Treatment plant to allow mine water release from Morro Da Mina, Brazil

Sam Hawker[1], Jamie Robertson[2]

[1] AECOM, 540 Wickham Street, Fortitude Valley, Brisbane, PO Box 4006 Queensland, Australia, samuel.hawker@aecom.com

2 AECOM, 540 Wickham Street, Fortitude Valley, Brisbane, PO Box 4006 Queensland, Australia, jamie.robertson@aecom.com

Abstract

Managing acid rock drainage and high salinity water are at the crux of mine water management or at least its origins. Building storages, treatment plants and conrolled releases are potential solutions to enable mining whilst limiting the environmental impact. Each of these are often considered seperately.

Using a case study, this paper outlines a process which considers all components of mine water management infrastructure as part of managing acid rock drainage.

Keywords: acid rock drainage, treatment, mine water, water balance

Introduction

The Morro da Mina mine in Minas Gerais, Brazil is an existing metalliferous mine which has been operating for over 100 years. The primary activities undertaken at Morro da Mina are the mining and primary processing of rhodonite ore $(Mn,Ca,Fe,Mg)SiO_3$. The milled ore is trucked off site for further processing. It is estimated that the total mineral reserve is in the order of 6.8 million tonnes.

The mine operators identified acid rock drainage (ARD), in particular elevated concentrations of manganese, copper, nickel and sulfate in water storages and groundwater. These solutes are entering the adjacent watercourses resulting in concentrations above the level considered safe by the Brazilian Environmental Agency. It was proposed that a treatment plant be developed to reduce the contaminant load from the site, with the objective of improving the water quality to Class 2 (Brazilian Environmental Agency Limit) at the point of discharge.

Methodology

To size the treament plant a water balance was prepared to understand the volume, contaminant concentration and transport mechanisms. The water balance model was developed using GoldSim, a dynamic simulation program, widely used for water and mass transport modelling on mine sites. GoldSim can model hydrology, logical controls such as pumping, and mass transport.

The objectives of developing the water balance model were to:

- Size the proposed treatment plant operating capacity;
- Determine discharge periods and required site water storage capacity;
- Incorporate proposed rock dump rehabilitation (capping) and diversion of runoff from clean catchments;

- Determine the probability of failure for various water management strategies; and
- Develop a site water management master plan and formalise the site water management procedure.

The model tracks all water and contaminants from their origin to their downstream discharge. This allows idetification of a whole of mine water management and strategies to limit the capital expenditure on site. The storage volumes, treatment plant duty and contaminant removal performance, and discharge requirments are often considered separately. The mine site currently covers a total catchment area of approximately 280 ha of which approximately 46 ha consists of the open pit mining area, and 100-150 ha of waste rock dump area. The remaining area is either undisturbed or part of the administration and mining industrial area (MIA).

The mine site covers two water catchments, with the pit and associated dewatering ponds taking up one and the majority of the second catchment containing rock dumps around an existing stream. A weir has subsequently been constructed across the stream to form a water reservoir known as Lake Ipe. Future mining in the open pit is anticipated to require an additional waste rock dump to the west of the open pit within the pit catchment. This has a total additional area estimated to be 57 ha. It is also likely that part of the existing waste rock dump (WRD) areas will be expanded in the future. As the new WRD is developed to the west of the open pit, the existing main dumps surrounding Lake Ipe will be covered and rehabilitated. The rehabilitated and capped WRD will reduce surface water from infiltrating into the dumps, and as such reduce the contaminant load from these areas.

A probabilistic model was developed to determine the optimum treatment plant duty for various mine affected water supply reservoir sizes to limit the probability of a contaminated water discharge event to less than 10% per year, equivalent to a 1 in 10 year event. The associated treatment ratios, infrastructure and treated water storage size were developed to identify the full scope of works required to improve the mines discharge water quality. This allows a least cost option to be determined by balancing the capital costs of increasing storage sizes, site rehabilitation and clean water diversions with the capital and operational costs of running a treatment plant.

The model calculated the volume of water associated with the mine catchments from various sources including surface runoff, groundwater, site use and evaporation, and utilised the Contaminant Transport module to determine the target contaminant concentrations (manganese, copper, nickel and sulfate) in the raw water storage for treatment. Runoff, groundwater and existing storage contaminant concentrations were estimated from water samples taken across the site. The existing water storages recorded a low pH resulting in the heavy metal contaminants being predominantly present in dissolved phase and suspended in solution.

It was evident from the climatic data for the region that there is a distinct wet and dry season. Between October and March rainfall exceeds evaporation and between April and September evaporation exceeds rainfall. Thus it was assumed and later confirmed via modelling that the storages follow a stead state pattern i.e. every year between winters the water storage volume would start at the minimum storage volume and return to the minimum storage volume by the end of the year, thus allowing a Monte Carlo analysis to be complete over a one year period to give a probabilistic output.

It was agreed that Lake Ipe‘s purpose would change and it would form the major site water storage with water captured in the pit catchment channelled to detention ponds and subsequently pumped into the lake. The lake itself is long and narrow, has an average depth of approximately 2 m and covers an area of 72,700 m^2 at Full Supply Level (FSL). It is expected that sediments containing sulfides are likely to be present on the bed of the lake. To minimise oxidation of sediment at the base of Lake Ipe, a water cover is to be maintained. A minimum storage volume of 29,700 m^3, which corresponds with a depth of 0.5 m was selected.

Contaminants can be mobilised and released from the mine via surface runoff and groundwater seepage. Water monitoring data was provided by the mine operators from 2001 onwards, however sampling of some of the critical locations has only recently commenced and limited data was available. The study focussed on four key indicators: sulfate (SO_4), nickel (Ni), manganese (Mn) and copper (Cu). Solute concentrations in runoff and groundwater are represented in the water balance model by probability distributions. The model samples from these distributions each timestep throughout the simulation during the Monte Carlo analysis. Appropriate probability distributions were derived by statistical analysis of the available monitoring records. Given that the monitoring history is limited, some of the distributions are based on very small datasets and are a poor fit to the distributions. It is also noted that some analytes, such as sulfate, were increasing over time and this can or would skew the distribution.

With the completed model, treatment plant duty options were developed for multiple mine scenarios. Scenarios included the construction of clean water diversions, capping of the waste rock dumps and for the future mine extents to identify the treatment facility size for environmental compliance during the mine life and minimise infrastructure costs.

The proposed treatment process involves lime dosing of the incoming water, and precipitation of sludge in settling ponds. This will remove the manganese, copper, nickel, however does not target sulfate, which will rely on dilution with the Rio Gigante water to meet the discharge water quality targets.

Results and Discussion

As shown in Table 1, a reduction in the treatment plant capacity results in an increase in the minimum storage capacity of Lake Ipe. It is also evident that diverting the clean catchments and rehabiltating WRDs substantially improves the duty and storage requirement by reducing the runoff collected on site.

Figure 1 is provided as an example to demonstrate the process of determining the minimum required storage volume for Lake Ipe to achieve a 10% probability of an uncontrolled discharge off site with a treatment plant duty of 350 m³/h. Figure 2 shows the required average contaminant treatment ratio (percentage of contaminint needing to be removed) for each of the contaminants at the treatment plant.

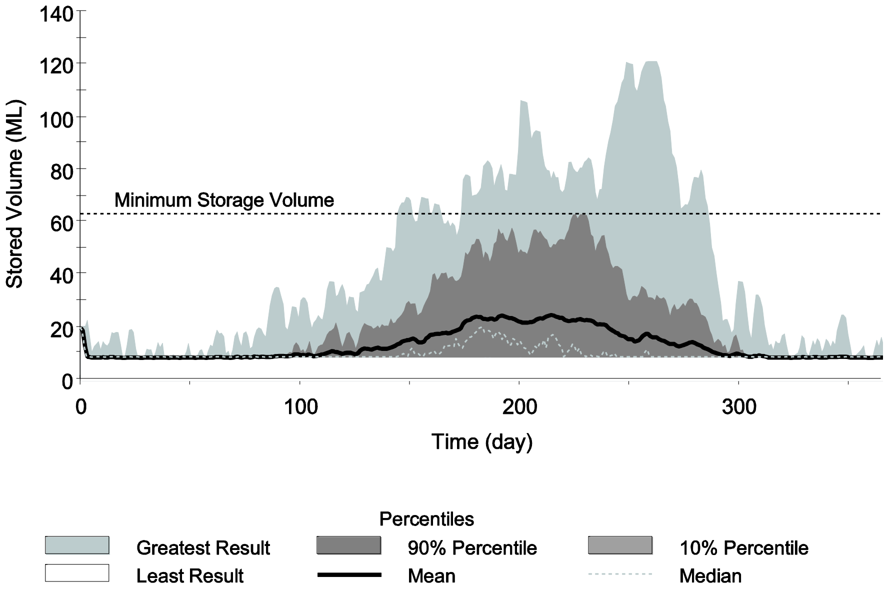

Figure 1 *Lake Ipe Minimum Storage Volume for 10% Probability of Uncontrolled Discharge.*

Table 1 *Treatment Plant Duty and Minimum Storage sizes*

Treatment Plant Duty (m^3/h)	Lake Ipe Minimum Storage Without Clean Water Diversions (ML)	Lake Ipe Minimum Storage With Clean Water Diversions (ML)	Storage Reduction (%)
300	341	285	16%
350	279	192	31%
400	213	135	37%
450	169	111	34%
500	123	80	35%

The river flow and quality was modelled upstream of the discharge point to determine background contaminants levels. It was noted the background contaminant levels are close to the water quality limits for the target metals, resulting in a high level of site water treatment to meet the downstream water quality targets. Sulfides are not removed in the proposed treatment plant process but rely on dilution with the river water to meet the required standard.

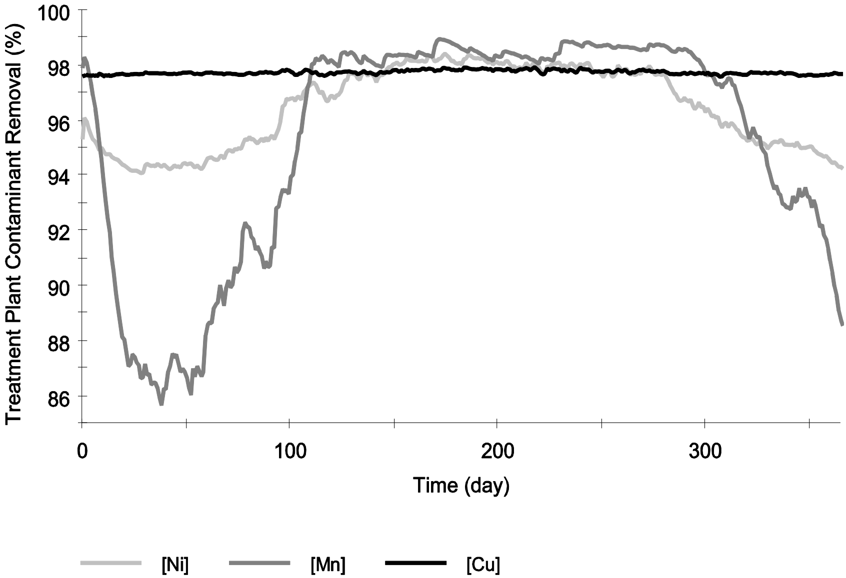

Figure 2 *Proposed Treatment Plant Contaminant Removal (Sulfides not treated)*

Conclusion

Using conventional water and contaminint modelling, this paper shows that it was possible to develop a water management strategy for the whole mine site, including a treatment plant duty and contamininat removal rate, the associated site water storage volumes and permeate release periods to demonstrate that the required infrastructure would meet the Environmental Authourities requirements. The next stage of the study would be to determine the whole of life cost considering the capital investment of increasing storage volumes, WRD capping and clean water diversions and the treatment plant capital as well as operating costs. As the investment in water storage capacity increases the treatment plant costs decrease, with the overall lowest cost solution being a balance between the each.

Acknowledgements

We would like to thank Edith Cowan University for hosting the IMWA 2012 Conference. We would also like to thank Chris Gimber and James Hughes for their involvement in the original project.