APPENDIX L

Groundwater Assessment

WATER
ENVIRONMENTAL
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EARTH SCIENCES
GIS

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Hydrogeological Baseline Assessment for the Proposed Thermal Solar Plants

Report

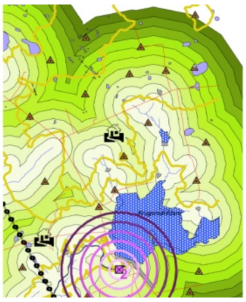
Version - 1

May 2010

Client Name: Bohlweki Environmental (Pty) Ltd
Project Number: 10-083

BOHLWEKI SSI
Environmental

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I. EXECUTIVE SUMMARY

GCS (Pty) Ltd (GCS) was appointed by Bohlweki Environmental (Pty) Ltd ("Bolweki) to undertake the geohydrological impact assessment for the proposed Thermal Solar Plant near Upington, Northern Cape. The aim of this assessment was to assess the baseline groundwater conditions for the local aquifer system and to supply an indication of possible risk to the groundwater environment accordingly.

The following basic steps were applied:

- A desk study was conducted which included the analysis of data obtained from the National Department of Water Affairs' National Groundwater Database (NGDB). Available specialist reports were obtained from Bohlweki Environmental and Gibb and were applied accordingly. Special references were made to the available geotechnical report
- GCS visited the sites and the local area on the 13th and 14th of April 2010. A hydrocensus survey was conducted within a 1km radius to determine the extent of groundwater use by the local community.
- Data collected during the hydrocensus survey as well as the data obtained from the NGDB were mapped for reporting purposes.
- Baseline groundwater quality was assessed by the collection of water samples from existing sources. Existing boreholes were mostly equipped with wind pumps and used for livestock farming. Groundwater supply boreholes are mainly equipped with wind pumps
- Water samples were submitted to M&L Laboratory for chemical analysis.

This report details the analysis of all available data sets and the conclusions and the recommendations that were made.

<u>Recommendations – Site 1</u>

The proposed site is bounded on the south by R64 main road and is characterised by relatively flat topographic terrains. The site is mainly covered with natural grass and is used as grazing land. No crop farming activities are taking place on the site. No surface water bodies exist within the site. The Orange River is located approximately 2 km south of the site

Geology and Hydrogeology:

- The general geology of the site mainly comprises red-brown, wind-blown sand and dunes. Magmatic, biotite-rich and aluminous gneisses and calcrete of the Areachap Sequence are also present, especially on the north-western part of the area.
- The hydrogeological map of the area indicates that two different aquifer systems occur in the area; intergranular and fractured aquifer types. The yield from the local aquifers range from 0.1 to 0.5 l/s. The site falls within the quaternary catchment D73F. Data obtained from GRDM data indicates that the area receives a mean annual precipitation of 158 mm. The average annual recharge for the area is 50.9 mm.

Water Quality:

- The chemical analysis of water samples collected from boreholes indicates that elevated levels of electric conductivity and nitrates exist in the groundwater, according to DWA Water Quality Guidelines. Water was of the NaCl type.

Impact/Risk:

- The significance of potential impacts, as determined using a ranking system prescribed by the DAEA, indicates that the potential impacts have low to moderate significance rating. This will only apply if leakages of site related contaminants occurred.
- If proper management measures, together with site- and operational monitoring (refer to next section), are applied, the potential impact on groundwater resources will have very low or no significance.

Recommendations – Site 2

The Proposed Thermal Solar Plant site is situated in the farm Bokpoort 390, approximately 75km south east of Upington and 13 km north west of Groblershoop, in the Northern Cape Province. It is bounded on the south by Orange River and N14 national road and is characterised by relatively flat topographic terrains. The site is mainly covered with natural grass and is used as a grazing land. No crop farming activities are taking place on site. No surface water bodies exist within the site.

Geology and Hydrogeology:

- The general geology of the site mainly comprises red-brown, coarse-grained granite gneiss; and quartz-muscouite schists, quartzite, quartz-amphibole schists and greenstones of the Groblershoop formation, Brulpan group. Calcrete is also found especially on the south eastern part of the area.

- Groundwater use takes place in the farms located further away from the Orange River. Groundwater in these farms is used mainly for domestic purpose and livestock (cattle and sheep) farming. Most of the boreholes are equipped with wind pumps.
- The hydrogeological map of the area indicates that the fractured aquifer type occurs in the area. The yield from the local aquifers range from 0.1 to 0.5 l/s.

Water Quality:

Groundwater in the area contains elevated levels of electric conductivity. The dominant cations were sodium and calcium and the dominant anions were chloride and sulphates. The samples also contained a high concentration of nitrates.

Impact/Risk:

- The significance of potential impacts, as determined using a ranking system prescribed by the DAEA, indicates that the potential impacts have low to moderate significance rating. This will only apply if leakages from sub-surface tanks and/or site related contamination occurred.
- If proper management measures, together with site- and operational monitoring (refer to next section), are applied, the potential impact on groundwater resources will have very low or no significance.
- However, a proper "warning" system in the form of monitoring wells is suggested. More detail on the suggested monitoring system in the following section.

General Recommendations for Site 1 and 2

- The general geology of the area presented in this report is not site specific. Exploration holes can be drilled to get a better understanding of the geology underlying the proposed site. Aquifer parameters can be determined from these boreholes to gain an understanding of the flow dynamics in the two aquifer systems. This can be achieved by drilling a shallow borehole up to bedrock level and the deeper borehole into the bedrock.
- It is recommended that the operational area of the power station must be paved with concrete material which will be inspected on a regular basis for cracks and leaks.
- It is further recommended that two monitoring/observation boreholes be drilled on site during the construction phase of the project. The existence of these boreholes will assist in the early detection of any leakage of contaminants into the groundwater system.

- The optimum drilling positions for these boreholes must be selected by a professional hydrogeologist. It is important that the topographic setting, possible geological structures, etc, are considered during this phase
- Groundwater levels can be measured on a monthly basis and initial water quality samples can be collected and analysed for reference purposes. Thereafter on-going sampling of groundwater can be conducted on quarterly basis. The chemical analysis of water must include the following determinants: pH; Conductivity; Calcium (Ca); Magnesium (Mg); Sodium (Na); Potassium (K); Bicarbonate (HCO32-); Chloride (Cl); Sulphate (SO42-); Nitrate (NO3); Iron (Fe); Manganese (Mn).

CONTENTS PAGE

LIST OF FIGURES

LIST OF TABLES

LIST OF APPENDICES

1 INTRODUCTION

GCS (Pty) Ltd was requested by SSI Bohlweki to undertake the hydrogeological baseline assessment study for the proposed thermal solar plant in Upington, Northern Cape. The hydrogeological assessment forms part of the Environmental Impact Assessment conducted for the proposed thermal solar plant site. The project aimed to conduct the gathering and assessment of the baseline hydrogeological data of the site and its surrounding area.

The area was visited on the 13th and 14th April 2010 to conduct the site assessment. The assessment involved desk study and literature review for the site area, conducting the hydrocensus within a 1km radius around the site, collection of groundwater samples, and reporting the findings of the data assessment.

This report details the findings of the desk study and field survey conducted on site.

2 SCOPE OF WORK

The deliverables of the site assessment were set as follows:

1. Description of the general geology and hydrogeological conditions;
2. Assessment of data obtained from the National Groundwater Database and WARMS;
3. the special distribution of boreholes within the site area and the neighbouring farms;
4. Identification of possible problem areas associated with groundwater;
5. Risk assessment based on the data obtained during the investigation; and
6. Compilation of a report detailing the findings from the above.

3 METHODOLOGY

The methodology for the geohydrological site assessment was as follows:

Desk Study

The desk study involved a review of all available geological and hydrogeological literature. This included aerial photos, topographical sheets, geological and hydrogeological maps. Data was requested from the National Department of Water Affairs for existing boreholes and groundwater use of the area.

Hydrocensus

A hydrocensus survey was conducted on the area within a 1km radius surrounding the site. The aim of the survey was to locate and map the groundwater users in the vicinity of the site. The farmers were visited to enquire about the extent of groundwater usage from boreholes and springs. Groundwater samples were also collected from some of the production boreholes on the farms.

4 SITE DESCRIPTION

4.1 Site Description: Site 1

The site is situated in the farm Olyvenhouts Drift, approximately 15km south west of Upington, in the Northern Cape Province. It is bounded on the south by R64 national road and is characterised by relatively flat topographic terrains. The site is mainly covered with natural grass and is used as a grazing land. No crop farming activities are taking place on site. No surface water bodies exist within the site. The Orange River is located about 2 km south of the site. Refer to Figure 4 1 for the general view of the site from south-eastern side.

Figure 4.1 General view across site 1

4.2 Site Description: Site 2

The site is situated in the farm Bokpoort 390, approximately 75km south-east of Upington and 13 km North West of Groblershoop, in the Northern Cape Province. It is bounded on the south by Orange River and N14 national road and is characterised by relatively flat topographic terrains. The site is mainly covered with natural grass and is used as a grazing land. No crop farming activities are taking place on site. No surface water bodies exist within the site. Refer to Figure 4.2 for the general view of the site from south-eastern side.

Figure 4.2 General view across Site 2

5 SITE ASSESSMENT

5.1 Site Assessment: Site 1

5.1.1 General Geology and Aquifer Type

The general geology of the site mainly comprises red-brown, wind-blown sand and dunes. Magmatic, biotite-rich and aluminous gneisses and calcrete of the Areachap Sequence are also present, especially on the north-western part of the area.

The hydrogeological map of the area indicates that two different aquifer systems occur in the area; intergranular and fractured aquifer types. The yield from the local aquifers range from 0.1 to 0.5 l/s. Refer to Figure 5 2 for the geological map of the site and the surrounding farms. The site falls within the quaternary catchment D73F. Data obtained from GRDM data indicates that the area receives a mean annual precipitation of 158 mm per annum. The average annual recharge for the area is 50.9 million cubic meters per annum over the entire catchment area.

5.1.2 Hydrocensus

The aim of the hydrocensus survey was to establish the extent of groundwater usage in the area. The farmers and the villages were visited to locate any production boreholes that might be used for water supply. From the hydrocensus survey it was established that the community living in the villages south of the site relies on municipal water for domestic water supply. The farms located far from areas covered by municipal water supply get water from the Orange River. The river water requires some treatment before it is ready for domestic use. Groundwater use takes place in the farms located further away from the river. Groundwater in these farms is used mainly for domestic purpose and livestock (cattle and sheep) farming. Most of the boreholes are equipped with handpumps. The data collected during the survey is presented in Table 1. Refer to Figure 5 1 for the location of the springs.

It was established during the hydrocensus that the area has shallow groundwater levels. The water levels measured from the boreholes ranged from 7.75 to 10.4 m below ground level. The pH levels ranged from 7.02 to 7.32; and the Total Dissolved Solids (TDS) ranged from 440 to 760 mg/l.

5.1.3 National Groundwater Database (NGDB)

A request was made to the National Department of Water Affairs (DWA) for borehole and groundwater data from the NGDB. Two boreholes from the data obtained plotted within a 2 km radius surrounding Olyvenhouts Drift farm.

The average water level for the NGDB boreholes was 39.3 m below ground level. As it was established during the hydrocensus survey, the boreholes on the surrounding farms are also equipped with wind pumps and are used for stock watering. Although groundwater resource is the sole source of water in the farms, the general use is at a small scale. Refer to Figure 5 2 for the location of these boreholes.

5.1.4 Groundwater quality

Four groundwater samples were collected and submitted to M&L Laboratory in Johannesburg for chemical analysis. The certificates of analysis are attached in Appendix A. GCS (Pty) Ltd established a database in AQUABASE (database system for the storage and retrieval of surface water and groundwater related data developed by VSA Earth Resources

Consultants (Pty) Ltd) and Microsoft Excel in which data was captured for storage and analysis.

Results of the chemical analysis were compared with the DWAF South African Water Quality Guidelines for Domestic Water Use and the SABS Standards. Table 2 below show the analysis results of groundwater samples and the limits from the DWAF Guidelines. Values that exceeded the DWA limits are highlighted in colours as assigned to water quality classes by DWA.

It can be seen from Table 2 that groundwater in the area contains elevated levels of electric conductivity. The dominant cations were sodium and calcium and the dominant anions were chloride and sulphates. The samples also contained a high concentration of nitrates. The results of the chemical analysis were also plotted on Piper and Schoeller diagrams (refer to Figure 5 3 and Figure 5 4) to indicate the dominant anions and cations. It can be seen from the diagrams that water from groundwater in the area is of NaCl type.

5.1.5 Aquifer classification

The local aquifers underlying the proposed site are the sole source of potable water for the communities living in the farming areas. The use of groundwater resource by the farmers is, however, at a very low scale. The community living in villages located south of the site depend on municipal water for their domestic water needs. The local aquifers can be classified as minor, according to Parsons Aquifer Classification system, due to the limited use of groundwater in the area as well as the quality of groundwater obtained from the chemical analysis results.

5.2 Site Assessment: Site 2

5.2.1 General Geology and Aquifer Type

The general geology of the site mainly comprises red-brown, coarse-grained granite gneiss; and quartz-muscouite schists, quartzite, quartz-amphibole schists and greenstones of the Groblershoop formation, Brulpan group. Calcrete is also found especially on the south eastern part of the area.

The hydrogeological map of the area indicates that the fractured aquifer type occurs in the area. The yield from the local aquifers range from 0.1 to 0.5 l/s. Refer to Figure 5 3 for the geological map of the site and the surrounding farms. The site falls within the quaternary catchment D73D. Data obtained from GRDM data indicates that the area receives a mean annual precipitation of 185 mm. The average annual recharge for the area is 40.0 million cubic meters per annum over the entire sub-catchment area.

5.2.2 Hydrocensus

The aim of the hydrocensus survey was to establish the extent of groundwater usage in the area. The farmers and the villages were visited to locate any production boreholes that might be used for water supply. From the hydrocensus survey it was established that the community living in the farms relies on municipal water for domestic water supply. The farms located on the southern side of the area get water from the Orange River. The river water requires some treatment before it is ready for domestic use. Groundwater use takes place in the farms located further away from the river. Groundwater abstraction on the farms are mainly used for domestic purpose and animal (cattle and sheep) farming. Most of the boreholes are equipped with handpumps. The data collected during the survey is presented in Table 1. Refer to Figure 5 2 for the location of the groundwater and springs.
Water level measurements could not be taken from the farm boreholes. However, the use of wind pumps in the boreholes indicates that water level is not very deep. The pH levels ranged from 7.36 to 8.06; and the Total Dissolved Solids (TDS) ranged from 420 to 490 mg/l.

5.2.3 National Groundwater Database (NGDB)

A request was made to the National Department of Water Affairs (DWA) for borehole and groundwater data from the NGDB. Six boreholes from the data obtained plotted within a 2 km radius around the boundaries of the Bokpoort farm. The NGDB data indicates that the average water level from the existing boreholes id 41.88 m below ground level. As it was established during the hydrocensus survey, the boreholes on the surrounding farms are also equipped with wind pumps and are used for stock watering. Although groundwater resource is the sole source of water in the farms, the general use is at a small scale. Refer to Figure 5 2 for the location of these boreholes.

5.2.4 Groundwater quality

Three groundwater samples were collected from the springs and submitted to M&L Laboratory in Johannesburg for chemical analysis. The certificates of analysis are attached in Appendix B. GCS (Pty) Ltd established a database in AQUABASE (database system for the storage and retrieval of surface water and groundwater related data developed by VSA

Earth Resources Consultants (Pty) Ltd) and Microsoft Excel in which data was captured for storage and analysis.

Results of the chemical analysis were compared with the DWAF South African Water Quality Guidelines for Domestic Water Use and the SABS Standards. Table 3 below show the analysis results of groundwater samples and the limits from the DWAF Guidelines. Values that exceeded the DWA limits are highlighted in colours as assigned to water quality classes by DWA.

It can be seen from Table 2 that groundwater in the area contains elevated levels of electric conductivity. The dominant cations in two of the sampled boreholes (Borehole 2 and Borehole 5) were sodium and calcium and the dominant anions were chloride and sulphates. The samples also contained a high concentration of nitrates. Borehole 3 had water of good quality with all the determinants falling in class 0 of the DWA standards. The results of the chemical analysis were also plotted on Piper and Schoeller diagrams (refer to Figure 5 3 and Figure 5 4) to indicate the dominant anions and cations. It can be seen from the diagrams that water is of Ca/MgHCO3 to CaMg/SO4 type.

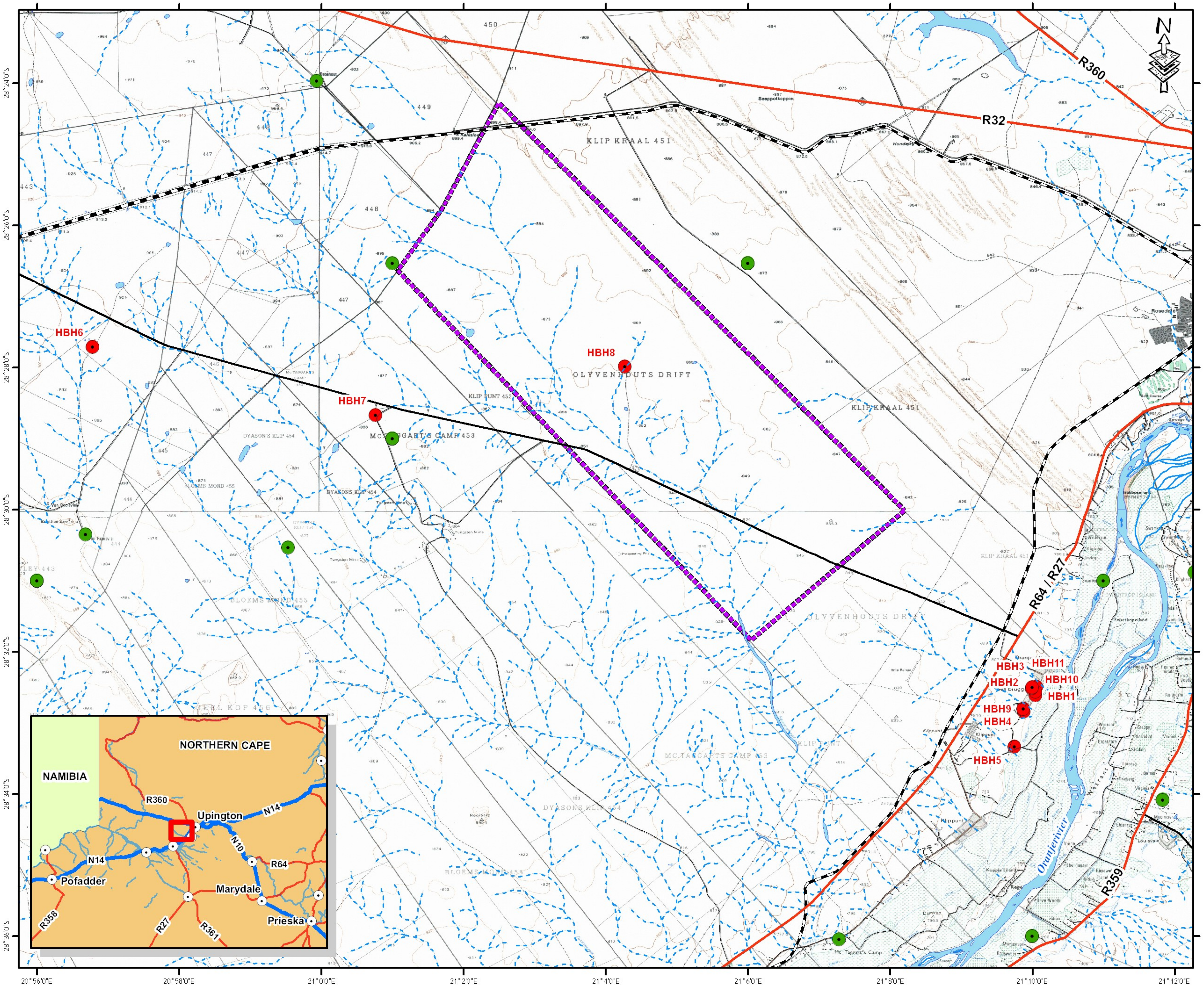
5.2.5 Aquifer classification

The local aquifers underlying the proposed site are the sole source of potable water for the communities living in the farming areas. The use of groundwater resource by the farmers is, however, at a very low scale. The community living in farms located along the Orange River depends on the river water for their domestic water needs.

The local aquifers can be classified as minor, according to Parsons Aquifer Classification system, due to the limited use of groundwater in the area as well as the quality of groundwater obtained from the chemical analysis results.

Figure 5.1 Site 1: Location of hydrocensus and NGDB boreholes

SITE 1: LOCALITY



LEGEND

Towns

NGDB Boreholes

Hydrocensus Boreholes

ROAD NETWORK

National Route

Main Road

Secondary Road

Other Access

Railway line

RIVERS & STREAMS

Perennial

Non-Perennial

Dams

Olyvenhouts Drift

Data Sources: The Chief Directorate of Survey & Mapping
1:50 000 Topographical Series: 2820BD,DB & 2821AC,CA

FIGURE NO.:	*****
MAP NUMBER:	10-083-20100511-01
DRAWN BY:	A.J. MAIN GIS TECHNOLOGIST
REVIEWED BY:	R.F. VAN DER MERWE GIS MANAGER (PGPT 0023)
DATUM: PROJECTION:	WGS84 GEOGRAPHIC
DATE:	21 APRIL 2010
CLIENT:	BOHLWEKI ENVIRONMENTAL (PTY) LTD
PROJECT:	BOHLWEKI SSI - UPINGTON THERMAL HYDROGEOLOGICAL ASSESSMENT (10-083)
SCALE:	1:96,000

0 1 2 4 Kilometers

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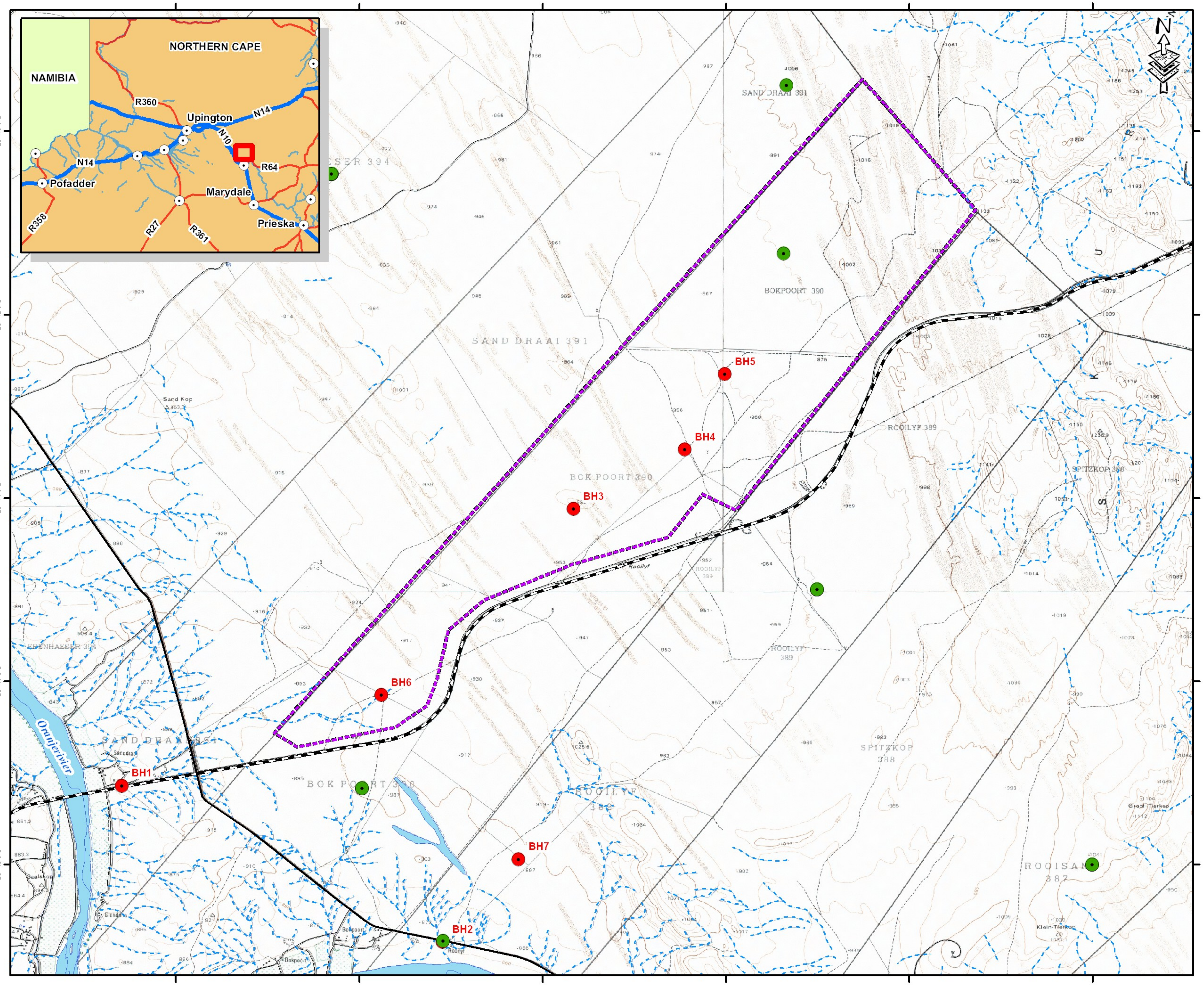
Figure 5.2 Site 2: Location of hydrocensus and NGDB boreholes

SITE 2: LOCALITY



LEGEND

- Towns
- NGDB Boreholes
- Hydrocensus Boreholes

ROAD NETWORK

- National Route
- Main Road
- Secondary Road
- Other Access
- Railway line

RIVERS & STREAMS

- Perennial
- Non-Perennial
- Dams
- RE Bokpoort

Data Sources: The Chief Directorate of Survey & Mapping
1:50 000 Topographical Series: 2822CA,CC,DB & 2821DB,DD

FIGURE NO.:	*****
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REVIEWED BY:	R.F. VAN DER MERWE GIS MANAGER (PGPT 0023)
DATUM: PROJECTION:	WGS84 GEOGRAPHIC
DATE:	21 APRIL 2010
CLIENT:	BOHLWEKI ENVIRONMENTAL (PTY) LTD
PROJECT:	BOHLWEKI SSI - UPINGTON THERMAL HYDROGEOLOGICAL ASSESSMENT (10-083)
SCALE:	1:75,000

0 0.5 1 2 Kilometers

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Figure 5.3 Site 1: Geological map

SITE1: GEOLOGY

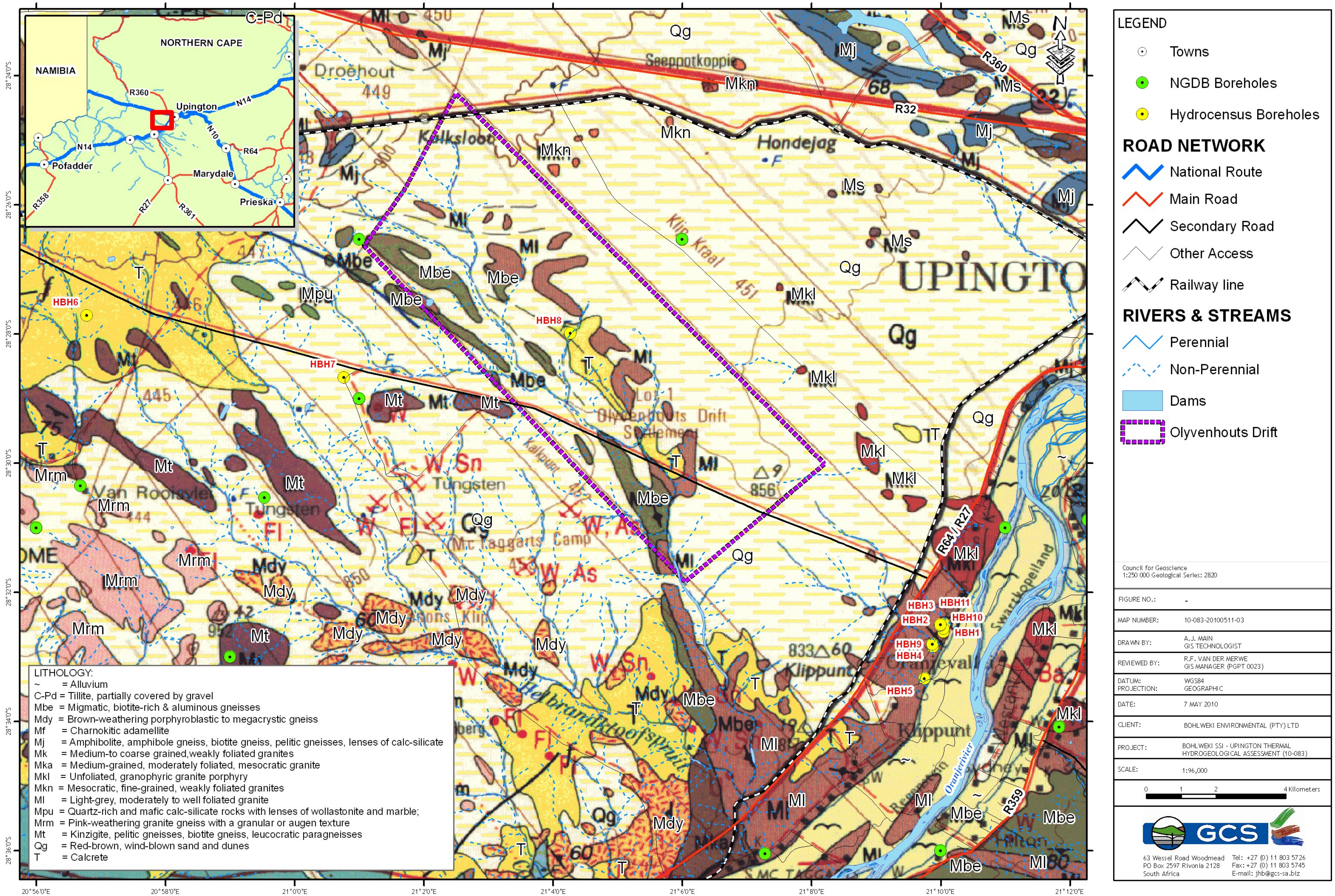
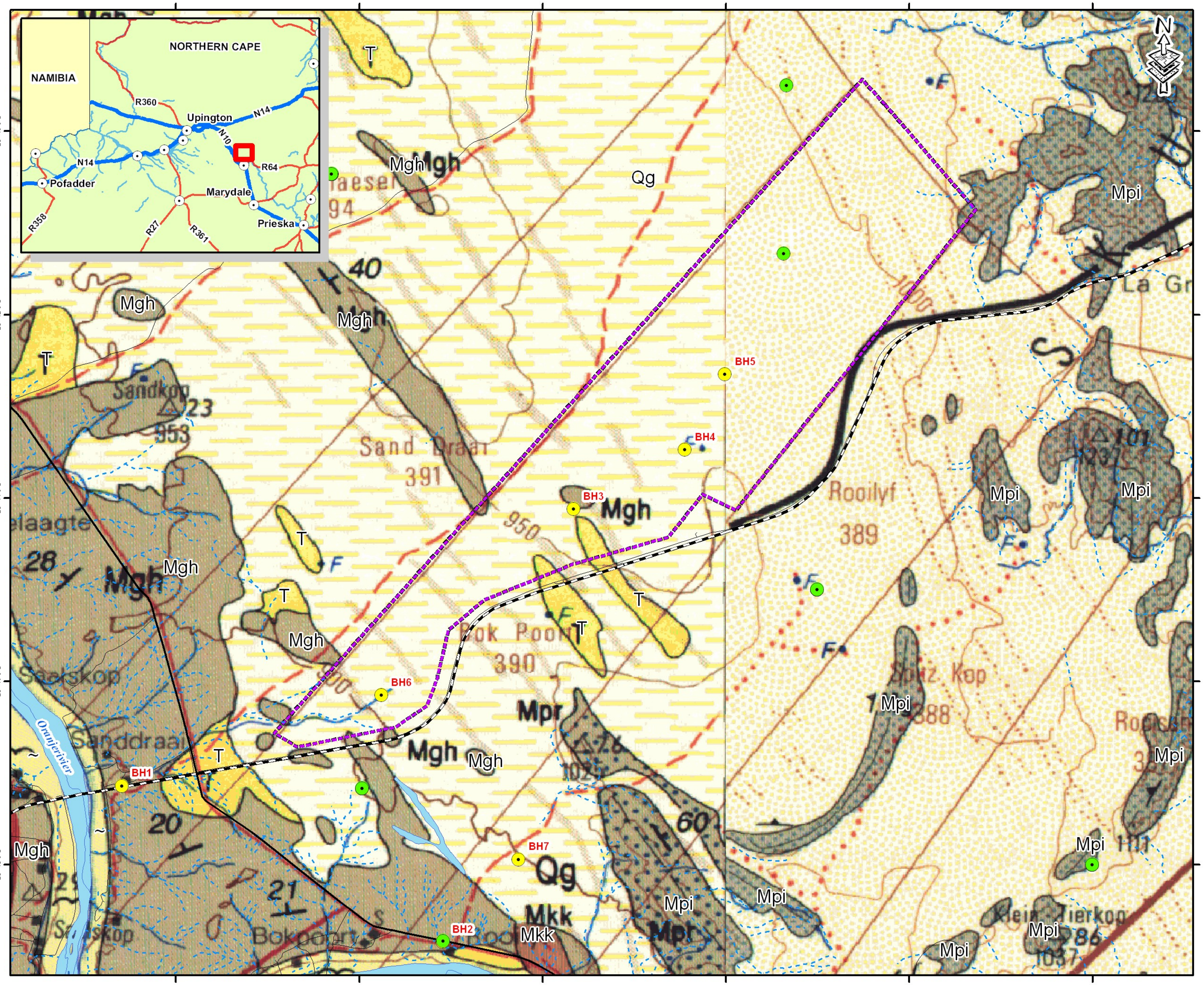


Figure 5.4 Site 2: Geological map

SITE 2: GEOLOGY



LEGEND

- Towns
- NGDB Boreholes
- Hydrocensus Boreholes

ROAD NETWORK

- National Route
- Main Road
- Secondary Road
- Other Access
- Railway line

RIVERS & STREAMS

- Perennial
- Non-Perennial
- Dams
- RE Bokpoort

LITHOLOGY:

~ = Alluvium
Mgh = Quart-muscouite schist, quartzite, quartz-amphibole schist; greenstone
Mkk = Red-brown, coarse-grained granite gneiss
Mpi = Medium- grained pink weathering gneiss
Qg = Red-brown, coarse-grained granite gneiss
T = Calcrete

Council for Geoscience
1:250 000 Geological Series: 2820, 2822

FIGURE NO.:	-
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REVIEWED BY:	R.F. VAN DER MERWE GIS MANAGER (PGPT 0023)
DATUM: PROJECTION:	WGS84 GEOGRAPHIC
DATE:	21 APRIL 2010
CLIENT:	BOHLWEKI ENVIRONMENTAL (PTY) LTD
PROJECT:	BOHLWEKI SSI - UPINGTON THERMAL HYDROGEOLOGICAL ASSESSMENT (10-083)
SCALE:	1:75,000

0 0.5 1 2 Kilometers

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Table 5.1 Site 1: Data obtained from hydrocensus survey

Site ID	Farm Name	Farm Owner/ Manager	Contact Details	S Coord	E Coord	WL (mbgl)	Equipment	pH	TDS (mg/l)	Use	Comments
HBH1		**Magda**		28.54154	21.16762		Wind pump			Unused	Access to the borehole could not be obtained from the tenants, the coordinates were taken at the gate. Domestic water is obtained from the municipal water supply.
HBH2		**Mr G. Cohen**	**076 335 4981**	28.54359	21.1674		Wind pump			Domestic	Borehole water is used for watering the garden. Domestic water is obtained from the municipal water supply.
HBH3		**Freddie Crawford**	**082 536 0117**	28.5427	21.1674	7.75	None			Unused	Open borehole located next to a house. The pump was removed. Domestic water is obtained from the municipal water supply.
HBH4		**Conrad Barnard**	**073 156 3494**	28.54739	21.16464		Wind pump			Unused	Borehole located next to a house. Currently unused, domestic water is obtained from the municipal water supply.
HBH5	**Plot 528, Olyvenhouts Drift**	**Arthor Schmidt**	**082 550 1748**	28.55557	21.16255		Submersible pump	7.32	730	Domestic	Domestic water is obtained from the Orange River. Borehole water is used only when there is a problem with the river water.
HBH6	**Vanrooisvlei**	**A. J. Vlok**	**082 786 7726**	28.4618	20.94635		Wind pump			Stock watering	Borehole located on a flat area on the sheep farm. Water is pumped into a tank for use in sheep farming.
HBH7	**Olyvenhouts Drift**	**Piet van Schalkwyk**	**083 285 1519**	28.4778	21.0127		Wind pump	7.18	760	Stock watering	Borehole located on a flat area on the sheep farm. Water is pumped into a tank for use in the sheep farming.

Site ID	Farm Name	Farm Owner/ Manager	Contact Details	S Coord	E Coord	WL (mbgl)	Equipment	pH	TDS (mg/l)	Use	Comments
HBH8	**Olyvenhouts Drift**	**Piet van Schalkwyk**	**083 285 1519**	28.46648	21.0711		Submersible pump			Stock watering	Borehole located on a flat area on the cattle farm. Water is pumped into a tank for use in cattle farming.
HBH9		**David Strauss**		28.54671	21.16461		Wind pump			Unused	Borehole located next to a house. Currently unused, domestic water is obtained from the municipal water supply.
HBH10		**P. A. Nel**	**083 966 6120**	28.54194	21.16653	10.4	Submersible pump	7.02	440	Domestic	Water is pumped into a concrete tank and used for watering the garden, small scale stock farming and sometimes in the owner's house.
HBH11		**J. B. Kuhn**	**083 443 8340**	28.54166	21.16665	10.07	Wind pump			Domestic	Borehole located on the yard of the homestead. Water is used for watering the garden, water for domestic use is obtained from the municipal water supply.

Table 5.2 Site 2: Data obtained from hydrocensus survey

Site ID	Farm Name	Farm Owner/ Manager	Contact Details	S Coordinate	E Coordinate	Equipment	pH	TDS (mg/l)	Use	Comments
BH1		**Johannes Fourie**	**083 785 0626**	28.78569	21.89017				Unused	Borehole located next a farm workers' house. The windpump is broken. The hole is blocked with stones.
BH2	**Rooilyf**	**Hennie Jooste**	**083 388 5314**	28.81411	21.94856	Wind pump	8.06	490	Domestic	Borehole located next a farm dwellers village along the Loop 16 gravel road.
BH3	**Bokpoort**	**Chris Honiball**	**082 372 3467**	28.73536	21.97234	Submersible pump	7.36	420	Domestic	Borehole located west of the farm house. Water is used in two farm owner's house and in the farm workers' village.
BH4	**Bokpoort**	**Chris Honiball**	**082 372 3467**	28.72458	21.9926	Wind pump			Stock watering	Borehole located on a flat area in the wild game farm.
BH5	**Bokpoort**	**Chris Honiball**	**082 372 3467**	28.71084	21.9999	Wind pump			Stock watering	Borehole located on a flat area in a goat and sheep farm. Water is pumped into a concrete tank for stock watering.
BH6	**Bokpoort**	**Chris Honiball**	**082 372 3467**	28.7692	21.93741	Wind pump			Stock watering	Borehole located on a flat area in a sheep farm. Water is pumped into two concrete tanks for stock watering.
BH7	**Rooilyf**	**Hennie Jooste**	**083 388 5314**	28.79907	21.96237	Wind pump			Stock watering	Borehole located on a sheep farm. Currently unused because there are no sheep in the farm.

Table 5.3 Site 1: Hydrochemical analysis results

Sample ID	Sample_Date	pH	Cond	Na	K	Mg	Ca	Mn	Fe	Cl	SO4	NO3 as N	NO 3	T-Alk	HCO 3
BH5	15/04/2010	7.9	198	153	4.2	68	151	<0.001	<0.001	207	204	53	235	228	278
BH6	15/04/2010	7.3	432	535	21	89	239	0.023	0.3	675	774	34	152	351	428
BH7	15/04/2010	7.4	362	467	19.6	53	232	<0.001	0.13	567	638	12.2	54	266	324
BH10	15/04/2010	7.5	176	171	7.3	51	133	<0.001	0.012	165	203	3	13.1	505	616
ID		**pH**	**EC**	**Na**	**K**	**Mg**	**Ca**	**Mn**	**Fe**	**Cl**	**SO4**	**NO3 as N**			
Class 0 Limits		5 - 9.5	70	100	25	70	80	0.1	0.5	100	200	6			
Class 1 Limits		4.5 - 10	150	200	50	100	150	0.4	1	200	400	10			
Class 2 Limits		4 - 10.5	370	400	100	200	300	4	5	600	600	20			
Class 3 Limits		3 -- 11	520	1000	500	400	>300	10	10	1200	1000	40			
Class 4 Limits		3 -- 11	>520	>1000	>500	>400		>10.0	>10.0	>1200	>1000	>40			

Quality of Domestic Water Supplies, DWA&F, Second Edition 1998	
Class 0	**- Ideal water quality** - Suitable for lifetime use.
Class 1	**- Good water quality** - Suitable for use, rare instances of negative effects.
Class 2	**- Marginal water quality** - Conditionally acceptable. Negative effects may occur in some sensitive groups
Class 3	**- Poor water quality** - Unsuitable for use without treatment. Chronic effects may occur.
Class 4	**- Dangerous water quality** - Totally unsuitable for use. Acute effects may occur.

South Africa Water Quality Guidelines, Volume 1: Domestic Use, DWA&F, First Edition 1993 & Second Edition 1996	
NR	- **Target water quality range** - No risk.
IR	**- Good water quality** - Insignificant risk. Suitable for use, rare instances of negative effects.
LR	- **Marginal water quality** - Allowable low risk. Negative effects may occur in some sensitive groups
HR	- **Poor water quality** - Unsuitable for use without treatment. Chronic effects may occur.

Table 5.4 Site 2: Hydrochemical analysis results

Sample ID	Sample_Date	pH	Cond	Na	K	Mg	Ca	Mn	Fe	Cl	SO4	NO3 as N	NO3	T-Alk	HCO3
HBH2	13/04/2010	7.8	243	259	3.1	82	175	<0.001	0.001	314	266	26	113	501	611
HBH3	13/04/2010	8.1	37.9	28	4	11.9	30	<0.001	<0.001	28	46	0.3	1.4	101	123
HBH5	13/04/2010	7.9	153	104	12.3	68	123	<0.001	<0.001	155	69	22	96	482	588
ID		pH	EC	Na	K	Mg	Ca	Mn	Fe	Cl	SO4	NO3 as N			
Class 0 Limits		5 - 9.5	70	100	25	70	80	0.1	0.5	100	200	6			
Class 1 Limits		4.5 - 10	150	200	50	100	150	0.4	1	200	400	10			
Class 2 Limits		4 - 10.5	370	400	100	200	300	4	5	600	600	20			
Class 3 Limits		3 -- 11	520	1000	500	400	>300	10	10	1200	1000	40			
Class 4 Limits		3 -- 11	>520	>1000	>500	>400		>10.0	>10.0	>1200	>1000	>40			

Quality of Domestic Water Supplies, DWA&F, Second Edition 1998	
Class 0	- **Ideal water quality** - Suitable for lifetime use.
Class 1	- **Good water quality** - Suitable for use, rare instances of negative effects.
Class 2	- **Marginal water quality** - Conditionally acceptable. Negative effects may occur in some sensitive groups
Class 3	- **Poor water quality** - Unsuitable for use without treatment. Chronic effects may occur.
Class 4	- **Dangerous water quality** - Totally unsuitable for use. Acute effects may occur.

South Africa Water Quality Guidelines, Volume 1: Domestic Use, DWA&F, First Edition 1993 & Second Edition 1996	
NR	- **Target water quality range** - No risk.
IR	- **Good water quality** - Insignificant risk. Suitable for use, rare instances of negative effects.
LR	- **Marginal water quality** - Allowable low risk. Negative effects may occur in some sensitive groups
HR	- **Poor water quality** - Unsuitable for use without treatment. Chronic effects may occur.

Figure 5.5 Site 1: Piper plot of hydrochemistry results

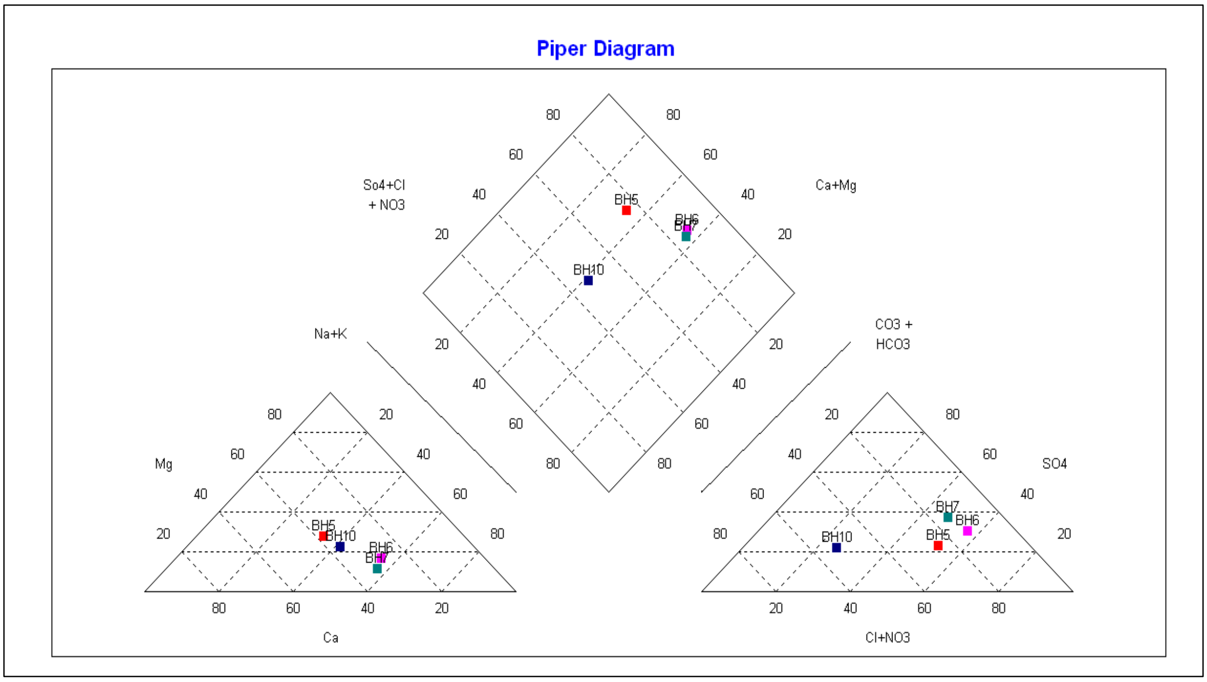


Figure 5.6 Site 2: Piper plot of hydrochemistry results

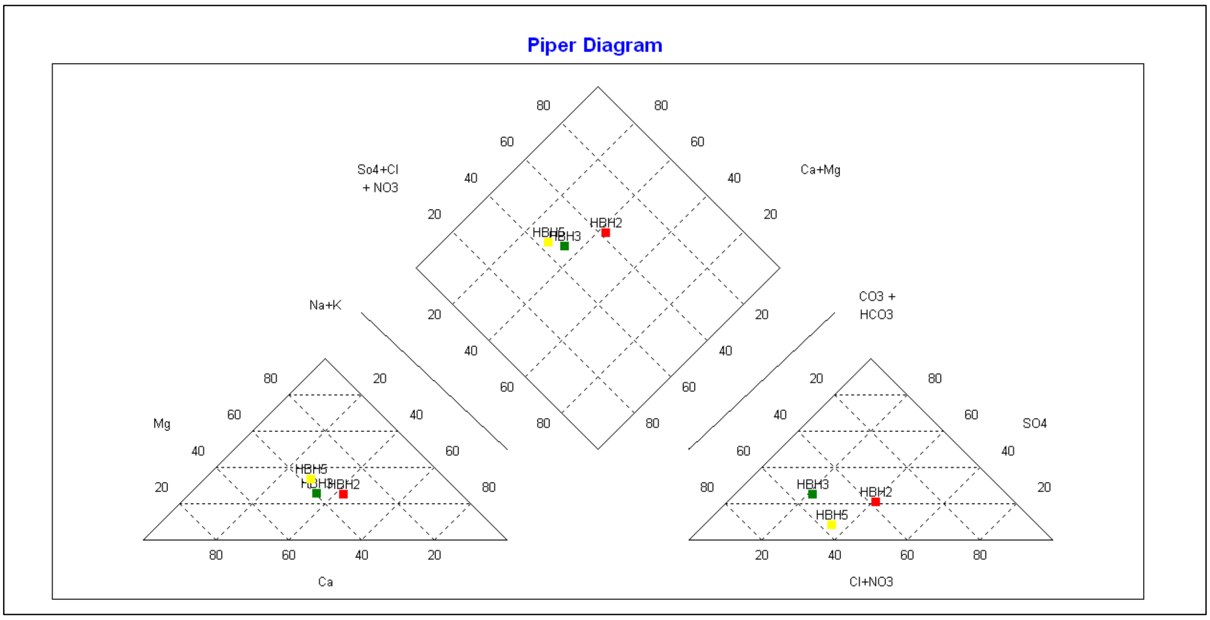


Figure 5.7 Site 1: Schoeller plot of the hydrochemical results

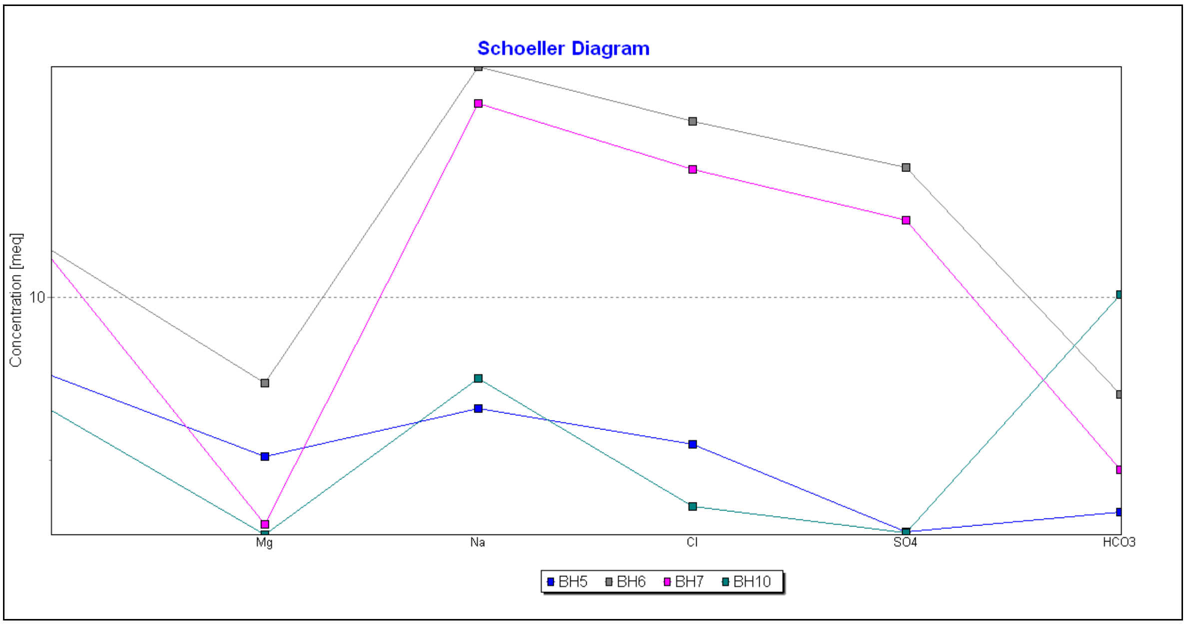
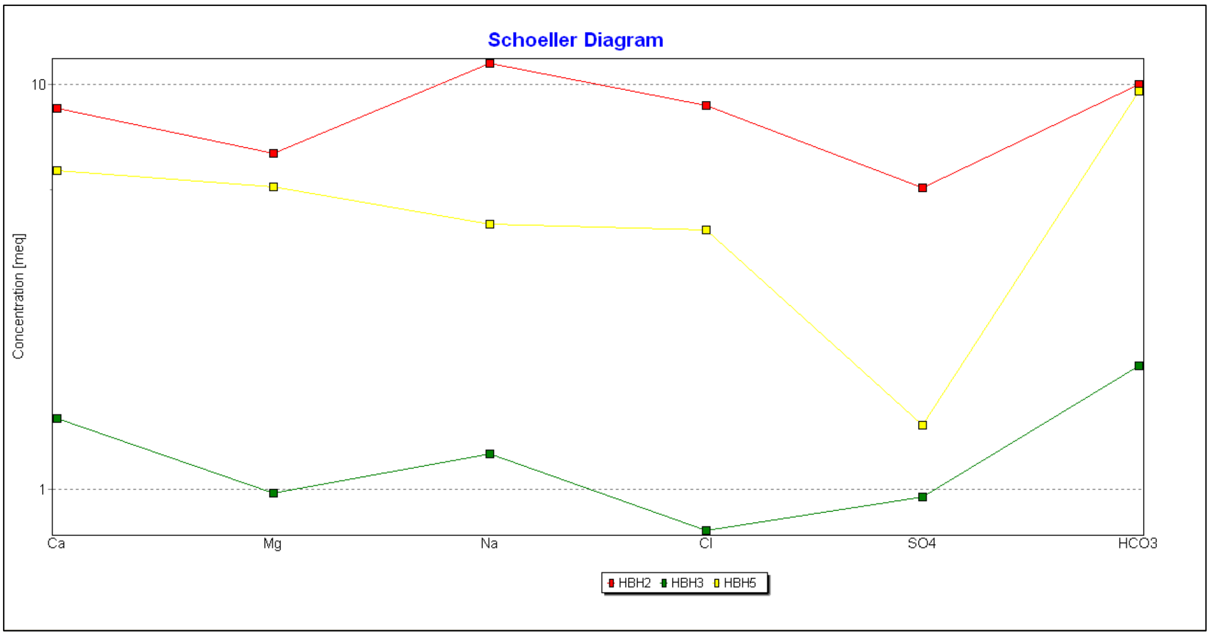


Figure 5.8 Site 2: Schoeller plot of the hydrochemisrty results



6 SITE IMPACT ASSESSMENT

It is indicated on the Environmental Scoping Report (Jude Cobbing, 2006) that the proposed solar power station will not use any groundwater. Water will be pumped from the Orange River to the station and used for steam generation, cooling washing of the plant mirrors and in the plant workers change rooms. Potential negative environmental impacts from this development include water and soil contamination resulting from liquid sodium/potassium nitrate salt used to collect heat from the boilers. If the salt can reach groundwater, elevated nitrate concentrations can be expected.

It was also indicated on the Environmental Scoping Report that an auxiliary power plant that uses hydrocarbon fuel will be constructed at the site. Leakage of fuel from this plant into the subsurface may result in the contamination of groundwater resource. These can, however, be mitigated and could be considered acceptable with proper planning and management of the facilities.

6.1.1 Limitations

The following limitations / information gaps were identified:

1. No detailed structural geological data was available; this can be seen as a limitation because of the uncertainty of possible dykes and faults that can cause preferred groundwater flow paths below the identified sites.
2. No site specific groundwater level data for the proposed site.
3. No data on the parameters of the fractured rock aquifer.

6.1.2 Risk Rating

The risk rating methodology was based on available public domain methodologies like the WASP and Risk Assessment for Water Quality Management.

The theoretical information of the above was applied and a customised risk rating methodology for the proposed IEC site was applied.

The following groundwater related aspects were considered:

- Soil Characterisation (Permeability).
- Shallow aquifer conditions in close proximity of the site.
- Presence of intrusive lithologies.

- Groundwater contribution to river flow.
- Unsaturated zone characteristics - aquifer vulnerability (lithology type & depth).
- Borehole density and in close proximity of the site.
- Groundwater Potential.
- Aquifer classification (importance, yield etc - Parsons).
- Down stream users.
- Distance to major water courses/discharge areas.
- Quantity and quality aspects of waste.

The significance of potential impacts were determined using a ranking system prescribed by the DAEA and are detailed below (terminology has been taken from the Guideline Documentation on EIA Regulations, of the Department of Environmental Affairs and Tourism, April 1998):

6.1.3 Occurrence

- Probability of occurrence (how likely is it that the impact may occur?)
- Duration of occurrence (how long may it last?).

6.1.4 Severity

- Magnitude (severity) of impact (will the impact be of high, moderate or low severity?)
- Scale/extent of impact (will the impact affect the national, regional or local environment, or only that of the site?).

Each of these factors have been assessed for each potential impact using the following scales:

Probability	**Duration**
1 - very improbable (probably will not happen 2 - improbable (some possibility, but low likelihood) 3 - probable (distinct possibility) 4 - highly probable (most likely) 5 - definite (impact will occur regardless of any prevention measures)	1 - of a very short duration (0–1 years) 2 - of a short duration (2-5 years) 3 - medium-term (5–15 years) 4 - long term (> 15 years) 5 - permanent
Extent	**Magnitude**
1 - limited to the site 2 - limited to the local area 3 - limited to the region 4 - will be national 5 - will be international	0 - small and will have no effect on the environment 2 - minor and will not result in an impact on processes 4 - low and will cause a slight impact on processes 6 - moderate and will result in processes continuing but in a modified way 8 - high (processes are altered to the extent that they temporarily cease) 10 - very high and results in complete destruction of patterns and permanent cessation of processes

The environmental significance of each potential impact was assessed using the following formula:

Significance Points (SP) = (Magnitude + Duration + Extent) x Probability

The maximum value is 100 Significance Points (SP). Potential environmental impacts will be rated as high, moderate or low significance on the following basis:

≤ 30 significance points = **Low** environmental significance.

31- 60 significance points = **Moderate** environmental significance

≥ 60 significance points = **High** environmental significance

The methodology of assessment presented in the WASP and Risk Assessment for Water Quality Management was applied to establish a customised risk assessment for the Olyvenhouts Drift and Bokpoort sites. Groundwater aspects that might be impacted by the proposed project were assessed. Refer to Table 3 for the rating of each hydrogeological aspect of the area. The significance rating tables below include a column of “with mitigation” assessment. The significance points for each aspect are summarised in the risk rating table, Table 4.

It is evident from the table that the potential impacts have low to moderate significance rating. If mitigation measures are applied together with proper management of the surface and underground infrastructure, all potential impacts will have very low or no significance. The availability of site specific geological and groundwater data would increase the confidence of the risk assessment.

Table 6.1 Site 1: Risk rating for each of the hydrogeological aspect of the environment

Source/Activity	Quantity of Waste /Overburden				Leakage potential & Liner /Decant, Seepage				Toxicity of leakage/seepage				Infiltration Potential (permeability/porosity of geology)				Mass Transport (Factor of permeability and gradient)				Depth to groundwater (shallow indicates higher risk)				Aquifer vulnerability (Sole source aquifer indicates high risk)				Downstream users/Receptors (human and aquitic)			
Olyvenhouts Drift Site	P	D	E	M	P	D	E	M	P	D	E	M	P	D	E	M	P	D	E	M	P	D	E	M	P	D	E	M	P	D	E	M
Without Mitigation	3	4	1	4	3	2	2	4	3	2	2	6	3	1	2	4	3	3	2	4	2	1	2	4	4	4	2	6	4	2	2	6
Significance Point	27				24				30				21				27				14				48				40			
With Mitigation and Proper Management	2	1	1	2	2	1	1	0	2	1	1	2	2	1	1	2	2	1	1	2	1	1	1	2	2	1	2	2	2	1	1	0
Significance Point	8				4				8				8				8				4				10				4			

Scoring of an aspect/ site:

P = Probability

D = Duration

E = Extent

M = Magnitude

*Significance Points = (D+E+M)*P*

Table 6.2 Site 2: Risk rating for each of the hydrogeological aspect of the environment

Source/Activity	**Quantity of Waste /Overburden**				**Leakage potential & Liner /Decant, Seepage**				**Toxicity of leakage/seepage**				**Infiltration Potential** (permeability/porosity of geology)				**Mass Transport** (Factor of permeability and gradient)				**Depth to groundwater** (shallow indicates higher risk)				**Aquifer vulnerability** (Sole source aquifer indicates high risk)				**Downstream users/Receptors (human and aquitic)**			
Bokpoort Site	**P**	**D**	**E**	**M**	**P**	**D**	**E**	**M**	**P**	**D**	**E**	**M**	**P**	**D**	**E**	**M**	**P**	**D**	**E**	**M**	**P**	**D**	**E**	**M**	**P**	**D**	**E**	**M**	**P**	**D**	**E**	**M**
Without Mitigation	3	2	1	4	3	2	1	4	4	2	2	6	2	1	2	2	2	3	2	2	3	1	2	4	3	4	2	2	3	2	1	4
Significance Point	**21**				**21**				**40**				**10**				**14**				**21**				**24**				**21**			
With Mitigation and Proper Management	2	1	1	2	2	1	1	0	2	1	1	2	2	1	1	0	2	1	1	0	2	1	1	2	2	1	2	2	2	1	1	0
Significance Point	**8**				**4**				**8**				**4**				**4**				**8**				**10**				**4**			

Scoring of an aspect/ site:

P = Probability

D = Duration

E = Extent

M = Magnitude

*Significance Points = (D+E+M)*P*

Table 6.3 Site 1: Groundwater Risk Rating Table

Impact Description	Significance Rating: High Significance (> 60); Moderate Significance (31-60); Low Significance (< 30); High Significance (positive > 60)	
	Without Mitigation	With Mitigation
Quantity of Waste /Overburden	27	8
Leakage potential & Liner /Decant, Seepage	24	4
Toxicity of leakage/seepage	30	8
Infiltration Potential (permeability/porosity of geology)	21	8
Mass Transport (Factor of permeability and gradient)	27	8
Depth to groundwater (shallow indicates higher risk)	14	4
Aquifer vulnerability (Sole source aquifer indicates high risk)	48	10
Downstream users/Receptors (human and aquatic)	40	4

Table 6.4 Site 2: Groundwater Risk Rating Table

Impact Description	Significance Rating: High Significance (> 60); Moderate Significance (31-60); Low Significance (< 30); High Significance (positive > 60)	
	Without Mitigation	With Mitigation
Quantity of Waste /Overburden	21	8
Leakage potential & Liner /Decant, Seepage	21	4
Toxicity of leakage/seepage	40	8
Infiltration Potential (permeability/porosity of geology)	10	8
Mass Transport (Factor of permeability and gradient)	14	8
Depth to groundwater (shallow indicates higher risk)	21	4
Aquifer vulnerability (Sole source aquifer indicates high risk)	24	10
Downstream users/Receptors (human and aquatic)	21	4

6.1.5 Site Selection

None of the sites can be regarded as a fatal flaw from a groundwater perspective; Site 2 was however recommended the most favourable site due to

- No Surface water drainage areas on Site 2 associated with shallow groundwater conditions.
- Water levels being deeper at Site 2 and therefore longer travel times for contaminants.
- Both alluvial and collegial sand formation present at Site 1 that will results in quicker travel times of contaminants, therefore Site 2 is recommended the most favourable site.
- Shallow bedrock conditions obtained at Site 2 which will result in longer travel times, coarse-grained granite gneiss which weathers into clayey formation and restrict groundwater flow.

7 SURFACE WATER

None of the sites are located within the 1: 50 year or 1: 100 year flood lines , the closest perennial surface water course to the site consist of the Orange River located approximately 5 km south and east from Site 1 and the 3.5 km south and west from Site 2

Several non-perennial drainage areas are mapped on Site 1. All of these drainage were however recorded dry during the field investigations

There are no non-perennial drainages located on the majority of Site 2; only a small drainage is mapped towards the Southern side of the site that was also recorded dry during the field investigations

8 CONCLUSIONS AND RECOMMENDATIONS

8.1 Site 1: Conclusion

- The proposed site is bounded on the south by R64 main road and is characterised by relatively flat topographic terrains. The site is mainly covered with natural grass and is used as a grazing land. No crop farming activities are taking place on site. No surface water bodies exist within the site. The Orange River is located about 2 km south of the site
- The general geology of the site mainly comprises red-brown, wind-blown sand and dunes. Magmatic, biotite-rich and aluminous gneisses and calcrete of the Areachap Sequence are also present, especially on the north-western part of the area.
- The hydrogeological map of the area indicates that two different aquifer systems occur in the area; intergranular and fractured aquifer types. The yield from the local aquifers range from 0.1 to 0.5 l/s. The site falls within the quaternary catchment D73F. Data obtained from GRDM data indicates that the area receives a mean annual precipitation of 158 mm. The average annual recharge for the area is 50.9 mm.
- Two boreholes from the data obtained from the NGDB plotted within a 2 km radius around the boundaries of the Olyvenhouts Drift farm. The average water level for the NGDB boreholes was 39.3 m below ground level.
- It was established during the hydrocensus survey that groundwater in the farms is used mainly for domestic purpose and livestock (cattle and sheep) farming. Most of the boreholes are equipped with wind pumps.
- The local community in the southern part of the farm, along the Orange River, is dependent on the municipal water for their domestic use. The few existing boreholes are privately owned and are used when there are problems with the municipal water supply. The community living farms depend on groundwater resource fro their domestic water supply.
- The chemical analysis of water samples collected from boreholes indicates that elevated levels of electric conductivity and nitrates exist in the groundwater, according to DWA Water Quality Guidelines. Water was of the NaCl type.
- The significance of potential impact, as determined using a ranking system prescribed by the DAEA, indicates that the potential impacts have low to moderate significance rating. This will only apply if leakages of site related contaminants occurred.
- If proper management measures, together with site- and operational monitoring (refer to next section), are applied, the potential impact on groundwater resources will have very low or no significance.

8.2 Site 1: Recommendations

- The general geology of the area presented in this report is not site specific. Exploration holes can be drilled to get a better understanding of the geology underlying the proposed site. Aquifer parameters can be determined from these boreholes to gain an understanding of the flow dynamics in the two aquifer systems. This can be achieved by drilling a shallow borehole up to bedrock level and the deeper borehole into the bedrock.
- It is recommended that the operational area of the power station must be paved with concrete material which will be inspected on a regular basis for cracks and leaks.
- It is further recommended that two monitoring/observation boreholes be drilled on site during the construction phase of the project. The existence of these boreholes will assist in the early detection of any leakage of contaminants into the groundwater system.
- The optimum drilling positions for these boreholes must be selected by a professional hydrogeologist. It is important that the topographic setting, possible geological structures, etc, are considered during this phase
- Groundwater levels can be measured on a monthly basis and initial water quality samples can be collected and analysed for reference purposes. Thereafter on-going sampling of groundwater can be conducted on quarterly basis. The chemical analysis of water must include the following determinants: pH; Conductivity; Calcium (Ca); Magnesium (Mg); Sodium (Na); Potassium (K); Bicarbonate (HCO32-); Chloride (Cl); Sulphate (SO42-); Nitrate (NO3); Iron (Fe); Manganese (Mn).

8.3 Site 2: Conclusion

- The Proposed Thermal Solar Plant site is situated in the farm Bokpoort 390, approximately 75km south east of Upington and 13 km north west of Groblershoop, in the Northern Cape Province. It is bounded on the south by Orange River and N14 national road and is characterised by relatively flat topographic terrains. The site is mainly covered with natural grass and is used as a grazing land. No crop farming activities are taking place on site. No surface water bodies exist within the site.
- The general geology of the site mainly comprises red-brown, coarse-grained granite gneiss; and quartz-muscouite schists, quartzite, quartz-amphibole schists and greenstones of the Groblershoop formation, Brulpan group. Calcrete is also found especially on the south eastern part of the area.
- The hydrogeological map of the area indicates that the fractured aquifer type occurs in the area. The yield from the local aquifers range from 0.1 to 0.5 l/s.
- Groundwater use takes place in the farms located further away from the Orange River. Groundwater in these farms is used mainly for domestic purpose and livestock (cattle and sheep) farming. Most of the boreholes are equipped with wind pumps.
- Groundwater in the area contains elevated levels of electric conductivity. The dominant cations were sodium and calcium and the dominant anions were chloride and sulphates. The samples also contained a high concentration of nitrates.
- The significance of potential impact, as determined using a ranking system prescribed by the DAEA, indicates that the potential impacts have low to moderate significance rating. This will only apply if leakages from sub-surface tanks and/or site related contamination occurred.
- If proper management measures, together with site- and operational monitoring (refer to next section), are applied, the potential impact on groundwater resources will have very low or no significance.

8.4 Site 2: Recommendations

- The general geology of the area presented in this report is not site specific. Exploration holes can be drilled to get a better understanding of the geology underlying the proposed site. Aquifer parameters can be determined from these boreholes to gain an understanding of the flow dynamics in the two aquifer systems. This can be achieved by drilling a shallow borehole up to bedrock level and the deeper borehole into the bedrock.
- It is recommended that the operational area of the power station must be paved with concrete material which will be inspected on a regular basis for cracks and leaks.

- It is further recommended that two monitoring/observation boreholes be drilled on site during the construction phase of the project. The existence of these boreholes will assist in the early detection of any leakage of contaminants into the groundwater system.
- The optimum drilling positions for these boreholes must be selected by a professional hydrogeologist. It is important that the topographic setting, possible geological structures, etc, are considered during this phase
- Groundwater levels can be measured on a monthly basis and initial water quality samples can be collected and analysed for reference purposes. Thereafter on-going sampling of groundwater can be conducted on quarterly basis. The chemical analysis of water must include the following determinants: pH; Conductivity; Calcium (Ca); Magnesium (Mg); Sodium (Na); Potassium (K); Bicarbonate (HCO32-); Chloride (Cl); Sulphate (SO42-); Nitrate (NO3); Iron (Fe); Manganese (Mn).

APPENDIX A: CERTIFICATES OF WATER QUALITY ANALYSIS

P.O. Box 82124,
Southdale, 2135,
South Africa.
TEL. (011) 496-2228
FAX (011) 496-2239

Registration Number 1974/001476/07 Vat Number 4780103505
M and L Laboratory Services (Pty) Ltd
Consulting Industrial Chemists, Analysts & Samplers
CONFIDENTIAL

Ref.No. : 10/01644L

Issued at : Johannesburg

Date : 07.05.2010

Page : 3 of 5

COMPANY NAME : GCS (PTY) LTD

ADDRESS : P.O BOX 2597 RIVONIA 2128

SUBJECT : ANALYSIS OF 7 samples of water

MARKED : Proposed Thermal Solar Plant

INSTRUCTED BY : Isaac Dindi

ORDER NO. : 10-083

DATE RECEIVED : 2010.04.21

DATE ANALYSED : 2010.04.23

LAB NO(S) : E65237 - E65243

Analysis on an as received basis:

Lab number	Sample mark	Manganese, Mn	Iron, Fe
E65237	HBH2	<0.001	0.001
E65238	HBH3	<0.001	<0.001
E65239	HBH5	<0.001	0.12

- The results are expressed in mg/l
- Method: Quantitative ICP scan (A.P.H.A 3120 B)

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Ref.No. : 10/01644L

Issued at : Johannesburg

Date : 07.05.2010

Page : 1 of 5

COMPANY NAME : GCS (PTY) LTD

ADDRESS : P.O. BOX 2597, RIVONIA, 2128

SUBJECT : ANALYSIS OF 7 SAMPLES OF WATER

MARKED : PROPOSED THERMAL SOLAR PLANT AND AS BELOW

INSTRUCTED BY : ISAAC DINDI

ORDER NO. : 10-083

RECEIVED ON : 21.04.2010

LAB NO(S) : E65237-E65247

DATE ANALYSES : 23.04.2010

Analysis on an as received basis:

Lab No:	E65237	E65238	E65239
Sample Marks	HBH2	HBH3	HBH5
pH Value @ 20°C	7.8	8.1	7.9
Conductivity mS/m @ 25°C	243	37.9	153
Calcium,Ca	175	30	123
Magnesium, Mg	82	11.9	68
Sodium,Na	259	28	104
Potassium,K	3.1	4.0	12.3
Total Alkalinity as CaCO3	501	101	482
P Alk as CaCO3	Nil	Nil	Nil
Bicarbonate,HCO3	611	123	588
Carbonate, CO3	Nil	Nil	Nil
Chloride,Cl	314	28	155
Sulfate,SO4	266	46	69
Nitrate,NO3	113	1.4	96
Nitrate as N	26	0.3	22
Sum of Cations meq/ℓ	26.822	3.796	16.569

Sum of Anions meq/ℓ	26.226	3.788	16.986
% Error	1.124	0.107	-1.245

The results are expressed in mg/l where applicable.

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Registration Number 1974/001476/07 Vat Number 4780103505

M and L Laboratory Services (Pty) Ltd

Consulting Industrial Chemists, Analysts & Samplers

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Ref No. : 10/00878L

Issued at : Johannesburg

Date : 18.03.2010

Page : 1 of 4

COMPANY NAME : GCS (PTY) LTD

ADDRESS : P.O Box 2597, Rivonia 2128

SUBJECT : Analysis of 3 Samples of Water

MARKED : Mbizana Eia and as below

INSTRUCTED BY : Isaac Dindi

ORDER NO. : 10-043

DATE RECEIVED : 01.03.2010

DATE ANALYSED : 16.03.2010

LAB NO(S) : E63714-E63716

Analysis on an as received basis:

Lab No:	E63714	E63715	E63716
Sample Marks	SP 1	SP 2	SP 3
pH Value @ 23°C	6.4	6.3	6.8
Conductivity mS/m @ 25°C	20.7	27.9	25.1
Calcium,Ca	2.9	4.8	8.9
Calcium Hardness as CaCO3	7	12	22
Magnesium, Mg	5.2	8.2	7
Magnesium Hardness as CaCO3	21	34	29
Total Hardness as CaCO3	29	46	51
Sodium,Na	28	30	29
Potassium,K	0.8	1.3	0.5
Total Alkalinity as CaCO3	55	22	77
P Alk as CaCO3	Nil	Nil	Nil
Bicarbonate,HCO3	67	27	94
Carbonate, CO3	Nil	Nil	Nil
Chloride,Cl	28	41	23
Sulfate,SO4	11.0	4.0	4.2
Nitrate,NO3	1.4	43	15.6
Nitrate as N	0.3	9.7	3.5
Oil and Grease	4.0	3.1	1.7
Sum of Cations meq/ℓ	1.857	2.252	2.294
Sum of Anions meq/ℓ	2.140	2.373	2.526

% Error	-7.073	-2.605	-4.814

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Registration Number 1974/001476/07 Vat Number 4780103505

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Consulting Industrial Chemists, Analysts & Samplers

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Ref No. : 10/00878L

Issued at : Johannesburg

Date : 18.03.2010

Page : 2 of 4

COMPANY NAME : GCS (PTY) LTD

ADDRESS : P.O Box 2597, Rivonia 2128

SUBJECT : Analysis of 3 Samples of Water

MARKED : As below

INSTRUCTED BY : Isaac Dindi

ORDER NO. : 10-043

DATE RECEIVED : 01.03.2010

DATE ANALYSED : 16.03.2010

LAB NO(S) : E63714-E63716

Analysis on an as received basis:

Lab Number	E63714	E63415	E63716
Sample Marks	SP 1	SP 2	SP3
Manganese, Mn	<0.001	<0.001	<0.001
Iron, Fe	1.3	0.23	0.014

-The results are expressed in mg/l
-Method: Quantitative ICP scan (A.P.H.A 3120B)

P.O. Box 82124,
Southdale, 2135,
South Africa.
TEL. (011) 496-2228
FAX (011) 496-2239

M&L

Registration Number 1974/001476/07 Vat Number 4780103505

M and L Laboratory Services (Pty) Ltd

Consulting Industrial Chemists, Analysts & Samplers

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Ref No. : 10/00878L
Issued at : Johannesburg
Date : 18.03.2010
Page : 3 of 4

DETERMINANT	METHOD	METHOD REFERENCES
pH Value	Electrometric	W044-08-W (A.P.H.A. 4500-H^+ B)
Conductivity	Potentiometric	W044-04-0 (A.P.H.A. 2510 B)
Total Dissolved Solids	Gravimetric	W044-03-W (A.P.H.A. 2540 C)
Total Solids and Loss On Ignition	Gravimetric	A.P.H.A. 2540 BE
Total Alkalinity	Titrimetric	Auto Analyser or A.P.H.A. 2320 B
Calcium	Atomic Absorption Spectrophotometry	W044-15-W (A.P.H.A. 3111 B)
Magnesium	Atomic Absorption Spectrophotometry	W044-01-W (A.P.H.A. 3111 B)
Potassium	Atomic Absorption Spectrophotometry	W044-01-W (A.P.H.A. 3111 B)
Sodium	Atomic Absorption Spectrophotometry	A.P.H.A. 3111 B
Colour Hazen Units	Lovibond Comparator	B.D.H. Nessleriser Method
Turbidity N.T.U.	Comparator	A.P.H.A. 2130 B
Odour	Physical Testing	A.P.H.A. 2150 B
Carbonate Hardness	By Calculation	A.P.H.A. 2340 A
Chloride	Titrimetric or Mercuric Nitrate Titration	Auto Analyser or A.P.H.A. 4500-Cl C
Sulfate	Gravimetric	A.P.H.A. 4500-SO_4 C
Sulfate	Turbimetric	A.P.H.A. 4500-SO_4 E
Sulfite,	Titrimetric	A.P.H.A. 4500-SO_3 B
Settle-able Solids	Volumetric Measurement	A.P.H.A. 2540-F
Nitrate	Colorimetric	EPA 352.1
Nitrate	Nitrate Electrode	Auto Analyser (A.P.H.A. 4500-NO_3 D)
Nitrite	Colorimetric	A.P.H.A. 4500-NO_2 B
Fluoride	Ion Selective Electrode	A.P.H.A. 4500-F C
Mercury	Cold Vapour Generation A.A.S.	A.P.H.A. 3112 B
Hexavalent Chromium	Colorimetric – Diphenyl Carbazide	A.P.H.A. 3500-Cr D
Total Cyanide	Titrimetric following distillation	A.P.H.A. 4500-CN CD
Phenolic Compounds as Phenol	Colorimetric following distillation	A.P.H.A. 5530 BC
Biochemical Oxygen Demand	Titrimetric	A.P.H.A. 5210 B
Chemical Oxygen Demand	Titrimetric	A.P.H.A. 5220 C
Total Suspended Solids	Gravimetric	A.P.H.A. 2540 D
Soap, Oil & Grease	Gravimetric	S.A.B.S. 1051
Sulfide Sulfur	Lead Acetate Method	S.A.B.S. 1056
Sulfide Sulfur	Titrimetric	A.P.H.A. 4500-S^2 F
Free & Saline Ammonia	Titrimetric following distillation	A.P.H.A. 4500-NH_3 BC
Kjeldahl Nitrogen	Titrimetric following distillation	A.P.H.A. 4500-Norg B
Acidity/ P Alkalinity	Titrimetric	Auto Analyser or A.P.H.A. 2310/2320 B
Dissolved Oxygen	Titrimetric	A.P.H.A. 4500-O C
Oxygen Absorbed (Permanganate Value)	Titrimetric	S.A.B.S. 220
Residual/Free Chlorine	Colorimetric	A.P.H.A. 4500-Cl G
Bromide	Ion Chromatograph	A.P.H.A. 4110 C
Calcium Carbonate Saturated pH	Potentiometric	P.C.I. 9.28
Free Carbon Dioxide	Nomographic	A.P.H.A. 4500-CO_2 B
Free Carbon Dioxide	Titrimetric	A.P.H.A. 4500-CO_2 C
Arsenic, Selenium, Titanium, Aluminium, Nickel, Manganese, Iron, Vanadium, Zinc, Antimony, Lead, Cobalt, Copper, Total Chromium, Silicon, Tin, Zirconium, Bismuth, Thallium, Beryllium, Cadmium, Boron, Phosphorus, Phosphorus as Phosphate, Uranium, Molybdenum, Barium, Silver,	ICP Quantitative Scan	A.P.H.A. 3120 B

Thorium, Lithium, (also Ca, Mg, Na, K)		

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Page : 4of 4

M&L Laboratory Services is an SANAS accredited testing laboratory. The Laboratory Accreditation Number is T0040. The Laboratory complies with ISO/IEC 17025:2005.

The following test schedule outlines only the test methods and/or techniques accredited. Uncertainties of Measurement for these accredited test methods are available upon request:

Materials/Products Tested	Types of Tests/Properties Measured, Range of Measurement	Standard Specifications, Equipment/ Techniques Used
CHEMICAL:		
Water	Total dissolved solids	W044-03-W
	pH	pH/EC Meter W044-05-W
	Electrical conductivity	pH/EC Meter W044-04-O
	pH and Electrical conductivity	DL70 ES Titrator W044-08-O
	Calcium	AAS W044-15-W
	Magnesium	AAS W044-01-W
	Potassium	AAS W044-02-W
	ICP metal scan	W044-17-W
Pharmaceutical and Veterinary Products	TECHNIQUE - HPLC Determination of Perindopril and degradation products.	PF.T.CTR.A02.R44.09490.01
MICROBIOLOGY:		
Water:	*Escherichia coli* per 100 ml	SANS 5221:2006, Edition 4.2/ ISO 7218: 1996 (E)
Borehole water	Faecal coliform bacteria per 100 ml	SANS 5221:2006, Edition 4.2/ ISO 7218: 1996 (E)
Tap water	Total coliform bacteria per 100 ml	SANS 5221:2006, Edition 4.2/ ISO 7218: 1996 (E)
Drinking water		
Environmental water	Standard (Heterotrophic) Plate Count cfu/ml	SANS 5221:2006, Edition 4.2/ ISO 7218: 1996 (E)
Sewage water		
Bottle water		
Other:		
Freshwater & seawater products	Escherichia coli count (cfu)	ISO 16649-2
Poultry, meat products	Total coliform bacteria (cfu)	SANS 4832: 2007
Spices, herbs	Total plate count (cfu)	SANS 4833: 2007
Egg & egg products		
Milk & dairy products		
Pre-prepared foods		
Vegetables & Fruit		
Pharmaceuticals		
Soils		
Beverages		
Canned products		
Sweets, cakes, dessert		
Processed food		
ENVIRONMENTAL:		
Water	G.C Technique for B.T.E.X	E042-13-W (Based on EPA 8015B)

	Components	
Solids	G.C Technique for B.T.E.X Components	E042-13-W (Based on EPA 8015B)
Solids	G.C Technique for D.R.O	E042-12-W (Based on EPA 8015B)
Water	G.C Technique for D.R.O	E042-12-W (Based on EPA 8015B)
Solids	G.C Technique for G.R.O	E042-14-W (Based on EPA 8015B)
FOOD Meat, Fish, Chicken, Dairy, Drinks, Vegetable, Fruits, Prepared foods	Protein content determination	HF041-03-W (Based on AOAC 18th Edition 2007, Method 991.20)

Please also refer to web site www.sanas.co.za for the full Certificate and Schedule of Accreditation

Tel : +27 82 784-2023 e-mail : aquisim-hvr@mweb.co.za
VAT No. 4570181877 Reg. No. 98/025374/02

AQUISIM CONSULTING (PTY) LTD

P.O. Box 1490 Faerie Glen 0043 Pretoria
5 Binga Place Faerie Glen Pretoria South Africa

For Attention:

Ms Marie Schlechter
Snr Environmental Scientist
Golder Associates Africa (Pty) Ltd
Date: 3 May 2016

RE: Proposed 75 MW Photovoltaic (PV1) Solar Power Development on the Remaining extent of farm Bokpoort 390 – DEA Reference Number: 14/12/16/3/3/2/881.

Dear Marie

I, Hugo Janse van Rensburg (CV attached), confirm that I have reviewed the project "**Proposed 75 MW Photovoltaic (PV1) Solar Power Development on the Remaining extent of farm Bokpoort 390 – DEA Reference Number: 14/12/16/3/3/2/881"** in conjunction with the report **"Hydrogeological Baseline Assessment for the Proposed Thermal Solar Plants"** by GCS (May 2010). Aspects considered in particular included the regional geology and hydrogeology covering aspects related to:

- Hydrocensus data
- Groundwater quality
- Aquifer classification and Type

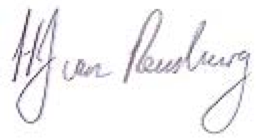
The assessment was conducted covering the Construction, Operational, Closure and Rehabilitation Phases of the project.

I can further confirm that:

1. The baseline information in the GCS Groundwater report is applicable to the Bokpoort II project area;
2. The Impact Statement and Mitigation is appropriate to the nature and scale of the project.

Please contact me should you wish to discuss further.

Yours sincerely



Hugo Janse van Rensburg
Director: AquiSim Consulting (Pty) Ltd.

Profession:	Geohydrologist
Nationality:	South African
Position in firm:	Director
Specialisation:	Groundwater Management & Numerical Modelling Techniques
Proposed position on project:	Specialist Scientist Groundwater Modelling — *Years of relevant experience:* 33

Qualifications and Achievements:

- Winner of the GROUND WATER DIVISION of the GEOLOGICAL SOCIETY of South Africa award for 1991 for paper entitled Walvis Bay: Determining Aquifer Potential by means of a Water Balance and Inverse Modelling presented at the biennial Ground Water convention.
- The first Geohydrologist to be appointed as Specialist Scientist in the Department of Water Affairs.
- Selected by the Commonwealth Science Council to represent South Africa as lecturer at the groundwater modelling conference and workshop in Mauritius (1994).
- Co-author of the “Manual on Quantitative Estimation of Groundwater Recharge and Aquifer Storativity” ISBN 1 86845 176 3.
- Experience in the following countries: Argentina, Botswana, Chile, Central African Republic, China, DRC, Ireland, Madagascar, Mali, Mauritania, Mozambique, Namibia, Russia, South Africa, Uganda, Zambia, Zimbabwe.

Education and professional qualifications:

1995	PhD, Geohydrology, University of the Orange Free State
1992	MBL, University of South Africa (UNISA) (Master in Business Leadership) (MBA)
1985	MSc, Geohydrology, University of the Orange Free State
1983	BSc (Hons), Geohydrology, University of the Orange Free State
1982	BSc, Geohydrology and Geology, University of the Orange Free State

Specialised Modelling Courses	
1994	Modelling Groundwater Flow and Pollution – Jacob Bear, Johannesburg South Africa
2005	Finite Element Groundwater Modelling. Applications for Saturated Flow and Transport, Density-Dependent Flow, Unsaturated Conditions for Groundwater Management. Waterloo Hydrogeologic, Waterloo, Ontario, Canada.

Membership	
	Member, Groundwater Division of the Geological Society of South Africa

Languages:	*Speaking*	*Reading*	*Writing*
Afrikaans	Native tongue		
English	Fluent	Fluent	Fluent
Dutch	Basic	Basic	
Sotho	Basic		

Professional career:

2000 to date **Director, AquiSim Consulting (Pty) Ltd**
Numerical modelling and design of open cast and underground mine dewatering systems, based on bord and pillar, high extraction and total extraction mining methods, pollution migration from tailings dams and industrial waste sites, remediation of contamination plumes and resource potential estimation of wellfields. General Groundwater Management issues.

1993 – 2000 **Hydrogeologist/Senior Hydrogeologist/Divisional Hydrogeologist, AAC, Civil Engineering Department**
Tasks included: Design of Open Cast Mine Dewatering Systems based on Optimisation Techniques. Optimisation of water supply systems from groundwater sources including risk analyses. Optimisations of water quality requirements in water supply systems. Reviewing of deep mine dewatering requirements. Groundwater Resource potential evaluation. Groundwater pollution risk determinations utilising mass transport modelling techniques and stochastic modelling.

1990 – 1993 **Specialist Scientist, directorate of Geohydrology, Dept of Water Affairs & Forestry**
Specialised tasks included aquifer modelling (forward direct modelling and inverse modelling techniques) and resource evaluation with water balance techniques as well as economical feasibility studies on aquifers based on risk analysis.

1983 – 1990 **Geohydrologist, Directorate of Geohydrology, Dept of Water Affairs & Forestry, Pretoria**
Regional geohydrological investigation of aquifers (tasks included; field mapping, photo geological interpretation, drilling and pumping test contract supervision, borehole construction and aquifer resource evaluation with different modelling techniques.

Professional experience:

South Africa 2016	**Specialist Groundwater Modeller. Consultant to Golder Associates Africa** Construction and Calibration of Groundwater Flow Model for Exxaro’s Underground Coal Gasification Project at Zonderwater Lephalale.
South Africa 2015	**Specialist Groundwater Modeller. Consultant to AngloGold Ashanti** Review of Groundwater Flow Model.
South Africa 2015	**Specialist Groundwater Modeller. Consultant to Golder Associates Africa** Update of the Pappas Quarry Mass Transport Model for Manganese Metal Company
Madagascar 2015	**Specialist Groundwater Modeller. Consultant to Graell Ltd** Construction & Calibration of QMM Model Madagascar.
Botswana 2015	**Specialist Groundwater Modeller. Consultant to Water Surveys Botswana** Construction and Calibration of the Orapa Wellfields Model.
South Africa 2014	**Specialist Groundwater Modeller. Consultant to Golder Associates Africa** Update of the Mass Transport Model for Vanchem.
Botswana 2014	**Specialist Groundwater Modeller. Consultant to Debswana** Construction and calibration of Jwaneng Mine Wellfield Model
South Africa 2014	**Specialist Groundwater Modeller. Consultant to Golder Associates Africa** Update of the Halve Pan Mass Transport Model for Sasol Secunda.
South Africa 2014	**Specialist Groundwater Modeller. Consultant to Tronox Richards Bay** Construction of CPC Tronox Groundwater Flow Model at Richards Bay.
South Africa 2014	**Specialist Groundwater Modeller. Consultant to Golder Associates Africa** Update of the Tubatse Ferrochrome Mass Transport Model.
South Africa 2014	**Specialist Groundwater Modeller. Consultant to Golder Associates Africa** Update of the Mass Transport Model for Metalloys Meyerton.
DRC 2014	**Specialist Groundwater Modeller. Consultant to Golder Associates Africa** Simulation of the Inflows into the proposed Kamoa Underground Mine in the DRC.
South Africa	**Specialist Groundwater Modeller. Consultant to Golder Associates Africa**

2014	Simulation of the Impacts of the Atcom South Pit and Beath Discard Dump on the environment.
South Africa 2014	**Specialist Groundwater Modeller. Consultant to Gold One** Construct a finite element aquifer model using **FEFLOW** for the simulation of groundwater flow and mass transport at their Randfontein and Westonarea Facilities.
Botswana 2014	**Specialist Groundwater Modeller. Consultant to Debswana** Construct a finite element aquifer model using **FEFLOW** for the simulation of groundwater flow at Jwaneng Mine's Northern Wellfield.
South Africa 2013	**Specialist Groundwater Modeller. Consultant to Golder Associates Africa** Update the finite element aquifer model using **FEFLOW** for the simulation of groundwater flow and Chrome (VI) migration at Tubatse Chrome.
South Africa 2013	**Specialist Groundwater Modeller. Consultant to Golder Associates Africa** Evaluation of the effectiveness and progress of aquifer cleanup using the monitoring information at IDC's African Chrome plant (decommissioned).
Mauritania 2013	**Specialist Groundwater Modeller. Consultant to Golder Associates Africa** Update of the finite element aquifer model using **FEFLOW** for the simulation of groundwater flow at Askaf El Aouj in Mauritania.
South Africa 2013	**Specialist Groundwater Modeller. Consultant to Aurecon** Update of the finite element aquifer model using **FEFLOW** for the simulation of groundwater flow at Valpre (Coca-Cola) Heidelberg.
South Africa 2013	**Specialist Groundwater Modeller. Consultant to Tronox** Construct a finite element aquifer model using **FEFLOW** for the simulation of groundwater flow at Hillendale (Empangeni).
South Africa 2013	**Specialist Groundwater Modeller. Consultant to Golder Associates Africa** Construct a finite element aquifer model using **FEFLOW** for the simulation of groundwater flow at Sasol Halvepan.
Botswana 2013	**Specialist Groundwater Modeller. Consultant to Golder Associates Africa** Construct a finite element aquifer model using **FEFLOW** for the simulation of groundwater flow at Jwaneng Mine for Pit Dewatering.
Botswana 2013	**Specialist Groundwater Modeller. Consultant to Golder Associates Africa** Construct a finite element aquifer model using **FEFLOW** for the simulation of groundwater flow at Letlhakane Mine for Pit Dewatering

Botswana 2013	**Specialist Groundwater Modeller. Consultant to Aqua Earth** Construct a finite element aquifer model using **FEFLOW** for the simulation of groundwater flow at the proposed Gaghoo Mine in the Central Kalahari Botswana.
South Africa 2013	**Specialist Groundwater Modeller. Consultant to Golder Associates Africa** Construct a finite element aquifer model using **FEFLOW** for the simulation of groundwater flow at Steenkoppies Dolomitic Compartment.
South Africa 2012	**Specialist Groundwater Modeller. Consultant to Rison Consulting** Construct a finite element aquifer model using **FEFLOW** for the simulation of groundwater flow at Leeuwkop Chrome Mine.
South Africa 2012	**Specialist Groundwater Modeller. Consultant to Golder Associates Africa** Construct a finite element aquifer model using **FEFLOW** for the simulation of groundwater flow at Life-X Operation for Anglo American Corp.
South Africa 2012	**Specialist Groundwater Modeller. Consultant to Golder Associates Africa** Construct a finite element aquifer model using **FEFLOW** for the simulation of groundwater flow for mine dewatering at Steelpoort Chrome Mines.
South Africa 2012	**Specialist Groundwater Modeller. Consultant to Golder Associates Africa** Construct a finite element aquifer model using **FEFLOW** for the simulation of groundwater flow at Kimberley Mines.
South Africa 2012	**Specialist Groundwater Modeller. Consultant to Golder Associates Africa** Construct a finite element aquifer model using **FEFLOW** for the simulation of groundwater flow at Finsch Mine.
South Africa 2012	**Specialist Groundwater Modeller. Consultant to Harmony Gold** Construct a finite element aquifer model using **FEFLOW** for the simulation of groundwater flow and mass transport at Harmony Welkom.
South Africa 2012	**Specialist Groundwater Modeller. Consultant to Golder Associates Africa** Construct a finite element aquifer model using **FEFLOW** for the simulation of groundwater flow at Orapa AK1Pit for Cut 3 dewatering.
Malawi 2012	**Specialist Groundwater Modeller. Consultant to Jones & Wagener** Construct a finite element aquifer model using **FEFLOW** for the simulation of groundwater flow at Kanxika Malawi.
South Africa 2011	**Specialist Groundwater Modeller. Consultant to Harmony Gold** Construct a finite element aquifer model using **FEFLOW** for the simulation of groundwater flow and mass transport for Harmony's Randfontein Operations.

South Africa
2011

Specialist Groundwater Modeller. Consultant to Sasol
Construct a finite element aquifer model using **FEFLOW** for the simulation of groundwater flow at Sasol Freestate Underground Coal Gassification.

South Africa
2011

Specialist Groundwater Modeller. Consultant to Metago
Construct a finite element aquifer model using **FEFLOW** for the simulation of groundwater flow at Implats No.5 TSF Dam.

South Africa
2011

Specialist Groundwater Modeller. Consultant to Harmony Gold
Construct a finite element aquifer model using **FEFLOW** for the simulation of groundwater flow at Harmony Evander.

South Africa
2011

Specialist Groundwater Modeller. Consultant to Golder Associates Africa
Construct a finite element aquifer model using **FEFLOW** for the simulation of groundwater flow at Metalloys.

South Africa
2011

Specialist Groundwater Modeller. Consultant to Golder Associates Africa
Construct a finite element aquifer model using **FEFLOW** for the simulation of groundwater flow at MMC Krugersdorp.

South Africa
2011

Specialist Groundwater Modeller. Consultant to Golder Associates Africa
Construct a finite element aquifer model using **FEFLOW** for the simulation of groundwater flow from the Calcine Dam at Vanchem.

South Africa
2011

Specialist Groundwater Modeller. Consultant to Golder Associates Africa
Construct a finite element aquifer model using **FEFLOW** for the simulation of groundwater flow from the Sappi Enstra Site

South Africa
2010

Specialist Groundwater Modeller. Consultant to Golder Associates Africa
Construct a finite element aquifer model using **FEFLOW** for the simulation of groundwater flow at the Arcelor Mittal Site at Vanderbijlpark.

South Africa
2010

Specialist Groundwater Modeller. Consultant to Jones & Wagener
Construct a finite element aquifer model using **FEFLOW** for the simulation of groundwater flow from the Scaw Metals Site.

South Africa
2010

Specialist Groundwater Modeller. Consultant to Golder Associates Africa
Update of Sappi Ngodwana Model

South Africa

Specialist Groundwater Modeller. Consultant to Golder Associates Africa

2010	Construct a finite element aquifer model using **FEFLOW** for the simulation of groundwater flow from the Upper & Lower Dams at Sasol Secunda
South Africa 2010	**Specialist Groundwater Modeller. Consultant to Golder Associates Africa** Construct a finite element aquifer model using **FEFLOW** for the simulation of groundwater flow for Bakouma.
South Africa 2010	**Specialist Groundwater Modeller. Consultant to Golder Associates Africa** Construct a finite element aquifer model using **FEFLOW** for the simulation of groundwater flow from the Calcine Dam at Vanchem.
South Africa 2010	**Specialist Groundwater Modeller. Consultant to Water Research Commission** Simulation of flow in Karst Aquifers by 3D model of the transport and reappearance of natural C14
Botswana 2010	**Specialist Groundwater Modeller. Consultant to Water Surveys Botswana** Construction and calibration of a four-layered aquifer model for Jwaneng.
South Africa 2010	**Specialist Groundwater Modeller. Consultant to Jones & Wagener.** Update of Holfontein Hazardous Waste Disposal Site
Botswana 2009	**Specialist Groundwater Modeller. Consultant to Water Surveys Botswana** Construct a five-layered finite element aquifer model using **FEFLOW** for the Jwaneng Wellfield and Gaotlhobogwe Wellfields in Central Botswana. The ultimate objective of the investigation was to determine the feasibility to abstract $17x10^6$ m^3/annum over the next 40 years from 28 high yielding boreholes. The model was calibrated utilising monitoring data covering a 27-year period. The information of 28 abstraction and 40 monitoring boreholes were included into the model. Total abstraction from the system is currently in the order of $12x10^6$ m^3/annum
South Africa 2009	**Specialist Groundwater Modeller. Consultant to Aurecon** Construct and Calibrate a groundwater flow model for the aquifer supplying water to Coca-Cola's Valpre Bottling Plant near Heidelberg. Sustainability studies were conducted and recommendations provided on resource potential.
Mozambique 2009	**Specialist Groundwater Modeller. Consultant to Golder Associates** Construct a five-layered finite element aquifer flow and mass transport model using **FEFLOW** for the proposed Benga Coal Mine in Mozambique. The objective of this investigation was to determine possible inflow rates into the opencast workings of the mine as well as to determine impacts from the proposed tailings storage facility on the hydrogeology of the area
Central African Republic 2008	**Specialist Groundwater Modeller. Consultant to Golder Associates** Construct and calibrate a 5-layered **FEFLOW** groundwater flow model for the proposed Bakouma Uranium deposit to determine dewatering requirements from highly permeable limestone/chert/dolomite aquifers. Four separate mine pits were evaluated.

China
2008

Specialist Groundwater Consultant. Consultant to ATD Anglo American
Conduct a high-level review of the pre-feasibility study conducted by URS China for the proposed Xiwan Coal Project in the Shaanxi Province, People's Republic of China.

Mozambique
2008

Specialist Groundwater Modeller. Consultant to Kenmare PLC Ireland
Construct and calibrate a seven-layered **FEFLOW** groundwater flow model to simulate the ***Dredge Mine Operation*** of Kenmare's Moma Mineral Sands Operation in Mozambique.

South Africa
2008

Specialist Groundwater Modeller. Consultant to Africon Civil Engineers
Construct and calibrate a two-layered **FEFLOW** groundwater flow model to simulate the impacts of the deepening of Crushco's Sand Mines east of Kempton Park on the groundwater regime.

South Africa
2008

Specialist Groundwater Modeller. Consultant to Golder Associates
Construct and calibrate a two-layered **FEFLOW** groundwater flow and mass transport model for Eskom's new Bravo ***Powerstation and Ash Dam*** to determine dewatering requirements in order to lower the natural water table below the footprint of the powerstation and to determine impacts from the Ash Dam on the environment.

South Africa
2008

Specialist Groundwater Modeller. Consultant to Jones&Wagener Consulting Engineers
Construct and calibrate a two-layered **FEFLOW** groundwater flow and mass transport model for the ***Margolis Hazardous Waste Disposal Site***. Simulate various mitigation measures in order to reduce/eliminate leachate migrating further into the groundwater system.

MAURITANIA
2008

Specialist Groundwater Modeller. Consultant to Golder Associates (Perth)
Construct and calibrate a four-layered **FEFLOW** groundwater flow model to simulate the feasibility of supplying the Guelb El Aouj Iron Ore Mine with groundwater from an aquifer situated in a desert environment.

SOUTH AFRICA
2007

Specialist Groundwater Modeller. Consultant to Golder Associates Africa
Construct and Calibrate a **FEFLOW** groundwater flow and mass transport model to simulate the impact of the South Deep TSF of Placer Dome on the groundwater regime.

BOTSWANA
2007

Specialist Groundwater Modeller. Consultant to Rison Groundwater Consulting & Marsh Vikela
Construction and calibration of a four-layered aquifer model to simulate the dewatering requirements and water supply of the open pit Gope Diamond Mine in the Central Kalahari Desert of Botswana

SOUTH AFRICA
2007

Specialist Groundwater Modeller. Consultant to Rison Groundwater Consulting and Jones & Wagener Consulting Engineers.
Construct and calibrate a two layered **FEFLOW** groundwater flow and mass transport model to simulate the impact of the Halvepan on the environment at Sasol's Secunda Plant.

SOUTH AFRICA

Specialist Groundwater Modeller. Consultant to Rison Groundwater Consulting

2007

Construct and calibrate a two-layered **FEFLOW** model to simulate the feasibility of the groundwater supply to the Millvale Country Estate.

SOUTH AFRICA

2007

Specialist Groundwater Modeller. Consultant to Rison Groundwater Consulting

Construct and calibrate a two-layered **FEFLOW** groundwater flow and mass transport model to simulate the environmental impacts of the underground Inyoni Colliery on the Chrissies Meer in the Mpumalanga Province.

SOUTH AFRICA
2007

Specialist Groundwater Modeller. Consultant to Golder Associates Africa

Construct and calibrate a **FEFLOW** groundwater flow model to simulate the groundwater resource potential in the dolomitic terrain of the Holcim Dudfield Cement Factory for expansion of their water supply.

SOUTH AFRICA
2007

Specialist Groundwater Modeller. Consultant to Golder Associates Africa

Assist and oversee the construction of a four-layered **FEFLOW** model to simulate inflow to the gasifier and environmental impacts at Eskom's Underground Coal Gasification Project at the Majuba Power Station.

SOUTH AFRICA
2007

Specialist Groundwater Modeller. Consultant to Golder Associates Africa

Construct a two-layered flow and mass transport **FEFLOW** model for the proposed Onverwacht Tailings Storage Facility at the Nkomati Mine to determine environmental impacts on the Gladde Spruit.

SOUTH AFRICA
2006

Specialist Groundwater Modeller. Consultant to Finsch Diamond Mine De Beers

Construct a five layered flow and mass transport model to determine the impact of the proposed fine residue dam (FRD) on the groundwater regime of the area.

DRC
2006

Specialist Groundwater Modeller. Consultant to Golder Associates (Canada).

Construct a three layered finite element aquifer flow and mass transport model using **FEFLOW** for the proposed Tenke-Fungurume Mine in the DRC to calculate anticipated mine dewatering requirements under various expansion/mine closure scenarios; determine the impact of current and anticipated groundwater abstraction (including mine dewatering) on groundwater flow, aquifer recharge and discharge, and the depth of the water table and pit lake formation. Apply the numerical model to calculate the probable spatial extent of pollution migration plumes from significant pollution sources identified.

SOUTH AFRICA
2006

Specialist Groundwater Modeller. Consultant to Golder Associates (Africa).

Construct a 2D flow and **heat transport** model to simulate the heat dissipation of disposed brines through gypsum cake for MMC's Kingstonvale Facility.

SOUTH AFRICA
2006

Specialist Groundwater Modeller, Consultant to Cullinan Diamond Mine De Beers

Construct a four layered finite element aquifer flow and mass transport model using **FEFLOW** for the 100-year old Cullinan Diamond Mine of De Beers to calculate anticipated mine dewatering requirements under various De Beers' expansion/mine closure scenarios; and the impact of current and anticipated groundwater abstraction (including mine dewatering) on groundwater flow, aquifer recharge and discharge, and the depth of the water table. Apply the numerical model to calculate the probable spatial extent of pollution migration plumes from significant pollution sources identified.

MOZAMBIQUE
2006

Specialist Groundwater Modeller. Consultant to Golder Associates (Africa).

Construct a five-layered finite element aquifer flow and mass transport model using **FEFLOW** for the proposed Moatize Coal Mine of CVRD in Mozambique. The objective of this investigation was to determine possible inflow rates into the opencast workings of the mine as well as to determine impacts from the proposed tailings storage facility on the hydrogeology of the area.

SOUTH AFRICA
2005

Specialist Groundwater Modeller. Consultant to Rison Groundwater Consulting.
Construct a three-layered finite element aquifer flow model using **FEFLOW** for Shafts 12, 14 and the Acid Plant of the Impala-Bafokeng Mining Complex of Impala Platinum near Rustenburg.

SOUTH AFRICA
2005

Specialist Groundwater Consultant. Consultant to Knowles, Husain, Lindsay Inc.
Expert witness in court case between Smit and Anglogold – Location Dankbaarpan and Kortlaagte Farm District Welkom.

SOUTH AFRICA
2005

Specialist Groundwater Modeller. Consultant to Khulani GeoEnvironmental Consultants.
Update of the Northwest Province Dolomitic Model to include the Paardenvallei, Tweefontein South and Uitvalgrond Wellfields. Determine the abstraction potential from these areas using the model.

BOTSWANA
2005

Specialist Groundwater Modeller and Project Leader. Consultant to Debswana Diamond Company.
Determination of wellfield requirements in order to ensure a safe water supply to Jwaneng Mine and Township.

MOZAMBIQUE
2005

Specialist Groundwater Modeller. Consultant to Golder Associates (Africa).

Construct a six-layered finite element aquifer flow model using **FEFLOW** for the proposed Moatize Mine of CVRD in Mozambique. The objective of this investigation was to determine possible inflow rates into the opencast workings of the mine.

SOUTH AFRICA
2005

Specialist Groundwater Modeller. Consultant to Golder Associates (Africa).

Update of the two-layered finite element aquifer flow and mass transport model using **FEFLOW** for the Tubatse Ferrochrome Plant near Steelpoort. The objective of this investigation was to determine feasible aquifer remediation options in order to rehabilitate groundwater polluted by hexavalent chromium (Cr^{6+}) originating from the plant area. A groundwater flow and mass transport model was constructed and calibrated in order to evaluate the effectiveness of various remediation abstraction alternatives.

ARGENTINA
2005

Specialist Groundwater Modeller. Consultant to Water Management Consultants of Santiago, Chile.
Update and verify the **FEFLOW** finite element aquifer flow model for the dewatering of the Bajo de la Alumbrera Mine in the Catamarca Province in

Argentina using the 2004/2005 monitoring data. Determine dewatering requirements to satisfy the mine plan over the period 2005 up to 2006.

SOUTH AFRICA
2005

Specialist Groundwater Modeller. Consultant to Rison Groundwater Consulting and Jones & Wagener Consulting Engineers.
Construct and calibrate a three-layered finite element aquifer flow and mass transport model using **FEFLOW** for the Holfontein Hazardous Waste Disposal Site near Delmas. Various management intervention alternatives were evaluated using the model amongst which were various states of dewatering of the hazardous waste cells in combination with clean and contaminated cut-off drains.

SOUTH AFRICA
2005

Specialist Groundwater Modeller. Consultant to Rison Groundwater Consulting and Jones & Wagener Consulting Engineers.
Construct and calibrate a two-layered finite element aquifer flow and mass transport model using **FEFLOW** for NCP's Chloorkop Industrial Landfill Sites. The objective of this investigation was to simulate the migration of chloride and HCH plumes from the landfill sites. Various management intervention alternatives were evaluated using the model.

SOUTH AFRICA
2005

Specialist Groundwater Modeller. Consultant to Golder Associates (Africa).

Construct a two-layered finite element aquifer flow and mass transport model using **FEFLOW** for the Pappas Quarry Manganese Residue Management Facility of Manganese Metal Company near Nelspruit. The objective of this investigation was to calibrate the historical manganese plume migration from the quarry into the groundwater regime and towards the Crocodile River and Gladdespruit and the subsequent effect of the implementation of the filter trench designed to capture the contamination plume.

BOTSWANA
2005

Specialist Groundwater Modeller and Project Leader. Consultant to Debswana Diamond Company.
Update the five-layered finite element aquifer model using **FEFLOW** for the Jwaneng Wellfield with 2004 monitoring information. The model was calibrated during 2001 utilising monitoring data covering a 21-year period. The information of 28 abstraction and 40 monitoring boreholes were included into the model. Total abstraction from the system is currently in the order of $11x10^6$ m^3/annum.

SOUTH AFRICA
2005

Specialist Groundwater Modeller. Consultant to VSA Earth Resource Consultants.
Update the three-layered finite element aquifer flow and mass transport model using **FEFLOW** for the Impala-Bafokeng Mining Complex of Impala Platinum near Rustenburg with 2004 monitoring information. The objective of this investigation was to determine the potential migration of sulphate plumes from tailings and processing facilities.

SOUTH AFRICA
2004

Specialist Groundwater Modeller. Consultant to Golder Associates Africa.
Construct and calibrate a five-layered finite element aquifer flow and mass transport model using **FEFLOW** for Eskom's Usutu Coal Mine near Ermelo. The objective of this investigation was to simulate the inflow of water into the opencast mine workings and from the neighbouring defunct underground mine. Post-closure were also simulated with forecasts on decant positions, quantity and quality.

SOUTH AFRICA

Specialist Groundwater Modeller. Consultant to Golder Associates Africa.

2004	Construct and calibrate a four-layered finite element aquifer flow and mass transport model using **FEFLOW** for Sappi's Ngodwana Paper Mill near Nelspruit. The objective of this investigation was to simulate the migration of chloride plumes from Sappi's mill effluent irrigation pastures to the Elands River and various springs draining to the river. Various management intervention alternatives were evaluated using the model.
SOUTH AFRICA 2004	**Specialist Groundwater Modeller. Consultant to Rison Groundwater Consulting.** Construct a three-layered finite element aquifer flow model using **FEFLOW** for the proposed Shaft 16 Impala-Bafokeng Mining Complex of Impala Platinum near Rustenburg. The objective of this investigation was to determine the potential dewatering requirements to maintain dewatered conditions in the surroundings of the shaft.
SOUTH AFRICA 2004	**Specialist Groundwater Modeller. Consultant to VSA Earth Resource Consultants.** Construct a three-layered finite element aquifer flow and mass transport model using **FEFLOW** for the Impala-Bafokeng Shaft7A Complex of Impala Platinum near Rustenburg. The objective of this investigation was to determine the potential migration of nitrate plumes from sludge ponds and the investigation of using an abstraction remediation scheme.
ARGENTINA 2004	**Specialist Groundwater Modeller. Consultant to Water Management Consultants of Santiago, Chile.** Update and verify the **FEFLOW** finite element aquifer flow model for the dewatering of the Bajo de la Alumbrera Mine in the Catamarca Province in Argentina. Determine dewatering requirements to satisfy the mine plan over the period 2004 up to 2010. Construct a post-mining re-watering mine model to simulate the forming of the pit lake post-mine closure.
SOUTH AFRICA 2004	**Specialist Groundwater Modeller. Consultant to Groundwater Consulting Services.** Construct a three-layered finite element aquifer flow and mass transport model using **FEFLOW** for the proposed Shaft 16 Impala-Bafokeng Mining Complex of Impala Platinum near Rustenburg. The objective of this investigation was to determine the potential migration of sulphate plumes from rock dumps and processing facilities.
SOUTH AFRICA 2004	**Specialist Groundwater Modeller. Consultant to Golder Associates Africa.** Construct a two-layered finite element aquifer flow and mass transport model using **FEFLOW** for the Tubatse Ferrochrome Plant near Steelpoort. The objective of this investigation was to determine feasible aquifer remediation options in order to rehabilitate groundwater polluted by hexavalent chromium (Cr^{6+}) originating from the plant area. A groundwater flow and mass transport model was constructed and calibrated in order to evaluate the effectiveness of various remediation abstraction alternatives.

SOUTH AFRICA 2004	**Specialist Groundwater Modeller. Consultant to Sasol Mining.** Determine the impact of Sasol Mining's Mohololo underground and Wonderwater opencast mines on private landowner's groundwater resources using a four-layered **FEFLOW** model.
SOUTH AFRICA 2004	**Specialist Groundwater Modeller. Consultant to E. Martinelli & Associates.** Construct a two-layered finite element aquifer model using **FEFLOW** for the Palabora Mine at Phalaborwa in a highly complex geological environment. The ultimate objective of this investigation was to determine the required dewatering infrastructure in order to dewater the Service Shaft for the new underground mine.
SOUTH AFRICA 2003	**Specialist Groundwater Modeller. Consultant to PMA Consortium and the Department of Water Affairs and Forestry.** Construct a **FEFLOW** model for the modelling of groundwater flow in the dolomitic areas of the Northwest Province for the bulk water supply augmentation to Zeerust, Mafikeng and Swartruggens. The area comprises of 26 springs draining 56 dolomite compartments and is the largest model ever constructed for a South African Aquifer.
SOUTH AFRICA 2003	**Specialist Groundwater Modeller. Consultant to VSA Earth Resource Consultants.** Construct a three-layered finite element aquifer flow and mass transport model using **FEFLOW** for the Impala-Bafokeng Mining Complex of Impala Platinum near Rustenburg. The objective of this investigation was to determine the potential migration of sulphate plumes from tailings and processing facilities.
SOUTH AFRICA 2003	**Specialist Groundwater Modeller. Consultant to Golder Associates Africa.** Construct a two-layered finite element aquifer flow model using **FEFLOW** for the dewatering of BHP Billiton's Lwala Chrome Mine near Burgersfort The objective of this investigation was to determine the inflow over time into the mine workings in order to satisfy a mine plan spanning a period of 6 years. Several other EIA related issues were also addressed using the model.
SOUTH AFRICA 2003	**Specialist Groundwater Modeller. Consultant to KLM Consulting Services.** Construct a three-layered finite element aquifer flow model using **FEFLOW** for the dewatering of The Oaks Mine in the Limpopo Province of South Africa. The objective of this investigation was to determine the inflow over time into the mine workings in order to satisfy a mine plan spanning a period of 5 years.
ARGENTINA 2002	**Specialist Groundwater Modeller. Consultant to Water Management Consultants of Santiago, Chile.** Construct a finite element aquifer flow model using **FEFLOW** for the dewatering of the Bajo de la Alumbrera Mine in the Catamarca Province in Argentina. The objective of this investigation was to determine aquifer-dewatering infrastructure in order to satisfy a mine plan spanning a period of 7 years. The highly transmissive copper-gold porphyry deposit is enclosed by lower permeable andesitic lava flows of varying events. Dewatering occurs from large diameter wells within the pit.

SOUTH AFRICA 2002	**Specialist Groundwater Modeller, Consultant to VSA Earth Resource Consultants.** Construct a five-layered aquifer flow model using **FEFLOW** for the dewatering requirements of the proposed Mooikraal Underground Coal Mine of SASOL COAL near Sasolburg. The mine, which is 150m beneath a layering of alternating dolerite and sandstone, will be utilising block and pillar extraction techniques and in some instances will apply high extraction mining techniques. The model constructed takes cognisance of both mining techniques.
SOUTH AFRICA 2002	**Specialist Groundwater Modeller. Consultant to Golder Associates (Africa).** Construct a two-layered finite element aquifer flow and mass transport model using **FEFLOW** for the Kingstonvale Residue Management Facility of Manganese Metal Company near Nelspruit. The objective of this investigation was to determine the potential migration of manganese once passing through a triple liner system.
SOUTH AFRICA 2002	**Specialist Groundwater Modeller. Consultant to E. Martinelli & Associates.** Construct a finite element aquifer model using **FEFLOW** for the dewatering of the Pappas Quarry of Manganese Metal Company near Nelspruit. The goal of this investigation was to determine the feasibility of dewatering the manganese nodules deposited into the old quarry within two years prior to the capping of the facility.
SOUTH AFRICA 2002	**Specialist Groundwater Modeller. Consultant to E. Martinelli & Associates.** Construct a three-layered finite element aquifer model using **FEFLOW** for the new Durban Point Aquarium Project. The objective of the investigation was to determine the feasibility to abstract 285 l/s from the sea bed sediments in order to supply seawater of acceptable quality from a well point system to the aquarium. The feasibility of abstracting seawater from large diameter (3m) caisons in the seabed sediments for the water supply was also investigated using the model.
SOUTH AFRICA 2002	**Specialist Groundwater Modeller. Consultant to Africon.** Construct a finite element aquifer model using **FEFLOW** for the Uitvalgrond dolomitic compartment near Zeerust. The objective was to determine the aquifer potential of the groundwater system and the effect that abstraction from this compartment will have on the flow of two nearby springs. Recommendations on the operation and abstraction rates of the abstraction boreholes situated in the compartment to the Welbedacht Water Supply Scheme were provided.
SOUTH AFRICA 2002	**Specialist Groundwater Modeller. Consultant to Wates, Meiring and Barnard Consulting Engineers.** Construct a two-layered finite element aquifer flow and mass transport model using **FEFLOW** for the African Chrome Site near Brits. The objective of this investigation was to determine feasible aquifer remediation options in order to rehabilitate groundwater polluted by hexavalent chromium (Cr^{6+}) originating from the plant area. A groundwater flow and mass transport model was constructed and calibrated in order to evaluate the effectiveness of various remediation abstraction alternatives.

SOUTH AFRICA 2002	**Specialist Groundwater Modeller. Consultant to Groundwater Consulting Services.** Construct a six-layered finite element aquifer model using **FEFLOW** for the Marula Platinum Mine of Impala Platinum near Burgersfort. The objective of this investigation was to determine the potential inflow rates and required dewatering infrastructure in order to dewater the underground mine which is following a highly complex mine plan.
BOTSWANA 2001-2002	**Specialist Groundwater Modeller and Project Leader. Consultant to Semane Consulting Engineers and Debswana Projects.** Construct a three-layered finite element aquifer model using **FEFLOW** for the Orapa Wellfields. The ultimate objective of the investigation was to determine the groundwater exploitation potential of the AK1 and BK9 Mining Lease Areas. The model included information from seven wellfields and the dewatering of two major open cast diamond mine pits. The model was calibrated utilising monitoring data covering a 20-year period. The information of 155 abstraction and 84 monitoring boreholes were included into the model. Total abstraction from the system is in the order of $10x10^6$ m^3/annum.
BOTSWANA 2001-2002	**Specialist Groundwater Modeller and Project Leader. Consultant to Debswana Diamond Company.** Construct a five-layered finite element aquifer model using **FEFLOW** for the Jwaneng Wellfield. The ultimate objective of the investigation was to determine the feasibility to abstract $17x10^6$ m^3/annum over the next 40 years from 28 high yielding boreholes. The model was calibrated utilising monitoring data covering a 21-year period. The information of 28 abstraction and 40 monitoring boreholes were included into the model. Total abstraction from the system is currently in the order of $9x10^6$ m^3/annum.
SOUTH AFRICA 2001	**Specialist Groundwater Modeller. Consultant to E. Martinelli & Associates for Palabora Mining Company.** Construct a three-layered finite element aquifer model using **FEFLOW** for the PP&V (Phosphate, Phlogopite and Vermiculite) Mine at Phalaborwa in a highly complex geological environment. The ultimate objective of this investigation was to determine the required dewatering infrastructure in order to dewater mine which is following a highly complex mine plan as a result of the complex geology.
SOUTH AFRICA 2001	**Specialist Groundwater Modeller. Consultant to VSA Earth Science Resource Consultants and SASOL COAL's SIGMA MINE.** Construct a six-layered finite element aquifer model using **FEFLOW** for SASOL COAL's SIGMA Mine near Sasolburg. A very complex mine plan consisting of two underground and two opencast sections were built into the model. The rehabilitation of the two opencast sections, which occurs in tandem with other operations, was constructed into the flow model. The model was calibrated utilising monitoring data covering a 13-year period. The close proximity of the Vaal River to the mining operations necessitated its inclusion into the model. A mass transport model was subsequently constructed to simulate the migration of sulphates post-mine closure.
SOUTH AFRICA 2000-2001	**Specialist Groundwater Modeller and Project Leader. Consultant to AngloGold's Freegold Operation in the Free State.** Construct a single-layered finite element aquifer model using **FEFLOW** for the Mahem Spruit area near Welkom. The objective of this investigation was to determine feasible aquifer remediation options in order to rehabilitate groundwater

polluted by sulphates originating from nearby gold tailings dams. A groundwater flow and mass transport model was constructed and calibrated in order to evaluate the effectiveness of various remediation alternatives.

SOUTH AFRICA
2001

Hydrogeologist. Consultant to Anglogold's Mponeng Gold Mine.

Determination of the origin of spring water next to the tailings dam at Anglogold's Mponeng Mine.

SOUTH AFRICA
2000

Specialist Groundwater Modeller and Project Leader. Consultant to Southern Africa Geoconsultants and Kynoch Fertilizer, Potchefstroom.
Construct a single-layered finite element aquifer model using **FEFLOW** for the Kynoch Gypsum Tailings Dam near Potchefstroom. The objectives of this investigation were to establish the current and future impact of the tailings dam on the hydrogeological environment as it is currently operated and planned. Seek remedial solutions to potential environmental impacts that may be associated with the hydrogeology of the site, test the proposed remedial actions' technical feasibility using the model. Recommend a remedial or group of remedial actions that could be best applied to the site. Such remedial solutions included the lining of the dam as well as the abstraction of contaminated water from boreholes strategically positioned around the site.

SOUTH AFRICA
2000

Specialist Groundwater Modeller. Consultant to the South African Nuclear and Energy Corporation.
Construct a single-layered finite element aquifer model using **FEFLOW** for the hydrogen-fluoride plant near Pelindaba. The objectives of this investigation were to establish the current and future impact of the plant on the hydrogeological environment as it is currently operated and planned. Seek remedial solutions to potential environmental impacts that may be associated with the hydrogeology of the site, test the proposed remedial actions' technical feasibility using the model. Recommend a remedial or group of remedial actions that could be best applied to the site. Such remedial solutions included the positioning of strategically located interceptor boreholes.

SOUTH AFRICA
2000

Specialist Groundwater Modeller. Consultant to the Gamsberg Zinc Operation's Project Team of Anglo American Corporation of South Africa.
Construct a finite difference aquifer model using **MODFLOW/MT3D** for the Gamsberg Zinc opencast mine near Pofadder. Conduct a modelling exercise in order to determine inflow rates into the open pit mine workings as well as a pollution plume modelling study to determine the risk of pollution from the tailings site at the proposed Gamsberg zinc mine in **South Africa.**

RUSSIA
1999-2000

Specialist Groundwater Modeller. Consultant to the Archangel Diamond Corporation, Denver, Colorado, USA.
Construct a 3-layered finite difference aquifer model using **MODFLOW** for the Grib Diamond Pipe in the Verkhotina License Area near Arkhangelsk, Russia. The objective with this modelling exercise was to determine the dewatering requirements in order to dewater the Grib Pipe taking cognisance of the proximity of a large lake. Feasibility studies were subsequently conducted to determine the possibility of mining the ore body by means of mechanical dredging taking into consideration slurry densities.

IRELAND
1999

Specialist Groundwater Modeller. Consultant to Lisheen Mine, Lisheen, Ireland.

Construct a water balance model for Lisheen Mine utilising abstraction, water level and rainfall information in order to determine the storage parameter and groundwater recharge from rainfall to the aquifer in order to determine mine dewatering abstraction rates. Methodologies developed during the recharge study conducted for the Water Research Commission was extensively used **(SVF-Package)**. Stochastically generated rainfall sequences were generated to forecast the aquifer's response to varying abstraction rates from the aquifer.

SOUTH AFRICA
1999

Specialist Groundwater Modeller. Consultant to Geohydro Technologies.

Conduct a groundwater modelling study for the aquifer supplying water to the town of Graaff-Reinet in the Eastern Cape Province of South Africa.

SOUTH AFRICA
1999

Specialist Groundwater Modeller. Consultant to AMCOAL.

Construct a finite difference aquifer model using **MODFLOW/MT3D** for the Nooitgedacht Colliery near Matla Power Station. Conduct a modelling exercise in order to determine inflow rates into the underground mine workings as well as a pollution plume modelling study to determine the risk of pollution from the mine post closure. Determine decant rates post closure.

RUSSIA
1998-1999

Specialist Groundwater Modeller. Consultant to De Beers Centenary, Moscow, Russia and the Severalmaz Corporation, Arkhangelsk, Russia.
Review the dewatering strategy proposed by Hydec Company of Moscow in order to dewater the Lomonosov Pipe near Arkhangelsk. Construct a 3-layered finite difference aquifer model using **MODFLOW** for the Lomonosov Mine to determine flows from the different aquifers during the dewatering process. Determine the salt load derived from the different aquifers to be discharged into the nearby Zolotitsa river.

ARGENTINA
1998

Specialist Groundwater Modeller. Consultant to the Cerro Vanguardia Project, Anglo American South America, Buenos Aires, Argentina.
Construct a finite element numerical flow and mass transport model for the aquifer at the Cerro Vanguardia Gold Mine, Patagonia, using **AQUAWIN** in order to determine the risk of groundwater pollution on the wellfield from the tailings dam site.

MALI WEST-AFRICA
1998

Specialist Groundwater Modeller. Consultant to the SADIOLA HILL Project team, Anglogold.

Construct a finite element numerical flow and mass transport model for the aquifer at the Sadiola Hill Gold Mine, Mali, using **AQUAWIN** in order to determine the risk of groundwater pollution on the wellfield from the tailings dam site.

SOUTH AFRICA
1997

Specialist Groundwater Modeller. Consultant to the Venetia Diamond Mine, De Beers.
Determine the feasibility of the construction of a second off-channel storage dam for the water supply to the Venetia diamond mine based on finite element groundwater flow modelling **(AQUAWIN)** and risk analyses techniques (stochastic modelling techniques) coupled to a financial decision model.

SOUTH AFRICA
1997

Specialist Groundwater Modeller. Consultant to The Oaks Diamond Mine, De Beers.

Determination of the sustainable yield of the aquifers at the Oaks Mine with reference to the impact of additional abstraction for mining activities on surrounding groundwater users using a finite element model **(AQUAWIN)**.

CHILE
1997

Hydrogeologist. Consultant to the Collahuasi Project team, Santiago, Chile, Anglo American South America.
Review the study conducted by E. Montgomery and Ass. of the USA on the water supply to the Collahuasi Copper Mine in Chile.

NAMIBIA
1996

Specialist Groundwater Modeller. Consultant to NAMDEB Diamond Corporation, De Beers.
Determine the feasibility of installing a wellfield for the supply of water to the dredging operations at NAMDEB's diamond mines on the **Namibian coast** by means of groundwater flow model and optimization techniques.

BOTSWANA
1996

Specialist Groundwater Modeller. Consultant to the Gope Diamond Mine Project Team, DEBSWANA, Botswana.
Determine the feasibility of installing a wellfield for the supply of water to the Gope mine operations (Central Kalahari Game Reserve, **Botswana**) as well as dewatering requirements by means of a finite element groundwater flow model **(AQUAWIN)**.

ARGENTINA
1995

Hydrogeologist. Consultant to the Cerro Vanguardia Project, Anglo American South America, Buenos Aires, Argentina.
Review the study conducted by HYDROAR on the water supply to the Cerro Vanguardia Gold Mine in Patagonia, Argentina, South America.

ZAMBIA
1995

Hydrogeologist. Consultant to Zambian Copper Investments.

Review the dewatering model of the Konkola Copper Mine in Zambia. This mine is generally accepted as one of the wettest mines in the world.

BOTSWANA
1995

Specialist Groundwater Modeller and Project Leader. Consultant to Orapa Mine Debswana.
Construct a numerical groundwater flow model for the Orapa wellfields in Botswana to optimally determine the groundwater potential of the system including recharge calculations and a flow risk analysis. Prof. S.S.D. Foster of the British Geological Survey reviewed this study.

BOTSWANA
1995

Specialist Groundwater Modeller and Project Leader. Consultant to Orapa Mine Debswana.
Construct a numerical groundwater flow model for the Orapa open pit diamond mine in Botswana to design the dewatering system.

BOTSWANA
1994

Specialist Groundwater Modeller and Project Leader. Consultant to Jwaneng Mine Debswana.
Construct a numerical groundwater flow model for the Jwaneng Northern Wellfield supplying water to the Jwaneng Diamond Mine and township in Botswana. During this study optimization modelling techniques were used to determine how mixing from different boreholes should be accomplished in order to obtain the best quality of water while still satisfying the demand of the mine and the township.

BOTSWANA
1993

Specialist Groundwater Modeller and Project Leader. Consultant to Orapa Mine Debswana.

	Construct a numerical groundwater flow model for the Letlhakane open pit diamond mine in Botswana to design the dewatering system required to satisfy drawdown constraints as dictated by the mine production plan.
SOUTH AFRICA 1992	**Specialist Groundwater Modeller and Project Leader. Consultant to Western Areas Gold Mining Company.** Construct a groundwater flow model to determine the inflow to the Western Areas Gold Mine from the Gemsbokfontein Eastern and Western Dolomitic Compartments.
SOUTH AFRICA 1992	**Specialist Groundwater Modeller and Project Leader. Consultant to the Water Authority of the Town of Potgietersrus.** Conduct a groundwater modelling study for the dolomitic aquifer supplying water to the town of Potgietersrus in the Northern Province of South Africa.
SOUTH AFRICA 1992	**Specialist Groundwater Modeller and Project Leader. Consultant to the Water Authority of the Town of Zeerust.** Conduct a groundwater modelling study for the Rietpoort dolomitic compartment that supplies water to the town of Zeerust in the Northwest Province of South Africa.
SOUTH AFRICA 1992	**Specialist Groundwater Modeller and Project Leader. Consultant to the Water Authority of the City of Mmabatho.** Conduct a groundwater modelling study for the Grootfontein dolomitic compartment that supplies water to Mmabatho the capital of the Northwest Province in South Africa.
SOUTH AFRICA 1991	**Specialist Groundwater Modeller. Consultant to the Venetia Diamond Mine, De Beers.** Determine the feasibility of the construction of an off-channel storage dam for the water supply to the Venetia diamond mine based on finite element groundwater flow modelling **(AQUAWIN)** and risk analyses techniques (stochastic modelling techniques) coupled to a financial decision model.
NAMIBIA 1990	**Specialist Groundwater Modeller. Consultant to the Water Authority of the City of Walvis Bay.** Conduct a groundwater modelling study for the Kuiseb river and delta aquifer in Namibia, which supplies water to Namibia's biggest harbour town.
SOUTH AFRICA 1987-1990	**Specialist Scientist/Hydrogeologist. Department of Water Affairs and Forestry.** Preparation of "Manual on Quantitative Estimation of Groundwater Recharge and Aquifer Storativity" for the Water Research Commission of South Africa. ISBN 1 86845 176 3.
SOUTH AFRICA 1985-1986	South African Defence Force. Completed Officer's Course (Rank Lieutenant). Appointed as Platoon Commander 26 Squadron Engineering Corps Bethlehem.
SOUTH AFRICA 1983-1984	**Hydrogeologist. Department of Water Affairs and Forestry**

Water supply investigations for the towns of Greylingstad, Balfour and Ottosdal.
Groundwater flow modelling of the Polfontein and Grootfontein Aquifer.

OVERSEAS CONFERENCES

1989 USA (Baltimore, Maryland) to present a paper on groundwater modelling.
1994 Modelling groundwater flow and solute transport. Jacob Bear, Johannesburg.
1994 University of Mauritius to lecture on groundwater modelling.
1994 Germany (Heidelberg) to present a paper at the conference on computational methods in water resources.