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BRENTON-ON-SEA, PORTION 76 OF THE FARM UITZICHT NR 216, KNYSNA, WATER SUPPLY INVESTIGATION – DESKTOP INVESTIGATION, GEOPHYSICAL INVESTIGATION & FEASIBILITY ASSESSMENT INTO GROUNDWATER ABSTRACTION

PROJECT NO: LL3203
REPORT NO: LL3203 Version 1
DATE: OCTOBER 2018

J. Du Preez *Pr.Sci.Nat.*

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30th October 2018 *Our Ref: LL3203*

The Project Manager
PTN 7 of the Farm Uitzicht
Knysna
6570

Attention: Dr. Hans Swart

Email to: hansswartinc@gmail.com
Mobile: 082 880 7335

RE: BRENTON-ON-SEA, PORTION 76 OF THE FARM UITZICHT NR 216, KNYSNA, WATER SUPPLY INVESTIGATION – DESKTOP INVESTIGATION, GEOPHYSICAL INVESTIGATION & FEASIBILITY ASSESSMENT INTO GROUNDWATER ABSTRACTION

Dear Sir,

The results of the geohydrological investigation, which included a feasibility study, hydrocensus and geophysical investigation in the Brenton-on-Sea - Southern Cape area is discussed in this initial report. Comments and recommendations on the drilling of new production boreholes, casing installation as well as proposals regarding the project procedure are also included.

I trust that this meets with your immediate requirements in this regard.

Yours Faithfully

Jacques du Preez
Hydrogeologist (Pr Sci Nat - BSc Hons)
ENGEOLAB cc - Hilton (KwaZulu-Natal)
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Report Type:	Geohydrological Feasibility Investigation
Project Title:	**BRENTON-ON-SEA, PORTION 76 OF THE FARM UITZICHT NR 216 KNYSNA, WATER SUPPLY INVESTIGATION – DESKTOP INVESTIGATION, GEOPHYSICAL INVESTIGATION & FEASIBILITY ASSESSMENT INTO GROUNDWATER ABSTRACTION**
Compiled for:	Dr. Hans Swart
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Engeolab Reference;	LL3203
Version:	Version 1-Final Draft
Date:	October 2018
Distribution List:	Dr. Hans Swart (1 electronic copy)

Disclaimer:
The results, conclusions and recommendations of this report are limited to the Scope of Work agreed between Engeolab cc and the Client who requested this investigation. All assumptions made and all information contained within this report, its attachments and maps depend on accessibility to and reliability of relevant information. All work conducted by Engeolab cc is done in accordance with the Engeolab Standard Operating Procedures.

Declaration:
I hereby declare:
1. I have no vested interest (now or in the future) in this project and that I have no personal interest with respect to the parties involved in this project.
2. I have not been offered, nor have I received any significant form of inappropriate reward for compiling this report.
3. I have no bias with regard to this project or towards the various stakeholders involved in this project.

……………………………….(electronic signature)　　　　Date:…30th October 2018……………
Jacques du Preez
Hydrogeologist (Pr Sci Nat - BSc Hons) ENGEOLAB cc

Glossary

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

Aquifer – A body of rock, consolidated or unconsolidated, that is sufficiently permeable to conduct groundwater and to yield significant quantities of water to wells and springs.

Compartment – In a slope-aquifer system, an area formed by an undulation of the water table generally conforming to an undulation in the overlying topography. The crests of the water-table undulations represent natural groundwater divides that, under natural conditions, restrict the movement of groundwater to the boundaries of the compartment.

Cone of Depression – A depression in the potentiometric surface of a body of groundwater that has the shape of an inverted cone and develops around a well/mine shaft/open pit mine from which water is being withdrawn.

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

Discharge Area – An area in which there is an upward component of hydraulic head in an aquifer. Groundwater flows toward land surface in a discharge area and escapes as a spring, seep, base flow to streams, or by evaporation and transpiration.

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

Drawdown – The decline of the water table or potentiometric surface as a result of withdrawals from wells or excavations.

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

Equipotential line – A line in a two-dimensional groundwater flow field on which the total hydraulic head is the same at all points.

Fault – A fracture or fracture zone along which there has been displacement of the sides relative to one another parallel to the fracture.

Fracture – A crack, joint, fault or other break in rocks caused by mechanical failure.

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

Heterogeneous indicates non-uniformity in a structure.

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

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

Hydraulic Head – Generally, the altitude of the free surface of a body of water above a given datum.

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

Interflow – The lateral movement of water in the unsaturated zone during and immediately after precipitation.
Interflow occurs when the zone above a low permeability horizon becomes saturated and lateral flow is initiated parallel to the barrier.

Joint – A fracture in rock along which there has been no visible movement.

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

Metamorphic Rock – A rock formed at depth in the earth's crust from pre-existing rocks by mineralogical, chemical and structural changes caused by high temperature, pressure and other factors. Examples include slate, schist and gneiss.

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

Perched Water Table – The upper surface of a body of unconfined groundwater separated from the main body of groundwater by unsaturated material.

Permeability is related to hydraulic conductivity, but is independent of the fluid density and viscosity and has the dimensions L2. Hydraulic conductivity is therefore used in all the calculations.

pH is a measure of the acidity or alkalinity of a solution, numerically equal to 7 for neutral solutions, increasing with increasing alkalinity and decreasing with increasing acidity.

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

Porosity – The ratio of the aggregate volume of interstices in a rock or soil to its total volume. It is usually stated as a percentage.

Potentiometric Surface – An imaginary surface representing the total head of groundwater and defined by the level to which water rises in tightly cased wells. The water table is a particular potentiometric surface.

Pumping tests are conducted to determine aquifer or borehole characteristics.

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

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

Sedimentary Rock – A layered rock resulting from the consolidation of sediment deposited by some geologic agent such as water, wind, or ice. Typical sedimentary rocks include sandstone, limestone and shale.

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

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

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

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

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

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

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

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

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

Abbreviations and Acronyms

DWS	Department of Water Affairs and Sanitation
EC	Electrical Conductivity (mS/m)
Fe	Iron (mg/l)
IWULA	Integrated Water Use License Application
K	Hydraulic Conductivity (m/day)
mamsl	Meters above mean sea level
m^3/month	Water Consumption – cubic metres per month
MAE	Mean Annual Evaporation
MAP	Mean Annual Precipitation
MAR	Mean Annual Runoff
mbgl	Meters below ground level
MIPI	Midgley & Pitman Method
NGDB	National Groundwater Database
NGA	National Groundwater Achive
NWA	The South African National Water Act, 1998 (Act No. 36 of 1998)
S	Storativity
SO4	Sulphate (mg/l)
TDS	Total Dissolved Solids (mg/l)
WR2012	Water Resources of South Africa 2012
WMA	Water Management Area
WUL	Water Use Licence
WULA	Water Use Licence Application

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BRENTON-ON-SEA, PORTION 76 OF THE FARM UITZICHT NR 216, KNYSNA, WATER SUPPLY INVESTIGATION – DESKTOP INVESTIGATION, GEOPHYSICAL INVESTIGATION & FEASIBILITY ASSESSMENT INTO GROUNDWATER ABSTRACTION

1. INTRODUCTION

Following an appointment by Dr. Hans Swart, *Engeolab cc* was tasked with assessing the feasibility of securing groundwater as primary or secondary source for the proposed new residential development in and around Brenton-On-Sea, located on Portions 76 of Farm Uitzicht 216, Knysna, South Africa. *Refer to Figure 1: Locality Map attached as Appendix A*.

The aim is to determine the feasibility of developing groundwater sources (boreholes) as alternative water supply to meet the establishment's water demand.

This report includes groundwater potential and feasibility as well as the risks associated and limitations of the project. This is done by an initial desktop investigation, hydrocensus and geophysical investigation as well as proposals in terms of the required actions to develop new production boreholes, if feasible.

2. BACKGROUND INFORMATION

The supply authority for the area is Knysna Municipality, and therefore their Technical Services Department was consulted previously on a nearby project, Portion 71 & &2 of Uitzicht 216, by the consulting engineer, Tuiniqua Consulting Engineers on all matters relating to the civil services for their development.

In that instance, the proposed development did not have access to the Municipal water and sewerage networks, due to limited network capacity. It was noted that additional studies will be carried out to asses if the existing network can be expanded to service the proposed development. We have used the same assumptions for this project.

Please note that a service agreement regarding increase water, sewerage, stormwater management and access may have to be entered with the Municipality. If any increase in civil services demand is required, augmentation fees and capital contributions in this regard will be calculated and payable in accordance with Council's policy.

2.1 WATER RETICULATION

The client propose to supply water for the development by means of the following:

- Installing boreholes – an application for a water licence will have to be submitted to Breede-Gouritz Catchment Management Agency.
- Supplemented the demand by installing rainwater tanks on every erf for flushing of toilets. Design of internal house reticulation must make provision for this.
- Any shortfall will be supplemented by municipal water.
- It is recommended that all gardens in the development utilize plants that do not require irrigation.

3. WATER DEMAND

The development is said to include the development of two nodes on the consolidated property. The first node will consist of a residential stand on the North-Western corner of the stand and the second node, also a residential development will is proposed on the South-Western corner of the site. Refer to Figure 2 – Proposed Development Layout received from the client.

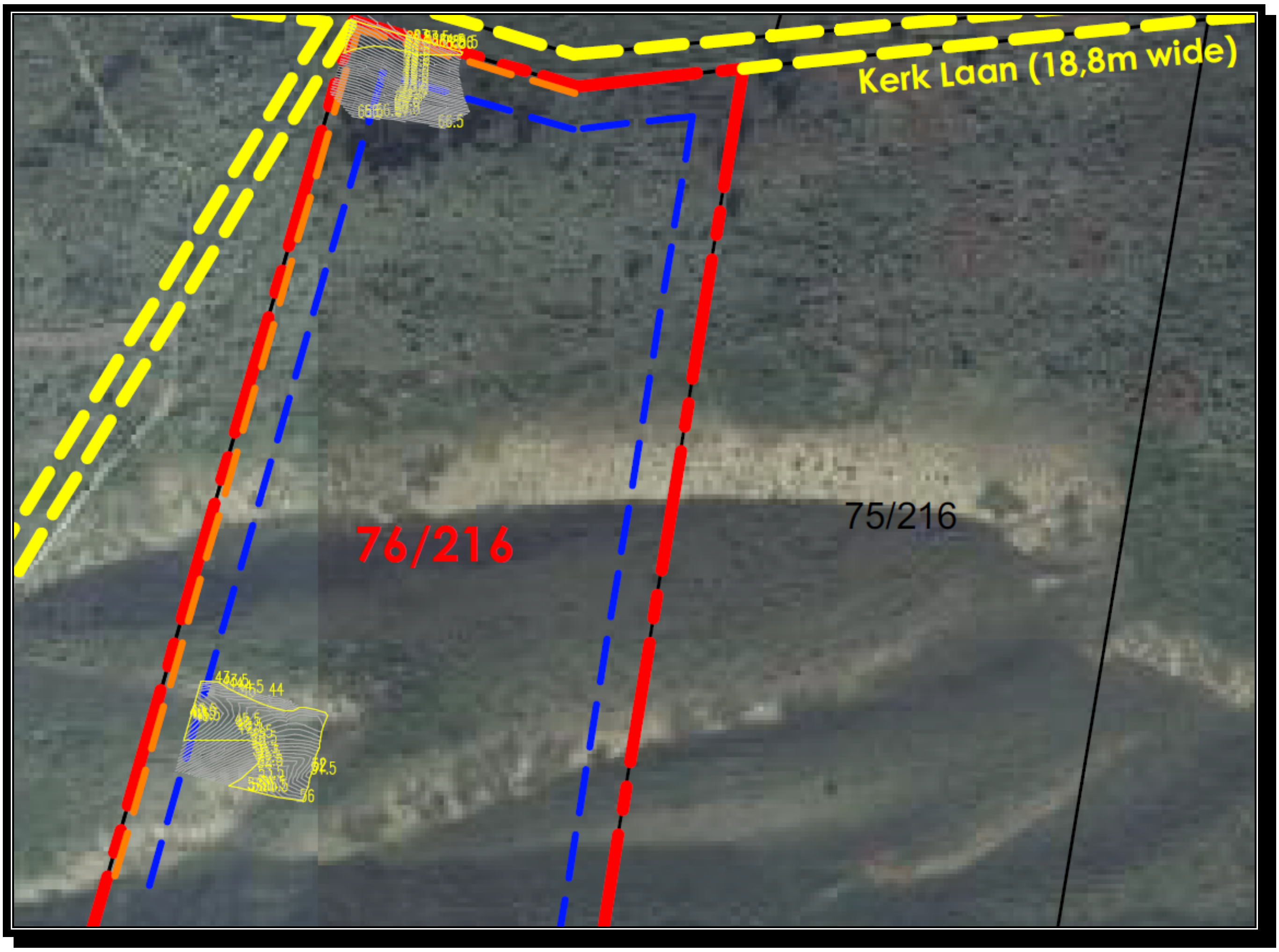


FIGURE 2: Conceptual Development Layout – Portion 76 of the Farm Uitzicht Nr 216, Knysna

The proposed water demand is taken from the "GUIDELINES FOR THE PROVISION OF ENGINEERING SERVICES AND AMENITIES IN RESIDENTIAL TOWNSHIP DEVELOPMENT". The proposed demand is only approximately 1000l/day. We have however allowed for additional water for firefighting, gardening and small scale irrigation (if required).

The total demand for the proposed development comprising TWO (2) residential units is therefore 10 kl/day. A peak factor of 12 is suggested. The development is categorized as a low-risk area with two-hour duration of design fire flow. A water tank or reservoir will be required to make provision for this (7m head is required). Some other related prescriptions could include:

- Rainwater tanks will be installed where practical and to be utilized for gardens and swimming pools.
- Total storage capacity required is 20kl (2 days including domestic & fire).
- It is recommended that guidelines prescribe to make provision for low water usage installations and equipment in all facilities.

4. SCOPE OF WORK

The scope of work proposed and accepted by the client comprises a phased approach to conduct subsurface investigations to determine the geology and soil conditions which included:

The scope of work proposed comprises a phased approach which includes:

Phase 1

- Desktop study followed by a hydrocensus to verify any existing infrastructure as well as the on-site conditions, existing equipment type and condition;
- Remote Sensing including, Aerial photographic interpretation and groundwater potential assessment for area under investigation;
- Geological Reconnaissance and Mapping,
- Analyzing data and prepare a Geohydrological Feasibility Study report on findings of the feasibility investigation;
- Define applicable legislative requirements regarding any permit applications required;
- Submit recommendations in terms of establishment of new production borehole sources.

Phase 2

This phase will only proceed upon approval of the client based on preliminary hydrogeological potential investigations and include:

- Arranging and Supervision of Drilling of new boreholes;
- Arranging and Supervision of controlled Test Pumping of new boreholes;
- Data Analysis and Recommendations findings,
- Reporting, including progress and completion reports and registration with DWA.

This report focuses on phase 1 only.

5. INVESTIGATION METHODOLOGY

In order to formulate a geohydrological model of the area, a desktop data search study that entailed the scouring of all available sources of information including the Department of Water Affairs' NGA (National Groundwater Archive) and other databases (GRIP database) to identify existing boreholes, springs and other water sources was conducted. All existing groundwater resources identified by the data search were then verified through a field hydrocensus process. This information would be used to determine if any of the verified existing sources could be developed as production boreholes for the area.

A lack of suitable existing sources would require additional desktop investigations, this time focusing on identifying potential drilling zones through remote sensing.

The third part of Phase 1 or the ***field geophysical Investigation*** phase focuses on the identification of potential drilling targets (geological lineaments) through geophysical investigation of the potential drilling zones identified by the remote sensing exercise. By conducting a thorough geophysical investigation of the most suitable geological features, a production borehole can be identified in the field and drilled. Considering the geology of the area and the most suitable and cost-effective geophysical techniques for groundwater exploration would be the Resistivity method.

6. RESULTS OF SITE ASSESSMENT

An assessment of the available database and desktop information combined with the brief field verification results was used to determine the current site status quo and proposed project procedure.

DESKTOP RESULTS

6.1 SITE DESCRIPTION

The proposed development is located on Portion 76 of Uitzicht Nr. 216, an elongated site (in the North – South direction) located to the West of Brenton-on-Sea village along the Indian Ocean near Knysna. The southern boundary of the property is the sea high water mark and the Brenton-on-Sea village is located to the East of the property. Five vacant plots is found between the village and Portion 76.

The size of the property is approximately 20.5ha. Two positions are proposed for construction, one in the North-Western corner of the property and one in the South-Western corner of the property.

The northern site is accessed via a gravel track from the Brenton road (CR Swart Drive) and the southern site was inaccessible via motorized vehicle at the time of the investigation. Refer to Figure 3 – Site Map and Plate 1 indicating the gravel access road below.

PLATE 1: Access road on the northern portion of the site

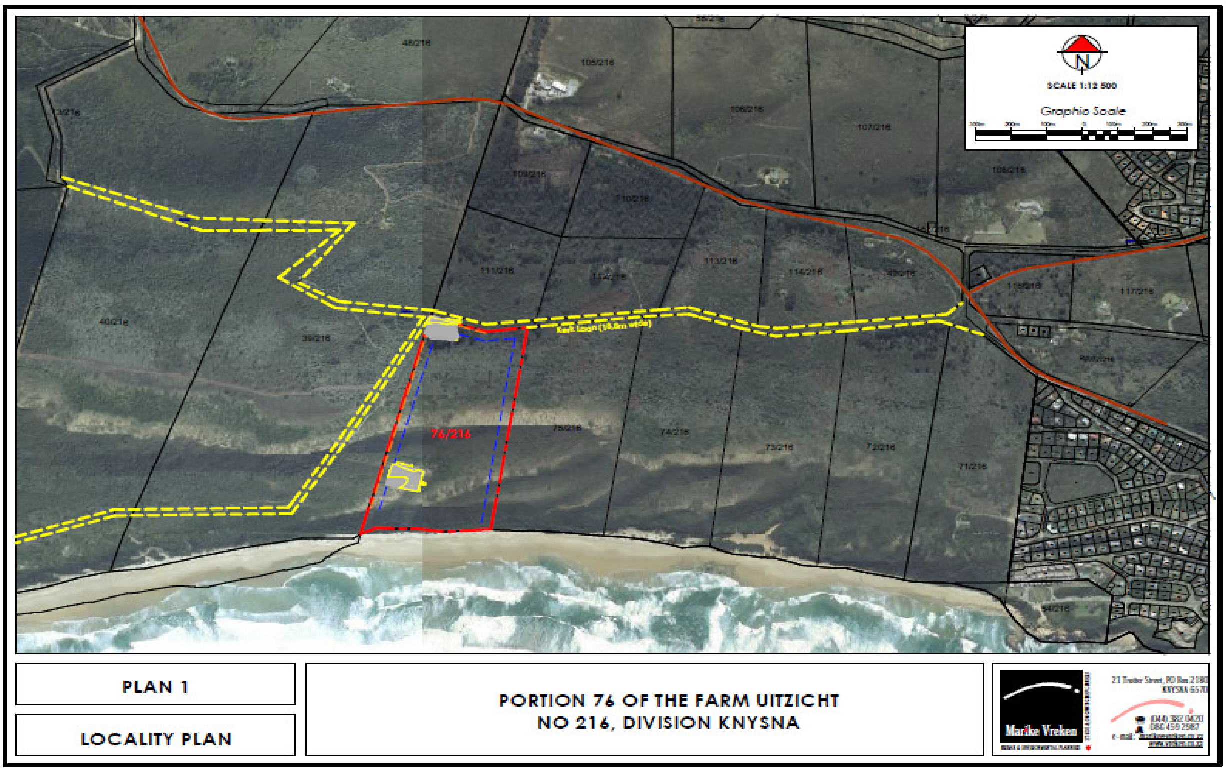


FIGURE 3: Site Map Portion 76 of the Farm Uitzicht No 216, Division Knysna

The planned access road to the remainder of the site is indicated in Figure 4 below.

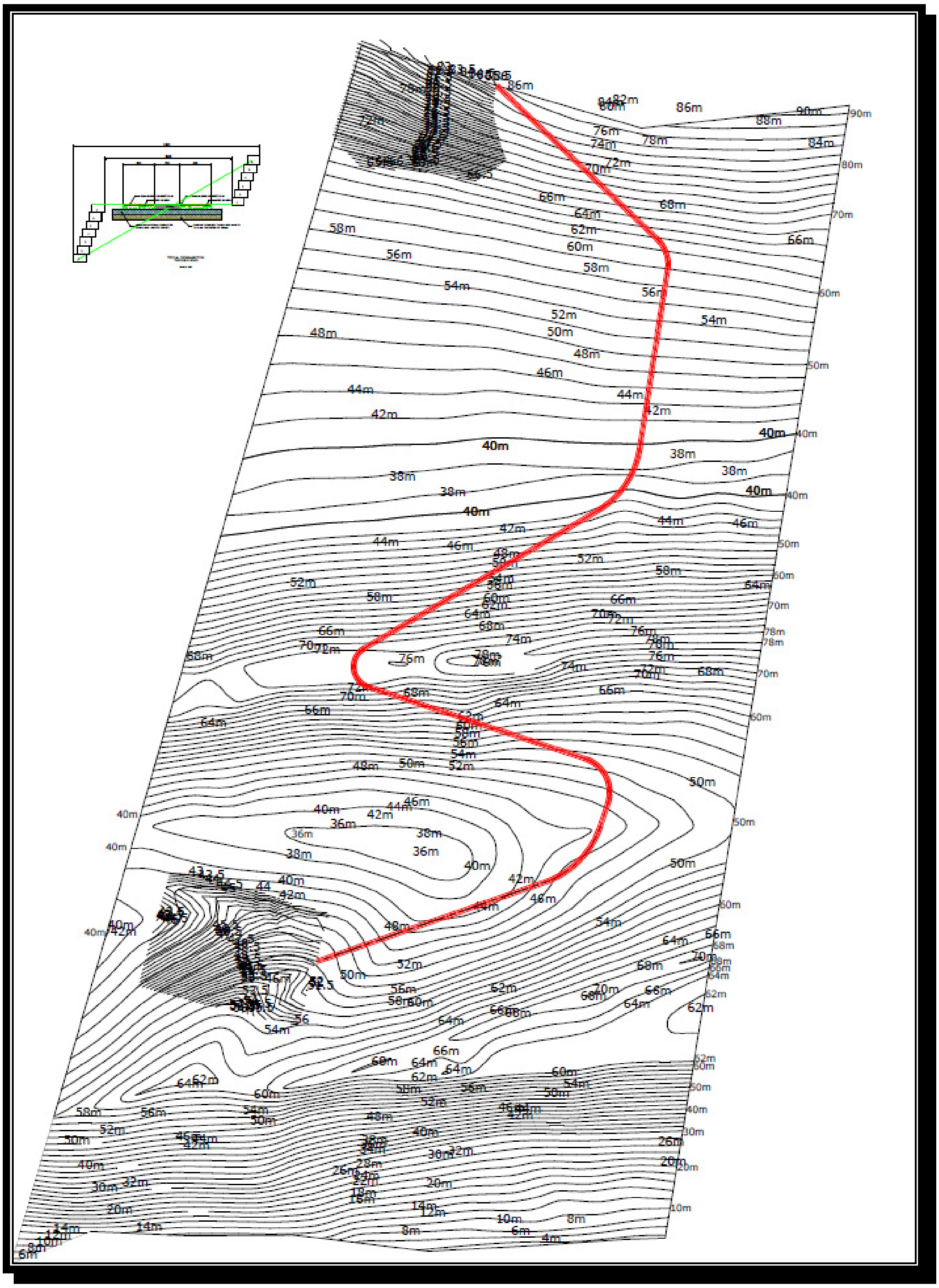


FIGURE 4: Proposed access road to the remainder of the site Portion 76 of Uitzicht No 216, Division Knysna, received from the client.

6.2 CLIMATE, RAINFALL & EVAPORATION

The climate of Knysna is temperate and very mild but typically wet, with little seasonal variation in minimum and maximum temperatures, which is strongly influenced by the cold Benguela ocean current and coastal winds. The Köppen-Geiger climate classification is BSk and has a (Weinert N-value of 1). The average annual temperature is 18°C, annual precipitation averages 881.94 mm and an average evaporation of 1400mm, the area is also characterised by dry warm summer months (October to April) and wetter cool winter months (from May to September) with an all-year rain season.

With this monthly pattern of rainfall and evaporation, groundwater recharge will be quite significant as the rainfall occurs when evaporation is lowest. The risk of flooding will also be highest during the months of June, July and August. Flooding can occur later in the year, especially if an exceptionally heavy rainfall event occurs.

6.3 DRAINAGE & QUATERNARY CATCHMENTS

On a regional level, the drainage follows the topography. The site has an undulating topography that rises from the high watermark to approximately 76m above sea level to form a coastal dune that lies parallel with the shore. See Plate 2 below.

Photo 1 – Westerly view from eastern boundary of the site – valley between Dune to the south and North of the Greenfield site

North of the dune series, the property descents into a valley from where it rises to the Divisional road situated approximately 130m above sea level. The south facing dune is relatively steep but culminates in a plateau in the north section of the property adjacent to the road. The study area falls within the quaternary catchment K50B which drains directly into the Indian Ocean. Refer to Figure 5A – 3D Regional Topographical Map & Figure 5B 2D Regional Topography Map.

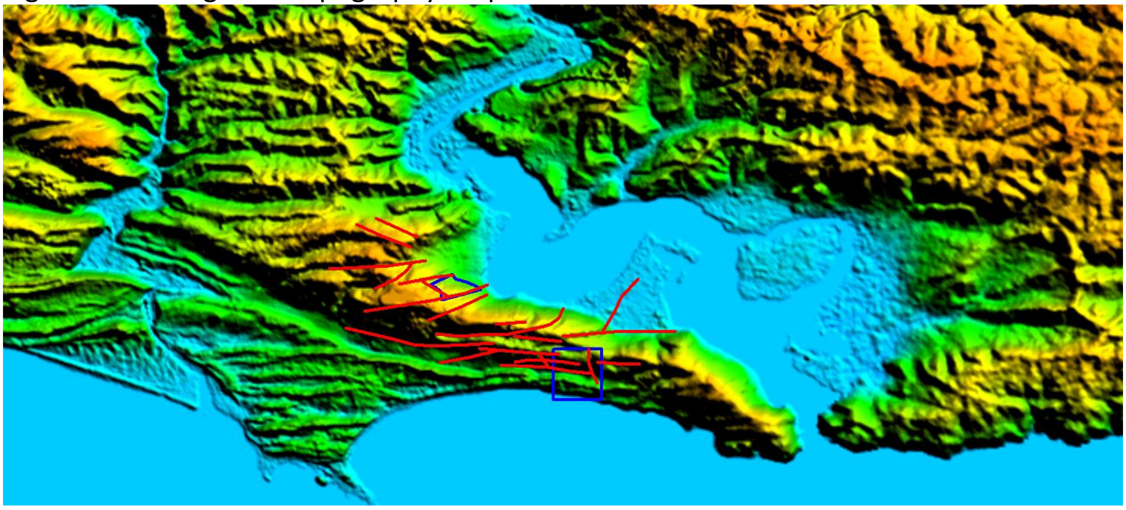


FIGURE 5A: 3D - Regional Topographical Maps

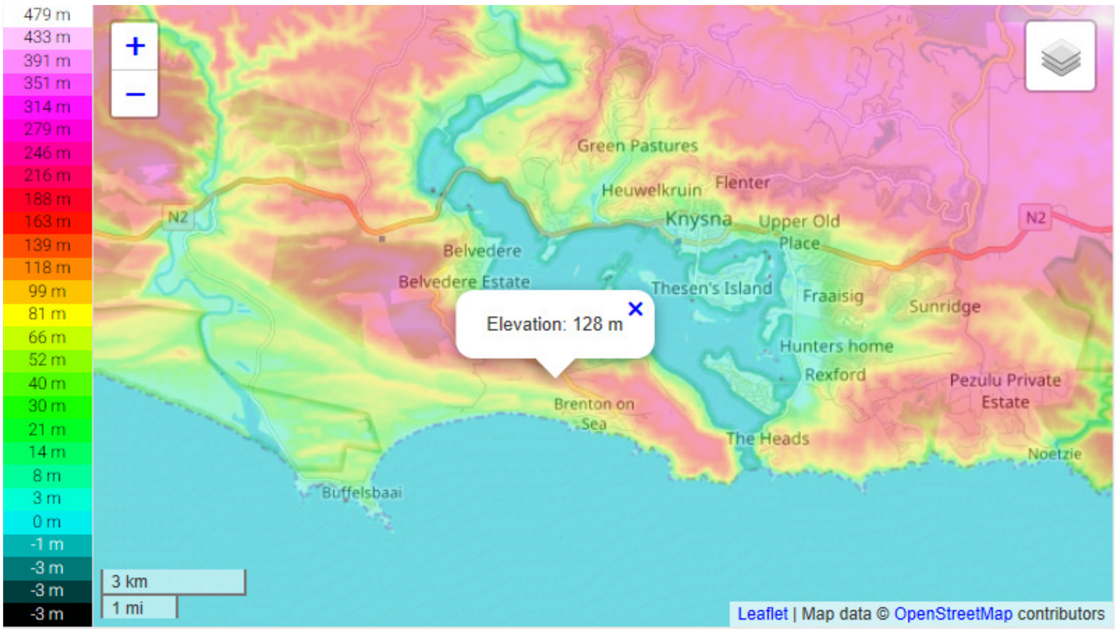


FIGURE 5B: 2D - Regional Topographical Maps

6.4 REGIONAL GEOLOGY

The 3322 Oudtshoorn geological series to a scale of 1:250 000 indicates that the site is underlain by thick aeolian (wind-blown) sand deposits but the sands on the northern site are slightly older and contain more fine grained particles (silt/clay). These deposits are generally termed "Coversands" or inland dune cordons and probably date to the Tertiary period. The dunes along the southern coastal section consist almost entirely of sand-sized particles and are younger deposits, dating to the Quaternary period.

The coastal dunes are known to have significant internal lithification in places, with the formation of soft aeolianite rock (dune rock), which is exposed along the shoreline below the sites. The aeolian deposits are tens of meters thick and underlain by quartzitic sandstone of the Peninsula Formation. The dunes are generally stable in their natural state. There are no geological faults near the site and the seismic risk is generally low. There has been no mining activity on or below the site. The geology is considered highly suitable for urban development, according to the geotechnical report completed by Outeniqua Geotechnical Services for adjacent portions of the investigation area. Refer to excerpt form 3322 Oudtshoorn Geological series below.

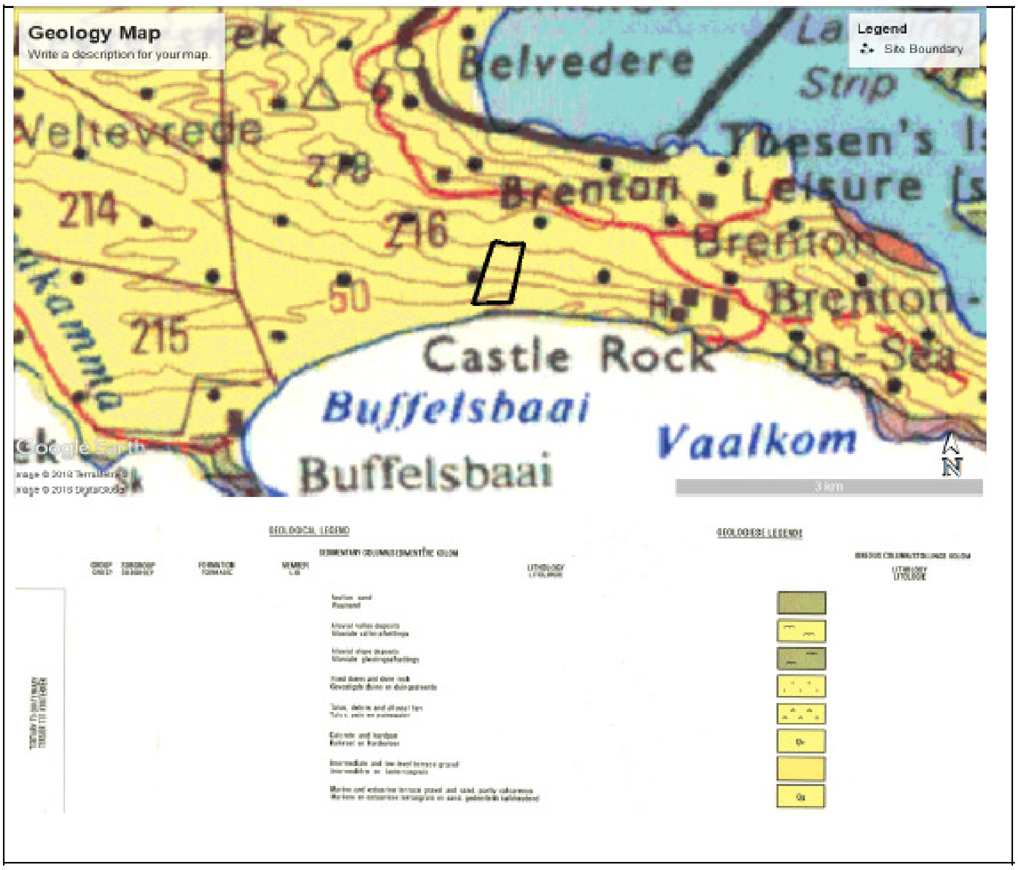


FIGURE 6: Regional Geology Map

6.5 SITE SOILS AND LOCAL GEOLOGY

Experience in the vicinity of the investigation area proposes that the site generally consists of a dark brown silty sand topsoil with abundant rootlets (max 800mm thick), underlain by light brown cohesionless sand. The sands are generally loose to medium dense, cohesionless and potentially compressible. The soils are generally dense to very dense, but some soils may have a slight collapse potential due to weak cementation, as there is some sporadic development of pedogenic calcrete and even hardpan, mainly on the higher-lying areas, and shallow refusals were recorded on these hardpan layers. The soil moisture is generally dry at surface and becoming slightly moist to moist with increasing depth. This is however a desktop observation and does not replace in-situ testing and geotechnical investigation.

6.6 HYDROGEOLOGICAL ASPECTS – GENERAL OVERVIEW

Groundwater flow in the study area is expected to be southerly to south-easterly as per the surface topography. According to the regional 1:500 000 scale groundwater map of Port Elizabeth (3324), produced by the Department of Water Affairs, the project area does host an intergranular aquifer with an average borehole yield of 0.1 ℓ/s to 0.5 ℓ/s.

The regional groundwater vulnerability is classified as having a "low to medium" vulnerability to surface based contamination.

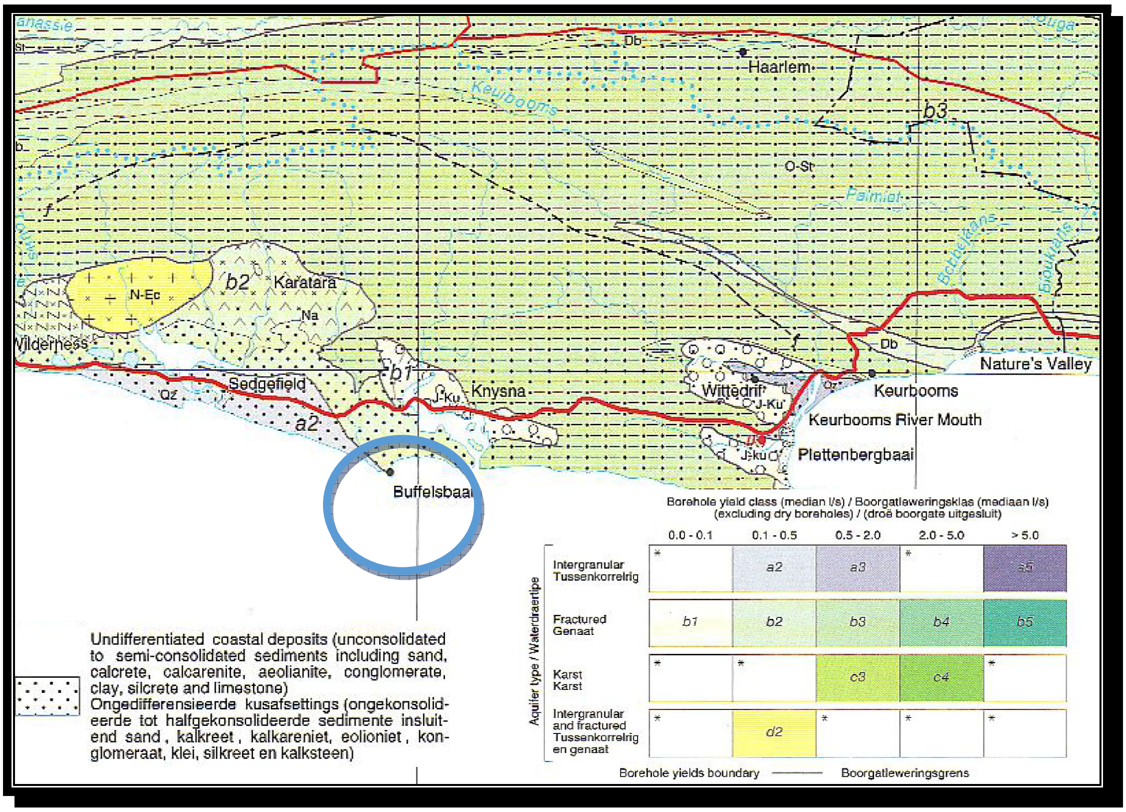


FIGURE 7: Excerpt from 3324 Port Elizabeth hydrogeological series (from DWS)

However, a dual aquifer is expected where top would be a primary intergranular aquifer as per the geohydrological series, however a secondary deeper fractured rock aquifer is expected below the intergranular aquifer.

The primary aquifer comprises the coastal dune, thick aeolian (wind-blown) sand deposits, and contain more fine grained particles (silt/clay) and the inland dune cordons consist almost entirely of sand-sized particles and are younger deposits. The coastal dunes are known to have significant internal lithification in places, with the formation of soft aeolianite rock (dune rock), which is exposed along the shoreline below the site.
The sand, where saturated, forms an aquifer which has primary permeability as the water is held in the pore spaces between the individual sand grains. Typical permeability values for the fine grained sand are 1- 3 m/day while the storage capacity is in the order of 20% (i.e. 200ℓ of water is stored per cubic meter of saturated sand).

The aquifer is recharged mainly by rainfall. Studies in the area, in similar hydrogeological environments (Wilderness & Sedgefield), calculated that between 20 & 30% of annual rainfall recharges the aquifer. There is no defined stream flow due to the porous nature of the sands, but the topography proposes groundwater migration towards the south & south-east as proposed by the geohydrological series. The remainder of the rainfall is utilized by evapo-transpiration.

The aquifer is extensive and pinches out against "impermeable" boundaries in the west whilst the southern boundary is defined by the sandstone exposed along the coastline. The thickness of the younger formation is approximately 60-80m.

The aeolian deposits are and underlain by older Quartzitic Sandstone formations of the Peninsula (Op) Formations of the Tafelberg Sub-Group is generally regarded as a high yielding porous formation, especially if associated with secondary fracturing. The aquifer is recharged directly principally from rainfall. The average annual temperature is 18°C, annual precipitation averages 881.94 mm and an average evaporation of 1400mm, the area is also characterised by dry warm summer months (October to April) and wetter cool winter months (from May to September) with an all-year rain season. The expected net groundwater recharge through unconfined sections of primary aquifer to the deeper secondary aquifer varies between 5% and 15% of the annual precipitation.

6.6.1 EXISTING BOREHOLE SOURCES – DESKTOP RESULTS

Existing database records scoured including the Department of Water Affairs' NGA (National Groundwater Archive) to identify existing boreholes, wellpoints, springs and other water sources yielded ***only 16 records of wellpoint, spring & boreholes*** within the K50B quaternary catchment. The average borehole depth is 43.64mbgl, the average water level is 23.35mbgl and the average yield is 1.83 l/s. See Figure 8 and

Table 1 below for details.

TABLE 1: Data Search Results – Existing Boreholes

Source Name / Number	Latitude S (CAPE)	Longitude E	ALTITUDE	DRAINAGE_R	Type & Equipment	Source Details			Water Quality		
						Borehole Depth (m)	Water Level (mbgl)	Yield (l/s)	Field EC	Field Ph	TDS
3423AA00004	-34.08124	23.05505	100	K50B	Borehole	29.87		0.280 l/s			
GZ00083	-34.06799	22.99677	27	K50B	Borehole	38	16	5.000 l/s	149.9	6.64	
GZ00107	-34.06399	23.08246	30	K50B	Borehole						
GZ00112	-34.06252	23.0298	60	K50B	Borehole	6.5	37.54		1940	6.04	
GZ00113	-34.06217	23.02747	50	K50B	Borehole						
GZ00108	-34.04778	22.99694	32	K50B	Borehole	62.5	31.59	2.500 l/s	117.6	6.49	
GZ00106	-34.04664	23.10128	100	K50B	Spring				68.3	5.86	
GZ00111	-34.04611	22.99611	23	K50B	Borehole	56	25.94	2.500 l/s	131.2	6.34	
GZ00109	-34.04611	22.99778	22.3	K50B	Borehole	63.05	21.19	1.700 l/s			
GZ00110	-34.04472	22.99778	20.9	K50B	Borehole	44.5	20.51	0.500 l/s			
3423AA00002	-34.04263	23.04393	20	K50B	Borehole	31.36					
GZ00084	-34.04189	23.00085	10	K50B	Well Point						
3423AA00001	-34.03624	23.06338	40	K50B	Borehole	60.96	10.67	0.330 l/s			
GZ00131	-34.01889	22.9864	25	K50B	Borehole						
GZ00132	-34.01889	22.98694	18	K50B	Borehole						
GZ00130	-34.01639	22.99028	14	K50B	Borehole				115.2	6.03	
					Average	**43.64**	**23.35**	**1.83 l/s**	**420.37**	**6.23**	**#DIV/0!**

FIGURE 8: Data Search Results of existing boreholes identified within quaternary catchment K50B.

6.6.2 HYDROCHEMICAL TRENDS OF GROUNDWATER

The lack of existing water quality data for groundwater sources limits the hydrochemical model of the area, however we highlight the following based on limited information:

- The groundwater quality within the main part of the aquifer generally has a low salinity yet a relatively high hardness. Due to the depositional history of the aquifer, zones of saline water may occur at different stratigraphic levels. For the study area the regional groundwater quality, indicated by Electrical Conductivity is in the range of 100 mS/m to 2000 mS/m or an average of 420mS/m (DWAF, 2000). Ph values averages around 6.23.
- The regional groundwater vulnerability is classified as having a "low to medium" vulnerability to surface based contamination.

6.6.3 RESOURCE CLASSIFICATION & RESERVE DETERMINATION

The quaternary catchment within which the study area falls (K50B), comprises 202.99 km^2 with an estimated mean annual precipitation of 881.94 mm/annum, an estimated baseflow of 63.54 Mm^3/annum and a recharge of 6.9% of MAP. The study area seems to be relatively unstressed in terms of groundwater abstraction according to South African Reserve Determination classification system. The current use is estimated to be very low (0.14 Mm^3/annum based on current records, but not confirmed by a detailed hydrocensus resulting in the ***total allowable groundwater abstraction of 0.8988 million m3/annum for the entire catchment*** based on the simple formula = Recharge - (Baseflow + Current Abstraction).
Groundwater allocation calculations are given in Table 2 below

TABLE 2: Reserve Determination – Groundwater Allocation

Current Use (Mm³/a)	0.1419
Baseflow (Mm³/a)	63.54
Aquifer Yield (Mm³/a)	1.0407
Allocable [OLD] (Mm³/a)	-51.3359
Allocable [NEW] (Mm³/a)	0.8988
Reserve (%Recharge)	514.6606
Physical	
Groundwater	
Level (mbgl)	35.7
Dead Storage (m)	5
Existing Use (l/s)	4.5
Firm Yield (l/s)	33
Firm Yield (l/s/km²)	0.1627
Specific Yield	Default
Recharge	Default
Default (%)	6.9
GRA2 (%)	6.9
Calculated (%)	0
Threshold	Threshold
Threshold (mm)	73
Hydrology	
MAP (mm/a)	881.9
MAR (mm/a)	238.9
MAE (mm/a)	1400
Baseflow/EWR	Default
Default (Mm³/a)	63.54
Hughes (Mm³/a)	130.02
Pitman (Mm³/a)	63.54
Schultz (Mm³/a)	73
VTonder (Mm³/a)	77.77
Calculate (Mm³/a)	0
No Flow (%)	0
Evapotranspiration	Constant

6.6.4 AQUIFER CHARACTERISTICS– CONCEPTUAL MODEL

The proposed conceptual model based on available information comprises:

- A layer of thick aeolian (wind-blown) sand deposits with more fine grained particles (silt/clay), significant internal lithification in places, which forms an aquifer which has primary permeability as the water is held in the pore spaces between the individual sand grains, when saturated. Typical permeability values for the fine grained sand are 1- 3 m/day while the storage capacity is in the order of 20% (i.e. 200ℓ of water is stored per cubic meter of saturated sand).
- The next tens of meters will be slightly to moderately weathered fractured bedrock, which consists of older Quartzitic Sandstone formations of the Peninsula (Op) Formations of the Tafelberg Sub-Group is generally regarded as a high yielding porous formation, especially if associated with secondary fracturing. The aquifer is recharged directly principally from rainfall. The permanent groundwater level resides in this unit and is about 40-60mbgl.
- Below a few tens of meters the fracturing of the aquifer is less frequent and the fractures less open due to increased pressure. This results in an aquifer of low hydraulic conductivity and very slow groundwater flow velocities.

Fracturing of the bedrock could consist of both major fault structures and/or minor pressure-relieve joints. Groundwater, originating from the vertical infiltration of rainwater through the upper layers (s) up to groundwater level, will flow mostly horizontally in the directions as discussed above. Water flow volumes and velocities will, on average, decrease gradually with depth.

6.6.5 REMOTE SENSING – IDENTIFICATION OF GEOLOGICAL FEATURES

The desktop study entailed the use of geological maps for the area as well as aerial photographic interpretation, Landsat, ASTER, Sentinel fusion for the specific area under investigation. Refer to Figures 9 & 10 on the following page.

Possible lineaments, geological structures intersecting the designated area were identified and targeted for subsequent field investigation, using geophysical methods. These features form the primary drilling targets as groundwater movement is perceived to be concentrated along these features, especially in a secondary (fracture rock) aquifer scenario as found below the dune cover sands in the study area.

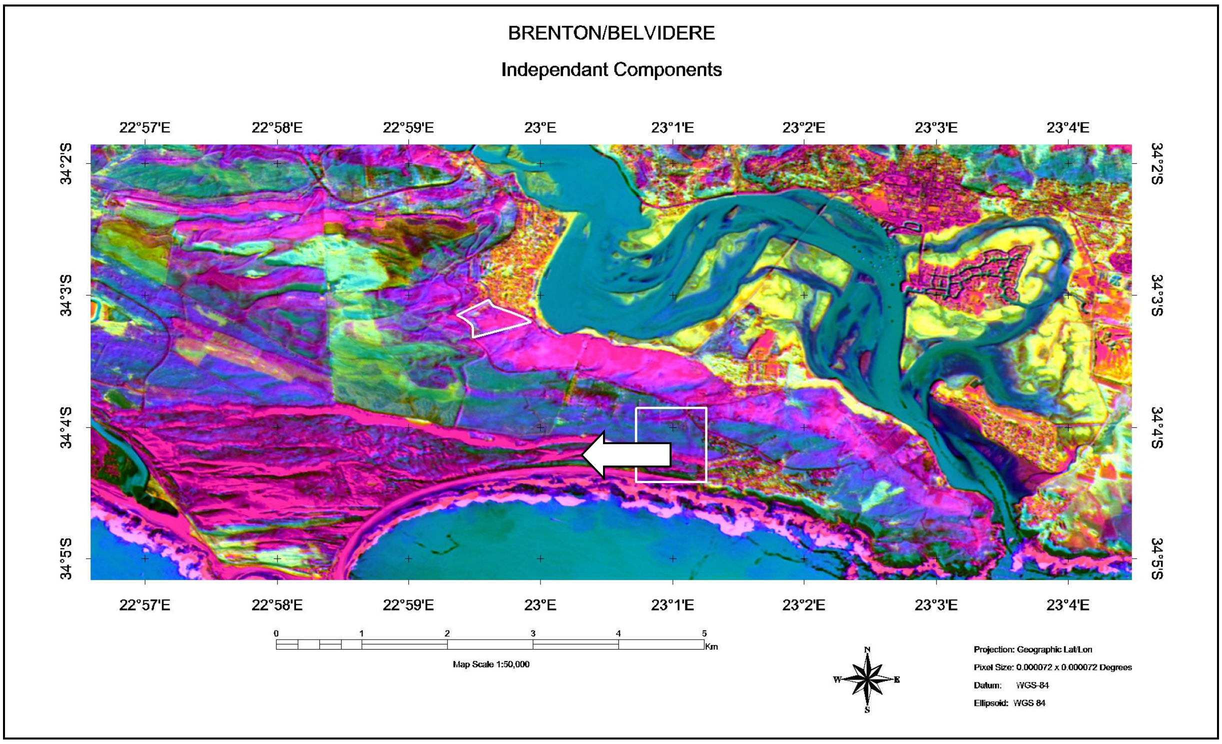


FIGURE 9: Independent Components Image

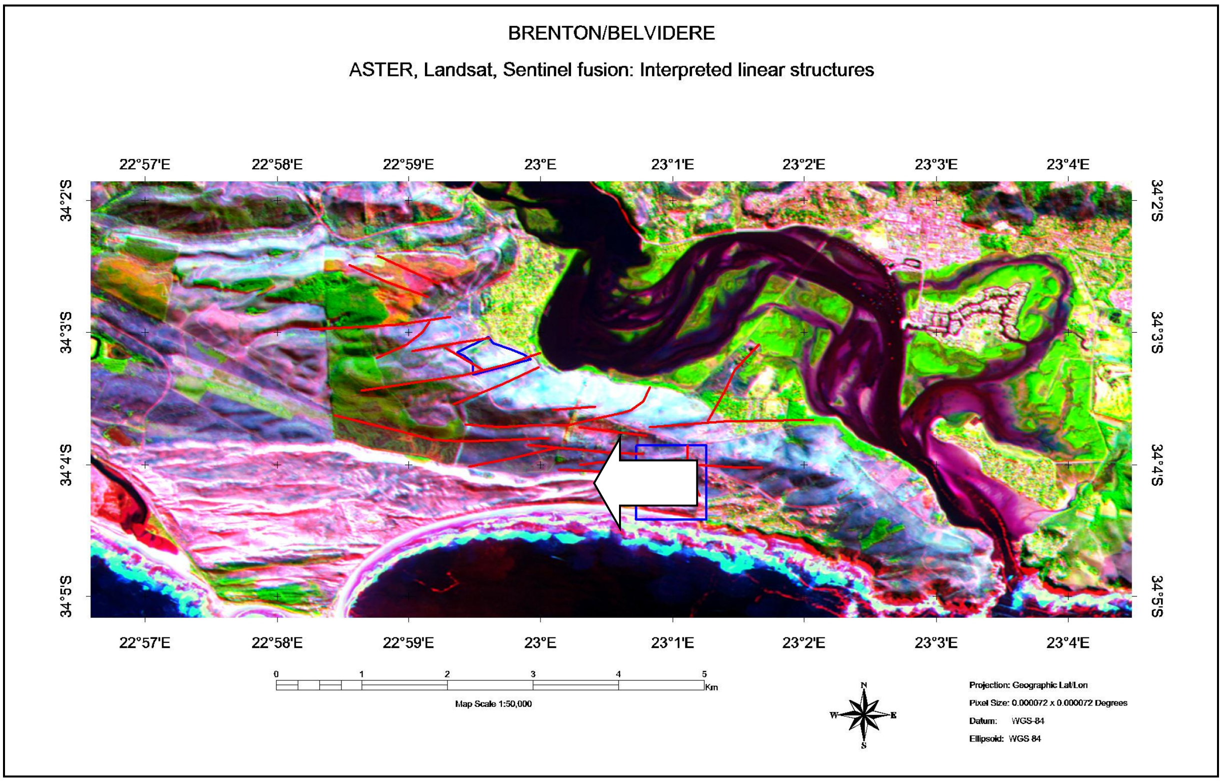


FIGURE 10: Landsat, ASTER, Sentinel fusion: Interpreted linear structures

From the results of the remote sensing it is perceived that the sandy dunes are aligned along the quartzitic sandstone bedrock that underlies the sands. This is quite evident from the images below. These possible lineaments appear to be mainly E-W in direction and one N-S lineament on the eastern side of the site (Refer to Figures 11 & 12. For this reason, the main focus of the geophysical investigation should be focused on intersecting these structures at a perpendicular angle.

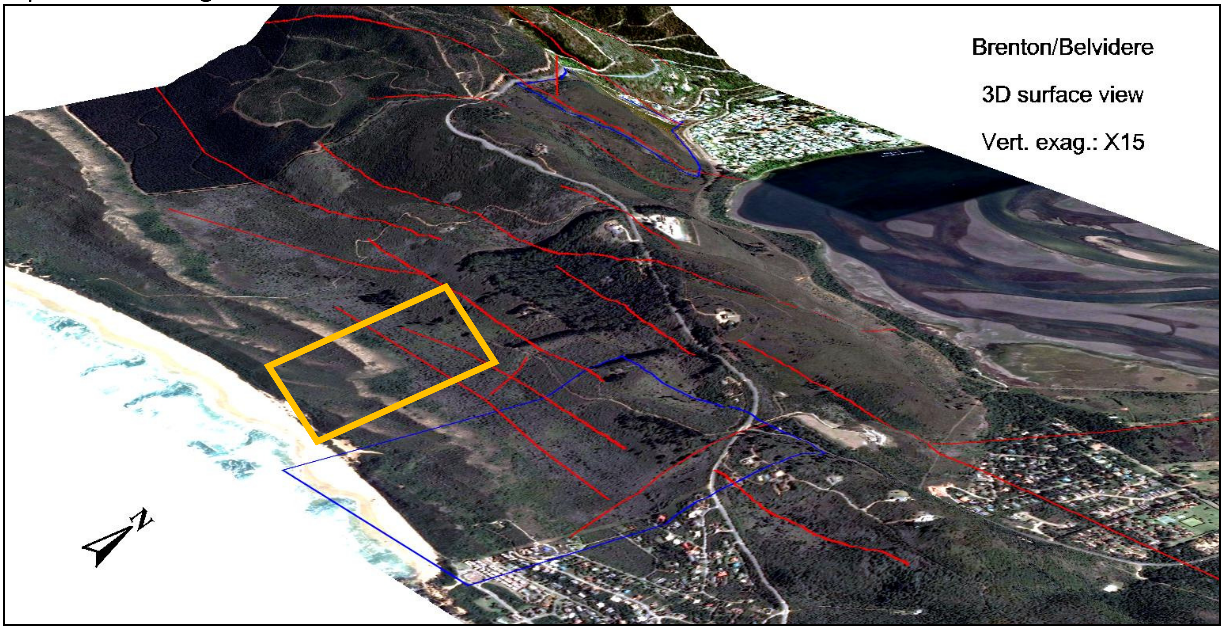


FIGURE 11: 3D Surface view with interpreted structures

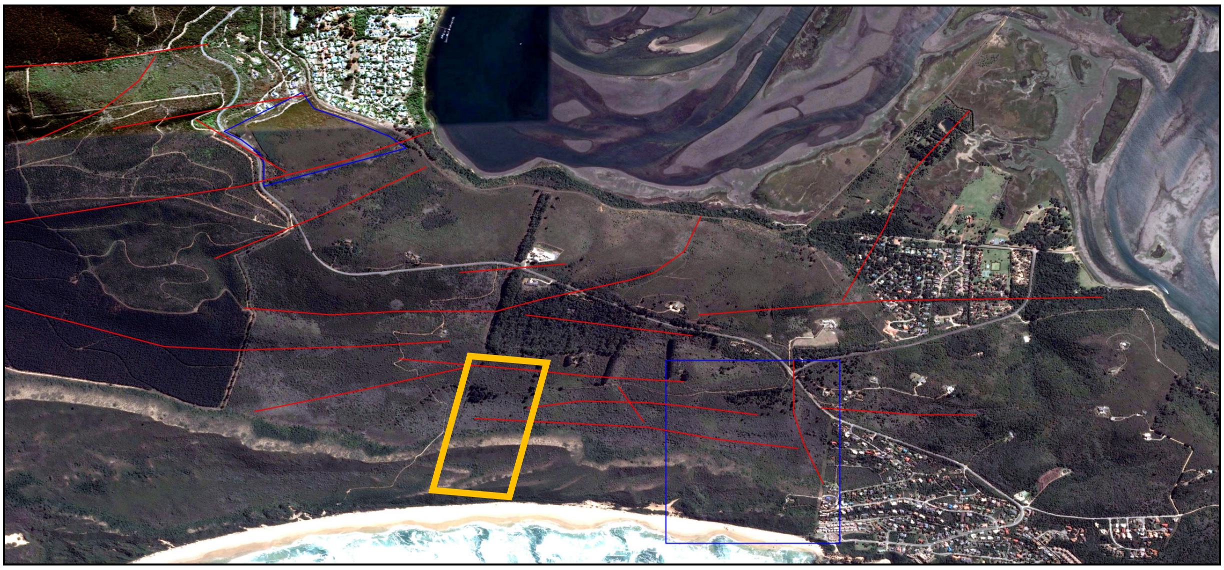


FIGURE 12: 2D view with interpreted structures

FIELD INVESTIGATION RESULTS

To confirm the proposed geohydrological model of the area, the existing groundwater resources found on site were verified and recorded using a handheld Global Positioning System (GPS). The methods used and results obtained are discussed in more detail below.

6.7 HYDROCENSUS RESULTS

The desktop search for existing groundwater sources confirmed the lack of boreholes in the immediate vicinity of the project area and more specifically the site boundary and ***yielded similar results to the data search.***

One (1) existing borehole was found on Erf 198 and one borehole was reported by the consulting engineer (Tuiniqua) at 242 CR Swart Road in the nearby village of Brenton-on-Sea. Two (2) production boreholes were developed recently on portions 71 & 72 of Uitzicht 216. The details are indicated in Table 3 below. The existing borehole individual "successful" well points are indicated in PHOTO 2 below.

TABLE 3: Hydrocensus Field Results – Existing Boreholes Verified

Source Name / Number	Latitude S	Longitude E	ALTITUDE	DRAINAGE REGION	Type & Equipment	Source Details			Water Quality		
	(CAPE)					Borehole Depth (m)	Water Level (mbgl)	Yield (l/s)	Field EC	Field Ph	T
BRENTON BH 1	34° 04' 08.97"S	23° 01' 06.94"E	64	K50B	None	127.6	50.10 mbgl	1.12	97.2	7.59	
BRENTON BH 2	34° 04' 11.66"S	23° 01' 07.04"E	52	K50B	none	80	50.32 mbgl	0.76	144.2	8.42	
Erf 198	34.069660	23.020404	50	K50B	Borehole	??	??	??	??	??	
242 CR Swart Drive	?	?	38	K50B	Borehole	51	??	1.2	??	??	

Photo 2 indicates existing borehole found on Erf 198 of Brenton-on-Sea.

Plate 2 – Completed boreholes with lockable cap and concrete collar on Ptn 71 & 72.

6.8 GEOPHYSICAL INVESTIGATION RESULTS

The remote sensing portion of the investigation was carried out to identify possible intrusions, fault zones or deeply weathered zones usually associated with groundwater occurrence in weathered and fractured bedrock, a geophysical survey was conducted in an east to westerly direction as well as north to south on selected areas of the site guided by the results of the remote sensing investigation. The geophysical survey's traverse lines are indicated on Figure 13, the Site Map.

In order to determine deeper seated structures in the bedrock formations, we proposed a geophysical investigation using the both the Magnetic and the Resistivity method. In this instance, the PQWT (300) instrument with intelligent cable and a 5m electrode spacing was employed.

Magnetic Method

This method measures the total field component of the earth's magnetic field. A G5 Proton Magnetometer was used. The different magnetic susceptibilities of the various rock types result in contrasting magnetic signatures. Magnetic data may be interpreted to represent dykes, geological contacts and faults, which may have a bearing on the occurrence, storage and movement of the groundwater. The absence of magnetic rock types (dolerite dykes and sills) in the project area deems this technique less effective.
A default station interval of 5m is adapted in order to delineate possible geological structures.

Electromagnetic Method

The apparent conductivity of the underlying geology can be measured using a Geonics EM 34-3, a horizontal loop frequency domain electromagnetic instrument. This property is proportional to the amount of weathering encountered in the underlying geology. Anomalies indicate lateral changes in the conductivity and facilitate the detection of conductor type targets. The 20 and 40m spacing were employed to investigate various depths. For resistive terrains (low conductivities), the vertical depth of exploration over homogeneous or horizontally stratified earth for coil separation of 20 and 40m are 30 and 60m (horizontal coils) and 15 and 30m (vertical coils) respectively. The lateral extent of the volume of the earth, which is sensed, approximates the vertical depth and small changes in conductivity (5 to 10mS/m) are readily and accurately measured.

Resistivity Method

Ground resistivity is related to various geological parameters, such as fluid and mineral content, porosity and water saturation. The resistivity measurements are normally made by injecting current into the ground through two electrodes and measuring the resulting voltage difference at two potential electrodes, which in this case was placed 5m apart. From the current and voltage values, an apparent resistivity value is calculated. The calculated resistivity value is not the true resistivity of the subsurface, but an apparent value, which is resistivity of a homogeneous ground which will give the same resistance value from the electrode arrangement. To determine the true resistivity an inversion of the apparent values must be carried out using computer software.

Normally the Wenner array setup with a 5m electrode spacing is used to determine the subsurface resistivity distribution.

AMT Receiver:

The usefulness of this meter for mineral exploration, particularly in groundwater has already been shown.

<u>Measurement point & spacing</u>

At the start of the survey, the tape is laid out and the operator's electrode (M electrode) is on 0m and the other electrode (N electrode) is on 10m. If a spacing of 5m is used, the next reading will have M on 5m and N on 15m. The actual measurement point is in the centre – the first measurement is at 5m and the second measurement is at 10m.

<u>Direction & length of survey line</u>

With confined aquifers (fractures, dykes, faults, karsts, mostly in the older rocks) it is advisable to lay your line perpendicular to the structure. This will make the determination of the contact much easier and whenever possible, do extra lines parallel and spaced 10m to 50m either side for a thorough interpretation. In the case of unconfined aquifers and paleochannels, run your first line along the assumed channel and subsequent lines perpendicular to establish width.

<u>The Process function in the Profile screen</u>

After profile data has been collected (10 readings minimum), the curves can be inverted to a contoured profile.

Normally, geophysical traverses are conducted perpendicular to inferred geological lineaments. However, the limited available space for the investigation required the use of available access roads and open areas as indicated in *Figure 2A – 2 in Appendix A*.

Field Data and Drill Targets:
The resistivity data of each of the potential borehole sites is graphically presented as 2 dimensional diagrams. The proposed drilling positions will be clearly marked in the field for easy identification by the drilling contractor

In total three (3) traverses were conducted and the results indicated that the weathered bedrock and fractured sediments would be encountered at approximately 50m in the lower lying areas and approximately 80m in the higher lying areas.

See also the 2-d graphs of the geophysical traverses (1 to 3) attached as *Appendix A* and summarized in *Table 4* below.

TABLE 4: Geophysical Traverses & Proposed Drilling Positions

Geophysics					
Site	**Traverse**	**Drilling station**	**Peg Name (on Map)**	**Propability**	**Max Drilling Depth**
Portion 76 of Uitzicht 216	Farm 216/76-1	Station 30	Priority 1	Good	150m
		Alternative 150	Alternative @ 150m	Good	150m
	Farm 216/76-2	Station 90	Priority 2	Good	150m
		Alternative 170	Alternative @ 170m	Good	150m
	Farm 216/76-3	Station 60	Priority 3	Good	150m
		Alternative 290	Alternative @ 290m	Good	150m

6.9 PROPOSED NEW BOREHOLE POSITIONS

Promising localized geological structures associated with groundwater movement in the deeper bedrock regions identified by means of remote sensing were confirmed during the geophysical investigation. These included contact zones and geological lineaments as well as and fracturing and weathering of the quartzitic sandstone bedrock.

At least 6 potential drilling positions of good potential have been identified and marked in the field for further investigation by means of exploration drilling. These potential sources of groundwater movement (formed by the fractures associated with secondary / fractured rock aquifers) will be targeted by means of percussion drilling. The proposed drilling positions are indicated on Figure 13 and Plate 3 below.

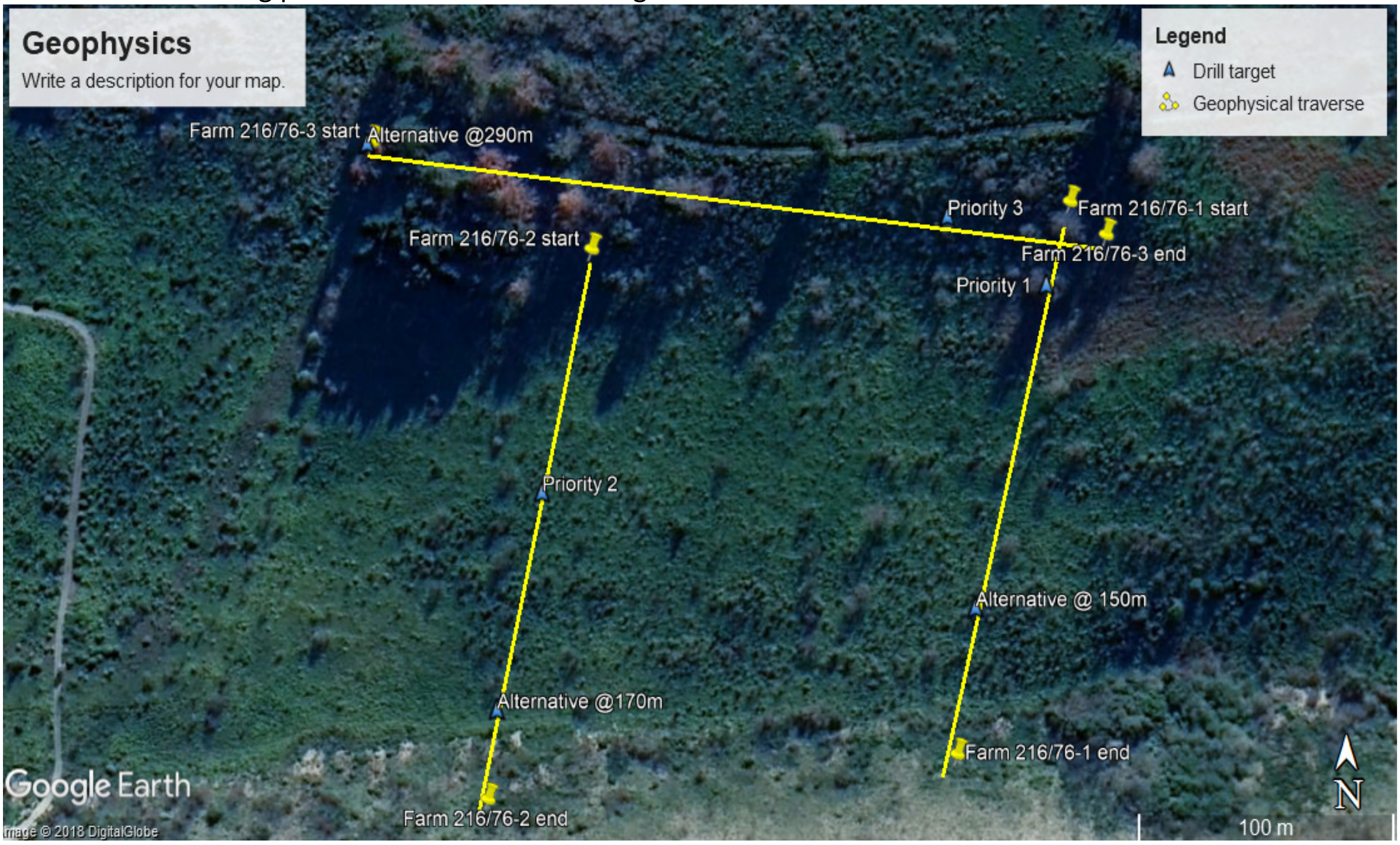


FIGURE 13: Geophysical Traverses & Proposed Drilling Positions

Plate 3: Marked drilling positions

Please note that due to the presence of unconsolidated materials and deposits estimated to be approximately 50-80m thick, the more expensive ODEX or Symmetrix drilling technique may be required.

7. ASSUMPTIONS, LIMITATIONS & ALTERNATIVES

7.1 ASSUMPTIONS

There is often a high degree of spatial variability in groundwater studies, relating to soil conditions, geological setting and geohydrological parameters. It is difficult to glean a lot of geohydrological information without drilling boreholes and sampling. Thus borehole information and associated data (such as drill logs, water levels, and groundwater chemistry) are useful for most geohydrological studies. It is assumed that the geohydrological conditions are relatively consistent between sampling points, unless there is clear evidence to the contrary. A lot of the work is based on averages, i.e. average annual rainfall and average groundwater conditions.

7.2 LIMITATIONS

The limitations pertain to the lack of assumed available investigation area using geophysical instruments. All the sites are nearly entirely fenced and includes many unknown factors including pipe lines, power cables, sewage lines and buildings.
Normally, geophysical traverses are conducted perpendicular to inferred geological lineaments. However, the limited available space for the investigation required the use of available access roads and open areas.

8. CONCLUSIONS

The desktop phase of the hydrogeological study concluded:

- The quaternary catchment K50B is estimated to meet the water demand based on the allocatable groundwater potential. The total allowable groundwater abstraction for the catchment is ***0.89 million m^3/annum*** vs the estimated maximum demand of ***0.00365 million m^3/annum*** as a result of the very low current abstraction of 0.1418 million m^3/annum coupled with a reasonable recharge value leaving a full complement of baseflow of 63.54 million m^3/annum for the effective catchment.
- The site is underlain by thick aeolian (wind-blown) sand deposits but the sands on the northern site are slightly older and contain more fine grained particles (silt/clay).
- The aeolian deposits are tens of meters thick and underlain by quartzitic sandstone of the Peninsula Formation. The aquifer transmissivity within the study area is approximately 5 to 10 m2/d.
- The site generally consists of a dark brown silty sand topsoil with abundant rootlets (max 800mm thick), underlain by light brown cohesionless sand. The sands are generally loose to medium dense, cohesionless and potentially compressible. The fill generally consists of a mixture of sand and rubble with minor rubbish.

- The soils are generally dense to very dense, but some soils may have a slight collapse potential due to weak cementation, as there is some sporadic development of pedogenic calcrete and even hardpan, mainly on the higher-lying areas, and shallow refusals were recorded on these hardpan layers. The soil moisture is generally dry at surface and becoming slightly moist to moist with increasing depth.
- The aquifer is recharged directly principally from rainfall. The permanent groundwater level resides in this unit and is about 3 – 20mbgl.
- Below a few tens of meters the fracturing of the aquifer is less frequent and the fractures less open due to increased pressure. This results in an aquifer of low hydraulic conductivity and very slow groundwater flow velocities.
- The project area does host an intergranular aquifer with an average borehole yield of 0.5 ℓ/s to 2.0 ℓ/s.

The results of the second part of phase 1 of the investigation confirmed initial assumptions and concluded that:

- Numerous smaller geological lineaments were identified through the remote sensing exercise and targeted for geophysical investigation.
- Geophysical investigations of these identified geological structures concluded ***at least 6 potential drilling positions*** with good potential on the site.
- Based on the average expected borehole yield (which is to be determined through drilling), the proposed number of boreholes required to meet the water demand (approximately 10kl/day) was calculated as ***minimum 1, but possibly 2 boreholes.***

9. RECOMMENDATIONS

The conclusions made by this initial study confirmed initial assumptions and we therefore recommend the following:

- ➢ The prioritized borehole positions proposed should be drilled according to their priority rating at the locations indicated.
- ➢ Geological conditions that can be expected include unconsolidated sediments or loose, decomposed clayey sand of up to 15m that may require specialized drilling techniques i.e. ODEX or Symmetrix type drilling. This loose section should be followed by highly to slightly weathered meta sediments including alternating layers of shale, siltstone and medium to fine grained impure sandstone (greywacke). The transition between the sands and the Peninsula rocks is characterised by a clay layer which is the product of weathering of the shale. The degree and depth of weathering can change over relatively short distances.
- ➢ The formation is expected to be stable following the previous two horizons.
- ➢ Normal percussion drilling techniques should be followed initially and only if the formation becomes too unstable to successfully install the casings can the more costly ODEX or Symmetrix route be explored.

- The expected maximum drilling depth is 150m, but may vary from approximately 60 – 100m in general.
- The installation of mild steel casing may require uPVC casing installation to the bottom of the borehole (post completion) with a lockable steel cap. In our opinion the mild steel casing past the weathered zone may not be sufficient.

Drilling Methods

Considering the sensitive nature of the proposed drilling positions as well as the regional geology, the standard rotary air flush percussion drilling method is suspected to be unsuitable, especially during the initial drilling process. The presence of approximately 50-80m of unconsolidated sandy and clayey material could require the use of the more expensive drilling technique namely ODEX or Symmetrix methods. The objective of drilling is to establish a borehole in the identified area that will be sustainable in the long-term. A secondary objective is to construct a borehole without disturbing the upper sandy aquifer, especially in light of the fact that rehabilitation of this portion of the aquifer is being conducted in the nearby vicinity.

<u>ODEX Drilling System</u>

This method is used for drilling loose or unconsolidated ground. This technology will enable the user to tackle jobs that would be difficult or even impossible using traditional drilling methods. Drilling through loose overburden is often problematic, due to the tendency of the earth to cave in behind the drill bit. This makes it difficult to retrieve the drill string and insert casing, after the hole has been drilled.

The system has a symmetrical drill bit system, which advances a casing pipe simultaneously when drilling the hole

ODEX can:

1. Drill straight holes at any angle (including horizontal), in any type of ground condition, and to depths beyond 100 meters.
2. Drill holes from 3 inches (76 mm) up to 48 inches (1,220 mm) in diameter.

Components:

1. A pilot bit, with large internal flushing holes and external flushing grooves
2. Symmetrical Ring Bit (reamer) with internal bayonet coupling
3. Casing shoe for driving of the casing
4. The Pilot Bit is attached to any common DTH hammer shank or top hammer rod thread.

Method

The casing shoe is welded to the casing. The pilot bit and ring bit are locked together by the bayonet coupling. Together they drill a hole large enough to allow the casing to be pulled into the hole. The pilot bit and ring bit rotate with the drill string while the casing shoe and casing do not rotate. After completing the hole, the pilot bit is unlocked by a slight reverse rotation of the drill string. The drill string and pilot bit are then retrieved through the casing. A simplified schematic drawing is indicated below.

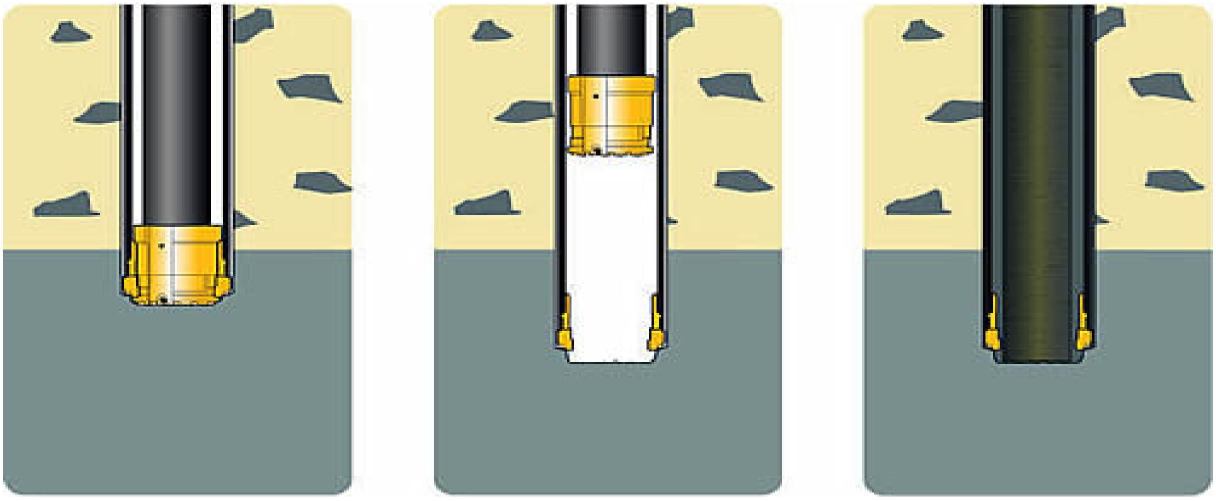


Plate 2 – Indicates the setup of the ODEX drilling technique equipment.

Borehole Construction

The drilling is to be carried out according to the *Development, Maintenance and Management of Groundwater Sources – SA Code of Practice Ref SABS 0299 1,2 &3 – Design and Construction of Groundwater Boreholes & Drilling of Groundwater Boreholes.* The following details are highlighted:-

Borehole diameter:	Symmetrix or ODEX air flush percussion drilling is to be done using the following procedure:- Drilling is as described previously using a 194mm

	diameter hammer until the more stable rock formation has been penetrated for at least 3m, followed by the installation of 4mm thick 165mm diameter solid mild steel casing, piloting the 165mm diameter borehole to the final depth. Finally 140mm solid and perforated uPVC casings are installed to the final depth.
Borehole Development:	This is done by flushing drill fluids, fines and debris from the borehole on completion of drilling. The method used is that of plunging and surging - using compressed air, flushing the debris from the borehole. On completion, a blow yield can be determined, which gives an indication of the potential yield of the borehole.
Borehole Protection	The borehole is capped with a lockable mild steel cap over the protruding 165mm casing.
Formation sampling	During the drilling process, a lithological sample for each meter drilled, was taken by the drilling contractor and placed on a cleared patch for the geohydrological consultant to inspect and describe and to discuss and eventually decide the depth of casing installation.
Water strike depth	The depth of each water strike is recorded by the drilling contractor, inclusive of seepage. Several water strikes may occur in one borehole and it is therefore important to determine the blow yield of each individual strike. This information is used when the borehole is tested and is vital for equipping of the borehole.
Blow Yield	On completion of drilling, the final blow yield of each borehole is measured and recorded.

10. REFERENCES

As part of the desktop investigation, the following geological and hydrogeological data sources were consulted:-

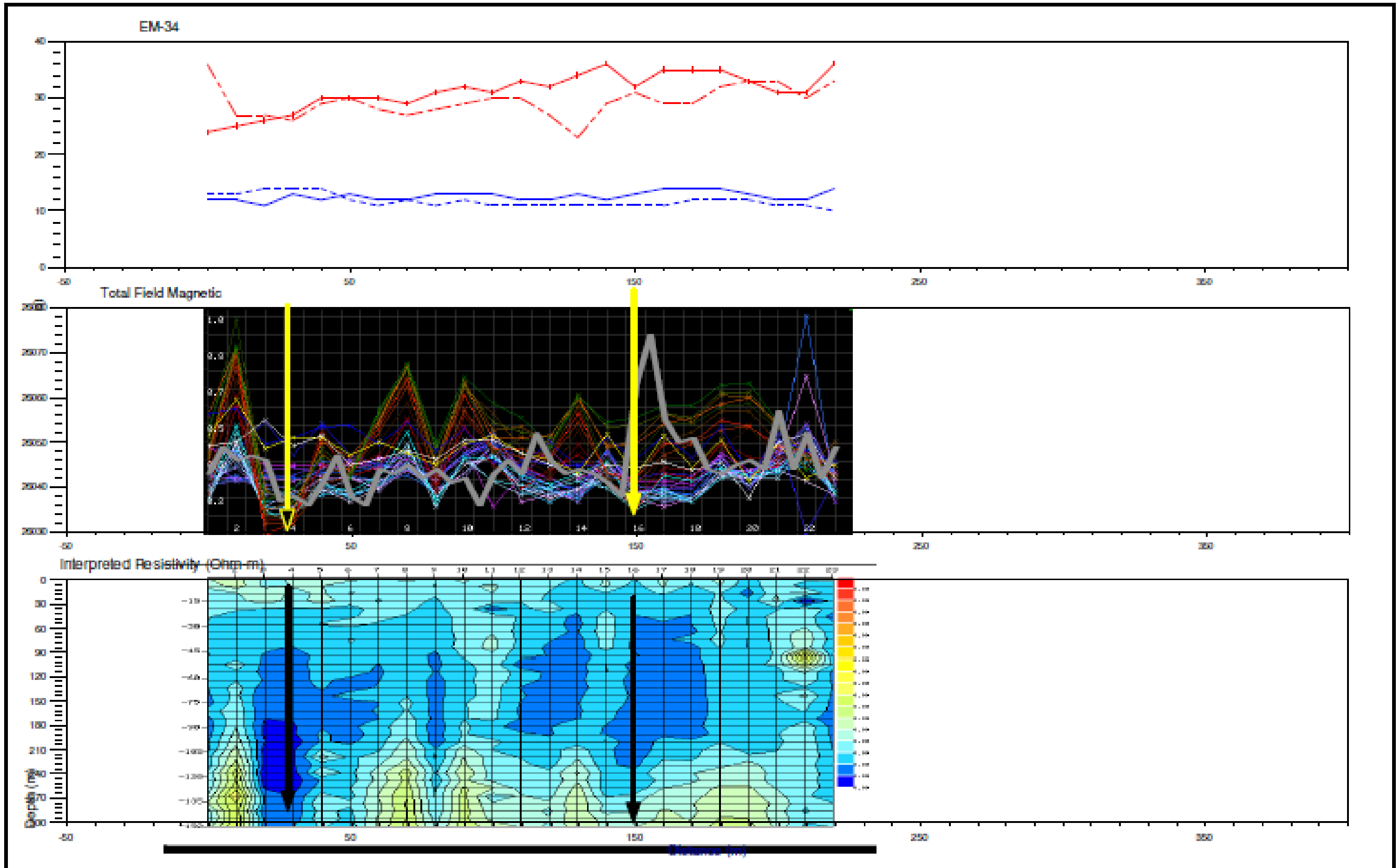
- Geological Map Sheet 3322 Oudtshoorn Town to a scale of 1:250 000, Government Printer, 1990
- Topographical map sheet 3423AA in digital format to a scale of 1:50000
- Aerial photographs in digital format, Google Earth 2017.
- National Groundwater Archive (NGA) data set obtained from the Department of Water Affairs (DWA).
- DWAF (2000). 1:500 000 Hydrogeological Map Series, 3324 Port Elizabeth
- DWAF. (1998). The South African National Water Act (36 of 1998). DWAF.
- Van Wyk, E. (2011). Characteristics of Local Groundwater Recharge in South African Semi-Arid Hard Rock Terrains - Rain Water Input. Water SA, 50-62.
- Marike Vreken Urban & Environmental Planners, received from client. OCTOBER 2018
- Outeniqua Geotechnical Services, GEOTECHNICAL REPORT PROPOSED NEW RESIDENTIAL DEVELOPMENT ON PORTIONS 71 & 72 OF FARM UITZICHT 216, KNYSNA, 17 February 2017
- Du Preez, (2018) LL3085 BRENTON-ON-SEA, PORTION 71 & 72 OF THE FARM UITZICHT NR 216, KNYSNA, WATER SUPPLY INVESTIGATION – INVESTIGATION & FEASIBILITY ASSESSMENT INTO GROUNDWATER ABSTRACTION

APPENDIX A

Geophysical Investigation Results – Traverses

FARM 216/76 TRAVERSE-1 RESULTS

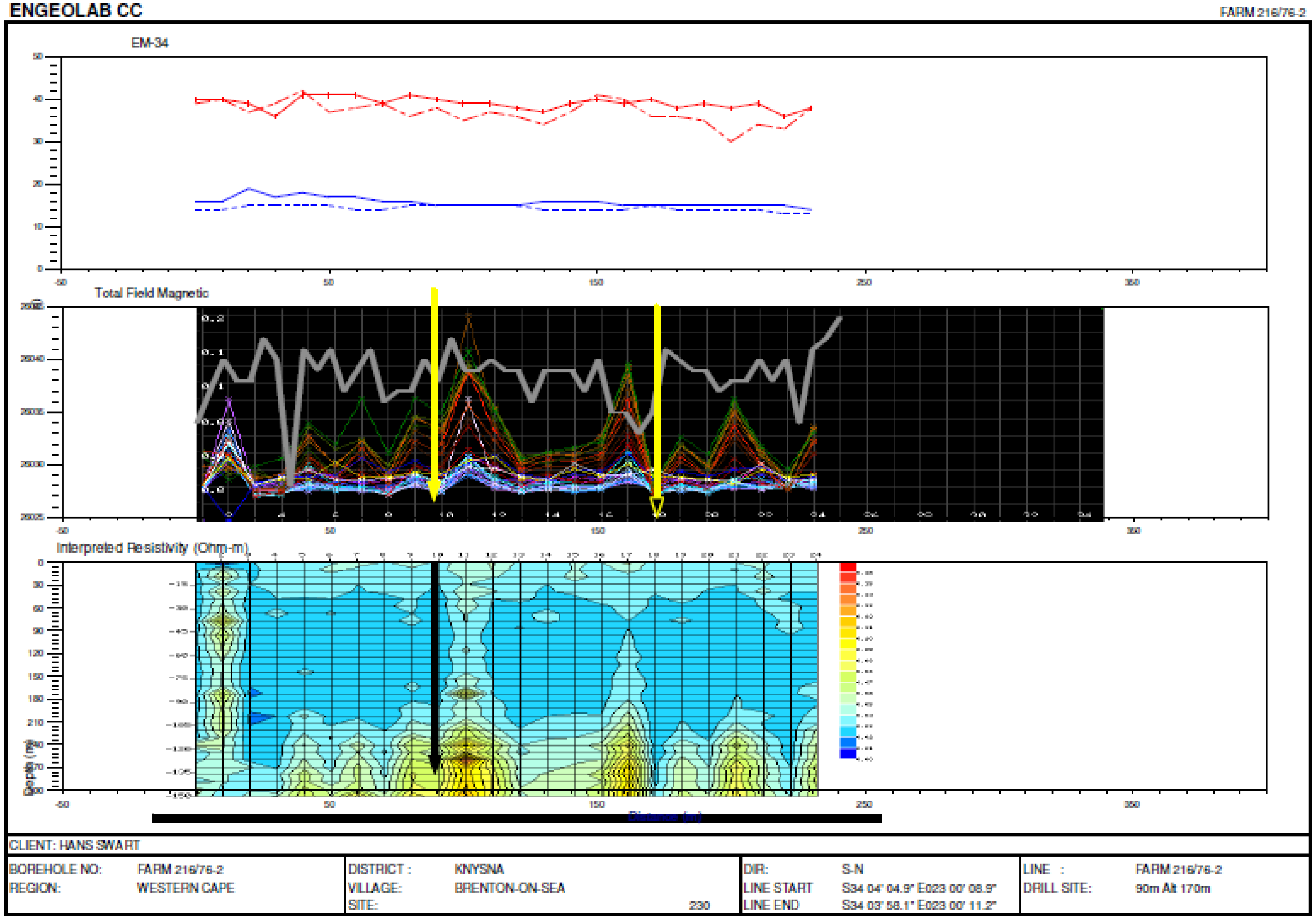
ENGEOLAB CC FARM 216/76-1



CLIENT: HANS SWART

BOREHOLE NO:	FARM 216/76-1	DISTRICT :	KNYSNA	DIR:	N-S	LINE :	FARM 216/76-1
REGION:	WESTERN CAPE	VILLAGE:	BRENTON-ON-SEA	LINE START	S34 03' 57.9" E023 00' 17.8"	DRILL SITE:	30m; Alt 150m
		SITE:	220	LINE END	S34 04' 04.4" E023 00' 15.8"		

FARM 216/76 TRAVERSE-2 RESULTS



FARM 216/76 TRAVERSE-3 RESULTS