Is Water Conservation and Water Demand Management a real option?

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Abstract

South Africa is amongst the 40 driest counties in the world with extreme weather conditions and is beset by both droughts and floods. Coupled with economic growth is an increased demand on water resources, and as with all other industrial developments mining requires large volumes of water that is likely to have an impact on the environment. Further to this the mining industry also realizes that minerals are a non-renewable resource and the contribution to wealth creation from mineral extraction is not everlasting. It serves as an economic boost and careful planning is required to ensure that the legacy of mining is sustainable, and that some of the returns from mining provide continual economic and social prosperity.

Keywords: 40 driest country, dynamic water balance, anthropogenic aquifers

Introduction

Lonmin acknowledges the necessity to understand the possible long-term advantages and disadvantages of open pit mining and aims to ensure that in the aftermath of mining the local community will inherit an invaluable renewable water resource. Lonmin has embarked on a long term project to use their Marikana Operations as a flagship to ensure that the legacy left behind is that of sustainability for the local people and their generations to come. These ideas were forged from world-wide programmes learnt from dewater measures of mines, typically from projects like the lignite deposit in West Macedonia, Greece where is is an ongong project with the first doctoral finished in 2001 and still learning from it (Dimitrakopoulus *et al*, 2008). As a result Lonmin began detailed modeling to understand the dynamics of variable rainfall within a drought stricken country. The data already available indicate that an integrated water resource management programme can create an opportunity to harvest and bank water when it is plentiful and available, and to release the water for use during dry periods, thereby limiting the impact on bulk water use. These methods are being applied in countries like Germany, with have high population densities within mining areas where harvested water is used as raw water as well as for remediation of pit lakes (Schultz *et al,* 2011). Such a project will enable Lonmin not only to extract mineral resources to give South Africa the economic benefits of mineral extraction, but will also leave behind a legacy of available water supply that will ensure a more sustainable future for all concerned.

Continuous economic growth in South Africa, means that the mining industry requires additional water resources – however, much of the existing bulk water resources are already allocated or insufficient. The Department of Water Affairs (DWA) continues to urge industry to consider water conservation and water demand management strategies to meet the continual increase in water demand. The latest integrated water use licensing conditions also requires mines to develop water conservation and water demand management (WC/WDM) strategies. As a result DWA developed a Water Conservation and Water Demand Management Guideline for the Mining Industry (Department of Water Affairs, 2011). The Guideline defines water conservation as “the minimisation of water loss or waste, the care and protection of water resources and the efficient and effective use of water”. Water demand management is described as “the adaptation and implementation of a strategy or a programme by a water institution or water consumer (such as a mine) to influence the water demand and use of water in order to meet any of the following objectives: economic efficiency, social development, social equity, environmental protection, sustainability of water supply and services and political acceptability”. Using this and other guidelines supplied by DWA, Lonmin continues to explore all avenues to ensure more effective and efficient use of water sources. The aims of the WC/WDM study are to:

- Develop a integrated water balance the reflects conditions on-site
- Identify use of dirty, grey, raw and potable water sources
- Identify opportunities to recycle and reuse grey and dirty water sources
- Identify opportunities to harvest and use grey water and use it as potable water
- Reduce Lonmin’s potable water dependency from the regional bulk water supplier
- Reduce and eliminate Lonmin’s dirty water discharges

Components considered as part of an integrated WC/WDM Strategy

It is foreseen that a number of traditional pollution control dams will still be part of the overarching WC/WDM strategy, with a large facility as a return water dam forming part of the new tailings development. However a number of non-traditional approaches were also considered and now forms part of an integrated WC/WDM Strategy for Lonmin:

- Water Balance Simulation Model (WBSM) to understand water resource management on-site
- Agree on current water operating rules and develop Water Balance Simulation Model accordingly
- Use the model to assess water use efficiencies and identify options
- Storm Water Management Plans (SWMP)
- Effective use of dirty water derived from rainfall
- Reduction of surface water ingress (Effective rehabilitation of open cast areas)
- Water treatment plants (WTP)
- Pollution control dams
- Effective management of clear grey water harvested from mines
- Default Aquifer Storage and Recovery (ASR) and active ASR
- Water use metering

From the 11 strategies only two will be discussed as part of this paper, the rest of the strategies will be discussed as part of the final report at the end of 2012. As a result the WBSM and the default ASR in the anthropogenic aquifers are discussed in this paper.

Methodology used for the Water Balance Simulation Model

Simulations are a valuable tool for decision support when future scenarios and risks need to be optimised. Lonmin developed a number of static water balance models with most of the associated flow information available. A baseline dynamic model was developed using Arena v13 software from Rockwell Automation. The WBSM enables Lonmin to:

- Integrate most dynamic variables that impact on water resources (reliability of source, plant maintenance/breaks, rainfall events, dam sizes, variable seepage and evaporation rates, variable production rates, flow logic, etc.);
- Incorporates natural variances in daily rainfall and runoff rates, production rates and maintenance events (scheduled and unscheduled);
- Records the frequencies and severity of droughts and flood events to show how often dams will run empty or what volumes dams will overflow;
- Calculates the average and peak raw water requirements and costs over the life of operation (if required for the Integrated Water Use Licence Application (IWULA));
- The dynamic simulation model enables Lonmin to identify risks or bottlenecks directly from the output graphs or during simulation.
- Alternative strategies, flow logic and dam sizes can be tested and optimised before actual capital is spent.
- During the development phase of the WBSM default water resource management operating rules were captured and developed. These operating rules can be captured in separate operating manuals and if possible, programmed into the operational Control and Instrumentation (C&I) management system.
- As part of the WC/WDM Strategy the WBSM needs continuous updating as different components are implemented and more metering information becomes available. This will result in a more refined model.

Philosophical approach to use anthropogenic or engineered aquifers as a form of ASR

The mining sector has for many years altered the hydrogeological and hydrological flows of aquifers and catchments to create anthropogenic or "man-made" conditions. The dynamic nature and spatial changes within the modern mining environment makes it difficult to build good predictive models (Brechenridge *et al,* 2011). Surface flows are affected by altering of soils and vadose conditions, resulting in higher permeability during and after mining. During rainfall events this results in higher recharge into the subsurface and aquifers. Pre-mining, most of the aquifers are semi-confined aquifers with low effective porosities, compared to the now backfilled open pits consisting mostly of fresh gravel and boulders with effective porosities of up to 25%. The pits may be as deep as 60 meters below ground level (mbgl) whereas the natural groundwater levels are much lower and groundwater continuously discharges from the semi-confined to the unconfined systems. Mining activities by default lead to enhanced aquifer conditions and are likely to store large volumes of water. At Eland Platinum Mine (EPM) both active ASR takes place where water from the irrigation board is stored in old backfill mining pits as a wells as passive ASR where ground discharges into the backfilled aquifers (Botha, 2011). In both instances boreholes are used to access clear grey water and use it for almost everything except potable water.

Results and Discussion

Water Balance Simulation Model (WBSM)

Key to the WBSM is to understand the influence of rainfall variability and how it influence the availability of return water from the open pits as well as water returned from the Tailings Dams (TD). Generally the TDs have a strong correlation with rainfall, however operation thereof plays a major role, therefore although TD 3 and TD 4 receive the same rainfall the amount of water taken from and placed on the TDs differs completely. As a result the operations experience early shortcomings from TD 4, especially during early dry winter seasons. Accurate data was used from Rand Water Board (RWB) data to calibrate the model results (Table 1) as a result most recent on-site measurements prove the WBSM to be within 90% accuracy.

Table 1 *Calibration results for RWB 2011*

Flow No.	Model results for 2011 (m^3/a)	RWB measured 2011 (m^3/a)	% Diff.
401	27528	27041	1.8%
403	25723	75878	1.7%
431	108861	106934	1.8%
451	36900	35935	2.7%
473	51209	49870	2.7%
475	145816	142004	2.7%
478	241363	241363	0.0%
479	649682	649682	0.0%
499	1376439	1335890	3.04%

All flows and levels were captured in and castomised excel sheet. As a results all resuls can be viewed quite easly by typing in the flow number as per the process from diagram. Typcally the user can view the rainfall results showing monthly modelled results as wells as peak demands (Figure 1), as well as minimum and maximum levels in reservoirs and dams (Figure 2).

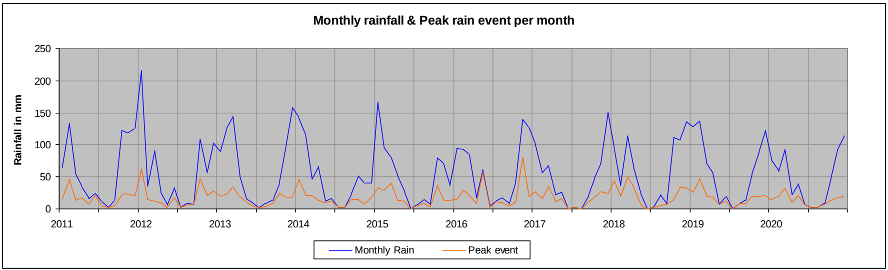

Figure 1 *Simulated rainfall max and minimum for month*

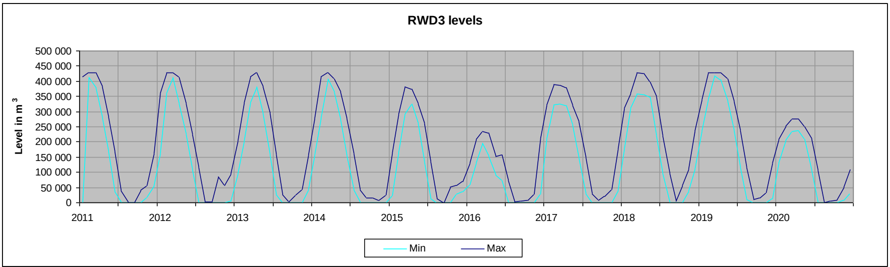

Figure 2 *Simulated levels of the Tailings Return WaterDam 3*

Anthropogenic aquifers

Boreholes in the backfill material were drilled using a symmetrix drilling setup, where the drill bit links to a drill-type casing shoe and becomes part of the casing. As a result the casing is pulled down through the backfill material. Normal ODEX or drill-and-drive methods can also be used but pushing through the loose material limits penetration depths. Initially three symmetrix boreholes and three observation boreholes were planned. However, four symmetrix boreholes and two monitoring boreholes were drilled. Once the boreholes reached the required depth, a casing cutter was used to do in-situ perforation. A 6 mm casing wall was used and the perforator was designed for a 4.5 mm casing wall. This required the drilling contractor to manufacture a casing shoe especially for the thicker casing walls.

The pilot study showed default aquifer storage and recovery (ASR) to be a viable option. In total three high yielding exploration boreholes were drilled and tested, confirming the availability of anthropogenic aquifers (Figure 3). Four different anthropogenic aquifers where identified:

- Slow leaking anthropogenic aquifers
- Rapid leaking anthropogenic aquifer Decanting anthropogenic aquifers where footwalls strikes dips towards topographical lows and decants either as fountains or in the subsurface

- Non-productive anthropogenic aquifers, shallow pits are less favourable to form anthropogenic aquifers with large storage or lower effective porosities

Figure 3 *Typical blow yields during borehole development*

Based on the pilot study and using the WBSM, detailed strategies were developed for the mine. For example the Karee WC/WDM Strategy (Karee S 2.1):

- To harvest water from default Karee ASR system and reduce spillage into the environment and reduce losses.
- Drill, test and equip four production boreholes in rehabilitated open pits at U1b,c,d and U5 (Figure 4). Equip boreholes to deliver between 50 and 70 m^3/hr, with a combined daily yield between 5000 - 6500 m^3/d
- It is believed that M1, U2, U3 and U4 are hydraulically connected. Currently water is dewatered with surface pumps and will be done so for the next 2 years or more. Recent measurements form the dry season indicate an average of 1700m^3/d pumped from U3/U2. These are much higher yields than expected and may also be attributed to the proximity of the Aquarius open pit and higher expected recharge on waste dumps.
- As soon as U3/U2 is rehabilitated place a minimum of two production boreholes of 70 m3/hour with a combine daily yield of 3300 m3/d and use default ASR.
- Construct combined concrete settler and return water dam (RWD), typically a 1000 m3 for U3 dewatering. The concrete settlers are to capture silt and are able to be mechanically cleaned. Lining of the dams is done to reduce losses and to ensure dirty water does not ingress into the groundwater or recycle back into the pit

- Construct new lined pollution control dam (PCD) of approximately 50 000 m3 and transfer all borehole and return water to Karee PCD
- Harvesting the default ASR systems will primarily occur during the dry season. This will augment lower return flows from the TSF and it is expected to reduce water in storage, thereby creating storage for the rainy season and reduce spillage
- Pipeline from U1b, c, d and U5 need to be designed to serve as a return line for possible aquifer recharge when there is too much water available in Karee PCD (Active ASR).

Figure 4 *Showing deepest positions for U1a,b,c and d, where production boreholes need to be drilled*

Conclusions

Periodically Lonmin Marikana is required to manage their operations with excess dirty water in the rainy season and insufficient water in the dry season. The water management system however was not designed to manage large variable conditions as a result increased yields or lack of water are managed “on-the-run”. The effects thereof are an inability to handle continually increased groundwater discharges and return flows. The Mine therefore had to make a mind shift to recognise (1) the availability of newly made anthropogenic aquifers lead to increasing groundwater availability (2) to use excess dirty water derived from rainfall run-off more efficiently and (3) take less water onto the Mine via the regional bulk water supplier. More effective use of dirty water will also result in limited discharges. As a result the Mine developed a water conservation and water demand management (WC/WDM) Strategy with the aims to reduce uptake of potable water, effective use of grey water and eradication of dirty water discharges. The WC/WDM Strategy consists of a number of components and includes development of anthropogenic aquifers, grey water balancing dams, dirty to grey water treatment plants and lining of surface water dams. For this purpose the Lonmin Marikana Operations were divided in three specific sub-areas and a baseline water balance simulation model was developed to identify and optimise WC/WDM options. Pilot boreholes were drilled to see if the mining area creates conditions that will lead to substantial anthropogenic aquifers and to evaluate the potential to develop the aquifers to supply the Mine’s future peak demands without using more potable water. The pilot study showed anthropogenic aquifers to be a feasible option. The detailed AR and WC/WDM Strategies are now being implemented over the next few years.

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