Groundwater Stratification and Impact on Coal Mine Closure

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Abstract On closure of the Ermelo Mines in 1992, initial monitoring indicated that a water treatment would be required to treat the mine decant. The evolution of the water quality can be attributed to sulphate reducing bacteria, vertical recharge from the hanging aquifer and stratification. Water level and quality monitoring have shown that the water in the old mine void will not decant to surface due to the depth of the mine void, hydrogeological conditions, a "hanging aquifer" and the recharge mechanisms. As a result no water treatment will be required and the mine will not impact on the surface water.

Keywords monitoring, water, quality, stratification, decant

Introduction

The paper discussed a case study of the closure of the Ermelo Colliery (Pty) LTD, an underground board and pillar coal mine, situated in the Mpumalanga Province of South Africa and how the mine closure strategy changed with a better understanding of the hydrogeology and stratification of water in the mine.

Initial closure plans anticipated the construction of water treatment plant to treat possible poor quality decant water. As more scientific work was undertake by various people and organizations there emerged a clearer understanding of the rebound of water levels, the evolution of the groundwater chemistry and the stratification of water. This has significantly changed the mine closure strategy. Data shows that the mine will not decant poor quality water and it will not impact on the ambient hydrological regime (surface and groundwater).

The paper describes the hydrogeology of the mine, the mechanism of rebound of water levels, evolution of the groundwater quality and the new closure strategy. Groundwater flow and solute transport models were undertaken to predict the long term groundwater flow regime and water quality and to determine the potential for decant. Routine monitoring of groundwater quality and levels is undertaken to ensure that the hydrogeological predictions are correct. The also paper details the importance of correct monitoring and conceptual hydrogeological model and the influence this has on the mine closure planning

Location

Ermelo Mine is located in the eastern part of South Africa in the Mpumalanga province at an altitude of 1600 mamsl. The area is characterised by warm wet summers and cold dry winters. The average yearly rainfall is 650 mm/a which occurs in summer. The original vegetation was grassland but this has given way in areas to commercial cultivated agriculture, with the main crops being maize and pastures (Fig. 1).

The mine is the only mine situated in the Brakspruit (C11F) catchment, which is in the headwaters of the Vaal River catchment. The Vaal River, is one of the main rivers that drain the coal and gold mining areas of South Africa, and is under extreme pressure due to poor quality decant and seepage from the aban-

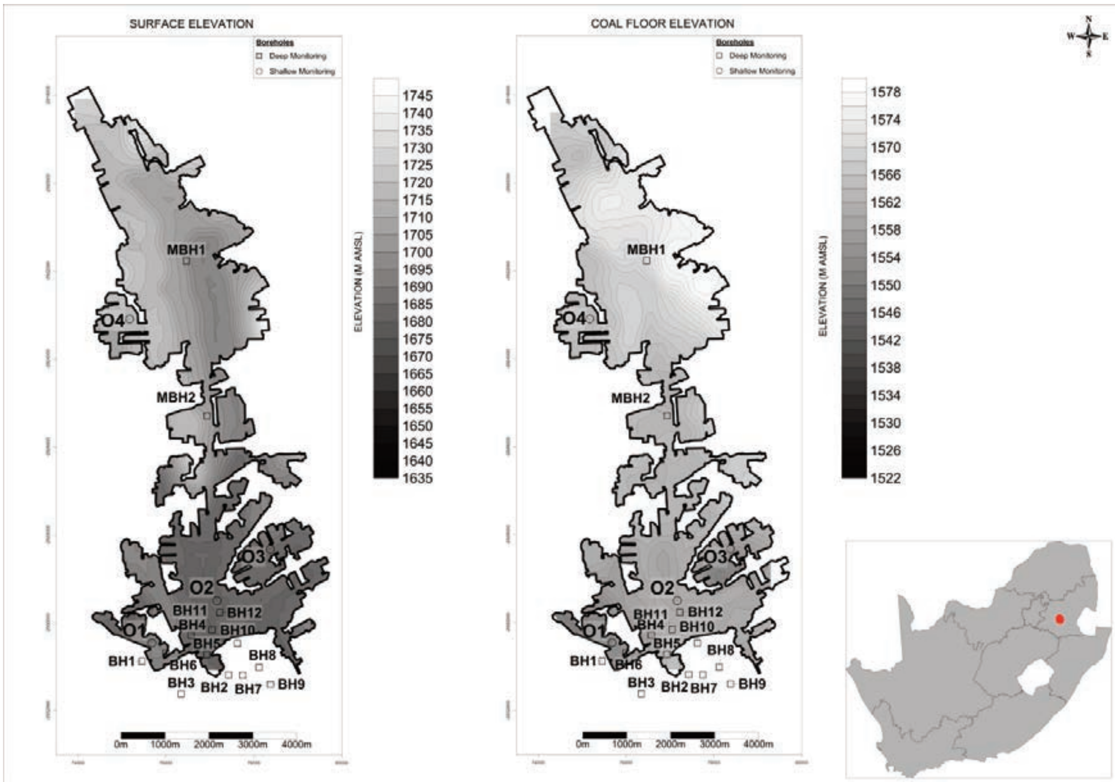

***Fig. 1** Locality plan*

doned, closed and operating mines. The Vaal River water quality is managed by strict control of decant, mine water treatment and dilution by means of intercatchment transfer from the Lesotho- Highlands scheme.

Farmers in the Brakspruit catchment rely on springs as well as boreholes that yield water from the shallow weathered aquifer. Most farmers boreholes are 40 m deep and do not intersect the coal measures. There are some small agricultural dams in the Brakspruit and theses are used for small scale crop irrigation.

Description of the Mine

Ermelo mine started in 1977 and was decommissioned in April 1997. The coal seam occurs between 90 and 180 meters below surface (mbs) and access to the coal was by means of shafts and declines. The mining method was board and pillar with limited pillar extraction (stooping). The mine was notorious for its high methane content which lead to some fatalities. The mine plan was largely controlled by faults, dolerite sills and dykes. The underground workings trend north-south, with the coal seam dipping 5 degrees to the south. The coal seam is the shallowest 90 mbs (1570 mamsl) in the north and the southern part being the deepest at 180 mbs (1520 mamsl). The surface elevation in the north is 1680 mamsl and the elevation at the south being 1600mamsl. As a result all rebound water flowing into the mine flowed down dip to the south (see Fig. 1).

Coal was processed on site in a washing plant and exported by rail. Discard were placed in a discard dump which has been shaped and vegetated. The dump is not discussed in this paper

On closure the envisaged logical places for the mine decant was in the southern area above the workings into the "Brakspruit" which flows into the Vaal River.

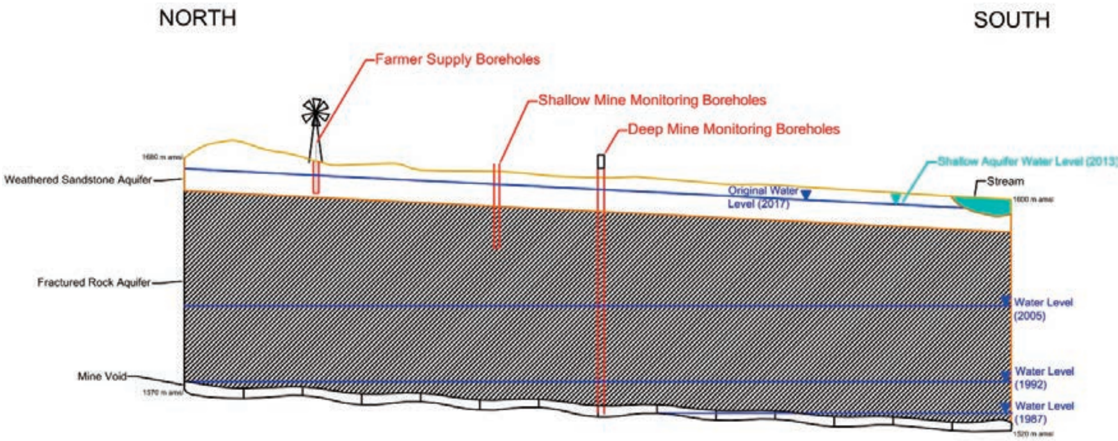

Fig. 2 *Conceptual Hydrogeological Model*

After decommissioning a number of deep boreholes were drilled into the mine void to monitor water quality and levels in the mined void. Shallow boreholes (0–60 m) were used to monitor water levels in the shallow "upper" aquifer. A very important hydrogeological observation was that only a few farmers' water supply boreholes were affected by the underlying mining operations.

Hydrogeology

The mine hydrogeological regime is a typical sedimentary weathered and fractured aquifer. The geology consists of slightly dipping sedimentary units, varying from shales, carbonaceous shales, coal, silts and the roof being a thick, medium to fine grained sandstone. The sandstone roof is up to 80 m thick and is very competent. The area has been intruded by post depositional igneous intrusions in the form of dolerite dykes and sills. The contact zones of dykes and sills have resulted in post depositional zones of permeability. In certain areas the dolerite sills and dykes can act as permeable or no flow boundaries. The base of the aquifer for this study was taken as the tillite below the coal seam.

Recharge to the aquifer was modeled by mine stage curve analysis and numerical modelling is 5 % of mean annual precipitation (MAP) which is 32.5 mm/a. Water levels in the aquifer ranges from 0 (springs and seeps) to 10 m below surface (hills)

The shallow aquifer comprises weathered and fractured sandstone which is very important as it is the main water supply aquifer and has a significant contribution to the baseflow of the streams. Water quality in the aquifer is very good. The deeper aquifer comprises fractured sandstone & shales, bedding plane permeability and lithological contact zones. This aquifer was intersected during the mining operations and historical information indicated that the aquifer did not yield much water during mining. The conceptual hydrogeological model is shown in Fig. 2.

Pyrite is ubiquitous in all the South African coal mines and this leads to the formation of acid mine drainage in the mine. The formation of poor quality leachate is a function of the surrounding lithology's that are disturbed during mining. At Ermelo there is pyrite in the coal seam as well as the roof and the floor.

Monitoring

On closure of the mine, a routine surface and groundwater monitoring program was instituted to determine the water quality and levels in the ground and surface water. The shallow aquifer was monitored by measuring water levels and water quality, in the farmers and dedicated mine monitoring boreholes

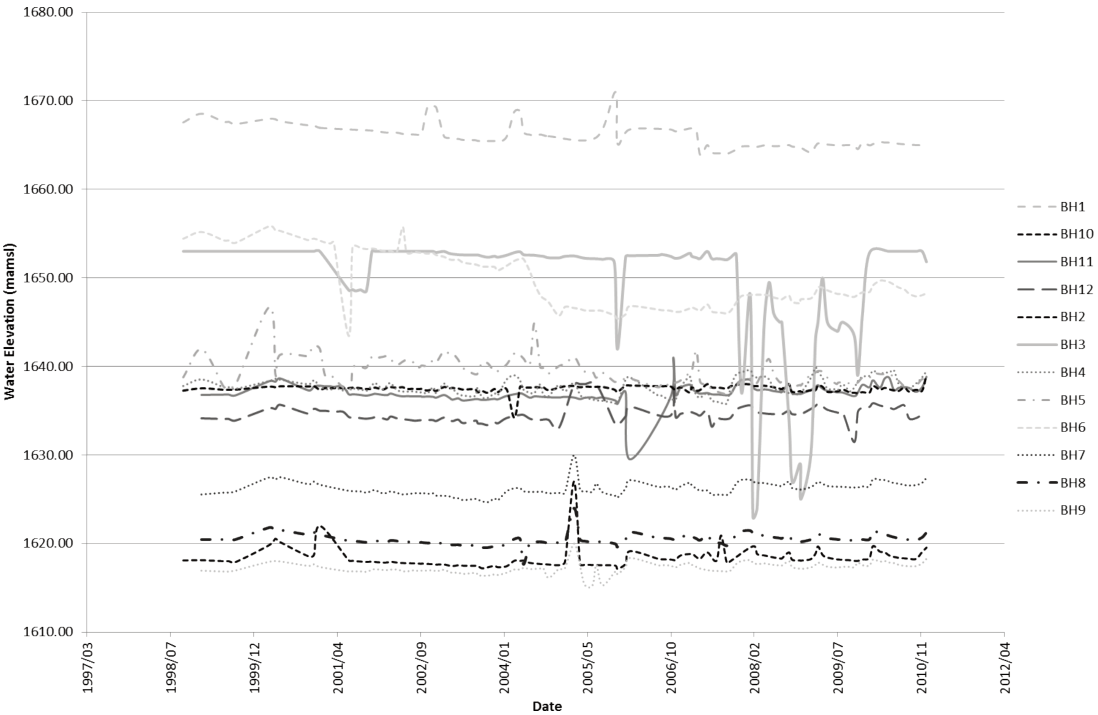

Fig. 3 *Shallow monitoring borehole time series water levels*

It is interesting to note that water levels in the shallow aquifer were not significantly impacted on during the mining operations and post mining, while water levels were recovering in the mine void. Groundwater level in the shallow boreholes is shown in Fig. 3. The majority of the boreholes are located above the mine void.

Dedicated deep boreholes were drilled into the mine void. These were used to monitor water quality and water levels in various areas in the mine (basins). The recovery of the water levels in various areas of the mine is shown in Fig. 4. The rebound of water levels indicates that the mine comprises of various

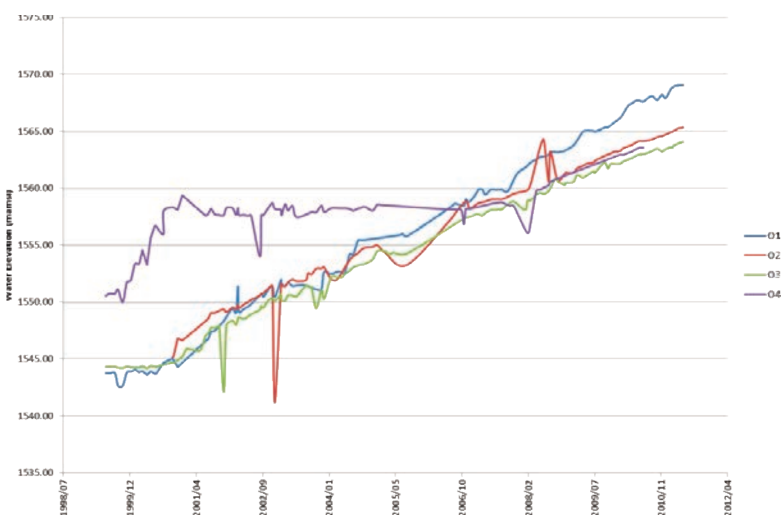

Fig. 4 *Deep Borehole in the mine void*

basins and these basins decanted into other basin depending on the coal floor contours and mine developments.

Groundwater Chemistry

The groundwater chemistry in the shallow aquifer is very different to the chemistry in the mine void. The water is low in dissolved solids and the chemistry shows it is recently recharged. The water quality on the Brakspruit is also good, despite its name.

The water quality in the mine void has proved very interesting. Initial water quality data indicated that the mine void water was very high in dissolve solids (5000 mg/L) mostly sulphate (3200 mg/L). This would be expected as all water in the void flowed to the southern area and was monitored in borehole 01 and 02. The water quality began to change and this lead to numerous disputes between practitioners working on the project. There were various theories from, "there is cascading water down the borehole which influences sampling, exchange with Na being substituted for SO4, incorrect sampling depths, impact of sulphate reducing bacteria".

During routine water sampling it was observed that there were hydrogen sulphides as well as a film in the deep holes. As a result it was decided to undertake a microbial investigation. Van Heerden and Botes (2012) undertook a study of the microbial activity at the mine. The recovering mine (methane filled void) and the flooded mine cavity presents an ideal environment for excluding oxygen from the system of acid rock drainage (ARD). Samples of the microbes were collected and the DNA was extracted and analysed. The result indicated that there were a high number of bacteria and numerous species and there is clearly an abundance of carbon sources, potential electron donors and most importantly a finite amount of terminal electron acceptors. At present there is sufficient buffering capacity to ensure neutral pH.

Stratification

There was difficulty in sampling the water quality in the mine boreholes and erratic re-

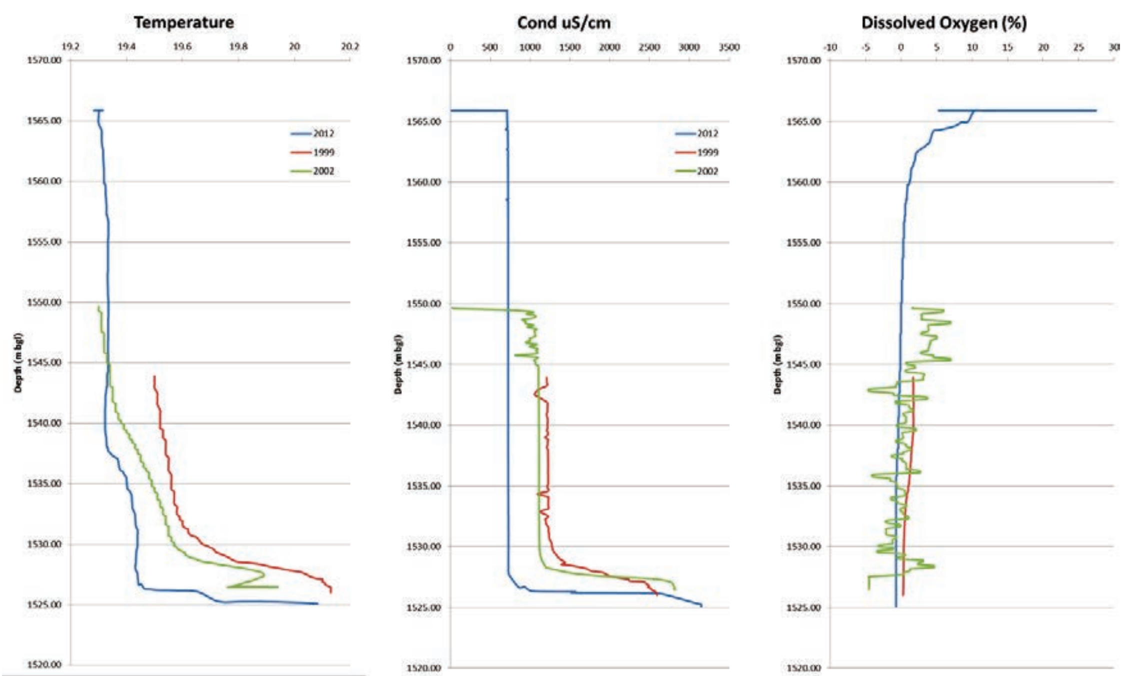

Fig. 5 *Borehole 04 Down hole profile*

sults were being received. In order to confirm the representativeness of the water quality that was collected from the mine void boreholes, a number of down hole profiles were undertaken in the deep mine monitoring boreholes. These were undertaken 1999, 2002 and 2012 and are shown in Fig. 5. The profiles clearly indicate the following:

- The water in the mine void is overlain by better quality water similar to the hanging aquifer
- There is stratification of water in the mine with better quality water above poorer quality water in the mine void
- The mine void water is essentially "trapped" in the mine void.
- In the unlikely event that the mine decants, the poor quality decant water will have to displace water in the upper aquifer. This is unlikely to occur as there is insufficient head and the roof is largely impermeable.

Conclusions

The closure plan for the mine has change considerable with a better understanding of the hydrogeology. It is clear that the mine will now not decant and the mine void water is confined to the old mine working and the water above the mine is ambient groundwater of good quality. There is not suffient head in the mine and the roof permeability is not suffcient to allow for large scale long term decant of poor quality water.

The paper shows the importance of hydrogelogical conditions in the deign of a mine in order to inhibit potential mine decant on closure. Factors that should be considered are shaft locations, aquifers, the importance of a "hanging aquifer" and the use of artificial recharge to flood mine voids on closure.

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