

Grootvlei Mine is pumping 75 Mℓ/day of water to retain access to its underground workings.

Research Seeks Answers for Century-Old Problem

More than a decade of research by the Water Research Commission (WRC) and other agencies has gone into finding solutions to the potential pollution caused by potentially harmful water emanating from the gold mines on the Witwatersrand.

Mining has formed one of the pillars of the South African economy for more than a century. But the riches that have come from drilling thousands of meters under the earth come at a price. Mines can cause environmental devastation decades and even centuries after they close.

One of the most pressing effects of mining, especially in water-scarce

South Africa, is the issue of contaminated water emanating from mine shafts and stopes into surface water resources.

ACID MINE DRAINAGE (AMD)

But where does this mine water come from?

The geological features that are mined contain varying proportions

of metal sulphides, for example iron pyrite. As mining takes place these pyrites in the broken and crushed rock are exposed to water and oxygen causing it to oxidise. This generates sulphuric acid, resulting in AMD. The acidity generated by the sulphuric acid formation can mobilise and release heavy metals previously bound in the wastes, including arsenic, nickel, copper, zinc and aluminium, as well as solubilisation of

salts of sodium, chloride, potassium and fluoride. It is mainly these dissolved metals that give rise to the toxic nature of AMD.

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Meiring du Plessis, research manager responsible for most of the mining related research at the WRC, reports that AMD is not a new phenomenon and occurs all over the world where mining takes place and sometimes even without mining where ore bodies are naturally exposed. "The problem is that this acidic water does not remain inside the mines."

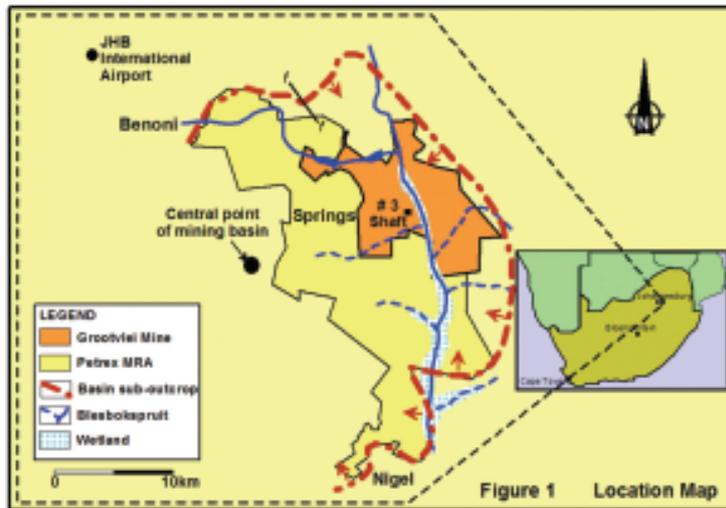
He explains that clean water from surface and underground infiltrates soil and enters the mine shafts and stopes and are then contaminated with the acid mine water. While a mine is operating this water is usually pumped out and treated to allow mining operations to continue unhindered. However, once mines close because of financial reasons or because the ore has run out, the water wells up in these old worked-out mine shafts.

When this contaminated water decants into streams and rivers above ground the acid attacks all available neutralising agents. As the pH rises the metals precipitate as hydroxides and oxides. It is the metals that remain in solution because of a lack of neutralisation or that are redissolved under changing environmental conditions, that is cause for concern and that pollute the surrounding environment. It is for this reason that DWAF insists on provision for the neutralisation of AMD wherever it enters the

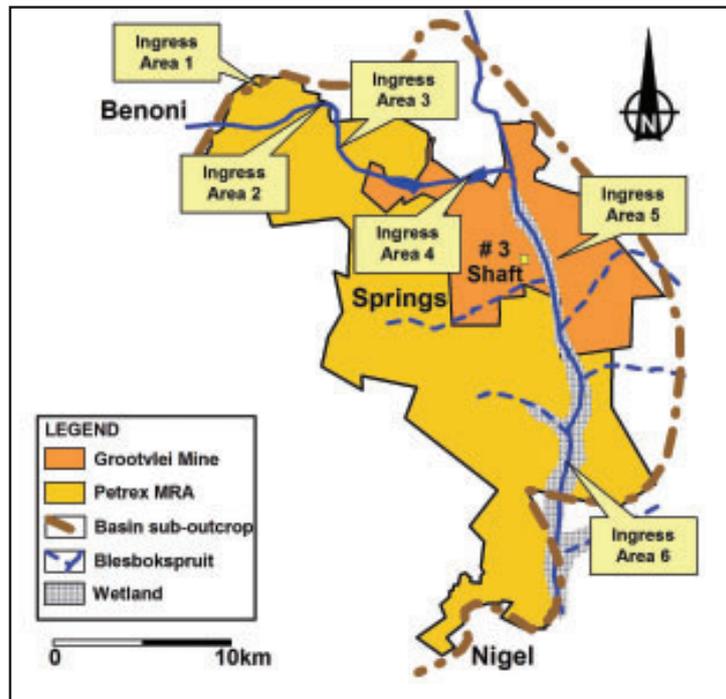
surface water environment even after mine closure.

Dr Steve Mitchell, director: water-linked ecosystems at the WRC points out that AMD and decanting mine water cannot be avoided. "The best we can do is to find out where this water will decant, what exactly the quality of that water will be, and how best to manage and treat the water in a sustainable and cost-effective

manner so as to reduce the pollution of South Africa's limited water resources to an absolute minimum." As a result, the WRC has been funding research into this phenomenon for more than a decade. "We believe that through this research, the WRC has proactively been identifying problems and finding possible answers to questions that will arise in the future," says Du Plessis. "We can learn much from the way in which



Grootvlei location.



Map of Grootvlei indicating the six identified ingress areas.



Map of the Witwatersrand Basin.

the rest of the world are dealing with their AMD problems. However, they are primarily concerned with the acidity and metal content of AMD and therefore concentrate their efforts at its neutralisation. In view of our water shortages and the fact that we thus cannot rely on dilution to deal with the large quantities of salts that AMD is adding to water supplies, South Africa has to deal also with the salinity problems brought about by AMD.”

WITWATERSRAND BASIN

One of the areas in South Africa where AMD and decanting mine water is becoming a real issue is the Witwatersrand Basin (Wits Basin). These goldfields, which stretch 350 km long and 200 km wide, have been mined to depths of about 3 500 m, and have yielded by far the most gold that has ever been mined in South Africa. But it has also left behind a myriad of shafts and stopes underground which has steadily filled up with water over the years.

The Wits Basin is subdivided into three main geological areas, namely the West Basin, the Central Basin and the Eastern Basin, which are all separated through geological features. It is believed that within these



Mining has been one of the pillars of the South African economy for more than a century, but not without cost. The effects on the environmental as a result of mining can be felt decades even centuries afterwards.

three basins, all the mines are interlinked through haulages, stopes, boreholes and worn-out plugs. Thus one mine will fill up with water, then the water will seep through to the next mine and so forth until it decants at the lowest point.

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In 1955, on the Eastern Basin alone there were 24 operating mines and at least 90 shafts. Most of the mines have had to pump water from underground to either dewater areas where development was intended or to keep the existing workings from flooding.

As more and more mines closed through the years it was left to fewer mines to pump the water out. Pumping most of the water from the Eastern Basin is Grootvlei Mine, on the Central Basin ERPM and on the Western Basin Randfontein Estates.



The Marievale Bird Sanctuary, which forms part of the RAMSAR wetland in the Blesbokspruit catchment is one of the areas threatened by acid mine drainage and decanting mine water.

The Institute for Groundwater Studies of the University of the Free State was one of the first institutions to undertake WRC funded research into AMD and decanting water on the Wits Basin. Published in 1995, the investigation focused on ways to control the inflow rate, water quality and the predicted impacts of flooded mines on the Central and East Rand Basins.

Among other things, the study found that there are four main sources of recharge into mines. These are direct recharge from rainfall events; seepage recharge; surface water losses from dams or streams; and recharge from groundwater (for example, on the East Rand most of the mining area is overlain by dolomites resulting in dolomitic groundwater contributing to the bulk of the inflow).

It was also one of the first reports to predict that, should Grootvlei Mine stop pumping water, the mine water would possibly decant at Nigel. Water ingress into mines is not new. Records of water ingress into these mines dates back to 1909 when Grootvlei abandoned the sinking of their No 1 shaft at 112 m due to an estimated 10 Mℓ/day ingress.

Another WRC report published in 2000 and undertaken by a research team from Stewart Scott, Pulles Howard & De Lange and Economic Project Evaluation, found that this mine water being pumped out on the Wits Basin had a definite effect on the area's water resources. In fact, the gold mines in the basin were contributing as much as 35% of the salt load entering the Vaal Barrage by way

of their point source discharges. It was further estimated that this salt load was contained in only 6% of the flow.

However, as the authors point out: "It is important to realise that the effluents which are currently being pumped from underground mining operations to surface are largely derived from mining which has taken place over the last 100 years and are therefore not the sole responsibility of the pumping mines." An evaluation of the available treatment and preventative measures indicated that prevention of water ingress into mines (thereby reducing the volume of contaminated water that needs to be pumped and treated) would be the most cost effective of all the alternatives that were considered.



The Ancor sludge pump station. Sewage sludge is used to biologically treat the acidic water from Grootvlei Mine.



The BioSURE pilot plant at ERWAT's Ancor works. The plant is now being extended to treat 10 Mℓ/day of mine water from Grootvlei.

The Council for Geoscience is currently undertaking a project on behalf of the Department of Minerals & Energy to investigate the extent of the problem on the Witwatersrand. The main aim of the project is to investigate the ingress of water into these mined-out voids, where the water is entering, how quickly the mines are filling up, and where the water might possibly decant.

It is believed that up to 70% of the water to be found in the Wits mines are from groundwater sources. In

addition, the project team has discovered about 460 openings, including shafts, stopes and sinkholes created by mining activities through the years, through which water might be entering the mined-out shafts (but it unlikely that all of these openings are leading to water ingress).

Moreover, chemical and isotope analysis on surface and underground water samples have shown that a significant percentage of water filling up the old mine shafts on the Wits Basin come directly from canals, rivers and dams.

THE CASE OF GROOTVLEI

To retain access to its gold reserves, Grootvlei pumps an average of 75 Mℓ of mine water a day. At present the water is treated at a high-density separation (HDS) plant to remove iron and condition pH levels before it is discharged into Blesbokspruit, reports environmental manager Irene Lea.

It is well known that a portion of this river downstream of the discharge point was declared an international RAMSAR wetland. However, while the HDS plant is effective in reducing iron concentrations in the mine water from more than 180 mg/ℓ to less than 1 mg/ℓ, the water discharged into the Blesbokspruit still contains high dissolved salt concentrations, specifically sulphate, calcium, magnesium, sodium and chloride, thus impacting on the downstream river water quality.

"As a result Grootvlei Mine is in the process of developing methods to reduce the impact of discharge on the river," says Lea. The mine's water management strategy is focused on two main objectives, firstly to reduce the volume of water pumped from underground and, secondly, to develop cost-effective, sustainable long-term treatment options.

REDUCING INGRESS

It is estimated that if surface water is effectively prevented from entering the underground basin, Grootvlei will have to pump only about 40 Mℓ/day of water in the long term.

The mine has identified six areas where surface infiltration can take place. Firstly, it has been found that about 2,5 Mℓ/day of water, mostly during the wet season, enters the mine through the shallow mining of the Main Reef outcrop in the north of the basin. Surface ponding also takes place over shallow mining in the north. Investigations have found that surface water influx to the mining basin via this area of ponding could

be as high as 40 Mℓ/day during the wet season and 7 Mℓ/day during the dry season.

The third area of possible water ingress is a fault that cuts across Cowles Dam. This fault was traced through the dolomitic aquifer into the underground workings. It is estimated that this fault could contribute up to 10 Mℓ/day of surface water to the underground workings. In addition, Ingress is taking place through Largo Colliery, a defunct coal mine that closed in 1953.

“The greatest challenge for the mine is to find a sustainable treatment technology that will be able to improve the quality of the mine water and be operational even after the mine closes.”

It is also estimated that up to 24 Mℓ/day of surface water could infiltrate along areas of shallow undermining in the southern part of the catchment, most notably in the wetlands associated with the Marievale Bird Sanctuary which forms part of the RAMSAR wetland in the Blesbokspruit. In this stretch of the river, inundation takes place over large stretches of the river due to insufficient drainage underneath roads and other infrastructure.

The last possible area where ingress probably takes place is through the shallow undermining of the Blesbokspruit in the northern part of the catchment. It is estimated that surface water inflow here could be as high as 24 Mℓ/day constantly during the wet and dry seasons. “Mine stopes only 7 m below the river have been found, and there is evidence of subsidence in the floodplain,” notes Lea. “What makes matters worse is that significant ponding takes place in this area due to inundation of water against the R29 road.”



The high-density separation plant thickeners at Grootvlei Mine.

Grootvlei Mine has budgeted R3 million to construct a canal across the area to reduce inflow into the mining basin. At the time of writing, the environmental impact assessment had already been completed, and the mine was awaiting final approval. “We hope to start the project as soon as possible,” says Lea. “If we are successful, we could reduce ingress by 10 Mℓ/day.”

IMPROVING WATER QUALITY

The second focus of Grootvlei Mine’s water management strategy is finding cost-effective and sustainable ways to improve the quality of the water it discharges into the Blesbokspruit. The mine has selected a treatment technology, the so-called BioSURE process, to undertake partial desalination of 10 Mℓ/day of mine water by September.

The treatment technology was developed by Rhodes University’s Environmental Biotechnology Group with support from WRC, East Rand Water Care Company (ERWAT) and BioPAD.

The process removes sulphate from the acid-rich mine water. Instead of

expensive carbon and electron donor sources, primary sewage sludge, a byproduct from ERWAT, is being used. The process is reportedly cheaper than any other alternative that uses carbon or electron donor sources, reducing costs from around R5/kℓ to about R1/kℓ operational expenditure.

A pilot plant has successfully treated mine effluent from Grootvlei for the last few years. A modular treatment plant is now being built by ERWAT on behalf of Grootvlei at the wastewater treatment company’s Ancor Works in Strubenvale. Existing infrastructure that is currently under-utilised is being upgraded for the water treatment process. ERWAT will also operate the plant on behalf of the mine.

“The greatest challenge for the mine, for which we are actively searching for a solution, is to find a sustainable treatment technology that will be able to improve the quality of the mine water and be operational even after the mine closes,” concludes Lea.

Photographs and graphics courtesy of ERWAT and Grootvlei Mine. 