Water management at a large opencast strip coal mine in South Africa

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ABSTRACT

Water is a scarce resource in Southern Africa. Potential mining impacts on this resource are crucial to the management of water on the national scale. This paper describes the water management issues and approaches taken by Anglo Coal's New Vaal Colliery from mine planning through to the full operational stage of the mine.

New Vaal Colliery produces up to 15 million sales tons of coal per annum from an opencast strip operation developed adjacent to large residential and industrial areas and to the Vaal Barrage, a strategic surface water resource in Gauteng Province. The mining area also overlies the largest and most utilised aquifer in South Africa, the Transvaal Dolomite. Opencast strip mining takes place in three seams previously mined by underground bord and pillar methods and which were flooded by water treatment effluent prior to re mining. Opencast mining commenced in 1984.

This paper describes the geohydrology, water management challenges and the management measures used to overcome the issues of mine flood control, mine drainage, and the prevention of surface and ground water pollution. The hydrology and the geohydrology, the results of water monitoring, pump testing, mine water chemistry determinations, ground water and surface water modeling, prediction of the post mining water scenarios are detailed. In particular, the relationship between three aquifers, river alluvium, Karoo rocks and the Dolomite and the flooded underground workings is described. The history of the water management investigations, the water management activities, and results of monitoring over an 18-year period are recorded. The future water issues facing the operation are also noted.

The relative successes of the water management measures, as well as the lessons learnt as the mine moved from the planning to the operational phase are discussed.

INTRODUCTION

New Vaal colliery is an opencast strip mine producing some 15 million sales tons of coal per annum. This coal is supplied solely to Eskom's 3708-megawatt (MW) Lethabo power station. The colliery is located some 75 kilometres south of Johannesburg on the south side of the Vaal River Barrage in the Orange Free State province. It is located in the industrial area known as the Vaal Triangle and one kilometre south of the town of Vereeniging. The mine is positioned on the inside curve of a meander of the Vaal River and is bounded on the east, north and the northwest sides by the river course. The mining reserve covers an area of approximately 2800 hectares (Ha).

The colliery commenced mining operations in 1984 and produced its first coal in 1985. The history of the coalfield, the previous activities within the mine lease area, and the activities that occur in the surrounding areas all have or have had an effect on the natural water regimes. New Vaal mining activities superimpose on these relatively complex geohydrological and hydrological regimes. Therefore it is necessary to know the history of activities as well as the geology of the area, to understand New Vaal Colliery water management actions.

This paper describes the history and the results of water investigations and management options and, in particular the open and transparent approaches that have occurred in dealing with the issues in times when such approaches were not de rigor.

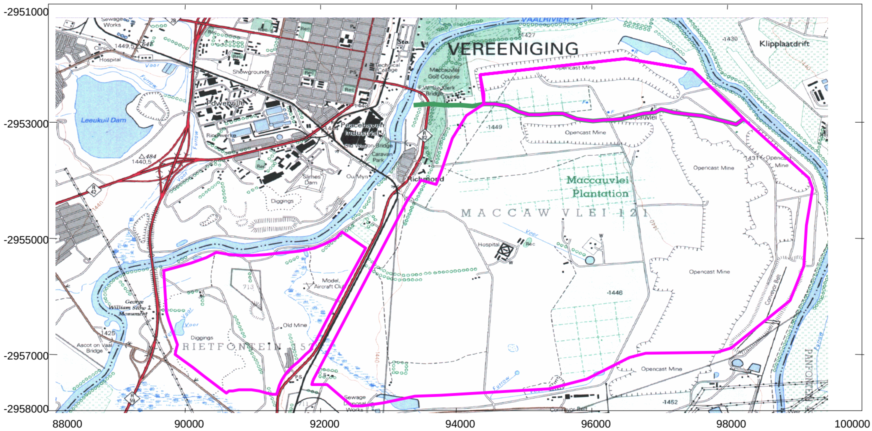

Figure 1. Locality plan of the New Vaal area showing the Main pit and the North pit, north of the dyke swarm. (Based on a plan produced by Hodgson 2000)

GEOLOGY

The New Vaal colliery coal reserves are located in the northernmost part of the Vereeniging – Sasolburg coalfield in an area locally referred to as the Cornelia coalfield. The coalfield field occurs on the northern edge of the Karoo basin. G.W. Stow discovered coal in 1878 at the confluence of the Taaibos and Vaal Rivers. The coalfield was exploited throughout the twentieth century. Some of the major mining operations include Cornelia Colliery that supplied the now defunct Vaal Power Station and the local coal market. To the south of Cornelia, Coalbrook Colliery supplied the Highveld and Taaibos Power Stations before they closed and to the south west, the Sigma Colliery still supplies coal to the first of the Sasol oil from coal plants.

STRATIGRAPHY

The Permian age Ecca Series are part of the Karoo System. The Vryheid Formation of the Ecca Series contains three major coal seams, the Top, Middle and Bottom seams. The Dwyka Series, a sequence of glacial and fluvio-glacial sediments occurs below the coal measures and lie unconformably on the Transvaal System. In the New Vaal area the Transvaal Dolomite underlies the Karoo except for a narrow strip of Black Reef Quartzite that occurs along the eastern edge of the New Vaal mine area.

The Dwyka series is not continuous across the whole area and, in places the coal measures lie on the Dolomite. The contact between the Dolomite and the overlying Karoo rocks is a glaciated surface that was previously affected by structural features of the Dolomite such as doline structures.

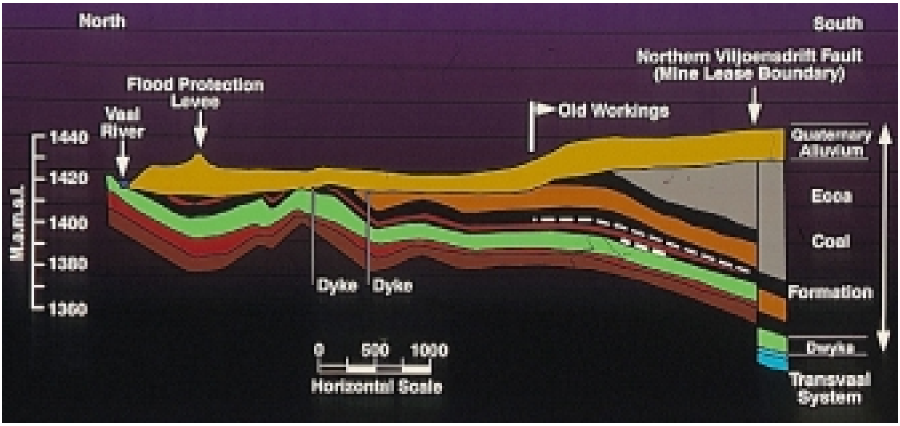

Figure 2. North – South cross section through the New Vaal area showing simplified stratigraphy and geological structures

Quaternary age river alluvium consisting of unconsolidated basal river gravels, sands, silts and clays were deposited onto the eroded Karoo surface. Wind blown, (aeolian) sand occurs in the upper few metres of this Quaternary sequence that ranges from 4 to 30 metres in thickness.

GEOLOGICAL STRUCTURES

The New Vaal mine floor is undulating but the overall dip of the coal bearing Ecca Series is 2 to 3 degrees to the south. Two major geological features occur and are significant in the geohydrological regime of the area. These are:-

- A dolerite dyke swarm that strikes east west through the northern part of the New Vaal reserves. The swarm zone is up to 60 metres wide and in places individual dykes are greater than 20 metres in width.
- The Viljoensdrift fault, also locally called the Valley fault, is a graben structure that strikes east west and forms the southern boundary of the New Vaal mine and separates it from the old Cornelia Colliery to the south. It has downthrown the Karoo rocks 60 to 100 metres below their original elevation. This graben varies between 1,3 and 2 kilometres in width.

MINING DEVELOPMENT

New Vaal mines by opencast methods into the previously mined underground bord and pillar workings of Cornelia Colliery. The area mined is referred to as the Maccauvlei reserve and this is divided into the Maccauvlei East and Maccauvlei West reserve areas. Maccauvlei East is presently mined by New Vaal.

Cornelia Colliery mined over a considerable area of the coalfield via two main shafts, the Betty Shaft and the Bertha Shaft. The Betty Shaft area in the north is the area into which New Vaal has developed. It is located on the north side of the Vaal River, in the Gauteng Province. The coal in Maccauvlei East was accessed via drives from the Betty shaft under the Vaal River. Mining from the Betty shaft stopped in 1969. The Bertha Shaft section of Cornelia Colliery occurs south of the Viljoensdrif graben and it closed down some 4 years after New Vaal Colliery commenced operations.

PRE MINING LAND USE

The surface area of New Vaal was used as a game farm immediately before the mine commenced operations. Prior to this time the farm, called Maccauvlei, was planted with oak forest over much of the area together with some Eucalyptus plantations. The acorns from the oaks were used as feed for a pig farm. Apple Orchards were also developed but these only lasted for a short period of time.

CLIMATE

This is a summer rainfall area with most rain occurring during the months of October to April. The average rainfall over the past 80 years of records is 570 millimetres per annum (mm/a). Evaporation is 1500 mm/a.

GEOHYDROLOGY

Three natural geohydrological regimes are recognised at New Vaal.

- The Quaternary age alluvial sands that are a free aquifer with permeability up to 33 metres per day.
- The Karoo rocks act as a semi-confined aquifer. However, the Dywka sequence is an aquiclude occurring between the coal measures and the mining operation, and the underlying Dolomite. Coal permeability ranges from 0,001 to 5 metres per day (m/d) with an average of 0,086m/d, and Dwyka permeability from 0 to 1m/d with an average of less than 0.0001m/d.
- The Dolomites are a confined aquifer with secondary permeability, through fractures and fissures, of up to 20 metres per day. In places these fractures feed into glacially weathered areas of chert pebbles and chert bands contained within a calcareous and dolomitic matrix that are porous and form sources of significant dolomitic water. These zones are locally referred to as the Transition Zone. The natural flow of the dolomitic water is from the northwest to the southeast. The dolomites are recharged in outcrops to the north of Vereeniging.

The geological structural features impact on these water regimes. The dolerite dyke swarm is semi impermeable and forms a natural barrier for the groundwater in the Karoo and the Dolomites. The Viljoensdrift fault breaks the lateral continuity of the water regimes in the Karoo and Dolomites between the New Vaal and Cornelia areas. However the fault lines along the northern and southern edges of the graben provide semi vertical conduits for the transmission of waters between the two mining areas

Some water qualities for dolomitic water are given in table 1.

SURFACE WATER

The Vaal River borders the New Vaal area on the eastern, northern and northwestern sides. It separates the mining operation from the town of Vereeniging that lies on the northern bank of the river. The Vaal dam occurs upstream from New Vaal while the Vaal Barrage dam occurs downstream. The river reach between the two dams is referred to as the Vaal Barrage. It is the main source of the water supply for the Gauteng region. It averages 130 metres in width and varies from 4 to 9 metres in depth. The water level in the Barrage is controlled and maintained on average at 1421 metres above mean sea level (mamsl). Two major tributaries join the Vaal Barrage at Vereeniging. These are the Suikerboschrand River and the Klip River.

Within the New Vaal mining area there are few surface drainage features because the alluvial sands are highly permeable. In the past, any runoff to the east accumulated in the vlei called Maccauvlei. A single, small drainage channel occurs in the southwest corner of the mine.

ACTIVITIES IMPACTING THE NATURAL GROUNDWATER REGIMES

The natural geohydrological regimes had been impacted on by various activities prior to the mining by New Vaal.

- Dolomitic aquifer water use
  The Dolomites are heavily utilised with abstraction by Vereeniging residents, farmers, small businesses, smallholdings and industries in the Vereeniging area north of the mine. The Dolomite aquifer is the second major source of water for the Gauteng province.
- Water treatment effluent in underground workings
  In 1969, when the Betty shaft section of Cornelia Colliery closed down, agreement was made between Cornelia Colliery and the bulk water supplier Rand Water (at that time called the Rand Water Board) to use the underground workings as a receptacle for water treatment plant effluent and sludge. It was estimated that 34563 Mm^3 of effluent water was contained in the underground workings when New Vaal commenced mining.
- Abstraction of dolomitic water by Cornelia Colliery
  Bertha shaft operations attempted to mine in the Viljoensdrif graben and link the Betty shaft workings to the Bertha Shaft workings. An incline to 170 metres below surface was constructed from where a drive was mined northwards from the Bertha area towards the Betty shaft area for a distance of approximately 1 kilometre. At this point Dolomitic water ingress was encountered that could only be controlled by the installation of plugs at the brow of the incline. Pumping at rates of 14 to 33 megalitres per day (Ml/d) occurred for 2,5 years to dewater the mining sections that where flooded. Pumping at 6 to 8 Ml/d continued for the remaining life of Cornelia Colliery to keep the area safe and dry for mining. The colliery was permitted to discharge the water via a concrete canal and natural surface drainage features to the Vaal River.

WATER ISSUES RELATED TO THE MINING AT NEW VAAL COLLIERY

A number of water issues related to the mining at New Vaal were identified. These included:-

- The flooding of the pit by the Vaal River
- The flooding of Vereeniging if the mine constructed a flood protection levee to protect the operation
- Seepage inflow of Vaal River water into the pit
- The risk of collapse of the drives under the Vaal River and an inrush of Vaal river water into the mine

- Pollution of the Vaal River during mining dewatering operations
- Pollution of the Vaal River after closure of the pit
- The impact of mining on the dolomite water resources in Vereeniging
- The ability of the dykes to be a hydraulic barrier for the flow of groundwater and the continuity of the dykes across the New Vaal reserve
- The potential for inrush of dolomitic water into the pit, in particular when mining occurred north of the dyke swarm
- Removal and discharge of the Rand Water effluent and sludge in the underground workings
- The high spontaneous combustion potential of the coal seams and the risk of coal losses if the underground workings were dewatered too quickly in advance of mining

Investigations and studies occurred to address these issues. These and the management options required to reduce risk or prevent impacts are summarised hereunder.

FLOODING OF THE PIT

To protect the mine from flooding a flood protection levee was built along the eastern and northeastern edges of the property to retain a 1:100 year flood return. The levee was constructed of materials dug from the alluvium. It averaged 11 metres in height and was vegetated.

The issue of flooding of the pit was revisited in 1990 when the colliery reviewed its insurance profile. Flooding and associated loss of equipment was a concern. The flood lines and volumes were modelled again. It was found that significant urban development had occurred in upstream catchments especially in the Klip river catchment. These increased the runoff factor. This, together with impacts from new road bridges crossing the river, changed the 1:100 year flood line resulting in the need to increase the height of the levee by 2 metres.

FLOODING OF VEREENIGING

Public concern centered on the impact that this levee may have on flooding in Vereeniging. The Vaal Barrage had a history of flooding Vereeniging. The last big flood occurred in 1975 when damaged of R1.85 million in 1975 money terms was caused. Work done by Midgely and Townshend (1984) showed that the design would not affect the town.

THE BETTY SHAFT DRIVES AND THE VAAL RIVER.

The risk of the drives beneath the Vaal collapsing and allowing an inrush of river water into the pit was of concern. To prevent this potential impact on the mine, the drives were sealed off by grouting, through boreholes from the surface, concrete plugs into the drives.

THE POSSIBLE INTERLINKAGE BETWEEN THE OPENCAST MINING AREA AND THE VAAL RIVER.

The potential interlinkage of Vaal river water through the pathway of the permeable alluvial sediments and weathered portion of the Ecca coal measures to the pit was a major mining issue. The Vaal Dam and Vaal Barrage Dam control the water flow in the Barrage, to a degree. With the reduction in flow velocity suspended material has settled and forms an impermeable clay bed to the river. Seepage from Barrage into the adjacent alluvial sediments and weathered Ecca rocks is effectively prevented. This was adequately demonstrated during the development of the initial box cut or first mining cut along the east side of New Vaal. This cut was dug 100 metres from the Barrage, was over 1 kilometre long and reached depths of 35 metres below the Barrage water level. This portion of the pit stayed open for many months. No seepage from the Vaal Barrage through the low wall side of the pit was experienced.

A second interlinkage issue is the reverse movement of water from the pit towards the Vaal River and the potential for contamination post closure. The latter is considered in more detail later in the paper.

IMPACT OF MINING OPERATIONS ON THE DOLOMITE WATER RESOURCES

The impact of the New Vaal mining on the Dolomite water sources in Vereeniging was a major public and stakeholder concern prior to mining. The investigations performed to determine the affects were extensive.

BASELINE STUDIES

A baseline study on the Dolomite water was performed by the Department of Water Affairs Geohydrological Section to determine the risk of opencast mining impacting on the dolomite water resources in Vereeniging. An extensive borehole monitoring system was set up throughout Vereeniging and its surrounds to determine the pre-mining situation. A number of these wells had continuous water level recorders installed.

This monitoring system provided an early warning system in case dewatering occurred after mining commenced. Monitoring of the upper weathered sediments, the Ecca and the Dolomites occurred in boreholes with multi piezometers as well as by individual boreholes drilled into each unit. The study indicated that mining north of the dyke swarm could have potential impacts on Dolomitic water resources in the Vereeniging area. The integrity of the dykes had to be determined to ensure that mining south of the dykes would also have no affect on the Dolomite regime under Vereeinging.

At the same time similar investigations were performed in the mine area and a monitoring system of some 34 wells was put in place. This monitoring system was extended with time.

DYKE INVESTIGATIONS

The integrity of the dykes, their lateral continuity across the planned mining area, and their hydraulic characteristics were investigated. The continuity of the dyke swarm across the coal reserve was confirmed by looking at aeromagnetic work performed by the Geological Survey of South Africa. This was followed up by ground magnetometry surveys across the swarm. These investigations confirmed the continuity of the swarm and of the major dykes across the mining area.

The semi impermeable nature of the major dykes within the swarm was determined by pump tests performed on either side of the major dykes within the swarm.

PUMP TEST SIMULATION OF DOLOMITE DEWATERING

A long-term pump test was performed to simulate an inrush of Dolomitic water into the mining pit north of the dyke swarm and to quantify the affects on Vereeniging. The purpose of the test was:-

- To simulate possible conditions if a large inflow of water entered the pit from the underlying dolomites as the pressure released from the removal of the overburden and coal occurred
- To determine the extent of the dewatering cone in Dolomite in the Vereeniging area
- To confirm the integrity of the dyke swrm as a semi impermeable barrier in the Dolomite aquifer and the Ecca and ensure the north pit and southern main pit could be treated as two separate hydraulic areas.

A borehole drilled north of the dykes as part of the mine dolomitic water investigation had yielded large quantities of water at a rate of 30m^3 per hour (Hodgson 1984). This borehole was chosen for the pump test. The pump was installed at 45 metres below surface and connected to columns of 100 mm diameter.

Twenty-nine observation boreholes, some equipped with piezometers to allow measurement of piezometric differences between the Dolomite and the Karoo aquifers, were used in the mining area. Additionally all boreholes in the Vereeniging area were used. Many of these were equipped with continuous water level monitors. The pump was run at a capacity of $27m^3$ per hour and resulted in a drawdown of 40 metres in the pumping borehole. The test was carried out for a period of 75 days from May to August 1984.

The results of the test indicated

- A cone of dewatering typical of a fractured system was developed. Water level drawdown in distant boreholes was greater than many observation wells sited closer to the pumped borehole.
- The cone of dewatering extended southwards up to the dyke swarm. There was no evidence of the cone developing south of the dyke swarm.
- The maximum drawdown found in the observation boreholes was less than 5 metres even though the drawdown in the pumping borehole was 40 metres
- In the Vereeniging area only one borehole (G34846) showed definite drawdown that could be related to the pumping test. The drawdown measured was 2,5 metres. This is shown in figure 3.
- In the area to the east of the mine the maximum drawdown observed was 4.2 metres.
- The water levels observed in the mine area fully recovered after 3 to 5 days.
- The water level in the borehole G34846 showed recovery over 20 days although this was superimposed upon by fluctuations created by pumpage in the Vereeniging area.

From the observations it was concluded that dewatering effect of the pumping test in the mine area was insignificant in comparison to daily and seasonal fluctuations of Dolomitic water levels in the Vereeniging area. In the event of a major inflow of Dolomitic water into the mine it was expected that the impact on Vereeniging Dolomitic water would not be substantial nor would it be long lasting. However, the impact on the mining operation could be considerable.

Additional surveys on the reserve north of the dyke swarm included a gravity survey to determine the presence or absence of dolomitic channel structures. However no channel structures were determined.

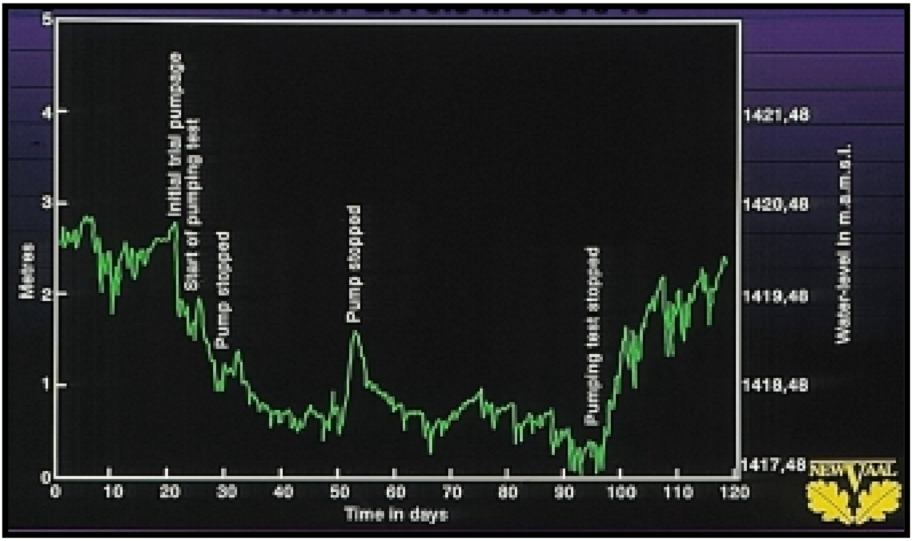

Figure 3. Graph of water levels in the Vereeniging observation well G34846

POTENTIAL INFLOW OF DOLOMITIC WATER INTO THE MINING OPERATIONS

To reduce the risk of inflow of Dolomite water into the pit north of the dyke swarm, procedures were established to ensure the integrity of the Dwyka was not compromised. In pit coal grade control drilling programmes were extended to determine the continuity of the Dwyka. Each of these boreholes was sealed after drilling was completed. No blasting boreholes were to be drilled below the Bottom seam. The stratigraphy was checked using a downhole geophysical density probe. The amount of explosive charge in each blast borehole was limited to minimise the chance of breaking or fracturing the Dwyka. A Dwyka risk plan identifying areas of thin Dwyka sediments was developed from the drilling information obtained.

DEWATERING THE UNDERGROUND WORKINGS

The underground workings had to be dewatered to ensure dry mining conditions. During the early 1980's, a severe drought caused Rand Water to investigate alternative sources of water. The water in the old underground workings was identifed as a large source of good quality water. Rand Water installed 4 boreholes three of which were equipped to abstract underground water that was discharged to supplement the Vaal Barrage. Rand Water abstracted 13Mm^3 of the 34.5Mm^3 from the underground workings at New Vaal over the period 1985 to 1989.

The mine continued to abstract water from various points after Rand Water stopped pumping.

The rate of dewatering the underground workings in advance of opencast mining was controlled. Dewatering was performed in a staged fashion to reduce the risk of spontaneous combustion as oxygen entered the workings as the water levels were lowered. However, this was not always successful. Local undulations in the seam floor topography often resulted in the need to dewater greater areas to achieve dewatering so mining could occur. Other methods to prevent and extinguish coal fires were introduced so reducing the need to limit dewatering.

As Rand Water and the mine abstracted underground workings water the monitoring of boreholes drilled in the Dolomites and the workings showed that

- The dykes were acting as an effective hydraulic barrier. Dolomite water levels dropped to the south of the swarm but not to the north. Therefore no impact of dewatering of the Dolomites south of the dyke barrier occurred on the resources to the north in the Vereeniging area. The Dolomitic water levels to the south of the dyke swarm dropped by 33 metres below the original water levels and the water levels in the Dolomites to the north of the dyke swarm. This drop in piezometric head also stopped any seepage or inflow of Dolomitic water into the pit.
- A hydraulic connection between the old underground workings and the Dolomites was confirmed. A concomitant lowering of Dolomite water levels occurred south of the dyke swarm as the water levels in the old workings dropped with the abstraction of water from them. The hydraulic pathways that allow this linkage are considered to be direct connections where the mined Bottom seam sits on or very close to the Dolomite and via old service and exploration boreholes drilled into the Dolomite and not subsequently sealed off.

These results are shown graphically in figure 4.

ALLUVIAL AQUIFER WATER INFLOWS

Expected high inflows from the sands were never experienced. Interception trenches and sumps handled the water reporting to the pit from this source. Inpit water is pumped to containment dams on surface and reused where possible for dust suppression. Water qualities for this water are given in table 1.

ACID MINE DRAINAGE POTENTIAL

Detailed characterisation of the geochemistry occurred well after the mine commenced operation. Such investigations were not the standard practice of the time. Also the water chemistry was well known from the Cornelia mine workings.

Table 1. Some average water qualities from different areas and the variations that occur

LOCATION	pH	E.C. mS/m	Acidity mg/l	Alkalinity mg/l	Ca Mg/l	Mg Mg/l	Na Mg/l	K Mg/l	SO_4 Mg/l
Variation in Dolomite b/h north of dykw	7.8 9.0	51.3 36.4	33.5 5.2	148.3 59.4	24.8 26.3	15.3 4.2	19.2 18.3	2.4 1.7	38.2 54.4
Variation in u/g areas New Vaal	7.4 7.8	224.1 43,1	54.1 22.0	292.0 96.0	157.4 30.9	59.6 15.2	253.5 29.0	6.2 3.4	1002.9 94.0
Variation in u/g areas Cornelia	7.3 7.6	78.4 48.1	214.0 18.6	121.0 126.9	61.8 29.9	29.4 10.4	36.7 43.5	4.2 4.2	125.6 96.9
New Vaal pit water in storage dam	8.2	305.5	17.5	145.9	162.7	100.6	369.6	9.3	1657.5

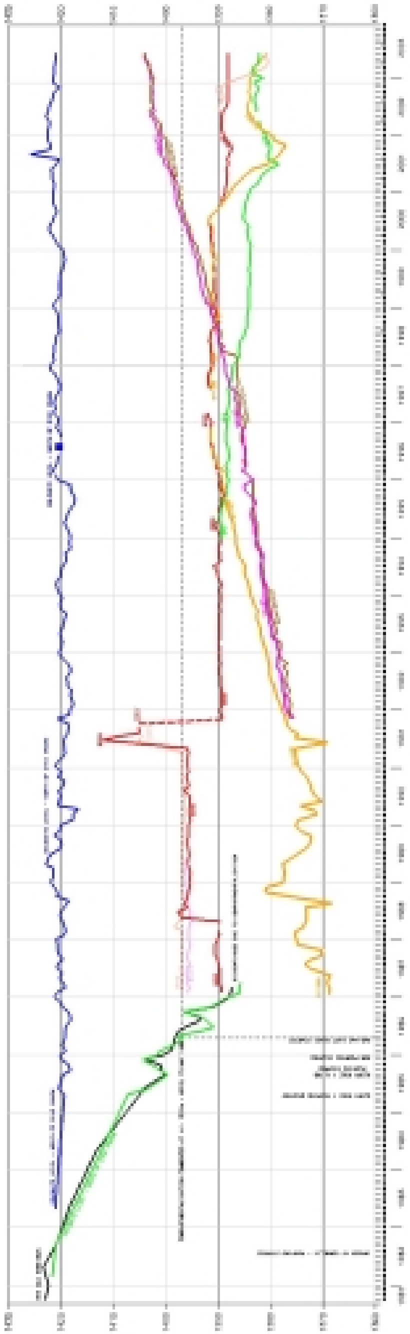

Figure 4. Graph showing the water elevations in the Dolomites and underground workings at New Vaal Colleiry north and south of the dyke swarm and the water elevations in the underground workings of Cornelia Colliery and the Viljoensdrift graben from 1981 to 2003.

However, the need to detail spoil characteristics became essential as inpit water salt loads increased requiring management actions and as post mine closure plans were developed. Acid Base Accounting indicated the presence of reactive and non-reactive spoil (Hodgson 2000). The usual management option to deal with this situation is selective spoil handling with the placement of reactive materials at the base of the pit. The New Vaal mining method involves dragline overburden stripping, in a confined pit producing coal from 3 seams. The production rates required to expose and mine coal make selective spoil handling impractical. It is considered that the dragline process of mixing material would allow reactive and non-reactive material to blend to reduce the acid generation although high salt levels in waters would occur. During the operational phase water is pumped to keep the pit dry so there is little salt build up from this source. This water is contained in surface water holding dams to evaporate or be reused in dust suppression or by the Lethabo Power Station.

WATER REUSE AND WATER TREATMENT

New Vaal mine dewatering was done under license, given for a limited duration of 5 years, to discharge specified volumes and qualities to the Vaal Barrage. During this time the mine investigated recharge scenarios, changes in water chemistry, reuses and water storage facilities required as the water regimes and mine plans changed. These investigations were performed to find the means to reduce direct discharge to the Vaal and improve water use efficiencies. However the studies indicated an excess of saline water. A partnership was established with the Lethabo Power Station whereby mine water is supplied to the station to supplement the cooling water requirement. This reduces the demand from the power station for new water sourced from the Vaal Barrage. To be able to use the mine water the power station constructed a 12 Ml/day capacity spiral wound reverse osmosis plant. The mine water is mixed with cooling water blowdown before being sent to the water treatment plant. Providing salt levels are not excessive the reverse osmosis plant can accept up to 9Ml/day mine water (Van Der Merwe, 2003).

DOLOMITE AND PIT WATER FLOW PATHS

The influx of dolomite water into the pit is estimated to be 14 to 20 ML/d based upon the inflows at Cornelia colliery. This will occur during mining, after mining at New Vaal has been completed and until water levels in the pit stabilise at 1421mamsl. This water is abstracted and stored in surface dams for reuse and evaporation. Dams are established around the mine perimeter as well as in the rehabilitated pit.

NEW VAAL OPEN PIT AND CORNELIA (BERTHA SHAFT) WORKINGS CONNECTIVITY

The underground development from the Bertha shaft area towards the north, through the Viljoensdrift graben, did not reach the Betty shaft area. Therefore no direct interconnection exists between Cornelia and New Vaal. The exact pathways that exist are not known but it is surmised that they would be as follows:-

- The interconnection of the Viljoensdrift graben workings with the Dolomites
- The faults in the graben providing zones for sub-vertical groundwater movement
- The Transition zone in the Dolomites at the Karoo unconformity.

The volume of water moving would vary as the pressure head between Cornelia and New Vaal changed.

The connectivity and direction of Dolomite flow has changed during the mine development. This is demonstrated by the water elevations shown in figure 4 and is summarised in table 2 below. While Cornelia Colliery was still operating the Dolomite levels were lowered due to the pumpage applied to keep the underground workings of Bertha Shaft dry. The levels were drawn down to 1365mamsl. To the north the undisturbed dolomite level in New Vaal was at 1421mamsl.

With the commencement of New Vaal (Old Betty shaft underground workings) dewatering, the Dolomite water levels in the New Vaal area south of the dyke swarm dropped due to the interconnectivity with the underground workings and the Dolomites. The combined New Vaal and Cornelia pumpage dropped the dolomite water levels to 1365 mamsl. This was maintained until Cornelia Colliery closed in the late 1980's. Pumping at Cornelia ceased and the water levels in this mine were left to recover. These levels progressively increased until they were higher than those in the dewatered New Vaal pit; the situation that exists at present.

As the water level in Cornelia has risen and the hydraulic gradient between Cornelia and New Vaal has steepened increased flow of water has been experienced in the New Vaal pit.

POST CLOSURE MINE WATER

The significant post-closure issues are the interlinakges and flowpaths between the pit water and the Vaal River, the Dolomites and Cornelia colliery. The final pit layout will probably result in 87% of the spoil being below the water table level of 1421 mamsl (Hodgson 2000). This will reduce AMD reactions. The remaining 13% of the spoil will be in the unsaturated zone where oxidation and moisture ingress will occur. The pit will therefore have a net base potential. The total volume of water that will be contained in the pit is estimated to be 300Mm^3 at an elevation of 1421 mamsl (Hodgson 2000).

Table 2. Summary of water level (in mamsl) and Dolomite water gradient changes over time.

Dates	Vereeniging & New Vaal North of Dyke	New Vaal South of Dyke	Cornelia Workings & Valley Area	Comments
1984	1421	1421	1370	Cornelia abstraction only
Late 1980's	1421	1385	1376	Cornelia abstraction ceases but New Vaal abstraction south of dykes continues
Late 1990's	1421	1390	1390	New Vaal abstraction only. Cornelia levels rising.
2003	1421	1380 -1385	1403	Cornelia levels above New Vaal. Increased New Vaal abstraction required to keep pace with additional water from Cornelia.

As the water level in Cornelia has risen and the hydraulic gradient between Cornelia and New Vaal has steepened increased flow of water has been experienced in the New Vaal pit.

POST CLOSURE MINE WATER

The significant post-closure issues are the interlinakges and flowpaths between the pit water and the Vaal River, the Dolomites and Cornelia colliery. The final pit layout will probably result in 87% of the spoil being below the water table level of 1421 mamsl (Hodgson 2000). This will reduce AMD reactions. The remaining 13% of the spoil will be in the unsaturated zone where oxidation and moisture ingress will occur. The pit will therefore have a net base potential. The total volume of water that will be contained in the pit is estimated to be 300Mm^3 at an elevation of 1421 mamsl (Hodgson 2000).

POST CLOSURE STRATEGIES

It is uncertain as to whether the pit may operate as a Closed or an Open pit water system after closure. However in either case management actions would focus on reducing precipitation infiltration into the pit. Some of the options that may be considered include:-

- Using covers other than just the alluvial sands and rough grass. Such a covers could be power station fly ash to reduce oxygen and moisture ingress
- The planting of tree species such as Eucalyptus that are big water consumers
- Maximising the size of the evaporative areas
- Preventing pit water movement towards the Vaal River. To manage this situation the areas where pathways and movement of pit water through the aquifer towards the Vaal River were determined by considering the elevation of the interface between the Alluvium and the Ecca around the edge of the pit
- Pumpage and treatment of excess pit water for discharge or for other uses
- The use of the water to irrigate crops on the rehabilitated pit surface

CONCLUSIONS

Water management at New Vaal commenced a decade before the new approaches to mine water management were established in South Africa during the early 1990's. The sensitivity of the water regimes in which the mine operates ensured that appropriate investigations and actions were taken to reduce and prevent impacts on the strategic water resources in the area.

Mine water management is dynamic and has to change as conditions and mine plans change. It is essential to understand this and provide the resources throughout the life of a mine to deal with water issues. The changing flood risk profile and the need to regularly re-model flood conditions is a classic example demonstrated in this case study.

Monitoring data and the ongoing reporting and review of it is essential to reduce risks.

Intermine flow and inter-aquifer flow are complex and require careful monitoring and modelling.

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