Geohydrological assessment and groundwater development at Atlantic Beach Estate, Melkbosstrand

REPORT: GEOSS Report No: 2017/08-34 ***PREPARED FOR:*** Harry White Chief Executive Officer Atlantic Beach Homeowners Association NPC Atlantic Beach Estate Melkbosstrand Cape Town 7441	***PREPARED BY:*** Corné Engelbrecht GEOSS - Geohydrological and Spatial Solutions International (Pty) Ltd Unit 12, Technostell Building, 9 Quantum Street, TechnoPark Stellenbosch 7600 Tel: (021) 880-1079 Email: info@geoss.co.za (www.geoss.co.za)

GEOHYDROLOGICAL AND SPATIAL SOLUTIONS INTERNATIONAL (PTY) LTD
GEOSS

05 September 2017

EXECUTIVE SUMMARY

Mr Harry White (Atlantic Beach Homeowners Association – CEO) approached GEOSS – Geohydrological & Spatial Solutions International (Pty) Ltd to conduct a geohydrological assessment and borehole siting at Atlantic Beach Estate near Melkbosstrand.

The geology underlying the site comprises of unconsolidated white sand with comminuted shell pebbles and shells of the Witzand formation (Qw) overlying the Tygerberg formation (Nt) basement rocks (Malmesbury Group) which consists of greywacke, phyllite and quartzitic sandstone. There are no major geological faults mapped in the study area. According to the 1:500 000 scale groundwater map of Cape Town (3317) the northern portion of the estate is underlain by a intergranular aquifer with a yield potential of 0.5 to 2.0 L/s and the southern portion in underlain by a fractured aquifer with a yield potential of 0.5 to 2.0 L/s. The groundwater quality in the area is classified as "poor" (having an electrical conductivity between 300 and 1 000 mS/m (DWAF, 1998)) in terms of domestic supply.

In order to evaluate the sustainable volume of groundwater that can be abstracted from the aquifer for the estate, the Aquifer Firm Yield Model (AFYM) was utilised (WRC, 2012). The model uses a single cell "Box Model" approach and makes use of a critical management water level, below which aquifer storage levels cannot be drawn down, to provide estimates of aquifer firm and assured yields. The Aquifer Firm Yield Model was run, and the Aquifer Firm Yield was determined to be 6 873 245.28 m^3/a (217.80 L/s) with a recharge of 10 423 900 m^3/a for the catchment G21B. The firm yield is estimated to be approximately 65.9% of recharge. For this study area there are clear geological features that enable the definition of a more localised aquifer (i.e. a geohydrological response unit (GRU)). On assessment of the geological map the GRU have an extent of approximately 17 km^2. Using the GRAII recharge values the direct vertical recharge (minimum recharge volume) is calculated to be in the region of 583 299.2 m^3/a for the GRU. The firm yield of the GRU is calculated to be 384 612.1 m^3/a.

A geophysical survey (resistivity method) was completed to determine a drill target on Erf 3594. Based on the resistivity competent bedrock will be intersected at a depth of 40 meters below ground level. Fine- to medium coarsed grained sandy alluvial materially is likely to be overlaying the bedrock.One drill target was delineated for the drilling of a water supply borehole – details are summarised in the table below. ALB_Drill drill target was sited using the resistivity method; zones of intermediate resistivity were targeted as it has been interpreted as weathered/fault zone.

ID	Latitude (WGS84)	Longitude (WGS84)	Drilling depth (m)	Target
ALB_Drill	-33.736497°	18.453540°	60 – 80	Fractured bedrock

Atlantic Beach Estate is situated on a primary aquifer (aquifers in which water moves through the integranular spaces/unconsolidated sediments) overlying a deeper secondary (fractured hard rock) aquifer. The saturated sand thickness in the upper unconsolidated aquifer is limited in the area and is therefore important to manage groundwater abstraction from the primary aquifer. Over-abstraction can cause a decrease in the water table (dewatering) which can ultimately lead to the loss of primary porosity in the unconsolidated sands and in severe cases, this compression can be observed on the ground surface as subsidence. Unfortunately, much of the subsidence from groundwater abstraction is permanent (elastic rebound is small). Thus, the subsidence is not only permanent, but the compressed aquifer has a permanently reduced capacity to hold water. Similar principles are also applicable to the deeper hard rock fractured aquifer.

It is important to note that the geohydrological response unit at Atlantic Beach Estate is quite limited in extent with a calculated direct vertical recharge (minimum recharge volume) in the region of 583 299.2 m^3/a. The firm yield of the geohydrological response unit is calculated to be 384 612.1 m^3/a, which is estimated to be approximately 65.9% of recharge. These volumes are quite limited in terms of groundwater availability and it is important that groundwater abstraction is closely monitored and managed within the estate.

Atlantic Beach Estate is situated in close proximity to the coast (approximately 400 m). Aquifers near the coast have a lens of freshwater near the surface and denser seawater under freshwater. Seawater penetrates the aquifer diffusing in from the ocean and is denser than freshwater. For primary aquifers near the coast, the thickness of freshwater atop saltwater is about 40 m for every 1 m of freshwater head above sea level. If large volumes of groundwater are abstracted near the coast, salt-water may intrude into freshwater aquifers causing contamination of potable freshwater supplies.

The following recommendations are made for the drilling and development of the borehole(s) for groundwater utilisation (Atlantic Beach Estate - Erf 3594):

- The borehole can be drilled up to a maximum depth of 80 m. Should sufficient water be intersected before then, the drilling should continue for 10 m beyond this water strike.
- During the borehole drilling, geological samples must be collected for every 1 m drilled. **A hydrogeologist should be on site to help with borehole construction and design and log the borehole details**. When drilling a borehole, the main issue is "when is the borehole deep enough" and this issue is best addressed by a hydrogeologist.
- The borehole should be developed with compressed air for at least four hours upon completion of the borehole (if successful).
- The borehole, once drilled, should be tested to determine the groundwater yield available. This is to be done according to scientifically acceptable standards (as outlined by the SABS) and will form part of the groundwater use license application process. **Please note that non-SABS yield tests (Farmer method or constant-head) are not accepted by Department of Water and Sanitation (DWS) during a license application.**
- A sample of the groundwater should be submitted to an accredited laboratory for analysis to determine if the quality is suitable for its intended use.

- Water Use Authorization (with the Department of Water and Sanitation) and compliance with municipal bylaws should be addressed upon successful completion of the borehole

The borehole, if successful, should also be equipped with monitoring infrastructure:

- Installation of a 40 mm OD (class 10) observation pipe from the pump depth to the surface, closed at the bottom and slotted for the bottom 10 - 20 m. This enables manual or automated water level monitoring.
- Installation of a timer switch set to pump according to recommendations made from the yield test.
- Installation of a sampling tap.
- Installation of a flow volume meter.

A geohydrologist should review the above information to ensure optimal groundwater abstraction and management occurs.

Based on the results obtained during the geohydrological investigation it is recommended that the following information is obtained from the home owners for existing and proposed groundwater abstraction (from boreholes and wellpoints):

- Erf no/property no/address
- Owner contact information
- Type of groundwater abstraction point (borehole, wellpoint etc)
- Depth of borehole/wellpoint
- Borehole blow/airlift yield (L/s or L/hour)
- Groundwater quality (laboratory certificate or general quality – good for drinking, saline, iron rich etc)
- Depth of water strikes (fracture depth)
- Driller information (contact details – borehole drilling certificate)
- Yield test certificate (contractor details – yield test certificate)
- How much water are they using from the borehole
- Intended use (irrigation, domestic etc)
- Groundwater monitoring infrastructure (flow meter and groundwater level monitoring)
- Is the borehole/wellpoint registered with the relevant authority (City of Cape Town / Department of Water and Sanitation)

Due to the concern over the possibility of land subsidence as a result of groundwater abstraction on the estate it is recommended that a geotechnical study is carried out to determine the sub-surface geological conditions and characteristics directly underlying the estate.

It is also recommended to further investigate the possibility of saline water intrusion at the estate by running a groundwater numerical model to determine the possibility (and magnitude) of saline water intrusion.

Ooooo OOO ooooO

TABLE OF CONTENTS

LIST OF MAPS AND FIGURES

LIST OF TABLES

ABBREVIATIONS

L/s	litres per second
m	metres
mbgl	metres below ground level
mg/L	milligrams per litre

mm/a	millimetres per annum
mS/m	milliSiemens per meter
WGS84	Since the 1st January 1999, the official co-ordinate system for South Africa is based on the World Geodetic System 1984 ellipsoid, commonly known as WGS84, with the ITRF91 (epoch 1994.0) co-ordinates of the Hartebeesthoek Radio Astronomy Telescope used as the origin of this system. This new system is known as the Hartebeesthoek94 Datum.

GLOSSARY OF TERMS

Aquifer: a geological formation, which has structures or textures that hold water or permit appreciable water movement through them [from National Water Act (Act No. 36 of 1998)].

Borehole: includes a well, excavation, or any other artificially constructed or improved groundwater cavity which can be used for the purpose of intercepting, collecting or storing water from an aquifer; observing or collecting data and information on water in an aquifer; or recharging an aquifer [from National Water Act (Act No. 36 of 1998)].

Groundwater: water found in the subsurface in the saturated zone below the water table or piezometric surface i.e. the water table marks the upper surface of groundwater systems.

Transmissivity: the rate at which a volume of water is transmitted through a unit width of aquifer under a unit hydraulic head (m^2/d); product of the thickness and average hydraulic conductivity of an aquifer.

Suggested reference for this report:

GEOSS (2017). Geohydrological assessment and groundwater development at Atlantic Beach Estate, Melkbosstrand. GEOSS Report Number: 2017/08-34. GEOSS - Geohydrological& Spatial Solutions International (Pty) Ltd. Stellenbosch, South Africa.

Cover photo:

Atlantic Beach Estate (www.atlanticbeachestate.co.za)

GEOSS project number:

2017_06-2169

---

1. INTRODUCTION

Mr Harry White (Atlantic Beach Homeowners Association – CEO) approached GEOSS – Geohydrological & Spatial Solutions International (Pty) Ltd to conduct a geohydrological assessment and borehole siting at Atlantic Beach Estate near Melkbosstrand.

2. SCOPE OF WORK

The client is looking for the following information:

1. A clarification of what they estimate the ground makeup would look like under the estate. (keeping in mind that the water drilling companies are drilling up to 70m+)
2. What the underground water potential on the estate resemble in respect of quantity and replenishment.
3. What effect the many boreholes could have on the underground water and what effect they could have to the stability of the ground ie can they cause sinkholes etc.
4. We would like to know that if the underground water is used extensively under the estate, would this cause a future danger and is there a chance that the sea water would start seeping in under the estate?
5. The report must also include professional recommendations as to how you believe the estate should deal with this newfound need for boreholes, ie permissions, requirements pre-drilling and at the time of drilling etc.
6. We would also like to know if it is feasible and safe for the association to drill a borehole or boreholes on erf 3594 in order to supplement the irrigation water for the golf course and estate gardens. (permissions, positioning, yield potential etc)
7. Any other information you feel would be appropriate and necessary for us going forward.

3. REGIONAL SETTING

3.1 General

Geographically, the estate is situated towards the south of Melkbosstrand, in the Western Cape. The estate is situated in quaternary catchment G21B of the Berg Water Management Area. This quaternary catchment is approximately 303.8 km in extent and has a General Authorisation (GA) of 150 m^3/a/ha for groundwater abstraction. The study area, within a regional context, is shown in **Map 1**.

Map 1: Location of the study area.

4. REGIONAL GEOLOGY

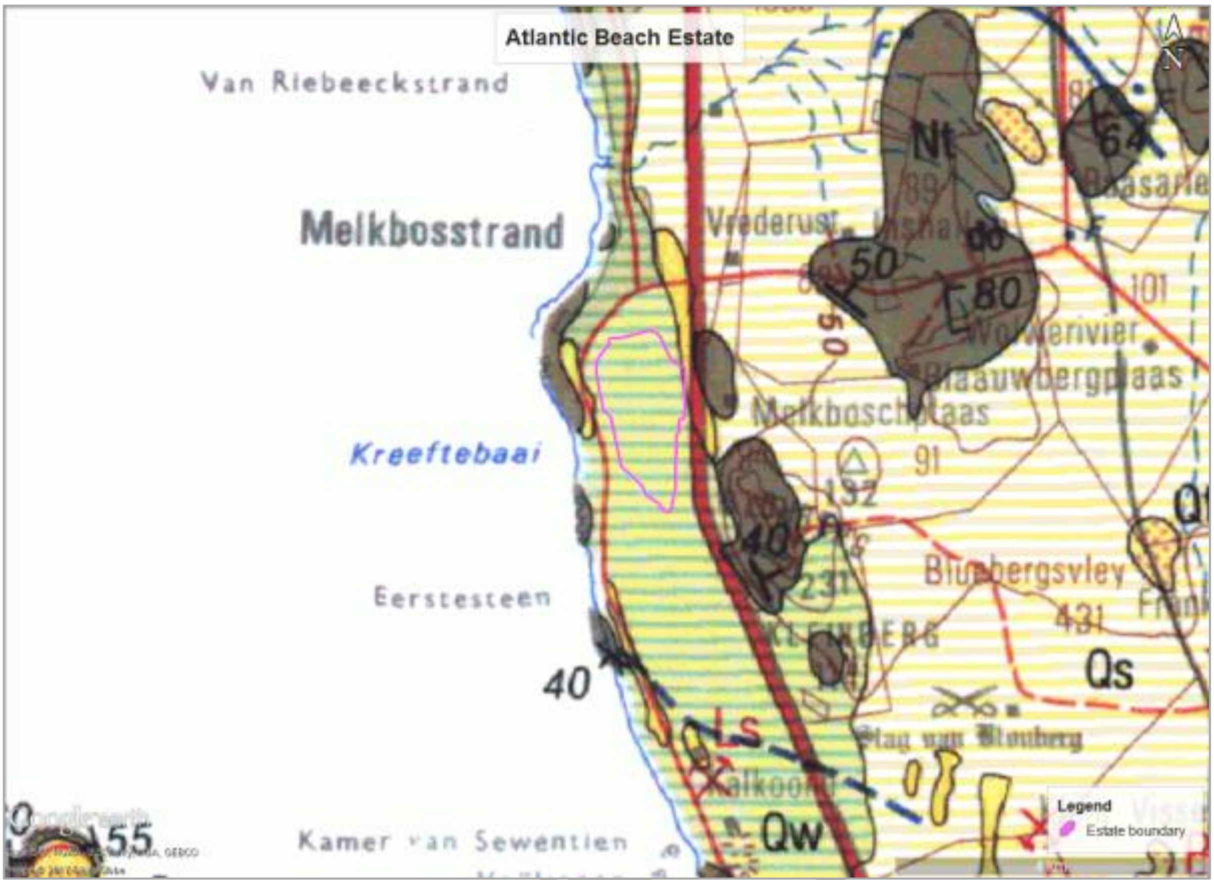
The Geological Survey of South Africa (now the Council for Geoscience) has mapped the area at 1:250 000 scale (3318, Cape Town). The geological setting is shown in **Map 2**.

The main geology of the area is listed in **Table 1.**

Table 1: Geological formations within the study area.

Code	Formation	Group	Description
Qwi	Witsand	Sandveld	White to light-grey calcareous sand
Ql	Langebaan		Light-grey calcified dune sand and calcrete
Qsp	Springfontyn		Light-grey to pale-red quartzose sand and dune sand
Nt	Tygerberg	Malmesbury	Quartzose greywacke and mudrock

The geology underlying the site comprises of unconsolidated white sand with comminuted shell pebbles and shells of the Witzand formation (Qw) overlying the Tygerberg formation (Nt) basement rocks (Malmesbury Group) which consists of greywacke, phyllite and quartzitic sandstone. There are no major geological faults mapped in the study area.



Map 2: Portion of Geological Map - Cape Town 3318.

5. REGIONAL HYDROGEOLOGY

5.1 Aquifer Yield

According to the 1:500 000 scale groundwater map of Cape Town (3317) the northern portion of the estate is underlain by a intergranular aquifer with a yield potential of 0.5 to 2.0 L/s and the southern portion in underlain by a fractured aquifer with a yield potential of 0.5 to 2.0 L/s (**Map 3)** (Meyer, 2001). The classification is based on a 1:500 000 scale map, and therefore only provides a preliminary indication of the sustainable yield that can be obtained from successful boreholes drilled in this setting.

Map 3: Aquifer type and yield (DWAF, 2002).

5.2 Aquifer quality

The groundwater quality in the area is classified as "poor" (having an electrical conductivity between 300 and 1 000 mS/m (DWAF, 1998)) in terms of domestic supply. Once again – this assessment is based on a 1:500 000 scale map, and therefore only provides an indication of what can be expected. The regional groundwater quality map is presented in **Map 4.**

Map 4: Groundwater quality as indicated by electrical conductivity (EC) (DWAF, 2002).

6. AQUIFER FIRM YIELD MODEL

In order to evaluate the sustainable volume of groundwater that can be abstracted from the aquifer for the estate, the Aquifer Firm Yield Model (AFYM) was utilised (WRC, 2012). The model uses a single cell "Box Model" approach and makes use of a critical management water level, below which aquifer storage levels cannot be drawn down, to provide estimates of aquifer firm and assured yields.

The "Box Model" approach is schematically presented in **Figure 1**.

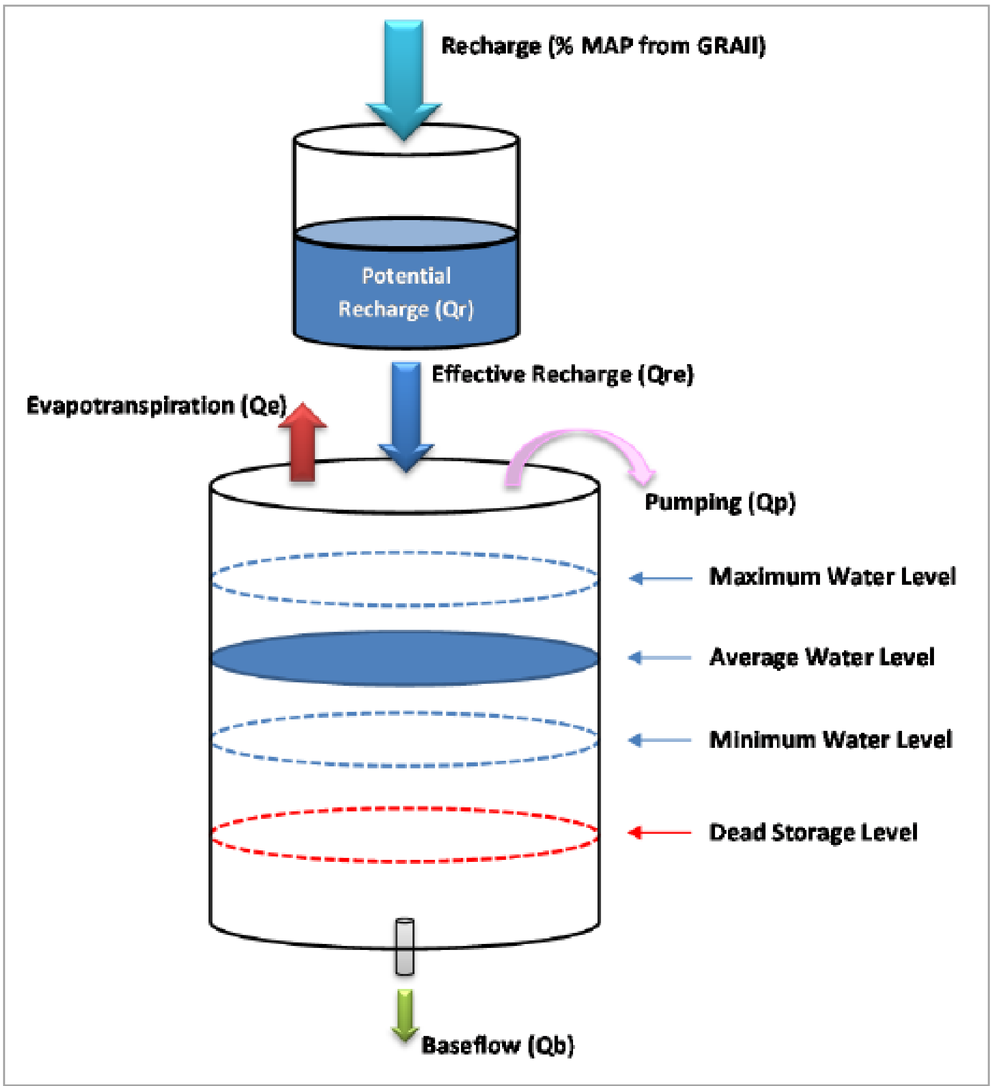


Figure 1: Aquifer Firm Yield lumped box model (WRC, 2012).

An evaluation was completed using the Aquifer Firm Yield model (WRC, 2012), and the results are presented in **Table 2**. The Input parameters used for the catchment are the default values presented in WRC (2012). These are taken from datasets like WR2005 (e.g. rainfall data) (Middleton and Bailey, 2008) and GRAII (e.g. specific yield and recharge (%MAP)) (DWAF, 2005), and others generated during the WRC (2012) (e.g. recharge threshold and riparian zone (% catchment area)). The parameters for quaternary catchment G21B, with an area of 303.8 km^2, are presented in **Table 2**.

Table 2: Hydrogeological Parameters for Quaternary catchment G21B (WRC, 2012).

Parameter	Value
Groundwater Level (mbgl)	9.7
Max Drawdown (m)	5
Specific Yield	0.004396
Current Use (l/s)	469.2
Firm Yield (l/s)	217.8
Firm Yield (l/s/km²)	0.7169
Recharge %	8.1
Recharge Threshold (mm)	18
MAP (mm)	423.6
Hydrological MAR (mm)	31.6
Hydrological MAE(mm)	1445
Baseflow: Default (Mm³/a)	13.83
ET Model	Linear
ET Extinction Depth (m)	4
Riparian Zone (%)	1.1

The Aquifer Firm Yield Model was run, and the Aquifer Firm Yield was determined to be 6 873 245.28 m^3/a (217.80 L/s) with a recharge of 10 423 900 m^3/a for the catchment G21B. The firm yield is estimated to be approximately 65.9% of recharge. The results of the Aquifer Firm Yield Model for Quaternary Catchment G21B are presented in **Table 3**.

Table 3: Results of the Aquifer Firm Yield Model for Quaternary Catchment G21B.

Name	Q [l/s]	Q [m³/month]	Q [m³/a]	R [m³/a]
G21B	217.80	564 537.60	6 873 245.28	10 423 900

For this study area there are clear geological features that enable the definition of a more localised aquifer (i.e. a geohydrological response unit (GRU)). On assessment of the geological map the GRU have an extent of approximately 17 km^2. Using the GRAII recharge values the direct vertical recharge (minimum recharge volume) is calculated to be in the region of 583 299.2 m^3/a for the GRU. The firm yield of the GRU is calculated to be 384 612.1 m^3/a, which is estimated to be approximately 65.9% of recharge. An east-west geological section has been included in **Figure 2** to assist with the geohydrological water balance. **Figure 2** shows a schematic and conceptual diagram indicating the geological setting.

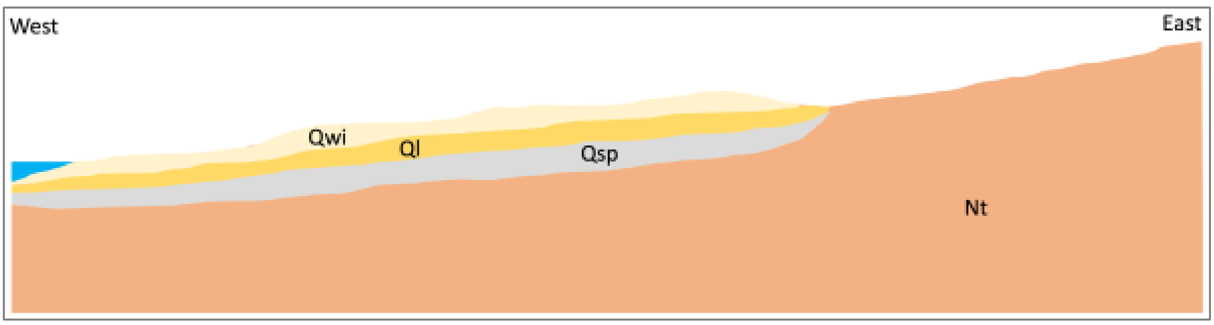


Figure 2: A schematic and conceptual west-east geological section.

Map 5 shows the profile line of the geological cross-section superimposed on aerial photography (Google Earth Image).

Map 5: Geological cross-section profile line and GRU superimposed on aerial photography.

It is important to note that a conservative approach was used to calculate the recharge and firm yield volumes and that the actual volumes might be slightly higher than the calculated volumes.

7. SITE SPECIFIC ASSESSMENT

7.1 Geophysical survey

The resistivity method was used to locate lateral and vertical changes in electrical properties that may be related to changes in the formation properties.

Resistivity is a non-invasive geophysical tool that can provide cost-effective solutions to geological questions. The bulk resistivity of different geological units varies mostly because of changes in water saturation or porosity and/or salinity of the pore fluid (Telford et al, 1990). The Lund imaging system is a completely automated resistivity tomography data acquisition system. The resistivity tomography method provides a pseudo-section of change in electrical properties in the subsurface along a specified line. Two multi-core cables with 16 electrode take-outs every 10 m were used. These cables were laid out in a straight line (as much as possible) on the ground end to end. An electrode (metal stake) is inserted into the ground next to every electrode take-out on the cable. The electrode take-out is then connected to the electrode with a short cable jumper. The multi core cables are connected to the ABEM electrode selector ES464 that controls the measurement sequence. The electrode selector is connected to the ABEM Terrameter SAS1000 that takes the apparent resistivity measurements. The data were collected using a standard protocol with the Wenner array. All data were acquired for n = 1 to 8 and 10, 12, 14, 16, 18 and 20 where "n" is the electrode separation multiplication factor. The apparent resistivity data acquired in the field were inverted using the RES2DINV software (Loke and

Barker, 1996) to provide a true-depth resistivity section. The only pre-processing required is to erase obviously erratic data points. The resulting true resistivity pseudo-section is used for the interpretation.

The inverted resistivity data profile for Res_line1 is shown in **Figure 3**. The resistivity values indicate the following:

- Dark blue to light blue contours (46 – 105 ohm.m) is likely indicative of alluvial saturated sandy material.
- Green, brown to red (105 – 529 ohm.m) is likely indicative of highly weathered material above bedrock which comprises weathered shales and clay material.
- purple (>795 ohm.m) is likely indicative of a fractured bedrock.

Based on the resistivity competent bedrock will be intersected at a depth of 40 meters below ground level. Fine- to medium coarsed grained sandy alluvial materially is likely to be overlaying the bedrock.

One drill target was delineated for the drilling of a water supply borehole – details are summarised in **Table 4**. ALB_Drill drill target was sited using the resistivity method; zones of intermediate resistivity were targeted as it has been interpreted as weathered/fault zone.

Table 4: Details of drilling targets.

ID	Latitude (WGS84)	Longitude (WGS84)	Drilling depth (m)	Target
ALB_Drill	-33.736497°	18.453540°	60 – 80	Fractured bedrock

The position of the drill target (ALB_Drill) is shown on **Map 6** below.

Map 6: Position of drill site (ALB_Drill).

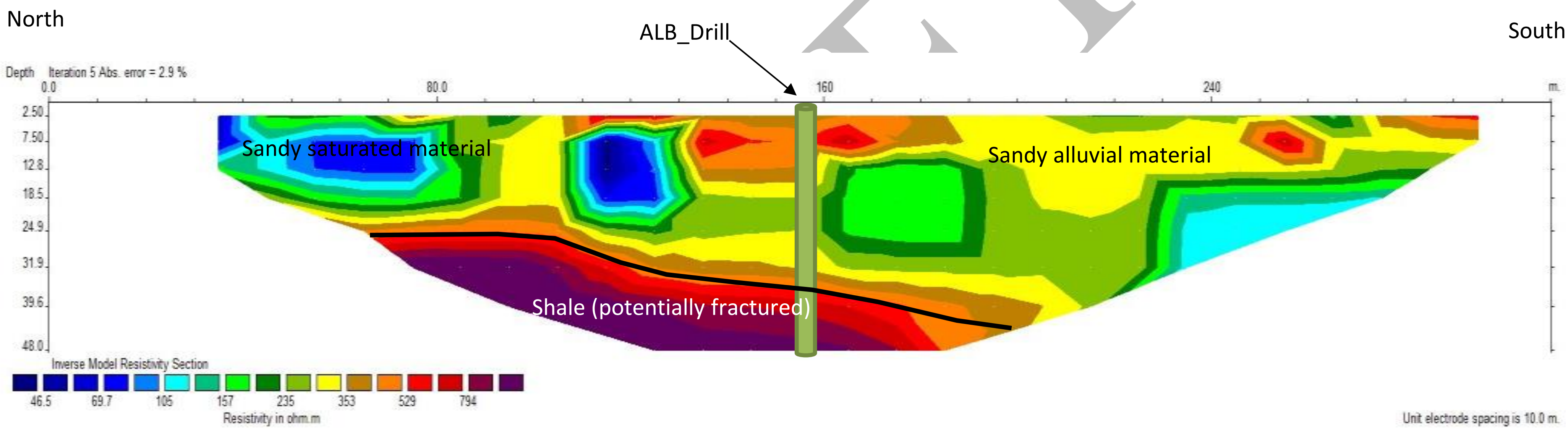


Figure 3: Inverted resistivity data profile, showing drill target ALB_Drill.

It must be noted that the drill target has been sited on a fractured aquifer with a classified yield potential of 0.5 – 2 L/s; this is rated as a moderate aquifer moderate. This, however, does not mean that any borehole drilled in the area will obtain a borehole yield in this range. As it is a fractured aquifer the groundwater only occurs in narrow fractures within the bedrock and if fractures are not intersected the borehole may be dry. Should the fractured bedrock be inadequate it is recommended that the casing then be slotted to allow for groundwater within the weathered zone to be abstracted. If the casing is slotted to allow for groundwater from the weathered zone it is highly recommend that PVC casing with slots be installed along with a gravel pack (correct size), this will prevent sand grains from entering the borehole and damaging the pump.

It is recommended that a hydrogeologist be on site to help define the depth and design of the borehole. Should the drilling be successful, the borehole should be properly developed with compressed air upon completion. If successful, abstraction from the borehole will also need to be carefully managed to ensure sustainable use.

8. DISCUSSION

Atlantic Beach Estate is situated on a primary aquifer (aquifers in which water moves through the integranular spaces/unconsolidated sediments) overlying a deeper secondary (fractured hard rock) aquifer. The saturated sand thickness in the upper unconsolidated aquifer is limited in the area and is therefore important to manage groundwater abstraction from the primary aquifer. Over-abstraction can cause a decrease in the water table (dewatering) which can ultimately lead to the loss of primary porosity in the unconsolidated sands and in severe cases, this compression can be observed on the ground surface as subsidence (not sinkholes – unfavorable geological conditions). Unfortunately, much of the subsidence from groundwater abstraction is permanent (elastic rebound is small). Thus, the subsidence is not only permanent, but the compressed aquifer has a permanently reduced capacity to hold water. Similar principles are also applicable to the deeper hard rock fractured aquifer.

It is important to note that the geohydrological response unit at Atlantic Beach Estate is quite limited in extent with a calculated direct vertical recharge (minimum recharge volume) in the region of 583 299.2 m^3/a. The firm yield of the geohydrological response unit is calculated to be 384 612.1 m^3/a, which is estimated to be approximately 65.9% of recharge. These volumes are quite limited in terms of groundwater availability and it is important that groundwater abstraction is closely monitored and managed within the estate.

Atlantic Beach Estate is situated in close proximity to the coast (approximately 400 m). Aquifers near the coast have a lens of freshwater near the surface and denser seawater under freshwater. Seawater penetrates the aquifer diffusing in from the ocean and is denser than freshwater. For primary aquifers near the coast, the thickness of freshwater atop saltwater is about 40 m for every 1 m of freshwater head above sea level. If large volumes of groundwater are abstracted near the coast, salt-water may intrude into freshwater aquifers causing contamination of potable freshwater supplies.

9. RECOMMENDATIONS

The following recommendations are made for the drilling and development of the borehole(s) for groundwater utilisation (Atlantic Beach Estate - Erf 3594):

- The borehole can be drilled up to a maximum depth of 80 m. Should sufficient water be intersected before then, the drilling should continue for 10 m beyond this water strike.
- During the borehole drilling, geological samples must be collected for every 1 m drilled. **A hydrogeologist should be on site to help with borehole construction and design and log the borehole details**. When drilling a borehole, the main issue is "when is the borehole deep enough" and this issue is best addressed by a hydrogeologist.
- The borehole should be developed with compressed air for at least four hours upon completion of the borehole (if successful).
- The borehole, once drilled, should be tested to determine the groundwater yield available. This is to be done according to scientifically acceptable standards (as outlined by the SABS) and will form part of the groundwater use license application process. **Please note that non-SABS yield tests (Farmer method or constant-head) are not accepted by Department of Water and Sanitation (DWS) during a license application.**
- A sample of the groundwater should be submitted to an accredited laboratory for analysis to determine if the quality is suitable for its intended use.
- Water Use Authorization (with the Department of Water and Sanitation) and compliance with municipal bylaws should be addressed upon successful completion of the borehole

The borehole, if successful, should also be equipped with monitoring infrastructure:

- Installation of a 40 mm OD (class 10) observation pipe from the pump depth to the surface, closed at the bottom and slotted for the bottom 10 - 20 m. This enables manual or automated water level monitoring.
- Installation of a timer switch set to pump according to recommendations made from the yield test.
- Installation of a sampling tap.
- Installation of a flow volume meter.

A geohydrologist should review the above information to ensure optimal groundwater abstraction and management occurs.

Based on the results obtained during the geohydrological investigation it is recommended that the following information is obtained from the home owners for existing and proposed groundwater abstraction (from boreholes and wellpoints):

- Erf no/property no/address
- Owner contact information
- Type of groundwater abstraction point (borehole, wellpoint etc)
- Depth of borehole/wellpoint
- Borehole blow/airlift yield (L/s or L/hour)
- Groundwater quality (laboratory certificate or general quality – good for drinking, saline, iron rich etc)
- Depth of water strikes (fracture depth)
- Driller information (contact details – borehole drilling certificate)
- Yield test certificate (contractor details – yield test certificate)
- How much water are they using from the borehole
- Intended use (irrigation, domestic etc)
- Groundwater monitoring infrastructure (flow meter and groundwater level monitoring)
- Is the borehole/wellpoint registered with the relevant authority (City of Cape Town / Department of Water and Sanitation)

Due to the concern over the possibility of land subsidence as a result of groundwater abstraction on the estate it is recommended that a geotechnical study is carried out to determine the sub-surface geological conditions and characteristics directly underlying the estate.

It is also recommended to further investigate the possibility of saline water intrusion at the estate by running a groundwater numerical model to determine the possibility (and magnitude) of saline water intrusion.

10. ACKNOWLEDGEMENTS

Mr Harry White is gratefully thanked for his input and support into this project.

11. REFERENCES

Council for Geoscience, 1997. Geological map 3318, Cape Town (1:250 000 scale). Pretoria, South Africa.

DWAF, 2001. Hydrogeological Map Series of South Africa, 3317 Cape Town (1: 500,000 scale). Department Water Affairs and Forestry, Pretoria.

Meyer, P. S., (2001). An explanation of the 1:500 000 General Hydrogeological map Cape Town 3317. Department of Water Affairs and Forestry, Pretoria.

National Water Act (1998). The National Water Act, No 36. Department of Water Affair and Forestry. Pretoria.

(last page)