Mt Leyshon Gold Mine Automated Monitoring Network: Meeting Environmental and Social Commitments

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Abstract

Newmont understands that stewardship of the environment and relationships with the communities in which they operate are inextricably linked to the success of the business. This has led to the recent implementation of a state-of-the art monitoring network at the Mt Leyshon Gold Mine (Charters Towers, Australia) that enables Newmont to automatically collect water monitoring data for statutory compliance and strategic purposes.

The monitoring network consists of seventeen different sites that monitor weather data, water levels, water flows and water quality in receiving waterways, dams and groundwater bores. The monitoring network has been configured to provide site personnel with cell phone SMS text message notification of sample collection and other events that are triggered by rainfall. The monitoring stations are solar powered and are equipped with mobile phone telemetry that sends the monitoring data back to an internet-based data server. The web server allows near real-time remote access to and visualization of the monitoring data.

In addition to meeting regulatory compliance monitoring requirements, the monitoring network is providing Newmont with an improved understanding of the site water balance which will inform decisions on the closure outcomes for the mine.

This paper demonstrates that a state-of-the art monitoring network approach can deliver data that will support the mine closure process.

Introduction

The Mount Leyshon Gold Mine is located near the town of Charters Towers in Queensland, Australia. The mine was an open cut mine producing gold and silver. Operations commenced in September 1986, initially as a heap leach operation of oxide ore and expanding in 1989 to Carbon-In-Pulp (CIP) processing of primary un-oxidised ore. Mining ceased due to depletion of the ore body in early 2001, after which ore was sourced from low grade stockpiles which were processed until their exhaustion in March 2002. The site was acquired by Newmont after operations had ceased.

The site comprises a single large open cut pit, three tailings storage facilities (capped and revegetated), three waste rock dumps (covered and rehabilitated), sedimentation traps and dams, seepage sumps, a water supply dam and a number of drainage channels. Initial decommissioning and rehabilitation earthworks were completed and the site is now in the post-closure monitoring stage. On-going rehabilitation works are being undertaken by Newmont.

The Mt Leyshon Gold Mine is located in the tropical region of Australia. Mean annual rainfall is 650 mm/year, but is also highly variable and can exceed 2,000 mm/year. The rainfall distribution is strongly seasonal, with the majority of rain falling during the summer wet season months of December to April and the majority of wet season rainfall occurring in a small number of high intensity storm events. Waterways in the region are highly ephemeral, with negligible stream flow during the dry season and only a small number of short duration, but often large magnitude, flow events during the wet season. Mean annual evaporation is 1,900 mm/year. Despite the fact that annual evaporation exceeds rainfall, the combination of high intensity rainfall and acid rock drainage makes the management of surface water at the mine site a difficult exercise.

The water management system at the mine consists of:

- Seepage sumps located downstream of tailings dams and water containment dams. Seepage flows are pumped from the sumps into water containment dams via electric and solar powered pumps.
- Water containment dams located around the perimeter of the mine footprint. The water containment dams intercept catchment runoff and direct seepage flows from mine-impacted areas and also receive water transferred from seepage sumps. Water collected in the water containment dams is pumped to the open mine pit via electric and diesel powered pumps.
- The open mine pit which receives runoff from adjacent facilities and mine impacted catchment runoff and seepage flows pumped from the water containment dams and seepage sumps. The water level in the pit is currently approximately 100 m lower than the regional groundwater level and the pit currently acts as a sink to groundwater flows.

The aim of this paper is to evaluate the feasibility of an advanced monitoring capability to support mine closure design.

Environmental regulation and justification

The site is regulated by the Queensland Department of Environment and Resource Management via an Environmental Authority, Environmental Management Plan and a Plan of Operations. It was identified following severe rainfall events (including a 160 year Average Recurrence Interval 8 hour duration rainfall event in January 2008) that the monitoring systems in place were not providing sufficiently reliable and detailed data to appropriately understand the water qualities through short and medium timeframes across a sufficiently representative section of the mine site. Although improvements to the water monitoring systems were already in progress, these were significantly augmented following the 2008 rainfall event.

The primary reasons for the installation of an automated monitoring network for the Mt Leyshon Mine were:

- More reliable and regular compliance monitoring in receiving waterways at the downstream mine lease boundary (i.e. compliance monitoring).

- Ability to detect whether mine discharges have an adverse impact on receiving water quality so that downstream landholders can be informed (i.e. incident monitoring).
- To demonstrate the effectiveness of drainage diversions and to obtain a better understanding of the site water balance and the relationships between flow conditions and water quality (i.e. strategic monitoring).
- To provide comprehensive monitoring data at various locations within the mine site to inform water models and strategic planning processes.

Description of the automated monitoring network

Consisting of seventeen different sites (Figure 1), the monitoring network includes:

- A weather station.
- Water level and water quality monitoring stations at five creek sites (three on-lease sites and two off-lease sites).
- Water level and water quality monitoring stations at two high flow drainage diversions.
- Water level sensors and flow meters on pumps at five water containment dams.
- Water level sensors in three groundwater monitoring bores.
- Water level and water quality monitoring probe within the residual mine pit.

The requirements for the monitoring network were developed collaboratively by Newmont, GHD Pty Ltd and Schlumberger Water Services. The monitoring network was supplied and installed by Greenspan Technology Services.

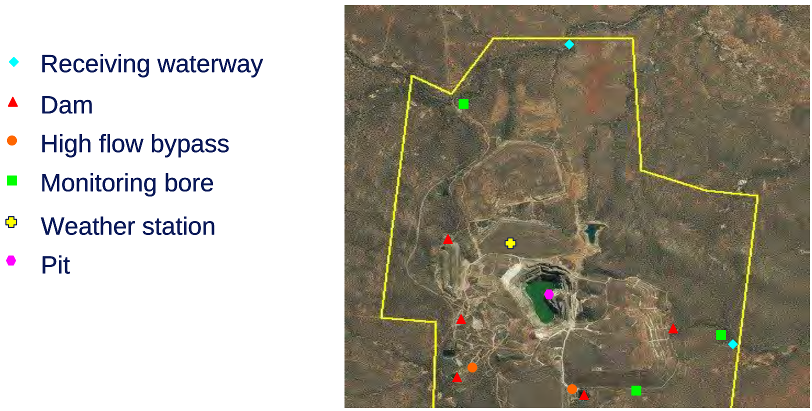

***Figure 1**: Locations of on-lease monitoring stations*

Each separate monitoring site is solar powered, contains a Campbell Scientific data logger, and is equipped with cell phone telemetry that sends the monitoring data back to an internet-based data server.

Details of each different type of monitoring site are summarised in Table 1. The following sections provide a brief description of the key aspects of each type of monitoring site.

Automatic weather station

The mine weather station (Figure 2) was an existing installation that previously recorded to a data logger. The weather station was provided with cell phone telemetry and is now part of the automated monitoring network. The station records a range of standard meteorological parameters and also includes a digital calculation of potential evapotranspiration.

Receiving waterways (on-lease)

The Mount Leyshon site lies on a catchment divide. Surface water drainage from the rehabilitated facilities is generally either to the north or to the south and there are three main ephemeral streams within the mine lease which exit the lease at the north-east, south-east and eastern boundaries.

The three on-lease receiving waterway monitoring sites are located at the mine lease boundary where the three ephemeral streams exit the site. These stations have replaced manual rising stage samplers which were previously used for compliance monitoring purposes. The primary purpose of the stations is to monitor the water level (surrogate measure of stream flow) and water quality of receiving waterway flows crossing the mine lease boundary.

Water level is monitored using a gas bubbler system to relay water depth signals to a pressure sensor located in the main instrument housing on top of the creek bank. Creek cross sections have been surveyed at the monitoring station sites and discharge rating curves developed to allow stream flow rates to be estimated from the water level measurements. The sites contain tipping bucket rainfall gauges which allow the water level and stream flow measurements to be related to local catchment rainfall.

Continuous measurements of water quality are made using an electrical conductivity (EC) probe installed at the base of the stream. EC is used as an indicator of poor water quality (e.g. low water pH, high concentrations of sulfate or metals) and relationships relating EC to sulfate concentration have been developed for each individual monitoring site using the monitoring database. Automatic sampler devices (Figure 3) collect water samples at pre-programmed sequences of water levels by pumping from the stream into a sample bottle carousel (up to 24 one litre samples can be collected in a single event). Over time, it is envisaged that a sufficient number of water samples will be collected and analysed to enable more detailed correlations to be developed between the field EC measurements and detailed laboratory analysis results for water quality. Cell phone telemetry allows automatic notification of sample collection via cell phone SMS text message.

The combination of continuous water level (stream flow) and EC measurements and collection of water samples at different depths facilitates the calculation of constituent loads for the receiving waterways.

Two of the monitoring stations are located on elevated platforms above the creek bank to protect the electrical equipment against inundation from floodwaters (Figure 3).

Figure 2: *Mine weather station (Left: main station. Right: tipping bucket rain gauge)*

Figure 3: *Receiving waterway station (Left: elevated platform. Right: automatic sample*

Table 1: *Details of monitoring sites*

Site Type	Sensors	Parameters Measured	Monitoring Frequency
Weather station	Campbell Scientific weather station	Air temperature, relative humidity, wind speed and direction, solar radiation	15 minutes
	0.2 mm tipping bucket rain gauge	Rainfall	Every 0.2 mm rainfall
Receiving waterway (on-lease)	Ott bubbler pressure sensor	Water level	5 minutes
	Greenspan EC1200 sensor	Electrical conductivity and water temperature	5 minutes
	0.5 mm tipping bucket rain gauge	Rainfall	Every 0.5 mm rainfall
	Sigma SD900 automatic sampler	Water sample (up to 24 x 1 litre sample bottles)	Triggered by water level
Receiving waterway (off-lease)	Greenspan CTD3100 multi-parameter sensor	Water level, electrical conductivity, water temperature	5 minutes
Dams	Greenspan PS1000 pressure sensor	Water level	5 minutes
	Siemens Mag Flow 5000	Flow rate, flow volume (pumps)	5 minutes
Dam high flow bypass	Ott bubbler pressure sensor	Water level	5 minutes
	Greenspan EC1200 sensor	Electrical conductivity and water temperature	5 minutes
	Sigma SD900 automatic sampler	Water sample (up to 24 x 1 litre sample bottles)	Triggered by water level
Groundwater bores	Greenspan PS7000 pressure sensor	Water level	1 hour
Pit	Greenspan CTDP300 multi-parameter sensor	Water level, electrical conductivity, pH, water temperature	1 hour

Receiving waterways (off-lease)

Combined water level/EC/temperature probes are located on the two principal receiving waterways downstream of the mine. Continuous monitoring data from these monitoring stations can be used to ascertain whether mine-impacted discharges have influenced water quality in receiving waterways so that Newmont can provide notification to downstream landholders.

Water containment dams

Monitoring stations have been installed at five water containment dams. These stations monitor the water level in the dams (pressure sensor) and the flow rate and cumulative flow volume (electromagnetic flow meter) passing through the electric and diesel powered pumps that dewater the dam contents to the open mine pit. Cell phone telemetry allows automatic notification of dam overflows via cell phone SMS text message.

The water level monitoring data can be used for operational purposes and also can be used to estimate catchment runoff inflows to the dams based on the rise in dam water level and the known storage characteristics of the dam (determined by ground survey). Metered pump flow volumes can be used to infer seepage inflow rates to the dams (during periods of no rainfall) and to quantify the contribution of the water containment dam pumping to the water balance of the pit.

Dam high flow bypass facilities

The purpose of the water containment dams is to intercept and store poor quality catchment runoff and seepage flows so that this water can subsequently be transferred to the pit. In many areas the mine rehabilitation works have been successful in preventing surface runoff from coming into contact with mine waste material. Newmont has observed that the poorest quality inflows to some dams are seepage flows that occur before and after significant rainfall events. Surface runoff during rainfall events can cause the dams to fill with relatively good quality water, leaving minimal storage capacity for poor quality seepage flows that can persist for some time after rainfall has ceased.

Newmont has constructed high flow bypass facilities upstream of two water containment dams. These structures consist of an embankment across the main inflow channel to the dam, with a number of pipes through the embankment. Low flows (e.g. poor quality seepage flows) pass through the low flow pipes into the water containment dam, while high flows (large catchment runoff flows) are diverted by the embankment over a spillway and into a channel that directs the bypass flows around the dam.

The high flow bypass facilities provide an adjustable automated method for segregation of poor quality and good quality water streams based on flow rate (Figure 4), maximise the storage capacity of the dams for containment of poor quality seepage water, and reduce the contribution of the water containment dams to the pit water balance.

Monitoring stations have been installed in the high flow bypass facilities to monitor the quantity and quality of bypass flows. These monitoring stations will be used to assess the effectiveness of the high flow bypass facilities, to adjust and calibrate their operation (primarily by modifying low flow pipe capacities) and to validate their operation to the regulatory agency. The monitoring stations are similar to the on-lease receiving waterway sites (continuous field measurement of water level and EC with automatic sample collection).

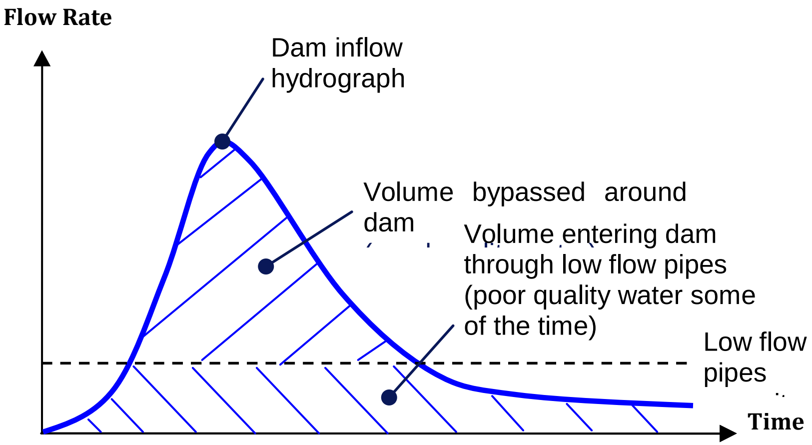

Figure 4: *Flow-based segregation of good and poor quality water in high flow bypass facility*

3.1 Groundwater bores

The mine has an extensive network of groundwater monitoring bores that are typically monitored on a quarterly basis. Pressure sensors have been installed in three groundwater bores to provide "continuous" groundwater level traces to better understand the relationships between rainfall, shallow seepage flows and groundwater recharge. The pressure sensors are vented to compensate for barometric pressure changes. A typical installation is shown in Figure 5.

Open mine pit

The mine pit receives inflows from:

- Direct rainfall within the pit rim.
- Rainfall runoff from external catchment areas that drain into the pit.
- Pumped inflows from the water containment dams.
- Groundwater inflows (pit currently acts as a sink to groundwater).

Because of pit wall instabilities, it has not been safe to access the pit for several years. Accordingly, there has been very limited monitoring of water levels and water quality in the pit since mine closure. Periodic estimates of pit water level have been obtained from aerial photography and satellite imagery, however the accuracy of these estimates is low, and the large time intervals between observations do not allow resolution of the dry season (groundwater dominated) and wet season (runoff dominated) responses of the pit lake.

Figure 5: *Groundwater bore monitoring station*

A multi-parameter water level and water quality (EC, pH and temperature) sensor has been installed in the pit. This monitoring station will facilitate an improved understanding of the pit water balance and provide input and calibration data for groundwater and water balance models that will be used to develop forecasts of future pit water levels and quality.

Web-based data server and interface with monitoring database

All monitoring data from the automated monitoring network is downloaded by cell phone telemetry every hour to a web-based data server (ENVAULT) that is maintained by Greenspan Technology Services. The data server is password protected and provides authorised users from any location with internet access with near real-time remote access to and visualization of the monitoring data.

Data from the automated monitoring network will be periodically (every six to 12 months) downloaded from the ENVAULT data server and imported into the Phoenix monitoring database maintained by the Centre for Mined Land Rehabilitation at the University of Queensland. Phoenix (Pudmenzky et al., 2006) is a data management system that provides all functionality necessary to store, retrieve, visualise and analyse environmental data. In this way ENVAULT will be used for storage of and access to recent monitoring data, while Phoenix will be used for storage of long-term monitoring data and more advanced visualisation and analysis of the monitoring data.

Applications of monitoring data for determining closure outcomes

The following sections provide examples of how the data from the automated monitoring network is being used to assist with the determination of closure outcomes for the mine.

Estimation of catchment runoff and seepage inflows to dams

The mine has experienced a number of large rainfall events in the last five years and there have been several incidents of discharges from the dams to receiving waterways. There has been an increased focus from operations personnel, Newmont management and the regulatory agency on the performance of water containment dams and pumping facilities.

GHD Pty Ltd developed a GoldSim (www.goldsim.com) water balance model of the Mt Leyshon Gold Mine site in 2007. The water balance model operates on a daily time-step and simulates the quantity and quality of water within the water containment dams and seepage sumps at the mine, the open mine pit, and waterways that have the potential to receive discharges of mine-impacted surface water during large rainfall events. At the time of the model development, there was very limited information available to define the characteristics of processes such as catchment runoff and seepage flows. Data from the water containment dam monitoring stations is currently being used to infer catchment runoff and seepage inflows to water containment dams.

The storage characteristics (storage volume vs. water level) of the water containment dams have been determined through ground survey. Catchment inflow volumes can be determined from dam water level rises and compared to measured rainfall totals to establish rainfall-runoff parameters for the catchment area of the dams (Figure 6). Similarly, pump flow monitoring data during periods of no rainfall can be used to determine seepage inflow rates to the dam (Figure 7). Rainfall conditions have resulted in seepage flows at the mine being higher than normal over the last two years and these have been the major contributor to an accelerated filling of the pit.

Performance of high flow bypass facilities

High flow bypass facilities have been constructed upstream of the Settlement Dam and Mt Hope Dam. These facilities enable larger catchment runoff events to bypass the dams, with smaller runoff events and seepage flows draining to the dams through low flow pipes. Monitoring of the quantity and quality of bypass flows is being undertaken to validate and calibrate the performance of the high flow bypass facilities.

Figure 8 shows the monitoring data for a bypass event in February 2010. Catchment inflows bypassed the Settlement Dam for a period of 35 minutes, during which the maximum recorded EC was 1,800 µS/cm. The maximum EC value was significantly smaller than the receiving waterway limit of 5,970 µS/cm defined in the Environmental Authority. This data validates Newmont's observation that moderate to large catchment runoff flows are typically of suitable quality for direct discharge to the environment.

The use of high flow bypass facilities significantly reduces the likelihood of uncontrolled discharges from the water containment dams, reduces dam pumping costs, and reduces the water inventory reporting to the pit.

Understanding pit water balance

A water level and water quality monitoring probe was installed in the open mine pit prior to the onset of the wet season in October 2009. The probe provides hourly water level and water quality readings. The ability to monitor changes in pit water level on a regular basis will facilitate an improved understanding of the inflows to the pit.

The GoldSim water balance model for the mine site utilises a simplified one-dimensional radial groundwater flow equation to calculate groundwater inflows to the pit. There has previously been limited available data to quantify the parameters required for this equation, or to develop a more sophisticated approach to groundwater estimation. Measurement of water level (volume) changes in the pit during periods of minimal rainfall allows the groundwater inflow rate to be inferred from other measured or estimated inflows and outflows (Equation 1).

Groundwater Inflow = Pit Volume Change + Evaporation – Direct Rainfall – Pumped Inflows (1)

Figure 9 shows the derivation of groundwater inflow rates to the pit for the period October 2009 to January 2010. The groundwater inflows were calculated using Equation 1, with evaporation and rainfall data obtained from the mine weather station and pumped inflows obtained from the flow meters on the pumps at the water containment dams. The estimated groundwater inflow rate during October is very small (i.e. pit water level decreases due to evaporation exceeding groundwater inflow), and then appears to increase during the months of November to January. The inferred groundwater inflow rates (0 to 5.9 L/s) are significantly smaller than the rate predicted by the one-dimensional radial groundwater flow equation utilised in the site water balance model (10 L/s at current pit water level), and reflect the departure of the fracture controlled groundwater system from the assumed homogeneous model.

The data from the monitoring network will be used to calibrate the water balance model, and to refine the prediction of groundwater inflows. The calibrated water balance model will be used to generate future void filling projections under various potential alternative management scenarios for the mine site.

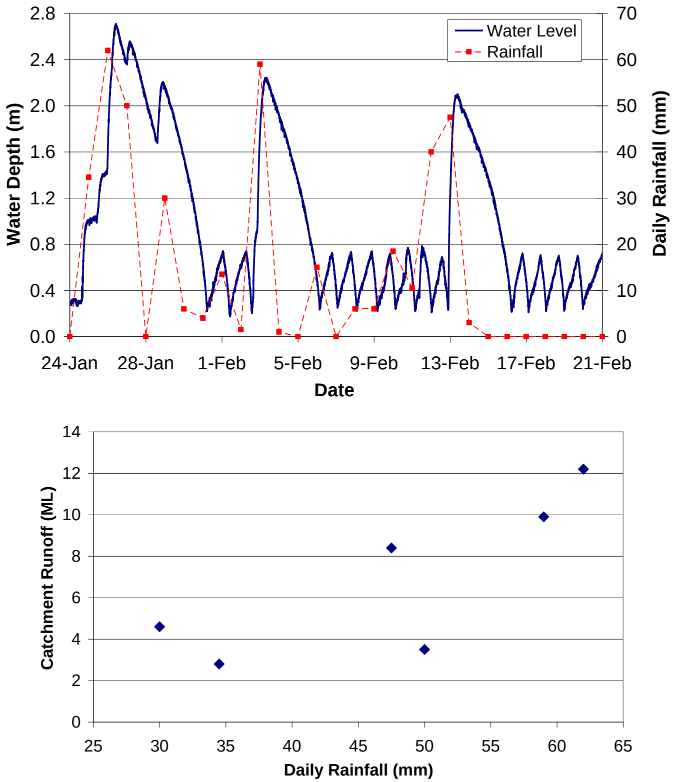

***Figure 6:** Catchment runoff derivation – Supergene Stormwater Dam*

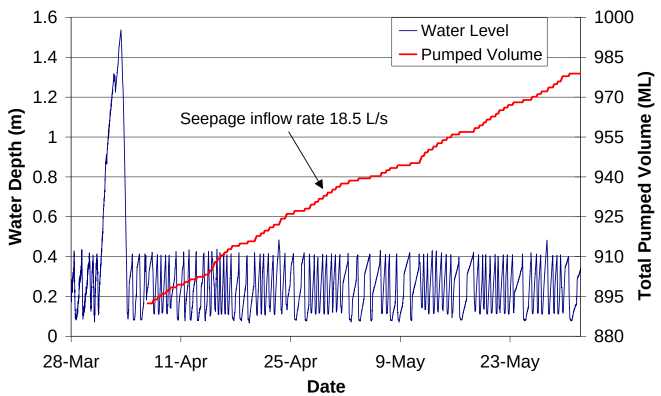

***Figure 7:** Dam seepage inflow derivation – Plumtree Creek Dam*

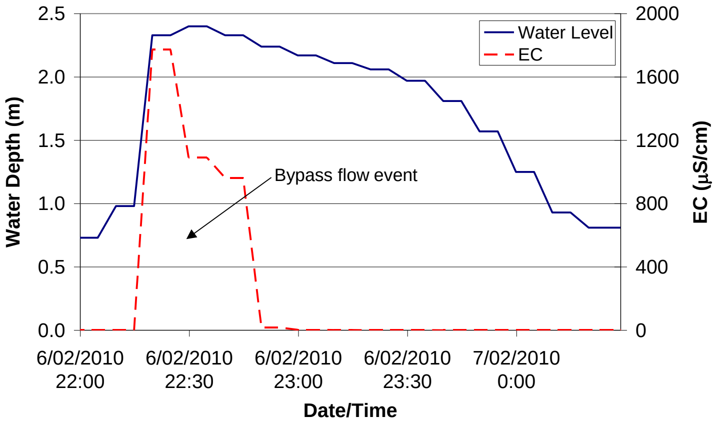

***Figure 8:** Performance of high flow bypass facilities – Settlement Dam*

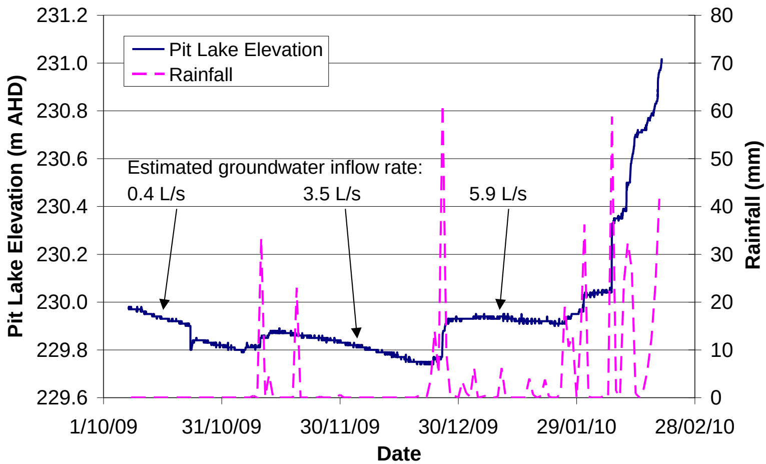

***Figure 9:** Groundwater inflow estimation for pit*

Conclusions

The monitoring network is assisting Newmont in achieving a wide range of objectives including:

- Improving the management of dams and pumping systems.
- Improving the development of void and groundwater models.
- Providing confirmation and assurance of mine influences on the surface water drainages and groundwater system to regulators and other downstream landholders.

- Improving sampling capability of critical events during extreme weather and poor access conditions.
- Development of internal and regulatory reporting.
- Improving the understanding of the site water balance.

Although the automated monitoring network has significant advantages with respect to transparency of compliance reporting, the most significant advantages are strategic. The capacity to inform models with data of this frequency and spatial distribution will, as seasons and periodic climatic patterns pass, provide essential insights into long term management performance and the risks and opportunities for the site wide water management system going forward. Large closed mine sites with acid mine drainage issues in tropical areas are both complex and dynamic. The system outlined above provides invaluable tools for the development of strategic management plans which in turn will maximise returns on investment and provide clarity and assurance to regulators and stakeholders.

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