Mining: The Value of Creating a Legacy of Water Resources within Unsurmountable Challenges

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Abstract

This article deals with water legacies in the mining sector within semi-arid regions and how food security may benefit from it. Water resource often results in fatal flaws for mining developments and new resources are developed, once mineral resources are depleted water resources remains available and may become part of food security plan. Water resources developed includes dams and wellfields and groundwater inflows because of mining. The case studies deal with anthropogenic aquifers, coastal sand aquifers, potassium mine in Ethiopia and gold tailings storage facilities (TSF). Finally, saltwater reclamation is discussed using greenhouse technology combined with injection wells to harvest seepage water at gold TSFs.

Keywords: Water, fatal flaws, manmade aquifers, coastal aquifers, saltwater reclamation, greenhouses

Introduction

In semi-arid regions water resources are often a fatal flaw to start new mining operations and therefore new water resources needs to be developed, however once the mineral resources are depleted then the water resources will still be available and these remaining water resources will become an integrate part of a water and food for many millennia to come.

This article deals with several case studies as examples, all situated in semi-arid to arid regions. The most common water resources developed for new mining projects are dams and wellfields therefore during feasibility studies the default water resources developed as a result mining are not always considered as part of the solution, however post-mining it often results in a water positive legacy behind. However, the water associated with mining is often considered contact water and not fit for human consumption and this is as a result of the contact water associated with gold and coal mining and created a stigma that the water resources legacies from mining is not fit for human or environmental use. There are mineral resources which that will result in post-mining water legacies that is fit for human and environmental use and they needcs to be identified in advanced and planned for as future water resources. Chrome and platinum mines within South Africa are good examples of derelict mines that result in good water quality resources and needs to be used as sustainable water resources.

The water resources typically left behind range from underground mines filled with water and new modified aquifers or AA. The case studies discussed specifically deals with the platinum mines in the Bushveld Igneous Complex (BIC), a phosphate aquifer created in the West-Coast of Southern Africa, potassium mine in Ethiopia transforming hypersaline alluvial fan to freshwater aquifers and even how a large gold TSF is harvested to aggressively reuse and reduce freshwater use. Finally, a brave step is taken into the future and consider how saltwater reclamation used in greenhouses in the Netherlands can be combined with injection wells to harvest and clean water from a large gold TSF in South Africa.

New large underground storage facilities or Anthropogenic Aquifers

South African platinum mines are mostly situated in the northern part of South Africa, with a semi-arid climate with low rainfall with significant variation in monthly and long-term annual rainfall. It therefore requires large raw/dirty water storage dams to augment process water during low rainfall and high evaporation periods. The mines were initially developed as open pits (60m deep) and currently many of these open pits are used as raw water storage facilities, however during closure, as part of the rehabilitation plan these pits are filled with waste rock and recharge again and forms man-made aquifer or AAs. AAs therefore refer to underground water storage (aquifers) that was created because of minging activity. Once these underground dams have filled, they will leak into the upper, more weathered, aquifer. Depending on the dip of the open pit floor and its extent a pit may even discharge as surface water. If not managed, it can also leak through the boundary and/or crone pillars and leak into underground workings or neighbouring mines.

The difference between *in-situ* aquifers in the BIC and the AAs is the increased porosity and subsequent increased acceptance and release of water. In-situ aquifers in the BIC have low K-values, in the order of 2.7*10−4, whereas high porosities of the backfill material estimated at 25%, lead to much higher storage and high yielding boreholes (Botha *et al*, 2011).

Nitrate levels are elevated at all platinum mines, primarily because of the explosives used, which largely consist of an ammonium nitrate emulsion. An effective natural way to deal with high nitrates is to create flooded soils or enhanced artificial wetlands or slowly run the waters through an oxygen poor anthropogenic aquifer. The AA can be used as passive denitrification cells.

The cases studies talk about similar results now found at four major platinum and chrome mining companies and the AAs all proof to be a sustainable water resources that can assist mines and communities with a sustainable water resource during prolonged drought periods and act as a natural denitrification

Figure 1 *A photo of a rehabilitated open pit mine near Rustenburg, South Africa. It is filled with backfill material covered with topsoil. It also shows three boreholes drilled into the backfill material pumping freshwater from the pit to be re-used rather than taking water from nearby agricultural irrigation channel (image: Botha et 2011).*

system. The main application of the work conducted is to transform all backfilled and rehabilitated open pits into operational AAs and take them off the mine's liability as part of their closure and rehabilitation plan. The message to take home are to reduce the cost of annual mining rehabilitation expenditure cost and leave a legacy of rehabilitated open pits behind underlain by a renewable freshwater resource, rather than a pre-mining perception of ravished contaminated mining area (Fig. 1).

Westcoast aquifer

The Westcoast aquifer is situated near the town of Hopefield, within the Westcoast of South Africa some 100 km north of Cape Town. It is a Phosphate Mine. It is a marine deposit and it is mined trough free digging and the range from 40 to 80 mbgl and 1000 m in length and 400 m in width. Initially the overburden was stockpiled on a soft stockpile and now the operation has moved to a progressive dig and fill progressive pit. Some 40 boreholes on the highwall are used to partially dewater the pit and some in pit dewatering takes place. The operation is now active for almost 8 years and the mine proved to maintain the pit water management in a sustainable manner. The water harvested is pumped into boreholes downstream and it is discharge back into freshwater aquifer that flows into sensitive freshwater/marine water interface environment.

Monitoring boreholes range from in pit monitoring and surface water monitoring to as far as 12 km at the discharge position. The current monitoring results shows zero impact on the freshwater aquifer. Challenges experienced during the project initiation was selecting the correct drilling method to enable boreholes to reach depths below the loose sandy aquifer and the right sizing of casing. During pumping of boreholes significant bioorganic growth around the casings and together with fine sand particles blinded the casing and it made dewatering ineffective. As a result, the operation had to adopt a cleaning programme with all the boreholes to be cleaned through reversed air and waterflow and mild environmentally acceptable additives.

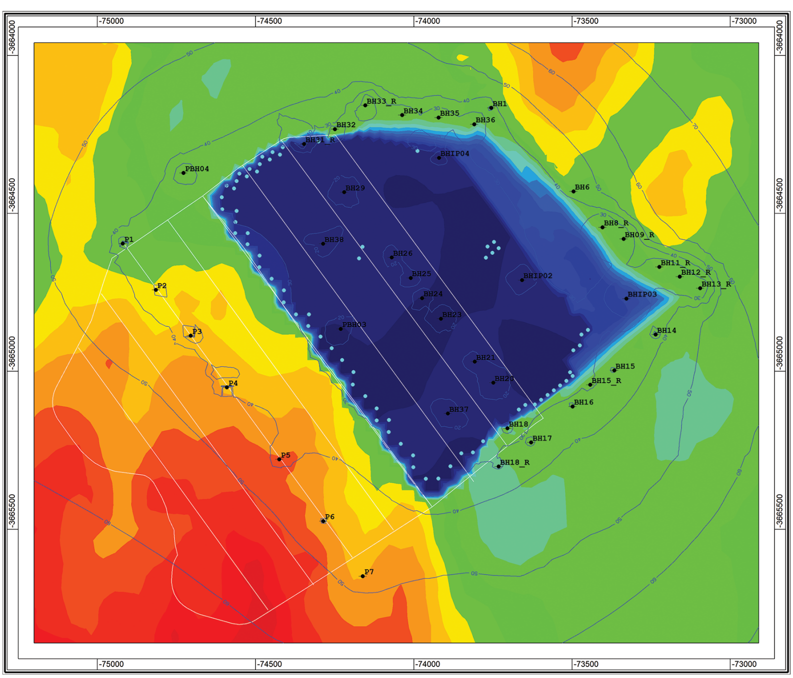

Figure 2 The calibrated model showing simulated results for December 2026 heads (blue isolines), ground elevation (contours) and residual inflow locations (blue markers). The pit is effectively dewatered, with some inflows into the pit.

Boreholes in the first phase were drilled at the edge of the open pit and not to below the targeted pit floor and resulted in less efficient dewatering. During secondary drilling phases the boreholes were drilled away from the planned pit walls and in doing so giving effect to the radius of influence not to be wide and deep enough, allowing large volumes of water to flow toward the open pit. By drilling the boreholes deeper, more water could be harvested, and the cone of depressions were deeper and wider and thereby decreasing the openings between the dewatering cones and allow less water to flow past the dewatering boreholes towards the pit.

The biggest lesson learnt were that Managed Aquifer Recharge (MAR) can be implemented within a sensitive ecosystem to conserve it, the operation requires constant monitoring and adaption based on monitoring results and initial designs needs to be adapted to meeting the conservation goals. The latest modelling (Fig. 3) demonstrate that the pit can be managed with limited water inflow and that aquifer recharge can take place to release on-contact water back into the freshwater aquifer. The aquifer is well understood, and the future use in this area may be a completely rehabilitated area and an additional water supply to an expanding Westcoast community.

Solution mine in Ethiopia

The next case study is a Potassium Mining Operation in the Danakil Dessert in the northern border between Ethiopia and Eritrea, in is well-known for its sulfuric acid volcano, the Dallol. It employs a solution mining method, and during the water resource development study conducted was part of the feasibility study a holistic water resource plan was considered. The northern border is formed by a freshwater river named the Ragali River. The project aimed to harvest saline water in alluvial fans with boreholes in the fan material and through boreholes in the orebody pumped water into the mineral deposition to dissolve the minerals and pump it back to surface and through controlled

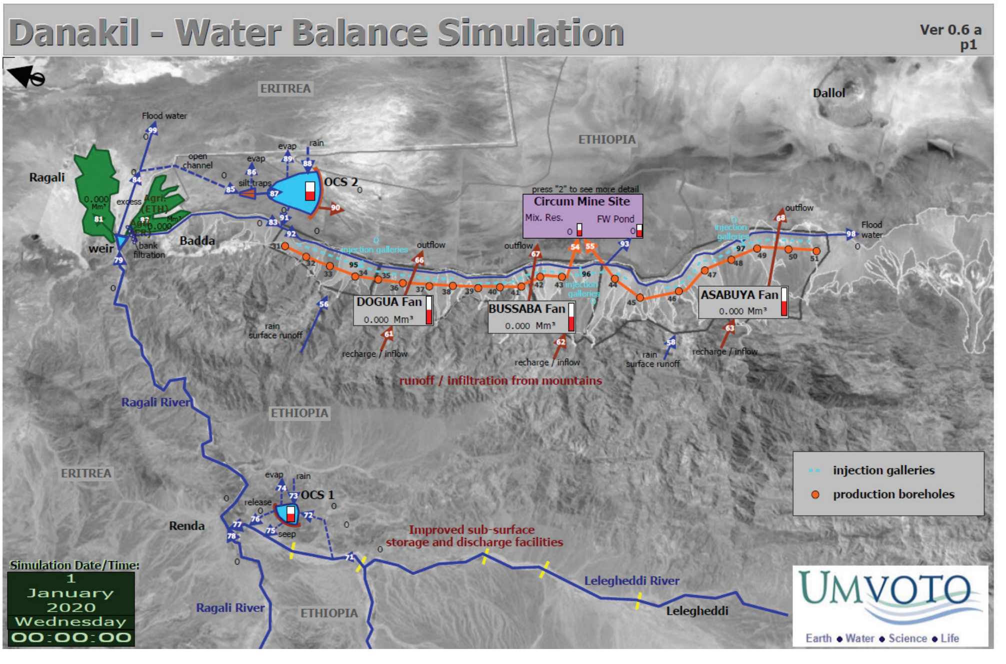

Figure 3 The flow diagram on a Google Earth Image showing the Ragali River and how the water can be harvested from the Ragali River into the different alluvial fans. It also shows the two off-channel storage facilities, one operational freshwater facility (OCS2) and one at Renda (OCS1), which will release water throughout the year to ensure constant flow in the dry season. Both OCS 1 and OCS 2 will ensure slow release of fresh water into the fans during the drier periods of the year (Botha et al*, 2017).*

crystallisation harvest potassium (Botha *et al*, 2017). During the development of the project a management approach was developed to harvest fresh water from the Ragali River (Fig. 3), flowing from the escarpment and rapidly harvest fresh water and though recharge trenches place it back into the alluvial fans to counter further salination of the alluvial fans.

The most significant lesson learnt was that although fresh water is limited, it is possible to rapidly harvest high volumes of freshwater from the Ragali River when it is available. Therefore, mining can be planned in such a way that an environment is left behind which will support the local communities with fresh water for thousands of years and if this is done then mining may become even more feasible in the most hostile environment and leaves behind a water resources legacy which may last thousands of years.

Harvesting recharged aquifer next to gold tailings Dam

The next case study is within the north-central parts of South Africa some 50 km south of Johannesburg, within the well-known gold deposits of South Africa and deals with the legacies of the old gold TSFs. The case study deals with the recharging aquifer conditions around the largest gold TSF in South Africa, with a surface area of more than 500 Ha and some 120 m high. During this case study three phases of scavenger boreholes where placed next to TSF. The aims were to ensure that the scavenger wells can be employed to harvest contaminant water in the vadose zone, reuse the water as process water and finally reduce the dependency on potable water to augment process water. The project was implemented in three phases and modelled over a period of six years to ensure scavenger boreholes were placed in optimal positions to harvest contact water. The project proofed that incremental implementation, though remodelling of monitoring data guided the team to optimise borehole positions during the project. Water harvested reduced the dependency on freshwater augmentation and make more fresh water available for municipal use, rather than industrial use.

Reclamation of freshwater using greenhouse and solar power

The last case study is still at concept stage and the plan is to take high saline contact water harvested from scavenger wells around gold TSFs and through the application of sun energy through aquaponics, greenhouse evaporation and condensation harvest fresh water and produce salts to be reused. The idea of harvesting clean water from reclaimed salt water though the use of greenhouse condensation was an idea which was first thought to be a new idea; however initial research proofed that Seawater Greenhouses harvesting through condensation was done in the Netherlands (Woodworthray (2016–2023). In the Netherlands sea water is evaporated using a radiator-like structure, blow it into a greenhouse and then harvest it using a condenser at the outlet of the greenhouse (Fig. 4). Condensed fresh water is them stored in a freshwater storage tank and pumped as drip irrigation to the greenhouse plants. Therefore, seawater is harvested to create fresh water. The saline water is discharged back into the sea and the salts that remains behind can be used as commercial evaporated sea salt.

The technology has not yet been used at a gold TSF however it has been used quite aggressively at other parts of the world. It is commonly referred to as Greenhouse Humidification − dehumidification (GHHD) (Kabeel *et al*, 2015). Solar energy is used as the electrical supply and it is proposed that solar panels must not be placed on the greenhouse and must rather be a standalone system, when it is placed on top of the greenhouse structure it may reduce the photosynthetic energy to about 52% (Kabeel *et al*, 2015). Therefore, if possible, the solar energy source needs to be a stand-alone supply to harvest sun energy. To boost the plant growth the greenhouse maybe designed as a closed system and therefore increase the CO2 in the greenhouse (Nour *et al*, 2015).

Further to this, the harvesting clean water using return water as a source at gold TSFs will become more relevant in South Africa now that new TSFs required to be lined. Prior to line TSFs, the aquifers below unlined facilities, through natural degradation played a major role in salt capturing and reduction,

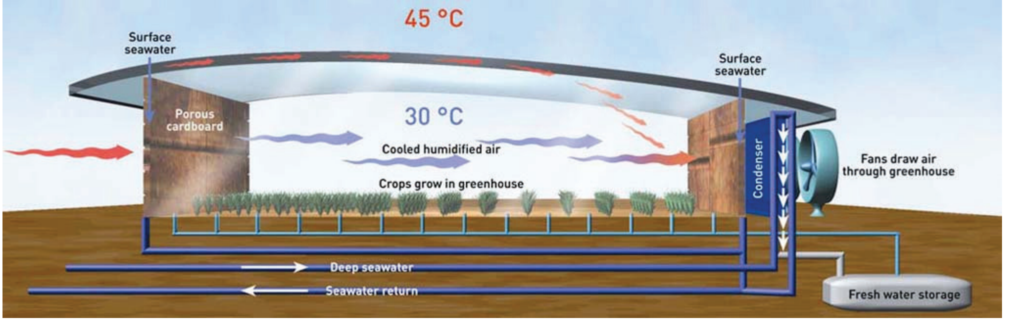

Figure 4 Schematic view of how seawater harvesting takes place in the Netherlands produce freashwater Seawater is evaporated through a porous cardboard radiator-like structure creating water vapor and before leaving the greenhouse the humid air condensates on a cold seawater radiator as fresh water, condensate is then harvested in a freshwater storage tank and use as fresh water for the plants in the greenhouse (image: Woodworthray, 2016 – 2023).

and water banking below the TSF. This salt sinks are eliminated when facilities are lined, and higher volumes of saline water will be recycled and reused and due to evaporation and a closed loop the salinity will increase over time. The salinity of the return water through the constant addition of salts will become too high to be used as process water and therefore desalination of return water derived from lined TSFs will become a challenge to be addressed in a cost-effective manner and the GHHD may offer a sustainable solution.

Nevertheless, the most burning question in the mining sector by all the owners and investors remains: "How to dispose the salts left behind?". The conventional and immediate answer are to harvest and dispose the salts at a certified waste disposal facility or it can be placed back on the TSF and captured within the TSF. There is also the possibility that harvested salts in the green houses may be harvested through selective crystallisation and reused.

Conclusions and recommendations

The mining sector alters the water resources environment, and the positive impact of mining is often not considered simply because society focus on the negative effect of mining. However, over the past decade operational mine water supply challenges were addressed though the development and use of AA and process water harvested next to TSFs. These options were all incorporated into site wide water management approach to harvest less water and create localised water resources. Post-mining, these local new water resources developed because of mining can then be used for various other applications to address food and water security concerns.

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