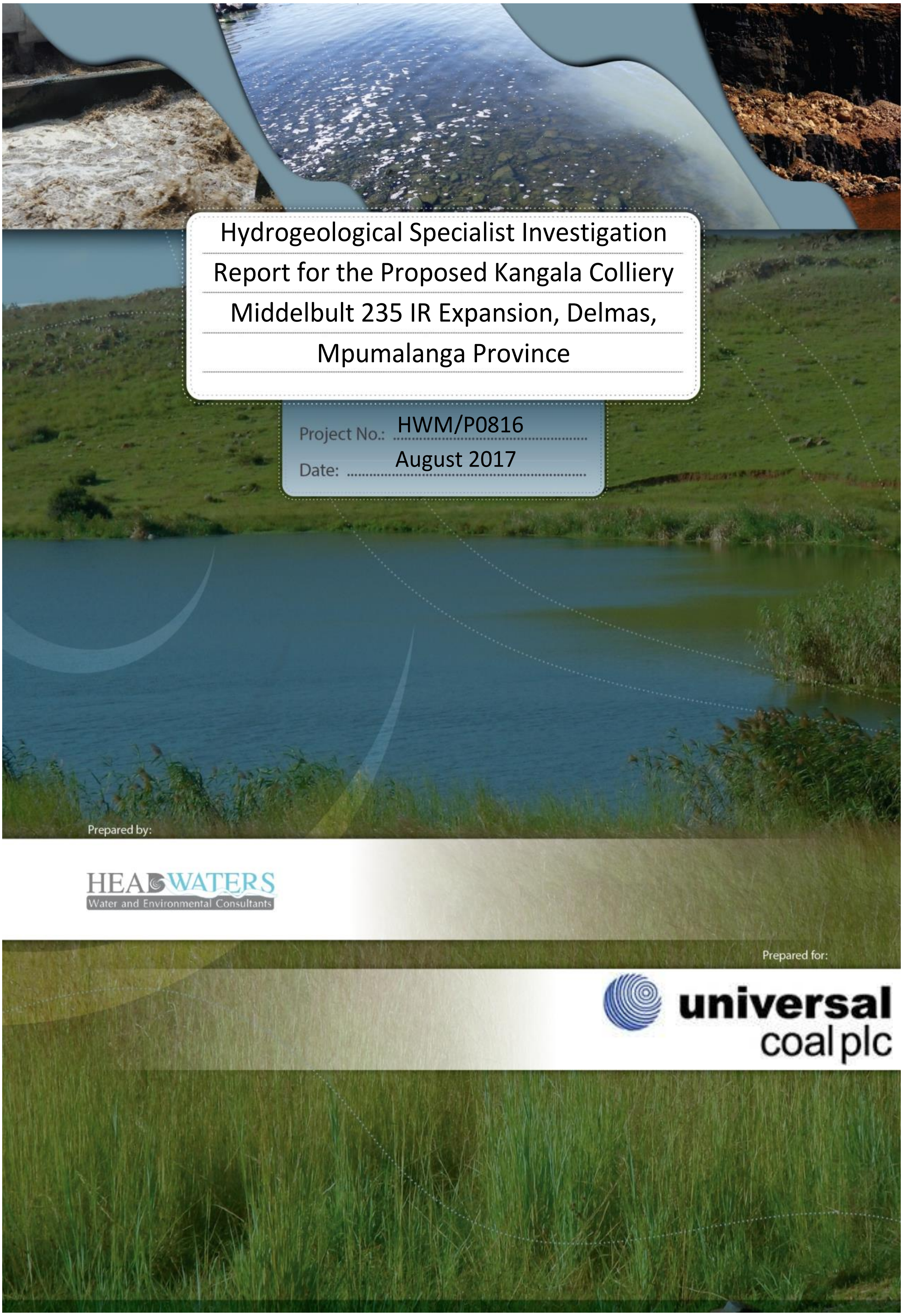

Hydrogeological Specialist Investigation Report for the Proposed Kangala Colliery Middelbult 235 IR Expansion, Delmas, Mpumalanga Province

Project No.: HWM/P0816

Date: August 2017

Prepared by:

HEADWATERS
Water and Environmental Consultants

Prepared for:

universal
coal plc

PROJECT INFORMATION

Report Name:	Middelbult Open Pit Coal Mine Hydrogeological and Hydrogeochemical Specialist Study for the Proposed Kangala Colliery Middelbult 235 IR Expansion, Delmas, Mpumalanga Province
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APPLICANT (PROPONENT)

Company Name:	**UNIVERSAL COAL DEVELOPMENT II (PTY) LTD**
Registration Number:	
Contact Person:	Ms. Minah Moabi
Designation:	Director: Corporate Affairs
Tel:	012 460 0805
Fax:	012 460 2417
Email:	m.moabi@universalcoal.co.za
Postal Address:	P. O. Box 2423, Brooklyn Square, 0075

CONSULTANT

Company Name:	**HEADWATERS cc**
Contact Person:	Mr. Joubert Bulasigobo
Designation:	Hydrogeologist (Groundwater Modeler)
Tel:	(+27) 10 005 6676
Fax:	(+27) 86 238 4157
Email:	Joubert@headwaters.co.za
Physical Address:	Birchwood Court, 43 Montrose Street, Vorna Valley, Midrand

Project Team

Name	Designation	Function	Qualifications
S Ferreira	Hydrogeologist	Specialist input, data interpretation and reporting	B.Sc. Hons Geohydrology (NWU)
L Le Roux	Hydrogeologist	Drilling and pump test supervision, and packer testing	B.Sc. Hons Geohydrology UFS
Joubert Bulasigobo	Hydrogeologist (Groundwater Modeller)	Groundwater Modelling	M.Sc. Water and Environment
Reuben Grobbler	Hydrogeologist Groundwater Modeller	Reviewer	M.Sc. Geohydrology
Dr JJP Vivier	Senior Hydrogeologist	Reviewer	B.Sc. Geology and Geochemistry, UFS. B.Sc. Hons. Geohydrology, UFS, M.Sc. Geohydrology UFS. Ph.D. Environmental Management, NWU Pr.Sci.Nat

Declaration of Independence

Headwaters cc is a sovereign and independent consulting company and do not have any financial interest in the proposed project other than the compensation for work performed in terms of this hydrological investigation.

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Signed

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List of Abbreviations

ABA	Acid Base Accounting
AP	Acid Potential;
BPEO	Best Practicable Environmental Option
CDT	Constant Discharge Test
CMB	Chloride Mass Balance
DWA	Department of Water Affairs
DWS	Department of Water and Sanitation
EC	Electrical Conductivity
EMPR	Environmental Management Programme Report
EWR	Environmental water requirements
GRDM	Groundwater Resource Directed Measures
I&AP	Interested and Affected Party
IGS	Institute for Groundwater Studies
LCT	Leachable Concentration Threshold
MAMSL	Meter Above Mean Sea Level
MAP	Mean Annual Precipitation
MAR	Mean Annual Runoff
MBGL	Meter Below Ground Level
NAG	Net- Acid Generation
NGA	National Groundwater Archive

NEMA	National Environmental Management Act, 1998
NNP	Net neutralising potential
NP	Neutralisation Potential
NPR	Neutralising Potential Ratio
NWA	National Water Act, 1998
PSC	Present Status Category
PSP	Professional Service Provider
RT	Recovery Test
ROM	Run of Mine
SDT	Step Drawdown Test
SPLP	Synthetic Precipitation Leaching Procedure
TCT	Total Concentration Threshold
TDS	Total Dissolved Solids
TWQR	Target Water Quality Range
WARMS	Water Authorisation and Registration Management System
WMA	Water Management Area
WR2012	Water Resources of South Africa 2012
WRPM	Water Resources Planning Model
WULA	Water Use Licence Application
WUL	Water Use Licence

XRD	X-ray Diffraction
XRF	X-ray Florescence

Glossary of Terms

Advection is the process by which solutes are transported by the bulk motion of the flowing groundwater.

Anisotropic is an indication of some physical property varying with direction.

Cone of depression is a depression in the groundwater table or potentiometric surface that has the shape of an inverted cone and develops around a borehole from which water is being withdrawn. It defines the area of influence of a borehole.

A **confined aquifer** is a formation in which the groundwater is isolated from the atmosphere at the point of discharge by impermeable geologic formations; confined groundwater is generally subject to pressure greater than atmospheric.

The **Darcy flux** is the flow rate per unit area (m/d) in the aquifer and is controlled by the hydraulic conductivity and the piezometric gradient.

Dispersion is the measure of spreading and mixing of chemical constituents in groundwater caused by diffusion and mixing due to microscopic variations in velocities within and between pores.

Drawdown is the distance between the static water level and the surface of the cone of depression.

Effective porosity is the percentage of the bulk volume of a rock or soil that is occupied by interstices that are connected.

Groundwater table is the surface between the zone of saturation and the zone of aeration; the surface of an unconfined aquifer.

A **fault** is a fracture or a zone of fractures along which there has been displacement.

Hydrodynamic dispersion comprises of processes namely mechanical dispersion and molecular diffusion.

Hydraulic conductivity (**K**) is the volume of water that will move through a porous medium in unit time under a unit hydraulic gradient through a unit area measured perpendicular to the area [L/T]. Hydraulic conductivity is a function of the permeability and the fluid’s density and viscosity.

Hydraulic gradient is the rate of change in the total head per unit distance of flow in a given direction.

Heterogeneous indicates non-uniformity in a structure.

Karstic topography is a type of topography that is formed on limestone, gypsum, and other rocks by dissolution, and is characterised by sinkholes, caves and underground drainage.

Mechanical dispersion is the process whereby the initially close group of pollutants are spread in a longitudinal as well as a transverse direction because of velocity distributions.

Molecular diffusion is the dispersion of a chemical caused by the kinetic activity of the ionic or molecular constituents.

Observation borehole is a borehole drilled in a selected location for the purpose of observing parameters such as water levels.

Permeability is related to hydraulic conductivity, but is independent of the fluid density and viscosity and has the dimensions L^2. Hydraulic conductivity is therefore used in all the calculations.

Piezometric head (ϕ) is the sum of the elevation and pressure head. An unconfined aquifer has a water table and a confined aquifer has a piezometric surface, which represents a pressure head. The piezometric head is also referred to as the hydraulic head.

Porosity is the percentage of the bulk volume of a rock or soil that is occupied by interstices, whether isolated or connected.

Pumping tests are conducted to determine aquifer or borehole characteristics.

Recharge is the addition of water to the zone of saturation; also, the amount of water added.

Remediation refers to the improvement of contaminated land or degraded water resource to a situation where a new viable sequential land use or acceptable water resource status is established.

Sandstone is a sedimentary rock composed of abundant rounded or angular fragments of sand set in a fine-grained matrix (silt or clay) and more or less firmly united by a cementing material.

Shale is a fine-grained sedimentary rock formed by the consolidation of clay, silt or mud. It is characterised by finely laminated structure and is sufficiently indurated so that it will not fall apart on wetting.

Specific storage (S0), of a saturated confined aquifer is the volume of water that a unit volume of aquifer releases from storage under a unit decline in hydraulic head. In the case of an unconfined (phreatic, water table) aquifer, specific yield is the water that is released or drained from storage per unit decline in the water table.

Static water level is the level of water in a borehole that is not being affected by withdrawal of groundwater.

Storativity is the two-dimensional form of the specific storage and is defined as the specific storage multiplied by the saturated aquifer thickness.

Total Dissolved Solids (TDS) is a term that expresses the quantity of dissolved material in a sample of water.

Transmissivity (T) is the two-dimensional form of hydraulic conductivity and is defined as the hydraulic conductivity multiplied by the saturated thickness.

An **unconfined, water table or phreatic aquifers** are different terms used for the same aquifer type, which is bounded from below by an impermeable layer. The upper boundary is the water table, which is in contact with the atmosphere so that the system is open.

Vadose zone is the zone containing water under pressure less than that of the atmosphere, including soil water, intermediate vadose water, and capillary water. This zone is limited above by the land surface and below by the surface of the zone of saturation, that is, the water table.

Water table is the surface between the vadose zone and the groundwater, that surface of a body of unconfined groundwater at which the pressure is equal to that of the atmosphere.

1 Introduction

Headwaters cc was appointed by Universal Coal to launch a hydrogeological specialist investigation for the proposed open cast extension on Middelbult 235IR Farm portion 40 and 82, bordering directly on the current existing Kangala Colliery site which is on portion 1 remaining extent (RE) of the farm Wolvenfontein 244 IR, all located within the Magisterial District of Delmas.

The Middlebult 235 IR farm is located approximately 2,5km south-west from the town of Delmas via and 1,5km south east from Eloff in the Mpumalanga Province of South Africa. The farm is located within the B20A quaternary catchment, situated in Olifants Water Management Area (WMA).The project area falls within ward 1 of the Victor Kanye Local Municipality which is under the jurisdiction of the Nkangala District Municipality.

The report focuses on the hydrogeological issues that could potentially have an impact on Middelbult Farm and surrounding areas .The Middelbult Farm is currently used for agricultural activities. The area size of the Middelbult 235 IR farm is roughly 942 Ha but the proposed expansion is 67Ha.The Middelbult opencast pit will mine seam#2 coals.

1.1 Purpose of the study

The main purpose of the groundwater flow model was to simulate the possible impact of the mine dewatering caused by the open pits and the mass transport associated with the mining activities on the local groundwater regime and sensitive receptors. The following objectives are achieved:

1. Estimate dewatering rates taking into account temporal and spatial factors such as the mining operational phases through Life of Mine (LoM).
2. Determine the radius of influence and volumetric impacts of dewatering on water users and the environment.
3. Quantify the potential for seepage plumes from the DFE and the pit.

1.2 Scope of Work

The completed hydrogeological investigation scope of work for the current study consisted of the following geohydrological actions:

- Geophysical investigation to determine whether there are any regional dyke/fracture zones that could form a link between the upper Karoo Aquifer and the basal Dolomite Aquifer. The geophysical survey was also used to determine the drilling positions of core boreholes (BH) to be established within the study area;
- Drilling of one percussion- and 4 core-boreholes to determine the hydrogeological layers and conduct a pumping test to determine the permeability values of the subsurface layers with specific reference to the Dwyka tillite, carbonaceous shale and dolomite layers;
- Collect all the relevant borehole information; this will include the status of existing boreholes, water levels, recommended yields as well as hydrochemistry;
- To demonstrate possible impact on Botleng Dolomitic Aquifer due to the proposed expansion of the mine ;
- Sampling and analysis of the groundwater to determine the status and distribution of the water quality;
- Development of the conceptual and numerical hydrogeological model;
- Based on the model results and site assessment, the recommendations will be made on the efficiency of management and mitigation measures.

1.3 Project Representation

Previous studies conducted in the Delmas area and within the project area indicated that the Dwyka tillite/diamictite geological beds forming part of the Dwyka Group acts as an aquitard that will provide a barrier/ protection for the dolomitic aquifer that is in use by the surrounding land owners for domestic and irrigation purposes.

2 Hydrogeochemistry

Characterisation of hydro geochemistry and risks to groundwater quality and knowledge of the processes that control natural water composition is a necessity for rational management of water quality. Hydrogeochemistry pursues to determine the origin of the chemical composition of groundwater and the relationship between water and rock chemistry as they relate to water movement. A basic and straightforward tool in hydrochemical studies used to summarize and present water quality data are graphical interpretation which are also used in this study.

Nineteen (19) groundwater monitoring points and thirteen(13)(10) surface water monitoring points were identified for baseline study and analysed for major cations and anions as well as trace metals like Mn.

2.1 Baseline Surface Water Quality Results and Discussion

Water samples were collected and analysed by SANS accredited laboratory Aquatico Laboratories. It was observed that most sampling points were dry in most months. Water chemistry results were observed and are within the stipulated limits in the IWUL for most months but for this assessment pH, TDS and Sulphates for the Discard facilities (DFE) and Pollution Control Dam (PCD) are shown in Figure 2-1 and Figure 2-2 below as a worst case assessment and for numerical modelling input .

The pH values are consistent throughout the period, remains in the neutral to slightly alkaline range, within the stipulated limits in the IWUL for most months and the pH value trends are represented in the graphs. TDS of the surface water fluctuates within the IWUL limit. The iron and manganese concentrations have often exceeded the limits stipulated by both the WUL Drinking water standard SANS 241:2015.

Sulphates (SO4) are good indicators for assessing probable coal mining impacts. Sulphate concentration trends fall within the Kangala WQO and Drinking water standards SANS 241:2015 except for Discard Facility Effluent and Pollution Control Dams (PCD) which are both lined.

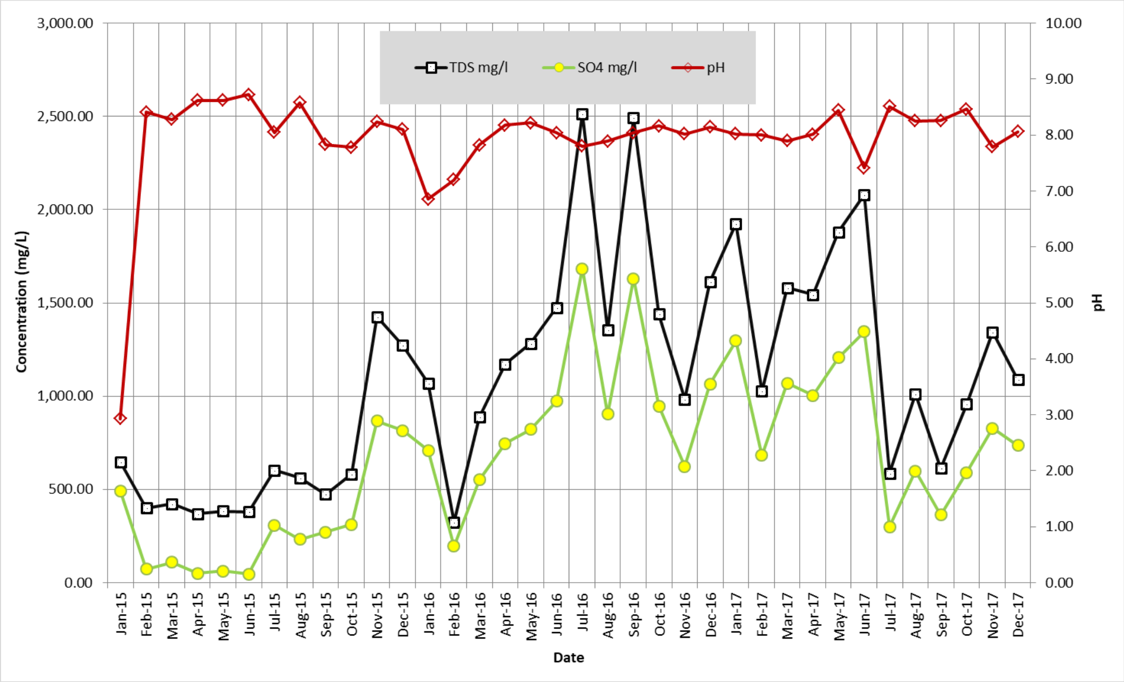

Figure 2-1 Physical parameters for surface water samples pH, SO_4 and TDS (DFE)

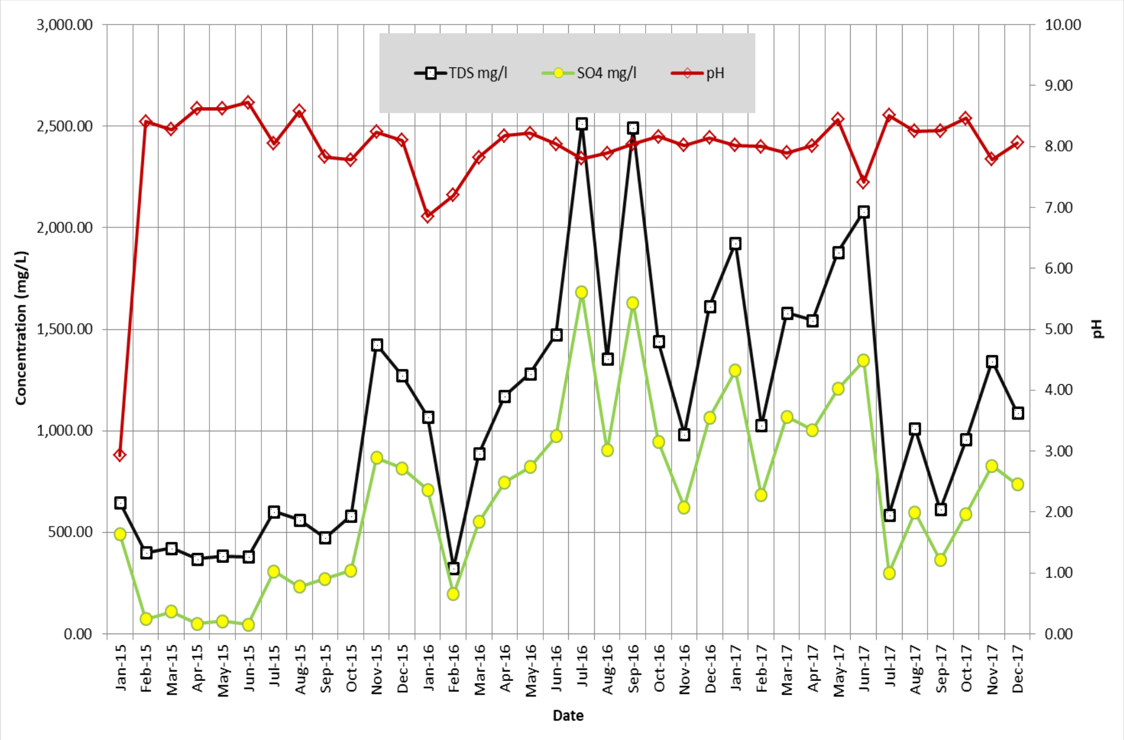

Figure 2-2 Physical parameters for surface water samples pH, SO_4 and TDS (PCD)

2.2 Baseline Groundwater Quality Results and Discussion

In July 2016 and April 2017 groundwater samples including Eloff areas were collected and submitted to Aquatico laboratories which is SANAS accredited laboratory. To interpret groundwater quality results the following standards were used: South African National

Standard 2015 SANS 241:2015 and Kangala Water Resource Quality Objectives. Groundwater monitoring points were identified for baseline study and analysed for major cations and anions as well as trace metals like Mn.Twelve (12) boreholes are identified as Dolomitic Aquifer boreholes while seven (7) boreholes are identified as Karoo Boreholes(Table 2-1). Due to a lack of geological and construction logs of the boreholes, it must be noted that some of the boreholes located in the Karoo geology, may have been drilled through the Karoo strata into the underlying dolomite aquifer. The water in these boreholes may therefore be a mixture of both Karoo and Dolomite aquifer.

Only one existing special drilled borehole was adequately sited or constructed to establish the relationship between Karoo and dolomite ground water, or assess the behaviour of water in the Karoo (MBH1).In addition to the samples collected during the hydro-census, thirteen (13) historical surface water chemistry results were observed and are within the stipulated limits in the IWUL for most months.

2.2.1 Physical Parameters

Physical parameters analysed for the groundwater samples collected and the pH, Electrical conductivity (EC), Temperature and Total Dissolved Solids (TDS) were assessed. Laboratory results of physical parameter results indicate that for pH, EC and TDS of the boreholes are within the acceptable limits of Kangala's Water Resource Quality Objective and SANS 241:2015 water quality standards. Tables 2-1 below are graphic representation of physical parameters concentration.

2.2.2 Baseline Macro Determinants

Macro determinants analysed for the groundwater samples include major ions and metals. The laboratory results for the following determinants indicated that concentrations are of acceptable water quality according to SANS 241:2015 and Kangala Water Resource Quality Objective, Ammonium (NH4), Calcium (Ca), Chloride (Cl), Fluoride (F), Magnesium (Mg), Potassium (K), Sulphate (SO4) and Sodium (Na). The exception is nitrate in borehole KAG 40 and KGA21 with an elevated concentration of 12.7 mg/L and 14.9 mg/L respectively.

Common Nitrate sources are agricultural fertilizers, animal feed and organic waste in sewage. The current land use of the area of study includes crop cultivation, livestock farming. Nitrates are essential source of nitrogen in plants; however excess amount can cause adverse health and ecological effects.

2.2.3 Micro-Determinants (Trace Elements)

Micro determinants analysed for the sample were Aluminium (Al), Manganese (Mn) and Iron (Fe). It can be observed that all determinants are within acceptable water quality standards, except Mn which is above the limit at 022mg/ℓ Mn and the Kangala Water Resource Quality Objective.

2.2.4 Microbiological Determinant

Microbiological determinants included in the analyses are *E. coli* and Total coliform. It can be observed that *E.Coli* count is excessive by 2 and 21 for KGA1 and KGA40 respectively; it poses an unacceptable health risk if ingested over a period. The groundwater contamination could have been due to sewage waste.

***E.Coli* and Total coliform count**

The presence of *E.Coli* and total coliform indicate groundwater contamination with faecal waste that may contain harmful or disease causing microorganism. Total coliform in groundwater can be caused by agricultural runoff, sewage discharge, and poor maintained boreholes can increase the risk of bacterial contamination.

Table 2-1 Statistical dolomite and karoo boreholes water quality samples results

SampleID	Sample_ Date	pH	EC (mS/m)	TDS	Ca	Mg	K	Na	Cl	F	SO4	NO3	HCO3	Total Alk	Al	Fe	Mn
Determinants		Physical Parameters			Macro Determinants (Major ions)										Micro Determinants (Trace Elements)		
Water Resource Quality Objectives		5- 9			150	700		200			400	10				0,20	1,00
Operational		≥ 5 to ≤ 9.7	No limits	No limits	No limits	No limits	No limits	No limits	No limits	No limits	No limits	No limits	No limits	≤0.3	≤0.3	no limits	no limits
Aesthetic		No limits	≤170	≤1200	No limits	No limits	No limits	No limits	No limits	No limits	No limits	≤200	No limits	no limits	no limits	≤0.3	≤0.1
Chronic health		No limits	No limits	No limits	No limits	No limits	≤300	≤200	No limits	No limits	No limits	No limits	No limits	no limits	no limits	≤2	≤0.4
Acute health		No limits	No limits	No limits	No limits	No limits	No limits	No limits	No limits	No limits	≤500	No limits	No limits	No limits	No limits	No limits	No limits
Dolomite Aquifer																	
Average		7.58	32.63	266.47	31.12	17.29	12.58	5.71	15.26	0.24	10.07	5.89	166.83	137.45	0.09	0.01	0.02
Min		5.96	11.10	81.63	6.09	5.31	2.51	1.93	1.34	0.09	0.16	0.61	17.44	14.30	0.00	0.00	0.00
Max		8.11	59.70	641.79	65.00	31.50	43.90	14.00	50.60	0.38	44.50	14.90	297.50	244.00	0.52	0.09	0.14
95th		8.04	55.41	627.86	60.11	30.02	31.62	13.01	35.31	0.34	31.36	14.27	292.03	240.70	0.48	0.06	0.09
5th		6.28	14.29	99.43	9.56	5.93	3.12	2.17	2.11	0.13	0.23	1.49	35.47	29.37	0.00	0.00	0.00
Stdev		0.65	15.45	187.64	19.05	9.59	11.48	4.01	13.08	0.07	12.47	4.66	104.88	86.36	0.19	0.03	0.04
Karoo Aquifer																	
Average		7.98	22.90	135.43	19.32	12.97	9.12	5.48	8.86	0.33	1.11	3.97	147.31	123.24	0.005	0.004	0.126
Min		7.11	14.10	82.00	7.08	5.83	4.54	2.84	2.80	0.26	0.16	0.13	51.59	42.50	0.002	0.004	0.001
Max		8.89	47.60	300.00	53.60	30.00	18.70	10.80	14.30	0.43	3.08	13.10	338.45	281.00	0.025	0.004	0.600
95th		8.69	42.05	256.20	44.81	27.12	16.48	9.15	13.46	0.43	2.80	11.70	288.68	239.30	0.018	0.004	0.468
5th		7.25	14.19	82.90	7.58	5.84	4.91	3.17	3.14	0.26	0.16	0.13	62.19	51.47	0.002	0.004	0.001
Stdev		0.57	12.10	76.97	16.42	9.36	4.73	2.52	4.22	0.08	1.10	5.15	94.04	78.39	0.009	0.000	0.217

2.3 Groundwater Piper Diagram

The Piper diagram is one of the most commonly used techniques to interpret groundwater chemistry data. This method proposes the plotting of cations and anions on adjacent trilinear fields with these points then being extrapolated to a central diamond field. Here, the chemical character of the water, in relation to its environment, can be observed and changes in the quality interpreted. The cation and anion plotting points are derived by computing percentage equivalents for the main diagnostic cations of Ca, Mg, Na and K, and anions Cℓ, SO4 and HCO3.The Piper diagram for the selected boreholes surrounding the study area which were sampled during the hydro census, are shown on Figure 2-3 below.

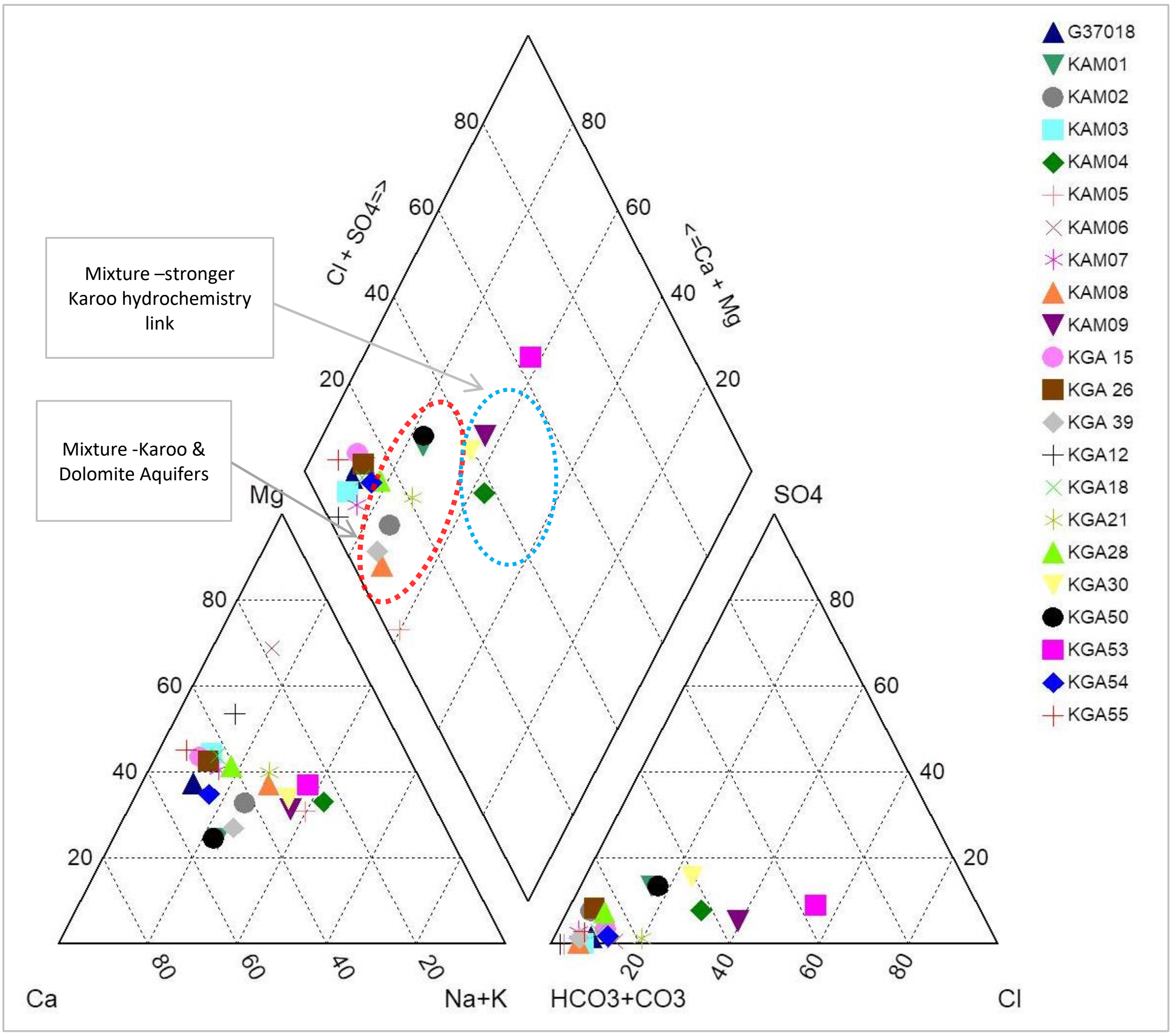

Figure 2-3 Piper diagram for groundwater boreholes

Due to a lack of geological and construction logs of the boreholes, it must be noted that some of the boreholes located in the Karoo geology, may have been drilled through the Karoo strata into the underlying dolomite aquifer. The water in these boreholes may therefore be a mixture of both Karoo and Dolomite aquifer water as shown in Figure 2-3.

2.4 Acid base accounting

Coal and many mine wastes contain sulphide material which may oxidise to produce acid mine drainage (AMD). A number of factors control the generation of AMD, however of primary importance are the relative abundance of acid producing minerals (generally the sulphides) and acid consuming minerals (generally carbonates and silicates), availability of water (moisture) and an oxidising environment (exposure to air). As ARD has the potential to impact significantly on surface and groundwater quality and the leachate characteristics of waste residue deposits, it is necessary to quantify the potential of waste to generate ARD during geochemical characterisation assays.

2.5 Sampling and Laboratory Tests

Digby Wells Environmental (hereafter Digby Wells) was appointed by Universal Coal (Pty) Ltd to undertake a waste assessment as part of the Middelbult open cast mine environmental impact assessment (EIA).Two sets of samples were taken from the three (3) available core boreholes drilled (MCH1, MCH2 and MCH3).Only one of the boreholes (MCH1) penetrated the entire lithology present on site which includes the following in order from top to bottom:

- Weathered overburden (sandstone and shale);
- Sandstone;
- Shale (carbonaceous shale);
- Coal seams;
- Tillite; and
- Dolomite.

The first batch of samples was sampled only for waste classification purposes. However data from the various tests performed on them also fed into the geochemical assessment. The above mentioned batch was made up of samples across all three boreholes (MCH1, MCH2 and MCH3) from the waste rock lithology that will be stored and placed back into the pit as overburden material. Composite samples were made up due to the small amount of material available from the 3 boreholes. Table 2-3 gives a description of the lithology sampled for each composite sample from each borehole.

Table 2-2: Waste classification composites

Sample ID	**Sections sampled per borehole (mbgl)**			**Description1**
	MCH1	**MCH2**	**MCH3**	
Composite 1	11.11 to 14.18	7.76 to 9.56		Karoo mudstone/siltstone
Composite 2	0 to 5.1	0 to 3.96	0 to 5.45	Soft overburden (weathered sandstone/siltstone)
Composite 3	28.8 to 36.95			Shales and carbonaceous shales (HW)
Composite 4	20.59 to 23.58			Coarse grained Karoo sandstone

The following tests were performed for waste classification purposes on the above mentioned composite samples as per NEM: WA guidelines:

X-Ray Diffraction (XRD) and X-Ray Fluorescence (XRF) to allow an evaluation of the mineral content and chemical breakdown of the sampled material;

Acid Base Accounting (ABA) and Nett Acid Generation (NAG) tests to inform the specialist and client on any acid generation potential from the material;

Aqua regia acid digestion tests were performed to assess the total elemental chemical makeup of the material and to serve as the total concentration (TC) values to be used in the waste classification process; and

Due to the waste being mono-disposed reagent water (distilled water) leachate tests (ratio 1:20) was performed in line with the prescribed tests in NEM: WA. The leachate tests are

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[1] Illustrations (photos) of the core are presented in the groundwater impact assessment report prepared by Headwaters (Pty) Ltd ((Bulasigobo, 2017).

done to allow an evaluation of the leachable concentration (LC) values that is used in the waste classification process.

A further five (5) samples were taken after concerns were raised by both the consultant team and the client on whether further work is needed. These 5 samples were taken from MCH1, the only borehole to penetrate all lithology on site. The following sample breakdown is provided with only individual layers samples (no composites) as illustrated in Table 2-4.

Table 2-3: Individual samples from MCH1

Sample ID	Sample Depth (m)	Description2
MS1	42 to 43	Coal material (Seam 3)
MS2	41.5 to 42	Hanging wall material (sandstone)
MS3	43.8 to 44.8	Footwall material (shale)
MS4	59 to 61	Malmani dolomite
MS5	48 to 49	Dwyka tillite/diamictite

In line with the prescribed DWS tests for geochemical characterisation the following laboratory work was completed on the above 5 samples:

XRD and XRF;

ABA, NAG and Sulphur speciation (Total S, Sulphide S, Sulphate S and Carbonate content);

Aqua regia; and

Reagent (Distilled) water leach tests at a ratio of 1:43. Leachate analysed for pH, EC, Alkalinity, TDS, F, Cl, NO3, SO4 and the full ICP-MS Quant list of parameters.

The additional five samples aimed at targeting individual lithologies whereas the waste classification samples were composites only targeting the waste lithologies.

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2 Illustrations (photos) of the core are presented in the groundwater impact assessment report prepared by Headwaters (Pty) Ltd ((Bulasigobo, 2017).

3 The prescribed ratio for waste classification is 1:20 (rock: water). However, for geochemical assessments a ratio of 1:4 is used to present a more conservative case.

2.6 Exploration Data - Middelbult

Sulphur content data from the exploration work done at Middelbult was made available by the Universal Coal geologists. The statistics as presented below in Table 2-5 was provided for 4 different seams (Zulu, 2017):

Table 2-4: Exploration – Total sulphur % distribution statistics

Seam	Max	Min	Average	Median	St Dev
SM	3.85	0.63	1.99	1.96	0.74
AB	1.64	0.31	0.76	0.76	0.31
BC	1.59	0.11	0.65	0.58	0.34
CD	2.9	0.16	0.59	0.45	0.53

The split of sulphur content between sulphide sulphur and sulphate sulphur was not made and this makes interpretation of the AMD potential difficult. However, the majority of samples with high sulphur content were within the middle of the proposed mining area with coal to the outer edges of the proposed bit all indicating low sulphur content (Zulu, 2017).

Although the sulphur speciation did not differentiate between the different species, to follow a conservative approach the total sulphur content presented was interpreted as sulphide sulphur. With this approach the average and median values for all tested seams illustrate values above the 0.3% guideline value (Price, 2010). The exploration results thus indicate a potential for acid generation and AMD with high variability across the mining area.

However, no prediction on the longevity (short or long term) of the acid producing reactions can be made due to the lack of data on the distribution of sulphide sulphur, sulphate sulphur and organic sulphur. The two last mentioned species will be high in the coal material due to the depositional environment and can influence the classification of the material being acid generating in the long term or short term, or not acid generating at all.

With the potential acid generation highlighted from exploration results, it is of the specialists opinion that any AMD issues will only be significant after operations have stopped during the post-closure phase of the project and not during operation as will be further discussed in section 2.2 based on monitoring results. The planned mining method will include concurrent backfilling of the void as mining continues. This will reduce oxygen ingress into the void which is the main catalyst along with water that increases the likelihood of AMD formation.

Concurrent backfilling along with the groundwater levels being expected to remain below the final mining depth (pit will be dry without dewatering needed) the acid generating potential will be significantly reduced in the post-closure phase as well. The high variability shown in the sulphur content across the mining area in the exploration results does however lead to the recommendation that further kinetic test and modelling work is needed if the environmental geochemistry is to be described in more detail

3 Baseline Groundwater Assessment

In general, both major and minor aquifers exist in the project area which is namely the Dolomite aquifer and Karoo aquifers. The minor aquifer consists of the fractured geology of the Karoo Supergroup with low yields of < 3 L/s while the high yielding dolomitic/karts aquifer forms part of the major aquifer. The minor and major aquifers are separated by the carbonaceous shale and Dwyka tillite/diamictite layers. Alluvium exists in the drainages north -west and south east of the project area

The topography indicates more elevated areas to the south-west in the study area and less elevated areas to the north east. Shallower water levels are found to the north east close to the alluvium and drainage line there. Deeper water levels were measured to the south of the proposed pit area, closer to the drainage line there where the dolomite also outcrops.

3.1 Status of existing boreholes

A detailed site specific, quantitative, hydrocensus investigation was conducted for the Middelbult Area 235IR on July 2016 and April 2017 respectively. The actions performed during this hydrocensus survey are listed below in Table 3-1 and Figure 3-1. The identified boreholes on site visited were fifty four (54) boreholes, of which twenty one (21) boreholes were equipped and in use for Irrigation and Livestock with submersible pumps while fourteen (14) were equipped and in use for domestic water supply and twelve (12) are used for monitoring

Table 3-1 Status of boreholes in the study area

Type of pump	Status	Equipped boreholes	Other Boreholes

	of Boreholes	**In use**	**Not in use**	**Not equipped**	**Destroyed**
No pump	Monitoring		12	**12**	**10**
Electrical Submersible pump	Irrigation & Livestock	20	0		
Electrical Submersible pump	Domestic Water Supply	14	1		
Mono Pump	Domestic Water Supply	**1**			
No Pump	DWS Dolomite Monitoring	**8**			
Total		**56**		**22**	

Hydrocensus statistics for this report were only calculated from the 2016/2017 updated hydrocensus. The hydrocensus survey was conducted in and around the mine lease area as well including Strydpan 243IR, Welgevonden 272IR, Wolvefontein 244IR and Witklip 232 IR and smallholding of Eloff farms.

However, it should be noted that in 2009, Digby Wells, conducted a detailed and comprehensive hydrocensus in the area for Wolvenfontein 244IR as well as including Strydpan 243IR, Welgevonden 272IR, Wolvefontein 244IR and Witklip 232 IR for Kangala Coal Mine, which is an operational Kangala Colliery Mine, all existing boreholes were identified on site namely KGA22 to KGA36 for Middelbult 235IR farm, KAM01 to KAG 21 for Wolvenfontein 244IR Farm and KAG01 to KGA 11 for Witklip 232IR and the Eloff Agricultural holdings KGA 40 to KGA 54.The naming of boreholes was adopted from existing Digby Wells Report conducted in 2009.

Databases containing borehole data on this area have been reviewed in order to form a comprehensible understanding of the present boreholes in the area in terms of their location, status, risks, use, equipment and possible yields.

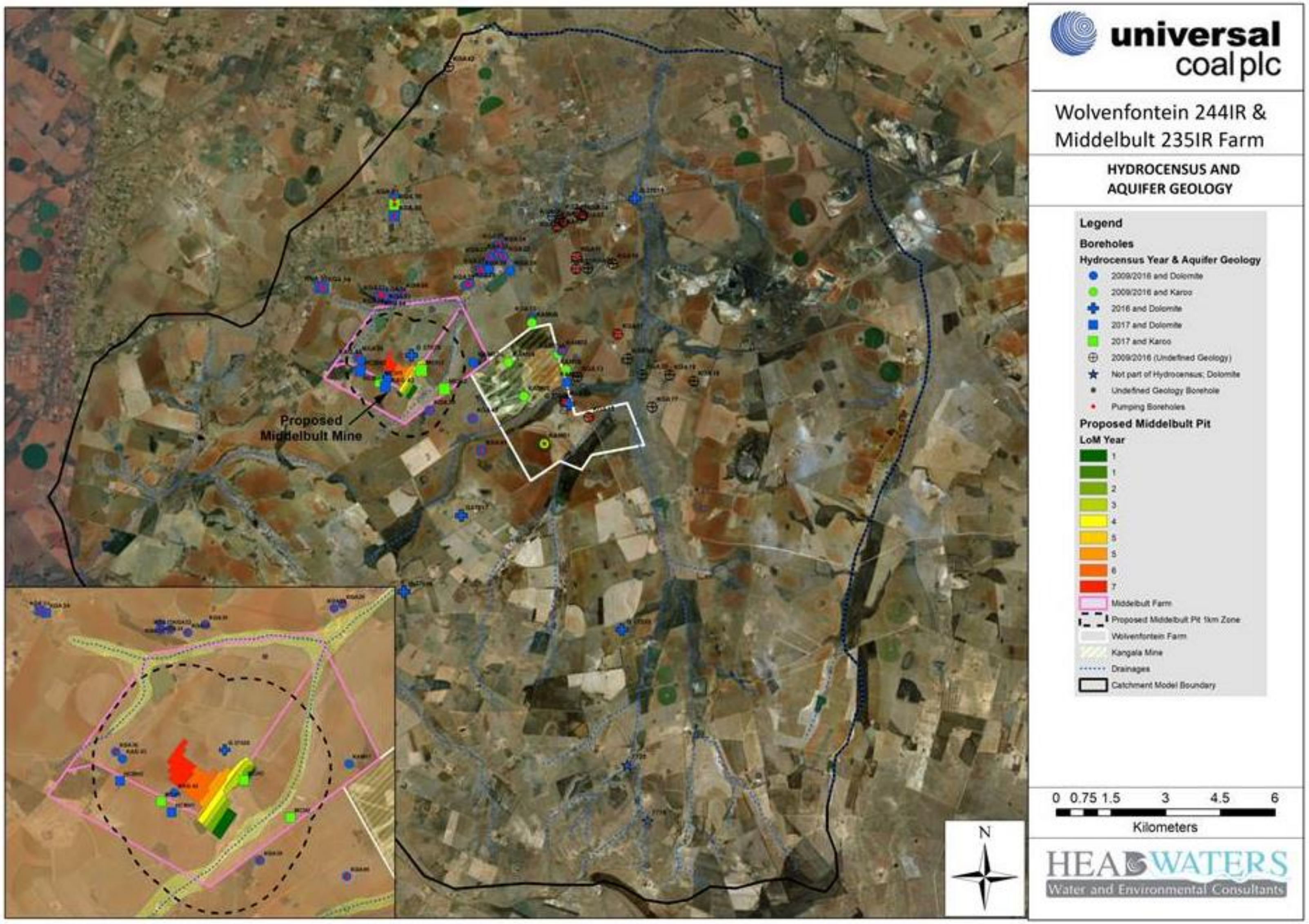


Figure 3-1 Hydrocensus boreholes 2016/2017

3.1.1 Abstraction Rates Delmas

In 2016/2017 hydrocensus estimates were made of possible abstraction from eleven (11) existing boreholes on the Middelbult 235 IR farm portion 80. These estimates amounted to a possible minimum abstraction of 6.942 Mℓ/d for irrigation and domestic use. All boreholes are between 20-30 years old and above. From the hydrocensus conducted annual abstraction from the boreholes was estimated as shown in Table 3-2 and Figure 3-2.

Table 3-2 Annual abstraction rate from hydrocensus

No.	Farm Name	Pump Type	No. of pumps	Yield/Pump (ℓ/s)	Pumping Rate(ℓ/h)	Total yield (m³/d)	Total yield (m³/a)
1	Middelbult Farm 235IR	Submersible Pump	18	Unknown	283240	6798	2 481 270
		Mono Pump	1	Unknown	6000	144	52560
		Bucket & rope	2	Unknown			
2	Wolvenfontein Farm 244IR	Submersible pumps	12	Unknown	54585	1310,04	478 165
3	Wolvenfontein Farm 244IR	Hand Pump	1	Unknown			
4	Witklip 232IR	Submersible Pump	10	Unknown			
5	Eloff Agricultural Holdings	Submersible Pump	5	Unknown	68708,33	1648,99	601881,35
6	**TOTAL**		**49**			**9901**	**3613876**
	Max					**6798**	**2481270**
	Average					**2475**	**903469**
	Min					**144**	**52560**

Middelbult 235IR Farm: They are currently pumping 6.942Mℓ/d based on hydrocensus The exact yields of the boreholes are not known. It is however known that abstraction rates for the pumps were calculated on 60% of the airlift yields at the time of pump installation

Major groundwater interceptions in Middelbult 235 IR are roughly between 87mbgl and 136 mbgl and boreholes depth for abstraction are 140 -200m deep.

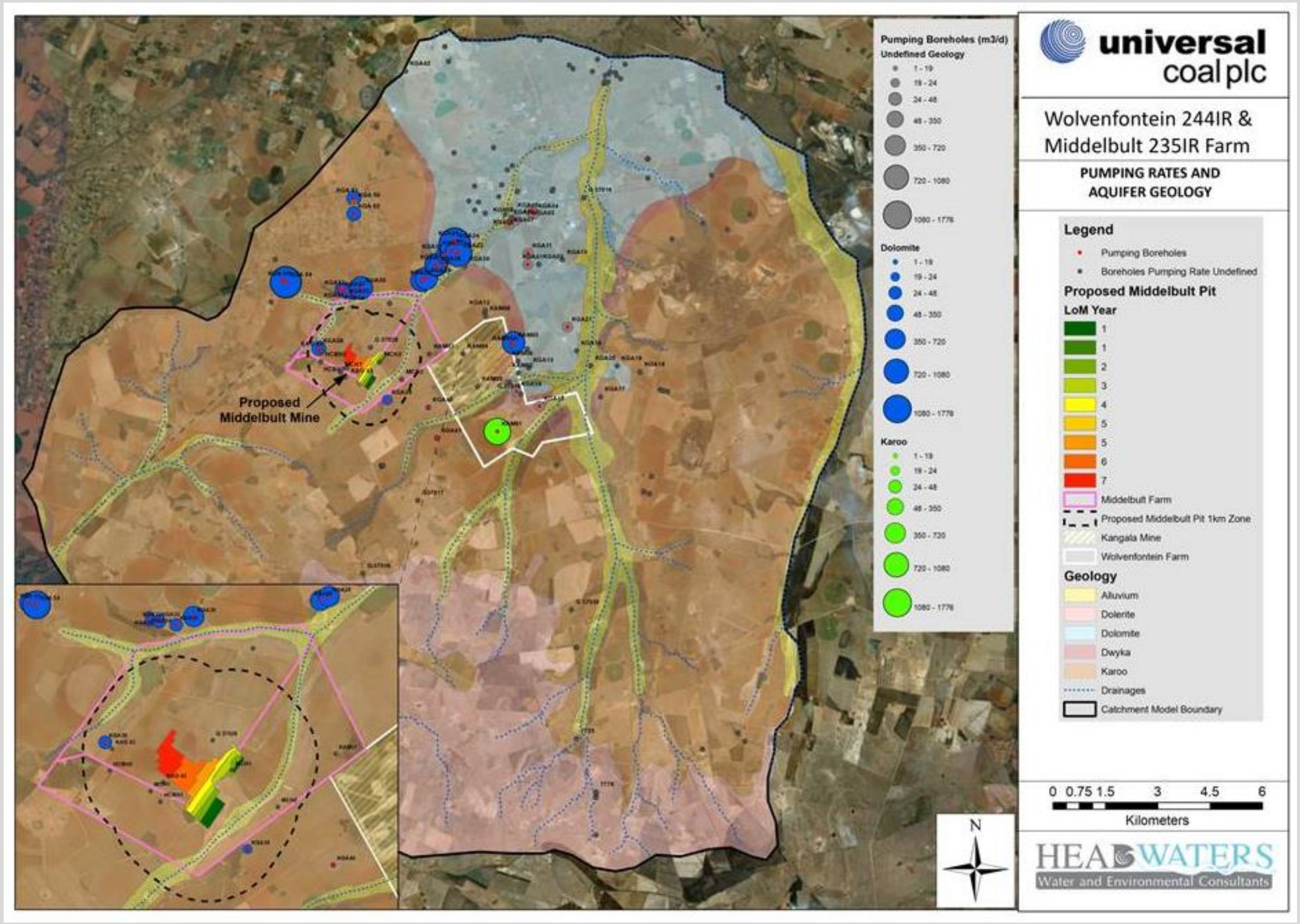


Figure 3-2 Pumping boreholes (Dolomite versus Karoo boreholes)

3.1.2 Baseline piezometric and regional water levels

Twenty five (25) water level measurements were recorded during the hydrocensus. The water levels (or hydraulic heads) were correlated with topographical elevations at the various points and the borehole depth and water levels were also correlated (Table 3-3).

The borehole water level elevation (i.e. head) was correlated to determine whether the water levels follow the topography .The poor correlation (R^2 = 0.37) as shown in Figure 3-3 indicates a heterogeneous system (Dolomite aquifer) with regards to groundwater flow and regime and mostly display the dolomite aquifer system while the Karoo aquifers shows a good correlation of (R^2 = 0.81) as shown in Figure 3-3, showing that water levels follows the topography. One would expect in a virgin environment that the water levels mimic the topographical contours for all aquifers.

Table 3-3 Statistical boreholes depth and their water levels

No	Component	Statistical Analysis	Borehole Depth(m)	Water Levels(mbgl)
1	Dolomite Aquifer	Average	118.1	25.4
2		Min	79.9	2.5
3		Max	212.0	57.7
4		95th Percentile	202.4	48.0
5		5th Percentile	80.0	3.8
6	Karoo Aquifer	Average	71.7	10.4
7		Min	60.0	7.5
8		Max	80.0	18.0
9		95th Percentile	80.0	16.3
10		5th Percentile	60.0	7.6

The correlation between the water levels and borehole depth for the Karoo shows a poor correlation (R^2=16) while for the dolomitic aquifers shows a correlation of (R^2=70).Due to a lack of geological and construction logs of the boreholes, it must be noted that some of the boreholes located in the Karoo geology, may have been drilled through the Karoo strata into the underlying dolomite aquifer. The water levels and water quality in these boreholes may therefore be a mixture of both Karoo and dolomite aquifer water, which minimise level of assurance in terms of the borehole groupings (Figure 3-3).

Water levels were measured in the project area surrounding the proposed pit area. Water levels were measured in both the upper minor aquifer (core boreholes) and the basal major dolomitic aquifer (air percussion boreholes). The water levels of the basal dolomitic aquifer are deep and on average vary from 25m mbgl to 60 mbgl with an average boreholes depth of 118mgbl.The water level distribution of the fractured Karoo aquifer varies from 7 mbgl to 10 on average with a maximum of 20mbgl (Table 3-3 and Figure 3-3) and average borehole depth of 70mbgl

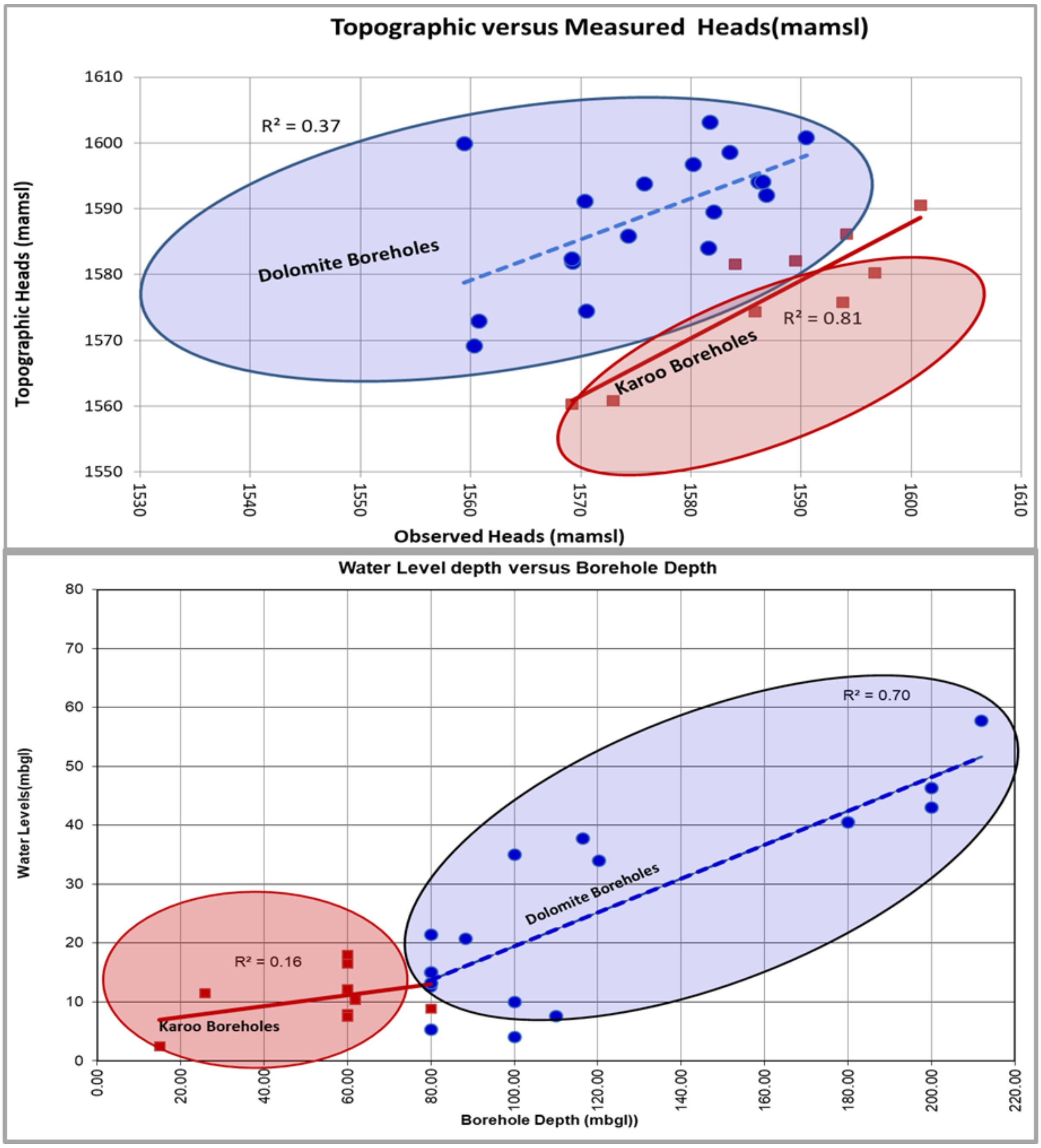


Figure 3-3 Water level depth versus borehole depth distribution

3.2 Recharge Estimates from Cℓ mass balance method (CMB)

The chloride mass-balance method can provide, under certain conditions, a time-integrated technique for evaluation of recharge flux to regional aquifers that is independent of physical parameters. The chloride mass-balance (CMB) in arid and semiarid environments is economical and provides insights into the nature of recharge that are difficult and expensive to obtain with physical-based methods. Other recharge methods other than mentioned above were not applied because they require enough representative data which is currently not available for this study.

The method is based on the fact that, chloride is a conservative element and is not taken from the soil by vegetation in its simplest form structure; the chloride is represented by the following relationship,

Where RE = Recharge;

CL_{rain} = Chloride from rainfall (mg/L);

CL_{gw} = Chloride in groundwater (mg/L),

R_f = Rainfall (mm/y).

It has been stated that application of the Chloride Mass Balance (CMB) methodology in Southern African geo-environments should be applied with great care and consideration. Isolated and accumulated collection of rainwater/groundwater samples is not advisable as the variation in rainwater and groundwater chloride content in time and space could be significantly high (>40%), as was observed.

Concentrations of chloride in rainwater are between 0 and 2 mg/L and for this study an average value of chloride in rainfall (CL_{rain} = 1 mg/L) was used which is equivalent or approximately equals to one (1). Numerous studies have been conducted to determine the effective recharge of an aquifer.

Based on the chloride method of recharge estimation, the aquifer recharge is high in Delmas areas as shown in (Table 3-4) and conservative recharge estimations were used in the model.

Table 3-4 Statistical recharge calculated from the chloride concentrations

No	Component	Statistical Analysis	Cℓ(mg/ℓ)	Recharge e	mm/yr	m/d
				(%)		
1	Dolomite Aquifer	**Average**	15.77	10.30	70.00	0.19
2		**Min**	2.74	1.98	13.44	0.04
3		**Max**	50.60	36.50	248.18	0.68
4		**95th Percentile**	35.31	23.94	162.78	0.44
5		**5th Percentile**	5.26	11.22	76.29	0.21
6	Karoo Aquifer	**Average**	5.72	22.45	152.64	0.42
7		**Min**	2.75	10.54	71.65	0.20
8		**Max**	9.49	36.36	247.27	0.68
9		**95th Percentile**	9.03	36.23	246.39	0.68
10		**5th Percentile**	2.76	11.22	76.29	0.21

4 Groundwater Modelling and Impact Assessment

Headwaters cc assembled a numerical groundwater flow model for the proposed Middelbult open cast (Project site). The model incorporated the detailed mine-scale geological unit. The numerical groundwater flow model was populated with newly acquired hydrogeological data obtained during fieldwork that was conducted to assess localized hydrogeological conditions. Information from falling head and aquifer tests were used to gain an understating of the flow regime associated with the hydrogeological setting. Other data used in conceptual model design and numerical model construction was compiled from a range of different sources. These include:

- Reports on geological, geotechnical and environmental investigations of the Delmas area within quaternary catchment B20A and the existing bordering farms
- Published regional geological maps and previous geohydrological reports
- Digital terrain model (DTM) for the B20A quaternary catchment
- GH Reports(1986) from the Department of Water and Sanitation (DWS)

4.1 Conceptual Model

Based on the interpretation of the available and gathered geological and hydrogeological information of the area, a conceptual hydrogeological model was developed as an adequate description of the groundwater system. The basic components of a conceptual hydrogeological model are the primary hydrogeological units derived from the geological settings of the area and the groundwater flow in the area. The components then serve as an input and basis for the numerical model as shown below in Figure 4-1 and Table 4-1.

4.2 Hydraulic parameters and permeability of Dwyka tillite

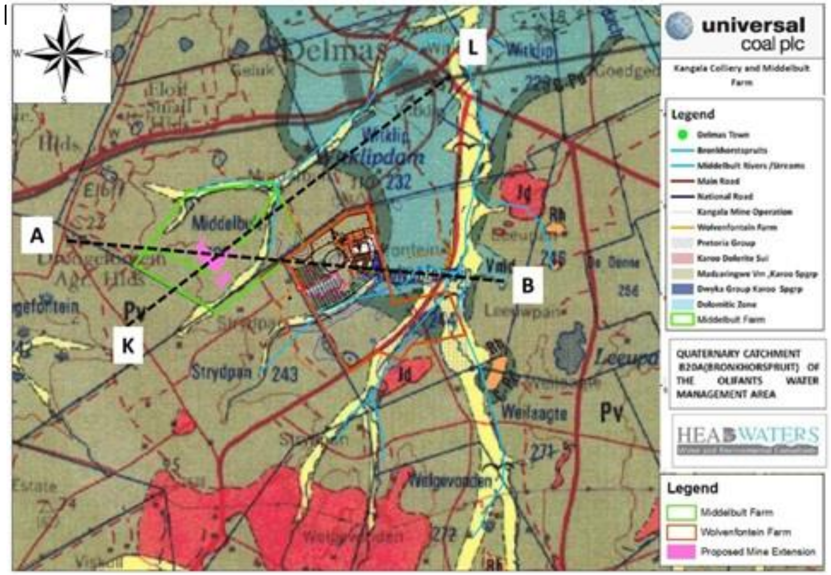
Middelbult field investigations including geophysics, packer tests, falling heads and a pumping test were performed for this study to determine hydraulic parameters for the geology present in study area as well as evaluate the presence of definite vertical fractures or geological lineaments. This was done in order to evaluate the possibility of direct hydraulic links between the proposed coal seam and shallow aquifer up to the No. 2 Seam floor and the deep dolomitic aquifer below. There are beds of siltstone/shale/fine-grained sandstone as well as Dwyka diamictite present between the coal floor (proposed pit floor) and the deep dolomitic aquifer as shown by drilling results. These geological strata were especially evaluated for their hydraulic parameters to determine whether these strata layers together constitute a geological barrier between the open cast mining and the deep dolomitic aquifer.

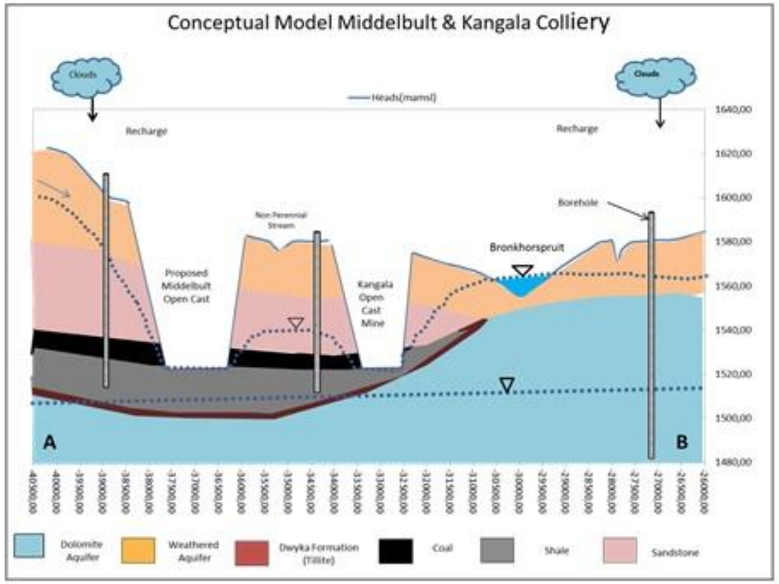
The geophysical survey did not indicate any lineaments/anomalies of regional fracture/dyke zones that could form a link between the Karoo aquifer and the sensitive dolomitic aquifer

As data becomes available, the groundwater flow model and management scenarios should be updated. The recharge values were based on rainfall data collected for this area from 1974 to 2010.Table 4-1**Error! Reference source not found.** summarises the input parameters and recharge values (Table 3-4) used to populate the numerical groundwater model.

4.3 Recharge

The study area is generally characterised by moderate summer rainfall .The average rainfall in the study area is 669 mm per annum. The rainfall distribution and total rainfall is typical of the Highveld region. For Middelbult area the recharge to typical Karoo aquifers/aquitards vary between 2 and 6% of the mean annual rainfall, while higher recharge percentages between 2 and 16% can be expected for dolomitic aquifers (Table 3-4). Recharge to the weathered aquifer drains towards the regional surface water courses and less than 60% of the recharge discharge in streams (Digby Wells, 2009).


universal coal plc
Kangala Colliery and Middelbult Farm
Legend
Delmas Town
Bronkhorstspruits
Middelbult Rivers /Streams
Main Road
National Road
Kangala Mine Operation
Wolvenfontein Farm
Pretoria Group
Karoo Dolerite Sui
Madzaringwe Vm ,Karoo Spgrp
Dwyka Group Karoo Spgrp
Dolomitic Zone
Middelbult Farm
QUATERNARY CATCHMENT B2DA(BRONKHORSPRUIT) OF THE OLIFANTS WATER MANAGEMENT AREA
HEADWATERS
Legend
Middelbult Farm
Wolvenfontein Farm
Proposed Mine Extension
A
B
K
L
Delmas
Klipdam
Middelbult
Strydpan 243


Conceptual Model Middelbult & Kangala Colliery
Clouds
Clouds
Heads(mamsl)
Recharge
Recharge
Non Perennial Stream
Borehole
Bronkhorspruit
Proposed Middelbult Open Cast
Kangala Open Cast Mine
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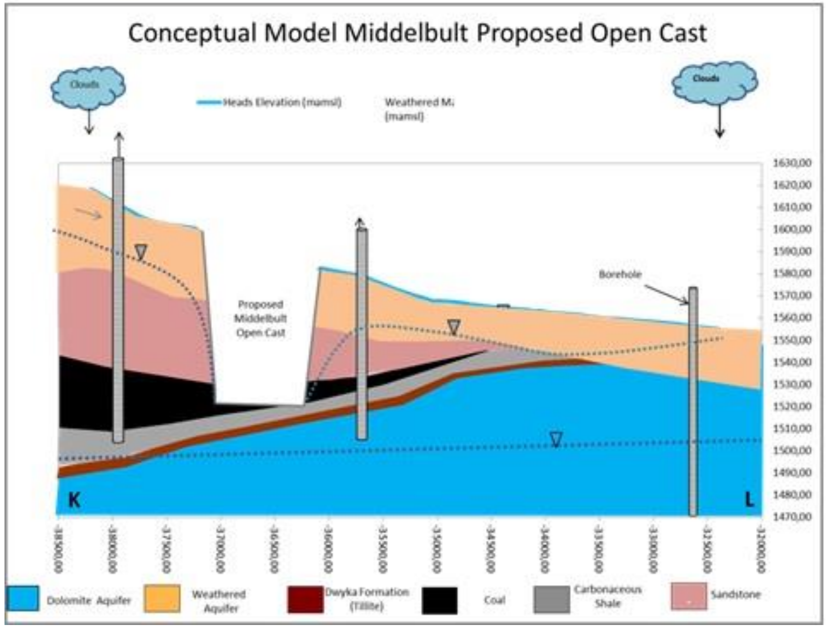
Dolomite Aquifer
Weathered Aquifer
Dwyka Formation (Tillite)
Coal
Shale
Sandstone


Conceptual Model Middelbult Proposed Open Cast
Clouds
Clouds
Heads Elevation (mamsl)
Weathered M. (mamsl)
Proposed Middelbult Open Cast
Borehole
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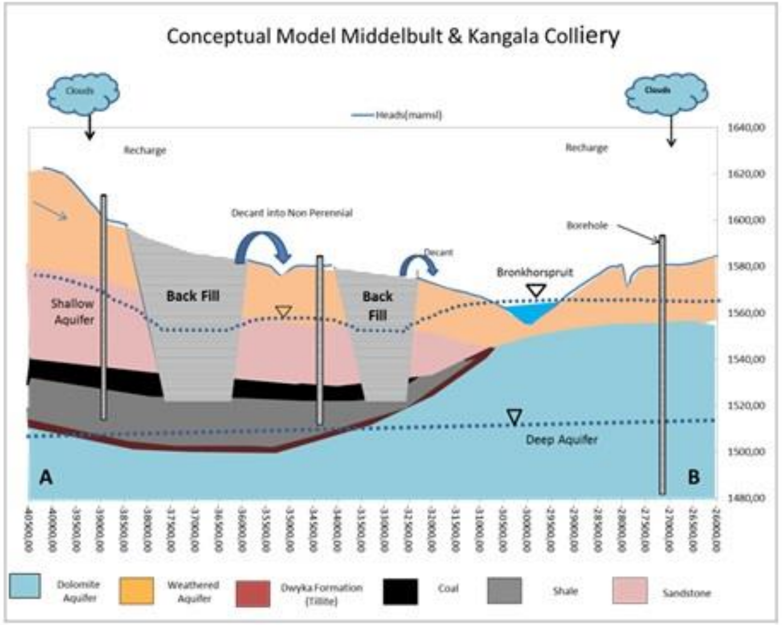
Dolomite Aquifer
Weathered Aquifer
Dwyka Formation (Tillite)
Coal
Carbonaceous Shale
Sandstone


Conceptual Model Middelbult & Kangala Colliery
Clouds
Clouds
Heads(mamsl)
Recharge
Recharge
Decant into Non Perennial
Decant
Borehole
Bronkhorspruit
Shallow Aquifer
Back Fill
Back Fill
Deep Aquifer
A
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1640,00
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1500,00
1480,00
Dolomite Aquifer
Weathered Aquifer
Dwyka Formation (Tillite)
Coal
Shale
Sandstone

Table 4-1 Hydraulic parameters used in model for Middelbult Farm

Zone	Hydraulic Zone	Hydrogeological unit	Layer	Thick- ness (m)	Trans- missivity (m^2/d)	Hydraulic Conductivity (m/d)		Stora- tivity (1)	Specific Storage (1/m)	Aquifer Tests				
						Kxy (m/d)	Kz(m/d)			Packer Test (K m/d)	Falling Head (K m/d)	Lab Test (K m/d)	Constant Discharge (T m^2/d)	Reference
1	Alluvium	Localised aquifer zone	1	10	25.00	2.50E+00	2.50E-01	5.00E-03	5.00E-04					
2	Weathered/fractured Karoo Sandstone/Siltstone	Minor Aquifer		10	3.00	3.00E-01	3.00E-02	1.00E-03	1.00E-03	8.21E-02	6.45E-04		2.20E-01	Digby Wells Aquifer Test 2009,2011& 2014 Reports
2	Solid/fractured Karoo Sandstone/Siltstone	Minor Aquifer		10	0.30	3.00E-02	3.00E-03	1.00E-03	1.00E-03	8.21E-02	6.45E-04		2.20E-01	Digby Wells Aquifer Test 2009,2011& 2014 Reports
3	Karoo Dolerite	Aquitard		10	0.30	3.00E-02	3.00E-03	1.00E-04	1.00E-03	8.21E-02	6.45E-04			
4	Solid Fractured Karoo	Minor Aquifer	2	25	0.50	2.00E-02	2.00E-03	1.00E-03	4.00E-04	5.19E-04				
5	Coal/Seam	Aquitard	3	3	0.06	2.00E-02	2.00E-03	1.00E-03	3.33E-03					Mining zone
6	Carbonacesous Shale	Aquitard / Aquiclude	4	2.7	3.70E-05	1.37E-05	1.37E-06	1.00E-03	3.70E-03	7.14E-03				
7	Dwyka Tillite Formation	Aquitard / Aquiclude	5	2.7	3.70E-05	1.37E-05	1.37E-06	7.41E-03	3.70E-03	2.49E-02	7.11E-04	1.37E-05		
8	Malmani Botleng Dolomite Aquifer	Major Aquifer	1 to 6	100	120.00	1.20E+00	1.20E-01	2.00E-04	1.00E-04				9.49-99.10	Exigo 2017 Report & Digby Wells Aquifer Test 2014 Report
			Min		3.70E-05	1.37E-05		1.00E-04	1.00E-04	5.19E-04	6.45E-04	1.37E-05		
			Average		1.66E+01	4.56E-01		1.97E-03	1.64E-03	4.65E-02	6.62E-04	1.37E-05		
			Max		1.20E+02	2.50E+00		7.41E-03	3.70E-03	8.21E-02	7.11E-04	1.37E-05		
			95th Percentile		8.20E+01	1.98E+00		6.44E-03	3.70E-03	8.21E-02	7.01E-04	1.37E-05		
			5th Percentile		3.70E-05	1.37E-05		1.40E-04	2.20E-04	2.17E-03	6.45E-04	1.37E-05		

4.4 Activity Life Description (LOD)

The proposed expansion for Middelbult Farm 235 IR Life of Mine (LoM) is estimated at seven (7) years and the surface area of the proposed pit is 67ha or 672571m^2 as shown in Figure 4-2.

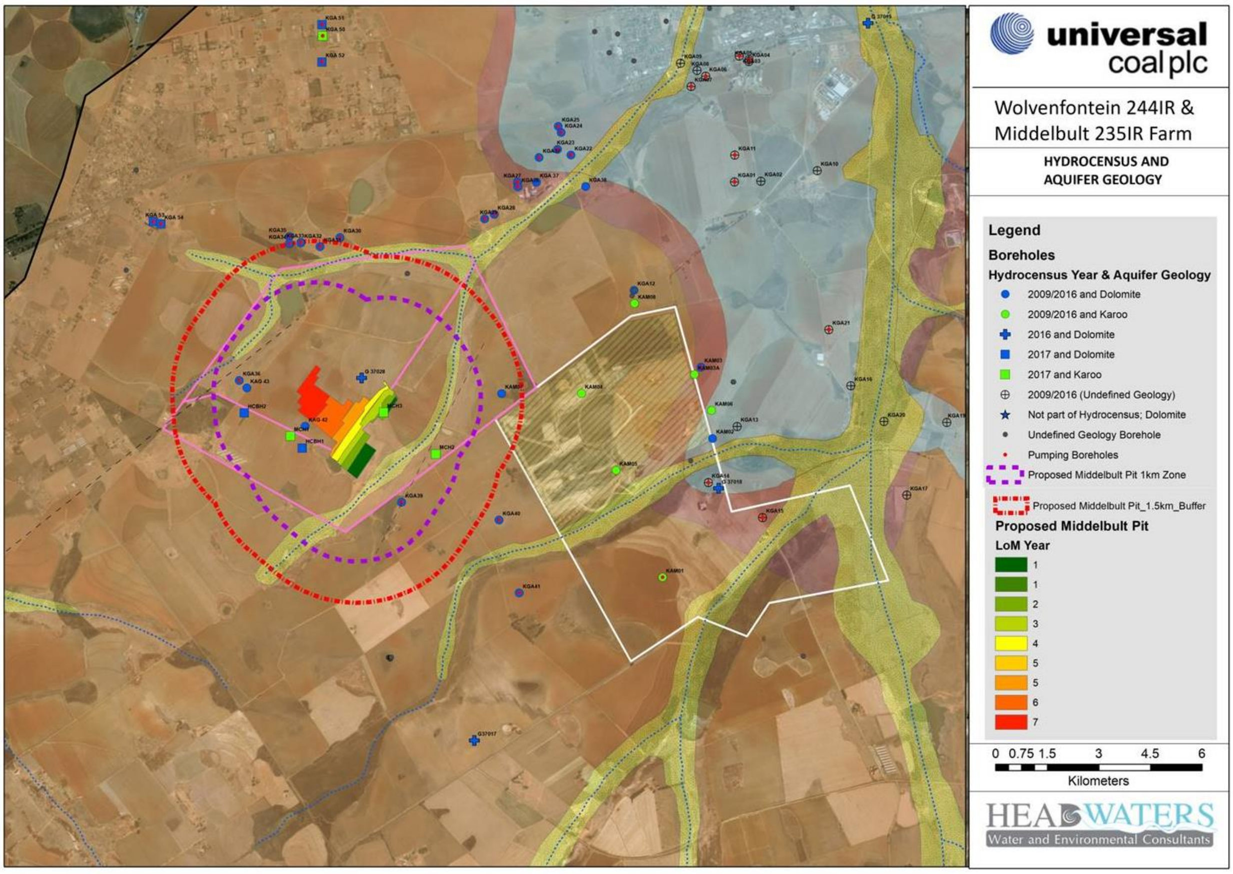

Figure 4-2 Preliminary mining schedule map

4.5 Model Setup

For the proposed open cast mine model, a numerical groundwater flow model was developed using the modelling package FEFLOW 6.1.Details of this software are provided at www.FEFLOW.info.

4.5.1 Modelling Software Selection

The modelling software selected for constructing and simulating the Middelbult proposed open cast pit groundwater model is FEFLOW.FEFLOW was selected for construction of the model because it is a highly interactive groundwater modelling system capable of simulating flow in two or three dimensions for uncoupled, variably saturated, transient or steady state flow. Specifically, FEFLOW is a finite-element based model with the ability to simulate flow of groundwater through complex geology in three dimensions(3D). Additionally, different pit geometries and dewatering strategies can be incorporated into the model so that the response of the groundwater system can be predicted. Furthermore, FEFLOW can be used to evaluate the spatial and temporal distribution of groundwater flow associated with the proposed mine dewatering plan.

4.5.2 Model Domain and Finite Element Network

The model domain covers an area of 400km², differentiated into a finite element network with 464418 mesh elements and 272986mesh nodes (Figure 4-3).Six(6)layers were included in the model domain .Refinement around specific features was done with the mesh generation due to calibration purposes. The mesh was smoothed as well to increase the quality and eliminate sharp angles that will destabilize the model domain and cause lengthy simulations in transient state.

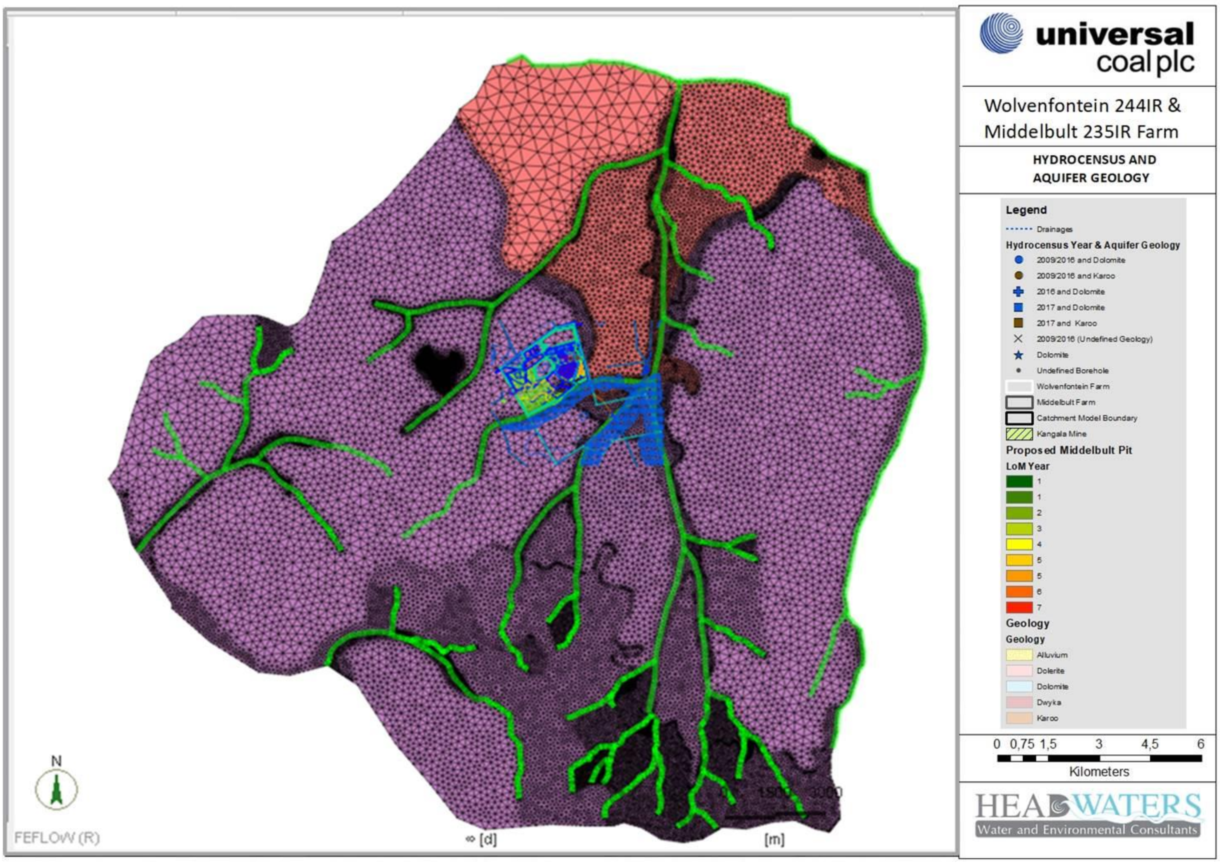

Figure 4-3 Model network and mesh construction

4.5.3 Model Limitations

The following assumptions were made with listed limitations:

1. Prior to development, the system is in equilibrium and therefore in steady state.
2. The accuracy and scale of the assessment will result in deviations at specific points e.g. on the boundaries of mine layout areas however this effect is minimal and the selected mesh elements would represent the footprint of specific infrastructure.
3. The three dimensional domain represent both the shallow(Karoo) and deep aquifer(Dolomite) system in order to incorporate the deep water strikes observed during the drilling and hydrocensus program.
4. The base model developed for calibration purposes did not include any dewatering operations, thus no stresses to the aquifer system were included, and so the system was in equilibrium (steady state).
5. Actual aquifer parameters for the study area are statistically well described and fifty four (54) existing boreholes within the proposed mining area, but only twenty five (25) formed the basis for the aquifer parameter estimates as input values into calibration of the groundwater flow model.
6. The Karoo aquifer (such as the one underlying the Middelbult Farm 235IR area is a highly complex system and is by no means homogeneous. The future predictions that were calculated with the calibrated groundwater flow and contaminant transport models are simplified versions of reality.

7. The water levels of abstraction boreholes used for irrigation and domestic use within the vicinity are unknown and these boreholes are estimated to be pumping an amount equivalent to 6.942Mℓ/d for the past 20-30 years without measuring water levels patterns. Only two (2) water levels from pumping boreholes were known and the rest no access was available during hydrocensus. This implies that currently, model validation through history matching cannot be performed and the model was calibrated on a snapshot of hydraulic heads that were available for a specific date. Water levels must be recorded over time as well as existing time series data combined and used to re-calibrate the model.

8. For lithological units different than that of the immediate study area hydraulic

parameters from literature were used for specific types of geology.

9. Monitoring borehole data (water levels) was only available within the immediate mining area and the surrounding farms.
10. Sections of the model domain were therefore not thereby affecting the confidence level of the model.
11. Only two (2) water levels from pumping boreholes were known and the rest no access was available during hydrocensus
12. Considering the spatial extent of the model domain and rainfall stations within the study area, rainfall data from a single station was used to represent entire study area. Once the model was calibrated, the mine proposed pits were incorporated into the model by applying drains to discharge water from the aquifer system.
13. The stream was constrained such that no water leaked from the streams to the groundwater system. By constraining infiltration
14. When the modelling assumptions were made or reference values used, a conservative approach was followed such that the trend was to overestimate groundwater discharges from dewatering .This gives a worst-case scenario for designing the dewatering system and impacts to the receiving environment .It should be noted that dewatering volumes should be less than those simulated by the model.

4.5.4 Model Simulations Conditions

The groundwater flow model was simulated in both steady state and transient state to simulate initial groundwater elevations, flow velocities and directions. Steady state (no time and storage) this means it has no influence on time and storage. In steady-state simulations, the number of variables is reduced since some of the variable inputs such as storage do not change with time thus simplifying the calibration process. A simple model approach will be to calibrate e.g. water levels, only transmissivity and recharge values are used and are adjusted to obtain an acceptable fit of simulated water levels to those observed or measured head.

In transient simulations (time and storage) takes into account time, storativity and time dependent recharge variables. Transient state simulations use many of the same variables as in steady state but they vary over a finite time period. Therefore, the unwanted influences of model boundary and contacts with hydrogeological features can be reduced with transient simulations since time is not infinite The model used is a 3-D (three-dimensional) finite element flow model that represents hydrogeological conditions surrounding the mine site. The model was based on data collected during hydrocensus and from recent drilling and testing. The model was first calibrated in steady state to obtain an acceptable fit of measured vs. simulated hydraulic heads. After completing the steady state calibration, a transient simulation was constructed to assess the effects from induced stress to the aquifer system from mine dewatering scenarios. The proposed new pit development layouts and associated infrastructure (mine schedule) were provided by the client.

4.6 Model Boundaries

Boundary conditions determine and regulate the initial conditions at the edges of the model domain and control the response during the simulation. They (boundary conditions) can be fluxes into or out of the model domain as well as hydraulic heads (constant heads).Application of these boundary conditions in various methods results in different solutions. Therefore, it is important that the numerical groundwater modeller selects the appropriate boundary conditions to offer and provide an accurate representation of the model to actual conditions. For the study boundary conditions used in a groundwater flow model were specified either as:

i. Dirichlet Type (or constant head) boundary conditions or;
ii. Neumann Type (or specified flux) boundary conditions; or
iii. A mixture of the two above.

A model was set-up to cover all the proposed expansion activities on Middelbult 235IR farm including the potential impacts. The model domain, taking cognisance of the above was chosen according to natural flow boundaries (water divides and rivers).The study area falls within the B20A quaternary catchment, Bronkhorstspruit and non-perennial streams were presented as a constant head boundary to simulate groundwater discharge

4.6.1 Interior model features

The groundwater system within the project area is recharged by precipitation that infiltrates through the weathered top layer. All the drainages in the modelled area were assigned constant head values along the streams to allow the model to simulate base flow to the streams from the groundwater system. These constant head values were specified in the model to be topographical elevations at same locations along the stream courses.

The use of constant head conditions allows the model to simulate groundwater discharge to the streams at a rate dependent on the stream's conductance (streams bottom hydraulic conductivity) and hydraulic gradient between the streams bottom and the potentiometric level of the adjacent aquifer unit. The constant head nodes in the model that represent the streams were held constant throughout the steady-state model simulation so that water could only drain from the aquifer system towards the streams. This model configuration does not allow the hydraulic gradient to reverse back towards the aquifer from the surface system and therefore does not allow water to enter the aquifer from the surface water system. This configuration represents a true "drain type" condition for these internal model features.

4.6.2 Model base boundary condition

The model domain was assigned to extend vertically to a depth of 400m. It is assumed that the base of the model is impermeable.

The mine development stages were simulated as follows:

1. Scenario 1: Current steady state conditions and initial groundwater regime
2. Scenario 2: Dewatering for a period of seven(7) years of mining period
3. Scenario 3: Mass transport from rehabilitated pit and tailings
4. Scenario 4: Post mining operations and rehabilitation over 100 year period

4.6.3 Scenario 1: Current steady state conditions and initial groundwater regime

The model was calibrated in steady state based on the known geological and hydraulic head distribution data for the project site. Calibration was accomplished iteratively by adjusting recharge and hydraulic conductivity values until a reasonable fit between the measured and simulated heads were obtained. The measured data consists of head elevation data from 21 boreholes.

4.6.4 Model Calibration and Sensitivity Analysis

The objective of the model calibration process was to demonstrate that the model was capable of simulating hydraulic heads that match as close as possible the observed heads in Delmas proposed expansion open cast groundwater levels. The calibration process involved the continual adjustment of hydrogeological parameters including recharge, hydraulic conductivity and specific storage until the closest match between model predicted water levels and field measured water levels was obtained. Calibration was done into two (2) stages that is steady state calibration and transient state calibration. The aim of the steady state calibration was to represent the average (i.e. long term) groundwater conditions at the Middelbult 235IR Delmas Aquifer. The resulting groundwater heads of the steady state model are used to initialise the transient groundwater models for transient calibration and predictions.

The aquifer parameters and boundary conditions determined during steady sate calibration were applied to the transient state model for manual calibration. The transient state calibration satisfied an adequate match to observed groundwater levels affected by abstraction and any modifications to the model during transient calibration required a re-assessment of the steady state calibration. The numerical model was calibrated and adjusted in steady state by keeping the model complexity to minimum. Calibration was achieved by varying recharge, hydraulic conductivity, river-bed conductance and abstraction rates from existing abstraction boreholes within their acceptable range in order to fit the simulated groundwater levels to observed groundwater levels. The quality of the fit between simulated and observed water levels was visually evaluated based on the elevations of the simulated hydraulic heads and by means of a statistical analysis.

The head elevation data from 20 observation boreholes were used to calibrate the steady-state flow model, six (6) of the boreholes had deep waters levels and couldn't be calibrated during steady state. The steady-state calibration of the measured and the simulated water levels resulted in an acceptable correlation of $R^2 = 0.71$ for the Karoo boreholes and $R^2 = 0.28$ for the Dolomite Boreholes and this is because of high pumping of Dolomite Aquifer and the boreholes are not following the topography Figure 6-6 and Table 6-2 below, shows the difference between observed and simulated heads from the calibration process.

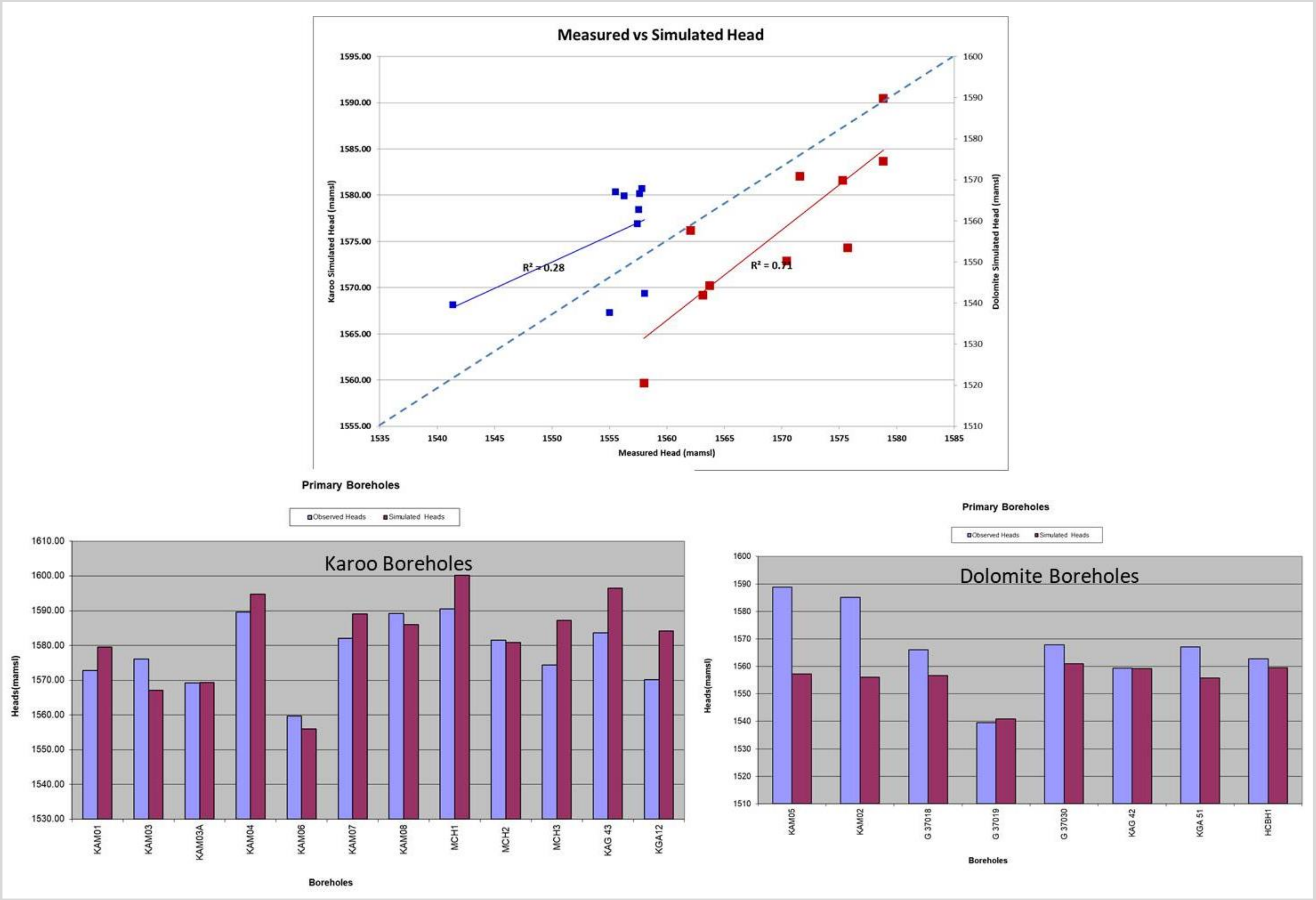

Figure 4-4 Dolomite and Karoo simulated versus measured calibrated heads

Table 4-2 Statistical model calibration –simulated versus measured heads

No.	Component	Statistical Analysis	Observed Heads	Simulated Heads	Errors	ABS Error
1	**Dolomite Boreholes**	**Max.**	1591.7	1561.0	1.3	1591.7
2		**Min.**	1539.6	1540.9	-1591.7	0.1
3		**Average**	1567.1	1555.8	-322.4	322.7
4		**95th Percentile**	1590.0	1560.4	7.6	1562.1
5		**5th Percentile**	1531.5	1547.2	-1562.1	0.8
6		**Correlation**	**0.53**			
7	**Karoo Boreholes**	**Max.**	1590.5	1600.3	13.9	13.9
8		**Min.**	1559.7	1556.0	-9.1	0.2
9		**Average**	1578.3	1582.6	4.3	7.1
10		**95th Percentile**	1590.0	1598.2	13.4	13.4
11		**5th Percentile**	1564.9	1562.1	-6.1	0.5
12		**Correlation**	**0.82**			

The model was calibrated in steady state with the parameters mentioned in Table 4-1. Measured water levels were compared with simulated water levels to get an acceptable fit which would represent a realistic aquifer system as it might be in nature. Table 4-2 indicates the fitted data as observed at all boreholes with known water levels. The groundwater balance (Table 4-3) indicates approximately 20,865m^3/d coming into the system from precipitation and subsequent recharge with almost the same rate of outflow through the drainages. A preliminary regional groundwater balance is presented for the various scenarios discussed in the previous section. There is an inflow/source of approximately 20865m^3/d (242ℓ/s) into the groundwater system of the model domain from groundwater recharge (Table 4-3).

The objective of the steady state model is to simulate the undisturbed groundwater status quo groundwater levels. The hydraulic head distribution of the steady state solution is then used as initial head distribution for the transient (time-dependant) model .The transient model time steps were divided into a 1 year period with 12 time steps. Current groundwater flow directions are from south to north directions in the direction of Bronkhorstspruit and in the middle of the model domain the localised depression on the head values indicates the dewatering impact of the proposed expansion existing pit.

Table 4-3 Initial steady state groundwater budget

No.	Component	Inflow (m³/d)	Outflow (m³/d)	Balance (m³/d)
1	Recharge Dolomite Aquifer	11366		11366
2	Recharge Karoo Aquifer	9288		9288
3	Recharge Open Cast Mine	31		31
4	**Existing Abstraction**			
5	Middelbult 235IR		-6942	-6942
6	Wolvenfontein 435IR		-1310	-1310
7	Eloff Holdings		-1649	-1649
8				
9	Baseflow and Losses		-10815	-10815
10	**Total**	**20685**	**-20716**	**-31**
11	**Imbalance (%)**			**0**

4.7 Piezometric Heads and gradients

The piezometric heads and gradients for the calibrated model showed that the gradient and general flow follows the topography which is from south-west and south-east to the north, via the Bronkhorstspruit towards the Bronkhorstspruit Dam, as base as shown below.

The general drainage direction is south to north in the study area and the groundwater drains in a northerly direction. The head constrained boundary conditions at both non-perennial and perennial streams including the Bronkhorspruit River influences groundwater to drain down gradient towards drainages and the Bronkhorspruit Dam

The piezometric head follows the topographic gradient for the Karoo aquifer while the Dolomitic aquifer doesn’t follow topography possibly due to high pumping of Dolomitic aquifer.

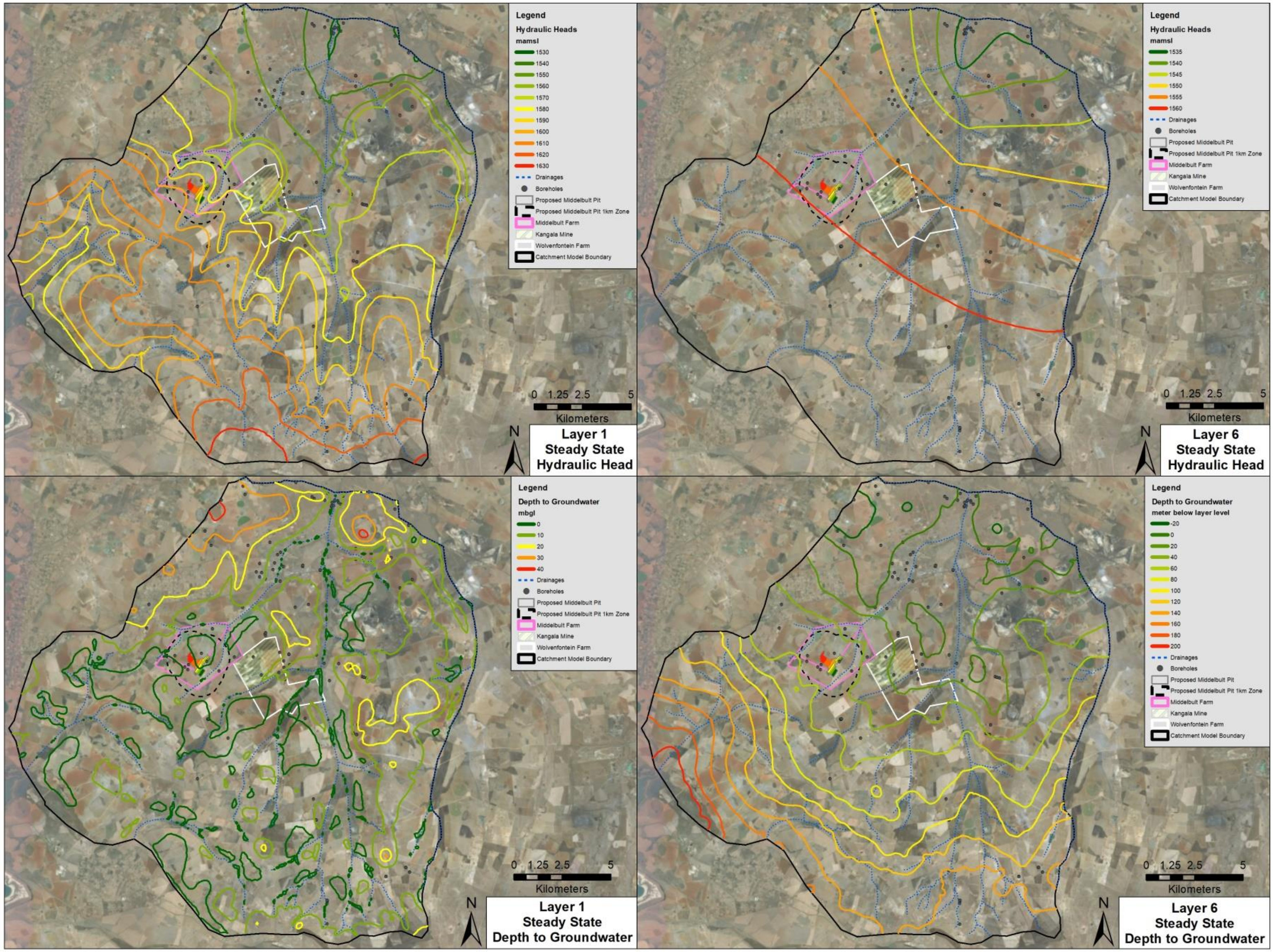

Figure 4-5 **Steady state and depth to groundwater levels map**

4.8 Transient Model

The transient state model calibration was conducted predominantly to estimate the aquifer storage values. The predictive model was setup according to the mine plan to estimate the inflow rates. The transient model is also applied to predict the cone of dewatering and contamination plume originating from potential sources. Aspects of the predictive model are discussed below.

Key aspects of the water balance are during transient state is summarised as follows (Table 4-4): The water balance of the aquifer during mining is altered due to inflows into the pits and has potential impacts on the water levels within and around the existing farms and subsequently on the aquifer water balance.

Scenario 2: Dewatering over seven (7) year mining period

Figure 4-6 indicates the simulated dewatering volumes. Initial dewatering equates to 0m³/d when mining commences as the water table has not been intersected. However, dewatering should commence within approximately one (1) to three (3) month of mining. The dewatering rates will increase gradually as the pits increase with depth, exposing larger areas to dewatering. The simulated dewatering rates peak at approximately ranges between 500m^3/d to 900m³/d for the first four (4) months of dewatering after which the mine will only dewater 100m^3/d or less throughout the life of mine(LoM). Due to the heterogeneity of the aquifer, dewatering rates could differ and the model should be updated once new monitoring data becomes available, to narrow the band of uncertainty and increase the confidence levels associated with the data.

The dewatering scenario was simulated for a seven (7) year period i.e. LoM. The open pits were simulated as drains in the numerical groundwater flow model, increasing with time as the mining progresses. The simulation indicated a maximum zone of influence (ZOI) depth located at the open pits approximately 40min depth (Figure 4-7). The maximum lateral extent of the ZOI is approximately 1km and less from the centre positions of the pits. No detectable and observable interaction is observed between Dolomitic aquifer and Karoo aquifer due to possible Tillite formation which acts as a barrier between the proposed open cast pit and the Dolomitic aquifer

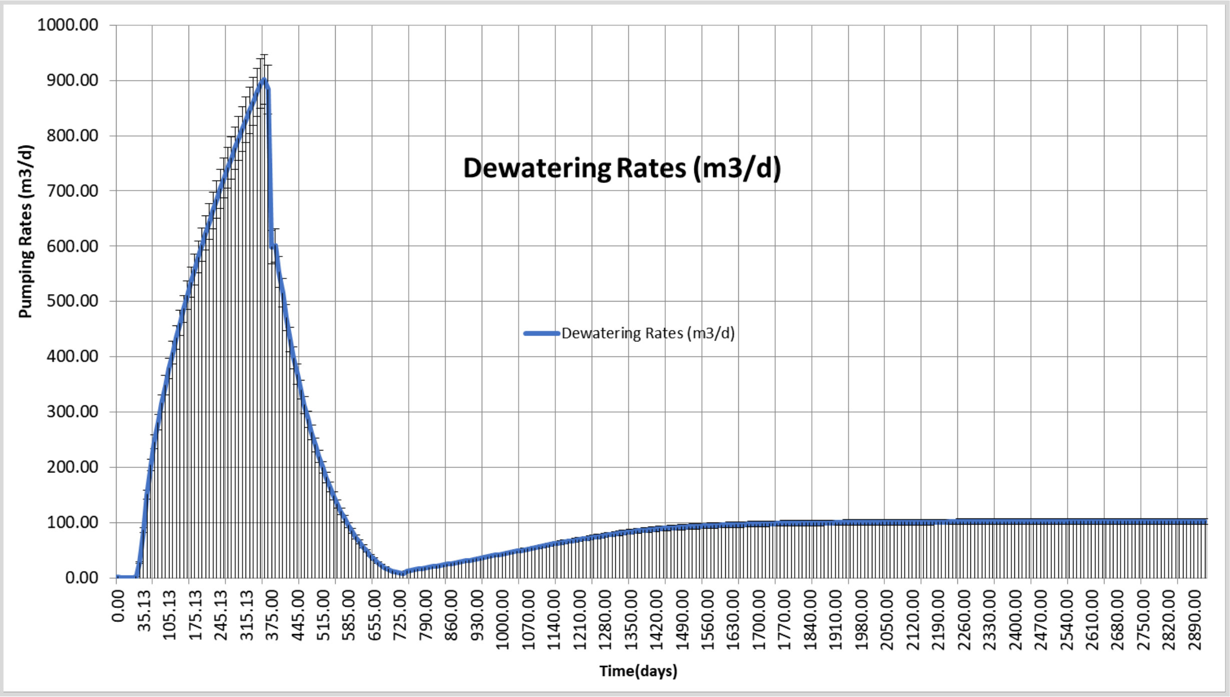

Figure 4-6 Dewatering rates for the pit

Table 4-4 Mine dewatering Groundwater budget

No.	Component	Inflow (m^3/d)	Outflow (m^3/d)	Balance (m^3/d)
1	Recharge Dolomite Aquifer	11397		11397
2	Recharge Karoo Aquifer	9288		9288
3	Recharge Open Cast Mine	31		31
4	**Existing Abstraction**			
5	Middelbult 235IR		-6942.00	-6942.00
6	Wolvenfontein 435IR		-1310.04	-1310.04
7	Eloff Holdings		-1648.99	-1648.99
8	Mine Dewatering		-900.00	-900.00
9	Baseflow and Losses		-10815	-10815
10	Groundwater from Storage	**65418**		**65418**
11	**Total**	**86134**	**-21616**	**64518**
12	**Imbalance (%)**	**Imbalance (%)**		**75**

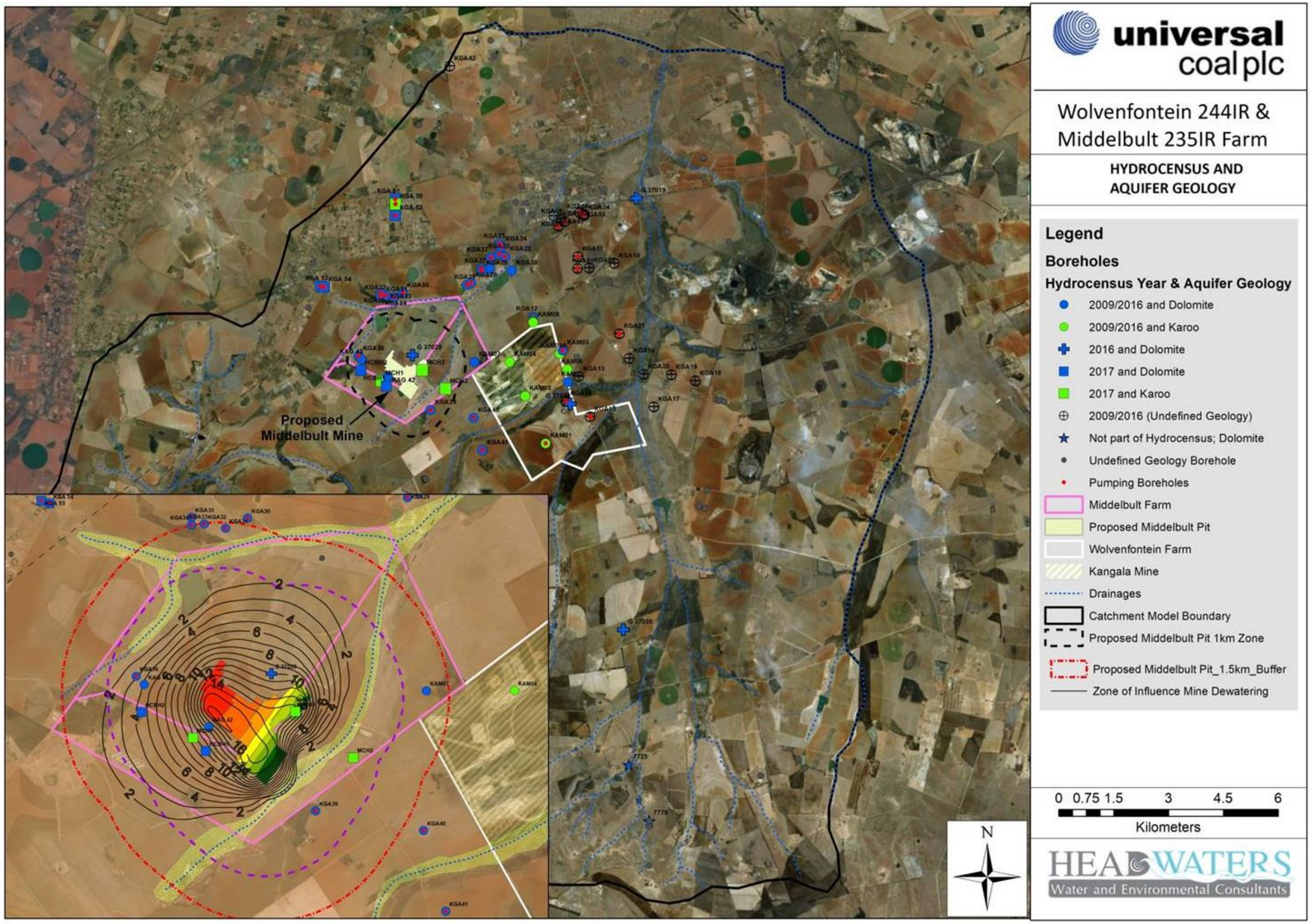

Figure 4-7 Zone of influence in seven (7) years of mining map

4.9 Scenario 3: Mass transport with simulated dewatering

Following the potential post-operational water quality, the values quantified by Digby Wells (2017) was adapted to various mean values and a conservative application of the data was applied with a TDS of 1500 mg/L and sulphate concentration of 600 mg/L(Table 4-5).

Table 4-5 : Kangala Colliery mine relative abundances of acid and buffer capacity

No	Variable	TDS (mg/L)	SO4 (mg/L)	Total Sulphur (%)
1	Sample Analysed at Kangala Mine Coal Seam (Digby Wells,2017)	420	75	0.22
2	Adapted to Arithmetic mean TS %	2117	378	1.11
3	Adapted to harmonic Mean TS %	**861**	**34**	0.45
4	Values used in the Model	**1500**	**600**	

It has been observed from Discard Facility Effluent (DFE) that Sulphate, Mn and TDS were identified as the main seepage constituent from the waste material. The Sulphate, Mn and TDS were simulated to originate from the DFE. A maximum seepage concentration of 600mg/ℓ for SO4, 022mg/ℓ of Mn and 1400mg/ℓ for TDS; were observed and used for numerical simulation as the final accumulation concentration.

The mass transport model was conservatively simulated using advective transport with a regional porosity value of 2 - 3%.The background sulphate(SO_4) and TDS concentration assigned to the regional area was 10 mg/ℓ in the Dolomitic aquifer and 1 mg/ℓ in the Karoo aquifer, whereas for TDS background concentration assigned to the regional area was 270 mg/ℓ in the Dolomitic aquifer and 140 mg/ℓ in the Karoo aquifer and background manganese (Mn) concentration assigned to the regional area was 0.02 mg/ℓ in the Dolomitic aquifer and 0.15 mg/ℓ in the Karoo aquifer.

The simulation results indicate a slow migration of mass from the rehabilitated pit and the following key observations:

- The TDS and Sulphate seepage from the proposed Slimes Dump is contained in the immediate facility as shown in Figure 4-8 and Figure 4-9 below;
- There is a tendency for the TDS and Sulphate to migrate towards the north from the proposed slimes dump probably because of the groundwater movement directions towards the northeren directions;
- The total migration distance towards the north from the proposed slimes dump is approximately less than < 100m during the life of proposed slimes dump. This would imply a migration rate of $4.14x10^{-4}$m a day, without any seepage capturing methods implemented; and
- Groundwater monitoring boreholes should be drilled up gradient and down-gradient of the proposed slimes dump .The boreholes should be both shallow (12m) and deep (80m) boreholes to monitor the shallow(Karoo) and deep(Dolomite) aquifer.

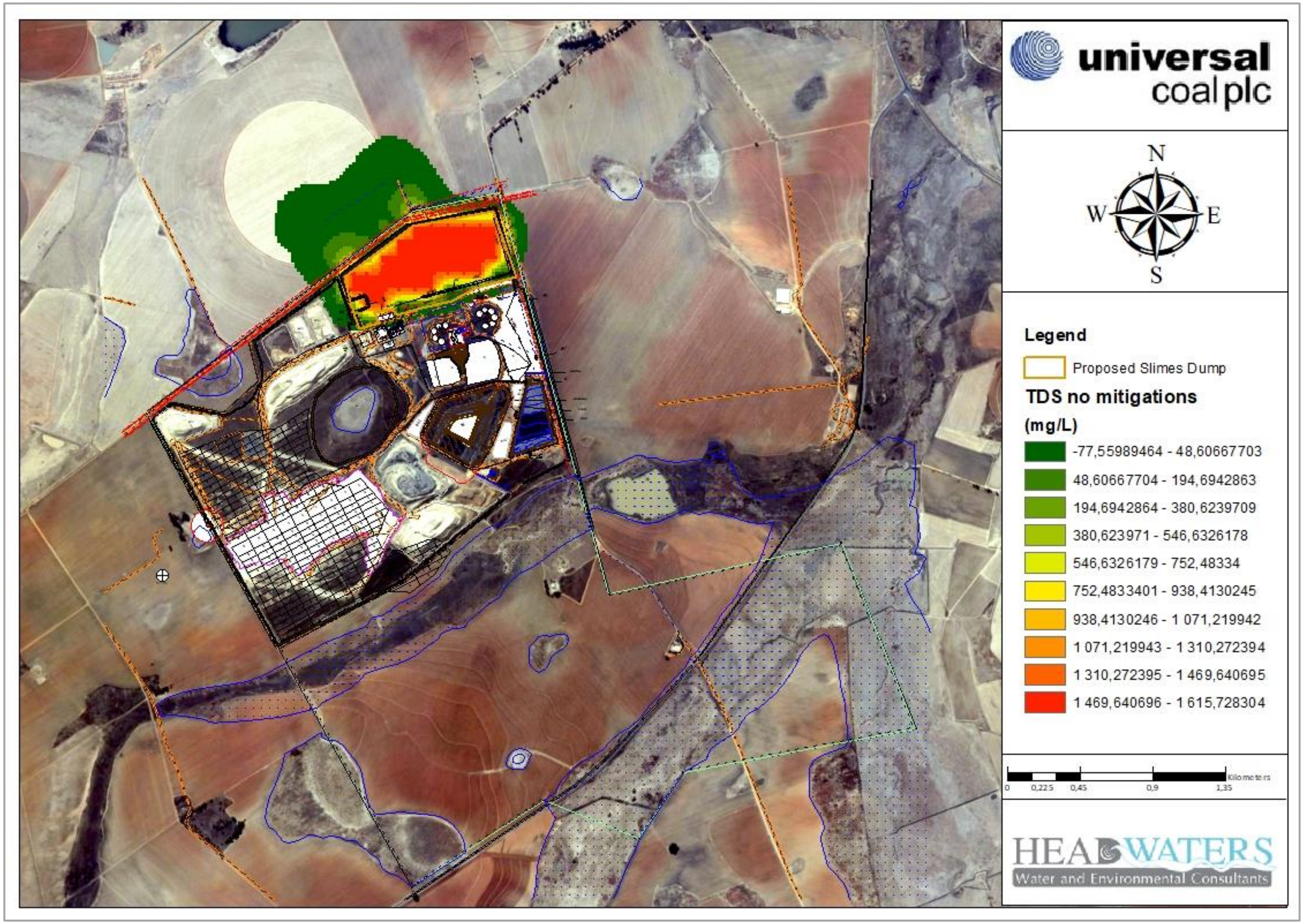

Figure 4-8 TDS migration no mitigation measures

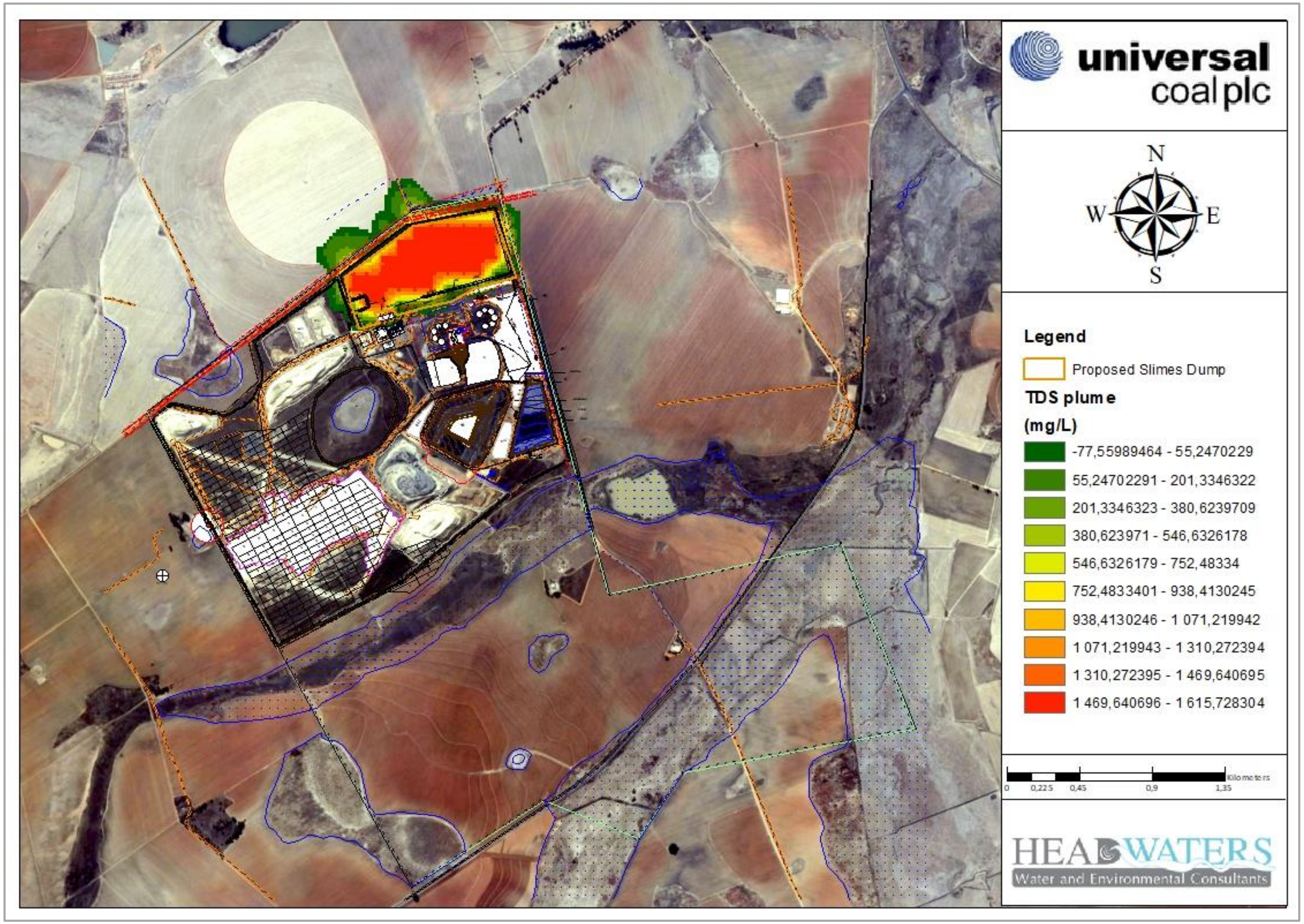

Figure 4-9 TDS with mitigation measures

4.10 Scenario 4: Post mining operations and rehabilitation

The following section focus on the post closure flooding of the open pit, and the associated water quality of the flooded events. An analytical numerical approach was taken to finalise and conceptualise the results. The analytical model indicates that, the water will only flow from the bedrock to the pit zone until it reaches the original water level, which happens in 66 years after mine closure as shown in Table 4-6.

Table 4-6 Post operation scenario

No	Description	Unit	Open Cast Pit
1	Pit Surface area	**m^2**	672571
2	**MAP(Mean Annual precipitation)**	**mm/y**	**669**
3	Recharge Coefficient -Surface Area	**% of map**	18.00
4	Porosity (n)	**% Porosity**	20.00
5	Mine Depth	**m**	40.00
6	Inflow into the Pit	**m^3/d**	222
7	**Time to fill the PIT**	**d**	24248
8	**Time to fill the PIT**	**(y)**	66

Subsurface decanting is possible from the open pits and the influence was simulated using the numerical groundwater flow model. The following conclusions can be drawn from this study: The development of acid mine drainage (AMD) conditions in the post-closure pit water is unlikely. The model pit water quality is shown to reach steady-state equilibrium at a pH value above 6, which is mildly acidic, but cannot be considered as AMD.

It is expected that the groundwater level in the rehabilitated opencast area will recover over time. The rate of increase of the groundwater level in the rehabilitated area will depend on inflows from surrounding weathered materials and Karoo aquifers.

Materials used and class of rehabilitation used will determine or influence the rate of recharge into rehabilitated mine and amount of water that can be stored or contained in the rehabilitated area.For the purpose of this study it was assumed that recharge from rainfall is increased to around 18 % of MAR for 100 years after rehabilitation is completed. Modelling simulations show that the groundwater is expected to recover within around 60 years depending on the storage coefficient of the rehabilitation material. Later after mine closure, contamination of the surrounding area from the rehabilitated backfilled open cast pits will continue. Recovery of pre-mining water levels in the rehabilitated pit will ultimately lead to the groundwater flow directions being restored.

Average concentrations of the poor quality leachate entering the stream range between approximately 10 % of the original source concentrations. Contamination migration through the weathered material and fractured Karoo aquifers poses a threat limited to a possible 1 km radius. The groundwater and surface water qualities remain a major threat to regional groundwater qualities only when contamination from the mining area enters the karstic dolomitic aquifer along which contamination can migrate very fast over large distances.

The upwelling of groundwater from the karstic dolomitic aquifer combined with the mitigatory effects of the low transmissivity shale/tillite in between pit floor and dolomitic aquifer will most likely prevent any contamination to migrate vertically downwards into the dolomitic material underlying the pit area from where contamination can spread.

The contamination plume contained in the weathered material and Karoo fractured rock aquifers will, without preventative mitigation measures, eventually reach the dolomitic aquifer where the Karoo aquifer pinches out, causing contaminants to flow into the dolomitic aquifer roughly in 66 years after operations stopped. Some natural attenuation of the original source term plume concentrations however occur over travelling distance and the average element concentrations will decrease over time to range between 10% the original source term concentration.

4.11 Decant Potential Areas

The potential for mine re-watering and decanting was simulated due to the changes in hydraulic conductivity created by the backfilled and rehabilitated overburden material in the mined out area. It is expected that the rehabilitated open cast area would decant on the south east of the proposed open cast through subsurface into the depression pans .The elevation for proposed expansion will be 1580 mamsl is predicted to stabilise (Figure 4-10).

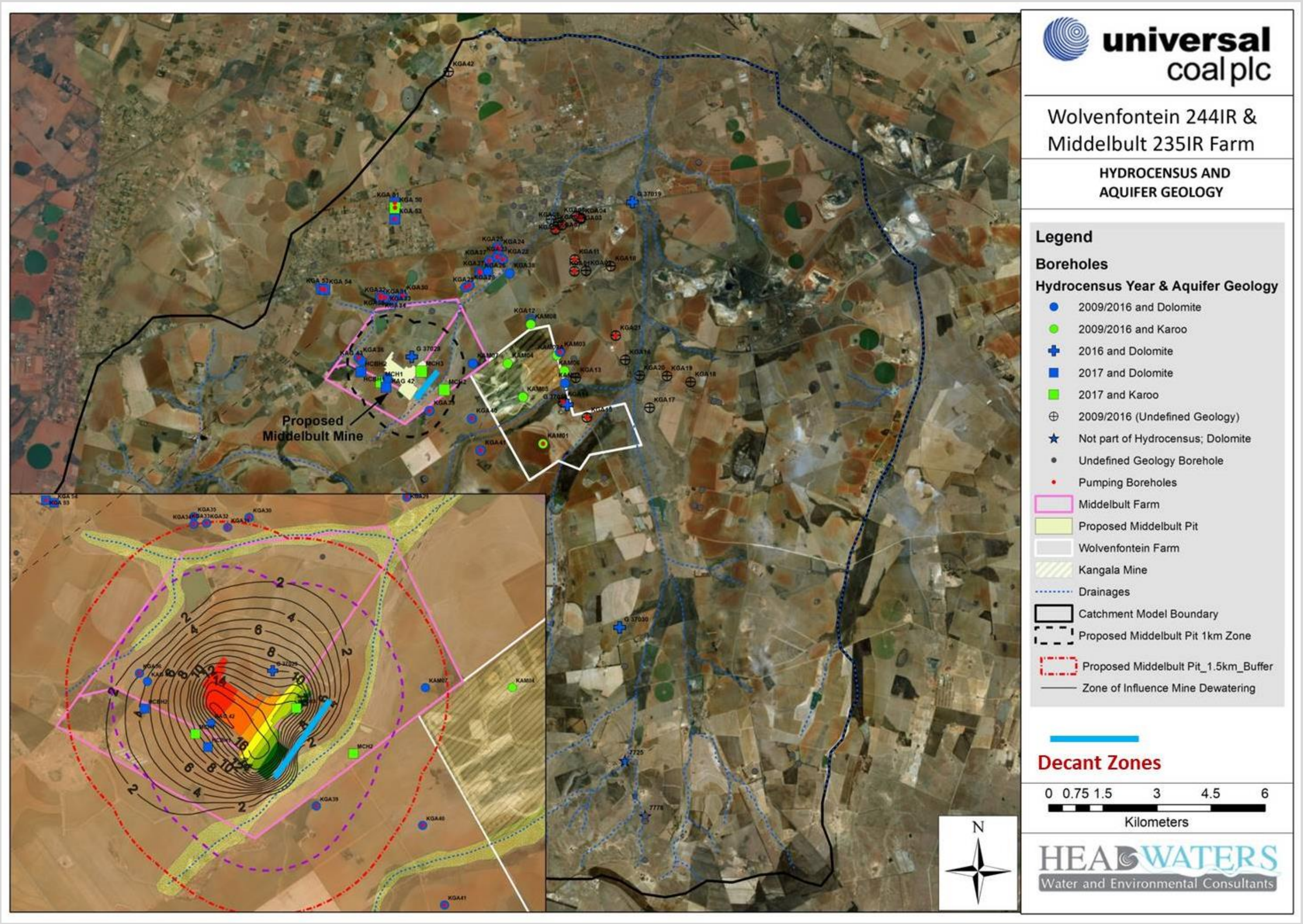

Figure 4-10 Decant zones map

4.12Recommended future work

- Monitoring systems: Setting up of monitoring piezometers close to where initial proposed open cast pit expansion open cast pit workings is. Transient state parameters of mining are at present best estimates and predictions cannot therefore be calibrated without data collected after mining starts.
- Water levels changes once the proposed expansion of the open cast pit immediately after mining starts, should be used to further refine the storage parameters in the groundwater model and drain conductance used for the mine workings. It is further expected that these estimates will affect projections made on inflows.

- Verifications of abstractions within and around the study area are essential.
- Model verifications of water levels and inflows are required to validate the model after mining begins.
- Model Verification: is conducted during the development of a simulation model with the ultimate goal of producing an accurate and credible model. This means comparing the model results against an independent data set from which the numerical groundwater model was calibrated against. This can be achieved by using monitoring data.
- Model Sensitivity Analysis: Once the model is complete with all the required information, supported by monitoring data, a sensitivity analysis needs to be undertaken to determine how sensitive the model results are to parameters with some uncertainty .This is achieved by conducting simulations with parameter values reduced and increased to define how it affects the calibrations results and the confidence in the selected parameter values.
- Simulation models are increasingly being used to solve problems and to aid in decision-making and this approach may be useful to address the challenges and needs for the Universal Coal Mine.

5 Conclusions

Surface water and catchment

The study area is located in the Mpumalanga Water Management area and falls within B20A quaternary catchments and is within drainage region and can be sub-divided into secondary drainage regions comprised of smaller catchment areas and streams. The surface topography of the area is typical of the Mpumalanga Highveld, mainly consisting of a gently undulating plateau. Tributaries and streams of Bronkhorstspruit and Koffiespruit have their origin in this area, sourced from springs occurring on the North East (NE) contact of the dolomite with the overlying Pretoria Group Strata. The drainage forms a dendritic pattern flowing north and north-east, and wetlands occur along the stream channels and several lower lying pans occur in the area.

Mine water balance and water supply

The mine make-up water requirement will be sourced from the existing boreholes supplying Kangala Colliery and can also be sourced from dewatering requirements or existing water use entitlements within the surrounding privately owned farms.

Hydrocensus and groundwater use

Historical boreholes data surveyed before were used to determine the groundwater potential of the area and the surveyed borehole data consists of fifty four (54) boreholes.

Twenty one (21) boreholes were equipped and in use for Irrigation and Livestock with submersible pumps while fourteen (14) were equipped and in use for domestic water supply and twelve (12) are used as DWS boreholes for monitoring within and around the proposed expansion of the mine.

The pump depths within Middelbult 235IR portion 40 and 82 are between 120-160 meters deep. Boreholes KGA 22 to KGA 28 and KGA 30 to KGA 36 are used for irrigation and livestock watering and fitted with electric pumps. The boreholes pump 6942 m^3/d within portion 80 of Middelbult Farm 235 IR of water to an irrigation and water use dam.

Water Quality

The hydrochemistry of the water sources sampled can in overall be regarded as good as stipulated by the SANS 241:2015 standards. The groundwater from the sampled boreholes is neutral to slightly alkaline with pH ranging between 6.0 and 7.8. The pH values are consistent throughout the period of sampling from Kangala Colliery remaining in the neutral to slightly alkaline range. The water quality is within the limits stipulated by both the WUL and the SANS 241-1:2011 standard. Sulphates are good indicators for assessing probable coal mining impacts. Sulphate concentration trends fall within the Kangala WQO and Drinking water standards SANS 241:2015.

Waste classifications

- Based on the data review and interpretation of the overburden material the following can be concluded:
- The mineralogy of the waste material is dominated by aluminosilicates, mica group minerals, dolomite and feldspar. The main minerals present are quartz, kaolinite, quartz, microcline, muscovite, siderite with traces/small amounts of pyrite and dolomite. The mineralogy indicated by the XRD is typical of the Karoo formations with which the coal is associated;
- Pyrite is present in small amount in composite sample 1 and 2, and is associated with the depositional environment in which the coal formation occurred. The presence of pyrite may lead to acid generation and thus the overburden material should be managed and monitored to minimise seepage and runoff of leachate;
- The presence of siderite in the samples indicates that oxidation and dissolution reactions of the pyrite have not started. This indicates that ARD formation is not at risk at present with the absence of SO_4. The current system is sealed off from atmospheric oxygen with only a limited dissolved amount available. But it should be noted that oxidation and dissolution reactions of the pyrite will start to occur as soon as the system is exposed to atmospheric oxygen;
- The presence of dolomite, aluminosilicate and mica group minerals are however allowing a high neutralising potential;
- Sample composite 3 can be considered as uncertain while all other samples can be classified as potentially acid neutralising and thus non-acid generating; and

All of the samples are classified as Type 3 waste because the total concentration of one or more constituents is between the TCT0 and TCT1 threshold values, and the leachable concentrations of one or more constituents is below the LCT1 threshold value, Disposal is therefore required at a Class C or GLB- landfill, both of which would require a pollution control barrier system as defined in the *National Norms and Standards for Disposal of Waste to Landfill* (2013).

Geophysical survey:

- The geophysical survey did not indicate any clear lineaments that can contribute to the distribution of water between the Karoo aquifer/aquitard and the sensitive dolomitic aquifer.
- The magnetic method did indicate a small anomaly on the magnetic profile of traverse 6 but this could not be confirmed in the Resistivity data on the same line. Traverse 6 is however located outside of the proposed pit extension

Water levels:

- Overall there is a clear difference in the measured water levels within the deep dolomitic aquifer and the shallow fractured Karoo aquifer. This indicates that there must be a barrier layer between the two aquifers.
- The water level within the deep dolomitic aquifer range from 25 mbgl-80 mbgl. The average depths of the boreholes are 118 mbgl.
- The water level within the shallow Karoo aquifer range from 7 mbgl- 118 mbgl. The average depths of the boreholes are 70 mbgl.
- Major groundwater interception in Middelbult 235 IR are roughly between 87mbgl and 136 mbgl and boreholes depth for abstraction or water supply are 200m deep

Packer tests:

- The packer test data indicated that the coarse grained sandstone with a total thickness of 11.81m (South of the proposed pit) is more competent than expected and indicated a maximum K value of 1.52 E-03 m/d and a minimum K value of <1 E-05 m/d. The packer tests determine the horizontal hydraulic conductivity but in Karoo Aquifers, the vertical conductivity which is in this case the determining factor for vertical leakage could be expected to be an order of magnitude lower.
- The Dwyka tillite/diamictite south of the proposed pit had total thickness of 1m. East of the proposed pit the thickness vary from 1.18 m to 2.21 m.

- The hydraulic conductivity of the Dwyka tillite/diamictite indicated a maximum K value of 6.21 E-02 m/d and a minimum K of < 1 E-05 m/d. The high K value was determined in the shallow weathered Dwyka tillite/diamictites tested in MCH 02.
- In some of the geological sections tested the Dwyka tillites/diamictites tested were more permeable than expected this is due to the presence of Dolomite in the transition zones which increases the permeability thus indicating a higher K value.
- Fresh competent Dwyka tillite/diamictite indicated a lower K (aquitard). In the paleo high areas the Dwyka tillite/diamictites were more weathered and had a higher K value.
- Black carbonaceous shale zones overlaying the Dwyka tillite/diamictite acts as the most important and continuous barrier between the mine target Karoo and the dolomitic aquifer.
- The carbonaceous shale had a thickness of 4.9 m (43-47.9 mbgl) below the coal seam in the south and a thickness of 5.25m in the east.
- From the packer test the horizontal hydraulic conductivity (Kh) of the shale indicated a lower K value than the Dwyka tillite/diamictite with a maximum K value of 2.79 E-03 m/d and a minimum K of 1 E-05 m/d.
- The paleo high areas located to the east are more weathered and indicate a potential risk for leakage to the sensitive dolomitic aquifer. Conceptually the paleo highs are areas where the coal beds are expected to be either thin or absent (to be confirmed).

Lab hydraulic permeability test:

- A hydraulic permeability test was conducted on the Dwyka tillite/diamictite core to determine the vertical hydraulic conductivity. The permeability or vertical hydraulic conductivity determined for the Dwyka tillite/diamictite core specimen was 1.37 E-05 m/d.
- The horizontal hydraulic conductivity value measured was at least and order of magnitude higher than the vertical hydraulic conductivity measured from the lab permeability test. The lab tests do not take horizontal fractures into account, which was determined with the packer tests.

Constant discharge test:

- A 24 hour constants discharge test was conducted in MBH 01 situated within the dolomitic aquifer. The hydraulic conductivity was determined at 0.11 m/d. The calculated sustainable yield is 1 l/s.
- After the constant discharge test was completed the water level recovered rapidly within 105 minutes to the original static water level.

Falling head test:

- The measured hydraulic conductivities vary from 0.0003-0.0188 m/d.
- HCBH 01 and HCBH 02 situated within the dolomitic aquifer had the highest hydraulic conductivity due to the high transmissivity of the dolomites.
- MCH 01, MCH 02 and MCH 03 indicated low hydraulic conductivity values and recovery of the water level this is an indication of the geological features of the Karoo aquifer (shale, mudstones and Dwyka tillite/diamictite).
- The average K-value determined in the Karoo aquifer from the falling head tests was 5.39E-04 m/d and for the packer test an average K of 1.68E-02 m/d was determined in the Karoo aquifer. The average K of the falling head tests in the dolomitic aquifer was 1.36E-02 m/d. The dolomite was packer tested in MCH 03 and the average K was < 1E-05 m/d. This is not a good representation of the dolomite and more tests should be done in the area. This dolomitic zone did not intersect any cavities or dissolution fractures, hence the low K value.

Groundwater modelling:

Piezometric heads and gradients: The piezometric head follows the topographic gradient and they are from south to north directions draining into perennial and non-perennial streams.

Groundwater modelling and contamination migration rate/s: Prospective case was simulated to determine the effectiveness of management and mitigation options:

- The model indicated that the groundwater recharge over the entire model domain is in the range of 242ℓ/s
- Dewatering of the pit is ranges between 500-900m^3/d for the first three (3) months and then 100m^3/d LoM.
- Current abstraction from noted boreholes KGA 22 to KGA 28 and KGA 30 to KGA 36

used for irrigation and livestock watering should continue to abstract 6.942Mℓ/d of water to an existing dam to assist with dewatering or minimise water levels recovery during mining period.

Drawdown due to mining operation

The predicted drawdown cones created by mining were determined during numerical modelling and the predicted monitoring borehole groundwater levels over time are illustrated in this report including the simulated hydraulic heads at end of mining and their groundwater level trends after mine closure

Key aspects of the groundwater flow regime during and after mining are as follows:

- The severity of groundwater drawdown on groundwater users will depend on the distance between the groundwater user and the pits. Higher drawdowns will be experienced by groundwater users closer to the pit. In the proposed pit expansion, the deeper the coal floor is compared to the pre-mining groundwater levels the higher the drawdown will be.
- The mining will progress with concurrent rehabilitation and according to the mine plan; Year 7 marks the last year for mining and a maximum drawdown of 40 mbgl is predicted.

Contamination transport.

- The contaminant plumes that could be generated from slimes dump dumps facilities could be captured by trenches around the proposes slimes dump.

Hydraulic parameters and Dwyka tillite permeabilities

Middelbult field investigations including geophysics, packer tests and a pumping test were performed for this study to determine hydraulic parameters for the geology present in study area as well as evaluate the presence of definite vertical fractures or geological lineaments.

This was done in order to evaluate the possibility of direct hydraulic links between the proposed coal seam and shallow aquifer up to the No. 2 Seam floor and the deep dolomitic aquifer below. There are beds of siltstone/shale/fine-grained sandstone as well as Dwyka diamictite present between the coal floor (proposed pit floor) and the deep dolomitic aquifer as shown by drilling results. These geological strata were especially evaluated for their hydraulic parameters to determine whether these strata layers together constitute a geological barrier between the open cast mining and the deep dolomitic aquifer. Based on the assessment conducted on site a barrier strata (Dwyka tillite) exists between the proposed pit and the dolomitic aquifer.

Decant Potential

The groundwater level within the backfilled open cast is expected to recover up to a level of 1580 mamsl where after it will stabilise due to seepage/decant and evaporation.

The groundwater level recovery in the rehabilitated pit area will reach the lowest topographical elevation of the pit perimeter at 1580 mamsl. This will lead to decant taking place. Decant volumes are calculated to potentially range between 100 - 250 m^3/d depending on the quality of the rehabilitation done.

Wetland Impacts

Agricultural activities and practices are largely responsible for the current impacts to all the current existing wetlands units in terms of their functioning .The removal of natural vegetation and hydric soils and open cast mine will lead to the degradation of the surrounding wetlands areas through the initiation of the increased erosion process and increased runoff of sediments into watercourses during high rainfall seasons Mine out current existing wetlands will be lost completely.

6 Recommendations

- Any existing water boreholes that would be destroyed by mining should be sealed to prevent it from acting as a conduit for vertical migration of contaminated coal mine void water to the basal dolomitic aquifer.
- Groundwater monitoring protocol should be developed and implemented in the follow up phases.
- The geophysical profiles on parcel no 82/235 should be completed and core boreholes should be drilled to improve the characterization of the Karoo and Dolomitic sub strata in the north.
- More geophysical traverses should be completed to better map the lineaments in the proposed pit and surrounding areas. Due to the depth restriction of the geophysical equipment (magnetometer 30m and DC resistivity 80m) the targeted dolomitic cavities for the air percussion hole were not detected.
- Gravimetric and resistivity surveys should be conducted in the immediate vicinity of the proposed pit extension to determine the location of the dolomitic cavities or paleo highs. This is due to the current access problem on parcel 82/235.
- The drilling and aquifer testing of four boreholes situated within the cavities surrounding the pit area is recommended. 72-hour constants discharge test should be conducted on these boreholes to determine the aquifer parameters of the Dolomite with cavities.
- Geological logs of the resource determination core boreholes should be made available for review and update of the conceptual hydrogeological model with specific reference to the thickness and continuity of the carbonaceous shale layer below the coalbed and the existence of paleo highs in the basal dolomite.
- If no previous soil assessment has been completed, a soil assessment and waste classification should be conducted on the material from the pit area to determine if there is a risk for acid mine drainage. The leachate potential should be determined and the material should be classified according to R 635 and R 636.
- The potential impact of acid mine drainage on potential leakage and/or decant should be determined on the regional dolomite aquifer.
- Water levels within the Middelbult 235IR pumping boreholes must be measured and

continuous pumping of boreholes (6.9Mℓ/d) during mining operation should continue to minimise water level recovery (assist with dewatering for safe mining environment).

- Water levels in boreholes up to 1 km from the mine must be monitored on a monthly basis before and after mining activities commenced to observe any possible decrease in water level.
- Flow meters should be installed to obtain legal water supply and water use information.
- The positions of flow meters are very important.
- The geochemical assessment conducted is static and provides the total amount of acid generation and/or neutralising potential. Static tests do not provide information on when the acid generation or neutralisation will occur. Long term (20 to 45 weeks) kinetic tests are often required to assess the long term geochemical behaviour of the residue stockpiles and are recommended in later phases of the proposed Middelbult project.
- Geochemical modelling should be undertaken which involves mixing models and/or kinetic weathering and reaction models to support the use or exemption of the liner requirements.
- Groundwater and surface water monitoring should be implemented in the vicinity (downstream and upstream) of the proposed stockpile and waste disposal areas as discussed in more detail in the surface water and groundwater reports.

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