Macraes Phase IV

Coronation – Surface and Groundwater Assessment

Oceana Gold New Zealand Ltd.

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→ **The Power of Commitment**

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The Power of Commitment

Executive Summary

OceanaGold New Zealand Limited (OGNZL) operate the Macraes Gold Project (MGP) in east Otago, situated approximately 56 km north of Dunedin. The MGP began operations in 1990 and currently comprises two operational open cast pits (Frasers and Deepdell North Pits) and two underground mines - Frasers Underground (FRUG) and Golden Point Underground (GPUG), and a processing plant. Waste rock is placed both in pit as backfill and at a number of waste rock stacks (WRSs) located around the open pit margins. Tailings from processing ore is currently stored at the Top Tipperary Tailings Storage Facility (TTTSF). There are also two decommissioned Tailings Storage Facilities (TSFs) on site; the Mixed Tailings Impoundment (MTI) and the SP11 Tailings Storage Facility (SP11).

The Macraes Phase IV project is the next phase of proposed development at the site which aims to extend the life of mine (LOM) to around 2030. Consenting MPIV has been undertaken in stages. So far the MPIV project has involved increasing the capacity of the existing TTTSF to a height of 570 m RL allowing an additional 3.2 Mm^3 of tailings storage, a minor expansion of the existing Innes Mills Open Pit (IMOP) and the placement of mixed dry tailings and waste rock to form an embankment structure within the existing Fraser's Pit (Frasers Co-disposal). Surface water and groundwater assessments for these stages have previously been undertaken by GHD (GHD New Zealand Limited). The final stage of MPIV consists of four main developments. These areas include the expansion and extension of the Golden Point Underground mine, the subject of standalone consent application, and three surface developments, comprising:

1. The central area comprising life of mine Tailings Storage in Frasers Pit and development of the open pit mining extensions in Innes Mills Pit (IMOP);
2. An expansion of the Coronation Pit (situated approximately 4 km to the northwest of IMOP); and
3. An expansion of the Golden Bar Pit (situated approximately 6 km to the southeast of IMOP).

The focus of this assessment is groundwater and surface water effects associated with the proposed development of the Coronation Pit Stage 6 and its associated waste disposal within the Mare Burn and Deepdell Creek catchments. Cumulative water quality effects (taking into consideration existing mine facilities and operations) are considered for the Mare Burn catchment (a tributary of the Taieri River). Cumulative effects in the Deepdell catchment are reported separately.

A numerical groundwater 3D model of the Coronation pit area has been developed using MODFLOW-USG (flow modelling code) and MODFLOW-USG-TRANSPORT (for solute transport modelling code) and used to assess groundwater inflow into the existing and proposed pit as well as groundwater recovery post mining. The model was calibrated in the steady-state condition using available pre-mining pit lake and groundwater monitoring data before undertaking model predictions.

The results of the groundwater modelling provide predictions of groundwater flows into and out of the existing and proposed Coronation Pit and Coronation North Pit as well as seepage from Trimbells WRS, Coronation WRS, Coronation North Pit WRS and Coronation North WRS with the majority of these seepages are expected to move laterally within the weathered schist and be captured in silt ponds and/or report to the receiving surface water catchment.

The groundwater contaminant plume (conservatively illustrated using sulphate due to its low potential for attenuation within the groundwater system and existing elevated nature in some receiving surface water bodies as a result of mining activity associated with MGP) is modelled to primarily impact Trimbell's Gully and the upper reaches of the Mare Burn to the north of the proposed development and the upper reaches of Coal Creek to the west of the proposed development with an estimated sulphate seepage flux of between 183 and 696 kg/day (20 and 200 years post closure respectively) at the compliance monitoring location MB02 within the Mare Burn. Comparatively, the Deepdell catchment is expected to receive a small flux in comparison (~<1 kg/day).

An existing sitewide Goldsim Water Balance Model (WBM) has been utilised to estimate future impacts on the receiving water quality as a result of mining and rehabilitation activities. Key updates to the WBM include revised WRS seepage and pit lake water quality estimates, recalibration of key monitoring and compliance points utilising revised catchment boundaries and up to date water quality, and revised groundwater inflow / outflow estimates from the groundwater model.

The WBM indicates that the Coronation Pit Lake overflow level is likely to be reached after a period of approximately 200 years post closure, following which water from Coronation Pit Lake would spill into the Deepdell Catchment via the low point on the southern pit perimeter (@ 660 m RL). Prior to the pit lake reaching this overflow level, it is expected that pit lake water will seep through the Trimbells WRS to the north via the natural pit spill level (where the undisturbed ground is overlain by waste rock) after a post closure period of approximately 90 years. The volume of water discharging through this flow path is predicted to increase as the lake level rises.

Pit lake water draining through the Trimbells WRS is assumed not to deteriorate further as it flows through the WRS to Trimbells Gully. This assumes that advective flow of oxygen through the WRS is limited/prevented via the saturation of the WRS toe (or similar). In the event that advective flow is not limited/prevented, the pit water could become a significant source of sulphate to the Mare Burn.

The WBM shows that in general, sulphate and Nitrate-N concentrations within the immediate receiving environment (Trimbells Gully and Mare Burn) are predicted to increase post closure relative to the mining phase due to the increase in sulphate and Nitrate-N mass from seepage waters with time. Median modelled sulphate concentrations are predicted to increase (from mining to closure) from 80 g/m^3 to 129 g/m^3 and 60 to 89 g/m^3 at the Mare Bare compliance locations - MB01 and MB02 respectively. During low flows, the concentrations of both sulphate and Nitrate-N in the receiving environment are buffered by the capture of seepage in both the Trimbells and Maori Hen Silt Ponds. Some minor increases in trace elements are also expected. Ammoniacal N concentrations are predicted to reduce post closure relative to the mining phase due to the increased presence of rehabilitated surfaces (compared to non-rehabilitated surfaces which provide a higher relative contribution of these parameters before the closure period).

Water quality within the Mare Burn catchment is expected to be within the consented limits. There is a low modelled risk of exceedance of sulphate and Nitrate N compliance limits during prolonged low flow periods. The consented Coal Creek Dilution Dam has not been included in the modelling presented as the requirement for dilution water to achieve in stream consented compliance limits is not necessarily required based on the modelling undertaken. However, the potential construction of the dam and the potential for flow augmentation (and dilution of impacted waters during low flows) provides contingency to address the modelled compliance exceedances. An adaptive management approach is considered appropriate.

In summary the development of the Stage 6 Coronation Project as outlined is considered to result in increasing sulphate and Nitrate-N concentrations within the upper tributaries of the Mare Burn relative to the current in stream water quality. However these concentrations are likely to remain below the current consent limits. Post closure, improvements in Ammoniacal N concentrations (relative to the mining phases) are expected as a result of rehabilitation efforts within the catchments.

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Appendices

Appendix A Water Balance Model Build Report
Appendix B Summary of Hydraulic Properties
Appendix C Groundwater Levels

Abbreviations

Term	Definition
AWBM	Australian Water Balance Model
C05	Coronation Stage 6 Pit
C06	Coronation Stage 5 Pit
DRN	MODFLOW Drain
EOY	End of year
FRUG	Frasers Underground Mine
FTSF	Frasers Pit Tailings Storage Facility
GHB	MODFLOW General Head Boundary
GHD	GHD New Zealand Limited
GPUG	Golden Point Underground Mine
GPUG ext	Golden Point Underground Mine extension
HMSZ	Hyde Macraes Shear Zone
IMOP	Innes Mills Open Pit
Kh (Kx, Ky)	Horizontal hydraulic conductivity
Kv (Kz)	Vertical hydraulic conductivity
L/s	Litres per second
L1	Model layer 1
L2	Model layer 2
L3	Model layer 3
LOM	Life of mine
m bgl	Meters below ground level
m RL	Meters relative level (above sea level)
MGP	Macraes Gold Project
MODFLOW – USG	Flow modelling code
MODFLOW – USG – TRANSPORT	Solute transport modelling code
MPIII	Current consented Macraes Operations
MPIV	Proposed consented Macraes Operations

MTI	Mixed Tailings Impoundment
NBGR	Waikouaiti River North Branch at Golden Bar Road and Griffin Road
OGNZL	Oceana Gold New Zealand Limited
PED	Potential evaporation deficit
RCH	MODEFLOW Recharge
RCP	Representative concentration pathways
RIV	MODFLOW River
RMS	Root mean square
SP11	SP11 Tailings Storage Facility
SRMS	Square root mean square
TSF	Tailings Storage Facility
TTTSF	Top Tipperary Tailings Storage Facility
WBM	Water balance model
WRS	Waste rock stack

1. Introduction

OceanaGold New Zealand Limited (OGNZL) operate the Macraes Gold Project (MGP) in east Otago, situated approximately 56 km north of Dunedin. The MGP began operations in 1990 and currently comprises two operational open cast pits (Frasers and Deepdell North Pits), two underground mines - Frasers Underground (FRUG) and Golden Point Underground (GPUG), and a processing plant. Waste rock is placed both in pit and at a number of waste rock stacks (WRSs) located around the open pit margins. Tailings from processing ore is stored at the Top Tipperary Tailings Storage Facility (TTTSF). There are also two decommissioned Tailing Storage Facilities (TSFs) the Mixed Tailings Impoundment (MTI) and the SP11 Tailings Storage Facility (SP11).

A current site layout plan highlighting the main site facilities is shown in Figure 1.1.

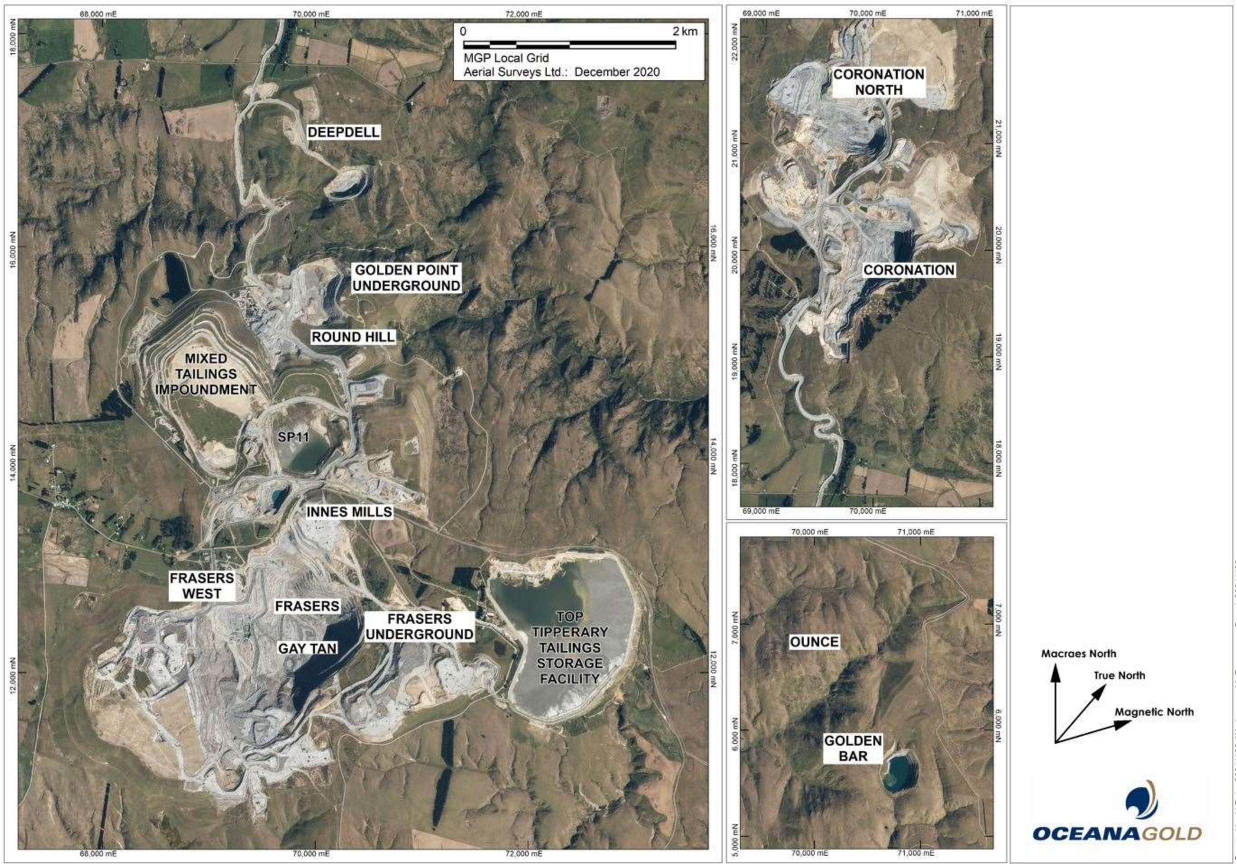


Figure 1.1 Macraes site plan

Stage 3 of the Macraes Phase IV project is the final stage in the next major proposed development at the site which aims to extend the life of mine (LOM) to around 2030 and is being consented in three stages. (1. Consent renewals; 2. Existing tailings facilities; 3. Open pit and underground mine extensions and Frasers TSF). Stage two of the MPIV project have involved increasing the capacity of the existing TTTSF to a height of 570 m RL allowing an additional 3.2 Mm^3 of tailings storage, the minor expansion of the existing Innes Mills Open Pit (IMOP) beyond the MPIII consented limits and the construction of a dry mixed tailings / waste rock embankment structure within the existing Fraser's Pit (Frasers Co-disposal[1]). Surface water and groundwater assessments of stage 2 (of MPIV) have previously been undertaken by GHD (GHD New Zealand Limited) and are reported in the following documents:

– GHD 2022b. TTTSF 570 Crest Raise. Surface Water and Groundwater Assessment. Prepared for Oceana Gold New Zealand Limited.

[1] Frasers Co-Disposal was consented in early 2023. Dry tailings will no longer be co-disposed with waste in the construction of the Frasers Backfill embankment. An initial stage including wet tailings is currently being consented.

- GHD 2022c. Frasers Co-disposal Surface Water and Groundwater Assessment. Report prepared for Oceana Gold (New Zealand Ltd, 10 November 2022.

Notwithstanding the previously assessed TTTSF 570 crest raise and the Frasers Co-disposal, the key components of the Stage three development in relation to surface water and groundwater effects are as follows:

- Frasers Pit Tailings Storage Facility (FTSF). Frasers Pit will be partially backfilled with waste and then partially filled with tailings leaving a Frasers Pit lake following mine closure at the southern end of the Frasers Pit boundary.
- Open Pit Mining extensions in Innes Mills, Golder Bar and Coronation Pits.
- Golden Point Underground extension – the subject of a separate consent application

For the purposes of the assessment presented here, it is assumed all current consented elements at the Coronation Mine Area are built to the full allowable extent. Cumulative effects (ie. in Deepdell Creek) are considered in a separate report covering surface and groundwater effects associated with the Innes Mills Pit extension and the FTSF.

1.1 Proposed mining activities

Specific details regarding the proposed expansion and mining activities which are incorporated in this assessment are included in Section 2. In summary mining activities include the expansion of the existing Coronation Pit to the southeast (Coronation Stage 6 (CO6)) and backfilling the existing Coronation North pit with waste rock (Figure 1.2).Existing consented structures and the proposed mining activities / structures within the Coronation Pit area are shown in Figure 1.2. Current rehabilitated / non-rehabilitated surface areas associated with the Coronation Pit are provided in Figure 7.6.

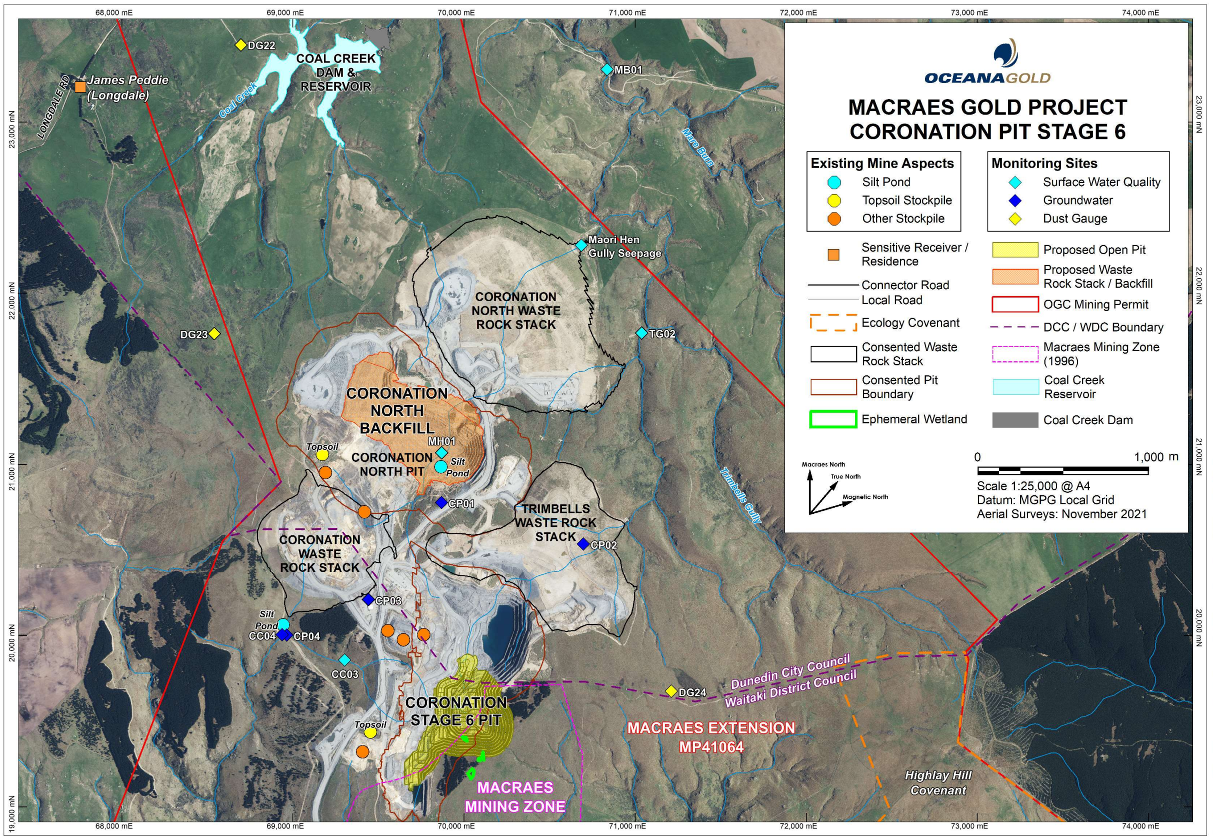


Figure 1.2 Coronation Open Pit Mining Area – Existing and Proposed.

1.2 Purpose of this report

The purpose of this report is to present the results of the groundwater and surface water modelling associated with the proposed Coronation Pit development – a component of the OGNZL proposed Stage 3 of the Macraes Phase IV project to support the Assessment of Environmental Effects. Assessing the potential effect on the receiving surface water bodies is the key objective of this report.

1.3 Scope and limitations

1.3.1 Scope of works

GHD New Zealand Limited (GHD) has been engaged by OGNZL to assess the surface and groundwater effects associated with the Stage III of the Macraes Phase IV project for the purposes of applying for resource consent. This report has been prepared in line with the GHD proposal dated 22 March 2022 and subsequent variations to that scope and presents the findings of the surface water and groundwater studies associated with the project.

The modelling scope and extents include:

- Groundwater dewatering and recharge/recovery and its effects associated with the development of the Coronation Pit.
- This report assesses the water balance and contaminant mass transport effects from the proposed Coronation Pit (CO6) extension and Coronation North Pit backfill. The scope of the outputs covers the effects

within the Mare Burn catchment to the extent of the existing compliance points MB01 and MB02. The modelling incorporates contributions from elements within the catchment, including the Coronation North Pit, Coronation, Coronation North and Trimbells Gully Waste Rock Stacks.

– Cumulative effects within the Deepdell Creek catchment as a result of the proposed Coronation Pit development are covered in GHD, 2024.

1.3.2 Limitations

This report: has been prepared by GHD for Oceana Gold New Zealand Ltd. and may only be used and relied on by Oceana Gold New Zealand Ltd. for the purpose agreed between GHD and Oceana Gold New Zealand Ltd. as set out in section 1.3.

GHD otherwise disclaims responsibility to any person other than Oceana Gold New Zealand Ltd. arising in connection with this report. GHD also excludes implied warranties and conditions, to the extent legally permissible.

The services undertaken by GHD in connection with preparing this report were limited to those specifically detailed in the report and are subject to the scope limitations set out in the report.

The opinions, conclusions and any recommendations in this report are based on conditions encountered and information reviewed at the date of preparation of the report. GHD has no responsibility or obligation to update this report to account for events or changes occurring subsequent to the date that the report was prepared.

The opinions, conclusions and any recommendations in this report are based on assumptions made by GHD described in this report. GHD disclaims liability arising from any of the assumptions being incorrect.

GHD has prepared the surface water and groundwater models for, and for the benefit and sole use of, Oceana Gold New Zealand Ltd. to support consenting and must not be used for any other purpose or by any other person.

The Models are a representation only and does not reflect reality in every aspect. The Models contains simplified assumptions to derive a modelled outcome. The actual variables will inevitably be different to those used to prepare the Models. Accordingly, the outputs of the Models cannot be relied upon to represent actual conditions without due consideration of the inherent and expected inaccuracies. Such considerations are beyond GHD’s scope.

The information, data and assumptions (“Inputs”) used as inputs into the Models are from publicly available sources or provided by or on behalf of the Oceana Gold New Zealand Ltd., (including possibly through stakeholder engagements). GHD has not independently verified or checked Inputs beyond its agreed scope of work. GHD’s scope of work does not include review or update of the Models as further Inputs becomes available.

The Models are limited by the mathematical rules and assumptions that are set out in the Report or included in the Models and by the software environment in which the Models are developed.

The Models are customised and not intended to be amended in any form or extracted to other software for amending. Any change made to the Models, other than by GHD, is undertaken on the express understanding that GHD is not responsible, and has no liability, for the changed Models including any outputs.

GHD has prepared this report on the basis of information provided by Oceana Gold New Zealand Ltd. and others who provided information to GHD (including Government authorities)], which GHD has not independently verified or checked beyond the agreed scope of work. GHD does not accept liability in connection with such unverified information, including errors and omissions in the report which were caused by errors or omissions in that information.

1.4 Key Assumptions

GHD has relied upon data (project timeline and schedule, shapefiles, volumes and material properties) provided by OGNZL to inform this assessment, we have assumed that the data is correct and representative of the groundwater and surface water environment. GHD has also relied upon the information presented in previous assessments. These sources are referenced through the report.

1.4.1 Modelling Limitations and Assumptions

The results of numerical models are dependent on the level of detail incorporated and the accuracy of the parameters used in the development and calibration of the model. As a result, modelled results (effects) are not exact. Actual effects will vary somewhat (and maybe larger or smaller) than those predicted. In general, the assumptions utilised in the modelling are considered conservative. It is not possible to collect all the data needed to fully characterise the aquifer system in detail and therefore a number of assumptions have been made and are discussed below.

- The production schedules and plans are an estimate of the LOM plan and assumptions have been made regarding the end of year (EOY) surfaces and timing.
- Waste rock deposited into Coronation North Backfill and Trimbells WRS has the same hydrogeological properties as other waste rock material across MGP site.
- Pumping at the base of the combined CO5/6 Coronation Pit ceases at the end of 2026 (end of mining phase).
- The consented Coal Creek Dilution Dam is not constructed and any effects on water quality within the Mare Burn (as a result of flow augmentation from the stored water) are not considered in this assessment.
- The existing Trimbells and Maori Hen Silt Ponds intercept seepage from Trimbells, Coronation and Coronation North WRSs. These silt ponds are assumed to be left in place and maintained post closure.
- Groundwater recharge is applied at the same rate to all units.
- A very small (0.0001 mg/L) background sulphate concentration (aquifer and rivers) was applied to all layers simulated in the groundwater model.

Future additional data, refinement of these assumptions and of the adopted parameter values by further calibration would help reduce predicted uncertainties and will improve accuracy.

Additional assumptions and limitations of the modelling undertaken are detailed throughout the report.

2. Mining Operations

2.1 Existing Coronation Mine

The existing Coronation Mine consists of two open pits - Coronation Open Pit 5 (CO5) and Coronation North Pit. The Coronation North WRS is located to the north of the Coronation North Pit and the Coronation WRS is located to the south of the Coronation North Pit and west of CO5. In addition, Trimbells WRS is located to the north of CO5. These features are outlined in Figure 1.2.

2.2 Proposed changes at Coronation Mine

A summary of activities and schedule for the proposed Coronation Mine is outlined below.

2.3 Open Pit Excavation

- The proposed CO6 consists of an approximately 250 m down dip expansion to the southeast from the existing Stage 5 pit (Figure 1.2).
- The expanded footprint is over fairly poor pine forest and rank grassland.
- The expanded pit is not as deep as the deepest part of the current Coronation 5 pit (CO5).
- During lake filling, seepage to the north towards the Mare Burn catchment via the Trimbells WRS occurs above 637 m RL.
- Lake filling will be controlled by an overflow level (660m RL) located to the south. Overflow water is to the Deepdell catchment via Highlay Creek and ultimately Deepdell Creek.
- Quantities: Ore 2.0Mt, waste 31.5Mt, total movement 33.5Mt.
- Ore will be transported directly to the process plant with mine trucks using the existing haul road.

2.4 Waste Rock Disposal

- The planned disposal of CO6 waste involves backfilling the existing Coronation North 5 pit (Figure 1.2). No additional backfill is proposed to be placed within existing (CO5) or proposed (CO6) pit.
- The top level of the Coronation North Pit infill is 600 m RL, about 20 m above the natural low point (580 m RL) situated to the west of the existing Coronation North Pit pit. This low pointdrains to Coal Creek.
- Waste rock storage capacity of the Coronation North Pit is approximately 34.5Mt.
- Ore will be transported directly to the process plant with mine trucks using the existing haul road.

2.5 Water Management

- CO5 pit is currently being used as a water storage reservoir. This will need to be emptied during CO6 mining before mining reaches the pit lake level.
- Dewatering of the current pit will be undertaken by one or more of the following methods (in order of priority):
  - Water pumped back to the processing plant to reduce the need for water from the Taieri
  - Water pumped back to Deepdell North Pit and stored for future use
  - Evaporation of pit water

- Operational water from stormwater runoff or groundwater ingress will be dealt with as per CO5 water (ie. dust suppression and/or captured in silt ponds).
- Silt ponds collect sediment laden water from operational / non-operational areas and discharge to the receiving environment as per CO5 following settlement and acceptable water quality.
- No new water control structures are planned.

2.6 Project Closure

- Pit: CO6 is not backfilled. The final Coronation Pit Lake will occupy the combined CO5 and CO6 areas..
- Waste Rock Stacks: Slopes shaped and revegetated progressively, using Macraes site rehabilitation techniques. The 'proud' top surface of the backfilled Coronation North Pit will be contoured so that surface water runoff will drain to the Coal Creek catchment.
- Site establishment areas and haul roads will be rehabilitated using standard site techniques.

2.7 Project Timeline

- Summer 2023/24: Tree felling, infrastructure re-establishment
- 2024-2026: Mining phase, including ore transport to process plant
- 2027: Full site rehabilitation

3. Site Setting

The environmental conditions present at Macraes have been summarised in a number of previous reports, including those written for the MGP MPIII resource consents. This assessment has relied solely on existing data and previous reports made available by OGNZL. The following subsections present a short overview of the environmental setting across the MGP site, as has been summarised in previous reports.

3.1 Topography / Surface Water Bodies

The topography of the wider Macraes site is driven by the geologic evolution of the region. Long term weathering and erosion of the underlying rock resulted in a distinctive low relief peneplain which is bounded by Waikouaiti River North Branch to the west, Deepdell Creek to the north, and Murphys Creek to the south. Deepdell Creek has been deeply incised into this erosional surface resulting in steep valley slopes and minimal alluvial deposition. In contrast, the Waikouaiti River North Branch is characterised by shallow relief, broad valleys and alluvial deposition.

The original topography has been altered by thirty years of mining and waste storage. Mining has been generally aligned with the orientation of the major shear zone (refer to Section 3.3). Mining operations have altered portions of original catchments in the main MGP site, but the primary streams and rivers surrounding the mining site remain and are intermittent / permanent in nature.

The MGP site is located within the Shag River/Waihemo, Taieri and Waikouaiti River North Branch catchments as shown in Figure 3.1 and Figure 3.2. The Shag River flows in a south-easterly direction and enters the ocean close to Matakaea. The Waikouaiti River North Branch flows in a southerly direction from the mine site and enters the ocean near Karitane. The catchments consist primarily of agriculture and forestry. The Taieri River flows in a southerly direction to the ocean south of Dunedin.

Discharges from the Coronation area have the potential to reach the Taieri River via the Mare Burn as a result of WRS seepages and the Shag River via the Deepdell catchments as a result of pit lake overflow and/or groundwater transport. The key surface bodies within the Mare Burn catchment referred to in this assessment are highlighted in Figure 3.3.The cumulative assessment of the impact within the Deepdell catchment is covered in GHD, 2024.

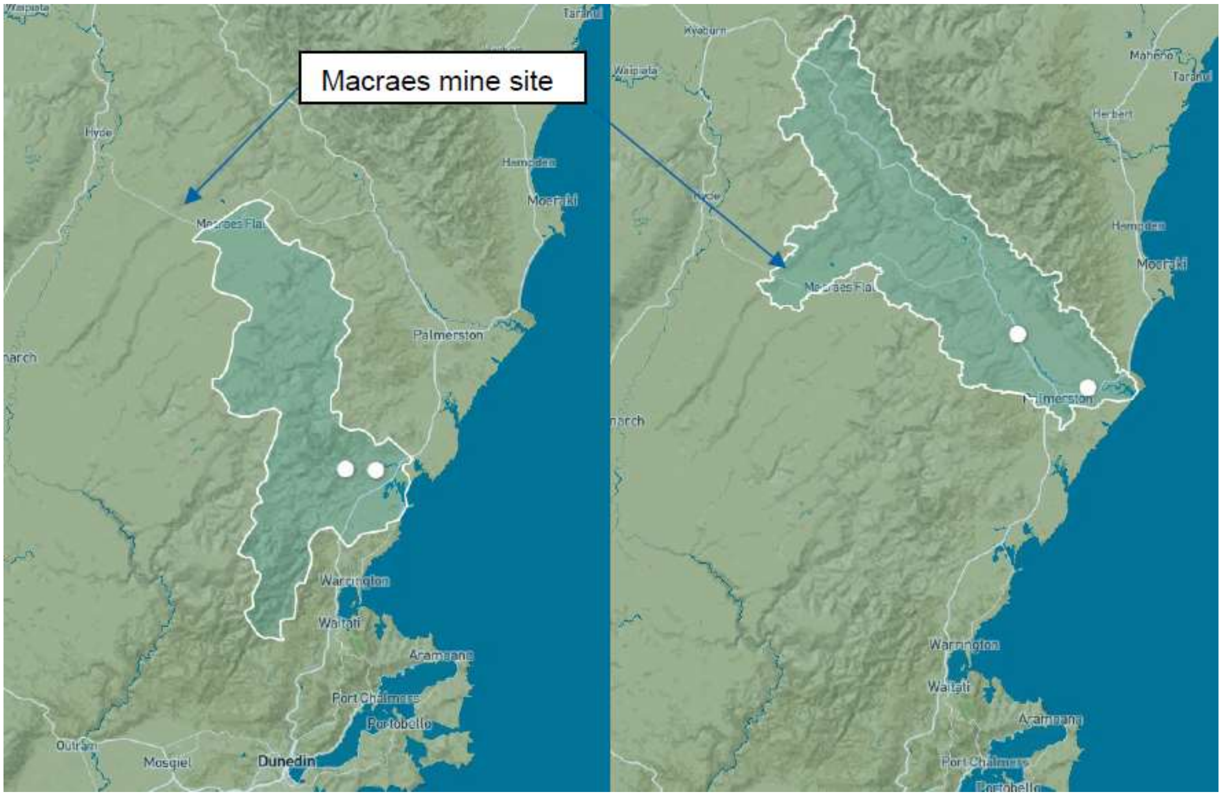


Figure 3.1 *Waikouaiti Northern Branch River (left) and Shag River / Waihemo (right) catchments*

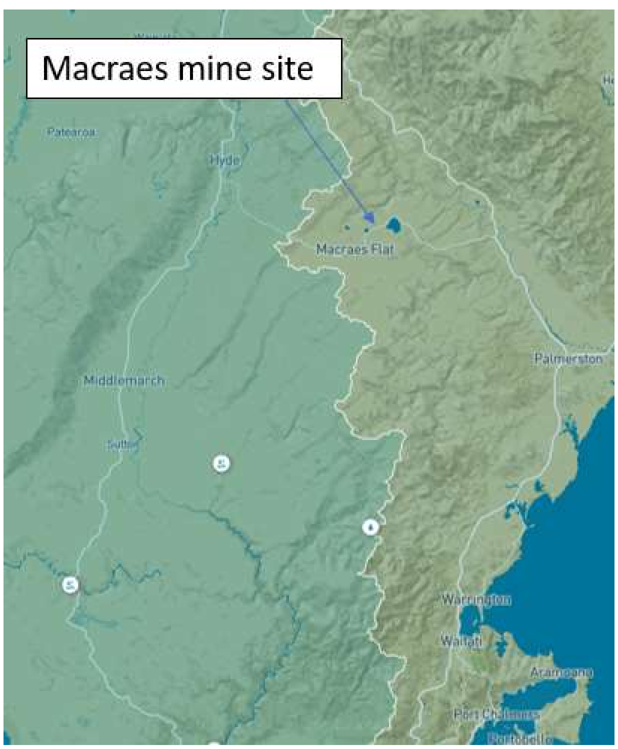


Figure 3.2 *Taieri River catchment*

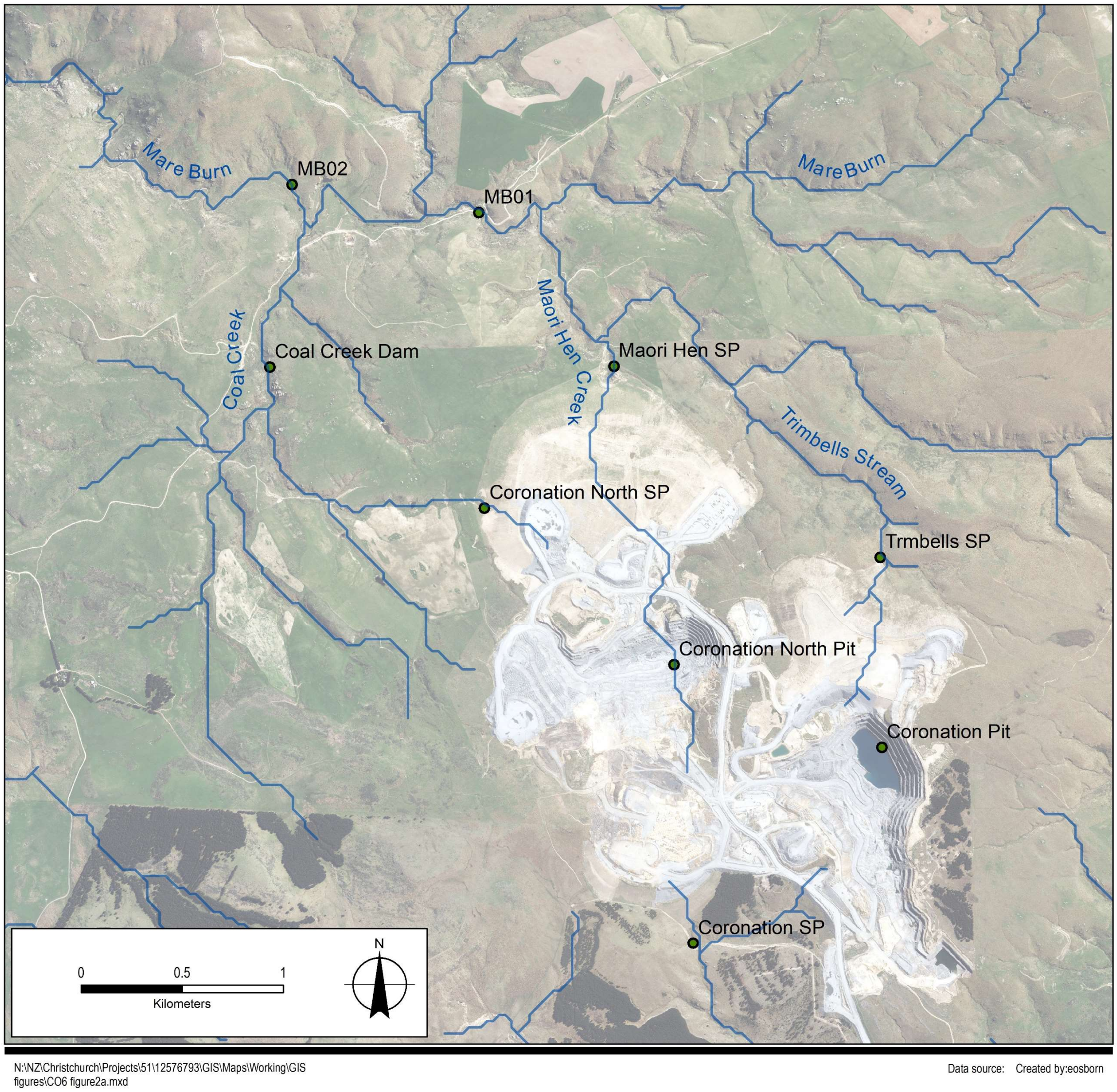


Figure 3.3 Key surface water features relating to the Coronation Stage 6 expansion

3.2 Climate

The climate at Macraes is controlled predominantly by the mountains to the west of the site (Rock and Pillar Range) which act as a barrier to incoming weather systems from the west, leading to a fairly dry climate with limited precipitation. Rainfall data from the MGP are available from three locations, Glendale, Deepdell and Golden Point stations. Deepdell and Golden point stations were installed to monitor rainfall at the MGP site while Glendale is part of the national climate monitoring programme. Glendale station data spans from 1959 to 2013. Climate and climate change representation is further discussed in Section 5.3.

3.3 Background Geology

Regionally, the geology is dominated by the Mesozoic-aged crystalline metamorphic rock of the Rakaia terrane Otago Schist (CDM Smith, 2016). Significant weathering and tectonic deposition resulted in the erosion of more recent alluvial sediments. The landscape is now dominated by widespread outcrops of Otago schist and a very thin surface layer of alluvium and colluvium. This alluvium and colluvium layer has been found at a maximum thickness of 1.8 m (Golder Associates, 2011b) and is generally not considered to have a major impact on the groundwater flow system. There is a localised basalt deposit located in the west of the Coronation Mine area. The basalt is of a minor occurrence regionally and does not influence the CO5/6 area.

3.3.1 Hyde Macraes Shear Zone (HMSZ)

The MGP began due to ore potential within the schist deformed by the HMSZ. This shear zone runs north-south through the Macraes site (aligned with Macraes Grid North). The shear zone comprises the Hanging Wall Shear and Footwall Fault zones which are considered to have enhanced hydraulic conductivity along the orientation of the features. The vertical separation between the top of the Hanging Wall Shear and the Footwall Fault is approximately 100 to 120 m.

3.3.2 Additional Structural Features

There are three major northeast-southwest trending faults that are present across the MGP site:

– The Deepdell Fault - aligned with Deepdell Creek

The Macraes Fault - intersects the northern end of Frasers Pit and extends out to Top Tipperary Creek forming the northern boundary of FRUG

– Unnamed Fault – aligned with Murphys Creek, south of Frasers Pit.

3.4 Hydrostratigraphy

Due to the structural complexities present within the schist body and the manmade waste deposition that has occurred, there are a number of hydrostratigraphic units which have been incorporated into previous groundwater models. The number of hydrostratigraphic units has reduced throughout the evolution of numerical groundwater modelling, opting for more simplified models (CDM, 2016; GHD, 2021). Throughout these simplifications, the values have not changed significantly. Units considered in previous groundwater models are listed below:

– Highly weathered schist
– Moderately weathered schist
– Slightly weathered schist
– Unweathered schist
– Basalt
– Footwall Fault
– Hanging Wall Shear
– Intra-shear schist
– Embankment materials
– Waste rock
– Flotation tailings
– Mixed tailings / Concentrate tailings
– Fine / coarse tailings

In 2016, CDM Smith compiled a review of all hydrogeological properties that have been applied to different groundwater models created and updated over the years. This summary has been reviewed and updated by GHD (2021) to include the values applied by CDM Smith in the groundwater model CDM (2016) and GHD (2021). Data are presented in Appendix B. In addition, hydrogeological investigations were undertaken recently associated with the GPUG Ext. development and are detailed in WSP (2023). The primary hydrogeological units and parameters used in this assessment are discussed in further detail in the subsections below.

3.5 Schist

The Otago Schist is a crystalline metamorphic rock with effectively no primary porosity or permeability except where weathered. The permeability and porosity in this unit are primarily driven by the defects within the rock mass (fractures and faults) which create groundwater seepage routes and flow paths. The foliation dips around 15° to 30° south-southeast but rotate approaching major faults in the area. The deformities and foliation within the schist make it anisotropic with slightly higher hydraulic conductivity in the north/south direction (Ky).

The intensity of the weathering of the schist rock mass decreases with depth. However, geotechnical investigations have indicated that the moderate weathering of the schist only extends to about 5 m, while slight weathering only extends to about 35 to 50 m (Golder, 2011b). Therefore, on the scale of mining extents, the weathering is not considered to have a significant impact on the groundwater flow regime.

CDM Smith (2016) compiled a summary of historic hydraulic testing of schist undertaken at around the MGP site originally sourced from Golder, 2011b. The raw data were reviewed in graphical format and the geometric mean (geomean) and averages from the CDM Smith summary are presented in GHD (2021) and in Table 3.1. Further testing, near GPUG, was undertaken by WSP (2023) and estimated hydraulic conductivity values are in the same order of magnitude as those presented and used in previous assessments and in this report.

Table 3.1 Hydraulic testing summary (Adapted from CDM Smith, 2016a)

Depth (m bgl)	Average minimum (m/s)	Average maximum (m/s)	Geomean (m/s)
<10	2.2E-07	2.4E-04	6.9E-07
10 – 20	5.1E-08	1.7E-04	3.9E-07
20 – 30	1.3E-07	1.9E-05	2.7E-07
30 – 40	3.5E-07	2.3E-04	4.4E-07
40 – 50	1.2E-07	6.7E-07	9.8E-08
> 50	9.7E-08	3.7E-06	4.5E-07
250-500	1.0E-08	7.0E-07	-

3.6 Waste Rock

Waste rock is dominated by the overburden that overlies the ore body but can include a component of the ore body if it contains insufficient gold to process economically. It is typically a mixture of coarse (gravel to boulders <1.5 m in diameter) and fine grained schist fragments, with a high proportion of fines and angular clasts, due to the blasting process used to fragment the schist prior to excavation. It is typically stacked and compacted in 15 to 20 m lifts in backfills and waste rock stacks. Waste rock. often contains sulphide minerals which has the potential to oxidise and create metalliferous leachate.

4. Groundwater Assessment

4.1 Overview – Conceptual flow model

The Coronation pit is located on the ridgeline that divides the Deepdell Creek and Mare Burn surface water catchments (Figure 4.1). Given its elevation the Coronation pit is interpreted to also coincide with the groundwater catchment divide which follows the surface water catchment divide shown in Figure 4.1.

The conceptual understanding of the groundwater system in the vicinity of the Coronation and Coronation North pits is as follows:

– Recharge of the groundwater system via rainfall infiltration through fractures within the schist bedrock and within the basalt (western wall of the Coronation North Pit). .
– Groundwater flow is generally topographically driven, with discharge via seeps and/or springs in topographic lows (streams and depressions).
– Hydraulic conductivity of the schist is primarily influenced by the degree of weathering in the schist bedrock, with variability (anisotropy) in horizonal hydraulic conductivity due to rock mass fracturing by structural features such as foliation-parallel fractures, faults and shear zones.

Based on the current hydrogeological understanding of the project area the groundwater flow direction for the Coronation site is presented in Figure 4.1 and Figure 4.2.

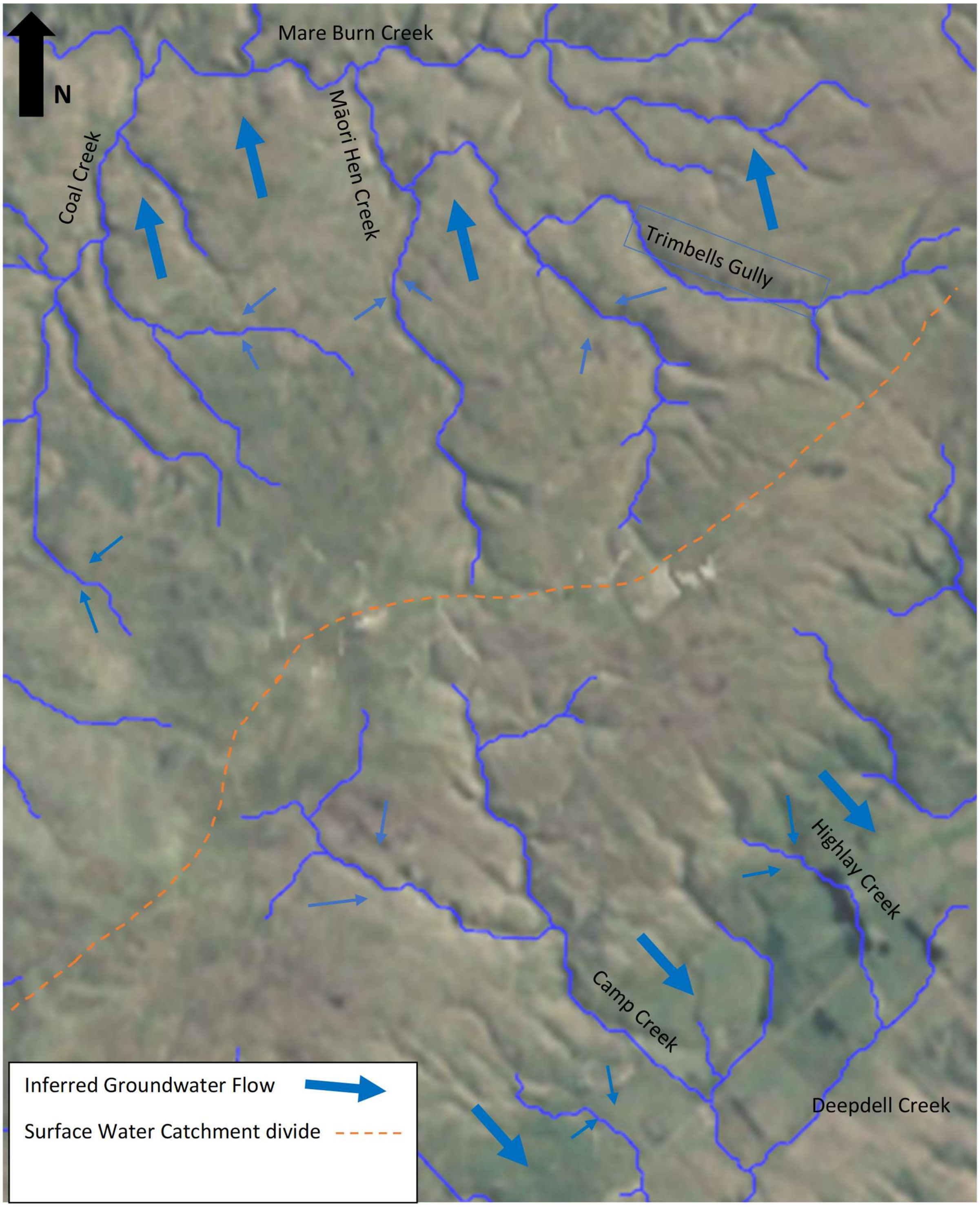


Figure 4.1 Inferred groundwater flow direction pre mining

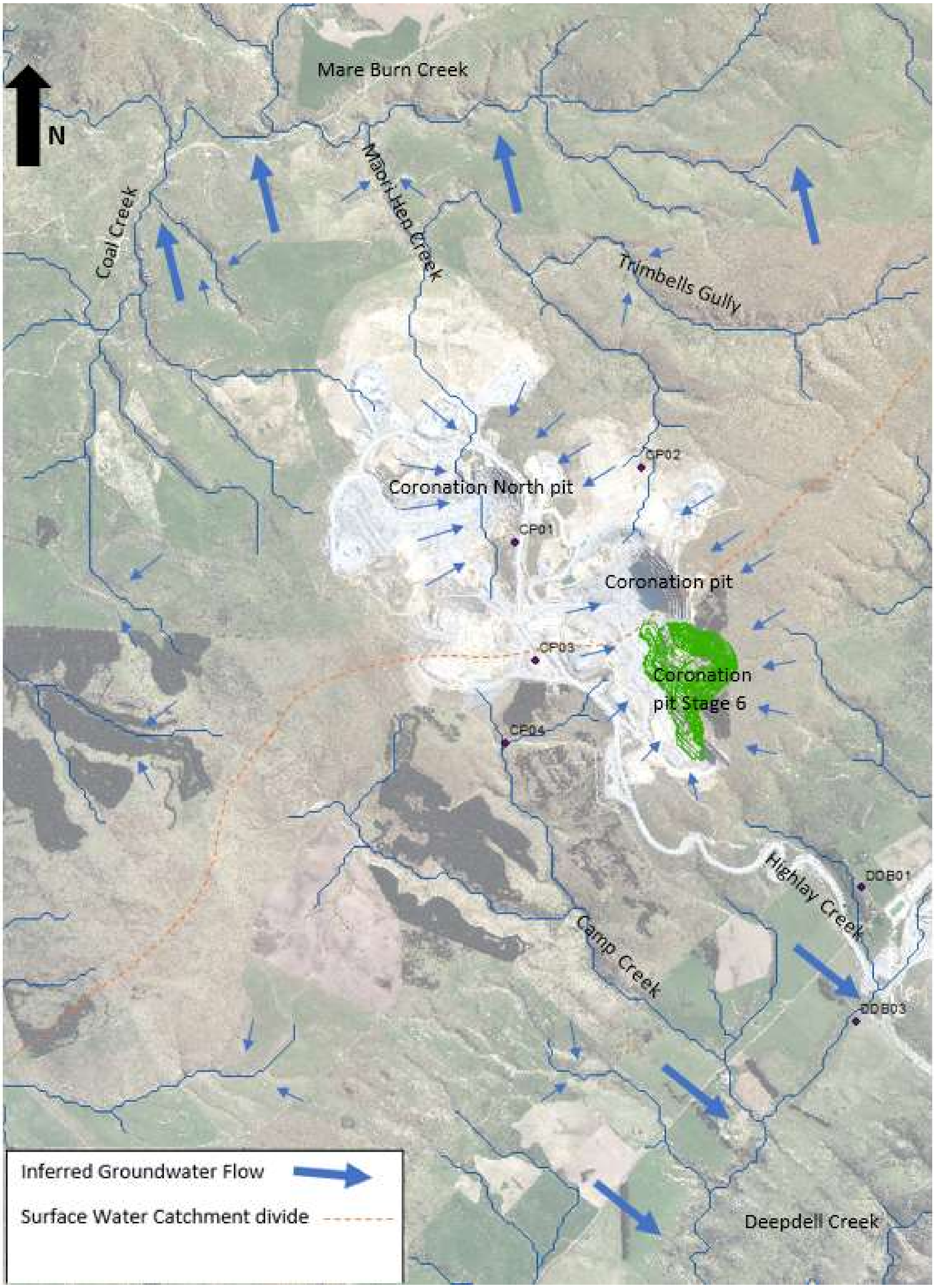


Figure 4.2 Inferred existing / proposed mining groundwater flow direction

4.2 Groundwater Model

4.2.1 Model Setup

Previous assessments for Coronation (Golder, 2016) have presented estimates of groundwater inflows into the closed pits. These assessments were undertaken prior to mining and were based on limited site data. The Golder assessment adopted an analytical approach to estimate groundwater inflows at closure and at lake overflow.

In this assessment a 3D numerical groundwater flow model of the Coronation pit area has been setup using MODFLOW-USG (flow modelling code). The objectives of the modelling are to:

– Estimate pit inflow for the existing pit and proposed pit expansion (CO6)
– Simulate groundwater recovery after the conclusion of the proposed expansion
– Undertake solute transport modelling during groundwater recovery

The model domain is 9 km by 9 km in east-west and north-south direction with the proposed pit at the centre of the model domain. The model has been setup in NZTM grid system.

Grid size has been refined to 25 m near the proposed pit and two creeks (Deepdell and Mare Burn); outside of that, a 50 m grid size has been adopted. Vertically, 8 model layers have been setup with the first layer being 30 m thick followed by 50 m thick layers 2 to 8, which has resulted in a total of 298,424 model cells. This provides enough grid resolution for pit-dewatering, recovery, and contaminant transport modelling.

The extent of the model domain is presented in Figure 4.3 and grid design is presented in Figure 4.4.

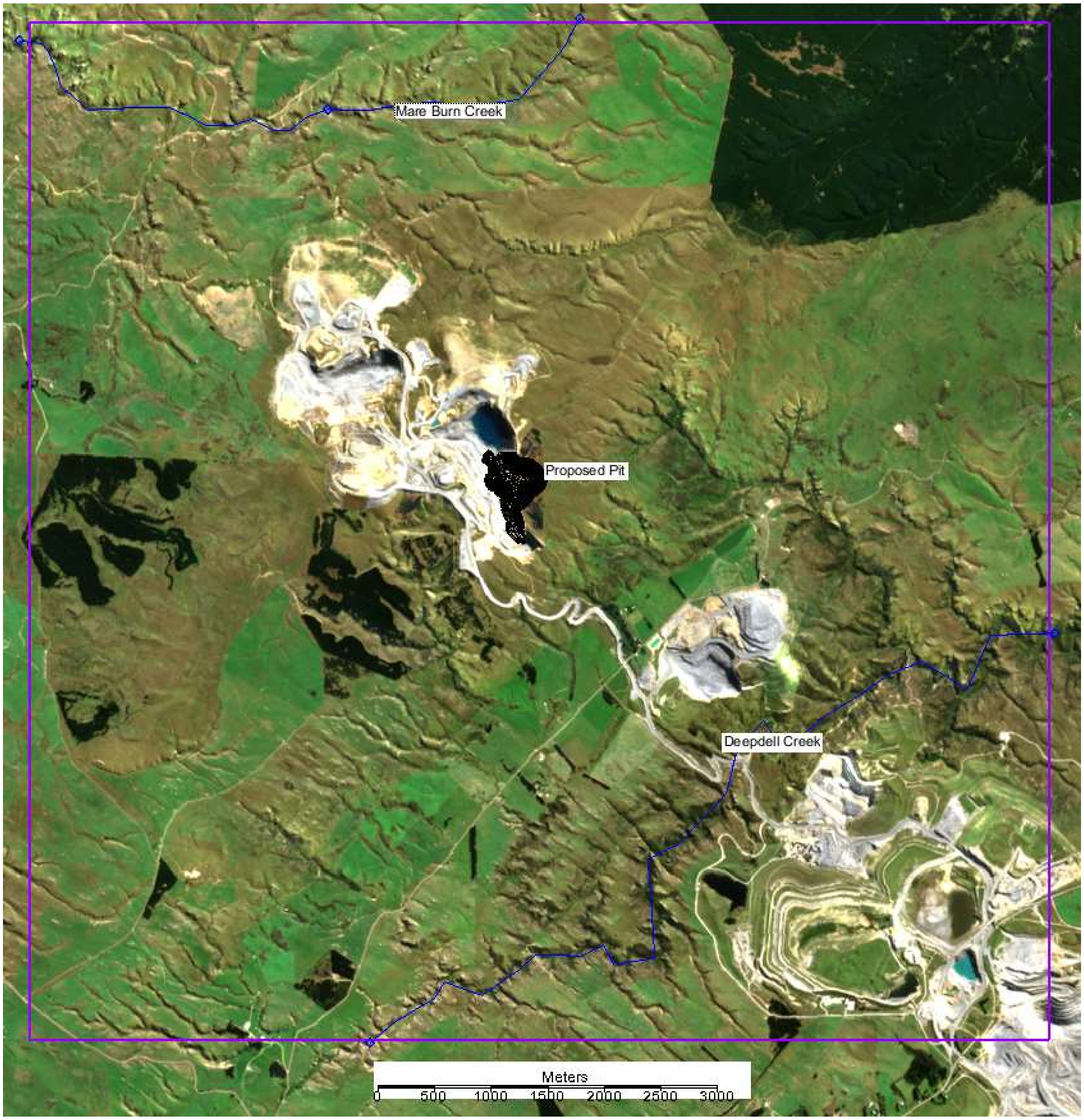


Figure 4.3 *Coronation model domain*

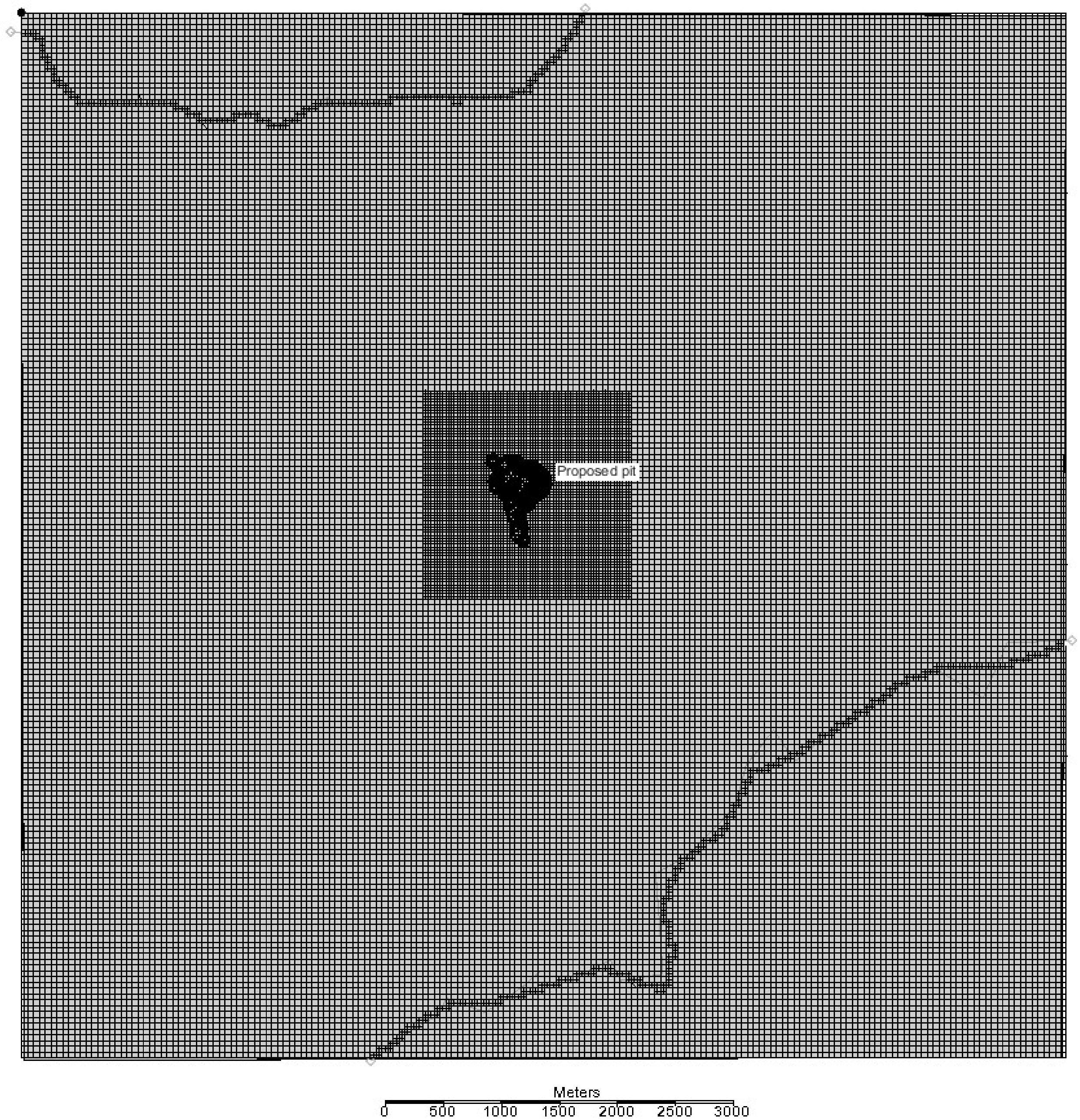


Figure 4.4 Coronation model grid design

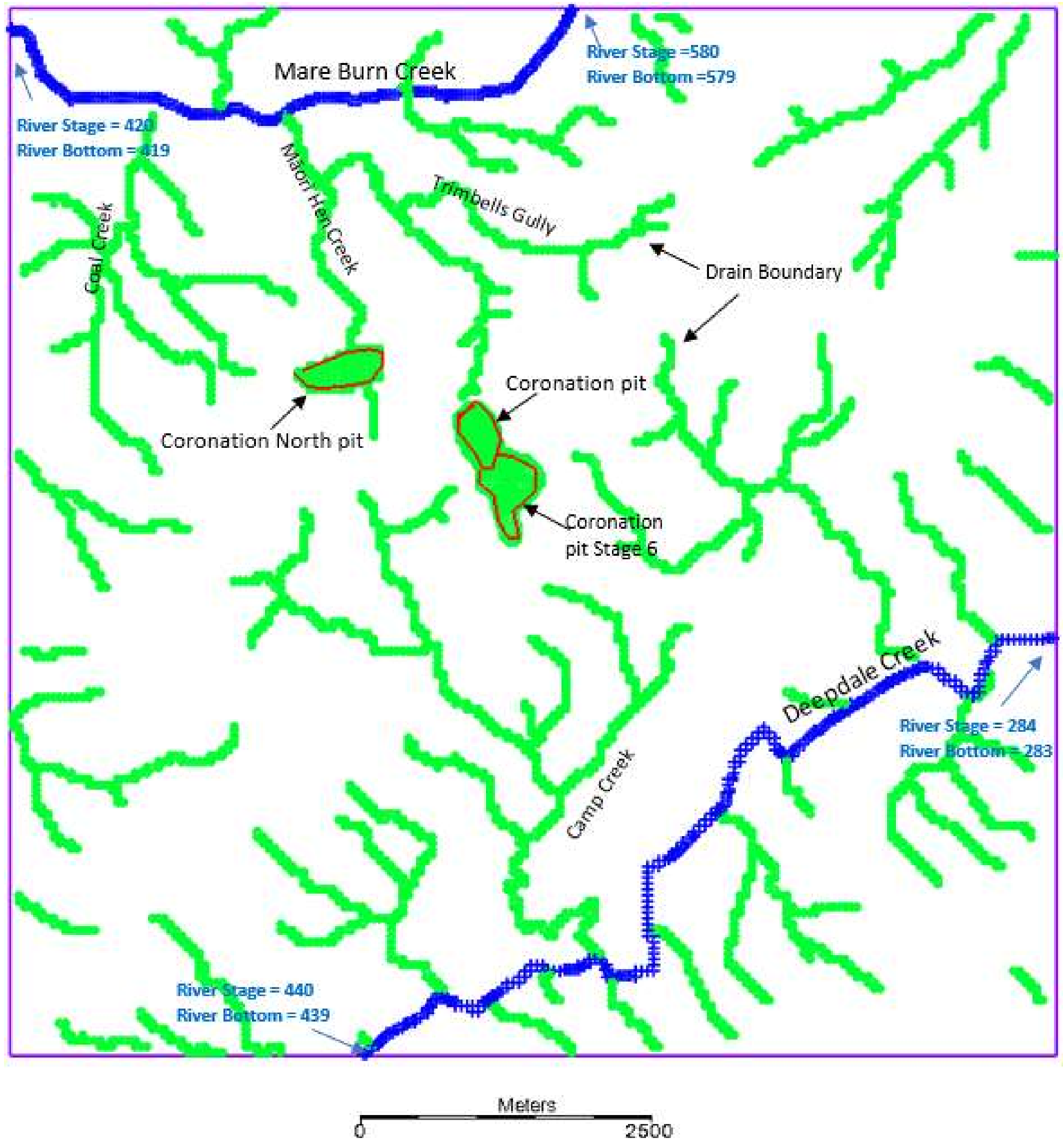
4.2.2 Boundary Conditions

The following boundary conditions have been applied in the model:

- **River Boundary:** The Deepdell Creek and Mare Burn have been modelled using the MODFLOW River (RIV) package (Figure 4.5). Riverbed conductance applied was 5 m^2/d/m with river stage applied at the topographic level, river bottom elevation was applied 1 m below the river stage level.
- **Drain Boundaries:** Dewatering of the pits has been simulated using the MODFLOW drain (DRN) package, with drain bottom elevation corresponding to the base of the mining. Small creeks and

tributaries boundaries have been modelled as drain boundary conditions (Figure 4.5). Drain conductance applied was 10 m^2/d/m with drain bottom elevation set at topographic level.

- **Recharge boundary**: The MODFLOW Recharge (RCH) package was used to simulate diffuse rainfall recharge. Several reports (Kingett Mitchell, 2005a and b, Golder, 2011a and b, CDM Smith, 2016) have stated that the accepted recharge rate of the area is 32 mm/yr (equating to 5.3% of annual rainfall of 607 mm). Golder (2011a and b) noted that the precipitation was slightly less than the original Kingett Mitchell report and therefore recharge might be slightly less. The GHD (2021) model calibration resulted in an applied recharge of 29.2 mm/yr. This value generally reflects 4.5% of GHD's synthetic annual rainfall average used in the Water Balance Model (GHD, 2021) and resulted in the best overall calibration under steady state conditions. In this assessment a rainfall recharge rate of 29.2 mm/yr was applied to the model in agreement with previous modelling.
- **No flow boundary:** Along the edges of the model domain (due to relatively low hydraulic conductivity of the material).
- **General Head Boundary**: The MODFLOW General Head Boundary (GHB) package was used to simulate head-dependent flux boundaries and was applied to model the recovery of water level post-mining within the pit. The location of GHB applied is presented in Figure 4.6. The head values for the GHB were derived from the surface water modelling results (refer Section 5.8).



Blue lines (Deepdell Creek and Mare Burn) represent river boundaries. Green lines represent drain boundaries (smaller creeks and dewatering in the pits).

Figure 4.5 Coronation model surface boundary conditions.

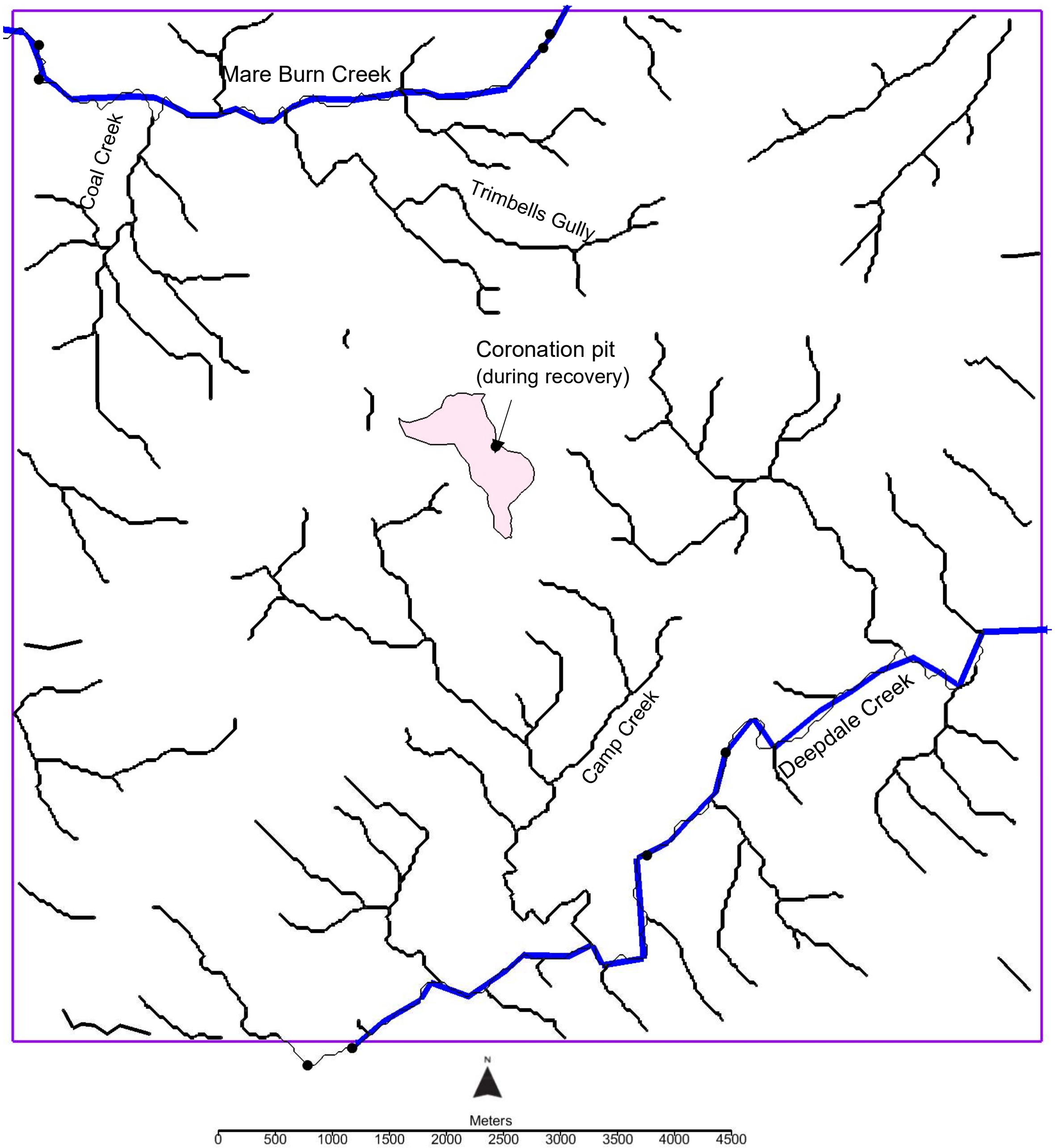
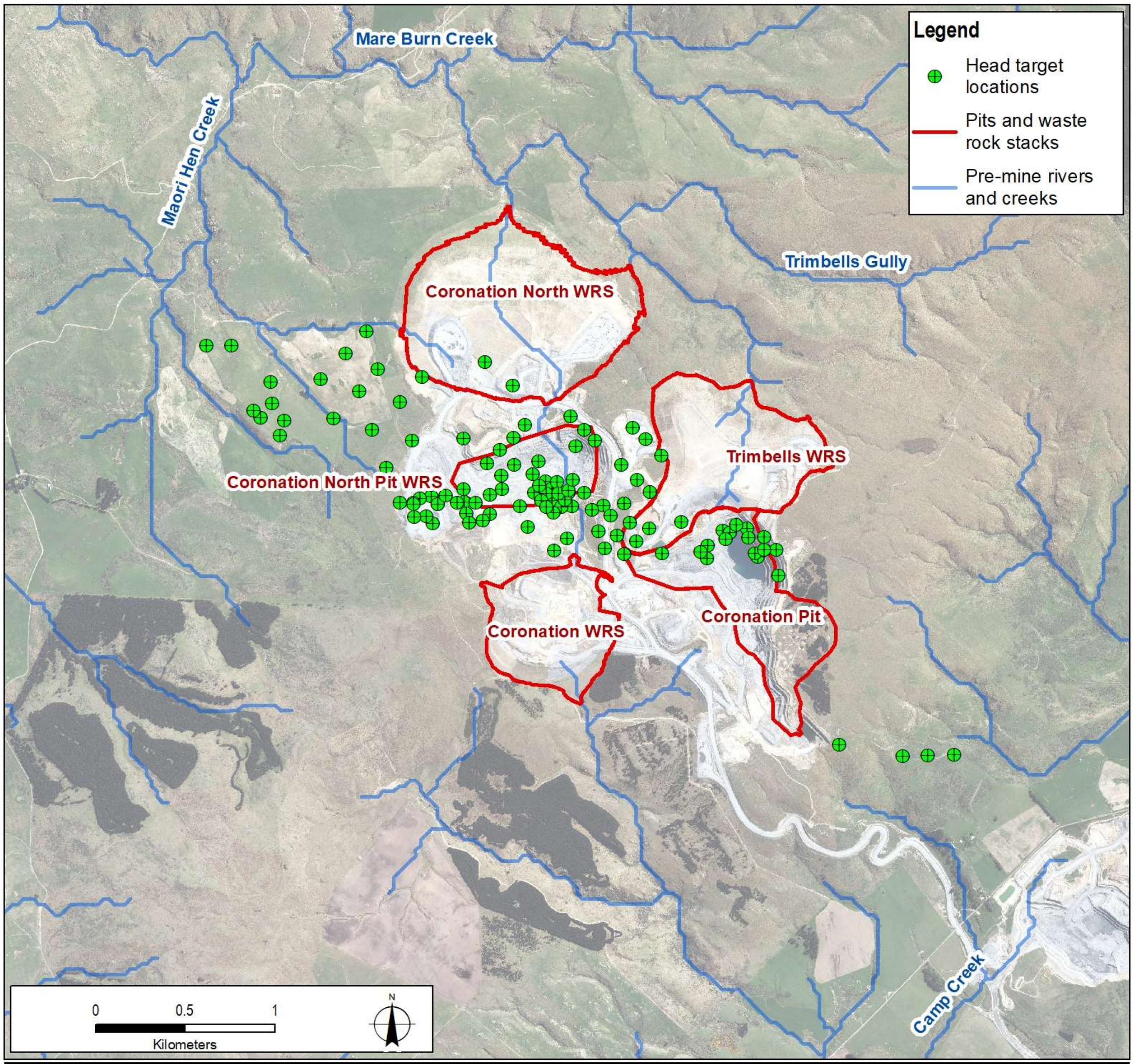


Figure 4.6 ***Location of the general head boundary (for the proposed pit lakes).***

4.2.3 Steady-State Model Calibration

For the model calibration, initial model parameters used were based on previous studies (Golder Associates, 2011a and b, Golder Associates, 2016, GHD, 2021 and WSP- Golder, 2022) and values were adjusted during the calibration process.

Groundwater level data available throughout the model domain (measured January 2016) representing pre- mining groundwater level conditions were used as calibration targets. The groundwater levels used as calibration targets are presented in Appendix C.



N:\NZ\Christchurch\Projects\51\12576793\GIS\Maps\Working\James D\CO6_figure_x.xx_coronation_gwl_cal_targets.mxd

Data source: Created by:JDommisse

Figure 4.7 ***Groundwater head targets used in steady-state calibration***

The final hydraulic parameters from the model calibration (Model run ID "Macraes_IV_CO_SS_013") are presented in Table 4.1. As discussed above, a uniform recharge rate of 29.2 mm/year was applied in the model.

Table 4.1 Steady-state model parameters

Unit Name	Model Layer (Thickness of layer)	Kx m/s (m/d)	Kz m/s (m/d)	Ky m/s (m/d)	Specific Yield *	Specific Storage 1/m*
Moderately Weathered Schist (Shallow)	1 (30 m thick)	1.0×10^{-7} (0.0086)	6.0×10^{-8} (0.0052)	2.5×10^{-7} (0.022)	0.02	1E-5
Slightly weathered shist	2 (50 m thick)	5×10^{-8} (0.0043)	5×10^{-9} (0.00043)	5×10^{-8} (0.0043)	0.01	1E-5
Slightly weathered - Unweathered Schist Bedrock	3 - 5 (50 m thick)	1.5×10^{-8} (0.0013)	1.5×10^{-9} (0.00013)	1.5×10^{-8} (0.0013)	0.01	1E-5
Unweathered Schist	6 – 8 (50 m thick each layer)	5×10^{-9} (0.000432)	5×10^{-10} (0.000043)	5×10^{-9} (0.00043)	0.01	1E-5
***Waste Rock**	1 (Various thickness)	1.0×10^{-6} (0.086)	1.0×10^{-6} (0.086)	1.0×10^{-6} (0.086)	0.15	1E-5
Notes:	Kx-denotes horizontal hydraulic conductivity in x direction Ky-denotes horizontal hydraulic conductivity in y direction Kz-denotes vertical hydraulic conductivity Vertical anisotropy represents ratio of hydraulic conductivity in horizontal x (Kx) to z (Kz) directions (Kx/Kz) *Parameter used in transient model only.					

The performance of model calibration is commonly associated with the difference between measured and modelled water levels. This measure is quantified through the scaled root mean square (SRMS) error. The SRMS is expressed as a percentage and is a more representative measure of the fit than the standard root mean square (RMS), as it accounts for the scale of the potential range of data values. Therefore, if the ratio of the RMS error to the total head change is small, the error is only a small part of the overall model response. The steady-state calibration for the Coronation model resulted in SRMS of 5.7% and is considered acceptable (Barnett et al, 2012).

The modelled computed vs observed head plot (scatter plot) from the steady-state model calibration is presented in Figure 4.8.

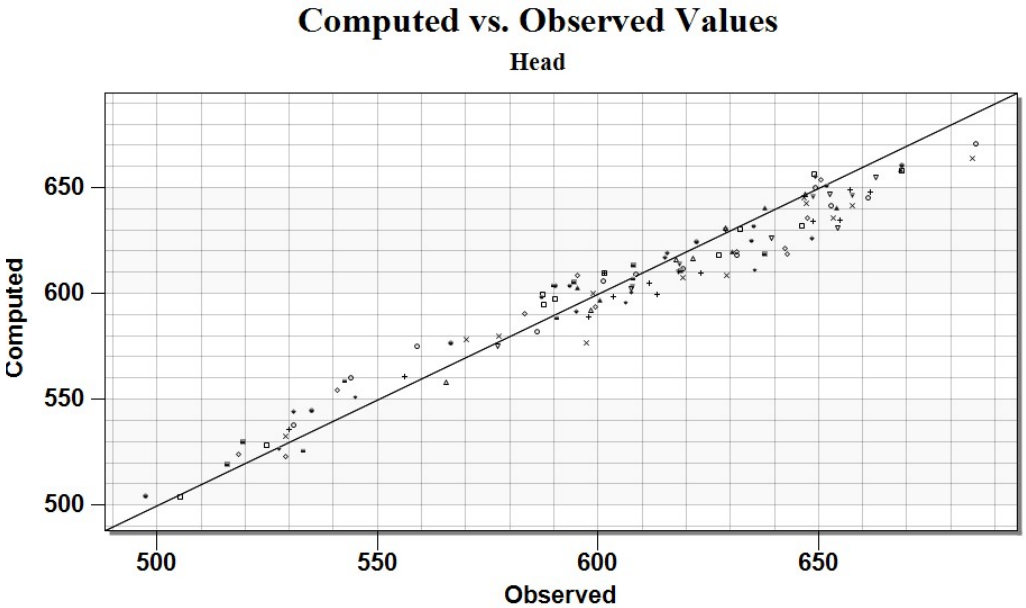


Figure 4.8 *Steady state scatter plot (model computed vs observed head)*

The overall mass balance error (outflows - inflows) for the steady state model (Figure 4.9) is <0.01%, suggesting that the model is numerically stable. As shown in this figure, the main input to the groundwater system is via rainfall recharge with inflow rate of 6,479 m^3/d (or 75 L/s) which accounts for 87% of the total model inflow. There is some localised recharge from river cells (referred to as river leakage in Figure 4.9), which is due to small differences in infered river bottoms and stages between adjacent cells. This leakage is countered by greater drainage to the adjacent river cells and does not influence the overall behaviour of groundwater flows in the model.

```
 VOLUMETRIC BUDGET FOR ENTIRE MODEL AT END OF TIME STEP       1 IN STRESS PERIOD       1
 ---------------------------------------------------------------------------------------

    CUMULATIVE VOLUMES      L**3       RATES FOR THIS TIME STEP      L**3/T
    ------------------                 ------------------------

          IN:                                   IN:
          ---                                   ---
            STORAGE =           0.0000            STORAGE =           0.0000
      CONSTANT HEAD =           0.0000      CONSTANT HEAD =           0.0000
             DRAINS =           0.0000             DRAINS =           0.0000
      RIVER LEAKAGE =         966.0818      RIVER LEAKAGE =         966.0818
           RECHARGE =        6479.8994           RECHARGE =        6479.8994

           TOTAL IN =        7445.9813           TOTAL IN =        7445.9813

         OUT:                                  OUT:
         ----                                  ----
            STORAGE =           0.0000            STORAGE =           0.0000
      CONSTANT HEAD =           0.0000      CONSTANT HEAD =           0.0000
             DRAINS =        5994.2279             DRAINS =        5994.2279
      RIVER LEAKAGE =        1451.7548      RIVER LEAKAGE =        1451.7548
           RECHARGE =           0.0000           RECHARGE =           0.0000

          TOTAL OUT =        7445.9827          TOTAL OUT =        7445.9827

           IN - OUT =      -1.4458E-03           IN - OUT =      -1.4458E-03

PERCENT DISCREPANCY =          -0.00     PERCENT DISCREPANCY =          -0.00
```

Figure 4.9 Steady state model water balance summary (Coronation pit)

Recent modelling undertaken by CDM Smith in 2016 and GHD in 2021 assumed a simplified approach and ignored the effect of weathering and relatively changes in values of hydraulic conductivity with depth (below 30 m bgl). The sensitivity of the vertical decrease in hydraulic conductivity with depth on the model calibration was tested by assuming that majority of layers (2 - 8) have the same hydraulic conductivity values (Table 4.2).

Table 4.2 Steady-state model parameters used in sensitivity analysis

Unit Name	Model Layer (thickness of layer)	Kx m/s (m/d)	Kz m/s (m/d)	Ky m/s (m/d)	Specific Yield *	Specific Storage 1/m*
Moderately Weathered Schist (Shallow)	1 (30 m thick)	$1.5x10^{-7}$ (0.013)	$9.3x10^{-8}$ (0.008)	$3.8x10^{-7}$ (0.033)	0.01	1E-5
Schist Bedrock	2 to 8 (50 m thick each layer)	$1.5x10^{-8}$ (0.0013)	$1.5x10^{-9}$ (0.00013)	$1.5x10^{-8}$ (0.0013)	0.01	1E-5
***Waste Rock**	1 (Various thickness)	1.0×10^{-6} (0.086)	1.0×10^{-6} (0.086)	1.0×10^{-6} (0.086)	0.15	1E-5
Notes:	Kx-denotes horizontal hydraulic conductivity in x direction Ky-denotes horizontal hydraulic conductivity in y direction Kz-denotes vertical hydraulic conductivity Vertical anisotropy represents ratio of hydraulic conductivity in horizontal x (Kx) to z (Kz) directions (Kx/Kz) *Parameter used in transient model only.					

The modelled computed vs observed head plot (scatter plot) from the sensitivity analysis on steady-state model calibration is presented in Figure 4.10. This simpler model run approach resulted in a better SRMS (4.6%) compared to the base case value of 5.7% (Figure 4.8). However hydraulic conductivity results in the wider area of Macraes indicate horizontal hydraulic conductivity values decrease with increasing depth and therefore the parameters presented in Table 4.1 were used for the predictive analysis runs.

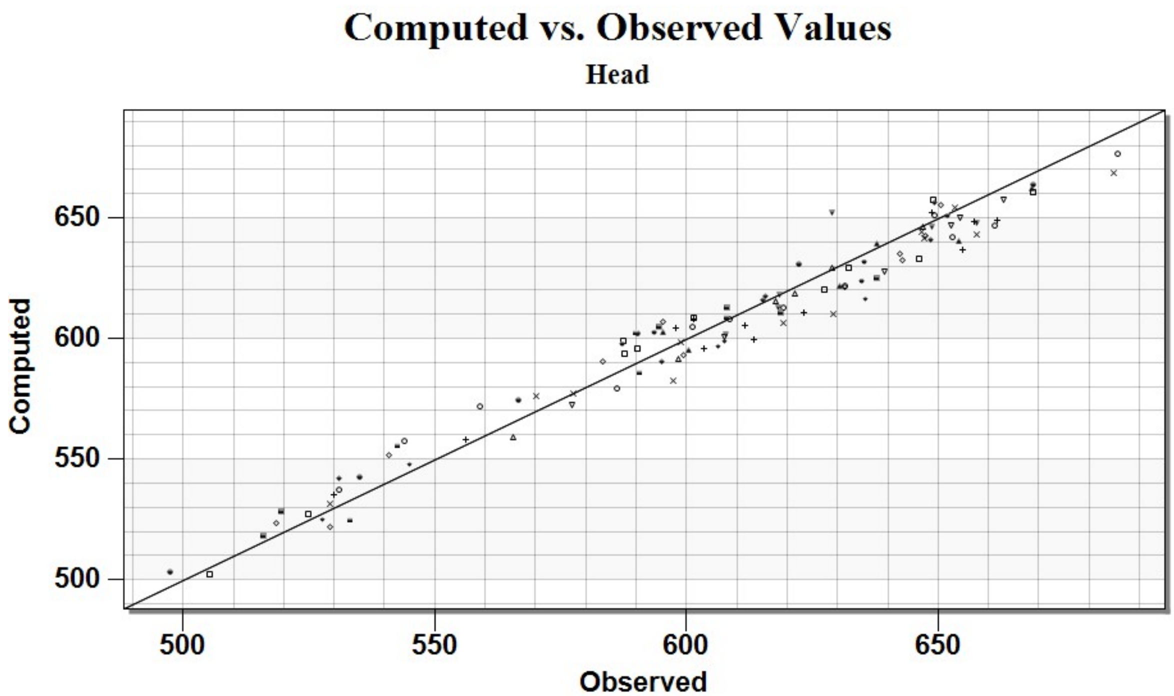
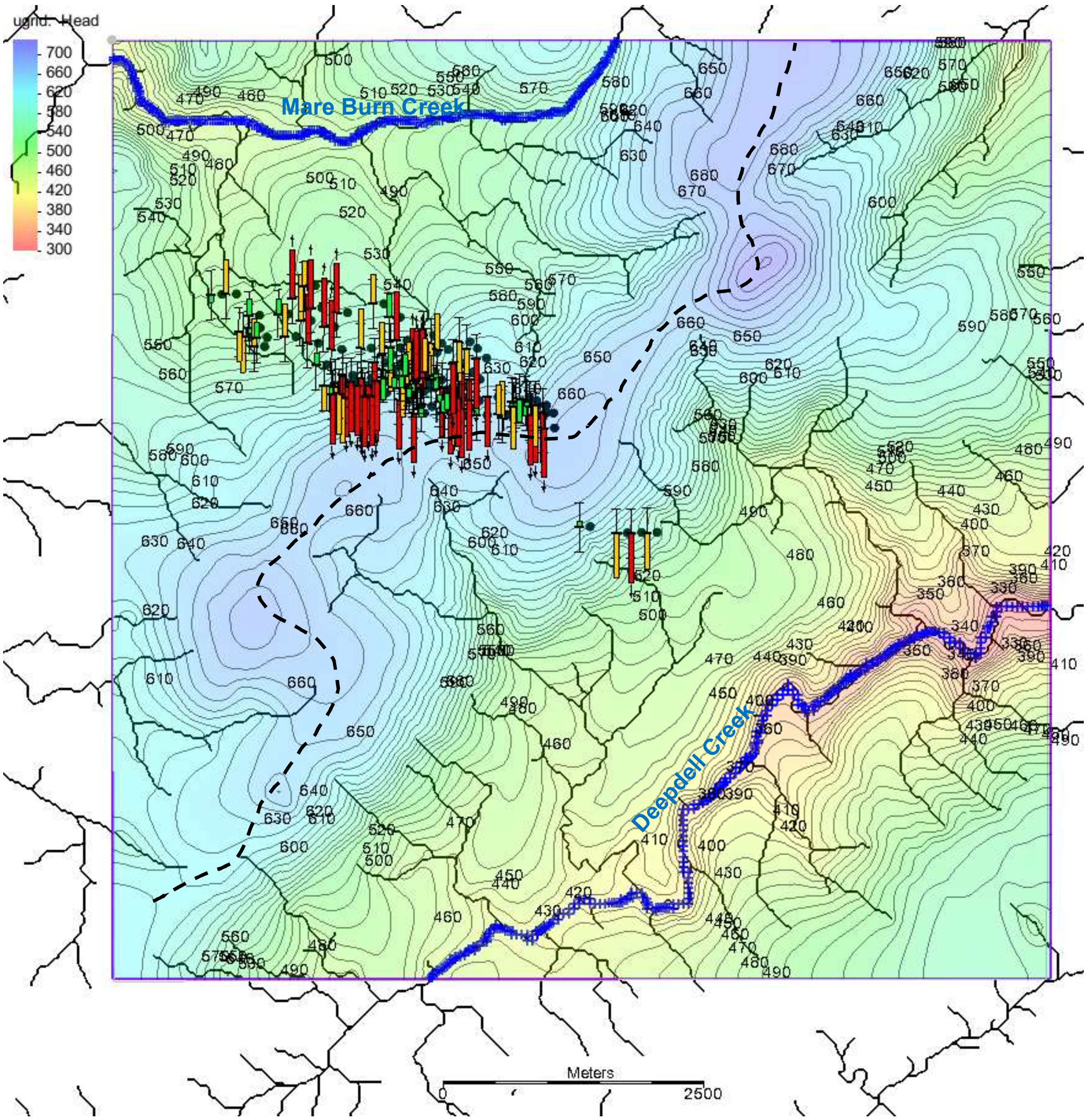


Figure 4.10 ***Steady state scatter plot (model computed vs observed head) using Table 4.2 hydraulic parameters***

Steady-state modelled head contours using the parameters presented in Table 4.1 are plotted in Figure 4.11. Modelling results are in agreement with the conceptual groundwater flow model discussed in Section 4.1 showing that the Coronation pit is located on a groundwater divide (dash line shown in Figure 4.11), with groundwater flowing towards the north and towards the south from the proposed pit area.



Note: red bars represent difference between modelled and observed head >10 m, Yellow bars represent difference between modelled and observed head <10 m but >5 m and Green bars represent difference between modelled and observed head <5 m

Figure 4.11 Steady-state modelled head contours (pre mining))

4.2.4 Predictive Analysis

4.2.4.1 Dewatering

It is understood that the Coronation pit has been in operation since 2016, with current water level in the pit at 600 m RL. Existing conditions have been simulated with a transient flow model from 2016 to 2030 (a total of 15 years) assuming topographic data of 2021 for the drain bottom elevation of the drain boundary conditions. Mining and associated dewatering of the proposed new pit CO6 has been simulated from 2024 – 2026 as per the Macraes mining schedule.

Modelled head contours using the parameters presented in at the end of dewatering are plotted in Figure 4.12.

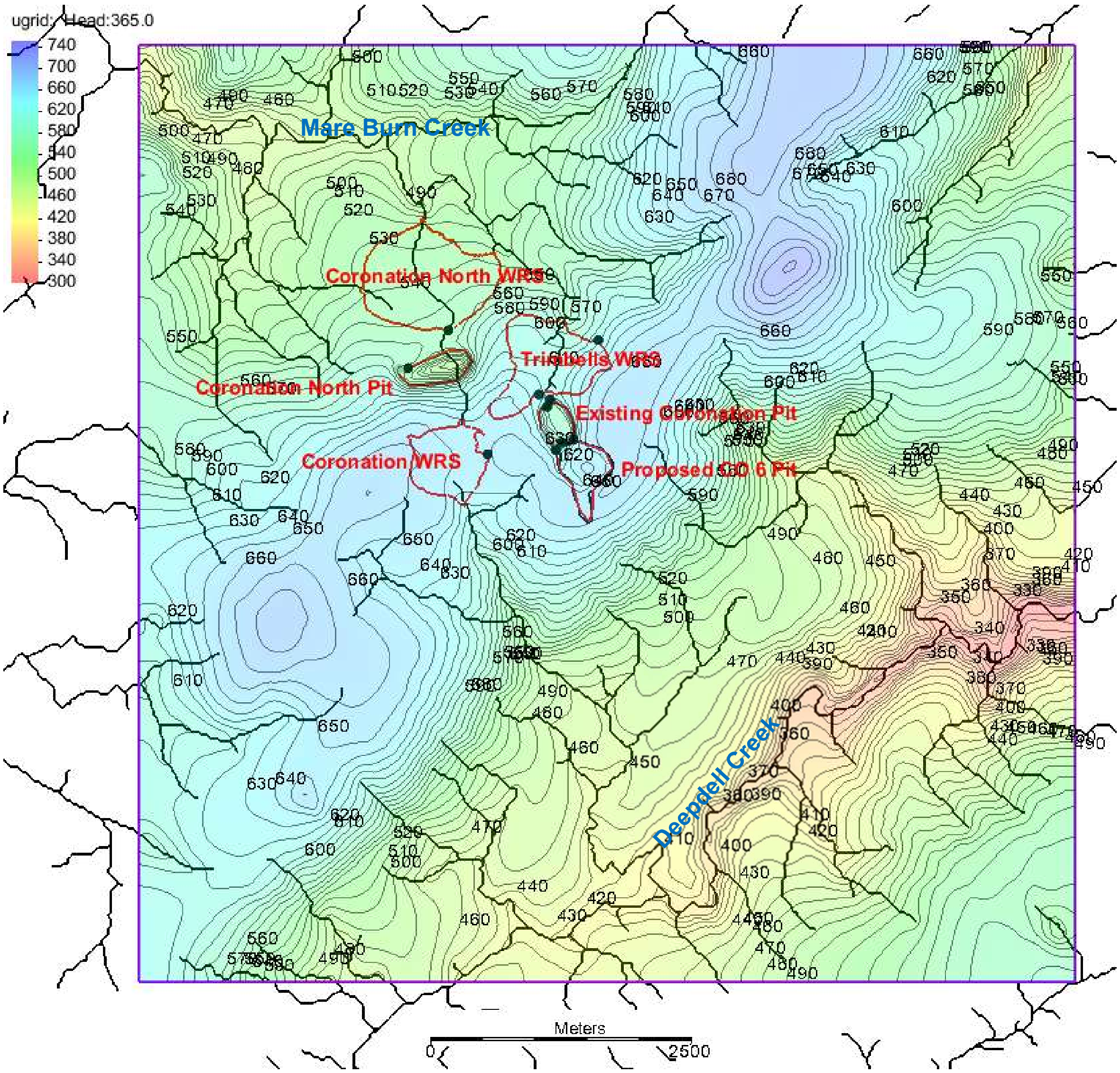


Figure 4.12 Pressure head contours at the end of dewatering (2026)

Estimated groundwater inflows into the existing and proposed Coronation pits are presented in Figure 4.13 and Figure 4.14 respectively. As presented in these figures, groundwater inflows into the existing (CO5) pit are estimated from 1.2 L/s to 0.9 L/s. For the proposed Stage 6 extension, the groundwater inflow rate is estimated to range from 2.0 L/s (at the beginning) to 0.8 L/s (towards the end of dewatering). The water balance at the end of proposed pit dewatering is presented in Figure 4.15.

Modelling results indicate there will be a relatively small reduction (~95 m^3/d or 1 L/s) in the groundwater contributions to the Mare Burn Creek flows due to pit dewatering which is ~ 4.5% of the total (river and drain boundaries) groundwater contribution estimated by the steady state simulation (~2,124 m3/day or 24.6 L/s). Changes to the groundwater contribution to the Deepdell Creek base flow from the existing and proposed additional pit dewatering at the Coronation pit are expected to be negligible.

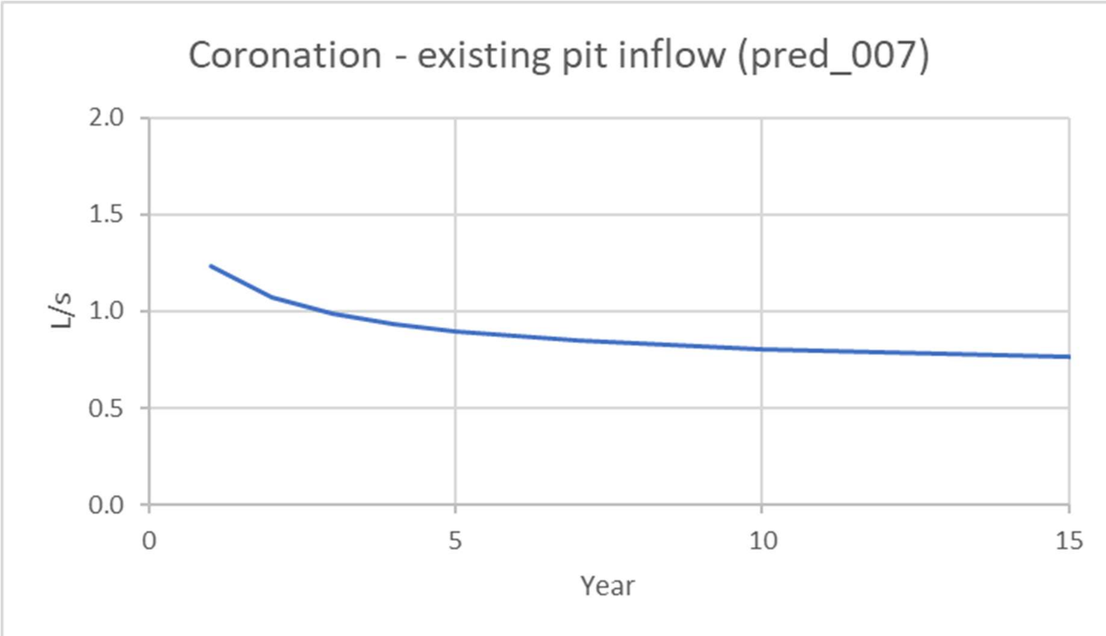


Figure 4.13 Existing pit inflow (Coronation pit)

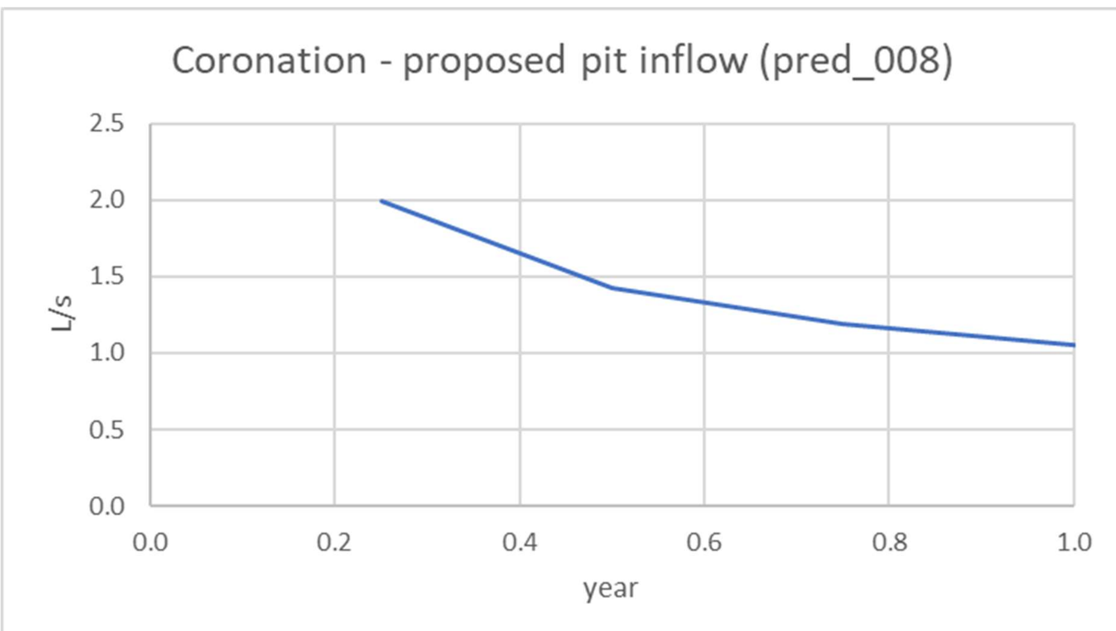


Figure 4.14 Proposed pit inflow (Coronation pit)

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 VOLUMETRIC BUDGET FOR ENTIRE MODEL AT END OF TIME STEP      3 IN STRESS PERIOD      4
 ------------------------------------------------------------------------------------

    CUMULATIVE VOLUMES      L**3       RATES FOR THIS TIME STEP      L**3/T
    ------------------                 ------------------------

          IN:                                   IN:
          ---                                   ---
            STORAGE =      133983.0307            STORAGE =         226.0576
      CONSTANT HEAD =           0.0000      CONSTANT HEAD =           0.0000
             DRAINS =           0.0000             DRAINS =           0.0000
      RIVER LEAKAGE =      352394.4248      RIVER LEAKAGE =         965.4637
           RECHARGE =     2365163.2367           RECHARGE =        6479.8994

           TOTAL IN =     2851540.6922           TOTAL IN =        7671.4207

         OUT:                                  OUT:
         ----                                  ----
            STORAGE =       20336.5452            STORAGE =          53.3896
      CONSTANT HEAD =           0.0000      CONSTANT HEAD =           0.0000
             DRAINS =     2304310.2506             DRAINS =        6174.4196
      RIVER LEAKAGE =      526893.9634      RIVER LEAKAGE =        1443.6117
           RECHARGE =           0.0000           RECHARGE =           0.0000

          TOTAL OUT =     2851540.7592          TOTAL OUT =        7671.4209

           IN - OUT =      -6.6995E-02           IN - OUT =      -1.7895E-04

PERCENT DISCREPANCY =           -0.00     PERCENT DISCREPANCY =           -0.00
```

Figure 4.15 Water balance summary at the end of Coronation Stage 6 pit dewatering

Similar results (slightly lower values) were estimated using the model parameters presented in Table 4.2. More specifically groundwater inflow into the existing (current pit) is estimated ~0.6 L/s and for the proposed new extension of the pit, inflow rate is estimated to range from 2.2 L/s (at the beginning) to 1.2 L/s (towards the end of the year). Graphs presenting the estimated groundwater inflows into the existing and proposed new pits are presented in Section 4.2.4.

4.2.4.2 Groundwater Recovery

Groundwater recovery was computed for 400 years with the proposed Coronation pit-lake level modelled as a General Head Boundary (GHB). The head values for the boundary condition were derived from the water balance model that was used to estimate filling rates and the long term equilibrium level (refer section 5.5, Figure 5.7). During the recovery run, contaminant (sulphate) transport modelling was also undertaken, and results are discussed in Section 4.2.4.3.

The water balance summary as well as modelled pressure head contours at the end of the recovery run are presented in Figure 4.16 and in Figure 4.17 respectively.

```
VOLUMETRIC BUDGET FOR ENTIRE MODEL AT END OF TIME STEP      60 IN STRESS PERIOD      74
------------------------------------------------------------------------------------------

   CUMULATIVE VOLUMES      L**3       RATES FOR THIS TIME STEP      L**3/T
   ------------------                 ------------------------

         IN:                                      IN:
         ---                                      ---
           STORAGE =     5528331.7604               STORAGE =       1.4718E-06
     CONSTANT HEAD =           0.0000         CONSTANT HEAD =           0.0000
            DRAINS =           0.0000                DRAINS =           0.0000
     RIVER LEAKAGE =   141022616.3919         RIVER LEAKAGE =         965.9003
   HEAD DEP BOUNDS =    18670955.9902       HEAD DEP BOUNDS =         171.2486
          RECHARGE =   946065314.4531              RECHARGE =        6479.8994

          TOTAL IN =  1111287218.5957              TOTAL IN =        7617.0483

        OUT:                                     OUT:
        ----                                     ----
           STORAGE =     8057703.8819               STORAGE =           1.1799
     CONSTANT HEAD =           0.0000         CONSTANT HEAD =           0.0000
            DRAINS =   885720283.9947                DRAINS =        6142.5946
     RIVER LEAKAGE =   211276933.7294         RIVER LEAKAGE =        1447.7952
   HEAD DEP BOUNDS =     6232299.6169       HEAD DEP BOUNDS =          25.4696
          RECHARGE =           0.0000              RECHARGE =           0.0000

         TOTAL OUT =  1111287221.2229             TOTAL OUT =        7617.0394

          IN - OUT =          -2.6272              IN - OUT =       8.9734E-03

PERCENT DISCREPANCY =          -0.00     PERCENT DISCREPANCY =          0.00
```

Figure 4.16 Water balance summary at the end of recovery run

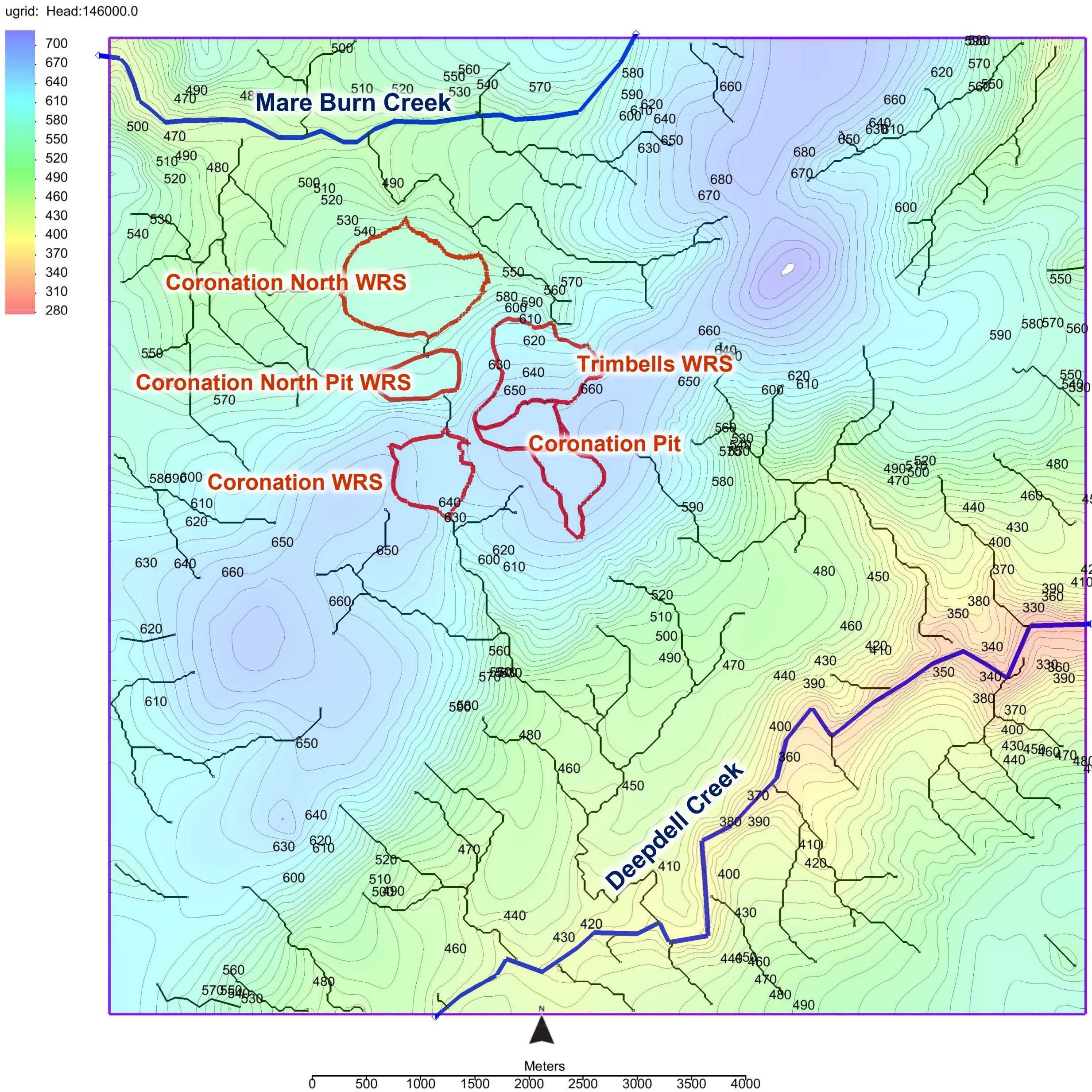

Figure 4.17 Pressure head at the end of the recovery run (400 years)

4.2.4.3 Contaminant Transport

Contaminant transport modelling was undertaken using MODFLOW USG-TRANSPORT (for solute transport modelling code) VERSION 1.8.0 at the start of the water level recovery run for the Coronation pit lake and for a total of 400 years with the following inputs:

– Sulphate has been modelled due to its expected elevated concentration (relative to other key contaminants), its existing elevated nature in some receiving surface water bodies as a result of mining activity, and its limited ability to attenuate within the groundwater system, It is therefore considered a conservative element with which to assess contaminant mobilisation and transport from the backfilled waste and subsequent pit lakes to receiving surface water bodies via the groundwater system.

– The sulphate concentration applied to the Coronation pit lake has been based on the concentration values estimated in MWM (2023a). Concentration values applied are changing with time as presented in Figure 5.4.

- The sulphate concentration applied to the Trimbells WRS (labelled zone 20 shown in Figure 4.22) is 3,584 mg/L based on an average WRS height of 35 m and the height / concentration relationship defined in MWM (2023b)
- The sulphate concentrations applied to the Coronation WRS (labelled zone 30 as per Figure 4.22) and Coronation North WRS (labelled zone 40 in Figure 4.22) are 1,653 mg/L and 1,933 mg/L based on average WRS heights of 26.6 and 28.8 respectively as defined in MWM (2023b). The Coronation North Pit WRS (labelled zone 50 in Figure 4.22) has a seepage sulphate concentration of 3,852 mg/L based on shake flask test data (MWM,2023a)
- Effective porosity values equal to specific yield values (Table 4.1)
- Longitudinal dispersivity (α_L) value = 20 m (assumed 10% of plume length based on initial test run where plume from CO6 pit expansion was expected to migrate approximately 200 m)
- Transverse dispersivity (α_T) value = 2 m (10% of the longitudinal)
- The groundwater model does not allow for capture of seepage in silt ponds which are assumed to significantly buffer the release of seepage waters into the receiving environment.

Water balance error and solute transport mass balance error for this run as well as all previous model runs was <0.00% suggesting all model runs completed were numerically stable.

The extent of the sulphate plume at the end of 400-year simulation is presented in Figure 4.18, Figure 4.20 and Figure 4.21 for model layers 1, 2 and 4 (L1, L2, L4) respectively. In these figures, plume is defined with the outer concentration of 10 mg/L. As presented in these figures, the maximum horizontal extent of the plume is approximately 1,600 m (Figure 4.18) to the north-west of the source area (Coronation North WRS) and approximately 1,600 m (Figure 4.20) to the south-east of the source area (Coronation pit lake).

A sensitivity analysis on dispersivity was undertaken by running the model with an α_L value of 10 m in accordance with the maximum suggested value by Zech et al (2015) and α_T value of 1 m. The lower dispersivity values resulted a plume extending approximately 5 m to 75 m less and concentrations approximately 5% less.

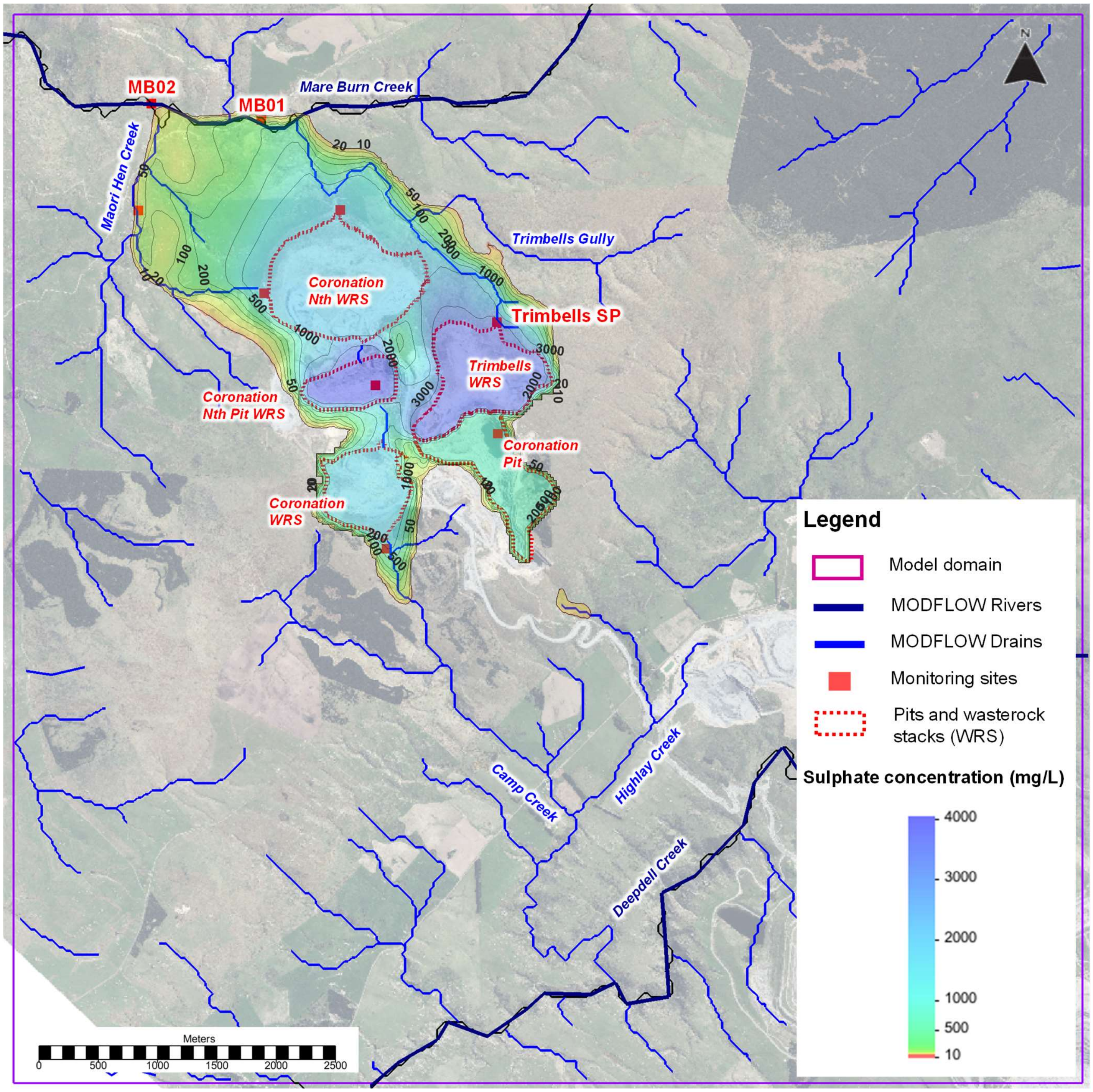

Figure 4.18 Contour plot showing plume after 400 years in model layer 1 within the entire model domain

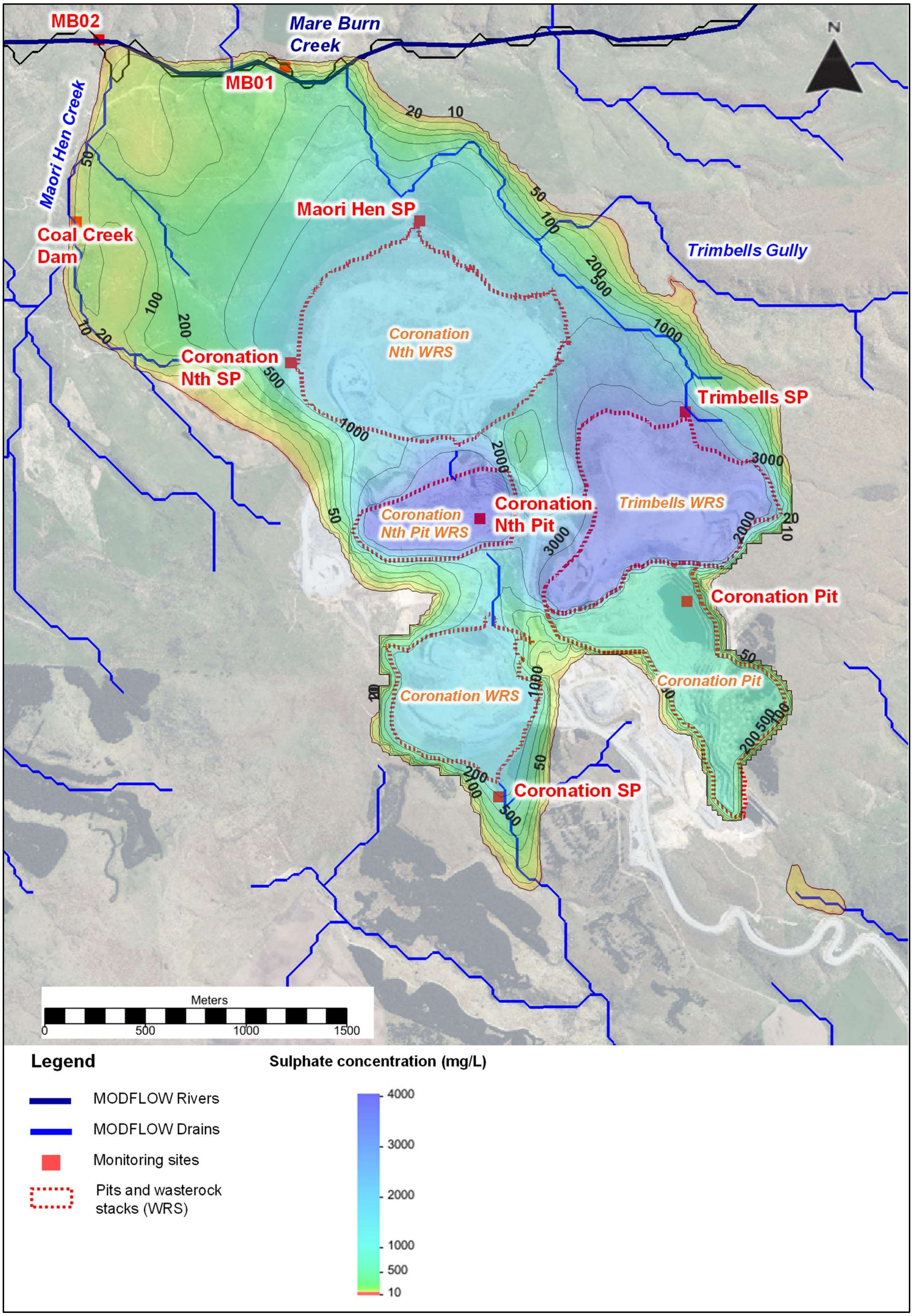

Figure 4.19 Contour plot showing plume extent after 400 years in model layer 1

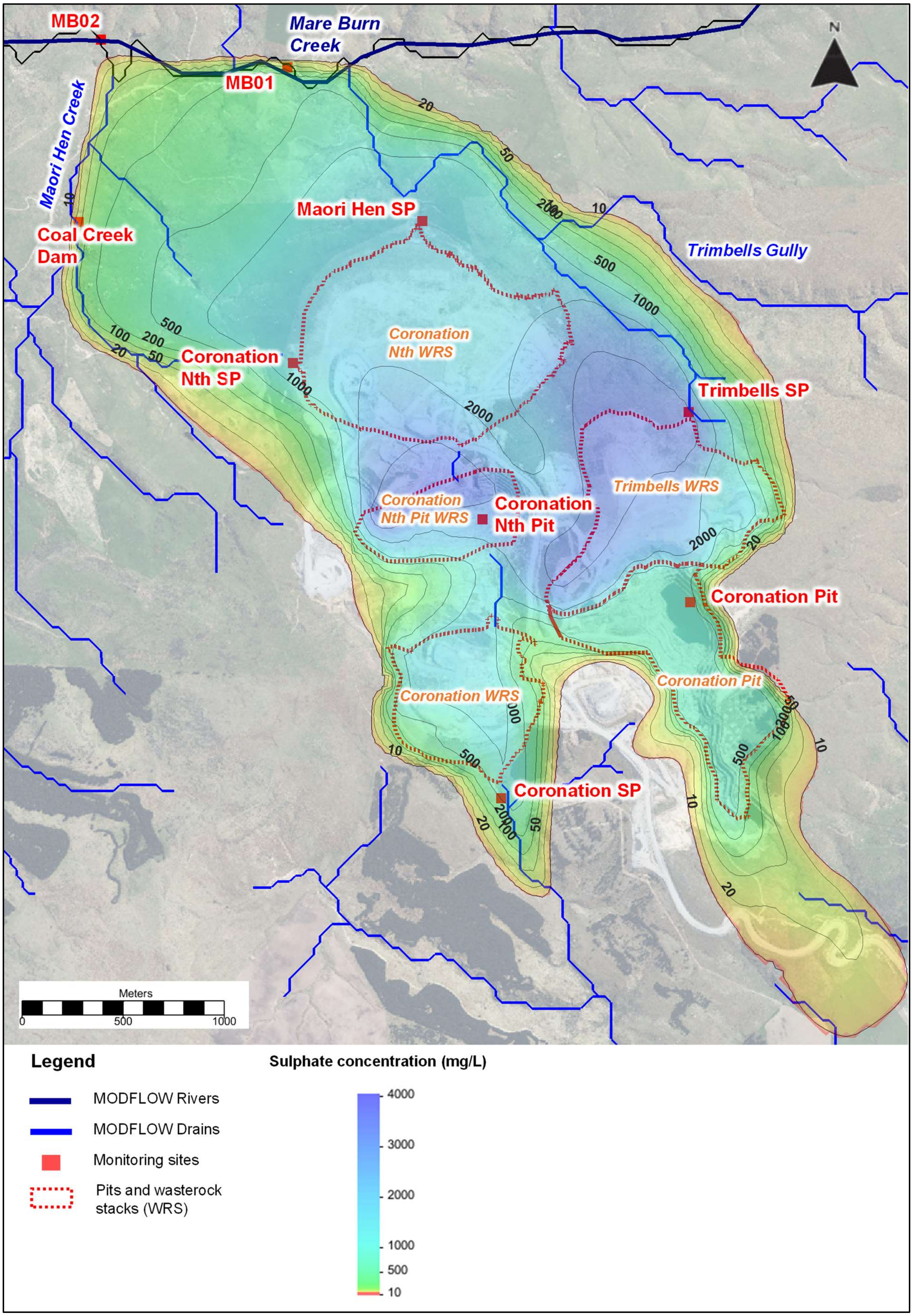

Figure 4.20 Contour plot showing plume extent in 400 years in model layer 2

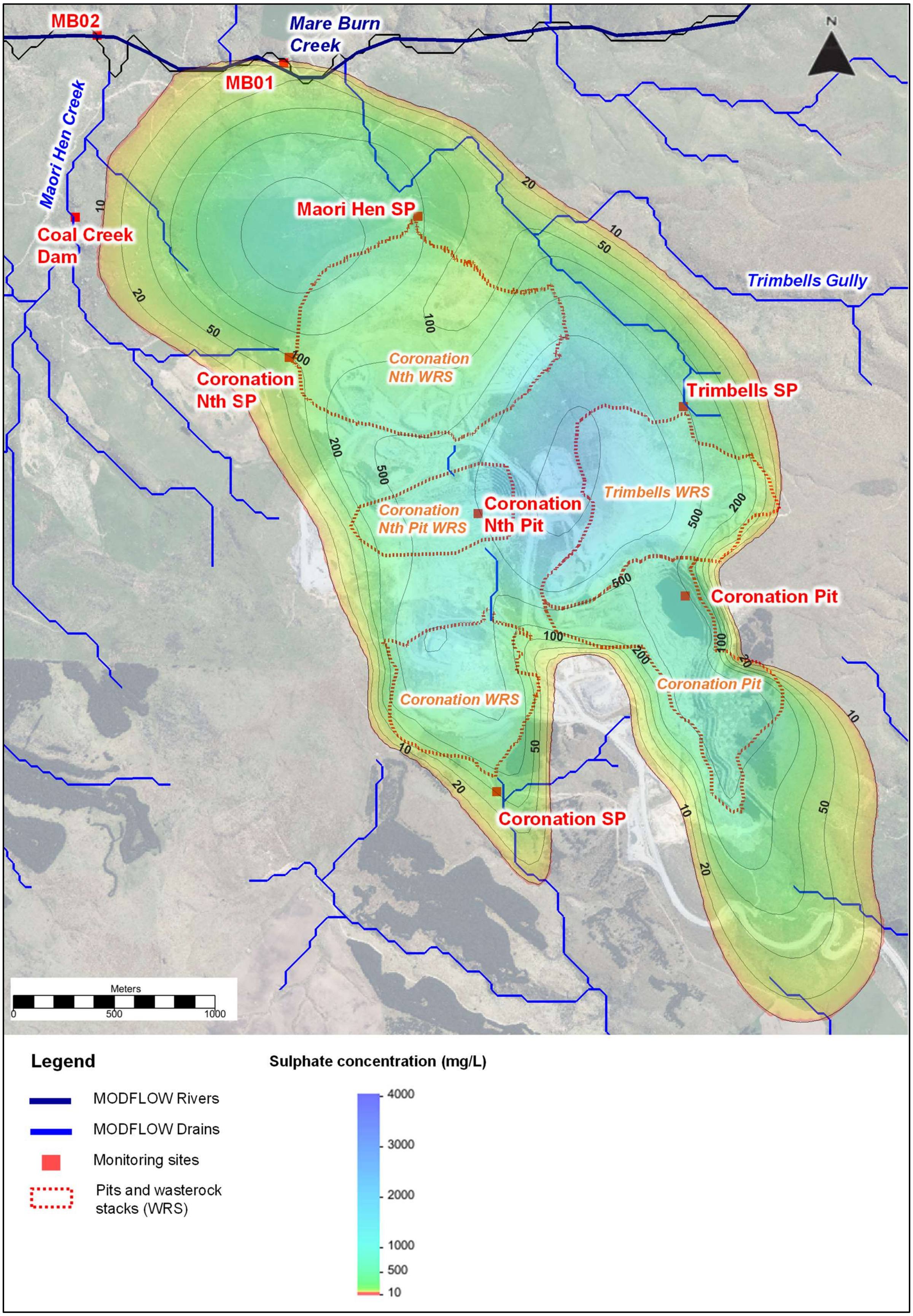

Figure 4.21 Contour plot showing plume extent in 400 years in model layer 4

As presented in Figure 4.18, the sulphate plume in layer 1 is moving towards the Mare Burn catchment, rather than the Deepdell Creek catchment, with the upper reaches of Mare Burn and Trimbell's Gully likely to receive higher concentrations of contaminants relative to the Deepdell catchment which is expected to have a relatively small impact from the Coronation area relative to the northern catchments.

Different zones were created to represent each WRS and pit lake to estimate inflows and outflows through those zones and these are presented in Figure 4.22. Groundwater flow rates from the four WRSs and the one pit lake (CO6) are presented in Figure 4.23 to Figure 4.27. As presented in these figures, the long-term seepage outflow from the four WRSs combined is estimated 4.6 L/s. Part of the estimated total seepage flux via layer 1 from the four WRSs (3.8 L/s) and the CO6 pit lake (0.5 L/s) is likely to end up in the surface water courses.

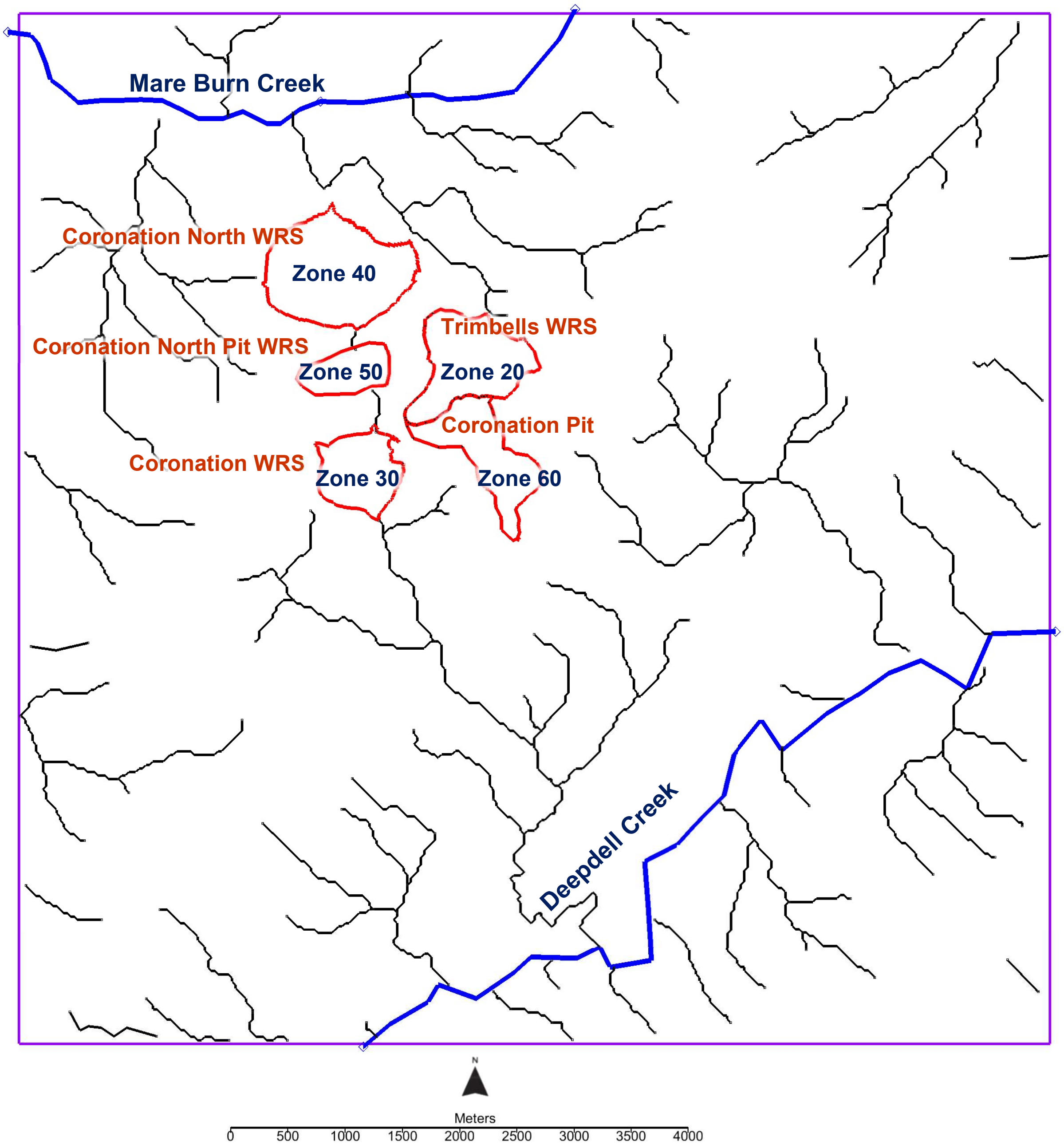

Figure 4.22 Location plan of zones to assess inflow and outflow during recovery.

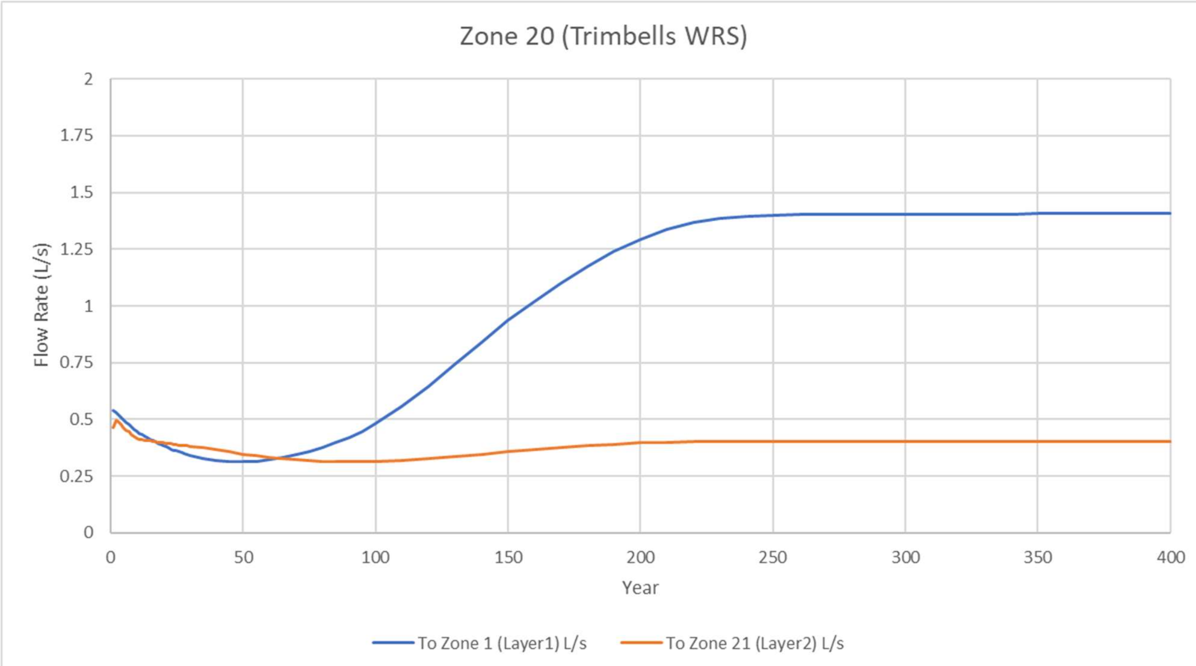

Figure 4.23 ***Seepage flow rate from Trimbells WRS (zone 20) to Zone 1 (Layer 1) and Zone 21 (Layer 2)***

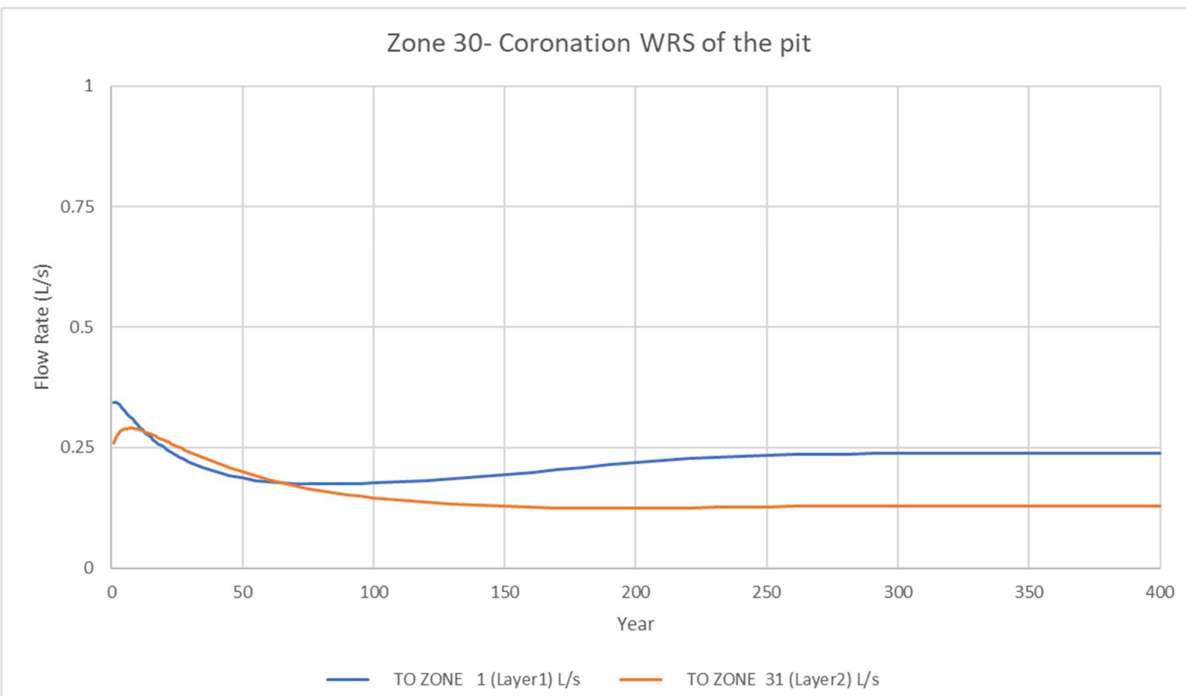

Figure 4.24 ***Seepage flow rate from Coronation WRS (zone 30) to Zone 1 (Layer 1) and Zone 31 (Layer 2)***

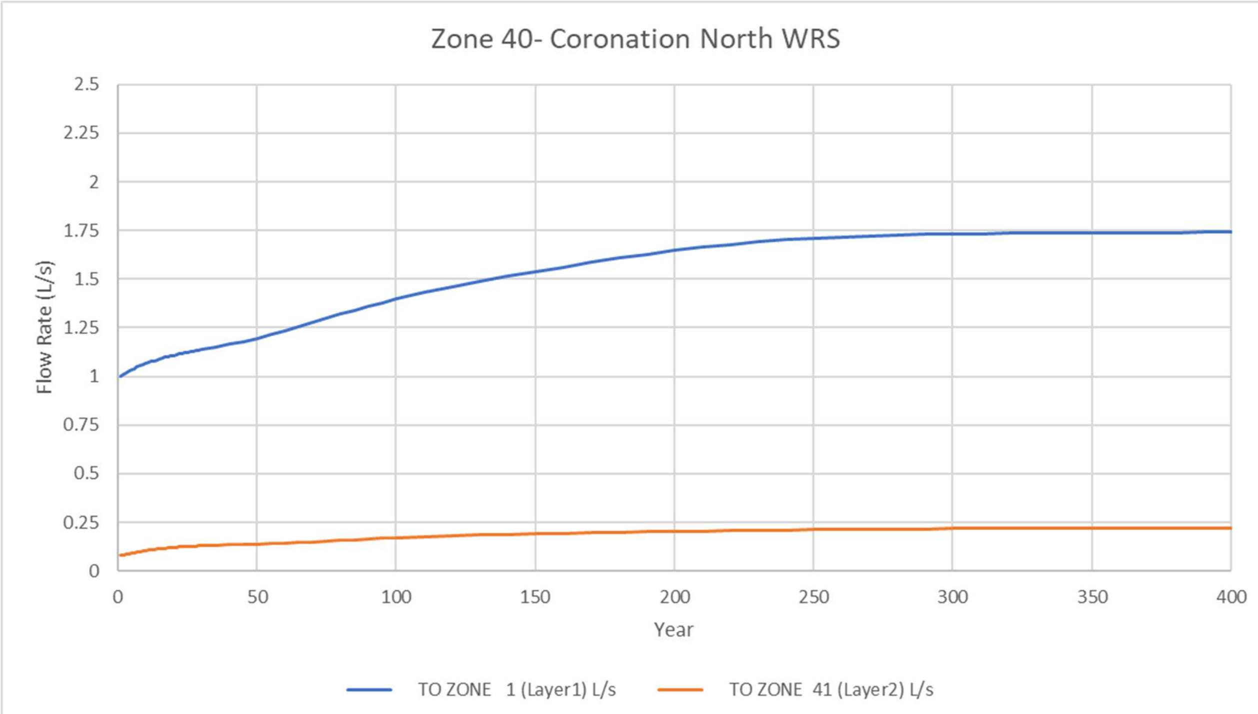

Figure 4.25 ***Seepage flow rate from Coronation North WRS (zone 40) to Zone 1 (Layer 1) and Zone 41 (Layer 2)***

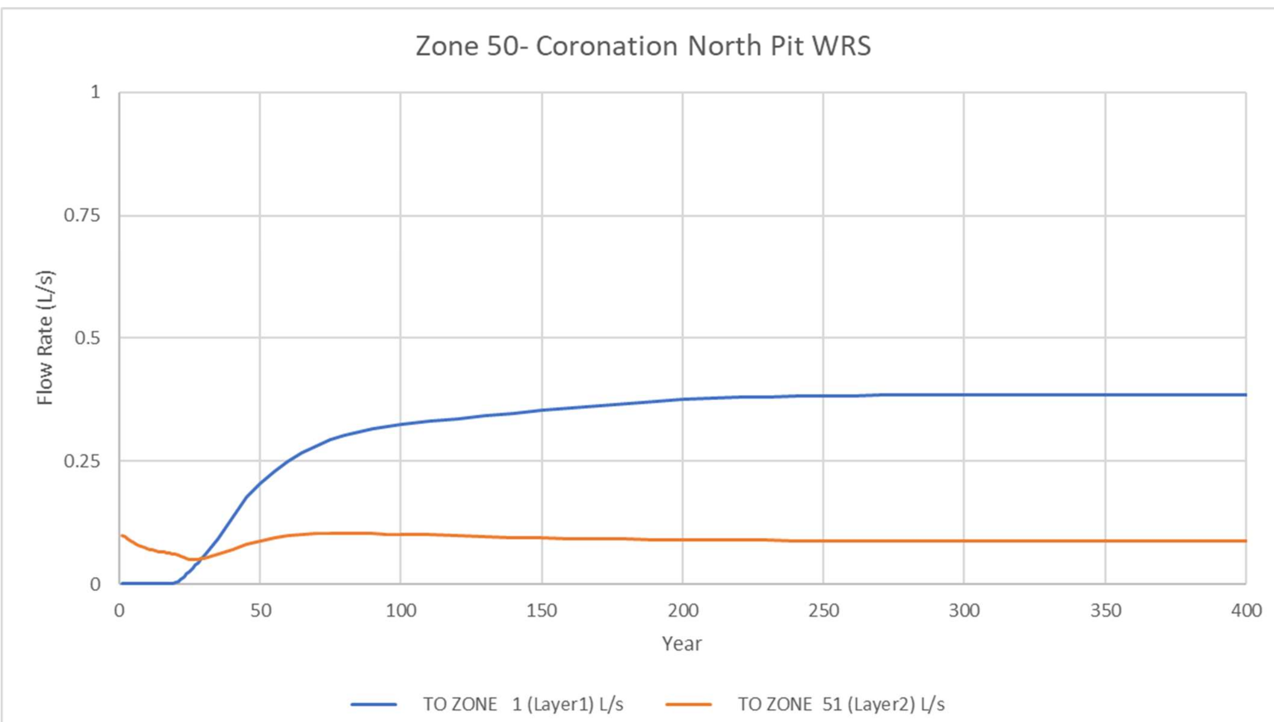

Figure 4.26 ***Seepage flow rate from Coronation North Pit WRS (zone 50) to Zone 1 (Layer 1) and Zone 51 (Layer 2)***

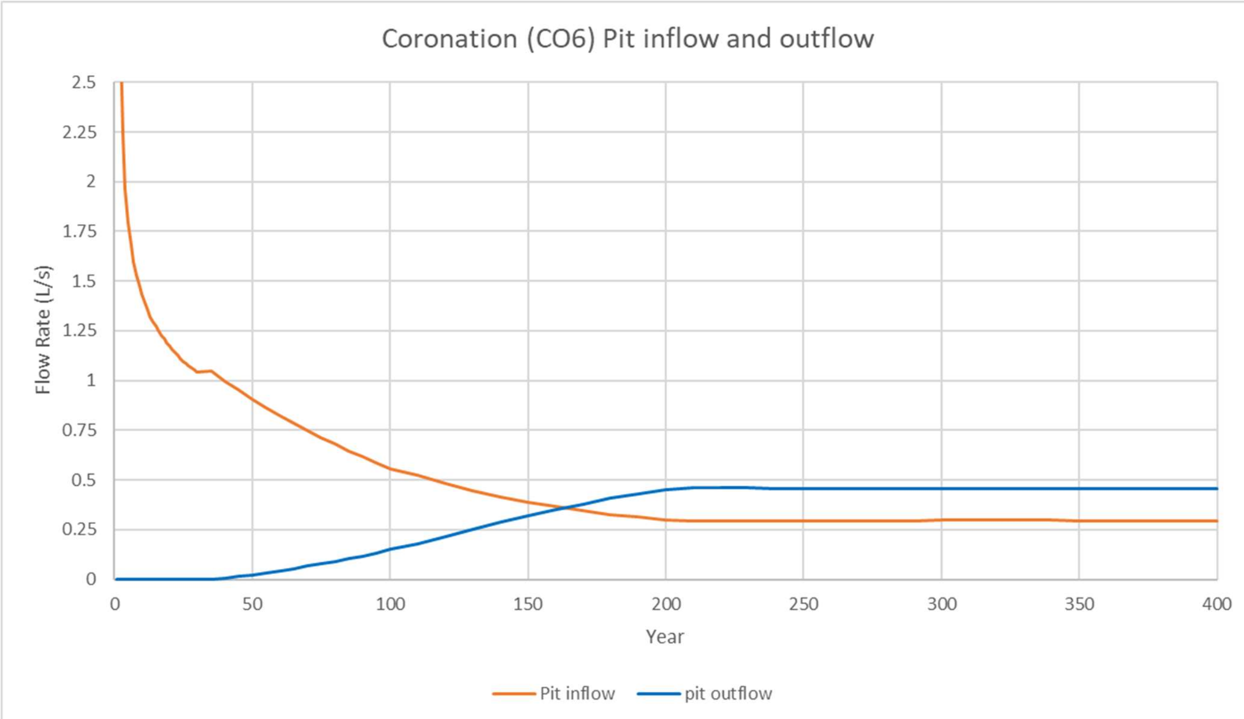

Figure 4.27 Groundwater in and outflow from the Coronation pit lake

The total modelled contaminant (sulphate) mass estimated to discharge into the tributaries of the Mare Burn Creek catchment has been calculated utilising the results from the contaminant transport modelling (Figure 4.18) and simulated flows through the surface water boundaries. The sulphate flux (of all surface water discharging up stream of the compliance monitoring location MB02 (Figure 5.5) is estimated to be 183 kg/day (20 years post closure) and 696 kg/day (230 years post closure). Using the lower values of 10 m α_L and 1 m α_T, the sulphate flux is estimated to be 173 kg/day (20 years post closure) and 661 kg/day (230 years post closure). The sulphate flux discharging to the Deepdell catchment is estimated to be <1 kg/day. The majority of the estimated sulphate mass is expected to be captured in the Trimbells and Maori Hen Silt Ponds where its release to the receiving environment will be buffered by other inputs (ie. Direct rainfall and runoff) before spilling to the receiving environment.

4.3 Groundwater Summary and Recommendations

As detailed in section 4.2 a numerical groundwater 3D model of the Coronation pit area has been developed using MODFLOW-USG and MODFLOW-USG-TRANSPORT. The 3D model has been used to assess groundwater inflow into the existing and proposed pit as well as during groundwater recovery for 400 years. The model was calibrated in the steady-state conditions using available pre-mining water level data before undertaking model predictions.

Modelling results indicate that dewatering rates from the proposed Coronation Stage 6 pit expansion range from 2.0 L/s (at the beginning of the excavation) to 0.8 L/s (towards the end). A relatively small reduction (~95 m^3/d or 1 L/s) is expected in the groundwater contributions to the Mare Burn Creek flows due to pit dewatering. This reduction is ~ 4.5% of the total (river and drain boundaries) groundwater contribution estimated by the steady state simulation. Changes to the groundwater contribution to the Deepdell Creek base flow from the existing and proposed additional pit dewatering at the Coronation pit are expected to be negligible.

The contaminant plume (defined by 10 mg/L concentration of sulphate) from the WRSs and the Coronation pit lake are modelled to reach approximately 1,600 m to the north-west and approximately 1,000 m to the south-east direction from these sources over 400 years. The sulphate plume in layer 1 is moving towards the Mare Burn catchment, rather than the Deepdell Creek catchment, with the upper reaches of Mare Burn and Trimbell's Gully likely to receive higher concentrations of contaminants relative to the Deepdell catchment which is expected to have a relatively small impact from the Coronation area relative to the northern catchments. The estimate of sulphate flux (of groundwater discharging to surface water up stream of the compliance monitoring location MB02) (Figure 5.5) is estimated to be 183 kg/day (20 years post closure) and 696 kg/day (230 years post closure) using the higher dispersivity values. The sulphate flux discharging to the Deepdell catchment is estimated to be <1 kg/day.

5. Surface Water Assessment

5.1 Introduction

In 2018, GHD developed a site wide water balance model (WBM) for OGNZL operations at the Macraes Gold Mine utilising the software Goldsim. This WBM later incorporated the Deepdell North Stage III Project and assessed the potential impact on downstream water quality associated with the project. The combined analysis showed a low potential for future non-compliance in Deepdell Creek and Shag River receiving water bodies and is reported in GHD, 2019. This WBM has since been optimised and updated to incorporate subsequent site changes, additional monitoring data and to assess surface water quality impacts of specific projects with the results of the later documented in following reports, each of which have been utilised to support the consenting of the specified projects:

- GHD 2020. GPUG Cumulative Effects Assessments. Report prepared for Oceana Gold (New Zealand) Ltd
- GHD 2021. TTTSF Crest Raise. [RL 560-568 m RL] Surface and Groundwater Assessment. Report prepared for Oceana Gold (New Zealand) Ltd
- GHD 2022a. Pit Lake Closure Modelling. Coronation and Coronation North Pits. Report prepared for Oceana Gold (New Zealand) Ltd
- GHD 2022b. TTTSF Crest raise. [RL 568-570 m RL] Surface Water and Groundwater Assessment. Report prepared for Oceana Gold (New Zealand) Ltd.
- GHD 2022c. Frasers Co-disposal Surface Water and Groundwater Assessment. Report prepared for Oceana Gold (New Zealand Ltd, 10 November 2022.
- WSP (2023). Golden Point Underground Mine (GPUG). GPUG Extension Hydrogeological Assessment (GPUG ext). April 2023.

The construction, calibration, and input data of the current Goldsim WBM are well documented throughout the above assessments and can be used to estimate future impacts of receiving water quality as a result of site activities and rehabilitation activities.

Updates to the WBM which have been implemented include:

- Revised WRS seepage quality estimates. The WBM now estimates contaminant concentrations in seepage water based on correlations with WRS dimensions as presented in MWM (2022). This also applies a sulphate ceiling in which geochemical equilibrium would limit forever increasing concentrations and correlations of other contaminants to sulphate concentrations to capture the key consenting parameters.
- Recalibration of key compliance points utilising revised catchment boundaries and up to date water quality monitoring data.

Inclusion of ground water interactions within the pits based on inflow/outflow relationships presented in Section 4.2.4 of this report.

5.2 Model Schematisation

An overview of the water schematic of the Coronation area is shown in Figure 5.1. The Mare Burn River ultimately discharge to the Taieri River catchment whereas Deepdell Creek ultimately discharges to the Shag River. Coal Creek Dam and Camp Creek Dam are consented fresh-water dilution structures that are not currently constructed. The WBM has the ability to turn these structures on and off. Current and closure runoff and seepage catchments maps are shown in Figure 7.2 to Figure 7.7 (Appendix A). Figure 5.5 shows the model domain with the relevant model nodes and key surface closure features. It includes the presence of the consented and yet to be constructed Coal Creek Dam with the WBM having the ability to turn the structure on and off to investigate its need and overall effects on modelled water quality compliance.

Key stage volume inputs and catchment areas are outlined in Appendix A.

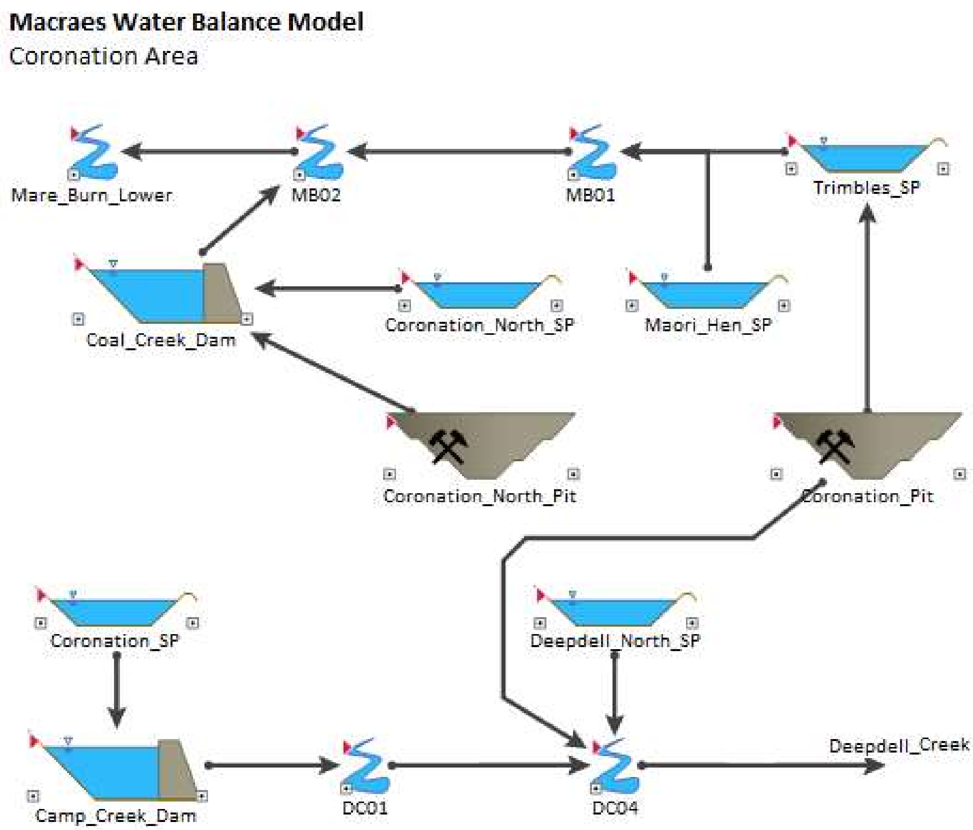

Figure 5.1 Schematic of the Coronation are elements of the Macraes Water Balance Model.

5.3 Climate and climate change representation

Climate data are applied to the model based on historical measurements, from which a synthetic rainfall time series is generated, and monthly evaporation statistics are derived. Where the model is applied for long term predictive modelling of flows and contaminant concentrations climate change adjustments are applied to the rainfall and evaporation inputs.

Van Vuuren et al (2011) set representative concentration pathways (RCPs) defining approximate total radiative forcing through to the year 2100. The paper presents an RCP8.5 scenario that represents a ‘business as usual’ response to climate change resulting in high greenhouse gas concentrations by 2100. Given the uncertainty of the global response to climate change and the subsequent effects to long-term water management at the Macraes Mine site, the RCP8.5 scenario is seen as the conservative approach to accounting for climate change and it is expected to lead to the following key outcomes:

- increased mean and maximum temperatures,
- increased dry days (no precipitation) and evaporation with more severe and frequent droughts,
- decrease in summer precipitation (December – February),
- increase in winter precipitation (June – August),
- increased mean precipitation concentrated on the extreme events.

5.3.1 Rainfall

Rainfall is represented in the WBM based on a stochastic synthetic data series produced for statistical similarity with recorded rainfall data. The algorithm producing the stochastic rainfall seeks to represent seasonal variation, daily rainfall depth distributions and antecedent rainfall conditions. This makes the extended synthetic rainfall series suitable for representing an increased range of scenarios than what could be achieved with a historic data series alone. The recorded rainfall includes daily rainfall data from Glendale Station (agent number 5370) between 1959 and 2008, and the Golden Point Station on the Macraes site between 1991 and 2018. The synthetic data represents daily rainfall depths for 1,000 years and has a mean annual depth of 664 mm with a range between 355 mm and 1155 mm (Table 5.1).

Table 5.1 Rainfall statistics

	Synthetic Record (1,000 years)	Golden Point Station (1991-2022)	Glendale Station No. 5370 (1959-2008)
Mean annual rainfall (mm)	664	665	634
Minimum annual rainfall (mm)	355	414	395
Maximum annual rainfall (mm)	1155	1034	950
Dry days	59%	59%	68%

Seasonal rainfall variations under the RCP8.5 scenario are expected to follow the trends as outlined in Table 5.2. Typically, this results in dryer summer periods and wetter winters than historical means. The net result is an overall annual increase in precipitation.

Table 5.2 Mean rainfall changes for RCP8.5 at Macraes Mine (Data extracted from NIWA, 2016)

Season	2055		2090	
	Lower	Upper	Lower	Upper
Summer	-10%	-5%	-10%	-5%
Autumn	5%	10%	10%	15%
Spring	-5%	0%	10%	15%
Winter	10%	15%	20%	25%
Annual	-5%	0%	10%	15%

5.3.2 Evaporation

Evaporation is represented in the model based on monthly statistics derived from pan evaporation data collected from site between 1991 and 2018 as shown in Figure 5.2. Mean annual evaporation is 952 mm and this is represented in the WBM as a monthly normal distribution with cut-offs applied as per the minimum and maximum values.

An evaporation reduction factor of 0.7 is applied to evaporation from the pit lakes to account for differences between pan evaporation rates and evaporation rates expected from large water bodies.

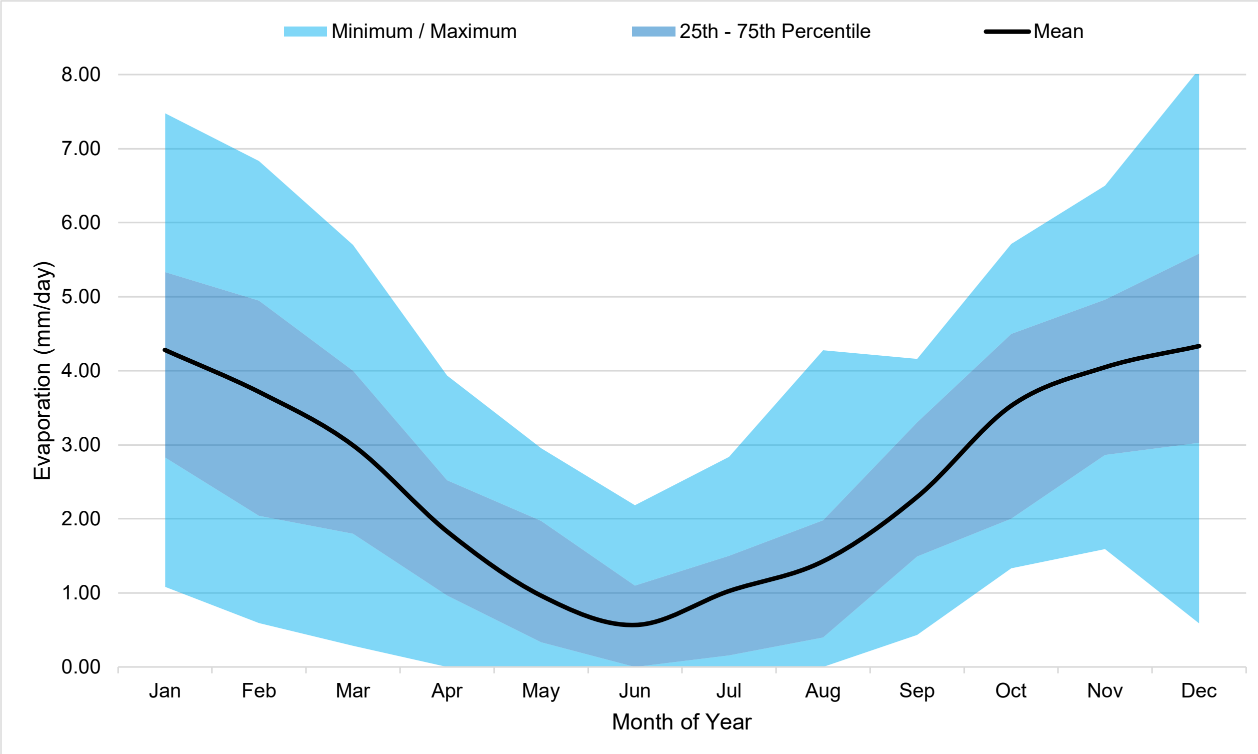

Figure 5.2 ***Evaporation statistics applied in WBM***

Under the RCP8.5 scenario an increase in potential evaporation deficit (PED) of approximately 120 mm could be expected by 2110 (Figure 5.3). At the Macraes Mine site this translates to an increase in mean evaporation potential of approximately 12.5 %. This evaporation potential is applied to the model as a multiplier of the existing evaporation rates, linearly increasing to 12.5 % by the year 2110. From the year 2110 evaporation is fixed to 1.125 times the historical statistics.

The net result from the applied evaporation and rainfall adjustments in the long term is a typical increase in annual runoff, with seasonal decreases in summer periods and increases in winter.

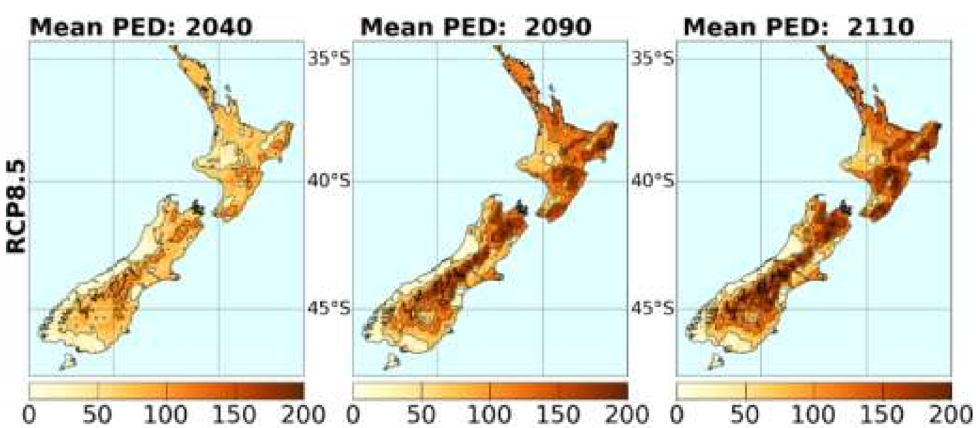

Figure 5.3 ***PED projections (exert from MfE 2018, Figure 55)***

5.3.3 Runoff

Runoff is represented in the WBM by two methods, the rational method is applied to areas impacted by mining and WRS runoff, and a calibrated Australian Water Balance Model (AWBM) (Boughton 2004) is applied to all other areas.

Table 5.3 outlines the runoff coefficients applied to impacted and WRS surfaces. Runoff coefficients are interpolated from these given values based on the daily rainfall depth. These coefficients increase with rainfall depth to represent the higher runoff rates from more wetted soils.

Table 5.3 Runoff coefficients for application of the rational method.

Daily rainfall (mm)	Impacted Areas	Waste Rock Stacks
0	0.05	0
10	0.2	0.05
50	0.4	0.15
90 +	0.7	0.4

Runoff to water body surfaces is modelled with a runoff coefficient of 1.0 and the surface area of these water bodies are adjusted based on the defined volume-area relationships, with a corresponding reduction in adjacent catchment area.

For flows from natural catchments a catchment runoff model based on the Australian Water Balance Model (AWBM) (Boughton 2004) is calibrated to gauging undertaken on the Waikouaiti North Branch River at Golden Bar Road and Griffin Road gauges (NBGR) between 1991 and 1998. This calibration is presented in Appendix A.

5.3.4 Surface Water Quality

The surface water quality parameters applied to the water balance model are listed in Table 5.4. These values have been derived based on the water quality data provided by OGNZ and based on analysis of typical distributions of the data, a ±30% distribution is applied to the values within the Monte-Carlo simulations.

These source terms are applied in the model based on the following definitions:

– **Natural** is used to define areas that have not been affected by modern mining operations. This may include native/non-native forestry, farmed land and wetlands among other land uses.

– **Impacted** areas are influenced by mine operations and disturbance is typically near the natural surface only, for example, haul roads, workshop areas and exploration activities.

– **Impacted-Rehabilitated** includes areas that have been impacted, then rehabilitated through establishing vegetation. This surface type is nominally considered to be equivalent to ‘natural’ surfaces once rehabilitated.

– **WRS** (Waste Rock Stack) is surface areas of mined rock placed for purpose of stockpiling or producing a WRS and does not have established vegetation.

– **WRS-Rehabilitated** includes areas that have been WRS, then rehabilitated through establishing vegetation. Typically, this is grass cover suitable for grazing stock.

Table 5.4 Water quality source terms – mean value inputs

Parameter (g/m^3)	Natural	Disturbed	Impacted	Impacted Rehab	WRS Non-Rehab	WRS Rehab
Ammoniacal N	0.011	0.011	0.120	0.012	0.500	0.010
Arsenic	0.002	0.002	0.037	0.019	0.011	0.011
Copper	0.001	0.001	0.001	0.001	0.002	0.001
Hardness	65	65	1200	630	200	220
Iron	0.05	0.05	0.03	0.14	0.08	0.08
Lead	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002
Nitrate N	0.1	0.1	0.1	0.4	1.0	0.4
Sulphate	24	24	930	470	470	150
Zinc	0.001	0.001	0.001	0.001	0.001	0.001

Coronation Pit lake surface water quality utilised in the model is as presented in MWM 2023. The pit lake water quality has been derived by developing source terms for each component of the GHD pit water balance and modelling of the annualised pit lake concentrations in a hydrogeochemical pit lake model. A timeseries plot for sulphate is presented in Figure 5.4.

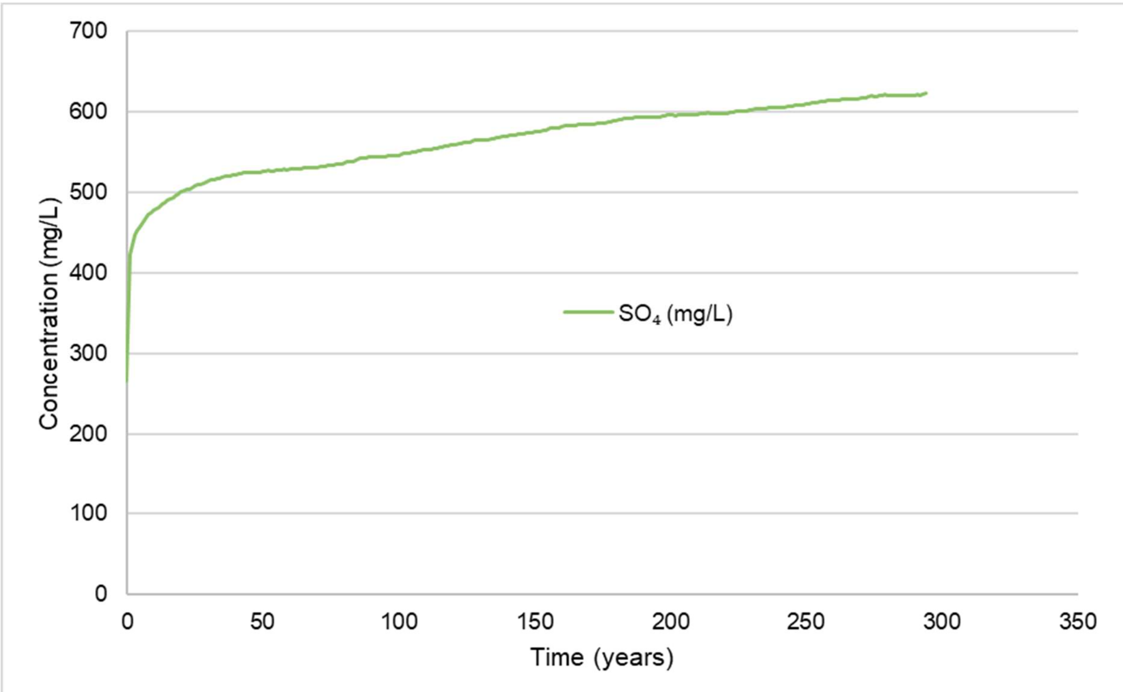

Figure 5.4 Coronation pit lake sulphate concentration (MWM, 2023)

5.4 Model Domain

The model domain includes the Mare Burn catchment in the northwest area for the Macraes mine. This includes the Coronation North and Coronation Pit along with the Trimbells WRS, Coronation North WRS and Coronation WRS. Figure 5.5 shows the model domain relevant to this assessment.

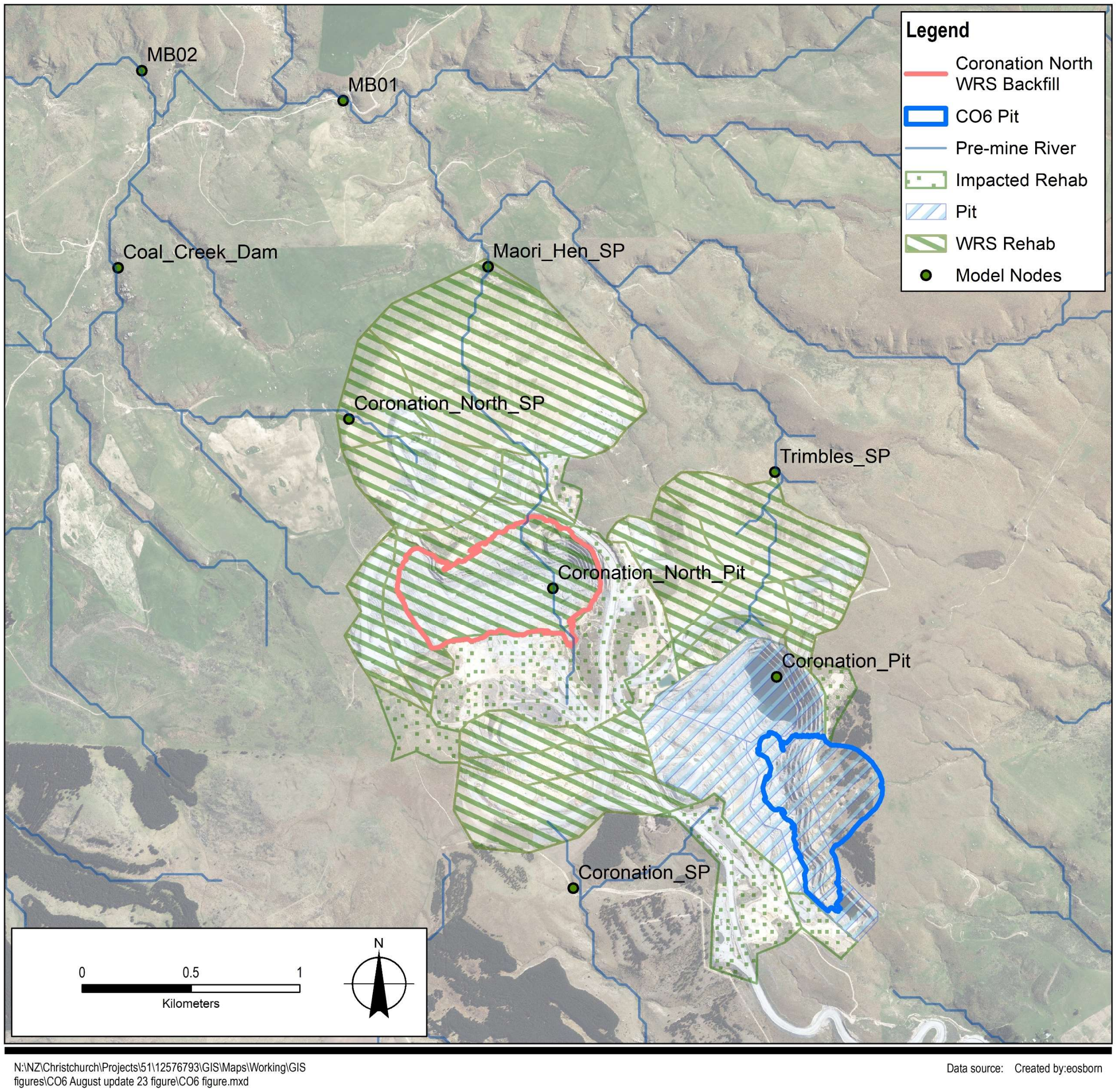

Figure 5.5 Coronation and Coronation North model domain

The modelling focuses on the outcomes associated with the Mare Burn catchment. MB01 and MB02 are the compliance points of significance for this model analysis. Any outcomes in the Deepdell Catchment caused by potential overflow of Coronation pit have not been included in this reporting and are assessed in the Stage 3 Surface Water and Groundwater Assessment (GHD,2024).

5.5 Existing Water Quality Compliance Criteria

The proposed Coronation Pit expansion (CO6) and waters seeping through the Trimbells WRS to Trimbells Creek, and the Trimbells, Coronation Pit and Coronation North WRSs will influence waters discharging to the Mare Burn. There are established water quality monitoring and compliance points on the Mare Burn (MB01 and MB02, refer Figure 5.5). These were established in previous phases of the Coronation and Coronation North projects and remain appropriate locations in order to assess downstream surface water impacts of the proposed CO6 development. A summary of the water quality compliance criteria for these pits is provided in Table 5.5. These criteria are applied as a reference point for assessing water quality discharges related to the proposed developments.

Table 5.5 Summary of current existing consented water quality criteria

Parameter	MB01	MB02
Project Reference	Coronation Project	Coronation North Project
Consent Reference	RM12.378.05	RM16.138.04, RM16.138.05 and RM16.138.09
Arsenic (g/m^3)	0.15	0.15
$Cyanide_{WAD}$ (g/m^3)	0.1	0.1
Copper (g/m^3)*	0.009	0.009
Iron (g/m^3)	1.0	1.0
Lead (g/m^3)*	0.0025	0.0025
Zinc (g/m^3)*	0.12	0.12
Sulphate (g/m^3)	1,000	1,000
PH (range)	6.0 – 9.5	6.0 – 9.5
Nitrate N-N, NO_3-N (g/m^3)	-	2.4
Ammoniacal Ncal Nitrogen NH_4-N (g/m^3)	-	0.24

* Copper, lead and zinc standards shall be hardness related limits in accordance with the following. Values given in the tables above assume a hardness of 100g/m3 $CaCO_3$.

5.6 Modelling Scenarios

Modelling covers the full time-domain from present day to long-term operation following spill from the pit lakes. Within this time frame three key phases (with the addition of a climate change scenario) of the project are considered, these are:

4. **Mining** – During active mining where waste rock stacks are under construction and pits are being dewatered and excavated. Active management of mine water is in place.
5. **Closure** – All surfaces are rehabilitated (other than pit walls), most pits not yet overflowing, seepage from WRSs may not have reached peak predicted values, active return pumping of TSF drains maintained.
6. **Long-term** – Pits that are projected to overflow have reached the overflow, all surfaces are rehabilitated (other than pit walls), seepage from WRSs have reached peak predicted values, all mine waters discharging to the environment other than where in-perpetuity pumping and treatment provisions are made.
7. **Long-term + Climate Change** – Equivalent to Phase 3 with the addition of climate change effects on rainfall and evaporation.

Table 5.6 Summary of modelling scenarios

Reference	Phase	Dates	Description
1	Mining	2024-2026	During active mining of Coronation Pit
2	Closure	2045-2050	Following full rehabilitation
3	Long-term	~2230 +	Following overflow of the Pit Lake
4	Long-term + CC	~2230 +	Following overflow of the Pit Lake with climate change allowance

5.6.1 Key assumptions

– Dewatering from pits during mining operations is not represented in the water quality outcomes. These operations are undertaken with a degree of manual control and could be inaccurately reflected in a predictive model. It is assumed that these discharges are undertaken based on existing consent requirements and done in a manner that does not negatively impact water quality within the receiving environment. Alternatively, these waters are recycled within the mine water management system and reused on site.

- Rehabilitation of remaining impacted and waste rock surfaces is undertaken and completed promptly on completion of mining.
- TSS levels discharging to the receiving environment are managed using appropriately sized silt ponds and other sediment and erosion protection measures.
- During the mining phase all operational waters are managed on site and remain within a closed system. For example, water from the tailing's impoundments (including captured seepage) is recirculated and re-used for mine operations. Losses of these waters to the environment is through either uncaptured seepage to ground or evaporation.
- Seepage from WRSs is modelled based on an increase with time to a maximum predicted value. The potential for seepage concentrations to reduce from this maximum due to depletion of contaminant sources is not accounted for.
- All contaminants are assumed to be conservatively transported within both the groundwater and surface water environments on a mass balance basis.
- The Coal Creek dilution dam is assumed not operational.
- Water quality of the overflow from the Coronation Pit Lake through the Trimbells WRS remains consistent and does not deteriorate further before entering the Trimbell silt pond and ultimately Trimbells Gully.
- Seepage from the Coronation North Pit WRS is partitioned into saturated and unsaturated seepage as per Figure 5.6 in order to quantify seepage volumes to Coal Creek (via the pit crest) and seepage to the surrounding schist. Seepage to Coal Creek is generated through the non-saturated portion of the backfill located above the pit crest of 580 m RL and reports to Coal Creek within the WBM. The movement of seepage in the surrounding schist is modelled within the Groundwater Model as are estimates of contaminant flux movements into the receiving water bodies through this pathway.

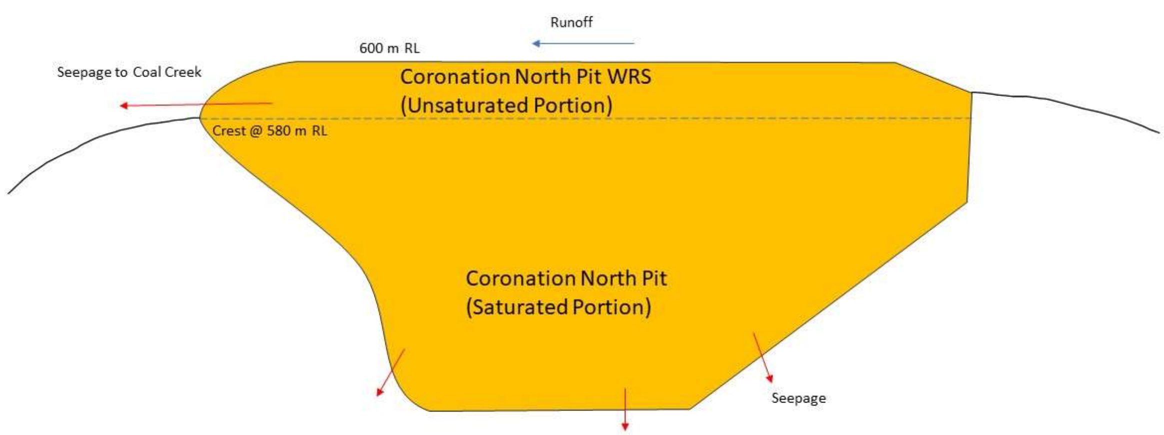

Figure 5.6 Schematic Coronation North WRS Long term Seepage conceptual summary

5.7 Inputs from Groundwater Modelling

Groundwater inflow and outflow into and from the Coronation Pit upon lake recharge is applied to the WBM at the rate as outlined in Figure 4.27.

Groundwater contaminant flux from the groundwater model is not explicitly replicated in the WBM, however the seepage fluxes from the WRS seepage are represented within the WBM utilising the relationships as described in MWM, 2023b and the assumed infiltration rates. The respective estimates of sulphate flux (from the groundwater modelling and the WBM are presented here for comparison). The contour plots from the groundwater modelling presented in Figure 4.18 to Figure 4.21 show the extent of the predicted plume is largely confined to approximately 1600 m north-west of the Trimbells WRS with the flux largely confined to the upper weathered schist layers. The estimated sulphate flux from the groundwater modelling is 183 kg/day (20 years post closure) and 696 kg/day (230 years post closure). The long-term mean discharge from the WBM is 894 kg/day, however that also includes flux from runoff. Given the water balance applies a ±30% distribution to seepage estimates it is considered that the ground water modelling shows good alignment with estimates from the WBM.

The majority of sulphate mass (and that of other elements of concern) draining to the Mare Burn catchment will likely be captured in the Trimbells and Maori Hen Silt Ponds where mixing with rehabilitated WRS runoff and natural runoff will occur. Post closure, the release of water from these silt ponds to the receiving environment will be controlled by the spillway and overflow during low flow periods is likely to be small and/or cease. This should enable the silt ponds to provide a 'buffering' effect to the receiving water in the Mare Burn. The surface water model therefore replicates this scenario and does not mirror the groundwater model which assumes constant discharge of seepage waters into the receiving water bodies.

Coronation Pit Lake water seeping to the north through the Trimbells WRS is represented by the pit lake water quality as presented in MWM, 2023a. It is assumed (for the purposes of this assessment) that the pit lake water quality does not deteriorate further as it flows through the WRS to Trimbells Gully. It is recommended that saturation of the Trimbells WRS toe (or an alternative method) together with further assessment will need to occur to ensure that this water does not become a significant source of contaminant flux to Trimbells Gully and/or to further quantify the effect on this water as it flows through the base of this WRS.

5.8 Results – Coronation Water Balance

The WBM has been applied to estimate filling rates for the Coronation Pit Lake (in the combined CO5 / CO6 Pit void) and estimate the long-term equilibrium level. Modelling projections (Figure 5.7) indicate that the overflow level could be reached after a period of approximately 200 years post closure, following which water from Coronation Pit Lake would spill into the Deepdell Catchment via the low point to the south. The mean overflow to the Deepdell Creek is estimated to be approximately 1.5 L/sec with water quality reflective of the pit lake water quality. The cumulative effect of this discharge within the Deepdell catchment is covered in GHD, 2023.

The key drivers in the Coronation water balance are direct rainfall and groundwater inflow with surface runoff a relatively minor contributor in comparison (Figure 5.8). An additional input to the pit lake is seepage from the Trimbells WRS which straddles the northern low point of the Coronation pit shell. A portion of rainfall falling onto this WRS provides a consistant source of seepage to the pit lake. Seepage and evaporation (not shown) provide losses of water from the pit lake throughout its development.

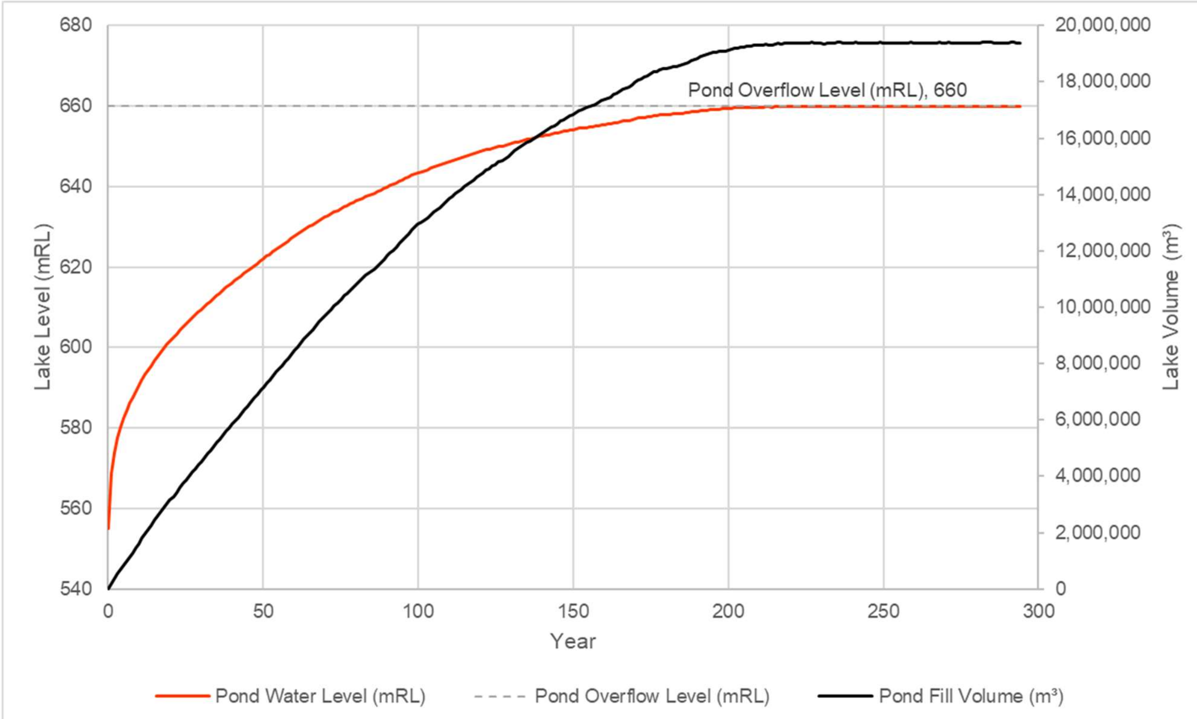

Figure 5.7 ***Coronation Pit Lake (CO6) filling assessment***

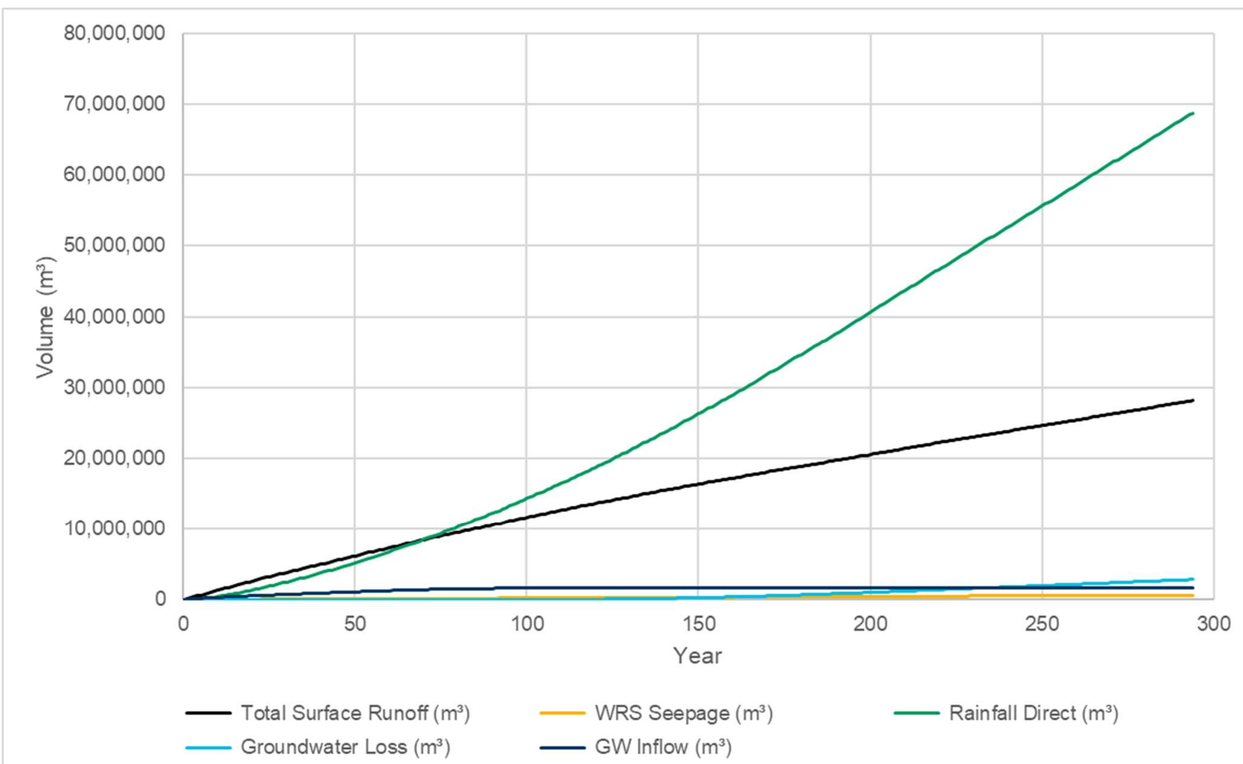

Figure 5.8 ***Coronation Pit Lake (CO6) cumulative water balance.***

Prior to pit lake reaching its overflow level, it is expected that pit lake water will flow through the Trimbells WRS to the north via the natural pit spill level (at 640 m RL) after a post closure period of approximately 90 years. The volume of water discharging through this flow path is predicted to increase as the lake level rises until the pit lake reaches its overflow level (660 m RL). The WBM model calculates groundwater loss through this pathway with the seepage volume rising from 0 L/sec to a maximum rate of 0.61 L/sec when the pit lake increases in elevation between 640 and 660 m RL. The conceptual understanding of the pit lake water balance including the spill level through the Trimbells WRS to the north (depicted as 9. Groundwater Outflow) and the overflow to Deepdell Creek to the south (depicted as 10. Downstream Receiving Environment) is depicted in Figure 5.9.

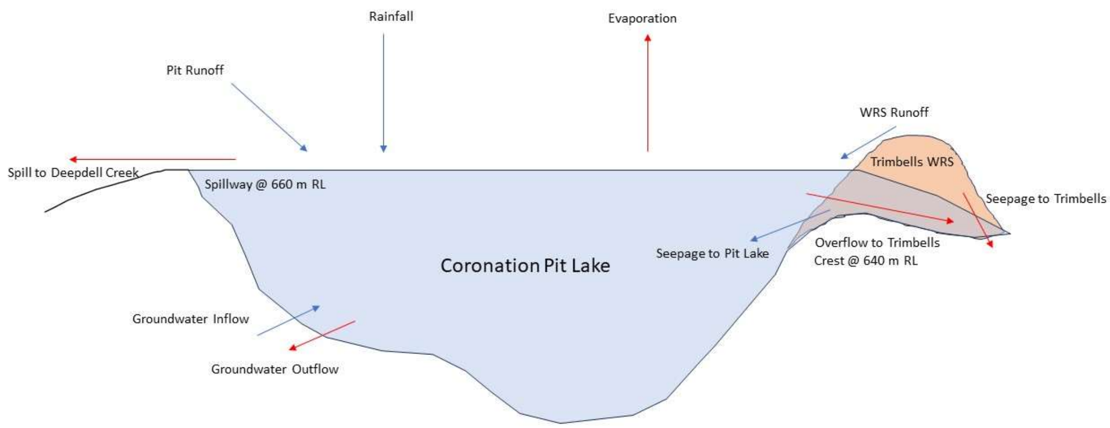

Figure 5.9 Coronation pit lake water balance – long term conceptual summary

5.9 Results – Water Quality

The water quality results are presented in terms of compliance with existing consented values (at MB02 and MB01). Cumulative effects on water quality within the Deepdell catchment are included in GHD, 2023 however the impact from CO6 is considered negligible based on low contaminant flux moving in this direction as depicted in Figure 4.18, Figure 4.20 and Figure 4.21. Sulphate, Nitrate N and Ammoniacal N predictions are presented as they are considered key elements in terms of the current and predicted future impacts. Other consented parameters (arsenic, cyanide, copper, iron, lead and zinc) are not considered key elements in terms of compliance and modelling suggests they are unlikely to exceed their consented concentrations at either MB01 or MB02 throughout both the duration of the operational period and post closure period based on the assumptions and considerations as outlined in this report. Modelled results for these elements are presented in Section 5.9.3.

5.9.1 Mare Burn Compliance Location MB02

Compliance location MB02 is located downstream of the confluence of Coal Creek and the Mare Burn as well as being the ultimate surface water receptor for the majority of surface and groundwater influenced by operations within both the Coronation Pit and the Coronation North Pit and their associated WRSs, pit lakes and rehabilitation efforts (Figure 5.5). The summarised WBM results for sulphate, Nitrate N and Ammoniacal N are presented in Figure 5.10, Figure 5.11 and Figure 5.12 respectively. The figures show the modelled probability exceedance for the key mining and closure periods.

The long term scenario shows a general increase in Nitrate-N and sulphate post mining. This increase is associated with an increase in WRS seepage volumes with time however low flow concentrations are balanced by capture and buffering of seepage within the Trimbells and Maori Hen Silt Ponds Conversely, the Ammoniacal-N concentrations are expected to decrease post mining as the WRS surfaces are rehabilitated. The mining, closure and long term scenarios show no exceedance at MB02 for sulphate and a low probability of exceedance (<1%) for nitrate in the long term scenario.

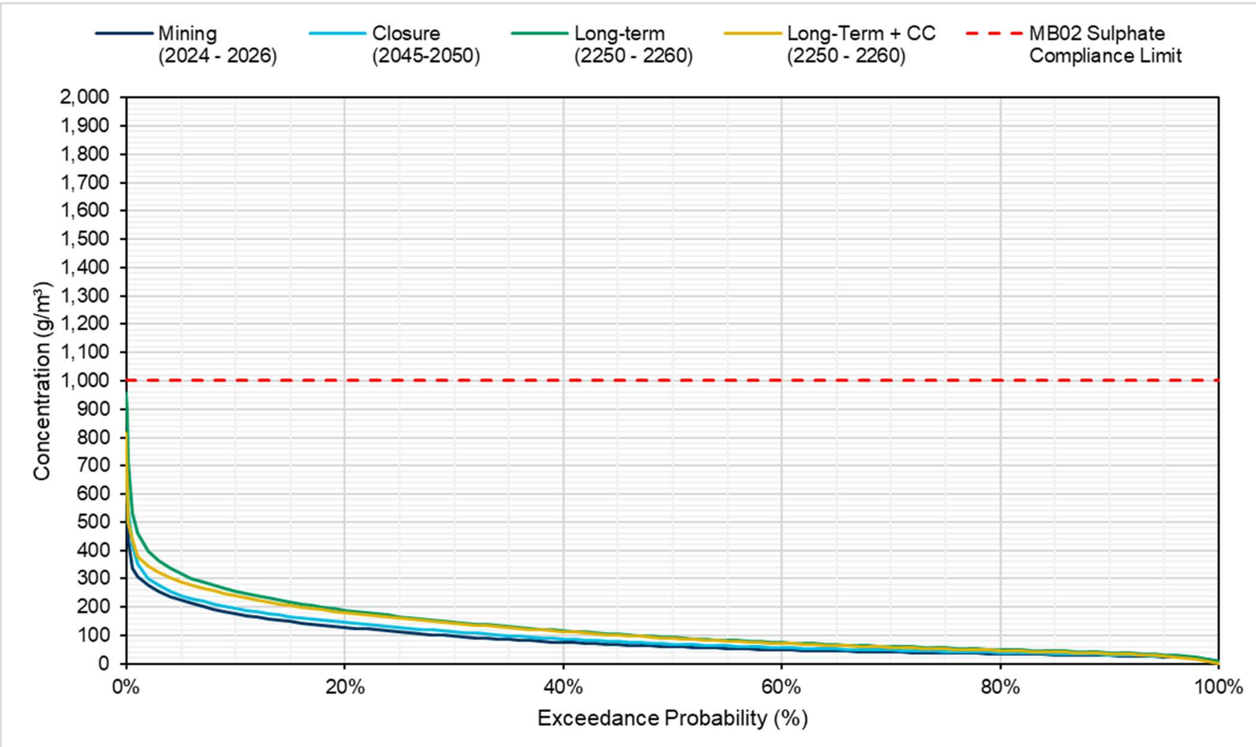

Figure 5.10 MB02 Sulphate – Modelled probability exceedance

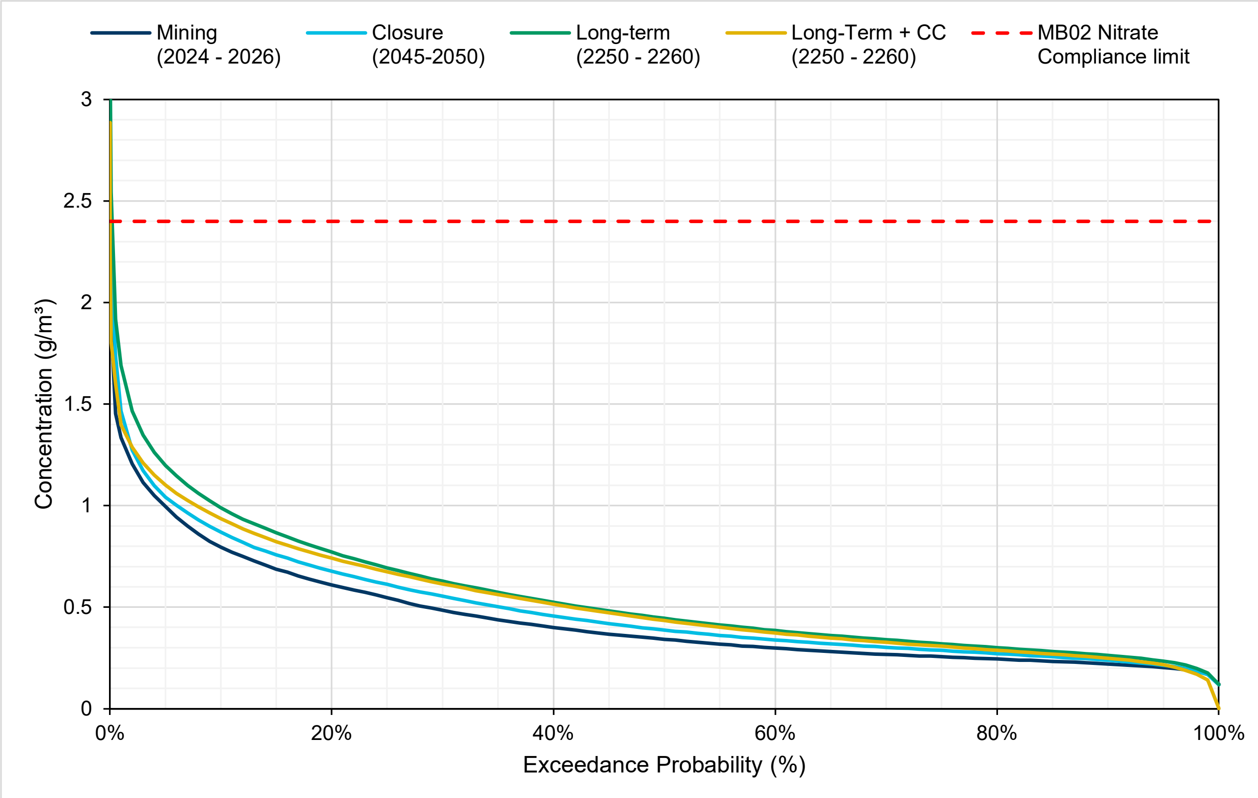

Figure 5.11 MB02 Nitrate N – Modelled probability exceedance

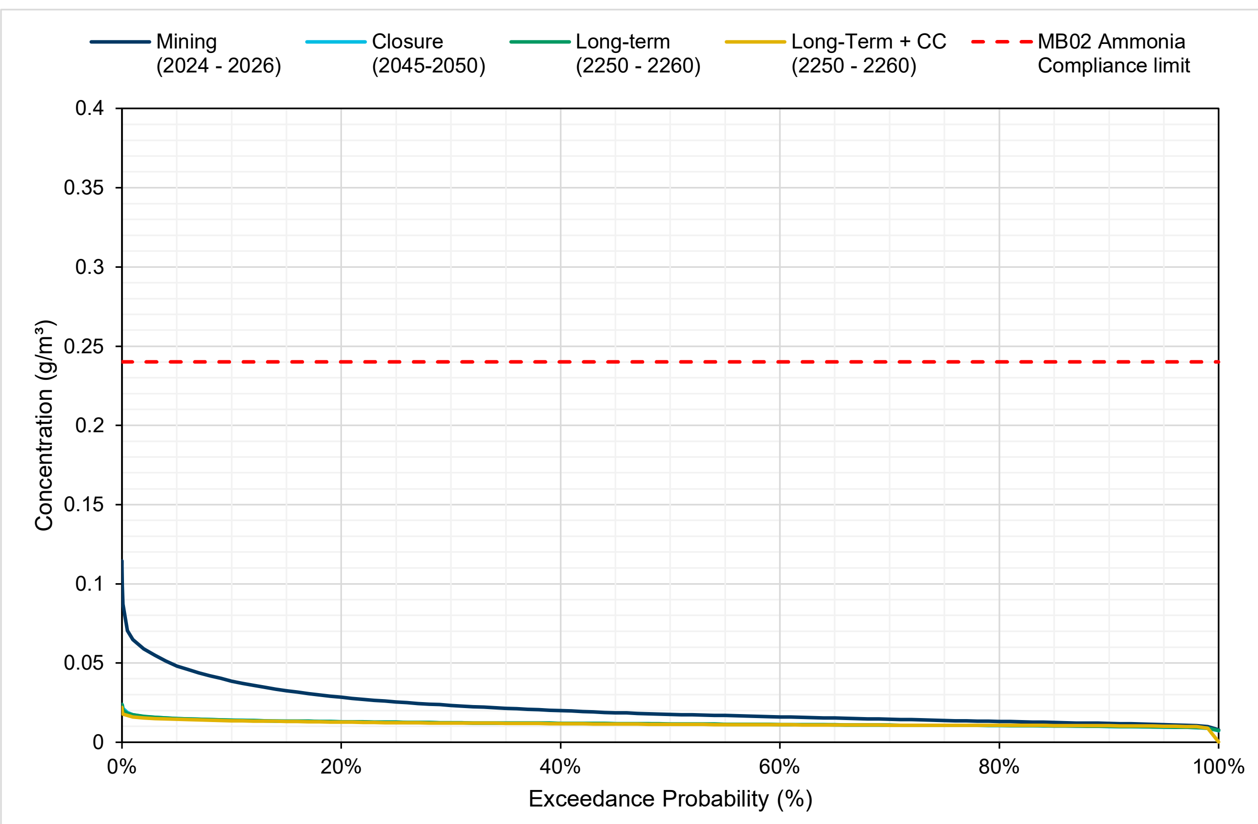

Figure 5.12 MB02 Ammoniacal N – Modelled probability exceedance

5.9.2 Mare Burn Compliance Location MB01

Compliance location MB01 is located within the Mare Burn downstream of the confluence of Trimbells Gully and the Maori Hen Creek and receives surface and groundwater influenced by operations within both the Coronation Pit and the Coronation North Pit and their associated WRSs, pit lakes and rehabilitation efforts (Figure 5.5). The summarised WBM results for sulphate, Nitrate N and Ammoniacal N are presented in Figure 5.13, Figure 5.14 and Figure 5.15 respectively. The figures show the modelled probability exceedance for the key mining and closure periods.

The long term scenario shows a general increase in Nitrate-N and sulphate post mining. This increase is associated with an increase in WRS seepage volumes with time, however low flow concentrations are balanced by capture and buffering of seepage within the Trimbells and Maori Hen Silt Ponds. Conversely, the Ammoniacal-N concentrations are expected to decrease post mining as the WRS surfaces are rehabilitated. The long term and scenario shows a low (<1%) probability of exceedance at MB01 for sulphate. There are no compliance limits set at this location for Nitrate N or Ammoniacal N.

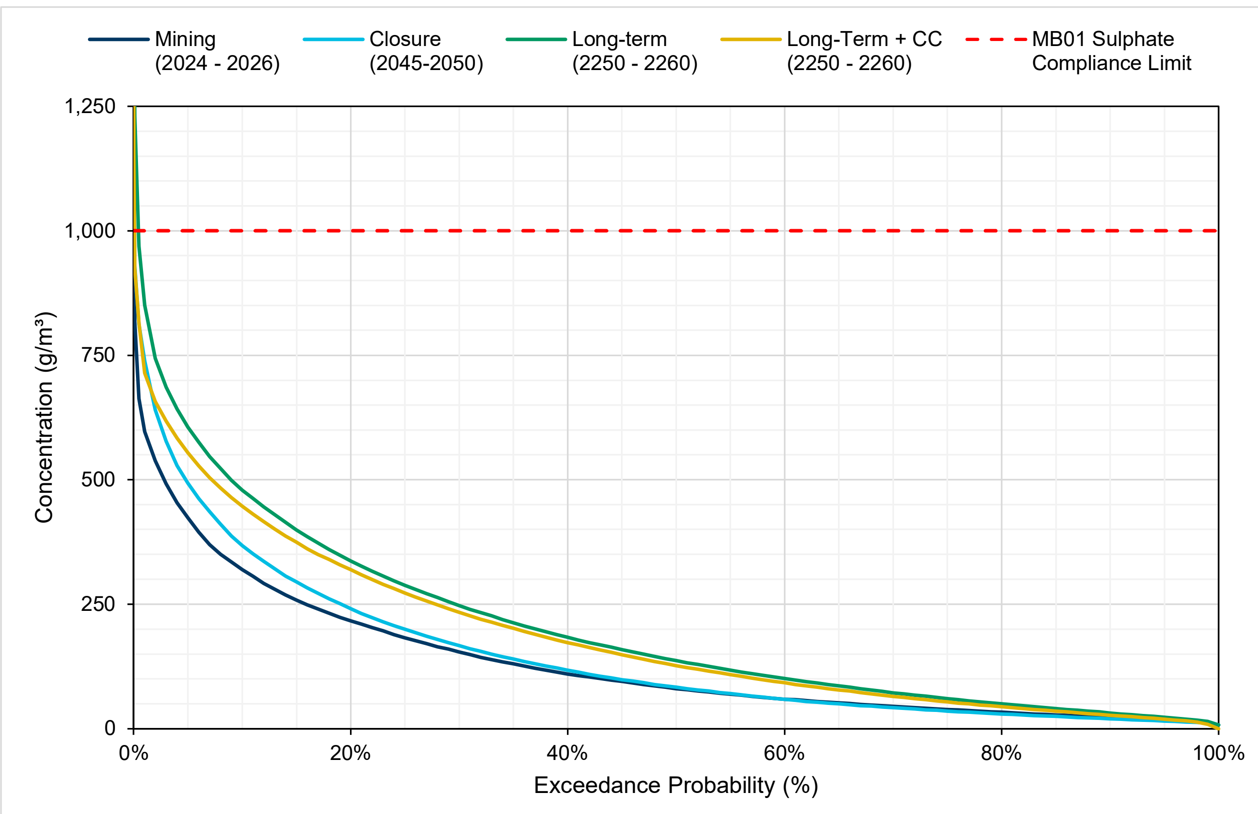

Figure 5.13 MB01 Sulphate – Modelled probability exceedance

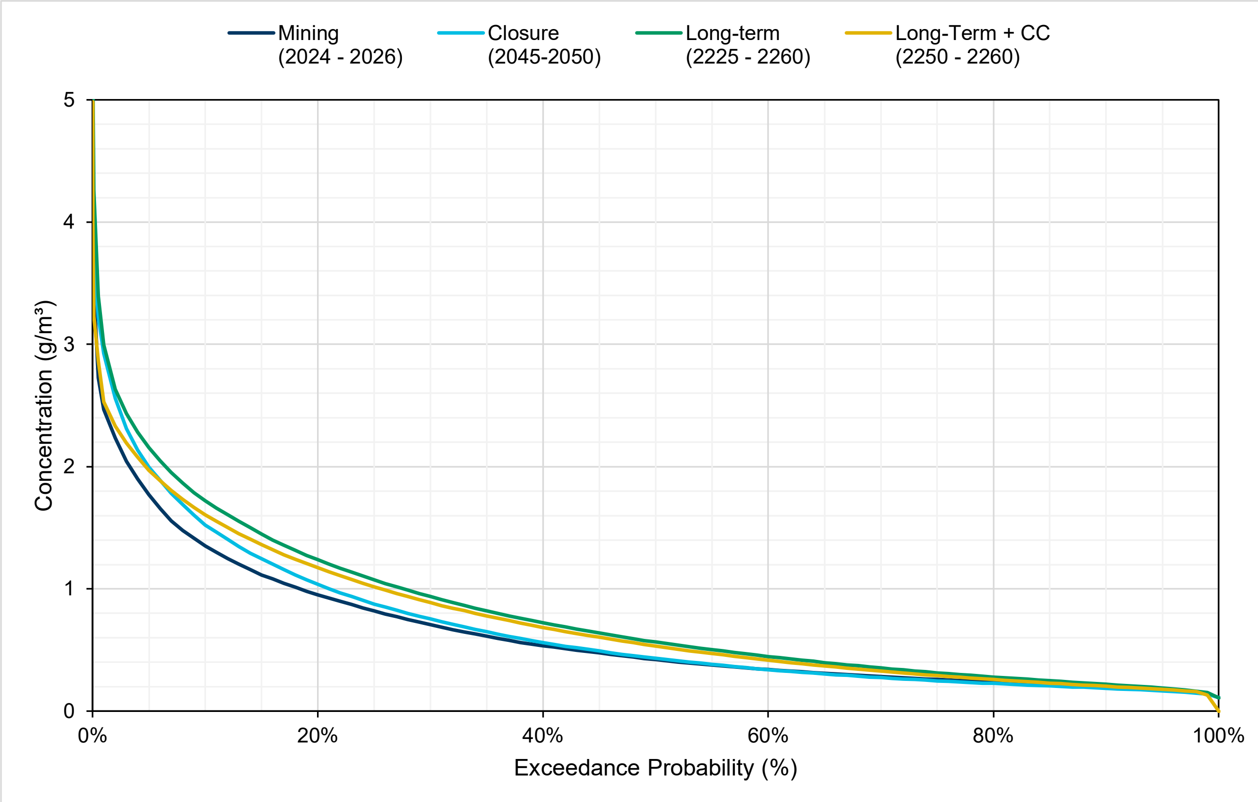

Figure 5.14 MB01 Nitrate N – Modelled probability exceedance

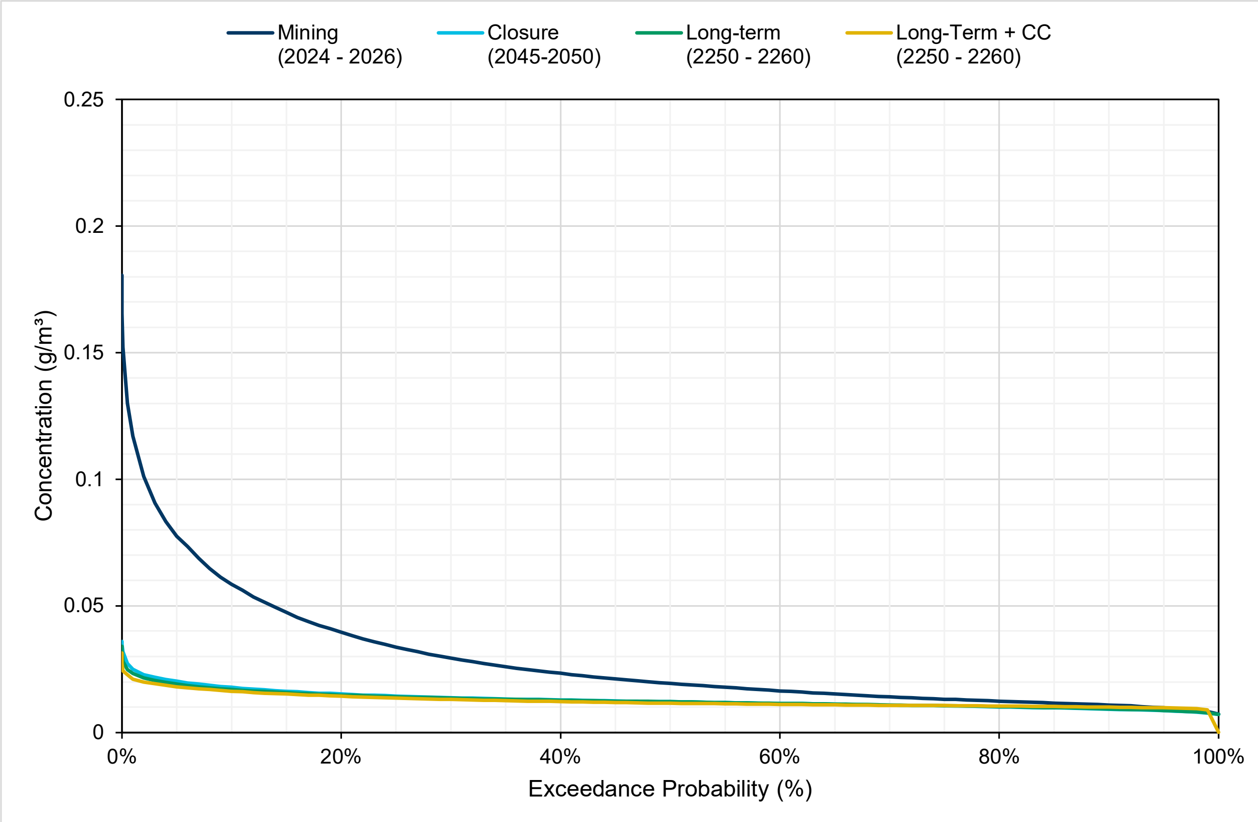

Figure 5.15 MB01 Ammoniacal N – Modelled probability exceedance

5.9.3 WBM Predictions

The modelled probability of exceedance and statistical predictions for the other compliance parameters are outlined in Table 5.7 for compliance locations MB01 and MB02. Modelled compliance limit exceedance is low (<1% probability) at MB01 and limited to sulphate in the long term scenario. Modelled compliance limit exceedance at MB02 is limited to <1% for Nitrate-N in the long term scenario. All modelled exceedances occur during prolonged low flow events where the proportion of WRS seepage in the total water volume is high.

Table 5.7 Probability of exceedance of compliance limits at MB01 and MB02

		Mining (2024-2026)	Closure (2045-2050)	Long-term (2250 - 2260)	Long-Term + CC (2250 - 2260)
MB01	Arsenic	0%	0%	0%	0%
	Cyanide	0%	0%	0%	0%
	Copper	0%	0%	0%	0%
	Iron	0%	0%	0%	0%
	Lead	0%	0%	0%	0%
	Zinc	0%	0%	0%	0%
	Sulphate	0%	<1%	<1%	<1%
MB02	Arsenic	0%	0%	0%	0%
	Cyanide	0%	0%	0%	0%
	Copper	0%	0%	0%	0%
	Iron	0%	0%	0%	0%
	Lead	0%	0%	0%	0%
	Zinc	0%	0%	0%	0%
	Sulphate	0%	0%	0%	0%
	Nitrate N	0%	<1%	<1%	<1%
	Ammoniacal N	0%	0%	0%	0%

*Grey highlighted cells indicate modelled exceedance

Table 5.8 and Table 5.9 show the selected statistics for the key contaminants of concern. In general, sulphate and Nitrate-N concentrations within the receiving environment (Trimbells Gully and Mare Burn catchment) are predicted to increase following closure relative to the mining phase due to the relative greater increase in sulphate concentration and mass from seepage water (from the WRS) with time. Ammoniacal N concentrations are predicted to reduce post closure relative to the mining phase due to the increased presence of rehabilitated surfaces (compared to non-rehabilitated surfaces which provide a higher relative contribution of before the closure period). Some minor increases in the concentrations of some trace elements are expected in the long term.

Table 5.8 Predicted MB01 Water Quality Statistics

Parameter (g/m^3)	Mining (2025 - 2027)	Closure (2045-2050)	Long-term (2250 - 2260)	Long-Term + CC (2250 - 2260)	Current (2020 - 2022)
Sulphate median	80	83	137	131	73
Sulphate 95 percentile	424	493	606	584	328
Nitrate N Median	0.4	0.4	0.6	0.5	0.4
Nitrate N 95 percentile	1.8	2.0	2.2	2.1	1.4
Ammoniacal N Median	0.019	0.012	0.012	0.012	0.032
Ammoniacal N 95 percentile	0.077	0.020	0.019	0.019	0.104
Arsenic Median	0.003	0.003	0.009	0.009	0.003
Arsenic 95 Percentile	0.004	0.004	0.031	0.030	0.004
Copper Median	0.001	0.001	0.001	0.001	0.001
Copper 95 Percentile	0.001	0.001	0.001	0.001	0.001
Iron Median	0.184	0.183	0.174	0.180	0.184
Iron 95 Percentile	0.235	0.236	0.231	0.205	0.235
Lead Median	0.0002	0.0002	0.0002	0.0002	0.0002
Lead 95 percentile	0.0002	0.0002	0.0002	0.0002	0.0002
Zinc Median	0.002	0.002	0.003	0.002	0.002
Zinc 95 Percentile	0.006	0.020	0.006	0.006	0.005

Table 5.9 Predicted MB02 Water Quality Statistics

Parameter (g/m^3)	Mining (2025 - 2027)	Closure (2045-2050)	Long-term (2250 - 2260)	Long-Term + CC (2250 - 2260)	Current (2020 - 2022)
Sulphate median	60	70	93	92	52
Sulphate 95 percentile	224	241	318	305	179
Nitrate Median	0.3	0.4	0.4	0.4	0.3
Nitrate 95 percentile	1.0	1.0	1.2	1.2	0.8
Ammonia Median	0.018	0.011	0.012	0.011	0.024
Ammonia 95 percentile	0.048	0.015	0.015	0.015	0.061
Arsenic Median	0.003	0.003	0.006	0.006	0.003
Arsenic 95 percentile	0.003	0.003	0.017	0.016	0.003
Copper Median	0.001	0.001	0.001	0.001	0.001
Copper 95 percentile	0.001	0.001	0.001	0.001	0.001
Iron Median	0.190	0.189	0.185	0.188	0.184
Iron 95 percentile	0.218	0.218	0.215	0.201	0.218
Lead Median	0.0002	0.0002	0.0002	0.0002	0.0002
Lead 95 percentile	0.0002	0.0002	0.0002	0.0002	0.0002
Zinc Median	0.002	0.002	0.002	0.002	0.002
Zinc 95 percentile	0.004	0.004	0.004	0.004	0.003

5.10 Surface Water Summary and Recommendations

The WBM indicates that the Coronation Pit Lake overflow level could be reached after a period of approximately 200 years post closure, following which water from Coronation Pit Lake would spill into the Deepdell Catchment via the low point to the south. The mean overflow to the Deepdell Creek is estimated to be approximately 1.5 L/sec. Prior to the pit lake reaching its overflow level, it is expected that pit lake water will flow through the Trimbells WRS to the north via the natural pit spill level (located at an elevation approximately 640 m RL) after a post closure period of approximately 90 years. The volume of water discharging through this flow path is predicted to increase to approximately 0.61 L/sec as the lake level rises until the pit lake reaches its overflow level (660 m RL). It is assumed that water draining through the Trimbells WRS from this flow path does not deteriorate further as it flows through the WRS to Trimbells Gully. This is a key assumption of the assessment carried out here and it is recommended that saturation of the Trimbells WRS toe (or alternative) together with further assessment will need to occur to ensure that this water does not become a significant source of contaminant flux to Trimbells Gully.

Water Balance Modelling has shown that in general, sulphate concentrations within the receiving environment (Trimbells Gully and Mare Burn catchment) are predicted to increase post closure relative to the mining phase due to the relative greater increase in sulphate and Nitrate N mass from seepage water (from the WRS) with time. Ammoniacal N concentrations are predicted to reduce post closure relative to the mining phase due to the increased presence of rehabilitated surfaces (compared to non-rehabilitated surfaces which provide a higher relative contribution of these parameters before the closure period). Some minor increases in the concentrations of some trace elements are expected in the long term.

In terms of compliance with the current water quality compliance conditions at MB01 and MB02, all parameters are expected to comply with the consented limits. The modelling shows a low probability of compliance exceedance for sulphate at MB01 and sulphate and nitrate at MB02 during prolonged low flow periods.

The consented Coal Creek Dilution Dam has not been included in the modelling presented as the requirement for dilution water to achieve in stream consented compliance limits is not necessarily required based on the modelling undertaken. However, the potential construction of the dam and the potential for flow augmentation (and dilution of impacted waters during low flows) provides contingency to address the modelled compliance exceedances. An adaptive management approach is considered appropriate.

6. Conclusions

The results of the groundwater modelling provide predictions of groundwater inflow and outflow into and out of the existing and proposed Coronation Pit and Coronation North Pit as well as groundwater seepage from Trimbells WRS, Coronation WRS, Coronation North Pit WRS (an in-pit fill), and Coronation North WRS with the majority of seepage expected to move laterally within the weathered schist and be captured in silt ponds and/or report to the receiving surface water catchment.

The groundwater contaminant plume is predicted to reach a maximum extent of approximately 1600 m to the north-west and to a much reduced extent in the south-east direction from these sources in approximately 400 years. The upper reaches of Mare Burn and Trimbells Gully are likely to receive higher concentrations of contaminants relative to the Deepdell catchment which is expected to have a relatively small impact from the Coronation area relative to the northern catchments. WRS seepage is expected to be captured in both Trimbells and Maori Hen Silt Ponds. This provides buffering of the seepage to the receiving environment and minimises the impact during low flow periods.

The WBM indicates that the Coronation Pit Lake overflow level could be reached after a period of approximately 200 years post closure, following which water from Coronation Pit Lake would spill into the Deepdell Catchment via the low point to the south. Prior to the pit lake reaching its overflow level, it is expected that pit lake water will flow through the Trimbells WRS to the north via the former low point in the Coronation Pit crest (now located beneath the Trimbells WRS) after a post closure period of approximately 90 years. The volume of water discharging through this flow path is predicted to increase as the lake level rises.

The WBM shows that in general, sulphate and Nitrate-N concentrations within the receiving environment (Trimbells Gully and Mare Burn catchment) are predicted to increase following closure relative to the mining phase due to the relative greater increase in sulphate concentration and mass from seepage water (from the WRS) with time. Ammoniacal N concentrations are predicted to reduce post closure relative to the mining phase due to the increased presence of rehabilitated surfaces (compared to non-rehabilitated surfaces which provide a higher relative contribution of before the closure period). Some minor increases in the concentrations of some trace elements are expected in the long term.

Water quality compliance within the Mare Burn at MB01 and MB02 is expected to be within the consented limits with modelling shows a low probability of compliance exceedance for sulphate at MB01 and sulphate and nitrate at MB02 during prolonged low flow periods. The consented Coal Creek Dilution Dam has not been included in the modelling presented as the requirement for dilution water to achieve in stream consented compliance limits it not necessarily required based on the modelling undertaken. However, the potential construction of the dam and the potential for flow augmentation (and dilution of impacted waters during low flows) provides contingency to address the modelled compliance exceedances. An adaptive management approach is considered appropriate.

In summary the development of the Stage 6 Coronation Project as outlined is considered to result in increasing sulphate and Nitrate-N concentrations within the upper tributaries of the Mare Burn relative to the current in stream water quality. However these concentrations are likely to remain below the currently consented limits. Post closure, improvements in Ammoniacal N concentrations (relative to the mining phases) are expected as a result of rehabilitation efforts within the catchments.

6.1 Recommendations

The long-term mass flux (of sulphate) and its impact on the Mare Burn (in terms of water quality) is expected to be increase (relative to the current state) as a result of the proposed expansion. Mitigation (seepage control) and monitoring is recommended, such that the potential impact to the surface water bodies are minimised. Groundwater monitoring (both water level and water quality) along the predicted path of the contaminant plumes is recommended to be undertaken utilising existing and new groundwater bores. This will provide calibration of the groundwater and surface water models and more certainty on the overall effects.

Pit lake water draining through the Trimbells WRS is assumed not to deteriorate further in quality as it flows through the WRS to Trimbells Gully. This is a key assumption of the assessment carried out here and it is recommended that saturation of the Trimbells WRS toe (or alternative) together with further assessment will need to occur to ensure that this water does not become a significant source of contaminant flux to Trimbells Gully.

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Appendices

Appendix A

Water Balance Model Build Report

A-1 Model Inputs

Key inputs into the Water Balance Model as outlined as provided.

– Stage volume area table for Coronation Stage 6
– AWBM Calibration
– Catchment runoff plans – current / closure

Table 7.1 Coronation Stage 6 volume area relationship

mRL	Fill Volume (m^3)	CO6 Cummulative Fill Vol. (m^3)	CO6 Cross-section Area (m^2)
552.5	3,747	3,747	1,500
555.0	5,062	8,809	2,000
557.5	14,317	23,125	5,700
560.0	23,101	46,227	9,200
562.5	29,915	76,142	12,000
565.0	38,666	114,808	15,500
567.5	49,521	164,330	19,800
570.0	64,095	228,424	25,600
572.5	86,120	314,545	34,400
575.0	103,763	418,307	41,500
577.5	123,179	541,486	49,300
580.0	137,236	678,722	54,900
582.5	171,712	850,434	68,700
585.0	185,903	1,036,337	74,400
587.5	239,363	1,275,700	95,700
590.0	278,274	1,553,974	111,300
592.5	310,746	1,864,720	124,300
595.0	328,640	2,193,360	131,500
597.5	346,064	2,539,424	138,400
600.0	363,232	2,902,656	145,300
602.5	401,695	3,304,351	160,700
605.0	416,554	3,720,905	166,600
607.5	433,415	4,154,321	173,400
610.0	466,016	4,620,337	186,400
612.5	484,213	5,104,550	193,700
615.0	499,442	5,603,991	199,800
617.5	535,747	6,139,738	214,300
620.0	548,853	6,688,591	219,500
622.5	563,262	7,251,852	225,300
625.0	578,610	7,830,462	231,400
627.5	595,055	8,425,517	238,000
630.0	613,444	9,038,961	245,400
632.5	670,737	9,709,698	268,300
635.0	696,564	10,406,262	278,600
637.5	712,906	11,119,168	285,200
640.0	733,986	11,853,154	293,600
642.5	766,572	12,619,726	306,600
645.0	797,253	13,416,979	318,900
647.5	859,659	14,276,638	343,900
650.0	906,290	15,182,928	362,500
652.5	963,829	16,146,757	385,500
655.0	1,055,229	17,201,986	422,100
657.5	1,092,140	18,294,126	436,900
660.0	1,132,105	19,426,231	452,800

A-2 Australian Water Balance Model (AWBM) Calibration

For flows from un-effected catchments an AWBM is calibrated to gauging undertaken on the North Branch Waikouaiti River at Golden Bar Road and Griffen Road gauges (NBGR) between 1991 and 1998. These two gauging sites are estimated to have reporting catchments of 250 ha and 640 ha respectively. Golden Point rainfall and evaporation records are applied in calibration of the AWBM. The calibrated runoff model predicts both surface runoff and total runoff including base flow recharge as shown in Figure 7.1, with these two outputs closely representing the statistical flows at the respective gauging sites. Given the specific runoff calculated at the lower gauging site – (NBGR) is lower and potentially unconservative, the total specific runoff model output is applied to the WBM for the purpose of pit lake filling projections.

Gauged flows above 10 L/s are estimates only, equivalent to a specific flow of 0.35 mm/d at Griffin Road and 0.135 mm/d at NBGR, corresponding to approximately the highest 15% of flows.

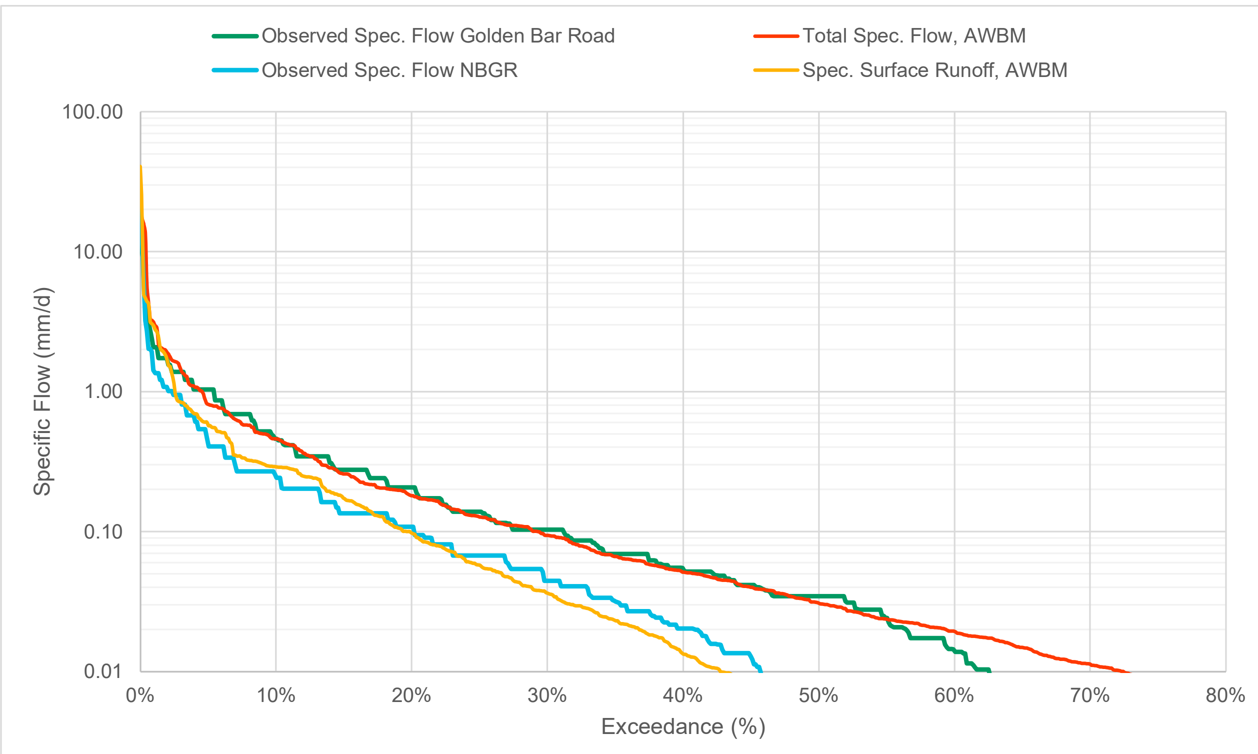
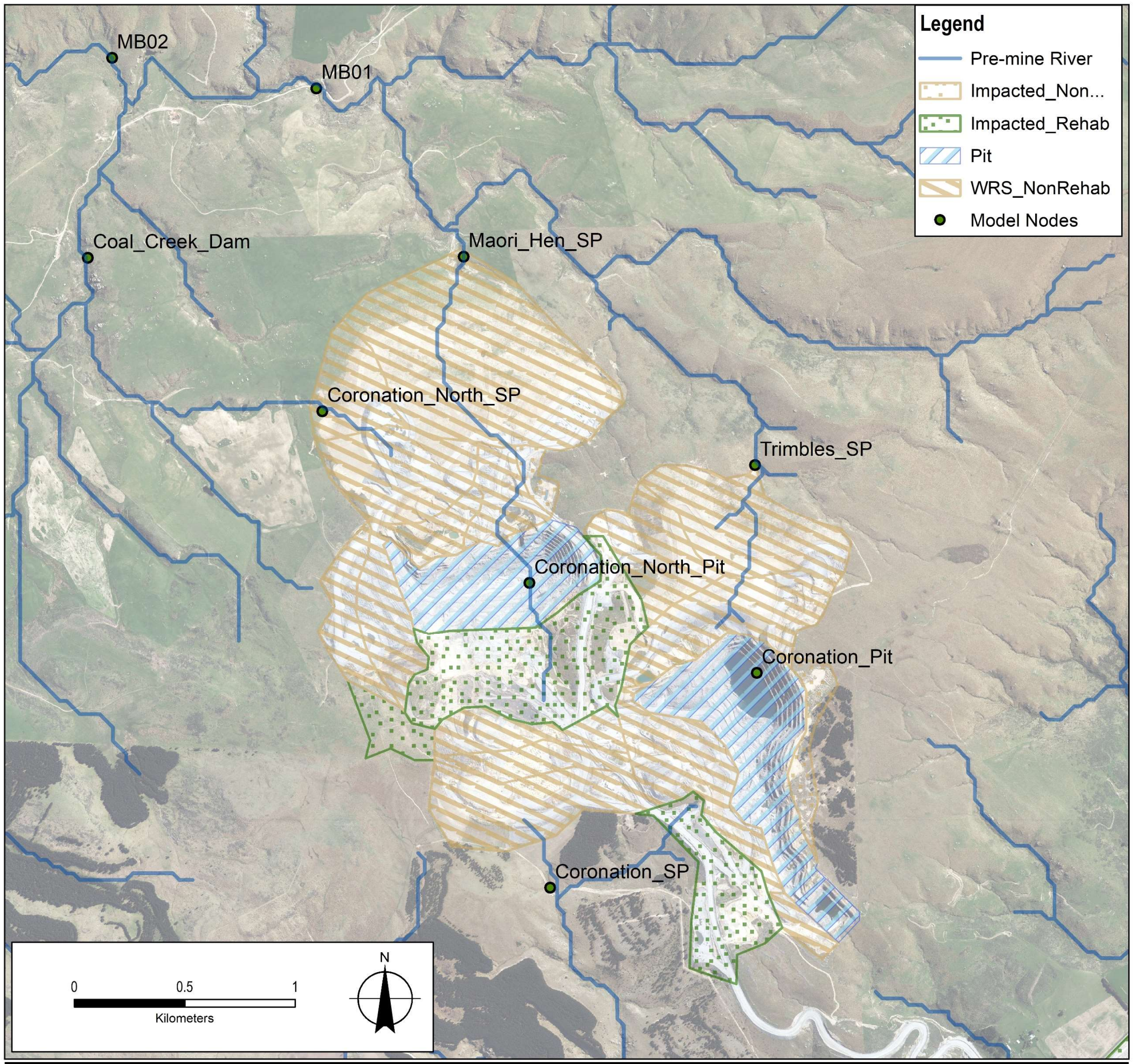


Figure 7.1 Calibration of the North Branch Waikouaiti River AWBM

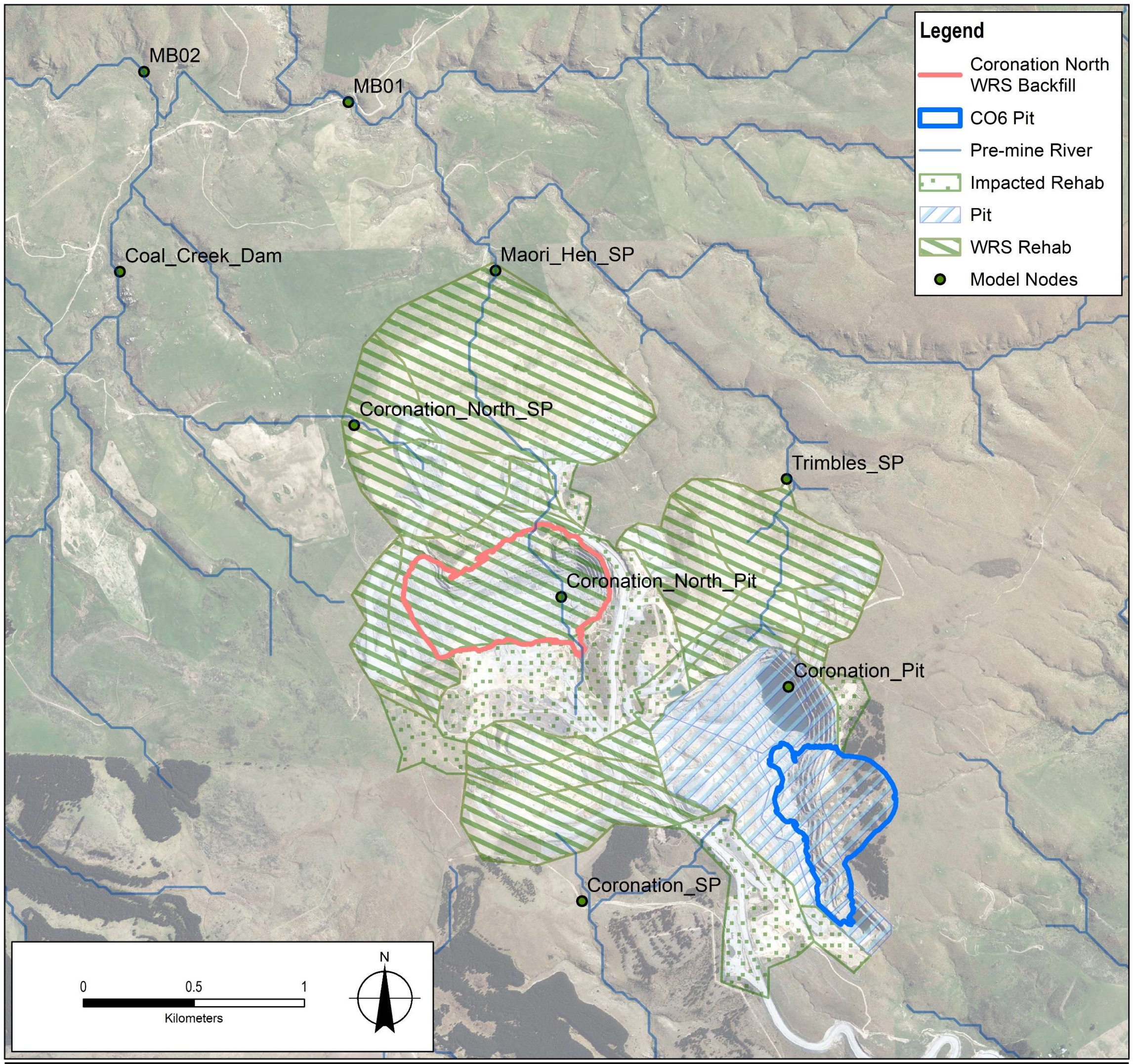
A-3 Catchment Maps for the Proposed Coronation Stage 6 Development



N:\NZ\Christchurch\Projects\51\12576793\GIS\Maps\Working\GIS figures\CO6 figures\CO6 figure3.mxd

Data source: Created by:eosborn

Figure 7.2 Coronation Waste Rock Stack Rehabilitated / Non-Rehabilitated Plan - Current



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Data source: Created by:eosborn

Figure 7.3 Coronation Waste Rock Stack Rehabilitated / Non-Rehabilitated Plan - Closure

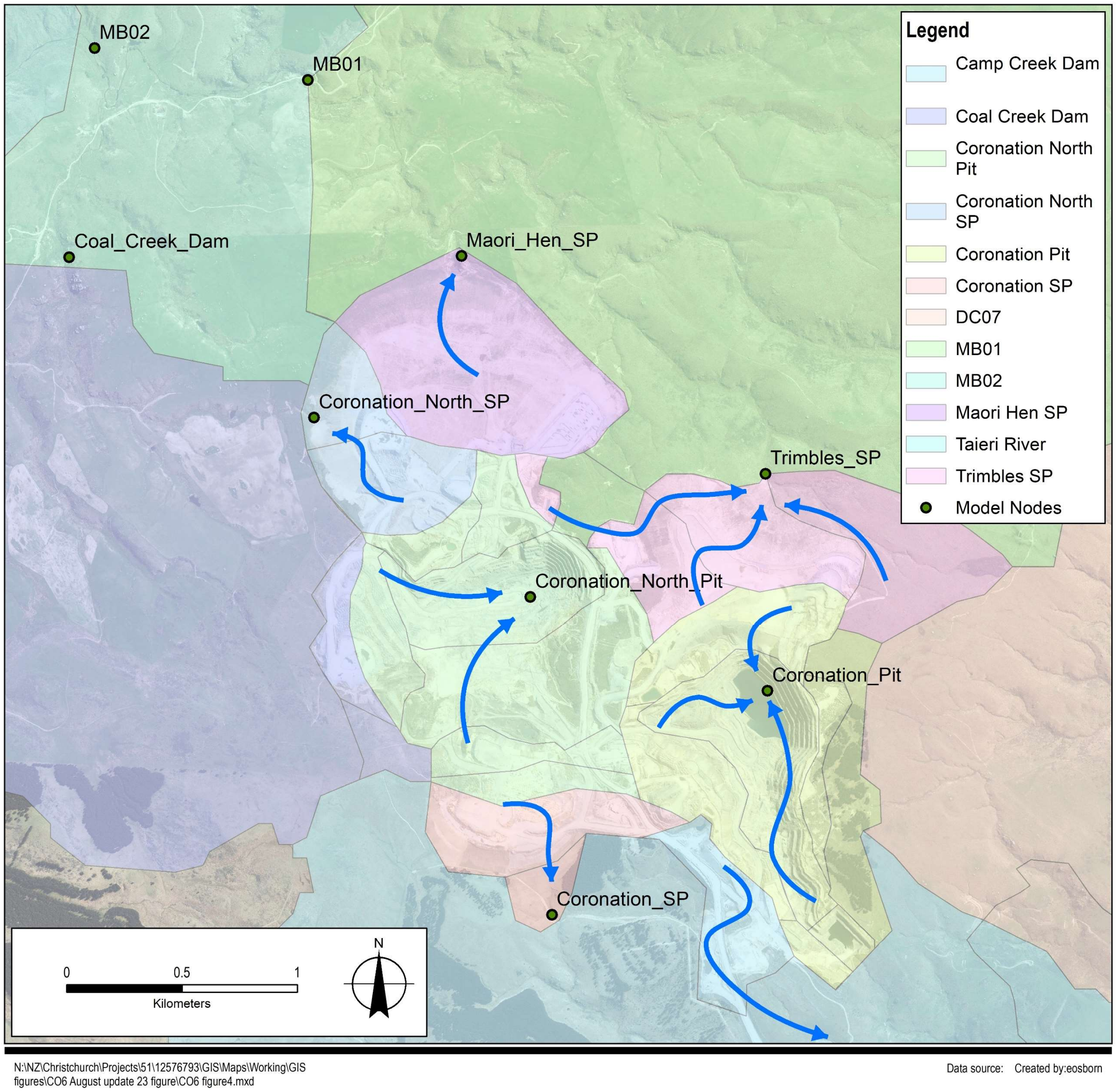
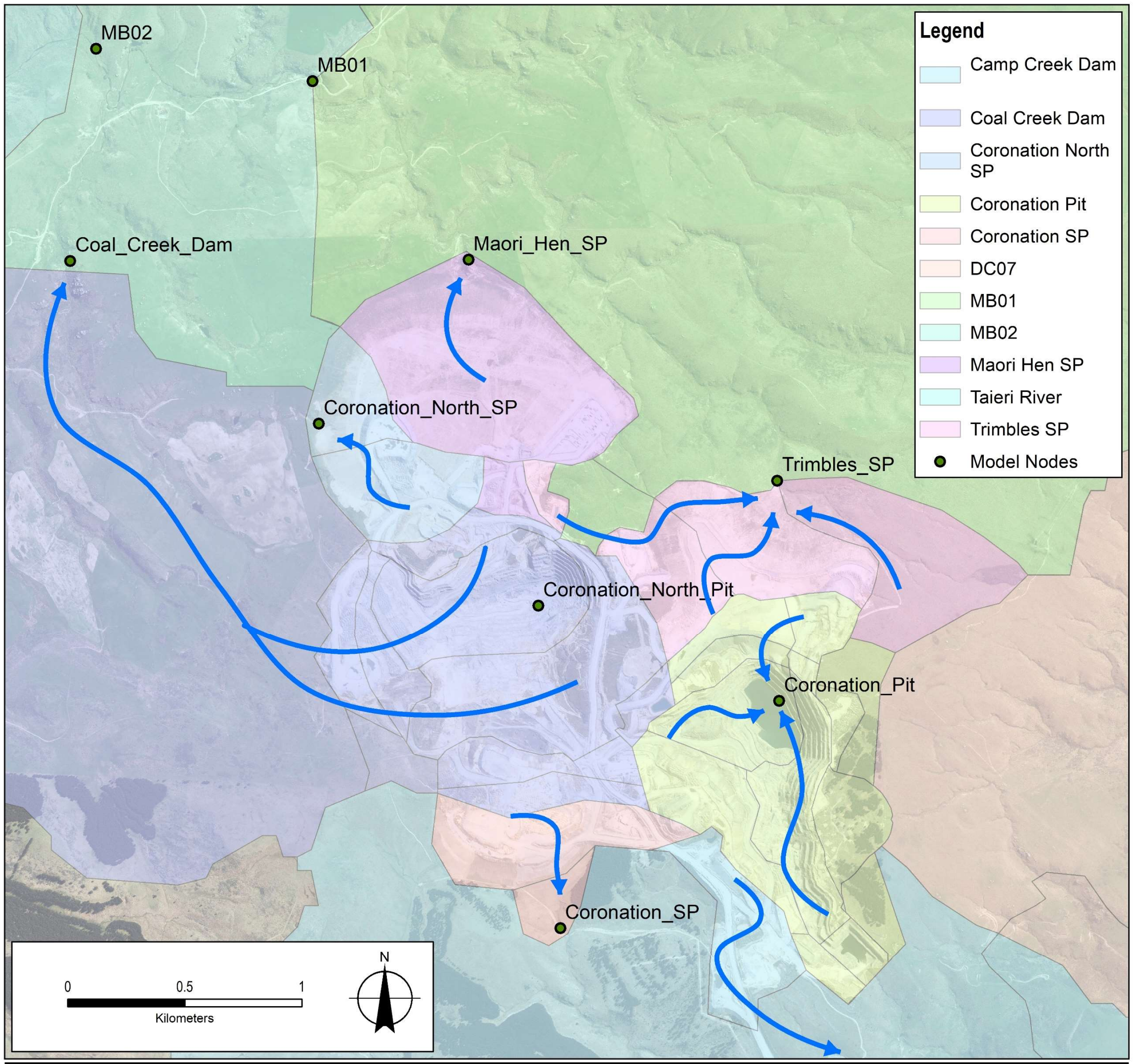


Figure 7.4 Coronation Catchment Map - Current



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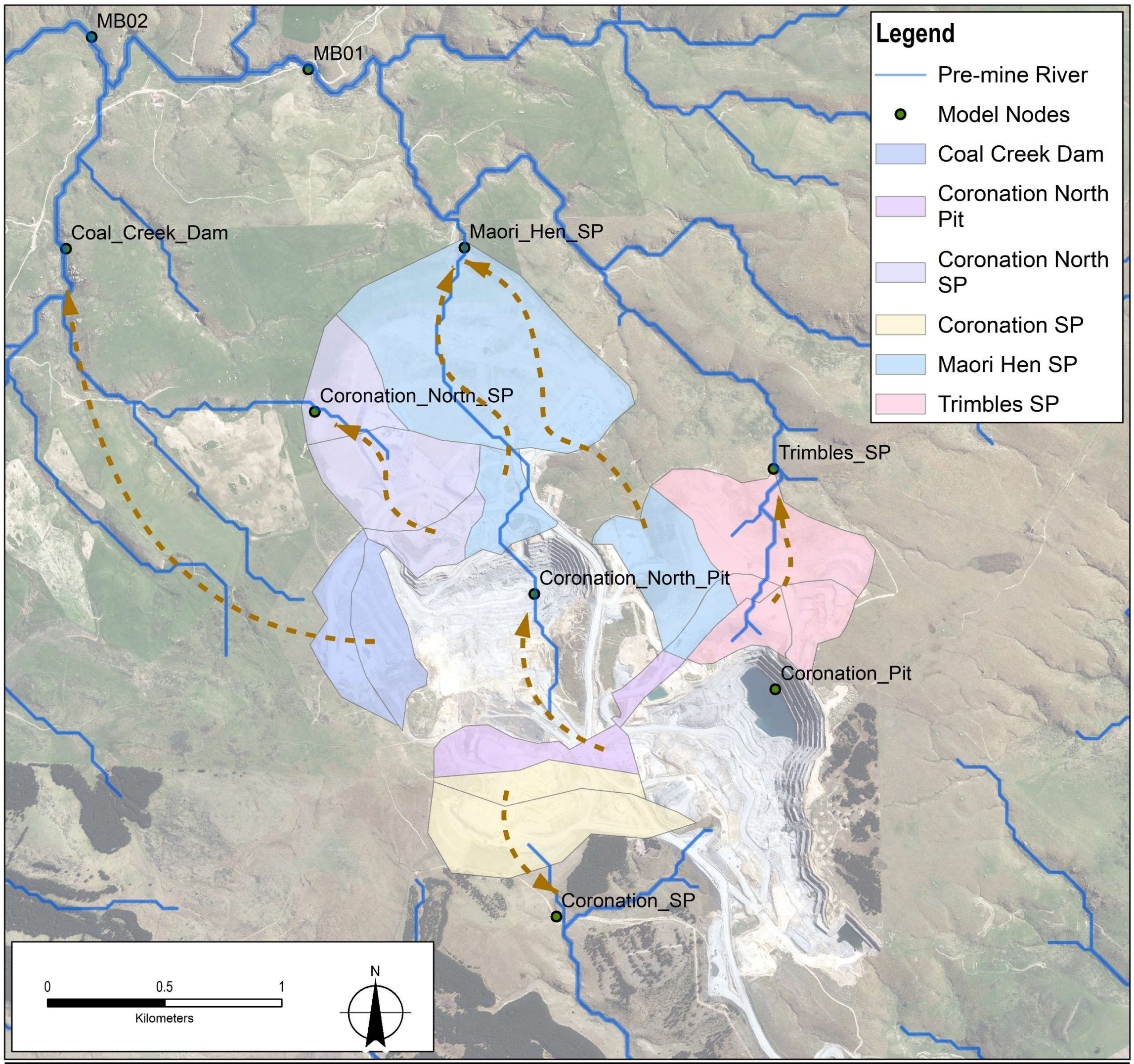
Data source: Created by:eosborn

Figure 7.5 Coronation Catchment Map - Closure



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Data source: Created by:eosborn

Figure 7.6 Coronation Seepage Catchment Map - Current

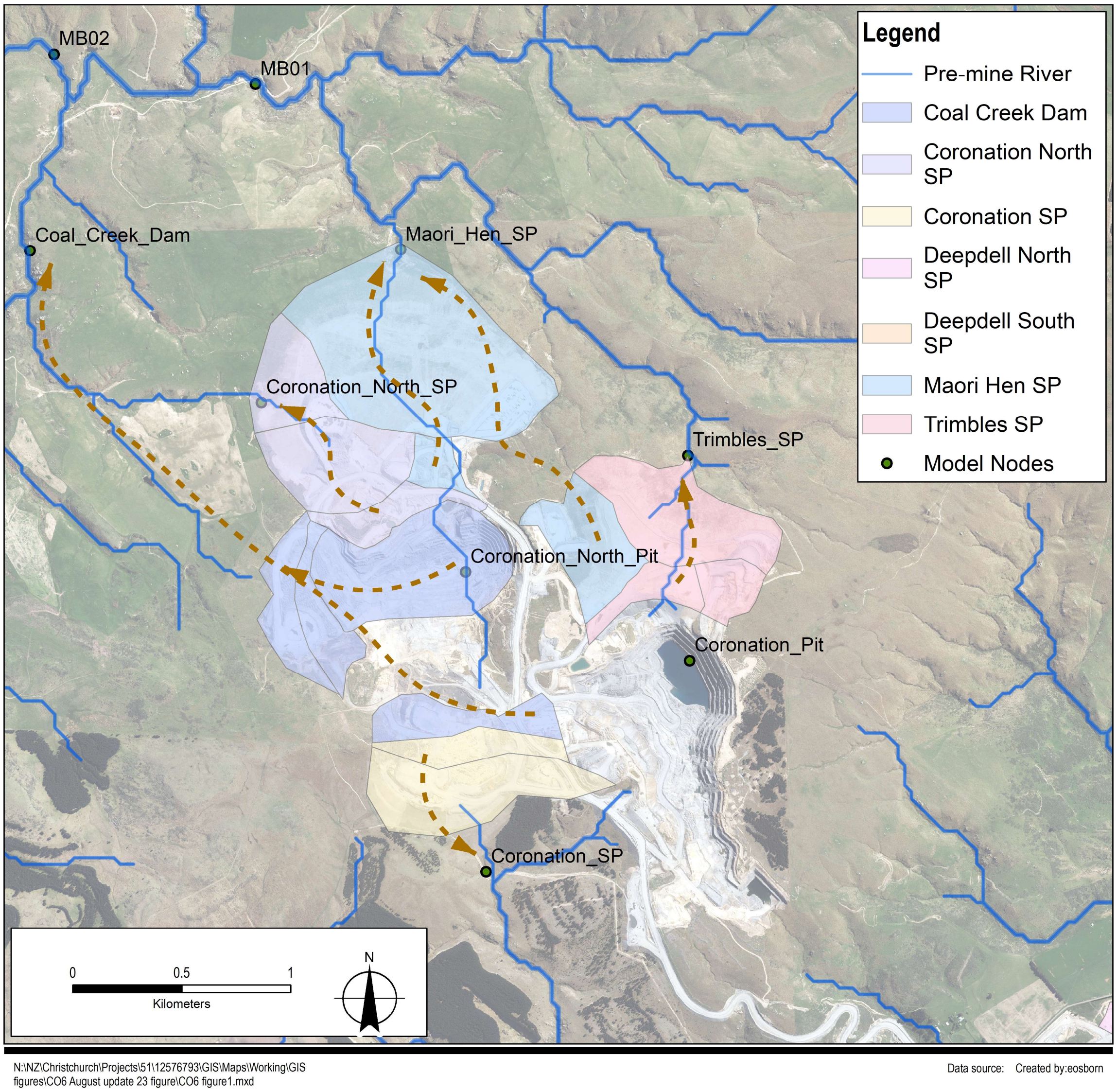

Figure 7.7 Coronation Seepage Catchment Map - Closure

Appendix B

Summary of Hydraulic Properties

Appendix B- Table A-1 Summary of Hydrogeological properties applied in previous groundwater models

Report	Property zone	Hydraulic conductivity (m/s)			Specific yield	Specific storage	Porosity (n)	
		Kx	Ky	Kz	Sy	Ss	Effective ne	Total pt
Kingett Mitchell Ltd 2002 Kingett Mitchell Ltd 2005a	Highly weathered schist	1.0E-06	1.0E-05	1.0E-06	-	-	0.02	-
	Moderately weathered schist	5.0E-08	1.0E-06	1.0E-07	-	-	0.02	-
	Slightly weathered schist	1.0E-08	5.0E-08	5.0E-08	-	-	0.004	-
	Unweathered schist	1.0E-09	1.0E-08	1.0E-8	-	-	0.004	-
	Footwall Fault	1.0E-08	1.0E-07	1.0E-09	-	-	-	-
	Hanging Wall Shear	1.0E-08	1.0E-07	1.0E-09	-	-	-	-
	Intra-shear schist	1.0E-09	1.0E-08	1.0E-08	-	-	-	-
	Embankment material	1.0E-07	5.0E-06	1.0E-07	-	-	-	-
	Waste rock	1.0E-06	1.0E-06	1.0E-06	0.25	-	-	-
	Flotation tailings	1.0E-07	1.0E-06	5.0E-08	-	-	-	-
	Mixed tailings	1.0E-07	1.0E-06	5.0E-08	-	-	-	-
	Concentrate tailings	1.0E-06	1.0E-06	1.0E-06	-	-	-	-
	HMSZ movement area	5.0E-06	5.0E-06	5.0E-06	-	-	-	-
Kingett Mitchell Ltd 2005b	Highly weathered schist	3.5E-07	1.0E-06	2.5E-07	0.01	0.00001	0.01	0.01
	Moderately weathered schist	1.0E-07	2.5E-07	6.0E-08	0.01	0.00001	0.01	0.01
	Slightly weathered schist	9.0E-09	9.0E-09	1.0E-09	0.004	0.00001	0.004	0.005
	Unweathered schist	1.0E-09	5.0E-09	5.0E-10	0.004	0.00001	0.004	0.005
	Shear zones of the HMSZ	8.0E-08	8.0E-08	1.0E-08	-	-	-	-
	Embankment material	1.0E-06	1.0E-06	1.0E-06	-	-	-	-
	Waste rock	1.0E-06	1.0E-06	1.0E-06	0.2	0.00001	0.15	0.2
	Fine tailings	1.0E-07	5.0E-07	1.0E-07	0.01	0.00001	0.01	0.02
	Coarse tailings	5.0E-06	5.0E-06	5.0E-06	0.01	0.00001	0.01	0.02
	Schist movement area	5.0E-06	5.0E-06	5.0E-06	-	-	-	-
	Highly weathered schist	3.5E-07	1.0E-06	2.5E-07	0.02	0.00001	0.02	0.03
	Moderately weathered schist	1.0E-07	2.5E-07	6.0E-08	0.02	0.00001	0.02	0.03

Golder Associates 2011a	Slightly weathered schist	5.0E-09	9.0E-09	1.0E-09	0.005	0.00001	0.005	0.006
	Unweathered schist	1.0E-09	5.0E-09	5.0E-10	0.005	0.00001	0.005	0.006
	Embankment Zone A	1.0E-07	1.0E-07	1.0E-07	-	-	-	-
	Embankment Zone B	5.0E-06	5.0E-06	5.0E-06	-	-	-	-
	Embankment Zone C and WRS	1.0E-06	1.0E-06	1.0E-06	0.2	0.00001	0.2	0.25
	Fine tailings	2.0E-07	2.0E-07	2.0E-07	0.38	0.00001	0.38	0.4
	Coarse tailings	5.0E-06	5.0E-06	5.0E-06	0.38	0.00001	0.38	0.4
Golder Associates 2011b	Highly weathered schist	3.5E-07	1.0E-06	2.5E-07	0.02	0.00001	0.01	0.02
	Moderately weathered schist	1.0E-07	2.5E-07	6.0E-08	0.02	0.00001	0.01	0.02
	Slightly weathered schist	9.0E-09	9.0E-09	1.0E-09	0.005	0.00001	0.004	0.005
	Unweathered schist	1.0E-09	5.0E-09	5.0E-10	0.005	0.00001	0.004	0.005
	Embankment material	1.0E-06	1.0E-06	1.0E-08	-	-	-	-
	Waste rock	1.0E-06	1.0E-06	1.0E-06	0.2	0.00001	0.15	0.2
	Fine tailings	1.0E-07	5.0E-07	1.0E-06	0.38	0.00001	0.35	0.4
	Coarse tailings	5.0E-06	5.0E-08	1.0E-07	0.38	0.00001	0.35	0.4
Golder Associates 2011d	Schist	1.0E-07	-	-	-	-	-	-
	Hanging Wall Shear	5.0E-08	-	-	-	-	-	-
	Backfill	3.0E-05	-	-	-	-	-	-
	Pit Liner	1.0E-07	-	-	-	-	-	-
CDM Smith 2016	Schist	5.8E-08	5.8E-08	5.8E-09	-	0.00001	-	0.01
	Waste rock	5.8E-07	5.8E-07	5.8E-07	-	0.00001	-	0.1
	Tailings	1.2E-08	1.2E-08	1.2E-09	-	0.00001	-	0.1
GHD, 2021	Schist	5.8E-08	1E-07	6.9E-09	-	0.00001	0.01	
	Schist (Frasers pit surfaces)	5.8E-07	5.8E-07	5.8E-08	-	0.00001	0.01	
	Waste rock	1E-06	1E-06	1E-06	-	0.00001	0.15	
	Tailings	2E-07	2E-07	2E-07	-	0.00001	0.35	
	FRUG	1E-05	1E-05	1E-05	-	0.00001	0.1	

Appendix C

Groundwater Levels

Hole ID	Easting	Northing	Elevation (m RL)	Depth to water (m)	Groundwater elevation (m RL)
DDW6025	1394141	4977983	635.15	11.84	623.31
RCD5678	1396030	4977728	696.011	11.04	684.97
RCD5682	1396040	4977585	699.768	14.22	685.55
RCD5683	1395925	4977690	688.012	19.1	668.91
RCD5684	1395908	4977707	685.531	16.67	668.86
RCD5842	1394287	4977996	652.478	14.74	637.74
RCD5914	1394567	4978203	610.908	11.57	599.34
RCD5945	1394300	4977930	666.505	17.91	648.60
RCD5961	1394956	4978398	615.767	17.37	598.40
RCD5962	1395018	4978338	625.25	30.03	595.22
RCD6039	1395254	4978120	649.817	10.44	639.38
RCD6040	1395228	4978411	637.692	19.48	618.21
RCD6068	1395324	4978051	661.015	6.06	654.96
RCH5007	1395731	4977837	665.884	19.1	646.78
RCH5014	1395498	4977884	670.847	9.67	661.18
RCH5022	1395647	4977752	677.942	26.12	651.82
RCH5220	1395642	4977681	683.718	34.75	648.97
RCH5234	1393152	4978466	538.747	5.56	533.19
RCH5235	1393114	4978505	534.795	5.61	529.19
RCH5236	1393217	4978545	529.518	1.92	527.60
RCH5252	1393260	4978366	540.416	10.37	530.05
RCH5314	1393284	4978451	533	3.8	529.20
RCH5316	1393559	4978462	531.29	0.43	530.86
RCH5319	1392989	4978869	501.95	4.45	497.50
RCH5320	1392851	4978866	518.59	13.24	505.35
RCH5328	1393211	4978665	520.34	4.47	515.87
RCH5587	1395394	4977709	679.421	28.93	650.49
RCH5596	1395606	4977715	681.591	32.36	649.23
RCH5739	1397022	4976585	585.066	19.51	565.56
RCH5743	1395143	4977808	670.64	16.42	654.22
RCH5747	1394431	4977927	689.789	35.39	654.40

Hole ID	Easting	Northing	Elevation (m RL)	Depth to water (m)	Groundwater elevation (m RL)
RCH5748	1396380	4976640	693.114	64.13	628.98
RCH5751	1396736	4976579	631.344	33.52	597.82
RCH5752	1396875	4976583	607.501	10.18	597.32
RCH5755	1394792	4977726	665.998	13.27	652.73
RCH5756	1395064	4977975	645.718	10.94	634.78
RCH5757	1394871	4978049	601.436	13.96	587.48
RCH5759	1394701	4978223	599.501	8.66	590.84
RCH5775	1394645	4977855	667.12	19.69	647.43
RCH5776	1394285	4978066	646.904	11.32	635.58
RCH5826	1394777	4978004	623.017	21.49	601.53
RCH5827	1394741	4978111	619.577	20.69	598.89
RCH5828	1394681	4978046	633.42	14.19	619.23
RCH5829	1394601	4977973	656.944	34.71	622.23
RCH5831	1394862	4977791	643.557	11.25	632.31
RCH5833	1394889	4977971	599.513	4.92	594.59
RCH5844	1394352	4977992	659.39	16.86	642.53
RCH5866	1395003	4977953	632.092	16.36	615.73
RCH5867	1395037	4977833	646.97	17.94	629.03
RCH5868	1395074	4977735	654.755	16.9	637.86
RCH5869	1395181	4977704	671.847	19.29	652.56
RCH5870	1395319	4977848	676.163	18.52	657.64
RCH5871	1395250	4977775	677.865	16.04	661.83
RCH5872	1395212	4977880	674.313	16.71	657.60
RCH5873	1394959	4978047	627.011	18.49	608.52
RCH5874	1395106	4977919	655.541	20.33	635.21
RCH5875	1395180	4977987	655.644	9.48	646.16
RCH5903	1394496	4978141	632.958	24.98	607.98
RCH5916	1394487	4978286	611.904	28.45	583.45
RCH5927	1394417	4978212	625.017	18.75	606.27
RCH5936	1394107	4978029	625.97	14.33	611.64
RCH5939	1394141	4977983	635.15	11.85	623.30

Hole ID	Easting	Northing	Elevation (m RL)	Depth to water (m)	Groundwater elevation (m RL)
RCH5940	1394186	4978030	634.803	5.55	629.25
RCH5946	1394249	4977992	648.189	16.75	631.44
RCH5950	1394780	4978072	615.765	25.44	590.33
RCH5951	1394745	4978043	626.602	25.03	601.57
RCH5952	1394718	4978004	634.912	26.89	608.02
RCH5953	1394832	4977967	613.902	18.54	595.36
RCH5954	1394788	4977935	624.504	9.29	615.21
RCH5955	1394745	4977969	628.957	11.27	617.69
RCH5959	1394670	4978150	617.735	17.23	600.51
RCH5963	1394882	4978472	587.934	10.66	577.27
RCH5967	1394500	4978067	645.994	27.41	618.58
RCH5969	1394318	4977882	687.271	38.58	648.69
RCH5970	1394393	4977892	692.964	39.7	653.26
RCH5971	1394706	4978086	626.464	25.16	601.30
RCH5973	1394849	4978009	594.805	1.22	593.59
RCH5974	1394808	4978107	600.807	10.64	590.17
RCH5975	1394813	4978045	600.004	10	590.00
RCH6011	1394433	4978034	654.534	11.65	642.88
RCH6020	1394040	4978017	619.685	12.06	607.63
RCH6022	1394105	4978090	620.334	6.87	613.46
RCH6027	1394283	4978351	598.491	28.36	570.13
RCH6029	1394563	4978354	596.969	10.7	586.27
RCH6030	1394627	4978425	587.077	20.56	566.52
RCH6032	1394112	4977877	642.193	14.74	627.45
RCH6034	1394078	4977915	632.597	13.88	618.72
RCH6036	1395167	4978201	646.278	14.87	631.41
RCH6038	1394911	4978308	616.817	21.72	595.10
RCH6041	1395300	4978347	639.535	18.03	621.51
RCH6042	1395388	4978254	633.878	3.41	630.47
RCH6052	1394004	4977993	616.109	8.5	607.61
RCH6053	1394007	4977985	616.489	8.7	607.79

Hole ID	Easting	Northing	Elevation (m RL)	Depth to water (m)	Groundwater elevation (m RL)
RCH6055	1393931	4977992	609.458	5.99	603.47
RCH6059	1394010	4977912	623.693	4.49	619.20
RCH6060	1393999	4978339	578.526	19.5	559.03
RCH6064	1394870	4978060	601.69	14.48	587.21
RCH6066	1394893	4978119	602.967	15.19	587.78
RCH6070	1393929	4978554	549.005	6.26	542.75
RCH6071	1394054	4978691	544.616	3.77	540.85
RCH6074	1394404	4978776	554.546	9.64	544.91
RCH6075	1394559	4978646	571.024	14.94	556.08
RCH6076	1393855	4978188	585.824	8.4	577.42
RCH6077	1393774	4978398	554.342	10.43	543.91
RCH6078	1393705	4978614	541.415	6.45	534.97
RCH6079	1393490	4978679	530	5.09	524.91
RCH6080	1393627	4978824	528.71	9.31	519.40
RCH6081	1393744	4978948	520.179	1.56	518.62
RCH6082	1393807	4978737	533.992	3.04	530.95
RCH6087	1395772	4977823	669.688	22.65	647.04
RCH6088	1395962	4977729	681.045	12.42	668.63
RCH6089	1395962	4977802	676.034	12.92	663.11
RCH6092	1395867	4977847	655	6.11	648.89
RCH6093	1395747	4977788	670.042	12.76	657.28
RCH6094	1395806	4977867	660.45	13.32	647.13
RCH6095	1395876	4977796	669.522	20.21	649.31

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