Appendix E

Water Balance Model Description

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E-1 Introduction

This appendix describes the Water Balance Model (WBM) used to model surface water flows and contaminant mass transport for the Macraes Phase 4 Fast Track Approvals project (Project). An overview of the project description is provided in Section 2 of the “Macraes Phase 4 FTA – Surface and Groundwater Assessment” of which this is included as Appendix E.

GHD have previously developed a site wide WBM for OGNZL operations at the Macraes Gold Mine in 2019. This WBM incorporated the Deepdell North Stage III Project and assessed the potential impact on downstream water quality associated with the project. This WBM was since refined and updated to incorporate subsequent site changes, additional monitoring data and to assess surface water quality impacts of specific projects at Macraes with the results of the latter documented in GHD’s Macraes Phase IV resource management act consent application reporting (GHD 2024a,b). Current work presented in this Appendix incorporates earlier model development with several key improvements and updates:

– Revised source terms for surface water quality, WRS seepage and pit lake water quality projections,
– Updated modelling of groundwater to surface water connections, and
– Additional surface water quality mitigation measures.

E-1.1 Purpose of this Appendix

The purpose of the appendix is to describe the WBM and its inputs which form the basis of the surface water quality predictions and assessment for the Macraes Phase 4 Fast Track Approvals project.

E-1.2 Scope and Limitations

This document is an appendix to GHD Report – Macraes Phase 4 FTA, Surface and Groundwater Assessment. Scope and Limitations apply as outlined in that document.

E-2 Water Balance Model

E-2.1 Model Schematisation and Overview

The WBM is a probabilistic model developed in GoldSim to simulate water flows, storage and contaminant mass transport across the Macraes Operation during active mining, closure, and post-closure periods. The model provides an integrated representation of catchment runoff, groundwater interaction, mine water seepage, water storages, and downstream receiving environments, allowing the cumulative effects of existing and proposed mine developments to be assessed.

The WBM is configured as a stochastic Monte Carlo simulation. Key climatic and hydrological inputs, including rainfall, evaporation, runoff generation, groundwater interaction, and selected water quality source terms, are represented using probability distributions derived from available monitoring data and supporting assessments. Multiple iterations of the model are undertaken to simulate the range of potential future conditions and quantify the uncertainty associated with model predictions. Climate inputs are based on historical monitoring data, with climate change adjustments applied for long-term sensitivity assessment.

The model represents the site as a network of interconnected nodes linked by surface water, seepage, and operational water transfer pathways. Surface water catchments are delineated based on topography and drainage infrastructure, with runoff generated using a calibrated runoff model and rational method calculations. WRS seepage flows are represented separately based on area assignments determined from WRS topography and derived percolation rates. TSFs are represented as water storage facilities that generate seepage based on measured values and forward projections. Pits, pit lakes, ponds, and other water storages are represented as dynamic reservoirs based on volume-area-height relationships within the model. Water levels and storage volumes fluctuate in response to inflows and outflows, with stage-volume relationships used to define changes in storage capacity and surface area. Inflows may include runoff, direct rainfall, WRS seepage, and operational transfers, while outflows can include evaporation, seepage losses, pumped withdrawals, and controlled discharges. Further, groundwater interactions represented as pit inflows and outflows are derived from groundwater modelling and applied in the WBM. This approach enables assessment of both operational water management and long-term pit lake development following closure.

To represent the interaction of these features and the modelled nodes, the model applies a daily timestep for the duration of the model run. Intermediate timesteps are added as required to represent key changes in the water management (i.e. a pond reaching overflow). Mine features and water management milestones are represented based on actual and projected dates defined within the model. Model outputs include flow rates, storage volumes and contaminant concentrations at the modelled nodes.

An overview of the WBM is shown in Figure E-2.1 indicating key nodes represented in the model and direction of surface water flows. Not shown in the figure is the surface water catchments areas and ground water / WRS and TSF seepage flows, nor all of the pumped/piped linkages. These catchments are outlined in Appendix I for the various stages of mining and site closure. The direction of flow (of some illustrated components) can be reversed and is dependent on the stage of mining (i.e. active, closure). Additional elements are shown for completeness even though they are not utilised in the current assessment.

Macraes Water Balance Model

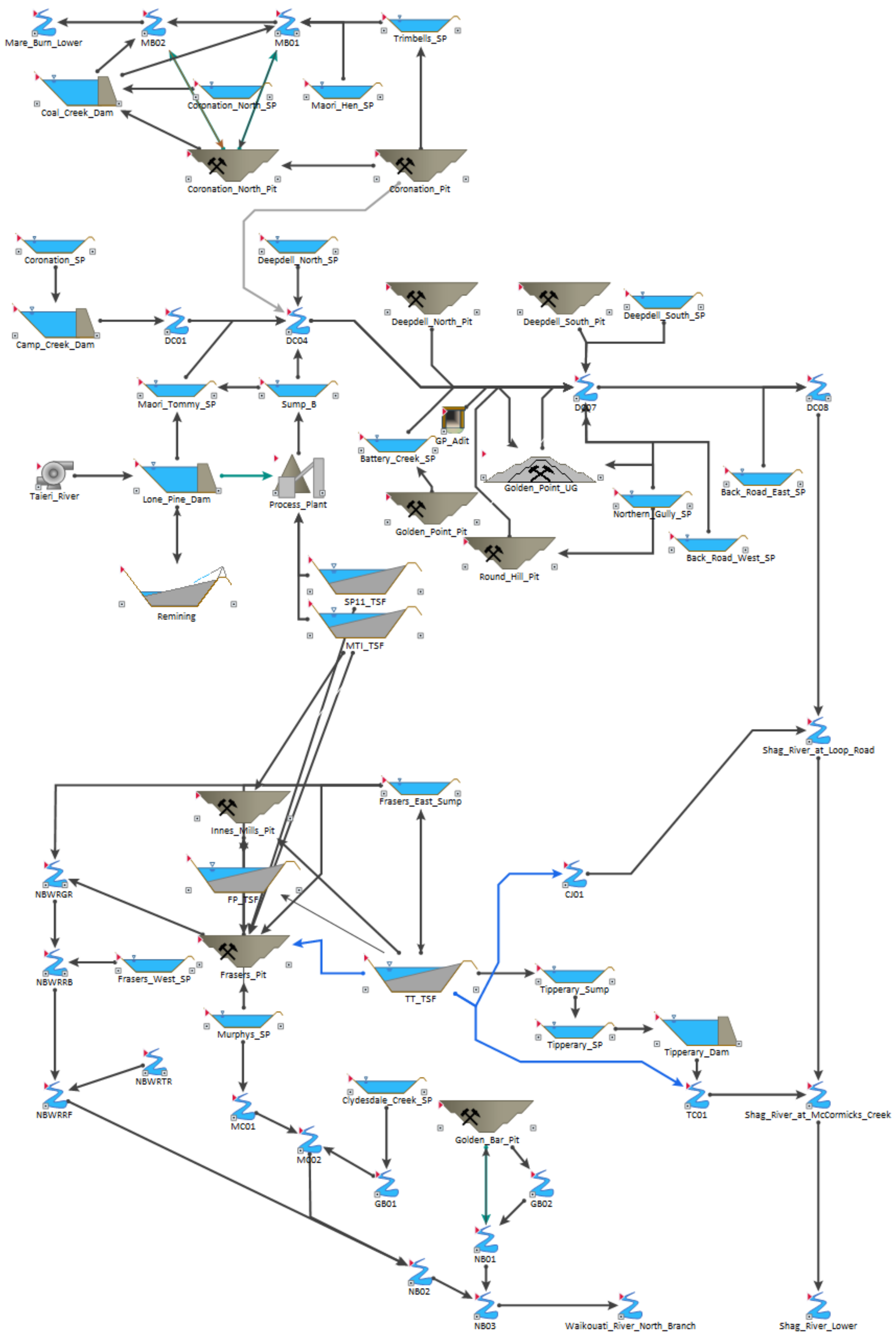

Figure E-2.1 Schematic of the Macraes Water Balance Model as setup for the Project

E-2.2 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
– increase in the potential evaporation deficit (PED)

E-2.2.1 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, Golden Point Station on the Macraes site between 1991 and 2018, and weather stations at Macraes mine and Macraes village covering 2017-2025 and 2020 – 2025 respectively. 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, the rainfall date is provided in Table E-2.1.

Table E-2.1 Rainfall statistics

	Synthetic Record (1,000 years)	Golden Point Station (1991-2022)	Glendale Station 5370 (1959-2008)	Macraes Mine (2017 – 2025)	Macraes Village (2020-2025)
Mean annual rainfall (mm)	664	665	634	733	635
Minimum annual rainfall (mm)	355	414	395	574	554
Maximum annual rainfall (mm)	1155	1034	950	1047	762
Dry days	59%	59%	68%	58%	58%

Seasonal rainfall variations under the RCP8.5 scenario are expected to follow the trends as outlined in Table E-2.2. Typically, this results in dryer summer periods and wetter winters than historical means. The net result is an overall annual increase in precipitation.

Table E-2.2 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%

E-2.2.2 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 ref. 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 valves.

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.

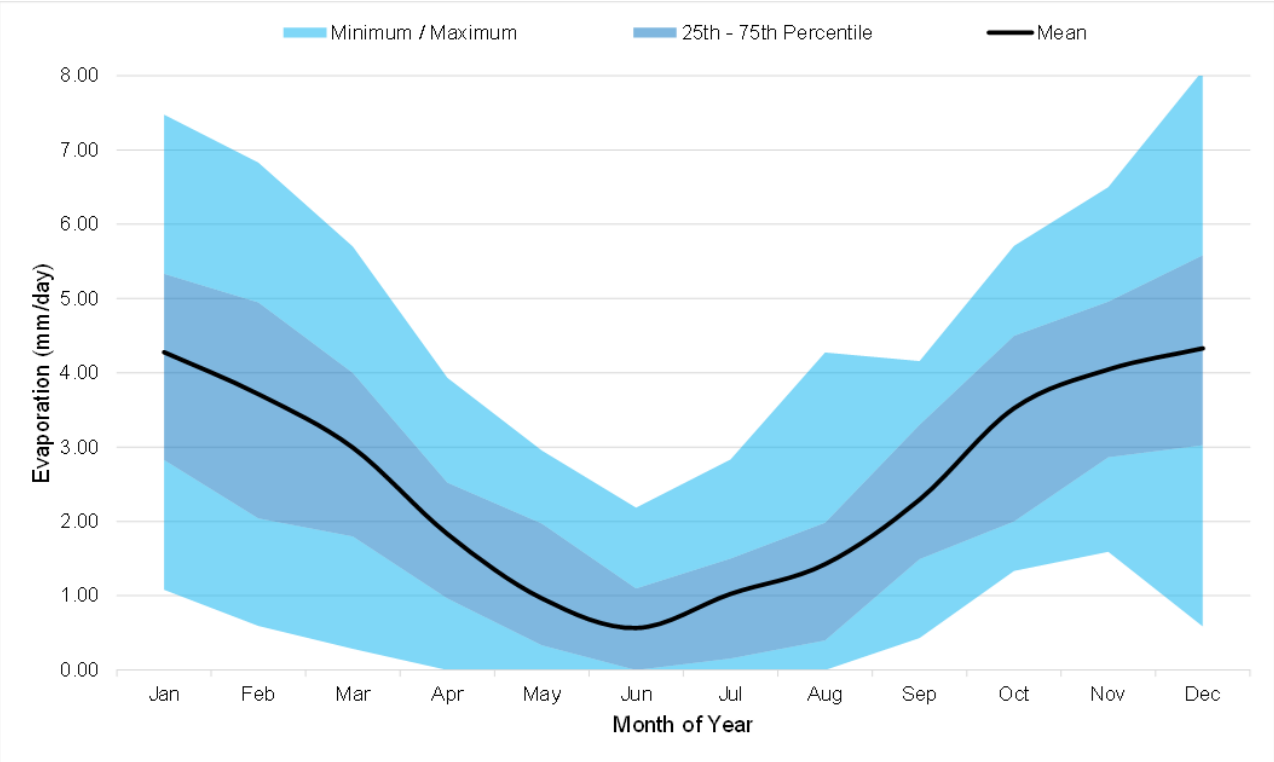

Figure E-2.2 Evaporation statistics applied in WBM

Under the RCP8.5 scenario an increase in potential evaporation deficit (PED) of approximately 120 mm could be expected by 2110 (Figure E-2.3). 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.

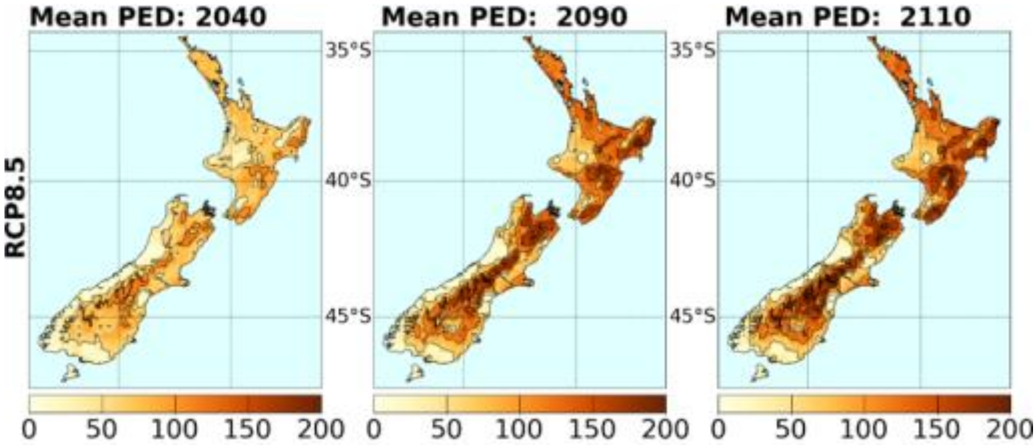

Figure E-2.3 PED projections (exert from MfE 2018, Figure 55)

E-2.2.3 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 E-2.3 outlines the runoff coefficients applied to impacted and WRS surfaces. Runoff coefficients are interpolated from these values based on the daily rainfall depth. These coefficients increase with rainfall depth to represent the higher runoff rates from more wetted soils.

Table E-2.3 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 are 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 the Golden Point flow gauge on Deepdell Creek (at DC03) using data recorded between 1991 and 2026. The statistical analysis against the observed flow at DC04 is presented in Figure E-2.4, where the error is a percentage calculated as (Modelled – Measured)/Modelled.

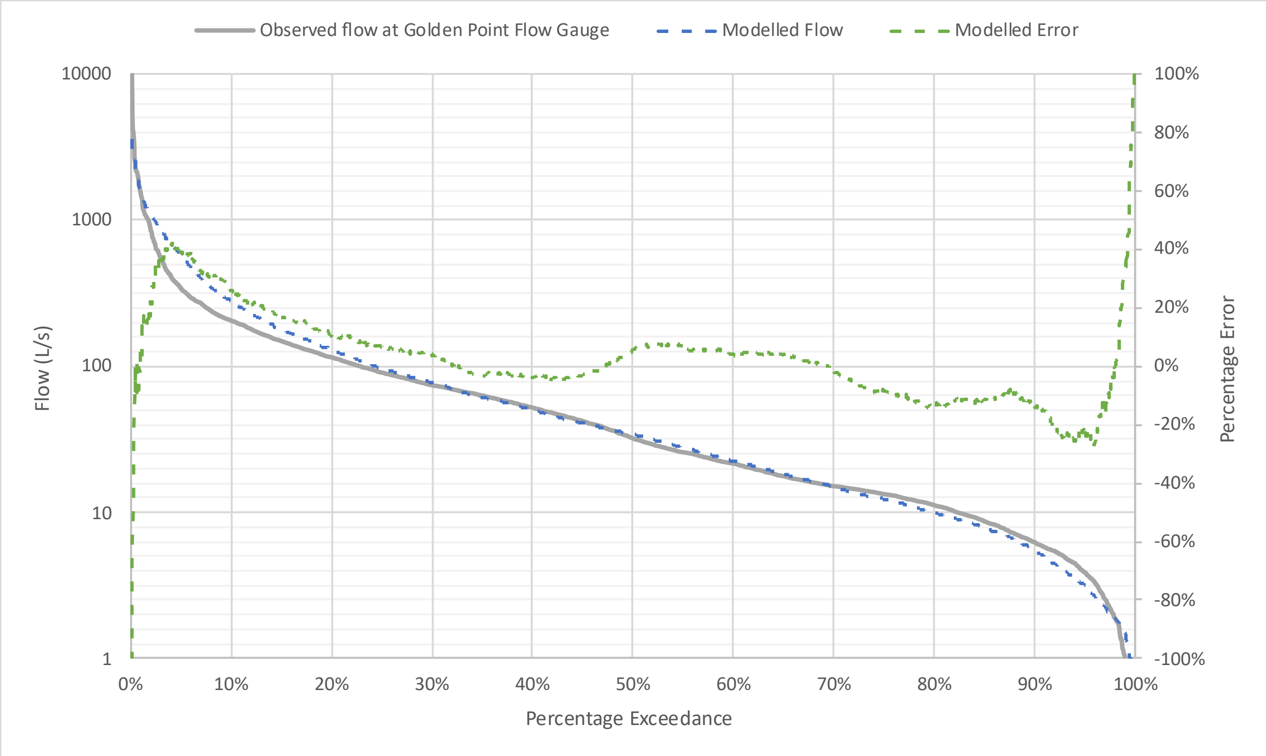

Figure E-2.4 AWBM Calibration Plot

The calibration was focused on the lower flows and aimed to be conservative in the low flow regimes. This is based on high concentrations in measured data being typically observed during dry and low flow conditions. During higher flow conditions the mine water contributions are relatively more dilute and have a lower influence on the receiving waters. The calibrated AWBM produces a lower flow rate below the 70^{th}%ile (flows below 30 L/s). In very low flow conditions (measured flows <2 L/s) the AWBM estimates a higher flow rate.:

– At a measured flow of 1 L/s, modelled flows are 1.5 L/s,
– At a measured flow of 0.5 L/s, modelled flows are 1.1 L/s.

In the context of the modelling undertaken, this calibration is considered suitable because:

– The flow gauge is unlikely to be suitably accurate under very low flow conditions, and
– In these very low flow regimes, the WBM does not reduce seepage water discharge rates as is likely to occur in practice. As the WRS seepage flows are not reduced in very low flow regimes, the relative portion of seepage water in stream increases in modelled results as natural catchment flows tend towards zero.

While high flow regimes are less important for water quality predictions and water quality compliance assessment, the total catchment discharge is important in determining lake and dam filling rates. AWBM predicts a total runoff of 98% of the observed runoff for the calibration period providing an acceptable representation of the natural catchment inflows to augmentation dams and lakes.

This flow calibration is assumed to be a suitable representation of the Deepdell catchment. Based on hydrological similarity, the flow model is also applied to other catchments across the Macraes Operation for the purpose of representing natural catchment flow regimes. Further flow monitoring within other catchments on site will be required to validate this assumption.

E-2.2.4 WRS Percolation

WRS percolation represents the rate of infiltration from rainwater through the stacks and presents as WRS seepage with degraded water quality. The WBM represents this seepage based on applying an infiltration rate (described in terms of mm/year) based on defined seepage catchment areas determined from pre-mine and as-mined topology. These catchments are developed with the assumption that the WRSs have significantly higher hydraulic conductivity compared to the underlying in-situ schist material. This results in the behaviour where seepage water percolates vertically until it reaches the underlying schist, then laterally along the underlying topology until seeping out from the WRS toes. Site observations support this behaviour, and flow monitoring is available to calculate the percolation rates.

The catchment maps defined for three key stages of mine development are presented in Appendix I, where the mine phases include:

1. Current catchments – defining the current state of WRS seepage catchments and typically representative of the mine over the last decade.
2. MP4 catchments – defining the WRS seepage catchments with MP4 implemented and consideration given to the mine plan to determine working or unrehabilitated areas that present higher percolation rates.
3. Closure catchments – defining the WRS seepage catchments post closure where all rehabilitation and proposed mitigation measures are fully implemented.

The WBM represents the seepage flows and contaminant mass fluxes by representing two key mechanisms;

1. Typical behaviour results in the total seepage flow from the WRSs reporting to the next downstream node within the WBM.
2. Where capture systems are implemented, the seepage flow is split into two components, a portion of the seepage water intercepted by the capture system, and a portion of seepage that bypasses the capture system and reports to the next downstream node (described as basal seepage).

Seepage flow through WRS structures typically shows a relationship with antecedent rainfall and climatic conditions, where toe seepage will show time lag and dispersion with respect to the rainfall driven infiltration rate. Where detailed flow monitoring is available, WRS seepage hydrology can be calibrated to model how seepage flow changes with climatic conditions as shown for the Devils WRS at the Globe Progress Mine (GHD, 2020a). These lag and dispersion relationships can vary based on WRS geometry, construction methods and material properties. Hence, measured data is required to form an accurate representation of climatic driven seepage flows.

Flow monitoring has been carried out on WRS seepage discharges at the Macraes Operation, however, monitoring records are not detailed enough to derive WRS specific seepage flow models. On this basis, seepage flow rates are represented in the WBM without dispersion or correlation to rainfall and climatic conditions. The WBM applies a mean seepage rate with an assumed ±30% distribution as shown in the probability density function in Figure E-2.5. This function is resampled for each hydrological year within the Monte-Carlo simulation. The WRS seepage rates are positively correlated between all WRSs within the WBM, such that there is an increased probability of all WRSs having simultaneous relatively high or relatively low seepage rates (compared to the WRS specific mean value) at the same time. WRS seepages are not represented with a correlation to seepage water quality such that model statistics will represent relatively high seepage flows, with relatively high seepage concentrations for some iterations of the probabilistic simulation.

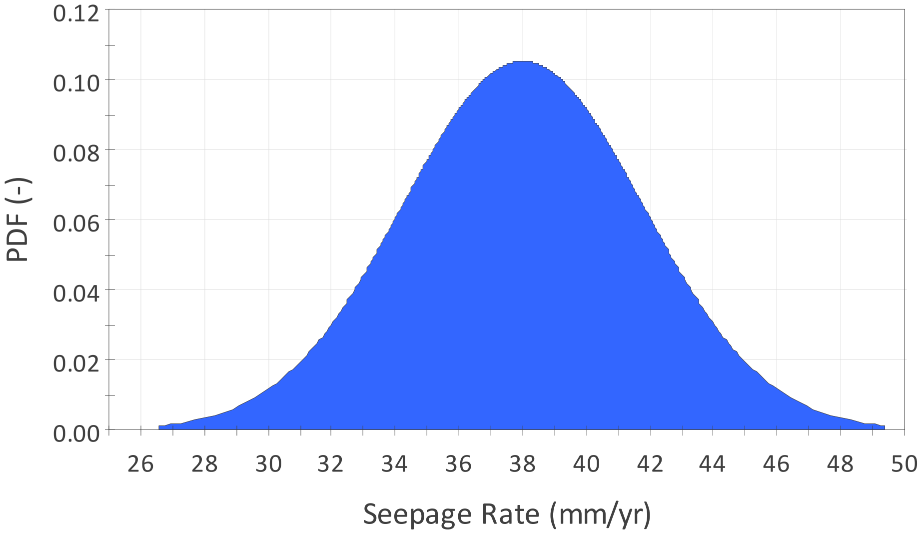

Figure E-2.5 Typical probability density function for WRS seepage rates for a mean seepage rate of 38 mm/yr.

Figure E-2.6 shows the results of seepage monitoring carried out by OGNZL on WRS toe discharges between 2018 and 2020. To allow for the monitoring, 'monitoring bunds' with a protruding discharge pipe were constructed at the WRS toes and flows determined using a 10 L bucket and stopwatch (Figure E-2.7). The exception is the Coal Creek 1 and 2 measurements, that were taken from existing dams downstream of the seepage discharge. Data from these two sites have been combined for assessment purposes. Note that the field data presented here has been cleaned by; adding decimal points where missing and transposing miss-recorded data, and removing likely erroneous recordings (typically low flow measurements not aligning with the data set trends and antecedent rainfall).

Mean percolation rates have been calculated from the seepage flow data presented in Figure E-2.6 as a percentage of the total annual rainfall. These outcomes for the monitored WRSs are provided in Table E-2.4 as annual infiltration rates.

Flow monitoring has also been recorded at Māori Hen and Trimbells Gully silt pond discharges between 1/09/2025 and 19/03/2026 (to date of assessment). The flow monitoring setup is shown in Figure E-2.8 and Figure E-2.9 for the Māori Hen silt pond. This flow monitoring represents combined seepage flows and surface water runoff from the catchments. The Trimbells Gully silt pond receives flow from the Trimbells Gully WRS and a significant catchment unaffected by mining. On this basis this flow monitoring is not considered in the seepage flow assessment. The Māori Hen flow monitoring record (with calculated daily mean flows) is shown in Figure E-2.14. Māori Hen silt pond receives surface runoff from approximately 20 ha or rehabilitated embankment and seepage flow from approximately 92 ha of Coronation North WRS based on an assessment of the topography underlying the WRS and run on water from up-gradient areas.

Included on Figure E-2.14 is an assessment of the seepage flow rates from the Coronation North WRS to Māori Hen silt pond. In this, a volume balance between measured flows and calculated flows (seepage and surface runoff) is presented that shows equivalent total discharges. The surface runoff is calculated for the contributing catchment area based on the runoff coefficients presented in Section E-2.2.3. A percolation rate (as percentage of rainfall) is calculated to balance the difference between calculated runoff and measured flows. The resultant seepage rates are shown as a percentage of the preceding 30 day average rainfall for illustration. Based on the seepage flow monitoring an annual average percolation rate of 35% mean annual rainfall is calculated, corresponding to a rate of 224 mm/yr. This rate is higher than other WRSs across the Macraes Operation and is expected due to the large area of the WRS surface utilised for water retention. The seepage rate applied to Coronation North WRS in the WBM corresponds to a flow range of 4.6 L/s to 8.6 L/s with a mean flow of 6.6 L/s.

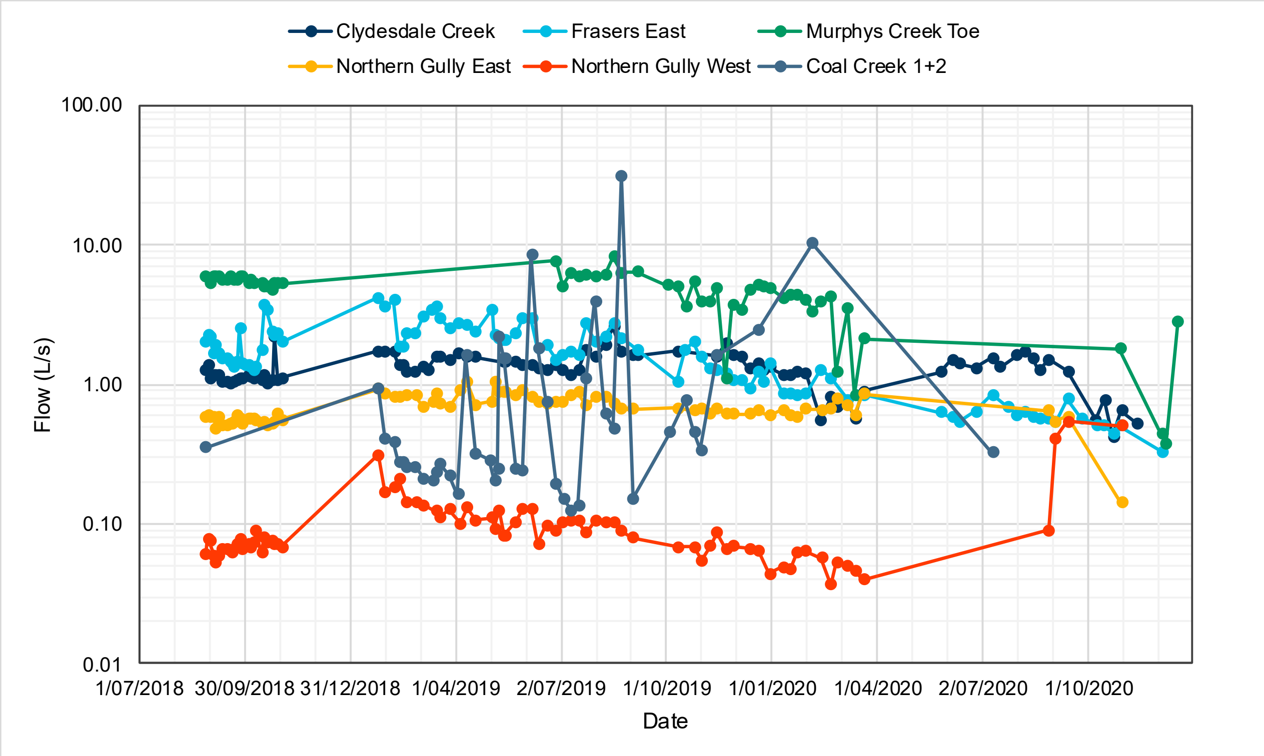

Figure E-2.6 WRS seepage monitoring

Figure E-2.7 Seepage flow monitoring, Above Murphys Creek silt pond, August 2018.

Figure E-2.8 Māori Hen silt pond flow monitoring (April 2026)

Figure E-2.9 Māori Hen silt pond from embankment (April 2026)

Figure E-2.10 Clydesdale WRS, looking down slope towards silt pond (May 2026)

Figure E-2.11 Clydesdale WRS surface in foreground (May 2026)

Figure E-2.12 Clydesdale WRS surface ponding (May 2026)

Figure E-2.13 Northern Gully WRS (April 2026)

A range of infiltration rates are determined across the Macraes Operation from the available flow monitoring data and there is a large spread in these values as given in Table E-2.4. Based on site observations the shaping of the WRS surfaces is expected to be influential in the infiltration rates. Clydesdale WRS is shown to have a high infiltration rate (22%) compared to the Northern Gully WRS (6.6%), both of which are largely rehabilitated. Figure E-2.10 to Figure E-2.12 show the Clydesdale WRS, which has a relatively small, sloped face area in a confined valley and large undulating top with localised low points serving as infiltration ponds. By contrast, Northern Gully WRS (Figure E-2.13) has a higher portion of water shedding surfaces and no permanent ponding areas. The WRS does have benches which retain water in wet periods, some unrehabilitated surfaces and some water retaining tops, indicating potential for reductions in infiltration to still be achieved.

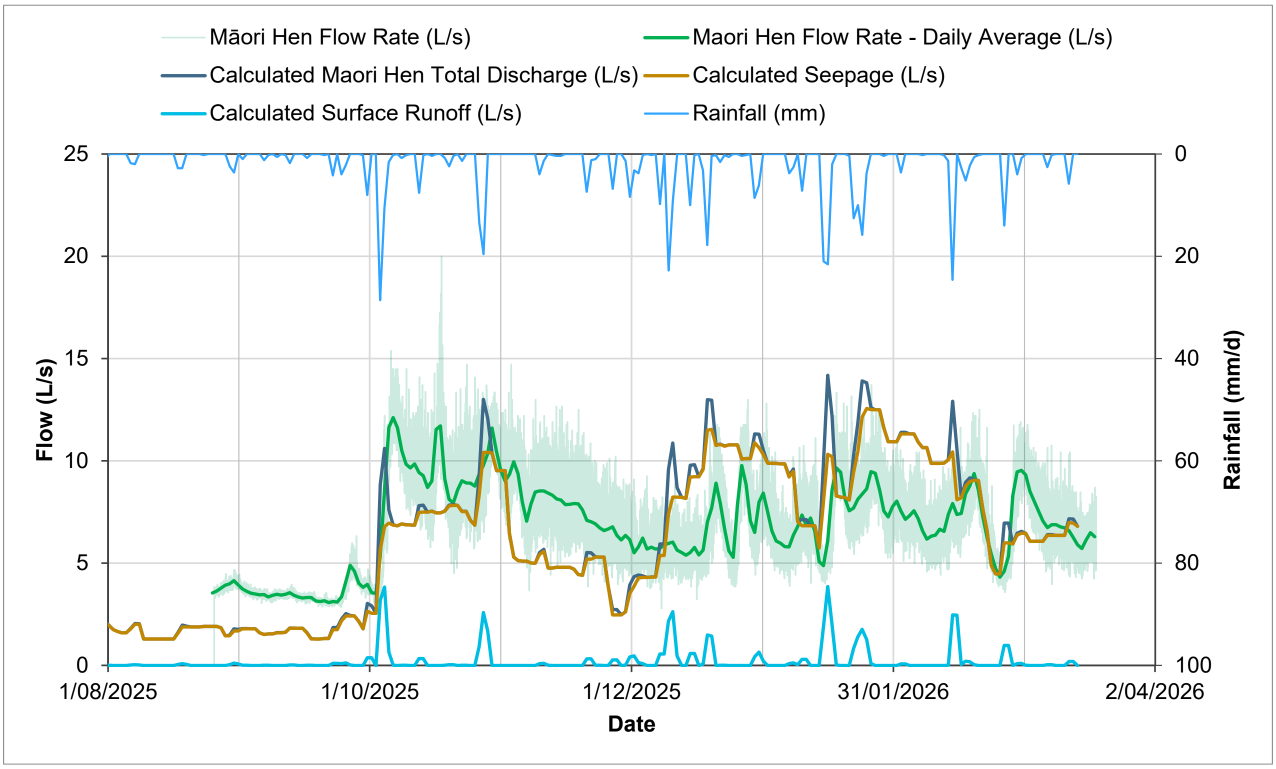

Figure E-2.14 Māori Hen silt pond discharge flow rates.

Table E-2.4 Summary of calculated and applied WRS seepage rates

WRS	Calculated Seepage Rate (mm/yr) [1]	Calculated Seepage Rate (% Precipitation) [1]	WRS State[3]
Seepage flow monitoring 2018-2020			
Northern Gully (East)	42	6.6%	Predominantly rehabilitated, high portion of water shedding surfaces
Clydesdale Creek	143	22%	Rehabilitated, high portion water retaining.
Frasers East	39	6.1%	In construction, high portion water retaining.
Coronation North (to Coal Creek)	40	6.2%	Partially rehabilitated, high portion of water shedding surfaces
Frasers West (Murphys Creek)	73	11%	Partially rehabilitated, high portion water retaining.
Silt pond discharge monitoring 2025-2026			
Coronation North (to Māori Hen)	224	35%	In construction, high portion water retaining.
Trimbells (to Trimbells Gully)[2]	160	25%	Partially rehabilitated
General Application			
Active WRS	128	20%	In construction, all states
Rehabilitated WRS (MP4 Mining)	38	6%	Initial rehabilitation
Rehabilitated WRS (Closure)	32	5%	Rehabilitation fully established.

[1]. Measured rates adjusted based on mean annual rainfall.
[2]. Calculated based on balance of runoff area and infiltration area determined for Coronation North WRS.
[3]. Description of WRS state of construction at time of flow monitoring.

The seepage rates summarised in Table E-2.4 (in mm/year) are applied in the WBM to the specific WRSs. Where there is no baseline monitoring to inform WRS specific rates, generalised rates are applied based on the following considerations:

- **Active WRS** – under construction and/or with significant unrehabilitated areas. Rate also applied to pit backfills that cannot be designed as water shedding or currently designed with large flat areas unlikely to achieve the lower infiltration rates.
- **Rehabilitated WRS (MP4 Mining)** – applied to rehabilitated WRS areas with established vegetation and predominantly water shedding surfaces. The assumed rate of 6% of mean annual precipitation is based on measurements from Northern Gully, Frasers East and Coronation North (to Coal Creek), with consideration given to expected seepage flow reductions from completed rehabilitation being completed.
- **Rehabilitated WRS (Closure)** – applied to rehabilitated WRS areas post closure. The assumed rate of 5% is based on an expected reduction from existing measurements once full rehabilitation and water shedding surfaces are constructed, with localised improvements to existing WRSs to reduce areas promoting ponding.

It is also noted that OGLNZ is proposing to develop a WRS construction management plan that will reduce unrehabilitated WRS areas during construction. Further discussion of the proposed mitigation measures for WRS seepage management is presented in Appendix F.

Regional Context

ORC (2011) presents an assessment of rainfall recharge rates for Otago groundwater basins. This work demonstrates recharge rates ranging from 5% to 25% of mean annual rainfall and between 10% and 20% for most basins. The report notes that the highest rainfall recharge rates typically correspond to the highest percentage recharge rates. To compare with this report, the Macraes site has a rainfall rate 664 mm/yr which is equivalent to the mean of the 13 catchments assessed, while the potential evapotranspiration rate of 952 mm/yr is higher than these catchments. The lowest two recharge sites presented with recharge rates of 5% are Strath and Maniototo, which are spatially the closest to the Macraes Mine.

It can also be noted that the potential evaporation deficit PED is expected to increase due to climate change in this region, where PED is the difference between the amount of water that could be lost from soil through evapotranspiration and the amount actually lost. With this groundwater recharge will typically decrease, due to less infiltrated water draining past the root zone. Well established vegetation on the WRSs and reducing focussed seepage pathways will assist in reducing this recharge rate.

E-2.3 Water Quality Inputs

E-2.3.1 Surface Water Quality

The surface water quality parameters applied to the water balance model are listed in Table E-2.5. These values have been derived based on the water quality monitoring data provided by OGNZL 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. Natural source terms are applied to all undisturbed (my mining) catchments.
- **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 E-2.5 Surface Water quality source terms – mean value inputs

Parameter [g/m³]	Natural	Impacted	Impacted Rehabilitated	WRS	WRS Rehabilitated
Ammoniacal Nitrogen	0.008	0.19	0.008	0.19	0.008
Arsenic	0.0014	0.006	0.005	0.006	0.005
Copper	0.0006	0.0004	0.0008	0.0004	0.0008
Hardness	50	680	143	680	143
Iron	0.17	0.25	0.08	0.2	0.2
Lead	0.00003	0.00005	0.0001	0.00005	0.0001
Nitrate-N	0.05	0.8	0.03	0.8	0.03
Sulphate	8	453	23	453	23
Zinc	0.001	0.003	0.0014	0.003	0.0014
DOC	6	0	3	0	0
Chloride	9	9	9	9	9
pH	7.7	7.7	7.7	8	8

E-2.3.2 Waste Rock Stack Seepage Water Quality

WRS seepage sulphate concentration predictions are based on the following MWM equation (MWM 2026b).

$$\left[SO_4 \frac{mg}{L}\right] \max = 87 \times Average\ WRS\ height\ (m)$$ Equation E-2.1

A distribution is applied such that Equation 2.1 represents the maximum sulphate concentration modelled. This distribution assumes a normal distribution curve with a standard deviation and cut-off at +/- 30% of the median value.

Sulphate concentration was found to correlate well with other dissolved components. Where there was no correlation, median values were used predict WRS seepage water quality. The following equation is used to calculate the median concentration of each component dissolved in seepage water.

$$Concentration\ \left[species \frac{mg}{L}\right] = Ax + B$$ Equation E-2.2

Where ‘A’ was the slope, ‘B’ was the intercept, and x is the maximum sulphate concentration calculated by Equation 2.1. Where there is no slope (i.e. no correlation with sulphate), A is assumed to be 0 which leaves the concentration as ‘B’ (the median concentration). Refer to Table E-2.6 for slope (A) and intercept (B) values presented for the WRSs that were studied in MWMs WRS Assessment – Seepage Quality (MWM 2026b). For WRSs that were not included in this assessment, a general WRS quality was applied in Table E-2.6. In most cases, this comprised of average median species concentrations from the assessed WRSs.

Table E-2.6 Summary of analytical parameters used for WRS seepage predictions (MWM 2026b)

Parameter	Golden Bar (Clydesdale)	Coronation	Coronation North	Trimbells	Frasers West	General	Comments
pH (pH unit)	6.8	7.1	7.6	6.8	8.2	7.4	General coeff based on mean of GB, CO, CN & FW coeffs
Hardness (g/m³ as CACO3)	98 (0.97)	103 (0.88)	137 (1.11)	70 (1.01)	371 (1.03)	169 (1.03)	General coeff based on mean of GB, CO, CN & FW coeffs
DOC	0.1	0.1	0.1	0.1	0.1	0.1	Assumed value.
Chloride	11	8	12.3	6	11	8	General coeff based on mean of GB, CO, CN & FW coeffs
Nitrate-N	8.0	1.1	3.9 (0.0077)	1.8 (0.0098)	14	7.9	General coeff based on mean of GB, CN, TR & FW coeffs
Ammoniacal Nitrogen	0.01	0.245	0.017	0.915	0.05	0.081	General coeff based on mean of GB, CO, CN & FW coeffs
Arsenic	0.001	0.0005	0.00075	0.0005	0.003	0.0015	General coeff based on mean of GB, CO, CN & FW coeffs
Copper	0.0011	0.0005	0.0006	0.003 (0.00003)	0.0015	0.0011	General coeff based on mean of GB, CO, CN & FW coeffs
Iron	0.02	0.05	0.05	0.19	0.02	0.045	General coeff based on mean of GB, CO, CN & FW coeffs
Lead	0.0001	0.000075	0.00005	0.0001	0.00025	0.0002	Frasers West lead concentration used for general concentration to be conservative
Zinc	0.052	0.36	0.0028	0.36	0.052	0.052	Golden bar zinc concentration used to be conservative

Note: Values are presented as ''B (A)'' where 'B' is the intercept and 'A' is the slope used to calculate the concentration using the equation concentration = Ax +B. Where there is no 'A' value, the intercept is zero and there is no correlation with sulphate.
All values in g/m³ unless otherwise stated.

E-2.3.2.1 Waste Rock Stack Definitions

Observations of the site WQ data typically show that WRS seepage dissolved components increase in concentrations over time before reaching a peak. The rate at which this develops is important for understanding past water quality trends observed and calibrating models. It also affects how mass fluxes to receiving waters will develop through mining and into closure. To represent the development of sulphate concentrations with time (and other correlated parameters), the following equation is applied:

$$Sulphate(t) = Sulphate_{initial} + (Sulphate_{final} - Sulphate_{initial}) \times \sin\left(\frac{\pi(t - t_i)}{2(t_f - t_i)}\right)$$ Equation E-2.3

The equation seeks to approximate the rate of observed sulphate concentration increase as depicted in Figure E-2.15 to Figure E-2.26.

Where *sulphate(t)* is the concentration of sulphate at any given time, $sulphate_{initial}$ and $sulphate_{final}$ are the initial and final concentrations (see Equation 2-1) for a given initial time (t_i) and final time (t_f).

WRSs are incorporated into the model by defining an area that seepage and runoff from each WRS reports to. These are then incorporated into existing nodes within the WBM. WRS and pit backfill outlines are combined in a GIS assessment where polygons are used to these calculate areas. Surface runoff and seepage are treated differently in the model. Surface runoff from the WRSs is determined by the above ground topology, WRS seepage is determined by below-ground topology.

Each WRS has the following:

- Area: determined by WRS and pit backfill outlines – split if reporting to different model nodes
- Average height (and average height 2 where relevant): mean height of the WRS as determined by OGL and or MWM. A second average height is included for WRSs that are proposed to be adapted as part of the MP4 Fast Track application
- Saturation time (and saturation time 2 where relevant): The estimated time for WRS seepage to saturate and reach its maximum contaminant concentration, given by $t_f - t_i$ within Equation 2-3. This is based on fitting existing WRS seepage measurements.
- Construction date/time: Existing or programmed WRS construction dates.
- Seepage/infiltration rate: Rate of rainfall infiltration through WRS as determined by past sampling and predicted WRS surface and rehabilitation method.

WRS input data is presented in Table E-2.7.

Table E-2.7 WRS average height input data

WRS	Seepage Rate [mm/yr]	Sat. Time [yr] [1]	Construction date (t_i)	Construction date 2	Mean Height [m]	Mean Height 2 [m]	References	Comments
Clydesdale (Golden Bar)	143	26	1/01/2003	1/01/2029	29.4	39.6	MWM 2026a	
Coronation	128	16	1/01/2014	1/01/2027	25.8	37.3	MWM 2026a	
Coronation Backfill	128	10	1/01/2027			17.5	OGL	Seepage is fully contained within the pit and does not have a direct influence on the receiving environment
Coronation North	224	20	1/01/2017	1/01/2029	45.2	60.4	MWM 2026a	
Coronation North Backfill	128	10	1/01/2021		48.82	20	OGL	Coronation North Backfill
Deepdell	38	10	1/10/2020		26.3	26.3	OGL	
Deepdell North	38	12	1/01/2001		18.8	23.7	MWM 2026a	
Finger 11	32	10	1/01/2010		15	15	OGL	
Frasers Backfill	128	10	1/01/2023					Backfill seepages are overridden by MWM pit water quality and therefore do not have a height in the model
Frasers East	39	16	1/01/2009		39.3	39.3	MWM 2026a	
Innes Mills Backfill	128	10	1/01/2010					Backfill seepages are overridden by MWM pit water quality and therefore do not have a height in the model
Frasers South	73	20	1/01/2005	1/01/2027	41.3	41.3	MWM 2026a	
Frasers West	73	17	1/01/2003	1/01/2027	38.3	55.9	MWM 2026a	
Golden Point Backfill	128	10	1/01/2026		20	80		
Māori Tommy	38	26	1/01/2010		10	12	OGL	
MTI	38	20	1/01/1991		36.9	34.5	OGL	
Northern Gully East	42	28	1/01/1995		31.2	37.2	MWM 2026a	
Northern Gully West	42	28	1/01/1995		35.4	37.2	MWM 2026a	
Round Hill	38	10	1/01/2020		60	60	OGL	
SP11	38	7	1/01/2002		30	46.0	OGL	
Top Tipperary	38	10	1/01/2010		35.5	35.5	OGL	
Trimbells	128	17	1/01/2020	1/01/2027	31.3	39.8	MWM 2026a	

[1]Where there is a construction date 2 in the table, there is a WRS lift constructed as part of MP4. Saturation time is assumed to be the same as the initial lift.

The following sections show the resultant maximum sulphate concentration curves based on the inputs from Table E-2.7 over time with relevant Macraes water quality monitoring data for reference. These are generally broken down into geographical areas. For context, the pit lake water levels from relevant pit lakes are included. Pit lake water quality projections and data sources are described in Section E-2.3.4. The projected sulphate concentrations are represented in the WBM. It is noted that the maximum sulphate concentration curves shown in the plots is represented across the whole WRS within the WBM, whereas the monitoring data included in the comparisons is typically from discrete seepage locations that form at WRS toes within valleys. Portions of WRSs that sit outside of these valleys typically have a lower average height, and hence, typically lower contaminant concentrations based on Equation E-2.1.

E-2.3.2.1.1 Golden Bar Area

Figure E-2.15 shows the maximum modelled and measured sulphate concentrations for the Clydesdale WRS and Golden Bar pit lake.

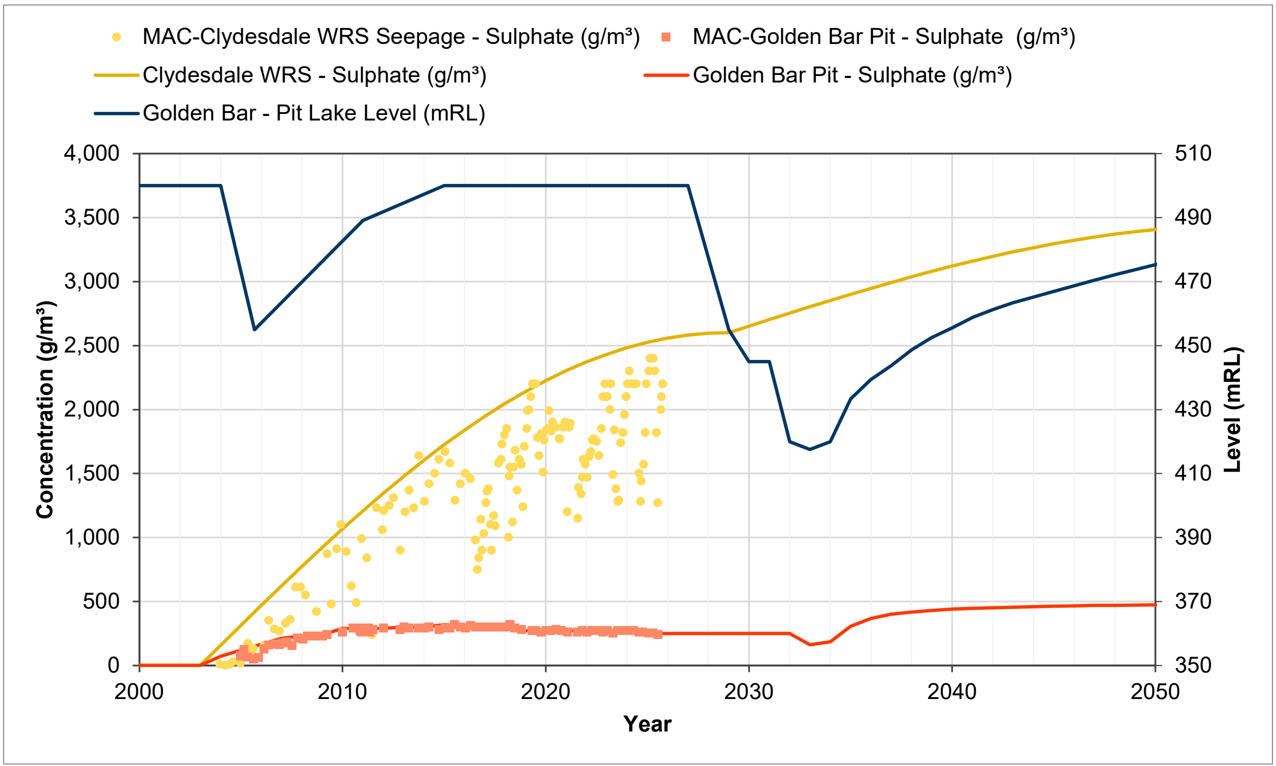

Figure E-2.15 Golden Bar area – Water quality measurements and projections

E-2.3.2.1.2 Coronation Area

Figure E-2.16 shows the modelled and measured sulphate concentrations for the Coronation North WRS and Coronation North pit. Note that seepage rates to Coal Creek (1 and 2) represent a small portion of the total seepage catchment area. Figure E-2.17 shows unrehabilitated WRS area in 2021 within the contributing seepage catchment area for the Coal Creek seepages and highlights ponding across unrehabilitated and rehabilitated areas of the WRS.

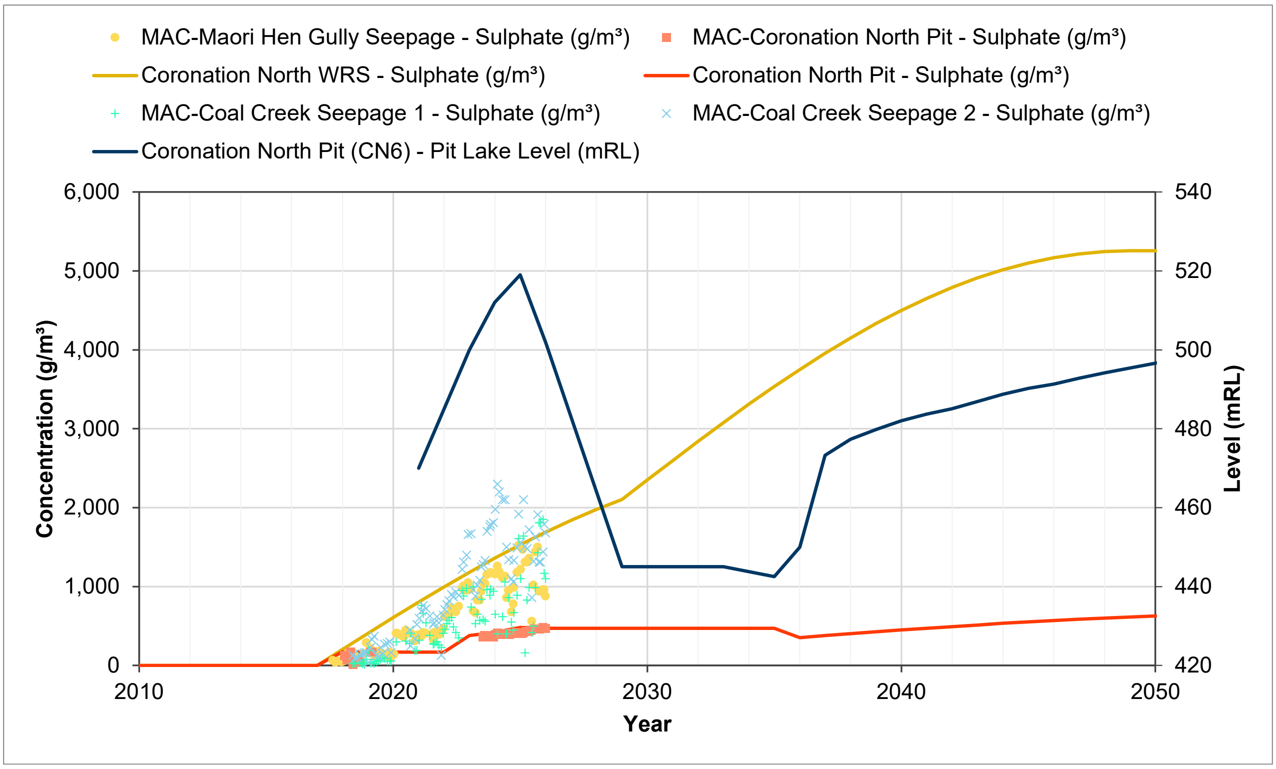

Figure E-2.16 Coronation North Pit area – Water quality measurements and projections

Figure E-2.17 Coronation North WRS – November 2021 (Source Google Earth)

Figure E-2.18 shows the modelled and measured sulphate concentrations for the Coronation WRS, Trimbells WRS and Coronation pit. Note that since 'approximately' 2022 Coronation pit has had water pumped to it from other mine sources affecting the stored water quality.

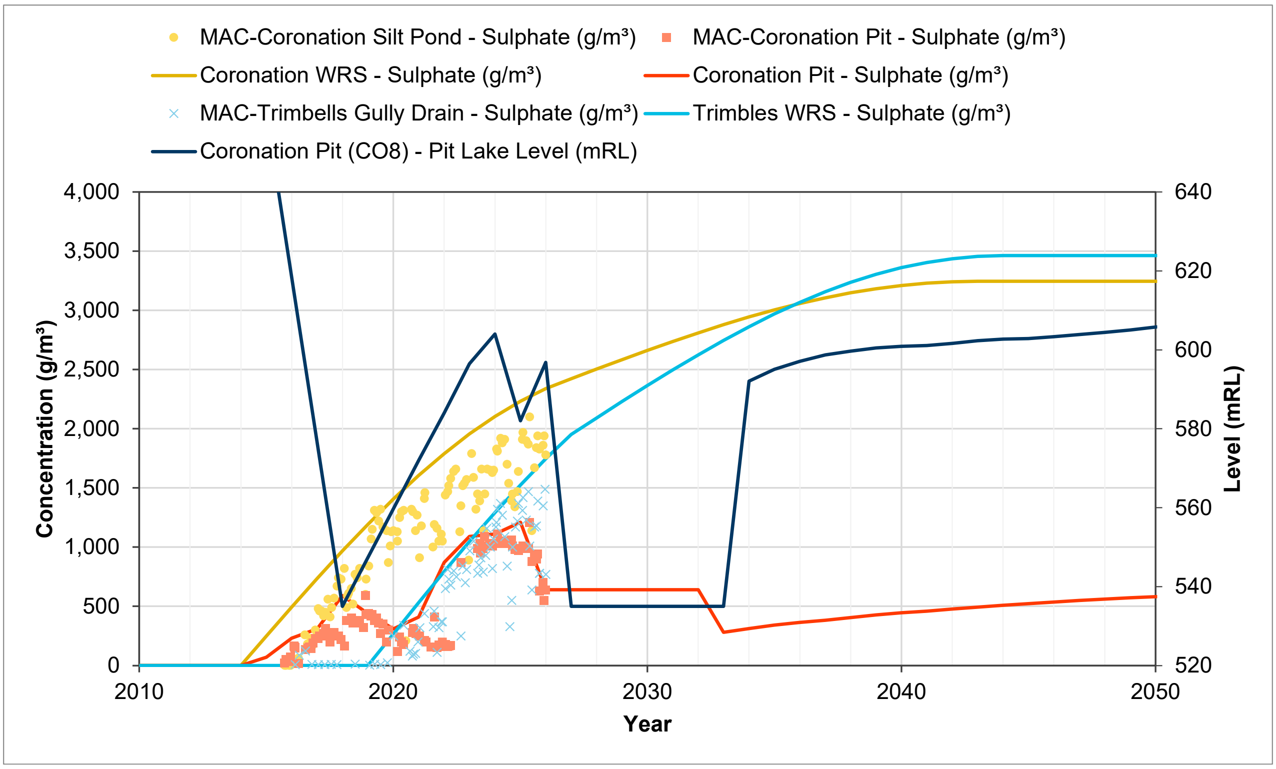

Figure E-2.18 Coronation Pit area – Water quality measurements and projections

E-2.3.2.1.3 Central Area

Figure E-2.19 shows the modelled and measured sulphate concentrations for the Battery Creek and Māori Tommy silt pond seepages, and the Lone Pine water storage reservoir.

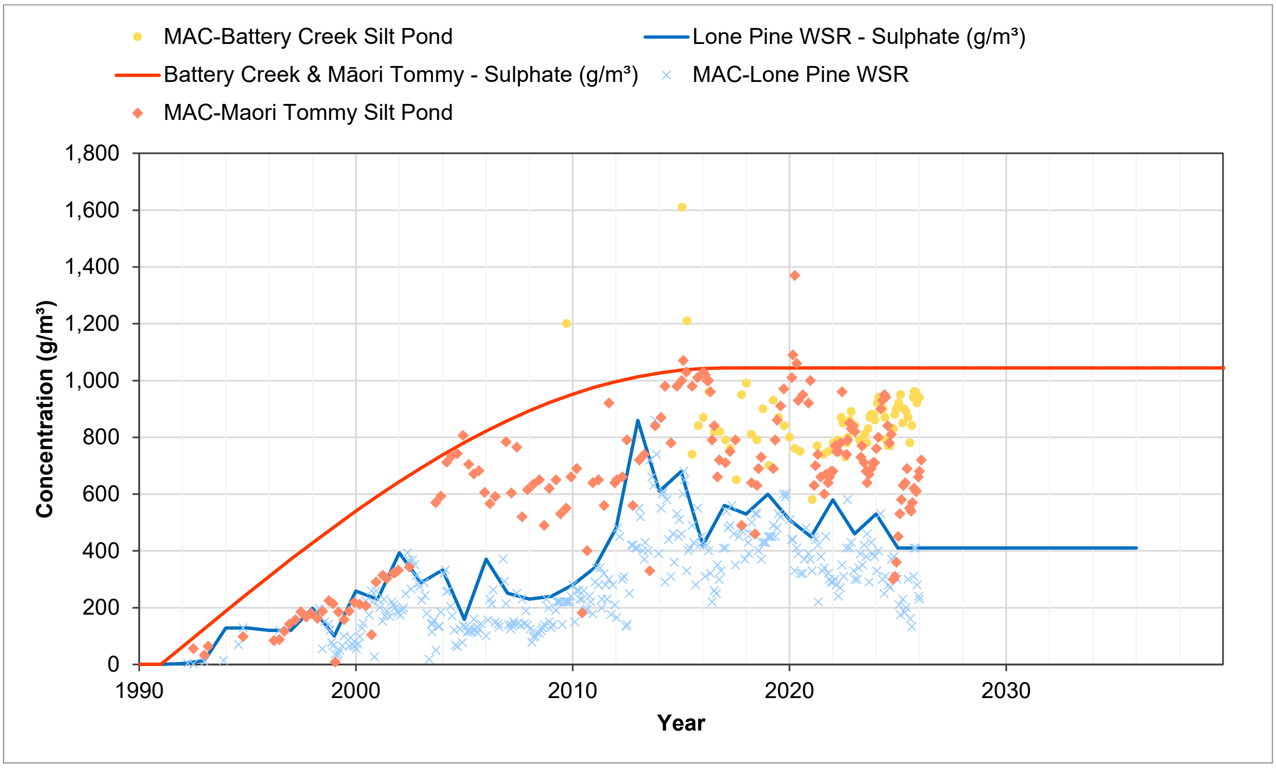

Figure E-2.19 Central area - Māori Tommy, Lone Pine and Battery Creek – Water quality measurements and projections

Figure E-2.20 shows the modelled and measured sulphate concentrations for the Northern Gully WRS east and west seepages. Note that the East seepage makes up most of the seepage flow contribution to the Northern Gully silt pond (SPMP3).

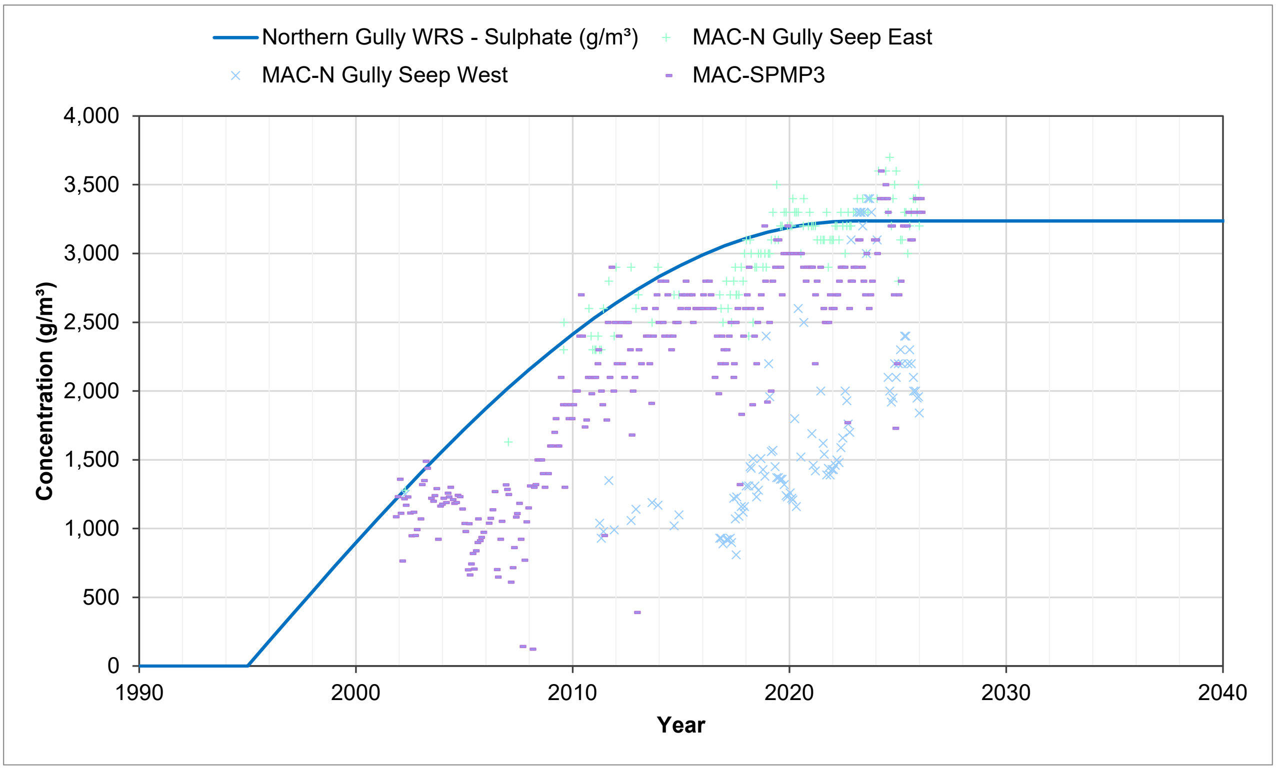

Figure E-2.20 Central area – Northern Gully WRS – Water quality measurements and projections

Figure E-2.21 shows the modelled and measured sulphate concentrations for the Golden Point backfill. This represents measured discharge water quality from the historic Golden Point adit. The rise in the Golden Point Pit backfill is associated with the proposed MP4 WRS.

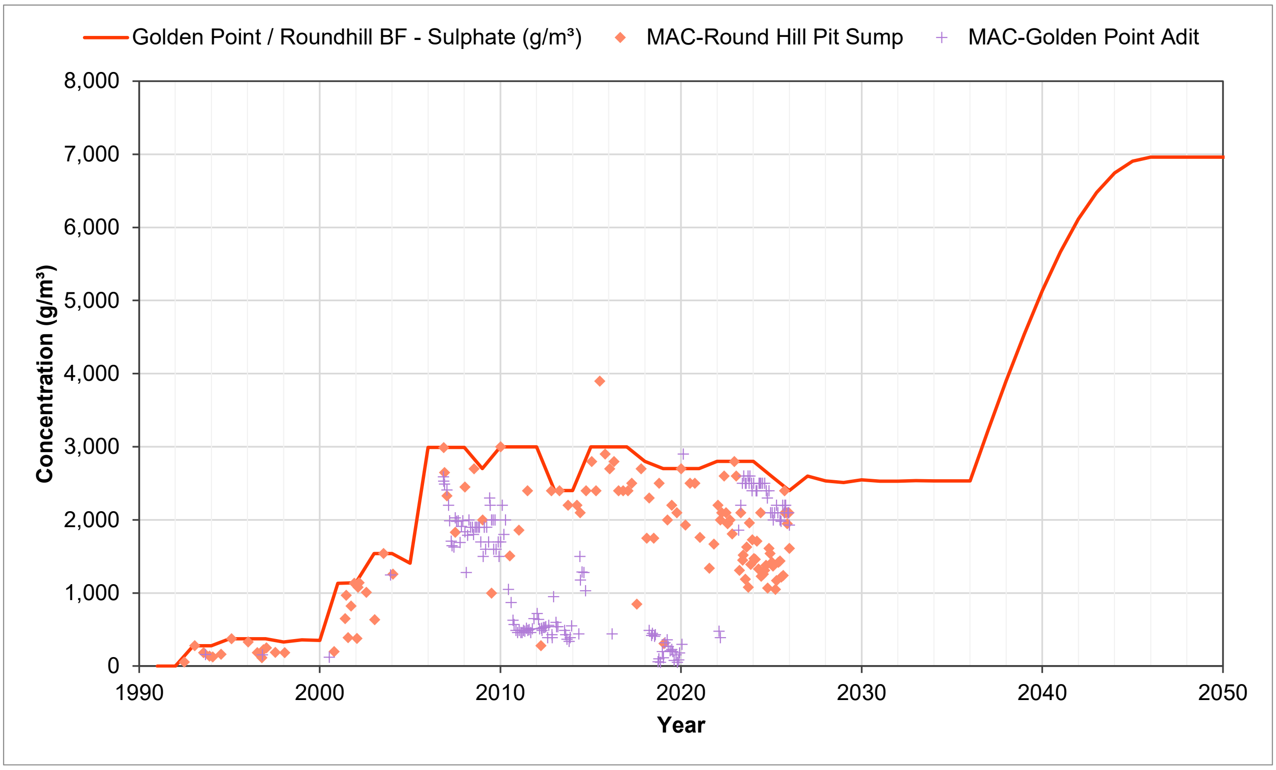

Figure E-2.21 Central area – Golden Point and Round Hill Pits – Water quality measurements and projections

Figure E-2.22 shows the modelled and measured sulphate concentrations for MTI and SP11 TSFs and TSF embankments. It is proposed that SP11 is removed through MP4 and replaced by Innes Mills pit lake (see Figure E-2.25). SP11 has not had any direct discharge to receiving waters, other than contribution to groundwater plume development. Uncaptured basal seepage from the impoundment maybe contributing to Roundhill pit sump that is used for operations. The elevated concentrations observed in the Southern Pit Impoundment and Southern Sump align with commissioning of the SP10 TSF in 2002 and SP11A TSF in 2006 (inundating SP10), through to end of deposition in 2013.

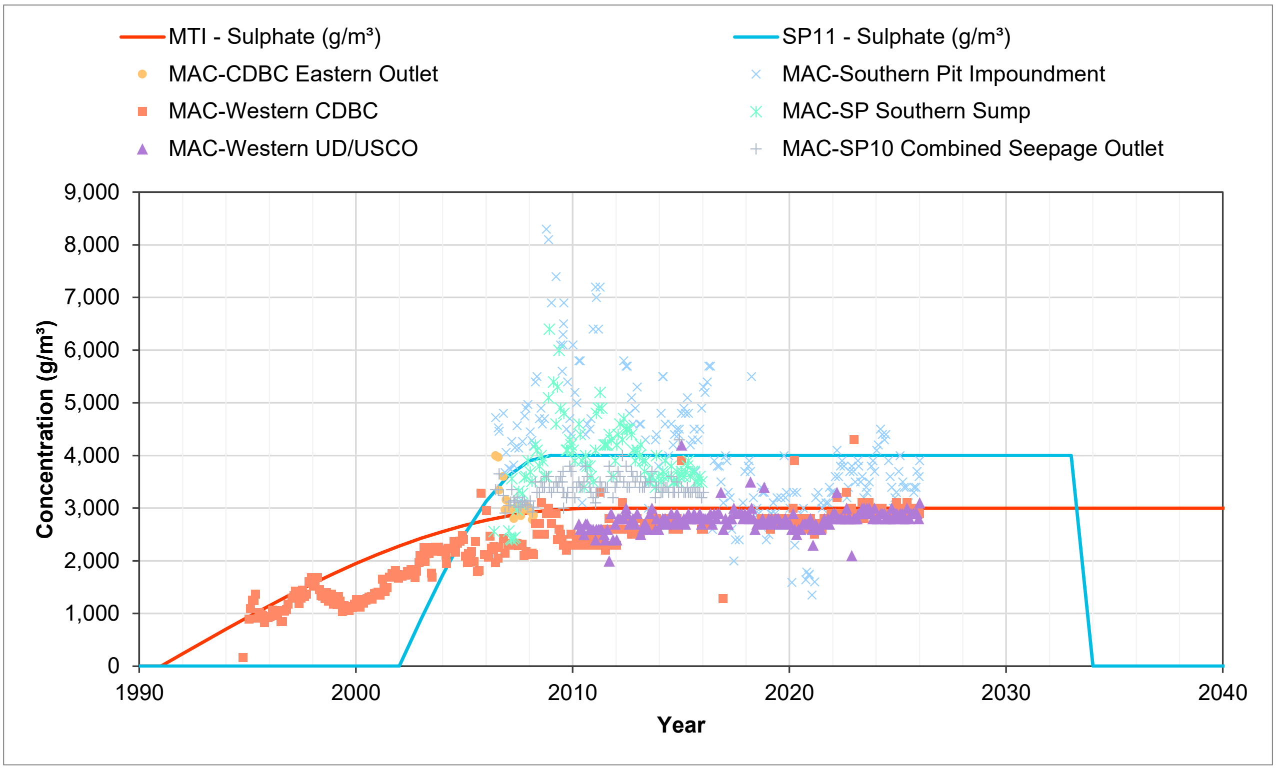

Figure E-2.22 Central area – MTI and SP11 TSFs – Water quality measurements and projections

Figure E-2.23 shows the modelled and measured sulphate concentrations for the Frasers East WRS and TTTSF and embankment.

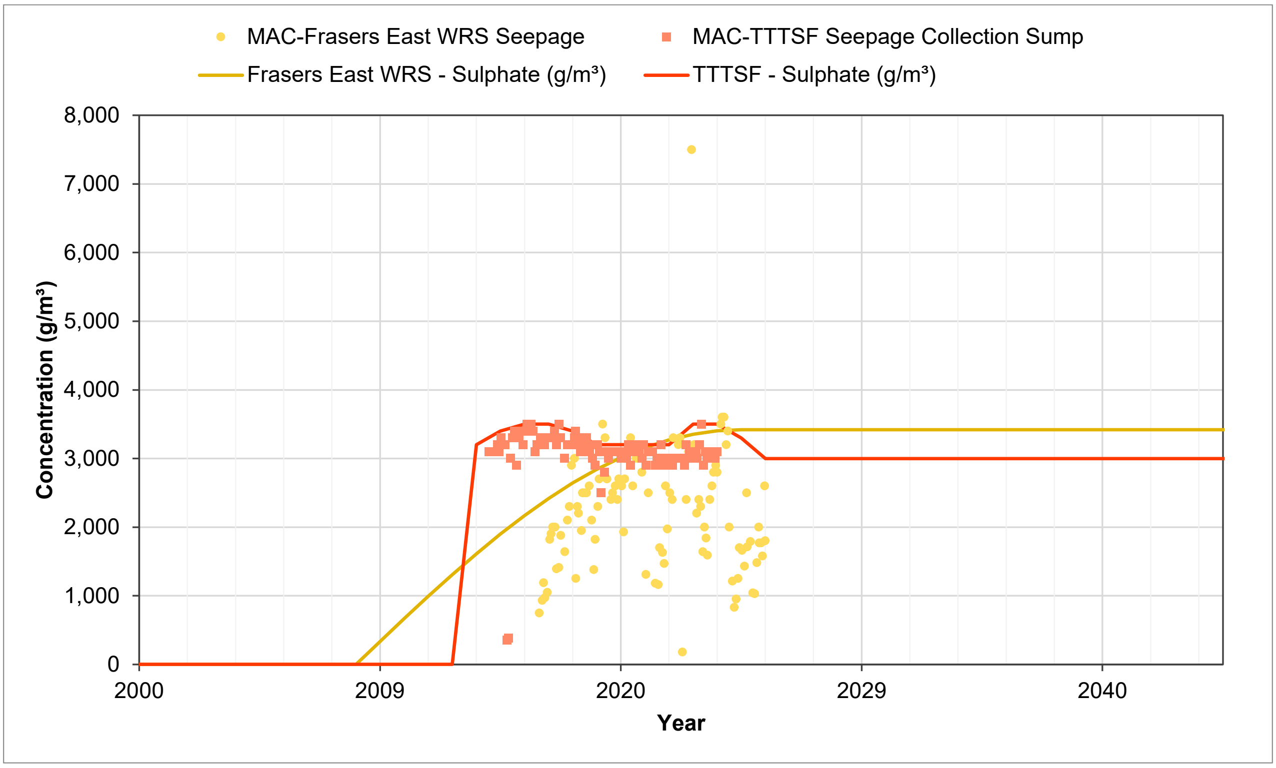

Figure E-2.23 Central area – Frasers East WRS and Top Tipperary – Water quality measurements and projections

Figure E-2.24 shows the modelled and measured sulphate concentrations for the Murphys Creek silt pond (which collects seepage primarily from Frasers West WRS). Note that the Frasers West silt pond measurements have been considered unreliable as an indicator of WRS seepage water quality due to evaporative concentration of pond waters. The Frasers pit concentrations represent the transition from water collected within the pit sump, to the current TSF impoundment water quality.

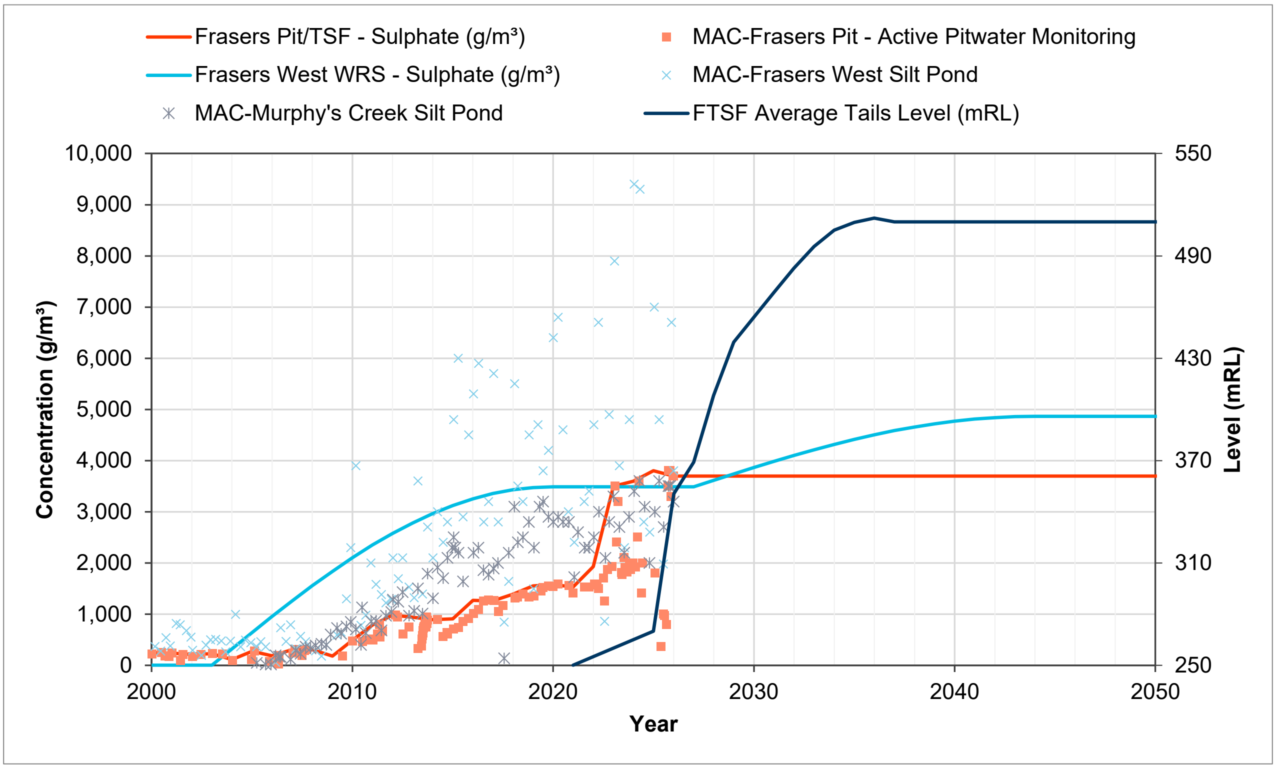

Figure E-2.24 Central area – Frasers West WRS and Frasers Pit – Water quality measurements and projections

Figure E-2.25 shows projected sulphate concentrations for the Innes Mills pit lake and Innes Mills backfill.

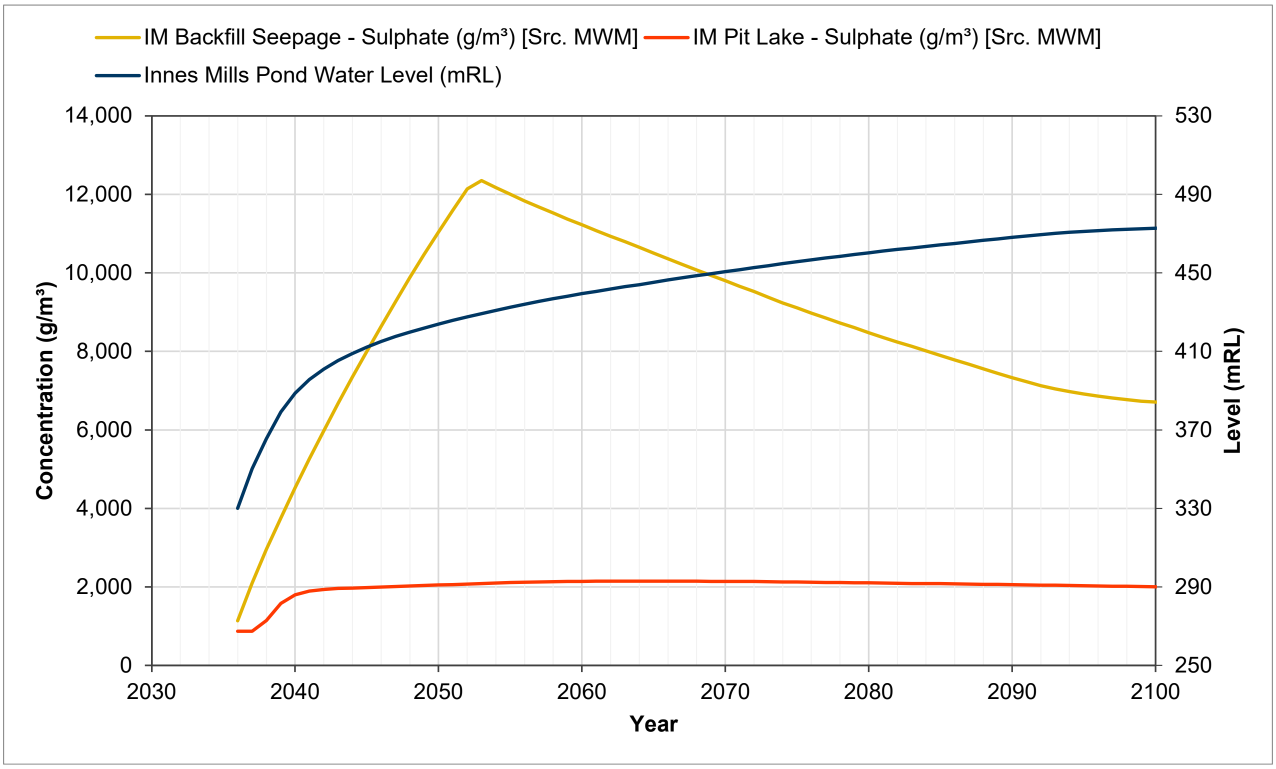

Figure E-2.25 Central area – Innes Mills Pit and Innes Mills Backfill (including Frasers TSF embankment) – Water quality projections

Figure E-2.26 shows the modelled and measured sulphate concentrations for the Deepdell WRSs and Deepdell North Pit. Note that water within the Deepdell North Pit has been pumped there from external sources, hence, is not representative of natural pit lake development. A sharp rise in sulphate concentrations in the Deepdell North silt pond is observed from 2021. This corresponds to the Deepdell North Stage 3 pit cutback which exposed (removed rehabilitation) large areas of the eastern aspect of this WRS.

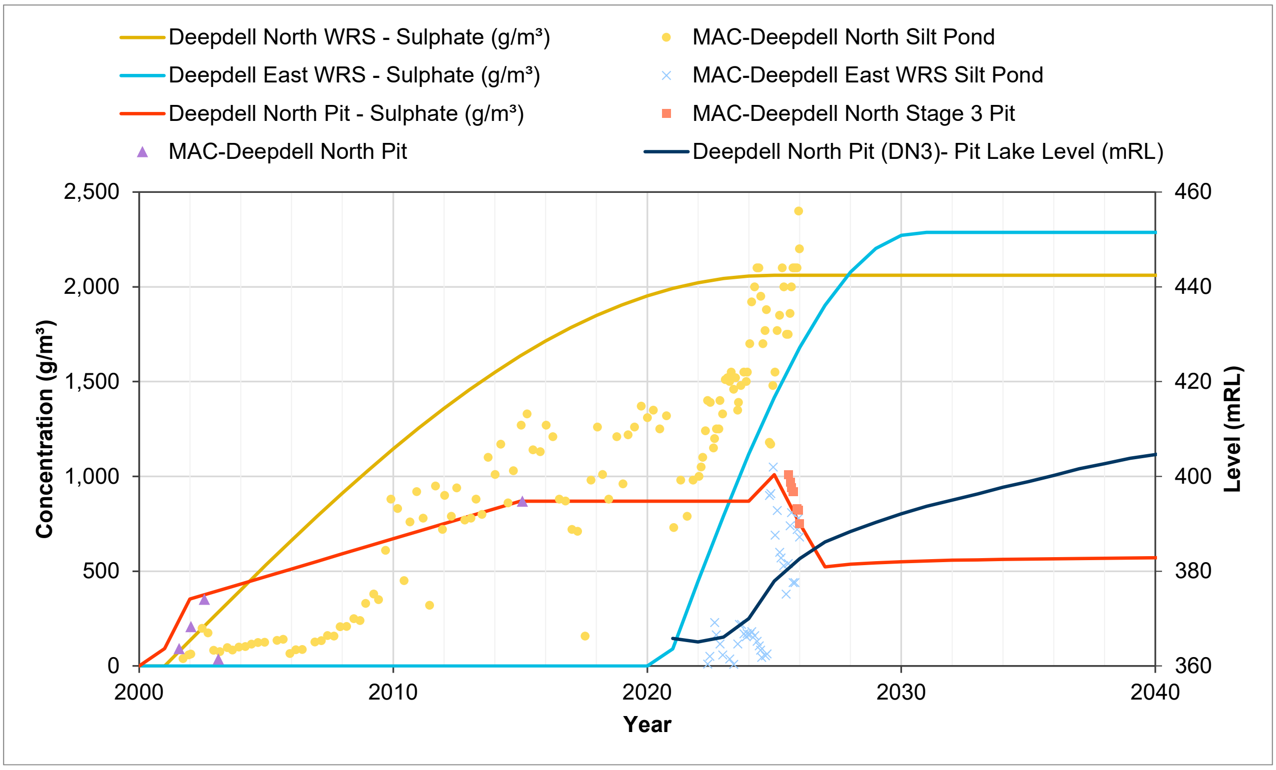

Figure E-2.26 Central area – Deepdell North WRS and Pit and Deepdell East WRS – Water quality measurements and projections

E-2.3.3 Groundwater Quality

Groundwater quality is not explicitly included in the WBM unless it is a direct link from a mine water source, i.e. uncaptured seepage waters, or pit lake water discharging to ground (assumed to contribute to groundwater plumes and reach receiving surface waters). Groundwater inputs are primarily captured within the pit lake inflows as outlined in Section E-2.3.4.

Pit backfill seepage water quality was provided by MWM for Coronation, Coronation North and Innes Mills Pits. The sources for this data are provided in Table E-2.8

Table E-2.8 Pit backfill seepage data sources

Pit Lake	Stage/s Represented	Water Quality
Coronation North	Existing (CNBF) / CNBF2 / CNBF3	CNBackfill_Seepage29062026.xlsx(MWM 2026e)
Coronation	Existing COBF / COBF1,2,3	COBackfill_Seepage29062026.xlsx (MWM 2026d)
Innes Mills	IMBF1 / IMBF2 / IMBF3	IM_Backfill_Seepage_29062026.xlsx (MWM 2026f)

E-2.3.4 Pit Lake Water Quality

Pit Lake water quality is implemented in the WBM as per Table E-2.9.

Where pits are developed in multiple future stages, the modelling approach represents only the final stage of pit development when assessing pit lake water quality. This is because, during intermediate stages, the pits are expected to remain dewatered or to contain recovering pit lake levels that act as localised hydraulic lows relative to the surrounding groundwater contours. Under these conditions, the pit lakes are not expected to contribute to plume development extending away from the pit.

Table E-2.9 Summary of pit lake water quality inputs

Pit Lake	Stage/s Represented	Water Quality – Pre 2026	Water Quality – Post Mining[1]
Coronation North	Existing (CN4) / CN6 CN Backfill: Existing CNBF, CNBF2, CNBF3	MAC-Coronation North Pit, Figure E-2.16	CN_Full_WQ_Results_2906206.xlsx (MWM 2026)
Coronation	Existing (CO5) / CO8	MAC-Coronation Pit, Figure E-2.18	CO_Full_WQ_Results_29062026.xlsx (MWM 2026)
Deepdell North	Existing (DN3)	MAC-Deepdell North Pit, Figure E-2.26	GoldenBar_Full_WQ_Results29062026.xlsx (MWM 2026)
Innes Mills	IM13	No formed lake	IM_Full_WQ_Results_Clean_with_BF_29062026.xlsx (MWM 2026)
Golden Bar	Existing / GB3	MAC-Golden Bar Pit, Figure E-2.15	GoldenBar_Full_WQ_Results29062026.xlsx (MWM 2026)

[1]. Commences on completion of mining in each individual pit lake.

Dissolved Organic Carbon (DOC) has not been historically sampled in pit lakes, and hence, there is no reference values to apply in the predictive modelling. DOC is a toxicity modifier for Copper, Nickel and Zinc (Viridis 2026a Table 3), where, increasing DOC raises the trigger value. On this basis it is considered conservative to assume DOC = 0 g/m³ in pit lake waters and this is applied in the modelling.

Deepdell North Pit does not form part of the Project, however, is included to appropriately represent cumulative effects. Water quality has been modelled with the assumption that the pits water balance is similar to the Golden Bar pit lake and applies the Golden Bar pit lake water quality as a proxy.

E-2.3.5 Tailings Storage Facilities

TSF seepage water is applied in the WBM as per Table E-2.10.

Table E-2.10 TSF seepage collection drains water quality source terms – mean value inputs

Parameter [g/m³]	MTI Combined	TTTSF
Ammonia	9.4	7.0
Arsenic[1]	6.3	5.2
Copper[1]	0.0019	0.0014
Hardness	1900	2600
Iron[1]	13	23
Lead[1]	0.00038	0.00027
Nitrate	0.01	0.85
Sulphate	2600	3100
Zinc[1]	0.0025	0.0025 [4]
DOC	0 [4]	0 [4]
Chloride	38	22
pH	7.1	7.3
Antimony	0.012	0.0005
Boron	0.5	0.4
Cn WAD	0.024	0.01
Data Source/s[2] [3]	MAC-CDBC Eastern Outlet MAC-Far Eastern UD/USCO MAC-Sump B - CDE MAC-Sump B - CDW MAC-Western CDBC MAC-Western UD/USCO	MAC-TTTSF Seepage Collection Sump

[1]. Based on total fraction.
[2]. Data summarised as median values from 2020-2026 and infilled with older data where parameters were not available.
[3]. Concentrations prorated by measured flows.
[4]. No data available, assumed value applied.

It is understood that while hydraulic mining of MTI is being undertaken the MTI pond will not be available for disposal of ‘Treated Industrial Wastewater’ as is current practice and it is proposed that this discharge be to FTSF decant pond via an oil separator. The discharge rate and contaminant load is low compared with other inflows to the sites operational TSF. This contribution has not been explicitly modelled, however, is expected to have a negligible influence on FTSF water quality.

E-2.3.6 Site Specific Mass Flux Additions

Model calibration identified that arsenic concentrations were underestimated by the WBM at DC07 and DC08 and indicate elevated arsenic contributions from legacy mining features. This is further discussed in Viridis 2026. To capture this input within the current effects assessment an arsenic base load is added to the model.

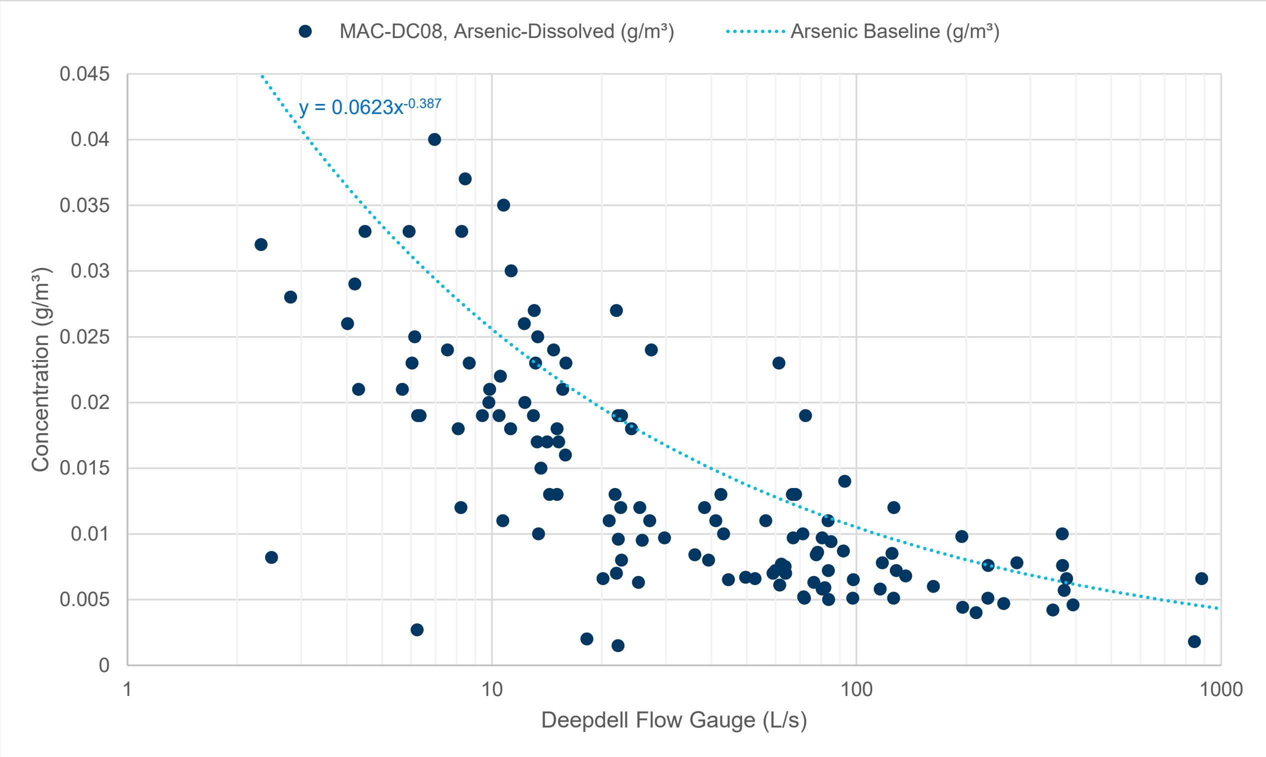

Figure E-2.27 DC08 measured arsenic concentrations (2012-2026)

Figure E-2.27 shows measured arsenic concentrations against measured flow rates within Deepdell Creek where data was collected between 2012 and 2026. A curve is fit to the data to approximate 70% of the maximum observed concentrations. An additional arsenic mass flux (no flow) to DC07 ($M_{As,DC07}$) is represented by the following equation:

$$M_{As,\ DC07} = Q_{DC07}\left(\min\left(0.04, 0.0623 \times Q_{DC04}{}^{-0.387}\right)\right) \qquad \text{Equation E-2.4}$$

Where Q_{DC07} is the flow at DC07 and Q_{DC04} is the gauged flow at DC04. Based on the measured data a maximum concentration of 0.04 is represented via this mechanism, however, other contributions can elevate the concentrations above this value. With this mass flux added at DC07, the resultant calibration can be observed as slightly conservative for arsenic within Section E-3.

E-2.4 Groundwater to Surface Water Interactions

Interactions between groundwater and surface water across the site are built into the WBM. These interactions are represented in the following ways:

1. Background (natural catchment) groundwater is represented through the calibrated AWBM for stream flow (see Section E-2.2.3) which includes surface and groundwater flows. These inflows are represented with contaminant concentrations as described in Table E-2.5.
2. Pits and Pit lakes can receive inflow from the surrounding rock mass or lose water from the lake based on the net inflow and net outflow relationships described in Section E-2.5.1. The contaminant mass flux associated with the inflows is captured within the derived pit lake water quality (refer to MWM 2026c,d,e,f), which is modelled as a source term in the WBM. The contaminant mass discharge associated with water flow from the lake to the surrounding rock mass is conservatively represented as immediately reporting to downgradient nodes. Where the receiving nodes are defined based on the understanding of plume development gained from the groundwater modelling as outlined in Appendices A-C. As the flow contribution is considered to be represented by the AWBM runoff model (see Section E-2.2.3) only the contaminant mass flux is added to the receiving node (not the corresponding flow). Where these mass fluxes from pit lake outflow via ground are modelled as discharging to a receiving stream, a conservative modelling approach is applied. This approach adds the mass flux to the stream node up to the limit where the instream concentration exceeds the pit lake concentration. In this case the contribution from pit lake seepage water would dilute (improve) in stream water quality and is conservatively ignored. This captures the behaviour whereby groundwater flow driven from large water bodies (i.e. pit lakes) will have a relatively larger contribution to receiving waters through dry / low flow periods. However, it remains conservative as during low flow periods, the un-diluted plume contribution can trend towards representing the total flow contribution to a node. A summary of the receiving water nodes is outlined in Table E-2.11.
3. WRS seepage flow (i.e. mine affected groundwater discharging from WRSs) is represented as reporting directly to the next downstream node, less any fraction captured through proposed mitigation measures. This includes direct and basal seepage components without delays or dilution applied to diffuse seepage flow paths.
4. TSF embankments are represented in the same manner as WRSs. In practice this likely represents a conservative representation of the embankments as drains constructed within the embankments may offer more effective drainage and capture than toe capture systems.
5. Impoundment seepage through long-term plume development from TTTSF is represented based on GHD (2022a) which assesses long-term plume development from TTTSF towards Frasers TSF, Cranky Jims Creek and Top Tipperary Creek.

Table E-2.11 Summary of Pit and TSF GW outflow integration to WBM

Pit	GW Outflow Receiving Nodes	Comments
Coronation North Pit	MB01 – 50% of net outflow MB02 – 50% of net outflow	Plume effects are conservatively considered to bypass the Coal Creek Dam and Māori Hen silt pond, which would result in the mass flux being diluted in the larger bodies of water.
Coronation Pit	Trimbells silt pond (100%)	Groundwater modelling indicates that the bulk of the plume develops through in-situ schist under the Trimbells Gully WRS.
Deepdell North Pit	DC07 - 100%	
Golden Point / Round Hill Pits	DC07 - 100%	Note that mitigations systems may be applied such that the water level / groundwater level is maintained low enough to avoid this GW discharge.
Innes Mills Pit	DC07 - 100%	Conservative application of net GW outflows given the dominant plume direction is towards the Golden Point Pit and GPUG workings.
Frasers Pit / TSF	Innes Mills Pit	Seepage from FTSF report to the Innes Mills Pit lakes based on the relationships described in Section E-2.5.2.5
	Murphys seepage capture system / silt pond	Seepage from the TSF via Frasers South Backfill to Murphys Creek is represented as per WRS seepage and reports to the proposed Murphys Creek Seepage capture system. Flow rates are described in Appendix D as a function of the tails level in FTSF.
Golden Bar Pit	GB02 – 100%	
TTTSF Embankment	TTTSF Sump	Captured seepage (75%) is returned to the MWMS and the uncaptured seepage fraction discharges to Top Tipperary Creek.
TTTSF Impoundment	CJ01, TC01, Frasers Pit	Plumes from uncaptured TTTSF impoundment seepage discharge to the down gradient surface water nodes based on the GW modelling presented in GHD (2022a)
MTI Embankment	Sump B – 100%	Captured seepage (75%) is returned to the MWMS and the uncaptured seepage fraction discharges to Deepdell Creek.
MTI Impoundment	MWMS/Sump B	Underdrains returned to the MWMS, then WTP on closure.

E-2.4.1 Groundwater Drawdown Representation

Groundwater drawdown occurs due to the dewatering of mining pits on site which results in a decrease in the water table. This in turn, influences the recharge of the streams and rivers on site. This effect is quantified from the groundwater modelling (Appendices A-C) through a percentage decrease of the mean recharge flow to the stream or river sections.

Table E-2.12 Summary of groundwater recharge reductions from groundwater modelling

Area	Surface water effected	Recharge Reduction (L/s)[1]	Change in SW Recharge[2]
Coronation	Mare Burn (MB01)	-0.5	4.0% increase
	Mare Burn (MB02)	-0.5	3.9% increase
	Deepdell (Camp Creek)	0.3	2.8% decrease
	Deepdell (DC08)	0.7	4.4% decrease
Central site	Deepdell Creek to DC08	1.5	3.4% decrease
	Waikouaiti River North Branch (NBWRRF)	0.1	<0.5% decrease
	Murphys Creek (MC01)	- 0.2	0.6% increase
	Tipperary Creek (TC01)	0.1	<0.5% decrease
	Shag River (at Loop Road)	0.1	<0.5% decrease
Golden bar	McCormicks Creek (Shag River at McC)	0.15	0.4% decrease
	Murphys Creek (MC02)	-0.07	0.2% increase

[1]. Reduction from current conditions as represented in the GWM.
[2]. Pecentage increases and decrease are represented based on mean recharge contribution to surface water bodies for the modelled length of reach only (i.e. not based on the total flow rate in those reaches).

Table E-2.13 describes how the groundwater recharge reductions from Table E-2.12 are applied in the WBM. Where the modelled reductions in recharge flows are less than 1% of mean river recharge flow rates, these are considered negligible and not included in the modelling.

Where the reduction in recharge is greater than 1%, this effect is incorporated into the surface water model through a reduction in the natural catchment recharge rates corresponding to the expected drawdown effects based on Equation 2 below. In this equation $Q_{Natural,Node}$ represents the reduced natural catchment flow contribution to a node in L/s (between that node and the next upstream node), $Q_{AWBM,Node}$ represents the natural catchment flow contribution to a node without drawdown effects, Q_{RR} represents the mean recharge reduction rate in L/s, and $A'_{Affected}$ is an approximation of the natural catchment area fraction affected by the drawdown (recharge reduction). This is important where an upstream node is considered, such that the WBM doesn't assume all contributing flows up to Q_{RR} are lost.

$$Q_{Natural,Node} = Q_{AWBM,Node} - Min(A'_{Affected} \times Q_{AWBM,Node}, \quad Q_{RR}) \qquad \text{Equation E-2.5}$$

Based on Equation E-2.5, where the affected area is assumed to be 1.0, the total natural flow recharge assigned to a node is modelled as zero where the recharge reduction is equivalent to the natural node flow contribution. The contaminant transport component of the WBM assumes that all flow lost is attributable to the natural catchment inflows, hence the reduction in mass contributions is based on the natural catchment water quality. This effectively results in a loss of diluting flows and hence increases the modelled concentrations at a node.

The recharge reductions provided in Table E-2.13 are applied in the WBM by assuming the effect is fully realised at the start of MP4 mining and maintained though the active mining phase as pits and underground features are generally dewatered gradually. The recharge reduction is then diminished linearly with time as the pits refill and groundwater levels recover.

Table E-2.13 Groundwater recharge reductions as applied in WBM

WBM Node	Flow Recharge Reduction, Q_{RR} (L/s)	Area Fraction, $A'_{Affected}$ (-)	Applied to Date	Comments
Camp Creek Dam	0.3	1 (Camp Creek)	1/1/2055 Coronation Pit dewatering is assumed to be the key driver of this flow reduction (Ref. Appendix G, Coronation Pit Lake filling)	Effect on the Camp Creek catchment and reflected at the Camp Creek Dam node within the WBM.
Deepdell Creek at DC07	2.2	1 (DC04-DC07)	1/1/2066 GPUG is assumed to be the key driver for this flow reduction. (Ref. Appendix C, GPUG recovery)	Representing the sum of effects represented in the Coronation area and Central area GWM. GWM discretisation represented the area to DC08, however, in practice most the effect is expected to be realised by the confluence with Highlay Creek, therefore is represented in the WBM as a reduction at DC07.

E-2.5 Pits

E-2.5.1 Modelling Approach

Groundwater movement occurs due to the difference in groundwater levels between the mine pits and the surrounding water table. Typically, inflows are high when pit lake levels are low and decrease as the pit lake level recovers with time. Groundwater outflows are generally low at low pit lake levels and increase as the pit lake recovers. Groundwater inflows and outflows for mine pits are determined through an iterative process between the WBM and GWM. This process involves:

1. An initial filling rate is determined by the WBM accounting for catchment delineations, stage volume relationships and previously GWM results.
2. The filling rate is applied in the GWM as a general head boundary. The model is run to determine net inflows and outflows (i.e. flow from the pit void to surrounding rock mass, and flow from the rock mass to the pit void) at each modelled timestep. This model run includes other modelled features changing within the timeline (i.e. the change in modelled infiltration rates and changes in adjacent pit water levels). The differentiation of inflow and outflow is important to define contaminant mass flows away from the pit.
3. The net inflows and outflow are represented in the WBM as a function of lake level (i.e. they are agnostic to time, based on the assumption that the groundwater flows are more strongly related to level rather than duration, particularly ling-term). The WBM is re-run with the revised groundwater flow representation for each pit lake to determine revised filling rates.
4. Steps 2 and 3 are repeated where there was a significant difference in the revised filling rates.

Refer to Appendices A-C for further details of the groundwater modelling. The applied pit inflow and outflow relationships are detailed in Section E-2.5.2 for each pit lake. The following points summaries how pit lake filling is represented in the WBM:

– Inflows and outflows are determined on a stage basis in the model, with the model utilising a look up at each time step to determine the relevant groundwater flows depending on the pit lake level. The stage relationships are simplified when inflows or outflows are relatively similar over a range of pit lake levels.
– Rainfall on surface is one of the pit lake inflows and describes the rainfall that directly falls on the pit lake surface. This is directly proportional to the pit lake area and therefore increases as a proportion of the total inflow as the pit lake level (and area) increases.

– Rainfall runoff is treated differently according to the surface it falls on before reaching the pits, with each surface having a defined runoff coefficient.
– Evaporation occurs on the surface of the pit lakes on site and is accounted for in the model as referenced in section E-2.2.2. The amount of evaporation is proportional to the pit lake surface area and is a significant pit lake outflow increasingly as surface area increases.

Where relevant, pit lakes have a defined spill level that once reached, will result in overflow to a nearby catchment. The pit lakes are assigned an overflow rating curve which determines the overflow rate depending on the lake level above the spill point. The overflow rating curve is represented by a broad crested weir with a v-notch that results in a large increase in the overflow rate with small increases in pit lake level. A typical curve is presented in Figure E-2.28.

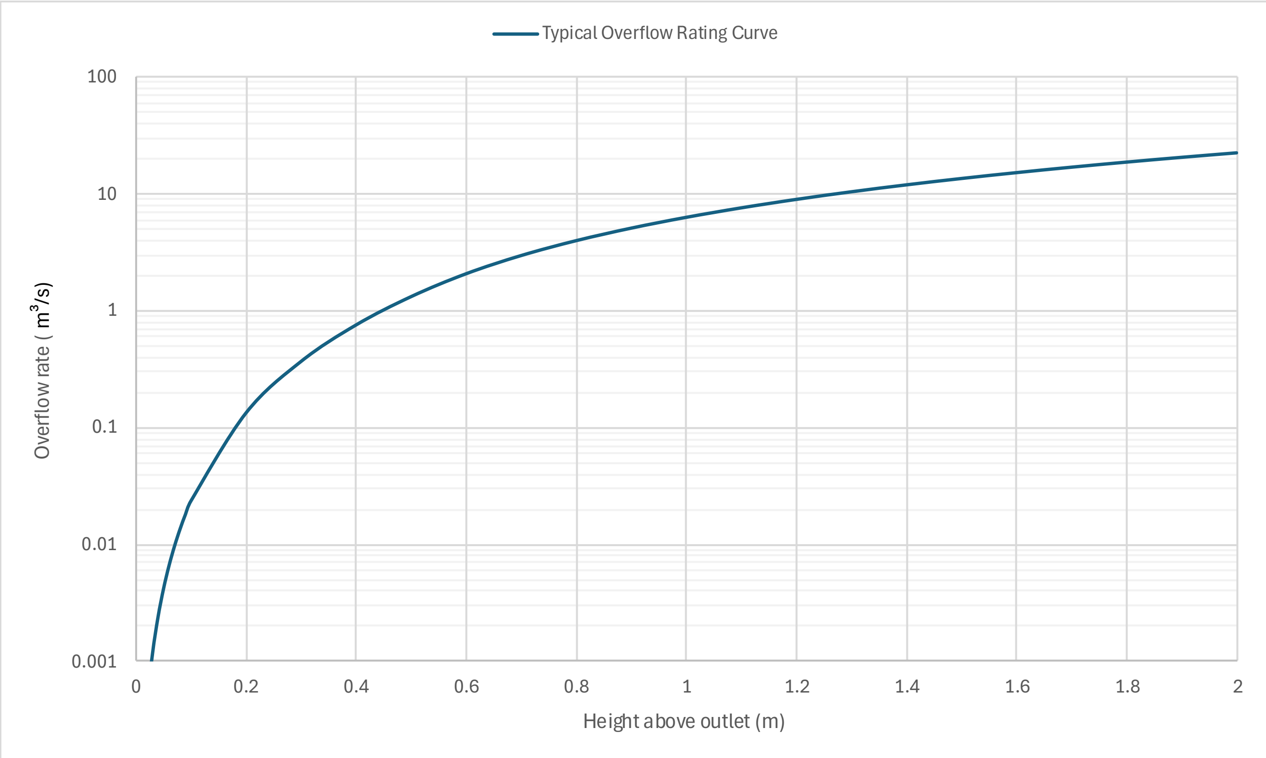

Figure E-2.28 Overflow rating curve for a broad crested weir with a v-notch

E-2.5.2 Input Data

Table E-2.14 defines both initial water levels and future overflow levels for each of the pits and the following subsections outline the water storage volumes and surface areas for the developing pit lakes. The storage volume represents the open void of each lake plus the void space within any pit backfill. Pit backfill is assumed to have a porosity of 19%. The table defines:

– The overflow level as the lowest discharge level (i.e. the invert of the discharge weir/channel), and
– The initial water level, representing either the conditions at the end of pit dewatering or initial model conditions where additional dewatering/pit workings are not undertaken.

Table E-2.14 Pit overflow and water level summary table

Pit Name	Overflow Level (mRL)	Initial Water Level (mRL)	Application Notes
Coronation Pit	625	535	Pit backfilled to 620 mRL prior to closure. Overflow to Camp Creek upstream of the Camp Creek Dam.
Coronation North Pit	562.5	450	Overflow to Coal Creek upstream of the Coal Creek Dam.
Deepdell North Pit	455	370	Overflow to Deepdell Creek
Deepdell South Pit	380	365	Pit is now backfilled and assumed saturated to the overflow, all seepage accumulated within the pit lake spills via the overflow level to Deepdell Creek.
Frasers Pit	520	510	Overflow level applies while the TSF is active, Once deposition is completed the surface is dry capped on closure and no water body represented. For the purposed of driving level dependent flows from FTSF to Innes Mills Pit and Murphys Creek the phreatic surface within the tailings is represented at 510 mRL.
Golden Bar Pit	500	418	Overflow to Golden Bar Creek upstream of GB02. Lake is modelled as fill and overflowing under current conditions, until dewatering commences. No overflow then occurs until lake has refilled.
Golden Point Pit	400	332	Pit and backfill dewatered permanently, will not fill. The surface overflow level would be hypothetically at 400 mRL should a lake form, however, flow through the historic adits at lower levels would prevent this from occurring. No pit lake formation (or backfill saturation) is represented above the adits.
Innes Mills Pit	473	330	Overflow to Deepdell Creek.

E-2.5.2.1 Coronation North Pit

Cumulative water volume and pit lake surface area data is defined by stage for mine pits in the model and can be visualised in Figure E-2.29 for Coronation North Pit. Note that the area representation is shown to decrease as the level rises in some instances. It is recognised that this will not occur in practice and is a function of the input geometry data representing small 1m high lifts within a coarser block model of the pits and WRS. This is not expected to introduce significant errors into the modelling.

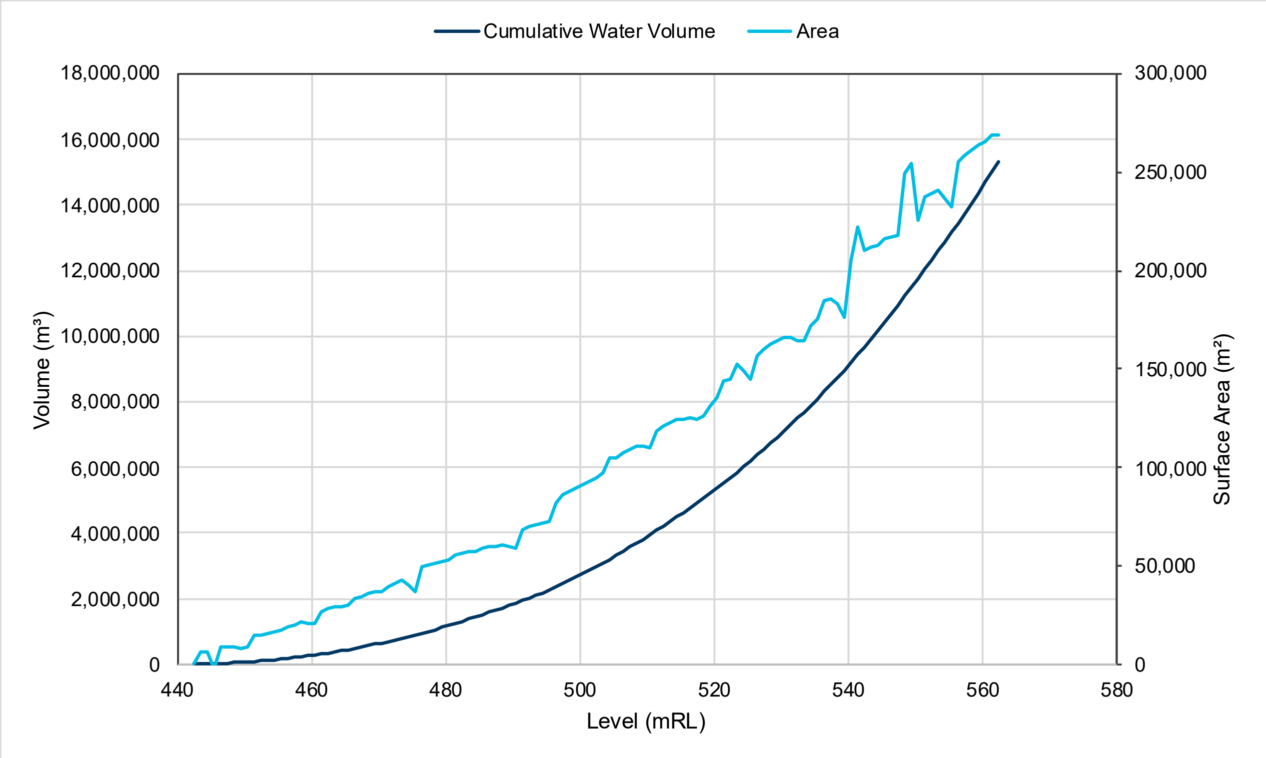

Figure E-2.29 Coronation North Pit Stage-Volume-Area Relationship

Groundwater inflows and outflows are also categorised by stage and are presented in Table E-2.15. Groundwater inflows decrease relatively uniformly with rising pit water level; no groundwater outflows are expected until the pit lake level reaches 555 mRL.

Table E-2.15 Coronation North Pit Groundwater Flows

Relative Level [m]	Groundwater Inflow [l/s]	Groundwater Outflow [l/s]
450	2.04	0
460	1.99	0
470	1.93	0
480	1.85	0
490	1.77	0
500	1.7	0
510	1.64	0
520	1.59	0
530	1.52	0
540	1.45	0
550	1.36	0
555	1.3	0.031
558	1.27	0.128
560	1.24	0.167
562	1.23	0.194
562.5	1.22	0.205

E-2.5.2.2 Coronation Pit

Cumulative water volume and pit lake surface area data is presented in Figure E-2.30 for Coronation Pit. As the pit is backfilled to 620 mRL, the pit volume below this level is determined as the void space in the backfill calculated as 19% of the total backfill volume. As filling of this void space is represented, there is no applied evaporation due to there being no exposed surface water body.

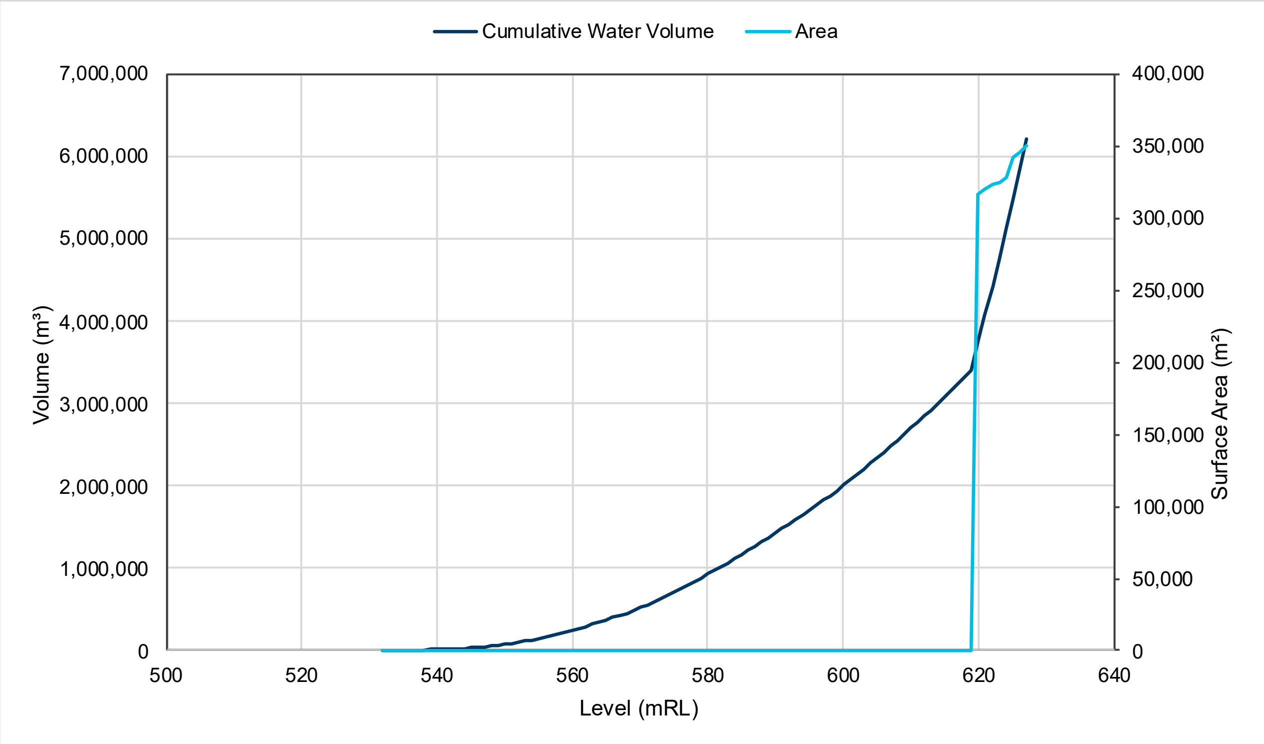

Figure E-2.30 Coronation Pit Stage-Volume-Area Relationship

Groundwater inflows and outflows are also categorised by stage in the model and are presented in Table E-2.15. Groundwater inflows decrease relatively uniformly with rising pit water level; no groundwater outflows are expected until the pit lake level reaches 614 mRL.

Table E-2.16 Coronation Pit Groundwater Flows

Relative Level [m]	Groundwater Inflow [l/s]	Groundwater Outflow [l/s]
535	1.63	0
545	1.49	0
555	1.36	0
565	1.22	0
575	1.09	0
585	0.95	0
590	0.88	0
595	0.82	0
600	0.74	0
605	0.66	0
610	0.59	0
612	0.56	0
614	0.53	0.01
616	0.53	0.014

Relative Level [m]	Groundwater Inflow [l/s]	Groundwater Outflow [l/s]
618	0.51	0.026
620	0.49	0.047
622	0.48	0.07
624	0.47	0.087

E-2.5.2.3 Deepdell North Pit

Deepdell North Pit Cumulative water volume and pit lake surface area data is presented in Figure E-2.31.

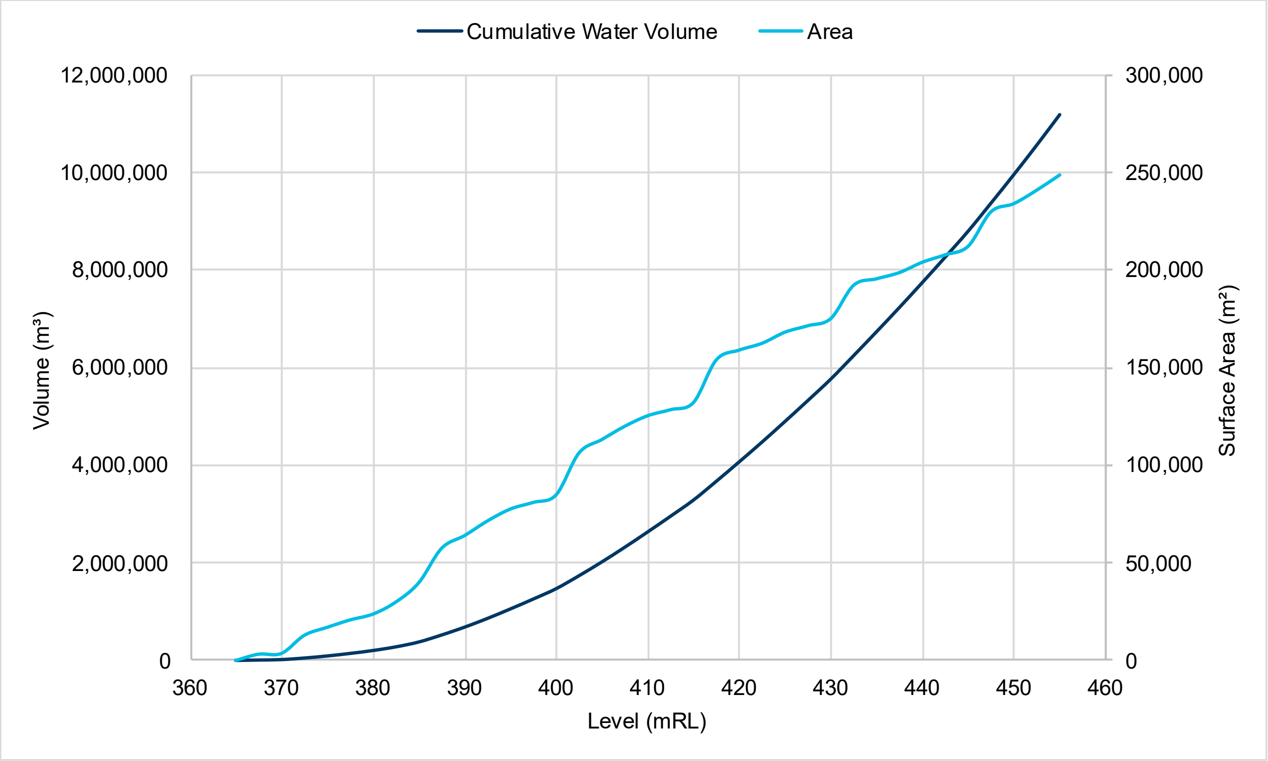

Figure E-2.31 Deepdell North Pit Stage-Volume-Area Relationship

E-2.5.2.4 Golden Bar Pit

Deepdell North Pit Cumulative water volume and pit lake surface area is presented in Figure E-2.32.

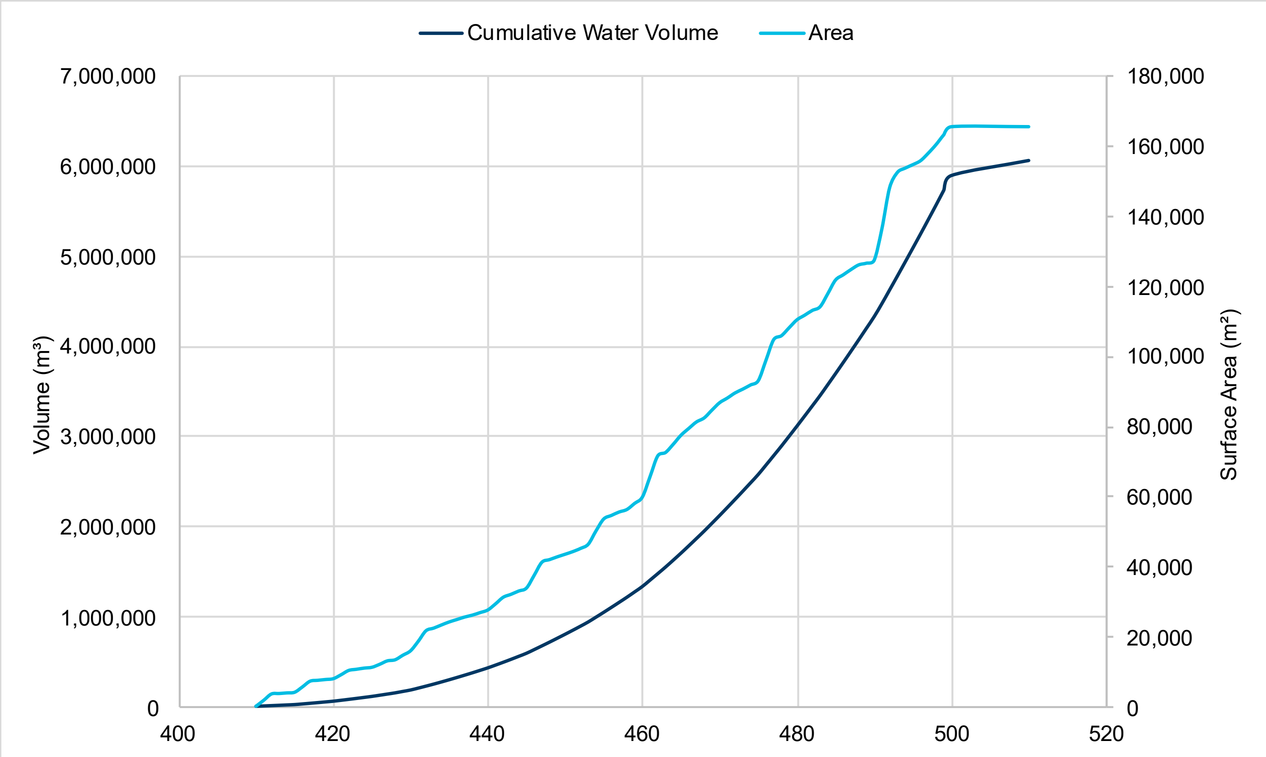

Figure E-2.32 Golden Bar Pit Stage-Volume-Area Relationship

Groundwater inflows and outflows defined in the model for stage 1 and 2 of the Golden Bar Pit are presented in Table E-2.17. Groundwater inflows decrease rapidly as the pit lake level recovers in both stages of Golden Bar Pit in the model. Outflows were only predicted for stage 2 and are modelled to be minimal.

Table E-2.17 Golden Bar Pit Groundwater Flows

Relative Level [m]	Groundwater Inflow 1 & 2 [l/s]	Groundwater Outflow[1] 2 [l/s]
423.2	3.2689	0.0034
430.7	0.6605	0.0035
454.1	0.5641	0.0046
497.6	0.314	0.0008
500	0.2795	0.0006

[1]No groundwater discharge was predicted for the initial Golden Bar Pit

E-2.5.2.5 Innes Mills Pit

Cumulative water volume and pit lake surface area is presented in Figure E-2.33.

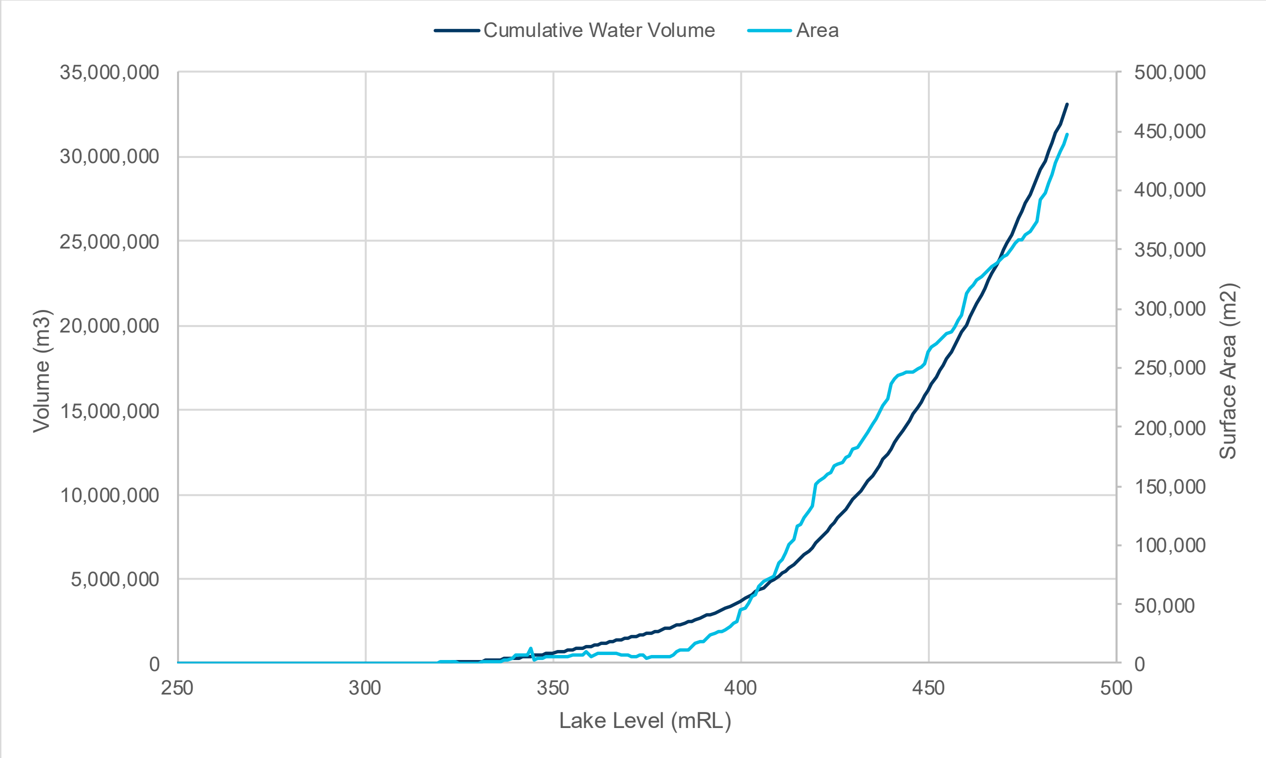

Figure E-2.33 Innes Mills Pit Stage-Volume-Area Relationship

Groundwater inflows and outflows defined in the model are presented in Table E-2.18 (these are derived from the groundwater model outputs shown in Figure E-2.34). Groundwater inflows decrease consistently with increasing pit lake levels. Groundwater outflows decrease with rising pit lake level until 440 mRL before beginning to increase until the overflow point is reached at 475 mRL. Due to the unique arrangement of the Frasers-Innes Mills pit voids, which are represented by a single as-mined void separated by a constructed embankment, a preferential GW flow direction will develop between the FTSF and Innes Mills pit lake. The rate at which water flows from FTSF to Innes Mills pit lake is captured in the groundwater modelling and represented as a quantified inflow because it represents the bulk of groundwater inflows.

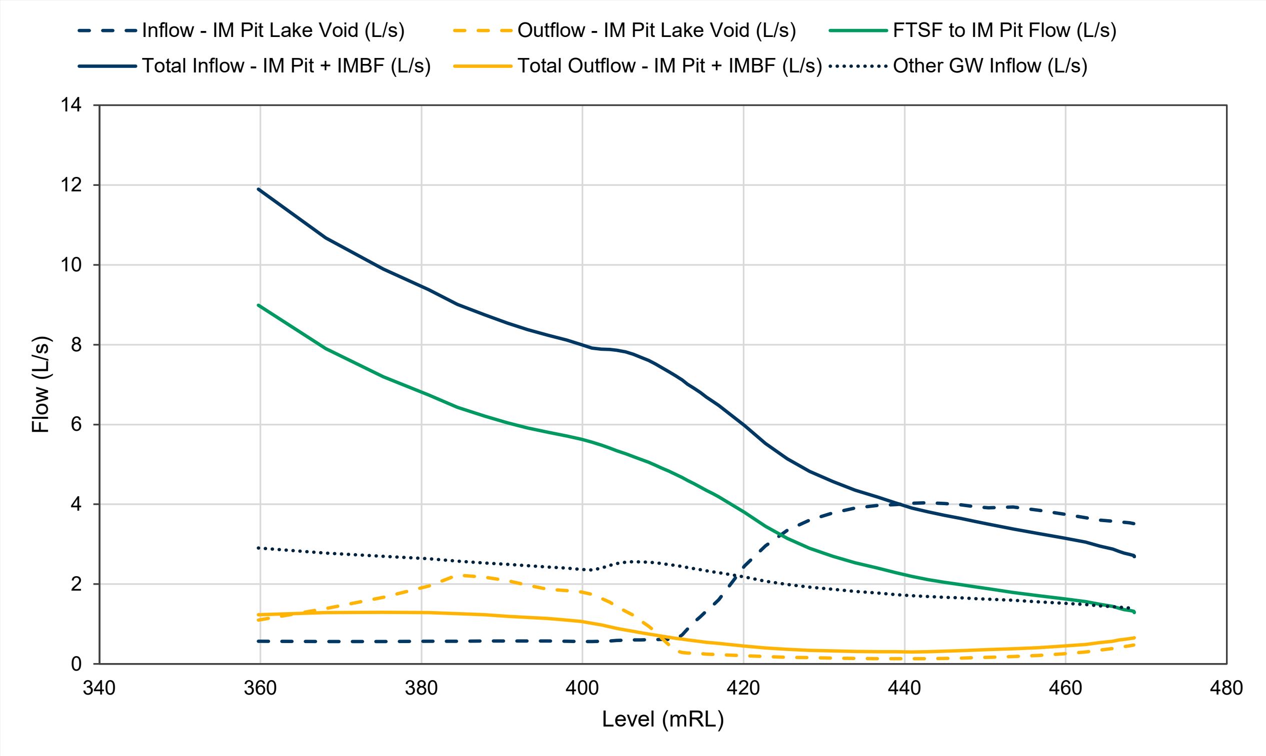

Figure E-2.34 Innes Mills pit lake groundwater interaction, from groundwater modelling.

Table E-2.18 Innes Mills Pit Groundwater Flows

Relative Level [m]	Groundwater Inflow [l/s]	Groundwater Inflow from FTSF [L/s][1]	Groundwater Outflow [l/s]
360	2.91	8.99	1.24
385	2.58	6.43	1.26
400	2.37	5.63	1.06
405	2.52	5.34	0.89
412	2.47	4.75	0.64
420	2.29	4.19	0.51
430	1.93	2.90	0.34
440	1.74	2.29	0.3
460	1.52	1.64	0.45
470	1.41	1.29	0.66
475	1.35	1.13	0.67

[1]. Groundwater inflow from FTSF via Frasers Backfill and Innes Mills backfill

E-2.6 Engineered seepage capture drain and treatment plant

The engineered seepage capture drain comprises of a series of drains that captures shallow WRS seepage in localised sumps before being transferred to the mine water management system (MWMS) or WTP. For a detailed explanation of this system and WBM implementation, refer to Appendix F. An overview of how this is applied in the WBM is outlined in Figure E-2.35.

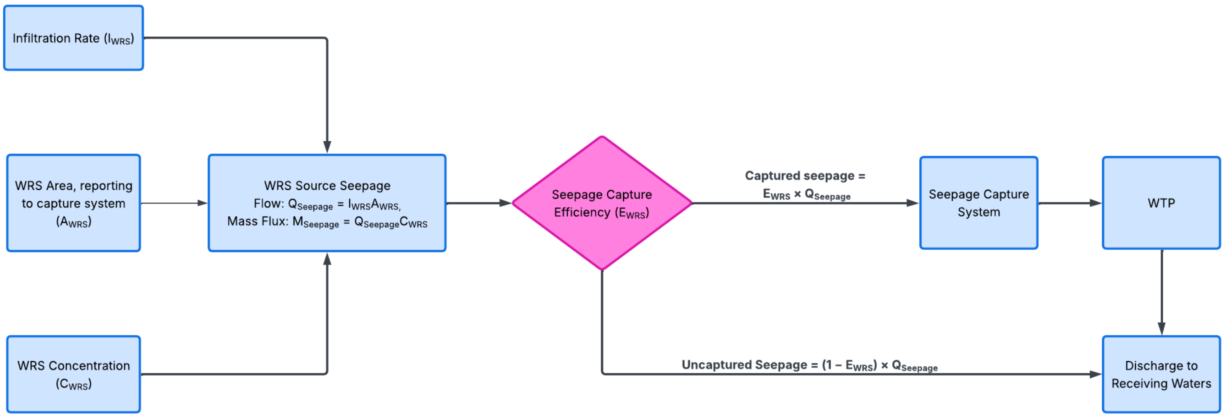

Figure E-2.35 Seepage capture system – WBM implementation

Within the WBM, seepage from WRSs with seepage capture systems is split based on a seepage capture efficiency (E_{WRS}), with the captured portion being directed to the MWMS or WTP. The remaining fraction discharges directly to the next downstream node in the WBM. When the WTP is activated in the model, seepage that was previously removed and assigned to the MWMS will be treated by the WTP. The contaminant load and flow are reduced by the defined treatment fractions before being returned to the node discharged to. As the flows may reduce through the WTP, the flow reduction is accounted for by removal of 15% of flow as brine from the discharge. For details on WTP operation refer to Appendix F.

E-2.6.1 Golden Point Seepage Capture Bores

The seepage capture system includes bores installed within the Golden Point Backfill that control mine water levels, such that flow is not induced through the historic Golden Point Adits to Deepdell Creek. Groundwater modelling shows that seepage capture from the bores will increase to approximately 3.8 L/s in the long term (Figure E-2.36). The flow is initially low as seepage reporting through the pit contributes to recharge of GPUG, and rates rise over a period of approximately 30 years after dewatering of GPUG ceases. A second raise in the flow rate occurs associated with the filling of Innes Mills pit lake. The flows captured by these bores include seepage from percolation through the Golden Point Backfill, with additional groundwater contributions from the Innes Mills Pit lake. Groundwater contributions from MTI and Northern Gully WRS could also occur due to hydraulic gradients towards the seepage capture bores. The WBM represents the seepage capture flows in Figure E-2.36 as reporting to the seepage capture system. These flow rates are assumed to include the long-term infiltration based on the seepage area assigned to the Golden Point Backfill. This flow data is abstracted from the GWM from the drain nodes defined in the Golden Point and Round Hill Pits. This component of the flow is modelled in the same manner as other WRSs with seepage capture infrastructure installed as described in Appendix F.

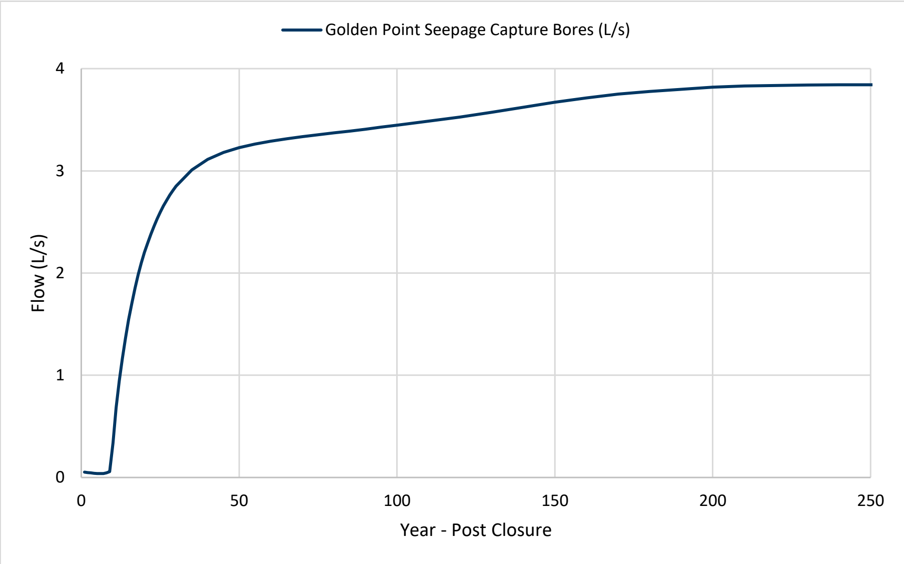

Figure E-2.36 Seepage capture bores – based on drain nodes within GWM

E-2.7 Tailings Storage Facilities

During the active mining phase, tailings storage facilities are used to store water utilised by the MWMS. Refer to Section E-2.11 for a description and application of the MWMS. TSFs include TTTSF, MTI, SP11 and Frasers TSF with the undertaking of MP4.

Upon closure of the mine, it is presumed that all TSFs are capped with a vegetated and water shedding surface. The resulting runoff is allocated by the water balance model via overland flow paths.

TSF underdrains are represented based on the flow rates in Table E-2.19. During the operational phase, water from the underdrains is used on site and managed by the MWMS. In the closure phase, underdrain waters are captured through the existing set of sumps and pumped to the WTP for treatment. The detailed drawdown assessments determining the underdrain flow rates are presented in GHD (2024c). This report present 2D groundwater modelling results estimating seepage rates from the facilities under 'current' conditions, closure (2030), post closure (2050) and long-term (~2430).

Table E-2.19 TSF under drain flow rates

Date	MTI [L/s]	SP11 [L/s]	TTTSF [L/s]	FPTSF [L/s]
1/01/2025	8.5	4.7	28	N/A[2]
1/01/2030	5.8	N/A[1]	22	
1/01/2050	3.9		12	
1/01/2430	1.5		4	

[1]. SP11 removed as part of the Project and will no longer generate underdrain seepage.
[2]. All Frasers TSF seepage is assumed to report to IM Pit, and the Murphys Creek SCS based on the differential level seepage flow rates.

E-2.8 Flow Augmentation Dams

Existing and consented dams have been incorporated into the WBM. This includes the existing Tipperary Freshwater Dam and Lone Pine water storage reservoir (WSR) and consented (but not constructed) Camp Creek and Coal Creek Freshwater Dams. Operational controls in the model include constant and variable discharge. For variable discharge, water for the dam is released inversely to the flow in the river. This maintains minimum flows during dry periods, augmenting recharge losses from mining and reducing the risk of contaminant exceedances through dilution.

The dams are implemented in the WBM with the following characteristics:

Lone Pine WSR – implemented for operational use only, integrated into the MWMS. This dam is only actively managed within the WBM for operational use during the mining phase. Post closure, it is assumed that the dam is retained and levels within the dam react to natural inflows and overflows. Refer to Table E-2.21 for staged data.

Tipperary freshwater dam – is modelled with a constant discharge of 2 L/s unless the natural overflow is reached, or the storage dries out and outflows match inflows. Refer to Table E-2.20 for staged data.

Coal Creek Dam – As per Consent No. RM16.138.08 a minimum discharge of 3 L/s is maintained to the creek downstream of the dam, with an additional rated discharge to achieve flow and water quality targets within the Mare Burn. Details on the proposed dam operation are outlined in Appendix F. Refer to Table E-2.22 for staged data.

Camp Creek Dam – As per Consent No. RM10.351.38 a minimum discharge of 2 L/s is maintained to the creek downstream of the dam, with an additional rated discharge to achieve flow and water quality targets within Deepdell Creek. Details on the proposed dam operation are outlined in Appendix F. Refer to Table E-2.23 for staged data.

Table E-2.20 Tipperary Freshwater Dam Height-Volume-Area Data

Height (mRL)	Volume (m^3)	Area (m^2)
444	0	0
444.5	50	200
445	200	428
445.5	478	1,300
446	1,500	2,479
446.5	2,957	3,338
447	4,838	4,174
447.5	7,131	4,988
448	9,826	5,778
448.5	12,909	6,545
449	16,371	7,289
449.5	20,199	8,011
450	24,381	8,709
450.5	28,908	9,385
451	33,766	10,037
451.5	38,900	11,000

Table E-2.21 Lone Pine Dam Height-Volume-Area Data

Height (mRL)	Volume (m^3)	Area (m^2)
420	0	0
421	51	160
422	561	830
423	1,842	1,700
424	4,167	2,860
425	7,620	3,940
426	12,204	5,140
427	18,104	6,550
428	25,435	8,020
429	34,757	10,240
430	45,973	12,020
431	59,274	14,430
432	75,159	17,090
433	93,730	19,780
434	115,020	22,560
435	139,326	25,850
436	167,262	29,740
437	199,417	34,200
438	236,341	39,260
439	278,500	44,670
440	326,932	51,750
441	383,550	61,060
442	449,818	71,280
443	526,785	80,800
444	593,846	86,160

Table E-2.22 Coal Creek Freshwater Dam Height-Volume-Area Data

Height (mRL)	Volume (m^3)	Area (m^2)
464	0	0
465	6,219	2,550
466	9,384	3,873
467	14,057	5,567
468	20,612	7,634
469	29,419	10,074
470	40,852	12,885
471	55,282	16,069
472	73,082	19,624
473	94,624	23,553
474	120,280	27,853
475	150,423	32,525
476	185,424	37,570
477	225,655	42,986
478	271,490	48,775
479	323,299	54,937
480	381,456	61,470
481	446,332	68,376
482	518,300	75,653
483	597,732	83,303
484	685,000	93,000

Table E-2.23 Camp Creek Freshwater Dam Height-Volume-Area Data

Height (mRL)	Volume (m^3)	Area (m^2)
413	0	0
414	200	654
415	2,261	3,665
416	6,865	5,617
417	13,571	7,870
418	22,680	10,424
419	34,493	13,278
420	49,312	16,434
421	67,437	19,890
422	89,168	23,648
423	114,808	27,706
424	144,656	32,066
425	179,015	36,726
426	218,184	41,687
427	262,464	46,949
428	312,158	52,513
429	367,565	58,377
430	428,986	64,542
431	496,723	71,008
432	571,076	77,774
433	652,347	84,842
434	740,836	92,211
435	836,844	99,881
436	940,672	107,851
437	1,052,622	116,123
438	1,172,993	124,695
439	1,302,088	133,569
439.5	1,370,000	137,000

E-2.9 Silt Ponds

Silt Ponds are constructed erosion and sediment control associated WRS construction and other site earthworks, allowing for the settlement of suspended solids in runoff on site before discharging to the environment via the pond overflow or decant systems. Silt ponds also capture seepage and surface runoff and typically discharge at a slow rate with much higher rates after rainfall events. Some silt ponds with poor water quality are pumped for used within the MWMS, minimising degraded water quality discharges to the environment.

Silt ponds included in the model and their volume to surface area relationship are presented below.

Table E-2.25 describes the Clydesdale Creek silt pond in its current arrangement. Through construction of the Golden Bar WRS, the pond will be infilled. The infilled pond is modelled as being retained with seepage capture through the existing decant system (this will require some modification to suit the purpose).

Table E-2.24 Battery Creek SP Volume Area Comparison

Volume (m^3)	Area (m^2)
0	0
15	115
103	243
269	392
483	466
736	550
1,034	642
1,381	745
1,781	867
2,251	1,012
2,817	1,255
3,492	1,447
4,263	1,651
5,172	1,952
6,208	2,181
7,355	2,417
7,853	2,417

Table E-2.25 Clydesdale SP Volume Area Comparison

Volume (m^3)	Area (m^2)
0	0
2,000	198
4,000	444
5,780	713
6,000	790
9,500	1,235
13,000	1,778
16,800	2,420
20,900	3,160
25,500	4,000

Table E-2.26 Coronation North SP Volume Area Comparison

Volume (m^3)	Area (m^2)
0	0
39	234
313	938
1,055	2,109
2,500	3,750
4,883	5,859
8,438	8,438
13,398	11,484
20,000	15,000

Table E-2.27 Coronation SP Volume Area Comparison

Volume (m^3)	Area (m^2)
0	0
2	10
14	41
46	91
109	163
212	254
366	366
581	498
867	650

Table E-2.28 Deepdell North SP Volume Area Comparison

Volume (m^3)	Area (m^2)
0	8
8	19
21	32
41	48
77	99
140	157
240	255
395	362
601	470
870	604
1,207	743
1,617	902
2,109	1,069
2,692	1,269
3,379	1,477
4,166	1,678
5,058	1,894
6,068	2,165
7,233	2,458
8,518	2,680
9,912	2,896
11,415	3,147
13,062	3,430
14,846	3,705
16,771	4,009
18,851	4,315
21,102	4,680
23,539	5,056
26,147	5,377
28,915	5,687

Table E-2.29 Deepdell South SP Volume Area Comparison

Volume (m^3)	Area (m^2)
0	0
10	33
36	72
85	125
163	188
275	262
427	349
626	450
879	564
1,193	697
1,578	840
2,034	987
2,566	1,142
3,179	1,316
3,894	1,548
4,729	1,794
5,691	2,050
6,777	2,295
7,986	2,542
9,321	2,800

Table E-2.30 Frasers East Sump Volume Area Comparison

Volume (m^3)	Area (m^2)
0	0
1000	1000

Table E-2.31 Frasers West SP Volume Area Comparison

Volume (m^3)	Area (m^2)
0	0
12	140
438	2,203
2,814	7,349
7,533	11,259
14,091	14,967
22,508	18,918
33,088	23,434
45,910	27,933

Table E-2.32 Māori Hen SP Volume Area Comparison

Volume (m^3)	Area (m^2)
0	0
39	234
313	938
1,055	2,109
2,500	3,750
4,883	5,859
8,438	8,438
13,398	11,484
20,000	15,000

Table E-2.33 Māori Tommy SP Volume Area Comparison

Volume (m^3)	Area (m^2)
0	0
74	405
467	1,048
1,097	1,465
1,905	1,758
2,873	2,059
4,038	2,653
5,460	3,037
7,079	3,445
8,925	3,945
11,036	4,670
13,542	5,358
16,344	5,825
19,363	6,254
22,615	6,818
26,134	7,332
29,860	7,660
33,791	8,069
37,928	8,487
42,267	8,875
46,803	9,266
51,534	9,662
56,466	10,074
61,649	10,657
67,104	11,198
72,819	11,673
78,768	12,145
84,960	12,618
91,384	13,090

Table E-2.34 Murphys SP Volume Area Comparison

Volume (m^3)	Area (m^2)
0	11
24	93
122	331
428	1,002
1,093	1,622
2,073	2,312
3,529	3,214
5,556	4,652
8,182	5,697
11,328	6,931
15,150	8,375
19,775	10,065
25,012	10,870
30,680	11,709
36,814	12,830
43,526	14,008
47,099	14,561

Table E-2.35 Northern Gully SP Volume Area Comparison

Volume (m^3)	Area (m^2)
0	0
32	133
140	302
340	506
655	764
1,105	1,048
1,696	1,329
2,441	1,661
3,368	2,059
4,513	2,532
5,915	3,092
7,597	3,635
9,552	4,188
11,784	4,748
14,302	5,325
17,111	5,908
20,213	6,495
23,608	7,086
27,300	7,682
31,292	8,284
35,590	8,899
40,217	9,550
41,178	9,674

Table E-2.36 Sump B Volume Area Comparison

Volume (m^3)	Area (m^2)
0	0
1000	1000

Table E-2.37 Tipperary SP Volume Area Comparison

Volume (m^3)	Area (m^2)
0	0
555	444
2,673	1,250
7,831	2,877
17,026	4,479
30,385	6,208

Table E-2.38 Tipperary Sump Volume Area Comparison

Volume (m^3)	Area (m^2)
0	0
479	383
2,013	844
5,378	1,848

Table E-2.39 Trimbells SP Volume Area Comparison

Volume (m^3)	Area (m^2)
0	0
39	234
313	938
1,055	2,109
2,500	3,750
4,883	5,859
8,438	8,438
13,398	11,484
20,000	15,000

E-2.10 Underground Workings

Dewatering flows from the underground workings are utilised within the MWMS during the operational phase of the mine and are not considered within the WBM. Upon closure, dewatering ceases and groundwater enters the void space left behind as groundwater levels recovers. The rate of the water level recovery is discussed in Appendix C. Note that groundwater model inputs applied in the WBM were developed without inclusion of brine storage in FRUG.

E-2.11 Operation Water Use and Mine Water Management System

The Macraes Mine generally runs at a water deficit and tops up water for processing use through a permitted water take from the Taieri River. This water is stored within the Lone Pine WSR prior to use on site. For the purpose of this WBM with a focus on environmental discharges and receiving water analysis, it is assumed that water within the MWMS can be considered a closed loop. This includes:

- Water used for processing and transport of tails,
- Water within the TSF impoundments,
- Water used for dust suppression, and
- Water used within the underground for drilling operations.

Where this water contributes to discharges to the environment via groundwater discharges as assessed by the Groundwater modelling (Appendix A-D) these flow paths are included within the WBM.

E-3 Model Calibration

The WBM was run under current conditions, including relevant surface and seepage flow paths, stages of WRS development and pit conditions for the purpose of assessing performance of the modelled results against measured data. Results are presented based on a statistical representation of data from 2020 to 2026. From the comparisons, potential under or overestimations of contaminant concentrations at the surface water compliance points can be made. Based on the ensemble of calibration results, the model is considered to offer a good representation of measured data and suitable basis for future projections of water quality associated with the Macraes Operation.

For the purposed of identifying model performance against measured data at each compliance point, contaminant concentrations have been normalised against reference values. The reference values are provided in Table E-3.1. This method highlights the differences in the modelled and measured data, while also highlighting the relative importance of each parameter from a compliance perspective.

Table E-3.1 Reference values for normalisation of contaminant concentration data

Contaminant	Reference value	Basis
Ammonia	0.52 mg/L	Proposed chronic limit
Arsenic	0.013 mg/L	Proposed chronic limit
Copper	0.004 mg/L	Proposed chronic limit
Hardness[1]	1,000 mg/L	Arbitrary value
Iron[1]	0.28 mg/L	Proposed chronic limit
Lead	0.045 mg/L	Chronic limit
Nitrate	2.6 mg/L	Chronic limit
Sulphate	1,000 mg/L	Chronic limit
Zinc	0.016 mg/L	Chronic limit
DOC[1]	4.5 mg/L	Standardised value
Chloride[1]	9.1 mg/L	Standardised value
pH[1]	7.8	Standardised value
Temperature[1]	20°C	Standardised value

[1] Based on a standardised values or compliance limits for Macraes Mine operating water receiving conditions

A summary table is included for each compliance point and key differences between modelled concentrations and sample data is presented in Table E-3.2 - Table E-3.11. The differences are described as conservative / unconservative depending on whether they are over or underestimated or if they are a modification factor and will influence chronic or acute limits. This is done only for notable differences in the calibration and parameters not discussed are otherwise considered to offer a fair representation in the WBM. Where these differences are identified and discussed, a note is made on the relationship to compliance projections, where:

– Low – indicates that the calibration difference is unlikely to have an effect on modelled compliance outcomes.
– Medium - indicates that the calibration difference is likely to have a small effect on the modelled compliance outcomes.
– High - indicates that the calibration difference is likely to have a significant effect on the modelled compliance outcomes.

A statistical comparison between modelled results and measured site data between 2020 and 2026 is also presented below for the compliance points from Figure E-3.1 - Figure E-3.10. The figures show the 10-90th percentile in light blue range, and the 25-75th percentile in darker blue and the median as a dark outline between the central quartiles.

In the following sections a discussion of the calibration results is presented. In general, the calibration can be used to highlight the following:

- Where there is good agreement between the modelled and measured data.
- Where input values may be conservative resulting in higher concentrations being predicted.
- Where attenuation within the environment is likely reducing contaminant concentrations and this effect is not represented in the WBM which applies a conservative mass balance and transport assumption (i.e. the sum of mass loads entering the system from sources equals the sum of mass leaving the system).
- Where input values may be unconservative likely resulting from underestimation of input concentrations or sources.
- Where there are inconsistencies between modelling assumptions and physical reality in either the representation of the physical site or representation of operational decisions made over the calibration period that are not captured in the WBM.

Further to these points, it is noted that across a number of the modelled sites representation of Iron is inconsistent and two factors are considered to be prominent in causing this. First, control sites (MB00 and DC00) represent high and variable iron concentrations compared to the proposed trigger values, and second, there appears to be significant attenuation of iron load with transport down catchment.

E-3.1 DC08

Table E-3.2 describes the key differences between modelled and measured data at DC08 as presented in Figure E-3.1. In addition to this, the following key considerations should be made:

- For extended periods within the calibration range, there has been discharge from the Golden Point Adit. Samples of this discharge have been taken, and it is known to be generally of poor quality resulting in measured data exceeding modelled outcomes. The flow rate of this discharge was not measured, and the discharge is not represented in the WBM.
- Northern Gully silt pond is typically pumped to the MWMS and generally does not discharge. It is understood that discharges have occurred over the calibration period and this is not represented in the WBM.

Table E-3.2 DC08 summary

Species	Conservative / Unconservative	Relationship to compliance	Discussion
Arsenic	Note	Low	Arsenic load additions are made in the Deepdell Creek between DC04 and DC07 to represent high baseline arsenic measurements, these influence DC08 concentrations, which are modelled with slightly elevated concentration predictions in the WBM.
Copper	Unconservative	Low	The WBM underpredicts the range of copper. The measured values are however significantly below the proposed compliance criteria. Therefore of less concern and unlikely to affect assessed compliance.
Iron	Conservative	Low	There is a smaller spread in modelled data than measured, indicating that source terms in the natural catchment contributions vary with climatic conditions. There is also expected to be attenuation of Iron within the streams that is not represented in the WBM
Nitrate-N	Conservative	Medium[1]	Comparison indicates potential microbial attenuation.
Zinc	Conservative	Low	Current data set has a low number of zinc measurements and is typically conservatively represented in the modelling; however, a longer data record is required to improve confidence in this evaluation.

[1]. Relationship is not important explicitly to the presented compliance statistics, however, may further consideration of the conservative nature of this value could be important in assessing Eutrophication potential.

E-3.2 GB02

Table E-3.3 describes the key differences between modelled and measured data at GB02 as presented in Figure E-3.2.

Table E-3.3 GB02 summary

Species	Conservative / Unconservative	Relationship to compliance	Discussion
Arsenic	Unconservative	High	Median concentrations are well represented, though comparison indicates that during low flow (dry) periods the model likely underestimates contribution to GB02. This is a likely outcome for arsenic that is elevated in the pit lake compared to compliance criteria. The result likely points to the physical representation of the Golden Bar pit lake outlet, that is a naturally formed overflow rather than an engineered structure, as such there is potential for low level discharges to continue from the pit during times where the modelled lake level has dipped below the outlet level.

E-3.3 MB01

Table E-3.4 describes the key differences between modelled and measured data at MB01 as presented in Figure E-3.3.

Table E-3.4 MB01 summary

Species	Conservative / Unconservative	Relationship to compliance	Discussion
Copper	Conservative	High	Significant attenuation indicated in the measured data that is not represented in the WBM.
Iron	Unconservative	High	Control site data (MB00) shows high peak Iron concentrations, exceeding typical natural catchment inputs resulting in underprediction of maximum by the WBM. Where compliance criteria allow for control site adjustment, this unconservative representation is of lesser concern in evaluating modelling results.
Nitrate-N	Unconservative	Medium	Modelled Nitrate-N is unconservative at MB01 and this is expected to be more significant where flows are dominated by WRS seepage. The unconservative outcome is not represented downstream at MB02, balanced by attenuation of load before this site.
Zinc	Conservative	Medium	Significant attenuation indicated in the measured data that is not represented in the WBM.
Chloride	Unconservative	Low	Chloride concentrations are higher in modelled data, however, given the purpose of modelling chloride is to provide toxicity adjustments for Nitrate-N levels, the difference has been checked and considered to not be substantial enough to make changes to the Nitrate-N adjusted compliance limits.

E-3.4 MB02

Table E-3.5 describes the key differences between modelled and measured data at MB02 as presented in Figure E-3.4.

Table E-3.5 MB02 summary

Species	Conservative / Unconservative	Relationship to compliance	Discussion
Copper	Conservative	High	Significant attenuation indicated in the measured data that is not represented in the WBM.
Iron	Unconservative	High	Control site data (MB00) shows high peak Iron concentrations in measured data, exceeding typical natural catchment inputs resulting in underprediction of maximum by the WBM.
Zinc	Conservative	Medium	Significant attenuation indicated in the measured data that is not represented in the WBM.
Chloride	Neutral	Low	Chloride concentrations are higher in modelled data, however, not by enough to have an effect on Nitrate-N adjusted compliance limits.

E-3.5 MC01

Table E-3.6 describes the key differences between modelled and measured data at MC01as presented in Figure E-3.5. In addition to this, the following key considerations should be made:

– Murphys silt pond is typically operated with return pumping to Frasers East sump or Frasers Pit Void and is represented in this manner with no overflows represented within the WBM. In practice, the pumps have had down periods and controlled releases have also taken place. These are not measured to understand the effect on the calibration.

– There are historical mine workings within the Murphys Creek catchment, the contaminant loads from these workings are not well understood or implemented in the WBM.

Table E-3.6 MC01 summary

Species	Conservative / Unconservative	Relationship to compliance	Discussion
Arsenic	Unconservative	Low	Arsenic is significantly elevated in measured data at MC01, this is a combination of real measurements with significant effects by high LDLs within the measured data.
Nitrate-N	Conservative (median) Unconservative (90^{th}%)	Medium	Nitrate-N was elevated in source waters in 2019-2020 and was not measured prior to this. There is significant livestock access to the waterways that may be influencing this measurement. Insufficient control site data is available to confirm this assertion. There is likely microbial attenuation in the creek not represented within the model. The discussion point from Sulphate below also applies.
Sulphate / Hardness	Unconservative	Low	The unconservative representation of sulphate, arsenic and hardness is primarily attributed to the assumed consistent operation of the Murphys silt pond return pumping system.
Zinc	Conservative	Medium	Conservative due to lack of site-specific source term data, thus insufficient justification available to adjust Frasers West WRS concentrations at this stage.

E-3.6 MC02

Table E-3.7 describes the key differences between modelled and measured data at MC02 as presented in Figure E-3.6.

Table E-3.7 MC02 summary

Species	Conservative / Unconservative	Relationship to compliance	Discussion
Arsenic	Unconservative	Low	As per MC01
Nitrate-N	Unconservative (90^{th}%)	Low	As per MC01
Sulphate/ Hardness	Unconservative	Low	As per MC01

E-3.7 NBWRRF

Table E-3.8 describes the key differences between modelled and measured data at NBWRRF as presented in Figure E-3.8.

Table E-3.8 NBWRRF summary

Species	Conservative / Unconservative	Relationship to compliance	Discussion
Arsenic	Unconservative	Low	Arsenic concentrations within Frasers West silt pond and NBWRGR are elevated compared to applied WRS seepage concentrations. Indicating an unconservative source term for Arsenic from the Frasers West WRS (assuming that this is the source).
Iron	Unconservative	High	Iron concentrations at upstream monitoring points show iron concentrations exceeding the reference value at this location, however, mass balance would indicate that there are non-mine mass load additions to the receiving waters and control site monitoring is required to improve the understanding of these sources.
Nitrate-N	Conservative	High	Significant attenuation indicated in the measured data that is not represented in the WBM.
Zinc	Conservative	High	Conservative due to lack of site-specific source term data, thus insufficient justification available to adjust Frasers West WRS concentrations at this stage.

E-3.8 NB03

Table E-3.9 describes the key differences between modelled and measured data at NB03 as presented in Figure E-3.7.

Table E-3.9 NB03 summary

Species	Conservative / Unconservative	Relationship to compliance	Discussion
Arsenic	Unconservative	Low	Refer to discussion in MC02, NBWRRF, GB02
Iron	Note	Medium	The modelled range for Iron is low, and this is primarily a function of the natural catchment input being a static value. Further control site data is required to improve this understanding.
Zinc	Conservative	High	Refer to discussion in MC02

E-3.9 Shag River at Loop Road

Table E-3.10 describes the key differences between modelled and measured data at the Shag River at Loop Road site as presented in Figure E-3.9.

Table E-3.10 Shag River at LR summary

Species	Conservative / Unconservative	Relationship to compliance	Discussion
DOC / Chloride	Unconservative	Low	Modelled values are higher than measured and further control site monitoring is required to improve the understanding of these inputs in the Shag catchment. These values represent toxicity modifiers for the modelled results and the unconservative outcomes here are not expected to materially influence the compliance evaluation.

E-3.10 Shag at McCormicks

Table E-3.11 describes the key differences between modelled and measured data at the Shag River at McCormicks Creek site as presented in Figure E-3.10.

Table E-3.11 Shag at MC summary

Species	Conservative / Unconservative	Relationship to compliance	Discussion
DOC / Chloride	Unconservative	Low	As per Shag at Loop Road

E-3.11 Calibration plots

The following figures show the normalised model results compared to the measured data for each of the assessed compliance points. To interpret these figures, consider the following points.

– The comparison between the box plots for each parameter indicates the closeness of the calibration. Modelled boxes higher than measured indicate a conservative calibration and lower than measured indicate unconservative calibration. I.e. the relative position of modelled and measured data matters, not the position on the y-scale.

– The position of the box plots against the y-scale provides some indication of the importance of a parameter with respect to potential compliance risks, i.e. those <<1.0 are less likely to cause compliance risk based on current conditions. Note that this does not apply to the four parameters to the right of the plots (Hardness, DOC, pH and Chloride) which are generally used as toxicity modifying parameters.

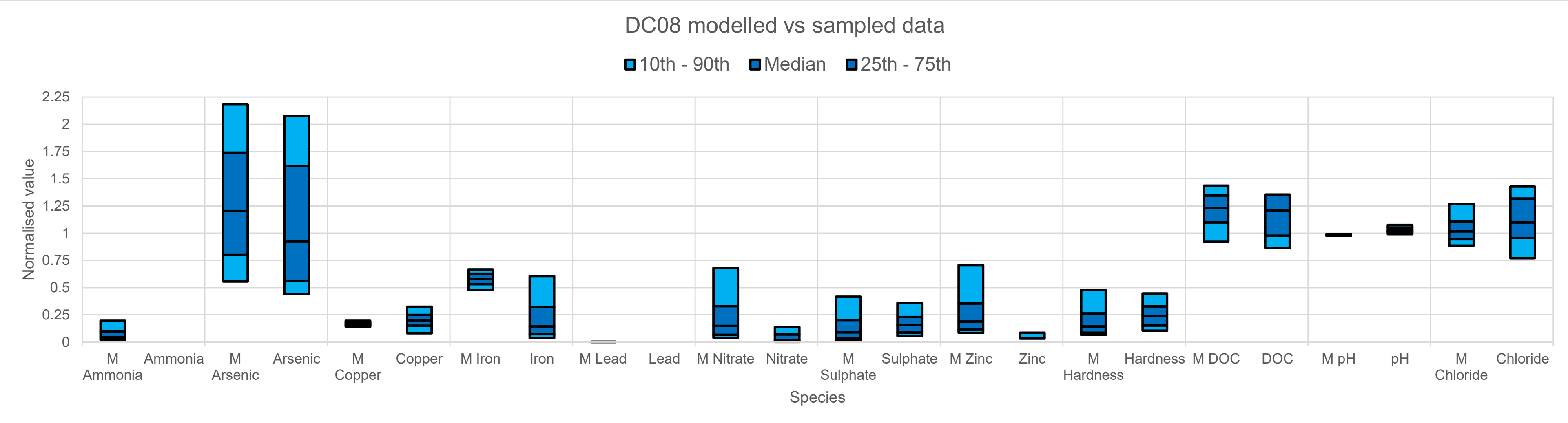

Figure E-3.1 A comparison of modelled and sampled data for DC08

Note that from Table E-3.2 the reference normalisation value for arsenic is applied, not the site-specific trigger value for DC08 which would lower the position of the boxes on the y-scale.

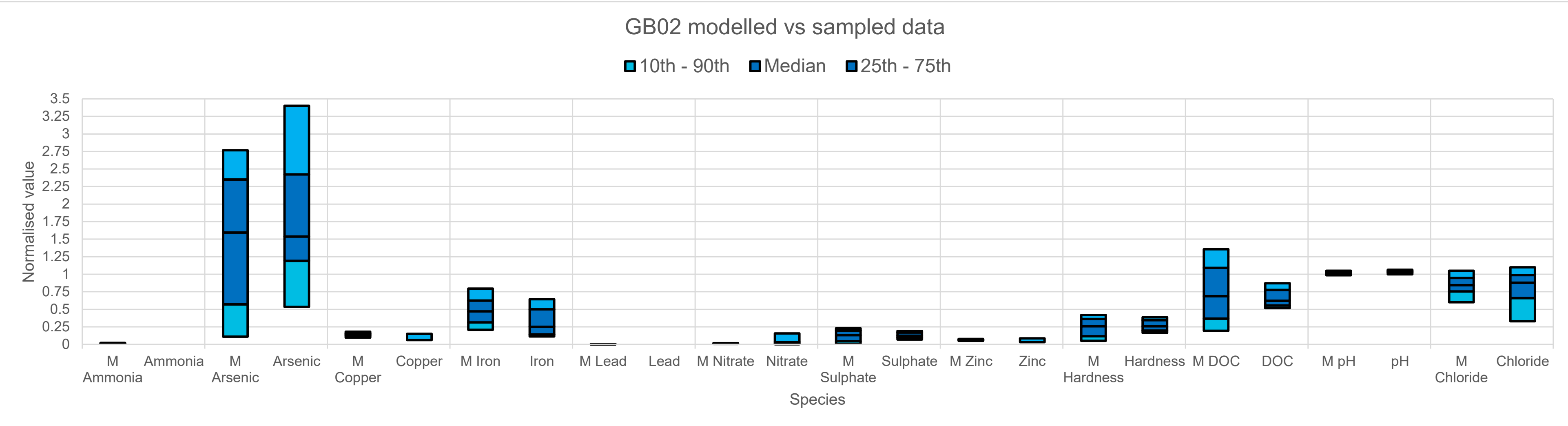

Figure E-3.2 A comparison of modelled and sampled data for GB02

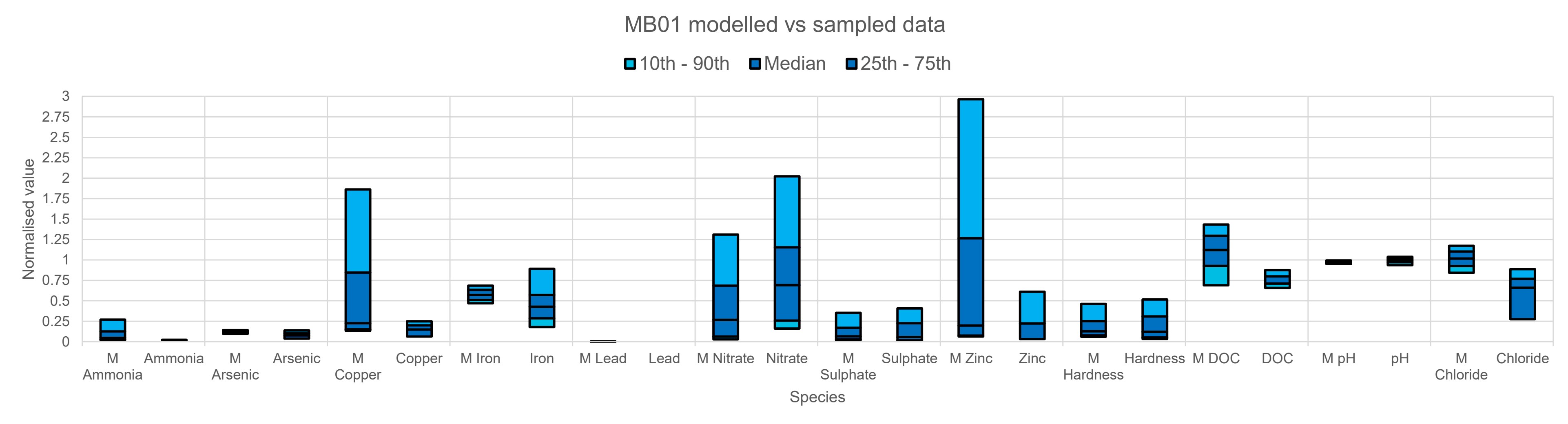

Figure E-3.3 A comparison of modelled and sampled data for MB01

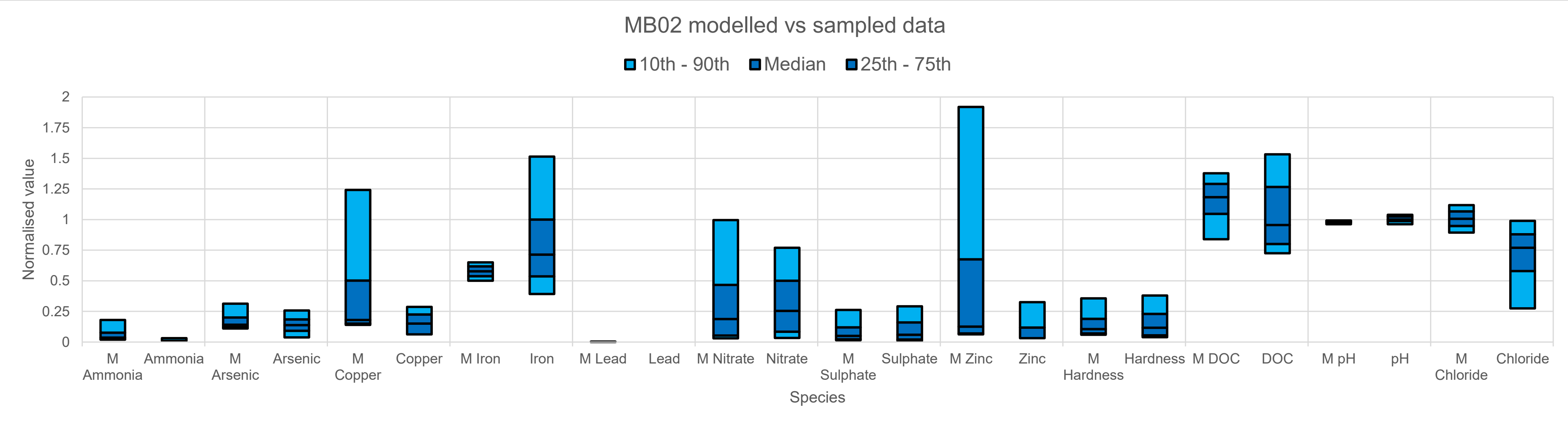

Figure E-3.4 A comparison of modelled and sampled data for MB02

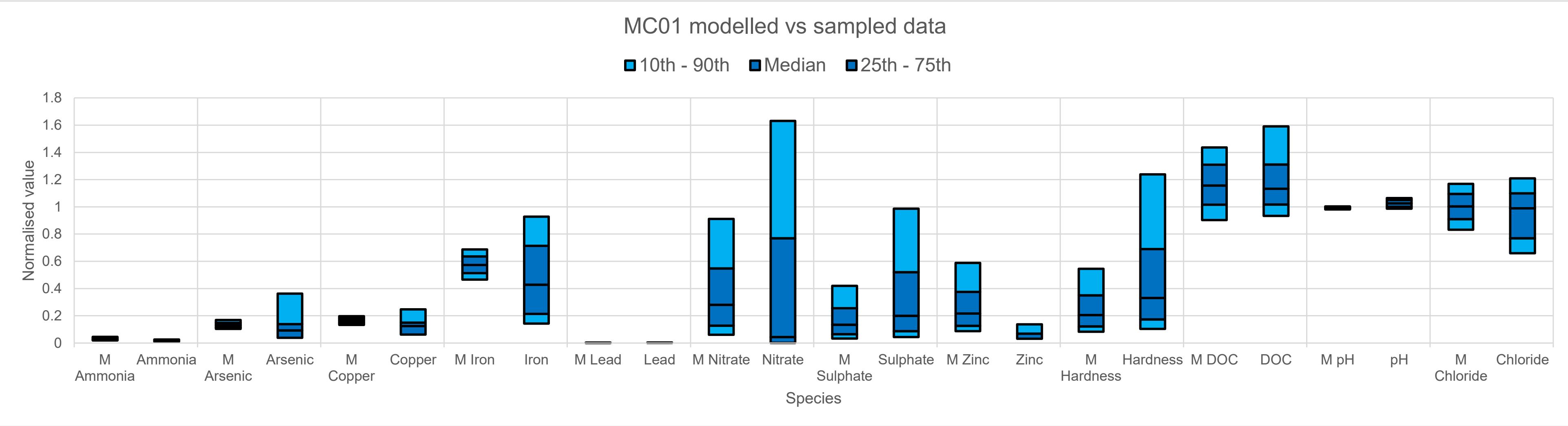

Figure E-3.5 A comparison of modelled and sampled data for MC01

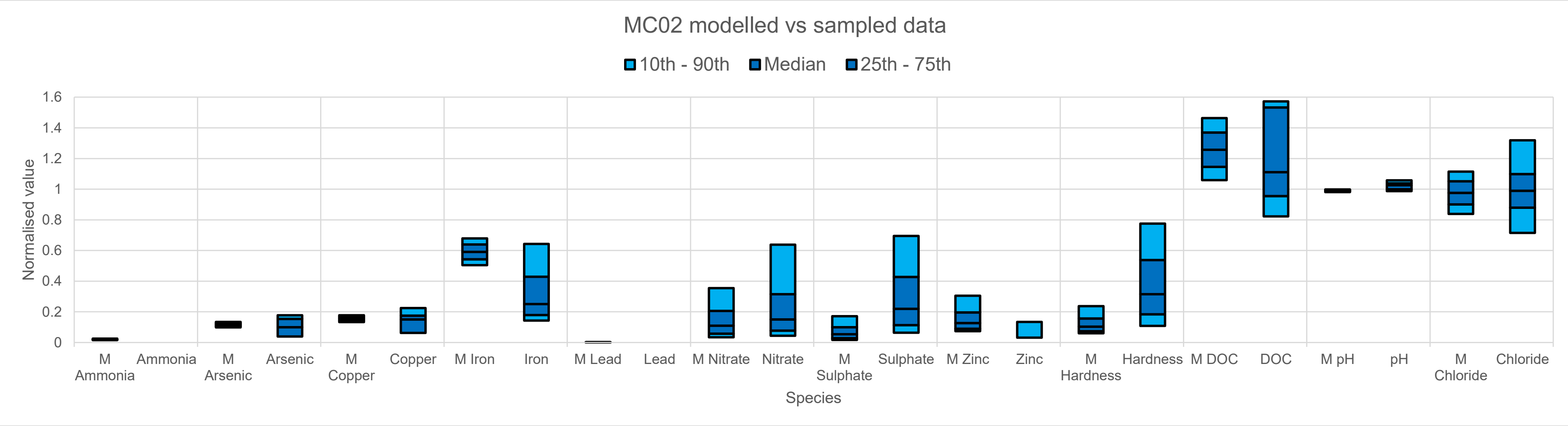

Figure E-3.6 A comparison of modelled and sampled data for MC02

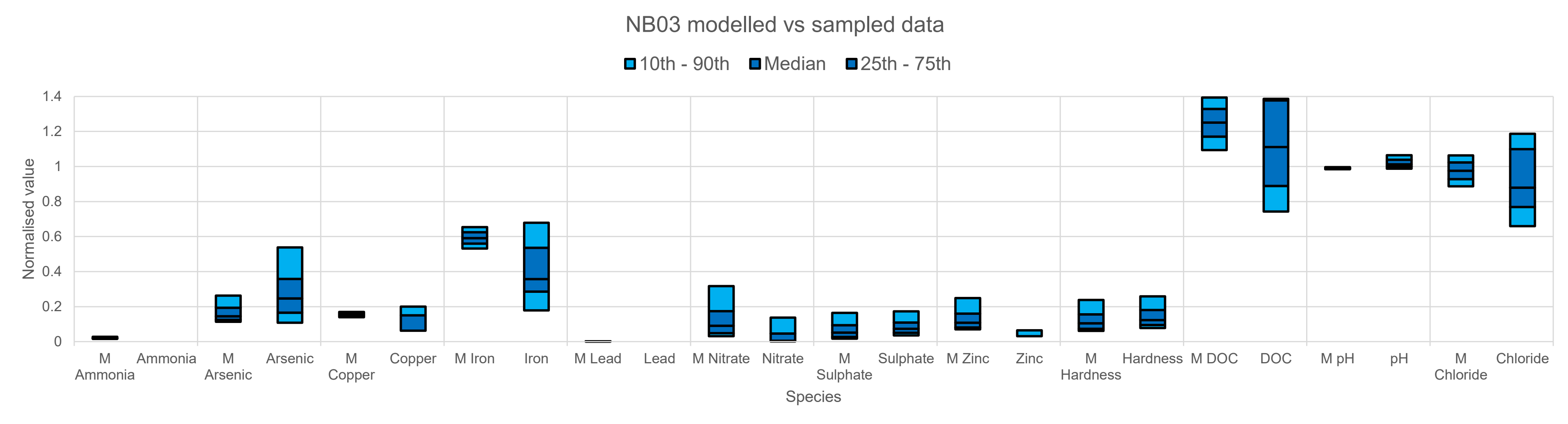

Figure E-3.7 ***A comparison of modelled and sampled data for NB03***

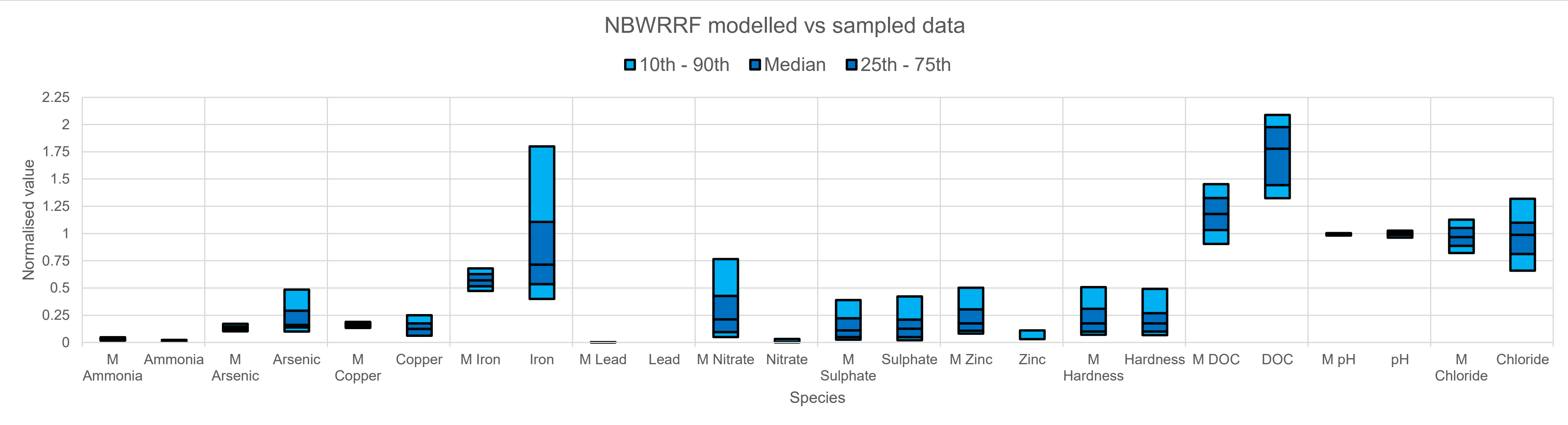

Figure E-3.8 ***A comparison of modelled and sampled data for NBWRRF***

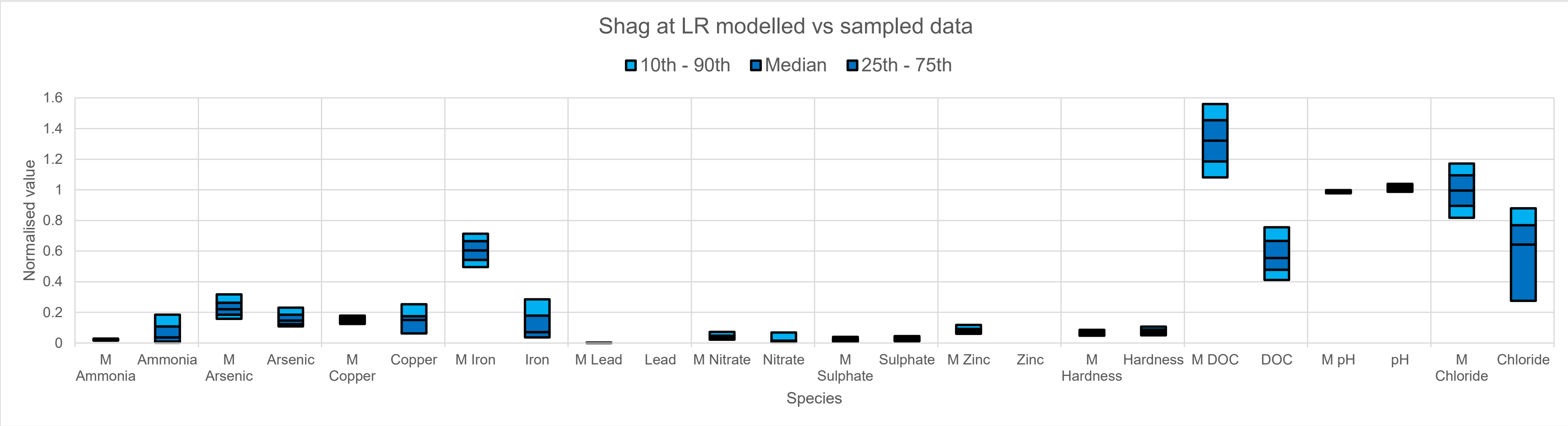

Figure E-3.9 ***A comparison of modelled and sampled data for Shag at LR***

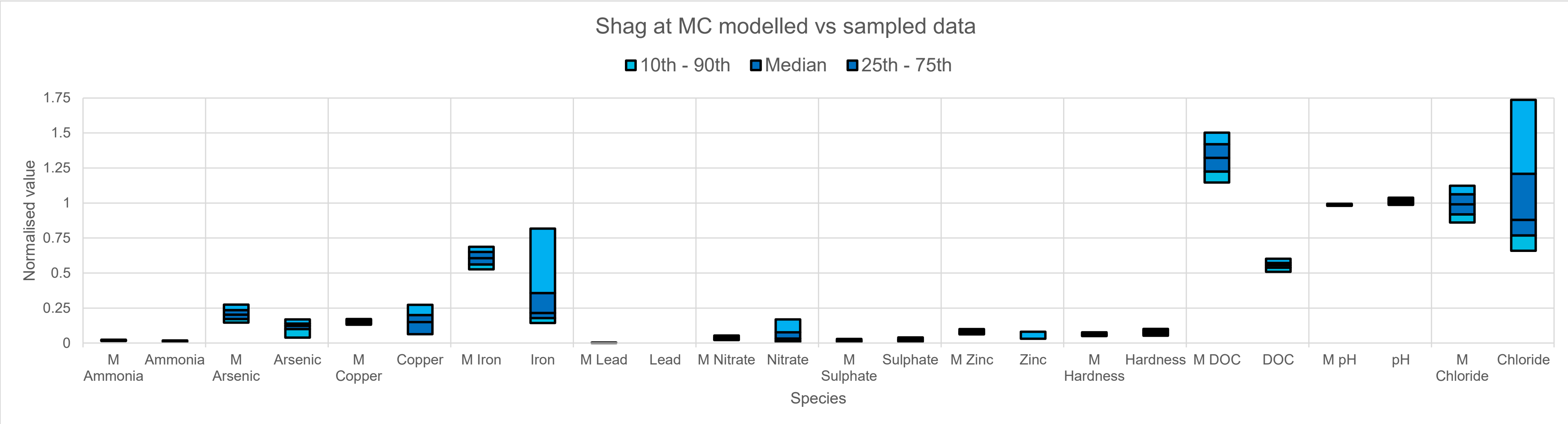

Figure E-3.10 ***A comparison of modelled and sampled data for Shag at MC***