MEMO

Date:	1 February 2022
To:	Paul Hedley
From:	Cassie Turvey
Pages:	4 inc. this page, plus attachment
Regarding:	EWP19192.003 Brockman Syncline Pit Lake Modelling

Brockman Syncline Pit Lake Modelling

1 INTRODUCTION

Groundwater modelling to assess the cumulative impact of proposed mining within the Brockman Syncline has been undertaken by RPS. Part of this modelling included prediction of the water level recovery post mining. Two closure options are possible, one being to leave mine voids open, whereby groundwater recovery has the potential to rise above the pit floor and form a pit lake; and the other involving partial backfilling of the pits with spoil. Modelling of the predicted water level rise within backfilled voids was reported in RPS 2021 (to which this memorandum forms an addendum). Long term recovered water levels predicted by the groundwater model at 300 years post mining are shown in Figure 1. However, for pit voids, the model is only able to predict groundwater inflow rates and an additional water balance assessment is required to determine an equilibrium lake level that takes into account the other expected water inflows and outflows at the lakes. This water balance information and a simplified evapoconcentration for lake water quality evolution is presented herein.

2 METHOD

2.1 Pit Lake Water Balance

A simple analytical method has been used to calculate the post-closure pit lake water balance for the pits proposed to be mined below water table. The water balance follows the general law of conservation of mass whereby:

$$\sum \text{Inflows} - \sum \text{Outflows} = \Delta\ \text{Storage}$$

Inflows include direct precipitation onto the lake surface, runoff from pit walls above the pit lake surface and groundwater inflow from the regional groundwater aquifers. No seepage from a TSF or other water source is included as a potential input volume, nor surface water inflow from any catchment area outside of the closure bunding (which is planned to fully encircle the pit rims), nor any interflow from groundwater that may occur after large rainfall events through shallow alluvial sediments. The only outflow considered is the evaporation from the lake surface, assuming that the pit lakes remain as a groundwater sink (i.e. groundwater gradient is towards the pit).

The stage/volume/area relationship was used to determine the lake stage and surface area in each pit, using a daily timestep to calculate the change in lake volume after accounting for inflows and outflows at that timestep. Daily rainfall and evaporation values were obtained from SILO data for a central location at the Brockman Syncline over the period 1960 to 2019, with the sequence repeated to fill a time series for 300 years. Direct rainfall and evaporation to/from the lake are a function of the lake surface area at a given timestep, increasing as the lake area increases; while the rate of groundwater inflow and volume of pit wall runoff are a function of the lake stage, both decreasing as the lake stage increases.

Pit wall runoff is estimated to be 30% of the net rainfall (i.e. daily rainfall minus daily evaporation) that falls on exposed pit wall area. This is likely to be conservative in the initial stages of pit lake development after mine closure as runoff is often trapped on individual benches with the majority unlikely to make it to the pit lake prior to evaporating or infiltrating, except during major rain events. Pit wall runoff of 30% is considered to be a more reasonable approximation at later times due to a combination of wall erosion and increased lake levels reducing the potential for stranded water storage on individual benches.

An evaporation co-efficient of 0.7 times pan evaporation was used, being the median of typically used coefficients to convert pan evaporation to lake evaporation of between 0.65 to 0.75.

Groundwater inflow is equal to that predicted in recovery modelling for the relevant stage of the lake (Appendix D of modelling report). The rate of inflow calculated in the groundwater model is commensurate to the interaction between the cone of depression resulting from dewatering at the various pit voids, therefore the inflow rate may change if the mine plan is significantly altered from that which was modelled.

It is important to note that this modelling is preliminary in nature and considers the lake formed within each final pit void as being a single connected feature. It is likely that in reality discrete lakes will form at separate areas of the pit floor, particularly within the larger pits where there are multiple pockets of deep excavation, and these individual lakes may behave differently in terms of water level and chemical evolution due to local variations in surface area for evaporation and runoff capture.

2.2 Evapoconcentration

As the only outflow from the lake is evaporation (of fresh water), the change in TDS over time can be simply calculated as the sum of incoming TDS at each time step from the relative inputs added to the total from the previous time step, dived by the lake volume. This is a simplistic scenario that assumes uniform lake mixing, no precipitation of solids and no reaction with pit wall minerals, but is considered sufficient to provide a high level overview of the rate of evapoconcentration. Inflowing groundwater was assumed to have a TDS of 600 mg/L (average of data presented in Nammuldi and Brockman Syncline 4 Triennial Aquifer Reviews), rainfall TDS 30mg/L and pit wall runoff 100mg/L.

2.3 Climate variability

The pit lake level and evapoconcentration was predicted using a sequence of historical climate from 1960 to 2019. To test for uncertainty in future climate, two additional climate scenarios were used, being a “wetter” climate (10% increase in rainfall, 10% decrease in evaporation), and a “drier” climate (10% decrease in rainfall, 10% increase in evaporation).

3 RESULTS

Based on a combination of the groundwater modelling and the analytical water balance method, permanent pit lakes are predicted to form in 7 of the 11 below water table pits currently proposed to remain as open voids. Pits currently proposed to remain as open voids within the Nammuldi hub include Lens B, Lens CD, Lens EF and Lens G. Lens A is proposed to be a capped in-pit TSF. The groundwater level is not predicted to recover to the base of Lens B due to drawdown from other pits in the Nammuldi area. Within the BS4 hub pits of the BSMM and BSMN deposit will remain as voids. Of these, groundwater levels at pits BSMM O2, O3 and Q are not expected to recover to the base level of the lake due to drawdown from deeper pits. Rainfall may pond for a short duration at the base of these pits and ultimately infiltrate into the unsaturated zone below the pit or evaporate. It is unlikely that any long-term connection will form with groundwater at these pits. However, if this does occur the water quality is expected to be fresher than groundwater (excluding interaction with any potentially reactive pit wall minerals).

Equilibrium lake levels and long-term TDS values predicted for the pits are presented in Table 1. Graphs showing the predicted evolution of lake stage and TDS since the time of closure for these pits are presented in Attachment A.

Table 1: Pit lake evolution for below water table pits where groundwater recovers above pit floor.

Pit	Equilibrium Level (mAHD)	Min Level (mAHD)	Max Level (mAHD)	TDS at 300 years post closure	Min TDS at 300 years post closure	Max TDS at 300 years post closure
BS4 Hub						
BS4MM - O1	428	427	429	16,940	9,861	25,446
BS4MN- M2	484	484	485	59,765	40,952	75,884
BS4MN- N1	482	482	482	82,112	58,719	122,616
BS4MN- N2	481	480	482	29,903	22,260	34,969
Nammuldi						
Lens CD	442	437	449	7,461	5,566	9,485
Lens EF	492	489	495	11,062	8,447	13,807
Lens G	503	497	510	24,279	12,605	63,982

If clarification or additional information is required, please do not hesitate to contact the undersigned.

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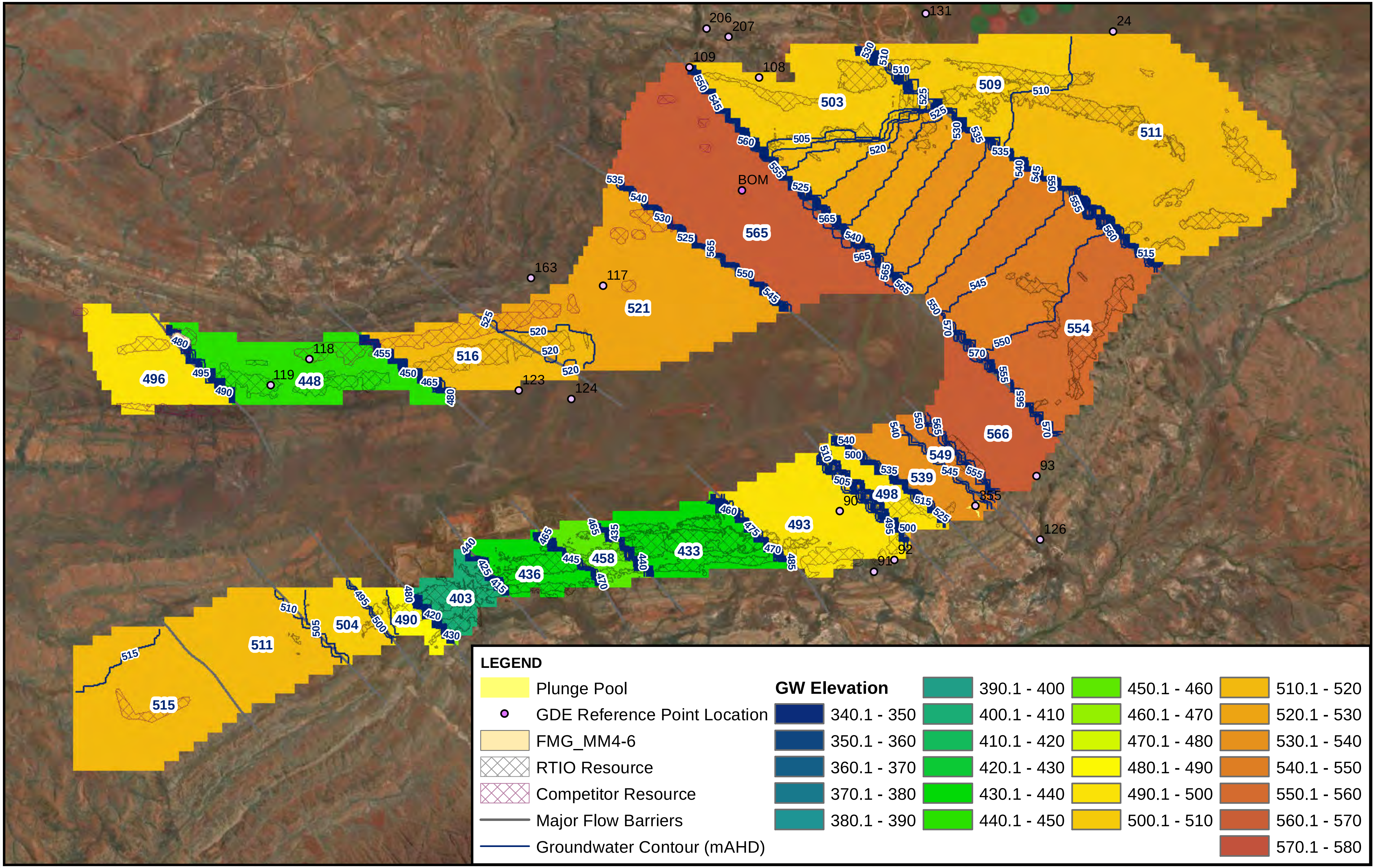

Figure 1

Predicted Regional Groundwater Elevation at 2350

GDA 1994 MGA Zone 50

0 2,000 4,000 8,000 m

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Scale: 1:200,000 @ A4
Created by: CT

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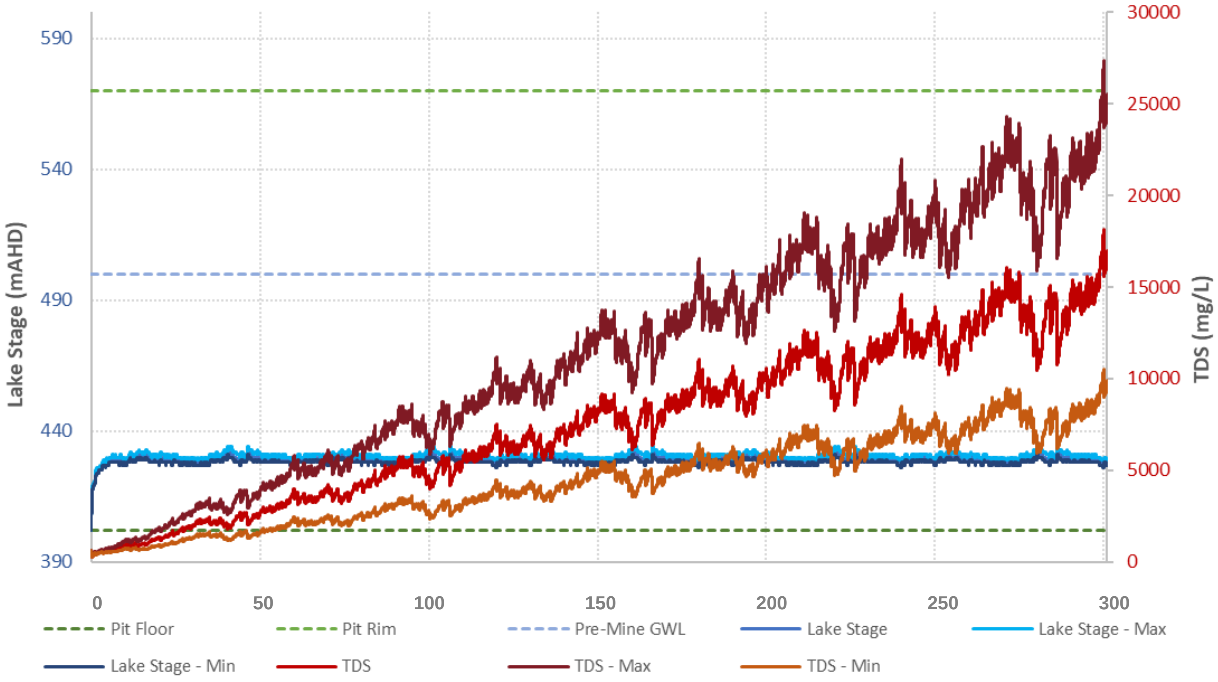
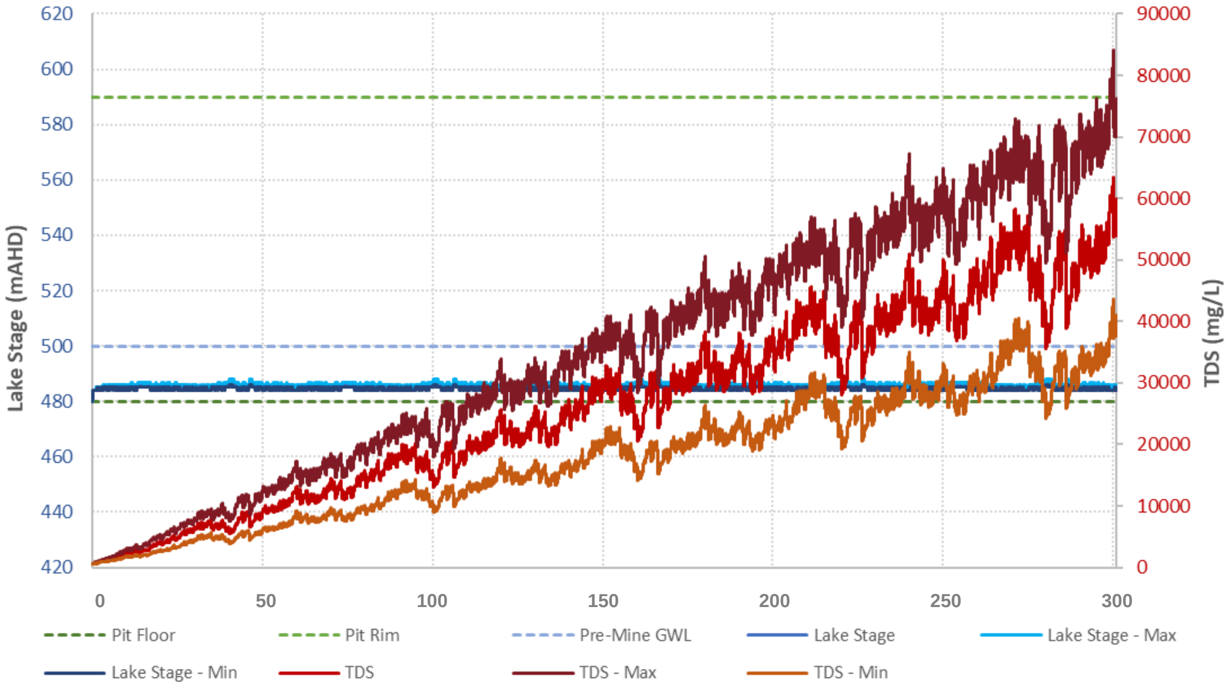
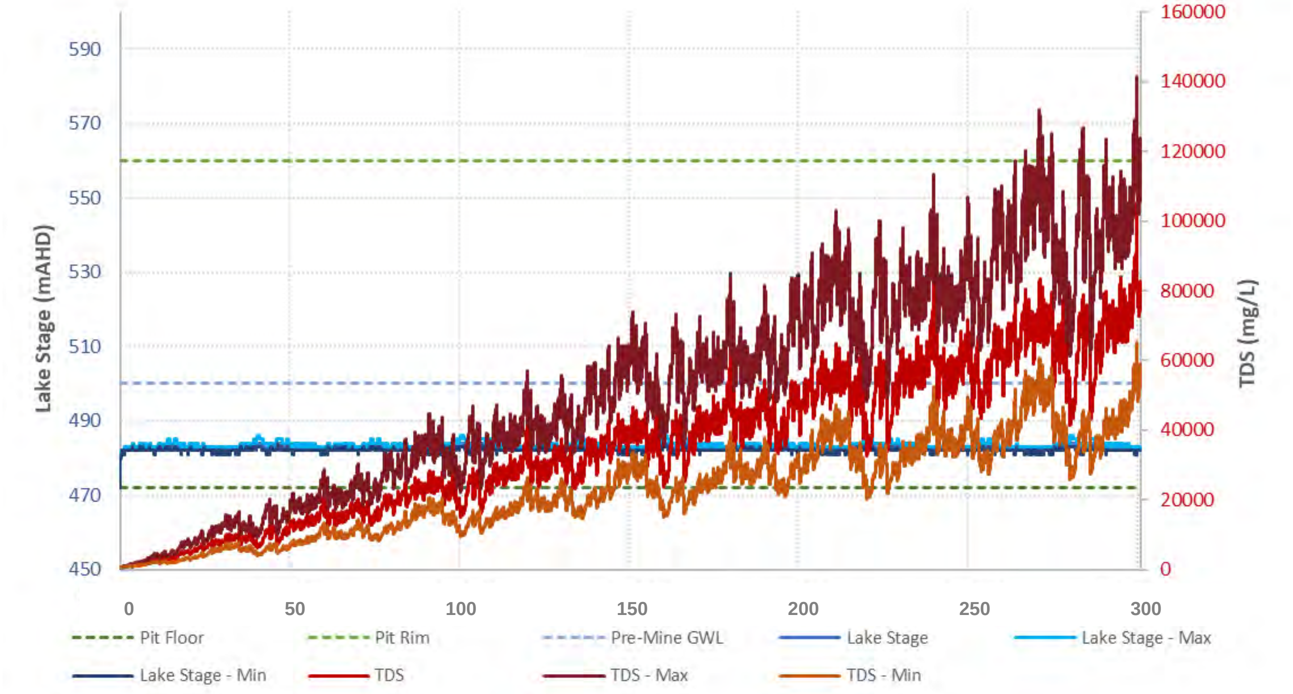
Attachment A: PIT LAKE HYDROGRAPHS



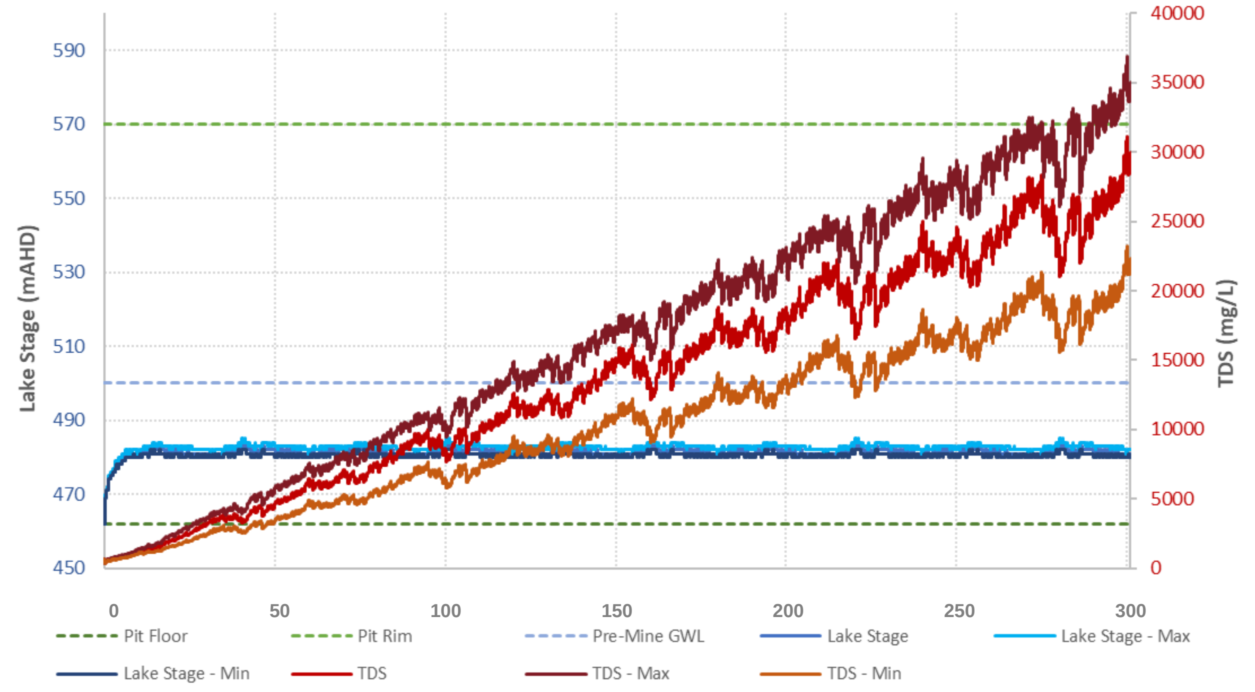
BS4MM O1 Lake stage and TDS evolution



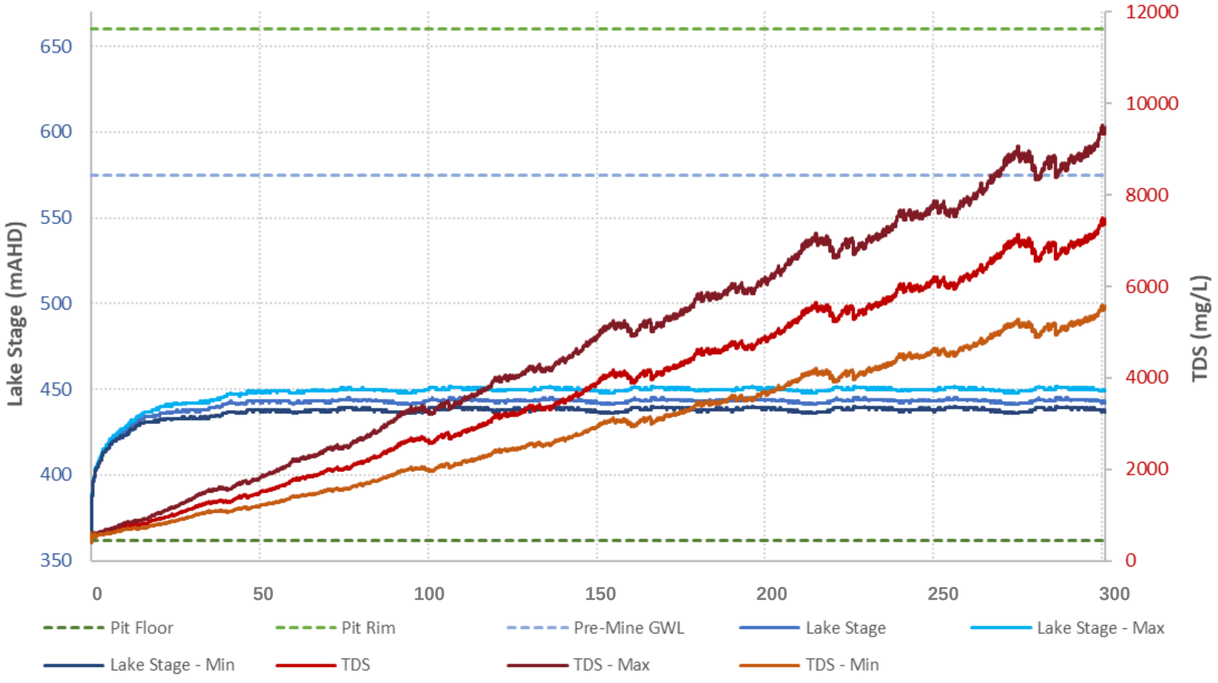
BS4MN M2 Lake stage and TDS evolution



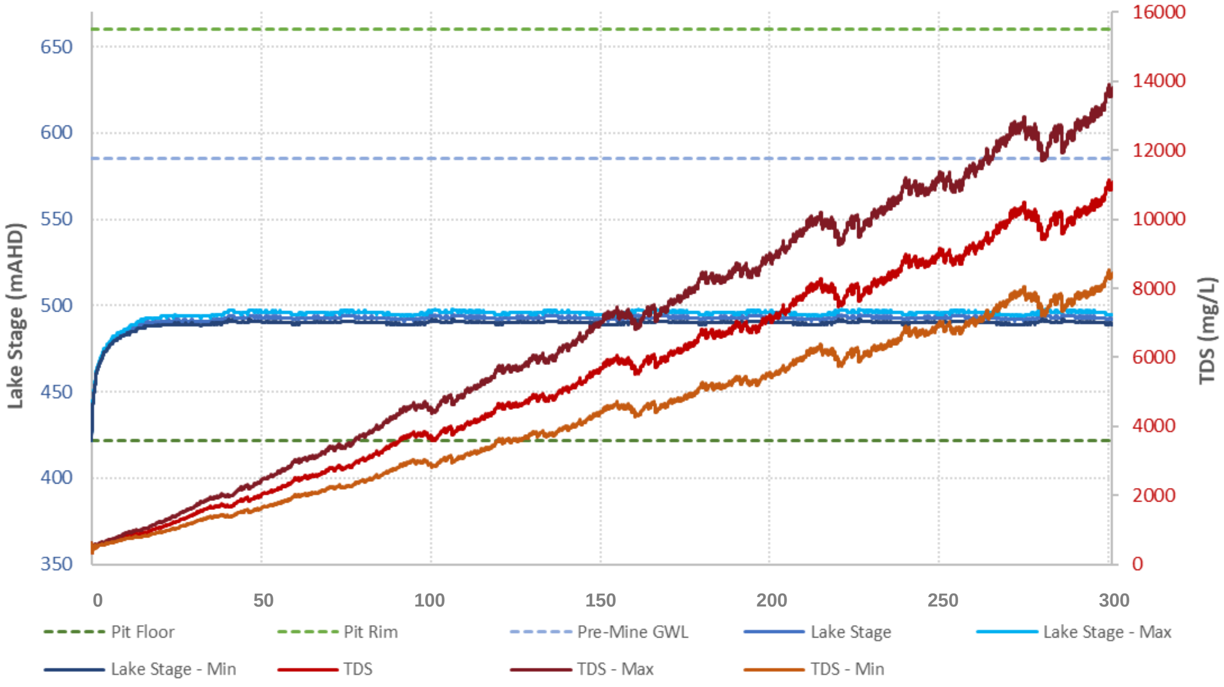
BS4MN N1 Lake stage and TDS evolution



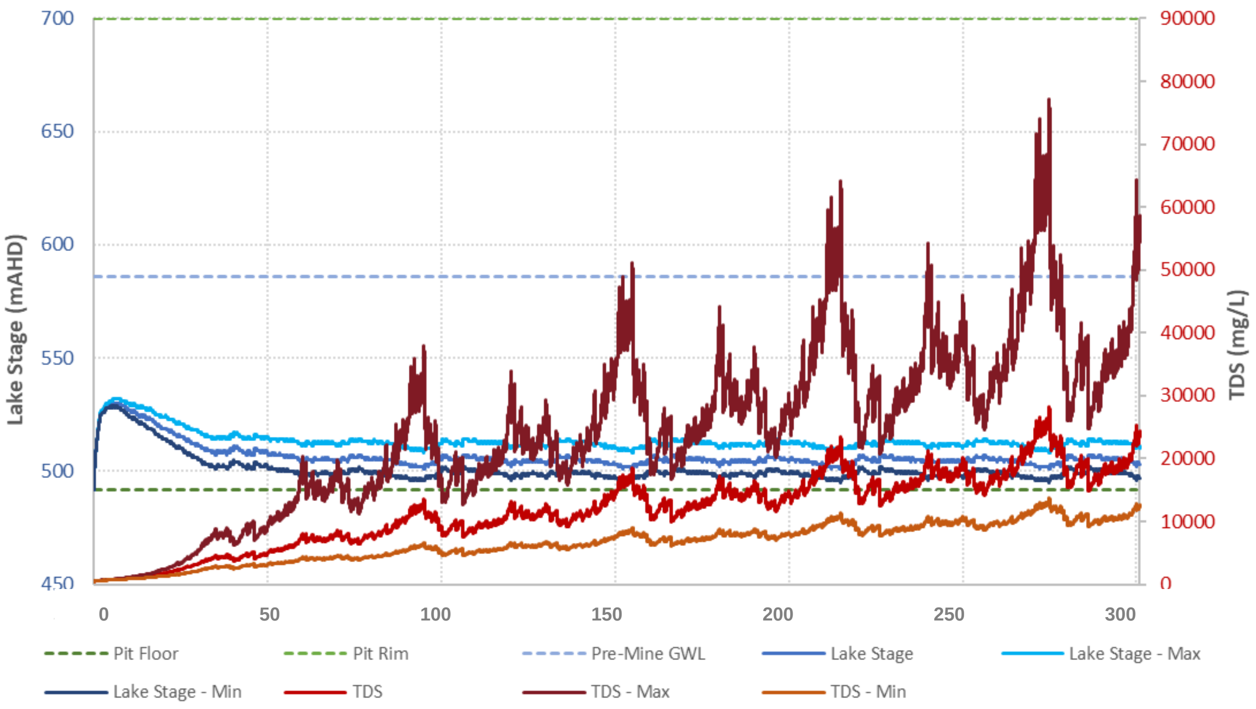
BS4MN N2 Lake stage and TDS evolution



Lens CD Lake stage and TDS evolution



Lens EF Lake stage and TDS evolution



Lens G Lake stage and TDS evolution