DEVELOPMENT AND OPERATION OF A WATER BALANCE AT RIO PARACATU MINERAÇÃO, BRAZIL[1]

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Abstract: RPM (Rio Paracatu Mineração) is evaluating several expansion alternatives that challenge the capacity of the current water supply system. Therefore, a site wide water model was developed to a) evaluate ways to optimise the operation of the existing water management system and b) evaluate alternative water infrastructure and water supply options that would meet the requirements of future mine expansions.

The water model was developed using a probabilistic dynamic system modelling platform. System simulation models provide a framework for organising the components, processes and operations at a mine and then explore the existing and alternative approaches to gain a diagnostic understanding of the mine system. The process of developing a system model provides a basis for sharing and documenting specialised knowledge, expertise, experience and priorities within the mining operation.

After developing a conceptual model the dynamic system modelling platform was used to produce a mathematical representation of the water management relationships. The model was then calibrated and validated before using it for optimisation and planning exercises.

The model development process has resulted in better documentation of the current water management operations and an improved understanding of the system components. This holistic view of water resourcing from freshwater withdrawal to tailings discharge as well as a convenient platform for performing "what if" experiments is facilitating ongoing improvements in water management at RPM. The model provided useful risk-based projections to assess the feasibility of expanding mine production from 20 to 30 million tonnes per year.

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Introduction

RPM is located at Paracatu, 230 km south from Brazil's capital Brasilia. The site (Fig. 1) is comprised of an open pit mine, a mineral processing plant, tailings storage facilities and related surface infrastructure, currently operating at approximately 20 million tonnes per year. RPM, wholly owned by Kinross Gold Corporation, is the lowest grade mill-operated gold mine in the world. The economic viability of this low-grade ore body has been partly derived from the soft rock and free gold in the weathered mantle. RPM's biggest challenges are related to the low gold content as well as the Acid Rock Drainage (ARD) generation and water management.

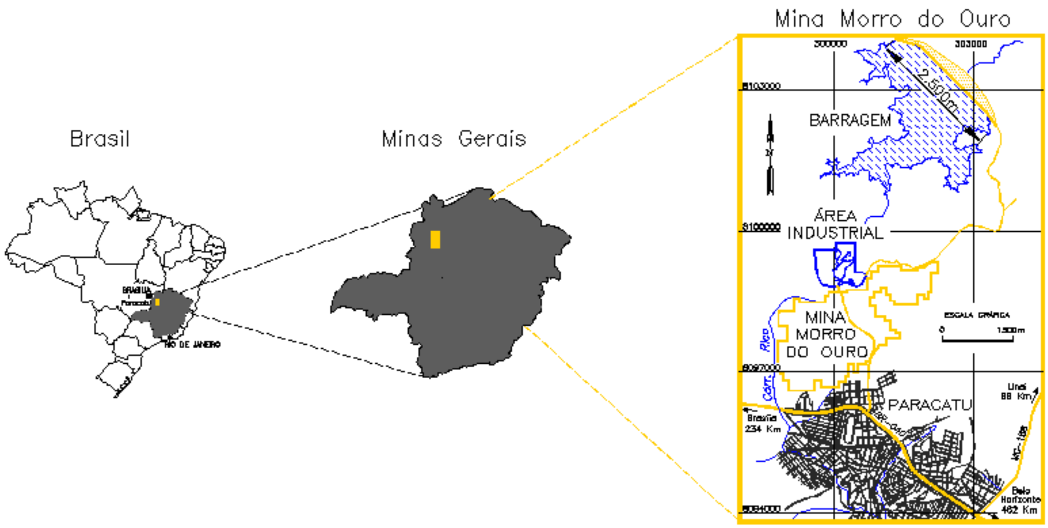

Figure 1: Location of Morro do Ouro mine

Geological Setting and Gold Mineralization

RPM comprises a generally flat-lying formation of silver-grey to dark grey phyllites and siltstones containing varying amounts of segregated quartz. The hill top is capped by remnants of a laterite layer and the rocks themselves are heavily weathered and oxidised to depths that average 20 m on the lower ground to 40 m on the higher ground. Three main oxidised rock types exist in sub-horizontal layers (termed from top to bottom as C, T and B1), defined mainly by the degree of weathering. The oxidised ore is underlain by a layer of sulfide ore (termed B2) containing concentrations of 0.42 g/t gold. Figure 2 shows a geological cross section.

The oxidized ore was mined exclusively up to 1997. Since 1998 primary sulfide mineralization has also been fed to the mill, which required a series of investments in the beneficiation and metallurgical circuits. Long-term leach testing of this B2 material using on-site lysimeters (kinetic test columns) indicates that it generates acidic, and metal and sulphate-rich rich leachates over time.

The intrinsic permeability of the phyllite is low. Groundwater flow is predominately in factures and faults within the phyllite bedrock (secondary permeability). Fracturing decreases with depth resulting in a decrease in hydraulic conductivity with depth.

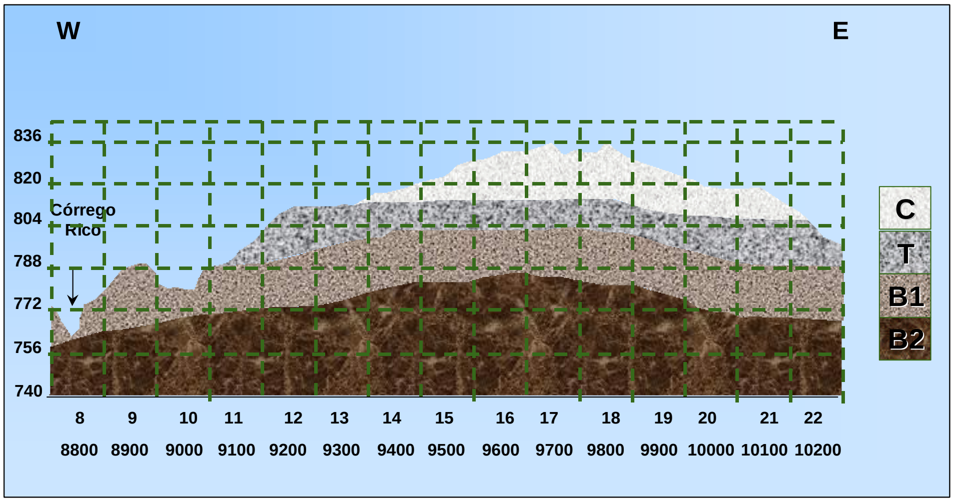

Figure 2: Geological cross section of the Morro do Ouro mineralization

Mining Operation

The open pit can be considered as a side-hill cut since there are no prominent pit slopes. Surface water runoff from the mine is collected in ponds located at the lower elevations of the open pit in the south and southwest corners. Waste stripping has not been required at the mine site. The weathered ore is ripped by bulldozers prior to excavation and requires only limited amount of blasting. Two faces are normally operated in the pit at any time, with one dozer, one loader, and four to five trucks per face. Loaded trucks haul to the crusher or dump onto a stockpile for later use.

Processing

Run-of-mine ore is crushed and sent to blending bins, which feed the grinding circuit of single stage ball mills. Ball mills are in closed circuit with hydrocyclones. A portion of the circulating load passes through jigs for gravimetric recovery of gold (Fig. 3).

Flotation is conducted in three stages: flash, scavenger and cleaner for Au and sulfide recovery. The floatation tails are thickened and then sent to the main tailings pond.

The sulfidic flotation concentrates are sent to the hydrometallurgy plant and average about 20 g/t Au. The coarser fraction of this concentrate, about 10 %, is treated gravimetrically in a Knelson concentrator recovering approximately 20% of the Au. Concentrate from the Knelson is sent to shaking tables and then on to the smelting furnace. The finer sulfide concentrate is reground, thickened and sent to the Carbon-In-Leach (CIL) circuit. The Au is recovered by electrowinning and then sent to the smelting furnace.

The products from CIL and from the shaking tables are calcined and smelted in an induction furnace resulting in bullion containing 75 to 80% Au and 20 to 25% Ag.

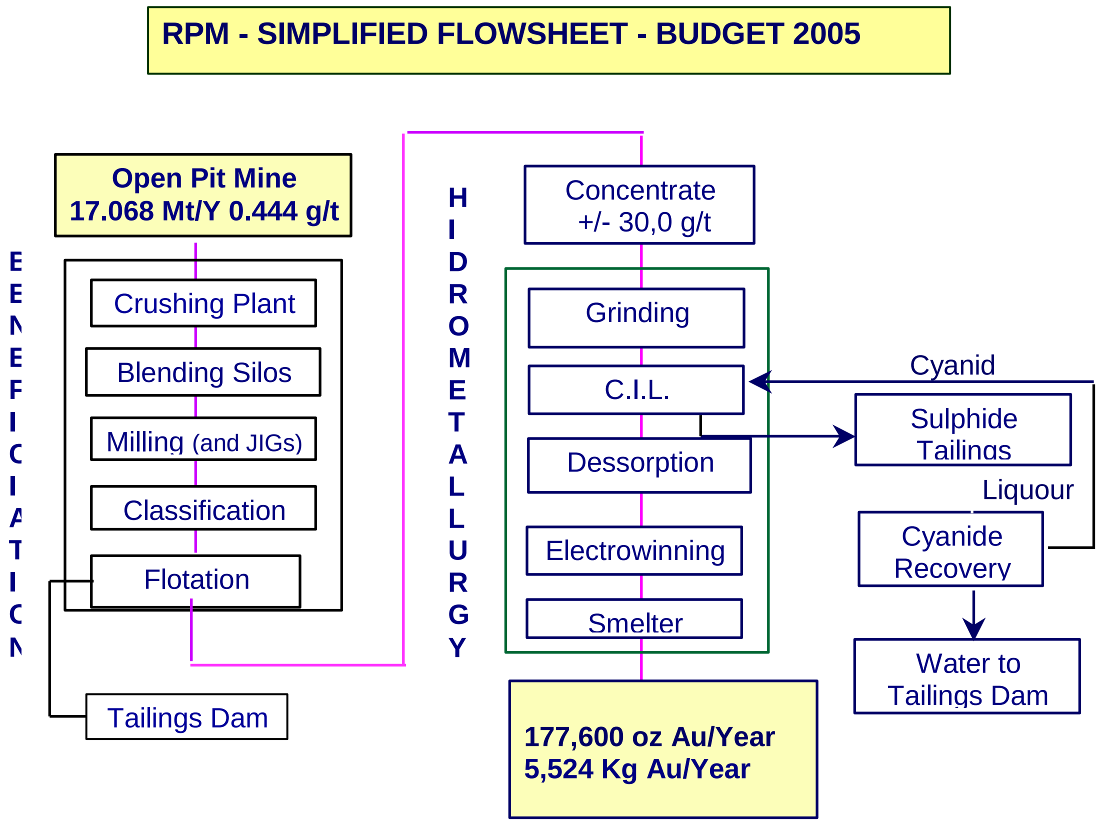

Figure 3: Simplified flow sheet (2005)

Water Management in the Pit

The open pit has a large surface area with sulfide mineralization exposed in places that produces acid rock drainage (ARD). Run off from the pit floor is captured in mine sumps located in the lowest points of the pit perimeter preventing off site migration of acidic water. There are two pumping stations installed at the lowest point of the largest mine sump and at a mine sump in the Northeast extension of the mine transferring the water to the mill for reuse.

Sulfide Tailings Disposal

A small fraction of the mill feed is recovered as a sulfide concentrate containing high levels of cyanide (CN) and As. This material is permanently disposed in lined waste cells referred to as "specific ponds".

The decant water from the ponds is returned to a special CN recovery circuit at the mill. The Acidification, Volatilisation and Recovery (AVR) Plant recovers an average 60% of the total CN and subsequent to the AVR process As concentration is reduced by the addition of $Fe_2(SO_4)_3$. The treated water is send to the main Tailings Dam. When the storage capacity of a specific pond is reached, a cover is constructed to prevent infiltration of water into the cell.

Floatation Tailings Disposal

The main tailings impoundment at RPM receives the bulk of the tailings stream (about 98%) from flotation. The tailings facility is approximately 3.5 km in length, 75 meters in height, with a surface area of approximately 600 hectares.

The flotation tailings contain a small amount of sulfide minerals that are not recovered in the beneficiation plant. The tailings facility also receives treated water from the AVR Plant. There have been no releases from the tailings facility as a result of upset conditions. The only outflow from the facility is from the underdrain of the dam at a flow rate of approximately 120 m^3/h. Limestone is added to run-of-mine in order to neutralise the residual sulfide minerals and avoid acidification of the tailings pond. As a result, the supernatant water is slightly alkaline with a pH between 7 and 8.

Approximately 85% of the process water used at RPM is recycled in order to minimize the consumption of freshwater. A majority of the recycled water is recovered from the tailings facility.

Figure 4 and 5 provides an overview of the pit and the tailings facility.

Figure 4: Morro do Ouro open pit mine

Freshwater Resources

RPM holds a permit for withdrawing freshwater from the São Pedro and Santa Rita rivers with a combined capacity of 2600 m^3/h. Only a fraction of the licensed limit has been utilised in the past because the majority of the water requirements have been met using recycled water.

Figure 5: Tailings dam facility

Expansion Project

Currently, annual production at RPM is around 20 million tonnes per year. A scoping study has been undertaken to determine the feasibility of increasing production to 30 million tonnes per year. An uncertainty about the feasibility of the expansion is whether there will be sufficient water supply available. Because of the complexity of the water management system and the uncertainty in many of the processes involved, a probabilistic Dynamic System Model (DMS) was developed of the water management processes at RPM to better understand all water fluxes on site and the capacity for expansion.

Developing the Dynamic System Model

The first step in developing the Dynamic System Model was to prepare a conceptual model of the existing water management system. The conceptual model consists of the system components and description of the interactions between the components. The system includes the storage capacity represented by the pit mine sumps and the tailings impoundment, consumption of water by the floatation cells, offsite water sources, and the generation of tailings and a sulfide waste stream. The boundary conditions for the model include the precipitation and evaporation rates in the area of the mine and the permitted extraction rates from the São Pedro and Santa Rita rivers.

The conceptual model was developed based on discussions with the operations and environmental management staff at the site. The pumping rates and production data were assembled following a detailed evaluation of the water management data from previous years. This included an assessment of the variability and uncertainty in the data and system operations. The interactions between the system components were represented by empirical relationships or rules derived from the operating record and analysis of the site data. For example, the operational rules for deciding whether to send water from the tailings impoundment or the rivers to the floatation circuit were documented and included in the model. A schematic picture of the conceptual model for RPM is shown in Fig. 6.

The climate can have a significant impact on the operation of the water management system. The tailings impoundment has a substantial catchment area that generates significant runoff volumes during the rainy season. The flows in the São Pedro and Santa Rita rivers and the ability to withdraw up to the permitted maximum rate are also influenced by the climate. Therefore, a detailed record of precipitation was assembled that included data from 1965 to the present. The record was sufficiently long to capture the long-term variability in rainfall for the area. Pan evaporation data during this period were also available and included in the climate record.

The conceptual model was the basis for developing a mathematical model of the water management system. A dynamic, probabilistic simulation program (GoldSim) was used. The major components in the model include a detailed representation of the ore processing plant, the water storage ponds and reservoirs within the open pit area, the tailings impoundment, and the climate model. The main inputs to the model were:

- Plant inputs – the production schedule to assume during the simulation period, thickener capacity and the percent solids in the plant discharge to the tailings impoundment;
- Initial conditions in the tailings impoundment – freewater volume, tailings volume, dam raise schedule, pump capacity, minimum allowable freeboard, runoff coefficient for the catchment area;
- Makeup water – limits for withdrawing water from the rivers during the wet and dry season and the capacity of the pumps and pipelines
- Catchment area and water storage capacity for the different mine sumps within the pit
- Climate – whether deterministic (constant) or stochastic climate conditions should be used in the simulation

The simulation model attempts to operate the plant based on the specified production schedule and the availability of water from the tailings impoundment and other sources (e.g., river makeup water). Monte Carlo simulations are performed to assess the likelihood the production schedule will be met based on the uncertainty in the input assumptions. Time histories of the volumes and flow rates within the water management system are generated for later processing and analysis providing insights into the cause-effect relationships between the different mine components and conditions.

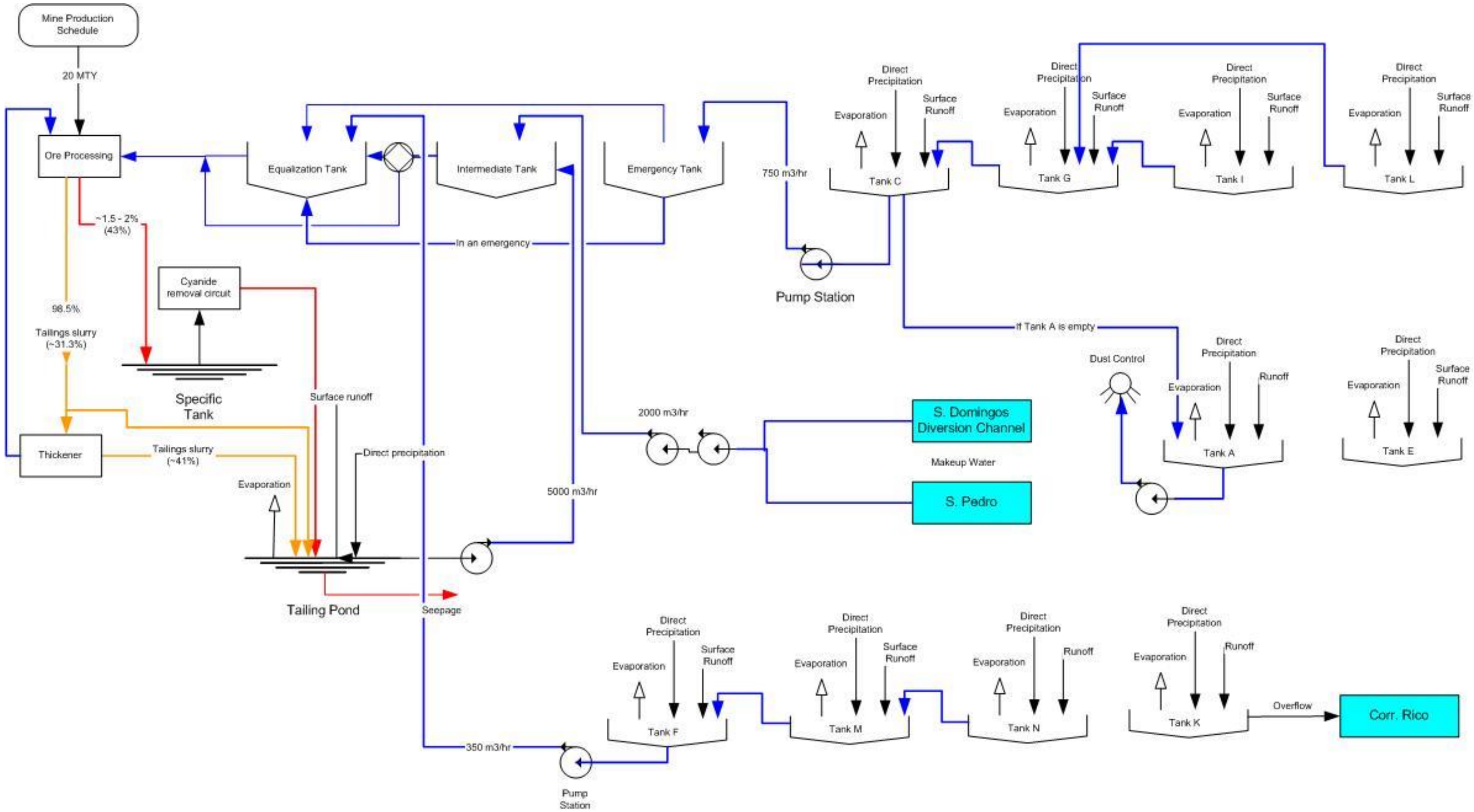

Figure 6: Conceptual model of RPM Water Management System

A graphical interface was developed for the model that consists of a series of dashboards for setting up different scenarios and viewing the model projections. Outputs from the model include:

- Production rate – equal to the production schedule unless there was insufficient water available to meet plant demand;
- Water usage – time history of the water use by source used to meet plant requirements;
- Water availability – freewater volume in the tailing impoundment as a function of time;
- Freeboard – difference between the water elevation in the pond and the spillway elevation
- Likelihood of meeting the production schedule – probability distribution function showing the likelihood the plant will meet the production schedule under the assumed conditions

The model was calibrated using historic production and climate data from May 2003 to December 2004 and comparing the projected tailing impoundment elevations and water use rates and sources with the operational records.

Model Application

Following calibration, the model was used to investigate whether the current configuration of the water management system was capable of supporting an increase in mine production from 20 to 30 million tonnes per year. The RPM mine planning group provided the production schedule indicating how long the mine would operate at the increased level and the reduced rates as the ore body is depleted. The simulation duration was set equal to the mine life for the specified production schedule. The model randomly selected a year within the climate record as the starting point for each simulation. A one-month time-step was used.

The simulation projections indicate that the current configuration of the water infrastructure will support the expansion to 30 million tonnes per year. No additional water resources are likely to be required. The increased production rate could not be sustained in less than 1% of the realisations and in these cases the available rate was nearly equal to the 30 million tonne per day goal. The simulation suggests that even during years with the lowest historical rainfall (852 mm), there is a small surplus of water available for processing.

Continuous Improvement in Water Management:

It is planned to use the model by the RPM Water Management Committee to evaluate water use on a monthly basis in order to optimise the operation of the existing water management system. Alternative pumping scenarios are being simulated to look for ways to improve the use of the water resources as well as minimise energy consumption by the pumping stations. This process facilitates communication and the exchange of ideas within the operations and environmental management teams and identifies opportunities to further improve the overall operation of the mine.

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