CITY OF TSHWANE METROPOLITAN MUNICIPALITY

BASIC ASSESMENT:

HYDROGEOLOGICAL INVESTIGATION

AT THE

MABOPANE CEMETERY

APRIL 2015

DOCUMENT NUMBER

111367	**MAB**	**2015**

Compiled by

aurecon

Project Title: Hydrogeological Investigation at the Mabopane Cemetery

Location: Mabopane, Gauteng Province

Co-ordinates (WGS84): S 25.48157^0
E 28.02052^0

Prepared for:
Environmental Management Services
04th Floor East
Old Mercedes Benz Building
11 Francis Baard Street
Pretoria
PO Box 1454
Pretoria 0001

Contact person: Ms Rudzani Mukheli

Compiled by:
Aurecon
Lynnwood Bridge Office Park
4 Daventry Street
Lynwood Manor
0081

Contact Person: Louis Stroebel
Tel No: 012 427 3151

Project team:

L Stroebel	Geohydrologist
M Terblanche	Geotechnician

Signed on behalf of Aurecon:

L Stroebel

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

EXECUTIVE SUMMARY

The Environmental & Advisory Unit of Aurecon SA (Pty Ltd) was appointed by the City of Tshwane Metropolitan Municipality to conduct a Basic Assesment for the Mabopane Cemetery. A hydrogeological investigation was conducted as part of Assesment requirements.

The investigation consisted of the following:

1. Desk study & Hydrocensus.
2. Borehole siting by means of a ground geophysical survey.
3. Appointment of a drilling contractor and supervising the drilling of a monitoring borehole.
4. Hydraulic testing & chemical analysis of the newly drilled borehole.
5. Report on the findings of the investigation.

Based on the existing data and newly acquired data, the following can be concluded:

- The Mabopane Cemetery is underlain by coarse grained Nebo granite of the Lebowa Granite Suite (Bushveld Complex). No linear structures or faults in close proximity to the cemetery are shown on the published geological map.
- The groundwater yield potential is classed as low since 82% of boreholes on record produce less than 2 l/s. This was confirmed during the drilling phase with the major water strike producing a blow yield of 500l/h.
- Due to the cemetery's close proximity to the Sand River, a relatively shallow water table can be expected. This was confirmed by the water level measured in the newly drilled monitoring borehole as well as the existing production boreholes which had waterlevels of 5.92 and 7.00mbgl respectively.
- A total of 1 magnetic and electromagnetic traverse was performed and an anomaly was detected at 150m in the form of deep weathering. A monitoring borehole (MA-BH2) was drilled at this location. Only 1 new (downstream) monitoring borehole was drilled.
- Localised groundwater flow in the vicinity of the will be in a south westerly direction towards the Sand River. Based on the results of the falling head tests, potential pollutants originating from the waste water treatment works and seeping to the groundwater would migrate at a rate of ~0.06 m/d towards the Sand River.
- The hydrocensus revealed the existence of one borehole. The borehole is equipped with a submersible pump, is located on the premises of the Mabopane Cemetery and is used for domestic purposes by its staff.
- A pumped groundwater sample was collected for chemical analysis from the borehole identified during the hydrocensus, as well as a bailed sample from the newly drilled borehole. The water quality in the boreholes exceeds the Standard Limits for human consumption due to elevated nitrate and fluoride concentrations. The elevated fluoride concentration is a function of the geology and is naturally occurring. The elevated nitrate concentration can most probably be attributed to the activities at the cemetery.
- A matter of concern is the elevated fluoride concentrations in borehole MA-BH1, as this borehole is used for domestic purposes. Long term consumption of water with fluroride

concentrations in excess of 1.5 mg/l will cause mottling of teeth and associated dental damage.

Based on the above conclusions, the following recommendations are made:

- Staff at the Mabopane Cemetery should be informed not to drink the water originating from borehole MA-BH1 due to elevated fluoride concentrations. Alternatively, the water should be treated prior to consumption.
- A groundwater monitoring program should be implemented to monitor the impact of the cemetery on the hydrogeological environment. Should it become evident from the monitoring program that pollution of the groundwater occurs, corrective and remedial actions should be implemented, especially due to the fact that the use groundwater as a source of drinking water.

.

1 INTRODUCTION

The Environmental & Advisory Unit of Aurecon SA (Pty Ltd) was appointed by the City of Tshwane Metropolitan Municipality to conduct a Basic Assesment for the Mabopane Cemetery. A hydrogeological investigation was conducted as part of Assesment requirements.

The investigation consisted of the following:

1. Desk study & Hydrocensus.
2. Borehole siting by means of a ground geophysical survey.
3. Appointment of a drilling contractor and supervising the drilling of a monitoring borehole.
4. Hydraulic testing & chemical analysis of the newly drilled borehole.
5. Report on the findings of the investigation.

This report is not intended to be an exhaustive description of the investigation at Mabopane Cemetery, but rather as a specialist hydrogeological study to evaluate the overall hydrogeological character of the site, as well as recommendations on a groundwater monitoring program.

2 METHODOLOGY

The work completed for the purposes of compiling a hydrogeological report comprised the following:

2.1 Desk Study

The collating of all existing published data. Aerial photos and geological maps were studied to identify possible structural features. This data was used to familiarise ourselves with the site conditions and project objectives. Target areas for the geophysical traverses were identified.

2.2 Site Visit

A site visit was conducted to familiarise ourselves with the site and to evaluate the geology, hydrogeology and potential receptors of pollution emanating from the cemtery.

2.3 Hydrocensus

A hydrocensus was carried out on the property of the cemetery as well as the adjacent area to identify legitimate groundwater users, the groundwater potential and quality. Where possible, groundwater levels were also measured to assist in the understanding of groundwater flow at the site.

2.4 Geophysical Survey

A geophysical survey was performed in pre-determined areas of the site to identify possible dykes, faults and/or fracture zones which may act as groundwater flow barriers or preferential pathways. The Electro-magnetic and Magnetic methods were used in the survey. The data was used to assist in the placement of the monitoring borehole.

2.5 Borehole Drilling

After interpretation of the geophysical data, a drilling target was selected. The borehole was drilled using an air percussion rig and the borehole will act a fourfold purpose: (1) verification of the geology; (2) determine aquifer parameters through hydraulic testing; (3) determine groundwater quality and (4) serve as a future monitoring borehole.

2.6 Hydraulic Testing

Hydraulic testing of the newly drilled borehole was done to determine aquifer parameters (hydraulic conductivity) which will give an indication of the rate at which groundwater flows in the investigated area. Falling head tests ("slug tests") were carried out.

2.7 Groundwater Sampling

Groundwater samples were collected for a major inorganic analysis in the newly drilled borehole, as well as boreholes identified during the hydrocensus.

2.8 Reporting

Upon completion of the desk study and field work, a document was compiled summarising the findings of the investigation.

3 AVAILABLE INFORMATION

The following information was available and was used in the investigation:

- 1:250 000 Geological Map (2528 Pretoria).
- 1:500 000 Hydrogeological Map (Johannesburg 2526)
- An Explanation of the 1:500 000 General Hydrogeological Map – Johannesburg 2526. HC Barnard, October 2000.

4 PHYSIOGRAPHY

4.1 Site Location

The site is located approximately in the suburb of Mabopane on the northern outskirts of Pretoria. It is accessible from Lucas Mangope Road (M21) via two unmarked roads (Map 1, Appendix A). The adjacent land-use mainly comprise of a number of smallholdings where a combination of agricultural activities are practised.

4.2 Topography & Drainage

The cemetery is located on a watershed between three local drainages. The majority of the drainage is towards the Sand River towards the south west of the site. Both the south-eastern as well as the northern boundary of the cemetery site is drained by tributaries of the Sand River. Local drainage from the cemetery will be in a south-westerly direction (0.03 or 3%) towards the Sand River which flows in a north westerly direction. The Sand River flows into the Pienaars River which eventually flows into the Crocodile River.

4.3 Geology & Hydrogeology

According to the published 1:250 000 geological map (2528 Pretoria) the cemetery is underlain by grey to pink coarse grained Nebo granite of the Lebowa Granite Suite, Bushveld Complex (Map 2, Appendix A). No linear structures or faults in close proximity to the cemetery are shown.

According to Barnard (2000), groundwater occurrence within the granite of the Lebowa Granite Suite is associated with deeper weathered zones while faults, fracture zones and dyke contact zones represent a less common mode of occurrence. The groundwater yield potential is classed as low since 82% of boreholes on record produce less than 2 l/s. The depth to groundwater level is generally shallow and seldom exceeds 15m below surface. The comparatively low storage of the granitic rocks is reflected in the appearance of numerous springs and seepages resulting from a rise in groundwater rest levels following rainfall and associated recharge events.

The general suitability of the groundwater for any use is indicated by the average EC value of 60 mS/m and a mean pH value of 7.6.

Due to the cemetery's close proximity to the Sand River, a relatively shallow water table can be expected. This was confirmed by the water level measured in the newly drilled monitoring borehole as well as the existing production borehole (<7mbgl).

It can be assumed that the regional groundwater flow direction will emulate to local topography. Groundwater flow will thus be in a south westerly direction towards the Sand River.

Due to nature of cemeteries and the associated disturbance of the vadose zone due to grave digging, the vertical as well as the horizontal hydraulic conductivity (K) is altered. This results in high K-values meaning that natural recharge in the area is higher than normal and that contaminants migrate at aI higher rate through this disturbed profile.

5 GROUNDWATER USE

A hydrocensus was carried out on the 11th of March 2015 on the property of the cemetery as well as the adjacent area to identify legitimate groundwater users, the groundwater potential and quality. The hydrocensus extended to a distance of ~1km from the cemetery, except where a river or a surface water body exists. The hydrocensus did not extend past such a feature as surface water bodies are usually hydraulically connected to an aquifer, acts as a constant-head boundary and a groundwater pollution plume would theoretically not extend past a constant head boundary.

One borehole was found and is equipped with a submersible pump. This borehole is located on the premises of the Mabopane Cemetery and is used for domestic purposes by its staff.

A pumped water sample was collected from the borehole and submitted to Aquatico Scientific (SANAS accredited laboratory) for a major cation/anion analysis. The results of the water quality are discussed in detail in section 9.

The location of the boreholes is indicated in Map 3, Appendix A. Table 1 summarises the details of the boreholes identified during the hydrocensus.

Table 1. Details of boreholes identified during hydrocensus

BH nr.	Coordinates (WGS84)	Owner/Contact details	Static water level (#mbgl)	Estimated Yield (liters/hour)	User application
MA-BH1	S 25.48220° E 28.02075°	Mabopane Cemetery 072 097 7174	7.00	1500	Domestic

#mbgl - meters below ground level

6 GEOPHYSICAL SURVEY

No linear structures traversing the site were identified on the regional geological map. However, geological maps are not intended to delineate structures on small scale, and thus geophysical methods had to be used to identify such structures, if present.

The objective of the field survey was to investigate possible geological lineaments or weathering to determine the location of possible water bearing structures which could act as preferred groundwater pathways. The ground geophysical survey would also aid to select suitable targets for the placement of the downstream monitoring boreholes. The magnetic and electro-magnetic techniques were used in this survey.

6.1 Magnetic technique

The earth's magnetic field, from an exploration geophysicist's perspective, consists of three parts:

- the main field (internal origin)
- a small field with external origin
- spatial variations of the main field which are caused by local magnetic anomalies in the near-surface crust of the earth.

The main field varies relatively slowly and can be shown to have an internal origin using spherical harmonic analysis. The present theory is that the source of this field is convection currents of conducting material circulating in the liquid outer core. The field closely represents that of a bar magnet with the two poles being closely to, but not exactly on, the geographical north and south poles of the earth. This field contributes to more than 99% of the total magnetic field.

The relatively small external field is caused by electric currents in the ionized layers of the upper atmosphere. Time variations of this part are much more rapid than for the main field. Variations are caused by solar lunar variations as well as magnetic storms which correlate with sunspot activity.

Local changes in the main field result from variations in the magnetic mineral content of near-surface rocks often indicating the presence of dykes and/or faults/shear zones. These anomalies do not persist over great distances and are the main targets of the groundwater explorationist.

The magnetometer used for the ground geophysics in this study is a proton-precession magnetometer. This instrument depends on the measurement of the free-precession frequency of protons that have been polarised in a direction approximately normal to the direction of the earth's field. Only the total field intensity (F) can be measured and the sensitivity is approximately 1 nT. The field procedure consists of taking a measurement at equal intervals along a profile. The values are presented as profile plots of amplitude versus distance. The shape of the magnetic profile is a function of the geometrical shape of the causative body, the direction of the profile, the inclination and declination of the main magnetic field at that position and whether or not the body has remnant magnetization.

6.2 Electro Magnetic technique

Electro-magnetic systems are based on the principles that all electrical currents have magnetic field associated with them and that all time varying magnetic fields will induce current in a conductor. A time varying magnetic field is generated by driving an alternating current through a wire loop. If any conductive material is present in the associated magnetic field, currents normal to the direction of the magnetic field will be induced in the conductor. These induced currents, in turn, create their own associated magnetic fields that, together with the primary field associated with the original transmitter, forms part of the total magnetic field. This resultant magnetic field is then measured in terms of the voltage induced in the receiver loop.

The EM-34 used during this study is a moving source (transmitter) – moving receiver type instrument. It consists of a transmitter coil and receiver coil, both small enough to be handled by a two man team. It has three standard coil separations, 10m, 20m, and 40m, corresponding to three different frequencies and different depths of investigation.

Two measurements (horizontal & vertical coil configuration) are taken at each point along a profile and presented as profile plots of amplitude versus distance. Dykes and/or faults/shear zones form anomalies which can be interpreted to yield conductance, depth and dip.

The EM-34 system allows easy and rapid measurements, is sensitive to changes in conductivities in the order of 5 or 10 % and the data can be interpreted fast and accurately.

6.3 Discussion of Results

One traverse was performed with a total length of 300m. An anomaly was detected at 150m and a monitoring borehole was drilled at this location. Coordinates of the electromagnetic and magnetic traverses and position of drilling targets are presented in Table 2. The geophysical profiles are presented in Appendix B.

Table 2. Coordinates of the geophysical traverses and drilling targets

Traverse nr.	Start Coordinates (WGS84)	End Coordinates (WGS84)	Drilling Target (Borehole nr)
MA-T1	S 25.48107^{o} E 28.02034^{o}	S 25.47849^{o} E 28.01958^{o}	MA-BH2 (150m)

7 BOREHOLE DRILLING

One downstream monitoring borehole was drilled on the 3rd of March 2015. The borehole was drilled down to a depth of 25m and delivered with 125 mm PVC casing, gravel pack, bentonite seal, concrete plinth, marker plate and lockable cap (Figure 1). Solid casing was installed in the upper 1m, together with a bentonite sanitary seal. Perforated (slotted) casing and a gravel pack was installed in the remainder of the borehole in order to allow seepage into the borehole.

Table 3. Details of the monitoring boreholes drilled at Mabopane Cemetery

BH nr.	Coordinates (WGS84)	Depth (m)	Static water level (mbgl)	Water Strikes	Blow Yield (l/hour)
MA-BH2	S 25.47982^{o} E 28.01993^{o}	25	5.92	5m, 7m, 20m	500

Figure 1. Borehole MA-BH2

8 HYDRAULIC TESTING

A falling head test ("slug tests") was carried out on the newly drilled borehole. The test involves continues measuring of the water level response in a borehole to the rapid displacement of water therein. This displacement or rise in water level is caused as a result from the introduction of a slug below the rest water level. "Slug tests" were carried out using a "Solinst Levelogger" recording water levels at very short intervals (5 seconds). Data acquired from the "slug tests" was used to calculate the hydraulic conductivity (K) used in the calculation of the flow velocity of groundwater on-site. Hydraulic conductivity provides an indication of the ease with which water moves through the subsurface and is used to calculate rates of groundwater movement.

The slug test analysis is presented in Appendix D and the results of the analysis are shown in Table 4.

Table 4. Calculated hydraulic conductivity as derived from the slug test data

BH nr.	K (m/d)
MA-BH2	6.36×10^{-2}

Hydraulic conductivity (K) measured in m/d can be defined as: *"the volume of a fluid passing through a porous medium in a unit time under a specific hydraulic gradient and moving through a unit area perpendicular to the flow direction."* Darcy's flow equation was used to calculate the groundwater flow velocity on-site. Darcy's Law states that the rate of flow through a porous medium is proportional to the loss of head, and inversely proportional to the length of the flow path. Alternatively Darcy's Law can be rewritten to be defined by the following equation:

$V = (K\ i)/n_e$

Where:

V = Flow velocity

K = Hydraulic Conductivity

i = Groundwater gradient/surface slope

n_e = Effective porosity

Applying the values calculated for the site and using a porosity of 3% (0.03), the groundwater flow velocity on-site was calculated to be:

V = (0.06 x 0.03)/0.03

= 0.06 m/d

Based on Darcy's flow equation potential pollutants originating from the cemetery site and seeping to the groundwater would thus migrate at an estimated rate of ~0.06 m/d towards the Sand River.

9 GROUNDWATER CHEMISTRY

A pumped groundwater sample was collected for chemical analysis from the borehole identified during the hydrocensus, while a bailed sampled was taken from the newly drilled borehole on the 3rd of March 2014. The groundwater samples were submitted to an accredited laboratory (*Aquatico Scientific in Pretoria*) for a major cation/anion analysis, as well as selected trace metals. The laboratory reports are attached in Appendix E.

The analytical results were compared with the SABS drinking water standards (SANS 241-1:2011, edition 1) (Table 5). Water is classified unfit for human consumption if the Standard Limits are exceeded.

Table 5. Chemical parameters compared to SANS 241-1:2011 (edition 1) drinking water standards

Sample Nr.	MABH1	MABH2					Standard Limits
Ca	24.00	55.30					~
Mg	2.29	10.50					~
Na	52.80	42.40					200
K	1.19	4.71					~
Mn	0	0					0.1
Fe	0	0					0.3
F	3.21	1.36					1.5
NO_3-N	0.23	21.70					11
NH_4-N	0.02	0.02					1.5
PO_4	0.065	0.065					-
Cl	21.1	25.2					300
SO_4	5.3	11.6					250
TDS	195	327					1200
T-Alk	138	130					~
pH	8.35	6.96					5.0 - 9.7
EC	33	53					170

Notes
Yellow = Acceptable
Exceeds standard limits
0 = below detection limit of analytical technique

EC measurements in mS/m, other parameters in mg/ℓ

From Table 5 it can be concluded that the water quality in boreholes MA-BH1 exceeds the Standard Limits due to the elevated fluoride concentration. The water quality in borehole MA-BH2 exceeds the Standard Limits due to the elevated nitrate concentration, most probably originating from activities at the cemetery. Nitrate in the concentration present in MA-BH2 will result in methaemoglobinaemia also known as “Blue baby syndrome”. This is the inability of red blood cells to carry oxygen in the blood stream. Furthermore, nitrate may react with secondary and tertiary amines and amides to from nitrosamines, which are known carcinogens.

A matter of concern is the high fluoride concentration in borehole MA-BH1. The borehole is an equipped production borehole and is used for domestic purposes by the staff of the cemetery as well as visitors to the site.

The health effects of flouride in the concentration present in MA-BH1 may result in mottling of teeth and tooth damage may occur in long term users.

10 AQUIFER CLASSIFICATION

The aquifer(s) underlying the project area were classified in accordance *with "A South African Aquifer System Management Classification, December 1995."*

Classification has been done in accordance with the following definitions for Aquifer System Management Classes:

- Sole Aquifer System: An aquifer which is used to supply 50% or more of domestic water for a given area, and for which there is no reasonably available alternative sources should the aquifer be impacted upon or depleted. Aquifer yields and natural water quality are immaterial.
- Major Aquifer System: Highly permeable formations, usually with a known or probable presence of significant fracturing. They may be highly productive and able to support large abstractions for public supply and other purposes. Water quality is generally very good (Electrical Conductivity of less than 150 mS/m).
- Minor Aquifer System: These can be fractured or potentially fractured rocks which do not have a high primary permeability, or other formations of variable permeability. Aquifer extent may be limited and water quality variable. Although these aquifers seldom produce large quantities of water, they are important for local supplies and in supplying base flow for rivers.
- Non-Aquifer System: These are formations with negligible permeability that are regarded as not containing groundwater in exploitable quantities. Water quality may also be such that it renders the aquifer unusable. However, groundwater flow through such rocks, although imperceptible, does take place, and needs to be considered when assessing the risk associated with persistent pollutants.

Based on information collected during the hydrocensus it can be concluded that aquifer system in the study area can be classified as a "Sole Aquifer System". Groundwater is the sole water supply in the area. The aquifer is important for supplying baseflow to the Sand River.

In order to achieve the Groundwater Quality Management Index a points scoring system as presented in Table 6, Table 7 and Table 8 was used.

Table 6. Ratings for the Aquifer System Management and Second Variable Classifications:

Aquifer System Management Classification		
Class	Points	Study area
Sole Source Aquifer System:	6	6
Major Aquifer System:	4	
Minor Aquifer System:	2	
Non-Aquifer System:	0	
Special Aquifer System:	0 – 6	
Second Variable Classification (Weathering/Fracturing)		
Class	Points	Study area
High:	3	
Medium:	2	
Low:	1	1

Table 7. Ratings for the Groundwater Quality Management (GQM) Classification System:

Aquifer System Management Classification		
Class	Points	Study area
Sole Source Aquifer System:	6	6
Major Aquifer System:	4	
Minor Aquifer System:	2	
Non-Aquifer System:	0	
Special Aquifer System:	0 - 6	
Aquifer Vulnerability Classification		
Class	Points	Study area
High:	3	
Medium:	2	2
Low:	1	

The occurring aquifer(s), in terms of the above definitions, is classified as a sole aquifer system.

The vulnerability, or the tendency or likelihood for contamination to reach a specified position in the groundwater system after introduction at some location above the uppermost aquifer, in terms of the above, is classified as **medium**. A shallow water table (<7 mbgl at places) and weathered rock underlie the site.

The level of groundwater protection based on the Groundwater Quality Management Classification:

GQM Index = Aquifer System Management x Aquifer Vulnerability

= 6 X 2 = 12

Table 8. GQM index for the study area

GQM Index	Level of Protection	Study Area
<1	Limited	
1 - 3	Low Level	
3 - 6	Medium Level	
6 - 10	High Level	
>10	Strictly Non-Degradation	12

Aquifer Susceptibility

Aquifer susceptibility, a qualitative measure of the relative ease with which a groundwater body can be potentially contaminated by anthropogenic activities and which includes both aquifer vulnerability and the relative importance of the aquifer in terms of its classification, in terms of the above, is classified as **low**.

Aquifer Protection Classification

The ratings for the Aquifer System Management Classification and Aquifer Vulnerability Classification yield a Groundwater Quality Management Index of 12 for the study area, indicating that **strictly non degradation protection** may be required.

Due to the high GQM index calculated for this area, a strictly non-degradation level of protection is needed to adhere to DWS's water quality objectives. Reasonable and sound groundwater protection measures are recommended to ensure that no cumulative pollution affects the aquifer, even in the long term.

In terms of DWS's overarching water quality management objectives which is (1) protection of human health and (2) the protection of the environment, the significance of this aquifer classification is that if any potential risk exist, measures must be triggered to limit the risk to the environment, which in this case is the (1) protection of the Secondary Underlying Aquifer, (2) the Sand River which drains the subject area and (3) the number of external users of groundwater in the area.

11 MONITORING PROGRAM

A groundwater monitoring network has been developed for the Mabopane Cemetery, incorporating the borehole identified during the hydrocensus and the newly drilled borehole (Table 9). It is important to note that a groundwater-monitoring network should be dynamic. This means that the network should be extended over time to accommodate the migration of contaminants through the aquifer as well as the expansion of infrastructure and/or addition of possible pollution sources.

Table 9. Monitoring boreholes to be included into the monitoring program

Borehole	Objective
MA-BH1	Downstream from the Cemetery. Impact Monitoring.
MA-BH2	Downstream from the Cemetery. Impact Monitoring.

Water samples must be taken from all the monitoring boreholes by using approved sampling techniques and adhering to recognised sampling procedures. Table 10 below presents the parameters and frequency that should form part of the groundwater monitoring program. The results should be recorded on a data base and reported annually to the Department of Water and Sanitation.

Table 10. Proposed monitoring requirements

Class	Parameter	Frequency	Motivation
Physical	Static groundwater levels	Monthly	Time dependant data is required to understand the groundwater flow dynamics of the site. An anomaly in static water levels caused by mounding below the drainage field may give early warning to spillages or leakages from lined/unlined facilities.
	Rainfall	Daily	Recharge to the saturated zone is an important parameter in assessing groundwater vulnerability. Time dependant data is required to understand the groundwater flow dynamics of the site.
	Groundwater abstraction rates (if present)	Monthly	Response of groundwater levels to abstraction rates could be useful to calculate aquifer storativity – important for groundwater management. Could also explain anomalous groundwater level measurements.
Chemical	Major chemical parameters: Ca, Mg, Na, K, NO_3, NH_4, SO_4, Cl, Fe, P, F, Alkalinity, pH, EC, TDS, COD, TOC, BOD, TON.	Quarterly (Jan., Apr., Jul., Sept) May be reduced to bi-annual (April & Sept.) as more data becomes available)	Background information is crucial to assess impacts during operation and thereafter. Changes in chemical composition may indicate areas of groundwater contamination and be used as an early warning system to implement management/remedial actions. Legal requirement.
	Stable isotopes	As needed	The monitoring program should allow for research and refinement of the conceptual hydrogeological model. This may, from time to time, require special analyses such as stable isotopes.
Bacteriological	E. Coli, Total coliforms, Heterotrophic plate count	Quarterly (Jan., Apr., Jul., Sept)	Microbial presence may indicate areas of groundwater contamination and be used as an early warning system to implement management/remedial actions.

12 CONCLUSIONS & RECOMMENDATIONS

Based on the existing data and newly acquired data, the following can be concluded:

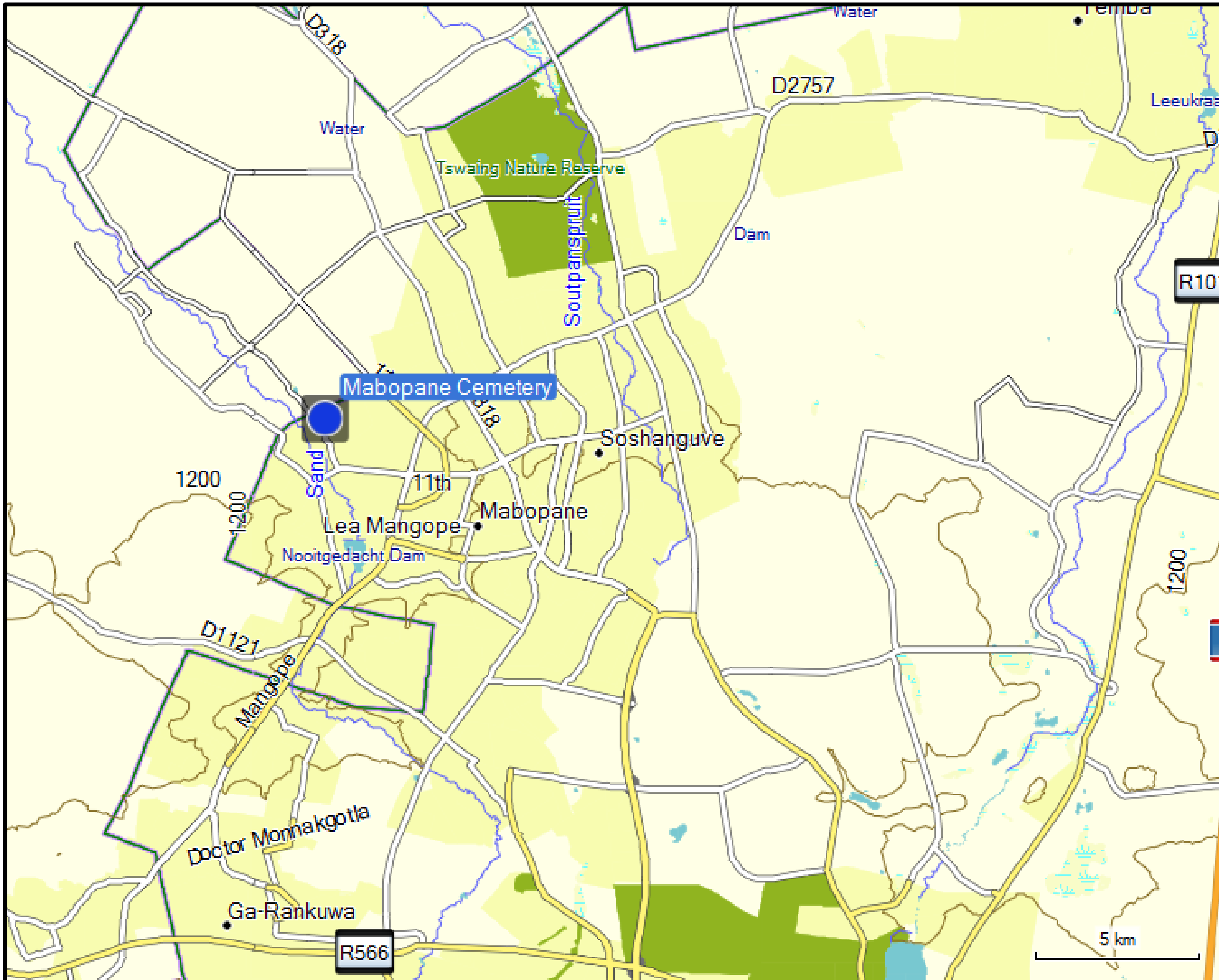
- The Mabopane Cemetery is underlain by coarse grained Nebo granite of the Lebowa Granite Suite (Bushveld Complex). No linear structures or faults in close proximity to the cemetery are shown on the published geological map.
- The groundwater yield potential is classed as low since 82% of boreholes on record produce less than 2 l/s. This was confirmed during the drilling phase with the major water strike producing a blow yield of 500l/h.
- Due to the cemetery's close proximity to the Sand River, a relatively shallow water table can be expected. This was confirmed by the water level measured in the newly drilled monitoring borehole as well as the existing production boreholes which had waterlevels of 5.92 and 7.00mbgl respectively.
- A total of 1 magnetic and electromagnetic traverse was performed and an anomaly was detected at 150m in the form of deep weathering. A monitoring borehole (MA-BH2) was drilled at this location. Only 1 new (downstream) monitoring borehole was drilled.
- Localised groundwater flow in the vicinity of the will be in a south westerly direction towards the Sand River. Based on the results of the falling head tests, potential pollutants originating from the waste water treatment works and seeping to the groundwater would migrate at a rate of ~0.06 m/d towards the Sand River.
- The hydrocensus revealed the existence of one borehole. The borehole is equipped with a submersible pump, is located on the premises of the Mabopane Cemetery and is used for domestic purposes by its staff.
- A pumped groundwater sample was collected for chemical analysis from the borehole identified during the hydrocensus, as well as a bailed sample from the newly drilled borehole. The water quality in the boreholes exceeds the Standard Limits for human consumption due to elevated nitrate and fluoride concentrations. The elevated fluoride concentration is a function of the geology and is naturally occurring. The elevated nitrate concentration can most probably be attributed to the activities at the cemetery.
- A matter of concern is the elevated fluoride concentrations in borehole MA-BH1, as this borehole is used for domestic purposes. Long term consumption of water with fluroride concentrations in excess of 1.5 mg/l will cause mottling of teeth and associated dental damage.

Based on the above conclusions, the following recommendations are made:

- ➢ Staff at the Mabopane Cemetery should be informed not to drink the water originating from borehole MA-BH1 due to elevated fluoride concentrations. Alternatively, the water should be treated prior to consumption.
- ➢ A groundwater monitoring program should be implemented to monitor the impact of the cemetery on the hydrogeological environment. Should it become evident from the monitoring program that pollution of the groundwater occurs, corrective and remedial actions should be implemented, especially due to the fact that the use groundwater as a source of drinking water.

APPENDIX A

MAPS



Project Title:

HYDROGEOLOGICAL INVESTIGATION AT THE MABOPANE CEMETRY

Map Title:

MABOPANE CEMETERY: Locality Map

Map Number:

Map 1

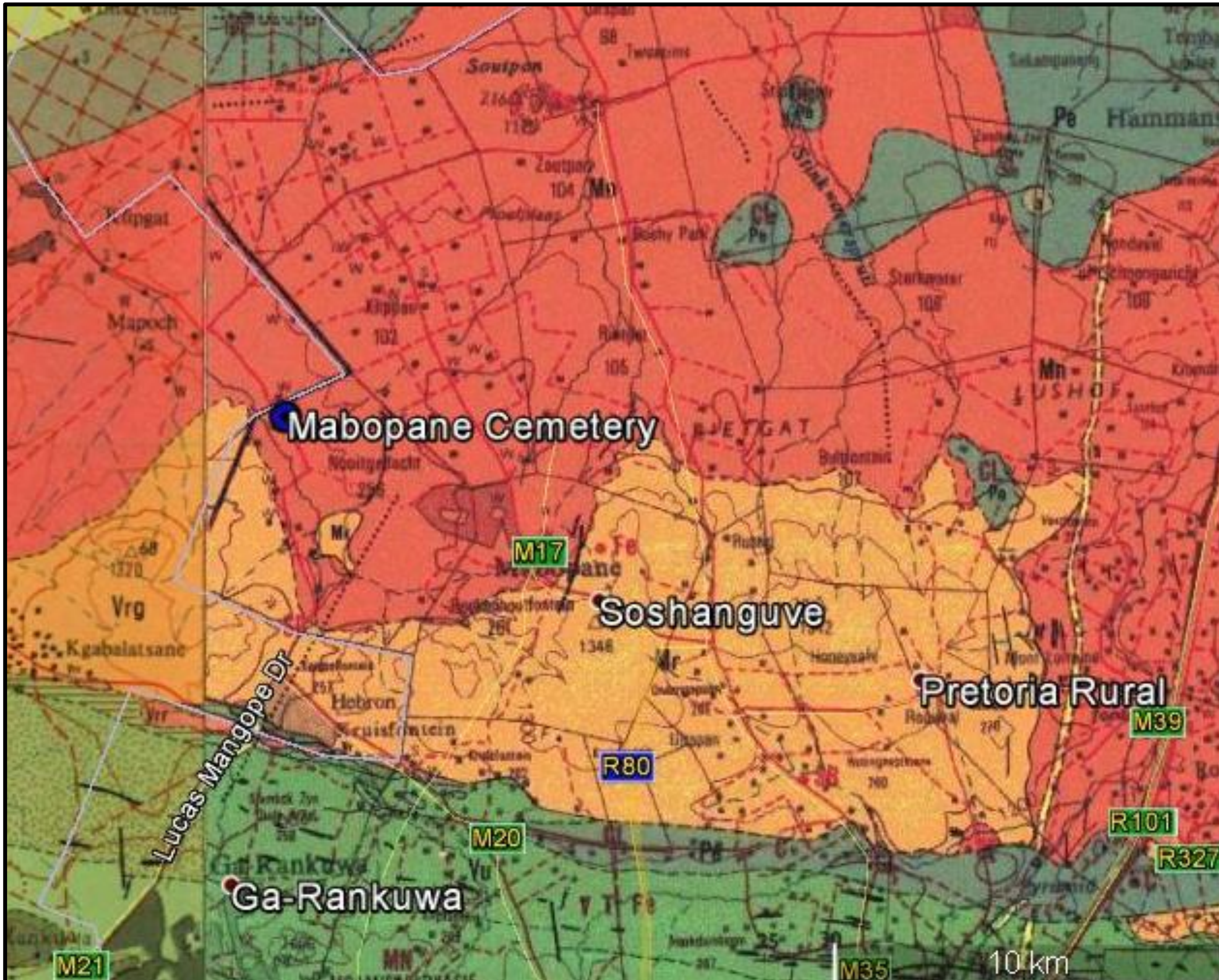
LEGEND

Cemetery

N

Project nr: 111367

aurecon
Lynnwood Bridge Office Park
4 Daventry Street
Lynwood Manor 0040
www.aurecongroup.com



Project Title:

HYDROGEOLOGICAL INVESTIGATION AT THE MABOPANE CEMETERY

Map Title:

MABOPANE CEMETERY: Geological Setting

Map Number:

Map 2

LEGEND

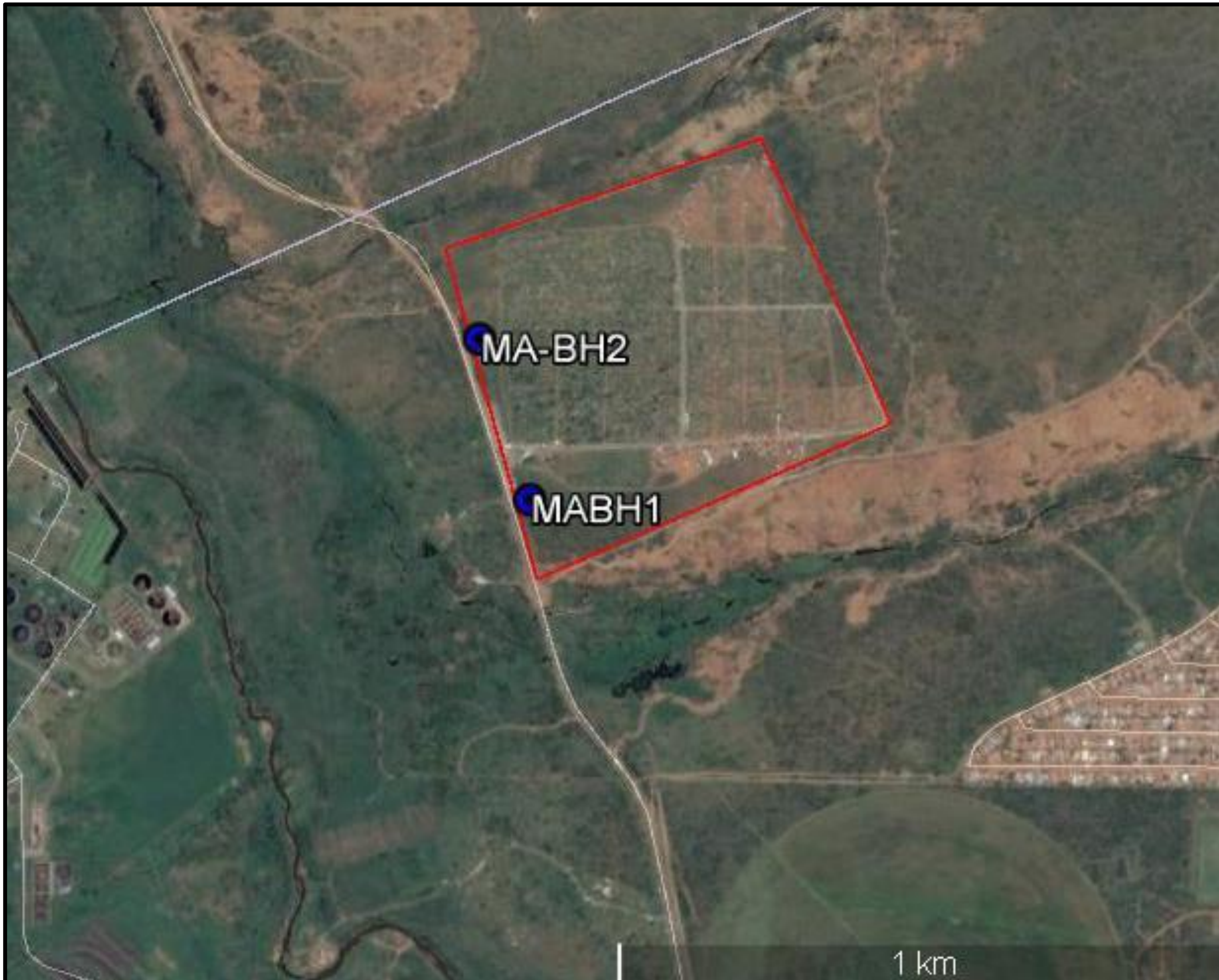
Mn: Nebo Granite

Mr: Rashoop Granophyre

N

Project nr: 111367

aurecon
Lynwood Bridge Office Park
4 Daventry Street
Lynwood Manor 0040
www.aurecongroup.com



Project Title:

HYDROGEOLOGICAL INVESTIGATION AT THE MABOPANE CEMETRY

Map Title:

Mapobane Cemetery: Borehole Locations

Map Number:

Map 3

LEGEND

◉ Borehole

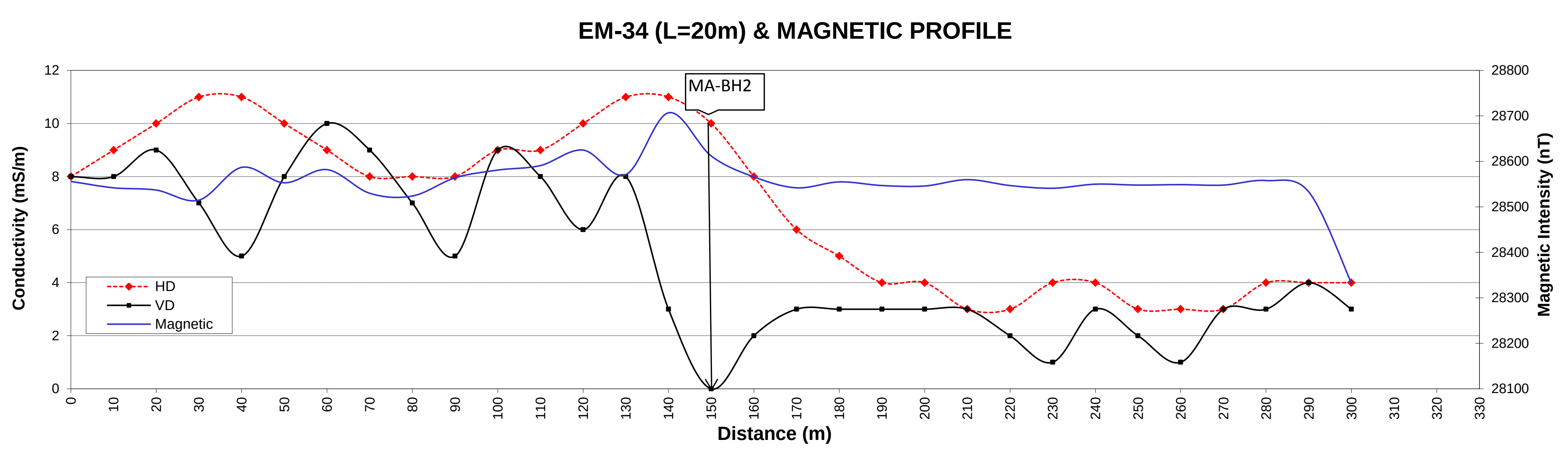
N

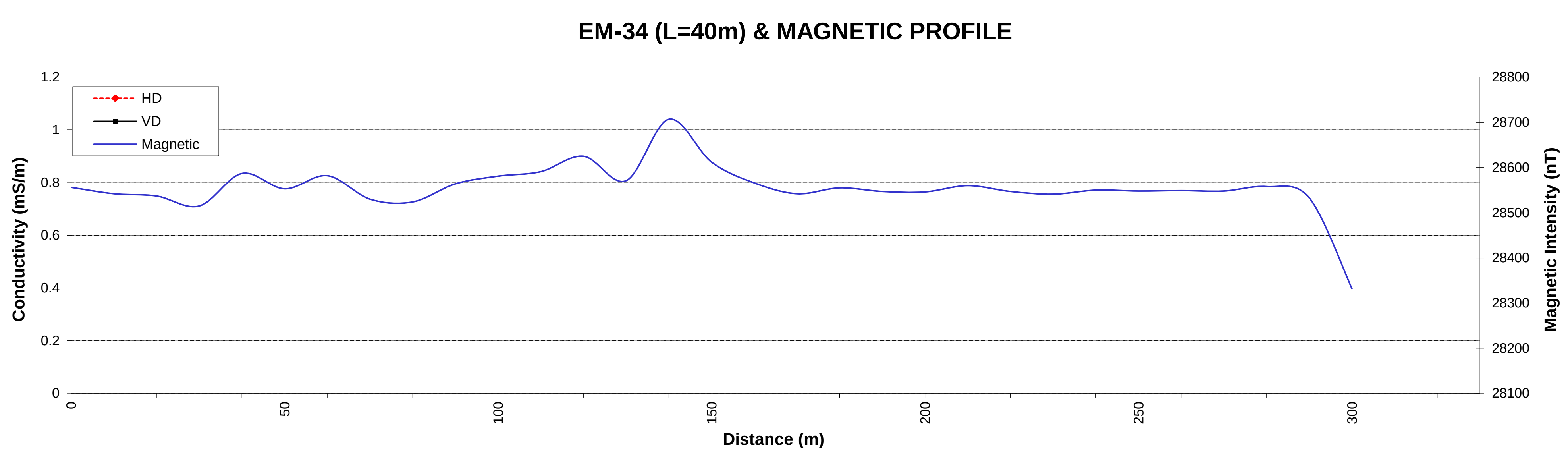
Project nr: 111367

aurecon
Lynnwood Bridge Office Park
4 Daventry Street
Lynwood Manor 0040
www.aurecongroup.com

APPENDIX B

GROUND GEOPHYSICAL PROFILES





Project:	Mabopane Cemtery	**Profile Number:**	T1	**Start Coordinate:**	**S**	25.48107 °	aurecon
Project Number:	111367	**Profile Direction:**	SSE-NNW	***(WGS84)***	**E**	28.02034 °	
Survey Area:	Mabopane	**Station Spacing:**	10m	**End Coordinate:**	**S**	25.47849 °	
Date of Survey:	23/02/2015	**Coil Spacing:**	20m		**E**	28.01958 °	

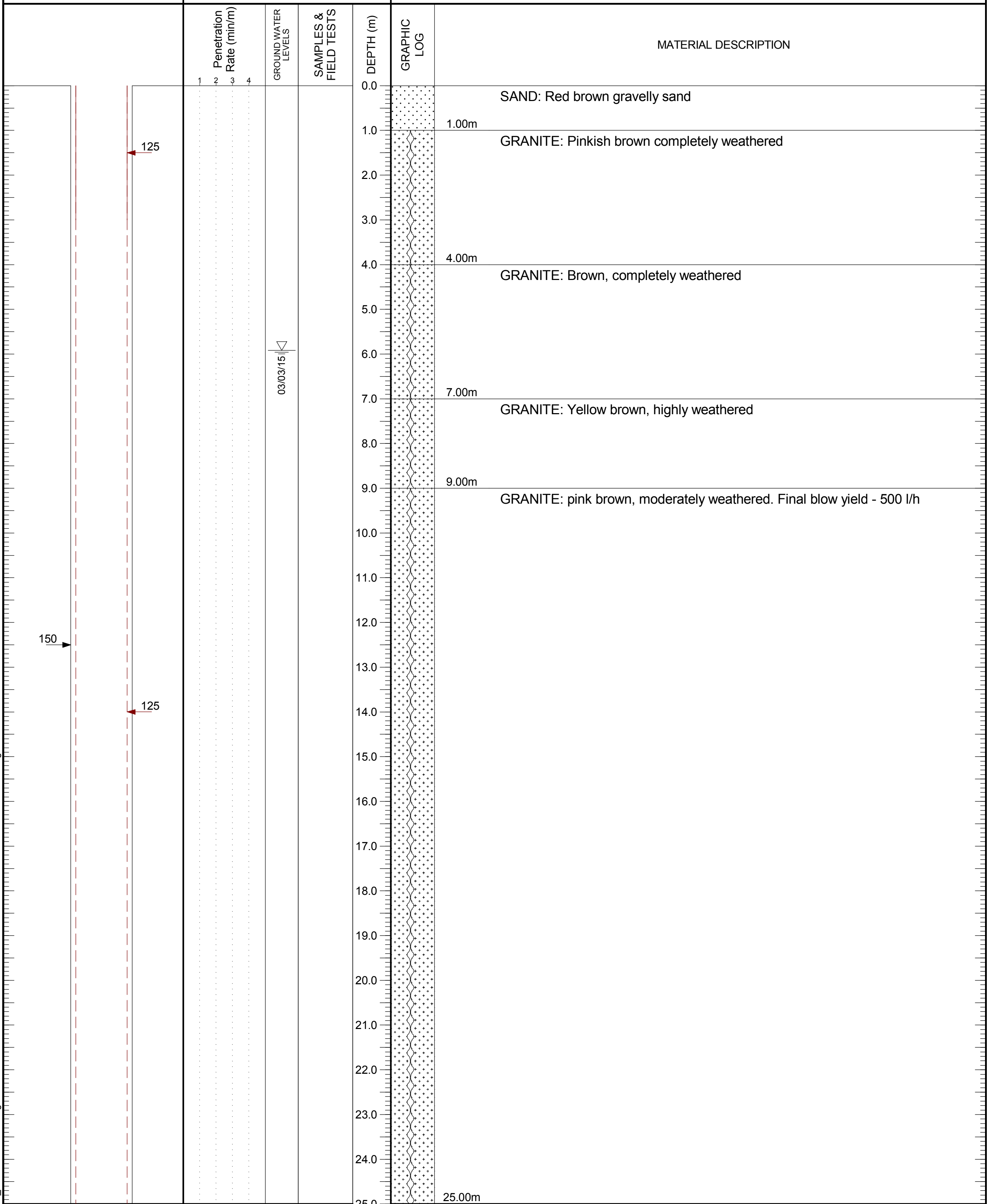
APPENDIX C

BOREHOLE LOGS

PROJECT : Mabopane Cemetery
LOCATION : Mabopane, Pretoria
CLIENT : City of Tshwane MM

HOLE NO : MA-BH2
FILE / JOB NO : 111367
SHEET : 1 OF 1

CONTRACTOR : SGRS	RIG TYPE : Audie Eng Spider	ANGLE FROM HORIZONTAL : 90°	LATITUDE : 25.47982°
DRILLER : Andries	LOGGED BY : MT	HOLE DIA : 150 mm	LONGITUDE : 28.01993°
DATE STARTED : 15/3/3	DATE LOGGED : 15/3/3	HOLE DEPTH : 25 m	ELEVATION : 1128.000 (MSL)
DATE COMPLETED : 15/3/3	CHECKED BY : MT	COLLAR HEIGHT : 0.46 m	GRID & DATUM : WGS84



Depth to (m)	Material description
1.00	SAND: Red brown gravelly sand
4.00	GRANITE: Pinkish brown completely weathered
7.00	GRANITE: Brown, completely weathered
9.00	GRANITE: Yellow brown, highly weathered
25.00	GRANITE: pink brown, moderately weathered. Final blow yield - 500 l/h

BOREHOLE MA-BH2 TERMINATED AT 25.00 m

Hole
Casing (plain / perforated)
Hole diameter (mm)
Casing diamater (mm)

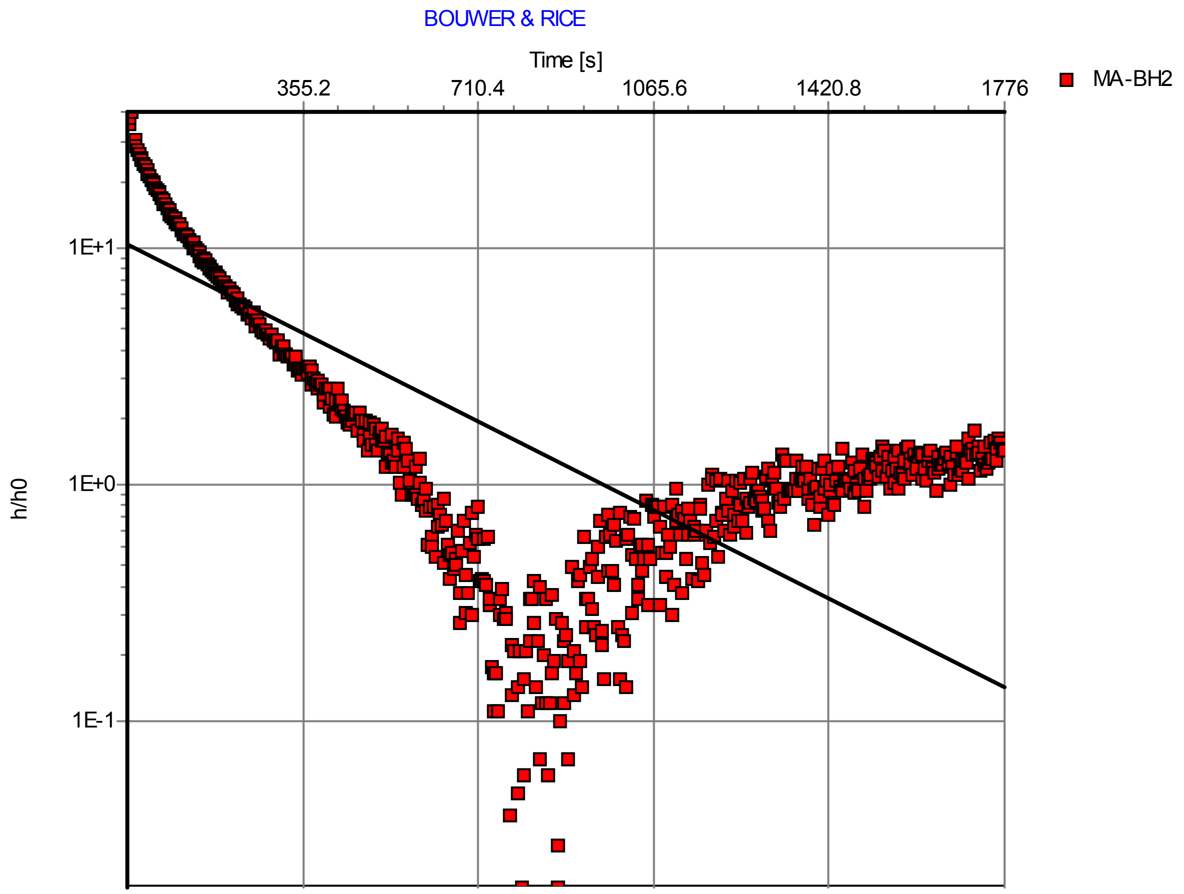
AURECON AGS 3_1 RTA 1_1 LIB 06.1.GLB Log AURECON ZA GEOHYDROLOGICAL MABOPANE CEMETERY.GPJ <<DrawingFile>> 31/03/2015 10:34

APPENDIX D

SLUG TEST ANALYSIS

Lynwood Bridge Office Park 4 Daventry Street Lynwood Manor		**Slug test analysis** No: Project: Mabopane Cemetery Client:

Location:	Slug test: MA-BH2	Test well: MA-BH2
Test performed by: M Terblanche Test date: 2015/03/16		Evaluated by: Evaluation date: 2015/03/16
Analysis method: BOUWER & RICE		Aquifer thickness: 19.08 [m]



Conductivity: 6.36×10^-2 [m/d]

APPENDIX E

LABORATORY REPORTS

aquatico Laboratories (Pty). Ltd.

T0374

Test Report

Client:	Aurecon	**Date of certificate:**	18 March 2015
Address:	Lynwood Bridge Office Park, No. 4 Daventry str., Pretoria, 0081	**Date accepted:**	12 March 2015
Report no:	23503	**Date completed:**	18 March 2015
Project:	Aurecon	**Revision:**	0

Lab no:				206254	206255
Date sampled:				12-Mar-15	12-Mar-15
Sample type:				Water	Water
Locality description:				MABH1	MABH2
	Analyses	**Unit**	**Method**		
A	pH @ 25°C	pH	ALM 20	8.35	6.96
A	Electrical conductivity (EC) @ 25°C	mS/m	ALM 20	32.9	53.1
A	Total dissolved solids (TDS)	mg/l	ALM 26	195	327
A	Total alkalinity	mg $CaCO_3$/l	ALM 01	138	130
A	Chloride (Cl)	mg/l	ALM 02	21.1	25.2
A	Sulphate (SO_4)	mg/l	ALM 03	5.31	11.6
A	Nitrate (NO_3) as N	mg/l	ALM 06	0.231	21.7
A	Ammonium (NH_4) as N	mg/l	ALM 05	0.019	0.019
A	Orthophosphate (PO_4) as P	mg/l	ALM 04	0.065	0.065
A	Fluoride (F)	mg/l	ALM 08	3.21	1.36
A	Calcium (Ca)	mg/l	ALM 30	24.0	55.3
A	Magnesium (Mg)	mg/l	ALM 30	2.29	10.5
A	Sodium (Na)	mg/l	ALM 30	52.8	42.4
A	Potassium (K)	mg/l	ALM 30	1.19	4.71
A	Aluminium (Al)	mg/l	ALM 31	<0.003	<0.003
A	Iron (Fe)	mg/l	ALM 31	<0.003	<0.003
A	Manganese (Mn)	mg/l	ALM 31	<0.001	<0.001
A	Total hardness	mg $CaCO_3$/l	ALM 26	69	181

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

M. Swanepoel
Technical Signatory