Development of a 3-D electrical conductivity image for a colliery in South Africa to determine post-closure management options

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Abstract The colliery is situated in the Vereeniging-Sasolburg Coalfield, immediately southwest of Sasolburg in the Republic of South Africa. The colliery is in the fortunate position that it has a very complete and concise monitoring program in place and over 200 boreholes were drilled throughout the life of mine. Down-the-hole chemical profiles of over 90 boreholes were created with a multi-parameter probe. From the data collected a three-dimensional image was created from the electrical conductivity values at different depths. This image is very helpful in aiding the decision making process in the future management of the colliery.

Keywords Colliery, electrical conductivity, three-dimensional image, management

Introduction

The stratigraphy of this coal field is typical of the coal-bearing strata of the Karoo Sequence. The succession consists of pre-Karoo rocks (dolomites of the Chuniespoort Group of the Transvaal Sequence) overlain by the Dwyka Formation, followed by the Ecca Group sediments, of which the Vryheid Formation is the coal-bearing horizon. Mainly the lava of the Ventersdorp and Hekpoort Groups underlie the coal. The Karoo Formation is present over the whole area and consists mainly of sandstone, shale and coal of varying thickness.

Mining at the colliery ceased in 2004 and the underground mine was flooded. An ash-filling project was undertaken by the colliery from 1999 to stabilize mine workings located beneath the main roads in the vicinity. A key issue is: if the mine eventually decants what the quality of the water will be? This information is important for the future planning of the company, as this will determine if a water treatment plant is necessary, and what the specifications for such a plant would be, if required.

It was therefore decided to do a down-the-hole chemical profile of each available and accessible borehole with a multi-parameter probe with the aim of observing any visible stratification. It was possible to create chemical profiles of over 90 boreholes. From the data collected a three-dimensional image was created from the electrical conductivity values at different depths to see if any stratification was visible in the shallow aquifer. Due to the ash-filling operations the normal aquifer conditions were disturbed, creating different pressures than normally expected at a deeper underground colliery. According to the Mineral and Petroleum Resources development Act (RSA 2002:49) no closure certificate may be issued unless it has been confirmed by the Inspector of Mines and the Department of Water Affairs that the management of pollution to water resources has been addressed. It is for this reason that the three-dimensional image may prove to be very helpful in the aiding in the decision making process in the future management of the colliery and eventually obtaining a closure certificate, and also to determine whether ash-filling is a viable option in discarding the ash.

Materials and Methods

The down-the-hole chemical profiling was carried out using a multi-parameter probe which measured the temperature, the specific conductivity, the dissolved oxygen concentration, the depth, the pH and the oxidation reduction potential. The data recorded by the probe was immediately downloaded onto a laptop computer. Fig. 1 indicates the position of the 94 boreholes that the down-the-hole chemical profiling was done on, the #2 coal seam as well as the #3 coal seam, Wonderwater open-pit mine, Mohlolo underground mine and the ashfill areas indicated in yellow.

After the chemical profiling was completed the downloaded data was entered into a WISH (Windows Interpretation System for

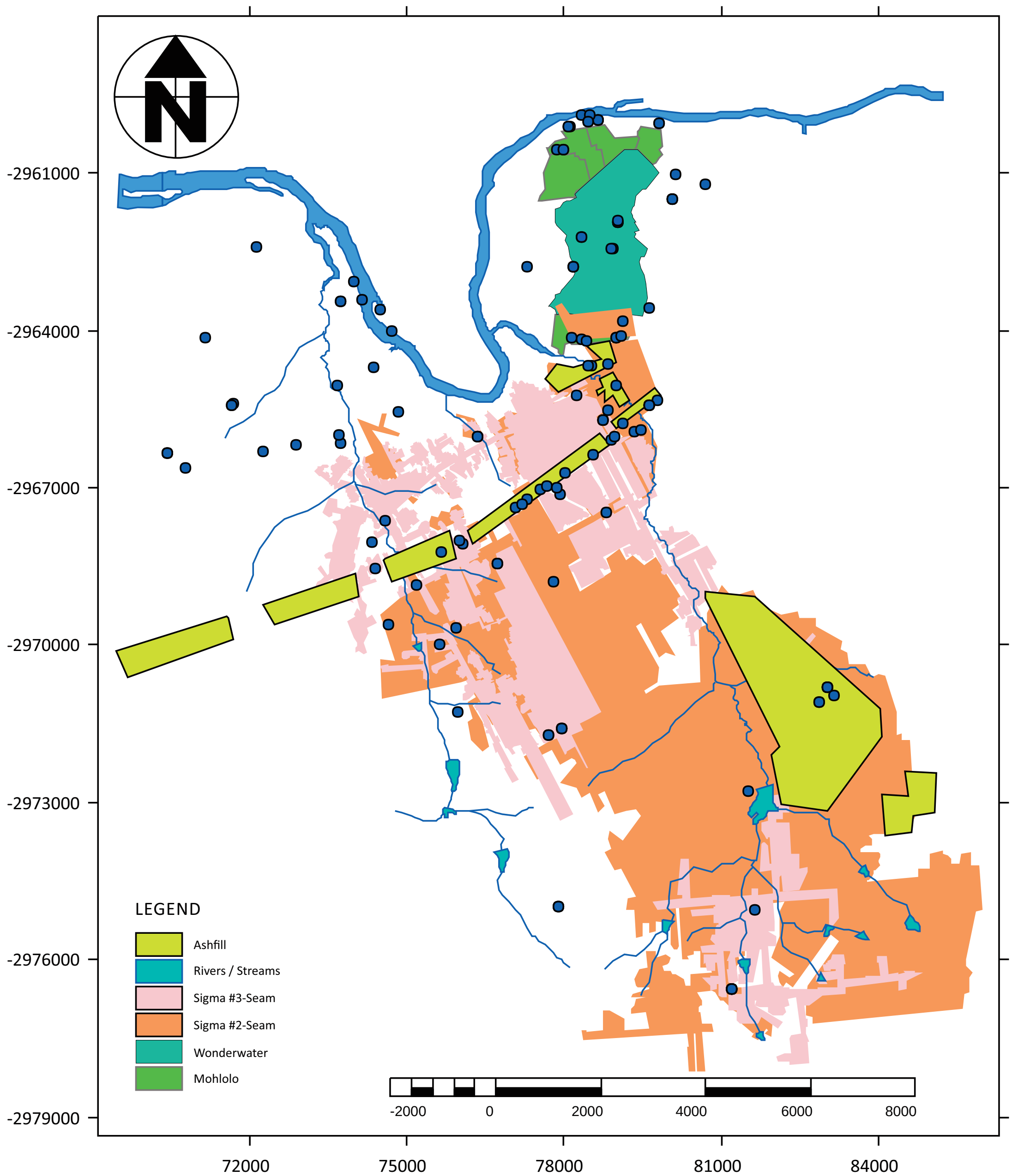

Fig. 1 *The boreholes profiled with the down-the-hole chemical profiling with the ashfill areas indicated in yellow.*

the Hydrogeologist) database. WISH was developed especially for the Hydrogeologist and is a hybrid between a CAD system, a Geographical Information System, Chemical analysis package and pumping test programs. It was decided to use the electrical conductivity values to create a three-dimensional image since electrical conductivity is a measure of the ability of water to conduct an electric current and this is dependent on the concentration of the ions, such as Ca^{2+}, Mg^{2+}, K^+, Na^+, HCO_3-, Cl-, SO_4^{2-} and NO_3-, present in the water. WISH was then used to create the three dimensional image of the electrical conductivity of the boreholes in relation to the local topography.

To get a more concise image of whether decant will occur and what the water quality will be in the event that decant does occur, sections of water level versus topography were also created with WISH where the water level was very shallow. The three dimensional image of the electrical conductivities of the boreholes in close vicinity to these shallow water levels was then also used to determine the water quality of the possibly decanting water.

Results and discussion

The three-dimensional image of the electrical conductivity profiles in relation to the local topography and the underground mining area can be viewed in Fig. 2. From this image the high electrical conductivity areas (in red and yellow) are clearly visible and these areas can be focused on by creating sections in these specific areas.

Four sections were created in areas of shallow water levels where possible decant might occur. These sections are section A –AA, section B – BB, section C – CC and section D – DD.

The locality of section A – AA, section A – AA and the three dimensional image of the electrical conductivities of the boreholes in close vicinity to section A – AA can be viewed in Fig. 3.

The areas on Section A – AA (Fig. 3) encircled with red, are areas where the water level appears to be very shallow, and could thus be possible decant positions. The second area where the water level appears to be shallow is close to a river. Boreholes close to these areas are identified on the locality map in Fig. 3. From the EC logs it is evident that the EC of these boreholes varies between 1.7 mS/m and a 99 mS/m. This is well within the ideal to acceptable range for electrical conductivity values according to SANS241:2006 drinking water standards which is between 0 and 150 mS/m. It can be assumed that in the event that decant would occur, the water quality of the decanting water will be within the acceptable range.

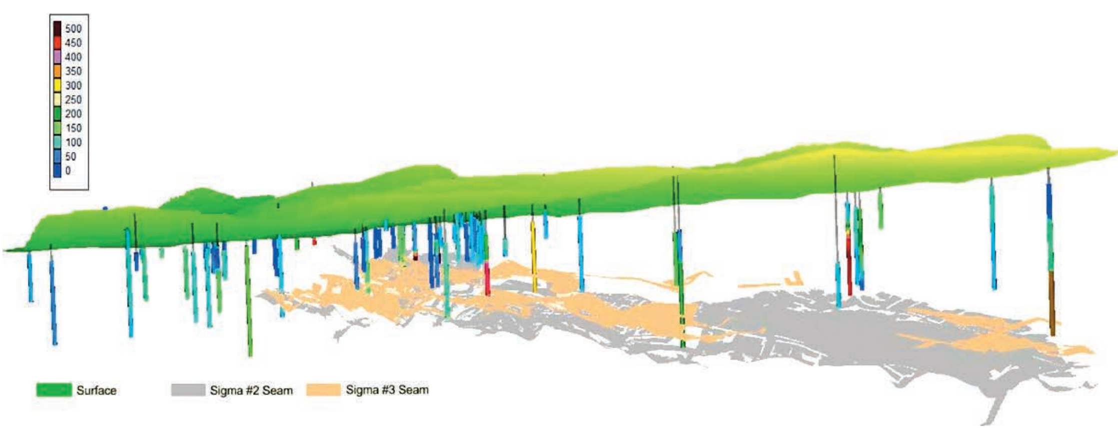

Fig. 2 *Electrical conductivity profiles of boreholes in relation to the local topography with a topographic high where the red contours are displayed.*

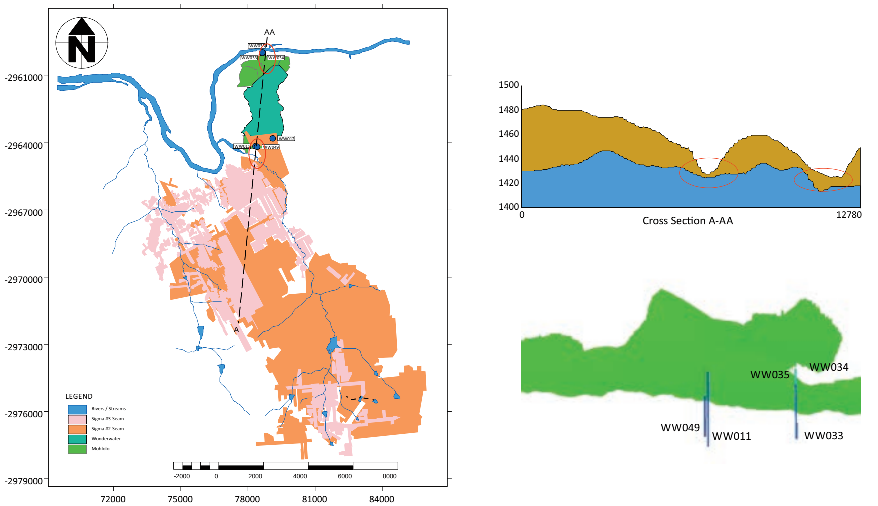

Fig. 3 *The locality map of section A – AA with the section A – AA and the 3D-image of the electrical conductivity values in relation to topography in close vicinity to section A – AA.*

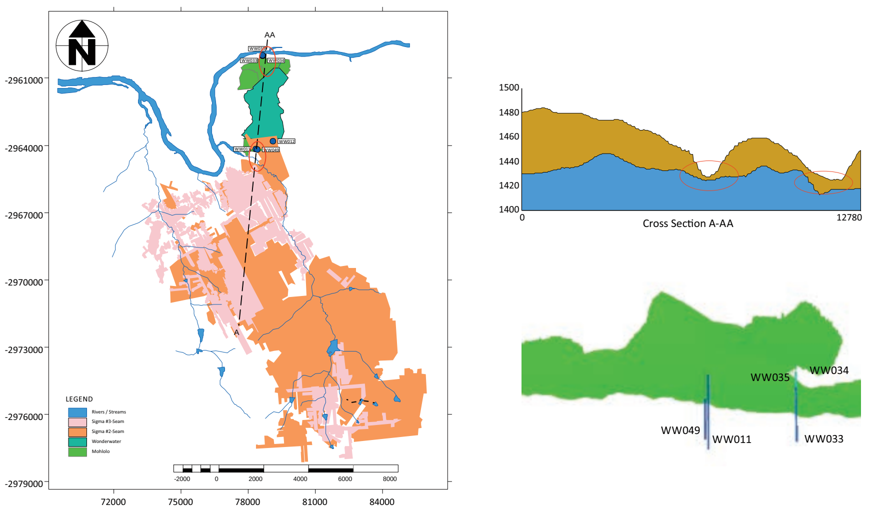

Fig. 4 *The locality map of section B – BB with the section B – BB and the 3D-image of the electrical conductivity values in relation to topography in close vicinity to section B – BB.*

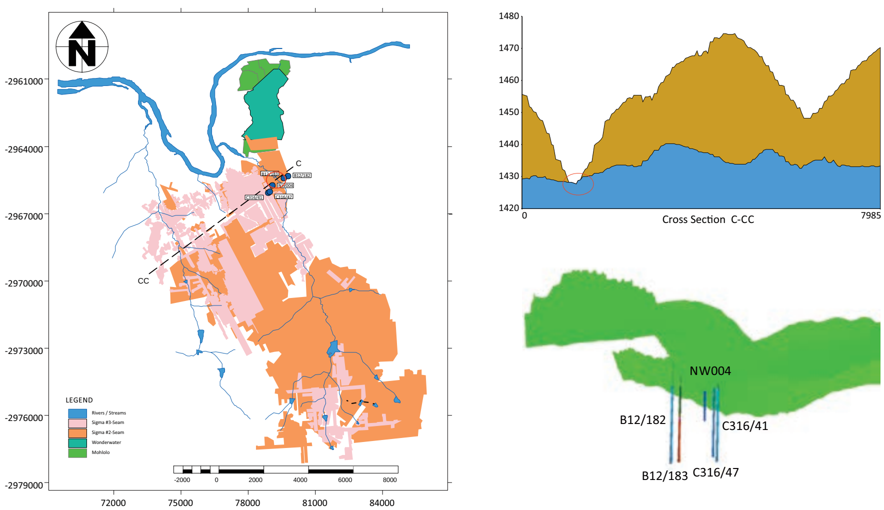

Fig. 5 *The locality map of section C – CC with the section C – CC and the 3D-image of the electrical conductivity values in relation to topography in close vicinity to section C – CC.*

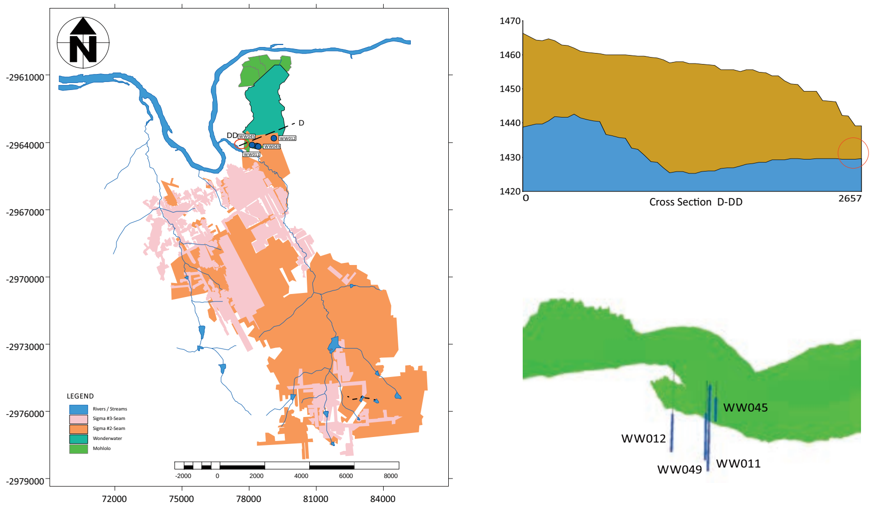

***Fig. 6** The locality map of section D – DD with the section D – DD and the 3D-image of the electrical conductivity values in relation to topography in close vicinity to section D – DD.*

The locality of Section B – BB, section B – BB, and the three-dimensional image of the electrical conductivities of boreholes in close vicinity to section B – BB can be viewed in Fig. 4.

The areas encircled in red (Fig. 4) again are areas where the water level appears to be very shallow and could be possible decant positions. The first two areas where the water levels appear to be shallow are close to rivers. Boreholes nearby to these areas are visible on the locality map in Fig. 4. From the three-dimensional image of the electrical conductivity logs it is evident that the EC of these boreholes range between 70 mS/m and 132 mS/m. These values are still within the acceptable range according to SANS241:2006 drinking water standards, which is between 0 and 150 mS/m. It can be assumed that should decant occur in the areas encircled in red (Fig. 4) the decanting water will still be within the acceptable range according to SANS241:2006 drinking water standards and will not be polluted water.

The locality of section C – CC, section C – CC and the three-dimensional image of the electrical conductivities of the boreholes in closse vicinity to section C – CC can be viewed in Fig. 5.

The area encircled in red (Fig. 5) is an area where the water level appears to be very shallow and could indicate a possible decant position. Boreholes close to this area are identified on the locality map in Fig. 5. The EC values for the boreholes range between 12 mS/m and 450 mS/m. The high EC values are found in borehole B12/183 and could be attributed to the fact that this borehole is an ashfill borehole. Water decant from ashfill boreholes would be due to artificial pressure caused by the ashfill that was pumped into the boreholes. If decant should occur from this borehole the water quality of the decanting water would be in the "not allowable" range according to SANS241: 2006 drinking water standards. If any of the other boreholes discussed, or the area surrounding these boreholes, should decant the water quality of the decanting water will be within the acceptable range according to SANS214:2006 drinking water standards.

The locality of Section D – DD, section D – DD and the three-dimensional image of the electrical conductivities of boreholes in close vicinity to section D – DD can be viewed in Fig. 6.

The area encircled in red (Fig. 6) is an area where the water level appears to be fairly shallow and could be a possible area of decant. The boreholes in nearby this area are visible on the locality map in Fig. 6. From the EC logs it is evident that the EC of these boreholes varies between 1.7 mS/m and a 99 mS/m. This is well within the “ideal to acceptable” range for electrical conductivity values according to SANS241:2006 drinking water standards. It can be assumed that in the event that decant would occur, the water quality of the decanting water will be within the acceptable range.

Conclusions

Once the mine has filled up with water, the piesometric level of the mine will rise with the storage coefficient value of the mine as conditions have changed from unconfined to confined. The flux from the overlying aquifers into the mine aquifer will decrease as the two water levels approach each other. The flux from the underlying dolomitic aquifer towards the mine will also decrease as the mine level increases. Once the level of the mine aquifer is higher than that of the dolomite aquifer, water from the mine will flow towards the dolomite aquifer. It is only if the mine level increases above that of the level of the top weathered aquifer, that decant could occur. The chance that the water level of the mine would increase above the water level of the top aquifer is very small because the dolomite has a much higher transmissivity value than the top aquifer. Thus the chance of decant occurring is very unlikely. No stratification was visible in the top aquifer and it was only when ash filling of the mining voids was introduced that problems were created and stratification of the top aquifer became visible. The only place where decant and pollution of the shallow aquifer is evident is where ash filling has been done. Thus if the company then chooses to continue with the ash filling a water treatment plant will become necessary which will incur more costs.

Acknowledgements

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