GEOHYDROLOGICAL-AND CONTAMINATION RISK ASSESSMENT STUDY FOR A HIGH SPEED PROVING GROUND ON PORTION 6 OF THE FARM STEENKAMPSPAN 419 LOCATED NORTH EAST OF UPINGTON IN THE NORTHERN CAPE PROVINCE.

Prepared for

IngenAix GmbH

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Hydrogeological study done by

GEO - LOGIC Hydrogeological Consultants cc

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EXECUTIVE SUMMARY

This document presents the results of a Hydrogeological Investigation and Contamination Risk Assessment study aimed at establishing a baseline reference of hydrogeological data to form part of an Integrated Water Use Licence Application (IWULA) for a high speed proving ground for light vehicle testing in Upington in the Northern Cape.

Mercedez Benz South Africa (MBSA) plans to develop the proving ground on Portion 6 of the Farm Steenkampspan 419. The farm is located 35km north east of Upington in the Northern Cape Province. Refer to Figure 1 and 2.

Water will be tapped from existing and newly drilled boreholes for the project. Water will be used during two construction phase which will be 14 months for the first phase and 8 months for the second phase. The water demand during the first construction phase will be 300m^3/d and during the second construction phase will also be 300m^3/d. The time line for the second construction phase is not finalized yet but is expected to be concluded within the first 5 years after start of operations.

During the operational phase of the project, the water demand will be much lower. Water will be used at the office site for washing, cleaning and ablution facilities. Bottled water will be used for consumption. During the operational phase the water demand will be approximately 10m^3/d.

During the entire project the water demand for farming activities on Portion 6 of the farm Steenkampspan will be 6m^3/d. Farming activities will be in future limited to 80 head of cattle. Water will be sourced from the exiting boreholes that are currently used for farming. During later stages when construction water is not needed, the farming activities may also source water from the production boreholes used for construction purposes. The water demand for farming activities however will not exceed 6m^3/d.

Waste water will be managed at the office building by a sewerage conservancy tank (70m^3) which will be pumped by honey-sucker and disposed of off-site every 10 to 14 days. Oil separators for wastewater contaminated by hydrocarbons originating from the wash bay, fuel station and workshop areas will be removed off-site for recycling.

Geo-logic Hydro Geological Consultants cc was appointed by IngenAix GmbH, to do a hydrogeological - and contamination risk assessment study for the proposed development.

A desk study was performed to gather relevant geological and hydrogeological information. A hydro-census followed the desk study to establish borehole information in the region of the site. The farms directly bordering Portion 6 of the farm Steenkampspan was visited. The purpose of

this survey was to gather relevant hydrogeological information to study the groundwater regime, current groundwater useand borehole coordinates in the area. The water level depths in boreholes and pits were measured where possible. The groundwater abstraction volumes from boreholes in the area were gathered where possible to be able to calculate existing groundwater abstraction in the area.

A geological walk over study was done of the farm portion where outcrop was visible. This was done to be able to study the in-situ geology. A geophysical study consisting of four geophysical traverses were surveyed. The magnetic and Direct Current Continuous Vertical Electrical Sounding (DC CVES) method was used for the survey.

Five new boreholes were drilled on the geophysical survey information. Two boreholes yield enough water and were completed as production boreholes for the development. The three existing boreholes and two new boreholes were submitted to borehole yield testing procedures. This was done to be able to calculate aquifer parameters for the aquifer and to be able to recommend safe abstraction volumes for the individual boreholes.

Aquifer information such as storativity, specific yield, mean annual potential recharge, resource potential and exploitation potential were sought and used to calculate the aquifer potential for short to medium term groundwater abstraction.

To facilitate the contamination risk assessment study, four shallow test pits were dug and prepared for double ring inflow meter test. The aim of these tests were to establish percolation ratesor hydraulic conductivity rates for the upper soil consisting of Aeolian sand, calcrete and boulder layers to facilitate the contamination risk assessment for the planned office building site.

The percolation rate tests, geology, aquifer test information and water level depth and estimated groundwater flow directions were utilized to calculate the contamination risk for the site.

During the study the following conclusions could be made:

During the sustainable calculations a vast number of methods were used to calculate the availability of water on Steenkamspan and Duiker Rand. The availability of water in the large catchment area that could be delineated for the boreholes that will be used during the life of the project was also carefully considered. A vast number of answers were available after these calculations. A small number of these answers however need special attention.

1. The boreholes that are earmarked to be used for abstraction can easily deliver water according the yields recommended in the report.
2. None of the boreholes will be individually over pumped. In fact during the final calculations a very conservative approach was taken to calculate the final

recommended yields. These recommended yields were further cut from 350m^3/d to 300m^3/d. The actual water demand for construction phase 1 is 276m^3/d and for construction phase 2 is 264m^3/d. For calculation purposes and to be conservative a water demand for both construction phases of 300m^3/d was used.

3. The groundwater catchment feeding the aquifer is large and is calculated at 288.6km^3.
4. 39.1% of the harvest potential figure of the aquifer of **Steenkampspan** will be needed.
5. 52.1% of the harvest potential figure of the aquifer of **Duiker Rand** will be needed.
6. 12.4.1% of the harvest potential will be used of the **Delineated catchment aquifer** per annum.
7. 0.33% of the volume of water stored in the larger D**elineated catchment aquifer** of 288.6km^2 will be needed.

During careful consideration of the important facts above and the other evidence that the aquifer can sustain the water abstraction during the construction phase of 22 months spread over 5 years, we regard the abstraction viable. During the operational phase of the project the aquifer will have ample time to recover for the farm to be used as stock farming unit. The water demand after the construction phase will be very low if compared to other farming units in the area. The farm Steenkampspan will be an area in which the aquifer can recover to be available in future.

The following mitigation measures are recommended in the Construction phase:

- Abstract water at the recommended rates for each individual borehole.
- Do not over use one borehole by pumping one specific borehole at all times.
- Always use at least all four boreholes.
- Use water scarcely and do not waste water.
- Measure water levels in stipulated boreholes (Section 9) on a monthly basis.
- If water levels are declining constantly contact the hydrogeologist.
- Take water samples at borehole BH 1 and the new monitoring borehole on an annual basis.
- A groundwater monitoring report must be produced on a six monthly basis.
- Use proper sanitation systems on site during construction and keep systems serviced.
- Stagnant water must not be allowed in the borrow pit or quarry area during the construction phase. Contaminated water must be pumped out and treated before re-used for construction purposes.
- Service plant equipment regularly.

- Keep fuel and oil in safe conditions on site during construction.
- Have stringent safety margins on site for all equipment that have a contamination risk involved.

The following mitigation measures are recommended in the operational phase:

- Service oil traps as specified by provider.
- The conservancy tank must be emptied on an interval specified by the engineer or architect.
- Develop a master plan for accidental spillage of fuel and oil on site.
- Place a groundwater monitoring borehole at the southern side of the building site.
- Measure water levels in the four production boreholes (now out of duty) on a three monthly basis.
- Take water samples at borehole BH 1 and the new monitoring borehole on an annual basis.
- A groundwater monitoring report must be produced on an annual basis.

List of Definitions, Abbreviations and Acronyms

AGRP	Average Groundwater Resource Potential
CVES	Continuous Vertical Electrical Sounding
DWA	Department of Water Affairs (now DWS)
DWS	Department of Water and Sanitation
DC CVES	Direct Current Continuous Vertical Electrical Sounding
GEP	Groundwater Exploitation Potential
HP	Harvest Potential
IWULA	Integrated Water Use Licence Application
MAE	Mean Annual Evaporation
MAP	Mean Annual Precipitation
MAR	Mean Annual Runoff
NWA	National Water Act
URGP	Utilizable Groundwater Exploitation Potential
WULA	Water Use Licence Application

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1. INTRODUCTION

1.1 Background

This document presents the results of a Hydrogeological Investigation and Contamination Risk Assessment study aimed at establishing a baseline reference of hydrogeological data to form part of anIntegrated Water Use Licence Application (IWULA) for a high speed proving ground for light vehicle testing in Upington in the Northern Cape.

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During the operational phase of the project the water demand will be much lower. Water will be used at the office site for washing, cleaning and ablution facilities.Bottled water will be used for consumption. During the operational phase the water demand for the development will be approximately 10m^3/d.

During the entire project the water demand for farming activities on Portion 6 of the farm Steenkampspan will be 6m^3/d. Farming activities will be in future limited to 80 head of cattle. Water will be sourced from the exiting boreholes that are currently used for farming. During later stages when construction water is not needed, the farming activities may also source water from the production boreholes used for construction purposes. The water demand for farming activities however will not exceed 6m^3/d.

Waste water will be managed at the office building by a sewerage conservancy tank (70m^3) which will be pumped by honey-sucker and disposed of off-site every 10 to 14 days.Oil separators for wastewater contaminated by hydrocarbons originating from the wash bay, fuel station and workshop areas will be removed off-site for recycling.

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1.2 Scope of Investigation

The Hydrogeological and contamination risk assessment study will consist of the following actions:

1) Desk study of the geology and groundwater regime.
2) Site establishment of potential drill sites by doing a geophysical survey.
3) Drilling supervision of the production boreholes.
4) Supervision of the yield testing of production boreholes.
5) Taking of water samples for water quality analyses.
6) Contamination risk assessment for the storage of fuel and sanitation plant.
7) Hydrogeological study to assess sustainability of the planned water abstraction.
8) Water quality assessment for the development.

Figure 1: Regional locality map

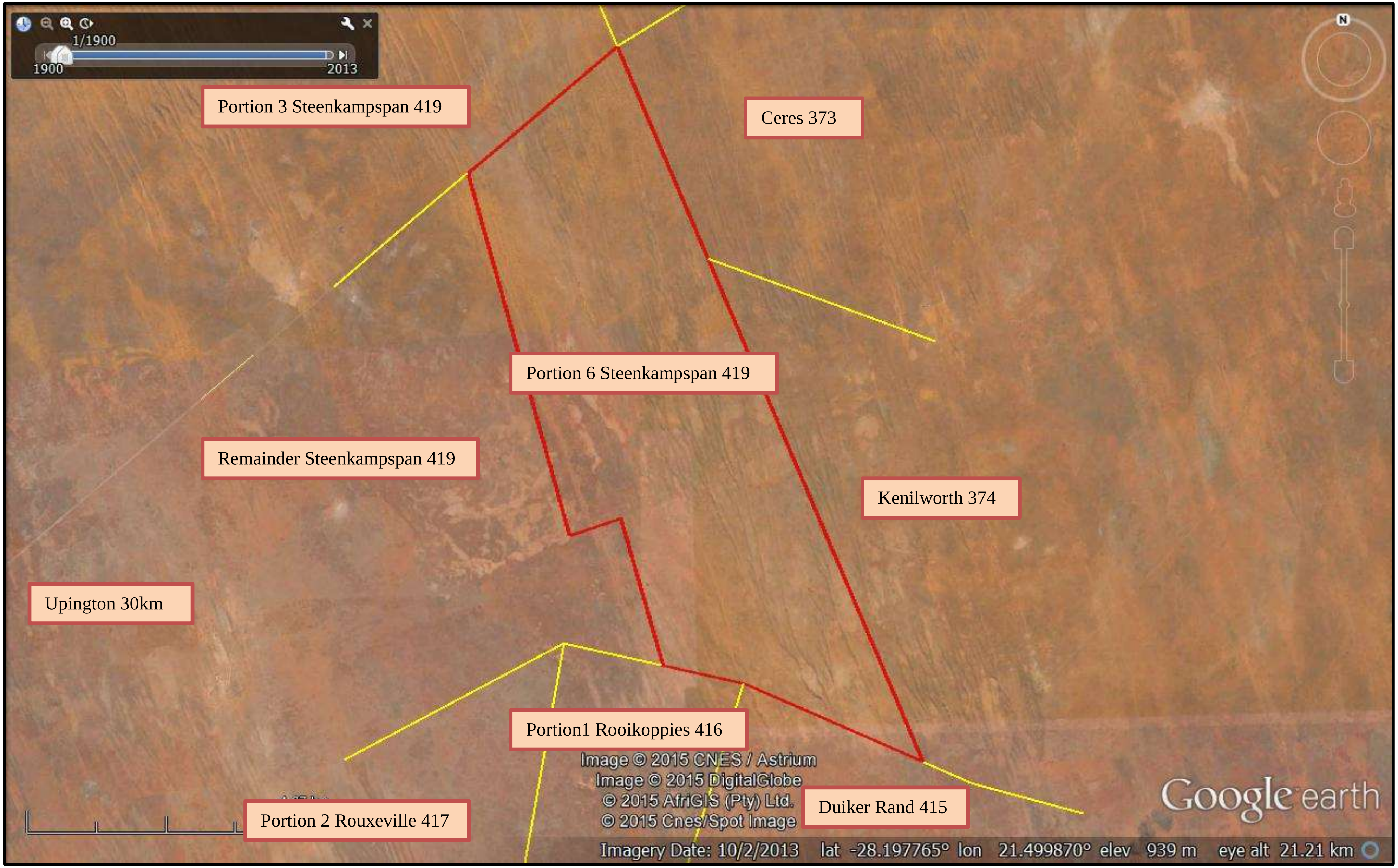

Figure 2: Local locality map of the farm portion and region around the proposed development area

2. CLIMATE AND REGIONAL SETTING

The proposed development portion, Portion 6 of the farm Steenkampspan 419 is located in quaternary sub-catchment D73E. The surface area of quaternary sub-catchment D73E is 3873km^2. The site is located in Weather Bureau section number 0317 and in rainfall zone D7D. The closest rainfall station still in use is 0282823 at Keimoes police station. This weather station is located approximately 40km south east of Upington.

The rainfall period for this station covers the years from 1920 to 1989. The Mean Annual Precipitation (MAP) for the period from 1920 to 1989 is 155.4mm/a. Rainfall occurs as typical summer thunderstorms with heavy lightning and strong winds. Summer rainfall is typically from November to April, in which approximately 79.6% of rainfall normally occurs. The typical dry period is between May and September each year, covering the winter months.

The proposed development portionis located in Evaporation Zone 3B. The closest Evaporation station D7E003, the Upington station which is located approximately 35km south westof the proposed development, gives a mean annual evaporation (MAE) of 2 750mm for the S-Pan value and 3728 for the A-Pan value. The evaporation measurements cover the years 1957 to 1979. The site is located in Hydro Zone L with a Mean Annual Runoff (MAR) of 0 to 2.5mm per annum.

3. METHODOLOGY

A desk study was performed to gather relevant geological and hydrogeological information. A hydro-census followed the desk study to establish borehole information in the region of thesite. The farms directly bordering Portion 6 of the farm Steenkampspan was visited. The purpose of this survey was to gather relevant hydrogeological information to study the groundwater regime, current groundwater useand borehole coordinates in the area. The water level depths in boreholes and pits were measured where possible. The groundwater abstraction volumes from boreholes in the area were gathered where possible to be able to calculate existing groundwater abstraction in the area.

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This was done to be able to calculate aquifer parameters for the aquifer and to beable to recommend safe abstraction volumes for the individual boreholes.

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The percolation rate tests, geology, aquifer test information and water level depth and estimated groundwater flow directions were utilized to calculate the contamination risk for the site.

4. GEOLOGICAL SETTING

The 1: 250 000 Geological Series 2825Upington indicate that the area of interest is mainly located on rocks of the Wilgenhoutsdrif, Koras and Kalahari groups.

Wilgenhoutsdrif Group

The Wilgenhoutsdrif Group consists of the Valcanic rocks such as the Grootdrink, Zonderhuis and Leerkrans Formations. The Leerkrans formation consists of Metabasalt, felsic lavas, greenschist and conglomerate which is visible to the north western corner of the site. The Leerkrans Formation is of early Mokolian age.

Koras Group

The Koras Group consists of the Christiana, Boom River, Rusplaas, Rouxeville, Welgevind and Kalkpunt Formations. The Rusplaas Formation is visible on the site and consists of conglomerate sandstone which is blueish in colour and is fine to medium grained. The Rusplaas Formation is also of early Mokolian age and is found on the central and western side of the site.

Blaubosch Granite

The Blaubosch Granite is a pinkish to blueish fine to medium coarse grained granite which can be found on the western side of the site. The Blaubosch Granite is intrusive rocks which can be seen as protruding koppies in the area. The Granite is of late Namibian age.

Dolerite

Dolerite dykes of the Jyrassic age are scarce in the area. To the west of the site a west to eastern trending dyke can be seen located to the west of the site. Dolerite is only present in dike like format in the area and does not present itself in sheet-like format. Dolerite is normally found in dykes of a few metres up to tens of metres. Dolerite is normally a fine to medium grained bluish rock weathering to a fairly productive aquifer.

Calcrete

Calcrete outcrops are rare in the area, largely because the area lies within the active drainage of the Orange River. Sand covers most of the calcrete on site. Hardpan calcrete only occurs some 400 metres above the Orange River. These disconnected patches are too small to be depicted on the map, and seem to be related to certain lithologies such as calcsilicate rocks, metabasalt and dolorite. In the latter case, a nodular variety is formed in the overlying saprolite. The calcrete deposits are mostly sand covered.

Sand and dunes

The area is covered by a veneer of red Aeolian sand. The sand forms prominent longitudinal dunes which traverse in a south south-east to north north-west direction. Some of these dunes are semi-permanent and they support scant vegetation. The dunes are parallel to each other in most cases. The sand is from the Gordonia Formation of the Kalahari Group which is from the quaternary age. Pediment deposits relate to an early erosion cycle. These deposits consist of a local basal layer of talus boulders, overlain by a succession of gravel and coarse sand, consisting mainly of locally derived rock waste. Fine material is notably absent.

Two fault zones traverse the farm portion. Both these fault zones are prominent lineament structures depicted by large magnetic anomalies.

Figure 3 below gives a condensed geological legend. Figure 4 is the local geology map for the area. It was adopted from the 1: 250 000 map series 2820 Upingtom published in 1988 by the Government Printers.

Figure 3: Geological Legend (Condensed)

	SEDIMENTARY AND VOLCANIC ROCKS					INTRUSIVE ROCKS	
Era	**Sequence**	**Group**	**Formation**	**Lithology**	**Colour**		
QUATERNARY		KALAHARI	Gordonia	Sand and dunes: Red brown, wind-blown	Qg		
TERTIARY				Calcrete	T		
JURASSIC				Dolerite: dolerite dyke shown as pink line		Jd	
CARBONIFEROUS TO PERMIAN	KAROO		Dwyka	Tillite partially covered by gravel	C-Pd		
NAMIBIAN						Nb	Blaubosch Granite
NAMIBIAN		KORAS	Kalkpunt	Re-brown sandstone, conglomerate	Nka		
NAMIBIAN		KORAS	Welgevind	Red-brown qaurtz-feldspar porphyry; inter-bedded	N-Mw		
MOKALIAN		KORAS	Rouxeville	Andesitic to basaltic lava, commonly amygdaloidal; pyroclastics	Mru		
MOKALIAN		KORAS	Rusplaas	Conglomerate sandstone	Mrp		
MOKALIAN		KORAS	Boom River	Andesitic to andesitic lava	Mbm		
MOKALIAN		KORAS	Christiana	Brown, micaceous and feldspathic sandstone, conglomerate and sandstone	Mch		
MOKALIAN		WILGENHOUTS DRIF	Leerkrans	Metabasalt, felsic lavas, greenschist, conglomerate, ferruginous chert	Mle		

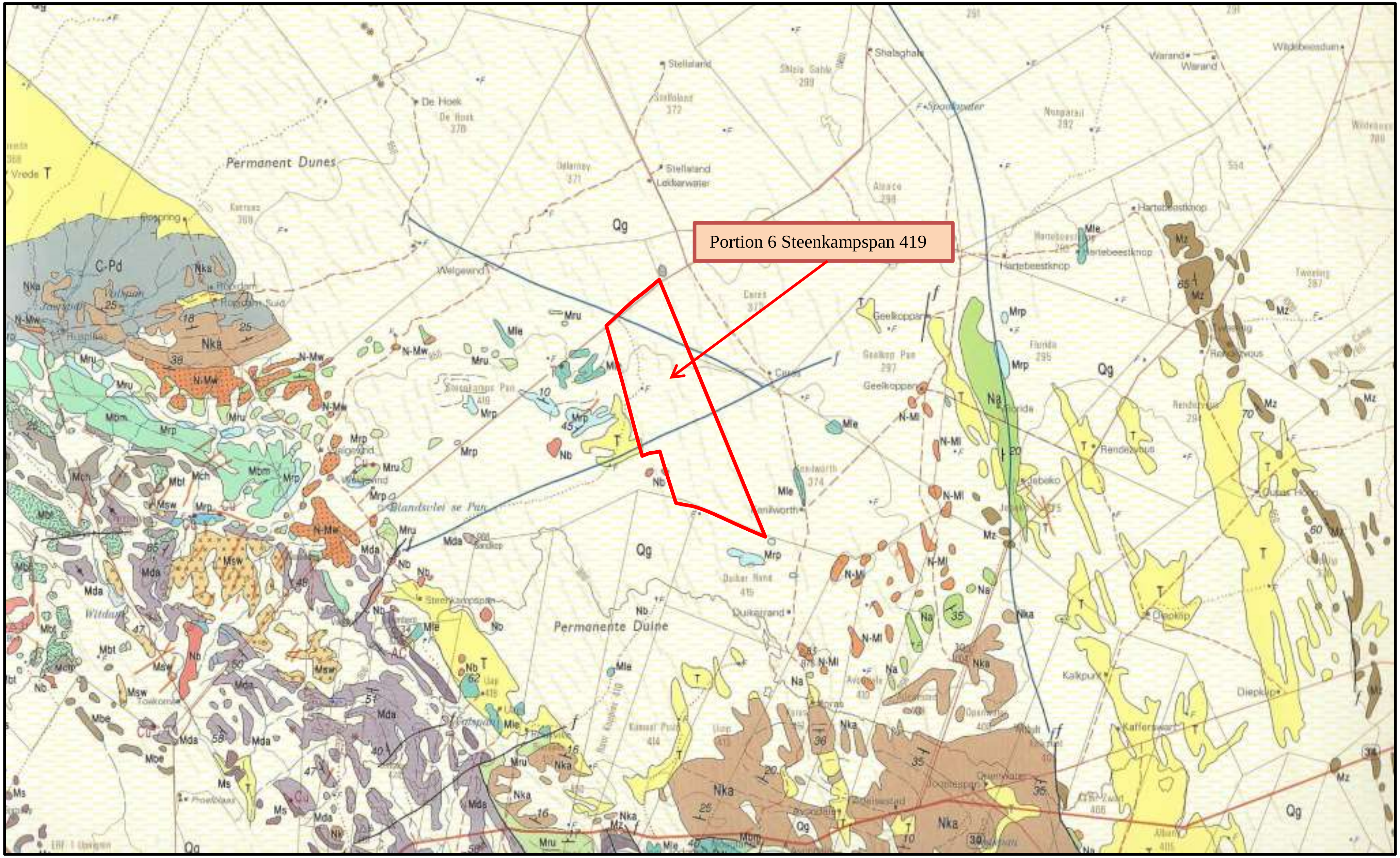

Figure 4: Regional geological map 2820Upington 1: 250 000.

5. FIELD WORK

5.1 Desk study and Hydro-Census Data

During the desk study the geology of the area was studied. During the hydro census study, information on twenty seven boreholes located outside the proposed development area could be gathered. Four existing boreholes located on the proposed development portion were also visited. Information on five new boreholes drilled on the development portion could also be gathered. Valuable information regarding borehole coordinates, water level depth, borehole depth, water use volumes and existing equipment could be gathered. This information is assembled in Table 1 below. Information regarding the land owners is also listed in Table1.

From the four existing boreholes located on the proposed development portion only one is not equipped.Three are currently equipped and are used for stock watering. From the five newly drilled boreholes two can be used as production boreholes. Four of the five newly drilled boreholes were cased and can be used for future water level measurements. One of the newly drilled boreholes was destroyed and was not cased.

Water level depths could be measured in twenty two of the twenty seven boreholes visited outside the proposed development area.

The water level depth on the development portion range between 23 and 26.5 metres below ground level. At one location namely at BH 2 and BH 7, the newly drilled borehole, the water table is in the region of 50 metres. We propose that the deep water level depth is only due to the localized water abstraction from borehole BH 2. The water level depth on the outside of the proposed development portion measures between 16.82 and 46.5 metres below ground level.

Figure 5 gives detail information regarding the locality of the boreholes. The boreholes marked in redare boreholes located outside the development area. The boreholes marked in blue are the boreholes located on the development area which can be used for the farm portion or the proposed development. Borehole H/BH 10 is located outside the proposed development portion and is earmarked to be used for the proposed development.

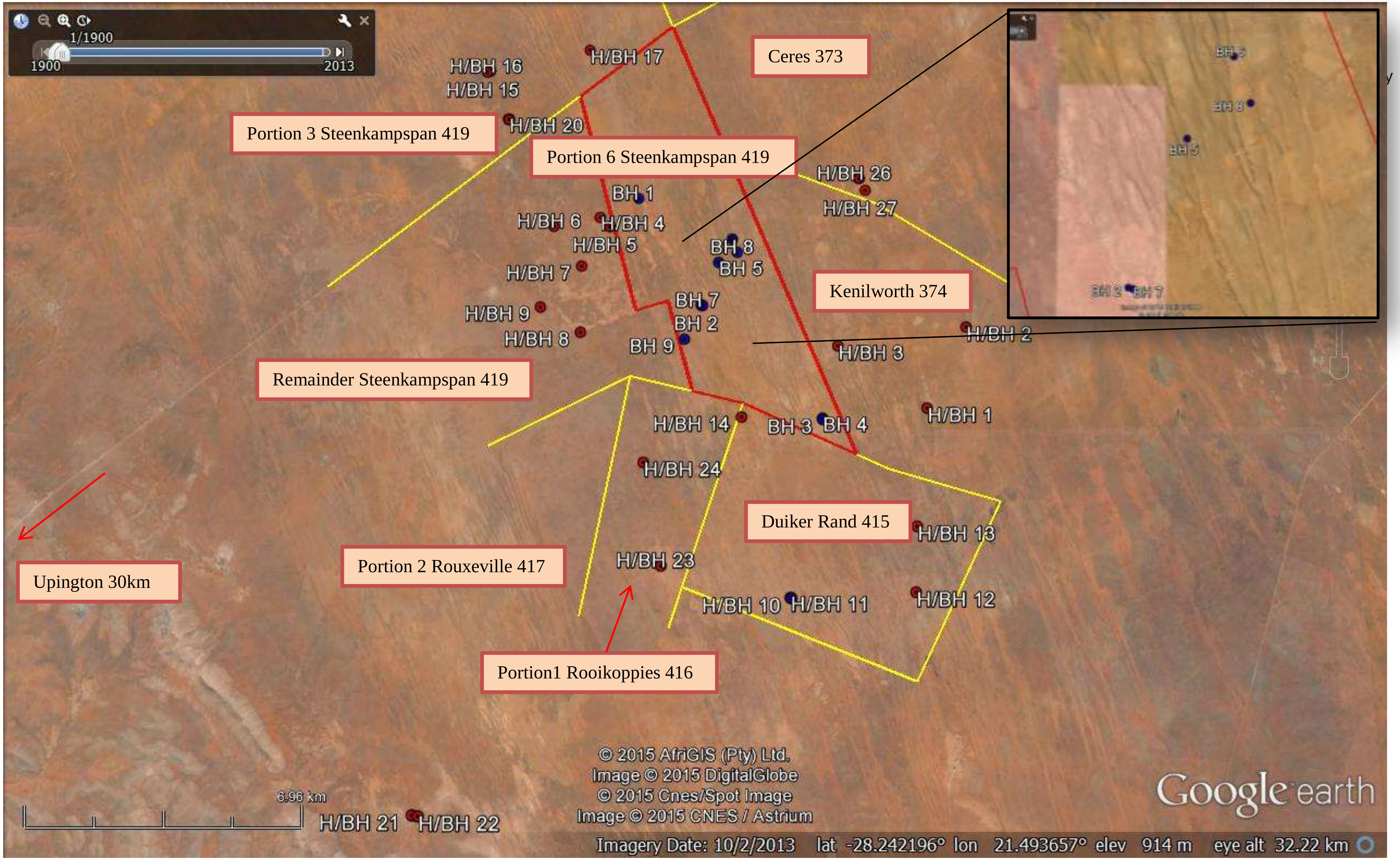

Figure 5: Hydro-census map

TABLE 1: Borehole hydro-census details

Borehole number	Co- ordinates		Water level (mbgl)	Groundwater Elevation (mamsl)	Remarks
	Latitude And Longitude	Ground Elevation (mamsl)			
Boreholes located on the Portion 6 of the farm Steenkampspan 419					
Owner: Albert Human: 082 774 1781					
BH 1	-28.184615° 021.478047°	940	24.72	915	Submersible pump. Can be used as water supply borehole for development.Pump water to large cement dam which feeds four drinking troughs.
BH 2	-28.21177° 021.49552°	932	51.40	881	Located in field. Windmill. Low yielding BH. Life stock watering. Delivers water to 6 X 10 000l tanks. Delvers water to 3 drinking troughs. Low yielding borehole.
BH 3	-28.23996° 021.52847°	922	23.15	899	Casing only. Can be used as water supply borehole for development. **Submitted to yield testing.**Located near BH 4
BH 4	-28.23965° 021.52835°	923	22.90	900	Windmill. Pump water into cement reservoir. Live stock watering.
BH 5	-28.200994° 021.503347°	937	25.73	911	Newly drilled borehole. Blow out yield 0.9l/s. BH depth 144.0m
BH 6	-28.19505° 021.50417°	938	26.10	912	Newly drilled borehole. Blow out yield <0.1 ℓ/s. BH depth 90m
BH 7	-28.21187° 021.49589°	932	±50	882	Newly drilled borehole. Blow out yield <0.1 ℓ/s. BH depth 150m
BH 8	-28.19842° 021.50554°	938	26.5	911	Newly drilled borehole. Blow out yield >2.1 ℓl/s. BH depth 150m
BH 9	-28.220260° 021.490910°	925	Dry	---	Newly drilled borehole. Blow out yield <0.1 ℓ/s. BH depth 150m
Boreholes located on land outside the proposed development area					
Owner:Phillip Coreejes: 082 491 7402, Kenilworth 374. Foreman Pieter vd Heefer: 082 727 4331					
H/BH 1	-28.23715° 021.55677°	926	24.72	901	BH located at farm house. Submersible pump with solar panels. 40mm pipe. Domestic and animal use. Borehole yield ±9000l/h. BH depth is 45metres.
H/BH 2	-28.21718° 021.56816°	930	29.66	900	BH located in field. Submersible pump with solar panels. Delivers water to 3 cement dams. Live-stock watering. 32mm pipe. BH depth is 33metres.

H/BH 3	-28.22190° 021.53291°	928	25.37	903	BH located in field. Windmill not working. Submersible pump with solar panels. Delivers water to 2 cement dams plus 10 000l tank. Live-stock watering. 32mm pipe.
Owner: Siebert Myburg: Remainder Steenkampspan 419					
H/BH 4	-28.18950° 021.46738°	939	46.33 Dynamic WL	893	BH located in field. Windmill working. Low yielding BH. Life stock watering. Delivers water to cement dam.
H/BH 5	-28.19189° 021.47006°	938	35.11	903	BH located in field. Submersible pump with solar panel. 40mm pipe. Live-stock watering.
H/BH 6	-28.19181° 021.45452°	935	38.99	896	BH located in field. Submersible pump with solar panels. Delivers water to 2 X 5000 l tanks. Live-stock watering.
H/BH 7	-28.20194° 021.46243°	934	31.31	903	BH located in field. Submersible pump with solar panels. Delivers water to 2 X 10 000 l tanks. Live-stock watering. 25mm pipe.
H/BH 8	-28.21855° 021.46240°	927	28.83	898	Pit located at homestead. Windmill working. Life-stock watering. Pit depth is 30m.
H/BH 9	-28.21228° 021.45127°	926	29.71	896	BH located in field. Life-stock watering. Submersible pump with solar panels.
Owner: Albert Human: 082 774 1781. farm Duikerrand 415					
H/BH 10	-28.28226° 021.51938°	900	16.82	883	BH located in field. Casing only. No equipment not used. High yielding borehole.**Submitted to yield testing.**
H/BH 11	-28.28208° 021.51907°	899	17.65	881	BH located in field. Windmill. Working. Delivers water to large cement dam. Water used for life-stock farming.
H/BH 12	-28.28080° 021.55229°	910	25.80	884	Pit located at homestead. Windmill working. Life-stock watering. Delivers water to 10 000ltank and feeds 3 drinking troughs.
H/BH 13	-28.26546° 021.55308°	920	33.19	887	BH located in field. Windmill. Working. Delivers water to cement dam. Water used for life-stock farming.
H/BH 14	-28.23936° 021.50644°	919	29.46	890	BH located in field. Windmill. Working. Delivers water to cement dam. Water used for life-stock farming.
Owner: Innes Burger: 072 731 7957 and Pieter Coetzee: 083 607 6272, Portion 3 of the farm Steenkampspan 419					
H/BH 15	-28.15137° 021.43464°	972	38.37	934	BH located in field. Submersible pump with solar panels. Delivers water to entire farm. Domestic and Live-stock watering.
H/BH 16	-28.15113° 021.43560°	971	40.89	930	BH located in field. Windmill, broken. Submersible pump no solar panels. Borehole not used.
H/BH 17	-28.14545° 021.46381°	972	±45	±927	BH located in field. Windmill. Working. Delivers water to cement dam. Water used for life-stock farming.

H/BH 18	-28.16393° 021.44106°	955	46.50	909	BH located near workers house. PVC Casing only. Borehole never used.
H/BH 19	-28.16391° 021.44128°	955	Closed up	909	BH located near workers houses. Windmill, broken. Not used.
H/BH 20	-28.16397° 021.44120°	955	Closed up	909	BH located near workers houses. No equipment. Not used.
Owner: S. A. (Fanie) Le Rouxe: 054 332 5483 or 074 489 3429, Portion 1 of the farm Rooikoppies 416 (Also called Kameelvlakte)					
H/BH 21	-28.33086° 021.42123°	871	18.6	852	Pit located near homestead. Windmill on top of pit. Windmill badly broken. Not working. Submersible pump but no solar panels. Water used for life-stock farming.
H/BH 22	28.33108° 021.42275°	869	Closed up	---	BH located near homestead. Windmill working. BH closed up. Can not measure WL. Delivers water to homestead and is used for live-stock farming.
H/BH 23	-28.274750° 021.484787°	899	±20	±879	BH located in field. Windmill working. Did not visit borehole. Delivers water to dam for live-stock farming.
H/BH 24	-28.250317° 021.479901°	907	±20	887	BH located in field. Windmill working. Did not visit borehole. Delivers water to dam for live-stock farming.
Owner: Gert Fortuin: 061 778 7126, Farm Ceres 373					
H/BH 25	-28.17932° 021.53969°	951	36.73	914	BH located near homestead. Windmill not working. Windmill badly broken. BH not used.
H/BH 26	-28.17940° 021.53975°	951	37.02	914	BH located near homestead. No equipment. BH not used.
H/BH 27	-28.274750° 021.484787°	950	44.83 Dynamic WL	905	BH located in field. Windmill not connected. Submersible pump with solar panels. Solar pump working.

5.2 Geophysical Study (Establishment of drill site positions)

Groundwater occurs in weathered or fractured host rock in the area. To be able to place a drilling position for groundwater exploration purposes the geology and more specifically the condition (state of weathering) of the host rock must be understood. A geophysical study is the measuring of certain parameters such as electrical conductivity and magnetic susceptibility of the in-situ geology. A number of geophysical methods do exist to measure these parameters.

For the geophysical study the Magnetic method and the Direct Current Continuous Electrical Vertical Sounding method (DC CVES) method were used to conduct the survey. The two geophysical methods are explained below.

5.2.1 Magnetic method

The magnetic method attempts to differentiate between lateral differences in the earth's magnetic field. These differences or anomalies indicate to different types of underlying rock formations and/or variations in depth of these different formations. The magnetic surveys are normally done in a linear pattern or traverse and found application in the following geohydrological regimes.

a) tracing of intrusive dolerite or diabase dykes or sills,

b) tracing of contact zones between different formations, and

c) Tracing of possible fault zones.

5.2.2 Direct Current Continuous Vertical Electrical Sounding method (DCCVES)

The resistivity method requires the measurement of resistance of the soil substrata. This is usually done by injecting a current into the ground using two electrodes and measuring the resulting potential across another two electrodes. The exploration depth that the measurement applies to depend on the electrode separation, thus a picture of resistance with depth can be derived by systematically increasing the electrode separation. This process is known as a vertical electrode sounding. A series of such soundings adjacent to each other provides a continuous vertical electrical sounding or CVES.

Purpose-built instruments are available for automatically collecting CVES data. The instrument that was used is an ABEM Lund set. Depending on the requirement different electrode configurations and separations can be programmed.

The resistivity data sets were processed using RES2DINV. RES2DINV automatically interprets the resistivity variations of the ground by fitting internally-generated model data to the field data through several iterations. Prior to inverting, obviously noisy or spurious data points are manually eliminated from the data sets. After the first interpretation pass of up to five iterations, further editing is carried out to remove data that are outliers compared with the computer-generated model readings. A final cycle of modelling then followed.

Anomalies are recognised in the model by virtue of a higher or lower resistance relative to the surrounding material.

5.2.3 Geological desk study

A desk study consisting of a geological interpretation of available information was conducted. Two fault zones, one covering the central part of the site, and one covering the northern part of the site was targeted as potential water bearing structures. Four traverses were laid out to cover the fault zone traversing the central part of the farm. Refer to Figure 6. The fault zone on the northern part of the farm will be less accessible for drilling exploration due to the planned roads to be constructed on this part of the site. This fault zone are also located on a topographical high area which limits the size of the groundwater recharge of this fault zone and were therefore not further exploited by geophysics.

5.2.4 Field survey

The four traverses were covered with the two geophysical methods explained above. The positions of the traverses and the recommended drill positions can be seen on Figure 6 and 7. The traverse data is explained below.

5.2.5 Recommended drill positions

The geological model for the site is a layered earth model where the top layers is expected to be more weathered with the result that these layers are also electrically more conductive. The deeper layers are expected to be un-weathered and more electrically resistive. No vertical structures such as dykes are expected in the area except for the fault zone that is expected to be vertical. The side is also expected to be weathered and therefore expected to be electrically conductive. The DC CVES method was therefore expected to be the best tool to site drilling positions for water exploration boreholes. The aim was therefore to find conductive zones deep enough to be a productive aquifer. The Magnetic method was used as indicative tool for magnetic intrusive material.

Traverse 1

The resistivity data show a two layer earth model with a conductor (“cold” or blue colors) on top with more resistive material (“hot” or red colors) in depth. The blue colors represent the weathered material which is down to a depth of approximately 30 metres. The water table is in the order of 25 metres. This means an aquifer in the order of only 5 metres thick. The dark green color shows a resistivity of 1000 ohm/m which is already un-weathered material. This traverse therefore shows a conductive layer that may be too thin to form a productive aquifer.

Only one drill position with a drill priority of 5 was selected on this traverse at 285metres.

Traverse 2

This traverse shows an even thinner top conductor with a more homogeneous un-weathered host rock in depth. No exploration drill position was placed on this traverse. The magnetic data is flat with no magnetic variance and verify the interpretation of the resistivity data.

Traverse 3

Traverse 3 shows a very conductive top later with two large high conductive zones in depth. The high conductive zones in depth could mean areas with weathered base rock which could form productive aquifer conditions. Two drilling positions could be established one at 170 metres and one at 500 metres.

Traverse 4

Traverse 4 also shows a very conductive top later with two large high conductive zones in depth. The high conductive zones in depth could mean areas with weathered base rock which could form productive aquifer conditions. Two drilling positions could be established one at 305 metres and one at 580 metres.

The following positions are recommended to be drilled for water exploration purposes in Table 2 below.

Table 2: Recommended drill positions placed on geophysical study information.

Traverse Number	Recommended Drill position	Coordinates	Drilling Priority
1	285m	-28.203864° 21.497447°	5
2	None		
3	170m 500m	-28.200994° 21.503347° -28.19851° 21.50164°	3 4
4	300m 580m	-28.19842° 21.50554° -28.196056° 21.504614°	1 2

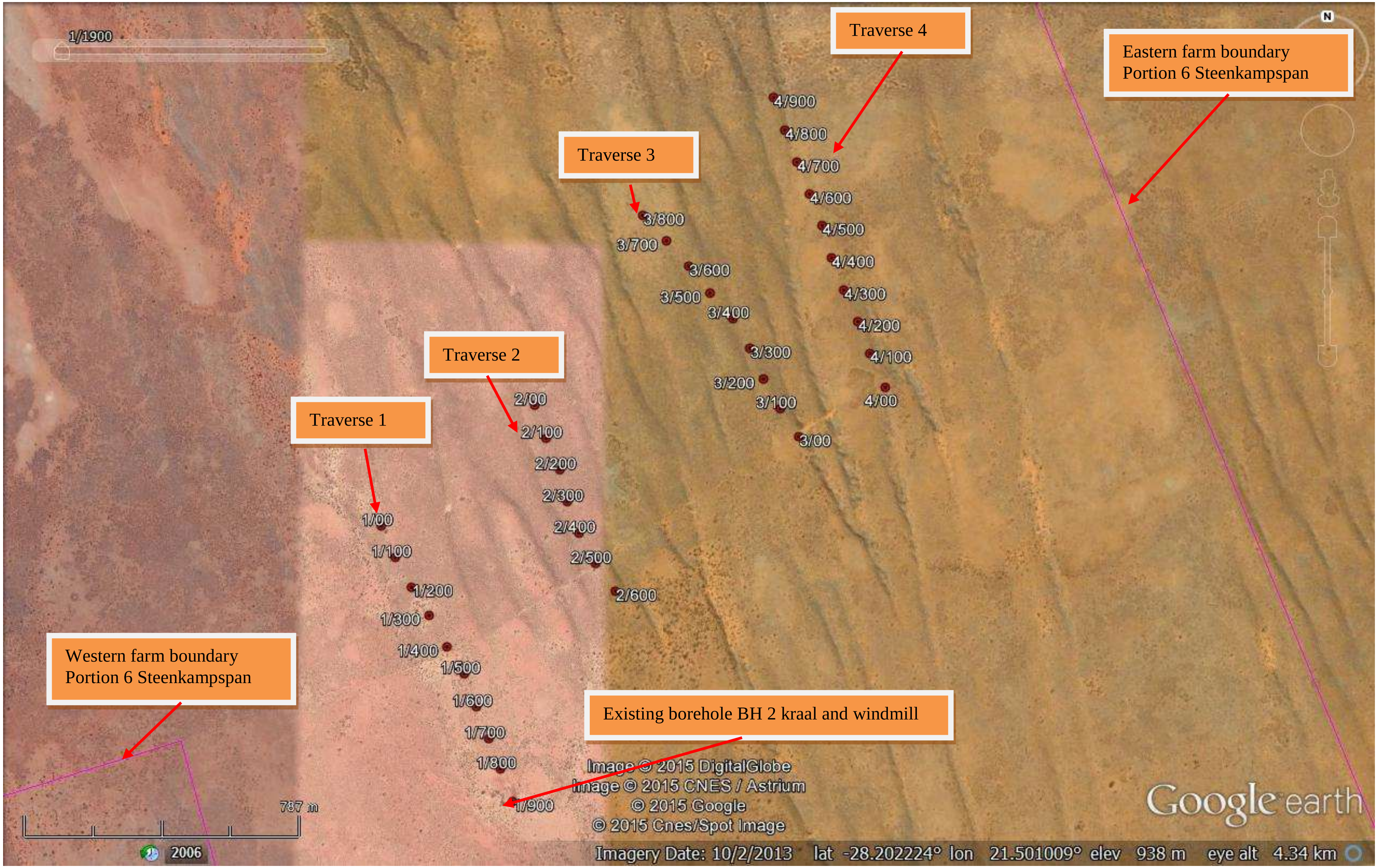

Figure 6 Positions of four geophysical traverses.

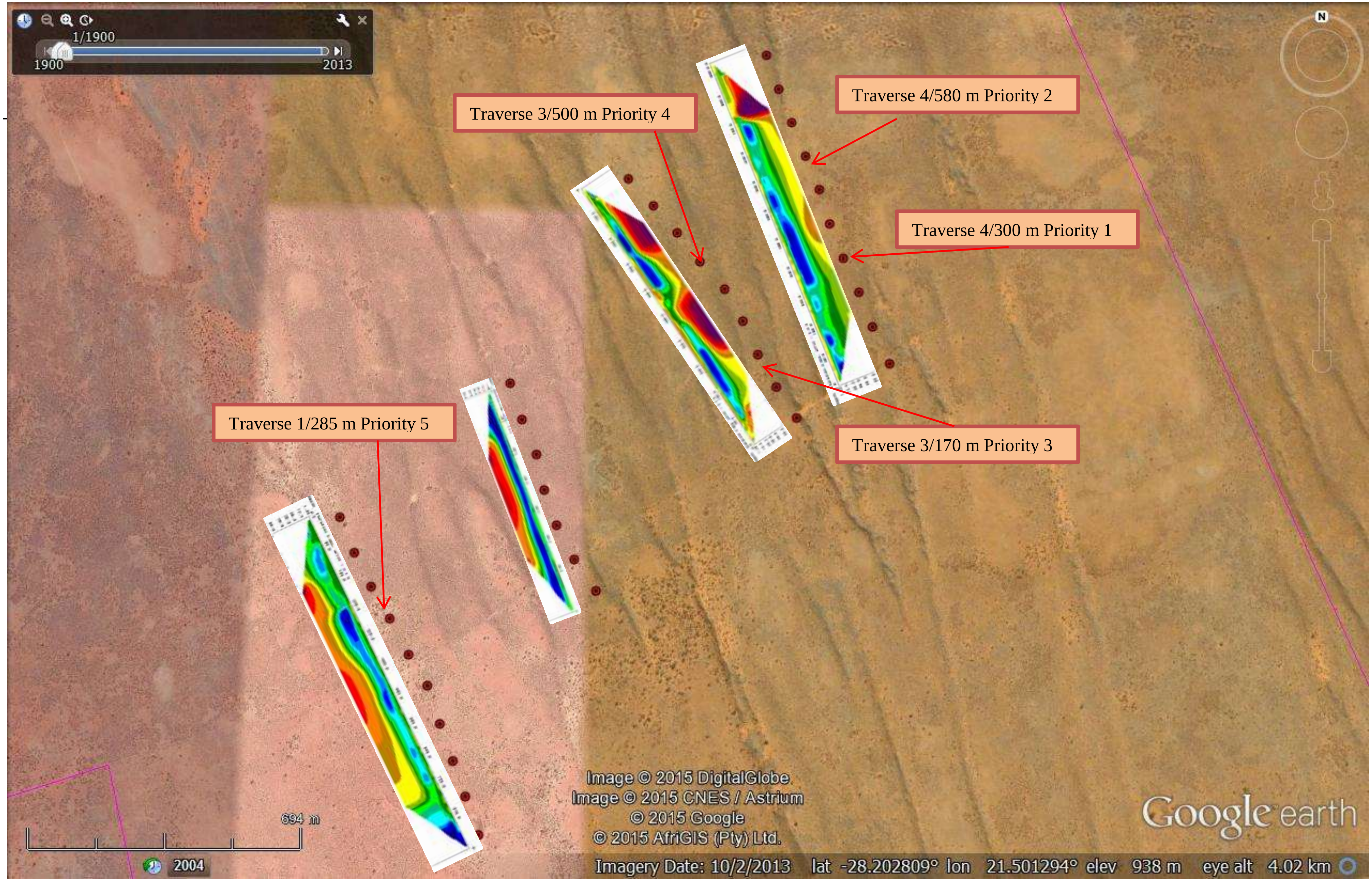

Figure 7: Geophysical Traverses with priority drill sites.

5.3 Borehole drilling

Borehole drilling supervision was done to be able to gather the hydrogeological information regarding the water strikes and lithology of the boreholes. Five boreholes were drilled on the geophysical traverses. The boreholes were numbered from BH 5 to BH 9. The drilling information is listed in Table 3 below.

The boreholes were drilled with a 205mm drill bit, until solid rock was encountered. The bore was then completed with a 165mm drill bit to depth. The top part of the borehole, where extremely weathered material was encountered was cased with PVC casing with 165mm diameter and with 8mm wall thickness. Reaming was done to a depth of at least 2 metres into solid host rock. Casing was installed to protect the boreholes from side wall collapse to a depth listed in table 3. Solid casing was installed where no water was encountered. Perforated casing was installed at positions where water strikes occurred.

After completion, the borehole was flushed with air until clean. The final blow out yield was measured after the cleaning and development by air. Refer to the locality map, Figure 8for the borehole positions.

Table 3: Borehole drilling information

BH number	Coordinates	Geophysical targets	Water strike depth	Borehole depth	Casing depth	Blow out yield
BH 5	S -28.200994° E 021.503347°	Traverse 3/170 Priority 3	Main water strikes at 38m (0.3 l/s) and 58m (0.6 l/s)	144	42	0.9ℓ/s
BH 6	S -28.19505° E 021.50417°	Traverse 4/700. On Magnetic dyke and fault	Dry. Steel casing for monitoring	90	7 m steel	<0.1ℓ/s
BH 7	S -28.21187° E 021.49589°	Traverse 1/900. On conductive zone	Dry. BH destroyed	150	None Destroyed	<0.1 ℓ/s
BH 8	S -28.19842° E 021.50554°	Traverse 4/300. Priority 1	Main water strike at 42m (2.1 l/s)	150	46	<2.1 ℓ/s
BH 9	S -28.220260° E 021.490910°	At fracture zone near proposed mining area	Dry. BH destroyed	145	5 m steel	<0.1 ℓ/s

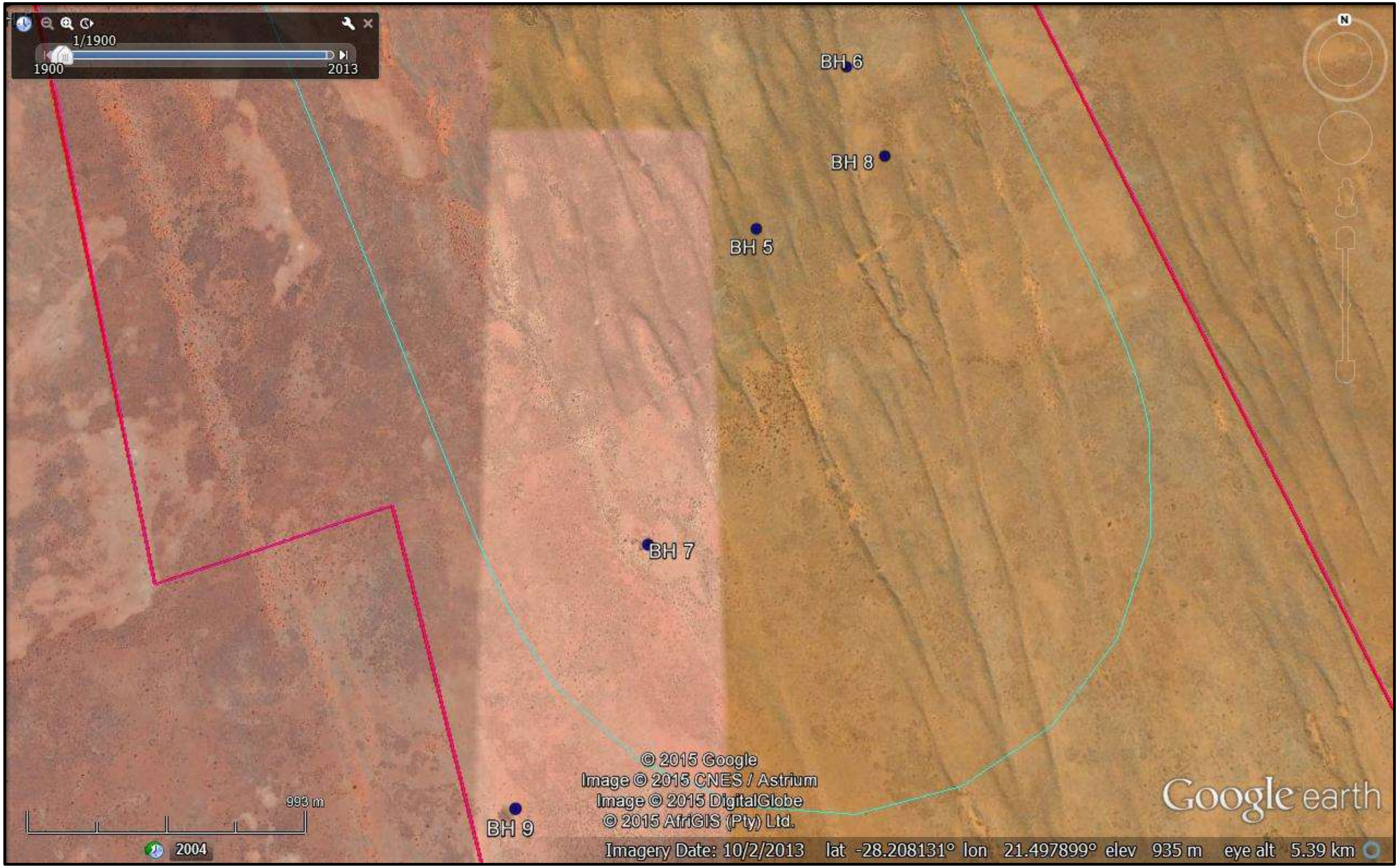

Figure 8: Map with positions of newly drilled boreholes

5.4 Test pumping of existing and newly drilled boreholes

Three existing boreholes and the two newly drilled production boreholes were submitted to borehole yield testing procedures. A borehole is submitted to a borehole yield test to be able to calculate a sustainable yield for each individual borehole. During the yield test the water level response to water abstraction is constantly measured. The reaction of the water level during a yield test can give valuable information regarding the aquifer parameters transmisivity and storativity of a groundwater regime. A borehole yield test normally consists of a step test and a constant yield test. A recovery test normally follows the step test and the constant discharge test. A recovery test measures the recovery rate of an aquifer during the period when water abstraction stops.

A **Step Test** or calibration test consists of pumping a borehole at different rates for fifteen to sixty minutes per step, until the maximum rate the borehole can deliver. The water level is constantly monitored and noted during each step. This gives an indication of the possible yield the borehole can sustain for a Constant yield discharged test. A step test also gives an indication of the potential of the aquifer in the immediate area around the borehole.

The **Constant Discharge Test** consist of pumping a borehole at a specific rate for a long duration which in this case is 24 hours, with a sudden switch off of the pump after the pump cycle, with a recovery test following immediately afterwards. The Constant Discharge Curves isthen analysed by curve fitting to give an indication of Transmisivity and Storativity values.

A more detailed description of the procedures followed for the tests is given in Appendix B. Table 4 below gives detail information of the steps durations the draw-downs reached during each step and the duration and draw-downs reached during the constant yield tests. Comments on the recovery tests are also listed in Table 4. The interpretation of the yield tests is explained in the next section.

TABLE 4: Test pumping results

BH No. BH Depth & Static Water Level	Step Test				Constant Discharge Test			Comment on the Water Level Recovery Rate of the Constant Discharge Test
	Step No.	Rate (l/s)	Dur. (min)	D/D (m)	Rate (l/s)	Dur. (min)	D/D (m)	
BH 01 (Solar Pump) Depth: 77.3m Static water level: 34.0m S 28.184615° E 021.478047°	1	0.72	15	15.12	0.31	1440	6.39	100% in 720 min
BH 03 (Casing only) Depth: 100 Plus m Static water level: 23.15m S 28.239960° E 021.528470°	---	---	---	---	0.21	1440	21.03	100% in 840 min
BH 05**(Newly drilled)** Depth: 144m Static water level:25.4m S 28.200994° E 021.503347°	1 2 3 4	0.15 0.31 0.78 1.32	60 60 60 20	1.64 3.41 5.47 27.03	0.67	1440	6.88	97.82% in 840 min
BH8**(Newly Drilled)** Depth: 150m Static water level: 26.50m S 28.19842° E 021.50554°	1 2 3	0.77 1.52 2.18	60 60 60	1.13 3.14 5.24	2.14	1440	5.68	97.0% in 360 min
H/BH10(Casing Only) Depth: 70m Static water level:16.85m S 28.28226° E 021.51938°	1 2 3	2.65 5.01 8.54	60 60 60	1.38 3.15 6.08	7.13	1440	7.88	86.8% in 1440 min
ST - Step Test CDT - Constant Discharge Test SWL - Static Water Level in metres below ground level					Dur. – Duration D/D – Draw down			

5.5 Recommended borehole abstraction figures

The Constant Discharge Curves of the test was analysed by utilizing the Basic FC, FC inflection point, Cooper-Jacob, Theis and Barker/Bangoy methods, to give an indication of Transmisivity and Storativity values. The average abstraction rate (based on a 24 hour duty cycle) of these methods were taken to calculate the yield for 12 hours per day. Please refer to Appendix B for detail description of each yield test. The summary sheet in Appendix B also gives the recommended abstraction of the different methods in the summary sheet.

The average recommended (Interpreted from all data available) abstraction rate for the borehole is given in Table 5 below. It is important to understand that the abstraction figure given below in Table 5 only makes provision for the aquifer parameters of the borehole tested. These figures do not make provision for borehole interference with other boreholes in the area, groundwater recharge that may or may not be enough or groundwater catchment size limitations. These abstraction figures below use assumptions such as a limitless catchment area size and no interference or abstraction from other boreholes in the area.

During the interpretation a conservative approach was constantly followed. For instance the thickness of the aquifer was always reduced and inputted in the FC programme to limit the recommended yield. The steepest part of the draw-down curve was always interpreted to reduce the transmissivity value. The groundwater recovery rate was always used as a limiting factor rather than a meridian factor. For instance borehole H/BH 10 was pumped for 24 hours at a rate of 7.13l/s. The draw-down during the constant yield test for borehole H/BH 10 was only 7.88 metres and the aquifer thickness was reported as 36 metres. An aquifer thickness of only 35 metres was used. The sustainable calculation gave a figure of 7.5l/s as a mean value and a mean value of only 5l/s were inputted as a value for the final calculations. The program recommended 7.07 l/s as a final recommended figure. We propose an abstraction rate of 54% of the calculated recommendation and gave a final recommendation of only 3.8l/s. The same conservative approach was used for the other four boreholes. The water demand is set as 276m^3/d as a maximum. The total recommended abstraction figures as a first round of calculations added up to 350m^3/d. A conservative approach was again followed and the final recommended abstraction volumes was again scaled down to 300m^3/. This was done by scaling down the recommended abstraction volume of each individual borehole until a final conservative figure of 300m^3/d was reached.

TABLE 5: Recommended abstraction schedule for production boreholes (FC method)

Borehole No.	Recommended Abstraction Rate		Dynamic water Level (mbcl)	Comments
	For 12h/d	in m^3/d		
BH1	0.35	15.1	40	Borehole recommended as production borehole
BH 3	0.1	---	---	Borehole recommended for stock farming
BH 5	0.6	25.9	31	Borehole recommended as production borehole
BH 8	2.2	95.0	31	Borehole recommended as production borehole
H/BH 10	3.8	164	21	Borehole recommended as production borehole
Total		300		

5.6 Test pits and percolation tests

To facilitate the contamination risk assessment study, the infiltration rate of the upper soil was measured on the proposed development site.

Infiltration rates of the upper soils or the Hydraulic Conductivity of the unsaturated zone are measured in the field by using a double-ring infiltrometer. This method describes a procedure for field measurement of the infiltration rate of soils. Infiltration rate is defined as a soil characteristic, determining and describing the maximum rate at which water can enter the soil under specified conditions, including presence of an excess of water. Infiltration rates have application to problems such as erosion rates, leaching and drainage efficiencies, irrigation, water spreading, rainfall runoff, and evaluation of potential septic-tank disposal fields, among other applications.

Rates determined by ponding of large areas are considered the most reliable method of determining infiltration rate, but the high cost makes the infiltrometer-ring method more feasible and economical. The infiltration rate is controlled by the least permeable zone in the subsurface soils. The double-ring infiltrometer is used to help divergent flow in layered soils by providing an outer water barrier to encourage only vertical flow from the inner ring. Many other factors affect the infiltration rate in addition to the soil structure, for example, the condition of the soil surface, the moisture content of the soil, the chemical and physical nature of the soil and the applied water, the head of applied water, and the temperature of the water. The tests done at the same site are not likely to give identical results and the rate measured by the procedure described in this test method is primarily for comparative use. Some aspects of the test, such as the length of time the tests should be conducted and the head of water to be applied, must depend upon the experience of the user, the purpose for testing, and the kind of information that is sought.

Two open cylinders, one inside the other, are driven into the ground and partially filled with water, which is then maintained at a constant level. The volume of water added to maintain the water level constant is the measure of the volume of water that infiltrated the soil. The volume infiltrated during timed intervals is converted to an infiltration velocity, usually expressed in metres per day or centimeters per hour or centimeter per second. The minimum infiltration velocity is equivalent to the infiltration rate.

The aim of the three infiltration rate measurements was to measure the infiltration rate or the hydraulic conductivity of the different lithological layers found on the building site. The building site will comprise a workshop, fuel station, a carwash bay and other small buildings. The contamination risk assessment is therefore aiming to calculate the rate at which contaminated water from the building site may reach the aquifer. The travel time of water reaching the aquifer will depend on the travel time for the different lithologies on the site.

On the building site the first layer consists of Aeolian sand, followed by a quartz pebble and or gravel layer, a calcrete layer and a meta-basalt layer in depth. The sand, pebble and calcrete layers are thin layers. The depth of the sand layer varies across the site from 0.1m to some 2m depending on the topography. The quartz pebbles and gravel layer varies from 0.2 to 2.5 metres in thickness. The calcrete layer is expected to be on top of the meta-basalt and is in most cases absent to a maximum thickness of 1.1 metres in thickness.

In Test pit 1 the hydraulic conductivity of the sand layer was measured. In Test pit 2 the hydraulic conductivity of the calcrete layer was measured and in test pit 3 the hydraulic conductivity of the gravel layer was measured. Test pit 4 was dug to a depth of 2.2 metres without reaching the meta-basalt host rock. The hydraulic conductivity of the most important lithology namely the meta-basalt could therefore not be measured. In a number of trial pits calctrete was found without reaching the meta-basalt.

The infiltration rates of the test pit done for the study can be found described in Table 6 below. The position of this test pit can be found on Figure 9. The description of each test pit is below.

Test pit 01

The position was chosen to measure the infiltration rate of the wind blown sand. Very silty fine red sand was found to a depth of 0.40 meters. The hydraulic conductivity rate measured at this pit range from 6.3 to 6.8 m/d. The hydraulic conductivity rate can be rated as very fastwhich is typical of wind graded Aeolian sand.

Test pit 02

The position was chosen to be located central of the site. The aim was to measure the hydraulic conductivity of the calcrete formation.The calcrete formation started at a depth of 0.6m. The hydraulic conductivity rate measured at this pit range from 1.9 to 2.2 m/d which is medium to slow which is expected of calcrete.

Test pit 03

The aim of this test pit was to measure the hydraulic conductivity of the gravel material on site. Gravel formation was found at a depth of 0.85 metres. The hydraulic conductivity rate measured at this pit is in the order of 2.5 m/d.

Test pit 04

The aim of this pit was to measure the hydraulic conductivity of the meta-basalt. A pit with a depth of 2.2 metres was constructed without reaching meta-basalt. The meta-basalt is a competent rock even near surface with an expected low hydraulic conductivity. Fractures in the rock are cemented with calcrete which lowers the rate of weathering.

TABLE 6: Information ontest pits

Co- ordinates	Time period (Min)	Elapsed Time (Min)	Total Quantity of water (ml)	Infiltration rate (cm/s)	Infiltration rate (cm/h)	Infiltration rate (m/d)
Test Pit 1 -28.18569° 021.47461° Fine wind-blown sand	15	15	5500	8.096×10^{-3}	29.15	6.97
	15	30	5000	7.36×10^{-3}	26.50	6.33
	15	45	5000	7.36×10^{-3}	26.50	6.33
	15	60	5000	7.36×10^{-3}	26.50	6.33
	30	90	10200	7.507×10^{-3}	27.03	6.46
	30	120	10500	7.728×10^{-3}	27.82	6.65
	30	150	10500	7.728×10^{-3}	27.82	6.65
	30	180	10800	7.949×10^{-3}	28.62	6.84
	30	210	10700	7.875×10^{-3}	28.35	6.78
	30	240	10600	7.802×10^{-3}	28.09	6.71
Test Pit 2 -28.18569° 021.47402° Calcrete	15	15	1535	2.260×10^{-3}	8.14	1.94
	15	30	1700	2.502×10^{-3}	9.01	2.15
	15	45	1650	2.429×10^{-3}	8.74	2.09
	15	60	1500	2.208×10^{-3}	7.95	1.90
	30	90	3500	2.576×10^{-3}	9.27	2.20
	30	120	3300	2.429×10^{-3}	8.74	2.09
	30	150	3300	2.429×10^{-3}	8.74	2.09
	30	180	3250	2.392×10^{-3}	8.61	2.05
Test Pit 3 -28.18523° 021.47395° Gravel	15	15	3500	5.152×10^{-3}	18.55	4.43
	15	30	2500	3.68×10^{-3}	13.25	3.17
	15	45	2000	2.94×10^{-3}	10.60	2.53
	15	60	2000	2.94×10^{-3}	10.60	2.53
	30	90	4000	2.94×10^{-3}	10.60	2.53
	30	120	4000	2.94×10^{-3}	10.60	2.53
Test Pit 4 -28.185418° 021.474913° Meta Basalt	---	---	---	---	---	---

Figure 9: Map of proposed building area with test pit positions (green test pitsare from ARQ Consulting Engineers and red pits are from Geo-Logic)

5.7 Water quality

Eight water samples were taken from boreholes on Portion 6 of the farm Steenkampspan and around the farm. Boreholes BH 1, BH 2 and BH 3 are existing boreholes located on Steenkampspan. Borehole BH 5 and 8 are newly drilled boreholes also located on Steenkampspan. Boreholes H/BH 10 and H/BH 14 are located on the farm Duiker Rand which borders the southern boundary of Portion 6 of the farm Steenkampspan. Borehole H/BH 15 is located on Portion 3 of the farm Steenkampspan which is located north of Portion 6 of the farm Steenkampspan.

Borehole **BH 1** is located on the northern portion of the farm where the service buildings for the proving ground will be. This borehole is located 300 to 400 metres from the planned buildings. Currently this borehole is used for stock watering and is located at a kraal. A solar pump unit currently abstract water for stock watering. It is expected that the water of this borehole may be contaminated by kraal manure. This borehole was submitted to borehole yield testing procedures. The borehole can be used to supply 15.1m^3 of water per day for the development.

Borehole **BH 2**is located in the central part of Portion 6 of the farm Steenkampspan. This borehole is also located at a kraal and the water may be contaminated by the kraal. This borehole is equipped with a windmill which feeds water to six 10 000 l tanks. The water is used for stock watering. This borehole is reported to be a low yielding borehole. The borehole was not submitted to yield testing procedures. This borehole is not earmarked to be used for the proposed development.

Borehole **BH 3 and BH 4** are located at the southern part of Steenkampspan at a kraal. Borehole **BH 4** is equipped with a windmill which feeds water to a cement dam. The water is used for stock watering. Borehole **BH 3** is not equipped. This borehole is reported to be a low yielding borehole. This borehole was submitted to borehole yield testing procedures. The borehole is recommended to be used for stock watering.

Boreholes **BH 5 and BH 8** are newly drilled boreholes. They are located in the central part of Portion 6 of the farm Steenkampspan. They are both recommended to be used for the proposed development. No contamination source such as a kraal is located in a 1km radius from these boreholes.

Boreholes **H/BH 10 and H/BH 11**are located on the farm Duiker Rand. These two boreholes are located 43 metres apart. Borehole **H/BH 10** is a high yielding borehole that is not equipped. Borehole **H/BH 11** is equipped with a windmill and is used constantly for stock watering. Borehole **H/BH 10** was submitted to borehole yield testing procedures. The borehole can be used to supply 164m^3 of water per day for the development. Borehole H/BH 11 was not submitted to borehole yield testing procedures.

Borehole **H/BH 14** is located on the farm Duiker Rand just south of the farm boundary between Duiker Rand and the farm Steenkampspan. This borehole is located at a kraal and is equipped with a windmill. This borehole is used for stock watering.

Borehole **H/BH 15** is located on Portion 3 of the farm Steenkampspan. It is equipped with a solar pump. The water is used for domestic purposes and for stock watering.

Sample procedure and Classification

Where possible the water samples were taken at the end of the 24hour constant yield test. Samples were taken elsewhere at open pipes where windmills were delivering water into cement dams. The water samples were preserved and delivered to Aquatico Laboratories, an accredited water laboratory, to be analysed for water quality purposes. The analyses include the major cation and anions, Total Coliform Bacteria count and E. Coli count. The results of the chemical and bacteriological analyses performed on the groundwater sample are presented in Table 8. The quality of water is classified according to the SANS 241-1 and 2: 2011as in the Publication "South African National Standard"Part 1 and Part 2, SABS. Table 7 below gives the Risk guideline. Please refer to Appendix C for the original analyses from Aquatico Laboratories.

Table 7: Risk Guideline Legend

Aesthetic	Determinand that taints water with respect to taste, odour and colour and that does not pose an unacceptable health risk if present at concentration values exceeding the numerical limits specified.
Operational	Determinand that is essential for assessing the efficient operation of treatment systems and risks to infrastructure.
Acute Health - 1	Routinely quantifiable determinand that poses an immediate health risk if consumed with water at concentration values exceeding the numerical limits specified.
Acute Health - 2	Determinand that is presently not easily quantifiable and lacks infomration pertaining to viability and human infectivity which, however, does pose immediate unacceptable health risks if consumed with water at concentration values exceeding the numerical limits specified.
Chronic Health	Determinand that poses an unacceptable health risk if ingested over an extended period if present at concentration values exceeding the numerical limits specified.
(orange)	Exceeds Acute health - 1, Acute health - 2 and Chronic health guideline values
(yellow)	Exceeds only Operational and Aesthetic guideline values

Chemical Water Quality

The **Total Dissolved Solids** of boreholes BH 1, H/BH 10 and 11 and H/BH 14 are above the Standard limits of SANS 241.

The **chloride** levels in all the boreholes can be regarded as marginally high with only borehole H/BH 14 elevated above the SANS 241 Standard limits.The chloride levels give a relative idea of the groundwater recharge in an area. It also gives a relative idea of the age of the water if compared to each other. For instance boreholes that are used for a number of years in an arid region normally presents water with a higher level of chloride than newly drilled borehole in areas where water abstraction did not yet take place. An example of such a phenomena is borehole BH 8 with a chloride level of 120mg/l which is much lower than borehole BH 1 with a chloride level of 275mg/l which was used extensively for a long period. None of the boreholes earmarked for use for the development is above the Standard limits.

The **nitrate** levels of boreholes BH 1, BH 2, BH 8 and H/BH 10 is above the Standard limits of SANS 241. The risk for using this water for domestic use is Acute health 1 which means that it poses an immediate health risk if consumed. Boreholes BH 1, BH 8 and H/BH 10 are earmarked to be used for the proposed development.

The **calcium levels** of the water arehigh which may leads to high Calcium Carbonate in the water. The water in general of the boreholes earmarked to be used for the development can be regarded as hard which may result in an inability for soap to lather. It will also affect heating elements and will leave calcium carbonate traces on windows and washed surfaces. For road building the calcium carbonate load in the water will effectively help to bond soil particles. For domestic and industrial uses such as car wash and heating elements the water needs to be treated by reverse osmosis or chemical water softening.

None of the other chemical determinants analysed for reveals levels above the Standard limits.

Bacteriological Water Quality

The E.coli count of the water analysed for is below detection limits. The Total coliform bacteria count of boreholes BH 1, BH 3 and H/BH 14is above the Standard limits and need to be chlorinated prior to human consumption.

Table 8: Water quality of boreholes analysed.

Determinant	Unit	Risk	Standard limits	BH 1	BH 2	BH 3	BH 5	BH 8	H/BH 10 and 11	H/BH 14	H/BH 15
pH value at 25 C	pH units	Operational	≥ 5 to ≤ 9.7	7.42	8.31	7.63	7.69	7.25	7.61	8.35	7.88
Electrical Conductivity at 25 C	mS/m	Aesthetic	≤ 170	192	125	115	137	140	156	163	120
Total Dissolved Solids	mg/ℓ	Aesthetic	≤ 1200	1263	965	860	881	857	1245	1240	895
Total alkalinity	Mg CaCO3/l			298	327	367	353	268	427	373	420
Chloride as Cl	mg/ℓ	Aesthetic	≤ 300	275	167	121	139	120	221	321	151
Sulphate as SO4	mg/ℓ	Acute health - 1	≤ 500	95.6	75.0	54.8	72.3	70.1	78.3	104	33.9
Nitrate (NO3) mg/ℓ N	mg/ℓ	Acute health - 1	≤ 50	77.7	51.2	41.1	41.6	50.8	64.2	40.5	35.8
Ammonia as N	mg/ℓ	Aesthetic	≤ 1.5	0.036	0.034	0.029	0.02	0.104	0.025	0.045	0.022
Orthophosphate (PO4) as P	mg/ℓ			0.097	0.045	0.045	0.079	<0.002	0.045	0.041	0.047
Fluoride as F	mg/ℓ	Chronic health	≤ 1.5	0.714	0.567	0.914	0.409	0.473	0.879	0.687	0.520
Calcium as Ca	mg/ℓ			191	134	108	140	145	149	128	157
Magnesium as Mg	mg/ℓ			89.2	75.4	62.4	57.5	59.6	97.0	91.9	57.5
Sodium as Na	mg/ℓ	Aesthetic	≤ 200	78.8	79.4	98.4	66.1	66.9	162	176	75.1
Potassium as K	mg/ℓ			7.07	6.61	8.92	6.46	6.41	10.6	12.0	6.10
Aluminium as Al	mg/ℓ	Operational	≤ 0.3	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Iron as Fe	mg/ℓ	Chronic health	≤ 2	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004
Manganese as Mn	mg/ℓ	Chronic health	≤0.5	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Chemical oxygen demand (COD)	mg/l			<5.1		<5.1	<5.1	17.2			
Oil and grease (SOG)	mg/l			1.9		2.0	1.7				
E.coli	CFU/100mℓ	Acute health – 1	Not detected	<1	<1	<1	<1	<1	<1	<1	<1
Total coliform	CFU/100mℓ	Acute health - 2	≤10	14	<1	350	6	<1	1	130	3
Total hardness	mg$CaCO_3$/ℓ			844	648	527	587	608	698	697	628

6. HYDROGEOLOGICAL ASSESSMENT

6.1 Groundwater Level Depth

The “static” water level depth information of 26 boreholes was available in the area. From the water level depth data it can be seen that the water level depth on the farm Steenkampspan range from 23.15mbgl to 26.5mbgl. One borehole namely borehole BH 2 presents a water level depth of 51.4mbgl. This is an anomalous data point if compared to the other boreholes which present a median level of 24.85mbgl.

The water level depth as measured in boreholes located on the farms around the proposed development site range from 16.82mbgl on the farm Duiker Rand in borehole H/BH 10 to 46.5mbgl in borehole H/BH 18 on Portion 3 of the farm Steenkampspan.

From the water level depths it is clear that the boreholes located on or near catchment boundaries which are located along the topographical high areas present water level depths of 20 to 30 metres deeper than boreholes located topographically lower in regional valleys. For instance borehole H/BH 10, which is located in a large regional valley, presents a water level depth of only 16.82 metres and borehole H/BH 18 which is located on a quaternary catchment boundary presents a water level depth of 46.50mbgl.

6.2 Groundwater contours

The water level depths of the 26 boreholes were used to generate groundwater contours. Figure 11 show the surface contours, groundwater contours and the groundwater flow directions. From the data available it can be seen that the water level elevation to a large degree follow the surface contours. It is important to note that the groundwater contours have a 5 metres interval and the surface contours have a 10 metre interval. The groundwater level depth increase towards the topographical high areas and decrease towards topographical low areas.

From this information an important assumption can be made that the aquifers located in the topographical low areas will be much more productive in terms of yields and will have a much higher sustainability in terms of long term water abstraction. The main reason for this is that the high water tables in the valleys forms a thicker aquifer with deeper saturated weathered host rock.

6.3 On Site Surface Water Drainage and Groundwater Movement

From the above section it is clear that ground water movement to a large degree is perpendicular to the surface contours. Groundwater movement will be in a southern direction towards the Orange River.

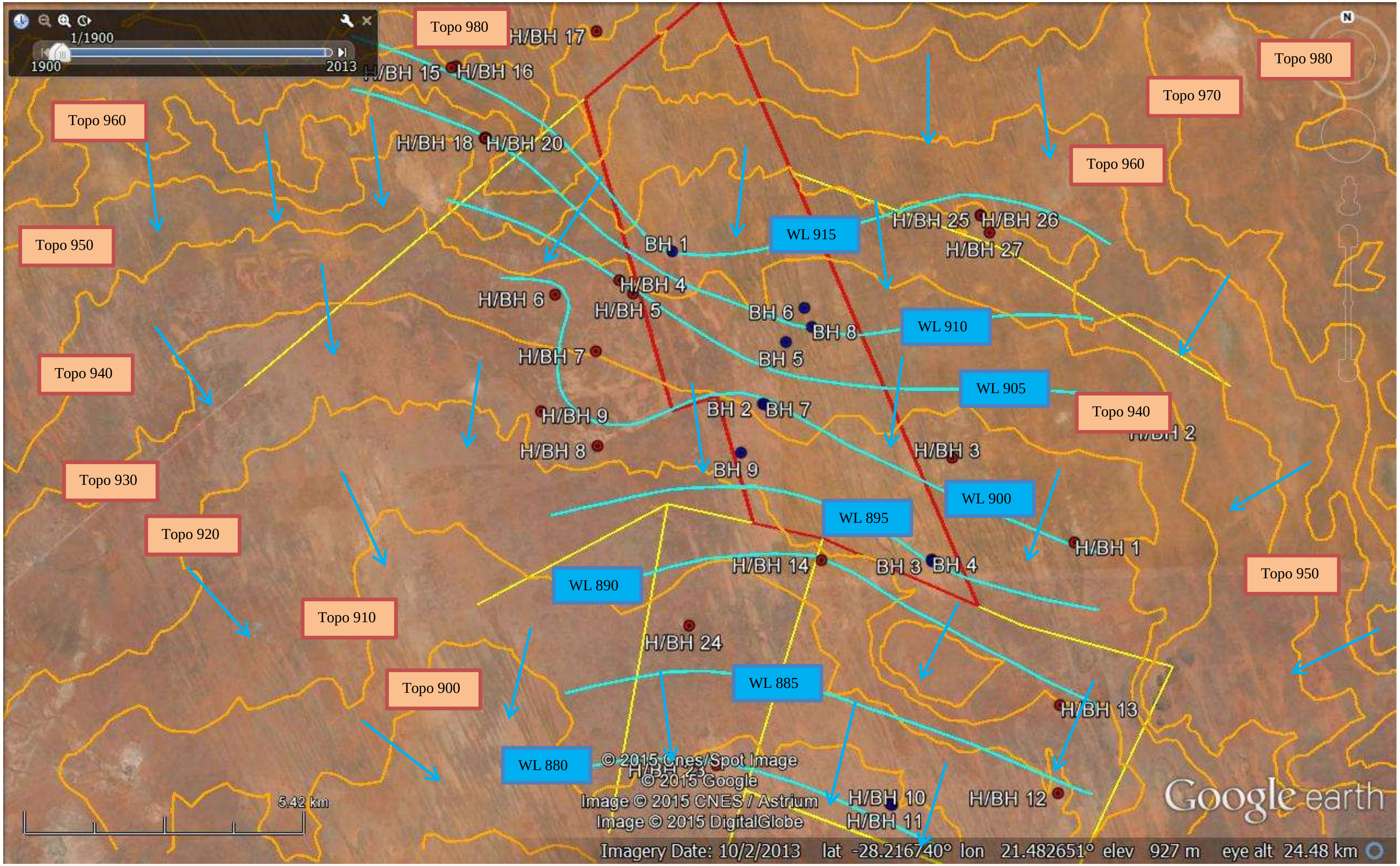

Figure 11: Surface and groundwater contours with groundwater flow directions (light blue arrows)

6.4 Groundwater catchment areas

The proposed development Portion is located in the upper end of quaternary drainage region D73E. Refer to Figure 12 for the location in the quaternary drainage region. On Figure 12 the Quaternary boundary between drainage region D42D and D73E is indicated in green. In quaternary drainage region D42D groundwater and surface water drains towards the north to the Kuruman River. In quaternary drainage region D73E groundwater and surface water drains towards the south to the Orange River.

From the assumptions above in section 6.2 and section 6.3 and the use of the surface contours a groundwater catchment area for the production boreholes on site was generated. The proposed production boreholes can gain water from this catchment area. Groundwater movement from groundwater recharged in this area will be towards the boreholes which can gain water from the aquifer.

The groundwater recharge area or catchment area for the proposed production boreholes for the proposed development can be seen as an area encircled with a dark blue line on Figure 12. All ground water recharged in this area will flow towards the proposed production boreholes. The dark blue arrows show the groundwater movement directions in the delineated groundwater catchment area. Theoretically the production boreholes can gain water from inside the delineated catchment area. The light blue arrows show groundwater movement directions outside the delineated groundwater catchment area from which the proposed production boreholes cannot gain water. The delineated catchment has a surface area of 288.6km^2.

Groundwater movement is not inhibited by man made boundaries but is mainly constrained by the geology and the topography. For groundwater use licence purposes man made boundaries must be used to calculate volumes available on a specific portion of land. For sustainability calculation purposes the surface area of the groundwater catchment which is 288.6km^2 must be considered.

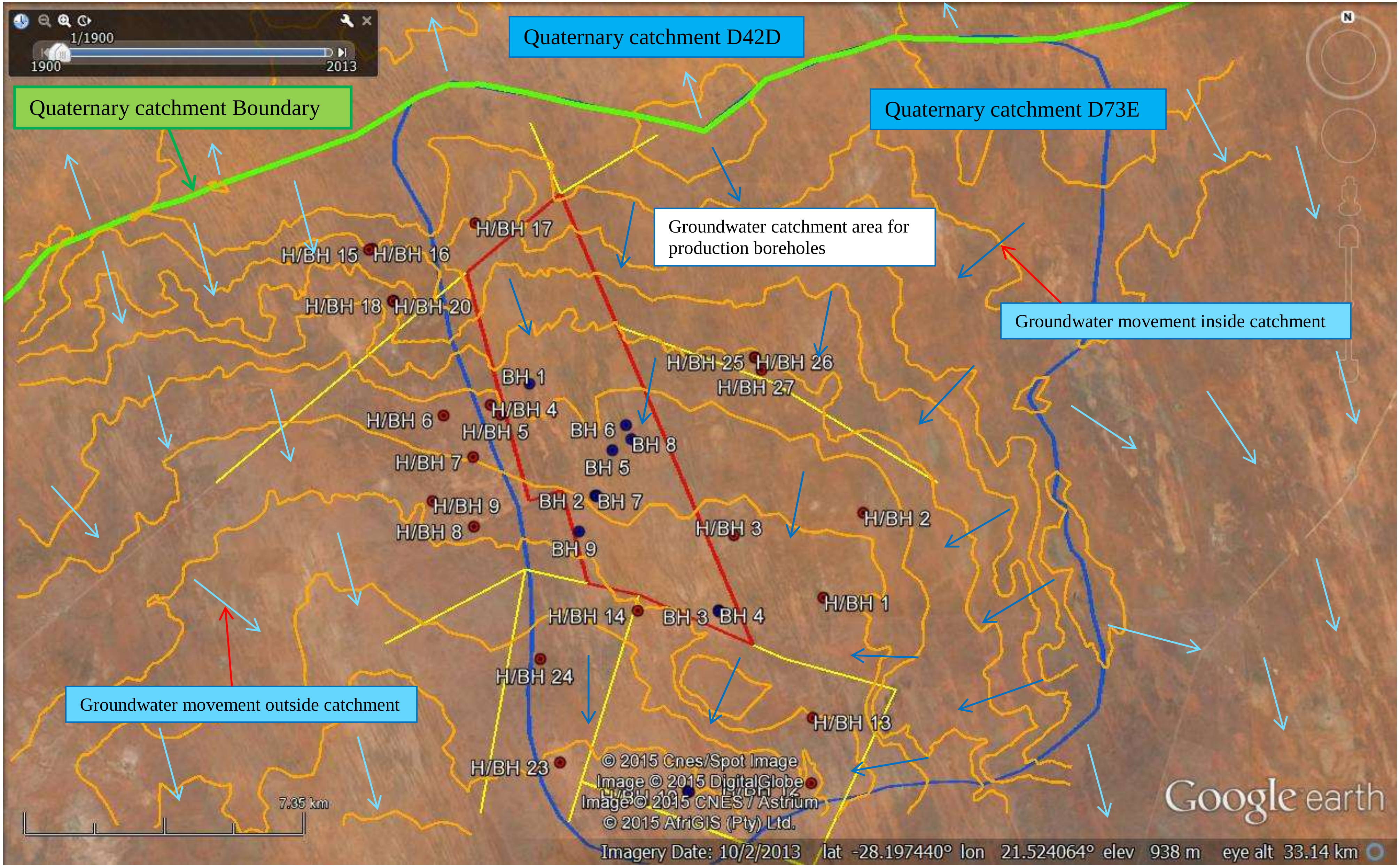

Figure 12: Groundwater catchment area for proposed production boreholes.

6.5 Groundwater demands

The water demand on the aquifer of the delineated catchment area during construction phases1 and 2 will be 348.4m^3/d.The two construction phases will be 22 months in total. During the 22 months the water demand on the aquifer will be 229 944m^3.The water demand of all the existing boreholes located in the groundwater catchment area was taken into consideration. Refer to Table 9 below. The recommended abstraction volumes were used for the proposed production boreholes for the development. The water demand of the other boreholeslocated in the catchment area was estimated as per information gathered during the hydro-census.The water demand on the aquifer of the delineated catchment area during the operational phase of the project will be 58.4m^3/d for12 months of the year. The water demand on the production boreholes for the development will be 10m^3/d for 12 months of the year during the operational phase. The farming activity on the farm will use 6m^3/d as calculated for boreholes BH 2, 3 and 4.

Table 9: Water demand on all boreholes located in delineated catchment area

BH number and use	Equipment	Water use in m^3/d during construction phases	Water use in m^3/d during operational phase
BH 1 (Development Borehole)	**Motorized**	**15.1**	**10**
BH 2, 3 and 4 (Steenkampspan farm use)	Windmills	6.0	6.0
BH 5 (Development Borehole)	**Motorized**	**25.9**	**0.0**
BH 8 (Development Borehole)	**Motorized**	**95**	**0.0**
H/BH 1 (Kenilworth)	Solar submersible	4.0	4.0
H/BH 2 (Kenilworth)	Solar submersible	4.0	4.0
H/BH 3 (Kenilworth)	Solar submersible	4.0	4.0
H/BH 4 (Remainder Steenkampspan)	Windmill	3.2	3.2
H/BH 5 (Remainder Steenkampspan)	Solar submersible	4.0	4.0
H/BH 10 (Development Borehole)	**Motorized**	**164**	**0.0**
H/BH 11 (Duiker Rand)	Windmill	3.2	3.2
H/BH 12 (Duiker Rand)	Windmill	3.2	3.2
H/BH 13 (Duiker Rand)	Windmill	3.2	3.2
H/BH 17 (Portion 3 Steenkampspan)	Windmill	3.2	3.2
H/BH 23 (Portion 1 Rooikoppies)	Windmill	3.2	3.2
H/BH 24 (Portion 1 Rooikoppies)	Windmill	3.2	3.2
H/BH 25 (Ceres)	No equipment	0.0	0.0
H/BH 26 (Ceres)	No equipment	0.0	0.0
H/BH 27 (Ceres)	Solar submersible	4.0	4.0
Water demand on 4 boreholes for development in m^3/d		**300**	**10**
Total demand on delineated catchment areain m^3/d		348.4	58.4
Total demand on delineated catchment area in m^3/a		127 166	21 316

6.6. Available groundwater resources

During the calculations for the sustainability of the aquifer from which water will be abstracted for the proposed development, a number of methods and data sources were used. The main source of groundwater availability related information was sourced from the DWS document "Groundwater Assessment Phase 2 Project". Information such as Harvest potential, Groundwater recharge during wet and dry periods, Resource potential during wet and dry periods and Exploitation potential could be used.

The groundwater recharge program developed by the Groundwater Institute of the University of the Free State was used to calculate groundwater recharge according the Chloride, Soil, Vegter, Acru and Harvest potential methods. These different methods were weighed according certainty to be able to give groundwater recharge values that have a high certainty rating. Throughout the calculation process conservative assumptions were used. Although a groundwater recharge of 1mm/a was finally achieved, a groundwater recharge figure of 0.5mm was used for the final calculations in the recharge program. All the methods and groundwater related volumes calculated during the study are contained in Table 10.

The following final figures were used in Table 10.

- The surface areas of Steenkampspan and Duiker Rand were used in the calculations to calculate the different volumes for the farm portions.
- The surface area for the delineated groundwater catchment area that will feed the production boreholes is 288.6km^2.
- The surplus and deficit calculations were made on the assumption that the catchment area for the aquifer is 288.6km^2.
- The Mean Annual Precipitation (MAP) for the area is 155.4mm/a. This figure was used during all calculations.
- A groundwater volume in storage of 243 662 m^3/km^2 was used during calculations.
- A Storativity value of 0.000439 and a Specific yield of 0.002867 were used for the aquifer.

Volume of water stored in Aquifer

The volume of water stored in the aquifer formed on **Portion 6 of the farm Steenkampspan** is 9 095 227m^3. The water demand on the 6 boreholes (BH 1, 2, 3, 4, 5 and 8) located on Portion 6 of Steenkampspan will be 142.0m^3/d or 51 830m^3/a. For the 22 months (660 days) of the construction phases93 720m^3 of water will be abstracted which is 1.03% of the water in storage on Portion 6 of the farm Steenkampspan.

The volume of water stored in the aquifer formed on **Duiker Rand** is 8 348 172m^3. The water demand on the 4 boreholes (BH 10, 11, 12 and 13) located on Duiker Rand will be 173.6m^3/d or 63 364m^3/a. For the 22 months (660 days) of the construction phase 114 576m^3 of water will be abstracted from these boreholeswhich is 1.4% of the water in storage on Duiker Rand.

The Volume stored in the **Delineated catchment area** is 70 320 853m^3. The water demand on the aquifer will be 348.4m^3/d or 127 166m^3/a. For the 22 months (660 days) of the construction phase 229 944m^3 of water will be abstracted from the aquifer which is 0.33% of the water in storage in the aquifer of the **Delineated catchment area**.

Harvest potential

The harvest potential figure is normally expressed in m^3/km^2/a. For **Portion 6 of the farm Steenkampspan** 132 448m^3 can be abstracted per annum. The water demand of the 6 boreholes located on Portion 6 of Steenkampspan will be 142.0m^3/d or 51 830m^3/awhich is 39.1% of the harvest potential figure.

For **Duiker Rand** 121 559m^3 can be abstracted per annum. The water demand of the 4 boreholes located on Duiker Rand will be 173.6m^3/d or 63 364m^3/a which is 52.1% of the harvest potential figure.

For the **Delineated catchment area** the Harvest Potential is calculated at 1 023 953m^3. The water demand on the delineated catchment area aquifer will be 348.4m^3/d or 127 166m^3/a which is 12.4% of the harvest potential figure.

Groundwater recharge

The groundwater recharge of 0.17mm/a (lower end) and 0.27 (upper end) gives a lower end groundwater recharge for **Steenkampspan** as 6 454m^3/a and the upper end recharge as 10 078m^3/a. The water demand of the 6 boreholes located on Portion 6 of Steenkampspan will be 51 830m^3/a. The groundwater recharge is 12.5% of the water demand for this farm if the lower end of recharge is used and 19.4% if the upper end of recharge is used.

If 0.5mm/a recharge is used the groundwater recharge will be 18 663m^3/a which means that that groundwater recharge is 36.0% of the water demand. If the 22 months construction period is used the water demand will be 93 720m^3 for construction after which groundwater recharge will need5.0 years to replenish the aquifer. If 0.17mm/a is used the aquifer needs 15.5 years to recover.

The groundwater recharge of 0.17mm/a (lower end) and 0.27 (upper end) gives a lower end groundwater recharge for **Duiker Rand** as 5 824m^3/a and the upper end recharge as 9 250m^3/a. The water demand on the 4 boreholes located on Duiker Rand will be 63 364m^3/a. The groundwater recharge is 9.2% of the water demand for this farm if the lower end of recharge is used and 14.6% if the upper end of recharge is used.

If 0.5mm/a recharge is used the groundwater recharge will be 17 131m^3/a which means that that groundwater recharge is 27.0% of the water demand. If the 22 months construction period is used the water demand will be 114 576m^3 for construction after which groundwater recharge will need 6.7 years to recover the aquifer. If 0.17mm/a is used for groundwater recharge, the aquifer needs 19.7 years to recover.

The groundwater recharge of 0.17mm/a (lower end) and 0.27 (upper end) gives a lower end groundwater recharge for the **Delineated catchment area** as 49 639m^3/a and the upper end recharge as 80 231m^3/a. The water demand of all the boreholes in the catchment area will be 348.4m^3/d or 127 166m^3/a. The groundwater recharge is 39.0% of the water demand for this catchment area if the lower end of recharge is used and 63.0% if the upper end of recharge is used. If 0.5mm/a recharge is used the groundwater recharge will be 144 300m^3/a, which means that that groundwater recharge is 113% of the water demand.

Average groundwater resource potential

For **Portion 6 of the farm Steenkampspan** the Average groundwater resource potential is 63 453m^3/annum as a minimum and 67 403m^3/annum as a maximum. The water demand of the 6 boreholes located on Portion 6 of Steenkampspan will be 51 850m^3/a, which is lower than the minimum and maximum resource potential figure.

For **Duiker Rand**the Average groundwater resource potential is 58 244m^3 as a minimum and 61 842m^3 as a maximum. The water demand on the 4 boreholes located on Duiker Rand will be 173.6m^3/d or 63 364m^3/a, which is slightly less than the minimum and maximum resource potential figures.

For the **Delineated catchment area** the Average groundwater resource potential is 490 620m^3 as a minimum and 520 923m^3 as a maximum. The water demand of all the boreholes in the catchment area will be 348.4m^3/d or 127 166m^3/a which is much lower than the minimum and maximum Average groundwater resource potential figures.

From the data available and the different methods discussed above it can be seen that during the 22 months of water abstraction for the 2 construction phases:

- That 1.03% of the volume of water stored in the aquifer of **Steenkampspan** farm will be needed.
- That 1.4% of the volume of water stored in the aquifer of **Duiker Rand** will be needed.
- That 0.33% of the volume of water stored in the larger **Delineated catchment aquifer** will be needed if the larger catchment area is used for calculation purposes.
- That 39.1% of the harvest potential will be used of the **Steenkampspan** aquifer per annum.
- That 52.1% of the harvest potential will be used of the **Duiker Rand** aquifer per annum.
- That 12.4.1% of the harvest potential will be used of the **Delineated catchment aquifer** per annum.
- That if a groundwater recharge figure of 0.17mm/a is used for **Steenkampspan,** the groundwater water recharge will be 12.5% of the water demand.

- That if a groundwater recharge figure of 0.27mm/a is used for **Steenpampspan**, the groundwater water recharge will be 19.4% of the water demand.
- That if a groundwater recharge figure of 0.5mm/a is used for **Steenpampspan**, the groundwater water recharge will be 36.0% of the water demand.
- That if a groundwater recharge figure of 0.17mm/a is used for **Duiker Rand**, the groundwater water recharge will be 9.2% of the water demand.
- That if a groundwater recharge figure of 0.27mm/a is used for **Duiker Rand**, the groundwater water recharge will be 14.6% of the water demand.
- That if a groundwater recharge figure of 0.5mm/a is used for **Duiker Rand**, the groundwater water recharge will be 27.0% of the water demand.
- That if a groundwater recharge figure of 0.17mm/a is used for the **Delineated catchment area**, the groundwater water recharge will be 39.0% of the water demand.
- That if a groundwater recharge figure of 0.27mm/a is used for the **Delineated catchment area**, the groundwater water recharge will be 63.0% of the water demand.
- That if a groundwater recharge figure of 0.5mm/a is used for **Delineated catchment area**, the groundwater water recharge will be 113% of the water demand.
- The water demand per annum on **Steenkampspan** is 81.7% of the Minimum groundwater resource potential.
- The water demand per annum on **Duiker Rand** is 108% of the Minimum groundwater resource potential.
- The water demand per annum on the **Delineated catchment area** is only 25.9% of the Minimum groundwater resource potential for the catchment.

Table 10: Groundwater potential in Quaternary Catchment D73E (Surface area 3873km^3)

Information source	Measurement Unit	Total Volume of water in Quaternary Catchment aquifer D73E(m^3)	Volume in Quaternary Catchment aquifer D73E per square kilometre (m^3/km^2)	Volume (mm/a)	Volume in (m^3)on Steenkampspan3 7.327185km^2	Volume in (m^3)on Duiker Rand 34.261280km^2	Volume in (m^3) on Delineated groundwater recharge area of 288.6km^2	Surplus or deficit if a volume of 127 166m^3 per annum is abstracted for the construction phase on the delineated catchment area
DWS) "Groundwater Assessment Phase 2 Project"	Volume of water stored in aquifer	943 704 000m^3	**243 662**	---	9 095 227m^3	8 348 172m^3	70 320 853m^3	70 193 687
	5m Drawdown Storage Volume	55 411 900m^3	**14 307**	---	534 049m^3	490 176m^3	4 129 000m^3	---
		(m^3/a)	**(m^3/km^2/a)**	**(mm/a)**	**(m^3/a)**	**(m^3/a)**	**(m^3/a)**	**(m^3/a)**
(DWS) "Groundwater Assessment Phase 2 Project"	Harvest Potential	13 742 600	**3 548**	---	132 448	121 559	1 023 953	+896 787
	Mean Annual Potential Recharge (Dry Season) (MAPR)	669 721	**172**	0.17	6345.6	5824	49 639	-77 527
	Mean Annual Potential Recharge (Wet Season) (MAPR)	1 077 800	**278**	0.27	10 078	9 250	80 231	-46 935
	Average Groundwater Resource Potential (Dry season) (AGRP)	6 583 860	**1700**	---	63 453	58 244	490 620	+363 454
	Average Groundwater Resource Potential (Wet season) (AGRP)	6 993 610	**1805**	---	67 403	61 842	520 923	+393 757
	Groundwater Exploitation Potential (Dry) (GEP)	1 644 350	**425**		15 848	14 561	122 655	-4 511
	Groundwater Exploitation Potential (Wet) (GEP)	1 751 530	**452**		16 880	15 486	130 447	3 281
	Utilizable Groundwater Resource Potential (Dry) UGRP	10 592 700	**2735**		102 090	93 705	789 321	+662 155
	Utilizable Groundwater Resource Potential (Wet) UGRP	10 999 300	**2840**		106 009	97 302	819 624	+692 458
	Utilizable Groundwater Exploitation Potential (Dry) UGRP	2 617 070	**676**		25 233	23 160	195 094	+67 928
	Utilizable Groundwater Exploitation Potential (Wet) UGRP	2 723 010	**703**		26 241	24 086	202 886	+75 720
Recharge program to estimate Groundwater recharge. G van Tonder and Y. Xu	Calculated Groundwater recharge	---	---	0.5	18 663	17 131	144 300	+17 134
	Phase 1 Total Water demand of 300m^3/d in 12 months (164m^3/d on Duiker Rand and 136m^3 on Steenkampspan)				49 640 m^3/a	59 860m^3/a		

6.7. Water level draw down calculations for the 22 months water abstraction period.

During the water abstraction period spanning over 22 months the worst case scenario will be a 22 months continuous abstraction without a rest period between phase 1 and phase 2 construction. Theoretically the boreholes will start to impact on each other with a resulting regional water level draw down.

If a rest period between the phases is allowed, the regional water level will start to recover and will therefore minimize the total water level draw down for the aquifer. The groundwater level impact calculations for the continuous pumping period of 22 months were calculated to be able to have the maximum impact figures. This was done by using the information such as storativity and transmissivity parameters, available draw down figures, water strike depth and aquifer yields which was gathered during the drilling and yield testing phases of the study. The Flow Characteristic method and Theis formula was used to calculate the individual expected draw-downs for the individual impacted boreholes. The accumulative draw-down figures are represented in Table 11 below.

The largest water level daw down is expected at borehole H/BH 5 which is 0.57m over the 22 month period. It must be remembered that the production borehole BH 1 which is located 1.127km from borehole H/BH 5 is already in use for many years. The expected impact that borehole BH 1 pose on H/BH 5 is therefore already been imposed. The impact on borehole H/BH 4 will therefore be less than calculated in Table 11.

The expected impact to be imposed by the water abstraction for the development for the 22 month construction period range from 0.0m to 0.57m which can be regarded as small. The low impact is mainly due to the large distances between the individual production boreholes. The prosed abstraction rates are also limited. The third positive factor is the short period of expected abstraction of water for the aquifer. Due to the expected low water level draw-downs that range between 0.0m and 0.57m for the individual boreholes, very limited borehole yield fluctuations on the impacted boreholes are expected. A maximum lowering in yield of 2.3% is expected in borehole H/BH 5 if an aquifer thickness of 25 metres is used for calculation purposes. The lowering of water levels expected for the boreholes involved can be regarded as acceptable if the short span of 22 months is taken into consideration. The lowering of the water levels will be gradual and will only realize during the last part of the 22 months. The recovery of the water table will be slow in general due to the low groundwater recharge volumes in the region.

Table 11: Table illustrating the maximum cumulative water level draw-down in the effected boreholes.

Production Borehole Number	Maximum radius of influence (m)	Boreholes influenced by water abstraction Distance from production borehole in m (Water level draw down in m at the end of the 22 month water abstraction period)												
		H/BH 1	**H/BH 3**	**H/BH4**	**H/BH 5**	**H/BH 6**	**H/BH 7**	**H/BH 12**	**H/BH 13**	**H/BH 14**	**H/BH 23**	**H/BH 24**	**H/BH 25 and 26**	**H/BH 27**
BH 1	1407	9 663 (0)	6 802 (0)	1 172 (0.19)	1 127 (0.3)	2 422 (0)	2 434 (0)	12 947 (0)	11 584 (0)	6 609 (0)	9 973 (0)	7 268 (0)	6112 (0)	6257 (0)
BH 5	5127	6832 (0)	3908 (0.06)	3468 (0.09)	3132 (0.12)	4604 (0.03)	3709 (0.08)	10 217 (0)	8 856 (0)	4308 (0.04)	8 373 (0)	5 845 (0)	4 554 (0.03)	4 540 (0.03)
BH 8	6170	6 626 (0)	3 732 (0.14)	3 904 (0.14)	3 539 (0.15)	5 045 (0.06)	4 257 (0.14)	10 257 (0)	8 740 (0)	4 529 (0.03)	8 718 (0)	6 260 (0)	3 963 (0.12)	3 946 (0.12)
H/BH 10	4429	6 167 (0)	6 824 (0)	11 474 (0)	11 116 (0)	11 867 (0)	10 505 (0)	3 247 (0.34)	3 813 (0.16)	4 900 (0)	3 493 (0.28)	5 226 (0)	11 615 (0)	11 259 (0)
Total cumulative draw down at the end of the 22 month water abstraction period		**0**	**0.2**	**0.4**	**0.57**	**0.09**	**0.22**	**0.34**	**0.16**	**0.07**	**0.28**	**0**	**0.15**	**0.15**

7. CONTAMINATION RISK ASSESSMENT

7.1 Parsons Rating System

The "Parsons Rating System" is an aquifer classification system developed to implement a strategy for managing groundwater quality in South Africa. Classification, vulnerability and susceptibility are rated for a specific aquifer to be studied. This system gives a classification on a regional scale which normally is seen as such.

a) Aquifer Classification

The aquifer at the proposed development area is classed as a **poor** aquifer region and can be described as a low to moderately yielding aquifer system of variable water quality.

b) Aquifer vulnerability

A **least** tendency or likelihood does exist for contamination to reach a specific position in the groundwater system after introduction at some location above the uppermost aquifer.

c) Aquifer susceptibility

The aquifer is rated to have a **low** susceptibility. Susceptibility is a qualitative measure of the relative ease with which a groundwater body can be potentially contaminated by anthropogenic activities and includes both aquifer vulnerability and the relative importance of the aquifer in terms of its classification.

d) Groundwater Quality Management Classification

The **GQM index of this option is rated at 2**, with a **low**protection level needed.

7.2 Water resources

The existing boreholes (Refer to Table 1) in the region are used for life stock farming. The four boreholes BH 1, BH 5, BH 8 and H/BH 10 are earmarked to be used for the proposed development.

7.3 Assessment of the vulnerability of the underground water resources

Three sites on the planned development can from a geohydrological point of view be regarded as sensitive areas in terms of groundwater pollution. Refer to figure 13 for the location of these sites. A borrow pit may be established in the south eastern corner of Portion 6 of Steenkampspan. The borrowpit will be used to source calcrete to a depth of 2 metres. This material will be G7 to G10 material and will be used as bulk filling. A quarry is planned to be located on the western boundary of the site and may mine G1 to G5 material for base and subbase material and asphalt paving. This quarry may be 10 to 15metres in depth.

Each of the three sites will be discussed in terms of its vulnerability, existing treats to groundwater quality, risk from surface contamination and the position in respect of domestic water sources.

1. **Borrow pit**

The borrow pit area may be located in the most southern corner of the site. The borrow pit will be an estimated 2 metres deep and will deliver sand and calrete to be used as base fill material. The water level is 23 metres below ground level as measured in borehole BH 3 and BH 4. If the borrow pit is mined to a level of 2 metres below ground level the water table will be 21 metres below the bottom of the pit. Refer to Figure 13 below for the conceptual hydrogeological model of the borrow pit. Groundwater flow will be from north to south. The geology below the site is expected to be Sand Calcrete and Meta-basalt in depth. Borehole BH 3 and 4 are located in the area earmarked for the borrow pit. Borehole BH 3 proofed to be very low yielding. The aquifer below borehole BH 3 is therefore expected to be low yielding aquifer with limited fracturing in the host rock.

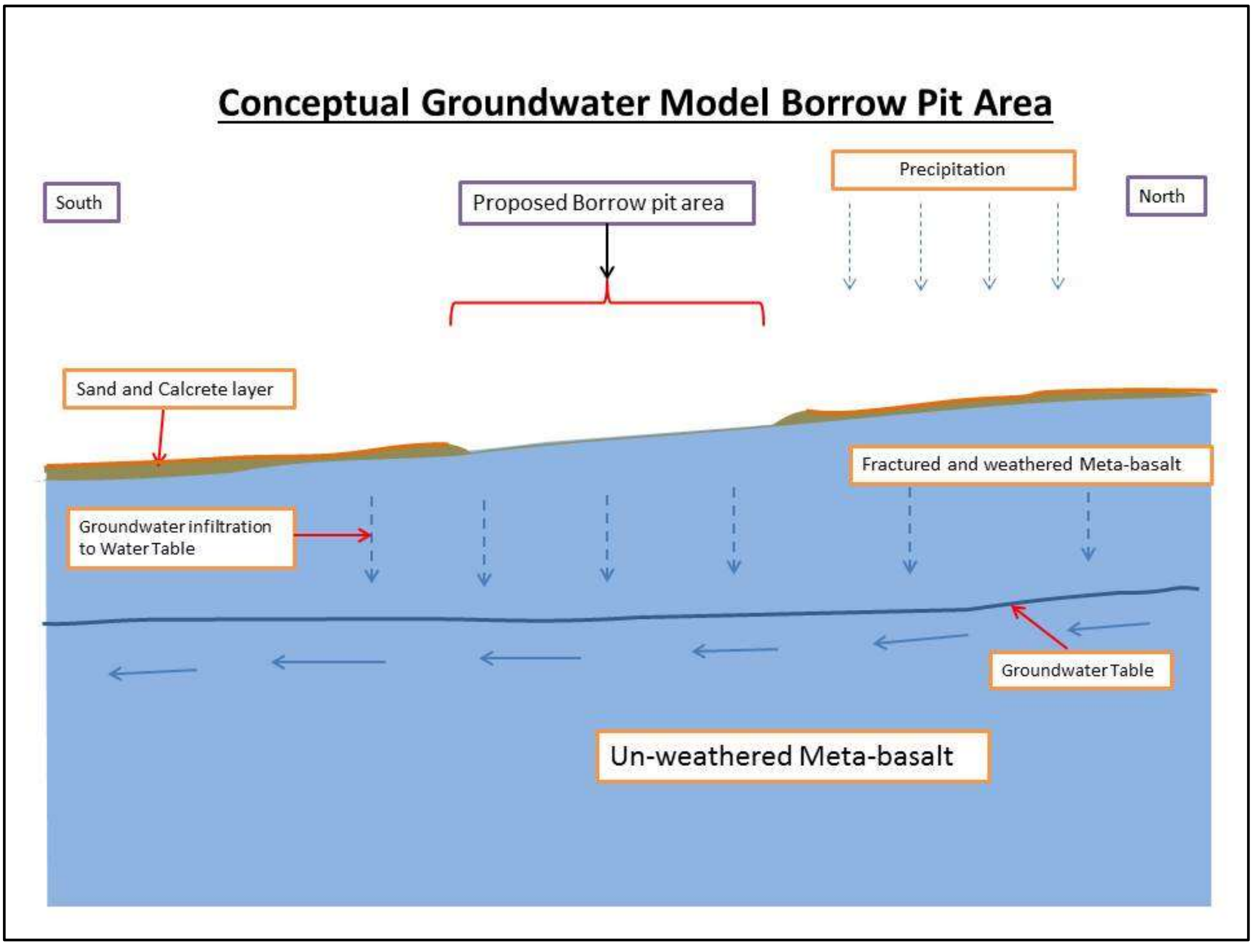

Figure 13: Conceptual hydrogeological model of Borrow pit.

2. Quarry area

The Quarry area may be located near the western boundary of the farm. The Quarry area will be an estimated 10to 15 metres deep and will deliver G1 to G5 material for road construction purposes. The water level is expected to be 26 to 27 metres below ground level as interpreted from the groundwater contour map. Borehole BH 9 was drilled next to the quarry to a depth of 150metres. No water strike was encountered in this borehole. No water level could be measured in this region. It is expected that groundwater movement in this region of the site in the Blaubosch Granite will be limited due to the un-weathered state of the host rock.

If the Quarry pit is mined to a level of 10to 15 metres below ground level the water table will be between 12 to 17 metres below the bottom of the pit. Refer to Figure 14 below for the conceptual hydrogeological model of the Quarry area. Groundwater flow will be from north to south. The geology below the site is expected to be Blaubosch Granitefrom surface to depth.The aquifer below the Quarry area is expected to be a very low yielding aquifer with limited fracturing in the host rock. The contamination risk for this site is very low due to limited groundwater movement.

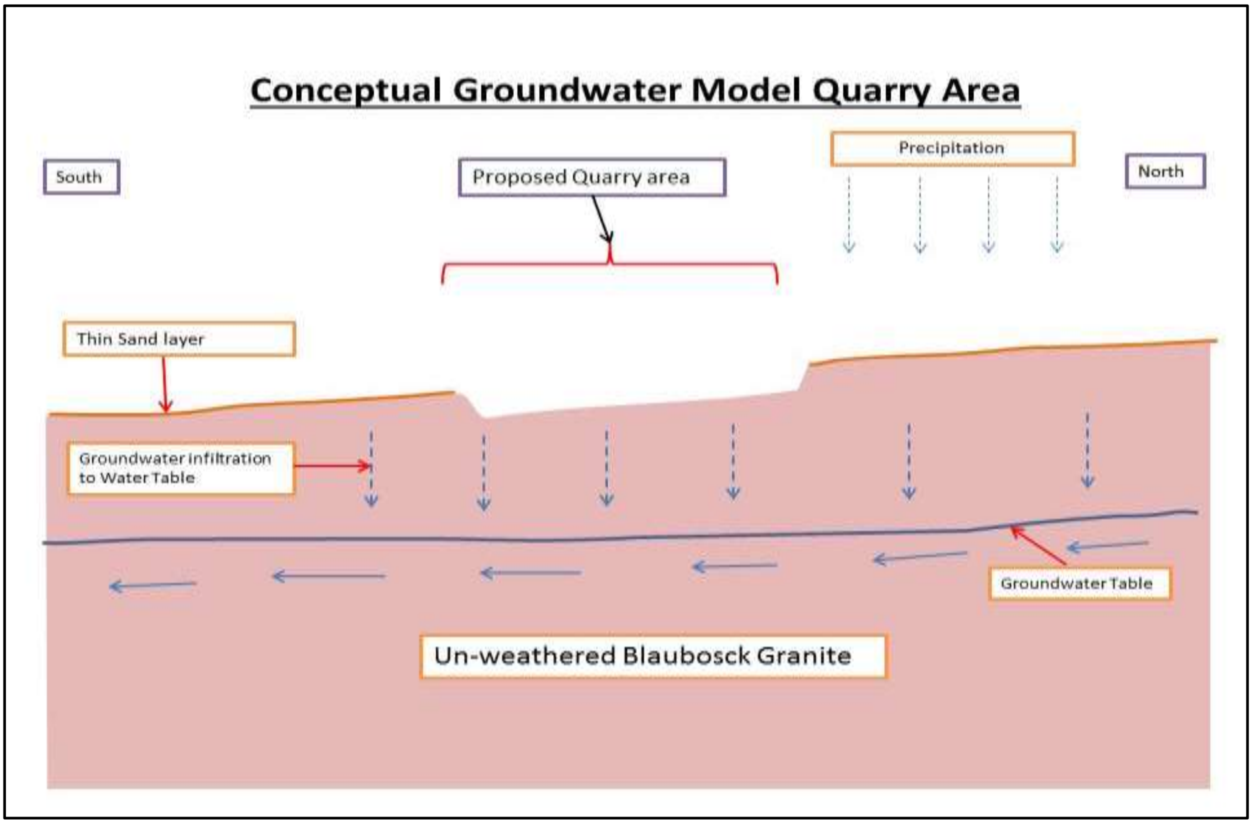

Figure 14: Conceptual hydrogeological model of Quarry area

3. Building Area

The Building area will be located near the western boundary of the farm in the central northern part of the farm. The building area will be a filled and compacted area. The buildings will include an office and workshop building with an oil separator, a logistic area, car wash with an oil separator, mobile fuel station with above ground storage tanks with a capacity of 8 X 3000l. The oil separator will be emptied on a 10 day interval.

The water level is expected to be 25 metres below ground level as interpreted from the groundwater contour map. Borehole BH 1,an existing borehole that is currently used for stock watering is located 300 metres to the east of the proposed building site. Borehole BH 1a low yielding borehole recommended to be used for the building site, can deliver 0.35l/s for 12h/d.

The building site will be slightly elevated by cutting away the sandy and gravel material and re-filling and compacting the material with a mix of more competent material. Fuel storage will be above the ground. The sewerage conservancy tanks will be below ground. Refer to Figure 14 below for the conceptual hydrogeological model of the Building area.

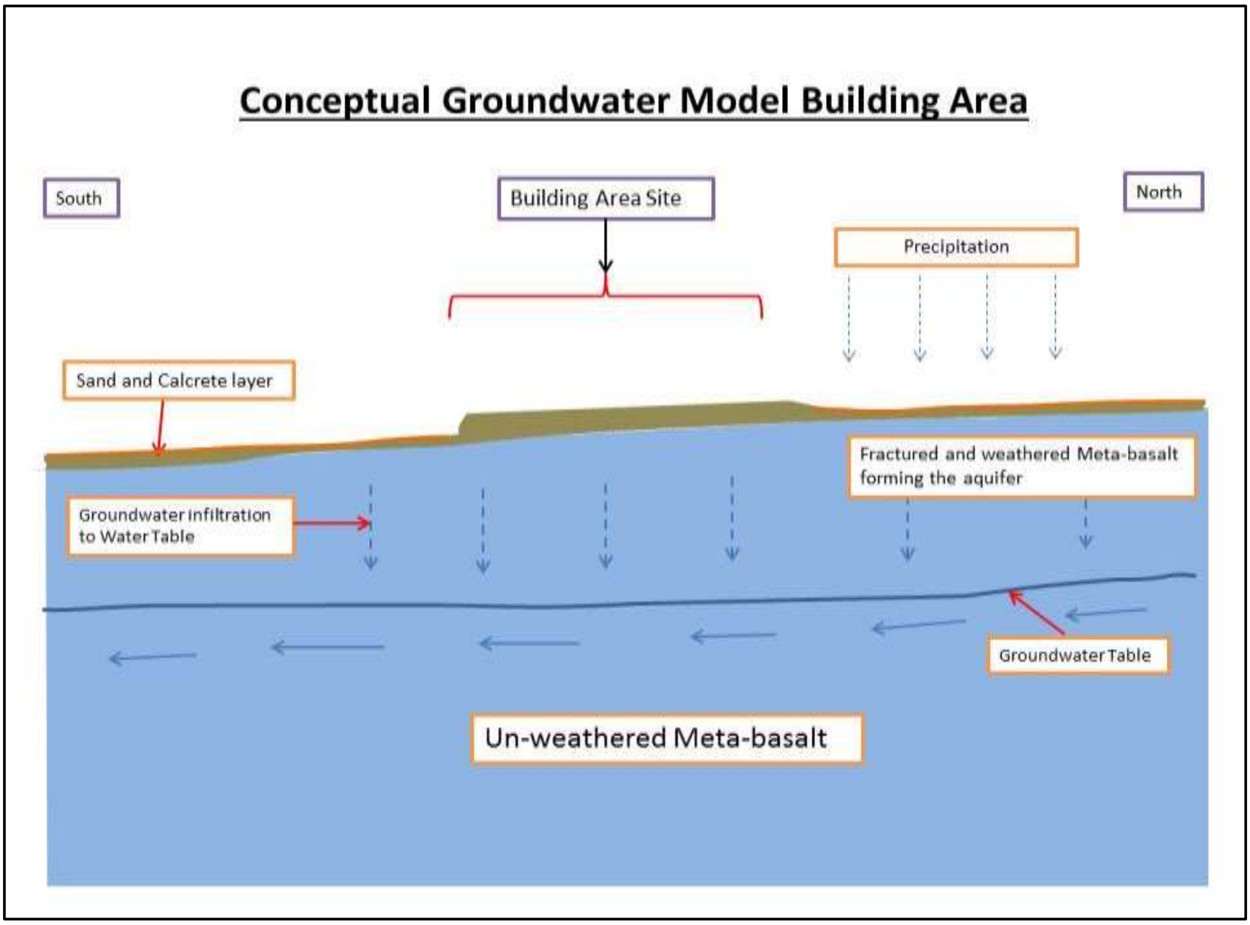

Figure 15: Conceptual hydrogeological model of Building area

Groundwater flow will be from north to south on this site. Borehole BH 1 is located to the east of the site which means that under normal conditions contamination will migrate to the south and not to the borehole. Excessive water abstraction at borehole BH 1 may alter the groundwater flow directions near the borehole.

The geology below the site is expected to be Sand and gravel, calcrete and Meta-basaltin depth. The sand and gravel will be excavated and mixed with calcrete to be compacted in layers on site. The hydraulic conductivities measured on site will be altered to be much lower than measured on site.

During the walk over study of the building site the test pits of the geotechnical study was inspected. During this inspection the Meta-basalt rock was found to be very competent rock with calcrete cementation of the fractures in the Meta-basalt.

The bottom of a sanitation conservancy tank will be 21 to 22 metres above the water table if the tank is constructed 3 to 4 metres deep. This means that water migrating to the water table will have a long travel time before reaching the water table.

Due to the low yield of borehole BH 1 the aquifer in this region is expected to be a low yielding aquifer with limited fracturing in the host rock. The contamination risk for this site islow due to limited groundwater movement.

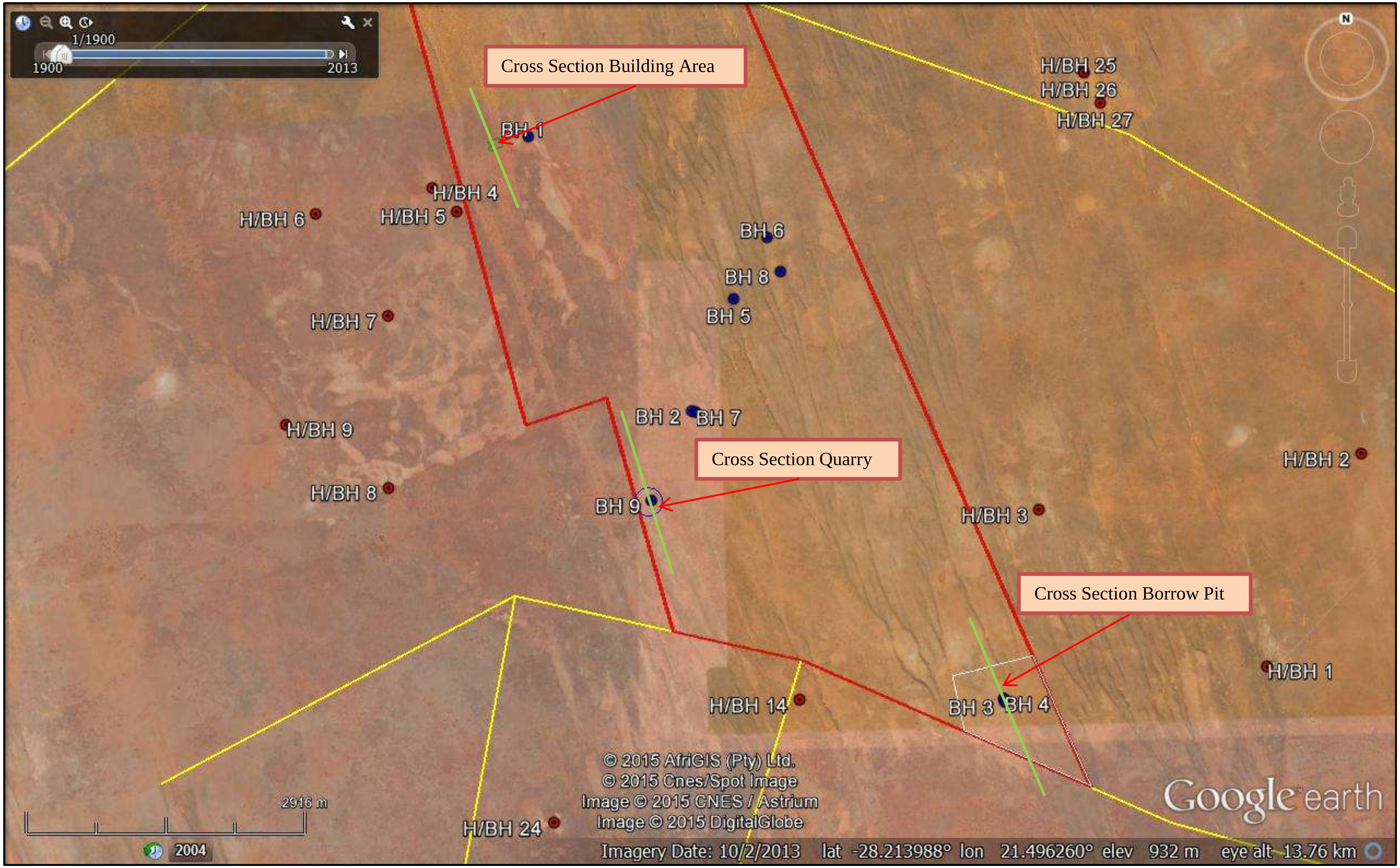

Figure 16: Locality of cross sections for Conceptual hydrogeological models

The vulnerability of the underground water sources is related to the distance that the contaminant must flow to reach the water table and the ease with which it can flow through the soil and rock layers above the water table. An assessment of the soil and rock types and the distance to the water table can be used to obtain a vulnerability class. (Groundwater Protocol document, Version 2, dated March 2003). Five broad classes of aquifer vulnerability are defined in Table 12 below:

Table 12: Vulnerability of groundwater aquifer due to hydrological conditions

Vulnerability Class	Measurements	Definition
Extreme (Usually highly fractured rock and/or high groundwater table).	High risk and short distance(<2m) to water table.	Vulnerable to most pollutants with relatively rapid impact from most contamination disposed of at or close to the surface.
High (Usually gravely or fractured rock, and/or high water table).	High risk and medium distance(2-5m) to water table.	Vulnerable to many pollutants except those highly absorbed, filtered and/or readily transformed.
Medium (Usually fine sand, deep loam soils with semi-solid rock and average water table > 10m).	Low risk and medium to long distance to water table.	Vulnerable to inorganic pollutants but with negligible risk of organic or microbiological contaminants.
Low (Usually clay or loam soils with semi-solid rock and deep water table >20m).	Minimal and low risk and long to very long distance to water table.	Only vulnerable to the most persistent pollutants in the very long term.
Negligible (Usually dense clay and/or solid impervious rock with deep water table).	Minimal risk with confining layers.	Confined beds present with no significant infiltration from surface areas above aquifer.

In Table 12 above, according to the Groundwater Protocol document, Version 2, dated March 2003 in Table A, the vulnerability of the groundwater aquifer due to the hydrogeological conditions at the proposed borrow pit and septic or conservancy tank of the building area can be rated as **Low risk**. The distance from the surface to the aquifer is in the region of 21 metres if the water level depth of boreholes BH 1, 3 and 4 is considered. The vulnerability of the groundwater aquifer due to the hydrogeological conditions at the Quarry area can also be rated as **Low risk** due to the water level depth of 17 metres and the aquifer conditions at the quarry which can be considered as a non-aquifer.

Table 13: Assessment of the reduction of contaminants in the unsaturated zone

Unsaturated Zone Conditions	Factor Effecting Reduction			Contamination Reduction			Comments
	Rate of flow in unsaturated zone	Capacity of the media to absorb contaminants	Capacity to create an effective barrier to contaminants	Bacteria and Viruses	Nitrates and Phosphates	Chlorides	
Clay	Very slow <10mm/d	High	High	Very high reduction	High Reduction	High Reduction	Very Good barrier to movement of contaminants. May have problems with water retention in pit
Silt	Slow 10-100mm/d	Medium	High	High Reduction	Some Reduction	Minimal Reduction	Good barrier to movement of biological contaminants, but little reduction in chemical contaminants.
Sandy loam	Slow 10-100mm/d	Medium	High	High Reduction	Some Reduction	Minimal Reduction	Good barrier to movement of biological contaminants, but little reduction in chemical contaminants.
Fractured or weathered sandstone	Medium 0.1 - 10m/d	Medium	Medium	High Reduction	Minimal Reduction	Minimal Reduction	Fair barrier to movement of biological contaminants, but little reduction in chemical contaminants.
Fine sand	Medium 0.1 - 10m/d	Minimal	High	High Reduction	Minimal Reduction	Minimal Reduction	Good barrier to movement of biological contaminants, but little reduction in chemical contaminants.

Table 13 above shows that the host rock found on site have a mediumcapacity to absorb contaminants and a mediumcapacity to create a fair barrier to the movement of biological contaminants.A high reduction of bacteria and viruses will be evident in the unsaturated aquifer if a leak in the septic or conservancy tank does happen. Nitrates,phosphates and chlorides will be minimally reduced. The top layer will form a good barrier to the movement of biological contaminants but will have little reduction in chemical contaminants.

7.4 Existing threats to groundwater quality

The existing boreholes are situated at kraals where life stock manure can be a source of contamination. No other sources of contamination do exist.

7.5 Contamination risk from an on-surface contamination source

As far as the contamination risk from the three sites is concerned, the assessment is based on the level of risk of the source. Risk levels are based on three factors: 1) attenuation ability in unconsolidated materials; 2) contamination load and travel time of degradable pollutants, in aquifer systems and 3) vulnerability of the aquifer and behavior of interstitial water regimes. Soil or unconsolidated material may provide a very effective attenuation buffer for certain contaminants and may have a very low attenuation on other contaminants. The nature of the soil materials and the thickness of this zone, are key issues in determining attenuation capacity.The host rock layers above the aquifer is thick enough and will sufficiently protect the aquifer below from on surface leaks.

7.6 Position in respect of domestic water sources

The location of a possible contamination source, in relation to water sources utilised for human consumption, is of primary concern. In most of rural Southern Africa and at many farming communities around our cities, the only domestic water supplies are obtained from boreholes.

It is therefore essential that minimum distances between possible contamination sources and the nearest domestic water resource that is in use,be prescribed. These safe distances depend on many factors due to the highly variable and uncertain nature of the factors that control the dispersion of pathogenic organisms from a contamination source. The criteria for determining the distance of a contamination source from water resources must therefore be conservative.

The recommended safe distances are based on the acceptable soil’s permeability range, in conjunction with the maximum survival times of bacteria, viruses and the breakdown of chemical components. Conservatism has been achieved through the effects of the harsh environmental conditions prevalent in most of Southern Africa, which lowers maximum pathogen survival periods, and by adding a moderate safety factor of 150m to the calculated distances (This ensures a minimum safe distance of 150m at all times). Due to the importance of ensuring pollution free domestic water resources, lowering of the recommend distances has not been considered for the more arid regions of the sub-continent.

Production borehole BH 1 is located 300 metres from the position of the building site. Borehole BH 1 is used for water abstraction and can be used as monitoring facility for the development. The contamination risk of the conservancy tank on borehole BH 1 is negligible mainly due to the distance of 300 metres from the borehole.

7.7 Position in respect of drainage features

The positioning of a contamination source, in relation to a drainage feature of any description, is of cardinal importance. Drainage features, including lakes, dams, rivers, streams, gullies, gulley heads and marshes should not be affected in any way by pollutants emanating from a possible contamination source. These drainage features must also not pose a flood hazard to any contamination source (contamination sources must be located above the 1 in 100 year flood level). These limitations necessitate the prescription of minimum distances between contamination sources and the nearest drainage feature.

The approach taken is virtually the same as for domestic water sources, the only difference being the reduction of the safety factor to 100 metres, and a further decrease of the recommended distances for arid regions (rainfall < 500mm). If the recommended safe distances prescribed are applied, surface water contamination will be negligible.

No drainage features are located on the farm Steenkampspan. No special precaution is needed in this case.

8. ENVIRONMENTAL IMPACT ASSESSMENT

8.1 Assessment methodology

An impact can be defined as any change in the physical-chemical, biological, cultural and/or socio-economic environmental system that can be attributed to human activities related to alternatives under investigation for meeting a project need. Assessment of impacts will be based on the Department of Environmental Affairs (DEA) (1998) Guideline Document: EIA Regulations. The significance of the aspects/impacts of the process is rated by using a matrix derived from Plomp (2004) and adapted to some extent to fit this process. This matrix uses the consequence and the likelihood of the different aspects and associated impacts to determine the significance of the impacts.

The **significance** of the impacts will be determined through a synthesis of the criteria below:

Probability This describes the likelihood of the impact actually occurring.

Improbable: The possibility of the impact occurring is very low, due to the circumstances, design or experience.

Probable: There is a probability that the impact will occur to the extent that provision must be made therefore.

Highly Probable: It is most likely that the impact will occur at some stage of the development.

Definite: The impact will take place regardless of any prevention plans, and there can only be relied on mitigatory actions or contingency plans to contain the effect.

Duration: The lifetime of the impact

Short term: The impact will either disappear with mitigation or will be mitigated through natural processes in a time span shorter than any of the phases of the project.

Medium term: The impact will last up to the end of the phases of the project, where after it will be negated.

Long term: The impact will last for the entire operational phase of the project but will be mitigated by direct human action or by natural processes thereafter.

Permanent: Impact that will be non-transitory. Mitigation either by man or natural processes will not occur in such a way or in such a time span that the impact can be considered transient.

Scale: The physical and spatial size of the impact

Local: The impacted area extends only as far as the activity, e.g. footprint of the project.

Site: The impact could influence the whole, or a measurable portion of the affected properties.

Regional: The impact could affect the area including the neighbouring areas.

Magnitude/ Severity: Does the impact destroy the environment, or alter its function.

Low: The impact alters the affected environment in such a way that natural processes are not affected.

Medium: The affected environment is altered, but functions and processes continue in a modified way.

High: Function or process of the affected environment is disturbed to the extent where it temporarily or permanently ceases.

Significance: This is an indication of the importance of the impact in terms of both physical extent and time scale, and therefore indicates the level of mitigation required.

Negligible: The impact is non-existent or unsubstantial and is of no or little importance to any stakeholder and can be ignored.

Low: The impact is limited in extent, has low to medium intensity; whatever its probability of occurrence is, the impact will not have a material effect on the decision and is likely to require management intervention with increased costs.

Moderate: The impact is of importance to one or more stakeholders, and its intensity will be medium or high; therefore, the impact may materially affect the decision, and management intervention will be required.

High: The impact could render development options controversial or the project unacceptable if it cannot be reduced to acceptable levels; and/or the cost of management intervention will be a significant factor in mitigation.

A matrix rating and assigning weights for the impacts is shown in Table 14below.

Table 14: Rating matrix legend for groundwater impacts

Aspect	Description	Weight
Probability	Improbable	1
	Probable	2
	Highly Probable	4
	Definite	5
Duration	Short term	1
	Medium term	3
	Long term	4
	Permanent	5
Scale	Local	1
	Site	2
	Regional	3
Magnitude/Severity	Low	2
	Medium	6
	High	8
Significance	**Sum (Duration, Scale, Magnitude) x Probability**	
	Negligible	<20
	Low	<40
	Moderate	<60
	High	>60

8.2 Impact identification and significance ratings

The impact matrix is listed below to show detailed activities and the related impacts of each individual activity. The potential impact identification is divided into impact during the Construction phases of the site and the Operational phase of the project. The Construction phase consists of two construction phases namely phase 1 and phase 2. The management and mitigation measures are discussed.

8.2.1 Potential impact during construction phase 1 and 2

The significance of thepotential impacts during the construction phase is “Low to Moderate”. The probable impacts are:

- Lowering of the water table at the farms Steenkampspan and Duiker Rand.
- Contamination of groundwater from the construction of the borrow pit.
- Contamination of groundwater from the construction of the quarry.
- Contamination of groundwater from the construction of the building area.

With mitigation, the significance of these activities is rate as “Negligible”.

8.2.2 Management and mitigation measures

The following mitigation measures are recommended in the Construction phase:

- Abstract water at the recommended rates for each individual borehole.
- Do not over use one borehole by pumping one specific borehole at all times.
- Always use at least all four boreholes.
- Use water scarcely and do not waste water.
- Measure water levels in stipulated boreholes (Section 9) on a monthly basis.
- If water levels are declining constantly contact the hydrogeologist.
- Take water samples at borehole BH 1 and the new monitoring borehole on an annual basis.
- A groundwater monitoring report must be produced on a six monthly basis.
- Use proper sanitation systems on site during construction and keep systems serviced.
- Stagnant water must not be allowed in the borrow pit or quarry area during the construction phase. Contaminated water must be pumped out and treated before re-used for construction purposes.
- Service plant equipment regularly.
- Keep fuel and oil in safe conditions on site during construction.
- Have stringent safety margins on site for all equipment that have a contamination risk involved.

8.2.3 Potential impact during operational phase

During the operational phase groundwater abstraction will decrease from a water demand of 300m^3/d to only 10m^3/day for 6 months of the year. The proving ground will only be used during six months of the year. During the following 6 months of the year no water will be used for the operational phase. Water will however be used for farming activities at a rate of between 6 and 12m^{3}for 12 months of the year during the entire operational phase of the project.

The significance of thepotential impacts during the operational phase is “Low”. The probable impacts are:

- Contamination of groundwater from the borrow pit, quarry and building area.
- Groundwater contamination from spillage of the septic tank or conservancy tanks.

- Groundwater contamination from oil traps on the building site.
- Groundwater contamination from fuel storage on site.

With mitigation, the significance of these activities is rated as “Negligible”.

8.2.4 Management and mitigation measures

The following mitigation measures are recommended in the operational phase:

- Service oil traps as specified by provider.
- The conservancy tank must be emptied on an interval specified by the engineer or architect.
- Develop a master plan for accidental spillage of fuel and oil on site.
- Place a groundwater monitoring borehole at the southern side of the building site.
- Measure water levels in the four production boreholes (now out of duty) on a three monthly basis.
- Take water samples at borehole BH 1 and the new monitoring borehole on an annual basis.
- A groundwater monitoring report must be produced on an annual basis.

Table 15: Significance Rating

Nr	Activity	Without or With Mitigation	Probability		Duration		Scale		Magnitude/ Severity		Significance	
			Score	Magnitude	Score	Magnitude	Score	Magnitude	Score	Magnitude	Score	Magnitude
Construction phase												
1	Contamination of groundwater during construction of the borrow pit	WOM	2	Probable	4	Long Term	1	Local	6	Medium	22	Low
		WM	1	Improbable	4	Long Term	1	Local	2	Low	7	Negligible
2	Contamination of ground water during construction of the Quarry	WOM	2	Probable	4	Long Term	1	Local	6	Medium	22	Low
		WM	1	Improbable	4	Long Term	1	Local	2	Low	7	Negligible
3	Contamination of groundwater during construction of the building area	WOM	2	Probable	4	Long Term	1	Local	6	Medium	22	Low
		WM	1	Improbable	4	Long Term	1	Local	2	Low	7	Negligible
4	Lowering of the water table on the farms Steenkampspan and Duiker Rand	WOM	4	Highly Probable	3	Medium Term	2	Site	6	Medium	44	Moderate
		WM	1	Improbable	3	Medium Term	2	Site	2	Low	7	Negligible
Operational Phase												
1	Contamination of groundwater after construction of the borrow pit	WOM	2	Probable	3	Medium Term	1	Local	2	Low	12	Negligible
		WM	1	Improbable	3	Medium Term	1	Local	2	Low	6	Negligible
2	Contamination of ground water after construction of the Quarry	WOM	2	Probable	3	Medium Term	1	Local	2	Low	12	Negligible
		WM	1	Improbable	3	MediumTerm	1	Local	2	Low	6	Negligible
3	Contamination of groundwater from fuel storage at the building area	WOM	2	Probable	3	Medium Term	1	Local	2	Low	12	Negligible
		WM	1	Improbable	3	Medium Term	1	Local	2	Low	6	Negligible
4	Contamination of groundwater from oil traps and sewerage tanks on the building site	WOM	2	Probable	4	Long Term	1	Local	6	Medium	22	Low
		WM	1	Improbable	4	Long Term	1	Local	2	Low	7	Negligible

9. MONITORING PLAN

It is important to have a monitoring system in place to monitor the potential impacts on the environment such as water level depth changes in the region and groundwater quality in the area on and around the development portion. It is important to monitorthe water level depth in an area where groundwater abstraction is taking place.

The main focus of a monitoring system must be to monitor and detect possible changes in a groundwater regime. This may be groundwater level fluctuations or water quality changes.

The planned groundwater abstraction boreholes BH 1, BH,5 BH 8 and H/BH 10 and the boreholes BH 2, BH 3, BH 4, H/BH 14and the newly planned monitoring borehole at the building site is proposed to be used as monitor points. Refer to Table 16.

Monitoring programmes are site-specific and need to be tailored to meet a specific set of needs or expectations (DWA 1998). The approach followed in developing this monitoring protocol was taken from the DWS (formerly DWAF) Best Practice Guideline – G3: Water Monitoring Systems (DWA, 2006b).

9.1 Monitoring Objectives

Monitoring, measuring, evaluating and reporting are key activities of the monitoring programme. These actions are designed to evaluate possible changes in the physical and chemical nature of the aquifer and geo-sphere and to predict/detect potential impacts on the groundwater.

The key objectives of the monitoring of groundwater changes are:

1. To provide reliable groundwater data that can be used for management purposes.
2. The early detection of changes in groundwater quality and quantity.
3. Provide an on-going performance record on the efficiency of the Water Management Plan.
4. Obtain information that can be used to redirect and refocus the Water Management Plan.
5. Determine compliance with environmental laws, standards and the water use licence and other environmental authorizations.
6. Refine the conceptual and numerical (management) models.

This will ensure that management is timely warned of problems and unexpected impacts that might occur, and can be positioned to implement mitigation measures at an early stage.

9.2 Possible pollution sources

Potential pollution sources include the following:

1. Quarry area, borrow pit and building site.
2. Fuel and oil storage, oil separatorsand conservancy tanks at building area development.

9.3 Receiving environment

The following hydrological units may be impacted by the project and related activities:

- The aquifer below the site.

9.4 Monitoring Network

The planned groundwater abstraction boreholes BH 1, BH, 5 BH 8 and H/BH 10 and the boreholes BH 2, BH 3, BH 4, H/BH 14 and the newly planned monitoring borehole at the building site is proposed to be used as monitor points

9.5 Monitoring Frequency

Table 15 below describe the monitor points during construction and operational phases.

Table 16: Water monitoring Frequency

Site name	Chemistry Sampling	Water Level Measurements
Construction phase		
Production borehole for development BH 1, BH 5, BH 8 and H/BH 10	Annually	Monthly
Life stock watering boreholes BH2, BH 3, BH 4 and H/BH 14	---	Monthly
BH 1 and Monitor borehole at building area	Annually	Monthly
Operational phase		
Production borehole for development BH 1, BH 5, BH 8 and H/BH 10	---	3 Monthly
BH 1 and Monitor borehole at building area	Annually	3 Monthly

9.6 Sampling parameters

An accredited laboratory, with the necessary quality assurance, must carry out analysis of key samples. Quality control measures should be in place and may include blanks, standards, duplicates, cation-anion balances etc. This will ensure consistency in monitoring and the verification and validation of water quality data. Data from groundwater and surface water quality monitoring must be stored together electronically to enable trend analysis and waste load calculations to be carried out.

Table 17 Sampling parameters

Sample Type	Field measurements	Laboratory analysis: Chemical and bacteriological
Groundwater	Water level depth	Refer to Table 8 and Table 1 for the coordinates of monitoring points

9.7 Sampling Procedures

The sampling procedure for groundwater should be done according to the protocol by Weaver, 1992. The actions can be summarised as follows:

1. Calibrate the field instruments before every sampling run. Read the manufacturers manual and instructions carefully before calibrating and using the instrument.
2. Purging a borehole can be done in the following ways:
   a. With a portable pump
   b. With an already installed submersible pump
   c. By lowering a bailer into the hole
3. Prior to sampling, measure the water level and record.
4. Install the pump (If not equipped) with the inlet close to the static water level.
5. Set up the EC, pH and temperature meter.
6. Start pumping and record the pumping rate in ℓ/s.
7. Continuously measure the pH and EC values.
8. If the field chemistry stabilizes the borehole is purged. Note that approximately one column of water should be removed. The volume of water to be removed is calculated using the following formula:
   Volume of standing water = π r^2 × h × 1000, where
   R = radius of borehole in meter
   H = height of water column in meter
9. Some boreholes are low yielding and go dry when purging. Leave the borehole to recover for a few hours. When returning, install the pump with the inlet close to the static water level and continue with the next step. Alternatively, bail the borehole.
10. Sample for chemical constituents – remove the cap of the plastic 1 litre sample bottle, but do not contaminate inner surface of cap and neck of sample bottle with hands. Fill the sample bottle without rising.
11. Leave sample air space in the bottle (at least 2.5 cm) to facilitate mixing by shaking before examination.
12. Replace the cap immediately.
13. Complete the sample label with a water resistant marker and tie the label to the neck of the sample bottle with a string or rubber band. The following information should be written on the label
    a. An unique sample number and description

   b. The date and time of sampling
   c. The name of the sampler

15. Place sample in a cooled container (e.g. cool box) directly after collection. Try and keep the container dust-free and out of any direct sunlight. Do not freeze samples.
16. Complete the data sheet for the borehole
17. See to it that the sample gets to the appropriate laboratory as soon as possible. Samples for chemical analysis should reach the laboratory preferably within seven days.

10. CONCLUSIONS

Water will be tapped from existing and newly drilled boreholes for the project. Water will be used during two construction phase which will be 14 months for the first phase and 8 months for the second phase. The water demand during the first construction phase will be $300m^3/d$ and during the second construction phase will also be $300m^3/d$. The time line for the second construction phase is not finalized yet but is expected to be concluded within the first 5 years after start of operations.

During the operational phase of the project, the water demand will be much lower. Water will be used at the office site for washing, cleaning and ablution facilities. Bottled water will be used for consumption. During the operational phase the water demand for the development will be approximately $10m^3/d$.

During the entire project the water demand for farming activities on Portion 6 of the farm Steenkampspan will be 6 m^3/d. Farming activities will be in future limited to 80 head of cattle. Water will be sourced from the exiting boreholes that are currently used for farming. During later stages when construction water is not needed, the farming activities may also source water from the production boreholes used for the construction purposes. The water demand for farming activities however will not exceed $6m^3/d$.

During the sustainable calculations a vast number of methods were used to calculate the availability of water on Steenkamspan and Duiker Rand. The availability of water in the large catchment area that could be delineated for the boreholes that will be used during the life of the project was also carefully considered. A vast number of answers were available after these calculations. A small number of these answers however need special attention.

1. The boreholes that are earmarked to be used for abstraction can easily deliver water according the yields recommended in the report.
2. None of the boreholes will be individually over pumped. In fact during the final calculations a very conservative approach was taken to calculate the final recommended yields. These recommended yields were further cut from $350m^3/d$ to $300m^3/d$. The actual water demand for construction phase 1 is $276m^3/d$ and for construction phase 2 is $264m^3/d$. For calculation purposes and to be conservative a water demand for both construction phases of $300m^3/d$ was used.
3. The groundwater catchment feeding the aquifer is large and is calculated at $288.6km^3$.
4. 39.1% of the harvest potential figure of the aquifer of **Steenkampspan** will be needed.
5. 52.1% of the harvest potential figure of the aquifer of **Duiker Rand** will be needed.
6. 12.4.1% of the harvest potential will be used of the **Delineated catchment aquifer** per

annum.

7. 0.33% of the volume of water stored in the larger D**elineated catchment aquifer** of 288.6km^2 will be needed.

During careful consideration of the important facts above and the other evidence that the aquifer can sustain the water abstraction during the construction phase of 22 months spread over 5 years, we regard the abstraction viable. During the operational phase of the project the aquifer will have ample time to recover for the farm to be used as stock farming unit. The water demand after the construction phase will be very low if compared to other farming units in the area. The farm Steenkampspan will be an area in which the aquifer can recover to be available in future for water abstraction for stock farming.

11. RECOMENDATIONS

The following mitigation measures are recommended in the Construction phase:

- Abstract water at the recommended rates for each individual borehole.
- Do not over use one borehole by pumping one specific borehole at all times.
- Always use at least all four boreholes.
- Use water scarcely and do not waste water.
- Measure water levels in stipulated boreholes (Section 9) on a monthly basis.
- If water levels are declining constantly contact the hydrogeologist.
- Take water samples at borehole BH 1 and the new monitoring borehole on an annual basis.
- A groundwater monitoring report must be produced on a six monthly basis.
- Use proper sanitation systems on site during construction and keep systems serviced.
- Stagnant water must not be allowed in the borrow pit or quarry area during the construction phase. Contaminated water must be pumped out and treated before re-used for construction purposes.
- Service plant equipment regularly.
- Keep fuel and oil in safe conditions on site during construction.
- Have stringent safety margins on site for all equipment that have a contamination risk involved.

The following mitigation measures are recommended in the operational phase:

- Service oil traps as specified by provider.
- The conservancy tank must be emptied on an interval specified by the engineer or architect.
- Develop a master plan for accidental spillage of fuel and oil on site.
- Place a groundwater monitoring borehole at the southern side of the building site.
- Measure water levels in the four production boreholes (now out of duty) on a three monthly basis.
- Take water samples at borehole BH 1 and the new monitoring borehole on an annual basis.
- A groundwater monitoring report must be produced on an annual basis.

REFERENCES

1. American Geological Institute, **Glossary of Geology**, (Robert L. Bates and Julia A. Jackson, Ed), 1980.
2. Building Publications Pretoria, **Engineering Geology of Southern Africa**, 1979.
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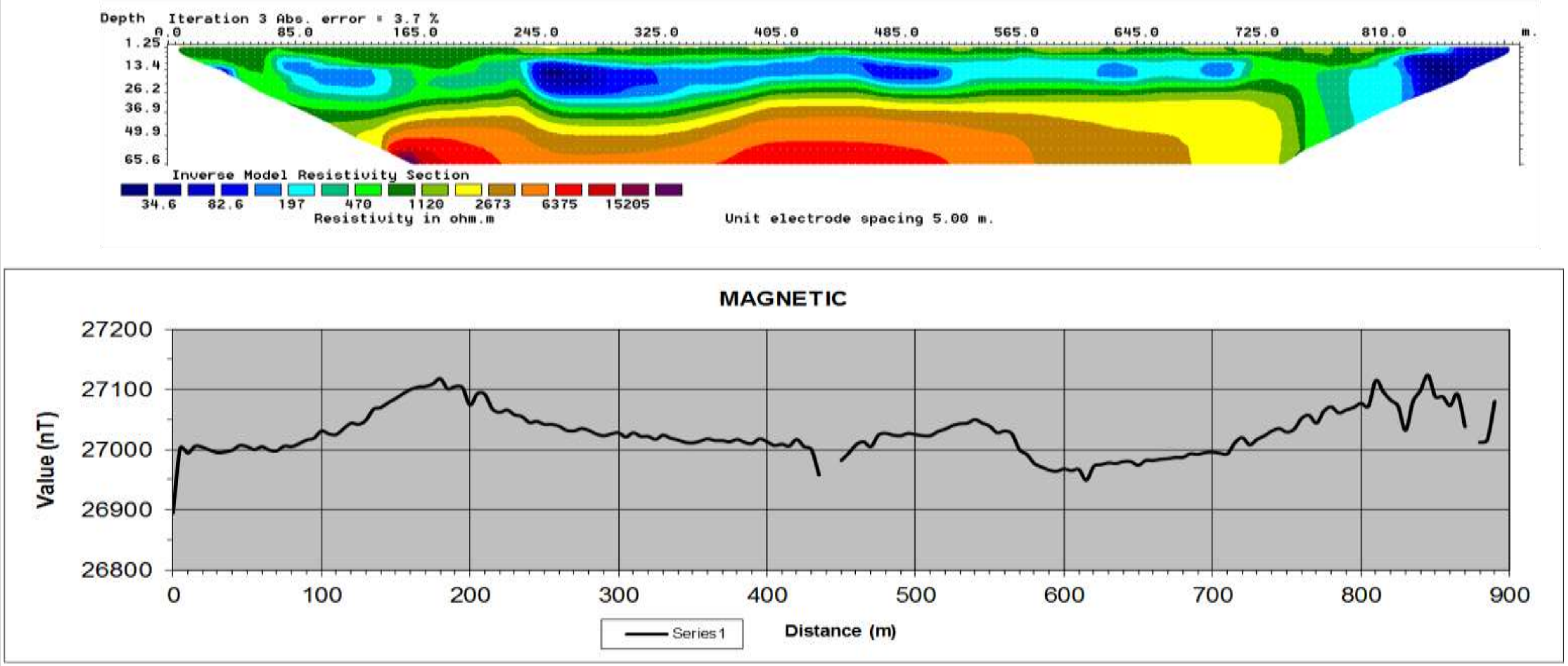
6. Johnson MR, Anhaeusser CR and Thomas RJ, **The Geology of South Africa**, 2006.
7. Water research Commission & Department of Water Affairs and Forestry, **Groundwater Resources of the Republic of South Africa**, (JR Vegter). August 1995.
8. SABS, **Specification for water for domestic supplies**. 241 - 1999.

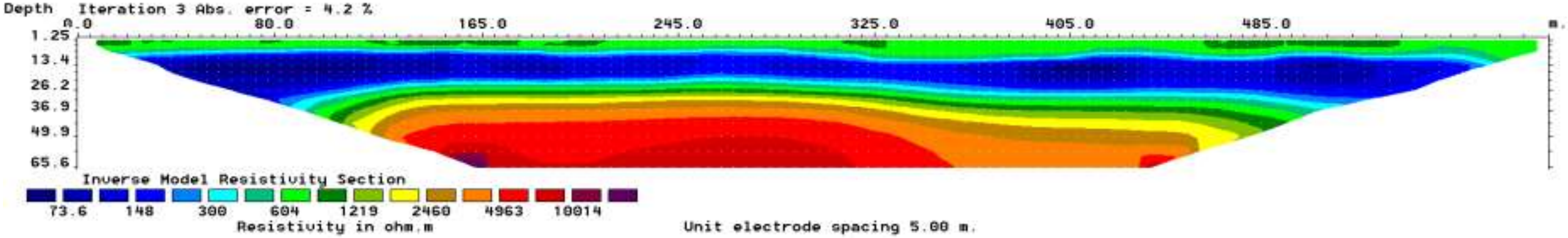
Appendix A

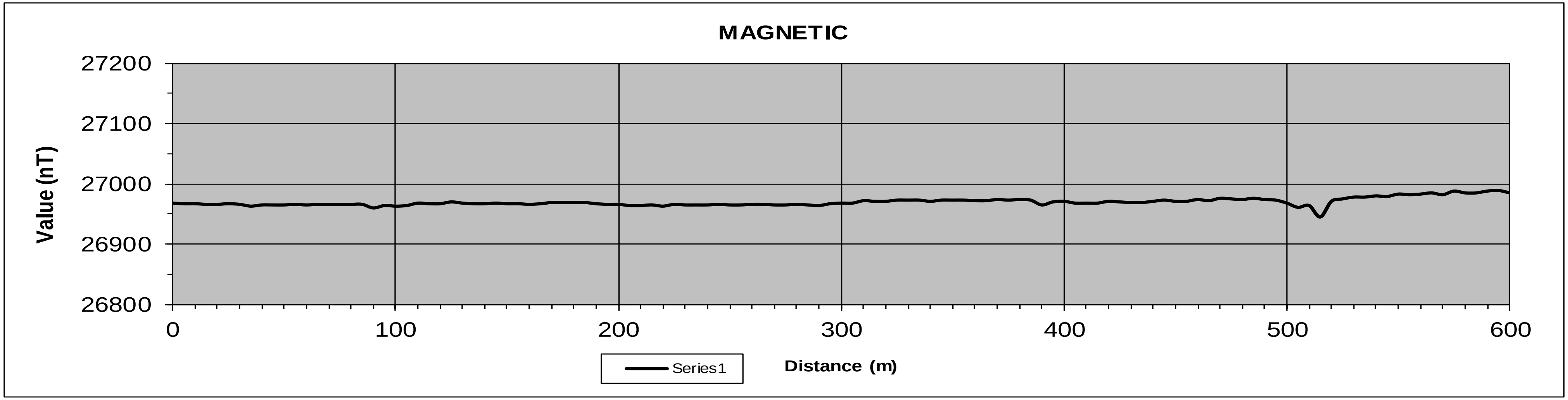
Geophysical study information



COUNTRY:	RSA	**FARM:**	Steenkampspan	**DIRECTION:**	**N - S**	**DATE:**	2015/05/18
PROVINCE:	North Cape	**TRAVERSE NR:**	Traverse 1				

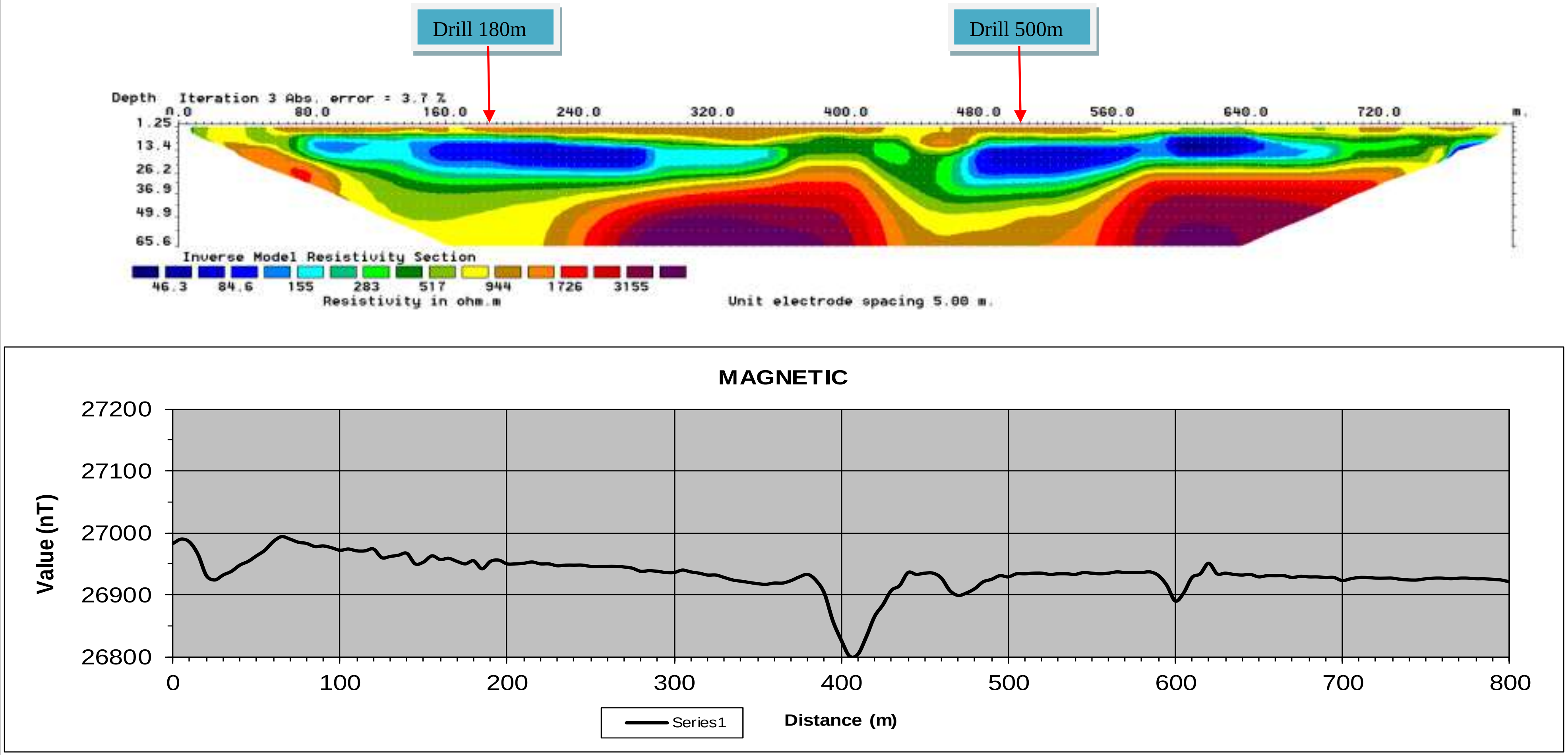
Geophysical Traverse 1, Magnetic and DC CVES methods





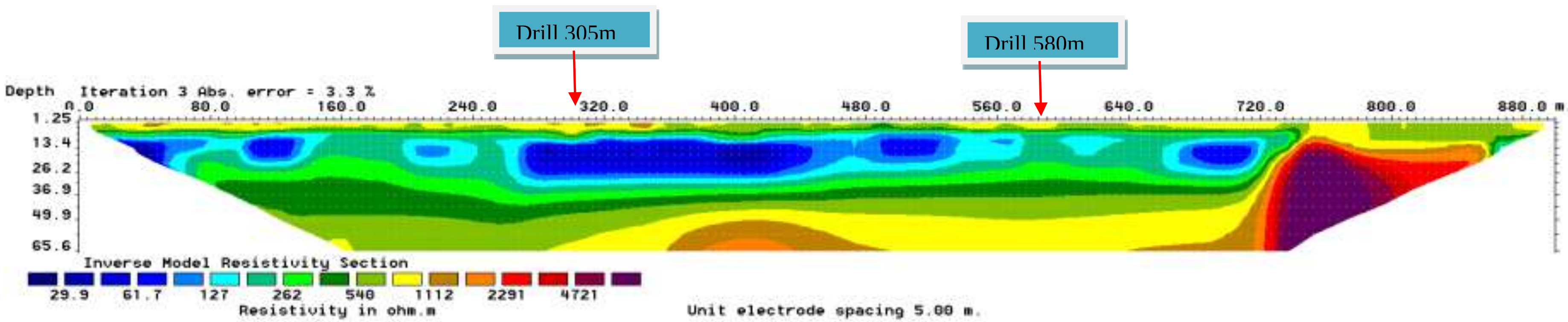
COUNTRY:	RSA	**FARM:**	Steenkampspan	**DIRECTION:**	**N - S**	**DATE:**	2015/05/19
PROVINCE:	North Cape	**TRAVERSE NR:**	Traverse 2				

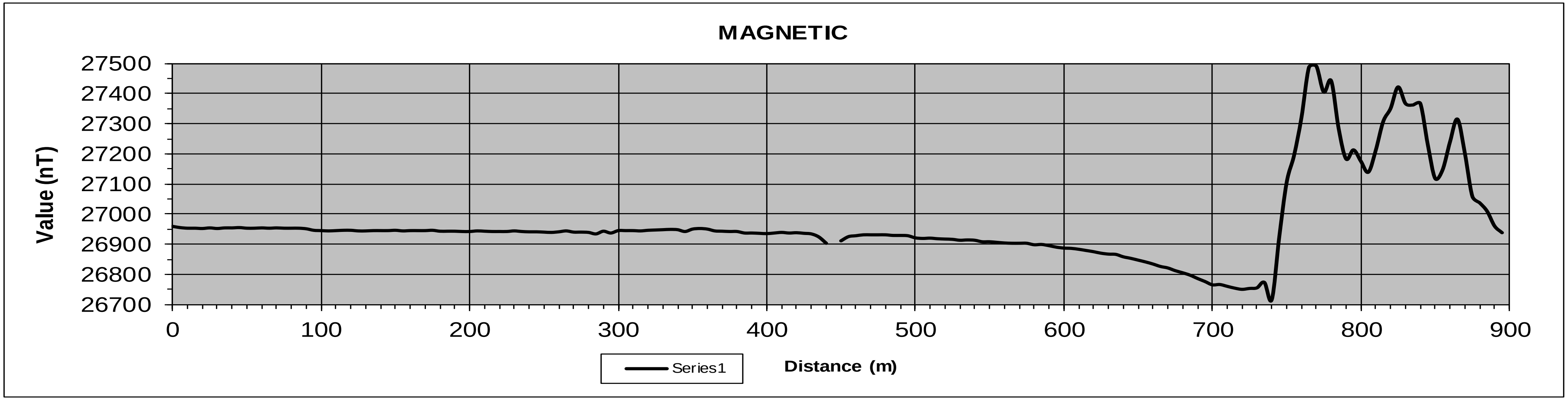
Geophysical Traverse 2, Magnetic and DC CVES methods



COUNTRY:	RSA	**FARM:**	Steenkampspan	**DIRECTION:**	**S - N**	**DATE:**	2015/05/19
PROVINCE:	North Cape	**TRAVERSE NR:**	Traverse 3				

Geophysical Traverse 3, Magnetic and DC CVES methods





COUNTRY:	RSA	**FARM:**	Steenkampspan	**DIRECTION:**	**S - N**	**DATE:**	2015/05/20
PROVINCE:	North Cape	**TRAVERSE NR:**	Traverse 4				

Geophysical Traverse 4, Magnetic and DC CVES methods

Appendix B

Borehole Yield Testing Information

Yield test information of the five boreholes submitted to test pumping.

Borehole **BH 1** is an existing borehole. This borehole is located on the farm Steenkampspan and is equipped with a submersible pump with solar panels. A windmill is also installed on top of the borehole. This borehole delivers water to a large cement dam and is used for life-stock watering.

The borehole is 77.3 metres deep, with a static water level at 34.00 metres below casing level. The borehole was pumped for one step of 15 minutes at a rate of 0.71 ℓ/s. The water level draw down was measured constantly during this step. The water level draw down after the step measured 15.12 metres below the original static water level. The water level did reach pump inlet at 20 minutes into step 1. A maximum inflow yield of 0.51 l/s could be measured. The pump was switched of and the water level allowed recovering for 120 minutes. The water level recovered back to the original static water level in the allowed 120 minutes. The water level recovery rate can be regarded as slow.

The borehole was then submitted to a constant discharge test with duration of 24 hours at a rate of 0.31 ℓ/s. The pump was switched off after 24 hours or 1440 minutes. The water level draw down was 6.39 metres below the original static water level. The borehole was allowed to recover for 720 minutes or 12 hours. The water level recovered to the original static water level in the allowed 12 hours. The water level recovery rate can be rated as fast.

Borehole **BH3**is an existing borehole. This borehole is located on the southern side of the farm Steenkampspan. It is not equipped.

The boreholeis 100 metres plus deep, with a static water level at 23.15 metres below casing level. The borehole was submitted to a constant discharge test with duration of 24 hours at a rate of 0.21 ℓ/s. The pump was switched off after 24 hours or 1440 minutes. The water level draw down was 21.03 metres below the original static water level. The borehole was allowed to recover for 840 minutes. The water level recovered to the original static water level. The water level recovery rate can be rated as very fast.

Borehole **BH 5** is a newly drilled borehole. This borehole was drilled on Traverse 3 at 170 metres. This borehole is located in the centre of the farm Steenkampspan. The borehole delivered a blow-out yield of 0.5 l/s.

The borehole is 144 metres deep, with a static water level at 25.4 metres below casing level. The borehole was pumped for four steps of 60 minutes at rates of 0.15, 0.31, 0.78 and 1.32 ℓ/s. The water level draw down was measured constantly during these steps. The water level draw down after the steps measured 1.64, 3.41, 5.47 and 27.03 metres below the original static water level. The water level did reach pump inlet at 20 minutes into step 4. A maximum inflow yield of 0.91 ℓ/s could be measured. The pump was switched of and the water level allowed recovering for 180 minutes. The water level recovered back to -0.17 metres below the original static water level in the allowed 180 minutes. The water level recovery rate can be regarded as normal.

The borehole was then submitted to a constant discharge test with duration of 24 hours at a rate of 0.68ℓ/s. The pump was switched off after 24 hours or 1440 minutes. The water level draw down was 6.88 metres below the original static water level. The borehole was allowed to recover for 840 minutes or 14 hours. The water level recovered to the -0.15 metres below the original static water level in the allowed 14 hours. The water level recovery rate can be rated as fast.

Borehole **BH 8**is a newly drilled borehole. This borehole was drilled on Traverse 4 at 300 metres. This borehole is located in the centre of the farm Steenkampspan. The borehole delivered a blow-out yield of±1.8 l/s.

The borehole is 150 metres deep, with a static water level at 26.5 metres below casing level. The borehole was pumped for three stepsof60 minutes at rates of 0.77, 1.52 and 2.16ℓ/s. The water level draw down was measured constantly during this step. The water level draw down after the steps measured 1.13, 3.14 and 5.24 metres below the original static water level. The water level did not reach pump inlet. A maximum inflow yield could therefore not be measured. The pump was switched of and the water level allowed recovering for 40 minutes. The water level recovered back to the original static water level in the allowed 40 minutes. The water level recovery rate can be regarded as fast.

The borehole was then submitted to a constant discharge test with duration of 24 hours at a rate of 2.14ℓ/s. The pump was switched off after 24 hours or 1440 minutes. The water level draw down was 5.68 metres below the original static water level. The borehole was allowed to recover for 360 minutes or 6 hours. The water level recovered to -0.17 metres below the original static water level in the allowed 6 hours. The water level recovery rate can be rated as fast.

Borehole **H/BH 10**is an existing borehole. This borehole is located on the farm Duikerrand and is not equipped. This borehole is not used.

The borehole is 70.0 metres deep, with a static water level at 16.85 metres below casing level. The borehole was pumped for three stepsof60 minutes at rates of 2.65, 5.02 and 8.54ℓ/s. The water level draw down was measured constantly during these steps. The water level draw down after the steps measured 1.38, 3.15 and 6.08 metres below the original static water level. The water level did not reach pump inlet. A maximum inflow yield could therefore not be measured. The pump was switched of and the water level allowed recovering for 1200 minutes. The water level recovered back to -0.18 metres below the original static water level in the allowed 1200 minutes. The water level recovery rate can be regarded as slow.

The borehole was then submitted to a constant discharge test with duration of 24 hours at a rate of 7.12ℓ/s. The pump was switched off after 24 hours or 1440 minutes. The water level draw down was 7.88 metres below the original static water level. The borehole was allowed to recover for 1440 minutes or 24 hours. The water level recovered to the -1.04 metres below the original static water level in the allowed 24 hours. The water level recovery rate can be rated as slow.

Cooper-Jacob method

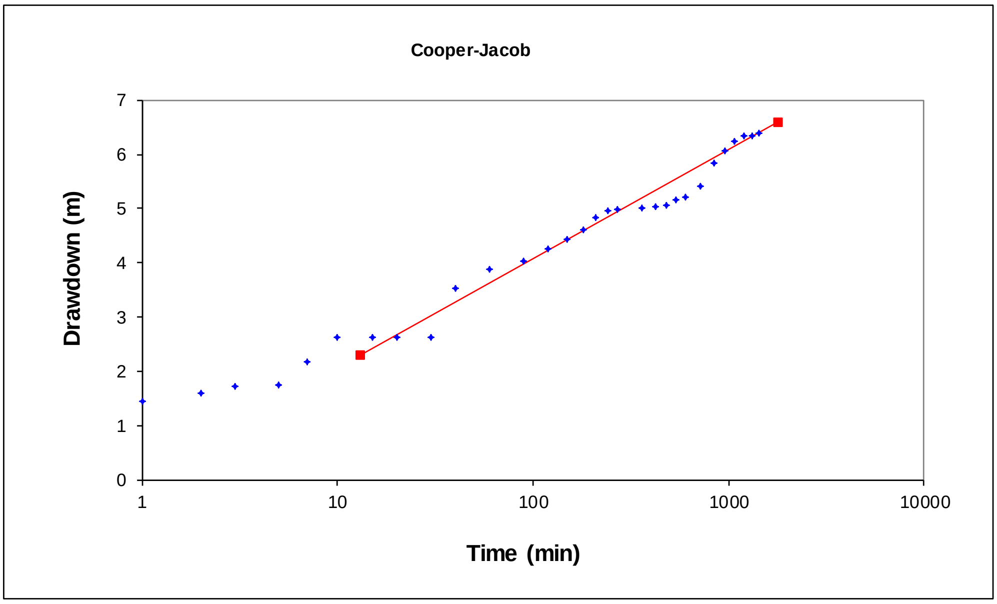
Main | Theis | Cooper-Jacob 2

BH 1

$T(m^2/d)$ =	2.4	r_e (m)=	1.52	1.52
S =	1.55E-03	Q (l/s) =	0.31	

	No boundaries	1 no-flow	2 no-flow	Closed
Q_sust	0.89	0.45	0.29	0.22
Avg. Q_sust =	**0.46**	std. dev =	0.30	

including influence of bh's

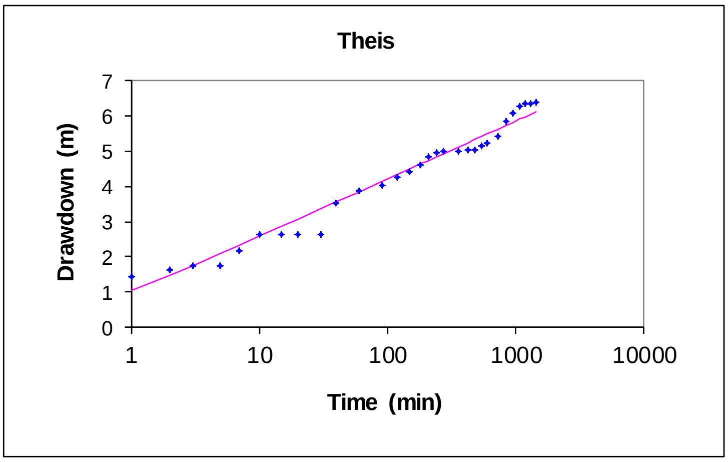


x0	**y0**	**x1**	**y1**
13.1	2.3	1795	6.6

Theis

T (m2/d)	S	r
3	5.00E-05	5.00

Top



Summary	Main	BH 1

Applicable	Method	Sustainable yield (l/s)	Std. Dev	Early T (m^2/d)		Late T (m^2/d)		S	AD used
☑	**Basic FC**	0.28	0.18	3		1.1		1.93E-03	35.0
☐	**Advanced FC**			3		1.1		1.00E-03	35.0
☐	**FC inflection point**	0.08	0.04						7.7
☑	**Cooper-Jacob**	0.46	0.30			2.4		1.55E-03	35.0
☐	**FC Non-Linear**	2.49	2.20			34.0		5.06E-03	35.0
☑	**Barker**	0.39	0.33	K_f =	8020		S_s =	1.01E-05	35.0
	Average Q_sust (l/s)	**0.38**	**0.09**	b =	0.01	Fractal dimension n =		1.80	

Recommended abstraction rate (L/s)		**0.30**	for 24 hours per day
Hours per day of pumping	**12**	**0.42**	L/s for 12 hours per day

Amount of water allowed to be abstracted per month	**777.6**	m^3
Borehole could satisfy the basic human need of	**1037**	persons
Is the water suitable for domestic use (Yes/No)	**Y**	

Cooper-Jacob method

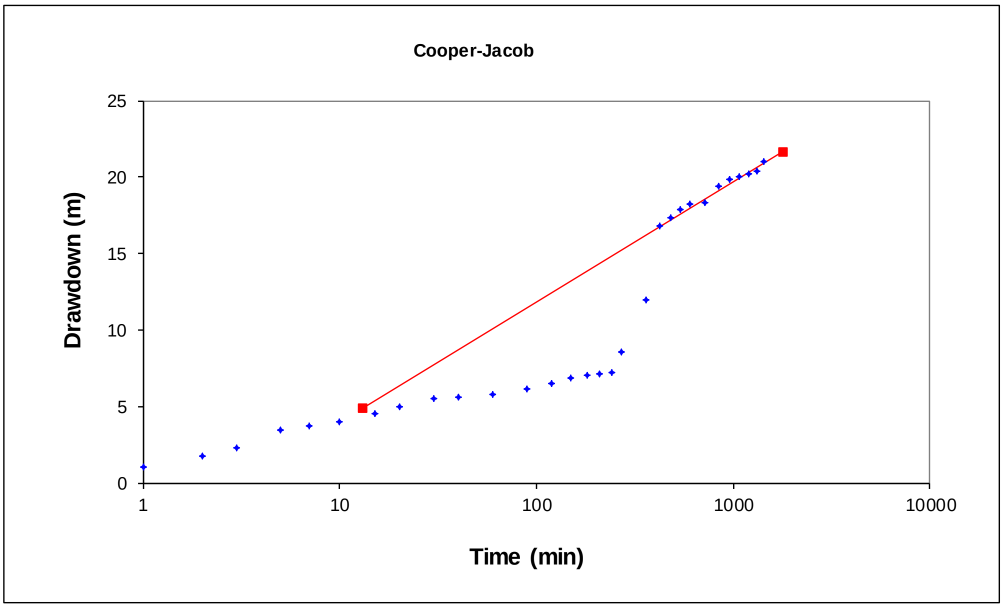
Main | Theis | Cooper-Jacob 2

BH 3

$T(m^2/d)$ =	0.4	r_e (m)=	1.52	1.52
S =	9.34E-04	Q (l/s) =	0.22	

	No boundaries	1 no-flow	2 no-flow	Closed
Q_sust	0.18	0.09	0.06	0.04
Avg. Q_sust =	0.09	std. dev =	0.06	

including influence of bh's

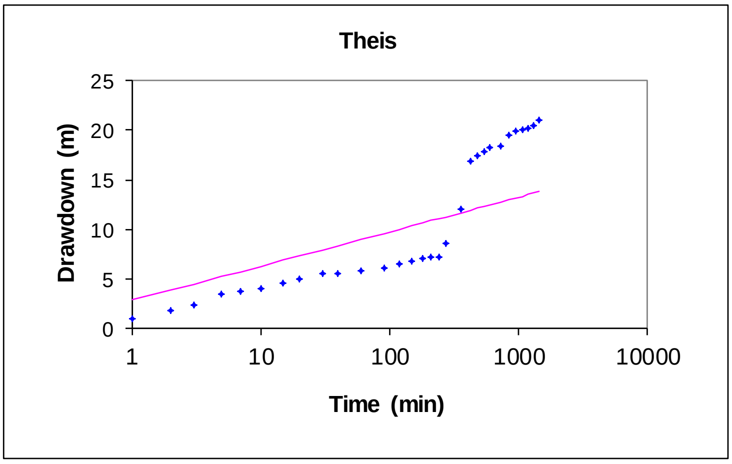


x0	y0	x1	y1
13.1	4.9	1795	21.7

Theis

T (m2/d)	S	r
1	1.00E-05	5.00

Top



Summary | Main | BH 3

Applicable	Method	Sustainable yield (l/s)	Std. Dev	Early T (m^2/d)		Late T (m^2/d)		S	AD used
☑	Basic FC	0.03	0.02	1		0.1		1.93E-03	35.0
☐	Advanced FC			1		0.1		1.00E-03	35.0
☐	FC inflection point	0.06	0.03						7.7
☑	Cooper-Jacob	0.09	0.06			0.4		9.34E-04	35.0
☐	FC Non-Linear	2.49	2.20			34.0		5.06E-03	35.0
☑	Barker	0.05	0.05	K_f =	8020		S_s =	1.01E-05	35.0
	Average Q_sust (l/s)	0.06	0.03	b =	0.01	Fractal dimension n =		1.68	

Recommended abstraction rate (L/s)		0.06	for 24 hours per day
Hours per day of pumping	12	0.08	L/s for 12 hours per day

Amount of water allowed to be abstracted per month	155.52	m^3
Borehole could satisfy the basic human need of	207	persons
Is the water suitable for domestic use (Yes/No)	Y	

Cooper-Jacob method

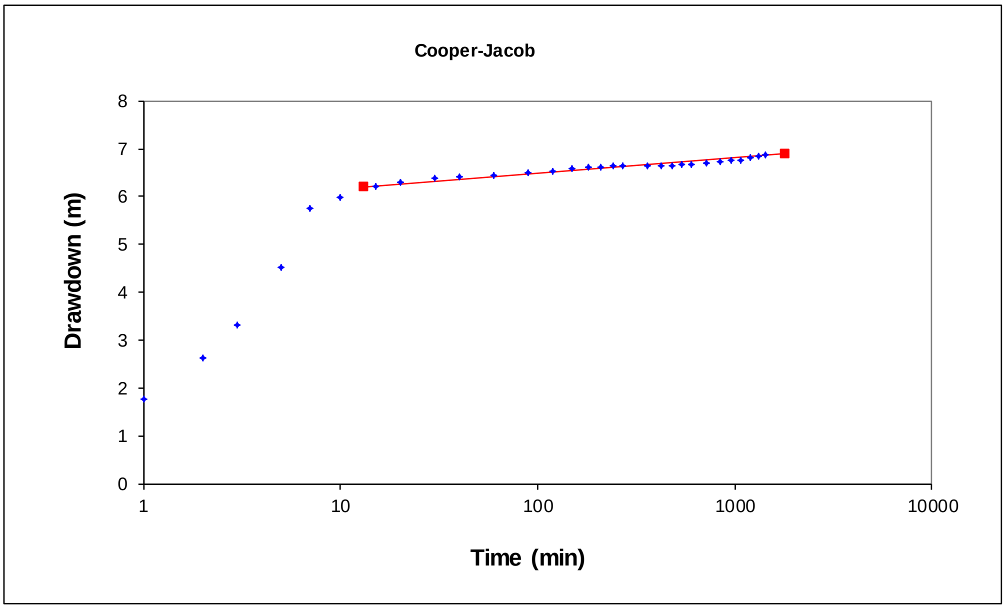
Main | Theis | Cooper-Jacob 2

BH 5

$T(m^2/d)$ =	32.4	r_e (m)=	1.52	1.52
S =	3.40E-20	Q (l/s) =	0.67	

	No boundaries	1 no-flow	2 no-flow	Closed
Q_sust	1.69	0.84	0.56	0.42
Avg. Q_sust =	0.88	std. dev =	0.57	

including influence of bh's

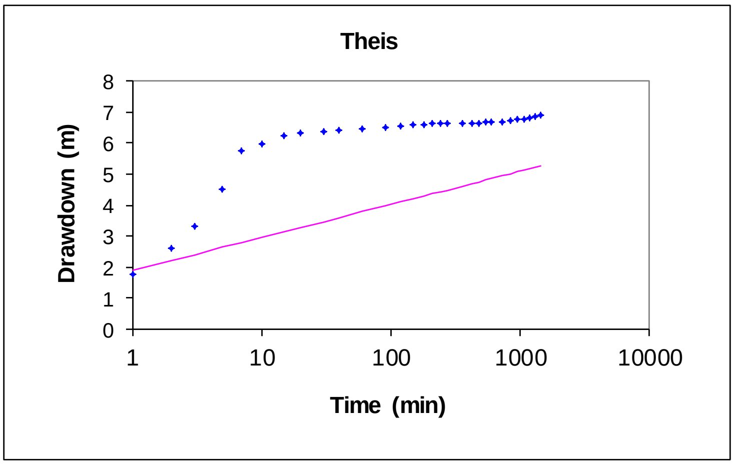


x0	y0	x1	y1
13.1	6.2	1795	6.9

Theis

T (m2/d)	S	r
10	1.00E-05	5.00

Top



Summary | Main | BH 5

Applicable	Method	Sustainable yield (l/s)	Std. Dev	Early T (m^2/d)		Late T (m^2/d)		S	AD used
☑	**Basic FC**	1.08	0.33	13		17.7		1.10E-03	20.0
☐	**Advanced FC**			13		17.7		1.00E-03	20.0
☐	**FC inflection point**	0.15	0.09						7.7
☑	**Cooper-Jacob**	0.88	0.57			32.4		3.40E-20	20.0
☐	**FC Non-Linear**	2.49	2.20			34.0		5.06E-03	20.0
☑	**Barker**	0.80	0.17	K_f =	8020		S_s =	1.01E-05	20.0
	Average Q_sust (l/s)	**0.92**	**0.14**	b =	0.02	Fractal dimension n =		1.80	

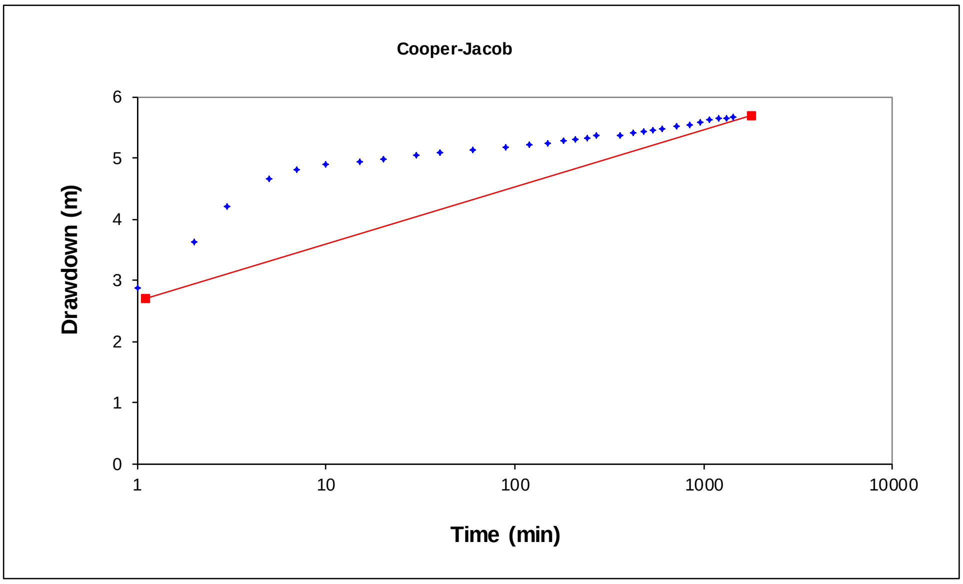
Recommended abstraction rate (L/s)		**0.60**	for 24 hours per day
Hours per day of pumping	**12**	**0.85**	L/s for 12 hours per day

Amount of water allowed to be abstracted per month	**1555.2**	m^3
Borehole could satisfy the basic human need of	**2074**	persons
Is the water suitable for domestic use (Yes/No)	**Y**	

Cooper-Jacob method	Main	Theis	Cooper-Jacob 2
BH 8			

$T(m^2/d)$ =	36.3	r_e (m)=	1.52	1.52
S =	3.46E-05	Q (l/s) =	2.14	

	No boundaries	1 no-flow	2 no-flow	Closed	
Q_sust	4.94	2.47	1.63	1.24	including influence of bh's
Avg. Q_sust =	2.57	std. dev =	1.66		

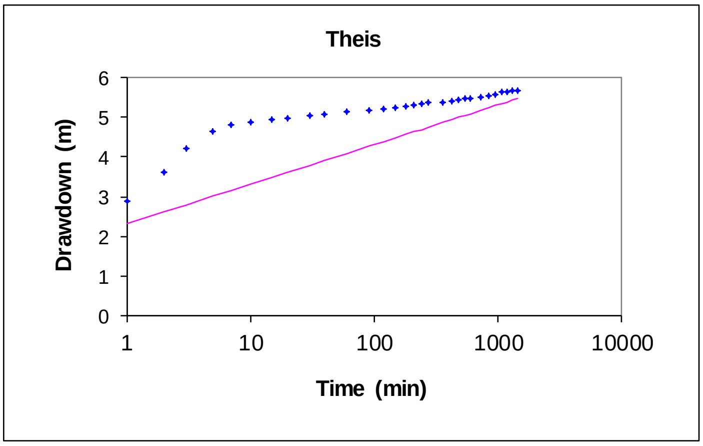


x0	y0	x1	y1
1.1	2.7	1795	5.7

Theis

T (m2/d)	S	r
34	1.00E-05	5.00

Top



Summary | Main | BH 8

Applicable	Method	Sustainable yield (l/s)	Std. Dev	Early T (m^2/d)		Late T (m^2/d)		S	AD used
☑	**Basic FC**	3.84	1.30	67		56.4		2.20E-03	20.0
☐	**Advanced FC**			67		56.4		1.00E-03	20.0
☐	**FC inflection point**	0.49	0.29						7.7
☑	**Cooper-Jacob**	2.57	1.66			36.3		3.46E-05	20.0
☐	**FC Non-Linear**	2.49	2.20			34.0		5.06E-03	20.0
☑	**Barker**	2.90	0.71	K_f =	8020		S_s =	1.01E-05	20.0
	Average Q_sust (l/s)	**3.10**	**0.66**	b =	0.06	Fractal dimension n =		1.80	

Recommended abstraction rate (L/s)		**2.20**	for 24 hours per day
Hours per day of pumping	**12**	**3.11**	L/s for 12 hours per day

Amount of water allowed to be abstracted per month	**5702.4**	m^3
Borehole could satisfy the basic human need of	**7603**	persons
Is the water suitable for domestic use (Yes/No)	**Y**	

Cooper-Jacob method

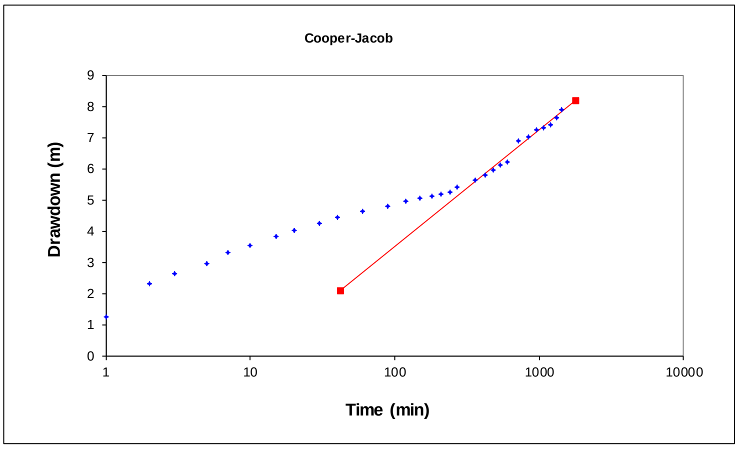
Main | Theis | Cooper-Jacob 2

H/BH 10

$T(m^2/d)$ =	30.1		r_e (m)=	1.52	1.52
S =	2.36E-01		Q (l/s) =	7.13	

	No boundaries	1 no-flow	2 no-flow	Closed
Q_sust	13.45	6.72	4.44	3.36
Avg. Q_sust =	6.99	std. dev =	4.53	

including influence of bh's

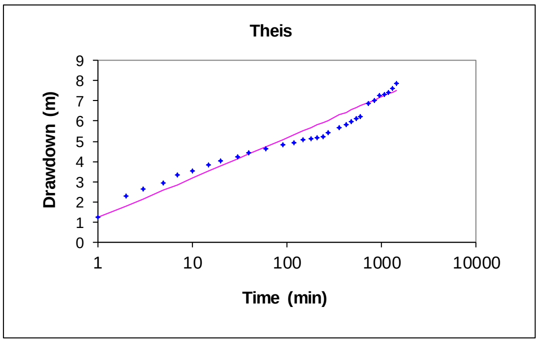


x0	y0	x1	y1
42.1	2.1	1795	8.2

Theis

T (m2/d)	S	r
56	9.50E-04	5.00

Top

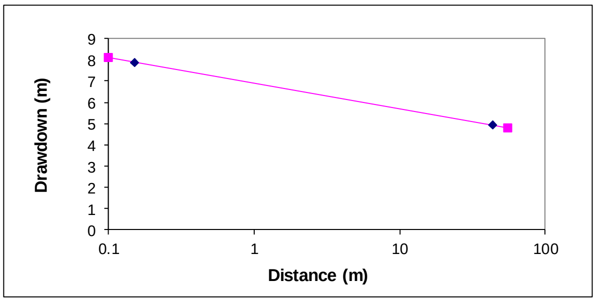


Cooper-Jacob 2: Distance drawdown

Top

	Obs 1	Obs 2	Obs 3	Obs 4	Obs 5	Obs 6
Distance r (m)	0.15	43.6				
Drawdown (m)	7.88	4.96				
Time (minutes)	1440					

$T (m^2/d)$ =	187.36	S	1.44E-05



0.1	8.10
55	4.80
	1.20

Summary — H/BH 10

Main

Applicable	Method	Sustainable yield (l/s)	Std. Dev	Early T (m^2/d)		Late T (m^2/d)		S	AD used
☑	**Basic FC**	6.09	3.82	80		25.1		1.93E-03	35.0
☐	**Advanced FC**			80		25.1		1.00E-03	35.0
☐	**FC inflection point**	1.81	1.02						7.7
☑	**Cooper-Jacob**	6.99	4.53			30.1		2.36E-01	35.0
☐	**FC Non-Linear**	2.49	2.20			34.0		5.06E-03	35.0
☑	**Barker**	7.98	6.26	K_f =	8020		S_s =	1.01E-05	35.0
	Average Q_sust (l/s)	**7.02**	**0.95**	b =	0.12	Fractal dimension n =		1.80	

Recommended abstraction rate (L/s)		**5.00**	for 24 hours per day
Hours per day of pumping	**12**	**7.07**	L/s for 12 hours per day

Amount of water allowed to be abstracted per month	**12960**	m^3
Borehole could satisfy the basic human need of	**17280**	persons
Is the water suitable for domestic use (Yes/No)	**Y**	

Appendix C

Water Quality Information

Aquatico

Cat and Anion analyses

aquatico Laboratories (Pty). Ltd.

ilac-MRA sanas Testing Laboratory T0685

Test Report

Client: Henk Kruidenier
Address: 25ste laan, 327, Villieria, Pretoria, 0186
Report no: 25674
Project: Geo-Logic

Date of certificate: 03 August 2015
Date accepted: 27 July 2015
Date completed: 31 July 2015
Revision: 0

Lab no:				222173	222174
Date sampled:				23-Jul-15	24-Jul-15
Sample type:				Water	Water
Locality description:				BH 01	BH 05
	Analyses	Unit	Method		
A	pH @ 25°C	pH	ALM 20	7.42	7.69
A	Electrical conductivity (EC) @ 25°C	mS/m	ALM 20	192	137
A	Total dissolved solids (TDS)	mg/l	ALM 26	1263	881
A	Total alkalinity	mg $CaCO_3$/l	ALM 01	298	353
A	Chloride (Cl)	mg/l	ALM 02	275	139
A	Sulphate (SO_4)	mg/l	ALM 03	95.6	72.3
A	Nitrate (NO_3) as N	mg/l	ALM 06	77.7	41.6
A	Ammonium (NH_4) as N	mg/l	ALM 05	0.036	0.020
A	Orthophosphate (PO_4) as P	mg/l	ALM 04	0.097	0.079
A	Fluoride (F)	mg/l	ALM 08	0.712	0.409
A	Calcium (Ca)	mg/l	ALM 30	191	140
A	Magnesium (Mg)	mg/l	ALM 30	89.2	57.5
A	Sodium (Na)	mg/l	ALM 30	78.8	66.1
A	Potassium (K)	mg/l	ALM 30	7.07	6.46
A	Aluminium (Al)	mg/l	ALM 31	<0.002	<0.002
A	Iron (Fe)	mg/l	ALM 31	<0.004	<0.004
A	Manganese (Mn)	mg/l	ALM 31	<0.002	<0.002
A	E.coli	CFU/100ml	ALM 40	<1	<1
A	Total coliform	CFU/100ml	ALM 40	14	6
A	Total hardness	mg $CaCO_3$/l	ALM 26	844	587
A	Chemical oxygen demand (COD)	mg/l	ALM 10	<5.1	<5.1
N	Oil and grease (SOG)	mg/l	ALM 29	1.90	1.70

A = Accredited N = Non accredited O = Outsourced S = Sub-contracted NR = Not requested RTF = Results to follow NATD = Not able to determine
The results relates only to the test item tested.
Results reported against the limit of detection.
Results marked 'Not SANAS Accredited' in this report are not included in the SANAS Schedule of Accreditation for this laboratory.
Uncertainty of measurement available on request for all methods included in the SANAS Schedule of Accreditation.

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aquatico Laboratories (Pty). Ltd.

ilac-MRA sanas Testing Laboratory T0685

Test Report

Client: Henk Kruidenier
Address: 25ste laan, 327, Villieria, Pretoria, 0186
Report no: 25679
Project: Geo-Logic

Date of certificate: 03 August 2015
Date accepted: 27 July 2015
Date completed: 31 July 2015
Revision: 0

Lab no:				222207	222208
Date sampled:				23-Jul-15	23-Jul-15
Sample type:				Water	Water
Locality description:				BH 02	BH 03
	Analyses	Unit	Method		
A	Chemical oxygen demand (COD)	mg/l	ALM 10	<5.1	<5.1
N	Oil and grease (SOG)	mg/l	ALM 29	1.20	2.00

A = Accredited N = Non accredited O = Outsourced S = Sub-contracted NR = Not requested RTF = Results to follow NATD = Not able to determine
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Uncertainty of measurement available on request for all methods included in the SANAS Schedule of Accreditation.

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aquatico Laboratories (Pty). Ltd.

ilac-MRA · sanas Testing Laboratory T0685

Test Report — Page 1 of 1

Client: Henk Kruidenier
Address: 25ste laan, 327, Villieria, Pretoria, 0186
Report no: 25778
Project: Geo-Logic

Date of certificate: 07 August 2015
Date accepted: 03 August 2015
Date completed: 06 August 2015
Revision: 0

Lab no:				222803
Date sampled:				03-Aug-15
Sample type:				Water
Locality description:				Upington - BH8
	Analyses	Unit	Method	
A	pH @ 25°C	pH	ALM 20	7.25
A	Electrical conductivity (EC) @ 25°C	mS/m	ALM 20	140
A	Total dissolved solids (TDS)	mg/l	ALM 26	857
A	Total alkalinity	mg $CaCO_3$/l	ALM 01	268
A	Chloride (Cl)	mg/l	ALM 02	120
A	Sulphate (SO_4)	mg/l	ALM 03	70.1
A	Nitrate (NO_3) as N	mg/l	ALM 06	50.8
A	Ammonium (NH_4) as N	mg/l	ALM 05	0.104
A	Orthophosphate (PO_4) as P	mg/l	ALM 04	<0.002
A	Fluoride (F)	mg/l	ALM 08	0.473
A	Calcium (Ca)	mg/l	ALM 30	145
A	Magnesium (Mg)	mg/l	ALM 30	59.6
A	Sodium (Na)	mg/l	ALM 30	66.9
A	Potassium (K)	mg/l	ALM 30	6.41
A	Aluminium (Al)	mg/l	ALM 31	<0.002
A	Iron (Fe)	mg/l	ALM 31	<0.004
A	Manganese (Mn)	mg/l	ALM 31	<0.002
A	E.coli	CFU/100ml	ALM 40	<1
A	Total coliform	CFU/100ml	ALM 40	<1
A	Total hardness	mg $CaCO_3$/l	ALM 26	608
A	Chemical oxygen demand (COD)	mg/l	ALM 10	17.2

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C. v.d. Westhuizen
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Test Report

Client: Henk Kruidenier
Address: 25ste laan, 327, Villieria, Pretoria, 0186
Report no: 25279
Project: Geo-Logic

Date of certificate: 08 July 2015
Date accepted: 02 July 2015
Date completed: 08 July 2015
Revision: 0

Lab no:				219277	219278	219279	219280	219281
Date sampled:				27-Jun-15	27-Jun-15	26-Jun-15	26-Jun-15	28-Jun-15
Sample type:				Water	Water	Water	Water	Water
Locality description:				BH2 - Steenkamps Pan	BH3 - Steenkamps Pan	H-BH 14	H-BH 11 Duiker Rand	H-BH 15
	Analyses	Unit	Method					
A	pH @ 25°C	pH	ALM 20	8.31	7.63	8.35	7.61	7.88
A	Electrical conductivity (EC) @ 25°C	mS/m	ALM 20	125	115	163	156	120
A	Total dissolved solids (TDS)	mg/l	ALM 26	965	860	1240	1245	895
A	Total alkalinity	mg $CaCO_3$/l	ALM 01	327	367	373	427	420
A	Chloride (Cl)	mg/l	ALM 02	167	121	321	221	151
A	Sulphate (SO_4)	mg/l	ALM 03	75.0	54.8	104	78.3	33.9
A	Nitrate (NO_3) as N	mg/l	ALM 06	51.2	41.1	40.5	64.2	35.8
A	Ammonium (NH_4) as N	mg/l	ALM 05	0.034	0.029	0.045	0.025	0.022
A	Orthophosphate (PO_4) as P	mg/l	ALM 04	0.045	0.045	0.041	0.045	0.047
A	Fluoride (F)	mg/l	ALM 08	0.567	0.914	0.687	0.879	0.520
A	Calcium (Ca)	mg/l	ALM 30	134	108	128	149	157
A	Magnesium (Mg)	mg/l	ALM 30	76.4	62.4	91.9	79.0	57.5
A	Sodium (Na)	mg/l	ALM 30	79.4	98.4	176	162	75.1
A	Potassium (K)	mg/l	ALM 30	6.61	8.92	12.0	10.6	6.10
A	Aluminium (Al)	mg/l	ALM 31	<0.002	<0.002	<0.002	<0.002	<0.002
A	Iron (Fe)	mg/l	ALM 31	<0.004	<0.004	<0.004	<0.004	<0.004
A	Manganese (Mn)	mg/l	ALM 31	<0.002	<0.002	<0.002	<0.002	<0.002
A	E.coli	CFU/100ml	ALM 40	<1	<1	<1	<1	<1
A	Total coliform	CFU/100ml	ALM 40	<1	350	130	1	3
A	Total hardness	mg $CaCO_3$/l	ALM 26	648	527	697	698	628

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M. Swanepoel
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Appendix D

Water Quality Information

Organic Analyses Laboratory

Hydrocarbons analyses

ORGANIC ANALYSIS LABORATORY

VAT No. 496 021 5889

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Tel: +27(0)12 333 1557/1479 Fax: +27(0)12 333 1557 Email: pietervanrossum@vodamail.co.za

GEO-LOGIC
25th Avenue 327
Villieria
Pretoria, 0186
Tel: 012 329 1352
henk@geo-logic.co.za

Date received: 27 July 2014
Report date: 28 July 2014

ATTENTION: H. KRUIDENIER

TPH determination in 3 samples of water

GC: F78/1 SAMPLE: Upington 23/07/2015 BH1

TOTAL:	0.00 mg/L
t-BME:	0.00 mg/L
benzene:	0.00 mg/L
tame:	0.00 mg/L
toluene:	0.00 mg/L
ethylbenzene:	0.00 mg/L
o-Xylene:	0.00 mg/L
m+p-Xylene:	0.00 mg/L
naphthalene:	0.00 mg/L

Alkanes (carbon number: mg/L)

C9:	0.00	C10:	0.00	C11:	0.00	C12:	0.00
C13:	0.00	C14:	0.00	C15:	0.00	C16-26:	0.00

GC: F78/2 SAMPLE: Upington 23/07/2015 BH2

TOTAL:	0.00 mg/L
t-BME:	0.00 mg/L
benzene:	0.00 mg/L
tame:	0.00 mg/L
toluene:	0.00 mg/L
ethylbenzene:	0.00 mg/L
o-Xylene:	0.00 mg/L
m+p-Xylene:	0.00 mg/L
naphthalene:	0.00 mg/L

Alkanes (carbon number: mg/L)

C9:	0.00	C10:	0.00	C11:	0.00	C12:	0.00
C13:	0.00	C14:	0.00	C15:	0.00	C16-26:	0.00

GC: F78/3 SAMPLE: Upington 23/07/2015 BH3

TOTAL:	0.00 mg/L
t-BME:	0.00 mg/L
benzene:	0.00 mg/L
tame:	0.00 mg/L
toluene:	0.00 mg/L
ethylbenzene:	0.00 mg/L
o-Xylene:	0.00 mg/L
m+p-Xylene:	0.00 mg/L
naphthalene:	0.00 mg/L

Alkanes (carbon number: mg/L)

C9:	0.00	C10:	0.00	C11:	0.00	C12:	0.00
C13:	0.00	C14:	0.00	C15:	0.00	C16-26:	0.00

TOTAL = Petroleum hydrocarbons up to $C_{26}H_{54}$ (hexacosane) plus unknowns
t-BME = MTBE = tert-butylmethylether

Analysed by: K. Pretorius

Dr. P.G. van Rossum
B.Sc. M.Sc. D.Sc. Pr.Sci.Nat.

K. Pretorius