until the TTTSF surface is adequately rehabilitated, at which time run-off is to be allowed to discharge to the Tipperary Creek.

Simulated inflows to the TTTSF reach a maximum of 83,600 m^3/d (Figure 21). Simulated outflows, including evaporation, pumping and seepage, are less variable and reach a maximum of 43,100 m^3/d (Figure 22).

The simulated mean volume of decant water within the TTTSF is approximately 91,000 m^3. The maximum simulated volume of decant water in the TTTSF during the operational period of the mine is approximately 800,000 m^3 (Figure 23).

In interpreting the information presented in Figure 21 through to Figure 23, it is important to recognise that the data represents a summary of 100 simulations. As such, the 95th percentile data presented represents the 95th percentile result for each individual day from these model runs. This information should not be interpreted as a single model run but a combination of the worst case outcomes from 100 model runs on a day by day basis.

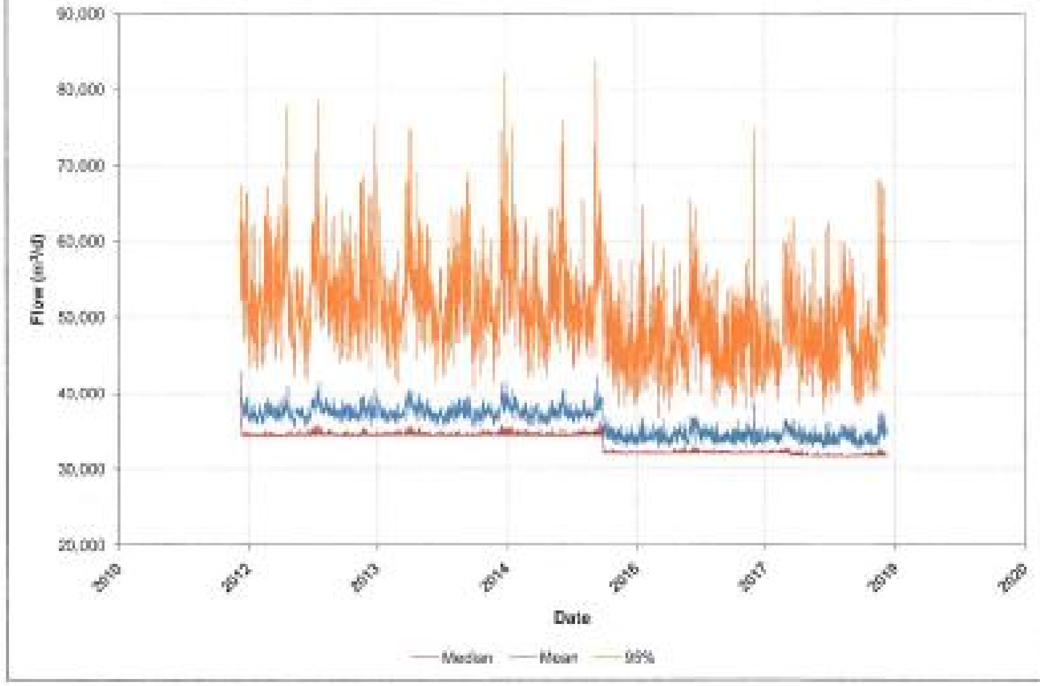


Figure 21: Simulated inflows to TTTSF.

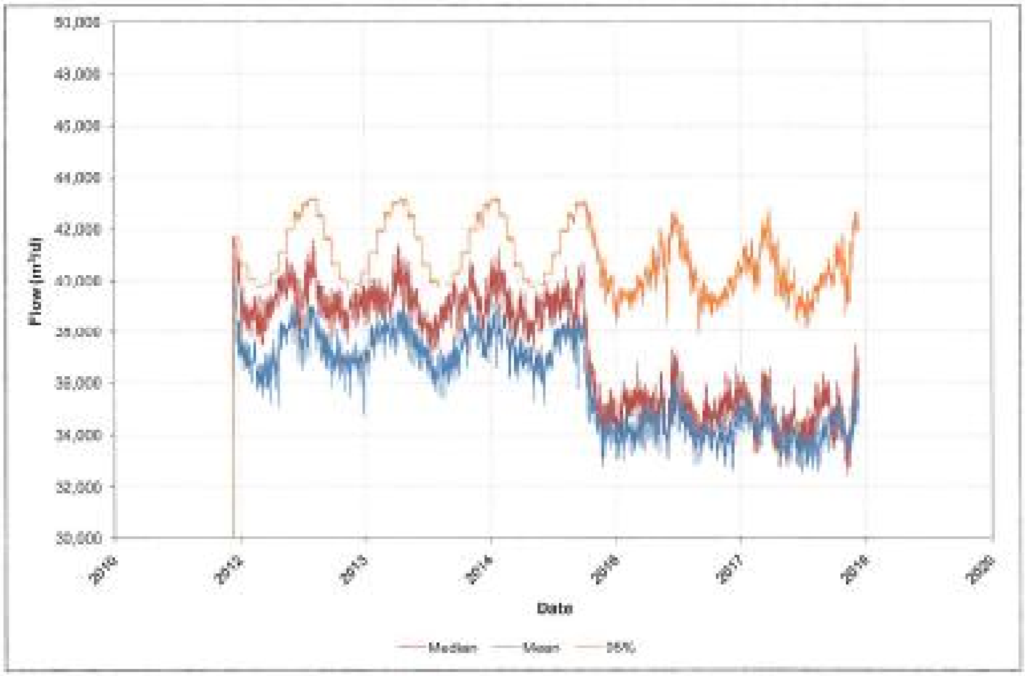


Figure 22: Simulated outflows from TTTSF.

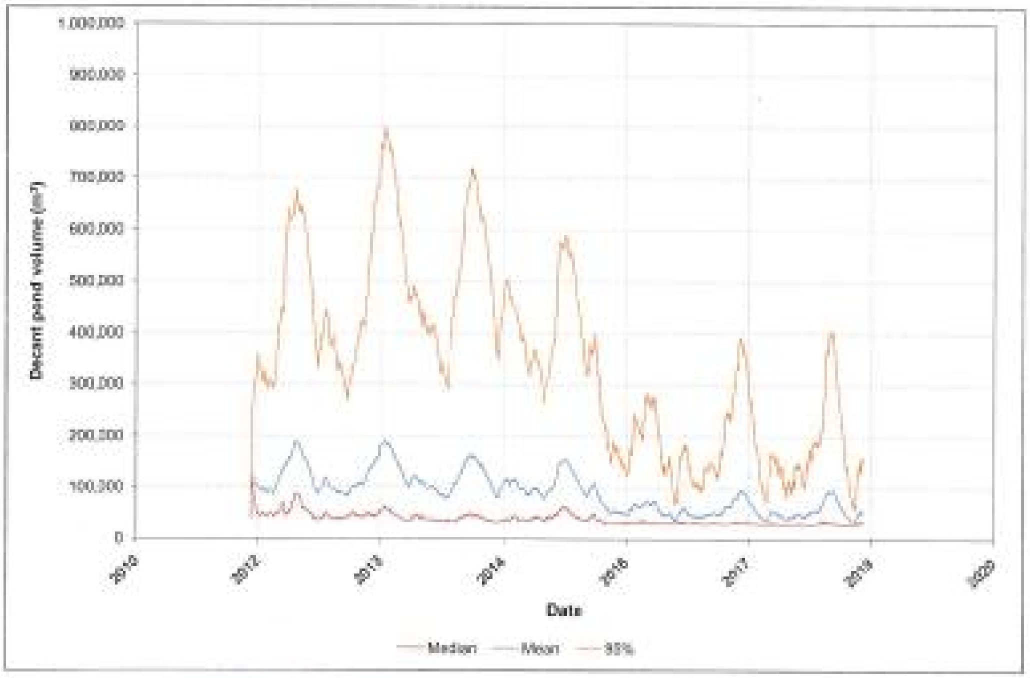


Figure 23: Simulated TTTSF decant pond volume.

For comparison purposes, design work undertaken by Engineering Geology Limited (EGL) on the TTTSF has assumed a decant pond water volume of 200,000 m^3 under normal operational conditions. For the flood induced dam breach scenario EGL estimated an additional 270,000 m^3 of run-off associated with a 48 hour 100 year rainfall (135 mm over 200 ha catchment). For the purposes of the analyses EGL rounded the total volume of decant water in the TTTSF up to 500,000 m^3.

These volumes are considered a realistic scenario for a dam break analysis, even though the maximum decant water volumes calculated from the site water management model are greater. The reason for the difference in outcomes relates back to the objectives of the two studies and assumptions built into the respective calculations.

The site wide water model assumes pumping of water from the Frasers Pit sump to the TTTSF would continue through such an event, irrespective of the water volumes accumulating in the TTTSF. The implied priority is to ensure minimal disruption to mining operations in the pit. In contrast, the EGL calculation does not take into account water being pumped from Frasers Pit to the TTTSF. This latter assumption is likely to be valid should accumulated water volumes in the TTTSF start to become overly large. In the event of a major rain event it would be possible to cease pumping and temporarily store water in the pits.

In addition, OceanaGold have been authorized to discharge water from Frasers Pit at up to 100 L/s provided water quality targets defined as consent conditions are met. This discharge, which has not been taken into account in the site wide water management model, may be activated to reduce water flows to the TTTSF under unusual conditions.

5.1.3 Lone Pine

During the operational period, the mean simulated inflow to Lone Pine is approximately 1,500 m^3/d, with inflows reaching a maximum of 26,500 m^3/d (Figure 24). During the same period the simulated discharge (including evaporation and pumped outflow) has a mean of 1,400 m^3/d, reaching a maximum of 43,500 m^3/d (Figure 25).

The mean volume of water within Lone Pine during the operational period is approximately 490,000 m^3. The maximum simulated volume of water within the reservoir over the operational period is 611,000 m^3 (Figure 26), implying overflow discharges could occur. Following site closure the model indicates water volumes stored in Lone Pine could reach capacity and overflow periodically, generally during the winter months.

The model indicates that during the operational period the mean flow of "make up" water pumped from the Taieri River is approximately 10 L/s. The simulated flows range from the 5,000 m^3/day maximum daily capacity of the system down to no daily flow (Figure 27).

In interpreting the information presented in Figure 24 through to Figure 27, it is important to recognise that the data represents a summary of 100 simulations. The 95th percentile data should not be interpreted as a single model run but a combination of the 95th percentile outcomes from 100 model runs on a day by day basis.

5.1.4 Process Sump

The process sump operates as the main water source and buffer for the process plant. The model assumes the process sump has a maximum capacity equivalent to the process water demand for one day (43,200 m^3). The process sump has a number of inflows during operational phases that include:

- Drain seepage from the tailings impoundments (MTI and SPI during model phases 0 – 1 and TTTSF during phases 1 – 3
- Non-process water from the Northern Gully silt pond
- Water from the Frasers West sump (includes Frasers Pit underground water)
- Process return water from the MTI, SPI and TTTSF decants during their respective operational periods and post closure prior to rehabilitation

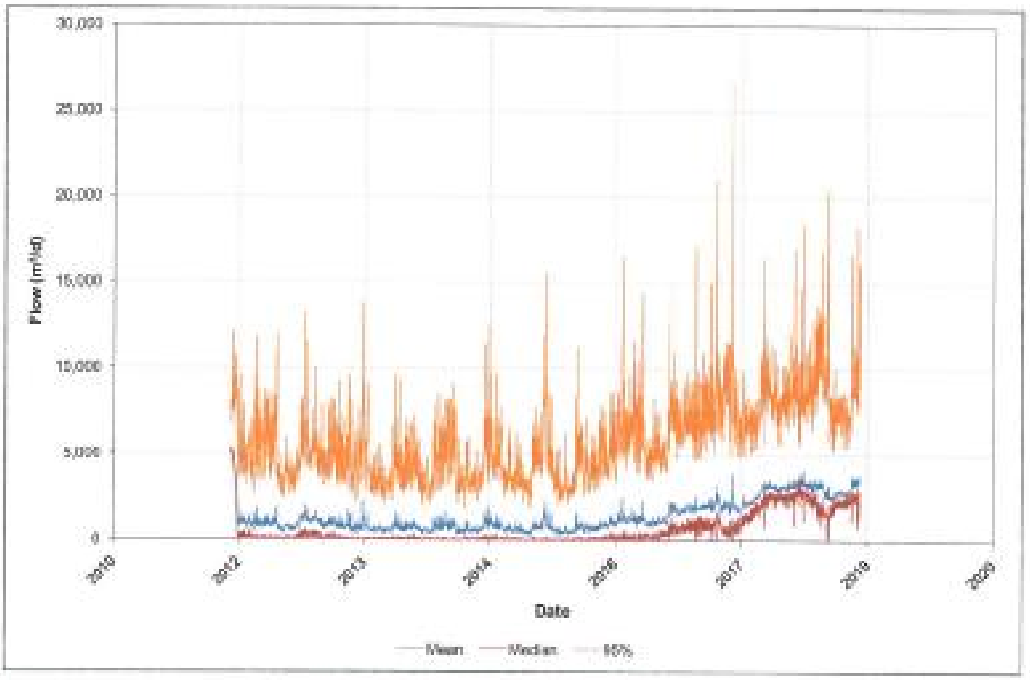


Figure 24: Simulated inflows to Lone Pine during the operational period.

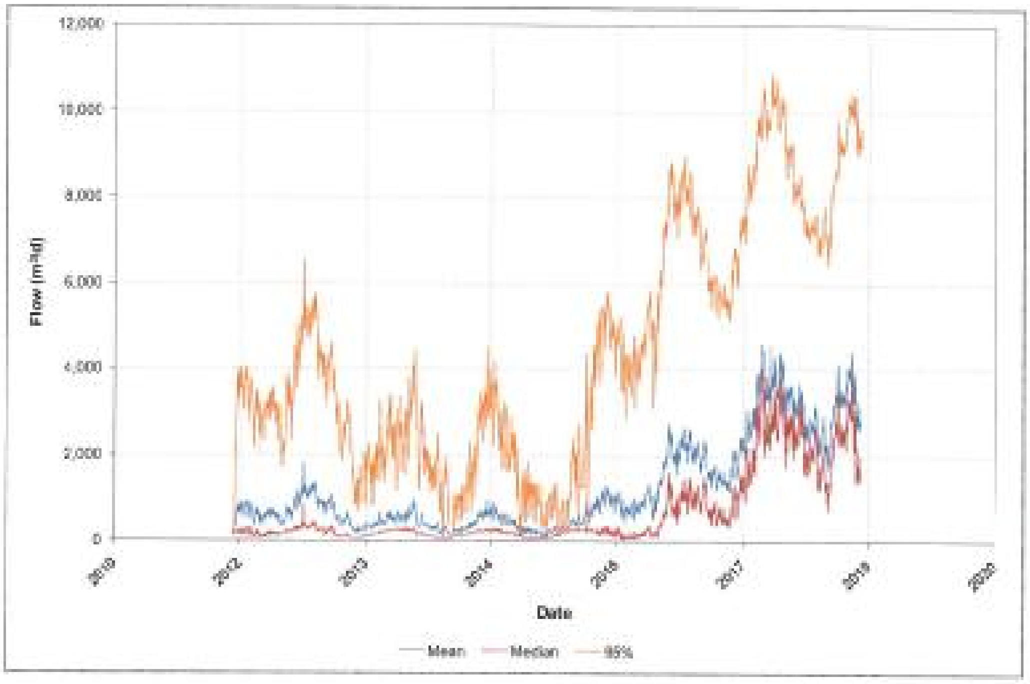


Figure 25: Simulated outflows from Lone Pine during the operational period.

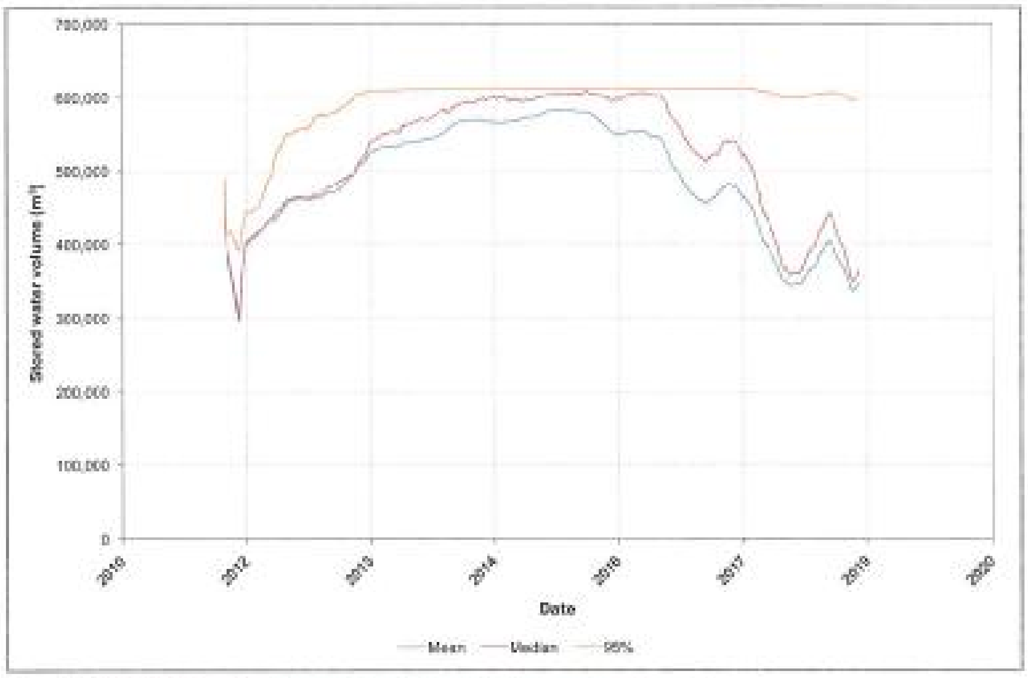


Figure 26: Simulated water volume in Lone Pine during the operational period.

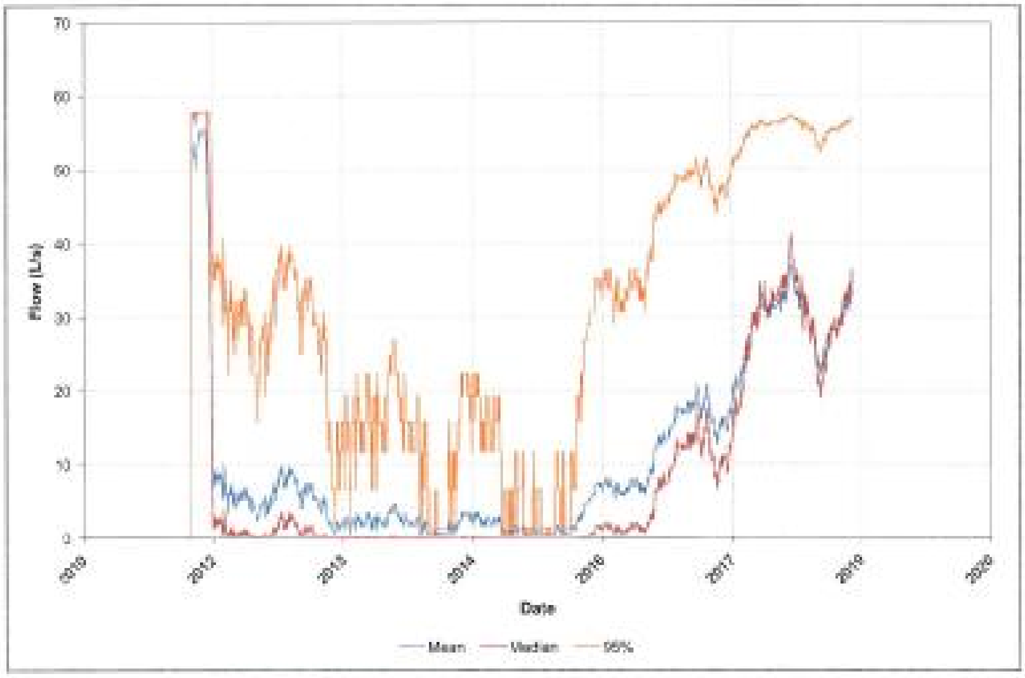


Figure 27: Taieri River "make up" pump rates.

The model has a simple allocator system that allocates the amount of water from each source available to meet the plant demand or 43,200 m^3/d. The allocator prioritises the source of the water based on the importance of that water to be utilised for the process. The TTTSF is assumed to be the most flexible storage reservoir for process water and hence this is the last source of water to be allocated to the process (Table 38). In essence it acts as a large process water storage sump. As discussed in Section 5.1.2, this priority is not necessarily representative of the site water management priorities under all conditions.

The process sump does not necessarily have adequate water to cope with plant demand (Figure 28). When the process sump pump rate is below the 43,200 m^3/d plant demand, top-up water is abstracted from Lone Pine to make up the balance. Where an excess amount of return water is present (such as after heavy rainfall events) process water is stored within the TTTSF where the excess is evaporated off.

Table 38: Process Sump allocation priorities.

Priority	Source	Maximum pump rate (m^3/d)
1	MTI Drain seepage	1,500
2	SPI Drain seepage	1,000
3	TTTSF Drain seepage	1,800
4	Frasers West sump	4,320
5	RHP/GPP and Southern Pit	4,320
6	MTI decant	20,000
7	SPI decant	20,000
8	TTTSF decant	40,000

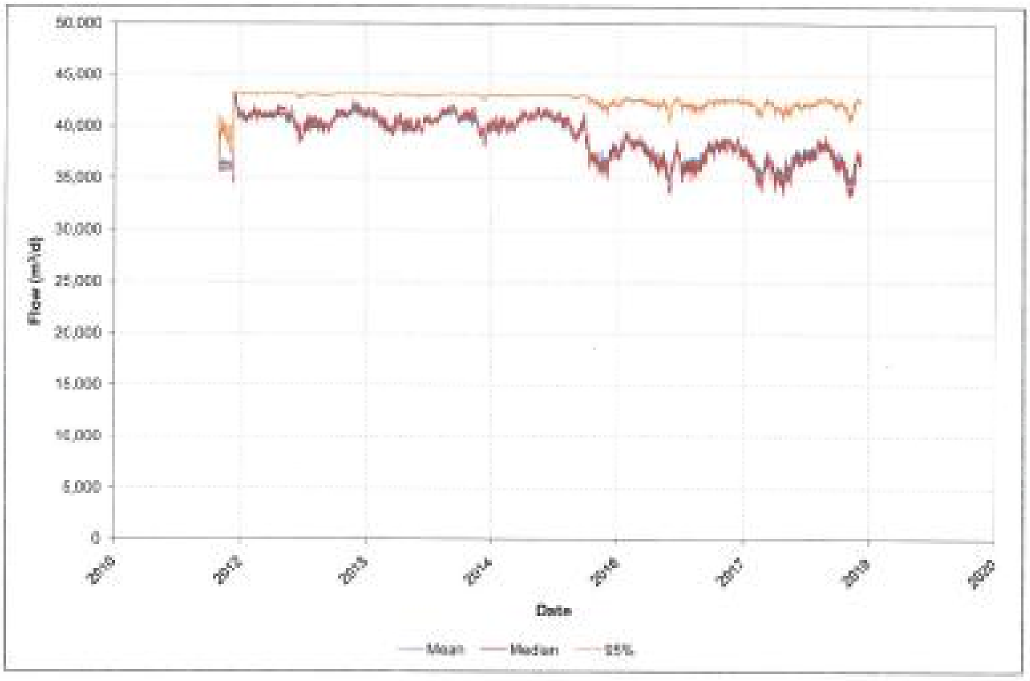


Figure 28: Process sump pump rate.

5.2 Pit Lake Projections

The site wide surface water model has been used to develop projections for pit filling rates and schedules following close of operations in the Round Hill / Golden Point Pit and in the Frasers/Innes Mills Pit. In the latter case these projections incorporate the assumption of 20 years of tailings drainage water from the TTTSF and about 10 years of drainage water from the MTI being discharged to the pit.

Projections for filling of the Frasers Pit incorporate the filling of the hydraulically linked Innes Mills Pit lake. These projections indicate the combined lake would not overflow within the 150 year simulation period of the model. The projection for pit lake volume (Figure 29) indicates the rate of filling would decrease over time as the evaporative area of the exposed lake surface increases. In contrast, the rate of rise in the water level in the lake (Figure 30) is much more rapid during the first decade following mine closure than during later decades. This initial rapid rate of water level rise is partially a function of the storage of tailings water in the pit and partially due to the inverted cone shape of the pit.

Projections for filling of the Round Hill Pit incorporate the filling of the connected Golden Point Pit. These projections indicate the pit lake would not overflow within the 150 year simulation period of the model. It has been assumed in the simulation that the historical adits intersecting the northern end of the pit have been effectively sealed (refer Section 2.3.2). The projection for pit lake volume (Figure 31) indicates the rate of filling would decrease over time as the evaporative area of the exposed lake surface increases. The rate of water level rise in the lake (Figure 32) is more rapid during the first decade following mine closure than later. This difference in water level rise is however not as substantial as for the Frasers Pit.

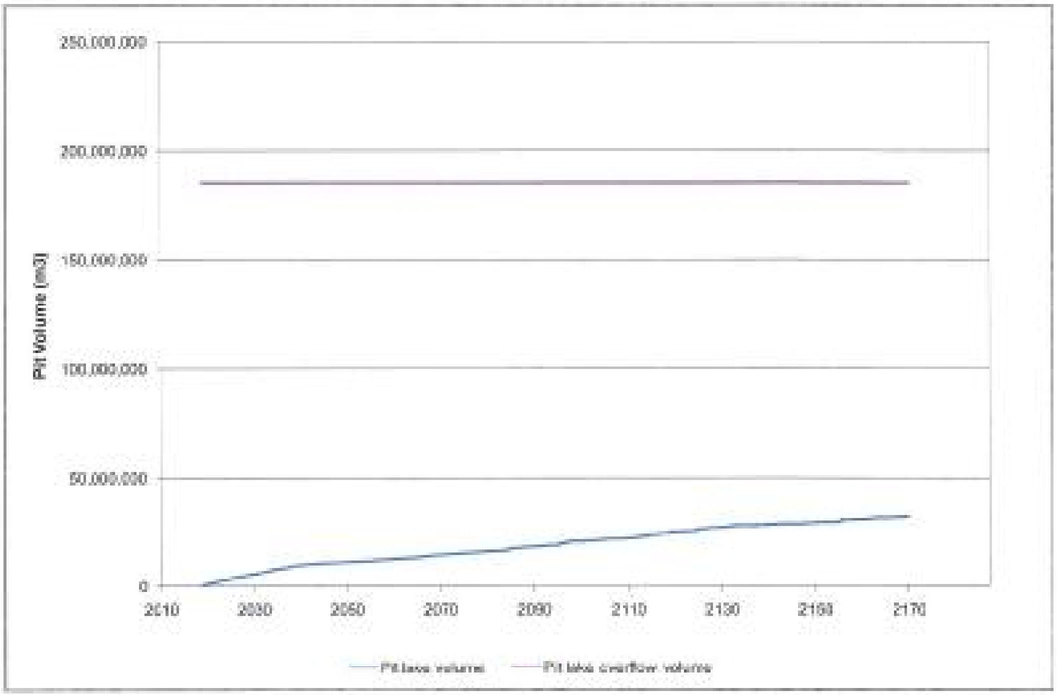


Figure 29: Frasers Pit lake post-closure volume projections.

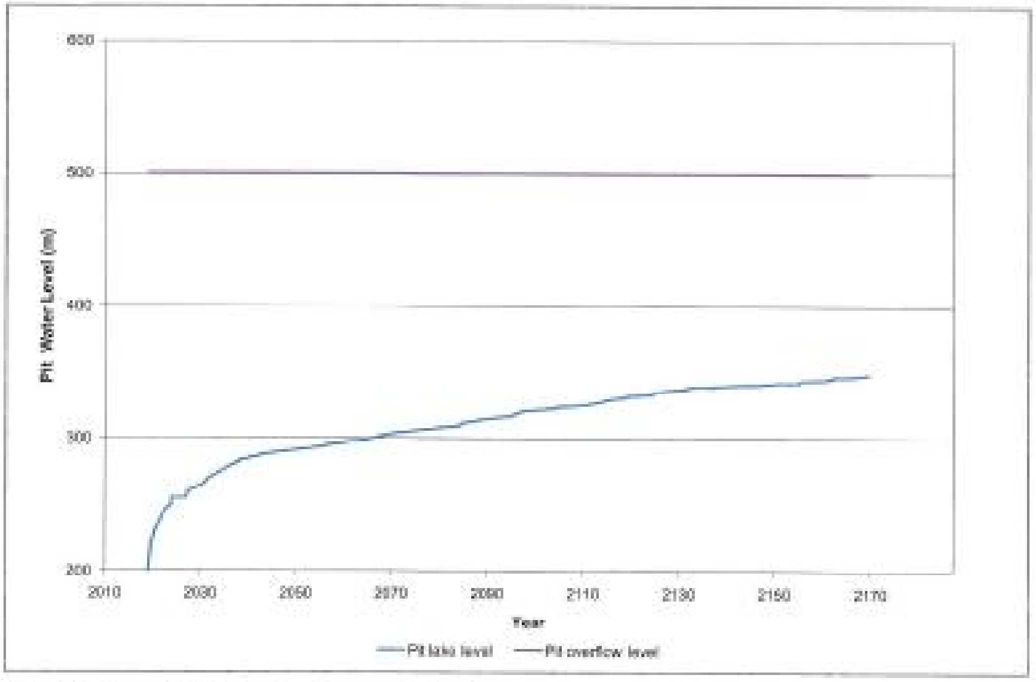


Figure 30: Frasers Pit lake post-closure water level projections.

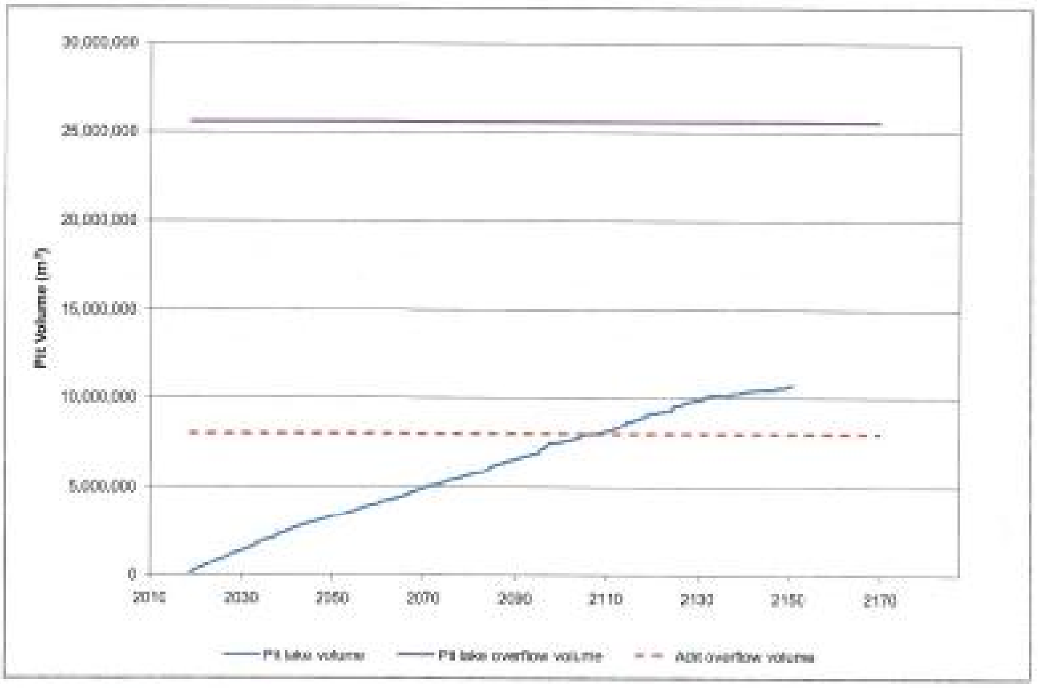


Figure 31: Round Hill Pit lake post-closure volume projections.

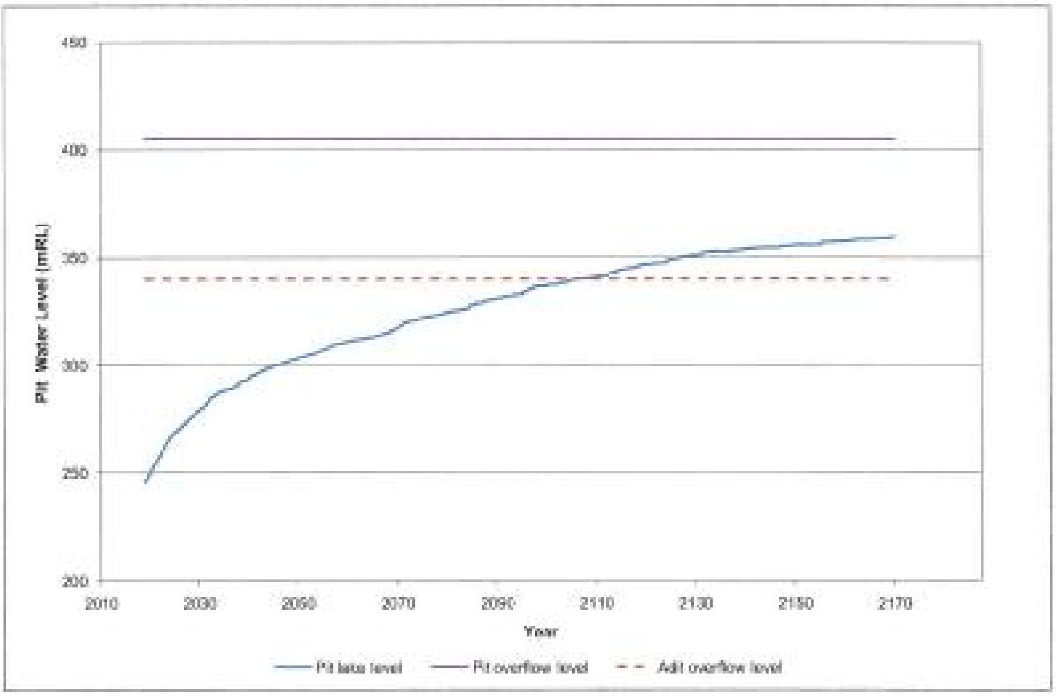


Figure 32: Round Hill Pit lake post-closure water level projections.

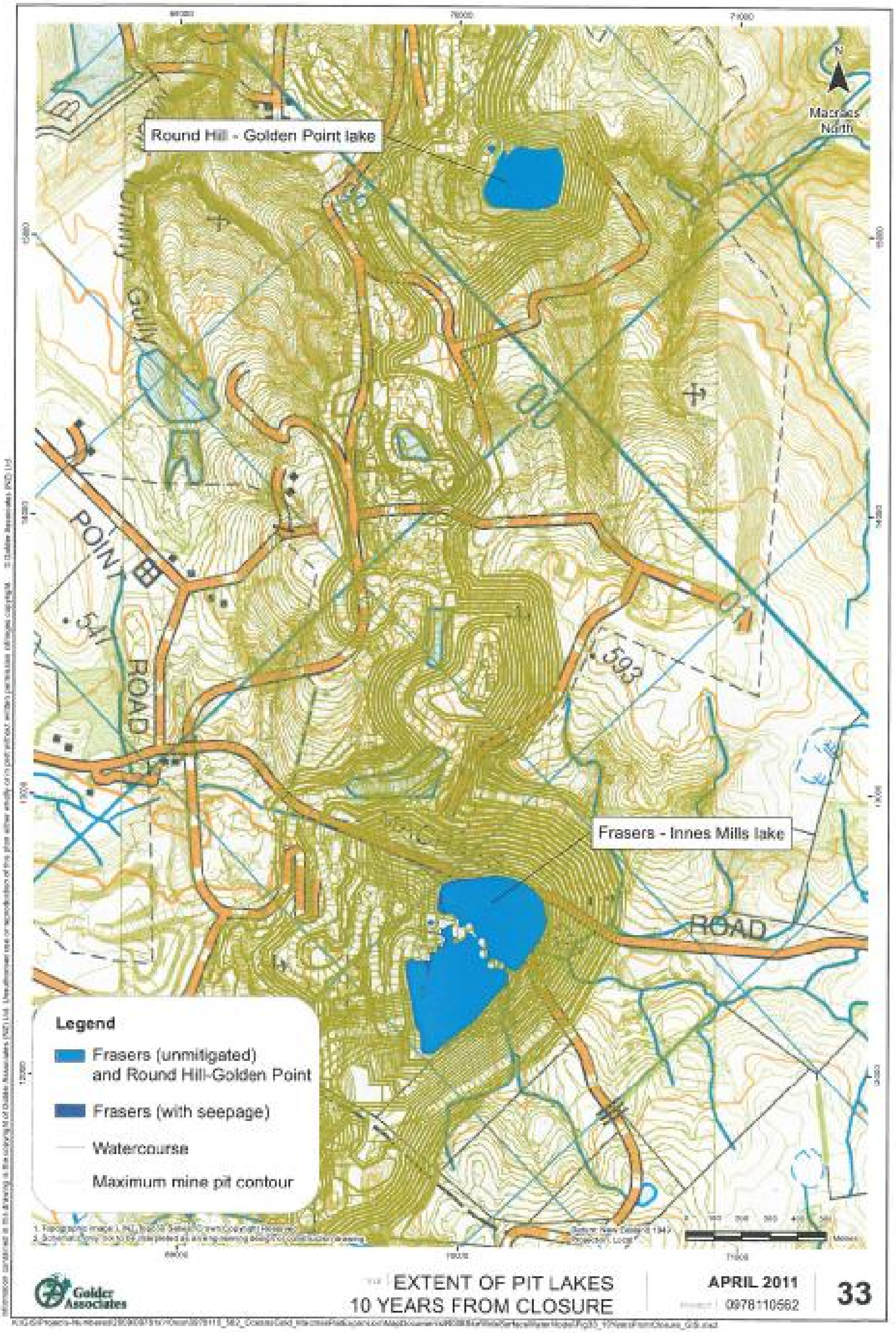
5.3 Receiving Water Flow Projections

During the operational period of the MGP, run-off from much of the mine site is captured and diverted to the process plant, rather than discharging to the natural receiving water bodies. Following closure of the mine, run-off from the rehabilitated mine surfaces including the TSFs will be allowed to discharge back to natural receiving water bodies. The exception would be water that discharges to the opencast pit lakes.

As outlined in the summary report (Golder 2011e), the flow statistics for the receiving water bodies around the MGP site are based on records from the Grange monitoring station on the Shag River, the Cloverdown monitoring station on the NBWR and the Golden Point Weir on Deepdell Creek. The sites have differing lengths of flow records, some of which overlap the operational period of the MGP. As such, some of these records already include the effects of mining and the numbers cannot be directly compared from site to site. Similarly there are errors associated with the estimated flow statistics that are likely to be in the order of 10%, which is standard for most hydrological flow measurements.

The reductions in catchment areas due to the MGP operations result in reduced flows downstream from the mine site. As you move down the catchment, the respective changes in flow are reduced. At the water quality compliance points of NB03, Loop Road and McCormicks, which are located upstream from consented water takes, the changes in flows are very modest. At these monitoring points, the reductions in flows are expected to be within the error associated with the current estimated flows.

A table providing summary statistics for the existing flows at surface water quality sites downstream from the MGP is presented in Appendix G. Summary statistics for flows during the operational period of the mine and following closure are also presented in Appendix G. As noted above, the statistics presented are likely to overestimate the reductions in flows, as existing flow records partially overlap the operational period at the MGP and therefore already incorporate some allowance for flow losses.



Golder Associates

EXTENT OF PIT LAKES 10 YEARS FROM CLOSURE

APRIL 2011

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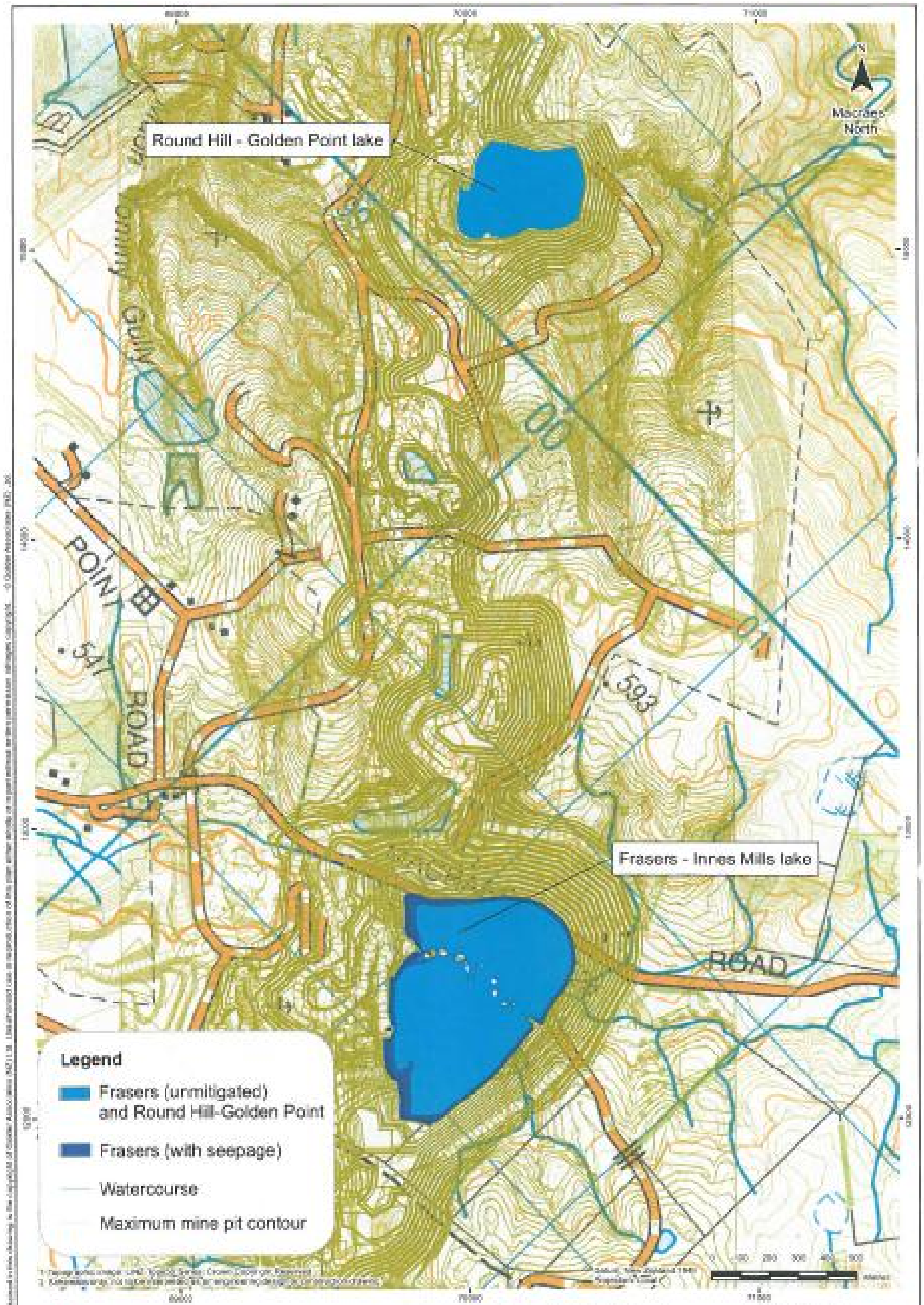
33



Golder Associates

EXTENT OF PIT LAKES
50 YEARS FROM CLOSURE

APRIL 2011

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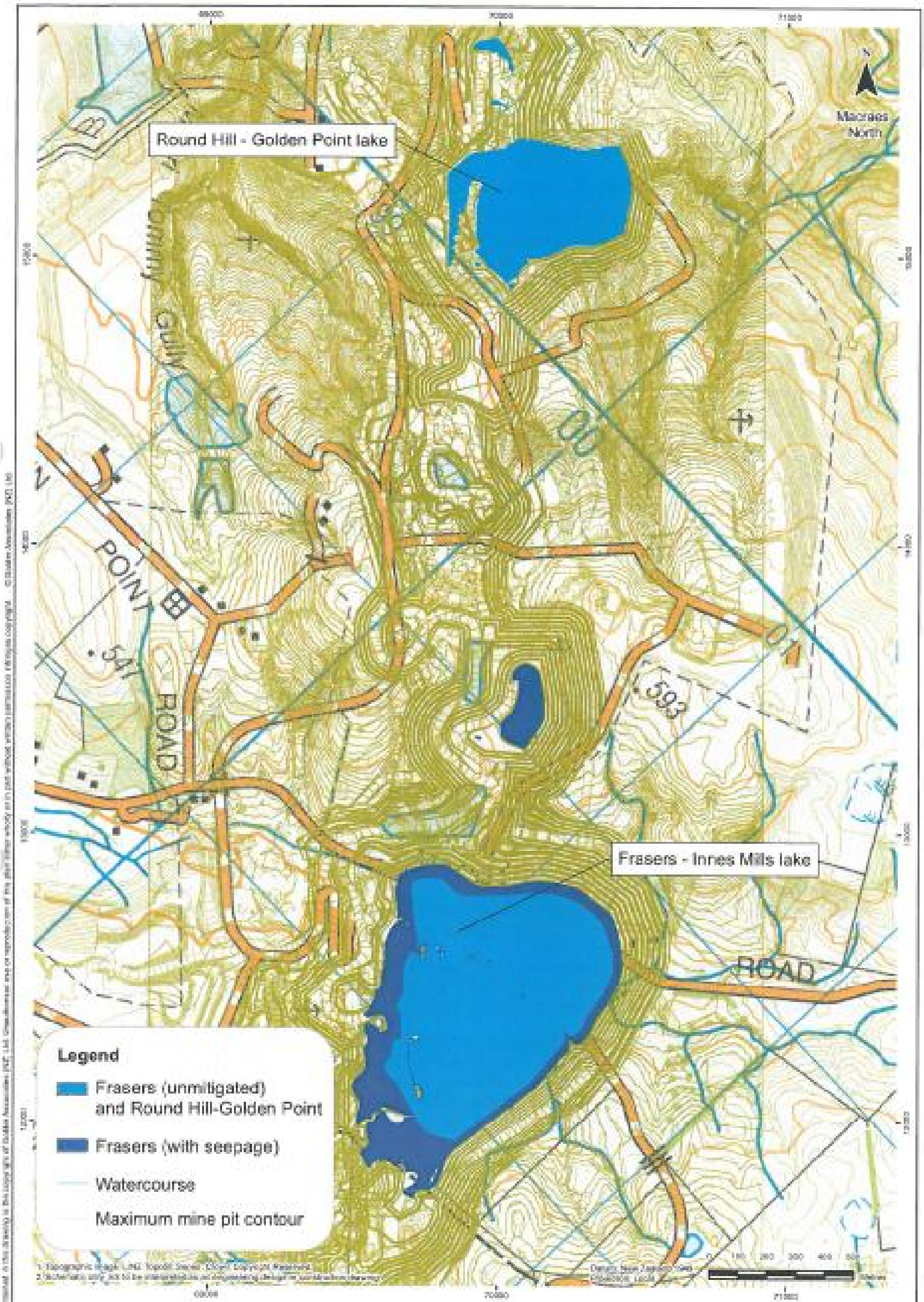
34



Golder Associates

EXTENT OF PIT LAKES
150 YEARS FROM CLOSURE

APRIL 2011

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35

6.0 RECEIVING WATER QUALITY PROJECTIONS

6.1 Adopted Consent Criteria

Modelled stream water quality has been compared to existing consent compliance criteria for current compliance points and these criteria have been adopted, as appropriate, for proposed compliance points. Existing and proposed compliance points are presented on Figure 3. A summary of the compliance criteria for existing and proposed surface water compliance monitoring points is presented in Table 39.

The development of the MGP over time has resulted in a range of compliance points related to different sections of the mine. In some cases, these compliance points are now unnecessary or will become unnecessary if the proposed compliance monitoring regime outlined in Table 39 is approved.

In the sections below, data available for each of the existing surface water compliance points is summarised. Projected water quality results are also summarised for both existing and proposed compliance monitoring points. Additionally, graphs of projected water quality exceedance curves are presented in Appendix F. The exceedence curves indicate what percentage of the time a compliance criterion is anticipated to be exceeded.

Measures to mitigate for possible water quality criteria exceedances are presented in a separate report (Golder 2011a). The water quality outcomes based on the instigation of selected mitigation measures are also documented in the mitigation report (Golder 2011a).

6.2 Deepdell Creek

Surface water quality downstream of the MGP within Deepdell Creek is proposed to be monitored at both DC07 and DC08, however only the latter is to serve as a compliance point. The primary usage of water from Deepdell Creek is considered to be stock watering. No potable water supply takes are known to exist along Deepdell Creek. Deepdell Creek receives discharges (drainage and seepage) from sources including the MTI, SPI and WRS's within this catchment.

The water quality measured at DC07 to date is summarised in Table 40. Projected water quality for DC07 and DC08 are summarised in Table 41 and Table 42, respectively. Projected water quality values exceed adopted compliance criteria at DC08 for arsenic, sulphate, cyanide$_{WAD}$ and iron.

The primary sources of arsenic and cyanide$_{WAD}$ to the water at DC08 are the discharges from the MTI drainage systems. Although conservative modelling indicates these two parameters would exceed the proposed compliance limits following closure, their attenuation within the surface water system is likely to result in few if any exceedances of the compliance limits (refer Section 6.9.1). Sulphate and iron (refer Section 6.9.2) are derived from more diffuse sources and are more likely to pose compliance issues.

For arsenic and cyanide$_{WAD}$ the simulation outcomes indicate the primary issues are contaminants carried by TSF drainage discharges following closure. In both cases the contaminants are treated as being conservatively transported within the surface water system, whereas this is unlikely to be the case.

Cyanide $_{WAD}$ is not conservatively transported within surface water systems, where breakdown occurs due to exposure to ultraviolet light and through other mechanisms. The situation with cyanide $_{WAD}$ is compounded due to the conservative simulation of cyanide $_{WAD}$ transport within the groundwater system. Site environmental monitoring indicates cyanide $_{WAD}$ attenuation with respect to conservatively transported parameters is occuring (Golder 2011b, c) and the mass load outcomes from the groundwater model are considered to be very conservative.

Table 33: MGP surface water quality compliance limits summary.

Compliance Point	Potential usage	pH (unitless)		Arsenic		Cyanide $_{WAD}$		Copper		Iron		Lead		Zinc		Sulphate	
		current	proposed	current	proposed	current	proposed	current	proposed	current	proposed	current	proposed	current	proposed	current	proposed
Deepdell Creek DC07 [1]	Stock watering	6 – 9.5	-	0.15	-	0.1	-	0.009	-	1	-	0.0025		0.12	-	1000	-
Deepdell Creek DC08 [1]	Stock watering	-	6 – 9.5	-	0.15	-	0.1	-	0.009	-	1	-	0.0025	-	0.12	-	1000
Shag River at Loop Rd [2]	Drinking	7 – 8.5	7 – 8.5	0.01	0.01	0.1	0.1	0.009	0.009	0.2	0.2	0.0025	0.0025	-	0.12	250	250
Shag River at McCormicks	Drinking	-	7 – 8.5	-	0.01	-	0.1	-	0.009	-	0.2	-	0.0025	-	0.12	-	250
North Branch Waikouaiti River NBWRRB [2]	Stock watering	6 – 9.5	6 – 9.5	0.15	0.15	-	0.1	0.009	0.009	1	1	0.0025	0.0025	0.12	0.12	-	1000
North Branch Waikouaiti River NBWRRF [2,3]	Stock watering	6 – 9.5	-	0.01	-	-	-	0.009	-	1	-	0.0025	-	0.12	-	-	-
Murphys Creek MC100 [2,4] (upstream)	Stock watering	6 – 9.5	-	0.15	-	-	-	0.009	-	1	-	0.0025	-	0.12	-	-	-
Murphys Creek MC01 [2,4] (downstream)	Stock watering	6 – 9.5	6 – 9.5	0.01	0.15	-	-	0.009	0.009	1	1	0.0025	0.0025	0.12	0.12	-	1000
North Branch Waikouaiti River NB03 [5]	Drinking	6 – 9.5	6 – 9.5	0.01	0.01	-	-	0.009	0.009	1	1	0.0025	0.0025	0.12	0.12	-	250
Cranky Jim Creek CJ01	Stock watering	-	6 – 9.5	-	0.15	-	0.1	-	0.009	1	1	-	0.0025	-	0.12	-	1000
Tipperary Creek TC01	Stock watering	-	6 – 9.5	-	0.15	-	0.1	-	0.009	1	1	-	0.0025	-	0.12	-	1000
ANZECC (2000) stock				0.5		NA		0.5	sheep	NA		0.1		20		1000	
NZDWS (2008)		7 – 8.5	(GV)	0.01	(MAV)	0.08	(MAV total)	2	(MAV)	0.2	(GV)	0.01				250	

Notes: All units g/m³ unless stated; [1] current compliance limits from ORC Resource Consents 2006.384, 2006.385, 2006.307, 2006.388; [2] current compliance limits from ORC Resource Consents 2006.835, 2003.836, 2003.837, 2003.838, 2004.162, 2005.208, 2005.209, 2005.210, 2007.181 (see Golder 2011c for further detail on compliance limit for copper at MC01 and NBWRRB); [3] Ross Ford NBWRRF compliance point proposed to revert to monitoring only, in favour of downstream compliance point NB03; [4] MC100 compliance point proposed to revert to monitoring only. Compliance limits currently applicable to MC100 to be applied at MC01; [5] current compliance limits from ORC Resource Consents 2001.481, 2002.769, 2002.763. NB03 becomes final downstream compliance point on the NBWR for all MGP operations; ANZECC (2000) drinking water quality guidelines for livestock; NZDWS (2008) drinking water standards for human consumption; and MoH (2008) drinking water limit equivalent to the maximum acceptable value (MAV) given in MoH (2008); MAV for total cyanide, short term.

Table 40: Summary of reported water quality at DC07 (2000 – 2010).

Parameter [1]	Minimum	Mean	95th Percentile	Maximum	Existing compliance limit	Exceedances
pH (unitless)	6.2	8.1	8.8	9.1	6.0 – 9.5	0
Conductivity (mS/m)	80	270	580	1,900	-	-
Calcium	9.1	37	120	250	-	-
Chloride	5.9	10	14	15	-	-
Magnesium	3.1	16	62	120	-	-
Potassium	0.59	1.8	3.8	8.9	-	-
Sodium	7.4	17	33	80	-	-
Sulphate	2.6	66	260	1,020	1,000	1
Cyanide $_{(WAD)}$	<0.001	<0.0049	0.0050	0.030	0.10	0
Arsenic	<0.005	0.012	0.0259	0.028	0.15	0
Copper	<0.0005	0.0011	0.002	0.0024	0.009 [2]	0
Iron	<0.020	<0.19	0.82	2.0	1.0	2
Lead [3]	<0.0001	NA	NA	0.001	0.0025 [2]	2 [4]
Zinc [5]	NA	NA	NA	0.0024	0.12 [2]	0

Notes: [1] All units g/m^3 unless otherwise stated; all data presented to two significant figures; [2] the consent compliance limits for these parameters is hardness dependent (for hardness dependent metals (copper, lead and zinc), the compliance limits provided in this table have been calculated assuming a hardness of 100 g/m^3 as CaCO; the evaluation of exceedances is based on compliance limits adjusted for measured hardness for each sampling event (Golder 2011d); [3] only three samples returned concentrations above the detection limit; [4] where upstream samples from Deepdell Creek on corresponding dates have been analysed for lead, the upstream water quality also exceeded the compliance limit; and [5] only one sample analysed for zinc during the period indicated.

Table 41: Summary of projected water quality at DC07 (2011 – 2170).

Parameter [1]	Minimum	Mean	95th Percentile	Maximum	Existing compliance limit (none proposed)	Exceedances
Arsenic	0.002	0.08	0.20	0.35	0.15	Yes
Sulphate	4.1	409	989	1,408	1,000	Yes
Cyanide $_{(WAD)}$	0.001	0.05	0.12	0.45	0.1	Yes
Copper	0.000	0.001	0.001	0.002	0.009 [2]	No
Iron	0.19	2.0	5.2	9.6	1	Yes
Lead	<0.001	<0.001	<0.001	0.001	0.0025 [2]	No
Sodium	5.2	46	108	194		
Potassium	1.000	3.0	6.1	9.0		
Calcium	13	86	189	268		
Magnesium	4.0	63	118	149		
Zinc	0.003	0.007	0.012	0.014	0.12 [2]	No
Chloride	1.4	14	22	33		

Notes: [1] All units g/m^3; all data presented to two significant figures; and [2] the consent compliance limits for these parameters is hardness dependent (for hardness dependent metals (copper, lead and zinc), the compliance limits provided in this table have been calculated assuming a hardness of 100 g/m^3 as CaCO; model projections for potential compliance limit exceedances have not been evaluated on a hardness dependent basis).

Table 42: Summary of projected water quality at DC08 (2011 – 2170).

Parameter[1]	Minimum	Mean	95th Percentile	Maximum	Proposed compliance limit	Exceedence
Arsenic	0.002	0.066	0.16	0.31	0.15	Yes
Sulphate	4.1	466	1,046	1,411	1,000	Yes
Cyanide $_{(WAD)}$	0.001	0.041	0.095	0.38	0.1	Yes
Copper	<0.001	0.001	0.001	0.002	0.009 [2]	No
Iron	0.19	1.7	4.3	8.6	1	Yes
Lead	<0.001	<0.001	<0.001	0.001	0.0025 [2]	No
Sodium	5.2	42	94	176	-	-
Potassium	1.0	3.3	6.3	8.8	-	-
Calcium	13	96	201	269	-	-
Magnesium	4.0	64	135	159	-	-
Zinc	0.003	0.008	0.013	0.015	0.12 [2]	No
Chloride	1.4	13	19	30	-	-

Notes: [1] All units g/m^3; all data presented to two significant figures; and [2] the consent compliance limits for these parameters is hardness dependent (for hardness dependent metals (copper, lead and zinc), the compliance limits provided in this table have been calculated assuming a hardness of 100 g/m^3 as CaCO; model projections for potential compliance limit exceedances have not been evaluated on a hardness dependent basis).

The conservative transport of arsenic within the surface water system contrasts with the simulated behaviour of arsenic in the groundwater model. In the latter simulation, adsorption of arsenic onto rock and soils has been taken into account (Golder 2011b, c). Investigations into arsenic transport within streams from mining sites in the Otago region indicates arsenic is rapidly deposited onto substrate materials (Craw et al. 2000).

For sulphate, the simulation outcomes indicate the sources are a combination of TSF discharges, seepage losses from the MTI through the underlying rock mass and leaching of the WRS's within the catchment. The exceedances identified are related to either:

- Near term TSF drain discharges.
- Long term groundwater transported contaminant loads from the MTI and the WRS's in the catchment.

6.3 Tipperary Creek

Tipperary Creek is a discharge point for drainage and seepage water from the TTTSF and Frasers East WRS. The surface water in Tipperary Creek is to be monitored at the proposed compliance point TC01 (Figure 3). Usage of surface water downstream of TC01 is considered primarily to be for stock watering. Table 43 summarises the projected water quality at the proposed compliance point TC01 into the future. Projected water quality exceeds adopted criteria at TC01 for arsenic, sulphate and iron.

Table 43: Summary of projected water quality at TC01 (2011 – 2170).

Parameter [1]	Minimum	Mean	95th %ile	Maximum	Proposed compliance limit	Exceedance
Arsenic	<0.001	0.09	0.16	0.21	0.15	Yes
Calcium	4.9	117	176	196	-	
Chloride	0.1	15	19	24	-	
Copper	<0.001	<0.001	0.0019	0.0022	0.009 [2]	No
Cyanide$_{WAD}$	<0.001	0.019	0.028	0.033	0.1	No
Iron	0.0090	4.8	7.4	8.4	1.0	Yes
Lead	<0.001	<0.001	<0.001	0.001	0.0025 [2]	No
Magnesium	3.8	70	103	111	-	
Potassium	0.11	4.8	6.6	7.4	-	
Sodium	0.58	94	146	168	-	
Sulphate	4	673	1031	1,144	1,000	Yes
Zinc	<0.001	0.010	0.013	0.014	0.12 [2]	No

Notes: [1] All units g/m^3; all data presented to two significant figures; and [2] the consent compliance limits for these parameters is hardness dependent (for hardness dependent metals (copper, lead and zinc), the compliance limits provided in this table have been calculated assuming a hardness of 100 g/m^3 as CaCO$_3$; model projections for potential compliance limit exceedances have not been evaluated on a hardness dependent basis).

6.4 Cranky Jims Creek

Construction of the TTTSF is expected to affect the water quality in Cranky Jims Creek, partly due to groundwater seepage in this direction and partly due to run-off and shallow seepage from the TTTSF embankment which encroaches on this catchment. The surface water in Cranky Jims Creek is to be monitored at a proposed compliance point CJ01. Usage of surface water downstream of CJ01 is considered to be primarily for stock watering purposes.

The projected water quality at the proposed compliance point CJ01 into the future is summarised in Table 44. Projected water quality exceeds adopted criteria at CJ01 for iron.

Table 44: Summary of projected water quality at CJ01 (2011 – 2170).

Parameter [1]	Minimum	Mean	95th %ile	Maximum	Proposed compliance limit	Exceedance
Arsenic	<0.001	0.003	0.005	0.005	0.15	No
Calcium	0.08	35	82	94	-	
Chloride	0.09	10.1	11.0	11.0	-	
Copper	<0.001	0.0013	0.0020	0.0020	0.009[2]	No
Cyanide$_{WAD}$	<0.001	0.0033	0.0049	0.0050	0.1	No
Iron	0.004	1.2	2.7	3.0	1.0	Yes
Lead	<0.001	<0.001	<0.001	0.001	0.0025[2]	No
Magnesium	0.03	24	61	70	-	
Potassium	0.02	2.2	2.9	3.0	-	
Sodium	0.09	23	48	54	-	
Sulphate	0.03	176	501	580	1,000	No
Zinc	<0.001	0.0033	0.0049	0.0050	0.12[2]	No

Notes: [1] All units g/m^3; all data presented to two significant figures; and [2] the consent compliance limits for these parameters is hardness dependent (for hardness dependent metals (copper, lead and zinc), the compliance limits provided in this table have been calculated assuming a hardness of 100 g/m^3 as CaCO$_3$; model projections for potential compliance limit exceedances have not been evaluated on a hardness dependent basis).

6.5 Shag River

The eventual receiving water for flows from Deepdell Creek, Cranky Jims Creek and Tipperary Creek is the Shag River. Water quality in the Shag River is measured at the Loop Road compliance point. An additional compliance point downstream from the confluence with McCormicks Creek is proposed to allow for the influence of discharges to Tipperary Creek and Cranky Jims Creek to be monitored.

Reported water quality data for the Shag River at Loop Road (Table 45) indicates the MGP is complying with the consented water quality limits. Simulated water quality for the Shag River at Loop Road indicates concentrations of arsenic, iron and sulphate may exceed the consent compliance criteria (Table 46).

Both iron and arsenic are modelled as being conservatively transported in surface waters. This is not the case in reality as both are subject to substantial attenuation in a surface water environment. The projected contaminant concentrations in the Shag River at Loop Road for these parameters are therefore considered to be very conservative.

Table 45: Summary of reported water quality at Shag River at Loop Road (2000 – 2010).

Parameter (1)	Minimum	Mean	95th %ile	Maximum	Existing compliance limit	Exceedances
pH (unitless)	6.9	7.7	8.0	8.2	7.0 – 8.5	1
Conductivity (mS/m)	100	180	280	460	-	-
Calcium	9.4	18	29	48	-	-
Chloride	4.4	5.6	8.0	8.2	-	-
Magnesium	2.4	5.3	8.9	17	-	-
Potassium	0.64	0.96	1.4	1.4	-	-
Sodium	6.5	9.6	14	17	-	-
Sulphate	6.5	27	62	150	250	0
Cyanide$_{WAD}$	<0.0010	<0.0025	0.0050	0.0050	0.10	0
Arsenic	0.0011	0.0034	0.0050	0.0050	0.010	0
Copper	<0.00050	<0.0013	0.0020	0.0020	0.009(2)	0
Iron	<0.02	<0.084	0.16	0.16	0.20	0
Lead	<0.00010	<0.00047	0.0010	0.0010	0.0025(2)	0
Zinc(1)	0.0027	NA	NA	NA	0.12(2)	0

Notes: (1) All units g/m^3 unless otherwise stated; all data presented to two significant figures; (2) analysed on only one occasion; (3) the consent compliance limits for these parameters is hardness dependent (for hardness dependent metals (copper, lead and zinc), the compliance limits provided in this table have been calculated assuming a hardness of 100 g/m^3 as CaCO; the evaluation of exceedances is based on compliance limits adjusted for measured hardness for each sampling event (Golder 2011d)).

Table 46: Summary of projected water quality in the Shag River at Loop Road (2011 – 2170).

Parameter [1]	Minimum	Mean	95th %ile	Maximum	Proposed compliance limit	Exceedence
Arsenic	0.002	0.010	0.029	0.10	0.01	Yes
Calcium	13	25	48	126	-	-
Chloride	1.3	11	12	16	-	-
Copper	0.00025	0.0011	0.0011	0.0013	0.009[2]	No
Cyanide$_{WAD}$	0.0013	0.0083	0.019	0.061	0.1	No
Iron	0.20	0.42	0.91	2.8	0.2	Yes
Lead	<0.001	0.00012	0.00013	0.00026	0.0025[2]	No
Magnesium	4.0	12	29	82	-	-
Potassium	1.0	1.3	2.0	4.2	-	-
Sodium	6	15	25	63	-	-
Sulphate	4	69	197	633	250	Yes
Zinc	0.003	0.005	0.006	0.010	0.12[2]	No

Notes: [1] All units g/m^3; all data presented to two significant figures; and [2] the consent compliance limits for these parameters is hardness dependent (for hardness dependent metals (copper, lead and zinc), the compliance limits provided in this table have been calculated assuming a hardness of 100 g/m^3 as CaCO; model projections for potential compliance limit exceedances have not been evaluated on a hardness dependent basis).

Projected water quality in the Shag River at the proposed McCormick Road compliance point, located downstream from the confluence with McCormicks Creek, is summarised in Table 47. Simulated water quality for the Shag River at Loop Road indicates concentrations of arsenic, iron and sulphate may exceed the consent compliance criteria (Table 47).

Table 47: Summary of projected water quality in the Shag River at McCormicks Road (2011 – 2170).

Parameter [1]	Minimum	Mean	95th %ile	Maximum	Proposed compliance limit	Exceedence
Arsenic	0.0015	0.011	0.030	0.095	0.01	Yes
Calcium	13	24	46	117	-	-
Chloride	1.3	11	12	16	-	-
Copper	0.00025	0.0011	0.0011	0.0012	0.009[2]	No
Cyanide$_{WAD}$	0.0012	0.0069	0.015	0.041	0.1	No
Iron	0.2	0.5	1.2	3.4	0.2	Yes
Lead	0.00002	0.00012	0.00014	0.00023	0.0025[2]	No
Magnesium	4	12	26	73	-	-
Potassium	0.97	1.3	2.0	4.2	-	-
Sodium	6	17	30	73	-	-
Sulphate	4	69	197	609	250	Yes
Zinc	0.003	0.005	0.006	0.010	0.12[2]	No

Notes: [1] All units g/m^3; all data presented to two significant figures; and [2] the consent compliance limits for these parameters is hardness dependent (for hardness dependent metals (copper, lead and zinc), the compliance limits provided in this table have been calculated assuming a hardness of 100 g/m^3 as CaCO; model projections for potential compliance limit exceedances have not been evaluated on a hardness dependent basis).

As discussed above, the conservative modelling of iron and arsenic transport in surface waters produces very conservative outcomes for these parameters. This is not the case in reality, as both parameters are subject to substantial attenuation in a surface water environment.

6.6 Murphys Creek

Murphy's Creek is a discharge area for drainage and seepage water from Frasers West and Frasers South WRS's. The surface water in Murphy's Creek is currently monitored at compliance locations MC100 and MC01 (Figure 3). Monitoring site MC100 is located a short distance downstream from the Murphy's Creek silt pond. Monitoring site MC01 is located approximately 1 km further downstream.

Reported water quality data for Murphys Creek at MC100 is summarised in Table 48. Simulated water quality projections for Murphys Creek at MC100 indicate concentrations of iron may exceed the existing consent compliance criteria (Table 49). Although the simulated water quality indicates sulphate concentrations at MC100, it is possible the model is understating the concentrations that may occur during the operational period of the mine. OceanaGold holds a consent authorising the disposal of water from Frasers Pit to Murphys Creek catchment. This facility has been used in the past, with mine water being irrigated to Frasers West WRS. The implication is the infiltration rates to this WRS exceed those applied in the groundwater model. The groundwater model is likely to understate contaminant mass loads to Murphys Creek during the operational period of the mine, however following closure this irrigation process would cease and the long term projections are considered valid.

Table 48: Summary of reported water quality at MC100 (2000 – 2010).

Parameter (1)	Minimum	Mean	95th %ile	Maximum	Existing compliance limit	Exceedances
pH (unitless)	7.1	7.9	8.2	8.3	6.0 – 9.5	-
Conductivity (mS/m)	63	640	1,300	1,700	-	-
Calcium	3.8	83	200	200	-	0
Chloride	5.9	10	13	15	-	-
Magnesium	1.6	49	120	150	-	0
Potassium	0.10	4.5	9.5	9.5	-	-
Sodium	7.8	16	27	28	-	-
Sulphate	<1.0	270	920	920	-	0
$\text{Cyanide}_{\text{WAD}}$	-	-	-	-	-	-
Arsenic	<0.0010	<0.0038	0.0080	0.010	0.15	0
Copper	0.0014	0.0015	0.0016	0.0016	0.009 (2)	0
Iron	0.030	0.18	0.57	0.86	1.0	0
Lead (3)	0.0001	0.0001	0.0001	0.0001	0.0025 (2)	0
Zinc (4)	0.0017	NA	NA	NA	0.12 (2)	0

Notes: (1) All units g/m^3 unless otherwise stated; all data presented to two significant figures; (2) the consent compliance limits for these parameters is hardness dependent (for hardness dependent metals (copper, lead and zinc), the compliance limits provided in this table have been calculated assuming a hardness of 100 g/m^3 as CaCO; the evaluation of exceedances is based on compliance limits adjusted for measured hardness for each sampling event (Golder 2011d)); (3) only three results above the detection limit, with all three returning the same value; and (4) analysed on only one occasion.

Table 49: Summary of projected water quality in Murphys Creek at MC100 (2011 – 2170).

Parameter [1]	Minimum	Mean	95th %ile	Maximum	Existing compliance limit (none proposed)	Exceedance
Arsenic	<0.001	0.0028	0.0090	0.10	0.15	No
Calcium	31	122	143	144	-	
Chloride	0.75	5.1	9.0	16	-	
Copper	0.00017	0.00095	0.0018	0.0060	0.009[2]	No
Cyanide$_{WAD}$	<0.001	0.0011	0.0034	0.0050	0.1	No
Iron	0.11	0.28	0.30	2.0	1.0	Yes
Lead	<0.001	<0.001	<0.001	0.0015	0.0025[2]	No
Magnesium	25	91	117	118	-	
Potassium	0.83	3.5	3.9	5.5	-	
Sodium	4	18	19	35	-	
Sulphate	144	598	754	760		
Zinc	0.002	0.008	0.010	0.010	0.12[2]	No

Notes: [1] All units g/m^3; all data presented to two significant figures; [2] the consent compliance limits for these parameters is hardness dependent (for hardness dependent metals (copper, lead and zinc), the compliance limits provided in this table have been calculated assuming a hardness of 100 g/m^3 as CaCO; model projections for potential compliance limit exceedances have not been evaluated on a hardness dependent basis.

Based on recorded water quality data from this site it is considered likely that the proposed water quality criterion for sulphate will be exceeded in the future, if only during the operation and immediate post-closure period of the mine. It is expected that mitigation measures would be required to meet existing compliance limits for sulphate at MC100. The MC100 compliance point is however so close to the Murphys Creek silt dam that diversion of water from the dam, treatment of that water and returning that water to Murphys Creek cannot be reasonably achieved upstream from this compliance point without some form of ongoing pumping regime. It has therefore proposed that the water quality limits applicable to MC100 be shifted to the existing compliance monitoring point MC01. OceanaGold owns the land adjacent to Murphys Creek between these two monitoring sites. This shift would provide opportunities for water quality mitigation if necessary over the long term.

Reported water quality data for Murphys Creek at MC01 is summarised in Table 50. Simulated water quality projections for Murphys Creek at MC01 indicate concentrations of arsenic, copper and iron may exceed the existing consent compliance criteria (Table 51). The maximum values calculated for arsenic and copper are considered to be conservative due to the lack of attenuation processes apart from dilution being incorporated in the model (refer Section 6.9.1) and to the use of high observed values as model inputs.

If the proposed change in compliance limits for MC01 is adopted (Table 39) the potential for iron and other parameters to exceed the new compliance limit remains. As discussed above, the application of mitigation measures upstream from MC01 would however be more reasonably achievable. The compliance point NB03, which is located upstream from the nearest water take from the NBWR, would remain with additional compliance limits defined in line with those applying to compliance points on the Shag River.

Table 50: Summary of reported water quality in Murphys Creek at MC01 (2000 – 2010).

Parameter [1]	Minimum	Mean	95th %ile	Maximum	Existing compliance limit	Exceedances
pH (unitless)	7.0	7.9	8.4	8.7	6.0 – 9.5	0
Conductivity (mS/m)	140	510	1,100	1,600	-	-
Calcium	13	61	150	150	-	-
Chloride	6.6	9.8	13	14	-	-
Magnesium	4.8	36	92	130	-	-
Potassium	0.79	3.2	7.0	7.1	-	-
Sodium	10	14	21	27	-	-
Sulphate	2.1	180	690	760	-	-
$\text{Cyanide}_{\text{WAD}}$	-	-	-	-	0.1	-
Arsenic	<0.0010	<0.0034	0.0050	0.0060	0.01	0
Copper	0.001	NA	NA	0.0015	0.009 [2]	0
Iron	0.040	0.3	1.2	1.95	1.0	2
Lead [3]	<0.00010	NA	NA	0.0001	0.0025 [2]	0
Zinc [4]	0.0045	NA	NA	NA	0.12 [2]	0

Notes: [1] All units g/m^3 unless otherwise stated; all data presented to two significant figures; [2] the consent compliance limits for these parameters is hardness dependent (for hardness dependent metals (copper, lead and zinc), the compliance limits provided in this table have been calculated assuming a hardness of 100 g/m^3 as CaCO; the evaluation of exceedances is based on compliance limits adjusted for measured hardness for each sampling event (Golder 2011d)); [3] only three results above the detection limit, which changed over time; and [4] only two results recorded above the detection limit.

Table 51: Summary of projected water quality in Murphys Creek at MC01 (2011 – 2170).

Parameter [1]	Minimum	Mean	95th %ile	Maximum	Proposed compliance limit	Exceedance
Arsenic	<0.001	0.006	0.010	0.096	0.01	Yes
Calcium	31	110	133	141	-	
Chloride	0.75	7.5	10	15	-	-
Copper	<0.001	0.0014	0.0019	0.0050	0.009 [2]	No
$\text{Cyanide}_{\text{WAD}}$	<0.001	0.0027	0.0044	0.0050	0.1	No
Iron	0.12	0.23	0.28	1.7	1.0	Yes
Lead	<0.001	<0.001	<0.001	0.0015	0.0025 [2]	No
Magnesium	25	69	100	114	-	-
Potassium	0.83	3.3	3.7	5.3	-	-
Sodium	4.1	18	19	34	-	-
Sulphate	147	422	635	732	-	-
Zinc	0.002	0.007	0.009	0.010	0.12 [2]	No

Notes: [1] all units g/m^3; all data presented to two significant figures; and [2] the consent compliance limits for these parameters is hardness dependent (for hardness dependent metals (copper, lead and zinc), the compliance limits provided in this table have been calculated assuming a hardness of 100 g/m^3 as CaCO; model projections for potential compliance limit exceedances have not been evaluated on a hardness dependent basis).

6.7 North Branch Waikouaiti River

The NBWR receives drainage and seepage water from the Frasers West WRS. The surface water in the NBWR is monitored at compliance locations Red Bank Road (NBWRRB) and Ross Ford (NBWRRF).

Reported and projected water quality for the NBWR at Red Bank Road are summarised in Table 52 and Table 53. Simulated water quality results for the NBWR at NBWRRB are projected to exceed consent compliance criteria for arsenic, iron and sulphate. The iron and sulphate projections appear to be in accordance with observed groundwater quality trends down-gradient from Frasers West WRS. The maximum result for arsenic is however anomalous and is considered very unlikely to eventuate.

Reported and projected water quality for the NBWR at Ross Ford are summarised in Table 54 and Table 55. Simulated water quality results for the NBWR at NBWRRF are projected to exceed consent compliance criteria for arsenic and iron. The iron and sulphate projections appear to be in accordance with observed groundwater quality trends down-gradient from Frasers West WRS. The maximum result for arsenic is however anomalous and is considered very unlikely to eventuate.

In the past excessive stormwater that has accumulated in Frasers Pit has been irrigated onto Frasers West WRS. These irrigation events have also potentially exacerbated the rate of contaminant seepage from this WRS toward the NBWR due to increased infiltration through the WRS. Following closure of mining operations at the MGP, further irrigation would cease and the annual infiltration rate is expected to revert to the regional average. For this reason, the concentrations of contaminants currently observed down-gradient from the WRS may not be representative of the post-closure condition.

Table 52: Summary of reported water quality in the NBWR at NBWRRB (2000 – 2010).

Parameter [(1)]	Minimum	Mean	95th %ile	Maximum	Exsiting compliance limit	Exceedances
pH (unitless)	6.7	7.3	8.0	8.3	6.0-9.5	0
Conductivity (mS/m)	100	500	1,300	1,500	-	-
Calcium	16	55	120	160	-	-
Chloride	7.5	14	21	30	-	-
Magnesium	5.0	40	96	150	-	-
Potassium	0.72	5.2	9.8	12	-	-
Sodium	7.2	21	45	49	-	-
Sulphate	4.0	210	610	900	1,000	0
$\text{Cyanide}_{\text{WAD}}$	<0.0050	NA	NA	<0.0050	0.1	0
Arsenic	<0.0050	<0.020	0.059	0.10	0.15	0
Copper	<0.00050	<0.0017	0.0023	0.010	0.009 [(2)]	0
Iron	0.020	1.0	3.5	12	1.0	8
Lead	<0.00010	<0.00066	0.0010	0.0010	0.0025 [(2)]	0
Zinc	<0.0040	<0.015	0.040	0.040	0.12 [(2)]	0

Notes: [(1)] All units g/m^3 unless otherwise stated; all data presented to two significant figures; and [(2)] the consent compliance limits for these parameters is hardness dependent (for hardness dependent metals (copper, lead and zinc), the compliance limits provided in this table have been calculated assuming a hardness of 100 g/m^3 as CaCO; the evaluation of exceedances is based on compliance limits adjusted for measured hardness for each sampling event (Golder 2011d)).

Table 53: Summary of projected water quality in the NBWR at NBWRRB (2011 – 2170).

Parameter [1]	Minimum	Mean	95th %ile	Maximum	Proposed compliance limit	Exceedance
Arsenic	<0.001	0.004	0.009	0.17	0.15	Yes
Calcium	10	158	201	204	-	
Chloride	0.25	6.8	10	23	-	
Copper	<0.001	0.0014	0.0019	0.0036	0.009 [2]	No
$Cyanide_{WAD}$	<0.001	0.0017	0.0042	0.0049	0.1	No
Iron	0.04	0.34	0.43	0.43	1.0	No
Lead	<0.001	<0.001	<0.001	0.0020	0.0025 [2]	No
Magnesium	9	116	165	168	-	
Potassium	0.29	4.7	5.7	7.6	-	
Sodium	1.4	23	27	50	-	
Sulphate	59	833	1,209	1,234	-	
Zinc	0.00075	0.0054	0.0080	0.011	0.12 [2]	No

Notes: [1] All units g/m^3; all data presented to two significant figures; and [2] the consent compliance limits for these parameters is hardness dependent (for hardness dependent metals (copper, lead and zinc), the compliance limits provided in this table have been calculated assuming a hardness of 100 g/m^3 as CaCO; model projections for potential compliance limit exceedances have not been evaluated on a hardness dependent basis).

Table 54: Summary of reported water quality in the NBWR at NBWRRF (2000 – 2010).

Parameter [1]	Minimum	Mean	95th %ile	Maximum	Existing compliance limit	Exceedances
pH (unitless)	6.7	7.3	7.8	8.1	6.0-9.5	0
Conductivity (mS/m)	48	310	560	4,700	-	-
Calcium	2.4	16	52	75	-	-
Chloride	6.3	9.0	12	13	-	-
Magnesium	1.1	9.4	37	49	-	-
Potassium	0.15	1.8	4.8	6.2	-	-
Sodium	3.6	10	21	29	-	-
Sulphate	<1.0	44	230	290	-	-
$Cyanide_{WAD}$	<0.005	NA	NA	NA	-	-
Arsenic	0.0011	0.0044	0.0073	0.0080	0.01	0
Copper [3]	<0.0005	0.0012	NA	0.0014	0.009 [2]	0
Iron	0.12	0.43	1.1	1.4	1.0	1
Lead [4]	<0.0001	NA	NA	0.0001	0.0025 [2]	0
Zinc	0.002	0.0035	0.0047	0.0049	0.12 [2]	0

Notes: [1] All units g/m^3 unless otherwise stated; all data presented to two significant figures; [2] the consent compliance limits for these parameters is hardness dependent (for hardness dependent metals (copper, lead and zinc), the compliance limits provided in this table have been calculated assuming a hardness of 100 g/m^3 as CaCO; the evaluation of exceedances is based on compliance limits adjusted for measured hardness for each sampling event (Golder 2011d)); [3] only four results above the detection limit; and [4] only two samples above the detection limit.

Table 55: Summary of projected water quality in the NBWR at NBWRRF (2011 – 2170).

Parameter [1]	Minimum	Mean	95th %ile	Maximum	Existing compliance limit (none proposed)	Exceedance
Arsenic	<0.001	0.010	0.010	0.11	0.01	Yes
Calcium	10	98	110	148	-	
Chloride	0.25	11	11	19	-	
Copper	<0.001	0.0019	0.0020	0.0030	0.009 [2]	No
Cyanide$_{WAD}$	<0.001	0.0047	0.0050	0.0050	0.1	No
Iron	0.036	0.18	0.21	0.43	1	No
Lead	<0.001	<0.001	<0.001	0.0015	0.0025 [2]	No
Magnesium	9	43	57	102	-	
Potassium	0.29	3.2	3.5	5.7	-	
Sodium	1.4	18	19	38	-	
Sulphate	77	230	340	910	-	
Zinc	0.0007	0.0050	0.0053	0.0088	0.12 [2]	No

Notes: [1] All units g/m^3; all data presented to two significant figures; [2] the consent compliance limits for these parameters is hardness dependent (for hardness dependent metals (copper, lead and zinc), the compliance limits provided in this table have been calculated assuming a hardness of 100 g/m^3 as CaCO; model projections for potential compliance limit exceedances have not been evaluated on a hardness dependent basis).

6.8 Pit Lakes

Water quality projections for the pit lakes following closure have been developed as part of the site wide modelling project. These projections are based on the water quality at the end of the 150 year post-closure modelled period rather than at overflow, as the pits are not projected to overflow within this period.

Water quality projections for Frasers Pit lake indicate an initially poor water quality as a consequence of disposal of tailings drainage water from each of the TSFs in this pit for a simulated period of 20 years following MGP closure. Subsequently the water quality in the pit improves as dilution from run-off water and direct precipitation forms an increasing fraction of the water in the lake. There are no projected seepage losses from Frasers Pit during the 150 year simulated post-closure period. The projected quality of the pit lake water at 150 years following closure is summarised in Table 56.Water quality projections for the Round Hill Pit lake (Table 56) indicate a progressive decline in water quality over time, primarily as the model does not include an allowance for seepage losses from this lake. Consequently, evaporative losses toward the end of the model run result in the simulated contaminants in the lake becoming progressively more concentrated. The eventual water quality balance was not reached during the run period.

These simulations of water quality in the pit lakes are derived from a simple mass balance model and have not been tested for hydrochemical stability. As with the stream water quality projections, the lake water projections are considered to be conservative for several parameters due to the potential for precipitation reactions to occur in the lake (refer Section 6.9.1). In addition, the water quality projections assume complete mixing of the lake water and are therefore presented as average concentrations for the lake water.

Table 56: Summary of projected pit lake water quality at 150 years post-closure.

Parameter [1]	Frasers Pit	Round Hill Pit
Arsenic	0.5	0.4
Calcium	150	220
Chloride	20	40
Copper	0.003	0.003
Cyanide$_{WAD}$	0.2	0.9
Iron	2.5	6.2
Lead	0.001	0.002
Magnesium	80	120
Potassium	9	7
Sodium	80	60
Sulphate	740	860
Zinc	0.009	0.01

Notes: [1] All units g/m^3; all data presented to two significant figures.

6.9 Discussion

6.9.1 Model conservatism

The simulation of water quality using the GoldSim model has been performed based on the assumption that contaminants are conservatively transport in surface waters. For a number of the simulated parameters, including metals, metalloids and cyanide$_{WAD}$ this is unlikely to be the case. For example, the outcomes from past investigations in southern New Zealand have indicated arsenic is attenuated not only in soils but also in the stream environment (Craw et al. 2000; Haffert & Craw 2008).

The GoldSim model was developed to fulfil several objectives, one of which is to provide conservative projections of water quality at existing and proposed consent compliance points into the future. The assumption of conservative transport within streams is useful for this purpose. Several parameters have been identified from the modelling process that that may eventually exceed compliance limits at some of the compliance monitoring points.

The GoldSim model used to simulate contaminant transport for this project is considered to generate conservative outcomes for a number of reasons documented earlier in this report. At this stage, a review of the initial assumption of conservative transport in surface water is important as the degree of conservatism built into the model has not been previously discussed.

PHREEQC is a physico-chemical modelling package that can be used for geochemical modelling of surface waters (Parkhurst & Appelo 1999). Such modelling can provide an indication of the degree of conservatism incorporated in load-based mixing calculations. A preliminary assessment of the hydrochemical stability of the simulated water quality in Deepdell Creek at DC08 has been performed. The assessment is preliminary and indicative only in that the water quality in Devils Creek can be expected to change daily. The hydrochemical stability of the mixed inflows from the various contributions to Deepdell Creek upstream from DC08 would therefore also change on a daily basis. For this reason the initial PHREECQ analysis has been undertaken on the mean and 95th percentile water quality outcomes from the GoldSim model.

In undertaking this assessment of the hydrochemical stability of the projected water quality in Deepdell Creek, the alkalinity was adjusted to achieve electro-neutrality and the simulations were run with and without equilibrium with atmospheric CO_2, both standard approaches. The outcomes indicate the major ions, including calcium, potassium, magnesium and sulphate, are effectively conservatively transported in surface water at the concentrations simulated by GoldSim at DC08. In contrast, most of the metals and metalloids including iron are likely to be attenuated through adsorption and precipitation reactions.

The simulated reductions in iron concentration from those generated by GoldSim for DC08 were at least two orders of magnitude, based on the precipitation of Ferrihydrite ($Fe(OH)_3$). A similar reduction in the concentration of lead in surface water was indicated. The simulated decrease in arsenic concentration was at least one order of magnitude. In contrast, copper, zinc and $cyanide_{WAD}$ showed effectively no change in concentration.

In reaching conclusions based on the surface water modelling undertaken for this project, the following factors need to be kept in mind:

- The inherent conservatism of the contaminant transport models generated during this project.
- The water quality adjustments indicated by the hydrochemical stability analysis.

The primary conclusion reached is that sulphate is likely to be the main dissolved contaminant that could present a long term issue for consent water quality compliance at the site.

6.9.2 Iron issues

Monitoring for iron in surface water and groundwater is required under current consents. The compliance concentration for iron is generally 1 g/m³ at groundwater compliance wells and surface water monitoring points, except at the Shag River where the compliance concentration is 0.2 g/m³ based on NZDWS (MoH 2008). Iron is an essential element with no listed maximum acceptable values for health significance. The limit in MoH (2008) is listed under "guideline values for aesthetic determinands" with a comment indicating the concern is related to staining of laundry or sanitary ware. ANZECC (2000) does not provide guideline values for protection of stockwater or aquatic ecosystems. The concentration of 1 g/m³ specified in the conditions of consent is a value based on a United States Environmental Protection Agency Gold Book criterion. This criterion was developed to limit the risk of iron flocculants developing in water receiving iron contaminated discharges.

The GoldSim surface water model projections indicate the current compliance criteria for iron would be exceeded in the local waterways. The review of model conservatism presented in Section 6.9.1, however, suggests dissolved iron is unlikely to be an issue at the mine site compliance points. Assuming however the input parameters to the models are valid, the implication is that iron flocculants are likely to develop close to the discharge points for TSF drains. These discharges are expected to require mitigation, as documented in Section 6.10, which should include addressing the potential for iron flocculation.

The transport of iron through the groundwater system at the site is not well understood at this stage. The concentrations measured in samples from detection wells down-gradient from the MTI suggest iron is over-represented in comparison to other conservatively transported contaminants. Environmental monitoring by OceanaGold indicates background iron concentrations in both groundwater and surface water vary considerably across the MGP site and across the wider Macraes area. For this reason the projections for iron concentrations generated from the model need to be treated with caution.

6.10 Scope of Mitigation Required for Compliance

The outcomes of the site wide surface water modelling program documented above identify locations where management measures may be necessary in order to ensure the MGP continues to operate within the current and proposed consent compliance limits, assuming natural attenuation does not result in contaminant concentrations being reduced to levels sufficiently to meet compliance levels. The outcomes of the modelling in terms of projected consent compliance are summarised in Table 57.

The GoldSim modelling outcomes indicate mitigation measures are likely to be necessary to ensure the MGP continues to meet consent compliance requirements at most of the sites listed in Table 57.

Table 57: Summarised un-mitigated and un-attenuated exceedances of proposed consent water quality limits.

Monitoring site	**Parameter** [1, 2]				
	Arsenic	**Copper**	**Cyanide$_{WAD}$**	**Iron**	**Sulphate**
DC08	(YES)	NO	(YES)	(YES)	YES
TC01	(YES)	NO	NO	(YES)	YES
Shag at Loop Road	(YES)	NO	NO	(YES)	YES
Shag at McCormicks	(YES)	NO	NO	(YES)	YES
NBWR Red Bank	(YES)	NO	NO	(YES)	YES
MC01	(YES)	NO	NO	(YES)	YES
NB03	(YES)	NO	NO	(YES)	YES
CJ01	NO	NO	NO	YES	NO

Notes: [1] Other parameters for these sites are projected to remain within compliance limits; [2] simulated exceedances presented in brackets are unlikely to eventuate (the in-built conservatism of the model and the lack of simulated natural attenuation processes leads to exceedances being indicated).

Taking into consideration the in-built conservatism of the model and natural processes that will likely attenuate arsenic and iron, as discussed in Section 6.9, the simulated exceedances of compliance criteria that are unlikely to eventuate have also been identified in Table 57. Monitoring is recommended for all bracketed parameters listed in Table 57 to confirm the expected conservatism of the model. Mitigation should be considered with respect to the parameters in Table 57 that are not bracketed due to the greater potential for exceedances at proposed surface water compliance monitoring locations.

A range of water management measures have been reviewed (Golder 2011a) with the objective of addressing the potential water quality compliance issues summarised in Table 57. A suite of measures has been identified suitable to mitigate for these projected compliance issues. The simulated improvements to water quality have also been documented (Golder 2011a). Water management measures that offer the potential to improve water quality at the site during the operational period of the mine have also been identified. Measures appropriate for the management of iron flocculants and the precipitation of other metals/metalloids has been reviewed (Golder 2011a) to provide a basis for assessing environmental effects related to surface water body substrates near discharge points.

It is expected that an appropriate set of water management measures can be instigated by OceanaGold that would enable the MGP to continue to operate within the proposed water quality criteria. Water management measures can be put in place prior to the closure of the site that would enable ongoing compliance with the proposed water quality criteria following closure (Golder 2011a).

7.0 CONCLUSIONS

OceanaGold is proposing to undertake a substantial expansion to the MGP operations, including the storage of tailings and waste rock in areas previously not influenced by the mining operation. As part of the environmental assessment of the Macraes Phase III Project, a mine water management model has been constructed to simulate dissolved contaminant transport in surface water from the MGP site. One set of input parameters for this mine water modelling is derived from groundwater contaminant transport modelling undertaken as part of the same project.

Construction of the Macraes Phase III Project would require an extension of the environmental compliance monitoring program. The proposed compliance monitoring regime includes:

- New compliance monitoring points downstream from the Back Road WRS and the TTTSF.
- Removal of unnecessary compliance monitoring points on Deepdell Creek and the NBWR.
- Shifting of one compliance monitoring point on Murphys Creek.

The water quality compliance limits are proposed to be standardised across the site. No water quality parameters have been removed from the list of compliance parameters, however at some sites new parameters have been added as part of the standardisation.

Modelling indicates the proposed compliance limits are likely to be exceeded at most compliance monitoring sites either during the operational period of the mine or following mine closure unless mitigation measures are undertaken. The modelled exceedances are mainly for sulphate, arsenic and iron, although the simulations also indicate copper and cyanide$_{WAD}$ may also exceed the compliance limits at individual sites.

As the surface water models used for this project incorporate an assumption of conservative contaminant transport within surface water bodies, the modelled exceedances for arsenic and cyanide$_{WAD}$ are unlikely to occur. Both are subject to geochemical reactions, precipitation, adsorption or breakdown in the natural environment. Dissolved iron is also unlikely to present an issue at the compliance points, due to its capacity to rapidly oxidise and subsequently precipitate. Mitigation measures may however be required to minimise any possible issues of iron flocculants and discolouration of stream beds close to the TSFs.

The primary water quality issue identified is the need to manage sulphate concentrations in receiving surface water bodies. As sulphate is conservatively transported in water, it does not become naturally attenuated except through dilution. Sulphate concentrations at all of the proposed compliance monitoring sites, except the site on Cranky Jims Creek, are likely to eventually exceed the relevant compliance limits on a seasonal basis. Mitigation measures are therefore considered to be necessary to ensure water quality on all of the creeks intersecting the MGP site, and in the Shag River.

It is expected that an appropriate set of water management measures can be instigated by OceanaGold that would enable the MGP to continue to operate within the proposed water quality criteria. Water management measures can be put in place prior to the closure of the site that would enable ongoing compliance with the proposed water quality criteria following closure (Golder 2011a).

The reductions in catchment areas due to the MGP operations result in reduced flows downstream from the minesite. As you move down the catchment, the respective changes in flow are reduced. At the water quality compliance points of NB03, Loop Road and McCormicks, which are located upstream from consented water takes, the changes in flows are very modest. At these monitoring points, the reductions in flows are expected to be within the error associated with the current estimated flows.

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