HYDROGEOLOGY REPORT

KANGALA COAL MINE

UNIVERSAL COAL

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EXECUTIVE SUMMARY

Digby Wells and Associates (Pty) Ltd (DWA) have been appointed by Universal Coal PLC as independent environmental consultants to undertake the environmental investigations and document compilation required by the various governmental departments in support of the Mining Right Application and to obtain environmental authorisation for the proposed project from both the Department of Minerals and Energy and Mpumalanga Department of Agriculture and Land Affairs.

This report addresses the hydrogeological issues and expected impacts of the Kangala development. During the investigation it was observed that the planned mining area is currently used for agricultural activities which include large scale maize production under irrigation from surface and groundwater resources. The groundwater is of good quality and the samples fall within the SANS 241 drinking water guidelines.

Cumulative impacts are mostly associated with reduced water resources available to other water uses and changes in water quality in the catchments with possible contribution from already existing mining activities.

The karstified Malmani dolomites present in and adjacent to the area should not be at risk if careful mine planning and operations are performed, however this will have to be carefully monitored for the life of mine and beyond.

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1 INTRODUCTION

Digby Wells and Associates (Pty) Ltd (DWA) have been appointed by Universal Coal PLC as independent environmental consultants to conduct the environmental investigations and document compilation required by the various governmental departments in support of the Mining Right Application for Kangala Coal Mine and to obtain environmental authorisation for the proposed project from both the Department of Minerals and Energy and Mpumalanga Department of Agriculture and Land Affairs.

With this in mind a specialist hydrogeological investigation to assess the aquifer dynamics was conducted at the Kangala project area on the farm Wolvenfontein, approximately five kilometers to the south-west of the town of Delmas in the Mpumalanga Province (**Appendix B,** Plan 1). With a holistic understanding of the geology and hydrogeology of an area certain predictions can be made regarding mining activities and its associated impacts on the receiving environment, which in this instance focuses on the surface and groundwater components.

The project area is underlain and to an extend bordering the outcropping Malmani group that is well known for its hydrogeological significance. This study focused mainly on the relationship of the upper Karoo aquifer with the underlying and bordering karstified carbonate aquifer. However it also addresses the hydrogeological issues in general and possible impacts on the local environment.

This document reports the detailed findings of the base line hydrogeological study completed.

2 GEOLOGY

The Kangala project area is situated at the edge of the Witbank coal field, which forms part of the Karoo basin extensively covering the central areas of South Africa (Plan 2).

2.1 Regional geology

2.1.1 Stratigraphy

The basement rocks within the Karoo Basin are overlain by the Karoo Super Group. The basement of the Karoo Super Group is the Dwyka tillites that are fairly regularly deposited over the basin with the exception of paleo-topographical highs (Plan 2). In the project area the basement is formed by the Malmani dolomites which is overlain by Dwyka tillites. The Dwyka tillites are overlain by the Vryheid formation which hosts the coal seams. The Vryheid formation consists of various sequences of sandstones, shales and siltstones with the various coal seams located within them. Higher units of the Karoo Super Group are not present within the study area.

2.1.2 Structural geology

During the Jurassic period a large number of dolerite dykes and sills intruded into the Karoo formation acting as important geological structures diverting and impending groundwater movements.

2.1.3 Geochemistry

The following table summarises the typical geochemistry for the different coal seams in the Witbank coal field.

Table 1: Typical analysis (air dry) for the different coal seams in the Witbank coal field (Smith & Whittaker, 1986)

	Raw coal				Washed coal							
	%H2O	%ash	%VM	CV MJ/kg	RD	%yield	%H2O	%ash	%VM	CV MJ/kg	S.I.	Roga index
No. 1 Seam Witbank area	1.7	25.4	21.0	24.0	1.6	38.2	2.0	9.7	25.2	29.1	-	-
No. 2 Seam Ogies area												
Top bench 0.97m	5.6	27.5	20.7	21.1	-	-	-	-	-	-	-	-
Middle bench 0.47m	5.3	21.3	21.2	21.2	1.6	65.6	5.7	14.7	23.6	25.3	-	-
Bottom bench 5.47m	3.7	23.5	22.4	22.4	1.6	64.6	4.5	13.2	26.8	26.3	-	-
No. 2 Seam Witbank area												
Bench 5 - 1.00m	1.7	26.6	18.4	20.2	1.6	57.8	2.4	11.5	26.8	29.3	1.5	22
Bench 4 -1.96m	2.3	19.2	20.4	25.5	1.6	82.3	2.4	15.8	21.5	26.3	1	0
Bench 3 -0.33m	2.1	8.3	27.7	30.6	1.6	98.0	2.1	7.8	27.9	30.6	1.5	22
Bench 2 -1.24 m	1.9	18.2	21.3	26.6	1.6	83.1	1.9	14.2	21.8	28.2	1	0
Bench 1 -1.26m	1.9	9.1	33.8	30.8	1.6	95.8	1.9	7.7	34.4	31.2	3	62
No. 4 Seam Witbank area	2.6	27.6	20.7	22.2	1.6	62.5	2.5	17	22.4	26.1	-	-
No. 4 Seam Ogies area	30.8	30.3	22.7	19.9	1.6	62.3	3.9	14.4	27.5	26.5	-	-
No. 5 Seam Witbank area	2.5	13.1	32.0	28.7	1.6	88.7	2.5	9.8	33.4	30.0	2.5	45

Table 2: Typical analysis (air dry) for the number 2 and 4 coal seams in the Wolvenfontein project area (Malan, 2008)

Wolvenfontein Coal Project Combined No. 4 and No. 2 Seam Raw and Washed Coal Qualities within the Multi-Product Area							
	Moisture %	**Ash %**	**Volatiles %**	**Fixed Carbon %**	**Sulphur %**	**CV (MJ/kg)**	**Yield %**
Raw Coal	4.82	31.33	20.51	43.33	1.27	19.30	100
Washed Coal at RD 1.55	5.42	15.70	23.57	55.31	0.76	25.40	44.32

2.1.4 Geomorphology

Weathering of the Karoo strata over the study area occurs between 5 m and 12 m below surface level (Hodgson & Krantz, 1998). The paleotopography was as a result of the extensive glaciations that had occurred about 320 Ma during the late Carboniferous to early Permian period. The lower lying coal seams (No.1 and No.2 seams) were generally formed within lower lying areas with the higher seams being more continuous. However later erosion has resulted in the overlying No.4 and No.5 seams being eroded away in current topographical lower lying areas in the north of the coal field.

2.1.5 Economic geology

The coal seam near Delmas forms part of the Witbank coal field. The economically important No. 2 and No. 4 Seams are the best developed in the area, whereas the No. 1 and 3 Seams occur sporadically and/or joined to the No. 2 Seam. The No. 2 Seam and No. 4 Seam are of economic interest.

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2.2 Site specific geology

2.2.1 Stratigraphy

The Wolvenfontein Coal Project lies at the western extent of the Witbank Coal Field towards the northern edge of the main Karoo sedimentary basin. The area is underlain by sedimentary sequences (predominantly sandstone, shale and coal) of the Vryheid

Formation deposited on tillite of the Dwyka Formation or directly on the glaciated basement topography (mostly Malmani dolomites).

The sandstone in the project area attains a maximum thickness of 41 m in the western part of Wolvenfontein.

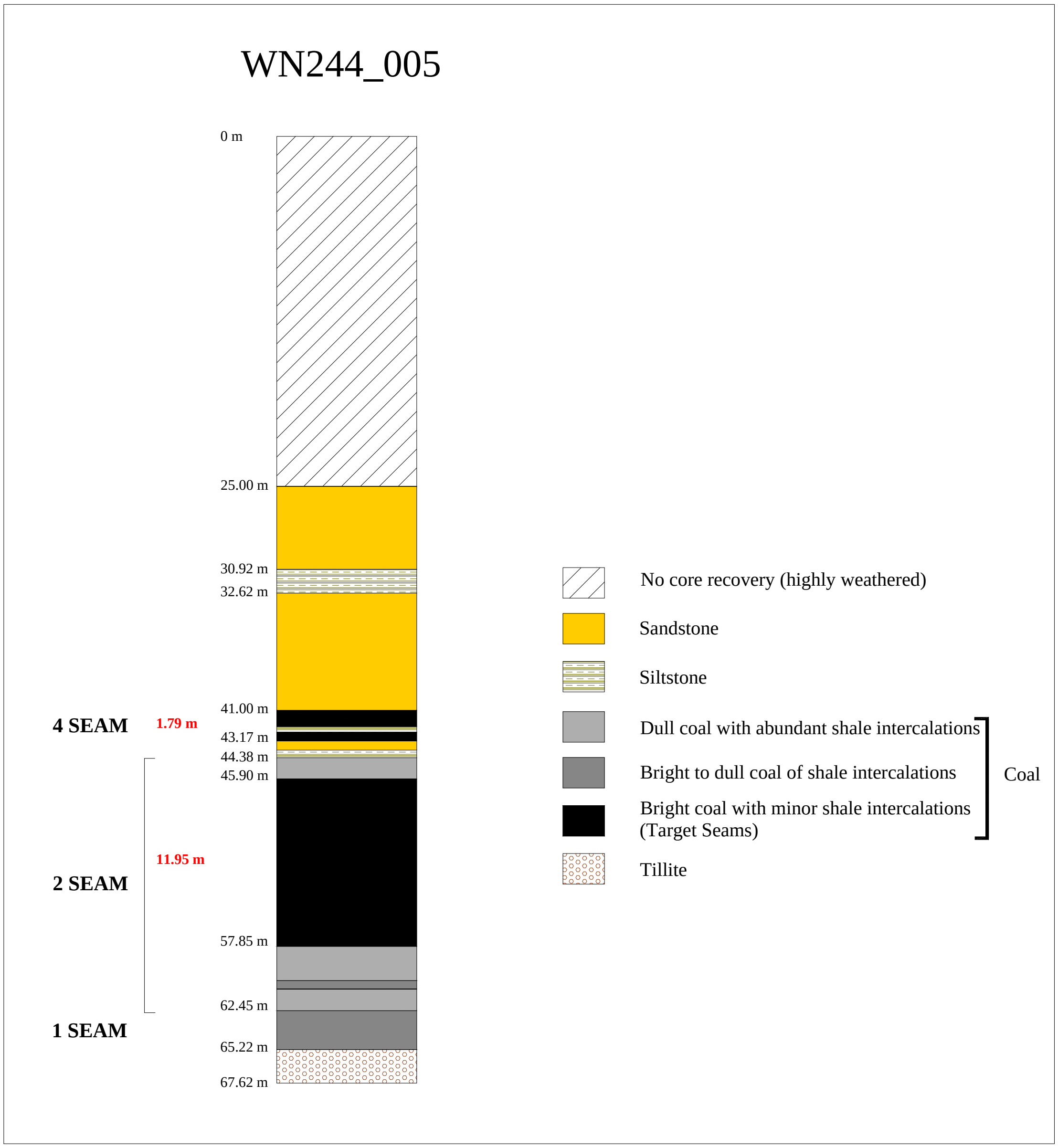


Figure 1: Geological exploration core borehole log (after Malan, 2008), depicting the lithology which is found in general at the Kangala project site.

The topsoil is between 4 to 10 m thick and consists of an upper 0.6 m of dark-brown sandy soil and an underlying yellow to brown clayey soil. Intense weathering occurs to a depth of 25 m in hole WN244_005 (Figure 1) and averages approximately 20 m over the entire property.

2.2.2 Structural geology

Dolerite intrusives (dykes and sills) are extensively developed south of the project area, with minor occurrences within the area of interest. No dolerites were intercepted in the exploration boreholes, however there is note of a dolerite sill in a DWAF groundwater exploration report (Leskiewicz, 1986), to the east of the project area.

2.2.3 Geochemistry

The coal intersection of the cores was split-sampled and individually assayed by SGS Lakefield Laboratories in Johannesburg.

3 CLIMATE

The area is characterised by moderate summers, cold winters and summer rainfall. The average rainfall in the target area is 768 mm per annum. The precipitation in the form of rainfall distribution and total rainfall is typical of the Highveld region. The region is characterised by thunderstorms in the summer. Temperatures are also typical of what could be expected in the Highveld region, although lower temperatures could be expected on the high lying regions (ELM, 2006).

4 DATA ACQUISITION

4.1 Hydrocensus

A hydrocensus was conducted on the 10th and 11th of September 2009. The purpose of the hydrocensus was to obtain information on the current hydrogeological baseline of the area, including water quality, water use, volumes used, site condition and the location of each site.

4.1.1 Methodology

Data was collected on the current groundwater users, location of water sources, current water quality, groundwater levels (where possible) and volumes of water available. This information is used to determine the possible effects that the proposed mining activities could have on the water users in the area, as well as to be compared to future monitoring data.

The hydrocensus was conducted on the farm portions directly bordering the Kangala site. Five farms were visited, namely Middelbult 235IR, Strydpan 243 IR, Welgevonden 272 IR Wolvefontein 244 IR and Witklip 232 IR (Plan 3). The data collected of the farm portions covered and the sampling locations are appended in **Appendix C**.

4.1.2 Results

The results from the hydrocensus are discussed per farm portion below:

Middelbult 235 IR

Seventeen boreholes were identified on this site, namely KGA 22 to KGA 36. The exact yields of the boreholes are not known, however, all boreholes are said to be low yielding (this is unlikely given the fact that they are irrigating from these), and are pumped to a central dam from where the water is pumped for irrigation and livestock watering, while the domestic boreholes are pumped directly to water tanks. The dam is labelled KGA 42. The boreholes and dam on this site can be summarised as follows:

- Boreholes KGA 22 to KGA 28 and KGA 30 to KGA 36 are used for irrigation and livestock watering and are fitted with electric pumps, which pumps the water to a dam.
- Boreholes KGA 29 and KGA 37 are used for domestic purposes and are pumped to water tanks, from where they supply the relevant houses and offices.
- Borehole KGA 38 is closed.
- The dam (KGA 42) is used for irrigation and livestock watering. The boreholes on the farm are pumped to this dam and redistributed as required.

Strydpan 243 IR

The portions of Strydpan 243 IR which are bordering the proposed mine site appeared to be inhabited by small scale subsistence farmers. Four boreholes were identified on these portions, one of which is a DWAF borehole (Report GH 3463). The following list summarises the boreholes identified:

- KGA 39 is equipped with an electric pump which pumps water to a water tank. The water is used for domestic purposes and livestock watering. The borehole yield is unknown.
- KGA 40 and KGA 41 are located at old wind pumps. Water for domestic use is obtained by lowering a bucket into the hole with a rope.
- Borehole G37017 (DWAF borehole) is located in a maize field and is sealed with a borehole cap.

Welgevonden 272 IR

The DWAF borehole G37030 is located on this site. The borehole is locked. The farm is located approximately three kilometres to the south of the site and thus no attempt was made to discover any other boreholes on this site.

Witklip 232 IR

Eleven boreholes and one surface water dam were identified on this farm. Borehole KGA 12 is a DWAF monitoring borehole. The yields of the boreholes are not known. The sites can be summarised as follows:

- Boreholes KGA 1, KGA 3, KGA 5, KGA 6 and KGA 11 are all used for domestic water supply and are equipped with electric submersible pumps which pump to water tanks. Borehole KGA 11 is used to supply water to the nearby school and community.
- KGA 2 is adjacent to the Eskom Delmas Substation and appeared not to be in use.
- KGA 4 and KGA 7 are used for domestic purposes and for irrigation. The boreholes are equipped with electric pumps which pump water to tanks.
- KGA 9 is not in use.
- KGA is a new borehole which was drilled to supply additional water to the aforementioned school and community. The borehole is not in use at the time of the hydrocensus and is closed.
- KGA 12 is a DWAF monitoring borehole. The water level in this borehole was 14.21 meters.

- KGA 8 is a dam in the stream which flows from west to east through the study area. The dam is used for irrigation.

Wolvefontein 244 IR

Seven boreholes, one of which was a DWAF Dolomite Report borehole, and three surface water dams were identified on this farm. They can be summarised as follows:

- DWAF borehole G37018 located on this farm. The borehole was located adjacent to a maize field and was locked.
- KGA 13 is a dam located on the mine site. It is used for livestock watering.
- Boreholes KGA 14, KGA 15 and KGA 21 are used for domestic purposes and are equipped with electric pumps which pumps water to water tanks.
- KGA 17 is used for irrigation and livestock watering. The water is pumped to a dam from where it is further distributed as needed.
- KGA 18 is used for domestic purposes and livestock watering. The borehole is equipped with an electric pump which pumps water to a tank.
- Borehole KGA 16 is located adjacent to a small community and is equipped with a hand pump. However, the hand pump appeared to have seized and thus the borehole is not in use anymore.
- KGA 19 is a small dam used for watering livestock
- KGA 20 is a larger dam used for irrigation and livestock watering. The water from borehole KGA 17 is pumped to this dam.

Table 3: Water quality of the five census boreholes in and adjacent to the project area

Sample ID		Total Dissolved Solids	Nitrate NO_3 as N	Chlorides as Cl	Total Alkalinity as $CaCO_3$	Sulphate as SO_4	Calcium as Ca	Magnesium as Mg	Sodium as Na	Potassium as K	Iron as Fe	Manganese as Mn	Conductivity at 25° C in mS/m	pH-Value at 25° C	Aluminium as Al	Free and Saline Ammonia as N	Fluoride as F
Class 0	(Ideal)	<450	<6.0	<100	N/S	<200	<80	<30	<100	<25	<0.01	<0.05	<70	6.0-9.0	<0.15	N/S	<0.5
Class I	(Acceptable)	450-1000	6.0-10.0	100-200	N/S	200-400	80-150	30-70	100-200	25-50	0.01-0.2	0.05-1.0	70-150	5-6 or 9.0-9.5	0.15-0.3	N/S	0.5-1
Class II	(Max. Allowable)	1000-2400	>10-20	>200-600	N/S	>400-600	>150-300	>70-100	200-400	50-100	>0.2-2	>0.1-1	>150-370	4-5 or 9.5-10	>0.3-0.58	N/S	1-1.5
Class III	(Exceeding)	>2400	>20	>600	N/S	>600	>300	>100	>400	>100	>2	>1	>370	<4 or >10	>0.58	N/S	>1.5
KGA 12		114.00	0.10	15.00	89.00	>0.01	9.92	10.30	10.50	5.59	>0.01	>0.01	21.00	7.67	0.06	1.10	>0.2
KGA 15		336.00	14.40	23.00	262.00	10.10	57.40	32.50	12.80	2.01	>0.01	>0.01	59.00	7.90	0.06	>0.01	>0.2
KGA 21		134.00	17.90	16.00	91.00	>0.01	16.70	11.70	13.90	3.52	>0.01	>0.01	27.10	7.09	0.06	>0.01	>0.2
KGA 26		324.00	1.40	13.00	275.00	25.60	52.30	29.80	15.90	0.97	>0.01	>0.01	51.90	7.89	0.07	>0.01	>0.2
KGA 39		280.00	0.19	15.00	227.00	5.90	38.90	14.10	33.40	3.70	0.01	0.09	44.20	7.59	0.07	>0.01	0.55

4.1.3 Water quality

Five of the boreholes found during the borehole census were sampled for water quality. These were boreholes Kga 12, 15, 21, 26 and 39 (See borehole details in **Appendix B**). The analysis was conducted by Regen Waters which is a SANAS accredited laboratory (Analysis Certificates in **Appendix C**) Table 3 summarises the quality of the groundwater and is a comparative analysis with the SANS 241:2005 Drinking Water Standards. Apart from boreholes Kga 15 and 21, which have elevated nitrate values most likely due to an influence from the local sewerage systems, the rest of the water is of good quality.

The tri-linear Piper diagram (Figure 1) indicates that the groundwater is a bicarbonate-calcium-magnesium type water and very typical of dolomitic terrain. There is a slight sodium-chloride presence and could indicate mixing from the Karoo aquifer (probably the coal layer influence).

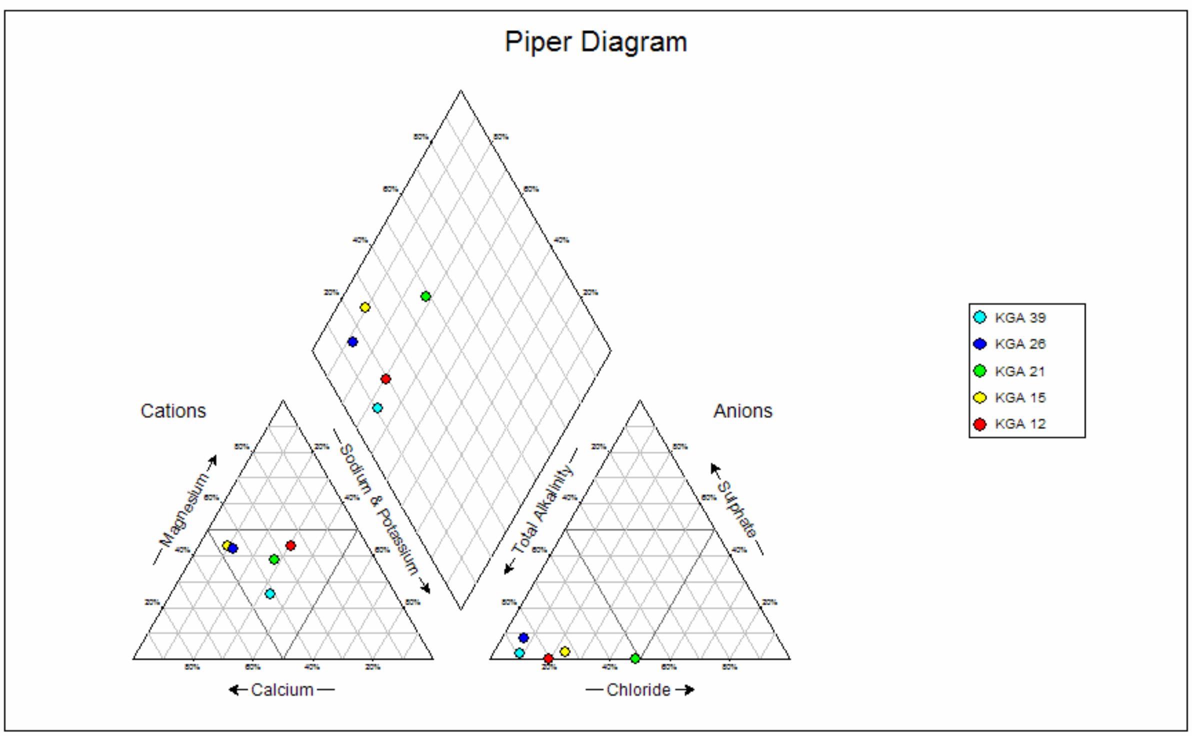


Figure 2: Piper Diagram of groundwater samples collected during the hydrocensus study.

4.1.4 Summary of the borehole census:

- A total of forty boreholes and five surface water dams were identified in the target area;
- Five of these boreholes were selected to be sampled for chemical analysis. The sample sites were selected in an effort to be most representative of the area;
- The water uses in the area were identified as domestic and agricultural (livestock and irrigation);
- Very little information on yields of the boreholes could be sourced, however from the DWAF boreholes it is clear that water from the Malmani aquifer could be very high yielding and figures reported were as high as 80 L/s and therefore very significant;
- The water in the area was found to be of a good quality, with the majority of the measured constituents falling into Class 0 and Class I of the SANS 241: 2005 Standard for Drinking Water, and as such pose no threat to human or environmental health; and
- It is of utmost importance to ensure that the proposed mining activities at Kangala do not impact on the water quality and quantity of the area, as all farms surrounding the site rely heavily on groundwater, both for agricultural and domestic purposes.

4.2 Geophysical Survey

A geophysical survey was conducted during the week of the 1st to the 4th of September 2009. The project area is mostly covered with worked agricultural land with very little surface outcrops visible, geophysics is a method used to characterise the subsurface physical conditions without the use of extensive intrusive drilling programmes. Due to the lithology present at the project area, possibly being karstified carbonate terrain, the use of the gravity method was essential to delineate possible voids in the subsurface. A magnetic and electromagnetic line was also surveyed to establish weathered zones for background monitoring boreholes.

4.2.1 Methodology

The three geophysical methods utilised in the project area included the gravity, electromagnetic and magnetic methods. The following is a description of these geophysical methods:

4.2.1.1 Gravity Method

Six lines were surveyed in a nnw-sse and e-w directions, with a line spacing of 100 m and station spacing of 30 m respectively (Plan 4). All these positions were surveyed by a land surveyor to ensure accurate elevation values necessary for the reduction of the gravity data to Bouguer level. The instruments used for the gravity method was a Scintrex Autograv CG3.

4.2.1.1.1 Theory

The gravity method is a surveying method employed to measure the variations in the earth's gravitational field caused by differences in the density of the subsurface rocks. Although known colloquially as the 'gravity' method, it is in fact the variation of the acceleration due to gravity that is measured (gravitational acceleration).

The theory of the gravity method depends on two of the laws derived by Sir Isaac Newton namely his Universal Law of Gravitation and his Second Law of Motion. The first of the two laws states that the force of attraction between two bodies with known mass is directly proportional to the product of the two masses and inversely proportional to square root of the distance to their respective centers of mass. Therefore the greater the distance away from the centers of mass the smaller the force of attraction between them.

$$F = \frac{G \times M \times m}{R^2} \qquad \ldots\ldots\ldots\ldots.. \qquad (1)$$

Where:

F is the force
G is the gravitational constant (6.67 x 10 Nm2 kg-2)
M is the mass of the earth
m is another mass
R^2 is the distance between the two respective bodies of known mass
Newton's second law of motion states that a force (F) is equal to the mass (m) times the acceleration.

$$F = m \times g \qquad \ldots\ldots\ldots\ldots\ldots \qquad (2)$$

When the acceleration is in the vertical direction, it is due to gravity (g).Combining equations (1) and (2) obtains another relationship:

$$F = \frac{G \times M \times m}{R^2} = m \times g; \text{ thus } g = \frac{G \times M}{R^2} \qquad \ldots\ldots\ldots\ldots\ldots \qquad (3)$$

The magnitude of acceleration due to gravity on earth is given by equation (3). Theoretically, acceleration due to gravity should be constant over the earth. In reality this is not the case as it varies all over the sphere due to the flattening at the poles due to its rather irregular shape, its rotation, irregular surface topography and variable mass distribution. Mathematically it is convenient to refer to the earth's shape as an ellipse of rotation. The equipotential surface or better known as the geoid, which is the sea-level when not disturbed by wind or tides. This is an important datum in gravity surveys as it is horizontal and at right angles to the direction of gravity everywhere. The irregularities on and within the earth mentioned above warps the geoid so that it is not identical to the ellipse of rotation. Long wavelength anomalies relate to very deep-seated masses whereas shorter wavelength anomalies relate to shallow effects within the mantle. These differences in anomalies can be used to determine mass distribution within the earth's crust.

The measurements of acceleration due to gravity in the SI units due to the extreme accuracy of modern instruments are measured in $\mu m/s^2$, which is rather cumbersome to use. This unit is also referred to us the gravity unit or 1 g.u. which is equal to 0.1 mGal and is the unit most popularly used throughout the geophysical community.

4.2.1.1.2 Instrumentation

The instruments used for the measurement of gravitational attraction can be divided into two classes, dynamic and static instruments. Dynamic instruments use the measurement of time as a reference in the determination of gravitational attraction; examples are the pendulum and the principle of falling masses. Static instruments use the measurement of some change in physical parameters caused by gravitational attraction for the determination of values; examples are the pressure of a gas, the length of a spring or the difference in capacitance between two metal Plans. The dynamic instruments measure absolute gravity and static instruments measure relative gravity (Gordon-Welsh, 1981).

The CG-3 Autograv used in this survey is a static (balanced) fused quartz elastic system. The gravitational force on the proof mass is balanced by a spring and a relatively small electrostatic restoring force. The position of the mass, which is sensed by a capacitative displacement transducer, is altered by a change in gravity. An automatic feedback circuit applies DC voltage to the capacitor Plans producing an electrostatic force on the mass, which brings it back to a null position. The feedback voltage, which is a measure of the relative value of gravity at the reading site, is converted to a digital signal and then transmitted to the instrument's data acquisition system for processing, display and storage. The resolution of the CG-3 is 0.005mGal and is thus perfect for regional to very high detailed surveys.

4.2.1.1.3 Corrections to gravity observations

The CG-3 gives a direct observed gravity (gobs) value that has the scale factor already calculated within the reading. Before these values can be interpreted in geological terms, these raw observed values needs to be corrected to a common datum such as sea level or the geoid, to remove effects of indirect geological significance. These corrections are more commonly known as data reduction. The difference between the observed gravity value and that determined from the International Gravity Formula/Geodetic Reference System 67 for the same location, or relative to a local base station is known as the gravity anomaly. The gravity processing system [2] Geosoft ® is used to calculate these different corrections, the corrections are calculated as follows:

- *Drift correction*

  The instrument drift on the Autograv is extremely small due to its enclosed sensing mechanism that is isolated from variations in atmospheric pressures. This means that the long-term drift of the instrument can be kept to below 0.02 mGals per day. A drift is calculated based on the closure error between the first and last base reading in each loop (usually at the start and end of everyday).

[2] Geosoft ®is a registered trademark of Geosoft Inc.

$$d = \frac{(r_{B2} - r_{B1}) - (g_{B2} - g_{B1})}{t_{B2} - t_{B1}}$$

where:

d is the drift in mGal/hour

r_{B1} is the base station one reading

r_{B2} is the base two reading mGal/hour *(same if only one base station is used)*

g_{B1} is the absolute gravity value of base one in milligals

g_{B2} is the absolute gravity value of station two in milligals

t_{B1} is the time of the reading at base one (hour)

t_{B1} is the time of reading at base two (hour)

- *Earth Tide correction* (ETC)

This is a time dependent variation and due to the effect of earth tides. The CG-3 does an automatic tidal correction using the Longman formula (Longman, 1959) when supplied with the latitude and longitude values of the survey area. The Geosoft program removes this factor when the data reduction takes place. It ads this factor into the calculation according to the Greenwich Mean Time difference and the position of the sun and the moon at the time and location of the observation. The full formula and the tables used for the calculation is to complex to mention here but can be obtained from the Dominion Observatory in Canada.

$$rt = rc + gtide$$

where:

rt is the tide corrected reading

rc is the scale corrected reading (which is one for this instrument)

gtide is the tide correction

- *Absolute Gravity*

The absolute gravity is the earth's gravitational attraction at the observed station.

$$g_a = g_{B1} + (r_h - r_{B1}) - (t - t_{B1})\, d$$

where:

g_a is the absolute gravity in milligals

g_{B1} is the base one absolute gravity in milligals

r_h is the instrument height corrected station reading (usually reading multiplied by one)

r_{B1} is the base one reading

t is the station reading time

t_{B1} is the reading time of base one

d is the drift obtained from the drift correction calculation

- *Latitude Correction*

The latitude correction requires the theoretical gravity at the station location on the earth's spheroid. There are two optional formulas for the theoretical gravity:

1930 formula:

$$g_l = 978049\,[\,1 + 0.0052884\sin^2(l) - 0.0000059\sin^2(2l)]$$ *and*

1967 formula:

$$g_l = 978031.846\,[\,1 + 0.005278895\sin^2(l) + 0.000023462\sin^4(l)]$$

where:

g_l is the theoretical gravity in milligals (latitude correction)

l is the latitude of the station

All surveys done with the differential GPS method is latitude corrected.

- *Free Air Anomaly*

The basis of this correction is that it makes allowance for the reduction in magnitude of gravity with height above the geoid, irrespective of the nature of the rock below. The free-air correction is the difference between gravity measured at sea level and that measured at an elevation *h* meters with no rock in between.

The free air correction is calculated by subtracting the latitude correction (theoretical gravity) from the absolute gravity and adding a correction for the station elevation:

$$g_{fa} = g_a - g_l + 0.308596h_s$$

where:

g_{fa} is the free air anomaly in milligals

g_a is the absolute gravity

g_l is the latitude corrected value

h_s is the station elevation in meters

- *Bouguer Anomaly*

Whereas the free air correction compensates for the reduction in that part of gravity due only to increased distance from the centre of mass, the Bouguer correction is used to account for the total rock mass between the measured station and sea level. It calculates the extra gravitational pull of a rock slab of thickness *h* (meters) and density ρh (mG/m^3). It is calculated as follows:

$$g_{ba} = g_{fa} - 0.0419088\ (\rho h_s)$$

where:

g_{ba} is the Bouguer anomaly in milligals

g_{fa} is the free air anomaly

ρ is the bouguer density of the rock in g/cc

h_s is the station elevation in meters

4.2.1.2 Electromagnetic method

One line was surveyed from nnw-sse with a station separation of 10 m and positions surveyed using a hand held Global Positioning System (GPS) unit (Geographical coordinates, WGS 84 datum).

A two man portable EM34-3 (with 20 meter coil separation) instrument was used for the electromagnetic survey. Both the vertical- VMD and the horizontal- HMD dipole modes were applied. These modes measure the out-of- phase component of the induced electromagnetic field, which gives an indication of the subsurface conductivity.

In the frequency domain electromagnetic method, which the EM34-3 instruments is a typical example of, a transmitter coil is energized with an alternating current at audio frequency (6400 Hz-10 m, 1600 Hz-20 m and 400 Hz-40 m). This current generates a primary magnetic field, which in turn induces secondary eddy currents in the subsurface. These currents then generate a secondary magnetic field which is then measured together with the primary magnetic field by the receiver coil. When operating at low induction numbers (i.e. conductivity low enough for a fixed frequency), the ratio of the secondary magnetic field to the primary magnetic field is linearly proportional to the average subsurface conductivity.

Using the VMD mode the maximum response originates from material at depth of approximately 0.4 x coil separation while the surface material has a small contribution. Deeper than x 0.4 coil separation the VMD mode has double the response of the HMD. For the HMD the surface material down to a depth of 0.4 x coil separation contributes to most of the signal (McNeill, 1980).

The out-of-phase component measures the average electrolytic ground conductivity through the moisture-filled pores and passages of the sampled volume. A maximum error of 30 % for the low induction number assumption is assumed, which allows for a maximum measured ground conductivity of 60 mS/m for the EM34-3. Provided the low induction number assumption is applicable, the effective depth of penetration is a function of the coil separation only (geometrically) and not of the skin depth (McNeill, 1980).

In the case where the low induction number assumption is violated by a certain percentage, the measured apparent conductivity is the same percentage lower than the true apparent conductivity (Stoyer, 1989).

The different dipole set-ups have different depths of penetration and different coupling with horizontal and vertical structures. Both the vertical and horizontal dipole set-ups have the same response over a vertical structure. The response of the vertical dipole will however be much larger if the contrast in conductivity remains constant with depth (McNeill, 1983a).

Several basic assumptions are made when empirical topographic corrections (Monier-Williams et al., 1990) are applied. The most important being that the background value (regional) is purely a function of elevation and that the stratigraphy should be horizontal and uniform. Unfortunately such ideal geological conditions are very seldom realized. Thus no elevation corrections applied during this survey.

4.2.1.3 Magnetic Method

A one-man portable Geotron G5 magnetometer was employed to conduct the survey. The G5 instrument is a Resonance, proton magnetometer and monitors the precession of atomic particles in an ambient magnetic field to provide an absolute measure of the earth's total magnetic field intensity in nanoTeslas (nT).

The proton magnetometer has a sensor, which consists of a bottle (casing) containing a proton rich fluid, usually water or kerosene, around which a coil is wound that is connected to the measuring apparatus. Each proton has a magnetic moment M and because it is always in motion, it also possesses an angular momentum G, rather like a spinning top. In an ambient magnetic field like that of the earth's magnetic field (F), the majority of the protons align themselves parallel with this field with the remainder anti-parallel to the field (Figure 3 A). Consequently, the volume of proton-rich liquid acquires a net magnetic moment in the direction of the surrounding ambient field (F).

A current is applied to the coil surrounding the liquid and generates a magnetic field roughly 50 to 100 times that of the ambient magnetic field but perpendicular to F. The protons align themselves to the magnetic direction (Figure 3 B.). When the applied current is switched of the protons precess around the pre-existing ambient field F (Figure 3 C.), at the Larmor precession frequency (fp) which is proportional to the magnetic field strength F.

$$F = 2\pi fp / \phi p$$

where:

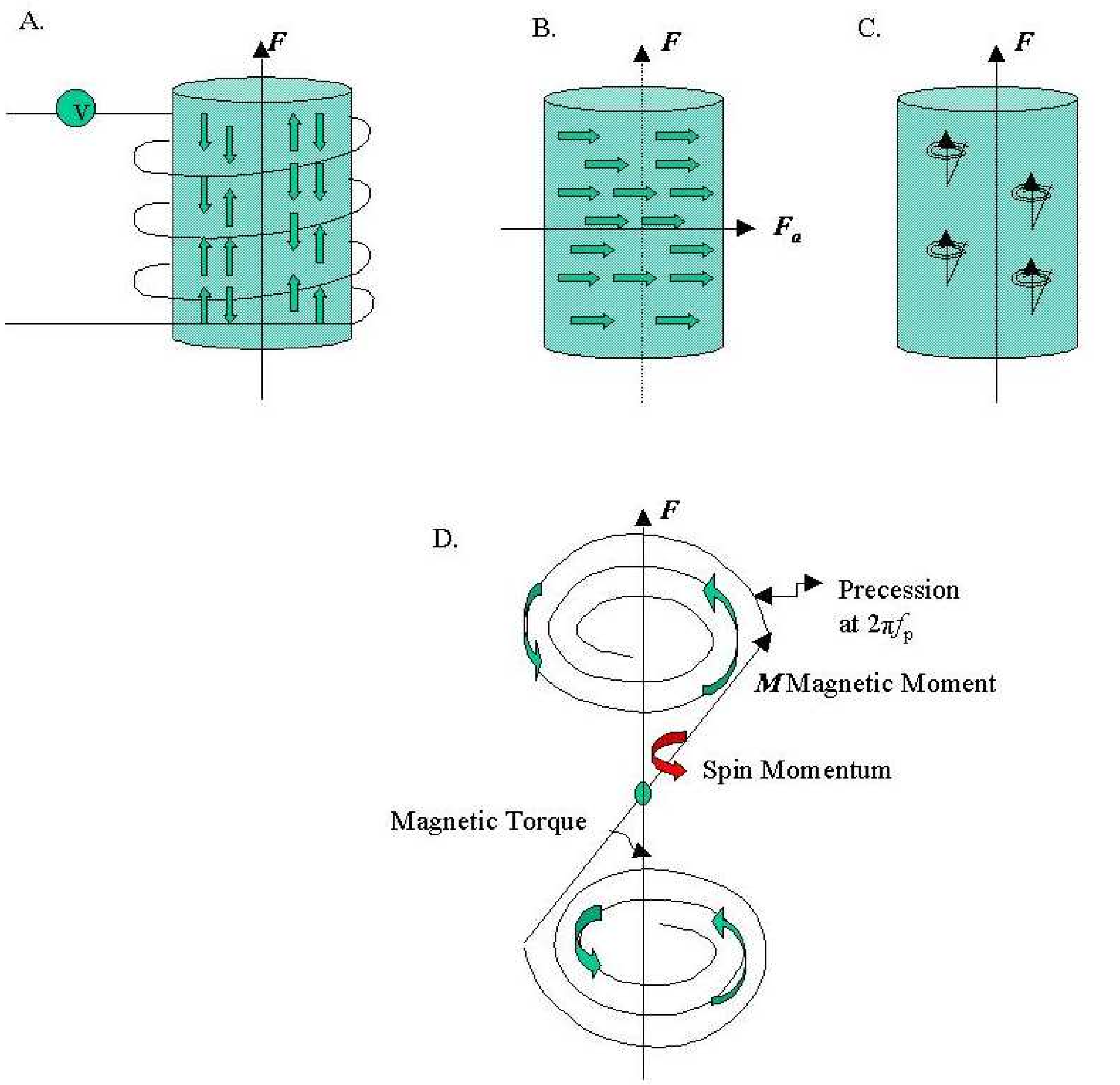
ϕ_p is the gyromagnetic ratio of the proton (ratio between magnetic moment and spin angular momentum, see Figure ? D.)

and ϕ_p = **0.26753 Hz/nT and** $2\pi/\phi_p$ **= 23.4859 nT/Hz**

Thus: $\boldsymbol{F = 23.4859 f_p}$

For example, for F = 50 000 nT, f_p = 2128.94 Hz.

Because protons are charged particles they will induce an alternating voltage during precession at the same frequency as f_p into the surrounding coil. Interaction between adjacent protons causes the precession to decay within 2-3 seconds, which is ample time for measuring the precession frequency. The G5 magnetometer gives a direct readout of the field strength in nanoteslas and can be output into a solid state memory



for downloading onto a computer (Reynolds, **1997).**

Figure 3: Basic operating principles of a proton magnetometer. After Kearey and Brooks (1991).

4.2.2 Geophysical survey results

The results from the gravity survey after the data was reduced yielded several low density anomalies as can be seen on Plan 4. After removing the regional fields and presenting the line data on a 2D graph these anomalies were targeted for the drilling programme. The low density anomalies could represent cavities or voids within the carbonate rocks and is normally drilled to explore tertiary aquifer systems within the dolomitic terrain and to ensure that all possible impacts are defined. It must be noted however that not all favourable anomalies could be drilled due to interference of the drilling equipment with the cultivated agricultural lands in the project area. Three of the boreholes were moved adjacent to coincide with the local road network and it is therefore unknown if any karstification has developed below the original target areas, however using extrapolation the new targets were also positioned at low density areas.

Figure 4 to 9 depicts the gravity lines. Bouguer anomaly values were filtered and the residual Bouguer values graphed. The ground geophysical data is appended in **Appendix D**. The drilling targets for the establishment of the monitoring boreholes can be seen on these. All five boreholes were drilled and only KAM01 intercepted a weathered zone in the dolomite which can probably be attributed to the weathered zone between the contact with the Karoo strata and the Malmani dolomite. The rest of the boreholes either stopped short of the dolomites (deeper than proposed mining depths) or did not intercept any major weathered zones and definitely no cavities or voids. The possibility of deeper lying cavities is very good as borehole G37018 indicated such a zone at 187 m (water strike in excess of 40 L/s) on the farm Wolvenfontein (eastern project area).

The results from the magnetic and electromagnetic survey indicated possible weathered zones along magnetic anomalies. Line 7 is depicted on the graph (Figure 10) and the anomalies is clearly evident from the magnetic and electromagnetic data. The magnetic data used in the graph has been filtered and the regional magnetic field removed using a third degree polynomial. Due to budgetary constraints only five boreholes were drilled and it was decided for now not to drill any of these anomalies. The line was surveyed to delineate possible weathered zones in order to establish a background monitoring borehole up-gradient of the project area. Borehole KAM04 was drilled in this area and would for the time being suffice as a background monitoring borehole.

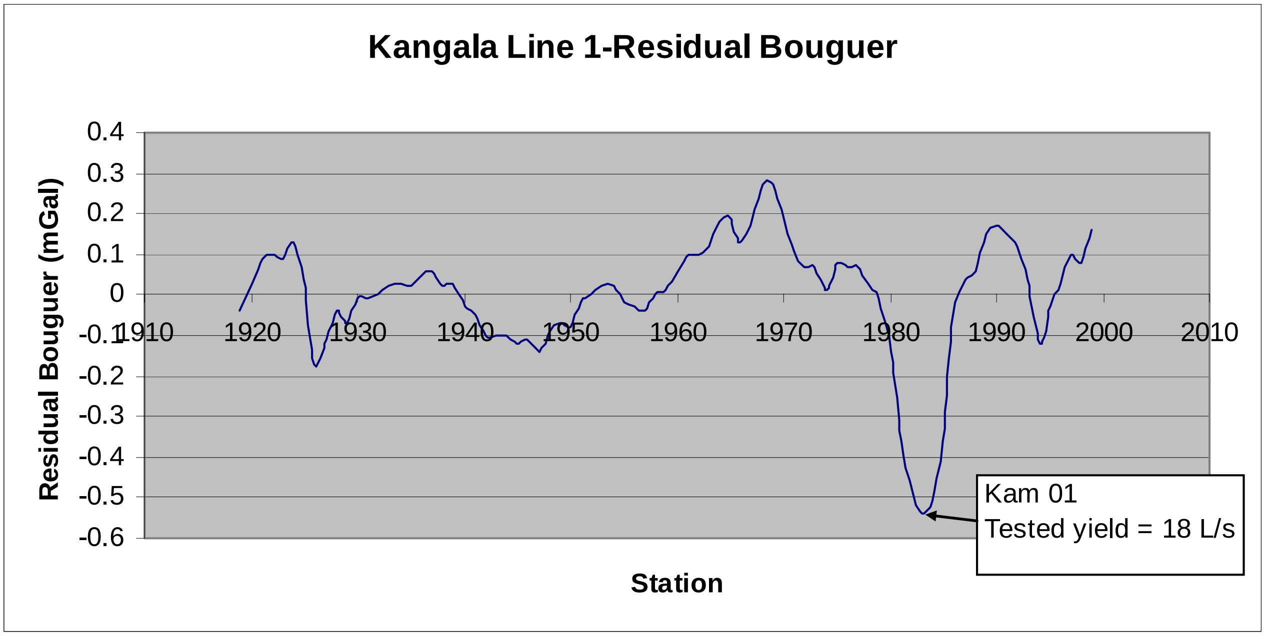


Figure 4: 2 D graph depicting the first line of gravity Residual Bouguer data at Kangala.

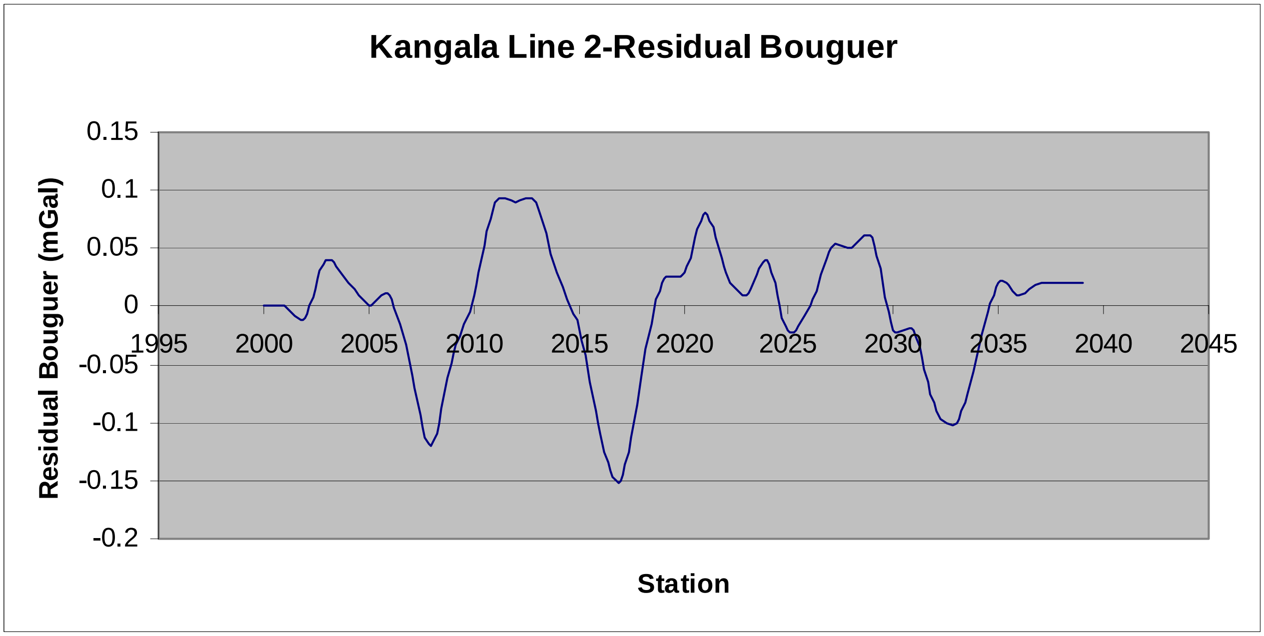


Figure 5: 2 D graph depicting the second line of gravity Residual Bouguer data at Kangala.

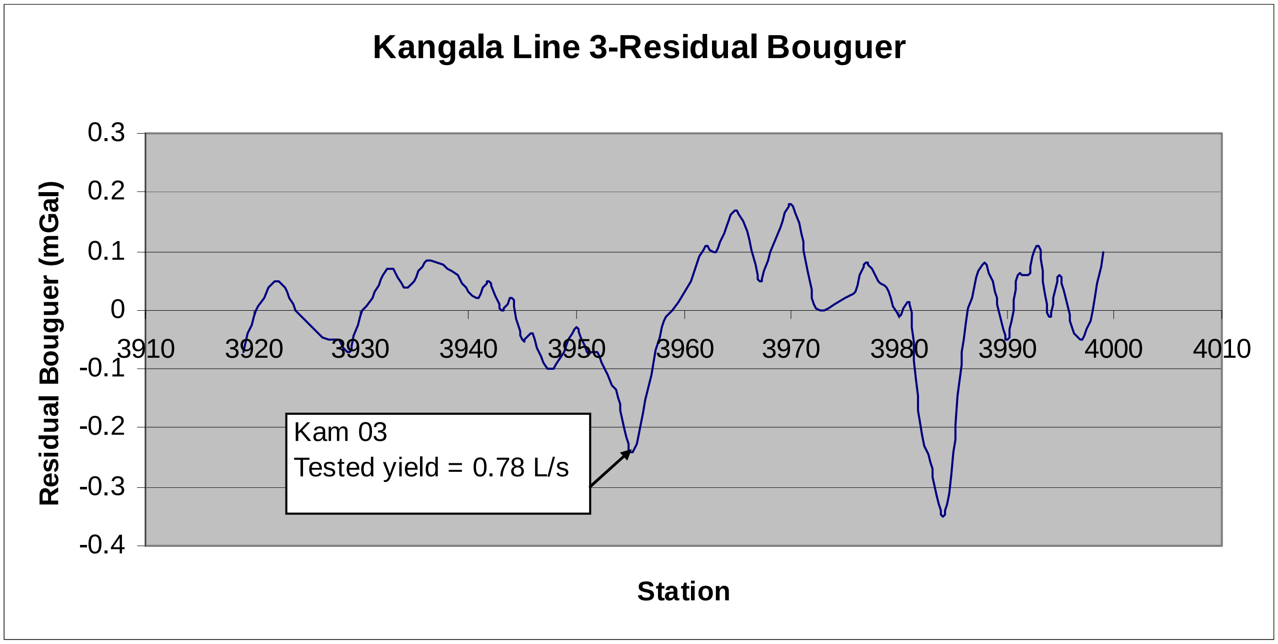


Figure 6: 2 D graph depicting the third line of gravity Residual Bouguer data at Kangala.

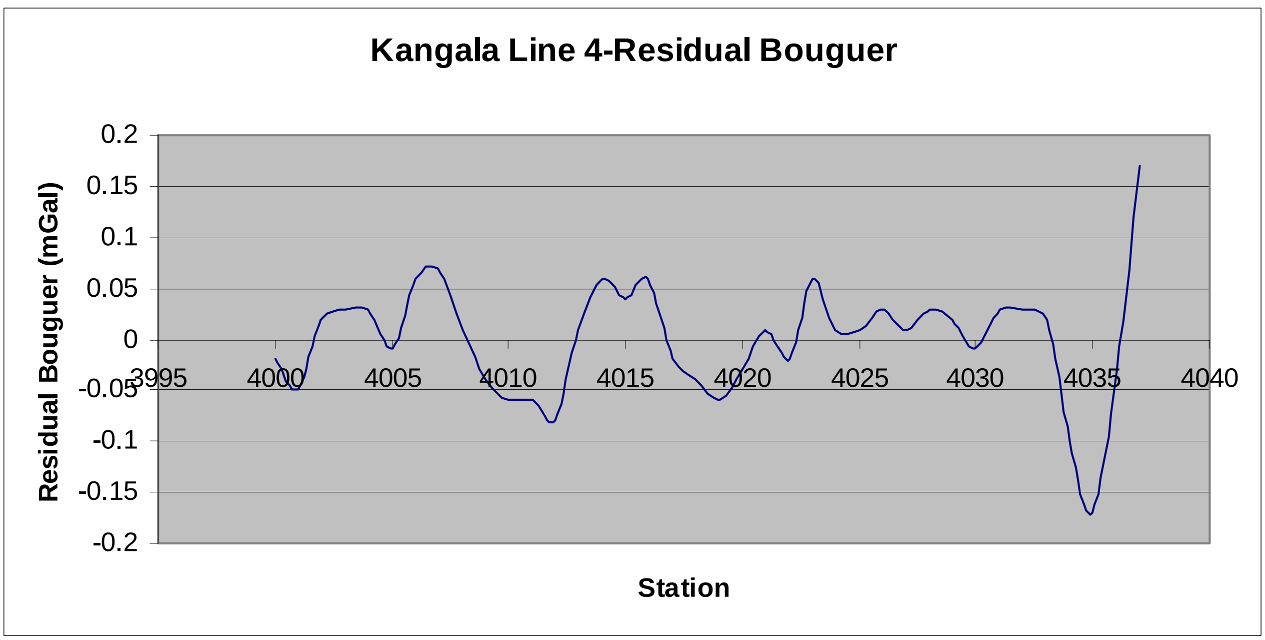


Figure 7: 2 D graph depicting the fourth line of gravity Residual Bouguer data at Kangala.

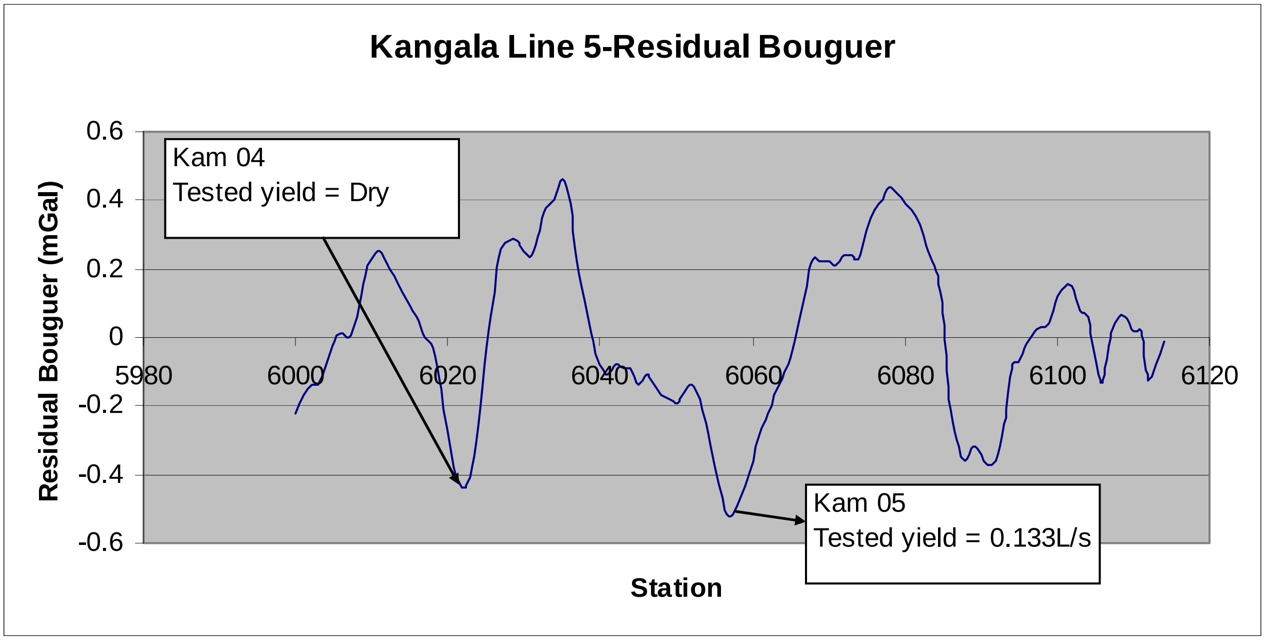


Figure 8: 2 D graph depicting the fifth line of gravity Residual Bouguer data at Kangala.

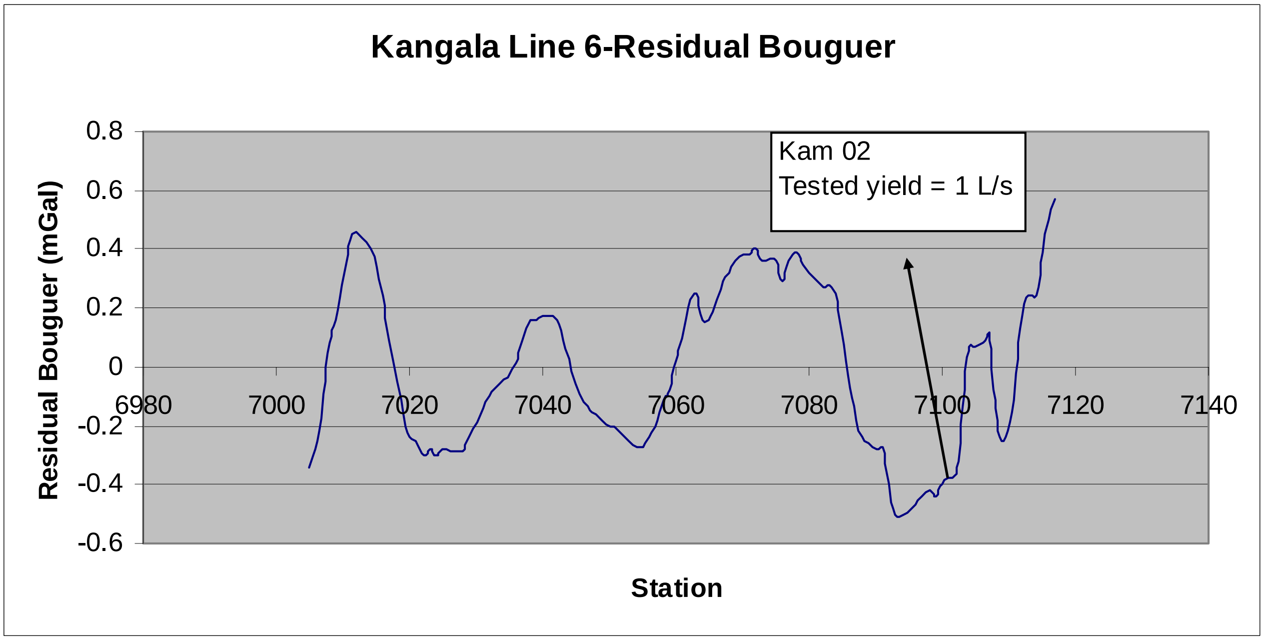


Figure 9: 2 D graph depicting the sixth line of gravity Residual Bouguer data at Kangala.

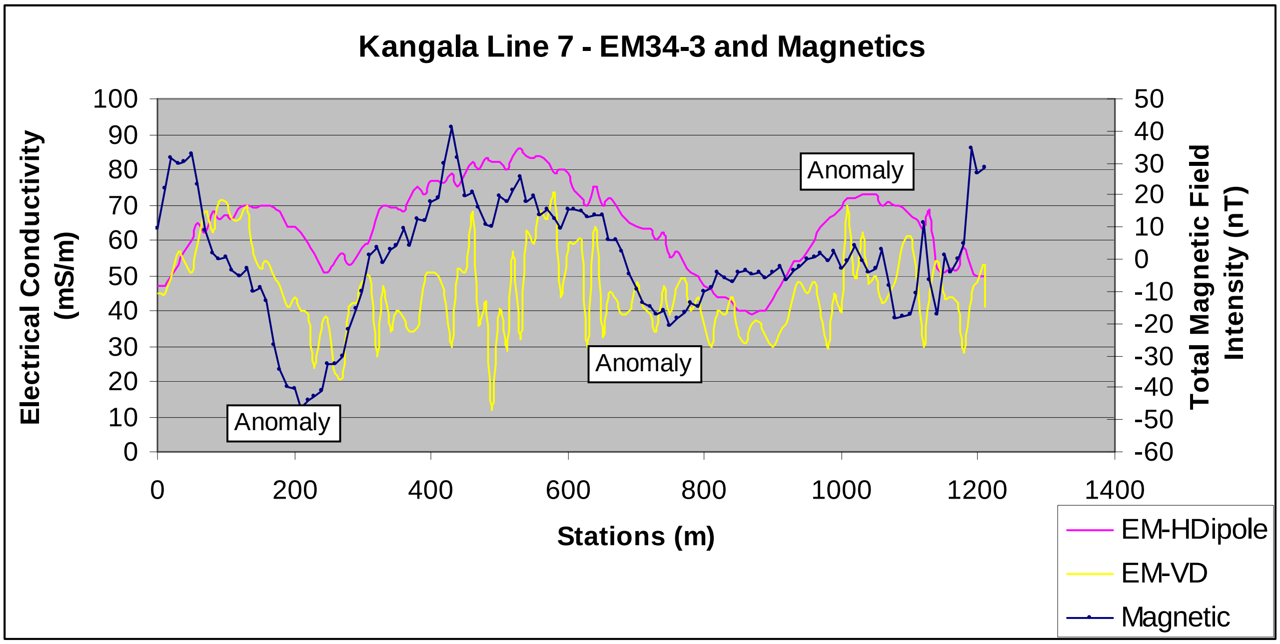


Figure 10: 2 D graph depicting the seventh line with magnetic and electromagnetic data.

It should be noted that line one and three is parallel, five and six as well as line two and four (Plan 4), hence the large anomalies on these lines were not all targeted for drilling, just one out of both lines.

4.3 Intrusive Studies

4.3.1 Drilling

The drilling phase was a follow on from the geophysical survey and five targets derived from the geophysics were drilled. The drilling was conducted between the 21st of September and the 24th of October 2009. The drilling was conducted using a Rotary Air Percussion drilling machine, with air delivered from a high volume compressor. Drilling contractors were also requested to record data on water strike depths, penetration rates and blow yields while also sampling drilling chips in one meter intervals and collecting them in sample bags.

The drilling positions with regards to the gravity residual Bouguer false colour anomaly map can be seen in Plan 4. The five boreholes varied between a depth of 60 and 80 m depending on the elevation sited. The boreholes were mainly drilled to characterise the aquifers in the project area and subsequently to serve as initial monitoring points for the groundwater monitoring required by DWAF.

Table 4 summarises the data for the five boreholes drilled including the finalised borehole construction data. The borehole lithological and construction logs can be found in Appendix E. Four boreholes yielded water with yields ranging from 0.13 to 11.5 L/s while borehole KAM04 was dry. However a water level has subsequently being monitored in KAM04 and was therefore constructed to serve as a monitoring borehole. The boreholes are placed strategically and only during a definitive study will additional boreholes be drilled around the infrastructure in the project area for more detailed site specific monitoring.

Table 4: Summary of the new characterisation / monitoring boreholes drilled at Kangala.

	Borehole ID	KAM01	KAM02	KAM03	KAM04	KAM05
Borehole Location	X (L.O. 29)	2900444.72	2898762.72	2897899.12	2898219.04	2899152.57
	Y (L.O. 29)	32815.99	32210.51	32352.21	33805.25	33382.29
	Z (masl)	1611.49	1591.98	1602.99	1613.88	1616.14
	Latitude (WGS 84)	-26.12.45.83	-26.11.51.23	-26.11.23.16	-26.11.33.36	-26.12.03.72
	Longitude (WGS 84)	28.40.17.87	28.40.39.84	28.40.34.81	28.39.42.72	28.39.57.66
Borehole Data	Water Strike / s Depth (m)	19; 32; 50.5	15, 24	41; 56	none	49
	Borehole Depth (m)	80	60	80	80	60
	Blow Yield (L/s)	11.5	0.45	0.78	0	0.133
	Static Water Level (m bgl)	11.59	11.2	11	4.73	9.28
Borehole Construction Data	Solid Casing (Diameter - ID mm)	165	165	165	165	165
	Depth from, to (m)	0-24	0-32	0-25	0-5	0-40
	Perforated Casing (Diameter - ID mm)	165	165	165	165	165
	Depth from, to (m)	24-60	32-60	25-60	5-40	40-60

The lithologies intercepted during drilling in general consisted of weathered upper Karoo sediments, intercalated shale / siltstone, sandstone and coal layers, with Dwyka tillites overlaying the basement Malmani dolomites (see Figure 1). The percussion borehole lithological logs and other detail are appended in **Appendix E** hereto.

4.3.2 Aquifer testing

Aquifer testing of the four successful boreholes was conducted from the 20th October to the 11 of November 2009, while the drilling was still in progress. Boreholes KAM01, 02, 03 and 05 was aquifer tested between four and 24 hour duration constant tests as well as two hour step drawdown tests. Aquifer test data for both the step drawdown test and constant discharge tests is appended in **Appendix F**, while graphical data is depicted in Plates 1 to 8, **Appendix G**.

Three types of tests were undertaken:

- Step-drawdown tests;
- Constant-discharge tests; and
- Recovery tests.

4.3.2.1 Step-drawdown Test

The variable rate-recovery step-drawdown tests were used to determine borehole pumping characteristics and estimate a pumping rate suitable for the constant-discharge test. These tests comprised pumping the borehole at rates that were increased incrementally (“steps”) after which recovery is measured. The steps were generally between 30 to 60 minutes duration and between 4 to 5 increasing steps. Analyses of these results were used to determine well and formation loss factors and to select a suitable rate for the constant -discharge test.

Methodology and analysis

Groundwater level drawdown in a pumping borehole has two components, formation loss and well loss. Formation loss is dependent on the hydraulic characteristics of the aquifer in the vicinity of the borehole and is directly proportional to the pumping rate. Well loss is caused by turbulent flow and friction head loss through casing slots and around the pump, and thus depends on bore construction and development. It is generally considered proportional to the square of the pumping rate.

Therefore, drawdown in a pumping bore can be expressed by the formula:

$$Sw = BQ + CQ^2$$

where: Sw = Groundwater level drawdown (m)

Q = Pumping rate (kL/day)

B = Formation loss factor (day/m^2)

C = Well loss factor (day^2/m^5)

$$WellEfficiency = \left(\frac{BQ}{BQ + CQ^2} \right) \times 100$$

The step-drawdown test results were analysed by the Hantush-Bierschenk method, whereby S_w/Q is plotted against Q, giving a line with a y-intercept of B and slope C (Table 5).

Well efficiency generally decreases as pumping rate increases, due to the higher proportion of well loss (CQ^2) contributing to total drawdown ($BQ + CQ^2$) in the well. At higher pumping rates, the higher velocity of groundwater entering the well causes a higher proportion of well loss resulting in lower bore efficiency. The calculated values of efficiency are relatively high in comparisons to wells completed with slotted casing in fractured rocks.

Table 5: Summary of Step-drawdown tests performed at Kangala.

Bore hole	Step length (min)	Step Test Rates (Q m³/d) 1	2	3	4	Aquifer Loss B (d/m²)	Well Loss C (d²/m⁵)	Apparent Well Efficiency (% at Q L/s)	Specific Capacity (m²/d at t min)
KAM01	30	691.2	1036.8	1296	1728	8.7×10^{-3}	5.63×10^{-6}	47 at 20	60 at 120
KAM02	30	9.5	20.7	47	86.4	0.12	4.9×10^{-4}	75 at 1	7.15 at 120
KAM03	30	10.37	35.4	57.9	82.9	0.219	3.1×10^{-3}	46 at .96	2.6 at 120
KAM05	60	12.4	19	23.9	33.7	0.491	0.013	52 at .39	.87 at 240

4.3.2.2 Constant Discharge Tests

The constant-discharge test in each production bore commenced following the step-drawdown tests and after groundwater levels had recovered to initial static levels. Upon completion of each constant-discharge test, recovering groundwater levels were also measured.

For the constant-rate tests, the production bores were pumped between 4 and 24 hours. Water levels were monitored in the pumped bore, while no monitoring boreholes were available to allow accurate storativity calculations.

A summary of the derived aquifer parameters and drawdown data obtained during testing are presented in Table 6.

Methodology and analysis

The constant-discharge test results enable the hydraulic characteristics of the aquifers intersected by each test production bore to be determined.

The following methods were used to analyse the constant discharge data acquired:

Flow Characteristic (FC-method) method (Van Tonder *et all*, 1999), utilising different analytical methods of flow characterization.

Theis straight line and recovery method for the pumping boreholes (Kruseman and De Ridder, 2000).

The Cooper-Jacob (“straight-line”) method (Kruseman and De Ridder, 2000) of analysis is a modification of the Theis equation and the data must meet certain requirements in order to validate. The validation requirements are derived using the following equation:

$$u = \frac{r^2 S}{4KDt}$$

Where:

$r =$ Radial distance between the observation bore and the production bore (m)

$S =$ Storativity value obtained from the analysis (-)

$K =$ Hydraulic Conductivity (m/day), [also referred to as permeability in this report]

$D =$ Thickness of the aquifer (m)

$t =$ Time (days)

where, the value of u is generally < 0.01.

Table 6: Summary of Constant Discharge and Recovery tests performed at Kangala.

Test Bore	Constant-Rate Test		
	Pumping Rate (m^3/d)	Available Drawdown (m)	Drawdown (m)
KAM01	1555.2	40	31.8
KAM02	86.4	21	16.53
KAM03	71.7	43	34.6
KAM05	31.968	46	46

Bore ID	Constant Test (period hours)	Blow Out Yield, Q (L/s)	Tested Yield, Q (L/s)	Transmissivity (m^2/d)					Storativity (Estimate)
				Logan Method	FC-Method		Theis Recovery Method		
					Early time	Late Time	Early time	Late Time	
KAM01	24	11.5	18	60	32	40	_	46	2.2 x 10-3
KAM02	4	0.45	1	6.4	3.2	2.3	_	2.4	1.1 x10-5
KAM03	4	0.78	0.83	2.5	0.9	1.1	_	1.6	1.1 x10-5
KAM05	Only step test	0.133	0.37	0.08	_	_	_	0.35	2 x 10-6

The data indicates that the upper Karoo sedimentary aquifer has low conductivity and moderate storage. It is well known that the Karoo sediments have low effective porosity and therefore only weathered zones or prominent fractures will yield fair conductivity values.

The Malmani aquifer have high conductivity values and high storage where fractured and weathered zones are intercepted, however fresh rocks have low to no conductivity. Karstified zones, where well connected, have extremely high conductivity and flow is normally high along these preferred flow paths. Transmissivity values in these zones are typically in excess of 300 m^2/d, it is therefore possible that borehole KAM01 only intercepted the weathered contact zone between the Dwyka and the Malmani and not the deeper lying possible cavities intercepted during exploration during 1986 (Leskiewicz, 1986).

5 HYDROGEOLOGY

The proposed mine site is located within the Western Bankeveld and Marico Bushveld and bordering the Eastern Highveld hydrogeological region (Plan 2). This region covers the whole eastern portion of the Mpumalanga Province. The rocks found here belong to the Vryheid Formation, which forms part of the Karoo Supergroup. The Malmani

Dolomites have extensive karstification and outcrops to the north of the project as well as forming the base in the project area where a regional fault enhanced dissolution processes and subsequently karst features within the dolomite, creating large tertiary aquifer systems.

5.1 Conceptual hydrogeology model

The conceptual hydrogeology model was derived from the data obtained from drilling and aquifer testing as well as the exploration geological logs obtained from Universal Coal PLC.

A conceptual model is a representation of probable geometry of an aquifer system hosted within a defined lithological area. Due to the diversity of the geology more than one aquifer system could exist within a vertical slice of layers. Groundwater flow direction and hydraulic conductivity is important to visualise the movement of groundwater due to gravity and pressure / hydraulic gradients.

Figure 11 is a graphical rendition of the geology and hydrogeology at the project site in order to conceptualise the groundwater occurrence and movement in the subsurface. Rainfall that infiltrates into the weathered rock soon reaches the layer of shale underneath the weathered zone. The movement of groundwater on top of this reatrding shale layer is lateral and in the direction of the surface slope. The water reappears on surface at the wetland areas.

Groundwater not influenced by evapotranspiration, which in this area will be a minimum due to the cultivated open land, will infiltrate weathered and fractured zones within the weathered shale / siltstone layer flowing vertically down into the coal seams from where it will move horizontally through the layer but also along the Dwyka contact towards the topographical lows eastwards and towards the wetland stream area. The area north east to east of the project has outcropping dolomites. The Dwyka clayey zone will most likely act as a retarding aquitard layer when still intact. The $\mathbf{k_6}$ or dolomite layer will most probably have regional flow associated with it on the contact weathered zone between the Dwyka and Malmani dolomite as well as in the effectively connected karst zones deeper within the dolomites. This will flow towards the northern to eastern outcropping dolomites.

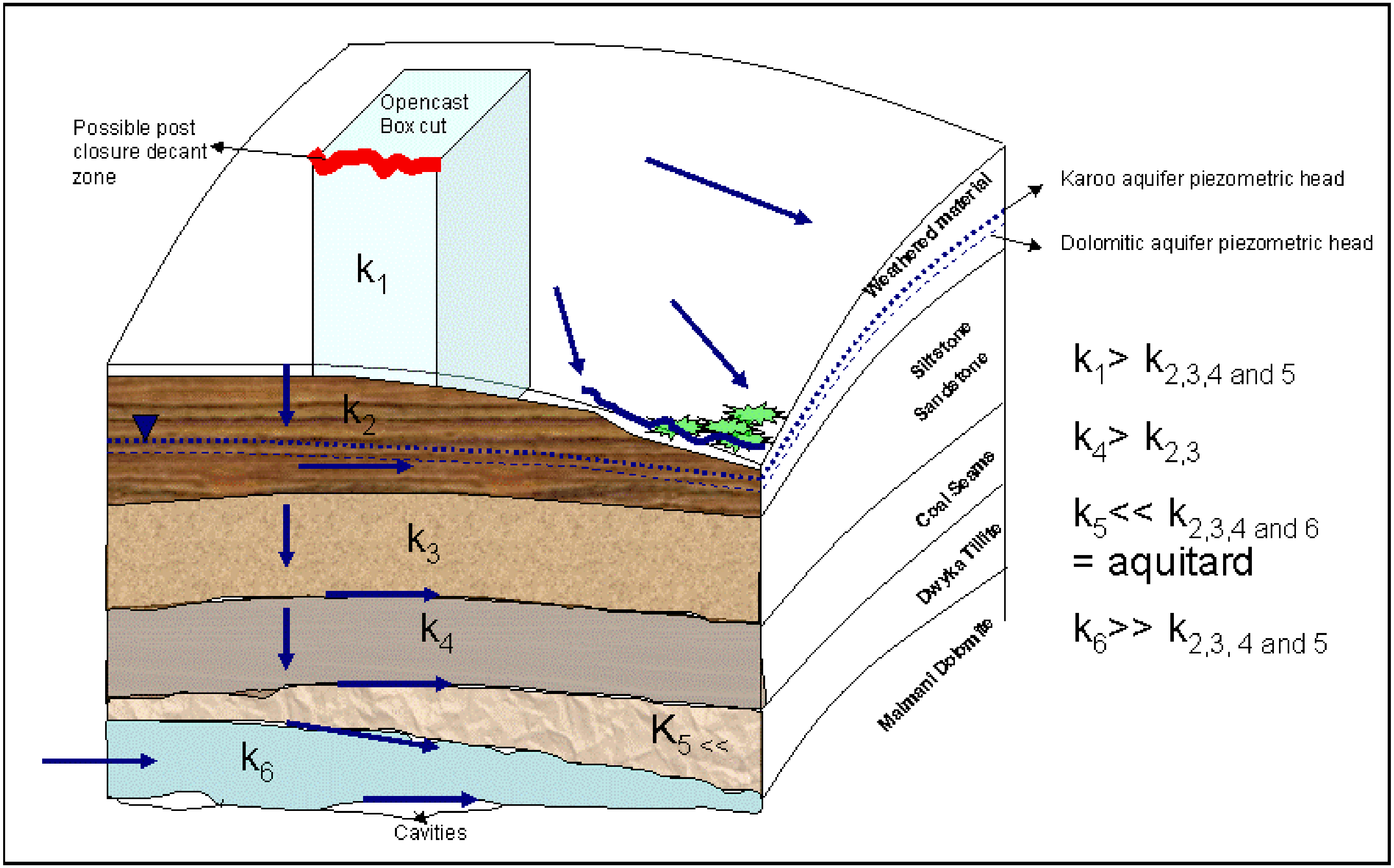


Figure 11: Hydrogeological conceptual model for the Kangala project area.

Two possible water levels will exist, the phreatic water table within the weathered zone k_2 and piezometric water level from the semi-confined Karoo aquifer and the confined dolomitic aquifer. These levels are fairly close to each other.

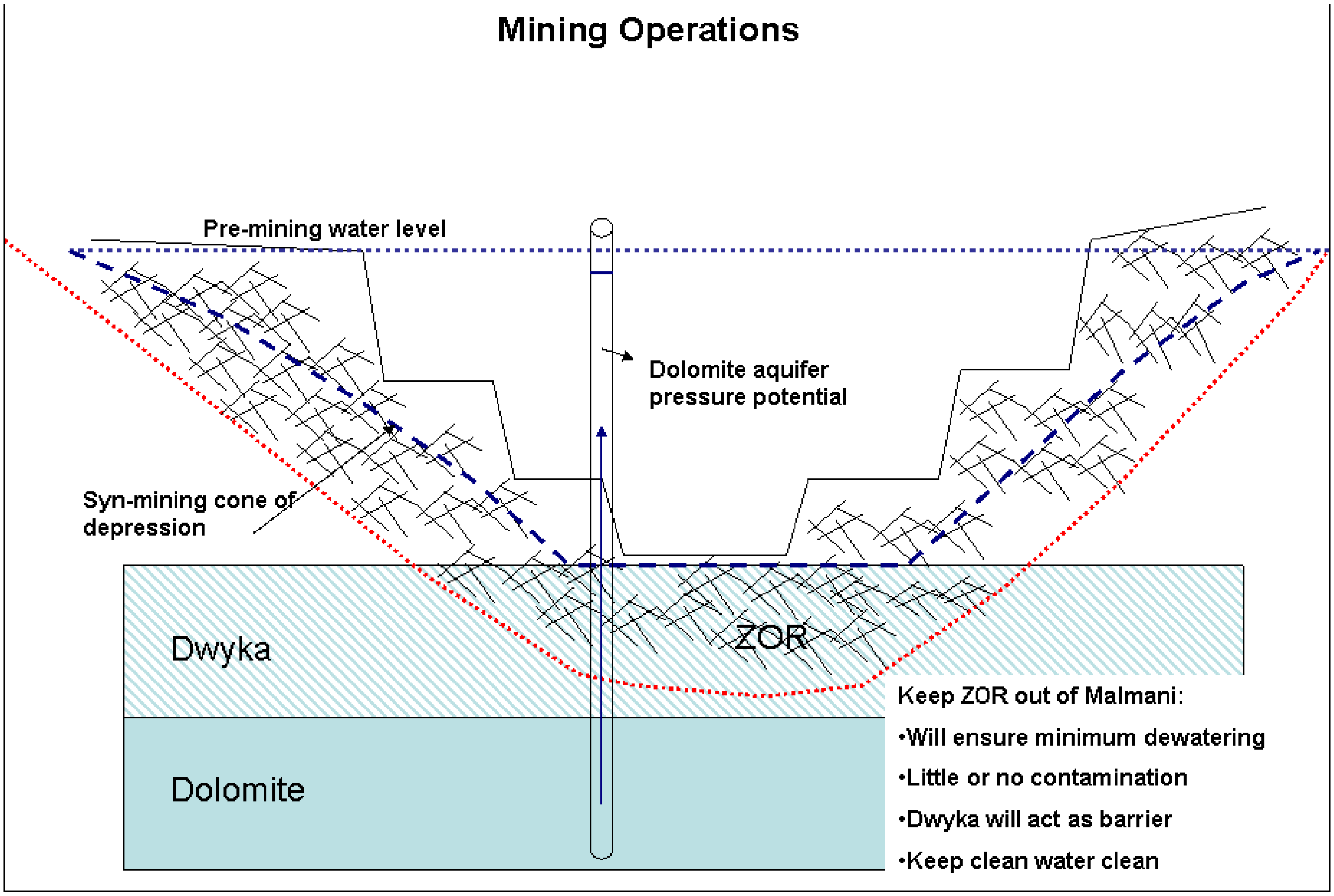


Figure 12: Mining conceptual model for the Kangala project area.

Hydraulic conductivites in the dolomites and open pit areas will be the highest with the Dwyka aquitard being the lowest. The weathered zone will have slightly higher conductivities than the Karoo different layers.

This will be significant as flow within the Karoo will be governed mainly by fractured and weathered zones, which will impede the movement of possible contaminants away from the mine infrastructure towards the lower lying wetland area.

The vertical flow regime will also be significant as the Dwyka aquitard should in theory impede flow towards the dolomites and specifically the karstified zones in the deeper sections of the dolomite.

However if the Zone of Relaxation (ZOR) usually created by opencast mining operations such as blasting and removal of material, would puncture the Dwyka layer the potential pressure within the dolomitic aquifer could cause severe dewatering issues and possible post mining decant along the red zone indicated in Plan 7 and Figure 11.

Cognisance will therefore need to be taken of this hydrodynamic system to ensure that minimum impacts will be caused by mining and that monitoring will have to be conducted to ensure management of the system.

The conceptual model of mining in a profile view (Figure 12) for the area and in relation to the most important layers, indicates the importance of the dolomitic aquifer pressure potential and the retarding Dwyka layer that needs to be kept in tact during mining operations. It also again reiterates the possible hydraulic potential of the dolomitic aquifer.

5.2 Flow direction and water level measurements

A general restriction applies when groundwater flow directions are defined using the normal approach of measuring static water levels in boreholes drilled for characterisation. The concept of a potentiometric surface is only valid for horizontal flow in horizontal aquifers. Obviously this is not the case in natural systems. Further it is possible to confuse a petentiometric surface with the water table in areas where both confined and semi-confined aquifers exist (Freeze *et all*, 1979). There should be at least three boreholes penetrating a specific aquifer, to ensure accurate flow direction measurements as well as gradients can be made from a specific potentiometric level. However in practise that is almost impossible due to costs etc. A general water level surface which is an average approximation of the potentiometric surface as well as semi-confined to unconfined water table values is therefore used for defining the groundwater flow in an area and is generally referred to as a potentiometric or piezometric contour map.

Plan 6 is a false colour (RGB) potentiometric surface contour map indicating the groundwater flow in the project area. There is a good correlation with the regional contour map (Plan 5), representing data obtained from the DWAF National Groundwater Archive (NGA) performed during the scoping phase (DWA, 2009) and onsite data from the five newly drilled boreholes (Table 7).

The flow is in an easterly to north-easterly direction towards the topographical low lying areas. This in general is towards the dolomitic outcropping area.

Table 7: Static water level data and surface data above datum for newly drilled boreholes at Kangala.

Borehole no.	Borehole collar elevation (mamsl)	Static water level (mamsl)
KAM02	1611.49	1600.29
KAM01	1591.98	1580.39
KAM03	1602.99	1591.99
KAM04	1613.88	1609.15
KAM05	1616.14	1606.86

The Bayesian correlation method below describes the relationship of flow and natural surface gradient:

Bayesian Correlation

The five boreholes with accurate collar elevations were used to establish the relationship of groundwater elevation with regards to surface topography. A scatter diagram of surface topography plotted against groundwater elevation above datum is used to analyse the relationship and is referred to as a Bayesian correlation for a specific aquifer system. Figure 11 depicts the relationship for the aquifer system / s in the project area. There seems to be a reasonable correlation apart from borehole KAM04 which was the dry borehole with no water strike and only a seepage static water level later on.

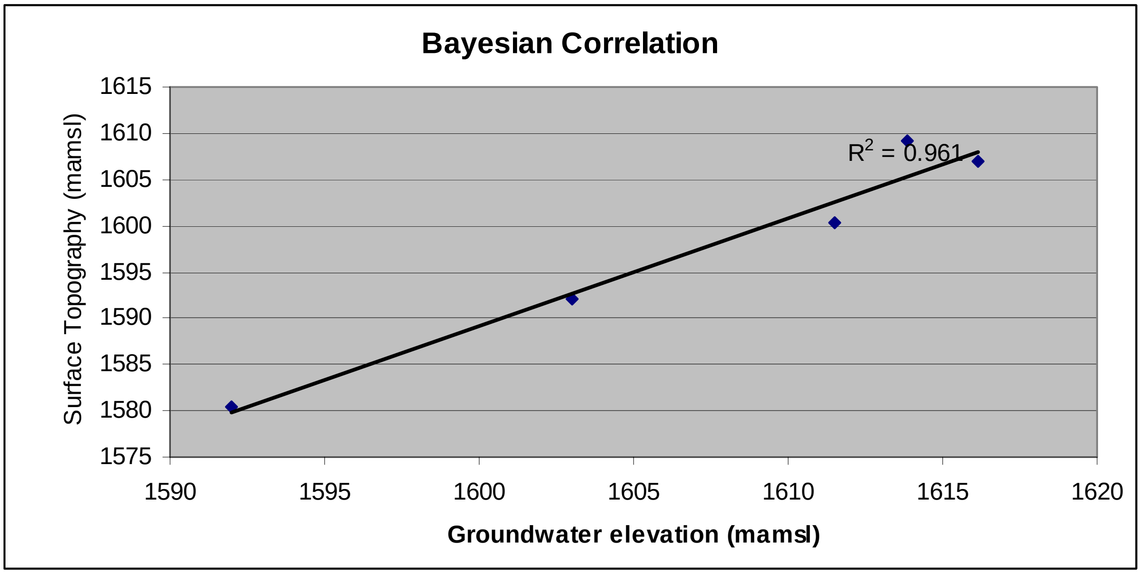


Figure 13: Bayesian correlation indicating reasonable relationship between groundwater levels and surface elevations

5.3 Water balance

5.3.1 Groundwater recharge

Highly variable recharge occurs over the area but values are generally between 1 and 3 % of MAP (Hodgson & Krantz, 1998) for undisturbed areas. Recharge to the weathered aquifer drains towards regional surface water courses and less than 60% of the recharge discharge in streams. The remainder is withdrawn through evapotranspiration from the weathered aquifer, recharged to the deeper fractured rock aquifers or abstracted through pumping. A low vertical permeability generally exists for the fractured aquifer in the Ecca Formation and this aquifer is recharged by interflow from the weathered aquifer. Recharge to the Malmani could be higher where it outcrops and where direct recharge occurs through preferential path ways. It is also possible that regional recharge occur in the dipping Malmani below the project site from interconnected karstified zones from the adjacent regional dolomites.

5.3.2 Baseflow

The shallow weathered perched aquifer in the area contributes water to the lower lying wet land / stream areas during the dry months while most probably receiving water during wet seasons. The volume of water contributed however is not difficult to define quantitatively.

5.3.3 Abstraction

Total registered abstraction from groundwater resources in B20A quaternary catchment from the GRDM is 0.02 Mm^3/a. The exploration potential for this catchment is 3 Mm^3/a thus making 2.98 Mm^3/a available for use. From the Department of Water Affairs and Forestry (DWAF) Water Use Registering and Licensing Data Base (WARMS), X11D indicate that a register volume of 81 004 m^3/a is being abstracted for mainly agricultural use.

5.4 Dewatering and re-watering of mining areas

5.4.1 Dewatering in the opencast mining areas

Dewatering in the area surrounding the opencast areas will occur as a result of groundwater flow under the influence of gravity to the bottom of the pit. Dewatering to keep the pit dry will have to be performed during operations. The radius of influence from the pit areas calculated as a function of the hydraulic conductivity can only be achieved if confident Storativity (S) values are known through aquifer testing with monitoring boreholes. This has not been achieved during this baseline study due to costs and will be conducted during the definitive study to be performed as part of the infrastructure design and planning phase. The re-watering post mining activities can also not be calculated due to the same restrictions.

5.4.2 Post mine ingress into the back filled areas

Although it is imperative to calculate the post mine ingress volumes after rehabilitation is completed during the closure phase, the same restriction as in section 5.4.2 holds for these calculations. A more reliable figure also needs to be derived for groundwater recharge in order to make informed calculations on post flooding scenarios of back filled pits. It is however important as the IWULA application will focus on backfilling with over and interburden in order to reduce discard piles. Flooding of this backfilled material should minimise the chances of acid generation normally associated with high sulphide mineral content, but fluctuating levels should be minimised (DWAF Guideline G4, 2008).

The coal seam elevations were obtained from the exploration drilling data completed at Kangala. To understand the current mining and post mining hydrogeological conditions, cross sections were completed indicating the relation between the No. 2 coal seam and the surface topography as well as the difference between the two which is a measure of what volume of material will be removed for mining and where the two levels could coincide, which can be related to direct decant if values are zero. Surface and coal seam elevations indicate two possible decant zones from the two profile sections depicted on Plan 7.

Section 1: (**Figure 14**) indicates a reasonable correlation between the surface topography and the coal seam floor elevation. The difference profile indicates no zero values which means that no direct decant will occur. As the coal seam is basically level with a slight rise towards point 1550 m the possible decant zones will foremost arise where the open pit coincides with the topographical low in this area and towards zone 250 to 500 m of the section.

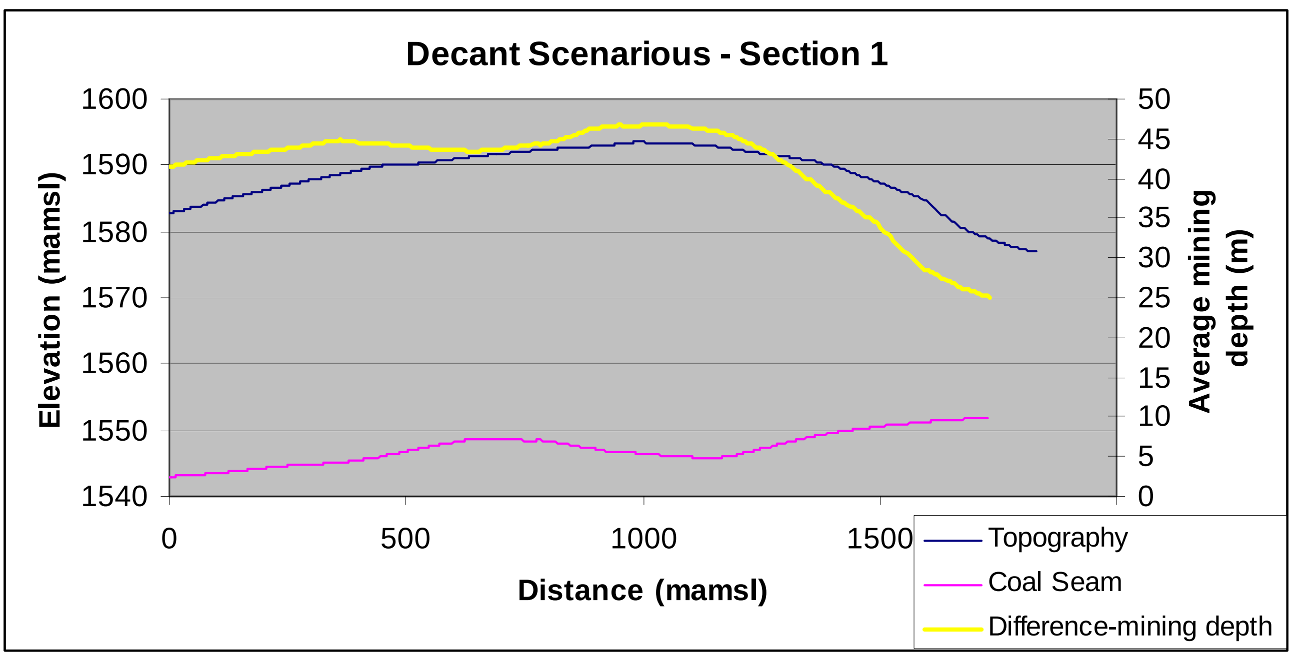


Figure 14: Profile section 1 depicting the elevation of the No. 2 coal seam, associated topography and difference or mining depth values.

Profile 2: Again no zero difference values can be seen on the graph and therefore no direct decant is expected. A possible decant due to the topographical low is indicated in Figure 15.

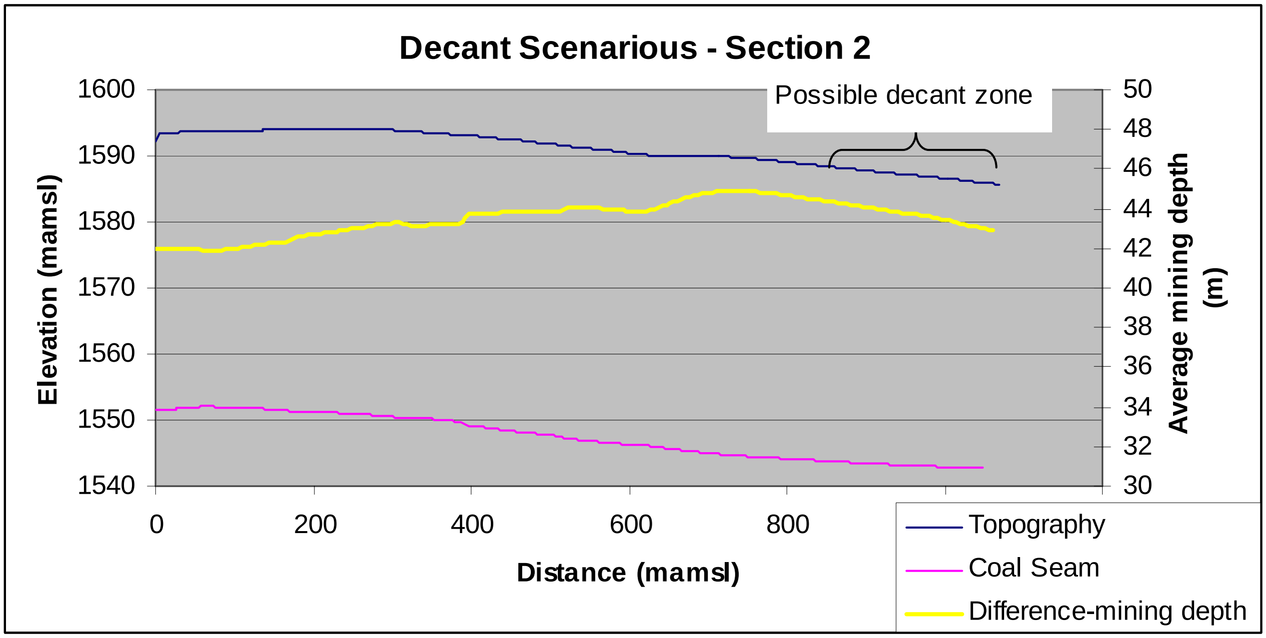


Figure 15: Profile section 2 depicting the elevation of the No. 2 coal seam, associated topography and difference or mining depth values.

It is essential that appropriate mitigation measures are put in place at the decant sites in order to effectively manage the water that is expected to decant after mine closure.

5.5 Groundwater quality

It is crucial to establish baseline quality conditions prior to any mining activities in a project area. This ensures that no degradation of the groundwater resources will occur and at best that improvement results. This also establishes the nature and degree of existing contamination practices and will help quantify cumulative impacts. Groundwater quality also helps establish the origin of the water and how to best manage impacts that could arrive.

The Five newly drilled characterisation boreholes were sampled for water quality. These were boreholes KAM 01, 02, 03, 4 and 05. Table 9 summarises the quality of the groundwater and is a comparative analysis with the SANS 241:2005 Drinking Water Standards. Sample analysis was conducted by Regen Waters and is a SANAS accredited laboratory, the analysis certificates are appended in **Appendix H**.

The sampling protocol used conformed to the DWEA (Weaver et al. 2007) as well as the SANS 241:2005 protocols. Purging of the boreholes was performed removing at least one and a half time the volume of each sampled borehole to ensure a representative sample. Inter hole decontamination of sampling equipment was also performed, while calibration of instruments was performed during sampling.

Graphical methods are employed to present the data in a convenient manner for visual inspection. The major ion compositions as a percentage of the total equivalents (milliequivalents per liter) are displayed using the tri-linear diagrams known as Piper and Extended Durov diagrams. The diagrams are useful to describe the differences in major ion chemistry in groundwater flow systems. The Stiff diagram facilitates rapid comparison as a result of distinct graphical shapes or signatures. The major ion constituents from the five samples collected is presented in these different diagrams and interpreted below:

The tri-linear Piper diagram (Figure 16) indicates that the groundwater is a bicarbonate-calcium-magnesium type water and very typical of dolomitic terrain, it is also very similar to the analysis completed on the hydrocensus data (section 4.1.3). There is a slight sodium-chloride presence and could indicate mixing from the Karoo aquifer (probably due to the coal layer influence). KAM01 also indicates some elevated sulphate values which can be contributed to the coal horizon intercepted during the drilling and possible mixing.

The Expanded Durov diagram uses similar ratio techniques as the piper diagram to plot the concentrations of the major ions, however six triangular diagrams are used, three for the anions and the other for the cations (**Figure 17** 17). The expanded Durov is divided into 9 areas, each corresponding to a water type; a brief description of each area is given below in **Table 8**. In each instance the dominant anions and or cations are presented. In certain instances there is no dominance by any particular constituents (area 5) or only dominant anions (area 8).

Table 8: Expanded Durov Legend

1 Calcium Bicarbonate	2 Bicarbonate Magnesium or Calcium Magnesium	3 Bicarbonate Sodium
4 Sulphate and/ or Calcium	5 No dominant anions or cations	6 Sulphate and/or Sodium
7 Chloride and Calcium	8 Chloride	9 Chloride and Sodium

The majority of the samples fall within the second field represented by a bicarbonate-magnesium or calcium-magnesium dominant water. Sample KAM01 again falls within field five indicating no dominant water type or mixing waters.

The Stiff diagrams (Figure 18) indicate an underlying dolomitic signature with prominent alkalinity and magnesium-calcium ratios. There is a definite addition of sodium and chloride as well as sulphate to these signatures again confirming a mixing water.

The water quality in general for all five samples falls within class one water according to SANS 241 (acceptable) with only elevated iron and manganese values which falls within the maximum allowable limit. High nitrate values could be due to agricultural activities as these boreholes were all drilled next to cultivated lands.

The Total dissolved solids ranges between 88 to 344 mg/L and the Electrical Conductivity (EC) between 15.2 and 54.3 mS/m which is classed as fresh water. The Piper display also indicates a freshly recharged water in general with little residence time.

The pH ranges between 6.89 and 7.75 which is slightly acidic but more towards the basic side of the scale. This again is typical of alkaline dolomitic waters.

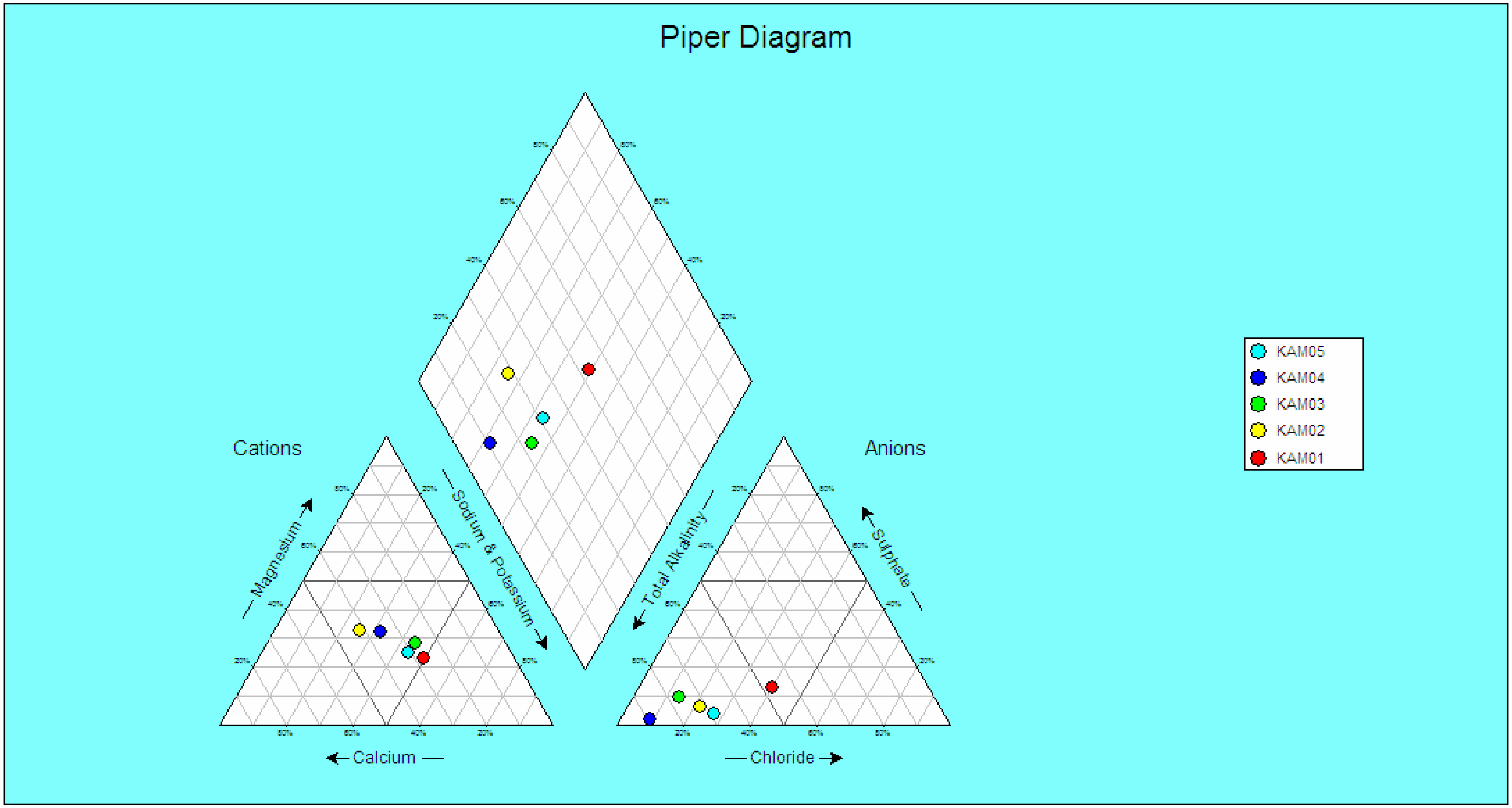


Figure 16: Piper Diagram from the groundwater samples collected during the drilling programme.

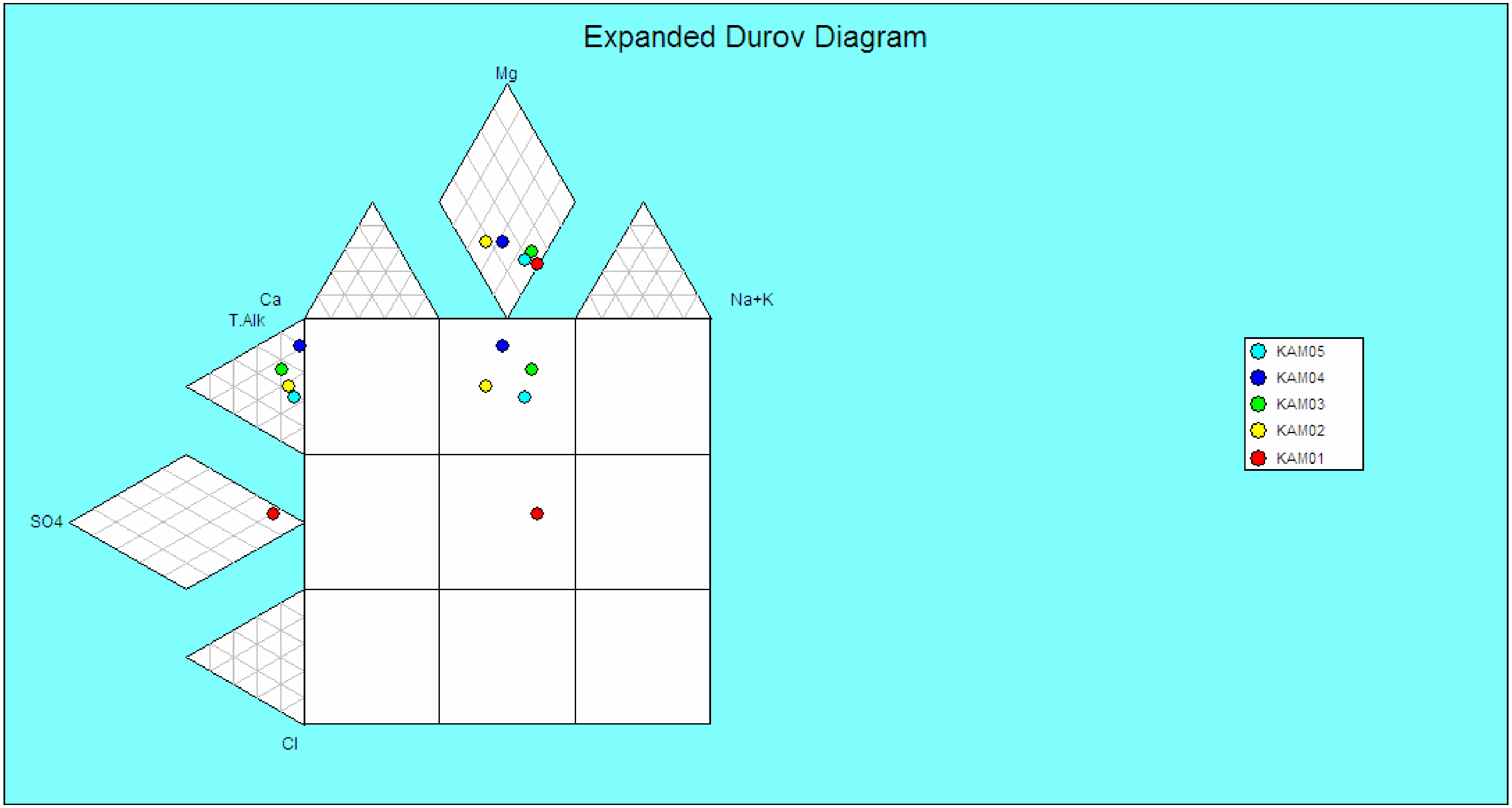


Figure 17: Expanded Durov diagram from the groundwater samples collected during the drilling programme.

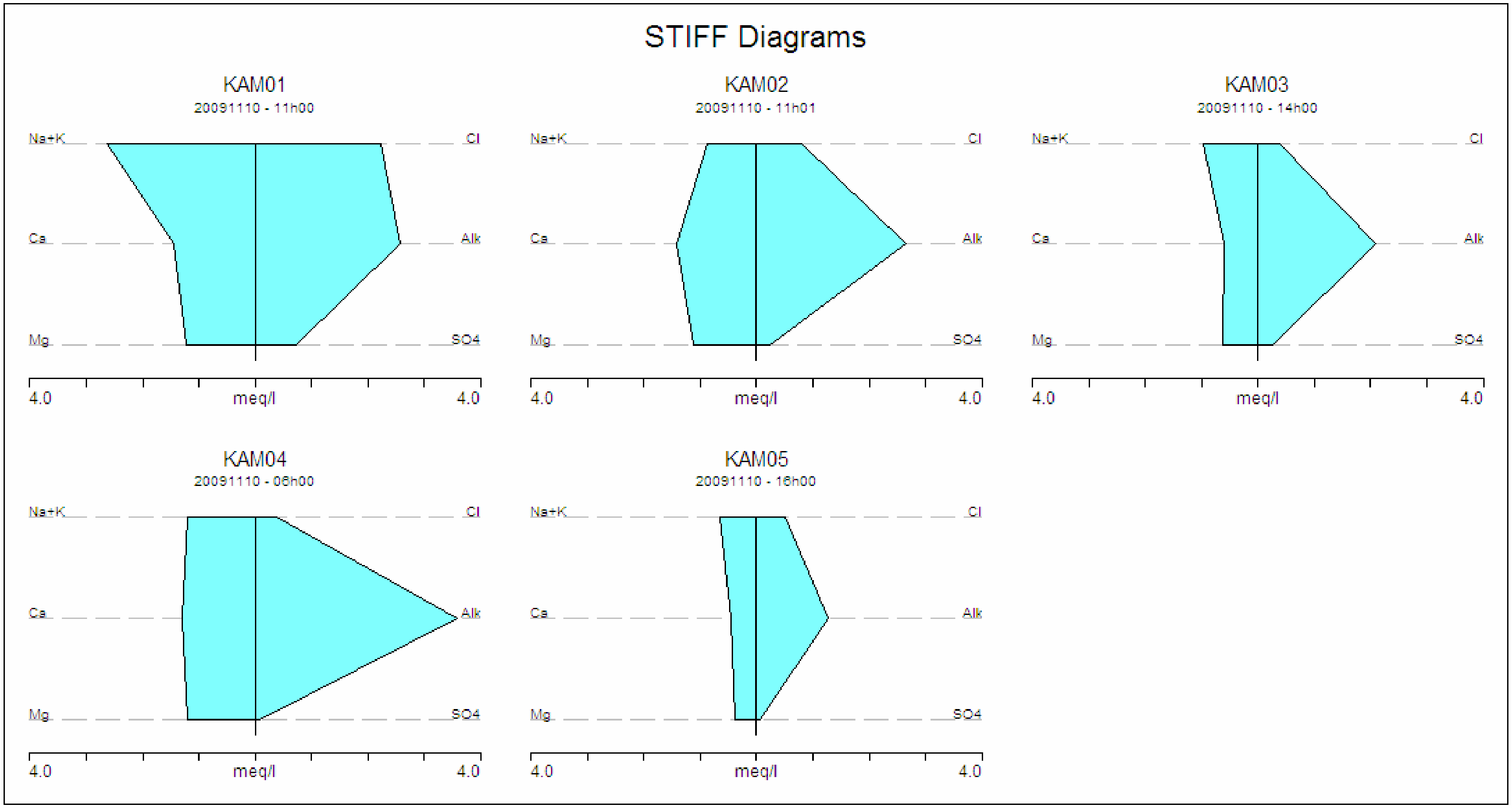


Figure 18: Stiff diagrams from the groundwater samples collected during the drilling programme**.**

Table 9: Water Quality analysis of borehole samples taken during the Hydrocensus in September 2008 (Values in mg/L unless otherwise noted)

Sample ID		Total Dissolved Solids	Nitrate NO3 as N	Chlorides as Cl	Total Alkalinity as CaCO3	Sulphate as SO4	Calcium as Ca	Magnesium as Mg	Sodium as Na	Potassium as K	Iron as Fe	Manganese as Mn	Conductivity at 25° C in mS/m	pH-Value at 25° C	Aluminium as Al	Free and Saline Ammonia as N	Fluoride as F
Class 0	(Ideal)	<450	<6.0	<100	N/S	<200	<80	<30	<100	<25	<0.01	<0.05	<70	6.0-9.0	<0.15	N/S	<0.5
Class I	(Acceptable)	450-1000	6.0-10.0	100-200	N/S	200-400	80-150	30-70	100-200	25-50	0.01-0.2	0.05-0.1	70-150	5-6 or 9.0-9.5	0.15-0.3	N/S	0.5-1
Class II	(Max. Allowable)	1000-2400	>10-20	>200-600	N/S	>400-600	>150-300	>70-100	200-400	50-100	>0.2-2	>0.1-1	>150-370	4-5 or 9.5-10	>0.3-0.58	N/S	1-1.5
Class III	(Exceeding)	>2400	>20	>600	N/S	>600	>300	>100	>400	>100	>2	>1	>370	<4 or >10	>0.58	N/S	>1.5
KAM01		334.00	0.10	79.00	129.00	34.80	28.80	14.90	59.00	2.23	0.01	0.08	54.30	7.21	0.01	0.33	0.66
KAM02		200.00	8.20	8.00	133.00	11.50	28.50	13.60	17.80	3.99	0.36	0.10	33.60	7.75	0.01	0.20	0.20
KAM03		148.00	3.70	4.00	104.00	12.40	11.80	7.52	20.70	2.99	0.18	0.19	22.70	7.24	0.01	1.00	0.25
KAM04		220.00	0.77	11.00	179.00	3.70	26.00	14.50	23.30	6.95	0.09	0.19	33.60	7.63	0.04	0.20	0.38
KAM05		88.00	5.40	4.00	63.00	3.40	9.20	4.52	11.50	6.06	0.45	0.04	15.20	6.89	0.04	0.20	0.20

Red Highlighted results = not within SANS 241 - 2005 target water range for drinking water standards

6 ACID BASE ACCOUNTING

Coal deposition is associated with pyrite being formed as the stratum is deposited in a reducing atmosphere. Mining activity will expose the pyrite to oxidising agents such as oxygen and ferric iron. The oxidation processes are as follows (Loos et al, 2000):

- $2FeS_2 + 2H_2O + 7O_2 \rightarrow 2FeSO_4 + 2H_2SO_4$ (A)

  (pH >4.5)

- $4FeSO_4 + O_2 + 2H_2SO_4 \rightarrow 2Fe(SO_4)^3 + 2H_2O$ (B)

  (abiotic at pH>4.5; biotic at pH<2.5)

- $Fe_2(SO_4)^3 + 6H_2O \rightarrow 2Fe(OH)^3 + 3H_2SO_4$ (C)

  (pH > 2.5)

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

The above equations lead to the formation of acidic conditions and the subsequent water quality deterioration due to heavy metal transport and salt loading, as the buffering capacity of the natural rock is utilised. Process (A) is an abiotic process occurring at a pH >4.5 due to spontaneous oxidation of the pyrite. Process (B) is the transformation of ferrous sulphate to ferric sulphate. This is an abiotic process when pH>4.5, but slows down and becomes biotic at pH < 4.5. At a pH below 2.5 the biotic process is most prominent. Process (C) produces ferric hydroxide (yellow boy), and further lowers the acidity. The abiotic process (D) then leads to the oxidation of the pyrite with the ferric iron product of process (B).

Process (B) is the rate limiting process in this mechanism. This process requires oxygen, therefore, the prevention of oxygen ingress and the creation of reducing conditions within the workings is crucial to slow down the oxidation of pyrite and the resulting low pH conditions.

Acid Base Accounting (ABA) include the neutralising potential (NP) of the formations will buffer the mine water and in cases where the NP significantly exceeds the acid potential (AP) this will lead to an increase in dissolved salts and neutral water quality. Acidic conditions with high salt loading are possible where the buffering capacity is insufficient or the reaction rated for neutralising are such that they can not neutralise the acid generated.

The generation of poor quality water from mine workings is characterised by low pH, high heavy metal content and high salts or a neutral pH and high salt content. Acidic mine water rich in heavy metals is termed Acid Mine Drainage (AMD).

ABA results

Geological core sample were collected during the drilling programme at Kangala for ABA testing. The samples from various lithologies were submitted to SGS Lakefield Laboratories in Johannesburg, Gauteng Province for static testing.

The main advantages of static tests are that they are quick to perform and quantitative results on acid, base and leaching parameters are obtained.

Samples from three representative boreholes were analysed to determine possible geochemical alterations during mining and post closure phases at Kangala. The borehole numbers and additional information can be seen in Table 10 below.

Table 10: Geological information from the different boreholes sampled for ABA testing

Sample number	**Depth (± mbgl)**	**Lithology**
UNI 13a	24	Shale. Dark grey. Very fined grained. Slightly weathered.
UNI 13b	29.24	Sandstone. Light grey to grey. Fine grained. Slightly fractured to fresh.
UNI 13c	34.24	Siltstone. Grey. Fine grained. Slightly fractured to fresh. Micaceous.
UNI 13d	36.26	Sandstone. Brownish grey. Medium grained. Slightly fractured to fresh.
UNI 13e	37.01	Shale. Grey to dark grey. Very fine grained. Highly fractured and broken.
UNI 13f	67	Dwyka Tillites. Brownish grey. Fine to coarse grained. Highly fractured and broken. Dropstones and inclusions of various shape, size and colours visible.
UNI20a	24	Shale. Dark grey. Very fined grained. Slightly weathered.
UNI20b	27	Sandstone. Light grey to grey. Fine grained. Slightly fractured to

		fresh
UNI20c	40	Siltstone. Grey. Fine grained. Slightly fractured to fresh. Micaceous.
UNI20d	43	Shale. Grey to dark grey. Very fine grained. Highly fractured and broken.
UNI20e	45	Dwyka Tillites. Brownish grey. Fine to coarse grained. Highly fractured and broken. Dropstones and inclusions of various shape, size and colours visible.
UNI23a	27.5	Shale. Dark grey. Very fine grained.
UNI23b	34.5	Siltstone. Light grey. Fine grained. Slighthly fractured to fresh.
UNI23c	51.1	Dwyka. Brownish grey. Fine to coarse grained. Slightly fractured to fresh.

*meters below ground level (mbgl)

In addition to pH measurements, the actual acid and base potential of the overburden and interburden have been determined. These results are presented in the following tables. Table 11 provides the criteria against which the analyses results will be interpreted.

Table 11: Modified Acid Base Accounting criteria for interpretation

TYPE I	Potentially Acid Forming(Strong AGP)	Sulphide > 0.3%, negative net NP (< -20), NP/AP ratio <1
TYPE II	Intermediate (Medium AGP)	Sulphide > 0.2 %, Negative net NP (> - 20), NP/AP ratio <1
TYPE III	Non-Acid Forming(Low AGP)	Sulphide < 0.3 %,Low NP, Negative net NP, NP/AP ratio <1
TYPE IV	Uncertain (Possible AGP or NP)	Low AP, Low NP, NP/AP RATIO BETWEEN 1&3

TYPE V	Low NP	Sulphide < 0.1%, Low NP
TYPE VI	Medium NP	Sulphide <0.5%, Positive net NP(> 10), NP/AP ratio > 3
TYPE VII	Strong NP	Strongly positive net NP(>20), NP/AP ratio > 4, High Carbonate

Table 12 provides the summarised results of the ABA analyses, while **Table 13** provides the detailed analyses.

Table 12: Modified Acid Base Accounting test results for Kangala.

Acid Generation Potential (AGP)	**Sample Identification**	**General reason for classification (with some exceptions)**
Strong NP	None	None falling within this class
Medium AGP	UNI13a; UNI13f	Sulphide > 0.3% Negative net NP(<-20) NP/AP ratio <1
Low AGP	UNI20b	Sulphide < 0.3% Low NP Negative net NP NP/AP ration <1
Uncertain possible AGP or NP	UNI13d; UNI20d	Low AP Low NP NP/AP ratio between 1 and 3
Low NP	UNI13e; UNI20c; UNI20e; UNI23e; UNI23c	Sulphide < 0.1% Low NP
Medium NP	UNI13c ; UNI20a ; UNI23b	Sulphide < 0.5%

Acid Generation Potential (AGP)	Sample Identification	General reason for classification (with some exceptions)
		Positive net NP)>10) NP/AP ratio > 3%
Strong NP	UNI13b	Strongly positive net NP (>20) NP/AP ratio > 4 High carbonate

Table 13: ABA test report for Kangala

Sample ID	UNI 13a	UNI 13b	UNI 13c	UNI 13d	UNI 13e	UNI 13f	UNI 20a	UNI 20b	UNI 20c	UNI 20d	UNI 20e	UNI 20f	UNI 23b	UNI 23c
Fizz Rating	1	3	1	1	1	1	2	1	1	1	1	1	2	1
Paste pH	5.5	8.0	7.7	7.5	7.6	6.5	7.4	5.7	7.8	7.1	6.9	7.1	7.4	6.6
Sample Weight(g)	1.98	2.00	1.98	1.99	1.99	1.99	1.98	2.00	1.98	2.01	2.02	2.00	1.98	2.01
Normal HCL(N)	0.107	0.107	0.107	0.107	0.107	0.107	0.107	0.107	0.107	0.107	0.107	0.107	0.107	0.107
Total HCL added(ml)	22.1	55.1	31.5	20.0	22.3	20.0	29.0	20.0	20.0	20.0	20.0	20.0	29.0	20.0
Normal NaOH (N)	0.098	0.098	0.098	0.098	0.098	0.098	0.098	0.098	0.098	0.098	0.098	0.098	0.098	0.098
Total NaOH added (ml)	20.8	22.8	25.5	18.9	21.4	19.7	20.3	20.0	15.8	19.5	19.6	17.9	21.0	20.6
NP	8.2	91.5	22.0	7.2	7.3	5.3	28.1	4.5	14.9	5.7	5.4	9.6	26.4	3.0
AP	26.3	0.31	1.6	4.38	1.25	17.8	0.31	7.19	0.94	2.19	0.31	1.56	0.31	0.31
Net NP	-18.0	91.2	20.4	2.9	6.0	-12.6	27.8	-2.7	14.0	3.5	5.1	8.1	26.1	2.7
NP/AP	0.3	293	14.1	1.7	5.8	0.3	90.0	0.6	15.9	2.6	17.4	6.2	84.4	9.6
Total S (%)	1.11	0.06	0.17	0.17	0.18	0.62	0.14	0.28	0.11	0.10	<0.01	0.18	0.11	0.02
Sulphide (%)	0.84	<0.01	0.05	0.14	0.04	0.57	<0.01	0.23	0.03	0.07	<0.01	0.05	<0.01	<0.01
SO_4 (%)	0.82	0.16	0.35	0.09	0.43	0.14	0.39	0.14	0.23	0.07	<0.03	0.41	0.29	0.04
CO_3 (%)	0.30	4.18	0.21	0.50	0.77	0.22	0.92	0.14	0.17	0.11	0.19	0.19	1.12	0.09

The geological core collected for ABA testing did not include any of the two coal seams present at Kangala. The coal have been removed from four boreholes and analysis by Kangala and the test results from the raw coal analysis from the No. 2 and No. 4 coal seam can be seen in **Table 14**.

Table 14: Summary of the total coal seams characteristics

No. 4 coal seam raw coal quantities within the initial mining area						
	Moisture %	Ash %	Volatiles %	Fixed Carbon %	Sulphur %	CV (MJ/kg)
Average	4.29	28.17	26.55	40.99	2.30	21.11
Maximum	4.65	30.31	29.50	43.70	2.63	22.66
Minimum	3.61	23.93	22.42	39.40	1.39	19.89
No. 2 coal seam raw coal quantities within the initial mining area						
Average	4.88	31.70	19.82	43.60	1.15	19.09
Maximum	6.39	33.88	22.73	47.43	1.36	20.50
Minimum	3.76	28.89	15.03	39.62	0.74	17.86

Several factors calculated in ABA by Soregaroli and Lawrence (1998) indicated that for sustainable long-term acid generation, at least 0.3% sulphide-S is needed. Values lower then 0.3% can yield acidy but it is only of short-term significance. From the results shown in the table above it can be seen that both coal seams have a high tendency to produce acid formation when exposed during excavation. It should be noted that only small quantity of coal will remain after mining have ceased minimising the potential for AMD formation.

In conclusion

The following conclusion can be reached from the above test results:

- High variability can be found in the geochemical characteristics in the overburden and interburden at Kangala. Sandstone layers fluctuate from strong neutralisation potential to low acid generation potential indicating a change in the chemical composition over the planned mining area.
- With the above taken into consideration Sandstone was the dominant lithology present (excluding the coal seams) in the overburden and contributed about 42 % of the total samples taken. The majority of the Sandstone indicated a strong NP and should be backfilled into the opencast pit to reduce the impact of AMD formation.
- The second largest percentage of lithological strata from the samples acquired from the overburden were shales and indicated a medium AGP and should consequently not be backfilled into the opencast pit but discarded to the discard dump.
- The majority of the static test results indicated low to medium acid neutralisation potential. This will decrease the risk of acid formation and possible acid neutralisation in the presence of acid mine drainage. Sample UNI13a, UNI13f and UNI20b show possible acid generating potential
- The analysis from the No. 2 and No. 4 coal seam showed high risk for acid generation. The majority of the coal will however be removed, but Kangala need to ensure that the Dwyka formation stay intact to prevent possible pollution to the underlying dolomites.
- Acid mine drainage can not be prevented and will remain a problem at all the collieries in the Mpumalanga Coal Field. The effect and long term impacts can however be reduced by sound management strategies.

The following recommendation is made:

- It is recommended that Kangala continue to sample and analyse geological rock samples during the operational phase as required by the Best Practice Guidelines for Impact Prediction, BPG G4. This will indicate the variability of the material, the identification of any material with a high risk not currently identified and the management, or separate handling thereof if required. This information is invaluable for the closure planning and mine water closure plan. The life of mine is estimated to be 10 years so very little acidification is expected during life of mine. Long term chemical prediction will have to be undertaken to accurately assess the quality of water expected post closure.

7 GROUNDWATER IMPACTS

The following groundwater impacts could be expected during the life of mine and post closure in the absence of mitigation and management:

- Dewatering (water users close proximity or downstream user)

Although the aquifer tests yielded low conductivity values for the top Karoo aquifer and in general a steep cone of depression directly adjacent to the open pit workings, care should be taken to keep the Dwyka tillite layer intact. The basement dolomitic layer was certainly proven to have high conductivity and potential pressure values associated with it and this could cause flooding and require large scale dewatering if not managed properly, which will have borehole interference with adjacent registered water users. This can therefore be rated as a high risk to the project but medium term recovering after life of mine.

- Acid mine drainage (risk ABA)

Studies undertaken by Universal Coal PLC indicated that the No. 2 coal seam could have a high acid generating potential. The ABA test conducted on the inter and overburden obtained from the geological core drilled during exploration, were tested for acid base accounting and neutralisation potential. It was found that a low acid generating potential can be expected from these with the exception of the carbonaceous shales and Dwyka tillite. The sandstone and siltstone indicated to have a low to medium neutralisation potential that will help neutralise the acid generation. Stockpiles therefore should be handled with care during operations and discard kept away from the pit once mined. The impacts can be rated as high risk, long term .

- Post mining water management (flooding decanting and down stream impacts)

High recharge values are obtained from the back-fill areas and high hydraulic conductivity values can be expected from the compressed spoils and waste rock. Surface and coal seam elevations indicate two possible decant zones along contours on site thus appropriate mitigation measures will have to be put in place to manage the water after mine closure. AMD could impact on the water quality while potentially negatively impacting on receiving water users and the wetland area down gradient to the east of the proposed pit area. More in depth studies will have to be performed to determine the geochemical characteristics of the groundwater during and after mining has commenced. A high risk is associated with the leaching of AMD, long term with only costly methodology for cleaning.

- Groundwater resource as a water supply to the mine

Borehole KAM01 has the potential to deliver 35 m^3/hour of groundwater from the dolomitic aquifer to the mine for processing. The risk to the adjacent users could be significant as well as creating a cone of depression below mining activities that could draw in possible contaminants to this sensitive aquifer system and will have to be investigated more comprehensively during the definitive study. A medium risk could be attached to groundwater interference, however if mitigated this can be kept a low risk.

- Cumulative impacts

Leeuwpan Exxaro and Stuart Collieries are within a 10 km radius from the proposed site. Both these mines drain the same catchment B20A into the Bronkhorstpruit River. Any seepages of contaminated water ending up in the local streams could drain into the Bronkhorstspruit which in turn could end up within the dolomite Karst aquifer towards the town of Delmas, cumulatively. Due to ground water mimicking surface flow to an extent, could mean that if contamination enters groundwater the cumulative effect between these collieries could ad severe pressure to the already stressed dolomitic aquifer. This is a high risk for the greater regional aquifer and a definitive risk to groundwater resources for the country.

8 GROUNDWATER IMPACT ASSESSMENT

The impact assessment was performed based on the available geological, hydrogeological and mining information. The following sections describe the expected impacts to groundwater at the proposed Kangala Coal Mining Project.

8.1 Construction phase

8.1.1 Groundwater quality

The potential spillage of hydrocarbons from construction machines during the construction of infrastructure, topsoil and overburden stripping, opencast areas construction and haul road construction has the potential to cause the pollution of groundwater resources. The risk is low and localised and of short term. However if one large spill from a hydrocarbon tanker occur this will have a severe negative impact over a longer time.

The operation of the fuel and lubricants storage facility has the potential for causing contamination of surface water due to infrastructure failure (emergency), leakage or spillages during normal operation. Included in normal operation is the potential for the incorrect disposal of spill absorbing material. This is usually of medium risk over a short duration and can be mitigated, impacts are potentially low.

The operation of offices, ablutions and maintenance workshops has the potential for the contamination of groundwater due to incorrect disposal of domestic and hazardous wastes, incorrect handling of workshop effluent spills and leaks. This is usually of medium risk over a short duration and can be mitigated, impacts are potentially low.

The use of nitrate-based explosives during blasting for the establishment of the opencast areas has the potential to cause surface water pollution due to the addition of nitrates to water. This is usually of medium risk over a short duration and can be mitigated, impacts are potentially low.

8.1.2 Groundwater quantity

The establishment of hard paved areas during infrastructure construction and haul road construction reduces the recharge of aquifers due to increased runoff. This is normally a low impact, localised and short duration, however if not mitigated and carefully managed large scale erosion could be the end product, which potentially could have a negative long term impact.

The establishment of the opencast areas is expected to have a negative effect on the surrounding aquifers within the immediate area which can cause lowering of water levels in boreholes below actual total depth, causing adjacent boreholes to be out of commission. The boreholes that could see possible influence from this could be, KGA 1, 2, 11, 14, 15, 16, 21, 28, 29, 39, 40 and 41 (See numbers on Plan 3). This is usually a medium negative impact, with medium duration, but returns to within approximately 90 % of the original level after mining ceases and can be mitigated by close monitoring..

8.2 Operational phase

The local aquifer systems are classified as sensitive and major aquifer systems and the regional utilisation thereof coincides with town water supply and the principle land uses of major irrigation, to a lesser extent grazing and to provide domestic water supply. The changes induced by mining may lead to a dewatering cone in the immediate vicinity of the mine, an increase in recharge, storage capacity (opencast workings) and deterioration in water quality.

8.2.1 Groundwater quality

During the performance of all opencast mining activities the potential exists for the contamination of groundwater due to the spillage of hydrocarbons by mining machines and the use of rock drill lubricant. Low impact over medium term but can be managed closely.

The spillage of ammonium nitrate based explosives during charging of holes, misfires and incomplete combustion of explosives may lead to an increase in nitrate levels in groundwater. Medium impact over medium term but can be managed closely through monitoring.

The operation of the fuel and lubricants storage facility has the potential for causing contamination of groundwater due to either an infrastructure failure (emergency) or spillages during normal operation. Included in normal operation is the potential for the incorrect disposal of spill absorbing material. High impact over short duration and must be managed very closely, potential for spillages to cause long term impact on groundwater is there for the duration of operations.

The potential incorrect disposal of domestic waste at the offices and ablutions may have an impact on groundwater quality. Medium impact over short duration with potential high impact over short term.

The potential incorrect handling of sewerage at the offices and ablutions may have an impact on groundwater quality. Medium impact, medium term with overall medium significance.

The potential incorrect disposal of hazardous wastes, workshop effluent as well as spills and leaks at the maintenance workshops may have an impact on groundwater. This can be a short term very high potential impact to groundwater in the form of non aqueous phase liquids with a long term impact.

AMD formation from spoil piles, exposed shale and backfilled spoils and discard in rehabilitated areas will affect groundwater quality through the acidification of groundwater and the leaching of salts and mobilization of heavy metals from rock. Depending on the buffering capacity of the host rock, AMD will either result in the formation of low pH, high dissolved salt and heavy metal content water (insufficient buffering capacity) or the formation of neutral pH, high saline (including sodium and sulphates) water, if high buffering capacity exists. This is potentially of high risk and long term duration and must be monitored carefully throughout and post mining, overall high significance if not mitigated.

8.2.2 Groundwater quantity

The establishment of hard paved areas during infrastructure construction and haul road construction reduces the recharge of aquifers due to increased runoff. Low potential and very localised with short duration.

The removal of vegetation during topsoil and overburden pre-stripping for haul road construction reduces the recharge of rain water to aquifers due to increased run-off. Low potential and very localised with short duration.

Mining of the opencast areas has the effect of dewatering adjacent aquifers or lowering the water table. Medium risk over medium term with medium overall significance.

Utilising groundwater as a resource could lower the water table within the dolomites, which could have subsidence and geotechnical associated issues. Short term high risk with a high overall significance.

8.3 Decommissioning phase

The quality of groundwater will be impacted upon by mining. Although not much can be done about the actual groundwater quality, mitigation is required against its surface water quality impacts. The mining area might produce a seepage zone or decant as the recharge to opencast workings have increased by the disturbance of the strata. Currently groundwater is the only source utilised in the area and poor quality groundwater emerging as seeps into the surface water environment can be seen as a negative, long term impact. Mitigation is usually not economically possible and the only reasonable control measures are to contain the polluted water and to minimise recharge (closed circuit). This will have a high risk over a long term with high overall significance if not monitored closely and contained.

The management of cumulative impacts and even the closure planning of existing operations need to be performed on a regional level. The mining companies, DWAF and water users associations need to be approached to establish a working relationship to allow the cumulative impacts to be determined and regional management measures from being implemented. High potential over a long period of time and will have a high potential overall significance.

8.3.1 Groundwater quality

The long term water quality impact for coal mining is the generation of AMD water. Opencast pits must be rehabilitated in such a way that recharge to the area is limited or does not occur at all. High potential impact and overall significance over a long term.

The potential spillage of hydrocarbons by construction machines may contaminate groundwater. Medium potential, short term risk, low overall significance.

Incorrect disposal of hazardous, industrial and domestic waste may affect groundwater quality. High potential impact and overall significance over a long term.

Potential exists for the contamination of groundwater due to incorrect sewerage handling. Medium potential, short term risk, low overall significance.

8.3.2 Groundwater quantity

In the opencast areas water levels will rise until the decant level is reached. Water quality in the opencast pits is not expected to be suitable for use and these areas will be sterilised in terms of available groundwater quantity. Groundwater use will also terminate during this phase and post mining and will recover to an extent depending on recharge. Medium impact over the medium term, medium overall significance.

8.4 Cumulative impacts

The cumulative impacts due to the proposed mining could be of a quantitative and qualitative nature. The aquifers within the region are classified as major aquifer systems. Recovery of the water level will result in a positive impact locally and could see the importance of groundwater increasing once again within the catchment. However, the water quality within the workings could be good or deteriorate depending on the geochemical characteristics of the material which could have disastrous impacts on the regional aquifer. The cumulative impact on the catchment will have to be taken into account for mining, agriculture and the remainder of the current surface and groundwater uses in the this catchment. High potential over a long period of time and will have a high potential overall significance, this will have to be closely monitored.

9 GROUNDWATER MANAGEMENT

Since this will be an opencast operation only, several management practices and options are discussed in general for opencast mining.

9.1 Opencast mining

Water Management strategies for Opencast mines are limited (and very little can be done cost effectively to minimize the surface water pollution from existing Opencast mining. The emphasis falls on prevention of pollution rather than treatment of affected water. Regulation 704 deals with the criteria and methodologies regarding the actions that can be employed in great detail.

Preventative measures include the rehabilitation of spoils. The aim of this is to control the rate and migration of acid generation. Techniques that can be followed include levelling, top soiling with a mixture of clay and coarser material as a growth medium and re-vegetation.

An alternative practice is selective spoil handling for example:

Table 15: Spoil handling in sequence of priority from top to bottom.

Sequence from top to bottom
Significant volume of the spoil is flooded
Weathered spoil
Spoil with high base potential
Spoil with high acid potential

Mixed acidic and basic coal discard disposal is not advised.

The advantages of spoil handling include:

- Acidic conditions in the spoil water may be eliminated.
- Heavy metals are precipitated within the spoil.
- The net salt load of the system is reduced.
- Weathered material at the top is a better growth medium than the unweathered spoils.
- Weathered materials inhibit the pyrite oxidation by reducing the influx of oxygen to the reactive surface.

The introduction of buffering agents such as lime, power station fly ash or sewage can also be used to improve the water quality but it can become an expensive exercise.

Containment; the purpose is to flood as much of the spoils as possible, thus eliminating oxidation of sulphides, this is advised for small pits. Another promising option is to contain and evaporate spoil water.

10 MONITORING

The main objective of any water monitoring program is to understand the short-, medium- and long-term impacts that mining may have on the integrated surface and groundwater regime of the immediate and receiving environment. Groundwater Monitoring forms an integral part in the management thereof. It serves ultimately as a pre-warning system for mitigative actions when anomalous concentrations or water level problems occur.

Monitoring at Kangala must be quantitative and qualitative due to the sensitive nature of the dolomitic aquifer. It is a very important management tool to ensure that groundwater resources are conserved effectively.

Currently there is no monitoring network in place at Kangala, as this is still regarded as a Greenfield project however the groundwater monitoring network will have to be implemented before mining activities commence.

It is recommended that a baseline sampling run be conducted, analysing as broad a spectrum of determinants as possible to ensure that the correct determinants are targeted during the long term monitoring programme. This will be achieved by analysis with Induced Coupled Plasma (ICP) and Mass Spectrometer (MS) methodology, which is a quick scan of the major cations, anions and full spectrum trace elements (within 5 % accuracy of normal laboratory analysis techniques). The results from this sampling programme will dictate the frequency and details of the surface and groundwater long term monitoring at the site.

A database using Windows Information System for Hydrogeologist (WISH) software or similar should be used to establish temporal data for the project area. The following reporting should also be conducted according to DWAF:

Quarterly monitoring reports with the combined results of the surface and groundwater monitoring. The monthly results are combined cumulatively in the quarterly reports. A quarter is typically three months. This will include all findings and results and typically includes the following information:

- Project description and objectives;
- Water use license detail and directives;
- Methodology and protocols;

- Comparison with legislative framework, i.e. quality standards and guidelines;
- Analysis results in the form of diagrams and graphs (Piper, Durov etc.);
- Recommendations and conclusions;
- Mitigative measures (if required); and
- Maps depicting project area and positions of monitoring.

The five newly drilled boreholes will be used initially along with three strategically placed boreholes from the hydrocensus. The detail of the three boreholes is listed in Table 15.

Table 16: Details of the hydrocensus boreholes and newly drilled boreholes to be used for monitoring

Site ID	Coordinates		Type	Farm
	Latitude	**Longitude**		
KGA12	26.18134	28.66826	DWAF Directorate of hydrogeology borehole	Witklip 232 IR
KGA21	26.18569	28.69183	Borehole	Wolvefontein 244 IR
KGA39	26.20445	28.64004	Borehole	Strydpan 243 IR
KAM01	26.21273	28.67163	Borehole	Wolvenfontein
KAM02	26.19756	28.67773	Borehole	Wolvenfontein
KAM03	26.18977	28.67634	Borehole	Wolvenfontein
KAM04	26.19260	28.66187	Borehole	Wolvenfontein
KAM05	26.20103	28.66602	Borehole	Wolvenfontein

The suggested frequency for groundwater monitoring is as follows:

- Monthly for the first six months; and
- Bi monthly for the next six months.

If results are stable (except for seasonal changes) and a trend is established, quarterly monitoring will be sufficient but will have to be revisited after the first year and adjusted according to results.

Table 17: Summary of minimum required constituents to be analysed for monitoring

Major Inorganic Constituents *(in mg/L unless stated otherwise)*	
Major Ions	
Cations	***Anions***
Sodium	Bicarbonate
Calcium	Chloride
Magnesium	Nitrate as N
Potassium	Sulphate
Minor Ions	
Fluoride	
Iron	
Nitrate as N	
Trace Elements	
Aluminium	
Manganese	
Physico-Chemical Parameters	
Electrical Conductivity (EC) - *L + F	
pH - *L + F	
Total Alkalinity - *L	
Total Dissolved sollids - *L + F	
Optional Trace Elements	
Arsenic	
Chromium (Hexavalent)	
Lead	
Ortho-Phosphate	
Uranium	
Zinc	
Bacteriological	
General hygienic quality indicators	
Standard plate count	
Faecal Coliforms	
Total Coliforms	
***Laborotary measured and Field measured**	

The minimum constituents to be analysed for during the groundwater monitoring are summarised in Table 16.

11 CONCLUSIONS AND RECOMMENDATIONS

The following conclusions are evident from the hydrogeological evaluation of the proposed Kangala-Wolvenfontein project area:

- A gravity survey was conducted to delineate possible voids in the subsurface linked to the dolomitic terrain, however no cavities were found to the drilled maximum depth of 80 m;

- The drilling of five characterisation boreholes was completed successfully while establishing all five holes as initial monitoring boreholes for quality and quantity;
- Only one borehole intercepted a weathered zone between the Dwyka and the Malmani dolomites and yielded high volumes of good quality water;
- Current land use practises include extensive irrigation agricultural activities and livestock production;
- Groundwater use in the immediate vicinity of Kangala, from groundwater includes irrigation as well as large town domestic supply schemes;
- Borehole yields from the Karoo aquifers are low while major groundwater development is evident in the Malmani karstified dolomitic aquifers;
- Hydraulic conductivity in the upper Karoo aquifer is low and could act as retarding factor when contaminant flow arises;
- Hydraulic conductivity in the Malmani aquifer is potentially very high in tertiary developed voids and fractures;
- Water levels are generally shallow and follow the surface topography. Therefore, groundwater will flow from highest to lowest elevation, in the direction of surface water drainage;
- Water quality is generally of a good drinking water quality and well within the South African National Standards for drinking water;
- Groundwater flow is towards the east to north-east from the project area;
- Groundwater supports the base flow into the wetland systems / streams;
- ABA suggests possible low to medium acid generating potential from the inter and overburden, while high AGP is evident from the coal seams;
- The large percentage of sandstone overburden has the highest percentage of NP values with the shales and Dwyka tillites making up 18 percent of the strata having a medium AGP; and
- The Malmani aquifer forms the basement of the lithological units underlying the possible retarding Dwyka tillite low conductive layer and should therefore act as a

barrier.

The following recommendations are made:

- A gravity survey to fill in the missing data for the complete area should be conducted and where low density anomalies occur closer station spacing should be filled in to ensure that further studies investigate the underlying dolomites in more detail;
- Pro-active monitoring of the eight suggested boreholes should commence first quarter 2010 with minimum parameters acquired as specified in the document;
- A definitive hydrogeological study is recommended to define the operational area of the mine, i.e. stockpiles, discard dumps etc. including a numerical model for the use of borehole KAM01 for supply water as well as inflow into the pit and dewatering scenarios which was not addressed in this document;
- From the definitive study more site specific monitoring boreholes should be established especially to monitor the mining in the vicinity of the ZOR adjacent and at the bottom of the pit;
- Proper bunding and lining of hydrocarbon storage facilities and close control of all contracting vehicles and proper maintenance;
- Careful storm water control and recirculation processes to manage clean and dirty water;
- Close control and management of all water uses onsite measured with calibrated meters especially groundwater use and upgrading of the water balance
- The spoils should be handled with care and only the low AGP and NP material should be bacfilled into the pit and flooded as soon as possible; and
- Acid generating material should be carefully monitored and retested for kinetic tests as mining operations continues, specifically utilising kinetic ABA testing methods.

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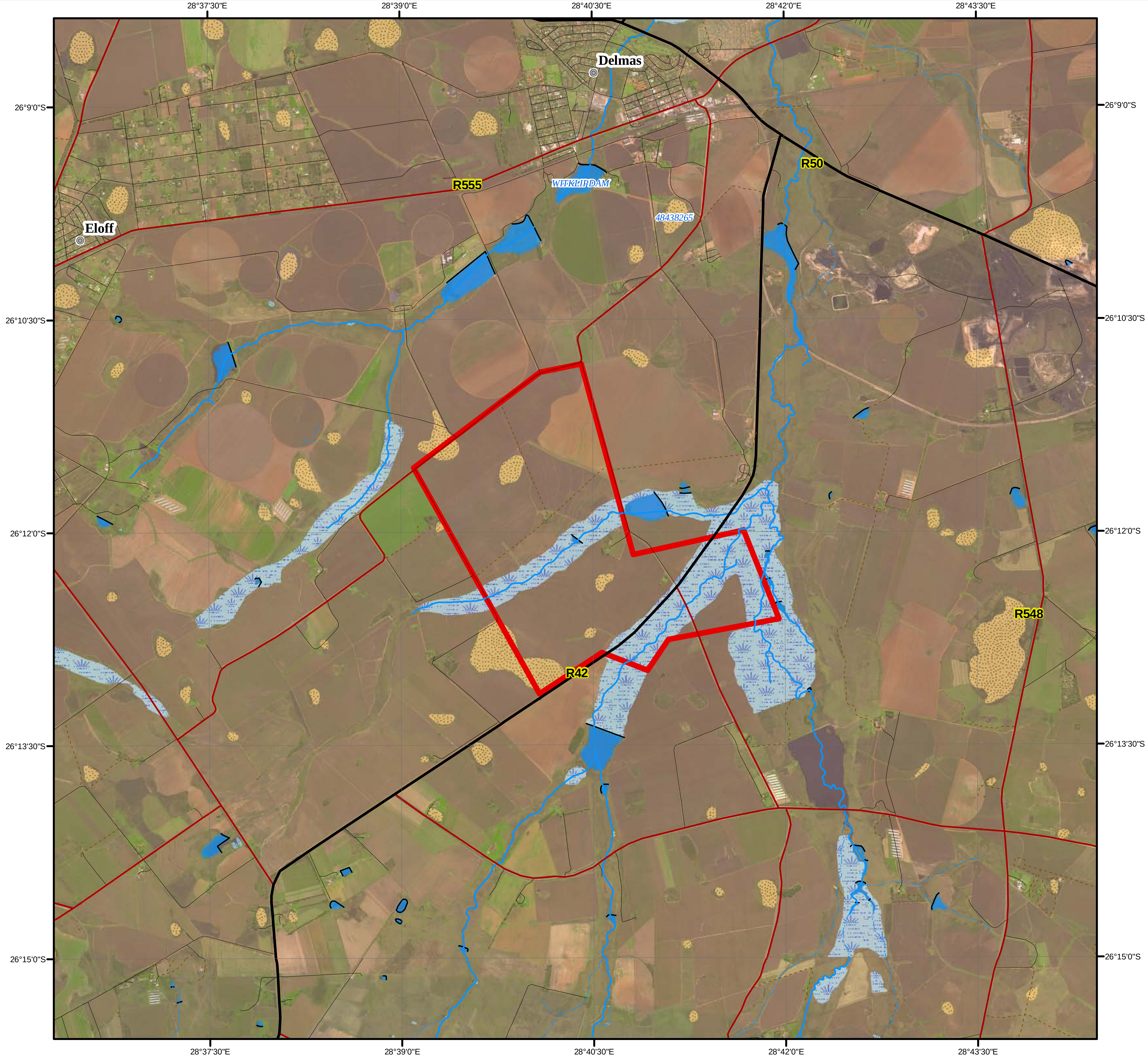
APPENDIX A

PLANS

Plan 1

Universal Coal Kangala Coal Mine

Local Setting



Legend

- Project Area
- Capital City
- Major Town
- Other Town
- Secondary Town
- Settlement
- Arterial / National Route
- Main Road
- Minor Road
- Track
- Non-Perennial Stream
- Perennial Stream
- Dam Wall
- Dam / Lake
- Non-Perennial Pan
- Perennial Pan
- Wetland

Universal Coal Development 1 (Pty) Ltd

DWA

Tel: +27 11 789 9495

Projection: Transverse Mercator
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Revision Number: 2
Date: 06/10/2009

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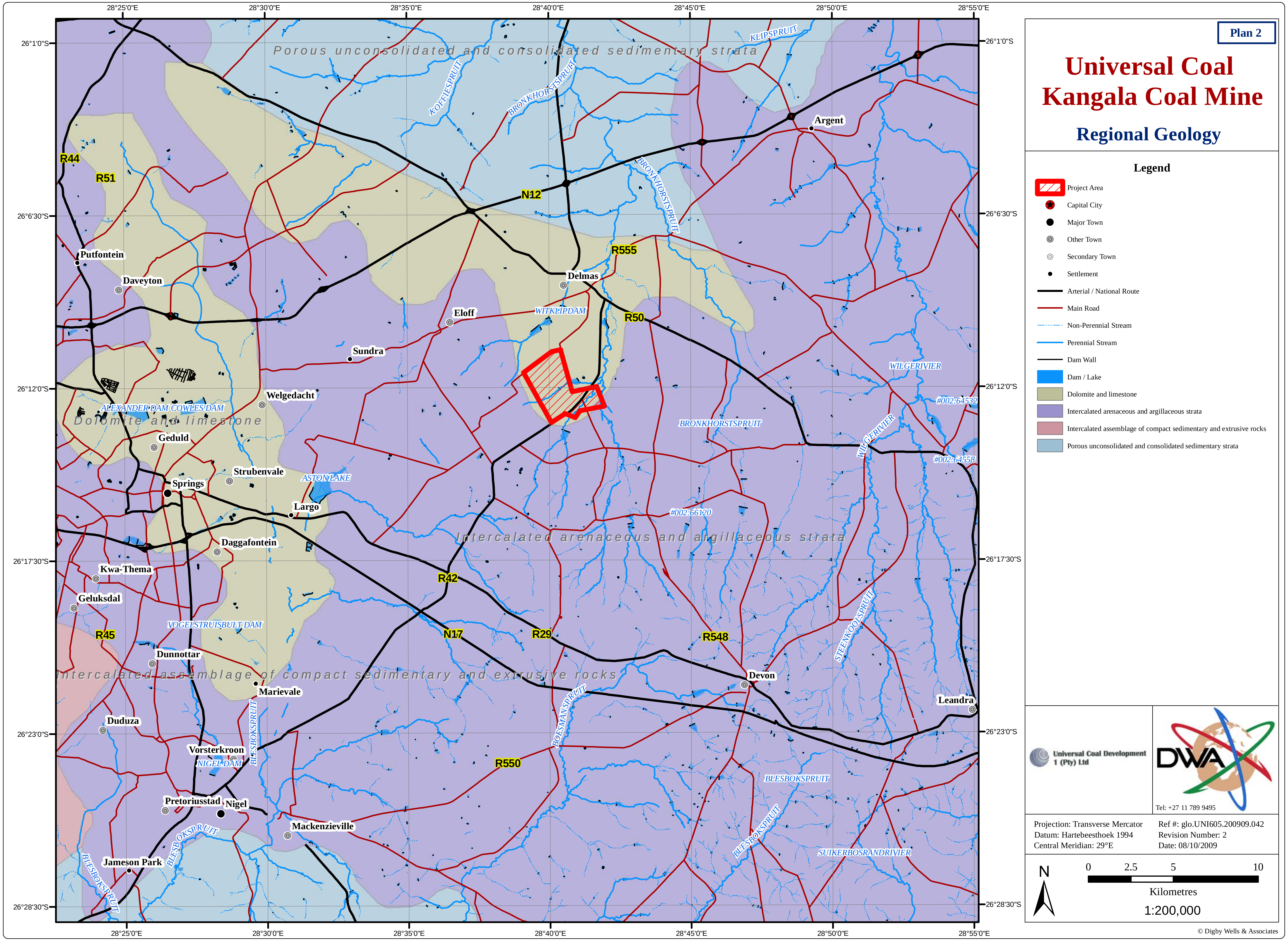
Plan 2
Universal Coal
Kangala Coal Mine
Regional Geology
Legend
Project Area
Capital City
Major Town
Other Town
Secondary Town
Settlement
Arterial / National Route
Main Road
Non-Perennial Stream
Perennial Stream
Dam Wall
Dam / Lake
Dolomite and limestone
Intercalated arenaceous and argillaceous strata
Intercalated assemblage of compact sedimentary and extrusive rocks
Porous unconsolidated and consolidated sedimentary strata
Universal Coal Development 1 (Pty) Ltd
DWA
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Projection: Transverse Mercator
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Revision Number: 2
Date: 08/10/2009
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© Digby Wells & Associates
Porous unconsolidated and consolidated sedimentary strata
Dolomite and limestone
Intercalated arenaceous and argillaceous strata
Intercalated assemblage of compact sedimentary and extrusive rocks
28°25'0"E
28°30'0"E
28°35'0"E
28°40'0"E
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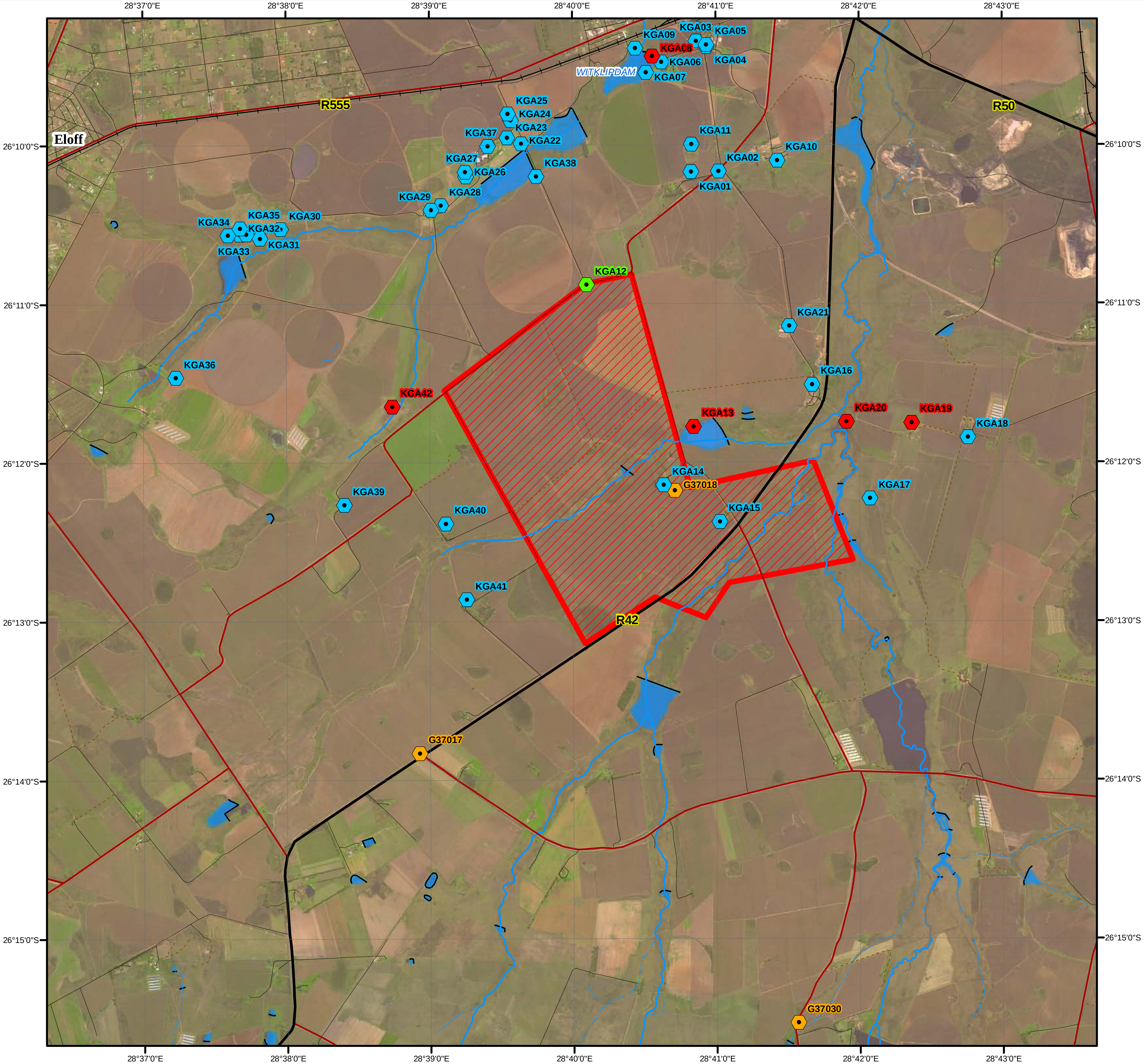
28°55'0"E
26°1'0"S
26°6'30"S
26°12'0"S
26°17'30"S
26°23'0"S
26°28'30"S
R44
R51
N12
R555
R50
R42
N17
R29
R548
R45
R550
Putfontein
Daveyton
Delmas
Eloff
Sundra
Welgedacht
Geduld
Springs
Strubenvale
Largo
Daggafontein
Kwa-Thema
Geluksdal
Dunnottar
Marievale
Duduza
Vorsterkroon
Pretoriusstad
Nigel
Mackenzieville
Jameson Park
Argent
Devon
Leandra
KLIPSPRUIT
KOFFIESPRUIT
BRONKHORSTSPRUIT
WITKLIPDAM
WILGERIVIER
#002:64532
#002:64558
#002:66120
ALEXANDER DAM COWLES DAM
ASTON LAKE
VOGELSTRUISBULT DAM
NIGEL DAM
BLESBOKSPRUIT
BOESMANSPRUIT
STEENKOOLSPRUIT
SUIKERBOSRANDRIVIER



Plan 3

Universal Coal Kangala Coal Mine

Groundwater Hydrocensus

Legend

Hydrocensus Points

- Borehole
- DWAF Directorate of Geohydrology Borehole
- DWAF Dolomite Report Borehole
- Surface Water Dam
- Project Area
- Railway Line
- Arterial / National Route
- Main Road
- Minor Road
- Track
- Non-Perennial Stream
- Perennial Stream
- Dam Wall
- Dam / Lake

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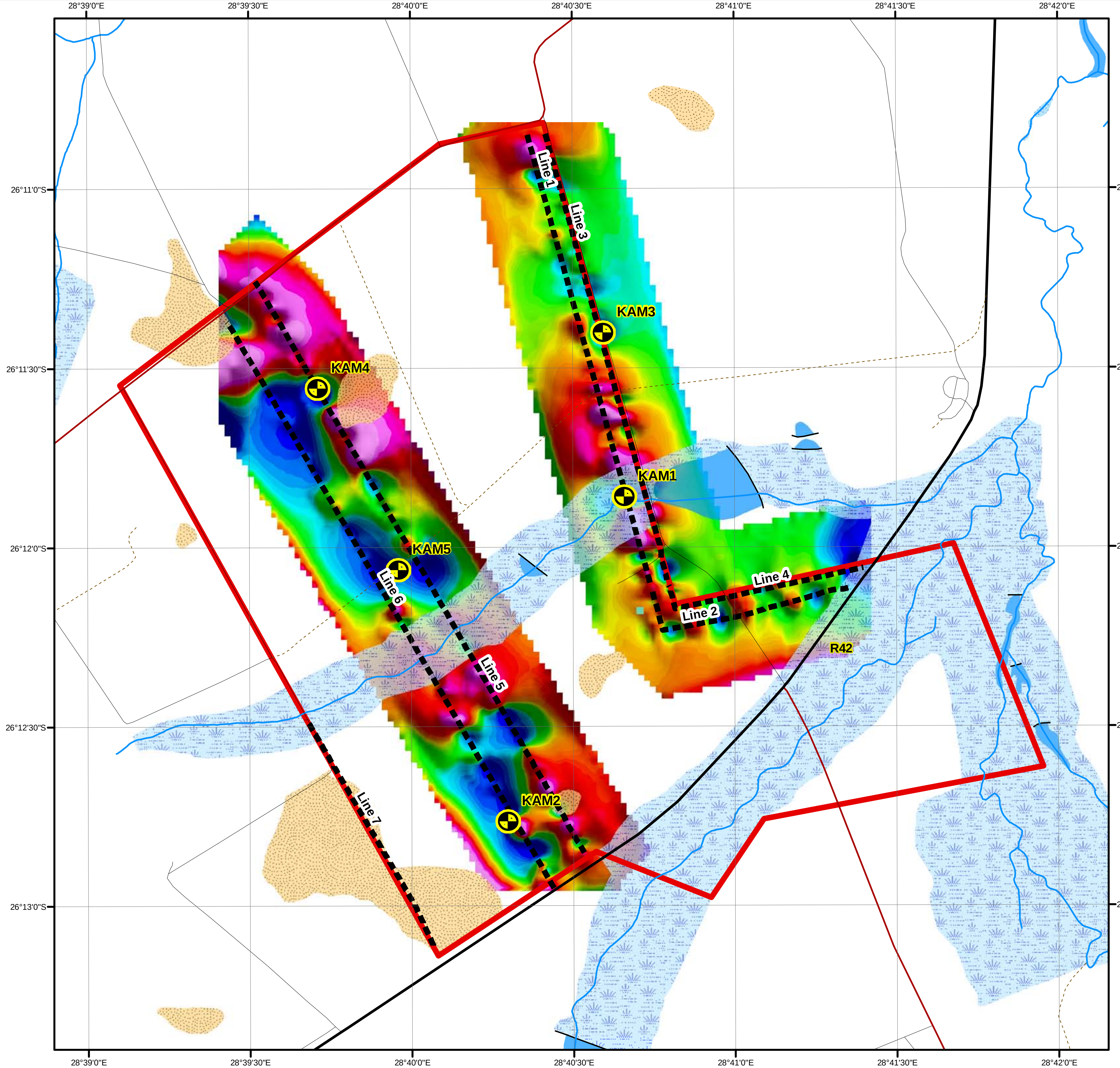

Plan 4

Universal Coal Kangala Coal Mine

Geophysics

Legend

- New Boreholes
- Survey Lines
- Project Area
- Arterial / National Route
- Main Road
- Minor Road
- Track
- Non-Perennial Stream
- Perennial Stream
- Dam Wall
- Dam / Lake
- Non-Perennial Pan
- Perennial Pan
- Wetland

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DWA

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Projection: Transverse Mercator
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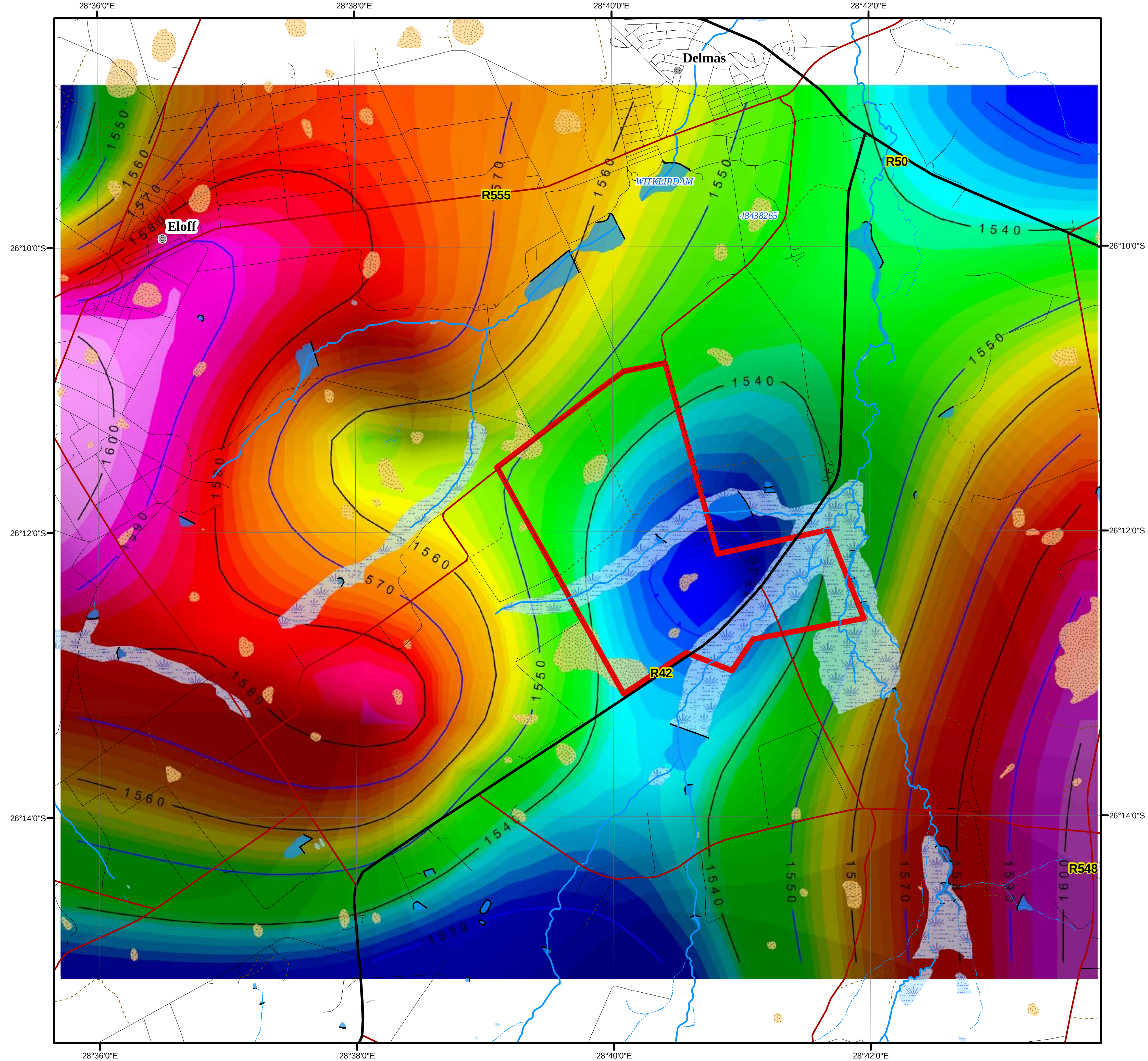

Plan 5

Universal Coal Kangala Coal Mine

Regional Groundwater Flow

Legend

- Project Area
- Capital City
- Major Town
- Other Town
- Secondary Town
- Settlement
- Arterial / National Route
- Main Road
- Minor Road
- Track
- Non-Perennial Stream
- Perennial Stream
- Dam Wall
- Dam / Lake
- Non-Perennial Pan
- Perennial Pan
- Wetland

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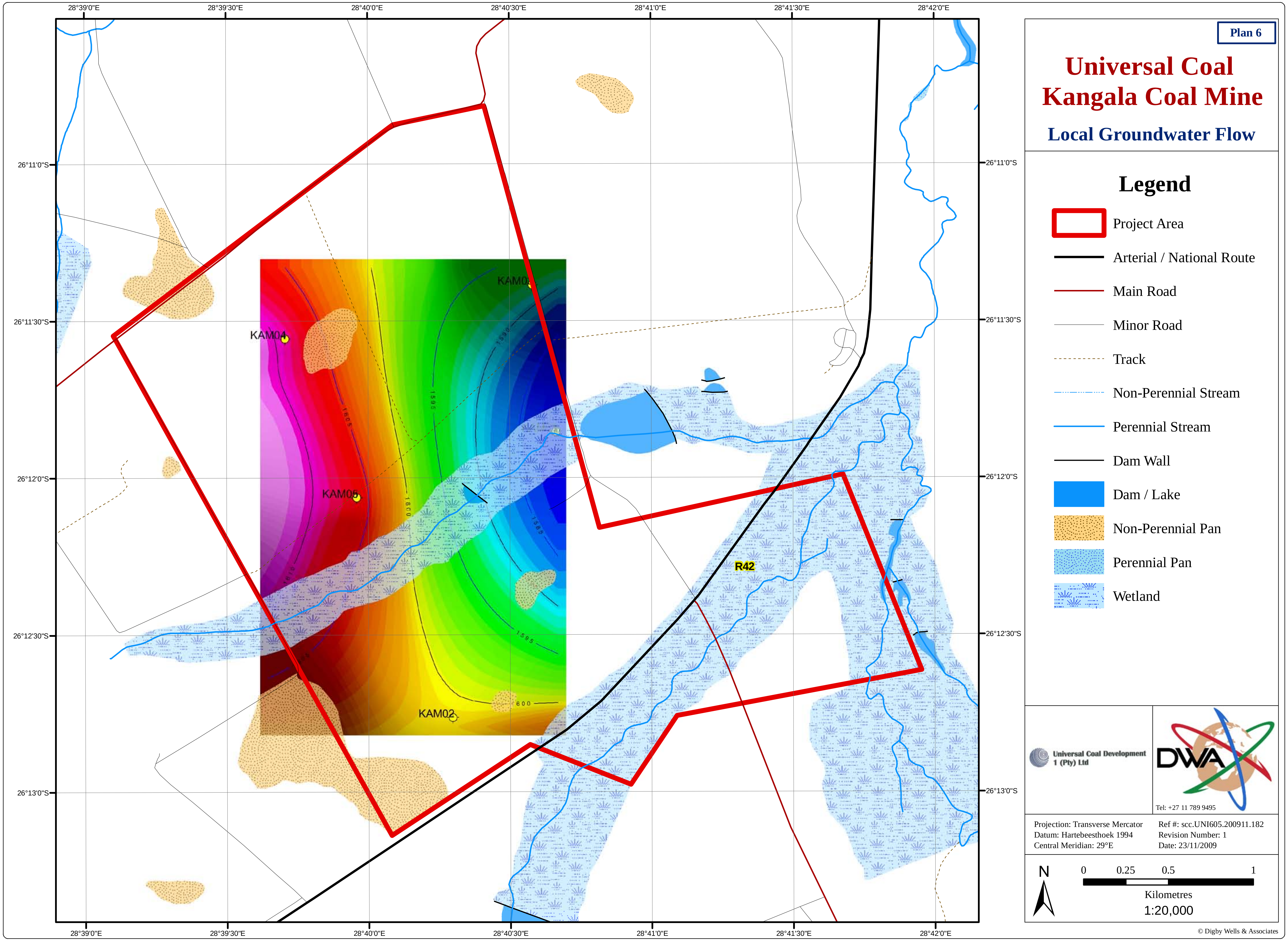
Plan 6
Universal Coal
Kangala Coal Mine
Local Groundwater Flow
Legend
Project Area
Arterial / National Route
Main Road
Minor Road
Track
Non-Perennial Stream
Perennial Stream
Dam Wall
Dam / Lake
Non-Perennial Pan
Perennial Pan
Wetland
Universal Coal Development 1 (Pty) Ltd
DWA
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KAM05
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R42
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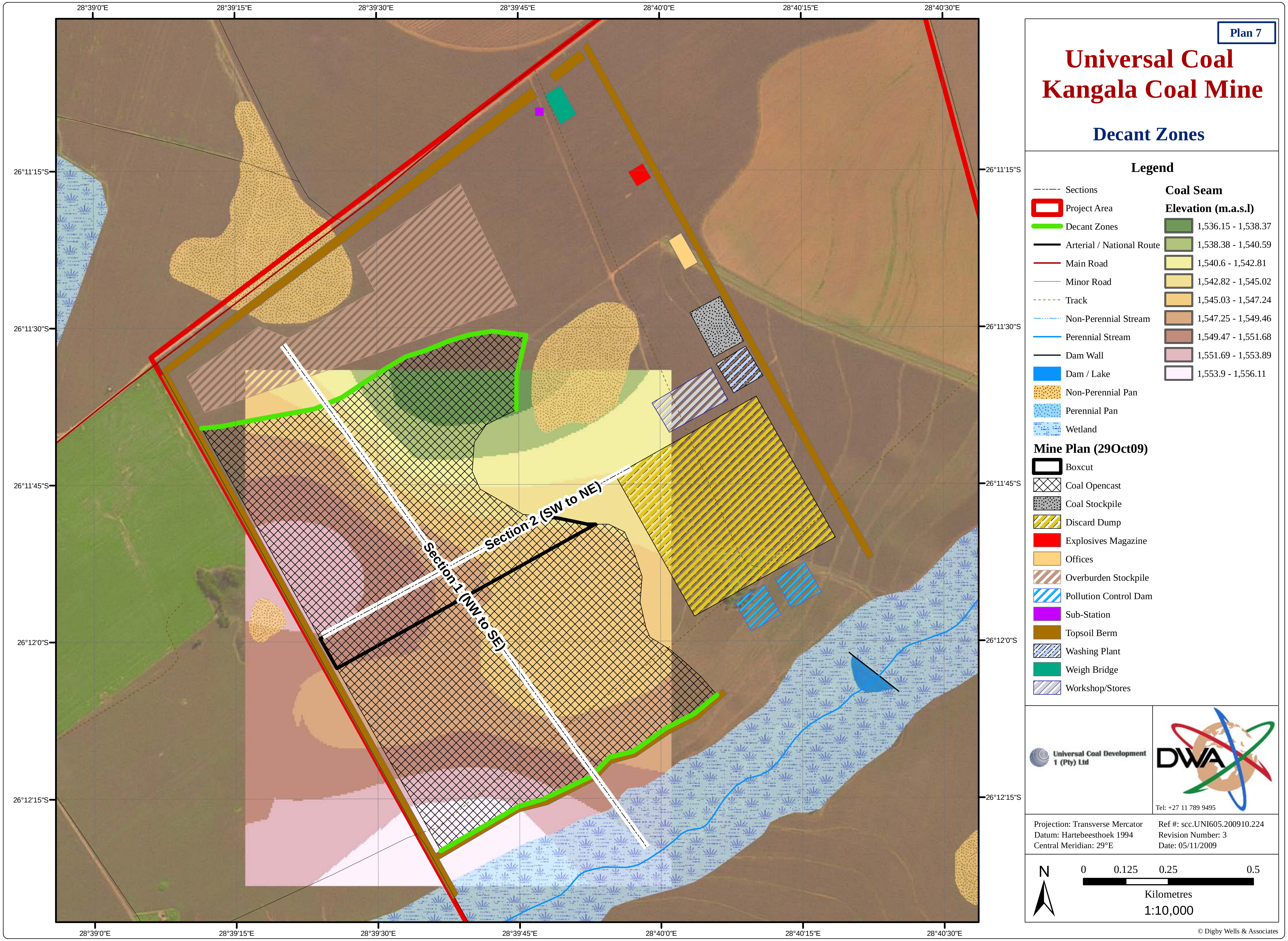
Plan 7
Universal Coal
Kangala Coal Mine
Decant Zones
Legend
Sections
Project Area
Decant Zones
Arterial / National Route
Main Road
Minor Road
Track
Non-Perennial Stream
Perennial Stream
Dam Wall
Dam / Lake
Non-Perennial Pan
Perennial Pan
Wetland
Coal Seam
Elevation (m.a.s.l)
1,536.15 - 1,538.37
1,538.38 - 1,540.59
1,540.6 - 1,542.81
1,542.82 - 1,545.02
1,545.03 - 1,547.24
1,547.25 - 1,549.46
1,549.47 - 1,551.68
1,551.69 - 1,553.89
1,553.9 - 1,556.11
Mine Plan (29Oct09)
Boxcut
Coal Opencast
Coal Stockpile
Discard Dump
Explosives Magazine
Offices
Overburden Stockpile
Pollution Control Dam
Sub-Station
Topsoil Berm
Washing Plant
Weigh Bridge
Workshop/Stores
Section 1 (NW to SE)
Section 2 (SW to NE)
28°39'0"E
28°39'15"E
28°39'30"E
28°39'45"E
28°40'0"E
28°40'15"E
28°40'30"E
26°11'15"S
26°11'30"S
26°11'45"S
26°12'0"S
26°12'15"S
Universal Coal Development 1 (Pty) Ltd
DWA
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Revision Number: 3
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APPENDIX B

HYDROCENSUS DATA RESULTS

Site ID	Coordinates		Type	Farm	Equipment	Use
	Latitude	Longitude				
DWAF Boreholes						
G37017	S26.23053	E28.64877	DWAF Dolomite Report Borehole	Strydpan 243 IR	None	Monitoring
G37018	S26.20297	E28.67848	DWAF Dolomite Report Borehole	Wolvefontein 244 IR	None	Monitoring
G37030	S26.25883	E28.69278	DWAF Dolomite Report Borehole	Welgevonden 272 IR	None	Monitoring
KGA12	S26.18134	E28.66826	DWAF Directorate of geohydrology borehole	Witklip 232 IR	None	Monitoring
Private boreholes and dams						
KGA01	S26.16952	E28.68045	Borehole	Witklip 232 IR	Submersible Pump	Domestic
KGA02	S26.16945	E28.68366	Borehole	Witklip 232 IR	None	None
KGA03	S26.15578	E28.68107	Borehole	Witklip 232 IR	Submersible Pump	Domestic
KGA04	S26.15638	E28.68224	Borehole	Witklip 232 IR	Submersible Pump	Domestic & Irrigation
KGA05	S26.15616	E28.68224	Borehole	Witklip 232 IR	Submersible Pump	Domestic
KGA06	S26.15796	E28.67700	Borehole	Witklip 232 IR	Submersible Pump	Domestic
KGA07	S26.15908	E28.67522	Borehole	Witklip 232 IR	Submersible Pump	Domestic & Irrigation
KGA08	S26.15734	E28.67595	Surface water dam	Witklip 232 IR	None	Irrigation
KGA09	S26.15654	E28.67398	Borehole	Witklip 232 IR	None	None
KGA10	S26.16831	E28.69048	Borehole	Witklip 232 IR	None	None (Planned for domestic use in future)
KGA11	S26.16661	E28.68050	Borehole	Witklip 232 IR	Submersible Pump	Domestic
KGA13	S26.19625	E28.68070	Surface water dam	Wolvefontein 244 IR	None	Livestock
KGA14	S26.20238	E28.67720	Borehole	Wolvefontein 244 IR	Submersible Pump	Domestic
KGA15	S26.20622	E28.68375	Borehole	Wolvefontein 244 IR	Submersible Pump	Domestic
KGA16	S26.19184	E28.69450	Borehole	Wolvefontein 244 IR	Hand Pump	None (Pump had seized)
KGA17	S26.20380	E28.70122	Borehole	Wolvefontein 244 IR	Submersible Pump	Livestock & Irrigation
KGA18	S26.19739	E28.71264	Borehole	Wolvefontein 244 IR	Submersible Pump	Domestic & Livestock
KGA19	S26.19586	E28.70609	Surface water dam	Wolvefontein 244 IR	None	Livestock
KGA20	S26.19575	E28.69849	Surface water dam	Wolvefontein 244 IR	None	Livestock & Irrigation
KGA21	S26.18569	E28.69183	Borehole	Wolvefontein 244 IR	Submersible Pump	Domestic
KGA22	S26.16655	E28.66067	Borehole	Middelbult 235IR	Submersible Pump	Livestock & Irrigation
KGA23	S26.16591	E28.65905	Borehole	Middelbult 235IR	Submersible Pump	Livestock & Irrigation
KGA24	S26.16408	E28.65949	Borehole	Middelbult 235IR	Submersible Pump	Livestock & Irrigation
KGA25	S26.16341	E28.65913	Borehole	Middelbult 235IR	Submersible Pump	Livestock & Irrigation
KGA26	S26.17000	E28.65423	Borehole	Middelbult 235IR	Submersible Pump	Livestock & Irrigation

Site ID	Coordinates		Type	Farm	Equipment	Use
	Latitude	Longitude				
KGA27	S26.16951	E28.65417	Borehole	Middelbult 235IR	Submersible Pump	Livestock & Irrigation
KGA28	S26.17301	E28.65134	Borehole	Middelbult 235IR	Submersible Pump	Livestock & Irrigation
KGA29	S26.17350	E28.65018	Borehole	Middelbult 235IR	Submersible Pump	Domestic
KGA30	S26.17548	E28.63268	Borehole	Middelbult 235IR	Submersible Pump	Livestock & Irrigation
KGA31	S26.17648	E28.63027	Borehole	Middelbult 235IR	Submersible Pump	Livestock & Irrigation
KGA32	S26.17605	E28.62793	Borehole	Middelbult 235IR	Submersible Pump	Livestock & Irrigation
KGA33	S26.17603	E28.62869	Borehole	Middelbult 235IR	Submersible Pump	Livestock & Irrigation
KGA34	S26.17613	E28.62655	Borehole	Middelbult 235IR	Submersible Pump	Livestock & Irrigation
KGA35	S26.17538	E28.62795	Borehole	Middelbult 235IR	Submersible Pump	Livestock & Irrigation
KGA36	S26.19107	E28.62043	Borehole	Middelbult 235IR	Submersible Pump	Livestock & Irrigation
KGA37	S26.16681	E28.65680	Borehole	Middelbult 235IR	Submersible Pump	Domestic
KGA38	S26.16999	E28.66242	Borehole	Middelbult 235IR	None	None
KGA39	S26.20445	E28.64004	Borehole	Strydpan 243 IR	Submersible Pump	Domestic & Livestock
KGA40	S26.20642	E28.65185	Borehole	Strydpan 243 IR	Bucket & Rope	Domestic
KGA41	S26.21439	E28.65425	Borehole	Strydpan 243 IR	Bucket & Rope	Domestic
KGA42	S26.19414	E28.64561	Surface water dam	Middelbult 235 IR	None	Livestock & Irrigation

APPENDIX C

HYDROCENSUS CHEMISTRY ANALYSIS CERTIFICATES

DIGBY WELLS AND ASSOCIATES

Private Bag X 10046
RANDBURG
2125

CHEMICAL ANALYSIS : WATER SAMPLES	Our Ref: DIG/ 130 - 134 / G / 09 / 09

Date received: 15 September 2009
Date completed: 1 October 2009
Quantity Analyzed: 5

Lab No	*G 130*	*G 131*	*G 132*
Analysis Results mg/l	KGA 12	KGA 15	KGA 21
Total Dissolved Solids	114	336	134
Suspended Solids	2.4	0.4	<0.4
Nitrate NO_3 as N	0.10	14.4	17.9
Chlorides as Cl	15	23	16
Total Alkalinity as $CaCO_3$	89	262	91
Fluoride as F	<0.20	<0.20	<0.20
Sulphate as SO_4	<1.0	10.1	<1.0
Total Hardness as $CaCO_3$	67	277	90
Calcium Hardness as $CaCO_3$	25	143	42
Magnesium Hardness as $CaCO_3$	42	134	48
Calcium as Ca	9.92	57.4	16.7
Magnesium as Mg	10.3	32.5	11.7
Sodium as Na	10.5	12.8	13.9
Potassium as K	5.59	2.01	3.52
Iron as Fe	<0.01	<0.01	<0.01
Manganese as Mn	<0.01	<0.01	<0.01
Conductivity in mS/m	21.0	59.0	27.1
pH-Value at 25 ° C	7.67	7.90	7.09
pHs at 21 °C	8.11	6.96	8.10
Langelier Saturation Index	-0.04	+0.94	-1.01
Aluminium as Al	0.06	0.06	0.06
Bicarbonate Alkalinity as $CaCO_3$	93	262	61
Free & Saline Ammonia NH_3 as N	1.10	<0.20	<0.20
Ortho Phosphate PO_4 as P	<0.1	<0.1	<0.1
Sodium Absorption Ratio	0.56	0.33	0.64
Copper as Cu	<0.01	<0.01	0.01
Total Chromium as Cr	<0.01	<0.01	<0.01
Lead as Pb	<0.01	<0.01	<0.01
Zinc as Zn	0.01	1.13	0.09

All heavy metal analyses have been performed on filtered samples.
*Tests marked with an asterisk * are not SANAS accredited*
These results are related only to the items tested

QUALITY CONTROL CHECKS			
Cation Balance	2.03	6.15	2.50
Anion Balance	2.20	6.10	2.27
% Difference	-4.1	0.5	4.8
Measured TDS	114	336	134
Calculated TDS	107	298	117
Limits > 1.0 - <1.2	1.1	1.1	1.1
Calcul TDS / E.C. (0.55 - 0.70)	0.5	0.5	0.4

P.L.G. UYS

DIGBY WELLS AND ASSOCIATES

Private Bag X 10046
RANDBURG
2125

CHEMICAL ANALYSIS : WATER SAMPLES	Our Ref: DIG/ 130 - 134 / G / 09 / 09

Date received: 15 September 2009
Date completed: 1 October 2009
Quantity Analyzed: 5

Lab No	*G 133*	*G 134*
Analysis Results mg/l	**KGA 26**	**KGA 39**
Total Dissolved Solids	324	280
Suspended Solids	<0.4	<0.4
Nitrate NO_3 as N	1.4	0.19
Chlorides as Cl	13	15
Total Alkalinity as $CaCO_3$	275	227
Fluoride as F	<0.20	0.55
Sulphate as SO_4	25.6	5.9
Total Hardness as $CaCO_3$	254	155
Calcium Hardness as $CaCO_3$	131	97
Magnesium Hardness as $CaCO_3$	123	58
Calcium as Ca	52.3	38.9
Magnesium as Mg	29.8	14.1
Sodium as Na	15.9	33.4
Potassium as K	0.97	3.70
Iron as Fe	<0.01	0.01
Manganese as Mn	<0.01	0.09
Conductivity in mS/m	51.9	44.2
pH-Value at 25 ° C	7.89	7.59
pHs at 21 °C	6.97	7.16
Langelier Saturation Index	+0.92	+0.43
Aluminium as Al	0.07	0.07
Bicarbonate Alkalinity as $CaCO_3$	275	237
Free & Saline Ammonia NH_3 as N	<0.20	<0.20
Ortho Phosphate PO_4 as P	<0.1	<0.1
Sodium Absorption Ratio	0.43	1.17
Copper as Cu	<0.01	<0.01
Total Chromium as Cr	<0.01	<0.01
Lead as Pb	<0.01	<0.01
Zinc as Zn	0.06	0.04

All heavy metal analyses have been performed on filtered samples.
*Tests marked with an asterisk * are not SANAS accredited*
These results are related only to the items tested

QUALITY CONTROL CHECKS		
Cation Balance	5.79	4.66
Anion Balance	6.40	5.11
% Difference	-5.0	-4.6
Measured TDS	324	280
Calculated TDS	305	250
Limits > 1.0 - <1.2	1.1	1.1
Calcul TDS / E.C. (0.55 - 0.70)	0.6	0.6

P.L.G. UYS

APPENDIX D

GEOPHYSICAL SURVEY DATA

station	x	y	boug	res	trend
Line1					
1919	-32717.75	-2896910	1.57	-0.04	1.61
1920	-32710.62	-2896940	1.57	0.03	1.53
1921	-32702.5	-2896968	1.55	0.09	1.46
1922	-32694.33	-2896997	1.49	0.1	1.39
1923	-32685.71	-2897027	1.41	0.09	1.32
1924	-32678.1	-2897056	1.38	0.13	1.26
1925	-32670.46	-2897084	1.24	0.04	1.2
1926	-32662.53	-2897113	0.97	-0.17	1.14
1927	-32654.86	-2897142	0.97	-0.11	1.08
1928	-32647.15	-2897172	0.99	-0.04	1.03
1929	-32638.39	-2897200	0.9	-0.07	0.97
1930	-32630.58	-2897230	0.92	-0.01	0.92
1931	-32622.51	-2897259	0.87	-0.01	0.88
1932	-32614.31	-2897287	0.83	0	0.83
1933	-32606.54	-2897317	0.81	0.02	0.79
1934	-32598.91	-2897344	0.78	0.03	0.75
1935	-32591.17	-2897374	0.73	0.02	0.71
1936	-32583.41	-2897402	0.72	0.05	0.67
1937	-32574.74	-2897431	0.7	0.06	0.64
1938	-32567.02	-2897460	0.63	0.02	0.61
1939	-32559.13	-2897489	0.6	0.03	0.57
1940	-32550.82	-2897519	0.51	-0.03	0.54
1941	-32542.96	-2897547	0.46	-0.05	0.52
1942	-32535.5	-2897576	0.38	-0.1	0.49
1943	-32527.35	-2897605	0.37	-0.1	0.46
1944	-32519.94	-2897633	0.34	-0.1	0.44
1945	-32510.98	-2897664	0.3	-0.12	0.42
1946	-32503.87	-2897692	0.28	-0.11	0.39
1947	-32495.47	-2897721	0.23	-0.14	0.37
1948	-32487.88	-2897750	0.26	-0.09	0.35
1949	-32480.2	-2897778	0.26	-0.07	0.33
1950	-32472.26	-2897807	0.23	-0.08	0.31
1951	-32464.39	-2897835	0.27	-0.02	0.3
1952	-32455.09	-2897866	0.27	0	0.28
1953	-32447.87	-2897893	0.28	0.02	0.26
1954	-32441.1	-2897923	0.26	0.02	0.25
1955	-32432.08	-2897952	0.21	-0.02	0.23
1956	-32424.19	-2897982	0.19	-0.03	0.22
1957	-32416.46	-2898011	0.16	-0.04	0.2
1958	-32407.91	-2898040	0.19	0	0.19
1959	-32400.3	-2898068	0.18	0.01	0.17
1960	-32392.91	-2898097	0.22	0.06	0.16
1961	-32384.46	-2898126	0.24	0.1	0.14
1962	-32376.35	-2898155	0.22	0.1	0.13
1963	-32368.78	-2898183	0.23	0.12	0.11
1964	-32360.56	-2898212	0.27	0.18	0.1
1965	-32352.99	-2898242	0.27	0.19	0.08
1966	-32344.85	-2898270	0.19	0.13	0.06
1967	-32337.19	-2898298	0.23	0.19	0.05
1968	-32329.49	-2898329	0.29	0.27	0.03
1969	-32320.97	-2898358	0.29	0.27	0.01
1970	-32312.94	-2898387	0.18	0.19	-0.01
1971	-32305.31	-2898415	0.09	0.11	-0.03

station	x	y	boug	res	trend
1972	-32298.04	-2898444	0.03	0.07	-0.05
1973	-32289.86	-2898473	0	0.07	-0.07
1974	-32281.7	-2898502	-0.09	0.01	-0.09
1975	-32274.08	-2898532	-0.03	0.08	-0.12
1976	-32266.06	-2898561	-0.07	0.07	-0.14
1977	-32257.37	-2898590	-0.09	0.07	-0.17
1978	-32250.21	-2898617	-0.17	0.03	-0.2
1979	-32241.36	-2898647	-0.23	-0.01	-0.22
1980	-32234.06	-2898677	-0.39	-0.14	-0.26
1981	-32226.56	-2898704	-0.65	-0.36	-0.29
1982	-32218.25	-2898733	-0.8	-0.48	-0.32
1983	-32210.51	-2898763	-0.9	-0.54	-0.36
1984	-32202.23	-2898791	-0.9	-0.51	-0.4
1985	-32193.96	-2898820	-0.79	-0.36	-0.44
1986	-32186.68	-2898849	-0.53	-0.05	-0.48
1987	-32178.47	-2898879	-0.48	0.04	-0.52
1988	-32169.82	-2898907	-0.5	0.06	-0.57
1989	-32162.85	-2898935	-0.47	0.15	-0.62
1990	-32154.66	-2898964	-0.5	0.17	-0.67
1991	-32146.87	-2898994	-0.57	0.15	-0.72
1992	-32139.24	-2899023	-0.66	0.12	-0.77
1993	-32131.05	-2899052	-0.79	0.04	-0.83
1994	-32123.03	-2899080	-1.01	-0.12	-0.89
1995	-32115.12	-2899109	-0.99	-0.03	-0.96
1996	-32106.46	-2899139	-1	0.03	-1.02
1997	-32099.59	-2899167	-0.99	0.1	-1.09
1998	-32090.92	-2899195	-1.08	0.08	-1.16
1999	-32083.54	-2899224	-1.08	0.16	-1.24

station	x	y	boug	res	trend
Line2					
2000	-32075.15	-2899251	-1.1	0	-1.1
2001	-32067.54	-2899284	-1.16	0	-1.16
2002	-32059.27	-2899314	-1.22	-0.01	-1.21
2003	-32051	-2899341	-1.21	0.04	-1.25
2004	-32042.75	-2899371	-1.27	0.02	-1.29
2005	-32036.03	-2899400	-1.33	0	-1.32
2006	-32027.38	-2899429	-1.34	0.01	-1.35
2007	-32019.15	-2899461	-1.43	-0.05	-1.38
2008	-31990.39	-2899456	-1.52	-0.12	-1.4
2009	-31960.25	-2899451	-1.45	-0.04	-1.42
2010	-31927.33	-2899445	-1.42	0.01	-1.43
2011	-31897.62	-2899439	-1.35	0.09	-1.44
2012	-31868.41	-2899434	-1.35	0.09	-1.45
2013	-31840.23	-2899429	-1.37	0.09	-1.45
2014	-31811.42	-2899424	-1.43	0.03	-1.46
2015	-31780.55	-2899418	-1.48	-0.02	-1.46
2016	-31749.37	-2899412	-1.57	-0.11	-1.46
2017	-31718.69	-2899406	-1.61	-0.15	-1.45
2018	-31685.2	-2899400	-1.51	-0.06	-1.45
2019	-31651.36	-2899394	-1.43	0.02	-1.45
2020	-31618.02	-2899388	-1.41	0.03	-1.44
2021	-31585.67	-2899380	-1.36	0.08	-1.44
2022	-31547.68	-2899368	-1.4	0.03	-1.43
2023	-31497.28	-2899352	-1.43	0.01	-1.43
2024	-31455.61	-2899341	-1.39	0.04	-1.43
2025	-31426.02	-2899333	-1.44	-0.02	-1.43
2026	-31399.26	-2899326	-1.43	0	-1.42
2027	-31376.21	-2899320	-1.37	0.05	-1.42
2028	-31350.27	-2899313	-1.37	0.05	-1.43
2029	-31324.4	-2899306	-1.38	0.06	-1.43
2030	-31297.53	-2899298	-1.46	-0.02	-1.44
2031	-31272.18	-2899292	-1.47	-0.02	-1.45
2032	-31252.77	-2899285	-1.55	-0.09	-1.46
2033	-31231.2	-2899280	-1.58	-0.1	-1.48
2034	-31204.38	-2899269	-1.54	-0.04	-1.5
2035	-31177.61	-2899261	-1.5	0.02	-1.53
2036	-31148.54	-2899254	-1.55	0.01	-1.55
2037	-31118.07	-2899250	-1.56	0.02	-1.59
2038	-31090.15	-2899248	-1.6	0.02	-1.63
2039	-31062.88	-2899242	-1.66	0.02	-1.67

station	x	y	boug	res	trend
Line3					
3919	-32631.33	-2896886	1.57	-0.07	1.64
3920	-32623.23	-2896916	1.54	-0.01	1.55
3921	-32614.31	-2896946	1.5	0.02	1.47
3922	-32607.28	-2896974	1.45	0.05	1.39
3923	-32598.2	-2897004	1.36	0.04	1.32
3924	-32591.19	-2897032	1.25	0	1.24
3925	-32582.4	-2897062	1.16	-0.02	1.18
3926	-32574.4	-2897091	1.07	-0.04	1.11
3927	-32566.49	-2897119	0.99	-0.05	1.05
3928	-32558.69	-2897147	0.94	-0.05	0.99
3929	-32551.36	-2897177	0.86	-0.07	0.93
3930	-32542.9	-2897206	0.87	-0.01	0.88
3931	-32535.06	-2897234	0.85	0.02	0.83
3932	-32527.46	-2897263	0.84	0.06	0.78
3933	-32519.1	-2897293	0.8	0.07	0.73
3934	-32510.74	-2897321	0.73	0.04	0.69
3935	-32503	-2897350	0.7	0.05	0.65
3936	-32494.27	-2897379	0.69	0.08	0.61
3937	-32487.33	-2897407	0.66	0.08	0.57
3938	-32479.96	-2897437	0.62	0.07	0.54
3939	-32471.11	-2897465	0.57	0.06	0.51
3940	-32463.34	-2897494	0.51	0.03	0.48
3941	-32455.21	-2897524	0.47	0.02	0.45
3942	-32447.32	-2897553	0.47	0.05	0.42
3943	-32439.41	-2897581	0.4	0	0.4
3944	-32431.53	-2897611	0.39	0.02	0.37
3945	-32423.45	-2897640	0.3	-0.05	0.35
3946	-32416.06	-2897669	0.29	-0.04	0.33
3947	-32408.14	-2897696	0.23	-0.09	0.31
3948	-32399.47	-2897726	0.2	-0.1	0.29
3949	-32392.03	-2897755	0.22	-0.06	0.28
3950	-32383.99	-2897785	0.23	-0.03	0.26
3951	-32375.89	-2897814	0.17	-0.07	0.25
3952	-32368.12	-2897842	0.16	-0.07	0.23
3953	-32360.82	-2897871	0.1	-0.11	0.22
3954	-32352.21	-2897899	0.06	-0.15	0.2
3955	-32344.59	-2897929	-0.05	-0.24	0.19
3956	-32336.81	-2897957	-0.01	-0.19	0.18
3957	-32328.96	-2897986	0.05	-0.11	0.17
3958	-32320.58	-2898016	0.12	-0.03	0.15
3959	-32312.75	-2898044	0.14	0	0.14
3960	-32305.07	-2898074	0.16	0.03	0.13
3961	-32296.92	-2898102	0.19	0.07	0.12
3962	-32289.33	-2898131	0.21	0.11	0.11
3963	-32280.83	-2898160	0.2	0.1	0.09
3964	-32273.41	-2898188	0.22	0.14	0.08
3965	-32265.66	-2898218	0.23	0.17	0.07
3966	-32257.59	-2898247	0.18	0.12	0.05
3967	-32249.68	-2898275	0.09	0.05	0.04
3968	-32240.91	-2898305	0.13	0.1	0.02
3969	-32233.29	-2898333	0.15	0.14	0.01
3970	-32222	-2898362	0.17	0.18	-0.01
3971	-32213.69	-2898390	0.1	0.13	-0.03

station	x	y	boug	res	trend
3972	-32205.55	-2898419	-0.04	0.01	-0.05
3973	-32197.13	-2898448	-0.06	0	-0.07
3974	-32189.46	-2898477	-0.08	0.01	-0.09
3975	-32182.51	-2898505	-0.09	0.02	-0.11
3976	-32173.72	-2898534	-0.11	0.03	-0.14
3977	-32165.42	-2898564	-0.08	0.08	-0.16
3978	-32157.88	-2898593	-0.14	0.05	-0.19
3979	-32149.46	-2898621	-0.19	0.03	-0.22
3980	-32140.86	-2898649	-0.26	-0.01	-0.25
3981	-32132.35	-2898678	-0.27	0.01	-0.28
3982	-32124.47	-2898708	-0.51	-0.19	-0.32
3983	-32116.67	-2898736	-0.62	-0.26	-0.36
3984	-32108.57	-2898765	-0.75	-0.35	-0.4
3985	-32100.58	-2898794	-0.68	-0.24	-0.44
3986	-32092.52	-2898823	-0.54	-0.05	-0.49
3987	-32084.28	-2898852	-0.5	0.04	-0.53
3988	-32076.37	-2898880	-0.5	0.08	-0.58
3989	-32068.86	-2898908	-0.61	0.03	-0.64
3990	-32058.94	-2898939	-0.74	-0.05	-0.69
3991	-32050.45	-2898968	-0.69	0.06	-0.75
3992	-32042.67	-2898995	-0.75	0.06	-0.81
3993	-32034.65	-2899023	-0.77	0.11	-0.88
3994	-32028.8	-2899053	-0.96	-0.01	-0.95
3995	-32028.06	-2899088	-0.96	0.06	-1.02
3996	-32020.02	-2899116	-1.13	-0.03	-1.09
3997	-32011.47	-2899144	-1.22	-0.05	-1.17
3998	-32004.54	-2899173	-1.26	0	-1.25
3999	-31996.83	-2899202	-1.24	0.1	-1.34

station	x	y	boug	res	trend
Line4					
4000	-31988.65	-2899230	-1.15	-0.02	-1.13
4001	-31980.13	-2899259	-1.22	-0.05	-1.18
4002	-31971.33	-2899288	-1.2	0.02	-1.21
4003	-31964.03	-2899317	-1.22	0.03	-1.25
4004	-31954.81	-2899351	-1.24	0.03	-1.27
4005	-31923.52	-2899343	-1.31	-0.01	-1.3
4006	-31893.27	-2899337	-1.26	0.06	-1.31
4007	-31865.12	-2899330	-1.25	0.07	-1.33
4008	-31835.12	-2899324	-1.32	0.01	-1.34
4009	-31806.28	-2899318	-1.38	-0.04	-1.34
4010	-31777.03	-2899312	-1.41	-0.06	-1.34
4011	-31746.99	-2899305	-1.4	-0.06	-1.34
4012	-31718.22	-2899299	-1.42	-0.08	-1.34
4013	-31688.4	-2899292	-1.33	0.01	-1.34
4014	-31659.59	-2899286	-1.28	0.06	-1.33
4015	-31630.59	-2899279	-1.29	0.04	-1.33
4016	-31601.82	-2899272	-1.26	0.06	-1.32
4017	-31571.31	-2899266	-1.34	-0.02	-1.32
4018	-31542.1	-2899259	-1.35	-0.04	-1.31
4019	-31512.72	-2899253	-1.37	-0.06	-1.31
4020	-31484.25	-2899247	-1.34	-0.03	-1.31
4021	-31454.71	-2899240	-1.29	0.01	-1.31
4022	-31424.8	-2899233	-1.33	-0.02	-1.31
4023	-31395.82	-2899227	-1.26	0.06	-1.32
4024	-31366.42	-2899221	-1.32	0.01	-1.33
4025	-31336.95	-2899215	-1.33	0.01	-1.34
4026	-31307.96	-2899208	-1.32	0.03	-1.36
4027	-31278.56	-2899202	-1.37	0.01	-1.38
4028	-31248.97	-2899196	-1.38	0.03	-1.41
4029	-31219.45	-2899189	-1.42	0.02	-1.44
4030	-31190.75	-2899182	-1.49	-0.01	-1.48
4031	-31161.75	-2899176	-1.5	0.03	-1.53
4032	-31132.47	-2899169	-1.55	0.03	-1.58
4033	-31103.82	-2899163	-1.62	0.02	-1.64
4034	-31073.8	-2899157	-1.81	-0.1	-1.71
4035	-31043.79	-2899150	-1.95	-0.17	-1.79
4036	-31015.01	-2899144	-1.91	-0.03	-1.87
4037	-30986.56	-2899137	-1.79	0.17	-1.97

station	x	y	boug	res	trend
Line5					
6000	-34119.84	-2897667	0.63	-0.22	0.85
6001	-34102.63	-2897692	0.6	-0.17	0.76
6002	-34086.76	-2897719	0.54	-0.14	0.68
6003	-34072	-2897744	0.46	-0.14	0.6
6004	-34056.92	-2897770	0.43	-0.08	0.52
6005	-34042.18	-2897796	0.43	-0.01	0.44
6006	-34026.38	-2897822	0.38	0.01	0.36
6007	-34011.23	-2897848	0.29	0	0.29
6008	-33996.15	-2897874	0.27	0.06	0.21
6009	-33981.15	-2897900	0.32	0.18	0.14
6010	-33965.65	-2897926	0.3	0.23	0.07
6011	-33951.66	-2897951	0.25	0.25	0
6012	-33936.84	-2897978	0.15	0.21	-0.06
6013	-33920.71	-2898004	0.05	0.18	-0.13
6014	-33906.11	-2898030	-0.07	0.13	-0.2
6015	-33891.6	-2898057	-0.16	0.09	-0.26
6016	-33877	-2898082	-0.26	0.06	-0.32
6017	-33861.5	-2898108	-0.38	0	-0.38
6018	-33847.99	-2898134	-0.47	-0.03	-0.44
6019	-33830.84	-2898160	-0.64	-0.15	-0.5
6020	-33816.73	-2898186	-0.83	-0.27	-0.55
6021	-33801.82	-2898213	-1.01	-0.4	-0.61
6022	-33787.4	-2898238	-1.1	-0.44	-0.66
6023	-33771.81	-2898263	-1.12	-0.41	-0.71
6024	-33756.4	-2898290	-1.03	-0.26	-0.76
6025	-33742.49	-2898316	-0.85	-0.03	-0.81
6026	-33727.56	-2898342	-0.73	0.13	-0.86
6027	-33712.13	-2898368	-0.65	0.26	-0.91
6028	-33696.37	-2898394	-0.68	0.28	-0.96
6029	-33683.02	-2898420	-0.72	0.28	-1
6030	-33666.52	-2898446	-0.79	0.25	-1.05
6031	-33652.37	-2898472	-0.85	0.24	-1.09
6032	-33636.72	-2898497	-0.82	0.31	-1.13
6033	-33622.18	-2898523	-0.79	0.38	-1.17
6034	-33607.32	-2898549	-0.82	0.4	-1.21
6035	-33591.97	-2898576	-0.79	0.46	-1.25
6036	-33577.34	-2898601	-0.9	0.39	-1.29
6037	-33562.45	-2898628	-1.11	0.22	-1.33
6038	-33546.76	-2898654	-1.27	0.1	-1.36
6039	-33532.8	-2898680	-1.41	-0.01	-1.4
6040	-33517.84	-2898705	-1.51	-0.08	-1.43
6041	-33501.6	-2898731	-1.57	-0.11	-1.46
6042	-33487.23	-2898757	-1.58	-0.08	-1.5
6043	-33471.78	-2898783	-1.62	-0.09	-1.53
6044	-33457.09	-2898810	-1.65	-0.09	-1.56
6045	-33442.69	-2898837	-1.73	-0.14	-1.59
6046	-33427.71	-2898862	-1.72	-0.11	-1.62
6047	-33412.46	-2898888	-1.77	-0.13	-1.65
6048	-33397.51	-2898915	-1.84	-0.17	-1.67
6049	-33382.7	-2898940	-1.88	-0.18	-1.7
6050	-33367.91	-2898965	-1.92	-0.19	-1.73
6051	-33352.11	-2898991	-1.92	-0.16	-1.75
6052	-33336.29	-2899017	-1.92	-0.14	-1.78

station	x	y	boug	res	trend
6053	-33321.51	-2899044	-1.99	-0.18	-1.8
6054	-33305.54	-2899072	-2.08	-0.25	-1.83
6055	-33292.92	-2899096	-2.22	-0.37	-1.85
6056	-33278.14	-2899121	-2.34	-0.47	-1.87
6057	-33263.09	-2899147	-2.41	-0.52	-1.89
6058	-33247.33	-2899173	-2.4	-0.49	-1.92
6059	-33232.61	-2899200	-2.37	-0.43	-1.94
6060	-33217.87	-2899225	-2.32	-0.36	-1.96
6061	-33202.5	-2899250	-2.26	-0.28	-1.98
6062	-33187.39	-2899277	-2.22	-0.22	-2
6064	-33172.57	-2899305	-2.14	-0.12	-2.02
6065	-33158.35	-2899330	-2.09	-0.06	-2.04
6066	-33142.86	-2899355	-2.02	0.04	-2.05
6067	-33127.54	-2899380	-1.93	0.15	-2.07
6068	-33113.58	-2899408	-1.86	0.23	-2.09
6069	-33097.75	-2899433	-1.89	0.22	-2.11
6070	-33084.38	-2899460	-1.91	0.22	-2.13
6071	-33069.1	-2899486	-1.93	0.21	-2.14
6072	-33053.05	-2899513	-1.92	0.24	-2.16
6073	-33038.12	-2899539	-1.94	0.24	-2.18
6074	-33024.34	-2899565	-1.96	0.23	-2.19
6075	-33007.86	-2899590	-1.9	0.31	-2.21
6076	-32993.72	-2899616	-1.86	0.37	-2.23
6077	-32979.74	-2899641	-1.84	0.4	-2.24
6078	-32963.4	-2899668	-1.82	0.44	-2.26
6079	-32948.58	-2899694	-1.85	0.42	-2.27
6080	-32932.25	-2899721	-1.9	0.39	-2.29
6081	-32917.69	-2899747	-1.94	0.37	-2.3
6082	-32902.97	-2899772	-1.99	0.33	-2.32
6083	-32888.29	-2899799	-2.09	0.25	-2.34
6084	-32872.93	-2899823	-2.16	0.19	-2.35
6085	-32858.7	-2899850	-2.27	0.1	-2.37
6086	-32843.87	-2899877	-2.6	-0.21	-2.38
6087	-32828.21	-2899901	-2.72	-0.32	-2.4
6088	-32813.79	-2899929	-2.77	-0.36	-2.42
6089	-32799.03	-2899954	-2.75	-0.32	-2.43
6090	-32785.56	-2899981	-2.79	-0.34	-2.45
6091	-32768.8	-2900006	-2.84	-0.37	-2.46
6092	-32753.16	-2900032	-2.84	-0.36	-2.48
6093	-32739.42	-2900058	-2.75	-0.25	-2.5
6094	-32724.59	-2900084	-2.6	-0.08	-2.51
6095	-32708.76	-2900110	-2.6	-0.07	-2.53
6096	-32692.69	-2900136	-2.57	-0.02	-2.55
6097	-32679.39	-2900163	-2.54	0.02	-2.57
6098	-32664.77	-2900189	-2.56	0.03	-2.59
6099	-32649.42	-2900215	-2.56	0.04	-2.6
6100	-32632.55	-2900239	-2.51	0.12	-2.62
6101	-32618.73	-2900266	-2.5	0.15	-2.64
6102	-32603.71	-2900292	-2.51	0.15	-2.66
6103	-32588.58	-2900318	-2.6	0.08	-2.68
6104	-32573.62	-2900344	-2.64	0.06	-2.7
6105	-32559.56	-2900369	-2.78	-0.05	-2.72
6106	-32543.35	-2900396	-2.87	-0.13	-2.75
6107	-32528.37	-2900421	-2.76	0.01	-2.77

station	x	y	boug	res	trend
6108	-32514.92	-2900447	-2.73	0.06	-2.79
6109	-32501.56	-2900474	-2.75	0.06	-2.81
6110	-32484.77	-2900500	-2.81	0.02	-2.84
6111	-32471.19	-2900527	-2.85	0.02	-2.86
6112	-32454.77	-2900552	-3.01	-0.12	-2.89
6113	-32440.36	-2900578	-2.99	-0.08	-2.91
6114	-32422.84	-2900607	-2.95	-0.01	-2.94

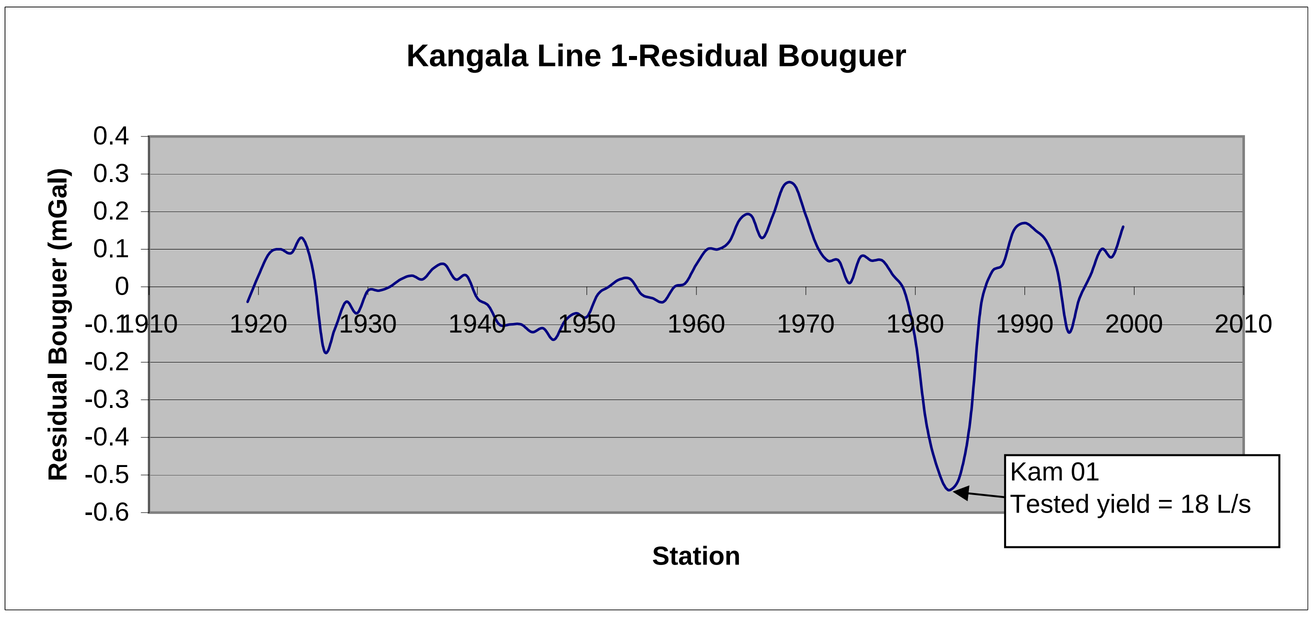
station	x	y	boug	res	trend
Line6					
7005	-34263.05	-2897876	-0.1	-0.34	0.23
7006	-34241.62	-2897909	-0.12	-0.25	0.13
7007	-34225.69	-2897935	-0.07	-0.09	0.02
7008	-34210.86	-2897961	0	0.08	-0.08
7009	-34195.8	-2897987	-0.01	0.16	-0.18
7010	-34181.47	-2898014	0.04	0.31	-0.27
7011	-34165.93	-2898039	0.07	0.43	-0.37
7012	-34151.1	-2898065	0	0.46	-0.46
7013	-34135.44	-2898091	-0.1	0.44	-0.54
7014	-34120.52	-2898116	-0.22	0.4	-0.63
7015	-34106.45	-2898143	-0.37	0.34	-0.71
7016	-34090.49	-2898168	-0.55	0.24	-0.79
7017	-34074.79	-2898194	-0.77	0.09	-0.86
7018	-34060.57	-2898221	-0.98	-0.05	-0.93
7019	-34045.63	-2898247	-1.16	-0.16	-1
7020	-34030.37	-2898272	-1.31	-0.24	-1.07
7021	-34016.24	-2898298	-1.39	-0.25	-1.14
7022	-34000.95	-2898325	-1.5	-0.3	-1.2
7023	-33986.57	-2898350	-1.55	-0.28	-1.26
7024	-33970.09	-2898377	-1.62	-0.3	-1.32
7025	-33955.67	-2898404	-1.65	-0.28	-1.37
7026	-33940.62	-2898428	-1.72	-0.29	-1.43
7027	-33925.07	-2898456	-1.77	-0.29	-1.48
7028	-33910.66	-2898481	-1.82	-0.29	-1.53
7029	-33896.65	-2898506	-1.82	-0.24	-1.58
7030	-33880.35	-2898533	-1.81	-0.19	-1.62
7031	-33866.13	-2898558	-1.8	-0.14	-1.67
7032	-33850.43	-2898585	-1.8	-0.1	-1.71
7033	-33836.25	-2898610	-1.81	-0.07	-1.75
7034	-33821.01	-2898637	-1.83	-0.04	-1.78
7035	-33805.74	-2898663	-1.84	-0.02	-1.82
7036	-33791.09	-2898689	-1.84	0.01	-1.85
7037	-33776.6	-2898714	-1.8	0.09	-1.89
7038	-33760.4	-2898741	-1.76	0.16	-1.92
7039	-33745.48	-2898767	-1.78	0.16	-1.95
7040	-33729.27	-2898793	-1.8	0.17	-1.98
7041	-33716.55	-2898819	-1.83	0.17	-2
7042	-33701.36	-2898844	-1.87	0.16	-2.03
7043	-33686.48	-2898870	-1.96	0.09	-2.05
7044	-33670.58	-2898897	-2.04	0.03	-2.08
7045	-33654.62	-2898922	-2.16	-0.06	-2.1
7046	-33641.72	-2898948	-2.23	-0.12	-2.12
7047	-33626.84	-2898975	-2.29	-0.15	-2.14
7048	-33610.75	-2899000	-2.31	-0.16	-2.16
7049	-33596.58	-2899025	-2.35	-0.18	-2.17
7050	-33581.19	-2899053	-2.39	-0.2	-2.19
7051	-33566.22	-2899078	-2.42	-0.21	-2.2
7052	-33551.19	-2899104	-2.45	-0.23	-2.22
7053	-33536.68	-2899130	-2.48	-0.25	-2.23
7054	-33521.27	-2899156	-2.52	-0.27	-2.25
7055	-33506.34	-2899182	-2.52	-0.27	-2.26
7056	-33491.17	-2899209	-2.51	-0.24	-2.27
7057	-33476.02	-2899234	-2.49	-0.2	-2.28

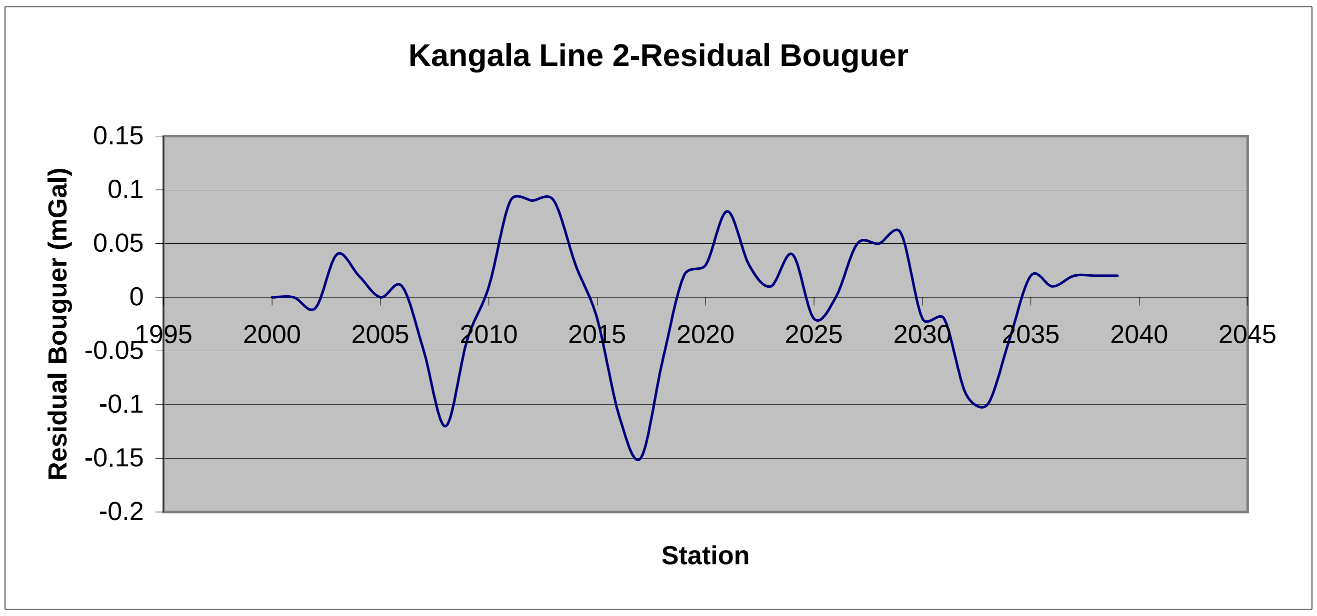
station	x	y	boug	res	trend
7058	-33462.76	-2899259	-2.41	-0.11	-2.29
7059	-33445.49	-2899286	-2.38	-0.08	-2.3
7060	-33435.42	-2899311	-2.29	0.02	-2.31
7061	-33416.1	-2899337	-2.22	0.1	-2.32
7062	-33401.03	-2899362	-2.1	0.23	-2.33
7063	-33386.17	-2899389	-2.09	0.25	-2.34
7064	-33370.39	-2899415	-2.19	0.16	-2.35
7065	-33356.3	-2899441	-2.19	0.16	-2.36
7066	-33341.36	-2899467	-2.14	0.23	-2.37
7067	-33325.66	-2899493	-2.09	0.29	-2.37
7068	-33311.19	-2899519	-2.06	0.32	-2.38
7069	-33295.89	-2899545	-2.03	0.36	-2.39
7070	-33281.25	-2899572	-2.02	0.38	-2.4
7071	-33266.75	-2899598	-2.03	0.38	-2.41
7072	-33251.37	-2899624	-2.02	0.4	-2.42
7073	-33236.2	-2899649	-2.06	0.36	-2.43
7074	-33221.25	-2899674	-2.07	0.37	-2.44
7075	-33205.69	-2899701	-2.09	0.36	-2.45
7076	-33191.32	-2899727	-2.16	0.29	-2.46
7077	-33176.28	-2899753	-2.11	0.36	-2.47
7078	-33160.89	-2899779	-2.09	0.39	-2.48
7079	-33146.37	-2899805	-2.14	0.35	-2.49
7080	-33131.31	-2899832	-2.18	0.32	-2.5
7081	-33116.24	-2899857	-2.22	0.3	-2.52
7082	-33101.56	-2899884	-2.26	0.27	-2.53
7083	-33086.47	-2899909	-2.26	0.28	-2.54
7084	-33071.71	-2899934	-2.31	0.25	-2.56
7085	-33055.69	-2899961	-2.45	0.12	-2.58
7086	-33042.28	-2899987	-2.67	-0.07	-2.59
7087	-33026.69	-2900013	-2.79	-0.18	-2.61
7088	-33011.75	-2900038	-2.88	-0.24	-2.63
7089	-32996.03	-2900066	-2.92	-0.26	-2.65
7090	-32982.54	-2900091	-2.96	-0.28	-2.67
7091	-32967.05	-2900117	-2.97	-0.27	-2.7
7092	-32951.27	-2900143	-3.13	-0.4	-2.72
7093	-32936.79	-2900170	-3.25	-0.5	-2.75
7094	-32921.31	-2900195	-3.27	-0.5	-2.77
7095	-32907.13	-2900220	-3.29	-0.49	-2.8
7096	-32891.87	-2900247	-3.3	-0.47	-2.83
7097	-32876.92	-2900274	-3.31	-0.44	-2.86
7098	-32861.5	-2900299	-3.32	-0.42	-2.9
7099	-32845.92	-2900325	-3.37	-0.44	-2.93
7100	-32831.34	-2900352	-3.36	-0.4	-2.97
7101	-32817.14	-2900377	-3.38	-0.38	-3.01
7102	-32801.8	-2900402	-3.41	-0.36	-3.05
7103	-32786.49	-2900428	-3.22	-0.13	-3.09
7104	-32772.14	-2900453	-3.07	0.07	-3.13
7105	-32757.35	-2900481	-3.1	0.07	-3.18
7106	-32741.4	-2900507	-3.15	0.08	-3.22
7107	-32727.11	-2900532	-3.17	0.11	-3.27
7108	-32711.24	-2900560	-3.46	-0.14	-3.33
7109	-32696.63	-2900585	-3.63	-0.25	-3.38
7110	-32680.85	-2900611	-3.62	-0.19	-3.44
7111	-32667.4	-2900638	-3.52	-0.02	-3.5

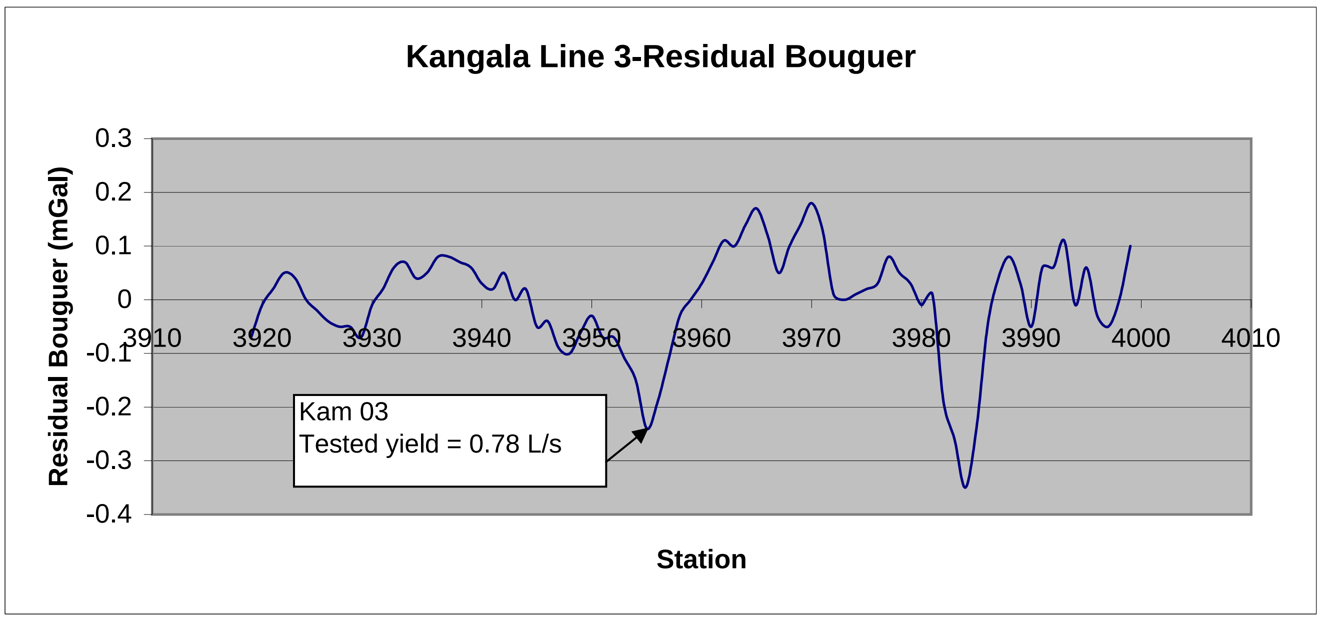
station	x	y	boug	res	trend
7112	-32651.88	-2900662	-3.38	0.17	-3.56
7113	-32637.46	-2900688	-3.38	0.24	-3.62
7114	-32621.67	-2900715	-3.44	0.24	-3.68
7115	-32606.97	-2900740	-3.36	0.39	-3.75
7116	-32592.37	-2900767	-3.32	0.5	-3.82
7117	-32579.08	-2900789	-3.33	0.57	-3.9

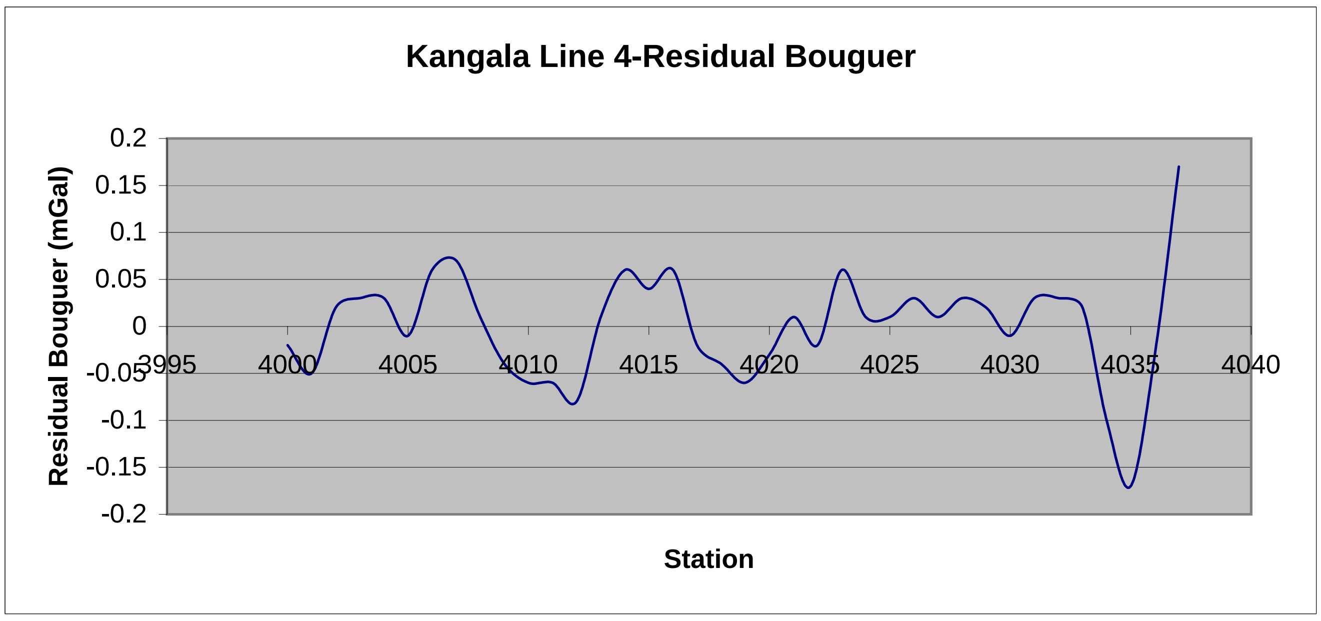
Station	x	y	Mag	HD	VD	res1	trend1
Line 7							
0	-33852.3	-2899923	28406	*	*	9.42	28396.58
10	-33846.7	-2899932.6	28419	47	45	22.15	28396.85
20	-33841.1	-2899942.2	28429	47	45	31.86	28397.14
30	-33835.5	-2899951.7	28427	50	49	29.54	28397.46
40	-33830	-2899961.3	28428	53	57	30.21	28397.79
50	-33824.4	-2899970.9	28431	57	54	32.85	28398.15
60	-33818.8	-2899980.5	28422	60	51	23.47	28398.53
70	-33813.2	-2899990.1	28408	65	59	9.07	28398.93
80	-33807.7	-2899999.6	28401	62	68	1.65	28399.35
90	-33802.1	-2900009.2	28400	68	62	0.21	28399.79
100	-33796.5	-2900018.8	28401	66	71	0.75	28400.25
110	-33790.9	-2900028.4	28397	67	71	-3.72	28400.72
120	-33785.3	-2900038	28396	66	66	-5.21	28401.21
130	-33779.8	-2900047.5	28399	69	66	-2.71	28401.71
140	-33774.2	-2900057.1	28392	70	69	-10.24	28402.24
150	-33768.6	-2900066.7	28394	69	56	-8.77	28402.77
160	-33763	-2900076.3	28390	70	52	-13.32	28403.32
170	-33757.5	-2900085.9	28377	70	54	-26.89	28403.89
180	-33751.9	-2900095.4	28370	69	50	-34.46	28404.46
190	-33746.3	-2900105	28365	68	47	-40.05	28405.05
200	-33740.7	-2900114.6	28365	64	41	-40.65	28405.65
210	-33735.2	-2900124.2	28360	64	44	-46.26	28406.26
220	-33729.6	-2900133.8	28363	62	40	-43.88	28406.88
230	-33724	-2900143.3	28365	59	39	-42.51	28407.51
240	-33718.4	-2900152.9	28367	56	24	-41.14	28408.14
250	-33712.8	-2900162.5	28376	52	36	-32.79	28408.79
260	-33707.3	-2900172.1	28377	51	38	-32.44	28409.44
270	-33701.7	-2900181.7	28380	54	22	-30.1	28410.1
280	-33696.1	-2900191.3	28389	56	21	-21.77	28410.77
290	-33690.5	-2900200.8	28396	53	41	-15.44	28411.44
300	-33685	-2900210.4	28402	55	42	-10.12	28412.12
310	-33679.4	-2900220	28414	58	48	1.2	28412.8
320	-33673.8	-2900229.6	28417	60	50	3.52	28413.48
330	-33668.2	-2900239.2	28413	67	27	-1.16	28414.16
340	-33662.6	-2900248.7	28418	70	47	3.15	28414.85
350	-33657.1	-2900258.3	28420	69	34	4.46	28415.54
360	-33651.5	-2900267.9	28426	69	40	9.77	28416.23
370	-33645.9	-2900277.5	28421	68	38	4.08	28416.92
380	-33640.3	-2900287.1	28430	72	34	12.39	28417.61
390	-33634.8	-2900296.6	28430	75	35	11.71	28418.29
400	-33629.2	-2900306.2	28437	73	50	18.02	28418.98
410	-33623.6	-2900315.8	28439	77	51	19.34	28419.66
420	-33618	-2900325.4	28450	77	50	29.66	28420.34
430	-33612.5	-2900335	28462	76	46	40.98	28421.02
440	-33606.9	-2900344.5	28453	79	30	31.31	28421.69
450	-33601.3	-2900354.1	28442	75	52	19.65	28422.35
460	-33595.7	-2900363.7	28444	79	51	20.99	28423.01
470	-33590.1	-2900373.3	28440	82	68	16.34	28423.66
480	-33584.6	-2900382.9	28435	80	36	10.69	28424.31
490	-33579	-2900392.4	28435	83	42	10.06	28424.94
500	-33573.4	-2900402	28445	82	12	19.43	28425.57
510	-33567.8	-2900411.6	28444	82	40	17.81	28426.19
520	-33562.3	-2900421.1	28448	80	29	21.2	28426.8
530	-33556.8	-2900430.5	28453	84	57	25.6	28427.4
540	-33551.3	-2900440	28446	86	32	18.02	28427.98
550	-33545.8	-2900449.5	28448	84	62	19.44	28428.56
560	-33540.2	-2900458.9	28443	83	59	13.88	28429.12
570	-33534.7	-2900468.4	28445	84	68	15.33	28429.67
580	-33529.2	-2900477.9	28443	82	66	12.8	28430.2
590	-33523.7	-2900487.3	28440	79	73	9.28	28430.72
600	-33518.2	-2900496.8	28447	80	44	15.78	28431.22
610	-33512.6	-2900506.2	28447	79	59	15.29	28431.71
620	-33507.1	-2900515.7	28447	74	59	14.82	28432.18
630	-33501.6	-2900525.2	28446	72	60	13.37	28432.63
640	-33496.1	-2900534.6	28447	70	30	13.93	28433.07
650	-33490.5	-2900544.1	28447	75	64	13.51	28433.49
660	-33485	-2900553.6	28440	70	33	6.12	28433.88
670	-33479.5	-2900563	28440	72	45	5.74	28434.26
680	-33474	-2900572.5	28437	70	43	2.38	28434.62
690	-33468.5	-2900582	28430	67	39	-4.95	28434.95
700	-33462.9	-2900591.4	28426	65	40	-9.26	28435.26
710	-33457.4	-2900600.9	28422	64	48	-13.55	28435.55
720	-33451.9	-2900610.4	28421	63	41	-14.82	28435.82
730	-33446.4	-2900619.8	28419	63	39	-17.06	28436.06
740	-33440.9	-2900629.3	28420	60	34	-16.28	28436.28
750	-33435.3	-2900638.8	28416	62	47	-20.47	28436.47
760	-33429.8	-2900648.2	28418	55	39	-18.64	28436.64

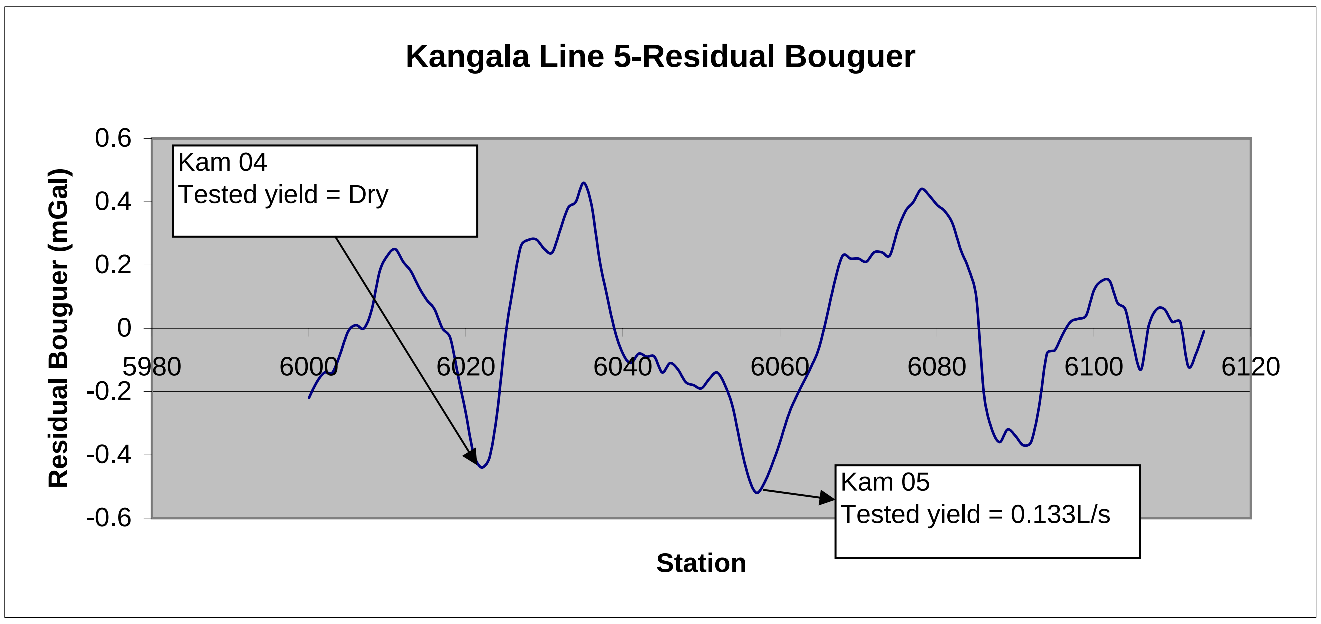
Station	x	y	Mag	HD	VD	res1	trend1
770	-33424.3	-2900657.7	28420	57	47	-16.78	28436.78
780	-33418.8	-2900667.1	28423	53	49	-13.89	28436.89
790	-33413.3	-2900676.6	28422	51	40	-14.97	28436.97
800	-33407.7	-2900686.1	28427	50	44	-10.03	28437.03
810	-33402.2	-2900695.5	28428	47	36	-9.05	28437.05
820	-33396.7	-2900705	28433	46	30	-4.05	28437.05
830	-33391.2	-2900714.5	28431	44	40	-6.01	28437.01
840	-33385.6	-2900723.9	28430	44	39	-6.94	28436.94
850	-33380.1	-2900733.4	28433	42	44	-3.84	28436.84
860	-33374.6	-2900742.9	28433	40	33	-3.71	28436.71
870	-33369.1	-2900752.3	28432	40	31	-4.55	28436.55
880	-33363.6	-2900761.8	28432	39	36	-4.35	28436.35
890	-33358	-2900771.3	28430	40	37	-6.11	28436.11
900	-33352.5	-2900780.7	28432	40	33	-3.84	28435.84
910	-33347	-2900790.2	28433	43	30	-2.54	28435.54
920	-33341.5	-2900799.6	28429	47	34	-6.19	28435.19
930	-33336	-2900809.1	28431	50	36	-3.81	28434.81
940	-33330.4	-2900818.6	28432	54	45	-2.39	28434.39
950	-33324.9	-2900828	28434	54	48	0.06	28433.94
960	-33319.4	-2900837.5	28434	57	45	0.56	28433.44
970	-33313.9	-2900847	28435	60	48	2.1	28432.9
980	-33308.4	-2900856.4	28432	64	40	-0.32	28432.32
990	-33302.8	-2900865.9	28434	66	29	2.3	28431.7
1000	-33297.3	-2900875.4	28428	67	45	-3.04	28431.04
1010	-33291.8	-2900884.8	28430	69	40	-0.34	28430.34
1020	-33286.9	-2900895.3	28434	72	70	4.41	28429.59
1030	-33282.1	-2900905.9	28428	72	49	-0.8	28428.8
1040	-33277.2	-2900916.4	28424	73	62	-3.96	28427.96
1050	-33272.4	-2900926.9	28424	73	48	-3.08	28427.08
1060	-33267.5	-2900937.4	28429	73	50	2.85	28426.15
1070	-33262.7	-2900947.9	28417	70	42	-8.17	28425.17
1080	-33257.9	-2900958.4	28406	71	45	-18.15	28424.15
1090	-33253	-2900969	28405	70	48	-18.08	28423.08
1100	-33248.2	-2900979.5	28405	69	59	-16.96	28421.96
1110	-33243.3	-2900990	28410	67	61	-10.79	28420.79
1120	-33238.5	-2901000.5	28431	66	52	11.43	28419.57
1130	-33233.6	-2901011	28412	63	30	-6.29	28418.29
1140	-33228.8	-2901021.5	28400	68	45	-16.97	28416.97
1150	-33223.9	-2901032.1	28417	52	54	1.4	28415.6
1160	-33219.1	-2901042.6	28410	51	43	-4.17	28414.17
1170	-33214.2	-2901053.1	28413	52	44	0.31	28412.69
1180	-33209.4	-2901063.6	28416	52	42	4.85	28411.15
1190	-33204.5	-2901074.1	28444	58	28	34.44	28409.56
1200	-33199.7	-2901084.6	28435	52	45	27.08	28407.92
1210	-33194.8	-2901095.2	28435	50	48	28.79	28406.21
1210	-33194.8	-2901095.2	*	50	53	*	28404.46
1210	-33194.8	-2901095.2	*	50	41	*	28402.64

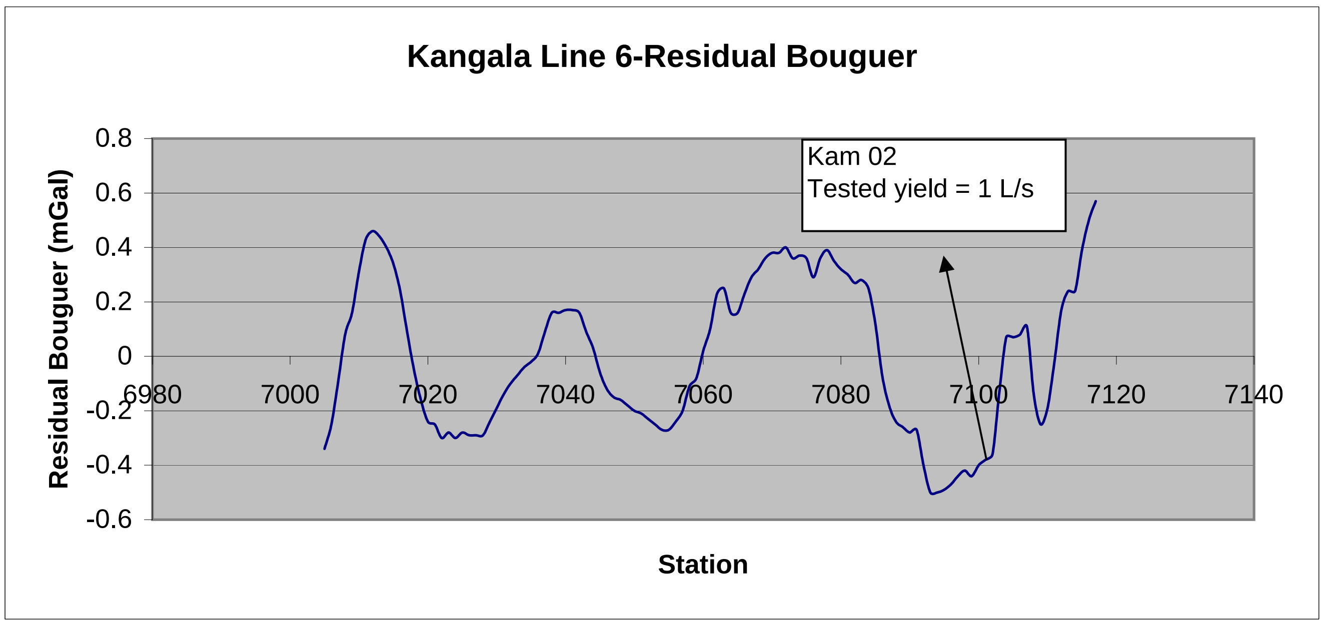

Kangala Line 1-Residual Bouguer
Residual Bouguer (mGal)
0.4
0.3
0.2
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.5
-0.6
1910
1920
1930
1940
1950
1960
1970
1980
1990
2000
2010
Kam 01
Tested yield = 18 L/s
Station


Kangala Line 2-Residual Bouguer
Residual Bouguer (mGal)
0.15
0.1
0.05
0
-0.05
-0.1
-0.15
-0.2
1995
2000
2005
2010
2015
2020
2025
2030
2035
2040
2045
Station


Kangala Line 3-Residual Bouguer
Residual Bouguer (mGal)
0.3
0.2
0.1
0
-0.1
-0.2
-0.3
-0.4
3910
3920
3930
3940
3950
3960
3970
3980
3990
4000
4010
Kam 03
Tested yield = 0.78 L/s
Station


Kangala Line 4-Residual Bouguer
Residual Bouguer (mGal)
0.2
0.15
0.1
0.05
0
-0.05
-0.1
-0.15
-0.2
3995
4000
4005
4010
4015
4020
4025
4030
4035
4040
Station

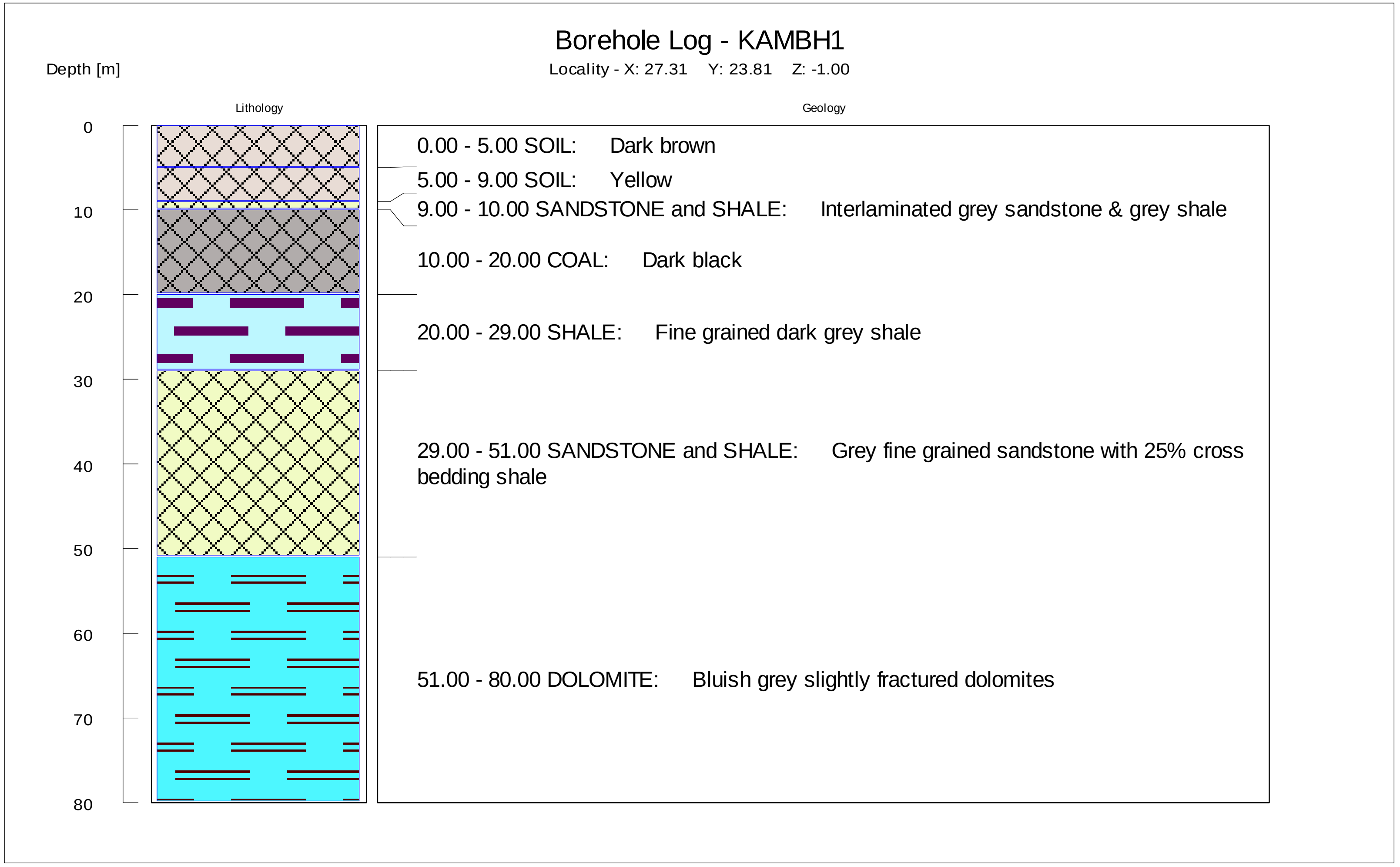

Kangala Line 5-Residual Bouguer
Residual Bouguer (mGal)
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
5980
6000
6020
6040
6060
6080
6100
6120
Kam 04
Tested yield = Dry
Kam 05
Tested yield = 0.133L/s
Station


Kangala Line 6-Residual Bouguer
Residual Bouguer (mGal)
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
6980
7000
7020
7040
7060
7080
7100
7120
7140
Kam 02
Tested yield = 1 L/s
Station

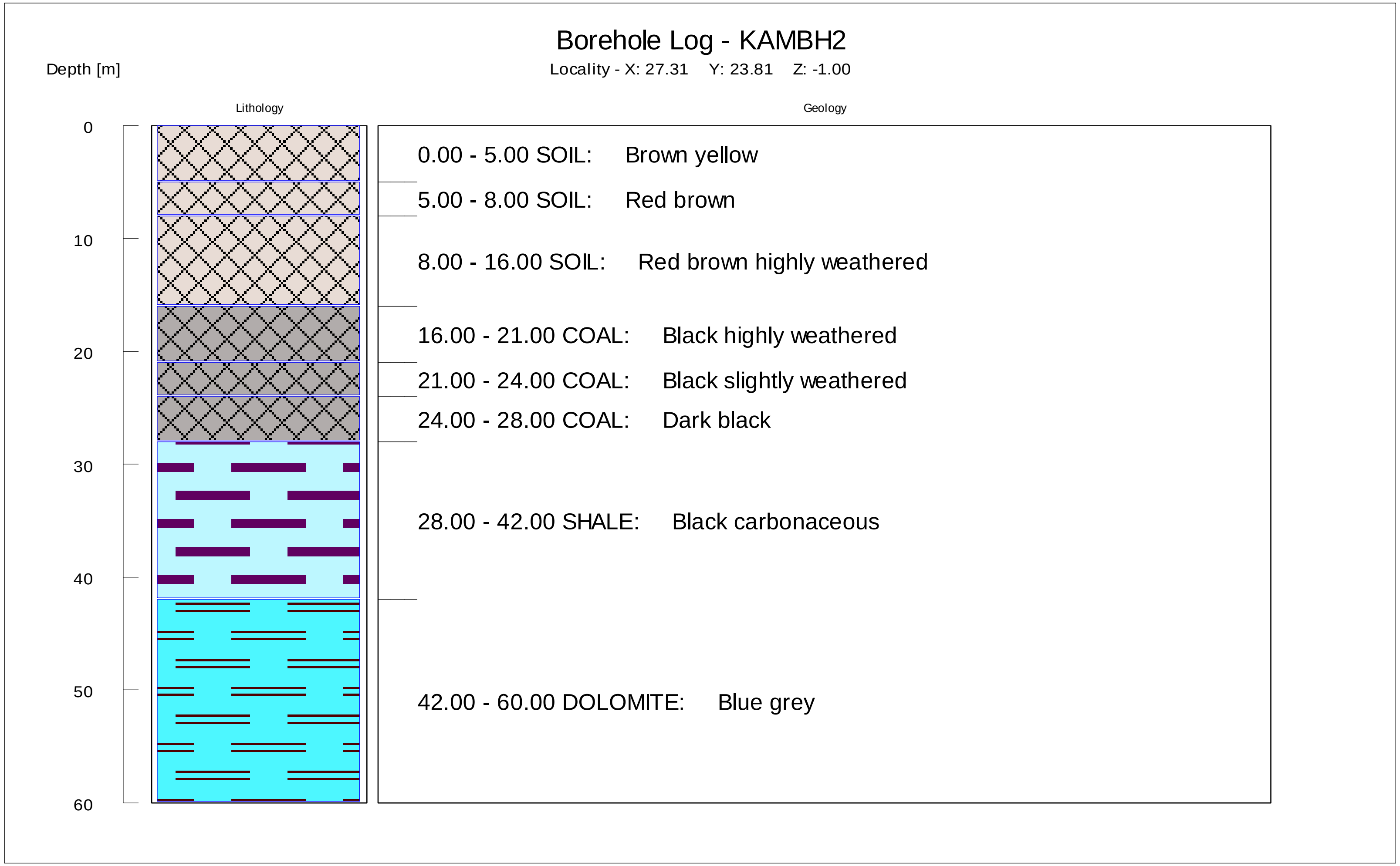
APPENDIX E

BOREHOLE LITHOLOGICAL DESCRIPTION OF NEWLY DRILLED BOREHOLES

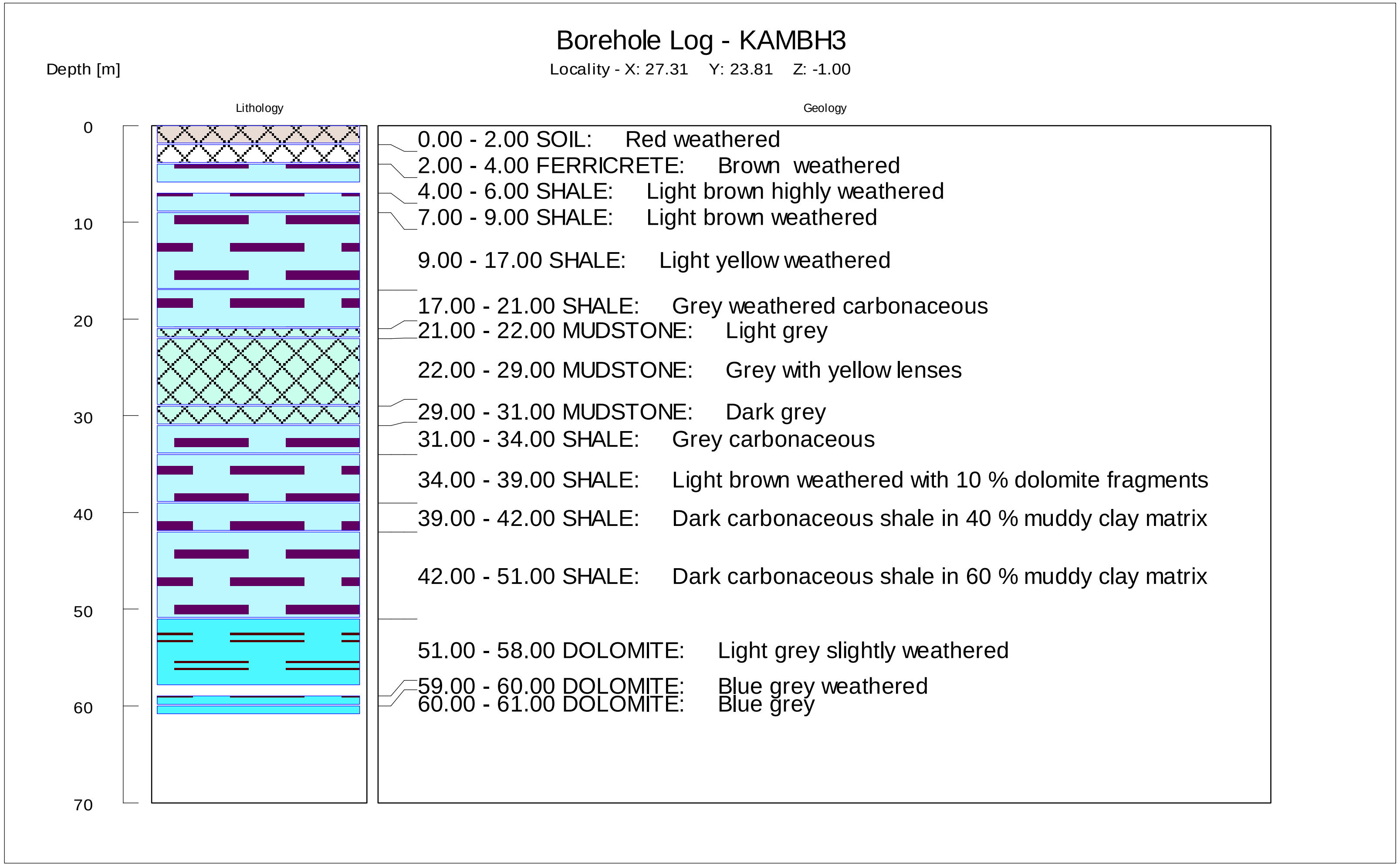
Appendix E – 1 Borehole Logs



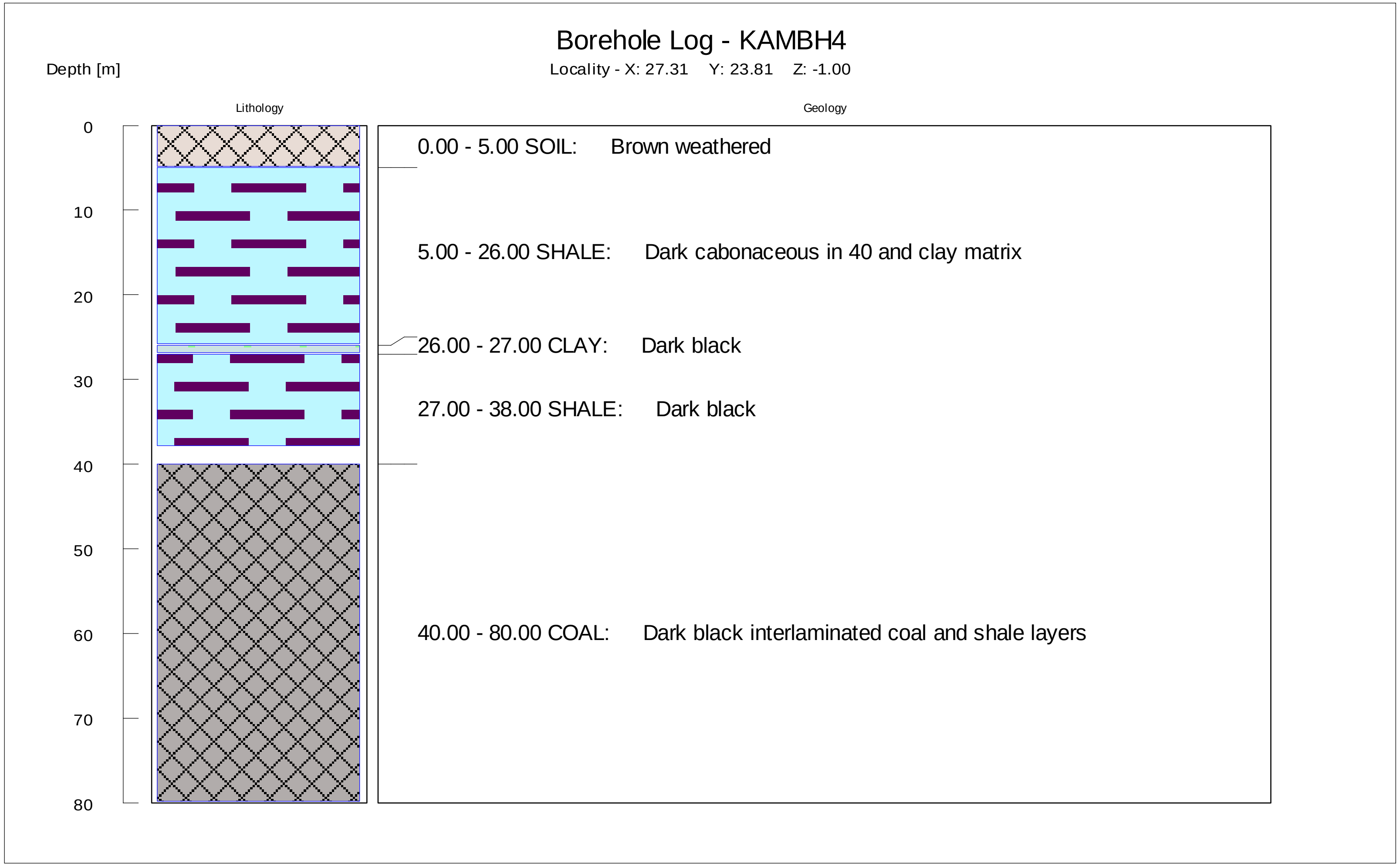
Appendix E – 2 Borehole Logs



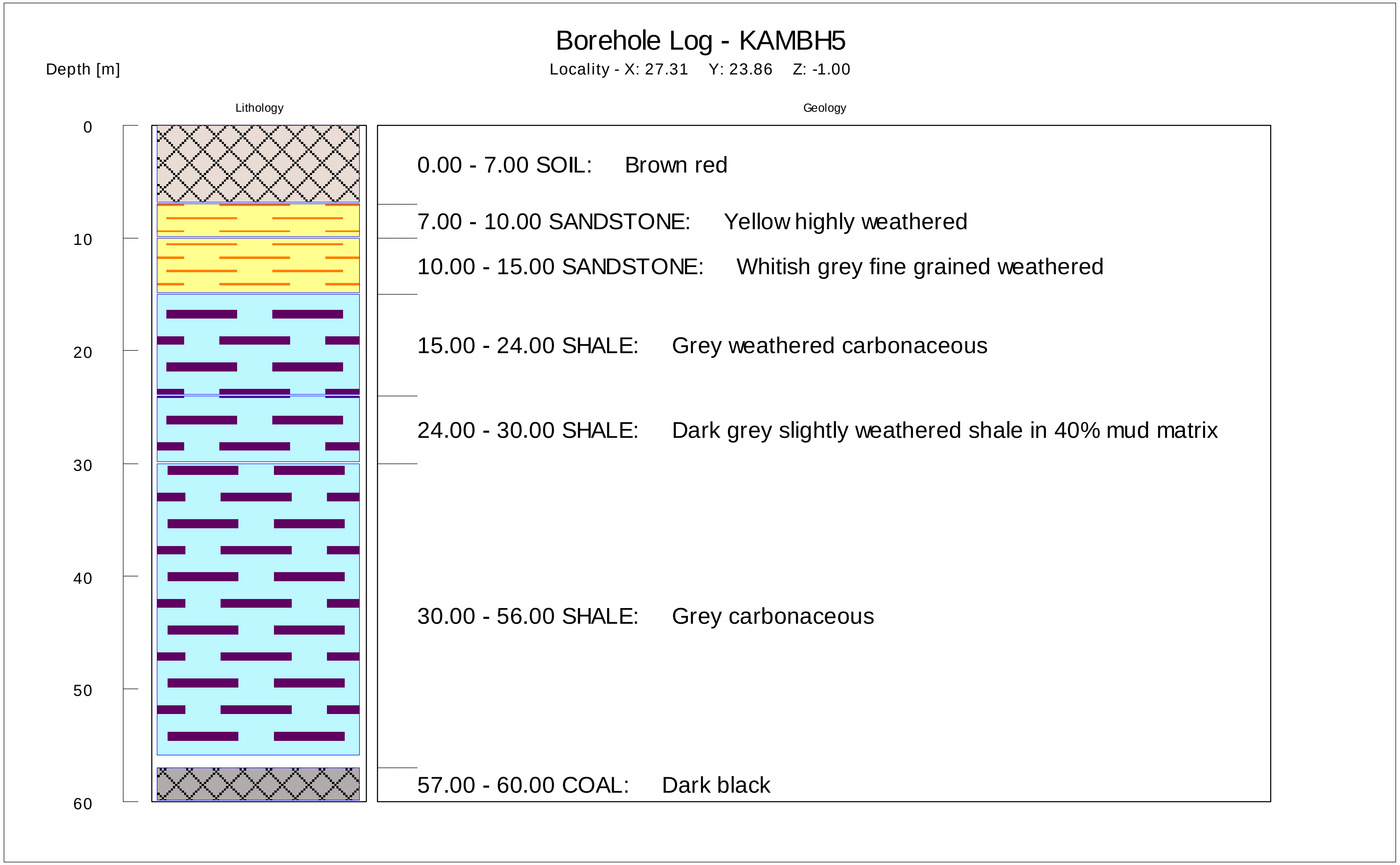
Appendix E – 3 Borehole Logs



Appendix E – 4 Borehole Logs



Appendix E – 5 Borehole Logs



Borehole Construction and Geological Log

BASIC SITE INFORMATION: ***Site Identifier:*** 2628DA00001 ***Number:*** KM1 ***Site type:*** Borehole

Distr./Farm No.: ***Site Name/Des.:*** DELMAS

Region Type: ***Region Descr.:***

Latitude [° ' "]:	284039.80
Longitude [° ' "]:	261151.60
Altitude [m]:	
Coord. acc.:	Accurate to within 1 unit
Coord. meth.:	Global Positioning System

Reg./BB.:

G-Nr.:

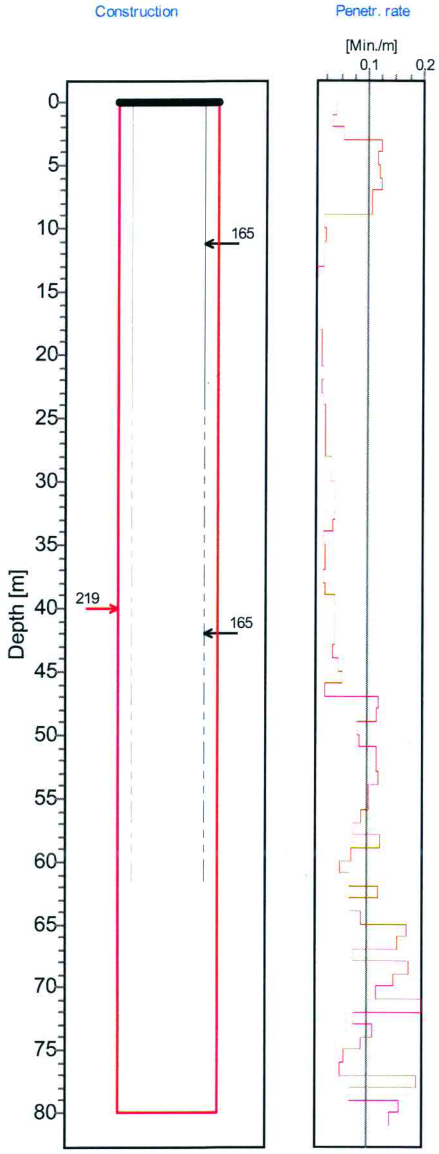
Topo-set.:	
Site status:	Unused
Site purp.:	Observation
Use applic.:	
Equipment:	No equipment

Depth [m]:	80.00
Col. ht. [m]:	
Diam. [mm]:	219
Drain. reg.:	
Rep. inst.:	

Coordinate System: Geographic Coordinates (deg, min, sec), Hartebeesthoek94 (WGS 84)

Construction and Geohydrological Legend

Hole	165 Hole diameter [mm]
Casing (plain / perforated, sloted)	152 Casing diameter [mm]
Screen / Mesh Screen	Waterlevel with date meas.
Piezometer	0:50 Piezometer (Nr. & Diameter [mm])



COMMENT: User name and adress

Borehole Construction and Geological Log

BASIC SITE INFORMATION: ***Site Identifier:*** 2628DA00002 ***Number:*** KM2 ***Site type:*** Borehole

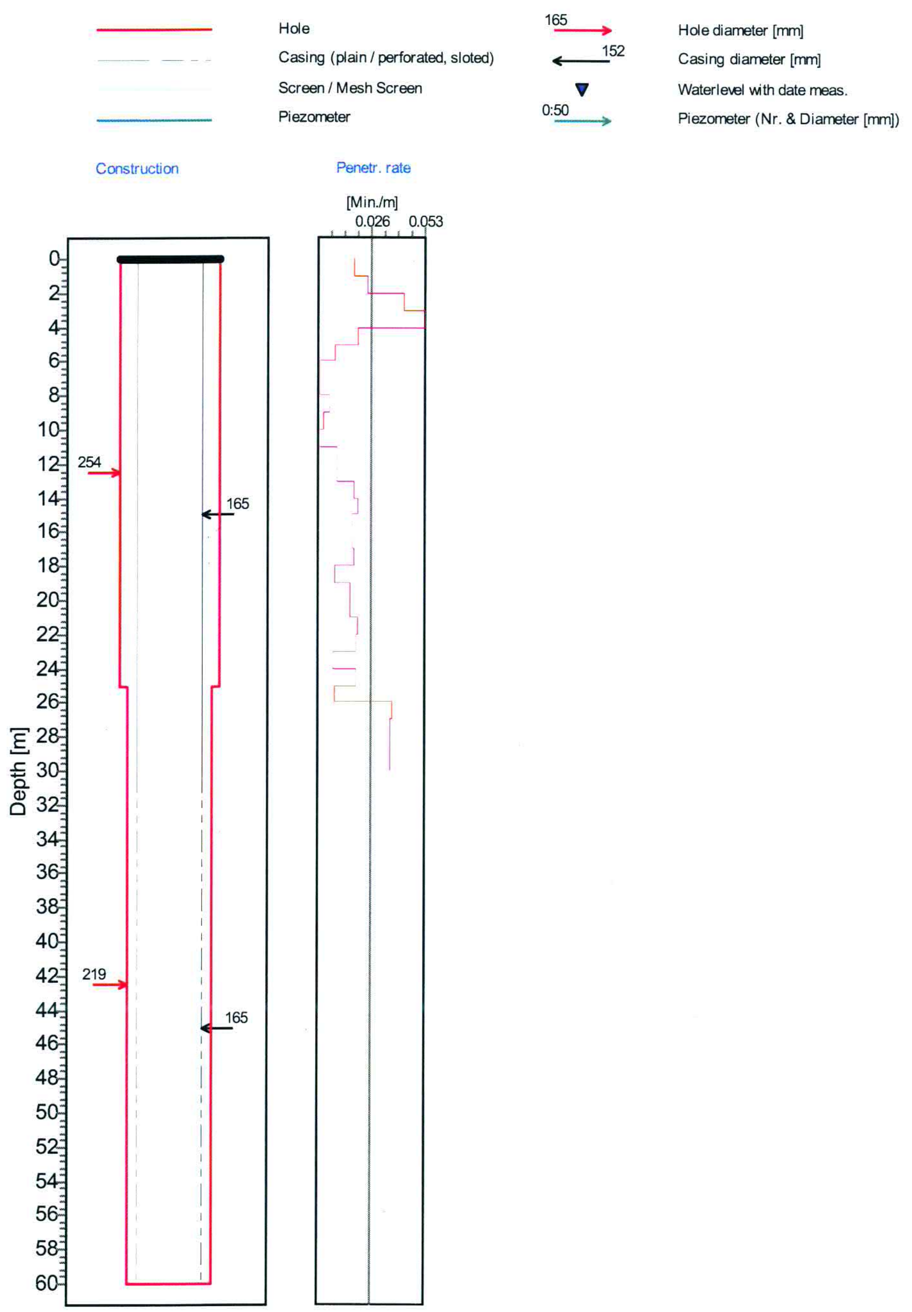
Distr./Farm No.: ***Site Name/Des.:*** DELMAS

Region Type: ***Region Descr.:***

Latitude [° ' "]: 284017.70	***Reg./BB.:***	***Topo-set.:***	***Depth [m]:*** 60.00
Longitude [° ' "]: 261245.60	***G-Nr.:***	***Site status:*** Unused	***Col. ht. [m]:***
Altitude [m]:		***Site purp.:*** Observation	***Diam. [mm]:*** 219
Coord. acc.: Accurate to within 1 unit		***Use applic.:***	***Drain. reg.:***
Coord. meth.: Global Positioning System		***Equipment:*** No equipment	***Rep. inst.:***

Coordinate System: Geographic Coordinates (deg, min, sec), Hartebeesthoek94 (WGS 84)

Construction and Geohydrological Legend



COMMENT:

User name and adress

Borehole Construction and Geological Log

BASIC SITE INFORMATION: ***Site Identifier:*** 2628DA00003 ***Number:*** KM3 ***Site type:*** Borehole

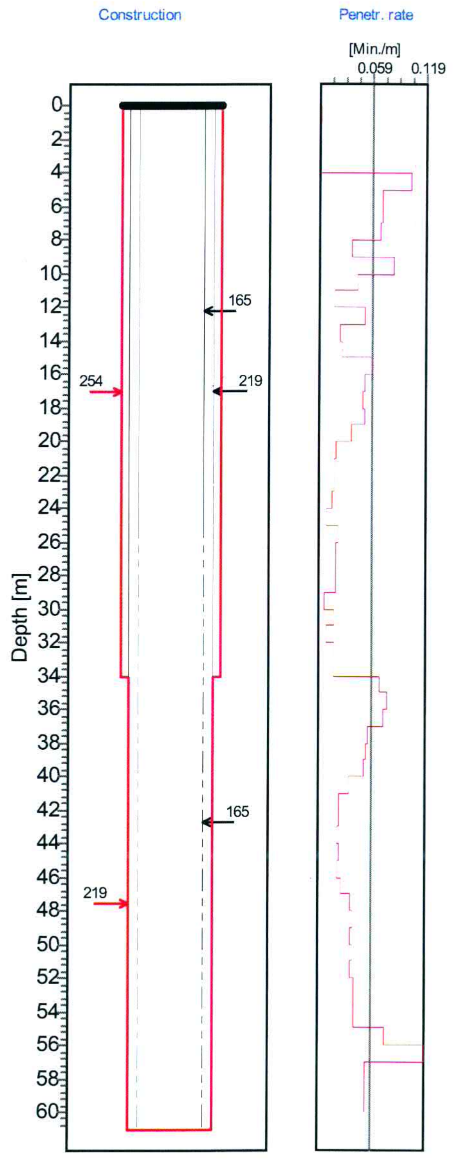
Distr./Farm No.: ***Site Name/Des.:*** DELMAS

Region Type: ***Region Descr.:***

Latitude [° ' "]:	284035.80	***Reg./BB.:***		***Topo-set.:***		***Depth [m]:***	61.00
Longitude [° ' "]:	261124.10	***G-Nr.:***		***Site status:***	Unused	***Col. ht. [m]:***	
Altitude [m]:				***Site purp.:***	Observation	***Diam. [mm]:***	219
Coord. acc.:	Accurate to within 1 unit			***Use applic.:***		***Drain. reg.:***	
Coord. meth.:	Global Positioning System			***Equipment:***	No equipment	***Rep. inst.:***	

Coordinate System: Geographic Coordinates (deg, min, sec), Hartebeesthoek94 (WGS 84)

Construction and Geohydrological Legend



COMMENT:

User name and adress

Borehole Construction and Geological Log

BASIC SITE INFORMATION: ***Site Identifier:*** 2628DA00004 ***Number:*** KM4 ***Site type:*** Borehole

Distr./Farm No.: ***Site Name/Des.:*** DELMAS

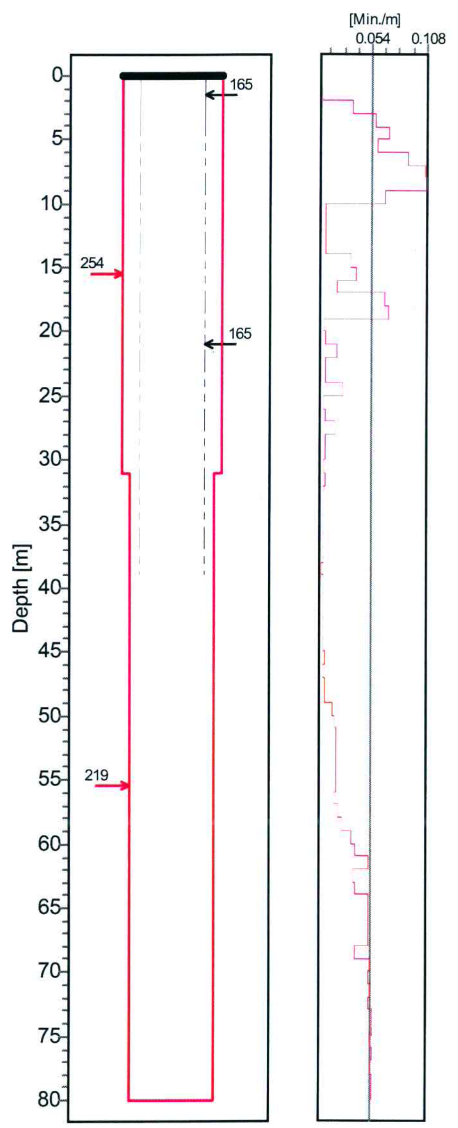
Region Type: ***Region Descr.:***

Latitude [° ' "]:	283942.70	***Reg./BB.:***		***Topo-set.:***		***Depth [m]:***	80.00
Longitude [° ' "]:	261133.30	***G-Nr.:***		***Site status:***	Unused	***Col. ht. [m]:***	
Altitude [m]:				***Site purp.:***	Observation	***Diam. [mm]:***	254
Coord. acc.:	Accurate to within 10 000 units			***Use applic.:***		***Drain. reg.:***	
Coord. meth.:	Global Positioning System			***Equipment:***	No equipment	***Rep. inst.:***	

Coordinate System: Geographic Coordinates (deg, min, sec), Hartebeesthoek94 (WGS 84)

Construction and Geohydrological Legend

	Hole	165	Hole diameter [mm]
	Casing (plain / perforated, sloted)	152	Casing diameter [mm]
	Screen / Mesh Screen	▼	Waterlevel with date meas.
	Piezometer	0:50	Piezometer (Nr. & Diameter [mm])



COMMENT:

User name and adress

Borehole Construction and Geological Log

BASIC SITE INFORMATION: ***Site Identifier:*** 2628DA00005 ***Number:*** KAM5 ***Site type:*** Borehole

Distr./Farm No.: ***Site Name/Des.:*** DELMAS

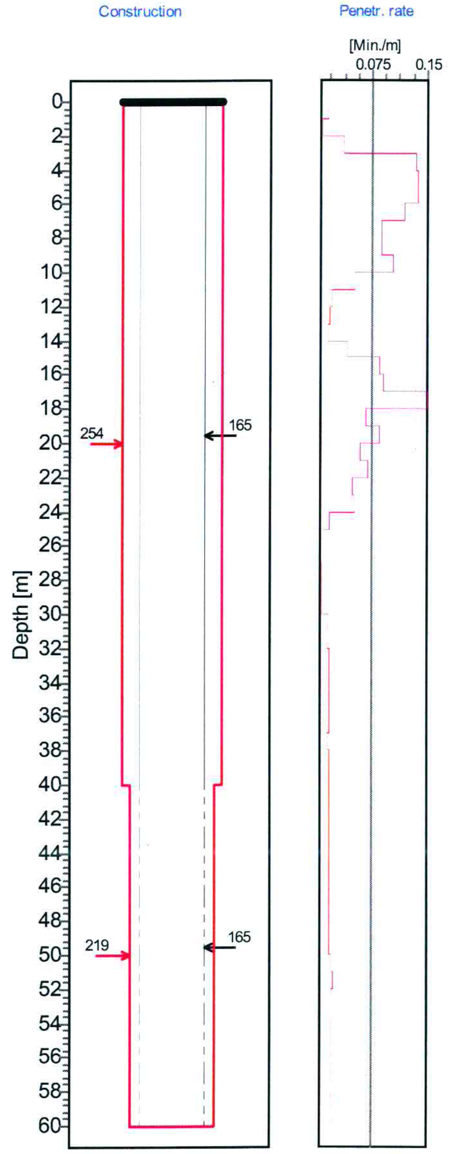
Region Type: ***Region Descr.:***

Latitude [° ' "]: 283957.70	***Reg./BB.:***	***Topo-set.:***		***Depth [m]:***	60.00
Longitude [° ' "]: 261203.80	***G-Nr.:***	***Site status:***	Unused	***Col. ht. [m]:***	
Altitude [m]:		***Site purp.:***	Observation	***Diam. [mm]:***	219
Coord. acc.: Accurate to within 10 000 units		***Use applic.:***		***Drain. reg.:***	
Coord. meth.: Global Positioning System		***Equipment:***	No equipment	***Rep. inst.:***	

Coordinate System: Geographic Coordinates (deg, min, sec), Hartebeesthoek94 (WGS 84)

Construction and Geohydrological Legend

	Hole	165	Hole diameter [mm]
	Casing (plain / perforated, sloted)	152	Casing diameter [mm]
	Screen / Mesh Screen	▼	Waterlevel with date meas.
	Piezometer	0:50	Piezometer (Nr. & Diameter [mm])



COMMENT:

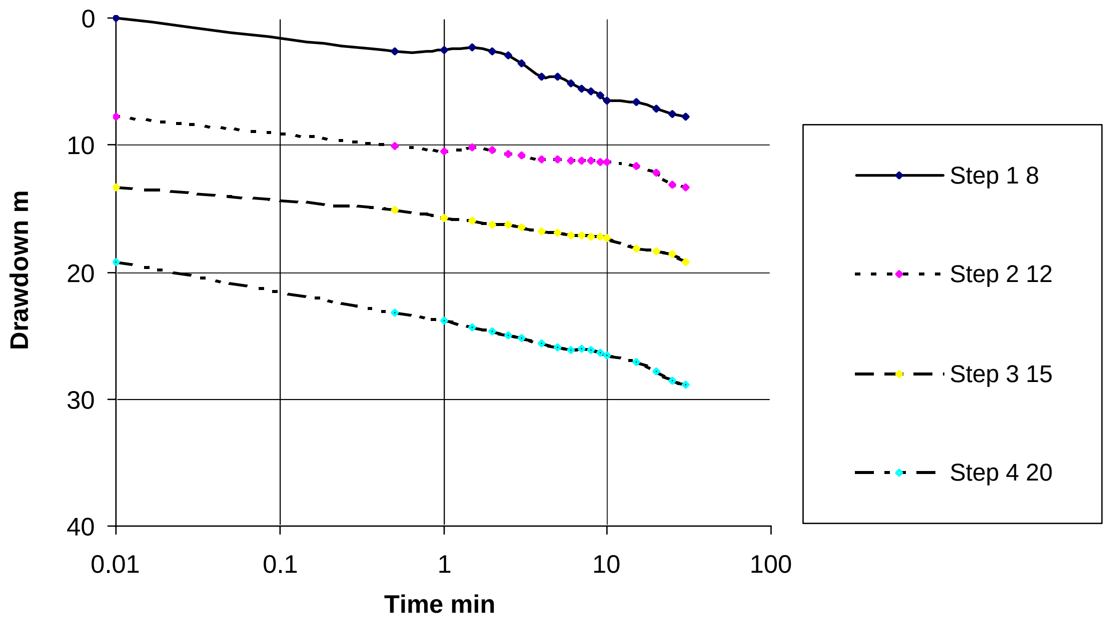
User name and adress

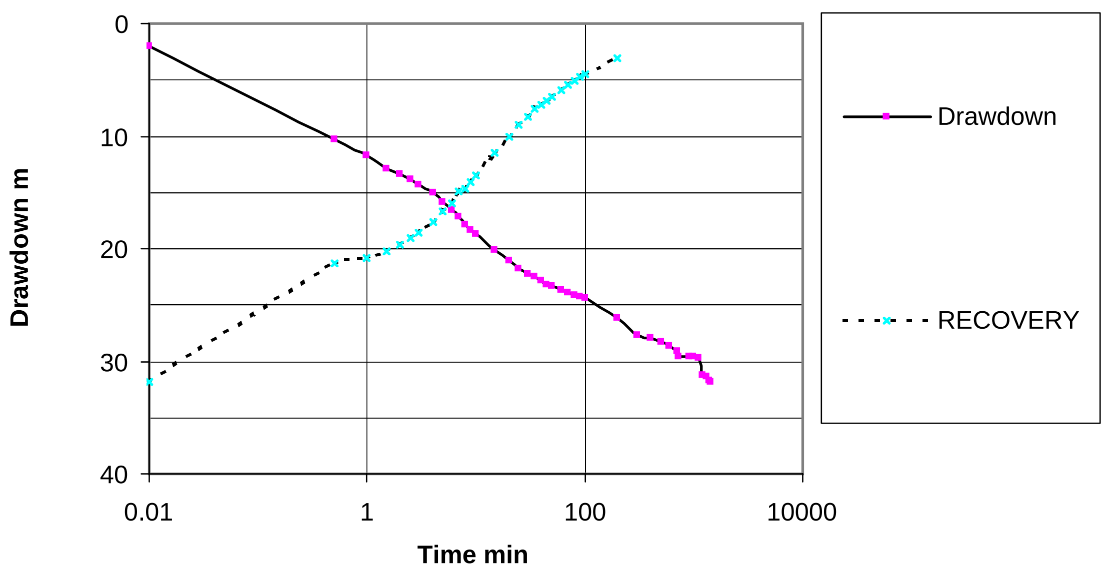
APPENDIX F

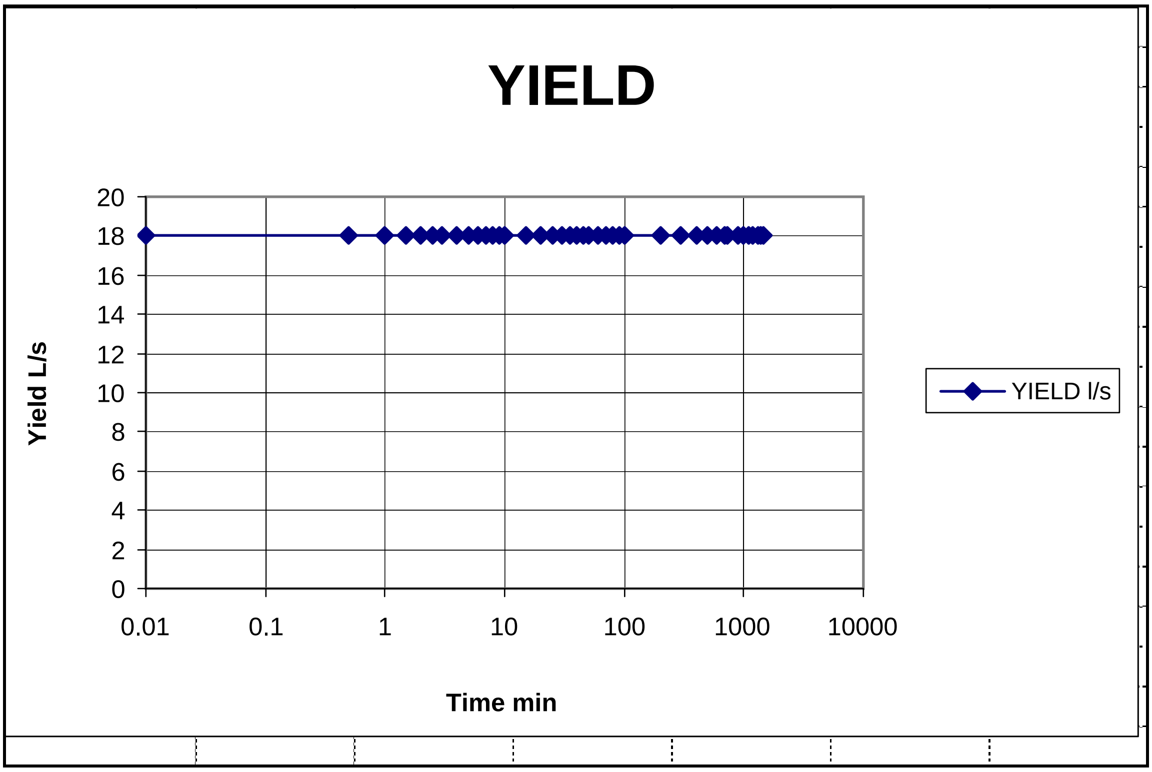
AQUIFER TEST DATA

Test Date:	6/11/2009			Boegman Borehole Testing		
Location:	Kangala			O836536109		
Lat:	26*11'51.5"s			O87224333		
Lon:	028*40'39.6"e			cboegman@netactive.co.za		
Datum used	wgs84					
Borehole No:	KAM1					
Casing ID	170mm					
Static w l	11.62m					
Depth	72.5m			Water strike	50.5m	
Measure point above ground:		700mm		Add	39.4m	
Pump inlet	51m					
		Measured drawdown in pumped well				
	Time{min}	Step 1	Step 2	Step 3	Step 4	Step 5
Yield	l/s	8	12	15	20	
	0.01	0	7.79	13.32	19.2	
	0.5	2.6	10.12	15.12	23.2	
	1	2.52	10.53	15.72	23.86	
	1.5	2.3	10.22	15.99	24.4	
	2	2.6	10.42	16.23	24.69	
	2.5	2.98	10.71	16.32	25	
	3	3.61	10.83	16.44	25.24	
	4	4.61	11.18	16.85	25.6	
	5	4.6	11.15	16.95	25.9	
	6	5.18	11.2	17.08	26.1	
	7	5.57	11.2	17.15	26.05	
	8	5.8	11.26	17.17	26.12	
	9	6.07	11.39	17.24	26.32	
	10	6.46	11.39	17.28	26.54	
	15	6.58	11.67	18.15	27.1	
	20	7.11	12.13	18.39	27.8	
	25	7.54	13.12	18.59	28.58	
	30	7.79	13.32	19.2	28.9	
	35					
	40					
	45					
	50					
	60					

Test Date:	6/11/2009			Boegman Borehole Testing	
Location:	Kangala			O836536109	
Lat:	26*11'51.5"s			O87224333	
Lon:	028*40'39.6"e			cboegman@netactive.co.za	
Datum used	wgs84				
Borehole No:	KAM1				
Casing ID	170mm				
Static w l	11.62				
Depth	72.5m			Water strike	50.5m
Measure point above ground:		700mm		Add	39.4m
Pump inlet	51	39.38			
	Time{min}	YIELD	Drawdown	Time {min}	RECOVERY
		l/s	LEVEL m		Water level m
	0.01	18	2	0.01	31.8
	0.5	18	10.3	0.5	21.3
	1	18	11.75	1	20.83
	1.5	18	12.95	1.5	20.26
	2	18	13.42	2	19.64
	2.5	18	13.86	2.5	19.03
	3	18	14.32	3	18.54
	4	18	15.01	4	17.69
	5	18	15.9	5	16.67
	6	18	16.61	6	15.92
	7	18	17.2	7	14.97
	8	18	17.9	8	14.68
	9	18	18.33	9	14.06
	10	18	18.69	10	13.5
	15	18	20.07	15	11.48
	20	18	21.01	20	10.05
	25	18	21.8	25	8.94
	30	18	22.19	30	8.32
	35	18	22.53	35	7.56
	40	18	22.87	40	7.2
	45	18	23.14	45	6.87
	50	18	23.34	50	6.5
	60	18	23.66	60	5.94
	70	18	23.95	70	5.5
	80	18	24.09	80	5.13
	90	18	24.26	90	4.71
	100	18	24.39	100	4.46
	200	18	26.2	200	3.04
	300	18	27.65	300	
	400	18	27.9	400	
	500	18	28.28	500	
	600	18	28.65	600	
	700	18	29.13		
	720	18	29.6		
	900	18	29.6		
	1000	18	29.6		
	1100	18	29.72		
	1200	18	31.2		
	1300	18	31.34		
	1400	18	31.69		
	1440	18	31.8		
Borehole Disinfected?		No			
Sample taken?		Yes			
Sample handed in?		>>>>			


0
10
20
30
40
Drawdown m
0.01
0.1
1
10
100
Time min
Step 1 8
Step 2 12
Step 3 15
Step 4 20


0
10
20
30
40
Drawdown m
0.01
1
100
10000
Time min
Drawdown
RECOVERY


YIELD
Yield L/s
20
18
16
14
12
10
8
6
4
2
0
0.01
0.1
1
10
100
1000
10000
Time min
YIELD l/s

TEST RECORD: KAM BH 2

Date Started:	26-10-09	**Test pump used:**	Mono-sub R4	**Borehole depth (m):**	60m	**CD Date started:**	26-10-09
Time Started:	07h35	**Pump depth (m):**	32	**SWL (mbgl):**	11.02	**CD Time started:**	11h15
						Waterlevel before constant started (m):	0.48

STEP TEST & RECOVERY

Step 1	RPM:			Step 2	RPM:		
Time (min)	Drawdown (m)	Yield (L/s)	Recovery (m)	Time (min)	Drawdown (m)	Yield (L/s)	Recovery (m)
1	0.44			1	1.26		
2	0.55			2	1.37		
3	0.65			3	1.48	0.24	
5	0.77			5	1.56		
7	0.87	0.11		7	1.63	0.24	
10	0.94			10	1.7		
15	1.02	0.11		15	1.78		
20	1.06			20	1.82		
25	1.08	0.11		25	1.86	0.24	
30	1.09			30	1.88		

Step 3	RPM:			Step 4	RPM:		
Time (min)	Drawdown (m)	Yield (L/s)	Recovery (m)	Time (min)	Drawdown (m)	Yield (L/s)	Recovery (m)
1	2.16			1	5.21		
2	2.41			2	5.74		
3	2.67			3	6.21	1.00	
5	3.05	0.54		5	7.00		
7	3.37			7	7.69	1.00	
10	3.75			10	8.49		
15	4.05	0.54		15	9.45	1.00	
20	4.21			20	10.05		
25	4.32	0.54		25	10.50	1.00	
30	4.37			30	10.84		
30							

Step 5	RPM:			Step 6	RPM:		
Time (min)	Drawdown (m)	Yield (L/s)	Recovery (m)	Time (min)	Drawdown (m)	Yield (L/s)	Recovery (m)
1	11.77			1			
2	12.08	1.47		2			
3	12.13			3			
5	12.2			5			
7	12.28	1.47		7			
10	12.4			10			
15	12.68			15			
20	13.52	1.47		20			
25	17.6			25			
30	21.6			30			
Pumpsuction		1.00 l/s					

Recovery	
Time (min)	Waterlevel (m)
1	17.14
2	14.2
3	12.88
5	12.44
7	12.3
10	12.08
15	6.22
20	2.6
30	0.88
40	0.64
50	0.54
60	0.48
75	
90	
105	
120	
135	
150	
165	
180	
195	
210	
225	
240	
270	
300	
330	
360	
420	
480	
540	
600	
660	
720	
780	
840	
900	
960	

CONSTANT DISCHARGE TEST

Constant Discharge Test		RPM:		
Time (min)	Drawdown (m)	Yield (L/s)	Rec Time (min)	Recovery (m)
1	1.45		1	13.81
2	2.36		2	12.74
3	3.12		3	12.56
5	4.50	1.00	5	12.40
7	5.52		7	12.25
10	6.54		10	12.05
15	7.80	1.00	15	5.78
20	8.82		20	2.72
30	10.00	1.00	30	1.13
40	10.86	1.00	40	0.85
60	12.04		60	0.68
90	12.12	1.00	90	0.60
120	12.25		120	0.57
150	12.38	1.00	150	
180	12.60		180	
210	13.86	1.00	210	
240	16.53		240	
300			300	
360			360	
420			420	
480			480	
540			540	
600			600	
720			720	
840			840	
960			960	
1080			1080	
1200			1200	
1320			1320	
1440			1440	
1560			1560	
1680			1680	
1800			1800	
1920			1920	
2040			2040	
2160			2160	
2280			2280	

Observation BH	
Time (min)	Drawdown (m)
BH no:	
Distance:	
Waterlevel:	
1	
2	
3	
5	
7	
10	
15	
20	
30	
40	
60	
90	
120	
150	
180	
210	
240	
300	
360	
420	
480	
540	
600	
720	
840	
960	
1080	
1200	
1320	
1440	
2280	
2880	
3480	
3900	
4320	
4920	
5760	

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259 KENT AVENUE, FERNDALE
011 787 5994

TEST RECORD: KAM BH 3

Date Started:	20-10-09	**Test pump used:**	Mono-sub R4	**Borehole depth (m):**	60m	**CD Date started:**	20-10-09
Time Started:	07h26	**Pump depth (m):**	55	**SWL (mbgl):**	11.21m	**CD Time started:**	11h15
						Waterlevel before constant started (m):	0.2

STEP TEST & RECOVERY

Step 1	RPM:			Step 2	RPM:		
Time (min)	Drawdown (m)	Yield (L/s)	Recovery (m)	Time (min)	Drawdown (m)	Yield (L/s)	Recovery (m)
1	0.1			1	2.37		
2	0.27			2	3.06		
3	0.4			3	3.74	0.41	
5	0.65	0.12		5	4.94		
7	0.82			7	5.78	0.41	
10	1.01			10	6.65		
15	1.13			15	7.81		
20	1.46	0.12		20	8.84	0.41	
25	1.53			25	8.96		
30	1.59			30	9.25		

Step 3	RPM:			Step 4	RPM:		
Time (min)	Drawdown (m)	Yield (L/s)	Recovery (m)	Time (min)	Drawdown (m)	Yield (L/s)	Recovery (m)
1	9.81			1	19.72		
2	10.5			2	20.78		
3	11.16			3	21.75		
5	12.47	0.67		5	23.48		
7	13.54			7	24.97	0.96	
10	14.8			10	26.02		
15	16.35			15	27.78		
20	17.38			20	29.43		
25	18.13	0.67		25	30.81	0.96	
30	18.6			30	31.8		
30							

Step 5	RPM:			Step 6	RPM:		
Time (min)	Drawdown (m)	Yield (L/s)	Recovery (m)	Time (min)	Drawdown (m)	Yield (L/s)	Recovery (m)
1	32.6			1			
2	33.51			2			
3	34.55	1.2		3			
5	36.24			5			
7	37.8			7			
10	39.63	1.2		10			
15	42.66			15			
20		0.89		20			
25				25			
30				30			

Recovery	
Time (min)	Waterlevel (m)
1	39.8
2	37.42
3	35.36
5	31.77
7	28.1
10	23.96
15	16.48
20	10.97
30	4.15
40	0.97
50	0.55
60	0.26
75	
90	
105	
120	
135	
150	
165	
180	
195	
210	
225	
240	
270	
300	
330	
360	
420	
480	
540	
600	
660	
720	
780	
840	
900	
960	

CONSTANT DISCHARGE TEST

Constant Discharge Test		RPM:		
Time (min)	Drawdown (m)	Yield (L/s)	Rec Time (min)	Recovery (m)
1	2.38		1	31.86
2	4.58		2	29.69
3	5.88	0.91	3	27.88
5	8.68		5	24.86
7	11.04	0.86	7	21.60
10	14.38		10	16.89
15	18.01	0.83	15	11.55
20	20.65	0.83	20	7.30
30	24.26		30	2.50
40	26.33	0.83	40	0.84
50	27.88		50	0.20
60	28.85	0.83	60	0.15
75	30.47		75	0.06
90	31.25	0.83	90	
105	32.03		105	
120	32.46	0.83	120	
135	33.03		135	
150	33.29	0.83	150	
165	33.65		165	
180	33.73	0.83	180	
195	34.14		195	
210	34.39	0.83	210	
225	34.53		225	
240	34.6	0.83	240	
270			270	
300			300	
330			330	
360			360	
420			420	
480			480	
540			540	
600			600	
660			660	
720			720	
780			780	
840			840	
900			900	

Observation BH	
Time (min)	Drawdown (m)
BH no:	
Distance:	
Waterlevel:	
1	
2	
3	
5	
7	
10	
15	
20	
30	
40	
60	
90	
120	
150	
180	
210	
240	
300	
360	
420	
480	
540	
600	
720	
840	
960	
1080	
1200	
1320	
1440	
2280	
2880	
3480	
3900	
4320	
4920	
5760	

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259 KENT AVENUE, FERNDALE
011 787 5994

TEST RECORD: KAM BH 5

Date Started:	23-10-09	**Test pump used:**	Mono Sub R4	**Logger depth (m):**		**CD Date started:**	
Time Started:		**Pump depth (m):**	55m	**SWL (mbgl):**	10.6m	**CD Time started:**	
						Waterlevel before constant started (m):	

STEP TEST & RECOVERY

Step 1 RPM:				Step 2 RPM:			
Time (min)	Drawdown (m)	Yield (L/s)	Recovery (m)	Time (min)	Drawdown (m)	Yield (L/s)	Recovery (m)
1	0.30			1	8.00		
2	0.49			2	8.25		
3	0.55			3	8.53		
5	1.14			5	9.04		
7	2.06			7	9.74	0.22	
10	3.05	0.14		10	10.16		
15	4.42			15	11.09		
20	5.39	0.14		20	11.90	0.22	
30	6.45	0.14		30	14.43		
40	7.1			40	17.08		
50	7.52	0.14		50	19.42	0.22	
60	7.81			60	21.30		
70				70			
80				80			
90				90			
100				100			
110				110			
120				120			

Step 3 RPM:				Step 4 RPM:			
Time (min)	Drawdown (m)	Yield (L/s)	Recovery (m)	Time (min)	Drawdown (m)	Yield (L/s)	Recovery (m)
1	21.69			1	33.04		
2	22.09			2	33.31		
3	22.42			3	33.64		
5	23.10	0.27		5	34.20		
7	23.72			7	34.82	0.40	
10	24.66			10	35.68		
15	25.88	0.27		15	37.09	0.40	
20	26.82			20	38.40	0.39	
30	28.52	0.27		30	40.87	0.39	
40	30.07			40	43.46	0.37	
50	31.54	0.27		50	46.00	0.35	
60	32.79			60			
70				70	Pump	0.19	
80				80	suction		
90				90			
100				100			
110				110			
120				120			

Recovery	
Time (min)	Waterlevel (m)
1	44.33
2	43.43
3	43.05
5	42.35
7	41.60
10	40.54
15	38.42
20	37.08
30	33.88
40	30.69
60	24.87
90	16.10
120	11.25
150	9.03
180	7.13
210	6.07
240	5.70
300	
360	
420	
480	
540	
600	
720	
840	
960	
1080	
1200	
1320	
1440	
2280	
2880	
3480	
3900	
4320	
4920	
5760	

CONSTANT DISCHARGE TEST

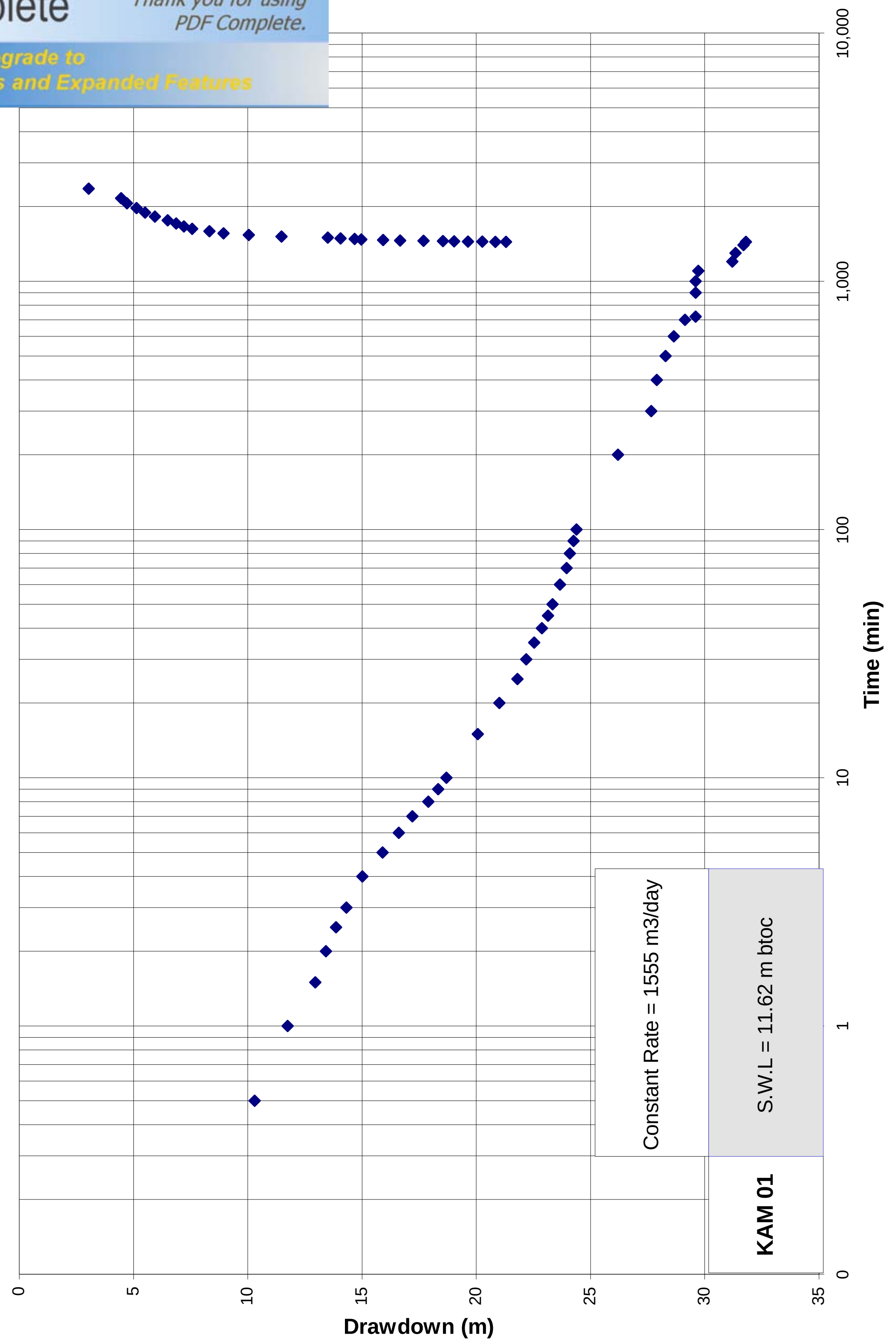
Constant Discharge Test		RPM:		
Time (min)	Drawdown (m)	Yield (L/s)	Rec Time (min)	Recovery (m)
1			1	
2			2	
3			3	
5			5	
7			7	
10			10	
15			15	
20			20	
30			30	
40			40	
60			60	
90			90	
120			120	
150			150	
180			180	
210			210	
240			240	
300			300	
360			360	
420			420	
480			480	
540			540	
600			600	
720			720	
840			840	
960			960	
1080			1080	
1200			1200	
1320			1320	
1440			1440	
2280			2280	
2880			2880	
3480			3480	
3900			3900	
4320			4320	
4920			4920	
5760			5760	

Observation BH	
Time (min)	Drawdown (m)
BH no:	
Distance:	
Waterlevel:	
1	
2	
3	
5	
7	
10	
15	
20	
30	
40	
60	
90	
120	
150	
180	
210	
240	
300	
360	
420	
480	
540	
600	
720	
840	
960	
1080	
1200	
1320	
1440	
2280	
2880	
3480	
3900	
4320	
4920	
5760	

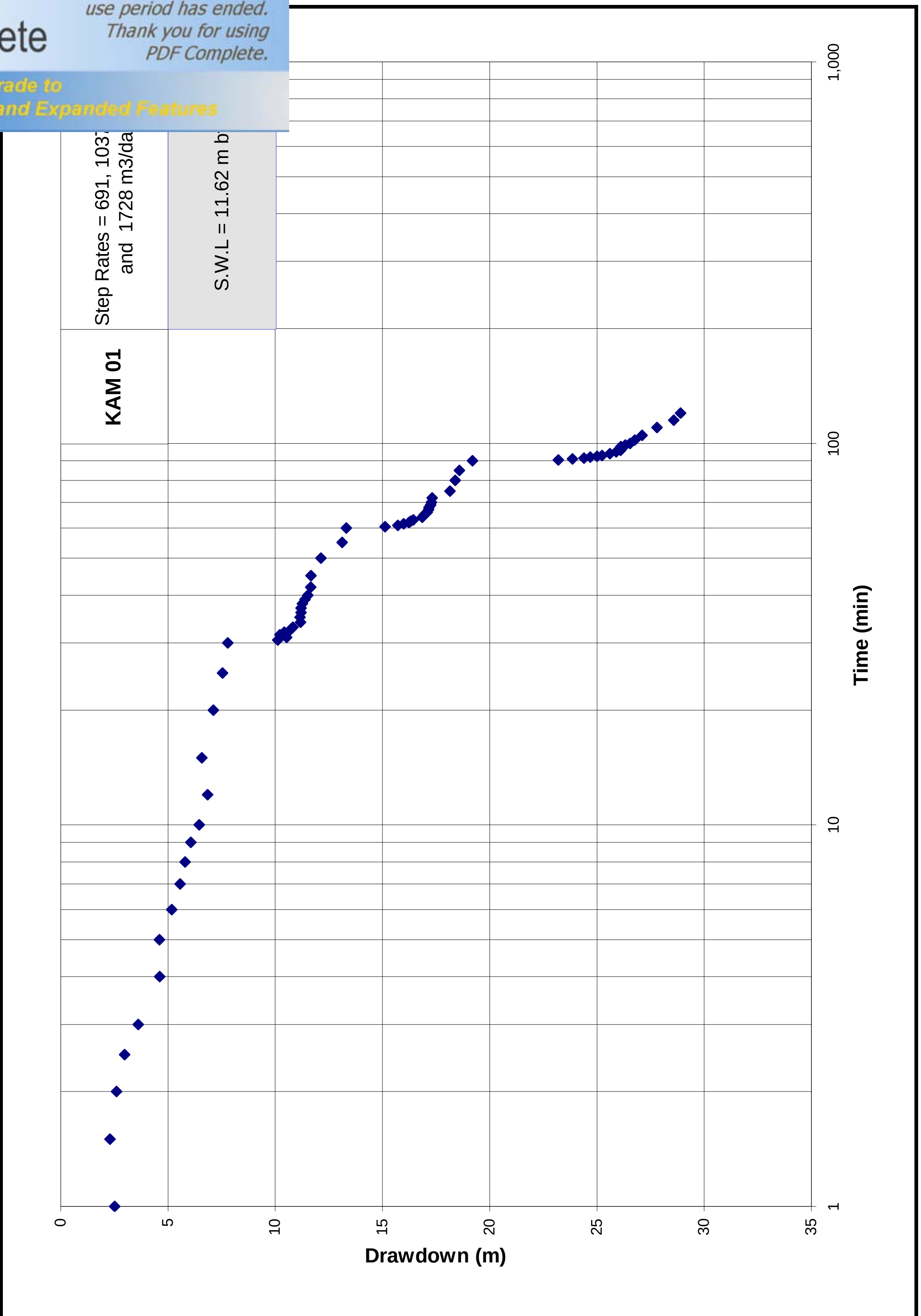
AQUA EARTH CONSULTING
259 KENT AVENUE, FERNDALE
011 787 5994

APPENDIX G

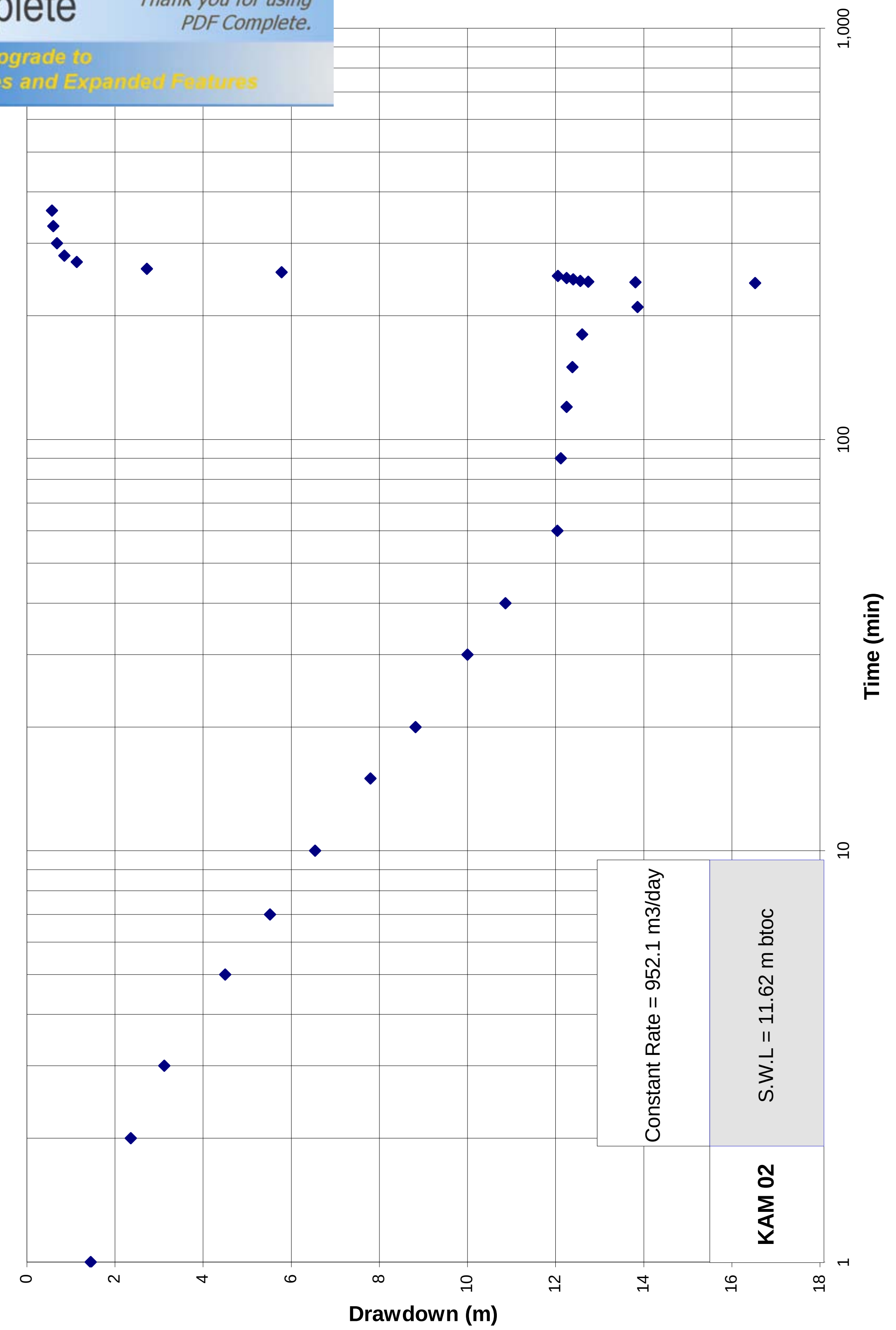
AQUIFER TEST GRAPHS



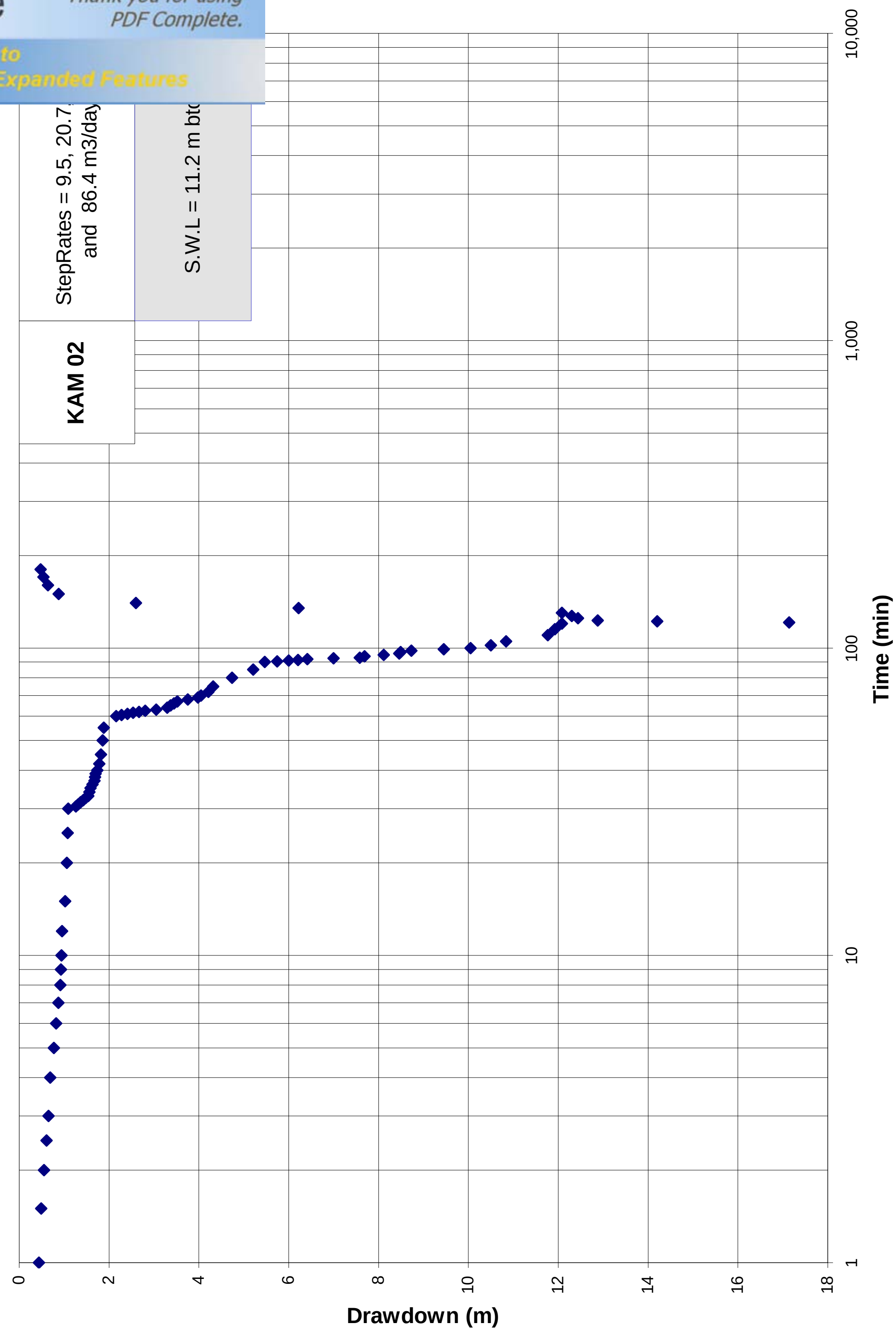
Job No.	Kangala		**Universal Coal PLC**
Prep. By	JG	19 Nov. '09	**Constant Discharge Drawdown Test**
Chk'd By	AW	20 Nov. '09	**KAM 01**
Revision No.		1	**Plate 1**



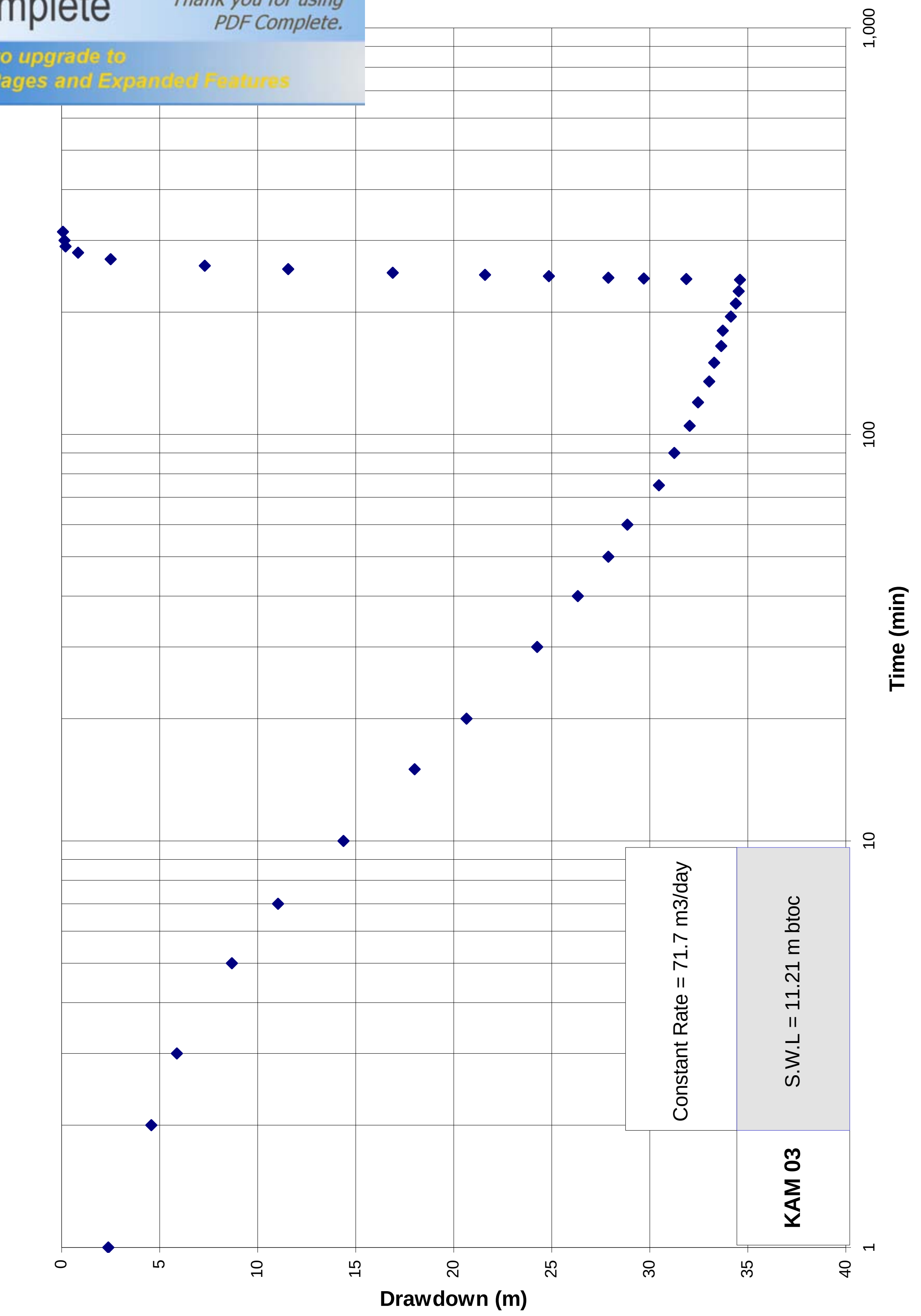
Job No.	Kangala		Universal Coal PLC
Prep. By	JG	19 Nov. '09	Step Drawdown Test
Chk'd By	AW	20 Nov. '09	KAM01
Revision No.		1	Plate 5



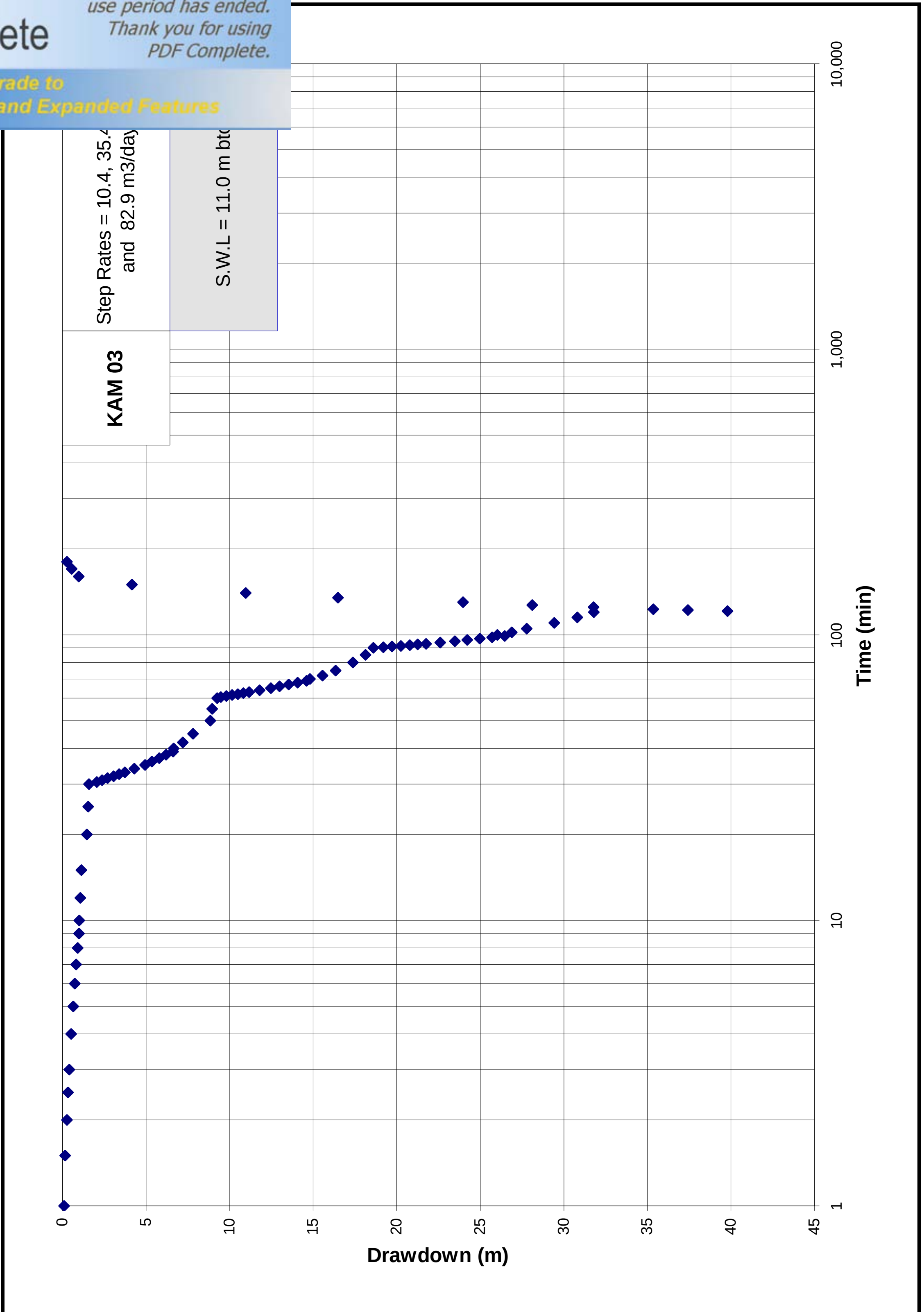
			Universal Coal PLC
Job No.	Kangala		**Constant Discharge Drawdown Test**
Prep. By	JG	19 Nov. '09	**KAM 02**
Chk'd By	AW	20 Nov. '09	**Plate 2**
Revision No.		1	



			Universal Coal PLC	
Job No.	Kangala		Step Drawdown Test	
Prep. By	JG	19 Nov. '09	KAM 02	
Chk'd By	AW	20 Nov. '09	Plate 6	
Revision No.		1		

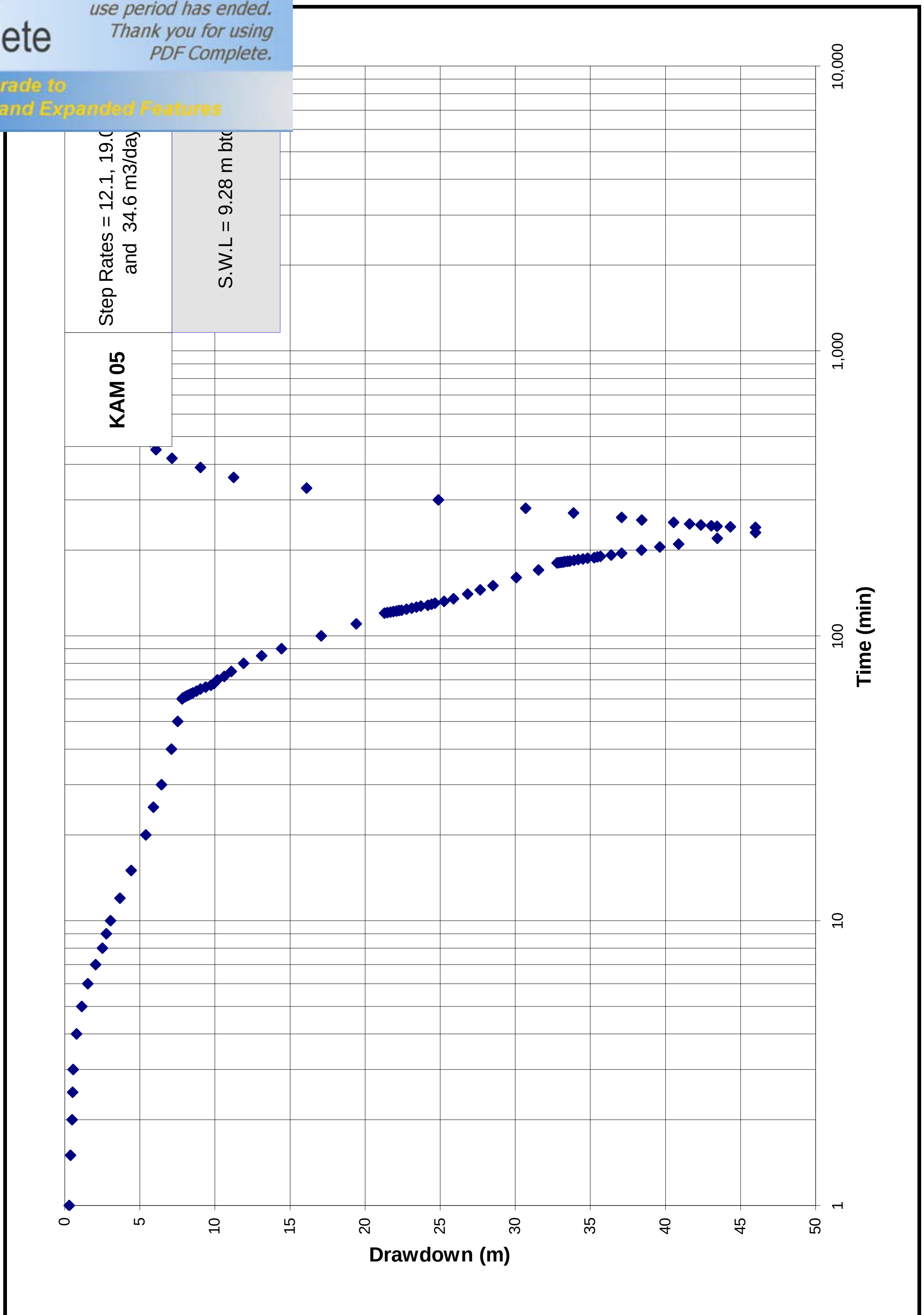


Job No.	Kangala		Universal Coal PLC
Prep. By	JG	19 Nov. '09	**Constant Discharge Drawdown Test**
Chk'd By	AW	20 Nov. '09	**KAM 03**
Revision No.		1	**Plate 3**

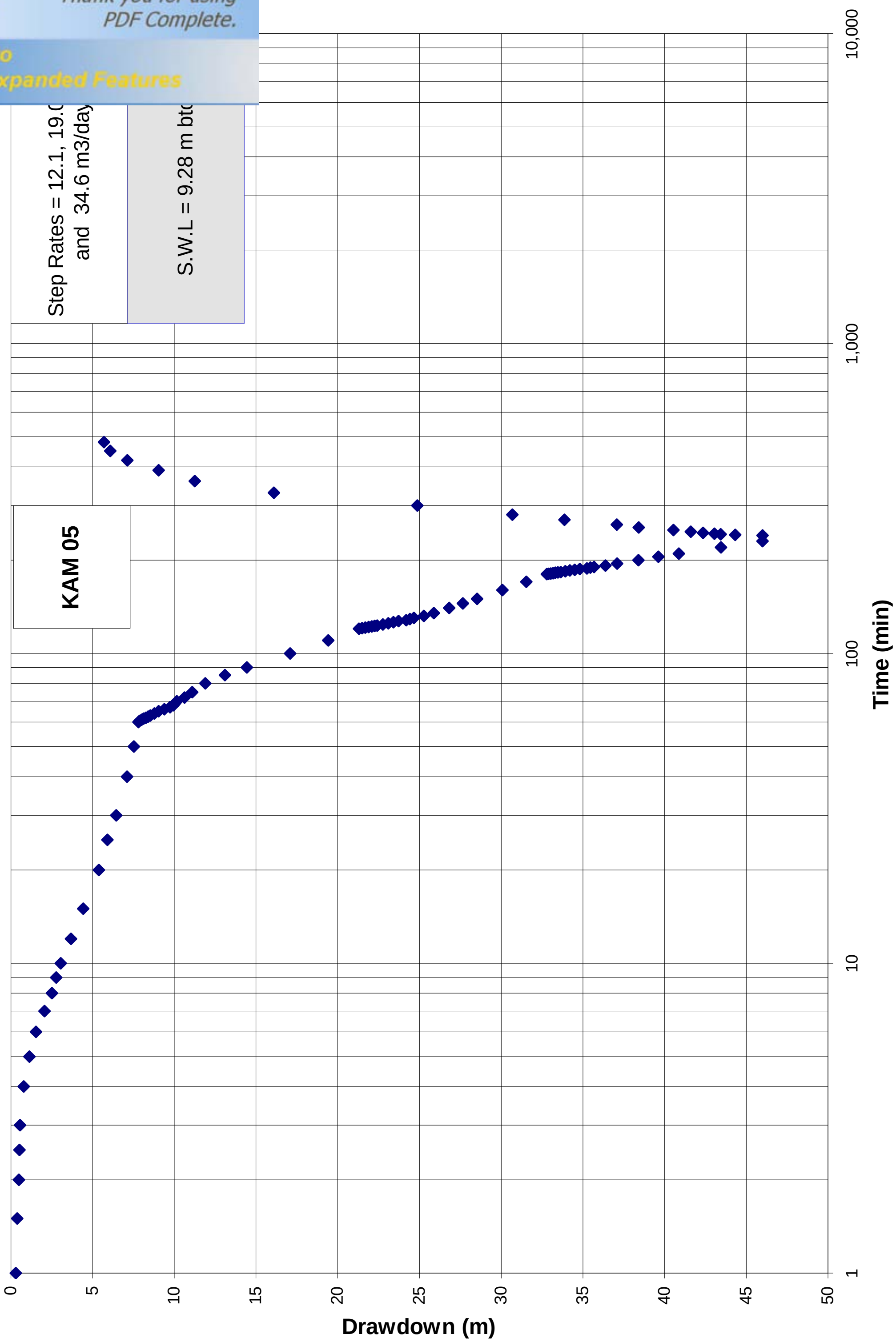


Job No.	Kangala		Universal Coal PLC
Prep. By	JG	19 Nov. '09	**Step Drawdown Test**
Chk'd By	AW	20 Nov. '09	**KAM 03**
Revision No.		1	**Plate 7**

DWA



Job No.	Kangala		Universal Coal PLC
Prep. By	JG	19 Nov. '09	**Step Drawdown Test**
Chk'd By	AW	20 Nov. '09	**KAM 05**
Revision No.		1	**Plate**



Job No.	Kangala		Universal Coal PLC **Step Drawdown Test** KAM 05 Plate 8
Prep. By	JG	19 Nov. '09	
Chk'd By	AW	20 Nov. '09	
Revision No.		1	

APPENDIX H

CHEMISTRY ANALYSIS CERTIFICATES OF NEWLY DRILLED BOREHOLES

DIGBY WELLS AND ASSOCIATES

Private Bag X 10046
RANDBURG
2125

CHEMICAL ANALYSIS : WATER SAMPLES	Our Ref: DIG/ 39 - 43 /E /10/09

Date received: 30 October 2009
Date completed: 10 November 2009 *Project Name: UNI 605*
Quantity Analyzed: 5

Lab No	*E39*	*E40*	*E41*
Analysis Results mg/l	**KAM 1**	**KAM 2**	**KAM 3**
Total Dissolved Solids	334	200	148
Suspended Solids	26.0	30.0	58.8
Nitrate NO_3 as N	<0.1	8.20	3.7
Chlorides as Cl	79	8.0	4.0
Total Alkalinity as $CaCO_3$	129	133	104
Fluoride as F	0.66	<0.20	0.25
Sulphate as SO_4	34.8	11.5	12
Total Hardness as $CaCO_3$	133	127	60
Calcium Hardness as $CaCO_3$	72	71	29
Magnesium Hardness as $CaCO_3$	61	56	31
Calcium as Ca	28.8	28.5	11.8
Magnesium as Mg	14.9	13.6	7.5
Sodium as Na	59.0	17.8	21
Potassium as K	2.23	3.99	2.99
Iron as Fe	<0.01	0.36	0.18
Manganese as Mn	0.08	0.1	0.19
Conductivity in mS/m	54.3	33.6	23
pH-Value at 25 ° C	7.21	7.75	7.24
pHs at 21 °C	7.56	7.54	7.97
Langelier Saturation Index	-0.35	+0.21	-0.73
Aluminium as Al	<0.01	<0.01	<0.01
Bicarbonate Alkalinity as $CaCO_3$	129	133	104
Free & Saline Ammonia NH_3 as N	0.33	<0.20	1.00
Ortho Phosphate PO_4 as P	0.11	<0.1	0.17
Sodium Absorption Ratio	2.22	0.69	1.16
Copper as Cu	<0.01	<0.01	<0.01
Total Chromium as Cr	<0.01	<0.01	<0.01
Lead as Pb	<0.01	<0.01	<0.01
Zinc as Zn	0.02	0.02	0.03

All heavy metal analyses have been performed on filtered samples.
*Tests marked with an asterisk * are not SANAS accredited*
These results are related only to the items tested

QUALITY CONTROL CHECKS			
Cation Balance	5.31	3.42	2.26
Anion Balance	5.57	3.12	2.46
% Difference	-2.3	4.5	-4.2
Measured TDS	334	200	148
Calculated TDS	299	165	125
Limits > 1.0 - <1.2	1.1	1.2	1.2
Calcul TDS / E.C. (0.55 - 0.70)	0.5	0.5	0.5

P.L.G. UYS

DIGBY WELLS AND ASSOCIATES

Private Bag X 10046
RANDBURG
2125

CHEMICAL ANALYSIS : WATER SAMPLES	Our Ref: DIG/ 39 - 43 /E /10/09

Date received: 30 October 2009
Date completed: 10 November 2009
Project Name: UNI 605
Quantity Analyzed: 5

Lab No	*E42*	*E43*
Analysis Results mg/l	**KAM 4**	**KAM 5**
Total Dissolved Solids	220	88
Suspended Solids	418	54.0
Nitrate NO_3 as N	0.8	5.4
Chlorides as Cl	11	4.0
Total Alkalinity as $CaCO_3$	179	63
Fluoride as F	0.38	<0.20
Sulphate as SO_4	3.70	3.40
Total Hardness as $CaCO_3$	125	42
Calcium Hardness as $CaCO_3$	65	23
Magnesium Hardness as $CaCO_3$	60	19
Calcium as Ca	26.0	9.20
Magnesium as Mg	14.5	4.52
Sodium as Na	23.3	11.5
Potassium as K	6.95	6.06
Iron as Fe	0.09	0.45
Manganese as Mn	0.19	0.04
Conductivity in mS/m	33.6	15.2
pH-Value at 25 ° C	7.63	6.89
pHs at 21 °C	7.45	8.40
Langelier Saturation Index	+0.18	-1.51
Aluminium as Al	0.04	0.04
Bicarbonate Alkalinity as $CaCO_3$	179	63
Free & Saline Ammonia NH_3 as N	<0.20	<0.20
Ortho Phosphate PO_4 as P	<0.1	<0.1
Sodium Absorption Ratio	0.91	0.78
Copper as Cu	<0.01	<0.01
Total Chromium as Cr	<0.01	<0.01
Lead as Pb	<0.01	<0.01
Zinc as Zn	0.05	0.14

All heavy metal analyses have been performed on filtered samples.
*Tests marked with an asterisk * are not SANAS accredited*
These results are related only to the items tested

QUALITY CONTROL CHECKS		
Cation Balance	3.69	1.49
Anion Balance	3.99	1.44
% Difference	-3.8	1.7
Measured TDS	220	88
Calculated TDS	195	77
Limits > 1.0 - <1.2	1.1	1.1
Calcul TDS / E.C. (0.55 - 0.70)	0.6	0.5

P.L.G. UYS