EVOLUTION OF MINE WATER MANAGEMENT IN THE HIGHVELD COALFIELDS

W.S. MEY[1] and A.M VAN NIEKERK[2]

[1]BHP Billiton Energy Coal South Africa Limited
eMalahleni, Mpumalanga, South Africa; E-mail: wendy.mey@bhpbilliton.com
[2]Golder Associates Africa
Midrand, Gauteng, South Africa; E-mail: AMvanNiekerk@Golder.co.za

ABSTRACT

The Highveld Coalfields is located within the Upper-Olifants River Catchment. This catchment is one of 18 strategic water management areas in South Africa and the water resources from this catchment is shared with the neighbouring country, Mozambique. Coal mining is concentrated in the upper part of the Olifants River Catchment. Impacts originating from this part of the catchment will propagate down the river and may influence the downstream water users. This paper briefly documents the progression of mine water management over time, to provide a perspective on the current drive for mine water treatment, reclamation and re-use.

The approach and the practice of mine water management in the Highveld Coalfields of Mpumalanga have changed and evolved substantially over the past 30 years. When coal mining started more than a century ago, water was approached as something to be avoided in the mining operations. When the large opencast mines were constructed and commissioned in the late 1970's and early 1980's, water was considered in mine planning, but the full impact of water on mining was not appreciated and recognized. More recently, the focus has shifted and mine water is now considered as critical to the management of a mining operation and may impact on the public and regulatory approval of the license to mine. In the evolution of mine water management, it became clear that the key drivers include the local Olifants River Catchment perspective, the type and extent of the coal mining operations, the changing environmental and water-related legislation and regulations and technology advances.

1. THE OLIFANTS RIVER CONTEXT

Based on the Overview of the Water Availability and Utilisation (Basson and Rossouw, 2003), the following background on the Olifants River catchment is given.

The Highveld Coalfields is located in the Upper Olifants River Catchment (depicted in Figure 1. Spacial Extent of the Upper Olifants River Catchment), situated near the watershed and therefore contains the headwaters of the Olifants River itself and some of its tributaries. The streams are relatively small, not being fed by large drainage areas and therefore vulnerable to impacts. The upper part of the catchment also has three large water impoundments being the Witbank Dam, Middelburg Dam and Loskop Dam. These major dams control in-stream flows along the main Olifants River stream and the Klein Olifants River stream.

The social and economic development of the upper catchment is strongly influenced by the Highveld Coalfields and the region is known for its extensive coal mining operations. Economic activity in the upper catchment is diverse and inter-dependant and includes mining, power generation, metallurgic industries together with farming and eco-tourism. The vast supply of coal exploited in this area over the past century has fueled the manufacturing and electricity supply industries. Likewise, the establishment of several thermal power stations in the area together with the opportunities to export coal through the rail linked Richards Bay Coal Terminal has rendered the establishment of large opencast mining operations viable. Thus the Upper Olifants River Catchment is a key economic hub of South Africa that has made and will continue to make a significant contribution to the South African economy.

However, this development does come at a cost to the environment and in particular, water resources are under stress from both a quantity and quality perspective. Any impacts on the Upper Olifants River can propagate downstream and be felt by numerous downstream water users. The Upper-Olifants River drains to the Middle-Olifants Catchment from which a number of irrigation schemes are supplied and large towns, including Polokwane, draw water. The Olifants River then continues to the Lower-Olifants Catchment and flows via Phalaborwa to the Kruger National Park. Mozambique, further downstream is also dependant on the Olifants River for diverse water uses, including agriculture, community water supply, aquatic ecosystems etc.

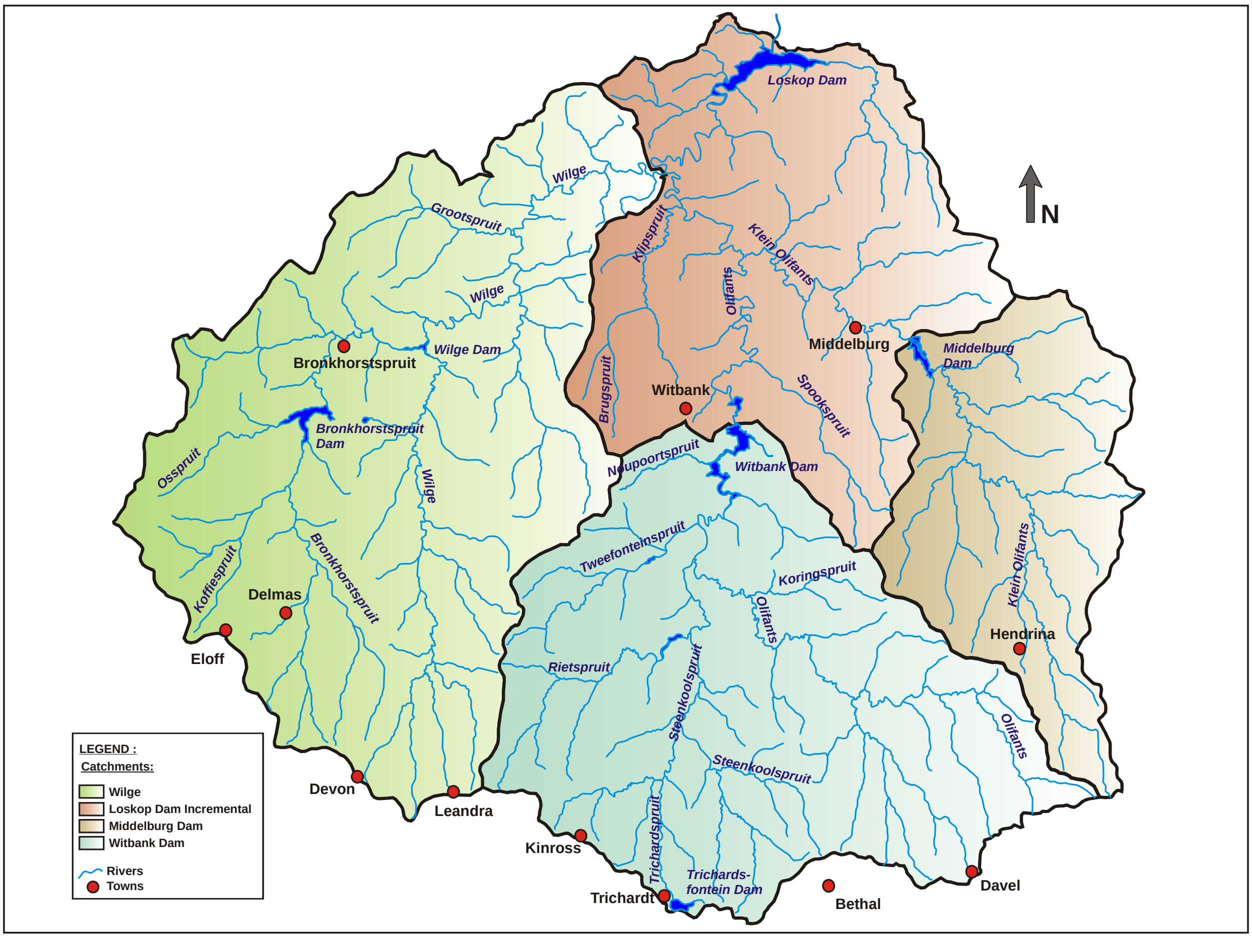

Figure 1. Spacial Extent of the Upper Olifants River Catchment

The Upper Olifants River Catchment faces a number of urgent water related issues. Averting further deterioration of the surface and ground water quality as well as access to sufficient water of an acceptable quality is a common denominator to all the urban, industrial, mining and power generation developments.

2. ROLE OF REGULATORY DRIVERS IN MINE WATER MANAGEMENT

The South African mining, environmental and water legislation and associated regulations have been completely re-written following the democratic transformation in South Africa in 1994. The regulatory requirements related to water, mining, environment and waste as reflected in the different Acts and Regulations have changed substantially over the last 10 years. (Hobbs, Oelofse and Rascher, 2008). It now requires an integrated regulatory process to obtain project approval from different regulatory authorities.

Mining-Related Legislation

The mining-related legislation as it is pertained to environmental protection on mines was first drafted in the form of the Minerals Act, Act No. 50 of 1991. This Act, for the first time contained specific requirements for the environmental management on mines in the form of Environmental Management Program Reports (EMPR). Mining authorisation was made conditional on the approval of an EMPR report. The approval process also required the Department of Minerals and Energy to consult other Government Departments, including Department of Environmental Affairs and Tourism, Department Water Affairs and Forestry, Department of Agriculture and the Department of Health. This was the stimulus for the development of mine water balances and mine water management plans.

The Minerals Act was replaced by the new Minerals and Petroleum Resources Development Act No. 28 of 2002 (MPRDA). The Act and subsequent regulations now require a comprehensive Environmental Management Plan (EMP), using current best environmental management practices. The MPRDA requirements went further to require public participation during the preparation of the EMP, require the post closure situation to be addressed and appropriate financial allowance be made for the post closure environmental and specifically water liabilities.

Mines can therefore no longer receive a mining authorisation without proper consideration of environmental and water aspects over the entire life of the mine.

Water-Related Legislation

Likewise, the water related legislation and laws have been completely revamped since the early 1990's. The focus of the national water regulator, the Department of Water and Environmental Affairs in the early 1990's was largely on pollution source controls and managing point discharge sources of pollution. The policy of protecting the national water resources based on integrated catchment management by considering instream water quality to protect all legitimate water users was introduced in 1992. This policy was particularly appropriate to mining-impacted catchments such as the Upper Olifants River, where diffuse pollution sources are more significant than point pollution sources.

The water quality situation in especially Witbank Dam had deteriorated to such an extent by early 1990's that the regulator compiled a Water Quality Management Plan for the Witbank Dam Catchment (WMB, 1993). This Plan had two pertinent requirements for mining operations:

- Development of an integrated mine water management plan based on the hierarchy of:
    - Pollution prevention at source, by for example electing to go for underground mining rather than opencast mining of a coal reserve, separation of clean surface water runoff etc.
    - Pollution minimisation by for example, separate disposal of highly polluting mining waste, accelerated rehabilitation of mining disturbed area, etc.
    - Impacted water collection and re-use in coal processing, waste disposal, dust suppression etc.
    - Impacted water treatment and discharge to the natural water courses.
- A controlled release scheme to allow mining impacted water to be discharged during favourable river flood conditions was implemented in the mid 1990's. This allowed saline (not acidic) mine water to be released during river flood conditions in a manner which did not result in unaccepted in-stream impacts.

The National Water Act 1998, Act 36 of 1998 (NWA) placed the national water resources management on a new legal foundation. Water uses of different types were regulated by the issuing of licenses by the regulator. The policy of integrated water quality management taking different land uses, surface and groundwater resources and diverse water use into account was formally entrenched. Special protection was afforded by the NWA to a Reserve of allocated instream flow and quality to protect the aquatic ecosystem and basic human needs for water.

The implementation of integrated water resource development plans, taking all quantity and a quality aspect into account is now a requirement. Such a plan is currently in the final stage of development for the Upper Olifants River and stipulates in-stream and in-dam water quality objectives. These objectives place further constraints on the release of mining impacted water.

The NWA also allows for the implementation of waste discharge charges (DWAF, 2004). The Department of Water and Environmental Affairs has advanced in its development of a waste discharge charge system. This will effectively impose a further levy on mines which discharge impacted water to the natural environment. The waste discharge charges will incorporate both diffuse and point sources of pollution. The Upper Olifants River Catchment has been selected as one of two priority catchments in South Africa for the demonstration and implementation of the waste discharge charge system.

Environmental Legislation

Environmental legislation was until the late 1990's contained in the Environmental Conservation Act 1989. The National Environmental Management Act, Act 8 of 2004 (NEMA) was promulgated in 2006 and a number of regulations were published in terms of the Act. The regulations stipulate the listed activities requiring a Basic Assessment or a full Environmental Impact Assessment. Both application processes require a supporting public participation and stakeholder consultation process. There is currently still some controversy about the application of the NEMA regulation on mine authorisation land (in terms of the MPRDA). The current understanding is that the NEMA-based regulations will increasingly be applied to mining and related minerals processing operations with the Department of Mineral Resources remaining as the competent authority approving the said applications. At this stage, both pieces of legislation are in the process of being amended with the Bills having been passed accordingly.

Waste Legislation

Up until recently, the different aspects of waste management were partially covered by different pieces of legislation. The regulatory approach was to apply for a waste disposal permit, including general and hazardous waste of a mining origin in terms of the Environmental Conservation Act, Act 73 of 1989 section 20. These Section 20 permit applications were prepared and processed in terms of the Minimum Requirements document, which was published in 1998. The new National Environmental Management Waste Act (Act 59 of 2008) was signed by the President of the Republic of South Africa into law in March 2009. This act will take effect from 1 July 2009. It is the intention of this act to address the fragmentation in waste legislation.

3. EFFECT OF THE TYPE AND EXTENT OF COAL MINING OPERATIONS

Mining activities alter the hydrological and topographical characteristics of the mining areas. These impacts of these alterations vary depending on the geology, climate and other site conditions but a key driver of the volume of water affected is the mining method. The volume of water affected by the mining operations is typically referred to the "recharge" and expressed in terms percentage of annual rainfall. Coal mining in the Witbank and Highveld Coalfields started out primarily by bord-and-pillar underground mining techniques. However, the coal seams are typically shallow (<80m) making large opencast operations viable. High extraction underground methods are also used in some areas.

The principles of water management in an underground mining operation are illustrated diagrammatically in Figure 2 to Figure 5. At mine start-up and subsequent to start-up (years 6-10), in order to continue mining, water needs to be pumped out and stored. During this period, it is likely that the water recharge will be similar to the water pumped out and the volume stored will not change. There will not be a requirement to manage excess mine water at this stage. As new shafts are opened, the old mined out areas can act as storage facilities, so that mine water can be pumped from the new workings and stored in the voids of the old workings. At this time there will be no or limited excess mine water as the volume of water stored in the old workings increases (Figure 4). In the final years and at closure of the mine, the storage space will be filled up and the mine water will need to be pumped elsewhere to avoid uncontrolled water decanting (Figure 5).

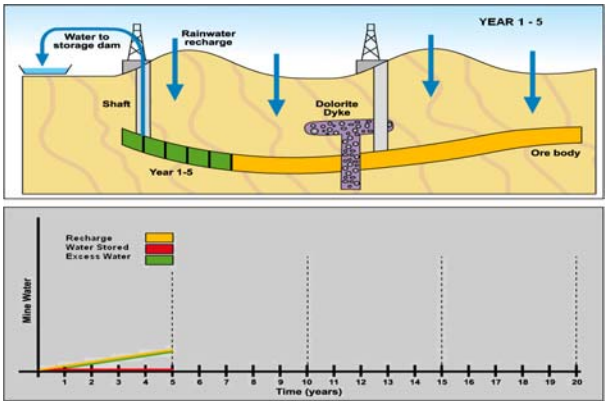

Figure 2. Water Management at Start-up of an Underground Mining Operation

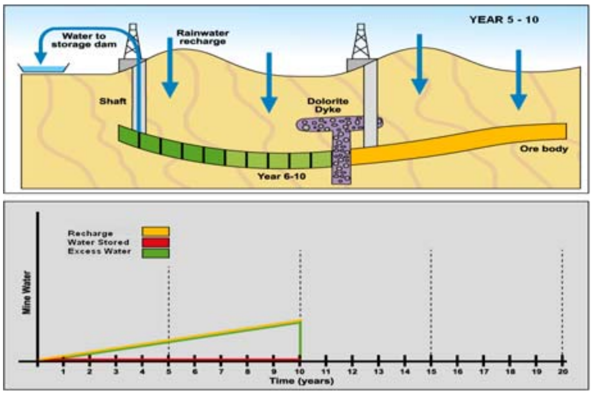

Figure 3. Water Management during an Underground Mining Operation

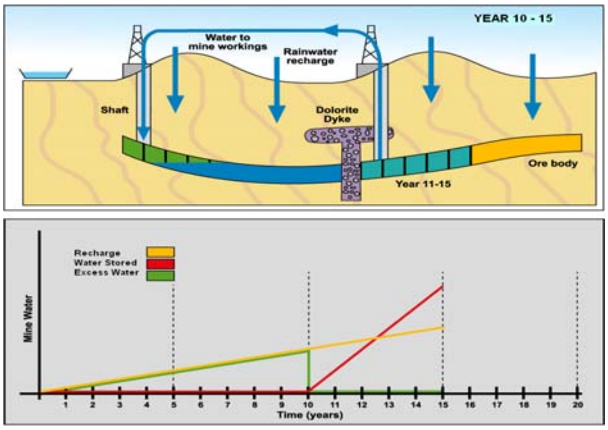

Figure 4. Water Management in a Mature Underground Mining Operation

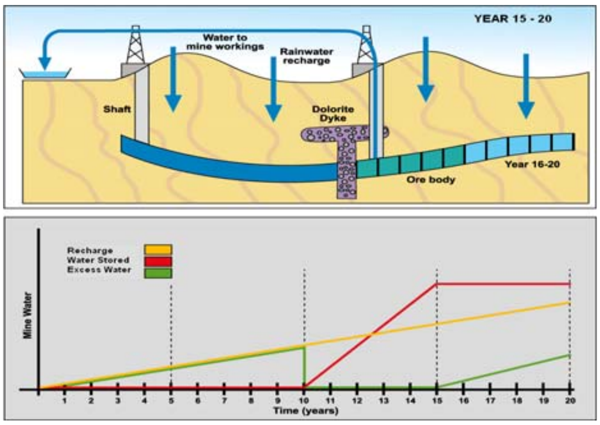

Figure 5. Water Management at the end of an Underground Mining Operation

Where underground mining techniques are employed, the depths of mining and mining technique are the key determinants in the volume and quality of water to be managed in the long term.

The principles of the interaction between mining and the water environment for an opencast mining operation are depicted in

Figure 6.

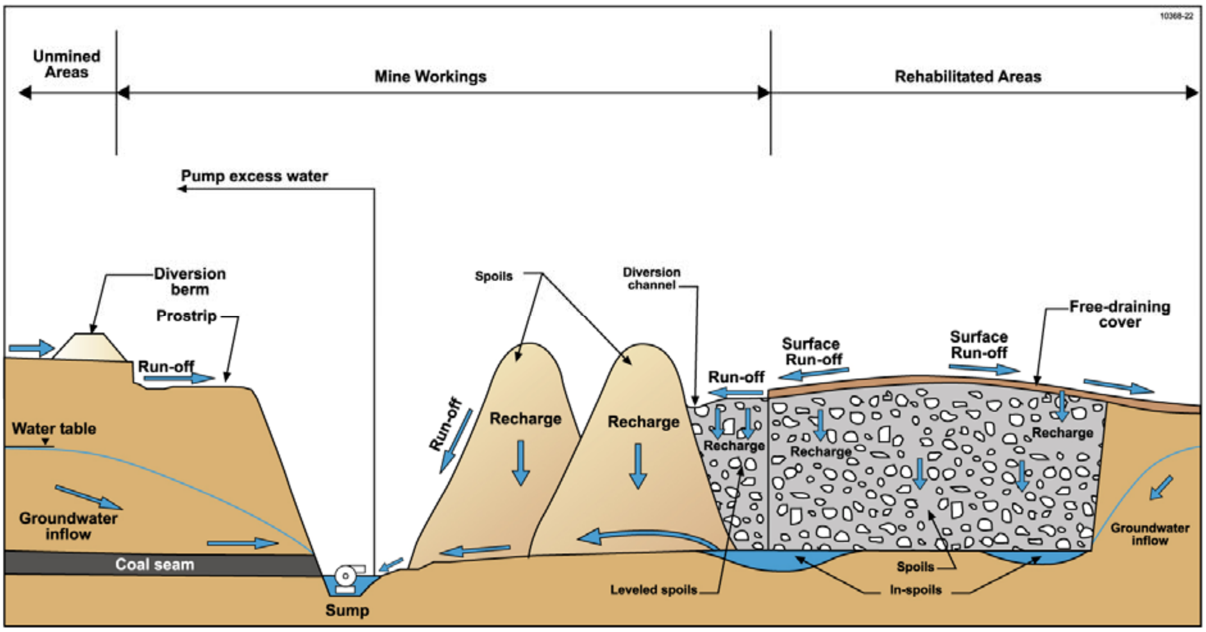

Figure 6. Diagrammatic Representation of Water Interaction in an Opencast Mining Operation

Opencast mine water management is fundamentally based on minimizing the volume of water that comes into contact with the mining operation. This is achieved through the use of cut-off trenches and collection dams upslope of the mine workings to intercept and divert the clean water around the mining area. Some water will come into contact with the coal seam during the mining operation as well as with the waste rock and spoils. Sources that will contribute to the volume of affected mine water to be managed include rainfall onto the ramps and voids, groundwater seepage as well as run-off and seepage from the spoils. The water recharge characteristics for each of these sources vary. The rehabilitation status of the spoils has a significant impact on the rainfall recharge and thus the volumes of water contaminated. For opencast mining areas, a key driver of the volumes of mine water to be managed in the long term is the state of the post mining rehabilitation. During the mining operations it is possible to re-use and store the water affected by mining. However, for the collieries operating in the Highveld and Witbank Coalfields, there does come a point in the life of the mine when the volume of contaminated mine water to be managed exceeds the re-use requirements. It is at this point that the requirement for measures such as treatment to render the excess contaminated water fit for release into the Upper Olifants River Catchment must be considered. The volume of affected water generated by an opencast operation is a function of the area disturbed and thus grows until mining operations cease. At the end of the life of mine, re-use opportunities taper off and additional water management measures are required. This is slightly offset by the decrease in the affected water make as rehabilitation is completed. However a legacy from the mining activity will remain and management measures to ensure that the post mining recharge of affected water does not impact the catchment.

The Witbank Dam was the first impoundment in the Upper Olifants River Catchment to suffer mining-related impacts, mainly due to the location and the number of coal mines in that catchment. Middelburg Dam more recently started reflecting an increase in salinity. It must be noted that the catchment is also impacted by diverse other land uses. The cumulative effects of the mining impacts together with that of the heavy industrial, commercial and urban loads on the water resources has resulted in the deterioration of the water quality that has attracted attention from the environmental, water and mining regulators.

4. IMPROVEMENTS IN MINE WATER MANAGEMENT

The impacts of different mining methods on the natural groundwater and surface water resources have been extensively studied and quantified. This knowledge base has been key in the development of the series of “Best Practice Guidelines for Water Resource Protection in the South African Mining Industry” published by the Department of Water Affairs and Forestry during 2008 (DWAF, 2007). Core to the management of mine water is the hierarchy of control which promotes firstly prevention, then minimization and lastly mitigation of impacts to the water resources resulting from the mining activities.

In the past, a typical mine water management plan included components related to:

- Surface rehabilitation and sloping of disturbed surfaces to reduce water recharge to mine workings.
- Storage of water in available underground or opencast mine workings. Storage in opencast workings allowed for some evaporation loss.
- Storage of water in constructed surface dams, also with the aim of evaporating excess water.
- Use of mine water in coal beneficiation and mine waste conveyance to residue disposal sites. These operations consume substantial water volumes due to retained water and evaporation.

Increasing regulatory pressure and the cost of imported water resulted in the coal mining industry, introducing some further water management measures since the 1990's:

- Selective handling of different mining waste and spoils materials to minimise pollution generation.
- Separation of clean and dirty water to further reduce the volume of impacted mine water.
- Implementation of better surface rehabilitation practices in terms of cover design, vegetation and shaping to further reduce water ingress.
- Free drainage of rehabilitated and disturbed areas
- Irrigation use of mine water to enhance rehabilitation vegetation cover and even farming on rehabilitated land.

Implementation of the full spectrum of what is considered best practice water management actions may, however, still result in excess water decanting from mining operations, especially in the later years of the life of the mine and in the post closure situation. This will require the treatment of excess mine water to a level fit for river/stream discharge or for some other beneficial use. Financial and technical evaluation of the mine water treatment options concluded that the river/stream discharge standards are so high, that treatment to a high standard fit for direct potable, industrial or mining use is attractive. This latter option typically allows the sale of the treated mine water to an end-user and reduces the water abstraction from the local catchment. The capital and operational costs associated with mine water treatment have, however, been an impediment to the implementation of such advanced water treatment processes.

5. ADVANCES IN MINE WATER TREATMENT TECHNOLOGY

The treatment of mine water has been a well researched topic for a number of years. In the case of the Highveld and Witbank Coalfields, the focus on mine water treatment technology research has been neutralisation of acidic mine water and metals removal, sulphate removal and desalination.

A number of organisations executed research work on bench, pilot and even demonstration scale, including the former Chamber of Mine Research Organisation, Water Research Commission, Coaltech 2020 and individual mines.

The treatment of mine water to a quality suitable for release to the receiving environment requires achieving product water quality standards that are generally higher than required for potable use. The main environmental discharge water quality requirements are summarized as follows (Palmer, 2001):

- The water must have a near neutral pH.
- The water must have low metal concentrations.
- A low salinity is required.
- The water must have low plant nutrient concentrations.
- The water must not contain excessive microbiological or pathogen levels.

In addition to the environmental discharge water quality requirements above, the following are additional requirements for the production of potable water (SANS 241, 2005):

- The water must be stable: it must be neither corrosive nor excessively scale-forming.
- Stricter microbiological pathogen limits apply.
- The water must not contain any taste or odour-causing compounds, such as organics or chlorine-derived compounds.

Significant strides have been made over the past 10 years, when considering the performance of different mine water treatment technologies. Neutralisation of mine water to adjust the pH and remove metals has been a practised way for years in the coal mining industry. Lime neutralisation was mainly done to enable re-use of mine water in coal processing. The Brugspruit Liming Plant was constructed by the Department of Water Affairs and Forestry to treat acid mine drainage from the old and defunct mines located north-west of Witbank. This project signified willingness by the national water regulator to invest in mine water treatment and set a precedent for the coal mining industry. Process developments over the last years, included the use of limestone (natural lime $CaCO_3$) as a supplement to the conventional lime (slaked or un-slaked) as neutralisation agent. There are now a number of such limestone/lime neutralisation plants in operation. Neutralisation treatment adjusts the pH, removes metals, but has limited capacity to remove salinity.

Mine water treatment is thus normally focused on desalination as the primary objective. The other water quality criteria are usually met through either pre-treatment before desalination, or polishing treatment after desalination.

Two broad categories of mine water desalination treatment are established in the market. These technologies are proven and many reference plants exist. The mine water treatment technology categories are:

- Biological Sulphate Removal followed by polishing treatment.
- Membrane based desalination treatment.

A number of other mine water desalination technologies (INAP 2003) have been developed to various degrees of technological readiness and include the following:

- Ettringite process – chemical precipitation based process.
- Sparro process – seeded slurry membrane based process.
- Gypcix process – ion exchange based desalination process.
- EcoDose process – electrochemical zinc dosing and precipitation of zinc-hydroxy-sulphate.
- Barium carbonate process – chemical precipitation based process
- Ion exchange using nitric acid and ammonium hydroxide generating metals nitrate and ammonium sulphate as saleable byproducts.

These mine water treatment technologies have generally not been developed beyond laboratory or pilot plant scale and are not proven in large-scale applications. Some of the reasons why they have not been developed further, or implemented at full scale, include the following:

- They are often more complex than the currently established processes.
- They are often more expensive, in terms of capital or operating and maintenance costs, than the currently established processes.
- They do not always achieve the same degree of desalination that the currently established processes achieve.
- Some are reliant on recovery and recycle of valuable products from the wastes formed and this recovery step is not proven or financially viable.

Membrane-based mine water desalination is currently the technology of choice for recovering high quality product water from mine water. However, challenges remain with respect to the handling and disposal of sludges and brines generated by these treatment processes. A number of research and demonstration projects are underway to recover useful by-products from the sludge and brine waste streams.

6. PARADIGM SHIFT

The approach and the practice of mine water management in the Highveld Coalfields of Mpumalanga have changed and evolved substantially over the past 30 years.

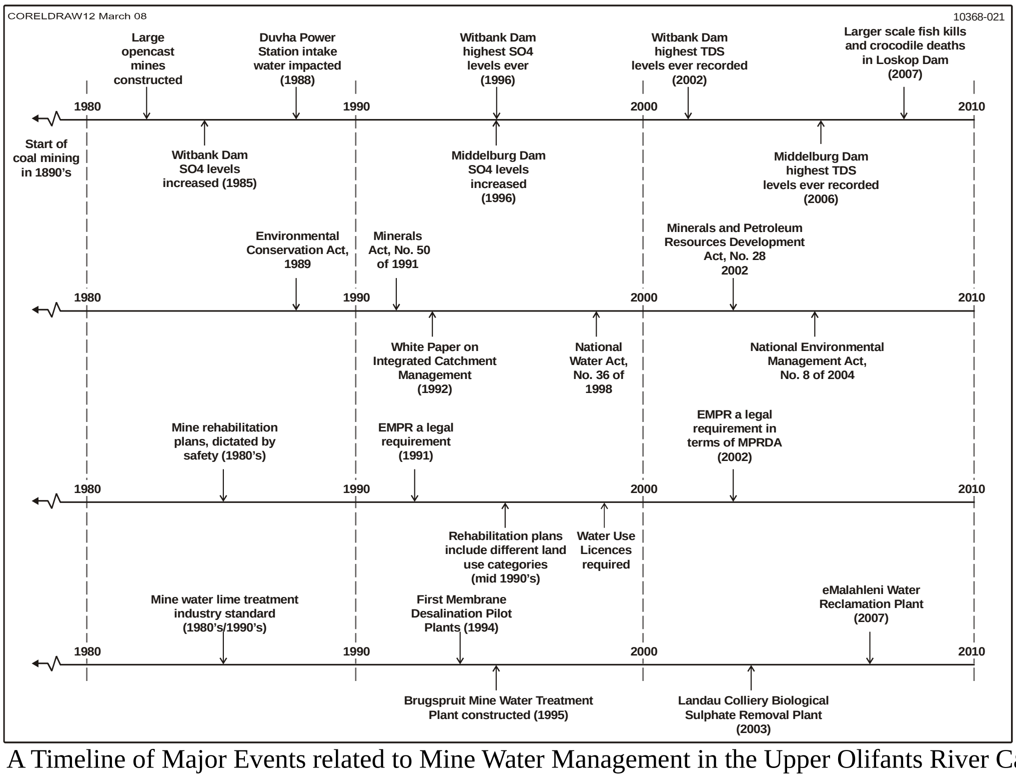

Figure 7. A Timeline of Major Events related to Mine Water Management in the Upper Olifants River Catchment

When coal mining started more than a century ago, water was approached as something to be avoided in the mining operations. When the large opencast mines were constructed and commissioned in the late 1970's and early 1980's, water was considered in mine planning, but the full impact of water on mining was not appreciated and recognized.

More recently, the focus has shifted and mine water is now considered as critical to the management of a mining operation and may impact on the public and regulatory approval of the license to mine. Major events in the evolution of mine water management in the Upper Olifants River Catchment are depicted in Figure 7.

The legacies of the historic sites will remain problematic for many years to come due to the vast magnitude of the associated impacts. There are no easy solutions to the problem, but concerted efforts could lead to vast improvements and reductions in the environmental impacts associated with the historic sites.

Access to sufficient water of an acceptable quality is a common denominator to all the urban, industrial, mining and power generation developments. The rapid economic development in South Africa and in the Upper Olifants River Catchment has placed the available water resources under strain. There is simply insufficient groundwater and surface water resources to supply new mining and industrial development. Consideration will therefore have to be given to non-conventional sources of water. It is clear that water has become a valuable commodity in the Upper-Olifants River Catchment and thus places the availability of excess mine water in a new perspective. The paradigm shift from considering excess impacted mine water as a nuisance to considering it as a valuable resource is currently taking place in the Upper-Olifants River Catchment. The successful implementation of the eMalahleni Water Reclamation Plant in 2007 bears witness to this shift (Gunther, Mey and van Niekerk, 2006).

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