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 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, which 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: Water conservation, water demand management, dynamic water balance, simulation, anthropogenic aquifers

Introduction

Lonmin acknowledges the necessity of understanding 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 dewatering measures at mines, typically from projects like the lignite deposit in West Macedonia, Greece, where there is an ongoing project. The first doctoral dissertation on this project was completed in 2001, and we are still learning from it (Dimitrakopoulus *et al.*, 2008). As a result, Lonmin began detailed modelling to understand the dynamics of variable rainfall within a drought stricken country. The data already available indicates 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, the 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 an integrated water balance that reflects conditions on-site
- Identify use of dirty, grey, raw, and potable water sources
- Identify opportunities to recycle and re-use grey and dirty water sources
- Identify opportunities to harvest and use grey water and use it as potable water
- Reduce Lonmin's dependency on potable water 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 form 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 the 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 opencast 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 these 11 strategies, only two will be discussed as part of this paper – the WBSM and the default ASR in the anthropogenic aquifers. The rest will be discussed as part of the final report at the end of 2012.

Methodology used for the water balance simulation model

Simulations are a valuable tool for decision support when future scenarios and risks need to be optimized. 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.)
- Incorporate natural variances in daily rainfall and runoff rates, production rates, and maintenance events (scheduled and unscheduled)
- Record the frequencies and severity of droughts and flood events to show how often dams will run empty or at what volumes dams will overflow
- Calculate the average and peak raw water requirements and costs over the life of operation (if required for the Integrated Water Use Licence Application (IWULA))
- Identify risks or bottlenecks directly from the output graphs of the dynamic simulation model, or during simulation
- Test and optimize alternative strategies, flow logic, and dam sizes before actual capital is spent

- During the development phase of the WBSM, capture and develop default water resource management operating rules. 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 make 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 per cent. The pits may be as deep as 60 m 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), active ASR takes place where water from the irrigation board is stored in old backfill mining pits, as well as passive ASR, where groundwater discharges into the backfilled aquifers (Botha, 2011). In both instances boreholes are used to access clear grey water, which is used for almost every requirement 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 (TDs). Generally the TD water levels have a strong correlation with rainfall, but operation thereof also 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 I), and the most recent on-site measurements prove the WBSM to be within 90 per cent accuracy.

Table I-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 a customized Excel spreadsheet. All results can be viewed quite easily by typing in the flow number as per the process from the diagram. Typically 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).

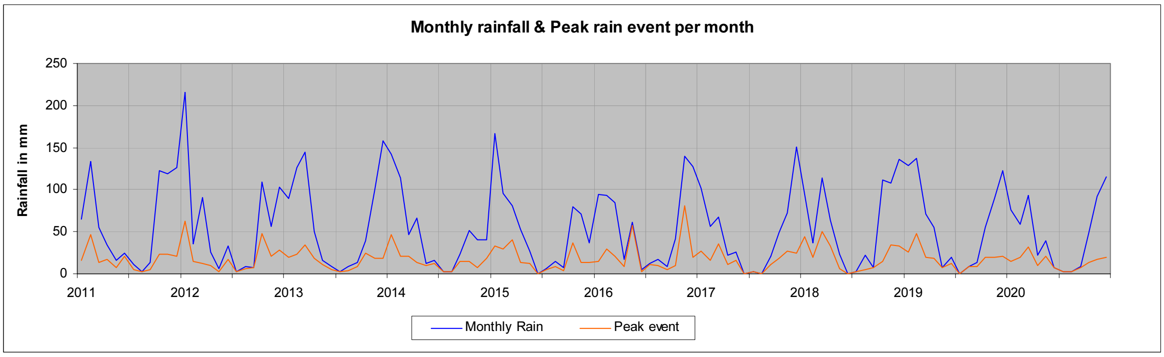

Figure 1-Simulated rainfall maximum and minimum for month

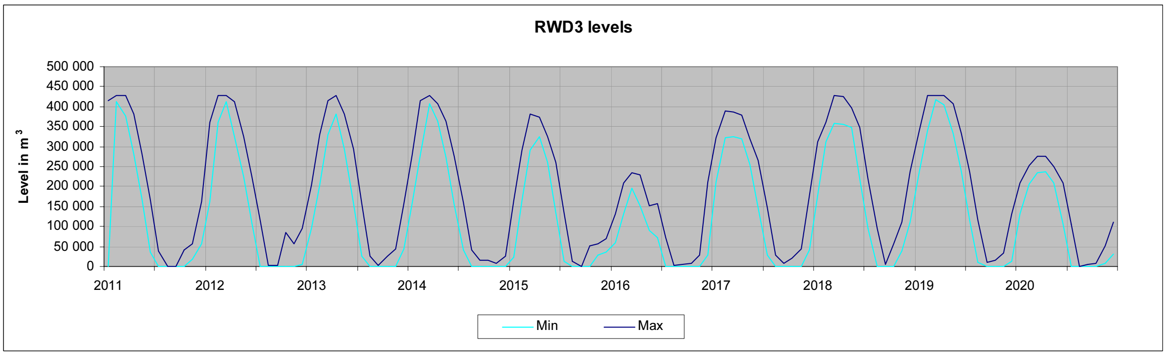

Figure 2-Simulated levels of the tailings return water dam 3

Anthropogenic aquifers

Boreholes were drilled in the backfill material using a symmetrix drilling set-up, 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 carry out *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 were identified:

- Slow-leaking anthropogenic aquifers
- Rapid-leaking anthropogenic aquifers
- Decanting anthropogenic aquifers, where footwalls dip towards topographical lows, and which decant either as fountains or in the subsurface
- Non-productive anthropogenic aquifers. Shallow pits are less favourable for forming 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) embodies the following:

- To harvest water from the 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/h, 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 reclaimed with surface pumps, and this will continue for the next two years or more. Recent measurements in the dry season indicate an average of 1700 m^3/day pumped from U3/U2. These are much higher yields than expected, and may also be attributed to the proximity of the Aquarius Platinum 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 m^3/h with a combine daily yield of 3300 m^3/dY and use the default ASR.
- Construct a combined concrete settler and return water dam (RWD), typically with 1000 m^3 capacity, for U3 dewatering. The concrete settlers are to capture silt and are able to be mechanically cleaned. The dams will be lined reduce losses and to ensure that dirty water does not ingress into the groundwater or recycle back into the pit
- Construct a new lined pollution control dam (PCD) of approximately 50 000 m^3 and transfer all borehole and return water to the Karee PCD
- Harvesting the default ASR systems will occur primarily during the dry season. This will augment lower return flows from the TSF, and is expected to reduce water in storage, thereby creating storage for the rainy season and reduce spillage
- The 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 the Karee PCD (active ASR).

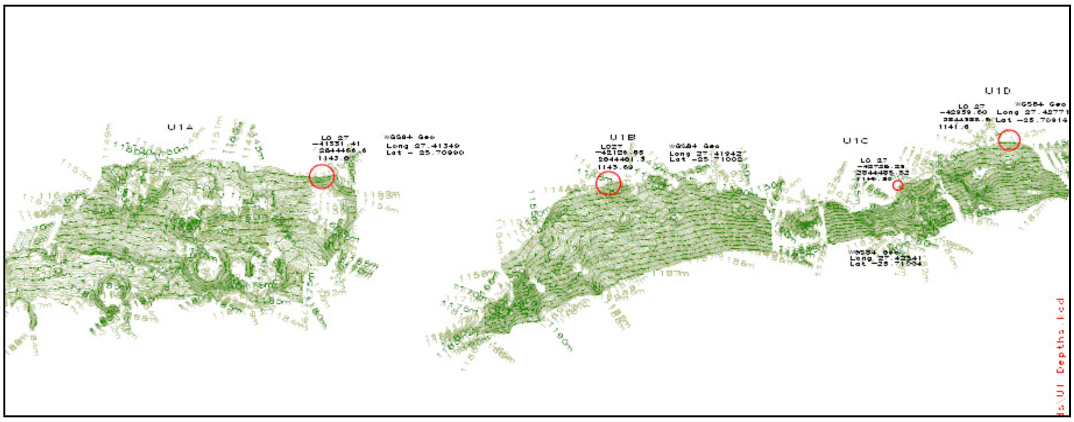

Figure 4-Showing deepest positions for U1a, b, c, and d, where production boreholes need to be drilled

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 consequences of this 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 runoff more efficiently, and (3) take less water onto the mine from 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 optimize 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 being implemented over the next few years.

Acknowledgements

Thanks to Lonmin management team for recognizing the opportunity and having the confidence to invest in new technologies and thereby making more potable water available for use within the larger water-use sector

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Dr Fanie Botha is a water resource specialist, with a PhD in groundwater and MSc in engineering geology, with 15 years' experience in the government and private sector. He was involved in a number of water resource assessment and planning studies, and for the last couple of years his focus has been on mine water management and planning. He works both at strategic and implementation level, primarily seeking ways on how to implement high-level policy goals within the natural environment and measuring the effectiveness thereof; ultimately limiting the mining's sector footprint on both raw water use and water quality degradation.