GEOHYDROLOGICAL REPORT

FOR

THE PROPOSED USUTU OPENCAST COLLIERY ON THE FARMS JAN HENDRIKSFONTEIN 263 IT AND TRANSUTU 257 IT, ERMELO, MPUMALANGA

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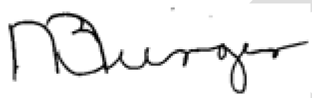

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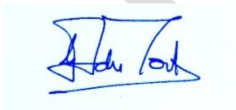

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EXECUTIVE SUMMARY

Geo Pollution Technologies (Pty) Ltd (GPT) was appointed by Environmental Assurance (Pty) Ltd (Envass) to conduct a hydrogeological impact study for Usutu Coal (Pty) Ltd for the proposed Usutu Opencast Colliery located approximately 15 km south-east of Ermelo, on the farm Jan Hendriksfontein 263 It and Transusutu 257 IT, Mpumalanga Province.

Results of the Investigation

- Groundwater levels were measured in twelve boreholes during a hydrocensus conducted in November 2011 for the proposed Usutu opencast on the farm Jan Hendriksfontein portion 263 IT/6B and Transutu 257 It. The depth of the static groundwater level was found to vary between 1m and 10m below ground level.
- A seasonal aquifer perched on the bedrock probably develops in the upper weathered soil layer, especially after high rainfall events. Flow in this perched aquifer is expected to follow the surface contours closely and emerge as fountains or seepage at lower elevations.
- From the chemical analysis of the water samples an overall assumption can be made that the groundwater sampled in the proposed mining area is of poor quality and not acceptable for domestic use. It can be deduced from the water quality of the sampled boreholes that the groundwater has been negatively affected by historic mining related contaminants.
- The acid base analysis (ABA) of exploration drill cores from the six opencast areas showed material that is intermediate to potentially acid forming material.
- Geophysics indicated that structures such as dykes are present across the opencast mining area.

Management/Mitigation Measures

- It is important to monitor static groundwater levels before and during mining on a quarterly basis in all boreholes within a zone of two kilometres surrounding the opencasts to ensure that any deviation of the groundwater flow from the idealised predictions is detected in time and can be reacted on appropriately.
- Water samples must be taken from all the monitoring boreholes by using approved sampling techniques and adhering to recognised sampling procedures. Samples should be analysed for both organic as well as inorganic pollutants, as mining activity often lead to hydrocarbon spills in the form of diesel and oil.
- The best possible scenario for minimising impacting on the wetland/streams is to start the boxcut parallel to the wetland/stream and at the farthest point from the wetland. In such a mining scenario the impact on the wetland will be delayed to the latest possible time before closure of the opencast.
- To minimise decanting in the opencast, all direct connection (if applicable) between the underground areas and opencasts should be thoroughly sealed to prevent direct groundwater seepage to the backfilled opencasts.
- All mined areas should be flooded as soon as possible to bar oxygen from reacting with remaining pyrite.
- Mining should remove all coal from the opencasts and as little as possible should be left.
- The final backfilled opencast topography should be engineered such that runoff is directed away from the opencast areas.

- The final layer (just below the topsoil cover) should be as clayey as possible and compacted if feasible, to reduce recharge to the opencasts.

- Leaving a final void in the opencast areas must be investigated. Once final mining plans are available, it will be essential to model this option.

- Quarterly groundwater sampling must be done to establish a database of plume movement trends, to aid eventual mine closure.

- Regular sampling and chemical analyses of the groundwater is imperative to establish a sound database:

    - Groundwater in all boreholes within a distance of less than two kilometres must be sampled regularly to establish a database against which future groundwater levels can be compared.

    - Sampling must be preferably quarterly, but at least twice annually, following the dry – and rainy seasons.

- If it is found during such a sampling event that groundwater from any extraction borehole is polluted beyond acceptable standards, alternative water will have to be supplied to the affected party.

- It is recommended that the closest box cut to the Witpuntspruit and wetland keep a distance of at least 150m form edge of the wetland.

- Another very important aspect to consider is the layout and order of the opencast cuts. The best possible scenario for minimising impacting on the wetland/Witpuntspruit is to start the boxcut parallel to the wetland/stream and at the farthest point from the wetland. In such a mining scenario the impact on the wetland will be delayed to the latest possible time before closure of the opencast.

Further work required

- 4 to 6 monitoring holes be constructed around each opencast upstream and downstream of the site. The geophysics results obtained during this should can used to site some of these boreholes.

- A monitoring network should be dynamic. This means that the network should be extended over time to accommodate the migration of contaminants through the aquifer as well as the expansion of infrastructure and/or addition of possible pollution sources. An audit on the monitoring network should be conducted annually.

- The numerical model should be recalibrated as soon as more hydrogeological data such as monitoring holes are made available. This would enhance model predictions and certainty.

- The wetland should be measured for flow upstream and downstream to determine the effect that the dewatering of the opencast has on the wetland before mining commences.

- In both cases the monitoring should commence before mining to establish background values for future reference.

- The cumulative pollution and dewatering impacts of all current mining in addition to the proposed new opencast could not be calculated as no data on surrounding mines were available. However a detailed model taking in consideration all Usutu Collieries mining activities underground and opencast will be required to estimate the cumulative impact Usutu has on the surrounding hydrogeological environment.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

ABBREVIATIONS

HCO3	=	Bicarbonate
NO3	=	Nitrate
Cl	=	Chloride
SO4	=	Sulphate
NH3	=	Ammonia
F	=	Fluoride
Na	=	Sodium
K	=	Potassium
Ca	=	Calcium
Mg	=	Magnesium
Fe	=	Iron
Mn	=	Manganese
Al	=	Aluminium
Zn	=	Zinc
B	=	Boron
Ni	=	Nickel
Co	=	Cobalt
Cd	=	Cadmium
Si	=	Silica
Se	=	Selenium
Cu	=	Copper
Pb	=	Lead
Ag	=	Silver
TDS	=	Total Dissolved Solids
EC	=	Electrical Conductivity
Cat/an bal%	=	Cation/anion balancing error
SSL	=	Soil screening level
SWL	=	Static Water Level
BDL	=	Below detection limit
AH	=	Auger hole
BH	=	Borehole
DRO	=	Diesel Range Organics
GRO	=	Gasoline Range Organics
ICP-OES	=	Inductively Coupled Plasma Optical Emission Spectroscopy
GC-MS	=	Gas Chromatography Mass Spectrometer
GPT	=	Geo Pollution Technologies
GW	=	Groundwater
ℓ	=	litre
m	=	metres
mamsl	=	metres above mean sea level
mbgl	=	metres below ground level
mg/l	=	milligram per litre
PAH	=	Poly Aromatic Hydrocarbons
n.a.	=	not analysed
ppm	=	parts per million
RBCA	=	Risk based corrective actions
RBSL	=	Risk Based Screening Levels

1 INTRODUCTION

Geo Pollution Technologies (Pty) Ltd (GPT) was appointed by Environmental Assurance (Pty) Ltd (Envass) to conduct a hydrogeological impact study for Usutu Coal (Pty) Ltd at the Usutu Opencast Colliery located approximately 15 km south-east of Ermelo, on the farm Jan Hendriksfontein 263 It and Transusutu 257 IT, Mpumalanga Province. The following opencast areas are to be mined, Portion 6A, 6B, 9, Block D, OC1, OC2 and OC3 (Figure 1).

This report is not intended to be an exhaustive description of the proposed project, but rather as a specialist interim geohydrological study to evaluate the geohydrological impact the opencast has on the environment.

This geohydrological study aims to contain and relate the following objectives:

- Description of the pre-mining geohydrological environment.
- Prediction of the environmental impact of the proposed mining activity on the geohydrological regime of the area. This includes the description of possible negative impacts during mining, construction, decommissioning and after closure.
- Forecasting the effect of the opencast on the receiving environment.
- Compilation of all the relevant data and recommendations in a geohydrological report, structured in such a way that it can be incorporated into the final Environmental Management Program document.

2 SCOPE OF WORK

The following work program was followed in order to adhere to the scope of work:

- Detailed site inspection, mapping of relevant geohydrological features and gathering of existing information from topographical maps, geological maps, hydrological information, meteorological information, previous groundwater studies in the area, discussions with relevant mine personnel, etc.
- Execution of a borehole/spring census in the area to assess groundwater utilisation by neighbours. Based on the information, gathered during the hydrocensus, the groundwater potential (quality & quantity) of the area will be evaluated. The data gathered during this phase will assist in the development of a groundwater-monitoring program. If suitable boreholes exist in the study area they will be incorporated into the monitoring program.
- Execution of a geophysical survey to map structures such as dykes and faults as potential preferred pathways.
- Groundwater flow and transport modelling to predict the long term impacts on the receiving environment. The impacts, associated with mining activities, can normally be subdivided into two aspects, namely the de-watering of the surrounding aquifer system and the deterioration of the water quality in the receiving aquifer system. Both these aspects will be addressed.
- Calculation of inflow into the opencast mining areas from groundwater.
- Geochemical characterisation of material associated with the coal seams and overburden was undertaken in this study through acid base accounting of core drilling samples.
- Available data was interpreted and collated for the prediction of the possible environmental impact and to conceptualise mitigation measures.

- Recommendation of a groundwater monitoring network was made and standard operational procedures for groundwater monitoring and management supplied.
- The report can be discussed with the client and authorities.

3 METHODOLOGY

The impact of the proposed opencast mining areas was investigated through field investigations, data analyses and the use of numerical models (flow and transport models). The work completed for the purposes of compiling a geohydrological report comprised the following:

3.1 DESK STUDY

A complete desk study was conducted, entailing the gathering of information from the relevant topographical map (1:50 000-scale 2630 CA Topographic Sheet), geological map (1:250 000 sheet 2630 Mbabane) and geohydrological map (Groundwater Resources of South Africa Sheets 1 and 2).

A mine layout plan and mine schedule was made available at the time of this study, together with some exploration borehole logs. Meteorological information was obtained from the Department of Water Affairs (DWA) Hydrological Services. Available monitoring data applicable to this area as well as previous groundwater studies done for the colliery, including previous EMPR(s), were also made available.

3.2 HYDROCENSUS

A detailed hydrocensus was conducted on and around the site to a distance of about two kilometres so as to obtain a representative population of the boreholes in the area. During the hydrocensus, all available details of boreholes and borehole-owners were collected and included in the hydrocensus forms. Water samples were collected from boreholes as described in the relevant paragraph below. Information was collected on the use of the boreholes in the area, the water levels and yields of boreholes, etc. The information can be used to assess the risk which potential groundwater pollution poses to groundwater users.

3.3 SAMPLING AND CHEMICAL ANALYSIS

Groundwater was sampled according to the GPT Standard Operating Procedure[1] for groundwater samples by bailing. In summary, the procedure is to measure the groundwater level before introducing any equipment in the borehole. Pump samples were collected from boreholes with restricted access by purging the hole for a period to ensure that a representative sample of the aquifer is obtained. The groundwater samples were contained in pre-cleaned one litre plastic bottles. All samples were kept on ice or in a refrigerator until delivered to a laboratory.

A total of 8 hydrocensus boreholes and 9 surface water points were sampled during the hydrocensus of November 2011. The water samples were sent to UIS analytical laboratory in Pretoria for major ion analysis to determine water quality in the area.

[1] Available on request from giep@gptglobal.com

3.4 RECHARGE CALCULATION

The groundwater recharge was estimated using the RECHARGE program[2], which includes using qualified guesses as guided by various schematic maps. The following methods/sources were used to estimate the recharge.

- Soil information
- Geology
- Groundwater Recharge Map (Vegter)
- Acru Recharge Map (Schulze)
- Harvest Potential Map
- Chloride (Cl) method

The above-mentioned programme incorporates all the different methods to calculate recharge. The following assumptions are necessary for successful application of the Cl Method:

- There is no source of chloride in the soil water or groundwater other than that from precipitation
- Chloride is conservative in the system
- Steady-state conditions are maintained with respect to long-term precipitation and chloride concentration in that precipitation, and in the case of the unsaturated zone
- A piston flow regime, which is defined as downward vertical diffuse flow of soil moisture, is assumed.

3.5 NUMERICAL MODELLING

The finite difference numerical model was created using the US Department of Defence Groundwater Modelling System (GMS8.1) as Graphical User Interface (GUI) for the well-established Modflow and MT3DMS numerical codes.

MODFLOW is a 3D, cell-centred, finite difference, saturated flow model developed by the United States Geological Survey. MODFLOW can perform both steady state and transient analyses and has a wide variety of boundary conditions and input options. It was developed by McDonald and Harbaugh of the US Geological Survey in 1984 and underwent several overall updates since. The latest update (Modflow 2000) incorporates several improvements extending its capabilities considerably, the most important being the introduction of the new package called the Layer-Property Flow Package.

MT3DMS is a 3-D model for the simulation of advection, dispersion, and chemical reactions of dissolved constituents in groundwater systems. MT3DMS uses a modular structure similar to the structure utilized by MODFLOW, and is used in conjunction with MODFLOW in a two-step flow and

[2] Gerrit van Tonder, Yongxin Xu: RECHARGE program to Estimate Groundwater Recharge, June 2000. Institute for Groundwater Studies, Bloemfontein RSA.

transport simulation. Heads are computed by MODFLOW during the flow simulation and utilized by MT3DMS as the flow field for the transport portion of the simulation.

4 REGIONAL SITE INFORMATION

The site is situated approximately 15 km south-east of Ermelo, in the Mpumalanga Province. The locality map is shown in Figure 1 and the topographical map showing the infrastructure of the area is shown in Figure 2.

4.1 CLIMATE

Climatic data was obtained from the DWA weather stations Nooitgedacht (rainfall data) and Driehoek (evaporation data) for the Ermelo area (Table 1)[3]. The proposed mining site is located in the summer rainfall region of Southern Africa with precipitation usually occurring in the form of convectional thunderstorms. The average annual rainfall (measured over a period of 70 years) is approximately 632.20mm, with the high rainfall months between October and March.

Table 1: Climatic Data for the Ermelo Area

Month	Average Monthly Rainfall (mm)	Mean Monthly Evaporation
January	112.7	157.4
February	70.36	140.7
March	70.72	135.0
April	37.70	106.7
May	13.12	92.96
June	8.25	76.19
July	6.96	80.82
August	9.71	110.8
September	26.60	141.4
October	78.59	155.8
November	114.2	152.7
December	111.9	160.8
	Mean Annual Rainfall (mm)	**Mean Annual Evaporation**
	632.20	1332.0

[3] Department of Water Affairs (DWA): www.dwa.gov.za

4.2 TOPOGRAPHY AND DRAINAGE

The topography (Figure 2: Topographical Map) can normally be used as a good first approximation of the hydraulic gradient in an unconfined aquifer. This discussion will focus on the slope and direction of fall of the area under investigation, features that are important from a groundwater point of view.

The area is characterised by a gentle undulating topography and in the area of the proposed mining site the slope is more or less in the order of 1:100 (0.01).

Locally drainage is towards the the Witpuntspruit that flows from west to east in between the opencast mining areas and an unnamed wetland area situated between Portions 9 and Portion 6B. The wetland area is located between the Humanspruit, which flows into the Witpuntspruit approximately 1.5 km from the northern corner of the proposed opencast. On larger scale, drainage occurs towards the generalised flow of the Witpuntspruit.

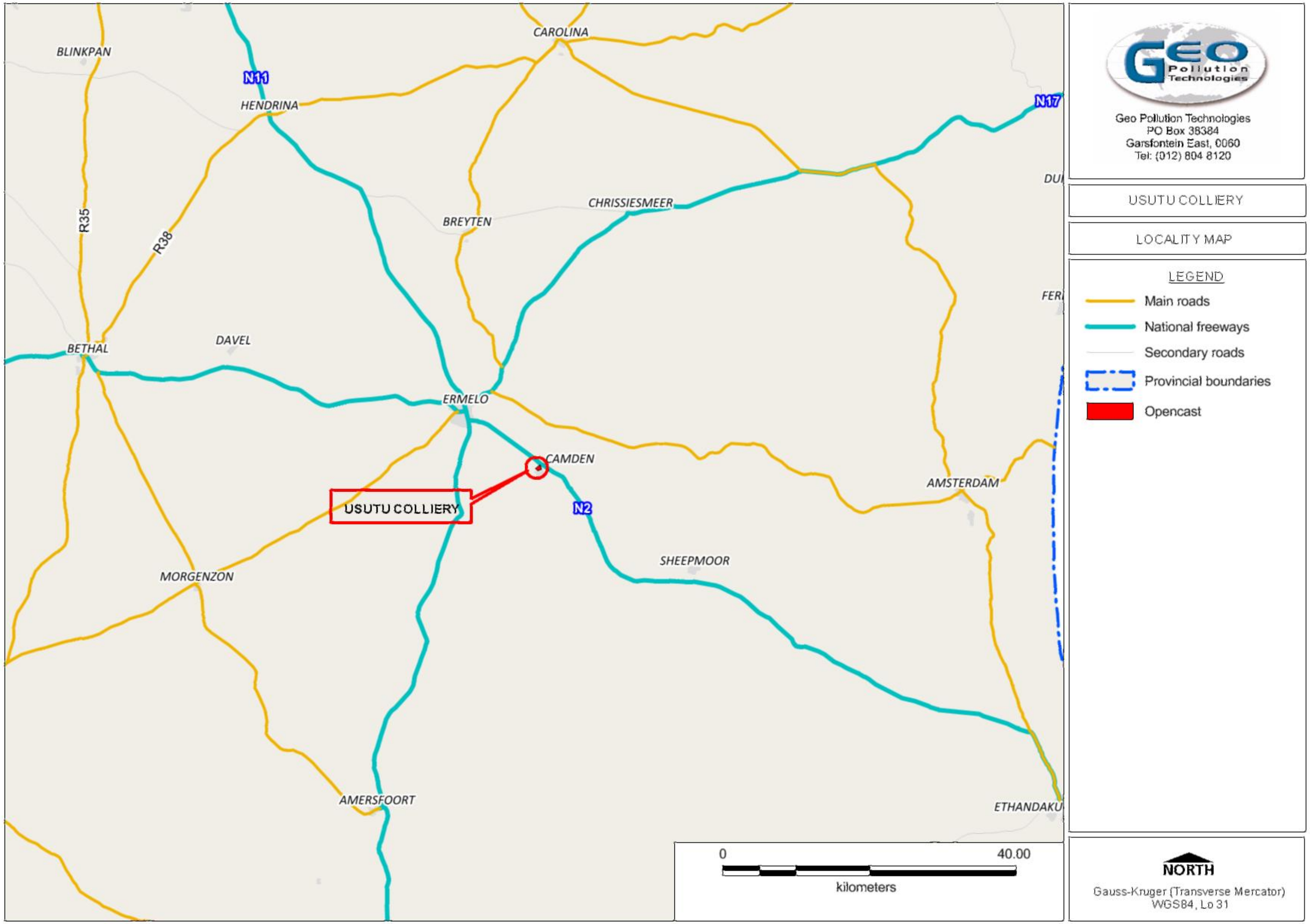

Figure 1: Locality Map

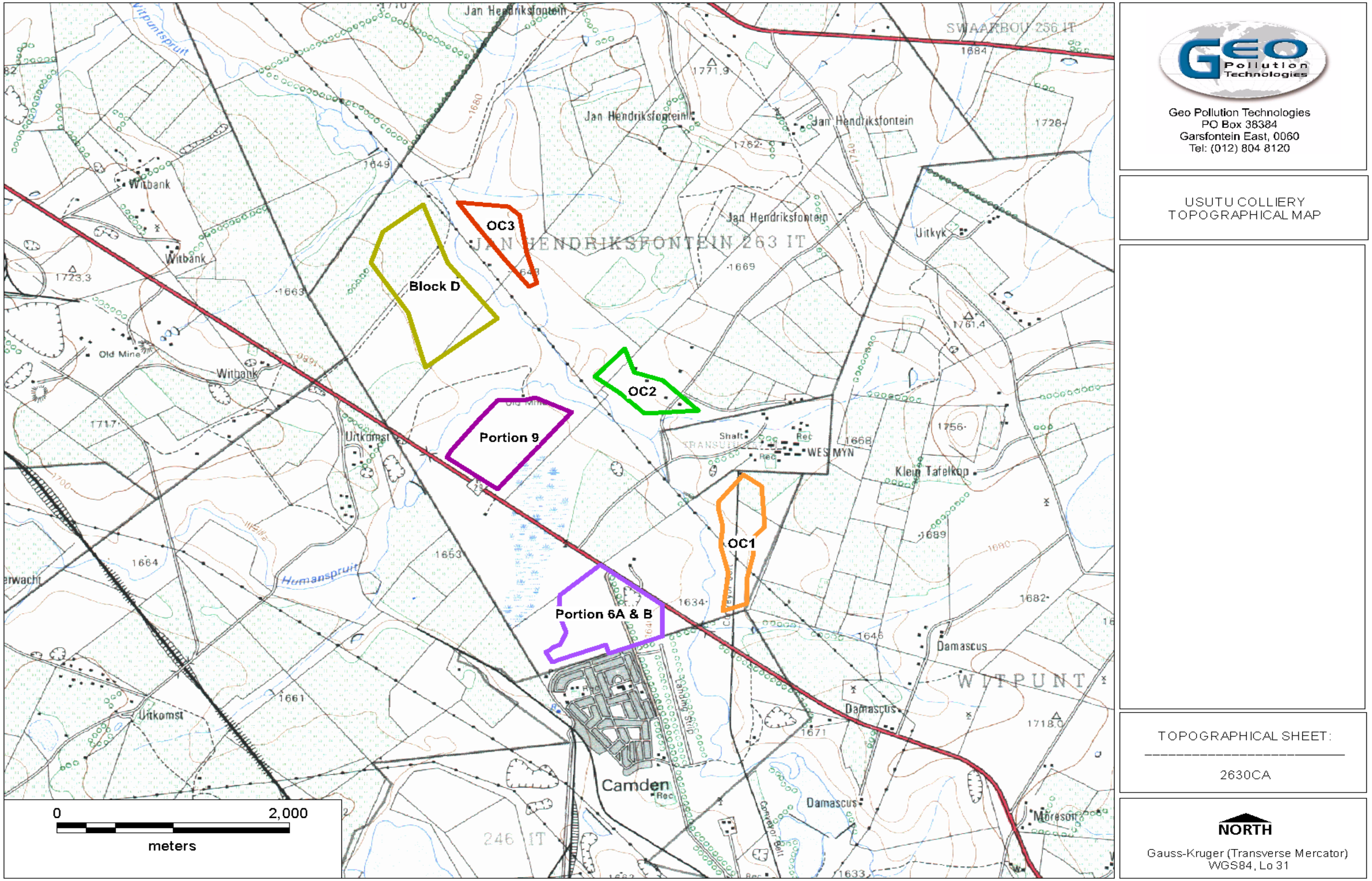

Figure 2: Topographical Map

5 PREVAILING GROUNDWATER CONDITIONS

Most mines and mining-related activities impact on groundwater quality and quantity. Quantification of such impacts on the groundwater regime requires knowledge of the pre-mining environment.

The purpose of this section is to describe the pre-mining environment; thus the current prevailing groundwater conditions. This will serve as a reference baseline for quantifying potential mining impacts on the existing groundwater regime. In this case, however, the area under investigation cannot be classified as a pristine pre-mining environment due to current underground and opencast mining activities throughout the area.

5.1 GEOLOGY

5.1.1 Regional Geology

The investigated area falls within the 2630 Mbabane 1:250 000 geology series map and is situated approximately 15 km south-east of Ermelo, Mpumalanga. An extract of this map is shown in Figure 3.

The proposed Usutu opencast mining areas falls within the Ermelo Coalfield, which extends from Carolina in the north to Dirkiesdorp in the south covering a surface area of approximately 11 250 km^2. The coal seams are alphabetically numbered from A (top) to E (bottom) and the distribution of these coal seams are affected by the topography of the pre-Karoo basement and the present day erosional surface. The area is characterised by consolidated sedimentary layers of the Karoo Supergroup. It consists mainly of sandstone, shale and coal beds of the Vryheid Formation of the Ecca Group and is underlain by the Dwyka Formation of the Karoo Supergroup. Jurassic dolerite intrusions occur throughout the area in the form of sills and outcrops is found throughout the whole area.

The Ecca Group, which is part of the Karoo Supergroup, comprises of sediments deposited in shallow marine and fluvio-deltaic environments with coal accumulated as peat in swamps and marches associated with these environments. The sandstone and coal layers are normally reasonable aquifers, while the shale serves as aquitards. Several layered aquifers perched on the relative impermeable shale are common in such sequences. The Dwyka Formation comprises consolidated products of glaciation (with high amounts of clay) and is normally considered to be an aquiclude.

The generally horizontally disposed sediments of the Karoo Supergroup are typically undulating with a gentle regional dip to the south. The extent of the coal is largely controlled by the pre-Karoo topography. Steep dips can be experienced where the coal buts against pre-Karoo hills. Displacements, resulting from intrusions of dolerite sills, are common. Abundant dolerite intrusions are present in the Ecca sediments. These intrusions comprise sills, which vary from being concordant to transgressive in structure, and feeder dykes. Although these structures serve as aquitards and tend to compartmentalise the groundwater regime, the contact zones with the pre-existing geological formations also serve as groundwater conduits. There are common occurrences of minor slips or faults, particularly in close proximity to the dolerite intrusives. Within the coalfield, these minor slips, displacing the coal seam by a matter of 1 to 2 metres, are likely to be commonplace.

5.1.2 Local Geology

From the sheet of 2630 Mbabane geology series map it is evident that the shale, mudstone and coal beds of the Vryheid Formation of the Ecca Group outcrop in the area.

The local geology is best concluded from information obtained from exploration borehole logs done for the Usutu Colliery and the lithology is best observed in the logs of boreholes drilled at higher elevations, where all coal seams have been encountered. The predominant coal seams located within the mining area are the B Upper seam, B Lower seam and C Upper seam. According to information provided by Envass, the Usustu Colliery intends to mine the following seams per opencast as shown in Table 2. A generalised geological stratigraphy (Table 3) was derived from borehole log PTNGA021, which was obtained from the colliery management.

Table 2: Opencast seam mining information

OPENCAST AREAS			
Mining Area	**Mining Seam**	**Average Thickness in m**	**Average Depth in m**
PTN9	B Lower seam	1.35	8
Block D	B Lower seam	1.5	12
OC1	B Lower and C Upper	B/L=1.5 C/U=1.5	25
OC2	B Lower	1.3	9
OC3	B Lower	1.4	11

Table 3: Generalised stratigraphic column of Borehole log PTNGA021

AVERAGE DEPTH (MBGL)	AVERAGE THICKNESS (METRES)	DESCRIPTION
0-9.70	9.7	Softs
9.70 – 18.30	8.6	Hards
18.30 – 18.40	0.1	B Upper Coal Seam
18.40-19.50	1.1	Parting
19.50-21.50	**2.0**	**B Lower Coal Seam**
21.50- 22.40	0.90	Parting
22.40-24.45	**2.05**	**C Upper Coal Seam**
24.45-26.47	2.02	coal / sandstone
26.47	-	End of hole

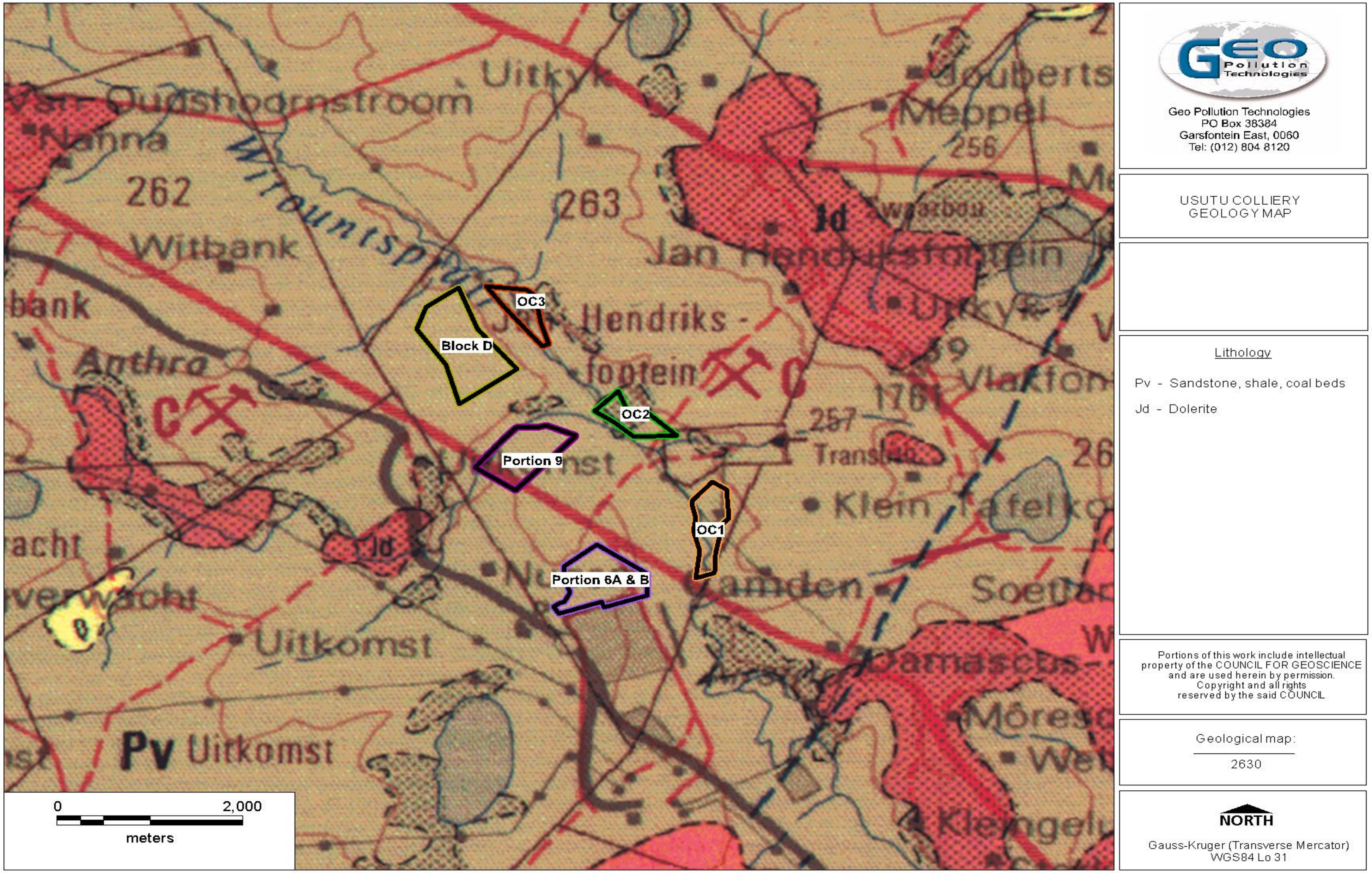

Figure 3: Geology Map

5.2 HYDROGEOLOGY

5.2.1 Regional Hydrogeology

The area of concern is situated in the Upper-Vaal Water Management area. On regional scale the hydrogeology consist of intergranular and fractured aquifers of the Bushveld Igneous Complex, the Transvaal Supergroup and locally the Karoo Supergroup as well as Jurassic dolerite intrusions, with predominantly arenaceous rocks (sandstone). Blow yields of 0.1 – 0.5 l/s can be expected regionally.

The aquifer represents an important source for base flow into the streams draining the area. The hydrogeology of the area can be described in terms of the saturated and unsaturated zones:

5.2.1.1 Saturated Zone

In the saturated zone, at least four aquifer types may be inferred from knowledge of the geology of the area:

- A shallow aquifer formed in the weathered zone, perched on the fresh bedrock.
- An intermediate aquifer formed by fracturing of the Karoo sediments.
- Aquifers formed within the more permeable coal seams and sandstone layers.
- Aquifers associated with the contact zones of the dolerite intrusives.

Although these aquifers vary considerably regarding geohydrological characteristics, they are seldom observed as isolated units. Usually they would be highly interconnected by means of fractures and intrusions. Groundwater will thus flow through the system by means of the path of least resistance in a complicated manner that might include any of these components.

Shallow perched aquifer

A near surface weathered zone is comprised of transported colluvium and *in-situ* weathered sediments and is underlain by consolidated sedimentary rocks (sandstone, shale and coal). Groundwater flow patterns usually follow the topography, often coming very close to surface in topographic lows, sometimes even forming natural springs. Experience of Karoo geohydrology indicates that recharge to the perched groundwater aquifer is relatively high, up to 3% of the Mean Annual Precipitation (MAP).

Fractured Karoo rock aquifers

The host geology of the area consists of consolidated sediments of the Karoo Supergroup and consists mainly of sandstone, shale and coal beds of the Vryheid Formation of the Ecca Group. Most of the groundwater flow will be along the fracture zones that occur in the relatively competent host rock. The geology map does not indicate any major fractures zones in this area, but from experience it can be assumed that numerous major and minor fractures do exist in the host rock. These conductive zones effectively interconnect the strata of the Karoo sediments, both vertically and horizontally into a single, but highly heterogeneous and anisotropic unit

Aquifers associated with coal seams

The coal seam forms a layered sequence within the hard rock sedimentary units. The margins of coal seams or plastic partings within coal seams are often associated with groundwater. The coal itself tends to act as an aquitard allowing the flow of groundwater at the margins.

Aquifers associated with dolerite intrusives

Dolerite intrusions in the form of dykes and sills are common in the Karoo Supergroup, and are often encountered in this area. These intrusions can serve both as aquifers and aquifuges. Thick, unbroken dykes inhibit the flow of water, while the baked and cracked contact zones can be highly conductive. These conductive zones effectively interconnect the strata of the Ecca sediments both vertically and horizontally into a single, but highly heterogeneous and anisotropic unit on the scale of mining. These structures thus tend to dominate the flow of groundwater. Unfortunately, their location and properties are rather unpredictable. Their influence on the flow of groundwater is incorporated by using higher than usual flow parameters for the sedimentary rocks of the aquifer.

5.2.1.2 Unsaturated Zone

Although a detailed characterization of the unsaturated zone is beyond the scope of this study, a brief description thereof is supplied.

The unsaturated zone in the proposed mining area is in the order of between 1 and 10 metres thick (based on static groundwater levels measured in the existing boreholes) and consists of colluvial sediments at the top, underlain by residual sandstone/siltstone/mudstone of the Ecca Group that becomes less weathered with depth.

5.2.2 Local Hydrogeology

Groundwater resources are spatially widespread (12 boreholes and 9 surface water points were found in the area), but no borehole yields were reported.

5.3 HYDROCENSUS

A hydrocensus was conducted for the Usutu Coal Colliery mining site and in the surrounding area, during November 2011. The position of all the boreholes relative to the mining area can be seen in Figure 4. A total of 12 boreholes and 9 surface water bodies and streams were identified during this hydrocensus study. The main characteristics of this data are summarized in Table 4 and Table 5. Although there were no privately owned boreholes identified, the area is utilized for grazing of large life stock and horses. All the boreholes are on the property of the Usutu Colliery and it can therefore be presumed that all the boreholes identified are monitoring points. Hydrocensus field forms containing details of the owner and use are attached under Appendix A and Appendix B as separate PDF-files.

The potential groundwater receptors in the area are the surface water points and it is important that these are included in the monitoring network. Therefore the Witpuntspruit and the adjacent wetland area on the western boundary area of the proposed site can be considered as potential receptors.

5.4 WATER LEVELS

Groundwater levels, varying between 1m and 54m below ground level, were measured in the surrounding area during the survey as mentioned in 5.3. These values were determined from borehole data where the owner was available on site and where it was possible to gain access to the boreholes for precise measuring of water levels.

Usually a good relationship should hold between topography and static groundwater level. This relationship can be used to distinguish between boreholes with water levels at rest, and boreholes with anomalous groundwater levels due to disturbances such as pumping or local geohydrological heterogeneities. The relationship using the boreholes from the hydrocensus is shown in Figure 5 below. It is evident that an unrealistic low groundwater level has been measured in BH9 (54.60 mbgl). Due to the presence of extensive underground mining activities in the area, it has most probably been drilled into the underground mine and is thus not representative of the general groundwater level in the area. This will most definitely lead to unrealistic water levels, as the water level in the mine is measured in such a case and not the actual groundwater level. Although boreholes BH1, BH3, BH4 and BH6 also show groundwater levels (between 20 - 24 mbgl) below the natural groundwater levels of 1-10 mbgl of the area, these probable outliers were not removed from the calculations below. Figure 6 shows the relationship with this outlier removed and a good correlation can indeed be observed. This general relationship is useful to make a quick calculation of expected groundwater levels at selected elevations, or to calculate the depth of to the groundwater level (unsaturated zone):

Groundwater level = Elevation x 0.9581

Depth to the groundwater level = Elevation x (1 - 0.9581)

= Elevation x 0.00419

This general relationship is useful to make a quick calculation of expected groundwater levels at selected elevations, or to calculate the depth of the groundwater level (unsaturated zone). However, due to the heterogeneity of the subsurface, these relationships should not be expected to hold everywhere under all circumstances, and deviations could thus be expected. The calibrated static water levels as modelled have been contoured and are displayed as Figure 7. Groundwater flow direction should be perpendicular to these contours and inversely proportional to the distance between contours. Using this relationship, the inferred groundwater flow directions are depicted as Figure 8 below. As can be expected, the groundwater flow is mainly from topographical high to low areas, eventually draining to local streams.

These static water levels were also subtracted from the elevations to determine the unsaturated aquifer thicknesses of different points over the study area. These values are intrinsically the same as the depth to the natural groundwater level measured from the surface. The average depth to the groundwater levels in the fractured aquifer in the proposed mining area are 3 meters.

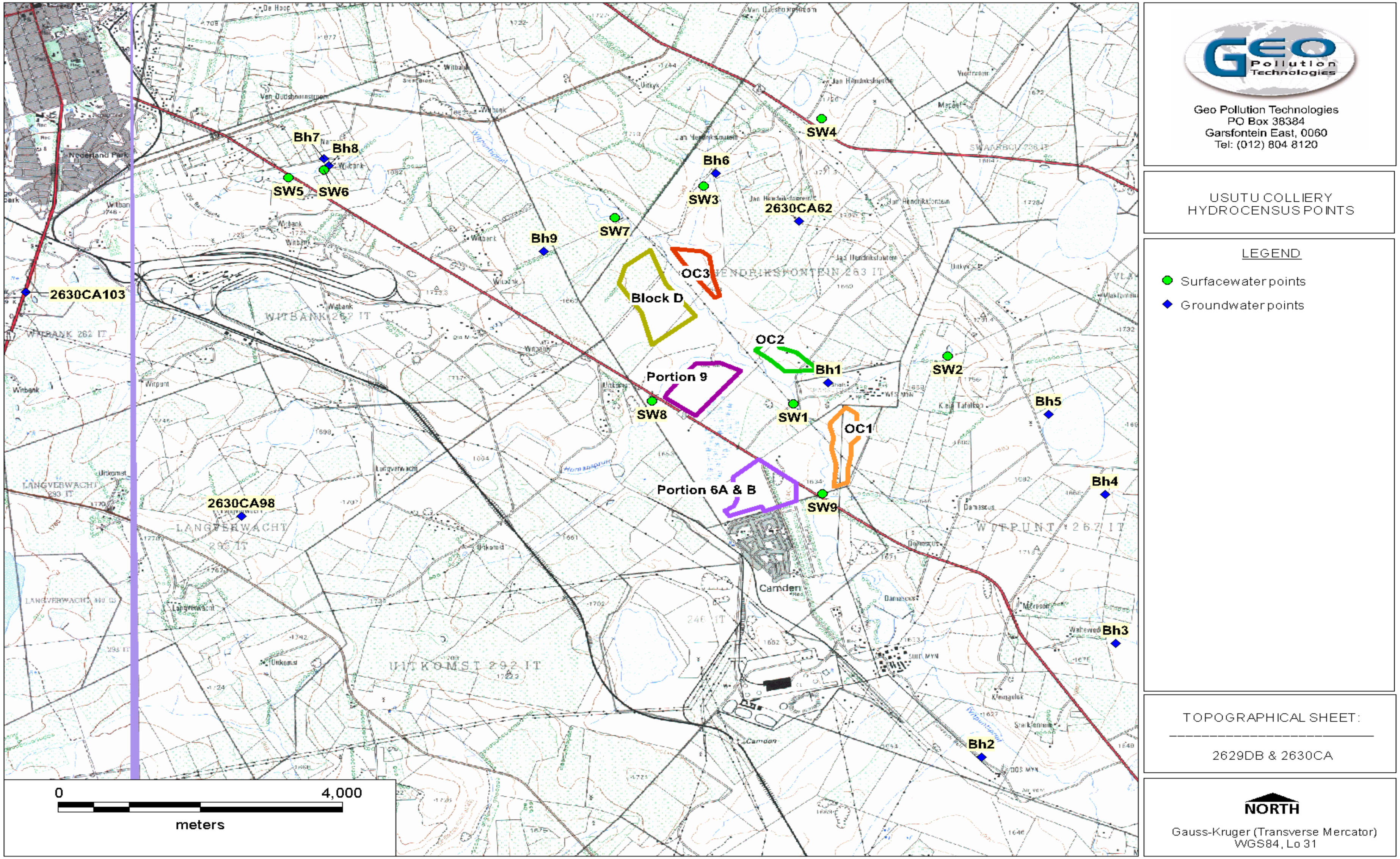

Figure 4: Positions of Hydrocensus Monitored Points

Table 4: Groundwater Hydrocensus and Borehole Information

Borehole name	X-coordinate	Y-coordinate	Z-coordinate (mamsl)	Water levels (mamsl)	Water level (mbgl)	Use	Pumped	Owner	Sampled	Comment
2630CA103	-101195.30	-2939582.70	1748.00	1740.00	8.00	unknown	unknown	unknown	No	NGD Borehole
2630CA62	-90334.80	-2938434.20	1705.00	1696.00	9.00	unknown	unknown	unknown	No	NGD Borehole
2630CA98	-98169.10	-2943195.30	1716.00	1715.00	1.00	unknown	unknown	unknown	No	NGD Borehole
Bh1	-89924.00	-2941047.00	1650.00	1629.12	20.88	Dust Control	Yes	Usutu Colliery	Yes	
Bh2	-87771.71	-2947098.48	1642.00	1636.84	5.16	Not in use	No	Usutu Colliery	Yes	
Bh3	-85888.60	-2945249.60	1653.00	1629.00	24.00	Not in use	No	Usutu Colliery	Yes	
Bh4	-86036.00	-2942844.00	1667.00	1643.06	23.94	Not in use	No	Usutu Colliery	Yes	
Bh5	-86828.00	-2941553.00	1694.00	1687.12	6.28	Not in use	No	Usutu Colliery	No	Not alowed to sample
Bh6	-91501.00	-2937665.00	1668.00	1644.84	23.16	Not in use	No	Usutu Colliery	Yes	
Bh7	-97007.30	-2937425.30	1695.00	1691.20	3.80	Not in use	No	Usutu Colliery	Yes	
Bh8	-96945.90	-2937533.30	1691.00	1688.70	2.30	Not in use	No	Usutu Colliery	Yes	
Bh9	-93920.00	-2938923.00	1678.00	1623.40	54.60	Not in use	No	Usutu Colliery	Yes	

Table 5 Surface Water Hydrocensus Information:

Surface point name	X-coordinate	Y-coordinate	Z-coordinate (mamsl)	Source	Use	Owner	Sampled	Comment
SW1	-90408.54798	-2941381.33929	unknown	spring	unknown	Usutu Colliery	Yes	
SW2	-88241.89429	-2940607.11721	unknown	river	unknown	Usutu Colliery	Yes	
SW3	-91675.23453	-2937865.48057	unknown	river	unknown	Usutu Colliery	Yes	
SW4	-90015.61039	-2936771.06171	unknown	dam	unknown	Usutu Colliery	Yes	
SW5	-97502.57885	-2937725.79153	unknown	river	unknown	Usutu Colliery	Yes	
SW6	-97010.19286	-2937600.14909	unknown	pan	unknown	Usutu Colliery	Yes	
SW7	-92923.26965	-2938376.47345	unknown	pan	unknown	Usutu Colliery	Yes	
SW8	-92395.57446	-2941336.84717	unknown	river	unknown	Usutu Colliery	Yes	
SW9	-90002.71399	-2942838.95680	unknown	river	unknown	Usutu Colliery	Yes	

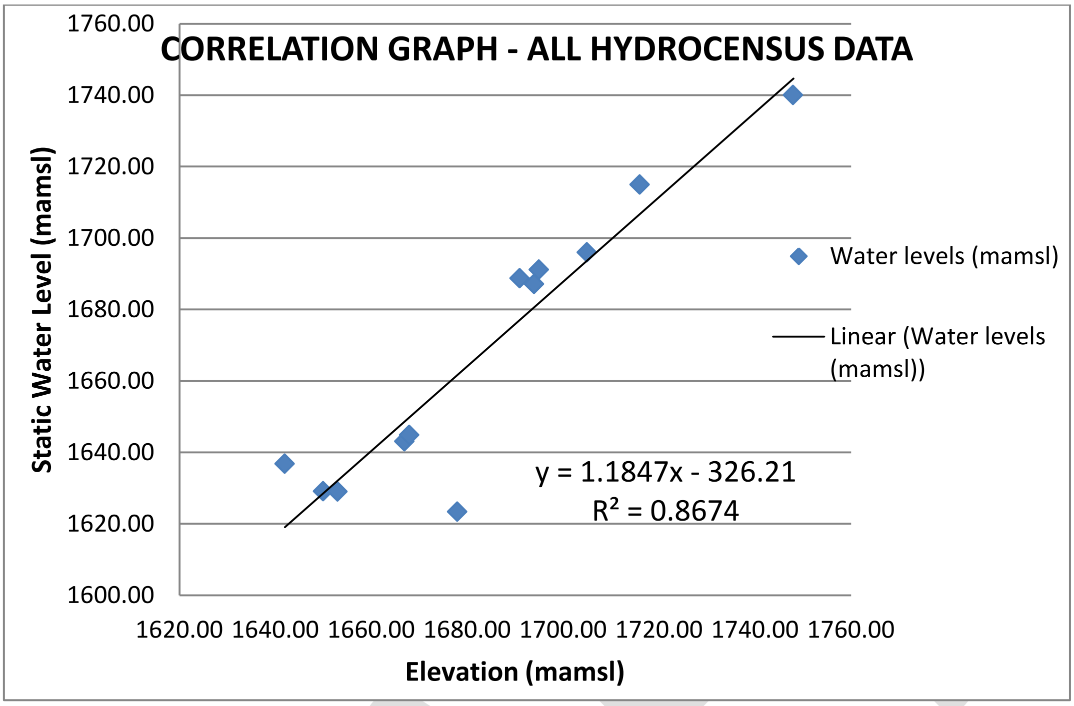

Figure 5: Correlation Graph - Using All Hydrocensus Data

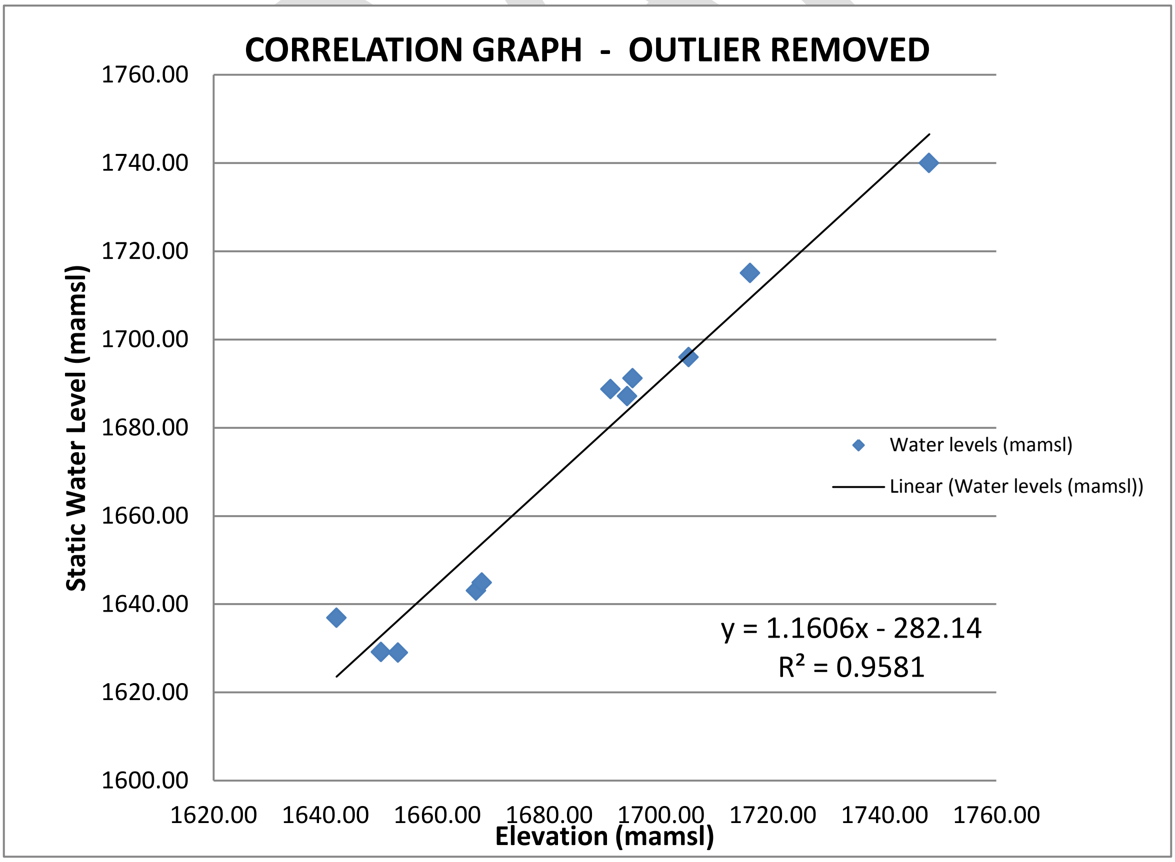

Figure 6: Correlation Graph - Outlier Removed

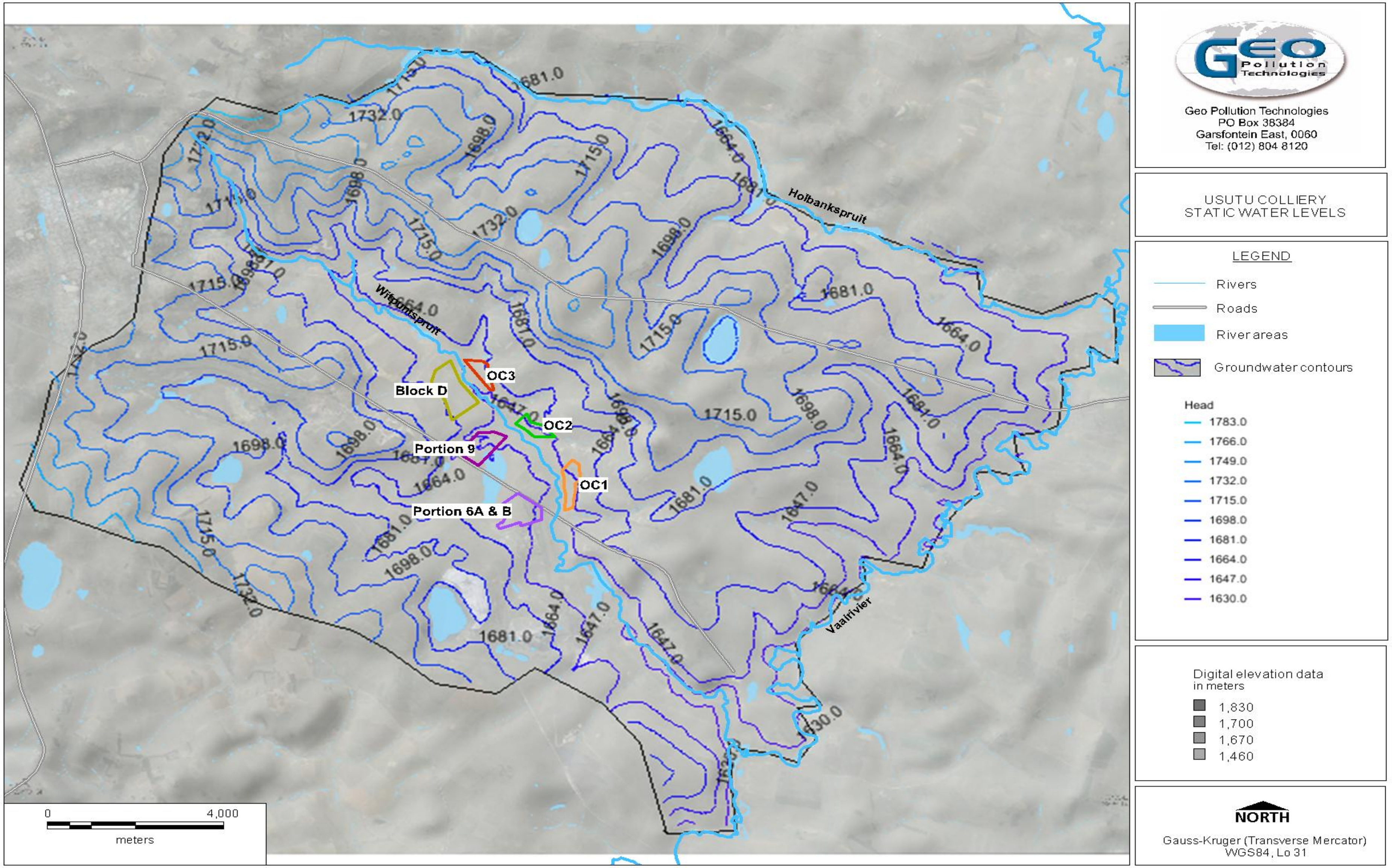

Figure 7: Static Groundwater Levels - Pre mining

Figure 8: Groundwater Flow Directions - Pre mining

5.5 WATER QUALITY

Groundwater samples were collected during the hydrocensus survey done during November 2011. All of these samples are within the two kilometre buffer area around the proposed mining site. Three of the borehole samples and four of the surface water samples were submitted for major cation and anion analyses to determine the present water quality in the area. The results from these analyses are contained in Table 6 and compared to the SABS Drinking Water Standards (SANS 241:2006, Ed. 6.1).Colours of individual cells refer to the drinking water classification of the specific groundwater sample.

The results from these analyses were plotted as Pie diagrams (circular graphs as in Figure 9), Stiff diagrams (Figure 10) and a piper diagram (Figure 9). The laboratory certificate of analyses and monitoring data can be seen attached as a separate Appendix C.

The pie diagrams show both the individual ions present in a water sample and the total ion concentrations in meq/L or mg/L. The scale for the radius of the circle represents the total ion concentrations, while the subdivisions represent the individual ions. It is very useful in making quick comparisons between waters from different sources and presents the data in a convenient manner for visual inspection.

A Stiff pattern is basically a polygon created from four horizontal axes using the equivalent charge concentrations (meq/L) of cations and anions. The cations are plotted on the left of the vertical zero axis and the anions are plotted on the right. Stiff diagrams are very useful in making quick comparisons between waters from different sources.[4]

The Piper diagram is a trilinear representation of the ions found in the water (cations, anions & combined properties) and is used in order to classify water types or chemical facies. On the Piper diagram the cation and anion compositions of many samples can be represented on a single graph. Certain trends in the data can be discerned more visually, because the nature of a given sample is not only shown graphically, but also show the relationship to other samples. The relative concentrations of the major ions in mg/L are plotted on cation and anion triangles and then the locations are projected to a point on a quadrilateral representing both cation and anions. Water types are designated according to the domain in which they occur on the diagram segments. Figure 11 show the classification diagram for anion and cation facies in terms of the major-ion percentages according to Morgan and Winner (1962) and Back (1966)[5].

Possible implications or failures were referenced by the Drinking water quality management diagnostic tool based on the requirements of the South African National Standards 2005 edition 6.

Groundwater:

The groundwater in the area can generally be classified as exceeding the maximum allowable standard for domestic use (recommended operational limit) according to the SANS Guidelines for Drinking Water in terms most of the cations and anions. The results of the groundwater chemical analysis are contained in Table 6 and the following is evident from these results:

Sulphate

Elevated sulphate concentrations were found in boreholes BH1 and BH9. Elevated sulphate concentrations are often an indication of boreholes being affected by acid mine drainage. AMD is probably the reason why these boreholes are elevated in sulphate due the presence of underground coal mining activities. From experience, signs of contamination from acid mine drainage is also

[4] EAS 44600 Groundwater Hydrology, Lecture 14: Water chemistry 1, Dr Pengfei Zhang

[5] Freeze, R. Allan, and John A. Cherry. 1979. *Groundwater*. Prentice Hall Inc, New Jersey.

reflected by elevated concentrations of heavy metals as well as some alkaline earth metals. In the case of Table 8, Mn, Fe,Ca, and Mg

Possible implications/failure

Consumption of excessive amounts of sulphate in drinking water usually results in diarrhoea. Sulfate also imparts a bitter or salty taste to water.

Calcium

Only borehole BH9 is elevated in calcium concentration indicating that its source water has low or high calcium (e.g. source water is soft and acidic or hard). This could be attributed to many factors such as geology. Dissolution of calcium can result as a result of AMD and which is most probably the case in BH9.

Possible implications/failure

Low concentrations of calcium can indicate a soft and acidic water, which could lead to corrosion of metals and aggression of cement concrete. High concentrations of calcium impair the lathering of soap, and can lead to staining on enamelled surfaces such as baths and hand basins.

Magnesium was found at elevated concentrations above the maximum standard for domestic use in borehole BH9 indicating that its source water has low or high magnesium (e.g. source water is soft and acidic or hard). Dissolution of magnesium can result as a result of AMD and which is most probably the case in BH9.

Possible implications/failure

The most common health effect of excess magnesium intake is diarrhoea. High concentrations of magnesium also impart a bitter taste to water. High concentrations of magnesium causes scaling (together with calcium) in distribution systems and appliances.

Manganese was found at elevated concentrations above the maximum standard for domestic use in borehole BH9 Both manganese and iron are naturally found at these concentrations in the coal-bearing Vryheid Formation especially where mining has already taken place.

Possible implications/failure

Although manganese is essential for human and animals it is neurotoxic when consumed in excess amounts. Manganese is also associated with staining of laundry and with metallic tastes in waters. Manganese is also harmful to patients with kidney disease.

Iron was found at elevated concentrations above the maximum standard for domestic use in borehole BH6 and BH9. Both manganese and iron are naturally found at these concentrations in the coal-bearing Vryheid Formation, especially where mining has already taken place.

Possible implications/failure

At the concentrations normally encountered in water, iron is predominantly an aesthetic concern as iron precipitates as insoluble ferric hydroxide which settles as a rust-coloured silt and is visible through staining of laundry, enamelled surfaces such as baths, hand basins, etc and walls. Health effects due to intake of excessive amounts of iron include acute poisoning in infants (massive concentrations) and chronic iron poisoning (haemochromatosis)

Diagrams

The results are confirmed in the pie diagrams and the Stiff diagrams, which gives a very good visual interpretation of the data. From the pie diagrams it appears that the spatial distribution of the major cations and anions are similar throughout the study area.

The piper diagram (Figure 12) shows both the groundwater (brown symbol) and surface water samplesin meq%, plotted on cation and anion triangles. According to the Groundwater Resources Map of South Africa, the groundwater in the area can be classified as being of type B, which means that the major cations are Ca and Mg, and the dominant anion HCO_3. Based on the interpretation regarding the Piper diagram, Pie and Stiff diagrams the following water can be differentiated between.

BH1, BH9, SW1, SW8, SW9- Fresh recently recharged water with a dominant SO_4 signature indicating that they have in some way been affected by mine activities.

BH6- Fresh unpolluted groundwater with a dominant HCO_3 signature.

From the above chemical analysis an overall assumption can be made that the groundwater sampled in the proposed mining area is of poor quality and not acceptable for domestic use. It can be deduced from the water quality of the sampled boreholes that the groundwater has been negatively affected by mining related contaminants at the time of the investigation. Borehole BH6 shows no effect of AMD as its upstream of any mining activities.

Sulphate is probably the most reliable indicator of pollution emanating from coal mining. Sulphate concentrations can however increase due to mobilisation during the mining process. The chemistry analyses supplied within this report should henceforth serve as baseline water quality throughout the life of the proposed mining operations. The following few paragraphs contains a brief overview of acid mine drainage (AMD) formation.

The reactions of acid and sulphate generation from sulphide minerals are discussed according to the three stage stoichiometric example of pyrite oxidation after James, (1997) and (Ferguson & Erickson, 1988) in which one mole of pyrite oxidized forms two moles of sulphate:

Reaction (2.1) represents the oxidation of pyrite to form dissolved ferrous iron, sulphate and hydrogen. This reaction can occur abiotically or can be bacterially catalysed by *Thiobacillus ferrooxidans*.

$$FeS_2 + 7/2\ O_2 + H_2O \rightarrow Fe^{2+} + 2SO_4^{2-} + 2H^+ \qquad (2.1)$$

The ferrous iron, (Fe^{2+}) may be oxidised to ferric iron, (Fe^{3+}) if the conditions are sufficiently oxidising, as illustrated by reaction (2.2). Hydrolysis and precipitation of Fe^{3+} may also occur, shown by reaction (2.3). Reactions (2.1), (2.2) and (2.3) predominate at pH > 4.5.

$$e^{2+} + 1/4O_2 + H^+ \rightarrow Fe^{3+} + 1/2H_2O \qquad (2.2)$$

$$Fe^{3+} + 3H_2O \rightarrow Fe(OH)_3\,(s) + 3H^+ \qquad (2.3)$$

Reactions (2.1) to (2.3) are relatively slow and represent the initial stage in the three-stage AMD formation process. Stage 1 will persist as long as the pH surrounding the waste particles is only moderately acidic (pH > 4.5). A transitional stage 2 occurs as the pH decreases and the rate of Fe hydrolyses (reaction 2.3) slows, providing ferric iron oxidant. Stage 3 consists of rapid acid production by the ferric iron oxidant pathway and becomes dominant at low pH, where the Fe^{2+} (ferric iron) are more soluble (reaction 4):

$$FeS_2 + 14\ Fe^{3+} + 8H_2O \rightarrow 15Fe^{2+} + 2SO_4^{2-} + 16H^+ \qquad (2.4)$$

Without the catalytic influence of the bacteria, the rate of ferrous iron oxidation in an acid medium would be too slow to provide significant AMD generation. As such the final stage in the AMD generation process occurs when the catalytic bacteria *Thiobacillus ferrooxidans* have become established. Reactions (2.2) and (2.4) then combine to form the cyclic, rapid oxidation pathway mainly responsible for the high contamination loads observed in mining environments.

According to the SANS Guidelines for Drinking Water, high concentrations of sulphate exert predominantly acute health effects. Sulphate also imparts a salty or bitter taste to water. The taste threshold for sulphate falls in the range of 200 – 400mg/L. Above 400mg/L diarrhoea occurs in most individuals and user-adaptation does not occur. It is also important to note that adverse chronic effects may occur in livestock if sulphate levels exceed 1000mg/L, such as diarrhoea and poor productivity. This contaminated water will eventually seep into the new opencast areas. This potential situation should be managed during mining in order to minimise the impact on water resources.

Surface Water:

Surface water was sampled from four locations during May 2011 at one river point and five dams. The analyses involved the measuring of the concentration of major cations and anions, as well as pH, total conductivity (TDS) and electrical conductivity (EC). The results from these analyses are contained in Table 6 and compared to the SABS Drinking Water Standards (SANS 241:2006, Ed. 6.1). Colours of individual cells refer to the drinking water classification of the specific surface water sample. Details of the chemical analyses are attached in Appendix C.

Sulphate is probably the most reliable indicator of pollution emanating from coal mining, because sulphates could be discharged from acid mine wastes. It was found that some of the water samples taken were exceeding the maximum allowable standard for domestic use. According to the SANS Guidelines for Drinking Water, high concentrations of sulphate exert predominantly acute health effects. Sulphate also imparts a salty or bitter taste to water. The taste threshold for sulphate falls in the range of 200 – 400mg/L. Above 400mg/L diarrhoea occurs in most individuals and user-adaptation does not occur. It is also important to note that adverse chronic effects may occur in livestock if sulphate levels exceed 1000mg/L, such as diarrhoea and poor productivity.

All surface samples except SW2 seem to have been affected by mining activities if sulphate is considered.

Table 6: Results of Major Cation and Anion Analyses

Sample Nr.	BH1	BH6	BH9	SW1	SW2	SW8	SW9		Class I	Class II
Ca	293.00	29.90	303.00	188.00	23.10	146.00	243.00		150	300
Mg	107.00	12.40	77.60	113.00	18.20	90.60	124.00		70	100
Na	145.00	56.90	173.00	62.90	23.40	58.60	66.80		200	400
K	7.31	2.10	6.19	10.70	9.15	7.31	11.40		50	100
Mn	0.92	0.31	2.13	17.20	0.00	11.70	22.60		0.1	1
Fe	0.00	13.60	25.50	0.08	0.17	0.12	1.81		0.2	2
F	0.79	0.94	0.44	0.60	0.63	0.42	0.63		1	1.5
N	0	0	0	1.38	0	0.346	0		10	20
NO3	0.00	0.00	0.00	6.11	0.00	1.53	0.00		44	88
Al	0.00	0.00	0.00	10.70	0.10	8.58	11.10		0.3	0.5
Zn	0.06	0.00	0.07	0.56	0.00	0.43	0.61		5	10
Si	13.00	12.20	9.22	11.10	2.71	10.30	11.80		-	-
HCO_3	441.38	318.15	125.64	0.00	136.33	0.00	0.00		-	-
Cl	28.10	23.60	20.10	16.40	15.10	14.90	17.60		200	600
SO_4	1040.00	6.84	1310.00	1140.00	54.10	902.00	1400.00		400	600
TDS by sum	1500.00	334.00	1780.00	1210.00	243.00	958.00	1390.00		1000	2400
M-Alk(CaCO3)	362.00	261.00	103.00	0.00	112.00	0.00	0.00		-	-
pH	6.79	6.95	6.14	4.08	7.36	4.09	4.01		5.0 - 9.5	4.0 - 10.0
EC	214.00	47.70	255.00	173.00	34.70	137.00	198.00		150	370
Cat/An Bal. %	0.81	-4.61	0.06	-3.23	3.59	-2.81	-5		-	-

Notes:
Class I
Class II
Exceeding maximum allowable standard for domestic use
na- not analysed
All concentrations are presented in mg/l, EC is presented in mS/m
0 = below detection limit of analytical technique

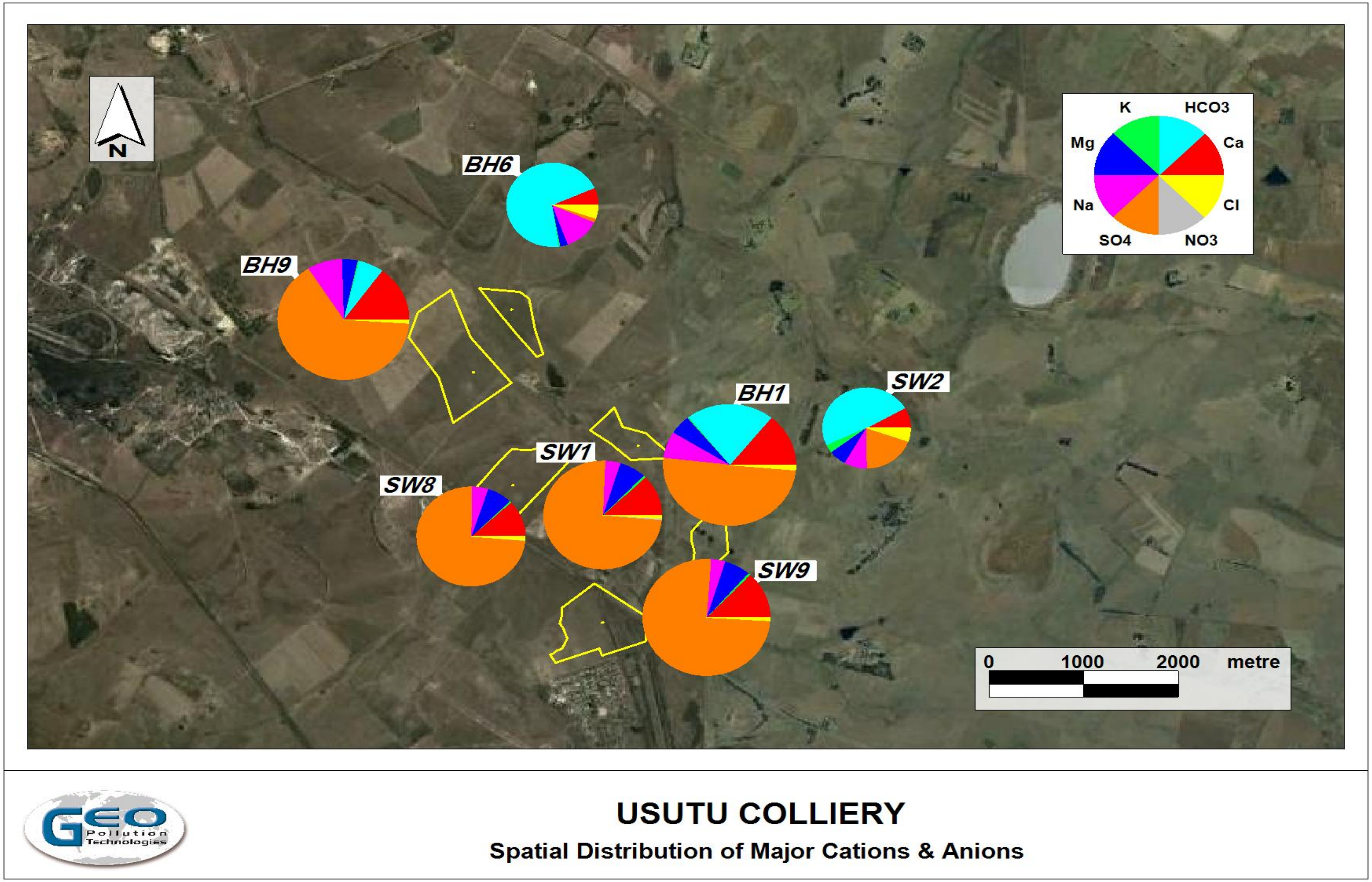

Figure 9: Pie Diagrams (groundwater and surface water)

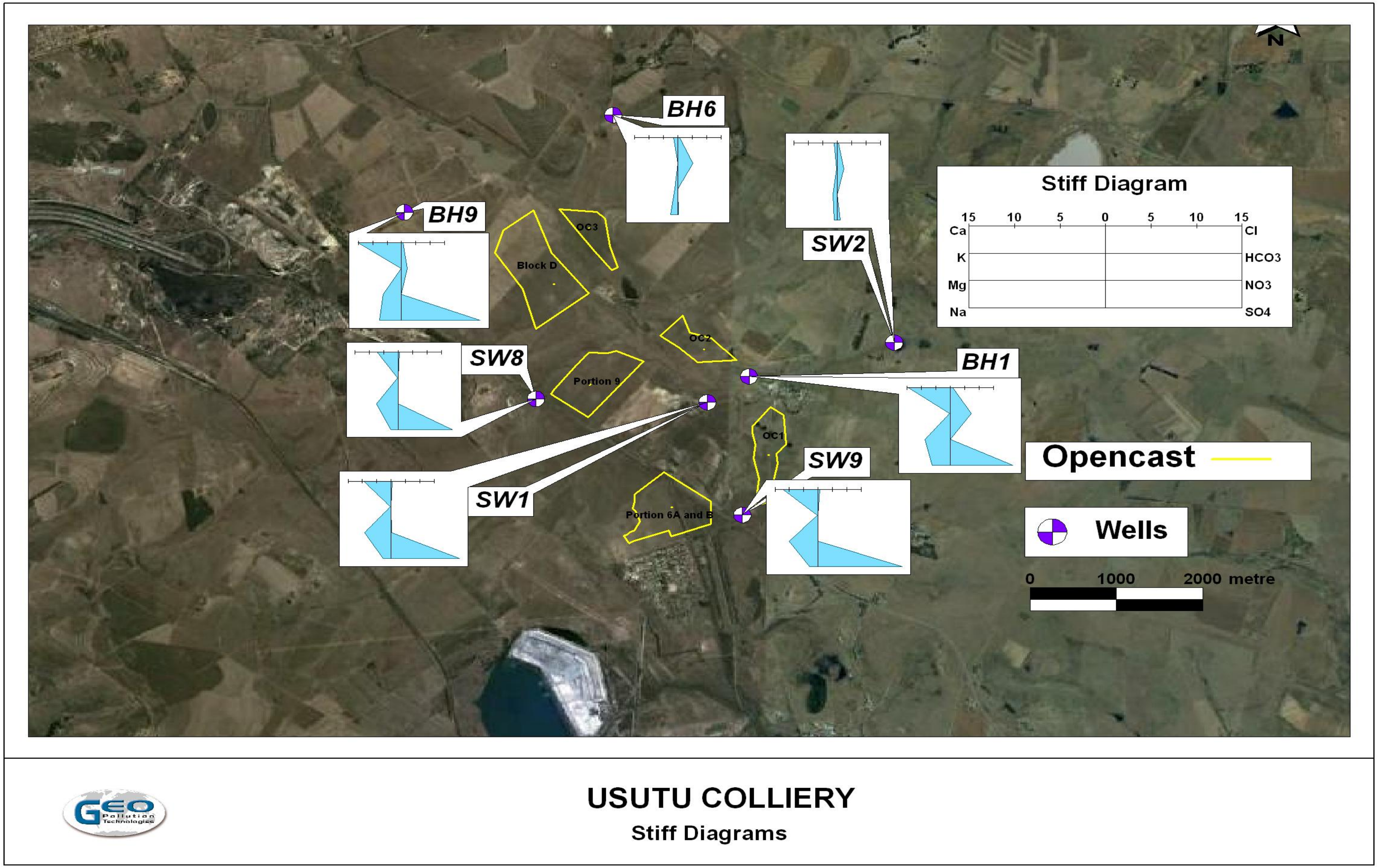

Figure 10: Stiff Diagram (groundwater and surface water)

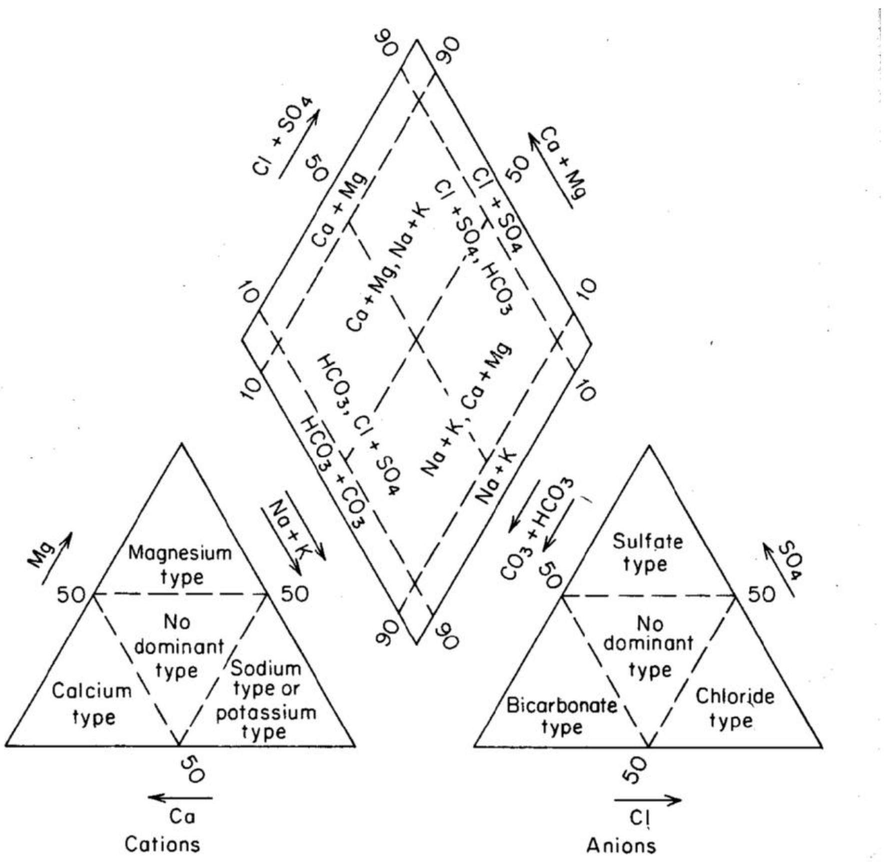

Figure 11: Classification Diagram for Anion and Cation Facies in Terms of Major-ion Percentages.[6]

[6]Freeze, R. Allan, and John A. Cherry. 1979. *Groundwater*. Prentice Hall Inc, New Jersey.

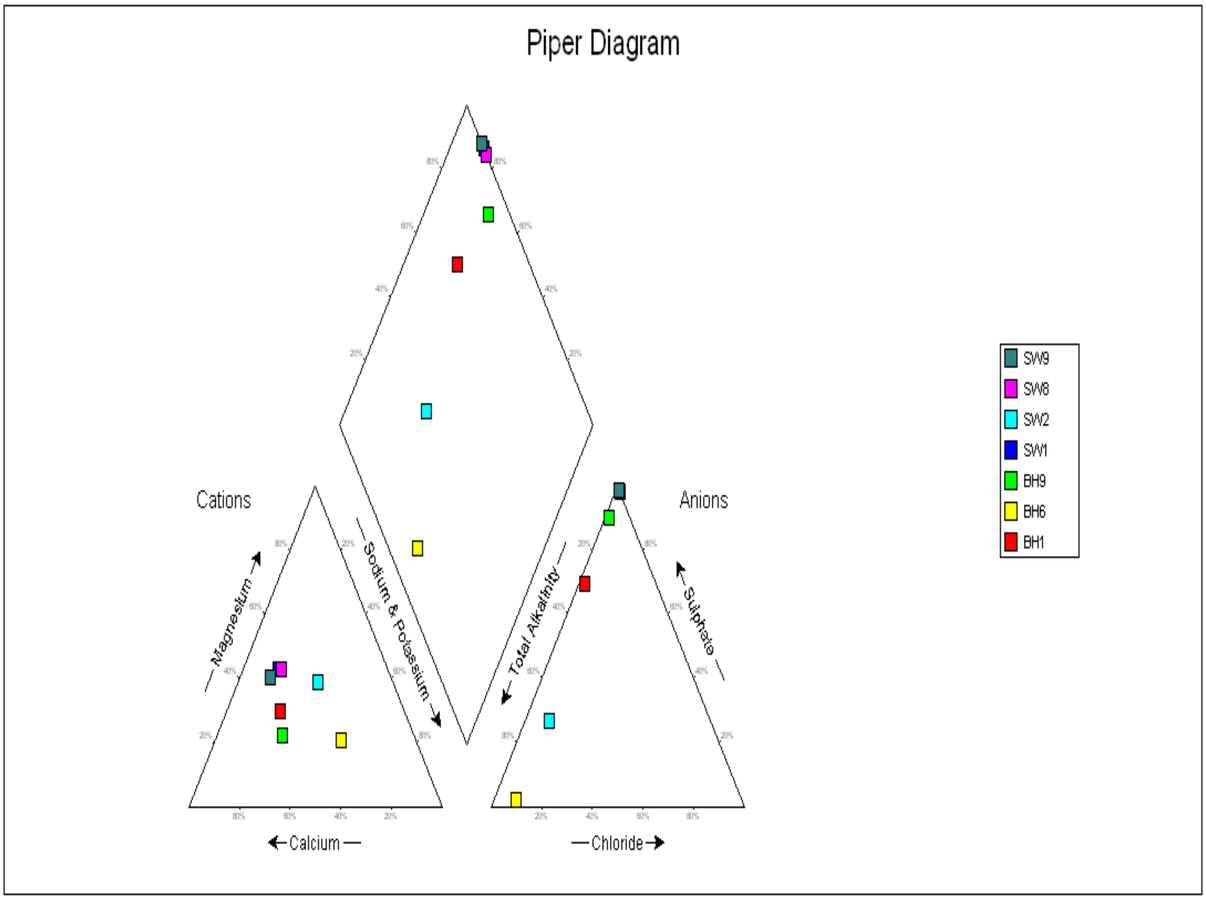

Figure 12: Piper diagram

5.6 POTENTIAL CONTAMINANTS

The potential contaminants associated with the mining activities may emanate from the opencast mining area, crusher area, product stockpile, and pollution control dam (PCD) and R.O.M. area.

Workshops and fuel and oil handling facilities are likely sources of hydrocarbon related contaminants. Oils, grease and other hydrocarbon products (such as petrol and diesel) handled in these areas may contaminate the environment by spillages and leakages. Oils and greases are removed and collected in oil traps. Run-off (contained with hydrocarbons) which is not collected may enter the storm water system from where it may contaminate surface water bodies and groundwater. Septic tanks and sewage treatment plants potentially contaminate groundwater. Contaminants associated with these plants include coliforms (e.g. E.coli), bacteria viruses, ammonia, phosphate, sulphate and nitrate. Effluent from these systems usually contains elevated concentrations of organic matter which may lead to elevated COD and BOD. Waste disposal areas may source a wide range of contaminants, ranging from metals, organic matter, hydrocarbons, phosphates, etc.

5.6.1 Acid generation capacity of the rock

Six exploration drill cores samples taken from each open cast area were made available for acid base analyses. The composite samples were taken to represent the material to be backfilled into the opencast once mining has been completed. A summary of the results are shown Table 7. The full description of the acid base analyses is included in Appendix D.

The acid base analysis (ABA) of exploration drill cores from the six opencast areas showed material that is intermediate to potentially acid forming material. Based on these results it can be concluded that acid rock drainage (ARD) potentially may occur from the opencast areas if not mitigated.

Backfilling the mined out coal discard. It is therefore imperative that the discard material from the coal seams be inundated below the groundwater level during rehabilitation to reduce the rate of potential AMD formation. As no sample was available for analysis, the rate of AMD formation and duration will have to be assessed during the commissioning/operational phase. It is known from experience that AMD is likely to emanate from the backfilled opencast area, should decanting occur.

Table 7: Summary of base analyses

Opencast Area	Drillhole Id	Y-coord	X-coord	Z-value	Acid Generation Potential
PTN6A	PTN6A019	-2941836.79	-90564.3	1649.63	Intermediate acid forming
PTN6B	PTN20	-2942499.97	-90899.8	1654.12	Potentially acid forming
PTN6C	PTN21	-2942325.64	-90649.37	1649.70	Potentially acid forming
PTN9	PTN22	-2940845.21	-91745.05	1644.88	Potentially acid forming
OC1	PTN25	-2941620.8	-89755.32	1637.21	Potentially acid forming
OC2	JH263012	-2940435.5	-90532.8	1639.84	Intermediate acid forming
OC3	JH263025	-2938614.13	-92690.47	1657.60	Intermediate acid forming
BLOCK D	JH263024	-2939695.7	-92349.44	1657.31	Potentially acid forming

5.7 GEOPHYSICAL SURVEY

A geophysical survey was carried out by GPT. Both the magnetometer- and electromagnetic method were employed. The main objective of the geophysical survey was to map geological structures such as dykes and faults. Magnetic surveys are able to detect the presence of dolerite intrusions; the electromagnetic method detects the presence of conductive zones normally associated with the presence of groundwater. The field data can be viewed in Appendix E.

The geophysical survey was conducted on 26 and 30 March 2012. Electromagnetic (EM) and Magnetic methods were employed during the geophysical survey to map preferential flow paths. While the magnetic method is used to detect basic intrusions like dolerite dykes and sills, which is normally associated with groundwater occurrence, the electromagnetic method detects changes in electrical conductance of the subsurface. As water is normally a conducting substance in the rock, the method is thus sensitive for the presence of groundwater. The combination of the two methods lends itself to the identification and preliminary quantification of groundwater occurrences.

The positions and orientations of the EM and magnetic profiles are shown in Figure 13 with the results in Appendix A. The choice of the profile positions, orientations and lengths was influenced surface constraints such as, high voltage power lines, roads and railway lines and inaccessibility due to thick brush.

The 6 traverses where completed and the results are interpreted below:

Traverse 1a

This traverse extends northeast-southwest. A possible structure may be present at approximately 420m where the horizontal and vertical dipoles split into higher and lower values. Magnetic readings also show a slight elevation in values around this area which may possibly indicate a dyke structure. Some elevated HD values are present between 0 and 100m, but are unlikely to indicate any significant structures.