

Effects of Dolerite Intrusions on the geohydrology of Karoo sediments in the Mount Frere area, South Africa

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Abstract

The Karoo Supergroup has a geohydrological regime which is largely controlled by Jurassic dolerite dyke and sill complexes. The study area is located in the central interior of the Eastern Cape Province, in the former Transkei. The sedimentary rocks of the middle Karoo constitute fractured and intergranular aquifers, due to relatively hydro-conductive lithologies. The main groundwater production targets within the upper Karoo are related to dolerite intrusions that have a number of characteristics that influence groundwater storage and dynamics. Magnetic and electrical resistivity geophysical techniques are used in this study to determine the different physical characteristics of the dolerite intrusions, such as size, orientation and the level of weathering. Trends in the data collected from a large-scale development programme, can provide evidence that intrusion characteristics also play a role in determining the geohydrological characteristics of the area. Interpreted geophysical, borehole drilling, aquifer testing and water chemistry data can be used to indicate geohydrological differences between dolerite intrusions, undisturbed sedimentary formations and structurally controlled lineaments. Using the Flow Characteristics (FC) software, pump testing data is analysed for the presence of no-flow boundaries and to determine sustainable duty cycle yields per successful borehole. The chemical content of each successful borehole is also determined by laboratory analysis. This is done to aid in determining the character of the water as well as determining correlations between basic chemical indicators such as pH, electrical conductivity (EC) and total dissolved solids (TDS) and problematic elements such as fluoride and iron. Observed trends in the data collected could be used to identify more accurately future well field target areas and the development thereof.

Keywords: Karoo, Umzimvubu, Dolerite, Groundwater, Lineaments, Drilling.

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1. Introduction

1.1 Background

Groundwater as a resource represents an underutilised and underdeveloped fraction of South Africa's hydrological system (Knüppe, 2011). With increasing pressure on surface water resources and the priority of supplying rural communities with water suitable for human consumption, it is evident that groundwater will play a larger role in the socio-economic wellbeing of South Africa (Braune and Xu, 2009).

This rapid growth in importance of the groundwater resource is met with an apparent lack of knowledge of the potential of this resource. Groundwater can be a reliable resource when properly managed; it is however, in general, seen as a second option to expensive and in places less reliable surface water schemes. This is because of the lack of knowledge regarding its potential and in some cases its existence (Smart, 1998).

This mind-set will have to change, because as is known in terms of the presence of fresh water on earth, groundwater constitutes up to 24.67% of the 25% that is not caught up in glaciers (Chevalier *et al.*, 2001). The above- mentioned misconception of groundwater being an unreliable resource is one of the major factors why groundwater contributes only 10% of the national water budget. Approximately 66% of South Africa's land surface consists of arid to semi-arid environments, especially the central and western areas. In places where these areas have no usable surface water, they rely almost exclusively on groundwater.

The general yield of these aquifers is, however, not very high with an average of 3600 l/h (1 l/s). Therefore, the commonly accepted view is that Karoo aquifers do not contain large quantities of water, hence the name Karoo, meaning dry in the indigenous language of the Khoikhoi people. In total, the Karoo Supergroup covers approximately 80% of South Africa's land surface and many large buildings that are built on these rocks constantly have to monitor and dewater the rock formations below their foundations to insure structural failure does not occur. This is not a situation which is expected to occur in a geological setting with limited yield (Botha *et al.*, 1998).

A significant geohydrologically influential feature to occur throughout the Karoo Supergroup is undoubtedly the Jurassic dolerite intrusions that intruded the mostly horizontal Karoo sedimentary rocks. The dolerite crystallized into three features during the intrusive process, namely dykes (vertical structures), sills (horizontal structures) and rings (conical structures) (Walker and Poldevaart 1949).

Associated with these intrusions are “fractured” as well as “fractured and intergranular” aquifers. Fractures associated with the intrusive process occur within the dolerite itself and extend outwards into the country rock. The dolerite rock itself can also become weathered as a result of fracturing which allows weathering agents such as groundwater to access the rocks as well as the susceptibility of dolerite’s mineral composition to weathering. When it is sufficiently weathered, the once dense intrusive rock can also act as an intergranular aquifer (Smart, 1998).

As a general trend, it is accepted that boreholes associated with dolerite intrusions are generally higher yielding than those associated with sedimentary rocks only (Chevalier *et al.*, 2001). Although dolerite structures, dykes in particular, are favoured as targets for groundwater supply scheme development, Vandoolaeghe (1980a) concluded that the dolerite structures do not stand out for their prolific yield production and “the exploration of these aquifers are not straight forward”.

1.2 Problem Statement and Research Objectives

An issue which is currently present in groundwater supply projects, especially those with lower budgets such as rural water supply projects, is unsuccessful drilling operations. Such projects, set in Karoo lithologies with dolerite intrusions and more specifically dolerite dykes, have been the primary targets for drilling operations. These have been successful in a theoretical sense in many cases. The dykes, however, have many characteristics that need to be taken into account such as width, orientation, the level of weathering, related fractures and type of country rock.

The study will attempt to address the following research aims and objectives:

- It is an aim of this study to attempt to determine which physical characteristics of the dolerite intrusions affect the yield and quality of water obtained most. The presence of lineaments is also rife throughout the Karoo Supergroup; this study aims to determine whether or not the dolerite intrusions make more attractive drilling targets. The primary aim of the study is to attempt to make recommendations towards more effective and therefore also more financially viable drilling.
- This study will then attempt to bridge the gap between regional and local scale data, by means of a multi spatial scale approach, by making recommendations on a regional scale using data collected during a field work operation over the study area. In many cases constraints such as time, manpower and financial viability don't allow for large scale ground based data collection, which then forces the study into a single scale approach. In the case of limited resource availability, a larger, regional scale is generally the norm, which is not necessarily accurate on a local scale.
- As an objective, all major lineaments within the study area have to be delineated to allow for the comparison to dolerite dykes as drilling targets. The structure orientation of the dykes and lineaments are to be compared to attempt to determine whether or not structure orientation plays a role in the success of borehole development.
- Studying drilling logs obtained from boreholes drilled during this study can allow for the determination of optimum drilling depths in terms of yield attained per strike depth. The presence of no-flow boundaries within the aquifer surrounding newly developed boreholes negatively affects the sustainable yield that can be recommended for water supply from a borehole.
- As an objective, it would be necessary to determine whether or not no-flow boundaries are more prevalent within dolerite intrusion when compared to other drilling targets.

- The potability or chemical makeup of the water obtained from a successful borehole also has an effect on whether or not the borehole can be used for human supply. The association of water strike depth and water chemistry is to be looked at, and whether or not water strike depth affects the groundwater quality that can be expected from a borehole.

1.3 Document Layout

Following the introduction, this document made up of the following sections:

2 Literature Review

All literary sources of information, which are of importance to the study area and study method, are summarised in this section.

3 Methodology

This section details the manner in which the study is approached and data collected, as well as processed.

4 Environmental Overview

The environmental setting of the study area is stipulated in this section.

5 Results

The collected data from all field work, software analyses and laboratory analyses is summarised in this section.

6 Discussion

All results are discussed in this section and any visible trends are noted.

7 Conclusions and Recommendations

The trends noted in the discussion section are concluded and recommendations for future research are made in this section.

8 References

A list of all literary references used in the study.

9 Appendices

All geophysical, drilling, pump testing analysis and chemical data used in the study are documented in these sections.

2. Literature Review

2.1 Study Area

In the Water Research Commission's (WRC) report, 'The Research needs for the eastern Karoo Basin (Murray *et al.*, 2006), approximately 14% of South Africa's population or 6.2 million people, live in the old Transkei. The residents of this area, because of the political turmoil in South Africa's past, have very little in terms of basic necessities, such as housing and sanitation. Groundwater is seen as an ideal solution for water provision and sanitation issues, because of its general good quality and its usability for small scale operations, such as the scattered villages of the rural Eastern Cape.

The locality of the project area is Ward 13 and 15 of the Mzimvubu Local Municipality, which is one of the four local municipalities of the Alfred Nzo District Municipality and can be seen in Figure 1. The Mzimvubu Municipality is located around the town of Mount Frere in the north-eastern region of the Eastern Cape.

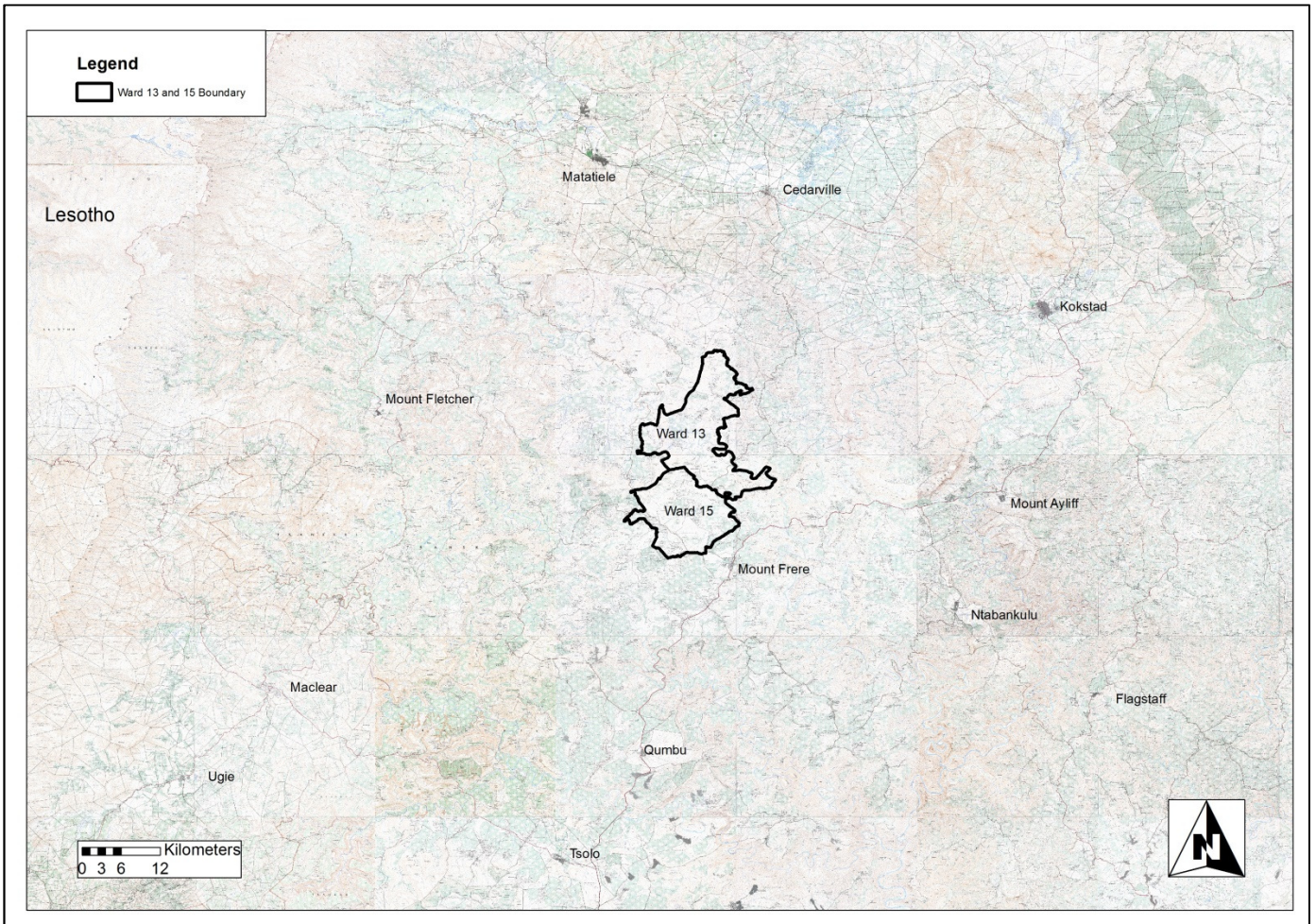


Figure 1 Locality map of the project area.

Management plans for sustainable future use of groundwater resources are of paramount importance to development projects in rural areas. The traditional issues with boreholes in rural areas are over-utilisation and neglect or vandalism of equipment (Department of Water Affairs and Forestry (DWAFF), 2009).

Two of the major future research needs for the eastern Karoo Basin, according to this document are the scientific siting of boreholes and well field development to accommodate water provision on a larger scale than the current well fields.

As limited work has been conducted to date in the eastern Karoo Basin, in comparison to the central and western areas of the Karoo Basin, many boreholes have been sited wherever it is most convenient to erect a wind pump or where a drill rig will struggle the least with establishment. In order to serve villages with large numbers of inhabitants, very accurate borehole siting is essential to obtain the maximum yield possible from an aquifer. Deep seated

fractures associated with regional structures, such as the dolerite intrusions of the Karoo, are to be the major targets for such large-scale supply projects. Because of this increased need for rural water supply, it is necessary to identify well fields in terms of highest potential yield, as well as highest abstraction rates (Smart, 1998).

The project area is situated in the geological setting of the Beaufort Group, which is subdivided into two main subdivisions namely the Tarkastad and Adelaide Subgroups. The regional geological setting is indicated on Figure 2.

The Adelaide Subgroup (252-242 Ma) is subdivided into the Koonap, Middleton and Balfour Formations, of which the Adelaide Formation is present in the study area. The Adelaide Formation consists mainly of bluish-grey, greenish-grey or greyish-red mudstone as well as fine to medium-grained lithofeldspathic sandstone.

The Tarkastad Subgroup (242-230 Ma) consists of two major formations, namely the Katberg and Burgersdorp Formations, with the Katberg Formation being present in the study area (Groenewald, 1996). The Katberg Formation is more than 90% sandstone (Groenewald, 1989). The majority of the boreholes drilled in this study were on Katberg Formation country rock.

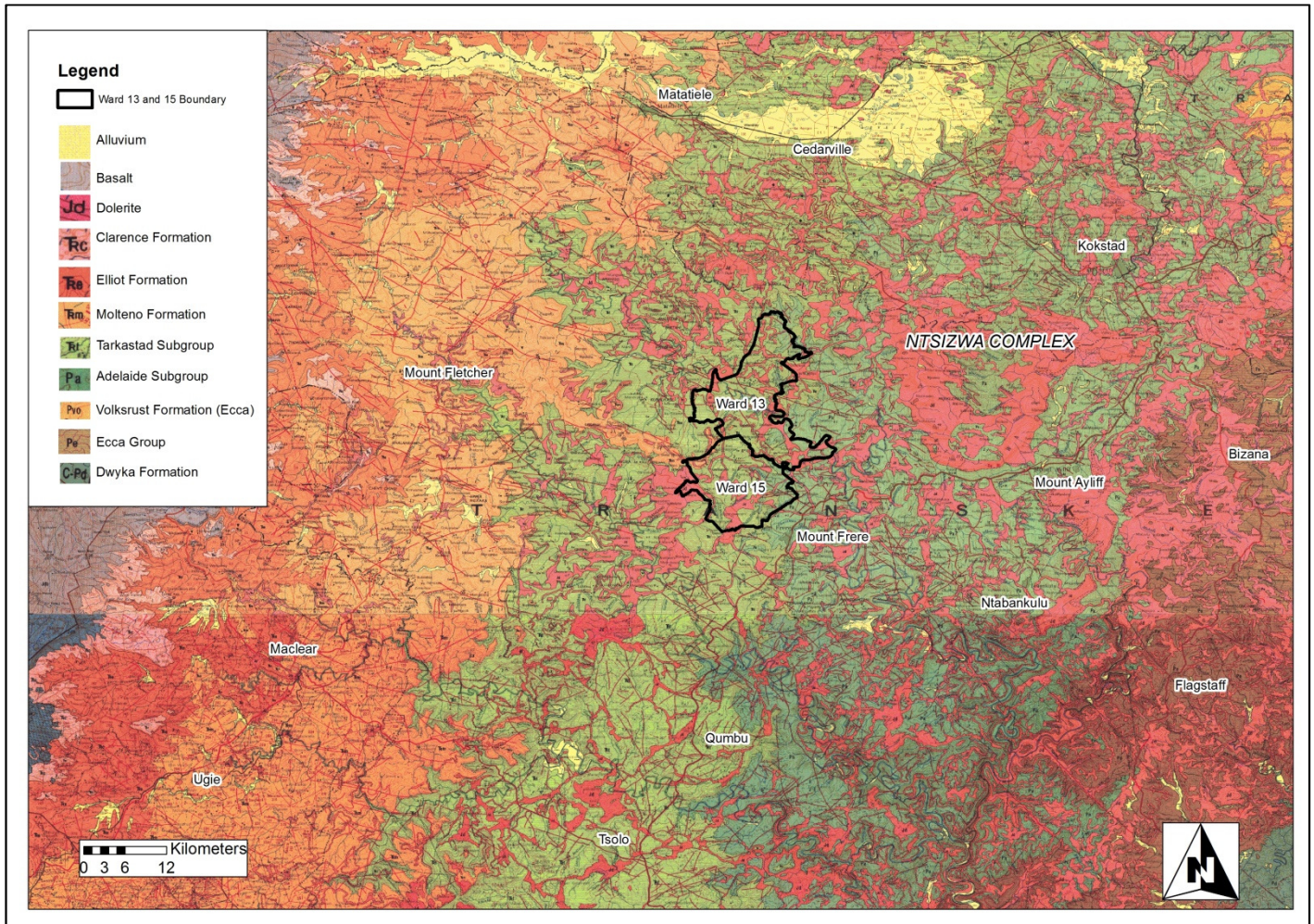


Figure 2 Regional geological setting modified from the 1:250 000 geological map of Kokstad.

The very first geological interpretations of the area and geological mapping expeditions were undertaken by Du Toit (1905) who attempted to accurately map out the Karoo Basin, including the former Transkei territories, most of which was conducted on horseback. The theories of their earliest publications were then later improved on in Du Toit (1920). Of major interest to the early explorers were the Dolerite or “Ironstone” formations which were igneous of origin. In his 1920 paper, Du Toit describes the large anti- conical dolerite structures as having an “egg box” shaped structure. This was the first attempt to describe what is now known as the dolerite ring structures, or inclined sheets.

Walker and Poldervaart (1949) undertook a very extensive study to better interpret the complicated Karoo intrusive province. The focus of this study was an attempt to interpret mineralogical data collected from samples throughout the

Karoo. Mentioned as goals of the study were to better understand the relationship between the Basutoland and Stormberg basalt escarpments as well as the ability of the dolerite intrusions to mobilise and metasomatize the surrounding country rock.

Their research on the dykes in the Karoo, specifically studying the intrusion angle, orientation and the interaction with the country rock is very important in understanding the nature and characteristics of the Karoo intrusions. The sole purpose of the study was to better define and map the intrusive rocks to better understand this origin; however, the study has many groundwater applications such as the nature of weathering of the Karoo intrusive rocks.

This study was then improved on by Hunter and Reid (1987) who attempted to identify variations in the mineralogical composition between what was perceived to be different members of the Jurassic Karoo intrusions. More advanced technology was available by then and interpretations were made from aerial photographs in conjunction with laboratory data. Separation of intrusive events could not be concluded with certainty as the intrusions are so extensive that it is almost impossible to single out an individual intrusive event (Chevalier and Woodford 1999).

The origin of the dolerite intrusions that riddle the Karoo Supergroup is from the breakup of Gondwana, the super continent, approximately 190-180 Ma. The breakup caused massive quantities of intermediate dolerite magma to intrude into the Karoo Supergroup from a triple point fault area of the coast off East London, which is possibly the epicentre for this large scale tectonic event. The greatest evidence for this is that it seems that the East-West trending dykes from the western Karoo and the North-Western and North-South trending dykes of the central and eastern Karoo merge at this triple point (Chevalier *et al.*, 2001).

2.2 Methodology

Several studies have cited the issue of implementing a multi scaled approach when studying a specific area, as most studies are based on regional norms or isolated to a small area where site specific data were collected both related and unrelated to groundwater studies (Lanini and Caballero, 2016; Fekete *et al.*, 2009 and Kanivetsky and Shimagin, 2005). This then highlights the importance

of first collecting and studying the information available on the regional setting of a study area during the desktop phase of study.

One method of making more accurate assumptions on the condition and make-up of the subsurface is by geophysically surveying a target area. Two geophysical methods were used during this study, namely making use of a proton precision magnetometer and electrical resistivity in the Wenner array setup.

The proton magnetometer consists of a sensor and an operating unit, joined together with a cable. The sensor contains a proton-rich fluid, usually kerosene, around which a wire coil is wound. The protons inside the liquid act as spinning magnets. The spin axes precess in the direction of the earth's magnetic field in much the same way as a gyroscope precesses in the direction of the earth's gravity field.

When the device is off, the magnetic field of the protons is randomly orientated. When it is turned on, a current is sent through the coil and all the spin axes of the protons are aligned in the direction of the magnetic field. When the device is turned off, the spin axes will start to oscillate because the protons will align themselves with the earth's magnetic field. This oscillation induces a voltage on the coil and the frequency of this oscillation will be equal to the precession rate proportional to the earth's magnetic field.

The operating unit (battery, switch, counter and amplifier) of the magnetometer provides the pulse current for the coil and contains the electronics that measure and record the earth's magnetic field, in nanoteslas (nT), (Roux, 1980) Figure 3 is a basic diagram showing the different components of the magnetometer.

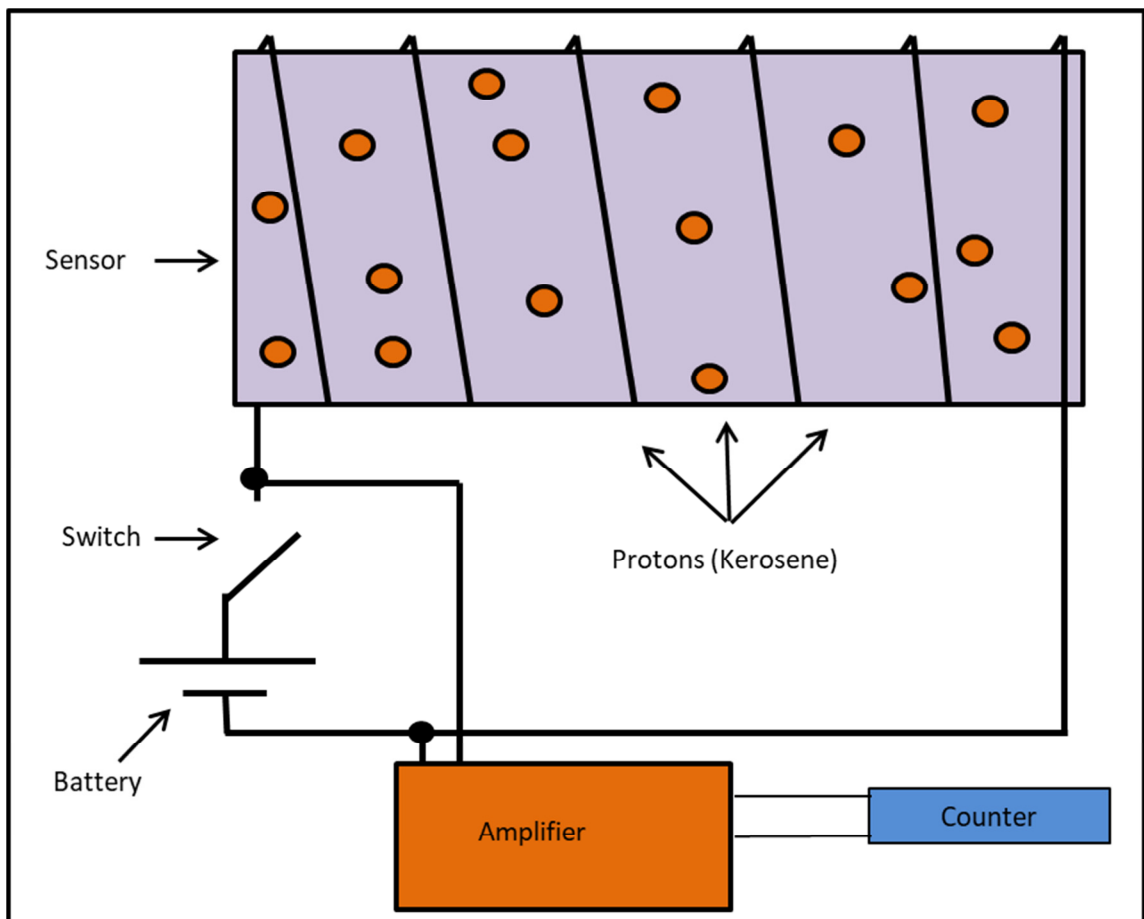


Figure 3 Proton precision magnetometer components diagram.

To maximise the effectiveness of the magnetic survey profile it is useful to attempt to detect the weathered zones along its margins, as the majority of water-bearing fractures are situated within the weathered zones in and along the margins of a dolerite intrusion.

The Resistivity method uses two sets of electrodes, two (AB) which conduct a current through the earth and two (MN) which measure the difference in potential between A and B. Depending on the objective of the survey, there are different arrays that can be used to collect data namely the Wenner, the Schlumberger, the pole-dipole or the dipole-dipole arrays.

There are two ways of conducting a resistivity survey, namely sounding or profiling. Sounding entails the device being stationary and the electrodes are moved further and further apart, to increase the depth of the investigation. When profiling is conducted, the electrodes are kept at constant distances and are

moved along a horizontal line on the surface at constant intervals, which allows the operator to view relative changes in resistivity over a distance.

For this survey, the electrical resistivity method is applied, using the Wenner array, with constant 40m spacing over a horizontal distance, Figure 4 demonstrates the electrode spacing implemented during the resistivity survey. This, coupled with the data from a proton magnetometer serves as a major information source on which siting boreholes is based (Van Zijl, 1987).

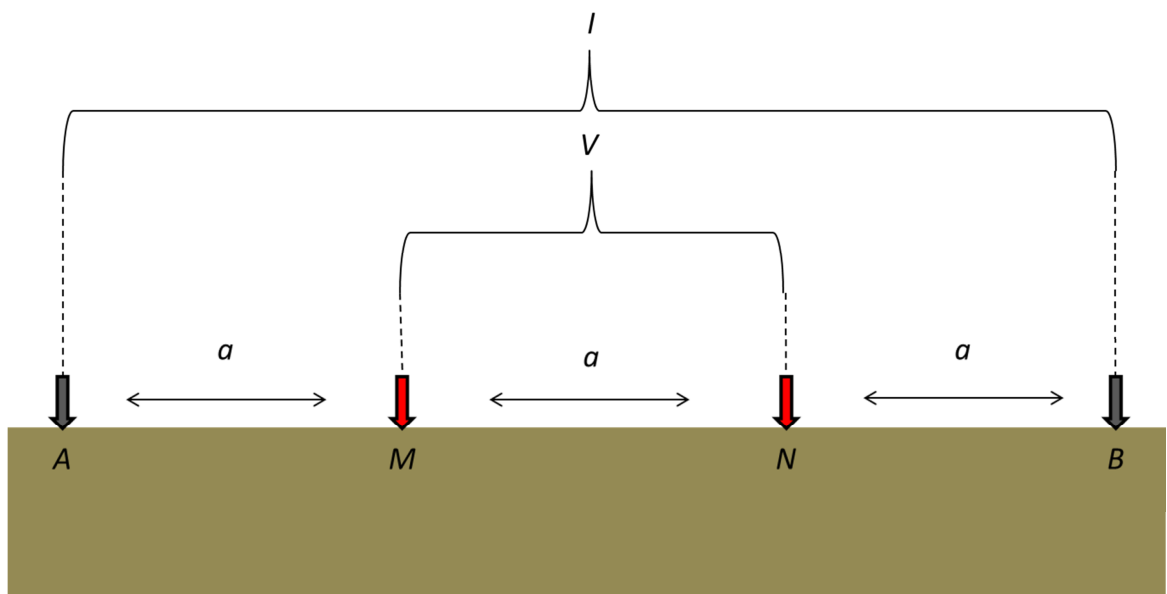


Figure 4 Electrical resistivity electrode arrangement (Wenner array electrode spacing)

The broader geohydrological features of the study area were defined by Smart (1998) in the explanation of the Queenstown hydrogeological map. The author used a groundwater development plan (Steffen Robertson and Kirsten, 1993) which was produced using historical borehole data as well as the existing geological maps of the area to allocate certain conceptual yields to specific lithologies.

These yields have been based on the simplified characteristics of the geological units, also dividing the geological units into four aquifer types for the purpose of the 1:500 000 map series. Classified as intergranular, fractured, intergranular and fractured or karst aquifers, the classification is strongly based on primary

porosity and permeability of the lithology itself. It also includes other aspects that are likely to have an impact on the groundwater occurrence, such as the presence of dolerite intrusions. As mentioned in the background section, the focus of this study will be the fractured as well as fractured and intergranular aquifers surrounding dolerite intrusions.

The mineralogical nature of dolerite intrusions allow it to weather in such a way as to form a coarse porous medium, which will transmit water in a similar way to alluvial sediments if advanced levels of weathering are present (Chevalier *et al.*, 2001). It is, however also, possible for clay weathering products to form, which reduce fracture transmissivities, in particular at shallow depths where infiltration, recharge and discharge are most prevalent (McAdam *et al.*, 2008). A large variance in associated transmissivities and fracturing along a specific dyke was noted by Dondo *et al.*, (2010).

The rate and pressure at which the dolerites intruded caused apparent high levels of secondary fracturing of the Karoo sediments along the chilled margins of the intrusions. It is this high tectonically disturbed area around dolerite intrusions which makes them attractive drilling targets. The description of these intrusions, is well noted by Chevalier *et al.*, (2001).

Even with the presence of abundant dolerite intrusions (dykes and sheets) in the research area, groundwater yields seldom exceed 3 l/s. The research area plays host to numerous heterogeneous aquifers, contact surfaces between sand and mudstone layers, and contributes the majority of high yielding aquifers, which contribute to the 0.2-1.4 l/s average yield (King, 2002).

Chevalier *et al.*, (2001) summarised the results of 603 boreholes around the Victoria West area, which are also situated within the Beaufort Formation. The summary was based on the morpho-tectonic class of the borehole. A summarising table separates the classes into linear dyke, feeder dyke, inclined sheet, inner sills, outer sills, sediments above sills and sediments. The mean yield of the boreholes classed to be drilled on sediments only was 2.2 l/s and this was considered to be the ambient groundwater conditions of Beaufort rock which has not been structurally disturbed. A maximum yield of 12.6 l/s was achieved on the undisturbed sediments, at a relatively low standard deviation of 2.17. Feeder

dykes and linear dykes have mean yields of 3.44 l/s and 2.8 l/s respectively and maximum yields of 15.9 l/s and 25 l/s respectively. The highest yielding morpho-tectonic class was the sediments above sill class, with a mean yield of 3.39 l/s and a maximum yield of 30.15 l/s. This class, however, has the highest standard deviation at 5.17 and no such structure was purposefully targeted during this study.

The extent of fracturing around dolerite intrusions, though prominent in comparison to post Jurassic tectonic fracturing, is limited. Therefore, Botha *et al.*, (1998) concluded that it is the formations and not the fractures that act as the main storage units in Karoo aquifers. This view is in contradiction to the more commonly accepted view that Karoo country rocks have low primary porosity and permeability (Woodford and Chevalier, 2001). Botha *et al.*, (1998) also stated that flow in Karoo aquifers resembles that of flow in a porous medium.

The groundwater map explanation booklet (King, 2002) contains a groundwater quality map, using electrical conductivity (EC) as the major variant. According to the author, the study area can expect EC ranges of 0-70mS/m, which are very low, and will be advantageous for rural supply projects. The presences of elevated salinity could indicate the presence of high concentrations of anions. The groundwater quality map for South Africa is shown in Figure 4.

Anthropogenic influences such as the construction of pit latrines and dip kraals and the expansion of burial sites, were not taken into account when the map was produced.

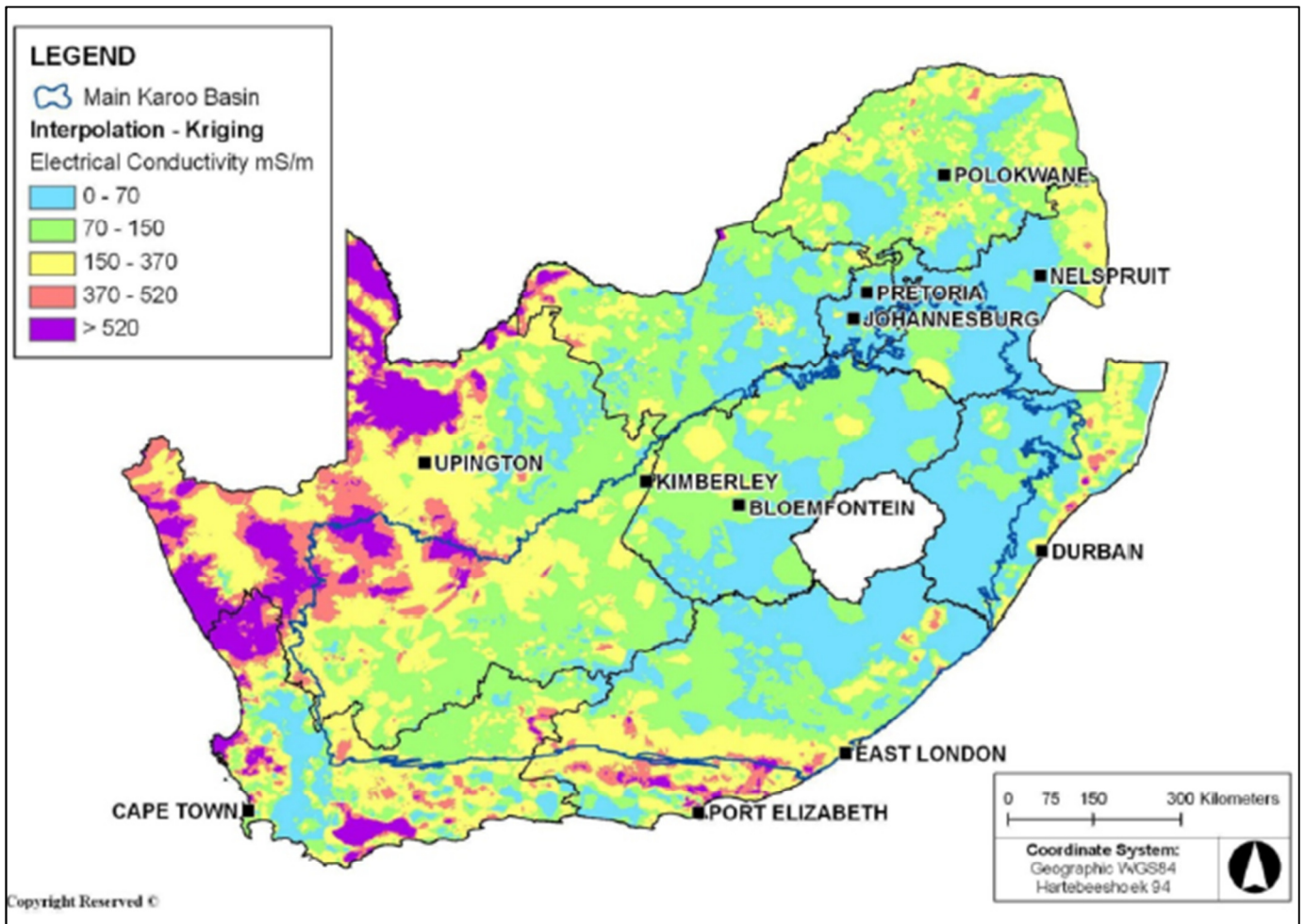


Figure 5 Groundwater quality map of South Africa in terms of EC. Modified from Murray *et al.*, 2012.

Precipitation is in all probability the most important environmental contributor to groundwater recharge. The highlands to the north of the study area receive frequent snow on the mountain tops, which also contributes a small portion of the groundwater recharge to the area. The Water Resource 2012 (WR2012) and Groundwater Resource Assessment II (GRAII) data sets provided monthly precipitation data as well as catchment-based annual precipitation data.

Recharge is explained by Connelly, *et al.*, (1989) in the investigation of rainfall recharge in groundwater. In this study, many versions of groundwater recharge calculation methods are discussed, such as the general recharge model, the direct measurement method, water balances, Darcian methods and tracer techniques. DWAf (2009), completed a large scale groundwater assessment as a part of the Mzimvubu development project, which was commissioned by the Department of Water Affairs (DWA). The allocable groundwater availability and

groundwater Reserve as a percentage of groundwater recharge, were major goals for the study team. According to the study, the research area has a medium groundwater potential with an allocable yield of 4-8Mm³/a. The most favourable groundwater recharge, is in the Tarkastad Subgroup, where 2-5% of groundwater occurrence is attributed to recharge. The WRMS 2005 (GRAII) data set provides accurate quaternary catchment based recharge data.

A groundwater resource development program, based on the DWAF (2009) groundwater assessment was carried out by a private company. The target areas are known as Ward 13 and Ward 15 of the Mzimvubu local municipality, which is the study area for this dissertation. The project area is situated north west of the town of Mount Frere in the central Old Transkei area of the Eastern Cape. The environmental setting of the study area has been described by Mucina and Rutherford (2006) as more moderate in terms of temperature and precipitation than is the norm in the Western Karoo.

Much work has been conducted on the Karoo by the WRC in an attempt to better understand the geohydrological system (Botha *et al.*, 1998; Woodford and Chevalier 2001; Woodford and Chevalier 2002a and Dondo *et al.*, 2010). Research in the study area for this dissertation however has been limited.

A large-scale study on the Mzimvubu to Keiskamma and Mvoti to Mzimkulu Water Management Areas (WMAs) was discussed in Dondo, *et al.*, (2010). The target of the study was to determine recharge and storativity of aquifers in the above mentioned WMAs, as well to create conceptual flow models for them.

As Lesotho is situated to the north of the study area, it is of international importance that the Karoo trans-boundary aquifer is better understood. According to The International Groundwater Assessment Center (IGRAC), the Eastern Karoo aquifer underlies a surface area of some 165 936 km², making it one of the largest trans-boundary aquifers in Sub-Saharan Africa (IGRAC, 2015).

The importance of groundwater monitoring is stipulated by Jousma (2006) in relation to preserving the aquifer so that future groundwater abstraction can be undertaken without damaging the aquifer.

Rotary air percussion drilling is the method most commonly used in groundwater exploration and production drilling. The method uses pneumatic pressure to drive the drilling action into a dual action drill bit. The drill bit's rotary action grinds rock fine and the percussion, or hammer action loosens and breaks up larger rock formations. This method of drilling is very popular, because the equipment is relatively affordable and it can drill through hard rock formations (Dunster, 2004).

The testing method is the standard of utilising calibration or step tests to determine a pump inlet yield, after which a constant test defined by Van Tonder *et al.*, (2001) is performed, sustainable yields were calculated for the boreholes by utilising the 2007 version of the flow characteristics or FC software developed by Van Tonder *et al.*, (2013). The FC program makes use of multiple analytical equations to determine various parameters of the aquifer.

The graphical output can indicate the presence of fractures and no flow boundaries as changes in the slope of the data. This information is of great importance to the protection and sustainability of the aquifer in question, as an issue that all rural development projects face is the maintenance and diligent management of the implemented infrastructure (Van Tonder *et al.*, 2013).

A combination of three methods is used in this study to determine the transmissivity, storativity and to detect the presence of no-flow boundaries. The Cooper-Jacob and Hantush methods are used in this study to determine storativity and transmissivity. Neither of these equations is ideally suited for the Karoo as both equations are designed for use in confined aquifers, with the Cooper-Jacob designed for non-leaky, heterogeneous, confined aquifers and the Hantush designed for use in leaky, heterogeneous, confined aquifers.

The Theis method, used to calculate the properties of homogenous, confined aquifers, is used to detect the presence of no-flow boundaries. This is done by plotting the data on a semi log – log graph to determine changes in the slope of the plotted data. A doubling in the slope of a plot indicates one closed no-flow boundary and a quadrupling of the slope indicates the presence of two no-flow boundaries.

The hydrochemical testing standards used in this study will be the two South African groundwater standard sets, namely the standards set by DWAF (1998) and the South African National Standard (SANS 241) limits for safe water use (SABS, 2015). The chemical testing was done in strict adherence to the national standards as set out by the SANS 241 guidelines for water quality by an independent South African National Accreditation System (SANAS) approved laboratory. The resultant hydro-chemical data is then graphically illustrated in Piper diagrams, following the methodology of Vegter (2001).

When considering the 1:500 000 hydrogeological map of South Africa, Vegter (1995) stated that the majority (50-60%) of all groundwater samples for the study area fall into the B-quadrant of a piper plot. The B-quadrant is the section that Ca,Mg,HCO₃ dominant samples fall into.

The method of Vegter (2001) is a comparative, statistical approach to the interpretation of borehole drilling results data that allows for simplified general interpretation. Comparisons such as water strike frequency versus total yield per depth can give an indication of the depth a borehole should be drilled for optimum production value. Vegter's approach was first to state what the current groundwater exploration knowledge was in specified area. Then he applied the knowledge gained from the statistical analysis of previous work and lastly he compared the results of his analysis to current knowledge. This was done not only in terms of borehole drilling itself, but also in terms of what geophysical methods are most useful when it comes to the task of siting a borehole for production purposes.

In his reports on the Limpopo Belt (Vegter 2001a), the Makoppa Dome (Vegter, 2001b), the Lowveld (Vegter, 2003) and Bushmanland (Vegter, 2006), he was able to give conclusions regarding the nature of the aquifers in these study areas, as well as how borehole siting should be approached. An example is that because only low yielding boreholes were drilled in the Beauty area of the Limpopo belt, it was recommended that revision of the method of borehole siting in the area was necessary. Also, sites that required further exploration were recommended, such as the Wellust area. This method also allows for the determination of certain hydrogeological features such as the general

geohydrological gradient. This can be achieved when taking into account the static water levels (SWLs) of the boreholes around a certain area.

The hydrochemical characterization of the borehole samples taken during the testing operation were plotted on a Piper Diagram, in accordance with the method followed by King (2002). Recommendations can also be made for chemical treatment or blending of water if the mean hydrochemical content of an identified area is understood. Kumar (2011) found that a relationship exists between the presence of fluorine (F^-) in borehole water and the alkalinity of the water, with more alkaline waters generally being more fluorine rich.

3. Methodology

3.1 Introduction

The method of field research is divided into four phases, with specified tasks handled in each phase. From the inception of the study, phase one commenced and included basic mapping of the study area, from which certain regional target areas could be identified. After regional target areas had been identified, the target areas were then further explored by means of geophysical equipment, such as magnetic, electrical resistivity and frequency domain electromagnetics. After the identification suitable target areas, the development phase can commence during which boreholes are drilled to reach the selected target structure.

If the source development is successful, the physical and chemical characteristics of the aquifer are determined and the physical properties, such as the transmissivity and storativity are interpreted by performing a constant rate pump test and collecting the water level drawdown and recovery data.

3.2 Mapping and Desktop study

A desktop study is at the heart of any scientific study, where results of previous work are reviewed. For this study the desktop study as mentioned in the literature review pointed towards dolerite intrusions making viable targets for groundwater development. The dolerite intrusions are then digitized and mapped out using the mapping programme ARC Maps V 10.1 (ESRI 2010). Two intrusion maps are generated, one of the dolerite dykes and the other of sills.

What is notable regarding the dolerite intrusions in the area is that the dolerite sills represent a very large portion of the surface geology. This is because the dolerites in the area are very closely related to the large Ntsizwa layered gabbro complex, which is present to the north-east of the study area.

Some linear structures are visible on aerial photographs of the study area. However, they do not appear on the geological map of the study area and area known as lineaments. As can be seen in Figure 6, the lineaments closely mimic the dolerite intrusions in terms of their orientation. This then indicates that the dolerite dykes and the lineaments are similar in age as they were likely formed

during the same tectonic event. What is also notable is that during the drawing of the geological map used to delineate the dykes, remote sensing was still a relatively new concept. It is possible that many of the delineated lineaments are actually dolerite dykes that were overseen during the map generation process. The existing geological map is also on a very large scale in comparison to the locality of the study area.

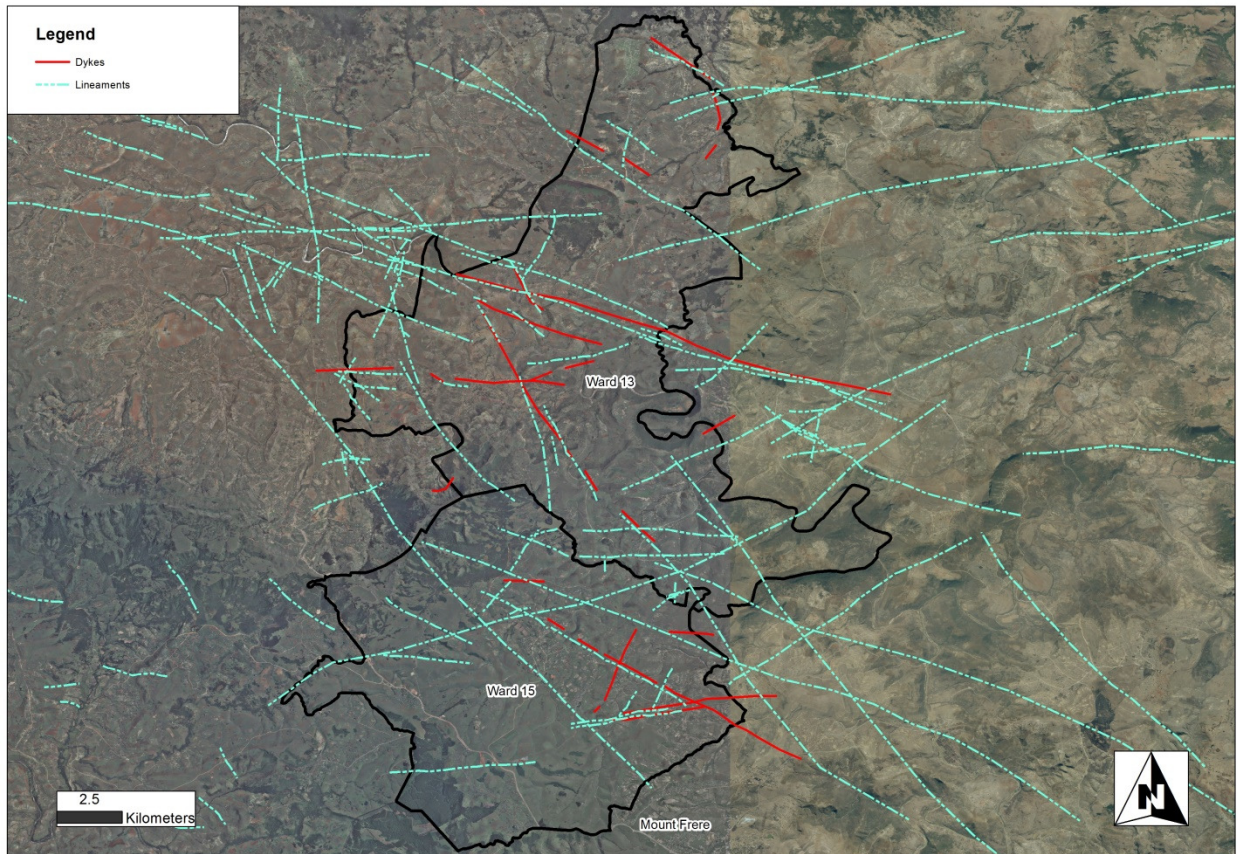


Figure 6 Dolerite dykes and mapped lineaments

3.3 Geophysical Methods and Materials

After successfully confirming the findings of the desktop study by mapping the geological structures on-site it is necessary identify specific exploration drilling sites. Surveying the target area with geophysical methods is ideal for this task. The two methods used in this study as mentioned in Section 2 of this report are the proton precision magnetic and Wenner array electrical resistivity methods.

The operator during the magnetic surveying of an area must consider the temporal changes in the earth's magnetic field when plotting the data. Ignorable changes in magnetic field strength, ranging in the tens of nT, naturally occur during the day. However, during solar-magnetic storms, changes of hundreds and even thousands of nT may occur. Therefore, due to the inaccurate and inconsistent readings, magnetic surveys are not performed during periods of high solar-magnetic radiation.

Figure 7 indicates the geophysical data retrieved from a single survey profile, using both geophysical methods. Running magnetic and resistivity profiles concurrently allows the user to plot the two data sets on the same graph. This method of capturing data enables the user to interpret the collected data rapidly.

In Figure 7A, a positive magnetic anomaly is encountered at approximately 400 to 490 metres from the start of the profile, which is associated with a dolerite dyke intrusion. The section from 340 to 600 metres is then targeted with the electrical resistivity device, in order to assess the levels of weathering and/or fracturing around the intrusion.

Figure 7B conceptually illustrates the geological setting of the profile as interpreted from the collected data. The zone where the highest levels of weathering and/or fracturing are encountered is indicated on the illustration.

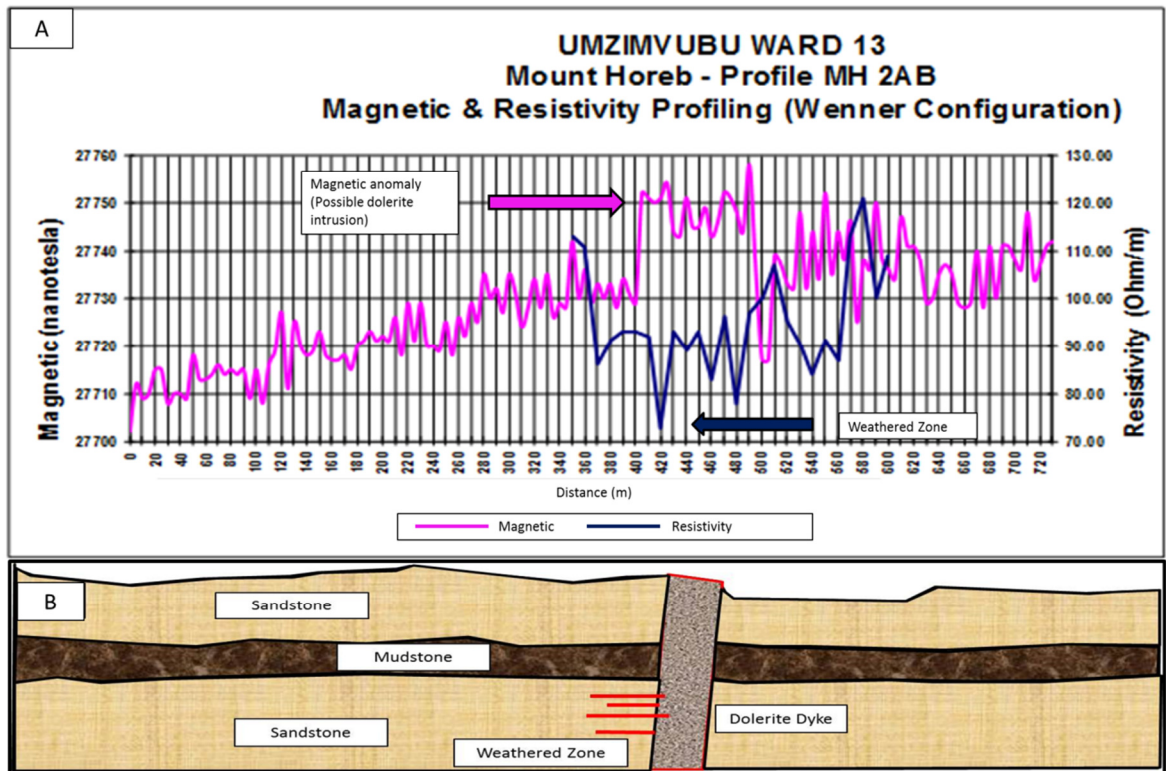


Figure 7 A) shows how Magnetic and Electrical Resistivity data can be combined to form a single picture, with an electrically less conductive zone around a magnetic anomaly. Figure 7(B) is a conceptual model of the possible geological setting of the profile MH 2 AB run in this example. The red lines indicate a possible weathered zone/fracturing.

3.4 Exploration Drilling Method

Phase two includes reviewing and interpreting geophysical data and deciding on drilling sites with the highest potential of producing a successful borehole. Rotary air percussion drilling is the drilling method used to develop the boreholes for the study. This drilling method is driven by air pressure generated by a compressor and channelled down the drill rods to the drill hammer or drill bit. The drill hammer or bit is covered with tungsten “teeth” which allows the hammer action to break up rock easily. The hammer action is further assisted by the rotary motor at the top of the drill which allows the drill to loosen solid rock more easily and blow it out of the top of the borehole.

For the purpose of this study any borehole with a blow yield of 0.3 l/s and higher is considered successful. The blow yield is calculated with the bucket and stopwatch method. This is done by capturing water that is blown out of the

borehole under constant air pressure in a small holding dam around the borehole, from where an outflow gulley can be constructed. When the inflow and outflow to and from the holding dam reaches an equilibrium state, the time it takes to fill a bucket with a known volume is measured. From the volume versus time calculation a blow yield rate can be calculated (Brassington, 1998).

Blow yield = Volume of bucket/Time to fill bucket.

This method is not very accurate, as certain variables can play a role in disrupting the flow of the water into the bucket. If a highly fractured yet low yielding zone is intercepted at shallow depth and a deeper lying water strike is intercepted with a moderate yield, the blowing process can blow the water into the shallower fractures. Also the general method of blowing water out of a borehole as opposed to abstracting water from a borehole with a pump is not accurate as the water can be blown back into the water bearing structure as well.

The blow yield can however provide the consultant/driller/client with a rough idea of what yield can be expected from a borehole. As most studies are run on a budget it is essential for the specialist parties involved to give as much input as possible, to conserve the budget. Figure 8 shows a drill rig in operation during the study.

The drilling procedure includes the use of a 214 mm percussion drill bit, to drill no less than six metres into solid rock to allow the installation of 177 mm steel casing. If a high yielding water strike and unstable formation are intercepted, slotted steel casing can be installed to allow water to flow into the borehole whilst protecting it against collapse (Dunster, 2004).



Figure 8 A drilling rig being operated during the study.

After the drilling operation and borehole construction are completed, the borehole is digitally designed using the Strater 3 software. The software uses drill log data collected on site by the drill operating team or consultant to plot a digital model of the borehole design, as can be seen in Figure 9. The borehole is designed to produce the highest yield as possible and also to be protected against collapse.

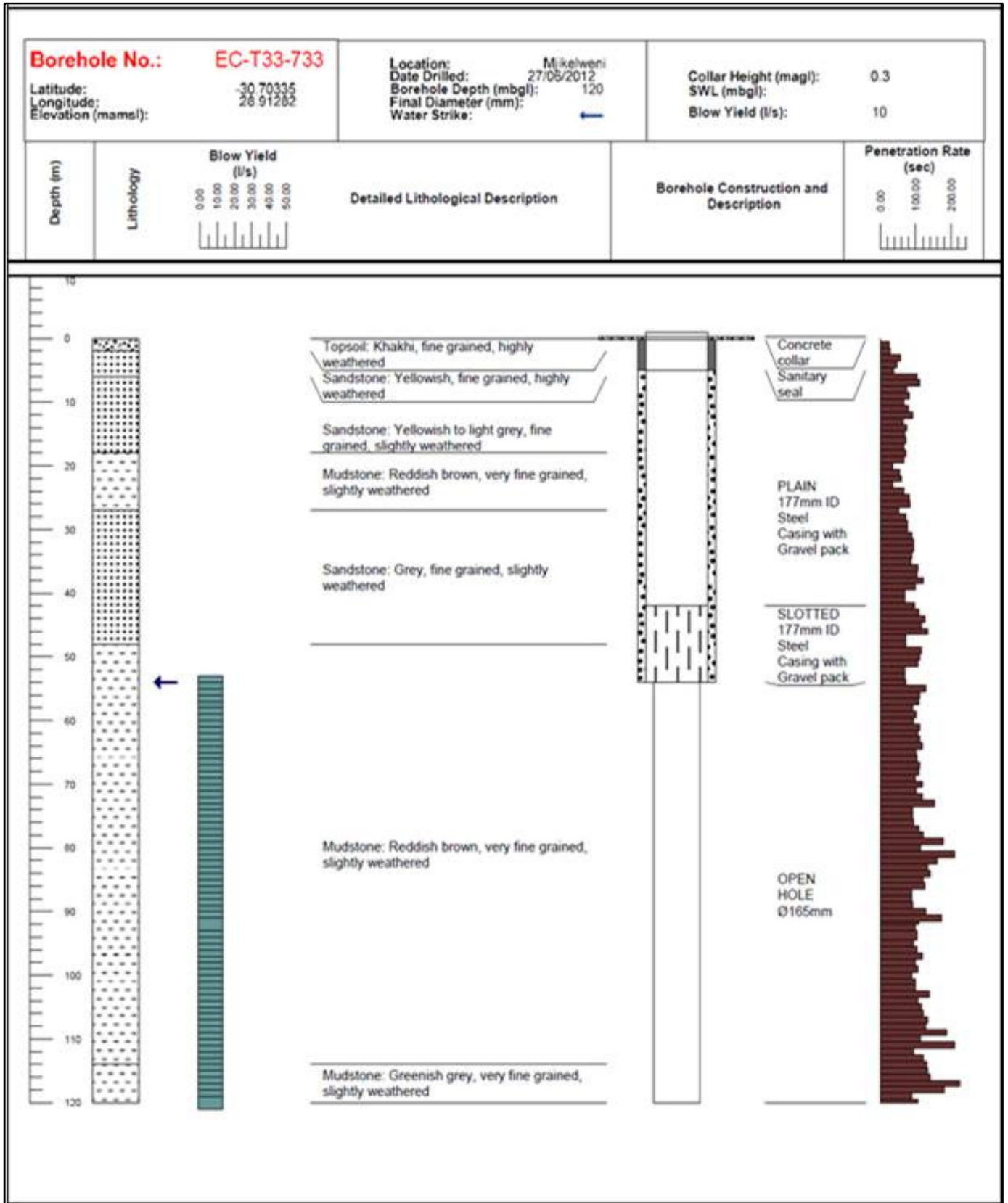


Figure 9 An example of a Starter 3 borehole log, showing the depth, lithology, blow yield, a lithological description, the borehole construction detail and the drilling penetration rate per metre.

3.5 Pump Testing Method

Following the successful development of a borehole, it is necessary to perform a pumping test as the data recorded from a blow yield test is not reliable enough to make a service duty cycle recommendation. Figure 10 shows an operational test pumping rig conducting a test during the project field work phase.

During the pumping test a submersible pump is lowered into the borehole as deeply as possible to allow for the maximum amount of drawdown to be available.

The borehole is then pumped at various rates for typically 30 minutes to 2 hours at a time per pumping rate; this method is known as a step test. The purpose of a step test is to find a rate at which a borehole can be pumped for an extended period of time as in a constant abstraction rate test and is generally performed at yields 0.3, 0.6, 0.9 and 1.2 times that reported by the driller. The constant rate test yield is established by determining the pump inlet yield during the step test. The pump inlet yield is determined by lowering the water level to that of the main water strike by increasing the pump yield rate. If more than one water strike is intercepted and the main water strike is the deepest, this will mean dewatering the upper strikes will be necessary to determine the pump inlet yield of the main strike. The rate at which the water level will stabilise just at the water strike, without pulling it dry, can be seen as the pump inlet rate (Sterrett, 2007).

The rate at which a constant abstraction rate test is run should be high enough to stress the fracture network, but not so high as to empty all the fractures, allowing the pump to suck air. During this test, the drawdown (water level drop) is measured at specified intervals. When the test is completed over the specified period, 12, 24 or 48 hours, the recovery of the water level is also monitored at the same specific intervals (Figure 11 and 12).



Figure 10 Pump testing rig on site during the project.

While the constant rate pumping test is being performed, adjacent boreholes can be monitored manually or remotely with a digital logger to determine the reach of the cone of depression created by pumping the borehole.

The drawdown and recovery rate data is entered into the FC analysis program (Van Tonder *et al.*, 2013).

The FC software produces rapid data results which are conservative in nature, therefore sustainable recommendations can be made towards pump duty cycles. The software also allows the user to determine the depth of the water strikes as well as detect the presence of no-flow boundaries with a fair amount of accuracy.

Borehole EC-T33-733														
TEST DESCRIPTION	STEP	1	2	3	4	5	6	TOTAL	RECOVERY:		RECOVERY TEST			
CALIBRATION TEST:								(mln) (hrs)	(m)	(mln)	TIME TOTAL (hrs): 32.00			
TEST DURATION (Minutes)								0	0.00	0.00	Cal	Steps	CD	Total
TEST YIELD (l/s)								MAXIMUM (%)	0.0		360	1560	1920	
DRAWDOWN (m)								MAXIMUM (m)			DRAWDOWN TOTALS (CD):			
MULTI-RATE / STEP DRAWDOWN:											AVAILABLE	UTIL-	%	
TEST DURATION (Minutes)	60	60	60	60				240	4.00	1.47	ISED			
TEST YIELD (l/s)	5.05	10.10	15.11	20.03				MAXIMUM (%)	20.0		72.4	67.00	92.57	
DRAWDOWN (m)	5.8	11.75	21.14	33.04				MAXIMUM (m)	33.0					
CONSTANT DISCHARGE TEST	TEST DURATION		TEST YIELD		DRAWDOWN		RECOVERY:							
	(mln)	(hrs)	(l/s)		(m)		(m)	%	(mln)	(hrs)				
	1821	27.02	14.97		67.00		3.74	94.42	1560	26.00				
OBSERVATION BOREHOLES:	No.	720	1440		2880		>2880 (mln)		TOTAL:					
	of boreholes	(mln)	(mln)		(mln)		nr.	Time	(mln)	(hrs)				
									0	0.00				

Figure 11 Step and Constant rate test data summary.

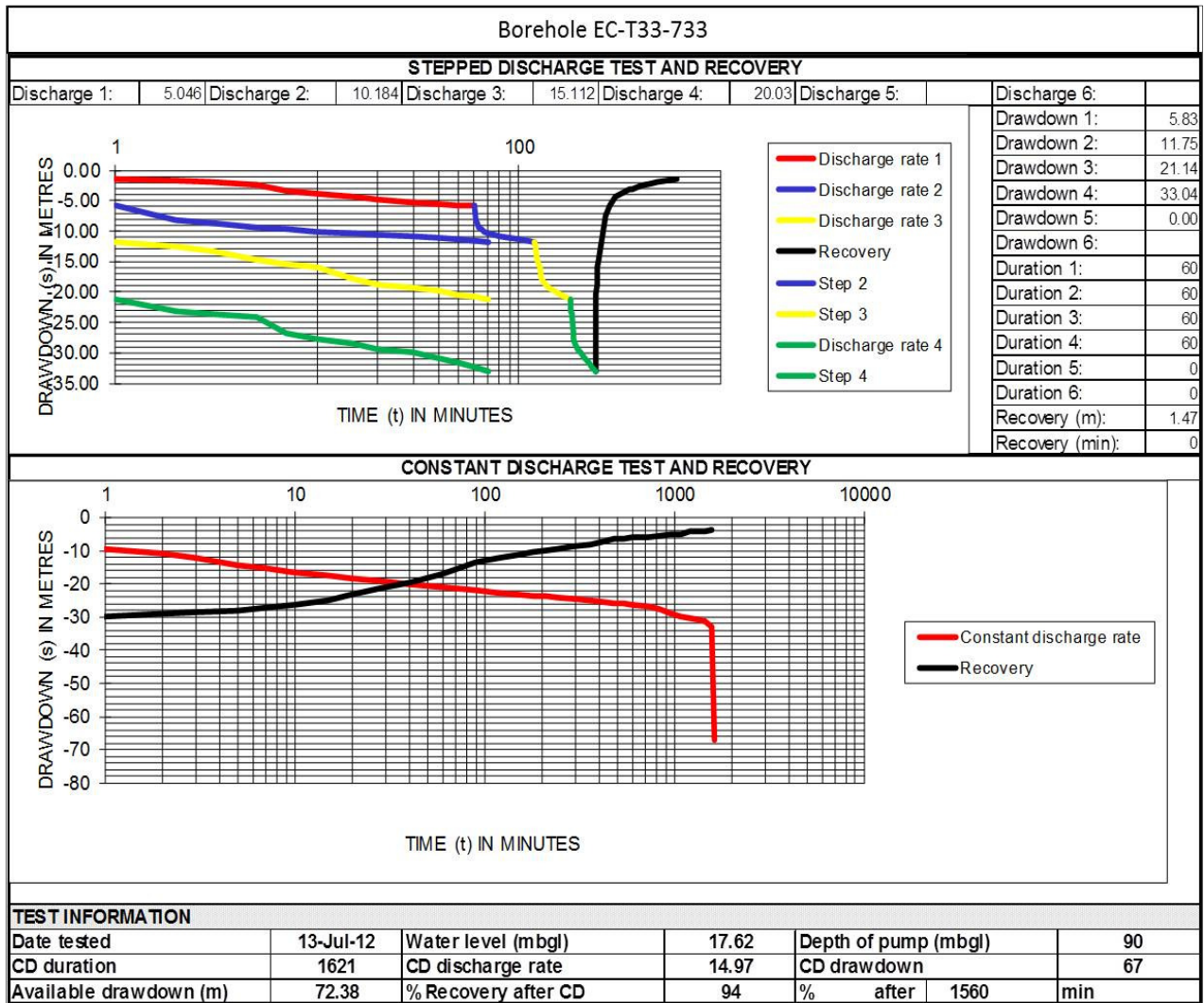


Figure 12 Step and Constant rate test graphical output.

The FC program then calculates borehole sustainable yield, based on the manner in which water enters the borehole, meaning whether flow into the borehole is radial by nature or whether there are no flow boundaries along the margins of the borehole. The presence of no-flow boundaries, such as hard, unweathered rock units within the aquifer, lowers the suggested pumping rate, as the borehole cannot be recharged from the side of the boundary.

Using the Cooper-Jacob (1946) and the Hantush (1956) equations, FC software can determine the average transmissivity and estimate the storativity per borehole as well as the presence of no-flow boundaries. The Cooper-Jacob equation is an approximation solution to the Theis non-equilibrium method explained by equations 1 and 2.

$$s = \frac{Q}{4\pi T} W(u) \quad (1)$$

$$u = \frac{r^2 S}{4Tt} \quad (2)$$

s = Draw down since the start of the pumping test

u = Dimensionless time parameter

Q = Pumping rate of the borehole

T = Transmissivity

S = Storativity

r = Distance of the observation borehole to where the drawdown was measured (m)

t = the time since pumping began

$w(u)$ = Well function (exponential integral) which is approximated by the infinite series (equation 3):

$$W(u) = -0.577216 - \ln(u) + u - \frac{u^2}{2*2} + \frac{u^3}{3*3} - \frac{u^4}{4*4} + \dots \quad (3)$$

Some assumptions are made whilst implementing the Theis equation, such as the borehole penetrates the full thickness of the aquifer, the aquifer material is homogenous, the borehole has a constant pump rate, the aquifer is horizontal and does not slope to either side (Theis, 1935). The Cooper-Jacob method attempts to solve this for non-leaky confined aquifers.

$$s = \frac{Q}{4\pi T} \left(-0.5772 - \ln \left(\frac{r^2 S}{4Tt} \right) \right) \quad (4)$$

The Cooper-Jacob equation is then converted into a decimal logarithmic equation, as follows.

$$s = \frac{2.303Q}{4\pi T} \log \left(\frac{2.25Tt}{r^2 S} \right) \quad (5)$$

This equation applies to the fitment line which the FC software provides. This line is then plotted through the steady state data to produce the resultant of the aquifer parameters such as transmissivity and storativity.

The Hantush method takes into account the possibility of leakage across the confining layer of the aquifer and that an unconfined aquifer exists above it.

$$\frac{\partial^2 h}{\partial r^2} + \frac{1}{r} \frac{\partial h}{\partial r} - \frac{(h_0 - h)K'}{Tb'} = \frac{S}{T} \frac{\partial h}{\partial t} \quad (6)$$

K' = Vertical hydraulic conductivity of the leaky aquifer

b' = Thickness of leaky aquifer

h = Head

$h_0 - h$ = Drawdown

The method however does also make a few assumptions, which are that the aquifer is bound by a leaky confining layer, a source bed (unconfined aquifer) overlies the confined aquifer, the initial water table in the source bed is horizontal, the water table in the source bed remains the same during pumping and the flow of groundwater into the leaky confining layer is vertical. The equation also assumes that the aquifer is compressible and that no water drains instantaneously with a decline in hydrological head and that the leaky confining layer is also compressible and does not lose water from its storativity during pumping.

3.6 Hydrochemical Data Collection Method

A sample is also taken from the borehole during the testing phase and sent for chemical analysis by an independent SANAS approved laboratory and results are summarised in Table 1. From the chemical results, it can be determined whether or not the water from the borehole is suitable for human consumption in accordance with the SANS 214 and DWA regulations.

DWA classes are numerically defined from 0 to 4 (0= Ideal, 1= Good, 2= Marginal, 3= Poor and 4= Completely Unacceptable). The water from the example below is therefore classified as class 1, as it has total and faecal coliforms as well as turbidity concentrations at class 1 levels.

Table 1 an example of the hydrochemical sheet produced from the test results received from the laboratory.

Umzimvubu Ward 13					
Borehole Id			EC-T31-200		
Date Sampled			16-Aug-12		
Drinking water class			1		
Sample Number			8795		
Micro biological properties	Viable organisms				Class
	Faecal coliforms				0
	Total coliforms				1
Physical Properties	Electrical Conductivity	EC	mS / m	31.00	0
	Total Dissolved Salts	TDS	mg / l	222.00	0
	pH Value	pH		7.50	0
	Turbidity		NTU	0.30	1
Chemical properties	Arsenic	As	mg / l		0
	Cadmium	Cd	mg / l		0
	Calcium	Ca	mg / l	24.00	0
	Chloride	Cl	mg / l	12.00	0
	Copper	Cu	mg / l		0
	Fluoride	F	mg / l	0.05	0
	Iron	Fe	mg / l	0.01	1
	Total Hardness	CaCO ₃	mg / l	113.00	0
	Magnesium	Mg	mg / l	13.00	0
	Manganese	Mn	mg / l		0
	Nitrate	N	mg / l	1.92	0
	Nitrate	NO ₃	mg / l		0
	Potassium	K	mg / l	0.40	0
	Sodium	Na	mg / l	11.00	0
Sulphate	SO ₄	mg / l	1.94	0	
Zinc	Zn	mg / l		0	
Chemical properties (not required for the classification of domestic drinking water supply)	Ammonia	NH ₄	mg / l	0.08	
	P - Alkalinity	CaCO ₃	mg / l	10.00	
	M - Alkalinity	CaCO ₃	mg / l	131.00	
	Calcium Hardness	CaCO ₃	mg / l	60.00	
	Magnesium Hardness	CaCO ₃	mg / l	54.00	
	Carbonate	CaCO ₃	mg / l		
	Bicarbonate	HCO ₃	mg / l		
	Silica	Si	mg / l		
Phosphor	PO ₄ as P	mg / l			

The chemical results are also then plotted on a Piper Diagram, such as in Figure 13, which shows the general plot areas for groundwater samples from the Eastern Karoo Basin. The samples plotted on Figure 13 are that of the eastern Karoo as in King (2002), where the water is classified as recently recharged bicarbonate, calcium/magnesium type water.

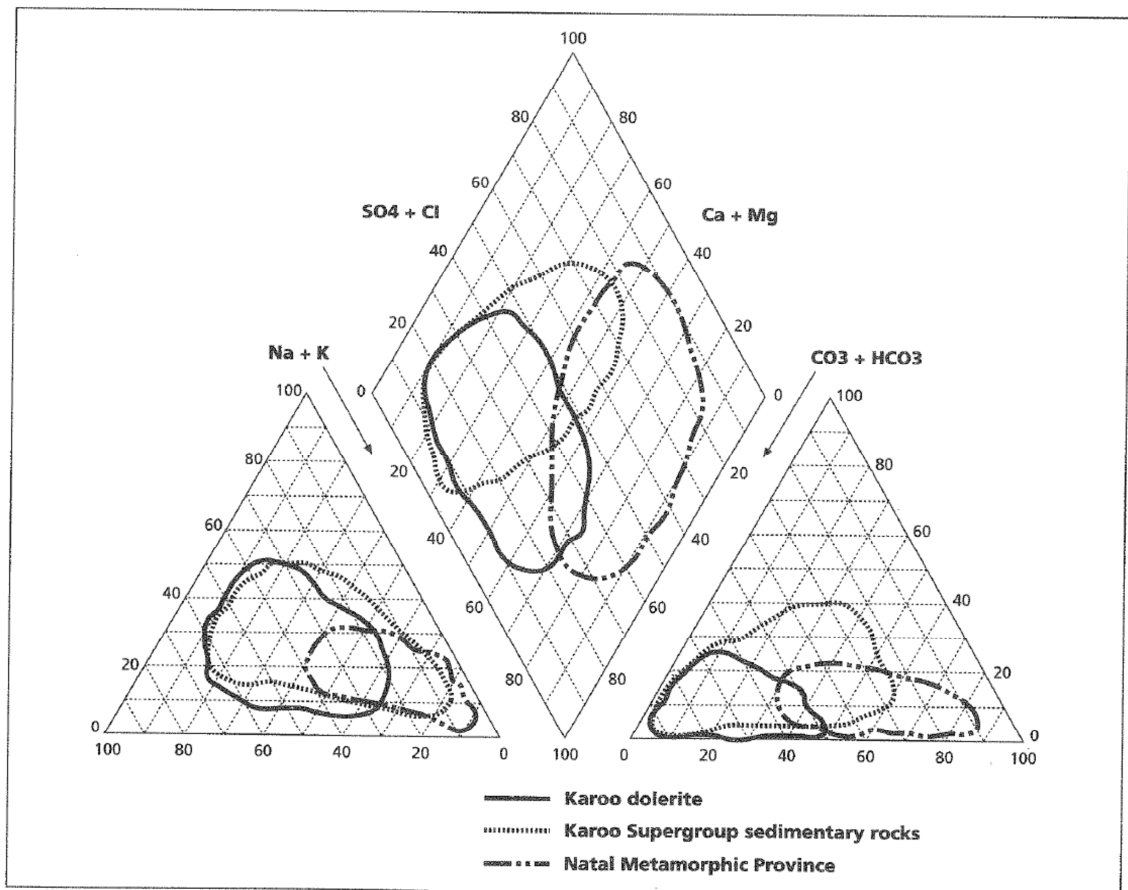


Figure 13 Piper Plot for Eastern Karoo Supergroup Basin. Taken from King, 2002.

Chemical data can also assist in the calculation of general recharge trends, by performing a chloride mass balance calculation. The estimated recharge for South Africa was calculated by Vegter (1995). The resultant recharge map is shown in Figure 14, and predicts that the average recharge for the study area is approximately 45 mm/yr.

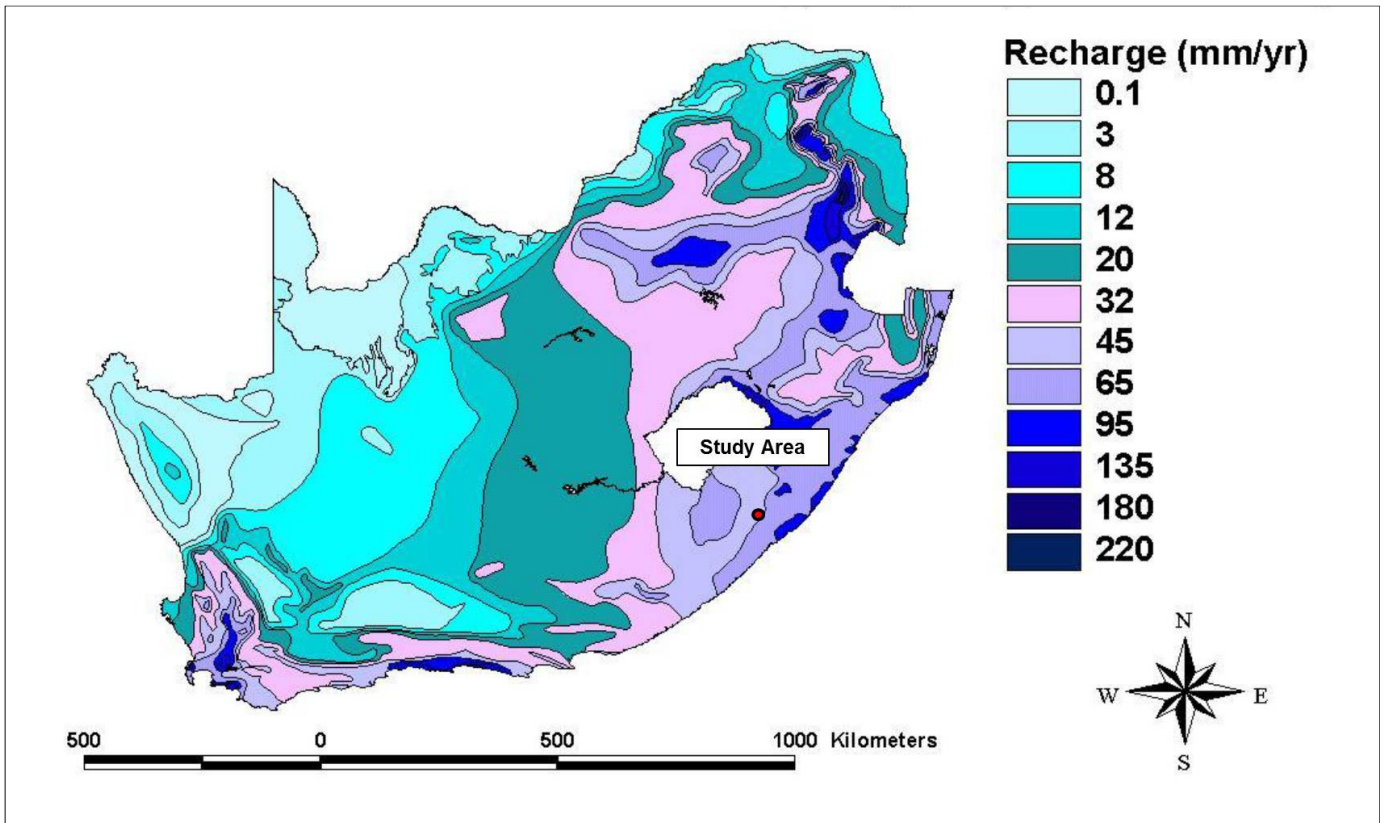


Figure 14 The estimated recharge map of South Africa, taken and modified from Vegter (1995).

This compares well with the average recharge value calculated in the GRAII data sets for the three catchments that fall within the project area namely T33G, T31H and T34H. The average recharge was calculated to 6.13% of MAP and amounts to 51.2 mm/a based on an average MAP of 835 stated the GRAII data.

During phase four, the results from all the phases, such as geophysics, drilling, testing, FC and chemical analysis, are compared to find possible correlations with the work conducted by Vegter (2001). This work, completed by Vegter in the early 2000s utilising National Groundwater Archive (NGA) data, is an attempt at using lessons learned in previous production borehole development schemes to assist future schemes in being more accurate and therefore more successful at lower costs.

4. Study Area overview

The environmental setting of the study area plays an important role in understanding the character of the geohydrological system of the study area. Factors such as precipitation, runoff, and geology all play a role in this regard.

4.1 Environmental Overview

The study area is situated approximately mid-way between the Lesotho highlands around Quthing and the coast at Port St Johns, being approximately 100km away from both these localities. It is located in the Mzimvubu to Keiskamma WMA which covers 62 211 km² and its boundaries comprise of the Mzimvubu River catchment in the east and the catchment of the Keiskamma River in the west. The northern border of the WMA is the Lesotho highlands and in the south the WMA has the Indian ocean as its border. The WMA is then further subdivided into quaternary catchments, of which the study area is underlain by the T34H, T31H and T33G catchments as can be seen in Figure 15.

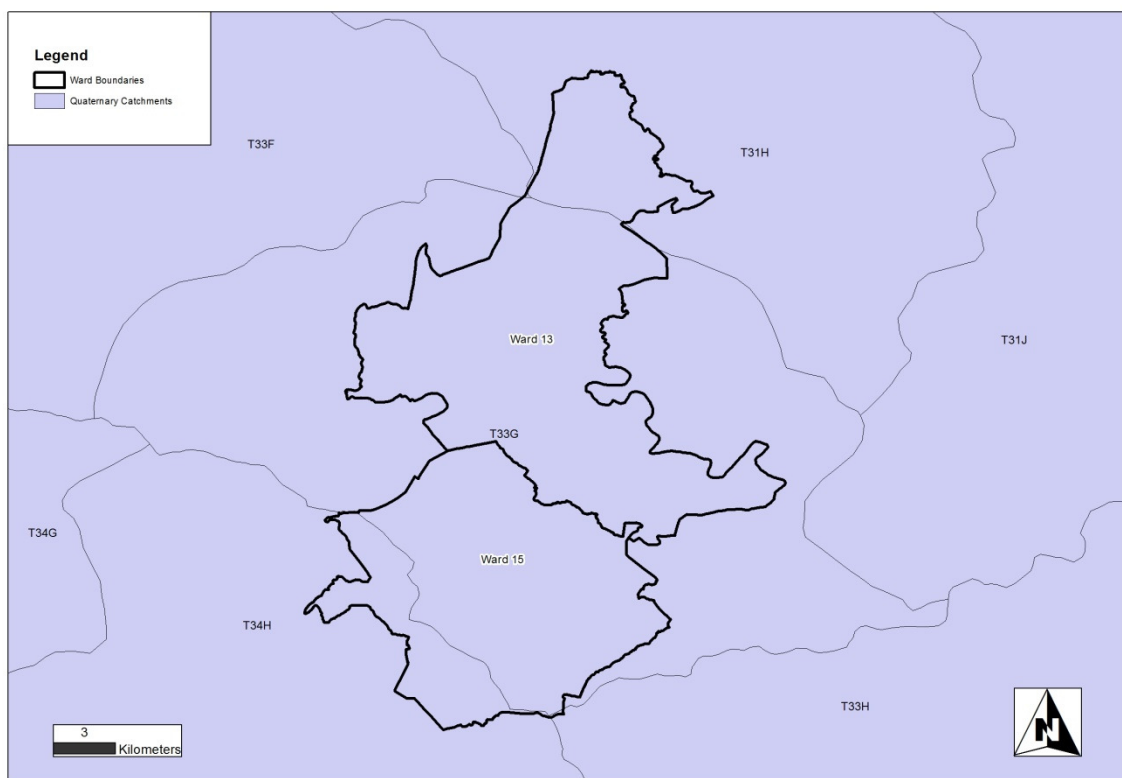


Figure 15 Quaternary catchments within the study area.

4.1.1 Climate

The study area has a relatively moderate temperature in comparison to the western and central Karoo Basins. The mean annual temperature in January is approximately 21°C and can range between 12 and 26°C. In June, the mean annual temperature is approximately 10.6°C with temperatures ranging between -1°C and 17°C. The lower temperature variations allow for more diverse vegetation variations (Midgley *et al.*, 1994).

South Africa is divided into two territories in terms of when it receives rain. Traditionally, the area around the Western Cape receives the majority of its rain during the winter months, with the rest of the country receiving the majority of its rain during the summer months. The study area falls into the latter. Figure 16 indicates the average rainfall and the rainfall patterns to be expected throughout the study area.

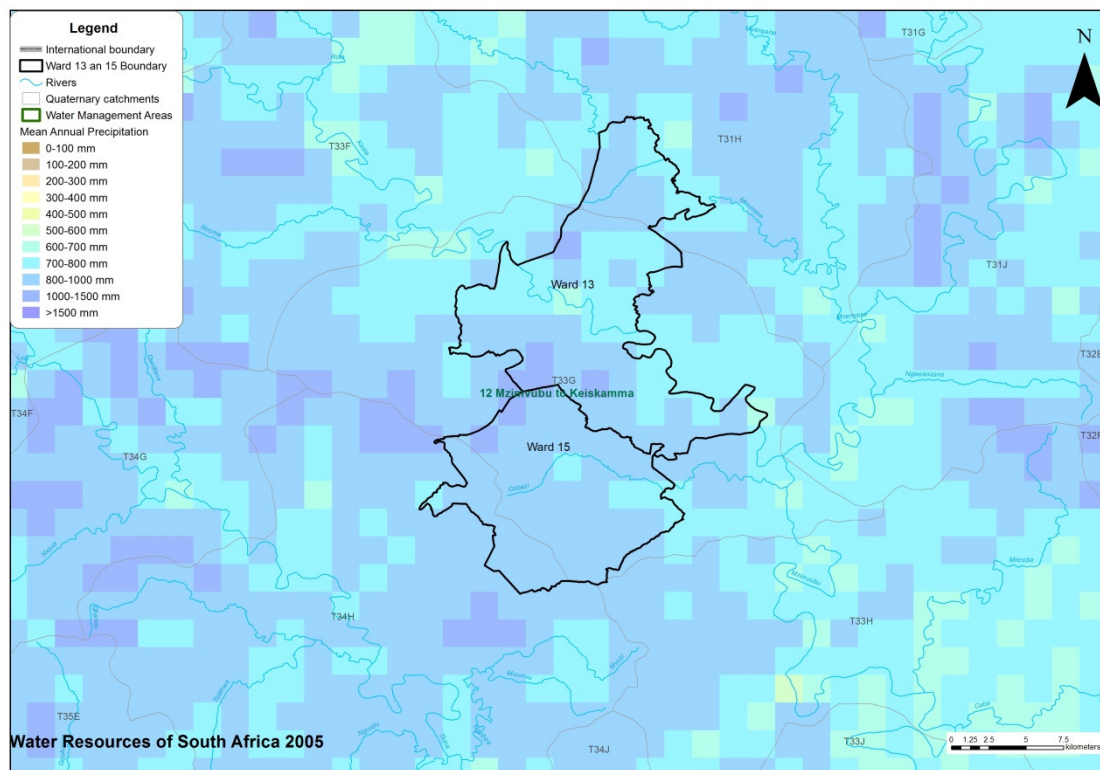


Figure 16 Study area rainfall map (Middleton and Bailey, 2005).

The regional mean annual precipitation (MAP) for the study area is approximately 780 mm per year, ranging between 620-816 mm. The majority of the MAP occurs during the months of October to March, with February being the

month with the highest specific average rainfall. This can be seen on Figure 17, which indicates the monthly rainfall figures for catchment T3A, which represents the study area. The data was sourced from the WR2012 data sets. The winter months, however, are not without rain, as approximately 30% of the MAP occurs between the months of April and September (Mucina and Rutherford, 2006).

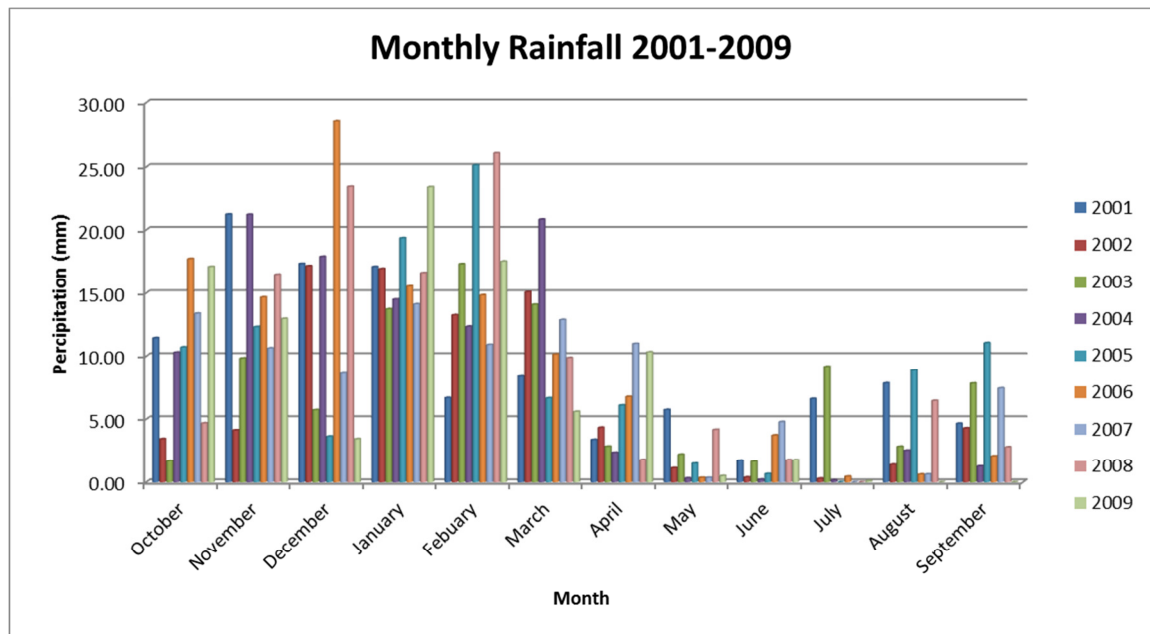


Figure 17 Monthly rainfall data 2001-2009.

The MAP of the specific catchments which fall into the study area are, however, higher than the regional norm (GRAII). The local MAP, in accordance with the GRAII data, is summarised in Table 2.

The recharge to groundwater from MAP according the GRAII data is also summarised on Table 2 and is relatively similar to one another. This is however expected as similar MAP values, geological and topographical settings reign over all three catchments.

Table 2 GRAII Precipitation and Recharge data

Catchment	MAP (mm)	Recharge (%)
T33G	836	6
T31H	808	6.8
T34H	863	5.6

4.1.2 Topography

The topography of the study area consists mainly of moderately rolling hills and mountainous landscapes with deep river incisions such as the Nkemané river valley (Figure 19). Apart from the large rivers another contributing factor to the landscape is the geology. From field experience it was noted that areas which are underlain mostly by sandstone; rolling hills are the more common landscape. In areas which are underlain by arenaceous sandstones higher above sea level, more high cliffs are seen. The study area topography is shown on Figure 18.

The general slope trend of the study area is South East in direction as can be seen by the general trend of the surface water drainage lines indicated on Figure 18. The map was drawn up using the 30m SRTM Data collected by NASA for the USGS.

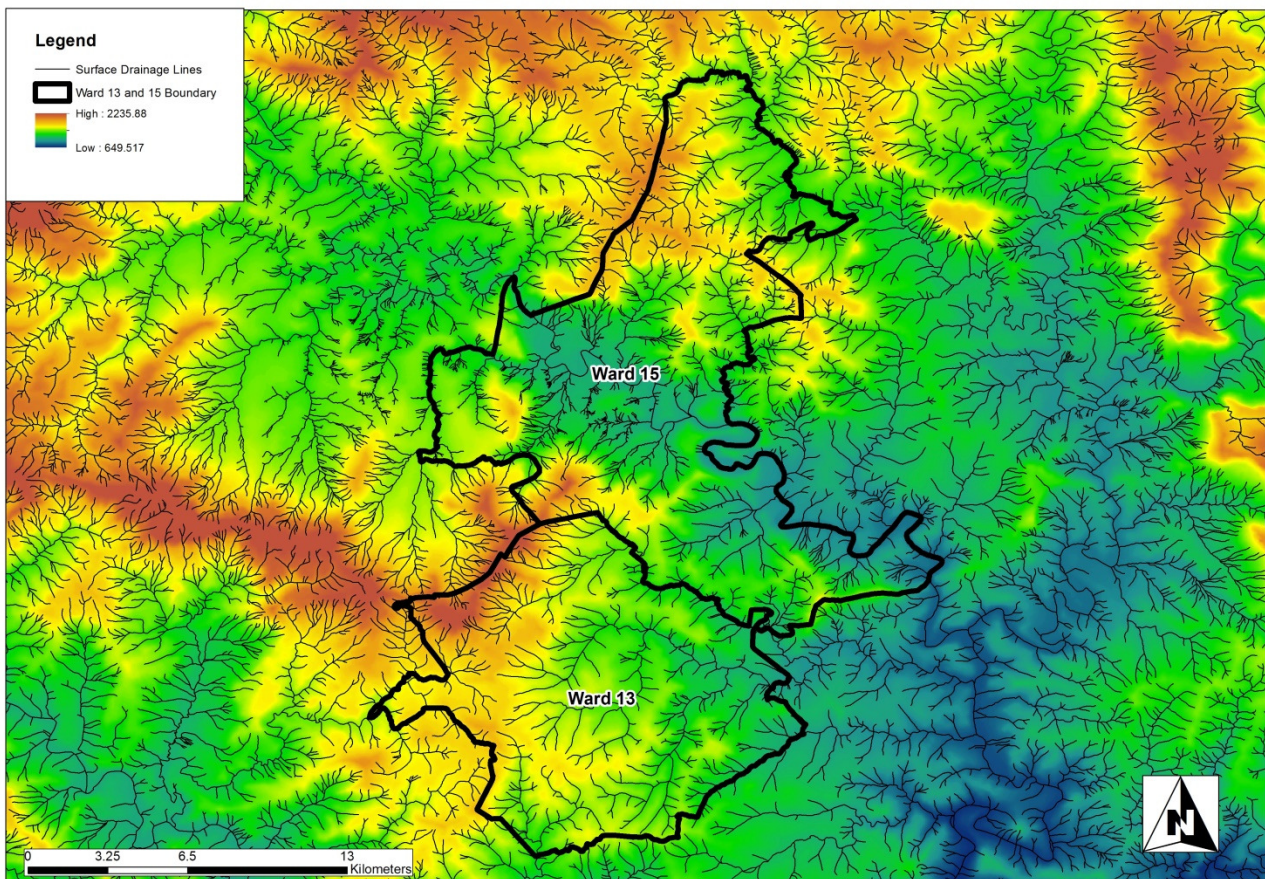


Figure 18 Elevation map of the study area 30m SRTM Data.

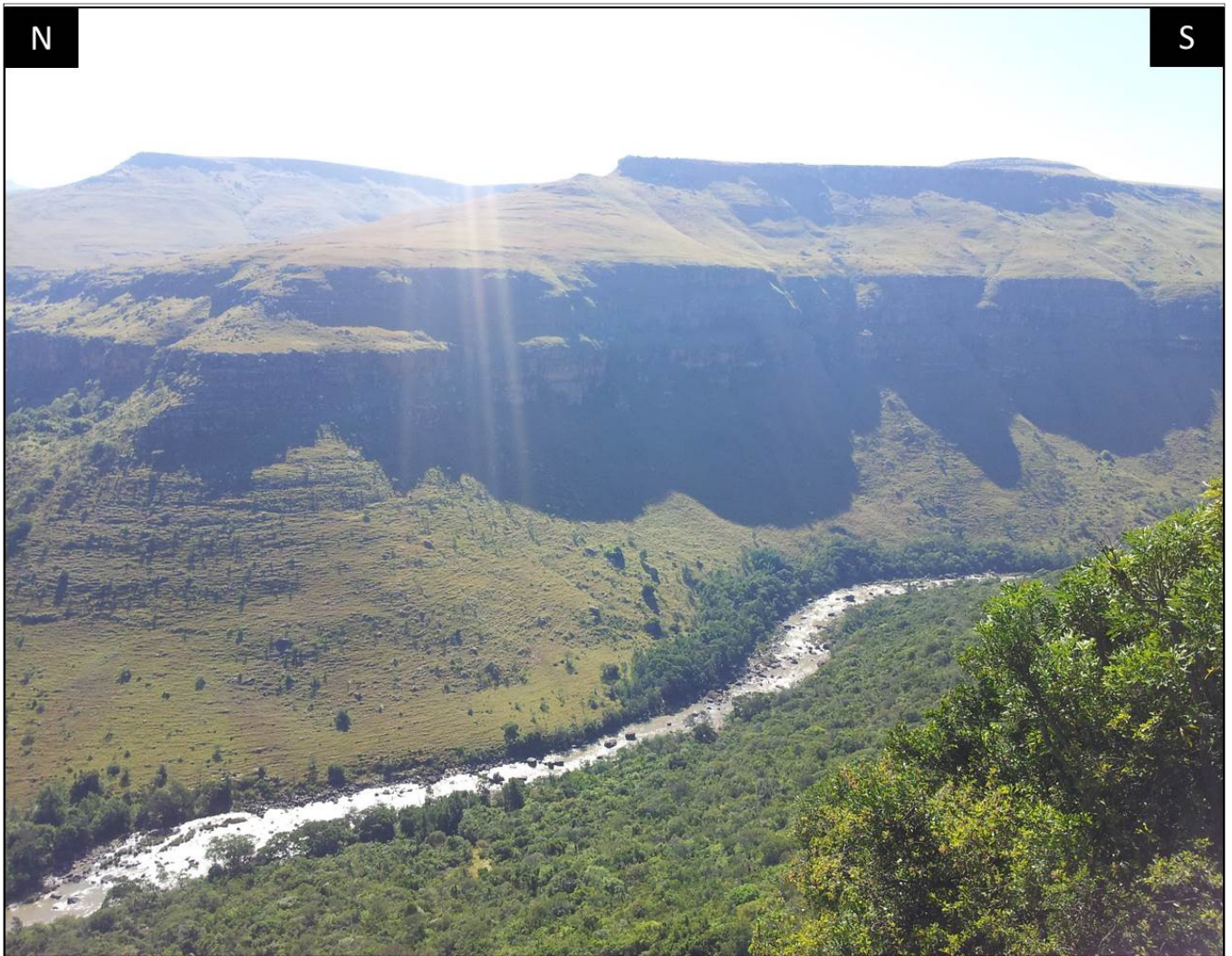


Figure 19 Nkemanane River

4.1.3 Surface water

The general drainage pattern for the study area is from a north-western to a southern-eastern direction. The presence of the Lesotho highlands to the north-west of the study area and the Indian Ocean to the south-east of the study area play a major role in defining the drainage pattern for the entire region, as can be seen on Figure 20.



Figure 20 The surface water drainage system of the study area.

There are two major rivers which run through Ward 13, namely the Kinira River, which runs through the central section of Ward 13 (Figure 21), and the Nkemané River, which forms the northern border of Ward 13. Ward 15's surface water follows multiple small drainage lines. All of the surface water from Ward 13 and 15 eventually feeds into the Mzimvubu River, before flowing into the Indian Ocean. The Mzimvubu River has a total length of approximately 400 km and has a catchment area of approximately 19 853 km². The total mean annual runoff from the Mzimvubu River amounts to approximately 2 897 Mm³/a at its mouth (DWAF 2004).



Figure 21 One of the meanders in the Kinira River.

4.1.4 Vegetation

The main vegetation type of the study area consists of temperate and transitional forest and scrub. This vegetation type covers approximately 60% of the Mzimvubu to Keiskamma WMA. This is therefore a relatively general veld type and consists of forest, grass and fynbos plant types. An example of this vegetation type is depicted in Figure 22, which was taken along the banks of the Thina River. This veld type occurs from 0-1350 metres above mean sea level (mamsl); the general veld type for the entire study area is temperate and transitional forest and scrub occurs in areas with a relatively high MAP (Mucina and Rutherford 2006).



Figure 22 A scene of the study area with the typical vegetation around the Nkeman River.

The study area is classified more specifically as East Griqualand grassland, (Mucina and Rutherford, 2006) with Kokstad and Matatiele as its centre, and surrounds between the altitudes of 920-1740 mamsl.

4.2 Local Geology

The local geology of the study area contains rocks of the Karoo Supergroup in particular the Beaufort Group, which is the upper middle formation group of the Karoo Supergroup (Figure 23). At its lower margins it is underlain by the Ecca Group and at its upper margin, it underlies the Molteno Formation, which in certain literature together with the Elliot, Clarens and Drakensberg Volcanic Formations forms the Stormberg Group (Johnson *et al.*, 1997).

The Beaufort Group sediments are the remnants of a period of progressive infilling into the Karoo Basin. Due to the gradual shallowing of the Karoo Basin the mudstones, siltstones and sandstones represent a subaerial depositional environment (Chevalier *et al.*, 2001).

There are two subgroups present in the study area, namely the Adelaide and Tarkastad Subgroups. The Adelaide Subgroup was deposited during the late Permian approximately 260 Ma. The Adelaide Subgroup has a thickness of approximately 5000m in the south-east, but rapidly decreases in thickness towards the centre of the Basin, where it is approximately 800m thick and on to an approximate thickness of 100m in the northern extent of the Basin. The geology underlying the study area of the Adelaide Subgroup consists of the Koonap, Middleton and Balfour Formations. Of the three formations mentioned it is the Balfour Formation that represents the Adelaide Subgroup.

The Tarkastad Subgroup was deposited during the early Triassic approximately 240 Ma. The Tarkastad Subgroup has an approximate maximum thickness of 2000m in the south which decreases to approximately 800m in the centre of the Karoo Basin and then decreases further to a thickness of 50m or less in the far northern reaches of the Basin. The Katberg Formation, forming the base of the Tarkastad Formation, is the major formation in which the study area is set.

This general thinning of the geological units represented in the study area supports the understanding that the flow regime during the time of deposition was from north/north-west to the south (Hälbich *et al.*, 1983).

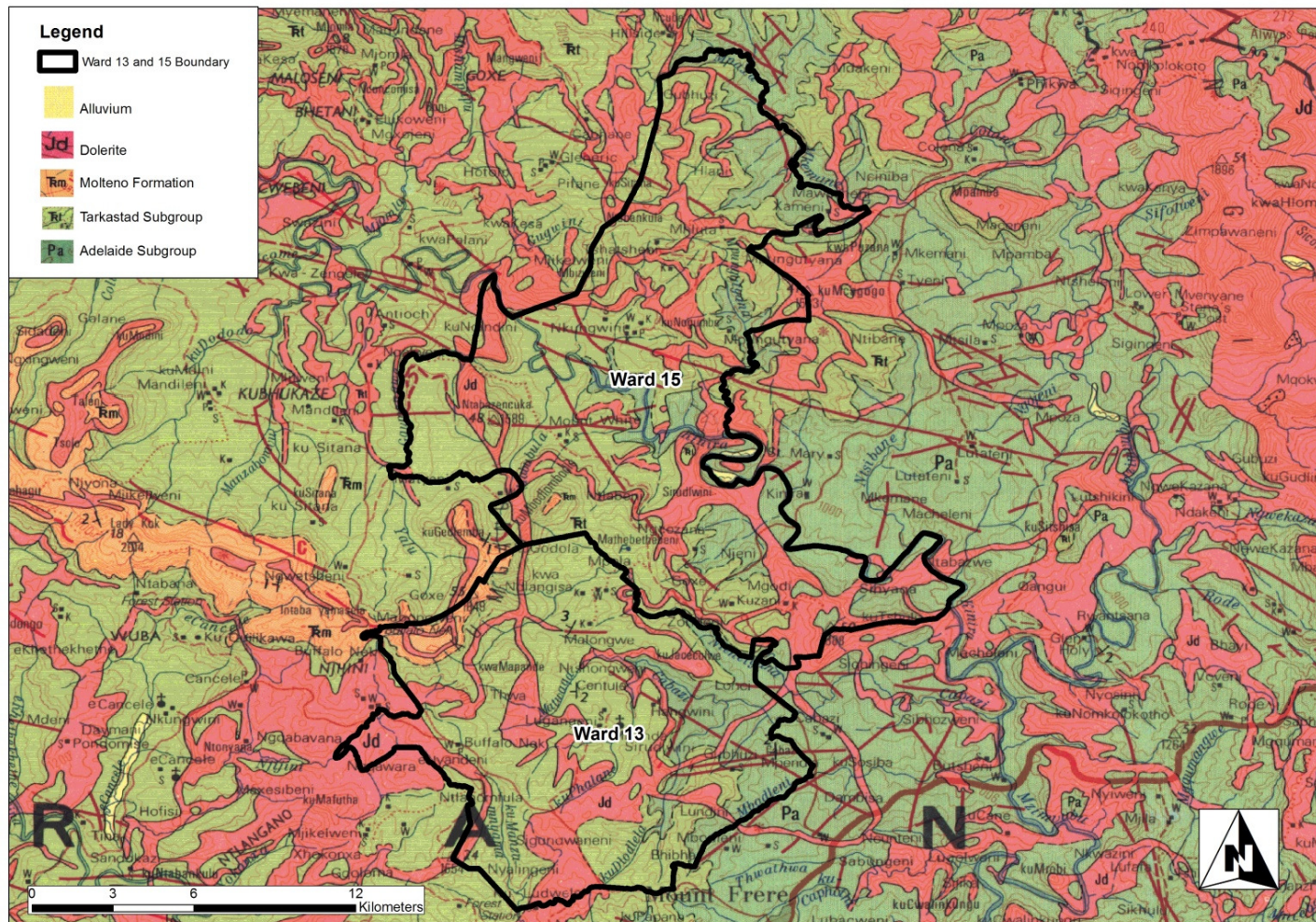


Figure 23 The local geology of the project area modified from the 1:250 000 geological Map of Kokstad.

4.2.1 Balfour Formation

The Balfour Formation represents the upper margin formation of the Adelaide Subgroup. It is underlain by the Middelton Formation to the south. Bluish-grey mudrock represents the major lithology of the Balfour Formation with minor grey, medium-fine grained sandstones. Sandstone generally contributes 20-30% of the Formation thickness. Certain areas contain sandstone-rich intervals and can represent up to 60% of the formation thickness. However, there are also certain areas where sandstone represents only 10% of the formation thickness (Groenewald, 1989).

The formation of the mudstone units occurred because of the deposition of sediments in a flood plain environment and the sandstone units were formed by the lateral migration of meandering rivers. From paleo surface water current data, it is evident that the transportation source for the sediments was situated south, south-east and south-west of the Karoo Basin. The deposition of the Adelaide Subgroup also occurs around the same time as the second large tectonic event of the Cape Fold Belt approximately 260 Ma (Hälbich *et al.*, 1983).

4.2.2 Katberg Formation

The Katberg Formation, which is underlain by the Balfour Formation, consists mostly of sandstone, constituting up to 90% of the formation in the south. The boundary between these two formations also acts as the boundary between the Adelaide and Tarkastad Subgroups. This boundary is the only boundary that can be followed with certainty throughout the entire Karoo Supergroup (Groenewald, 1989). The Katberg Formation is more than 900m thick in its southernmost reaches around East London, but thins towards the north.

As well as thinning, the sandstone/mudstone ratio decreases to the north, making it almost indistinguishable from the Burgersdorp Formation, which lies above the Katberg Formation.

The Katberg sandstones are generally brownish grey to greenish grey in colour and the sediments are mostly fine to medium grained. Scattered pebbles are not uncommon in the Katberg Formation and are generally around 15cm in diameter. Calcareous concretions of approximately 3-10cm in diameter are also common throughout the Katberg Formation. It is suggested from paleo current

that a northern to north-western regional paleo-slope existed within the Tarkastad Sub-group. The sharp increase of silica content from the Adelaide to the Tarkastad Sub-group is indicative of a period of strong uplift and weathering of the Quartzitic Cape Fold Belt to the south (Smith *et al.*, 1993).

4.2.3 Lineaments

Lineaments as defined by Waters *et al.*, (1990) are “*any straight or slightly curved feature or alignment of discontinuous features that are apparent on a map or image of an area*”. The success of lineament mapping, therefore is highly dependent on the capability of a mapper to visualize and distinguish between actual geological lineaments and other linear structures such as dirt roads, power lines, tree rows and drainage lines (Woodford and Chevalier 2002). Numerous geological features may be represented by geological lineaments, such as faults, joints, discontinuities, bedding planes or dykes. Authors have, in the past, suggested that lineaments should be classified based on their physical prominence.

This then would entail selecting classes for linear structures based on the size and extent of the structure (Wheeler, 1983). Waters *et al.* (1990) suggested that lineaments be classified based on their hydrological function, to distinguish whether the structure is, for example, a dyke which could act as a flow barrier or a highly transmissive fracture zone.

The geological lineaments are of great importance to this study, as many can be seen on Figure 24. The number of geological lineaments in the study area far outweighs the number of dolerite dykes in the study area according to the local geological map (Figure 23).

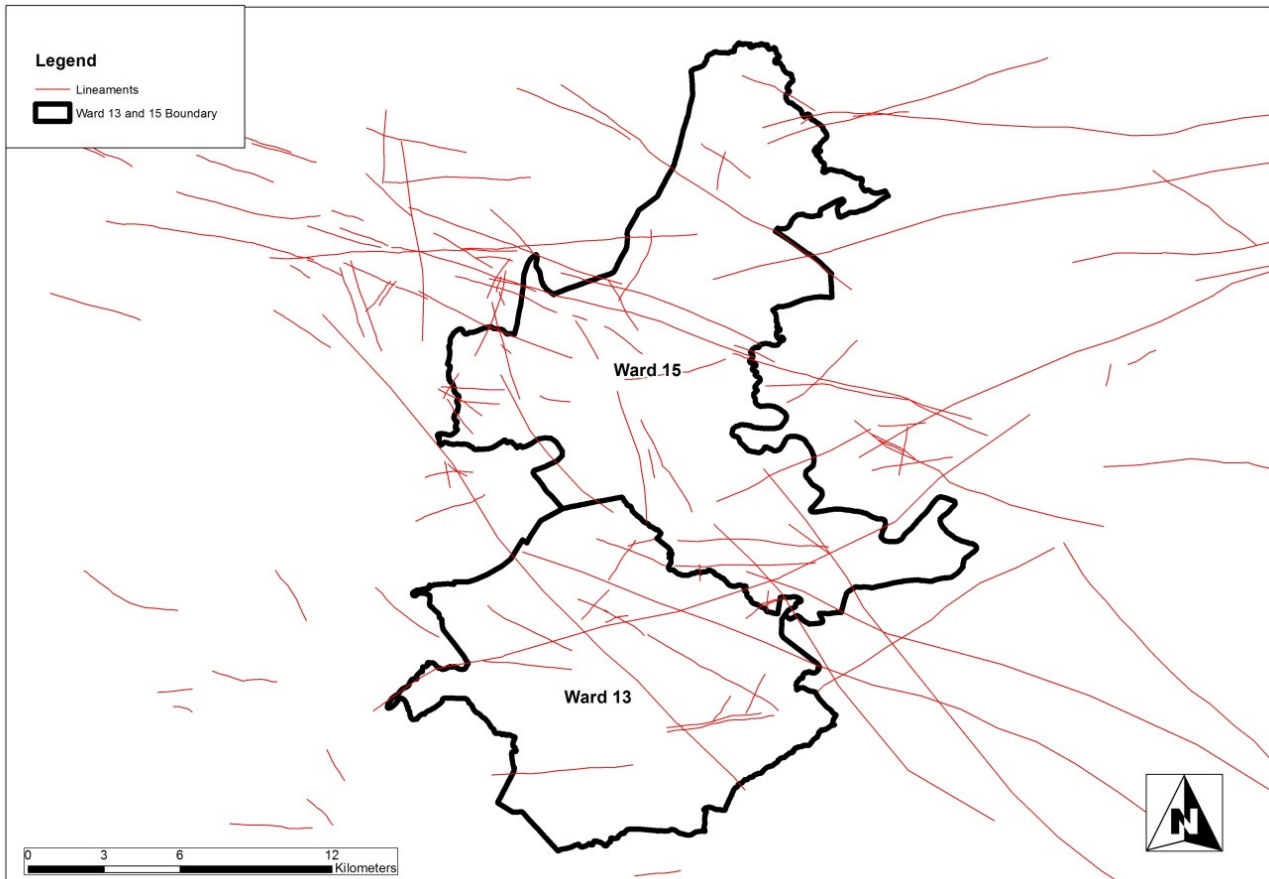


Figure 24 Lineaments delineated in project area.

The strike directions of the lineaments found within the project area are indicated in Figure 25 and Figure 26. Figure 25, which represents Ward 15, shows four major lineament directions, namely ENE, NW, NS and WNW, of which ENE and NW can be considered as the two primary strike directions. These structural strike directions are noted, with small directional variances, by Woodford and Chevalier (2002) in the Western Karoo Basin, as the two major structure directions relating to dolerite intrusions were EW and NNW striking. The EW structural strike direction is associated with the right lateral shear movement expected to have taken place during the break up of Gondwanaland and also show a strong tectonic relation to the dolerite shear zone. The NNW structural direction is thought to be related to the later emplacement of kimberlites. This volumetric overload is thought to have reactivated the existing shear zones within the Karoo Supergroup rocks.

The more northerly Ward 15, indicated on Figure 25 represents a more complex structural setting in comparison to the southerly Ward 13 is indicated on Figure 26. This is because of the larger number of structures that do not follow the two primary structural strike directions (ENE and NW) mentioned by Woodford and Chevalier (2002) in the Western Karoo basin. The data collected from Ward 15 is more compliant with the existing knowledge.

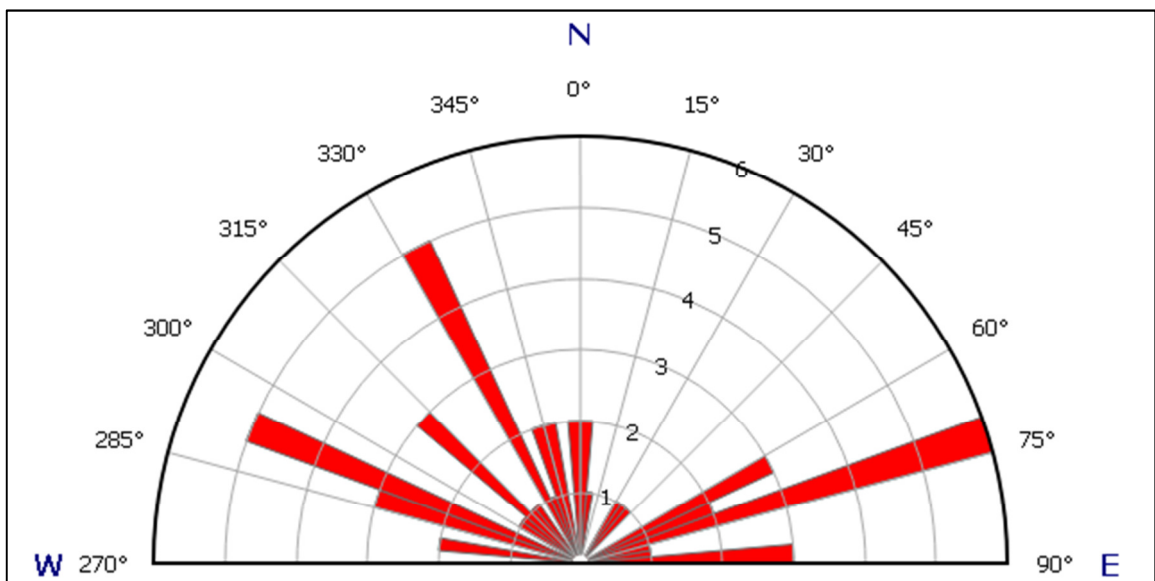


Figure 25 Rose diagram of the Ward 15 lineaments.

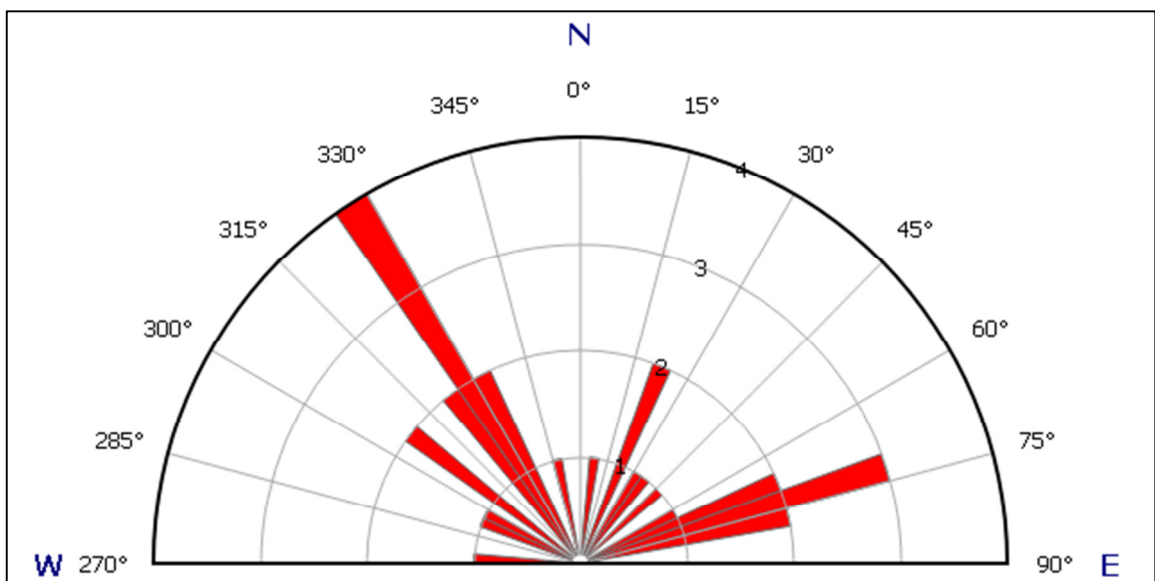


Figure 26 Rose Diagram of the Ward 13 lineaments.

4.2.4 Jurassic dolerite intrusions

The intricate dolerite dyke and sill complexes of the Karoo Supergroup are Jurassic (180Ma) in age and were emplaced during a period of extensive magmatic activity, which affected almost the entire Southern African sub-continent (Figure 27). The breakup of Gondwanaland is seen as the major tectonic event that contributed to the emplacement of the Karoo dolerites.

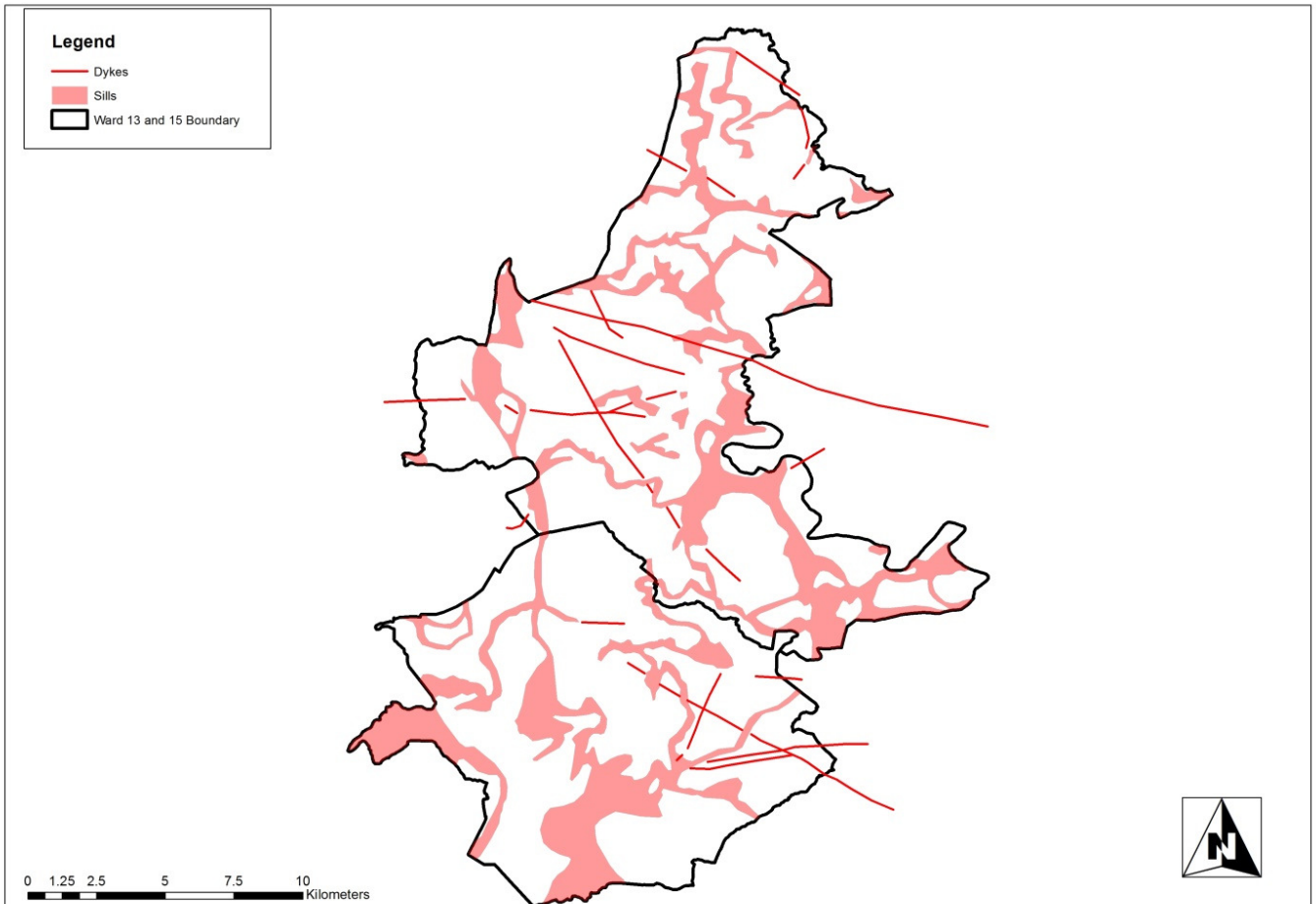


Figure 27 The regional extent of dolerite sill intrusions, some of which are inclined, within the study area boundaries are represented along with the regional extent of the dolerite dyke intrusions. The map was modified from the 1:250 000 geological map of Kokstad.

The estimated volume of the dolerite intrusions throughout the entire Southern Africa is placed at approximately 10 million km³. Erosion of the Karoo sedimentary rocks revealed the deeper dykes and sills and it was recognised that the Karoo intrusions had a level of complexity that had not been seen anywhere before in an intrusive magmatic system (Woodford and Chevalier, 2002).

The sill and ring structures that are present over the same geographical localities as the dykes represent the most general tectonic feature of the Karoo Basin. The sill/ring complexes are also the largest controlling factor of the Karoo geomorphology. Within the major sedimentary unit of the study area, namely the Katberg Formation, dolerite intrusions cover approximately 1 358km² of the total surface area, amounting to 16.14% of the total Katberg Formation surface area (Dondo *et al.*, 2010).

The “egg box” model which was described by Du Toit (1905, 1920), is no longer relevant today. Throughout the Beaufort Group, it is known that the sills and rings have a sub-circular shape that is inclined at the edges.

In some cases, a near vertical dyke is seen branching into or through a sill/ring complex, creating a very intricate network of sill and dyke complexes. In some cases, a dyke is seen branching out of one ring structure and connecting with another structure. This is seen as possibly acting as a shallow magma storage and feeding system for the basaltic Drakensberg plateau. A possible example of this can be seen in Figure 28. However, it is also possible that post Jurassic tectonic activity could be at the source of such displacement.

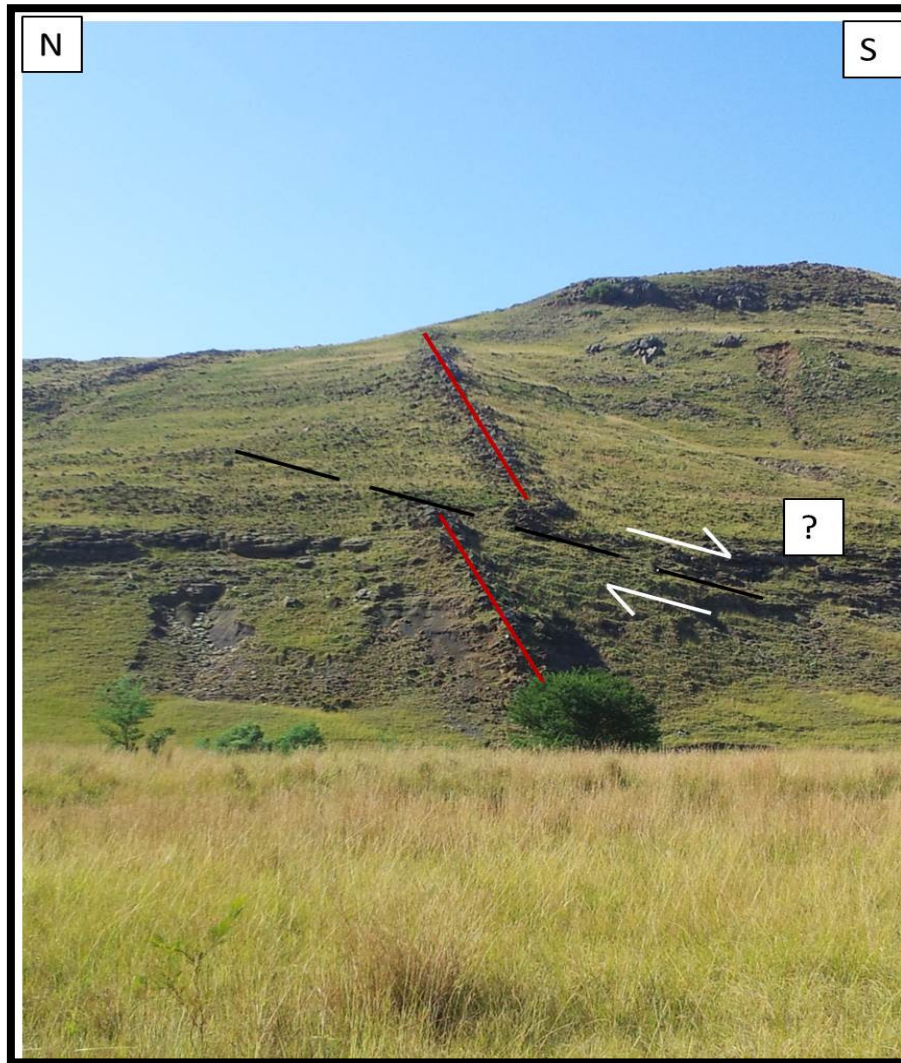


Figure 28 Displaced dyke, by possible post intrusion tectonics or sill contact.

Lower in the lithologies of the Ecca Group, there is a marked increase in intrusion density, when moving from the lower to upper Ecca Group rocks. This boundary also marks the appearance of the first sandstones and although many dykes are still found in the in the lower Ecca and the Dwyka, the majority of dykes are found in the lower Beaufort and Upper Ecca Groups. This is explanatory of the average length of dykes in the Beaufort Group rocks around the study area, as the intrusions propagated laterally instead of vertically along the strike (Chevalier *et al.*, 2001).

Within the study area, dolerite sill structures cover a large percentage of the surface area, at nearly 50%. They are much more prevalent than the general prevalence of 16.14% throughout the entire Katberg Formation. Whereas dolerite dyke intrusions occur very sparsely within the project area boundaries.

4.2.5 Post Jurassic Tectonic Deformation

In terms of post Jurassic tectonic activity, a regional north-westerly trending morpho-tectonic lineament lies north-east of the study area (Chevalier *et al.*, 2001). Two notable earthquakes with magnitudes of 5 on the Richter scale have occurred to the north-west of the study area, in 1986 at Msikaba in Lesotho and 1989 in the Mount Fletcher area. Figure 29 concurs with this statement, as a northerly striking fault zone was sighted to the west of the study area near the town of Maclear.



Figure 29 Evidence of post Jurassic tectonic deformation in the study area. In this specific instance an upwards movement of the rock face in view is evident from the lineation direction indicated by the red arrows.

4.3 Regional Hydrogeology

The regional hydrogeology of the study is controlled largely by the occurrence of tectonically induced fractures which are most common along the margins of the dolerite intrusions.

The dolerites have been associated as mentioned before, with the breakup of Gondwanaland because of the similarities in age of the dolerites and the expected age of the tectonic shift. The intrusion of the dolerites brought on a fracture regime around the intrusions which allows groundwater to enter the large fractures around the intrusion zones. The dykes, sills and rings have major fracture zones around the hinge zones between the roots and feeders of the intrusive system (Woodford and Chevalier, 2002).

According to the groundwater resource maps of South Africa (Vegter, 1995), the minimum borehole depth for the study area should be 30-50 metres below ground level (mbgl). Also stated on the maps is the probability for drilling a successful borehole with a yield of more than 2 l/s, which for the study area stands at between 30-40%.

As has been mentioned, the aquifer type for the study area is fractured and intergranular, meaning that the aquifers store and transmit water by means of both primary and secondary porosity. Primary porosity relates to the movement of water through the sedimentary matrix, thus called an intergranular aquifer and secondary porosity relates to the movement of water through fractures within the sedimentary matrix. While primary porosity is an inert characteristic of the sedimentary matrix and therefore relatively homogenous in occurrence throughout the aquifer, secondary porosity occurs only in structurally deformed areas throughout the Karoo Supergroup. Historically, the highest concentrations of fractures have been located around the Jurassic dolerite intrusions, because of the tempo and forcefulness of their intrusion (Smart, 1998).

When a dolerite intrusion weathers, it can, however, also store and transmit water as a porous medium, dependent on the manner in which the intrusion is weathered. If the weathering effects on the intrusion are mostly physical, coarsely weathered dolerite can form. This type of weathering drives the process

known as exfoliation, as can be seen on Figures 30 and 31 (Singhal and Gupta, 1999).



Figure 30 Weathered dolerite intrusion, exfoliated dolerite boulders.



Figure 31 A example of exfoliation weathering on dolerite.

However, if the weathering process is more chemical in nature, which would entail the water moving through the physically weathered zones having a higher carbonic acid content, the pedo-genesis for clay minerals can be initiated. This will have an effect on the permeability of the fracture matrix around the dolerite intrusion. It will decrease and can become completely impermeable to groundwater (Morehouse, 1959).

Figure 32 is an example of such an intrusion which has almost completely weathered down to its clay mineral state. The clay consists mostly of phyllosilicates or iron/aluminium silicates, that form when plagioclase feldspar is weathered by carbonic acid. Plagioclase is also readily available for this geomorphology, as dolerite consists of up to 70% plagioclase (Klein and Hurlbut, 1986).

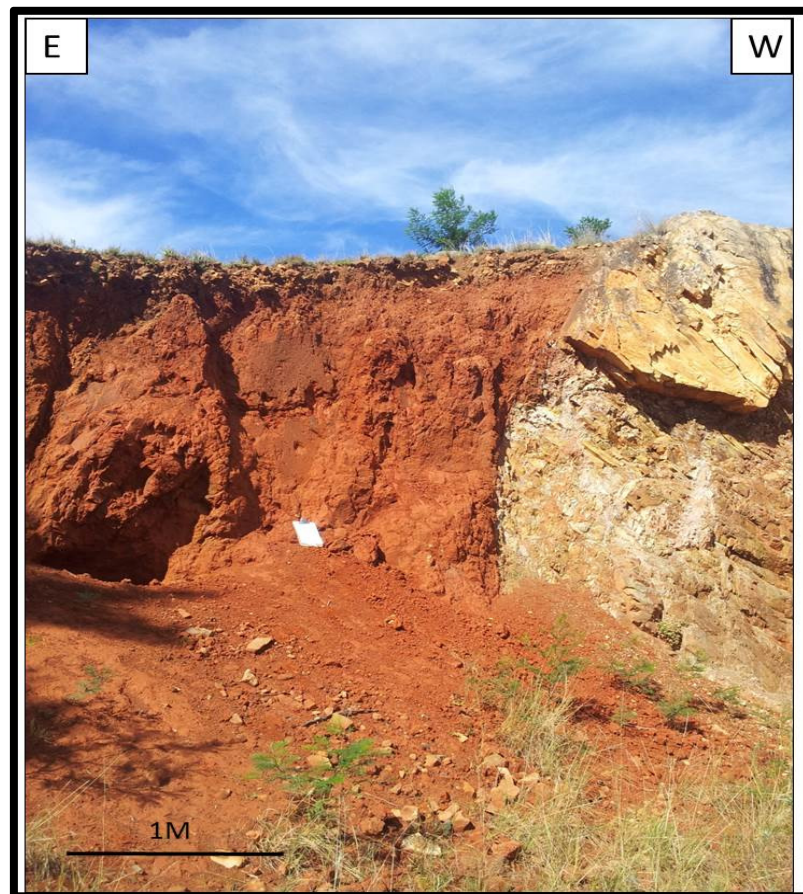


Figure 32 Highly weathered dolerite intrusion, intruded into a sandstone layer, has reached the final stages of pedo-genesis. Such an intrusion could possibly produce very low transmissivities, due to the presence of abundant clay minerals.

Based on the data collected from the GRAII data set it is apparent that the study area receives good to moderate recharge. The GRAII data is displayed on Figure 33, where it can be seen that the areas in the western region of the study area 110 – 75mm recharges into the underlain aquifer. The recharge figure gradually decreases to the east where the lowest predicted annual recharge of 50 – 37mm is expected annually. It is therefore expected that a borehole drilled into a well-connected fracture network and should receive ample recharge to sustain it if managed correctly.

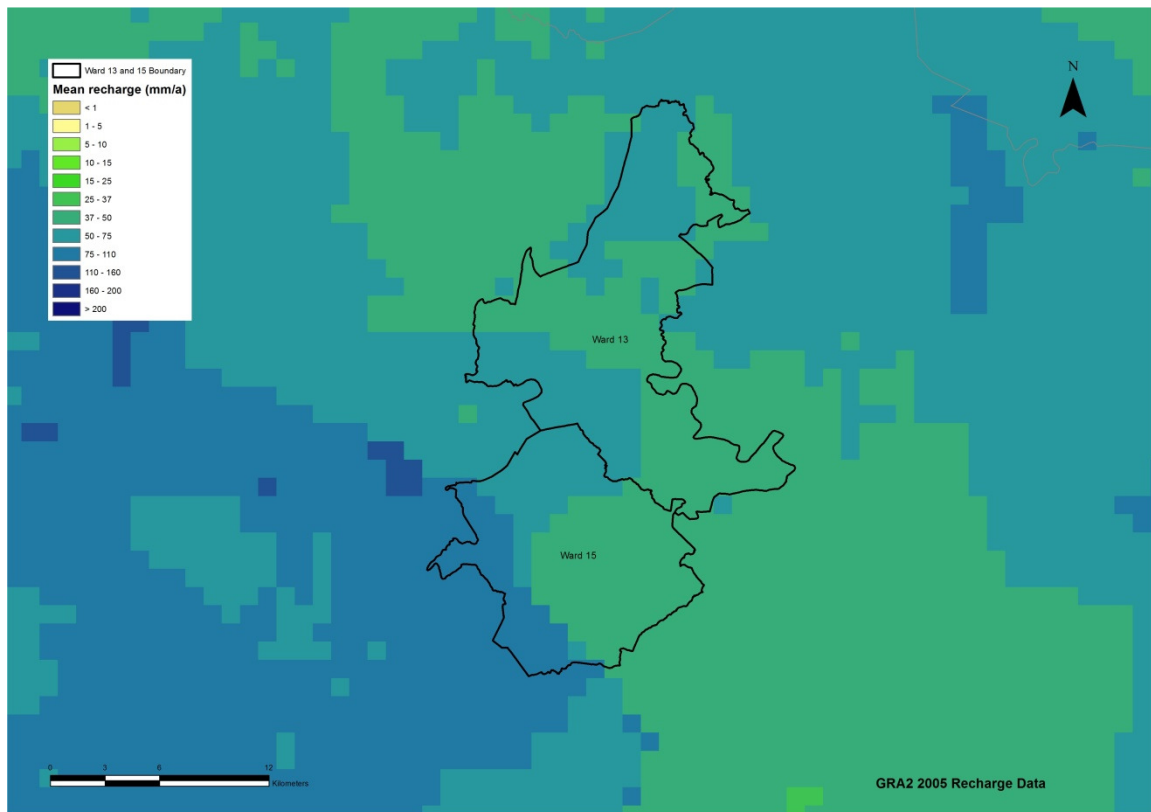


Figure 33 Study area recharge map (Middleton and Bailey, 2005).

The NGA has 43 registered existing boreholes in the vicinity of the study area. The available information on these boreholes is summarised in Table 3 and their localities are indicated on Figure 34. There are 18 NGA sites which have no yield data and 10 NGA boreholes which are registered as abandoned or destroyed.

Table 3 NGA borehole information (www3.dwa.gov.za/nganet)

Identifier	Latitude	Longitude	Elevation	Status	Quaternary Catchment	DWA Fuse	BlowYield (l/s)
3028DD00029	-30.7956	28.97632	1200		T33G		0.25
3029CC00001	-30.7878	29.01357	760		T33G		0
3028DD00006	-30.7745	28.96687	1060	In Use	T33G	Production (Water Supply)	4
3028DD00005	-30.7734	28.96548	1080	In Use	T33G	Production (Water Supply)	0.25
3028DD00016	-30.7661	28.94993	1380		T33G	Production (Water Supply)	0
3028DD00046	-30.7661	28.98277	980	In Use			0
3028DD00026	-30.762	28.92826	1400	Abandoned	T33G	Production (Water Supply)	0
3029CC00021	-30.7534	29.05357	1090	In Use	T33G	Production (Water Supply)	0.3
3029CC00017	-30.7531	29.00579	1000	In Use	T33G	Production (Water Supply)	2.53
3028DB00016	-30.7497	28.96076	1160	Abandoned	T33G	Production (Water Supply)	0.9
3028DB00015	-30.7495	28.96103	1180		T33G	Production (Water Supply)	0.2
3029CA00030	-30.7392	29.0569	1120	In Use	T33G	Production (Water Supply)	0.64
3029CA00035	-30.7392	29.05722	1025	Abandoned	T33G	Production (Water Supply)	0
MGUNGUNDL	-30.7383	29.00722	1073	Abandoned	T31J	Production (Water Supply)	0.5
3028DB00011	-30.737	28.91826	1320	In Use	T33G	Production (Water Supply)	0
3029CA00029	-30.7356	29.00635	1100	In Use	T33G	Production (Water Supply)	0.78
3028DD00002	-30.7348	28.91916	1420	In Use	T33G	Production (Water Supply)	2.2
3028DB00012	-30.7334	28.90965	1140		T33G	Production (Water Supply)	0
EC/T31/011	-30.7308	29.03639	1076	Abandoned	T31J	Production (Water Supply)	2.5
3029CA00031	-30.7275	29.05718	1100	In Use	T31H	Production (Water Supply)	0.18
3029CA00028	-30.7267	29.05579	1100		T31H		0
3029CA00063	-30.7015	28.97749	1040	In Use			0.66
3028DB00014	-30.6989	28.90437	1060	Abandoned	T33G	Production (Water Supply)	0.8
EC/T31/054	-30.6313	29.01886	1390		T31H		6.6
3029CA00001	-30.6198	29.01496	690		T31H		0
EC/T31/061	-30.607	28.99951	1300		T31H		2.5
3028DD00034	-30.8738	28.92128	1280				0
EC/T34/030	-30.8736	28.91853	1280	In Use		Production (Water Supply)	22
3029CC00064	-30.8659	29.00579	1080				0
3028DD00045	-30.8658	28.97666	1100	In Use			0
T30308B	-30.8636	28.97673	1280		T34H		0
303-1004A	-30.8461	28.97713	1170	Destroyed	T33G		0
EC/T34/033	-30.8439	28.87634	1420	In Use		Production (Water Supply)	0.3
3029CC00019	-30.842	29.00524	1040	In Use	T33G	Production (Water Supply)	4
303-1008	-30.8345	29.00636	1033	Destroyed	T33G		0
3029CC00015	-30.8325	29.00412	1010	In Use	T33G	Production (Water Supply)	1.89
303-1011	-30.8283	29.00738	990	Destroyed	T33G		0
3028DD00017	-30.8217	28.97826	1080	Abandoned	T33G	Production (Water Supply)	0.3
3028DD00029	-30.7956	28.97632	1200		T33G		0.25
3028DD00030	-30.7753	28.93326	1360		T33G		0
3028DD00006	-30.7745	28.96687	1060	In Use	T33G	Production (Water Supply)	4
3028DD00005	-30.7734	28.96548	1080	In Use	T33G	Production (Water Supply)	0.25
3028DD00031	-30.7722	28.92993	1380		T33G		0

The average yield of successful NGA boreholes is 2.32 l/s with 10 boreholes yielding above 1 l/s and the highest yielding borehole (EC-T34-033) yields 22 l/s. No boreholes or springs from the Groundwater Resource Information Project (GRIP) which was finalised in 2010 were found to be present within the study area.

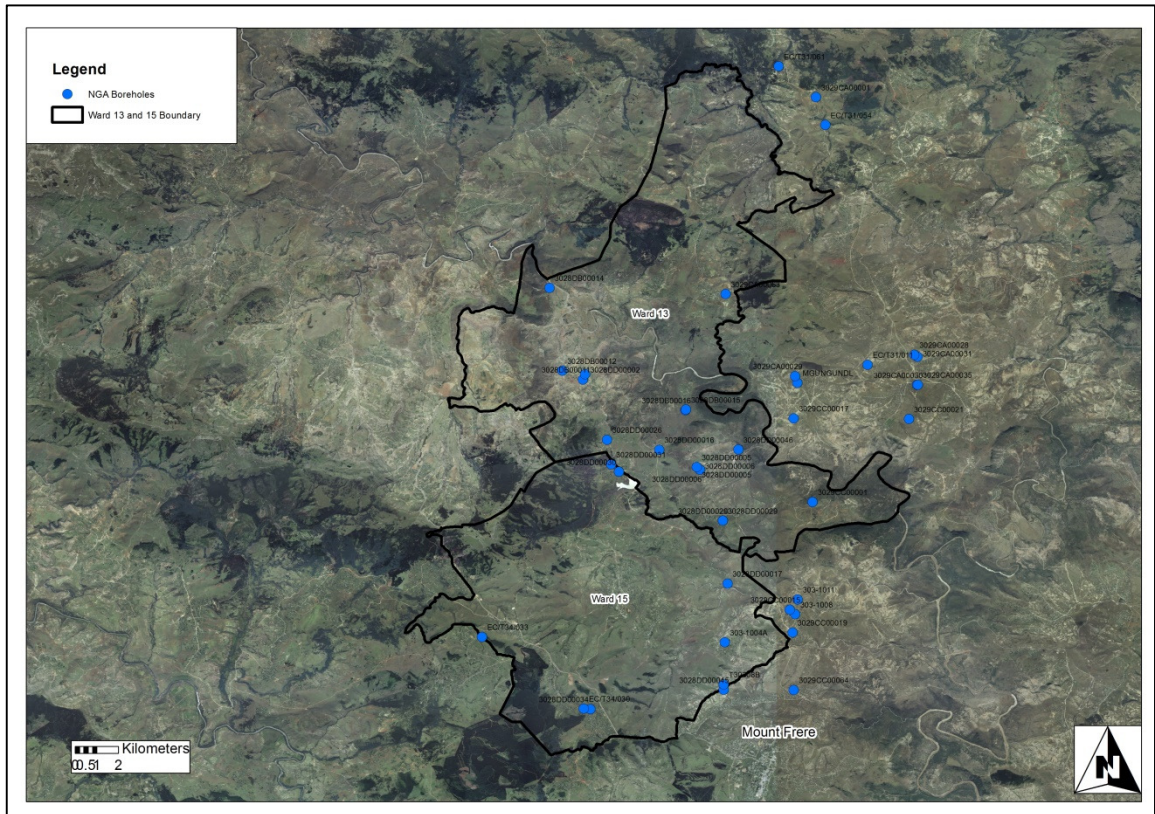


Figure 34 NGA borehole localities.

4.4 Conceptual Model

Cross-sections were generated along two section lines within the project area boundaries. The two section directions were selected to express both the nature of the dolerites in the area as well as the Karoo sediments. A cross-section runs from the north-eastern corner of the project area to the western margin and down to the south-eastern border (Figure 35). This section was selected to allow for the intersection of high and low lying confined and unconfined areas, as well as areas where perched unconfined aquifers may be present.

From the model (Figure 36), it is apparent that the larger dolerite sill and conical sill intrusions may be present in the lower Karoo Formations of the Adelaide Subgroup with dolerite propagating horizontally through the Tarkastad Subgroup rocks as well as the contact zone between the two subgroups. The model is designed to follow the statement by Walker and Poldevaart (1949) that linear dolerite dykes are only present in the Ecca and Beaufort Groups. The insight into the formation of linear dyke structures is limited. However, it is commonly

accepted that the dykes are younger than the ring and sill structures, as the dykes cut the latter structures on a regular basis (Chevalier *et al.*, 2001).

The average size of the dolerite ring structures appears to increase from west to east as the structures proximity to regional Insizwa layered mafic complex increases. In totality dolerite represents approximately 38% of the total surface outcrop present within the project area boundary.

As can be seen on the cross-section, the majority of the study area is underlain by undifferentiated Adelaide and Tarkastad Formations of the Beaufort Group. As the general elevation increases from south-east to north-west, the Adelaide Formation is gradually replaced by the Tarkastad Formation as the lithological group at surface.

The only sedimentary member of the Stormberg Group present is the Molteno Formation in the upper extreme elevations of the study area. It appears to be shielded from weathering by the presence of a large dolerite ring structure which dominates the central area of the cross-section and appears to be shielded from erosion by a dolerite sill minimal perched groundwater is expected to occur in this zone.

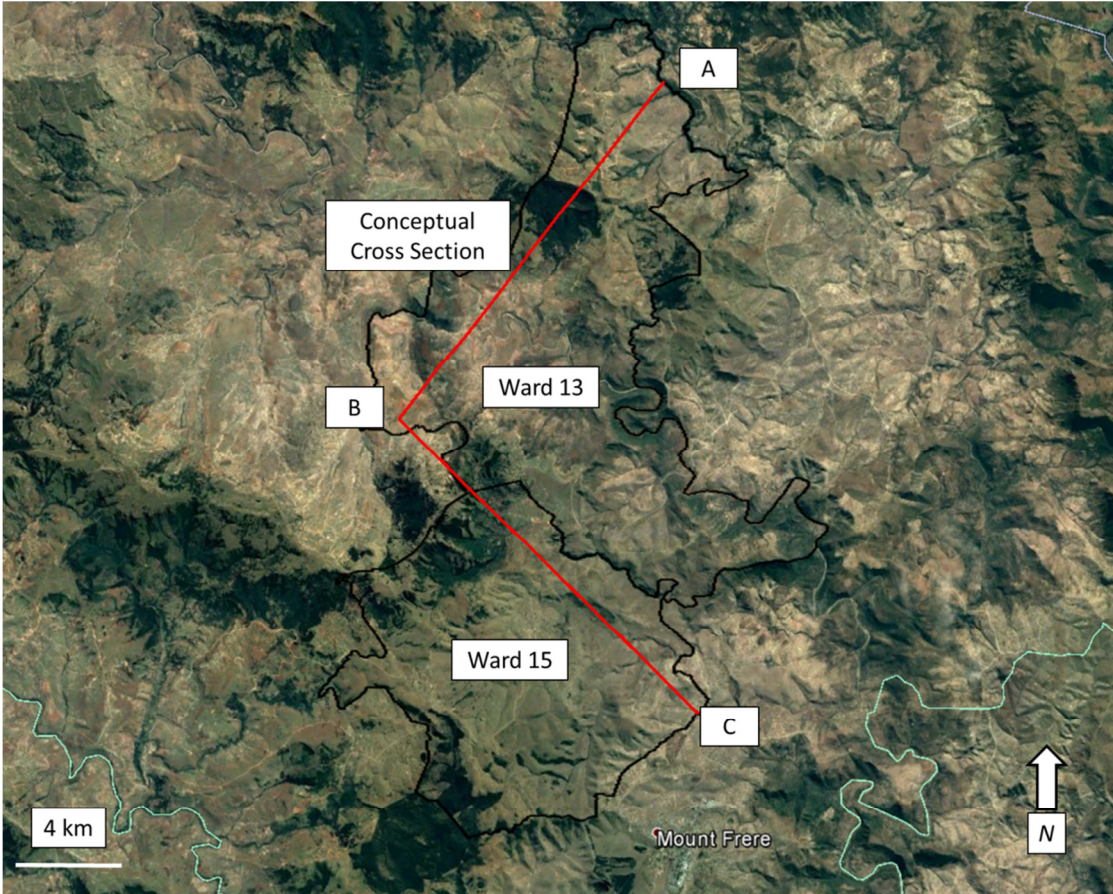


Figure 35 The cross section for the conceptual model.

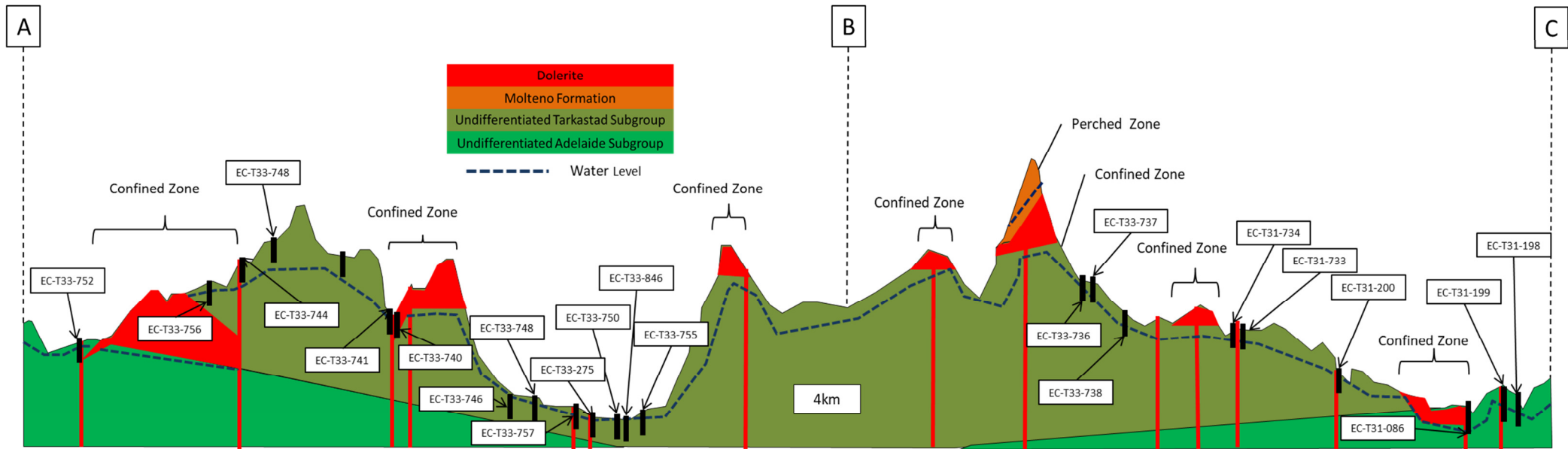


Figure 36 The conceptual model for Ward 13 and 15.

5. Results

5.1 Geophysical Results

Geophysics can be seen as a tool to confirm or disprove the hypothetical desktop and on site evaluation. Linear target structures evaluated by certain geophysical techniques may be disregarded as high potential groundwater targets if the geophysical data collected is not anomalous.

5.1.1 Geophysical Data Collection

A total of 52 geophysical profiles were completed totalling a distance of 15920m. As in many cases the geological maps for a project area appear to be obsolete, as more recent data, such as aerial magnetics have not yet been taken into account when the geological maps for the study area was drawn up. This is evident when viewing at the graphs generated by the geophysical profiles. A total 80 noteworthy magnetic anomalies were crossed during the geophysical exploration phase of the study. This then amounts to one magnetic anomaly being crossed every 199 meters of lateral survey distance. The geophysical data is summarised in Table 4.

The target when undertaking such a geophysical operation is to cross an anomalous structure every 200 meters. This then allows for the possibility to detect if the weathered areas on either side of the anomaly if it is a weathered intrusive anomaly. For the purposes of this study, a number of short exploration profiles were completed, which are then taken into account when deciding on the longer profiles intended for drilling purposes.

Table 4 Summary of geophysical data collected.

Profile Name	Lenth	Methods	Number of anomalies
CT1(A-B)	360	Mag/Res	1
CT1(C-D)	170	Mag/Res	1
CT2(A-B)	150	Mag/Res	1
CT2(C-D)	170	Mag/Res	1
CT3	310	Mag/Res	2
CT4	410	Mag/Res	2
CT5	100	Mag/Res	2
HG1	200	Mag/Res	1
HG2	200	Mag/Res	1
MG1	250	Mag/Res	1
LC1	240	Mag/Res	3
GB1	170	Mag	1
GB2(A-B)	270	Mag/Res	1
GB2(C-D)	200	Mag	1
MB1	130	Mag/Res	1
NT1	500	Mag/Res	4
NT2	410	Mag/Res	1
BF1	210	Mag/Res	2
BF2	600	Mag/Res	2
BF3	590	Mag	2
TH1	140	Mag	1
TH2	150	Mag/Res	1
TH3	600	Mag/Res	3
XY	210	Mag/Res	2
ZT	250	Mag/Res	2
UV	300	Mag/Res	3

Profile Name	Lenth	Methods	Number of anomalies
OS1	460	Mag/Res	2
OS2.2	290	Mag/Res	1
OS3	340	Mag/Res	2
OS4	400	Mag/Res	2
OS5	480	Mag/Res	3
OS6	200	Mag/Res	1
OS7	450	Mag/	5
OS8	520	Mag/Res	2
OS9	340	Mag	1
OS10	500	Mag/Res	2
MH1A	260	Mag/	2
MH1B	180	Mag/Res	1
MH2	720	Mag/Res/	2
MH3	360	Mag	0
MH4B	230	Mag/Res	1
MH4C	120	Mag	0
MH5	370	Mag	0
MH6	280	Mag/Res	1
MH7	450	Mag/Res	2
MH8	640	Mag/Res	1
MH9	130	Mag/Res	1
P2(A-B)	190	Mag/Res	1
P2(C-D)	200	Mag/Res	1
P2(D-E)	200	Mag/Res	1
P2(D-E) Continued	80	Mag/Res	0
P2(F-G)	160	Mag/Res	1

All geophysical profiles which were used in the successful drilling of a borehole are discussed in detail in Section 5.3 and all geophysical data collected are attached in Appendix A, Sections 9.1.1 and 9.1.2.

5.1.2 Geophysical Data Interpretation

The majority of all boreholes drilled during the study targeted both magnetic and conductive anomalies, as this would allow for the best possible chance to intercept a successful water strike. Because of the magnetic geophysical nature of the Karoo dolerites, it is in most cases indicated on the graph as a positive anomaly. However migration of magnetic minerals such as magnetite (Fe_2O_4), pyrrhotite ($\text{Fe}_{(1-x)}\text{S}$) and chromite (FeCr_2O_4) out of the dolerite by processes of weathering may cause a negative anomaly to be detected.

Figure 37 represents the magnetic geophysical data collected in the form of a box and whisker plot. It is apparent from the plot that the data collected for both wards generally grouped around 27750 nT. Slightly more variance can be seen

in the data collected from Ward 15, with larger upper and lower quartiles as well as a wider upper outlier and a definite lower outlier.

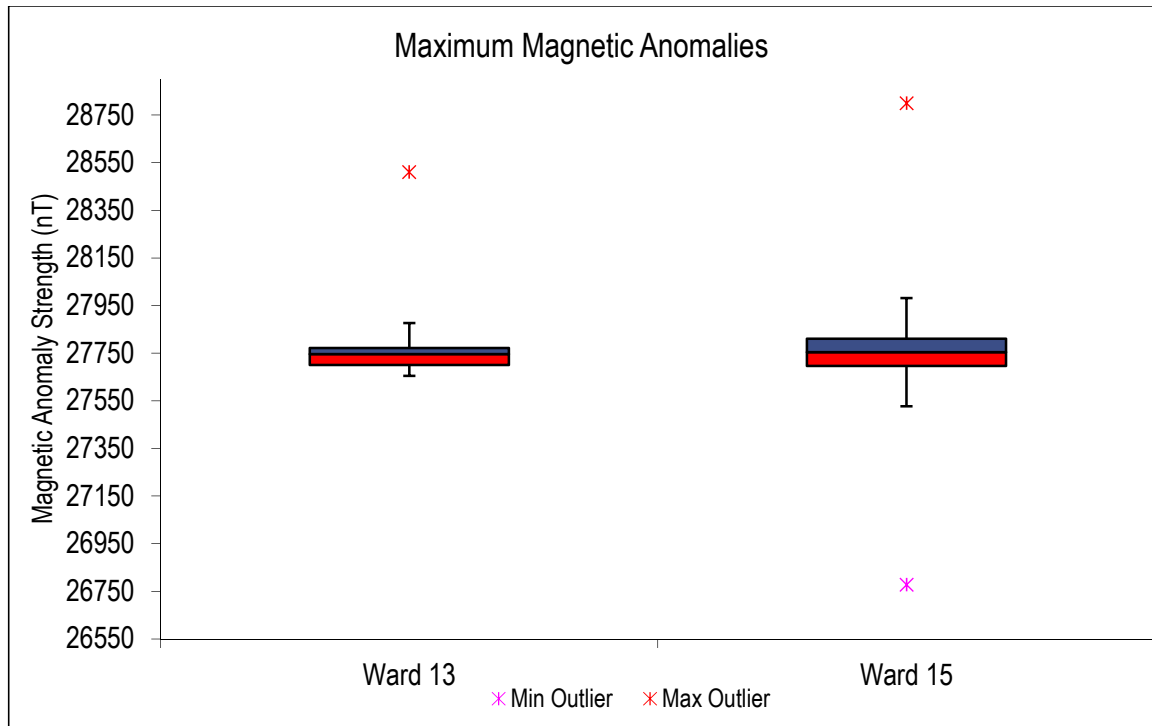


Figure 37 The maximum magnetic anomaly distribution in Nano Tesla (nT).

The study relies strongly on the magnetic data for the purposes of interpreting the presence of dolerite intrusions, as the regional geological map lacks accuracy. To produce a truer representation of the dolerite dyke intrusions present, more detailed evaluation of the on-site geological and geophysical character is necessary.

It is apparent from Figure 38 that a large regional linear magnetic structure, with a WNW strike, is present within Ward 13 of the project area. This linear magnetic structure is noted on the geological map as a dolerite dyke. An acute magnetic contact zone, with a NE strike, is also present within the southern section of Ward 15 of the project area. The northern section of the contact zone has a much lower fingerprint than the southern section of the contact. The western section of Ward 13 shows slight signs of NW trending magnetic structures.

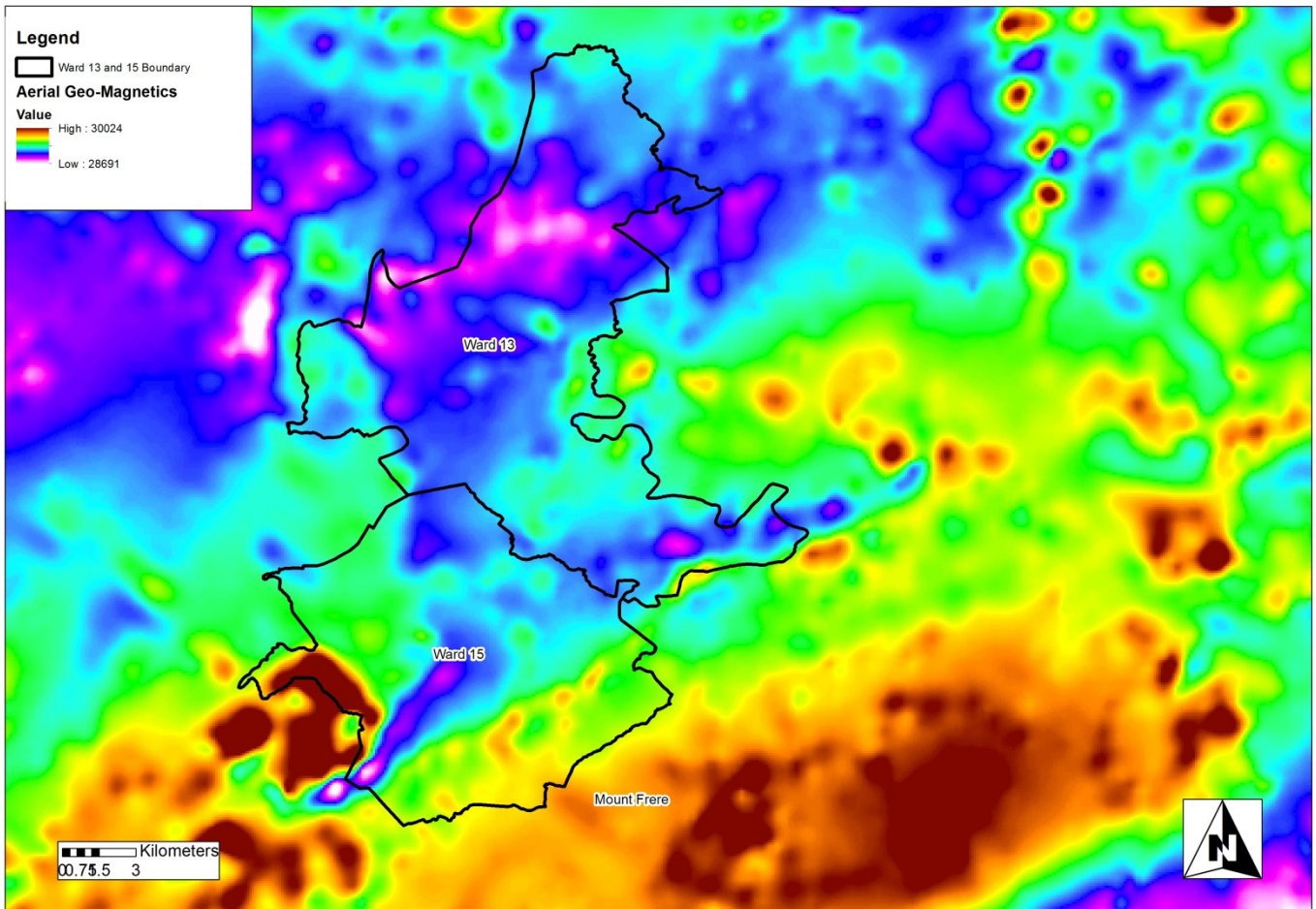


Figure 38 The aerial magnetic data (given in nano Tesla) available for the study area, collected by the South African Council for Geosciences (SACGS) flying a 1x1 km grid.

The general magnetic fingerprint of the study area is lower than that of the surrounding areas to the south and east. The general higher magnetic data surrounding the project area can be attributed to the presence of the Ntsizwa Complex to the east of the study area.

5.2 Drilling results

During the development process a total of 36 boreholes were drilled with 25 being successful, amounting to a 69.4% success rate. This statistic is illustrated in Figure 39.

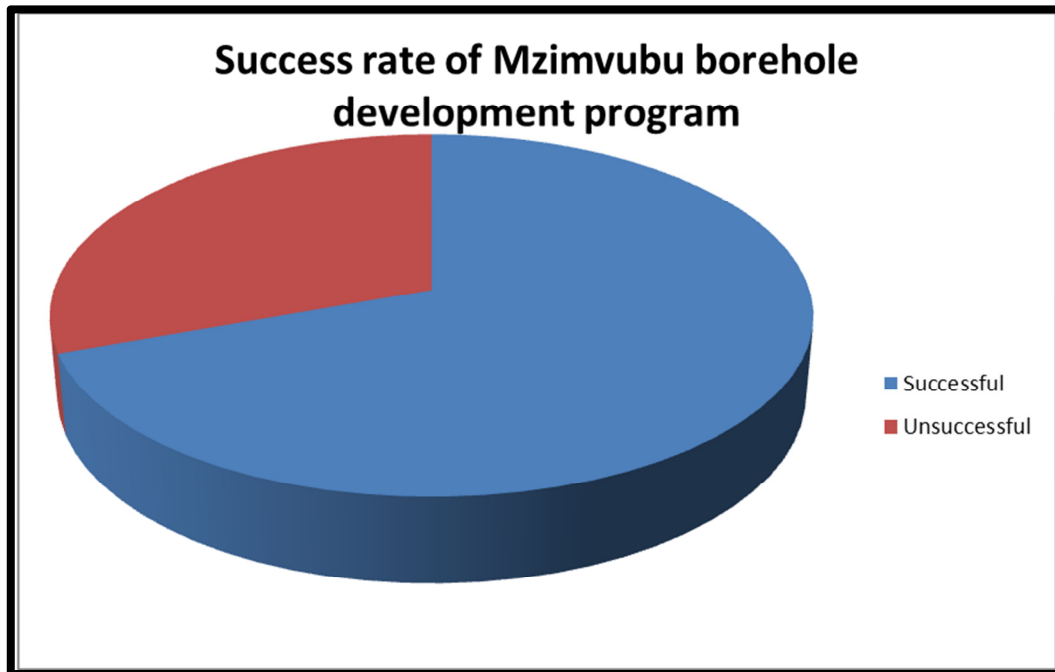


Figure 39 The number of boreholes drilled vs number of successful holes.

According to literature, tectonic displacement by dolerite intrusions as well as later tectonic activity, allows for fracturing around dolerite intrusions. In total, 52 water strikes were intercepted during the study, of which 35% of all water strikes were encountered directly in dolerite intrusions or associated fracturing in adjacent country rock formations. The fact that 65% of all water strikes intercepted during the study were not directly in dolerite intrusions may be indicative that more post Jurassic tectonic structures may exist than currently expected. Another interpretation can be that the intrusion of the dolerites in the study area was of a highly abrasive nature, therefore causing large areas of country rock to be fractured due to displacement. This would be especially suited to fractures in sandstone-rich formations, because of the low plasticity of sandstone compared to mudstone or shale (Senseny and Pfeifle, 1984).

Figure 40 is based solely on the lithological logs that were drawn up for the completed boreholes. It is therefore possible that portions of the water strikes are dolerite associated, but are labelled as strikes within country rock, as it cannot be stated with certainty what the horizontal extent of the dolerite-associated fractures within the country rock is.

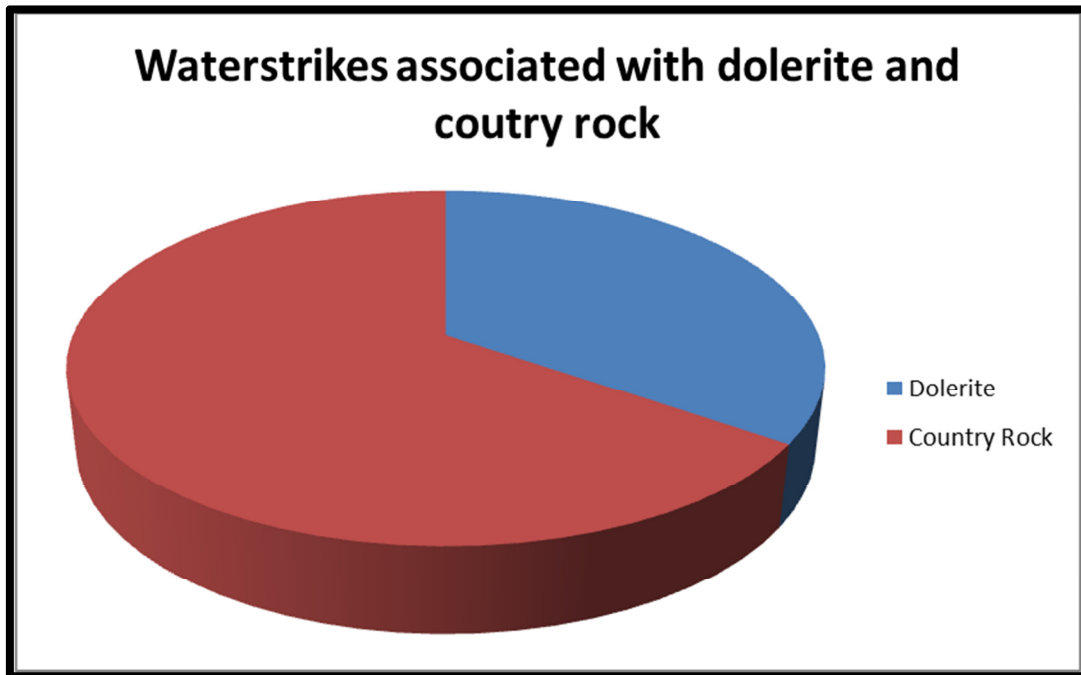


Figure 40 The number of successful boreholes with water strikes in dolerite versus country rock.

Figure 40 is based solely on the lithological logs that were drawn up for the completed boreholes. It is therefore possible that portions of the water strikes are dolerite associated, but are labelled as strikes within country rock, as it cannot be stated with certainty what the horizontal extent of the dolerite-associated fractures within the country rock is.

It is apparent from Figure 41, that the hydrogeological gradient in the project area closely mimics that of the topographical elevations. This also serves as justification for the conceptual static water level expected in the study area as indicated on Figure 36 (Conceptual Model).

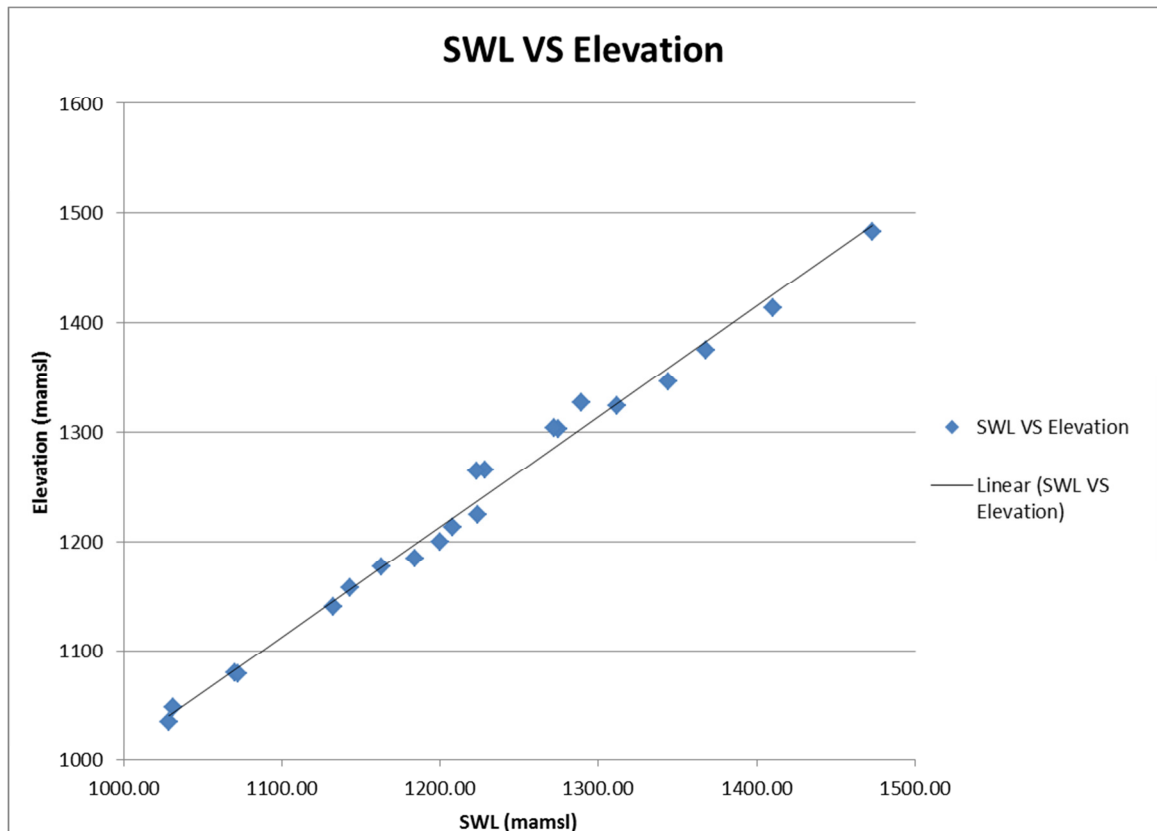


Figure 41 Static Water Levels of boreholes drilled within the project area vs the elevations of the sites.

5.3 Individual borehole descriptions

The following section describes the drilling process per borehole in both wards. The geophysical profile on which each borehole was drilled, the borehole construction log as well as an aerial map of each site is provided. Lineaments identified from the aerial photography are marked as white lines on the aerial photo maps. In many cases, the structures were only identified on site, therefore not forming part of the lineation maps. Some of the information regarding the boreholes was lost over time. All drilling sites with complete data sets, i.e. relevant coordinates for the geophysical profile as well as the exploration drilling site, the geophysical data and the drilling log of the borehole, were used during the individual site descriptions.

5.3.1 Ward 13 Boreholes

EC-T31-733

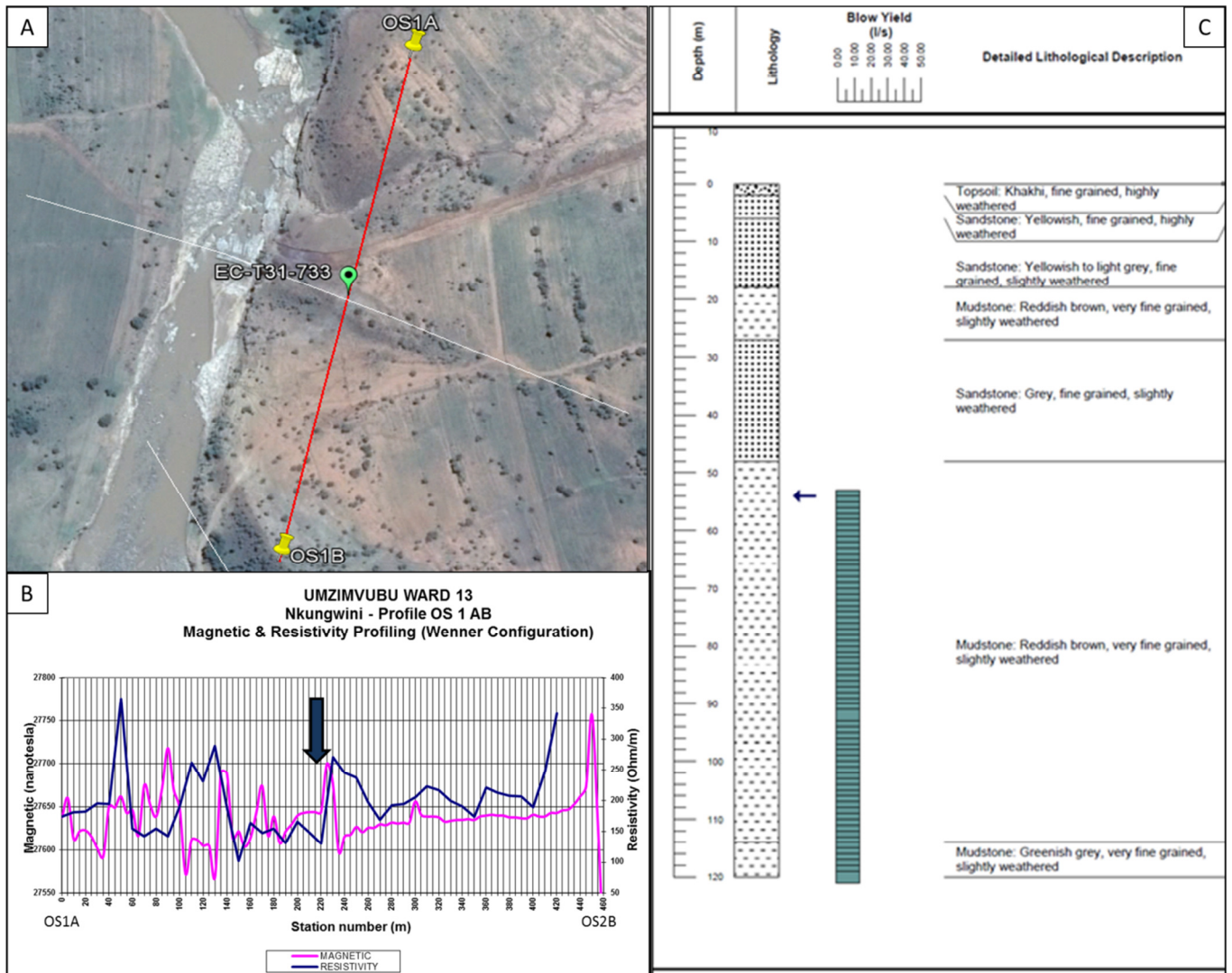


Figure 42 A) The spatial setting of the geophysical profile OS1 as well as the location of the borehole EC-T60-733 on the profile. B) The graphical display of the data collected from profile OS1 as well as the data station selected for drilling. C) The drilling log as well as strike depth and yield data collected during the drilling process, as plotted using the Strater software package. The strike depth is indicated by the horizontal arrow on the vertical lithological log. The blow yield is indicated by the blow yield scale on the upper heading bar of the Starter plot.

After identifying the north-west trending lineament along the banks of one of the tributaries of the Kinira River during the desktop study, a geophysical profile was performed targeting the lineament (Figure 42). A positive magnetic anomaly indicated the possible presence of a dolerite dyke intrusion. The shape of the magnetic anomaly is that of a structure that dips slightly to the north-east. A

positive anomaly was also detected during the resistivity profile, indicating that the dyke itself is relatively unweathered. The sharp rise in electrical resistivity value between what was expected to be the Karoo sedimentary rock and the perceived dolerite dyke intrusion was viewed as indicative of contact weathering and fracturing along its north-western margin.

An exploration borehole was drilled on the lineament which was perceived to be a dolerite dyke intrusion. The borehole produced a 10l/s blow yield, after a water strike was intercepted at 54 mbgl in a highly fractured fine grained mudstone. The final depth of the borehole is 120mbgl. No dolerite was intercepted during the drilling process and therefore it cannot be confirmed whether it was or was not a dolerite intrusion.

EC-T31-734

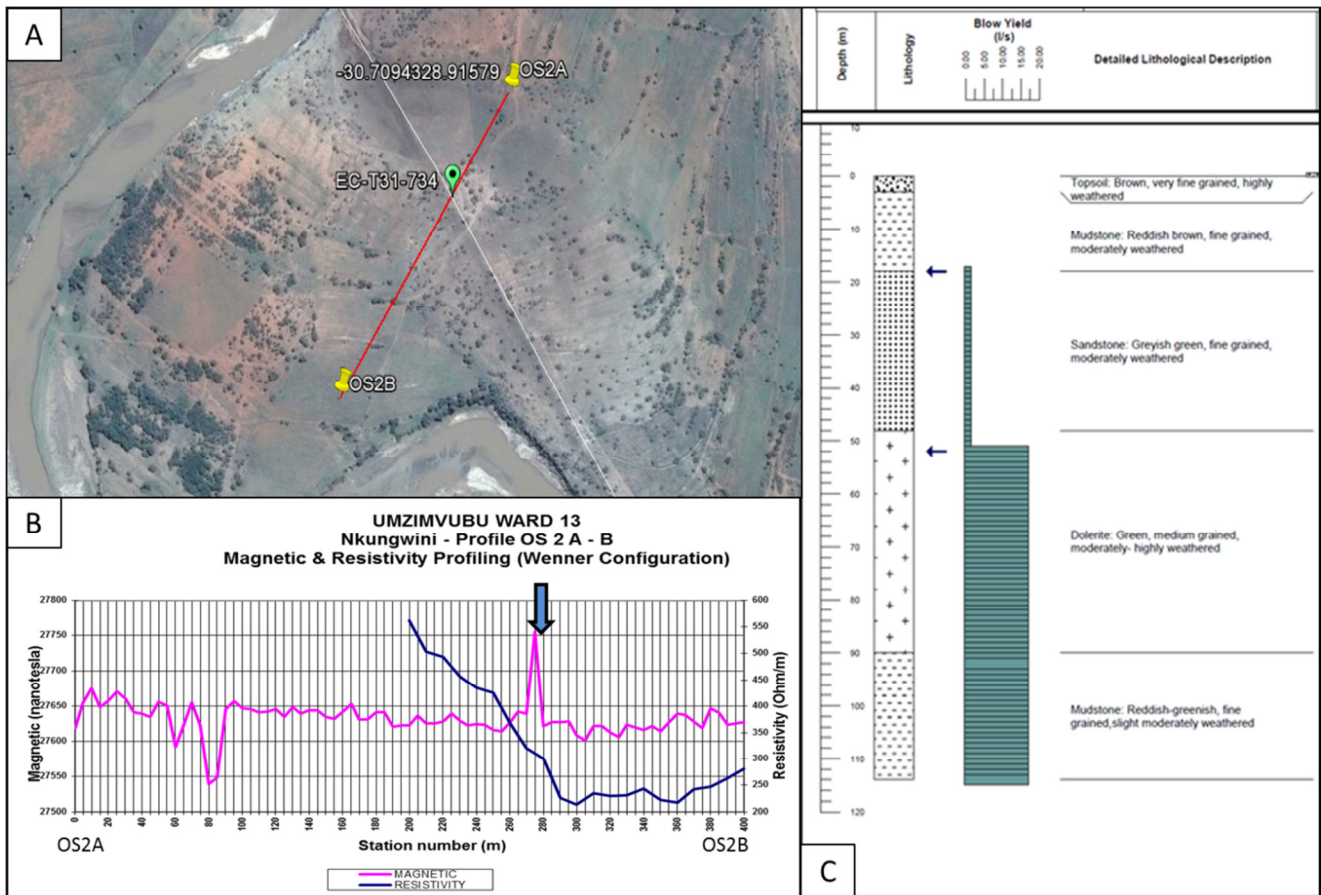


Figure 43 A) The spatial and structural setting of borehole EC-T31-734. B) The geophysical data collected from profile OS2 and the data station selected for drilling. C) The lithological log and depth and yield values of water strikes intercepted during the drill process.

A north-westerly trending lineament, north of a meander in an tributary of the Kinira River was observed during the desktop study and thus a geophysical profile was conducted (Figure 43).

Two water strikes were intercepted totalling a yield of approximately 20l/s after being drilled to a final depth of 114 mbgl. The upper strike was intercepted at approximately 18 mbgl in a moderately weathered sandstone formation and contributed approximately 0.5 l/s to the total final blow yield. The second water strike was at approximately 52 mbgl, on the contact zone of a highly fractured fine grained sandstone and dolerite. The dolerite was identified as a north westerly striking lineament on the satellite imagery. Solid steel casing was

installed down to a depth of 18 mbgl as well as from 24-42 mbgl to support unstable formations from collapse. Slotted steel casing was installed from 18-24 mbgl as well as 42-54 mbgl, which allows water to enter the borehole freely.

EC-T31-085, EC-T31-086 and EC-T31-089

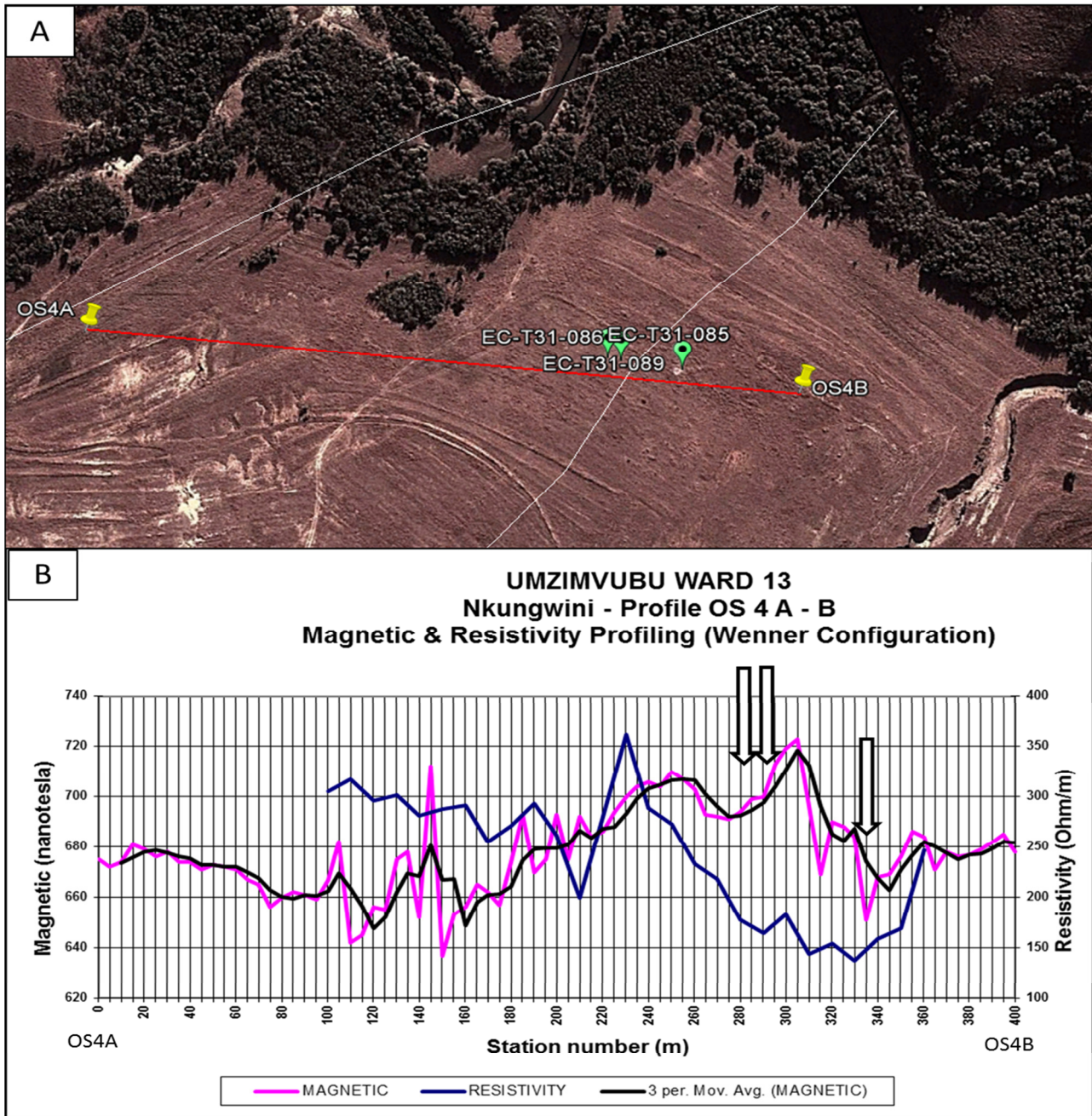


Figure 44 A) The spatial setting of the geophysical profile OS4 and the exploration boreholes EC-T31-085, EC-T31-086 and EC-T31-089 as well as the lineaments in the area. B) The geophysical data collected from profile OS4 and the data stations selected for exploration drilling.

A set of north easterly trending lineaments was observed in the north eastern section of Ward 13 adjacent to the Nkeman River and a geophysical profile was conducted over the most southerly of the two (Figure 44). At approximately 300m on the profile course, a magnetic anomaly was detected, which was confirmed on site to be a dolerite dyke, as dolerite outcrop was visible. The lowest electrical resistivity data was also collected in the area that would have been affected by the intrusion of the dolerite dyke.

Borehole EC-T31-085 was drilled down to a final depth of 100 mbgl and considered unsuccessful with a final blow yield of 0.13 l/s. A single water strike was intercepted in a dolerite formation at a depth of approximately 32 mbgl and indicated low levels of fracturing. The borehole was sighted on the dip side of the dolerite formation at 290m on profile OS4. The dyke was intercepted at approximately 11 mbgl and exited at approximately 58 mbgl. It was thus decided to move the drilling rig a further five metres towards the start of the geophysical profile to data station 285, for a second attempt at the dip side of the dyke.

Borehole EC-T31-086 was unsuccessfully drilled to a final depth of 84 mbgl. The dyke yielded 0.1 l/s from a water strike at 28 mbgl, which was intercepted in the dolerite formation with low levels of fracturing. The dolerite was intercepted at approximately 17 mbgl and exited at approximately 50 mbgl.

A final attempt to drill a production borehole on the dolerite dyke was made when borehole EC-T31-089 was sighted on the fall side of the dyke at approximately 330m on profile OS4, targeting possible contact fracturing between the dolerite dyke and the Karoo sedimentary rocks. The borehole was drilled to a final depth of 78 mbgl. The borehole was considered unsuccessful, as it too yielded only 0.1 l/s from a single strike at approximately 18 mbgl in a moderately weathered siltstone formation.

EC-T31-200

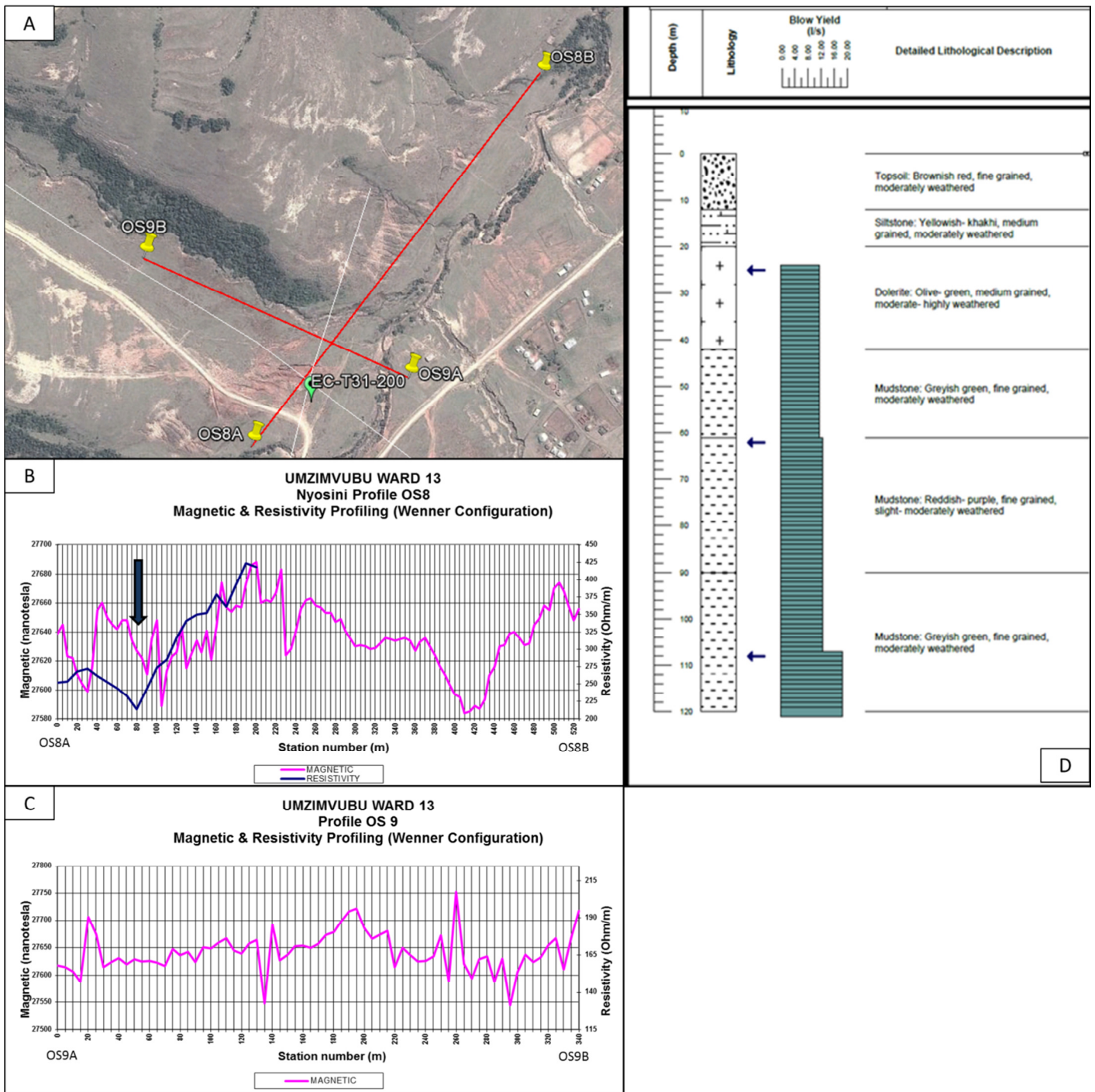


Figure 45 A) The spatial setting of geophysical profiles OS8 and OS9 as well as borehole EC-T31-200 and the lineaments visible from the satellite photo maps. B) The geophysical data collected from profile OS8 as well as the data station selected for exploration drilling. C) The data collected from profile OS9. D) The drilling log for borehole EC-T31-200 as well as the depth and yields of the water strikes intercepted during the drilling operation.

Two cross-cutting lineaments were detected, one trending in a north-westerly direction and the other trending north-north east, during the desktop investigation in a low-lying area with an adjacent higher area to the west (Figure 45). The area has multiple surface drainage lines as can be seen on Figure 45A. Two geophysical profiles were performed. The first (OS 8) targeted the north-westerly trending structure. Multiple magnetic anomalies were detected and what appeared to be a lithological contact zone was detected during the resistivity profile.

Three minor anomalies were detected during the data collection on profile OS 9, which targeted the north-north easterly trending lineament. The contact zone detected on profile OS 8 was selected for exploration drilling before resistivity could be carried out on profile OS 9.

Borehole EC-T31-200 was drilled to a final depth of 132 mbgl, with a final blow yield of 16.1 l/s. The borehole was drilled on a north-westerly striking lineament, confirmed to be a dolerite dyke, near the area where it is expected to be cross cut by the north-north easterly striking lineament. A strike yielding approximately 6 l/s was intercepted in a highly weathered dolerite formation at 25mbgl. Strikes yielding 2 and 8.1 l/s were intercepted in highly fractured mudstone formations at 62 and 109 mbgl respectively.

EC-T31-198

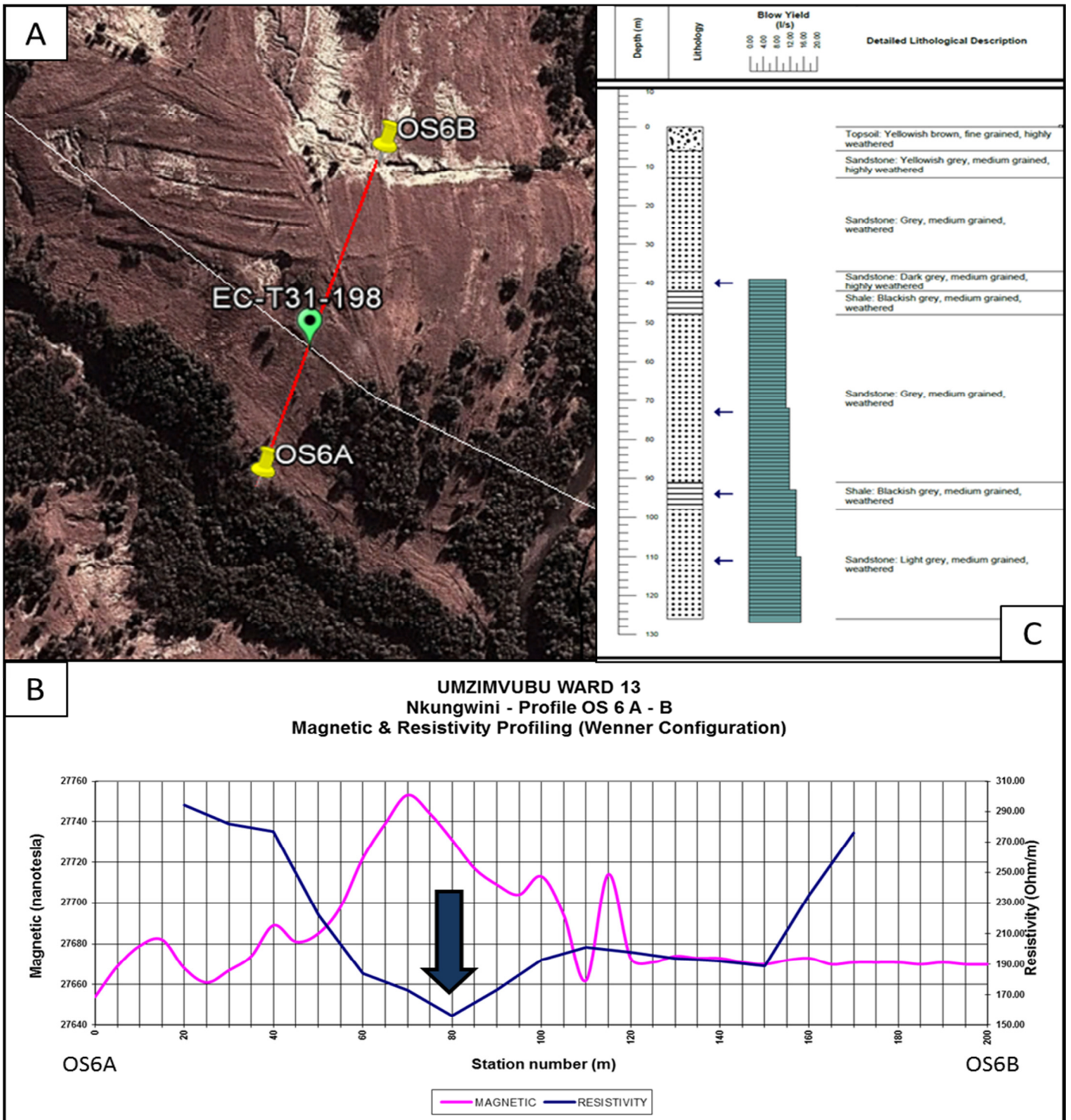


Figure 46 A) The spatial setting of the geophysical profile OS6, borehole EC-T31-198 and the lineaments in the area. B) A graphic display of the data collected on profile OS6, as well as the data station selected for exploration drilling. C) The drilling log as well as water strikes and yields obtained from the water strikes during the drilling process.

A north-easterly trending lineament was detected from the desk top study adjacent to one of the tributary drainage lines of the Nkemane River. A geophysical survey was conducted over the lineament and a magnetic as well as electrical resistivity anomaly was detected over the lineament (Figure 46).

The anomaly detected on the resistivity profile was selected for exploration drilling. After being drilled to a final depth of 126 mbgl, borehole EC-T310198 was considered successful, with a final blow yield of 10.8 l/s (Artesian). No dolerite was intercepted during the drilling process thus the structure was classified as a magnetic fault.

In total, four water strikes were intercepted during the drilling process. The first strike was intercepted at 40 mbgl in a highly weathered sandstone formation and yielded 6 l/s. At 73 mbgl, a water strike was intercepted in a weathered sandstone formation which yielded 1 l/s. A water strike yielding 1.5 l/s was intercepted at 94 mbgl in a weathered shale formation. A fourth water strike was intercepted at a depth of 111 mbgl in a weathered sandstone formation, which yielded 1.5 l/s.

EC-T31-199

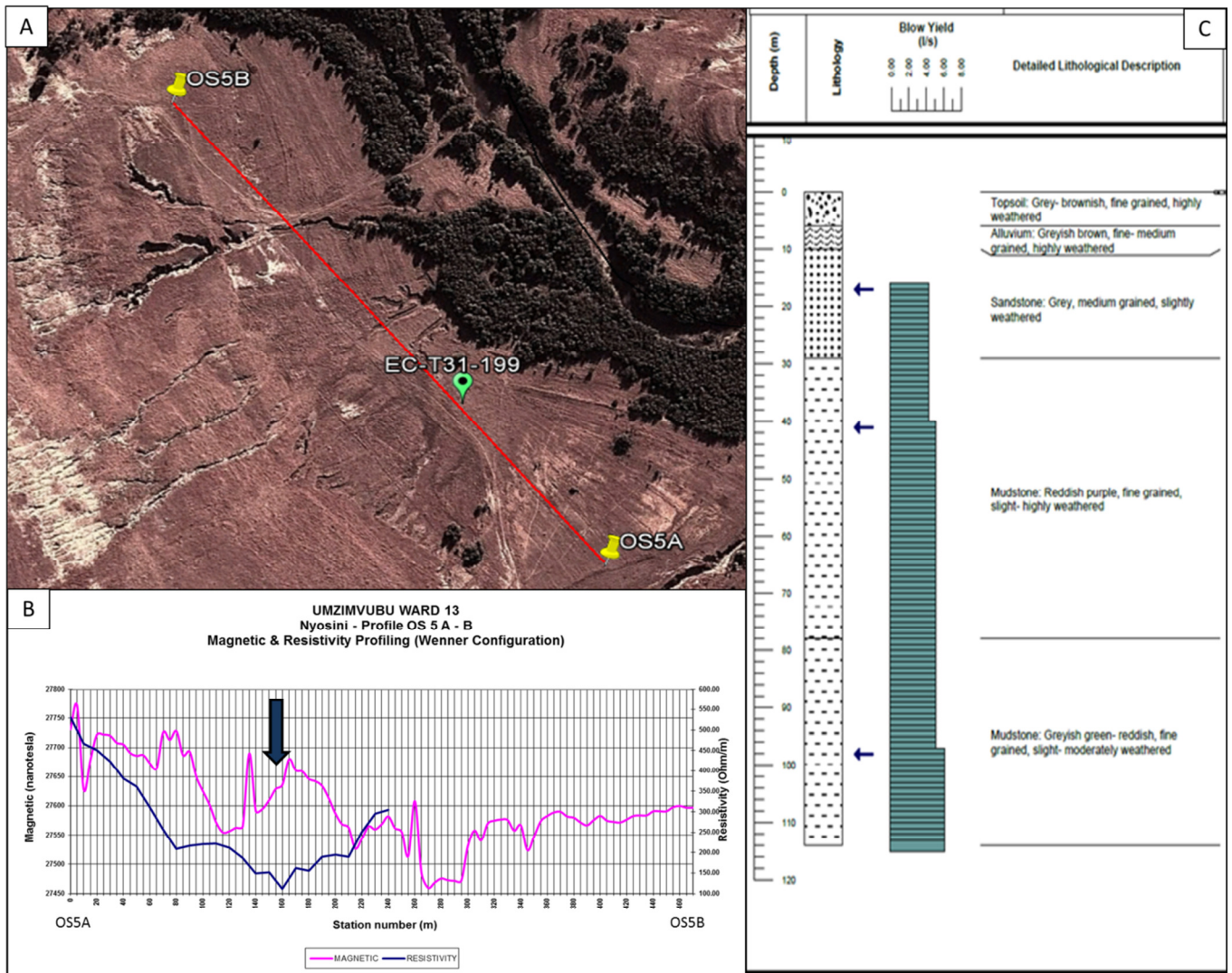


Figure 47 A) The spatial setting for the geophysical profile OS5 as well as the borehole EC-T31-199. B) A graphical representation of the data collected from profile OS5 and the data station selected for exploration drilling. C) The drilling log as well as depth of the water strikes intercepted during the drilling process and the yields obtained from the strikes.

During the site investigation, a geophysical investigation was performed along a section of the Nkemané River. The area appeared to receive good groundwater recharge from the surface water catchment, as multiple springs were noticed in the erosion gullies to the west of the planned profile. A prominent magnetic geophysical anomaly was detected during the survey and was thereafter surveyed with the electrical resistivity method (Figure 47). An anomaly was

detected during the resistivity profile which nearly mirrored that of the magnetic data collected.

The data station which delivered the lowest resistivity reading was selected for exploration drilling. The borehole was drilled to a final depth of 114 mbgl and successfully produced 5 l/s. A water strike of 3 l/s was intercepted at 17 mbgl in a weathered in sandstone formation. At 40 mbgl a water strike of 1 l/s was intercepted in a weathered mudstone formation. A third water strike was intercepted at 97 mbgl in a weathered mudstone formation, which yielded 1 l/s.

EC-T33- 736

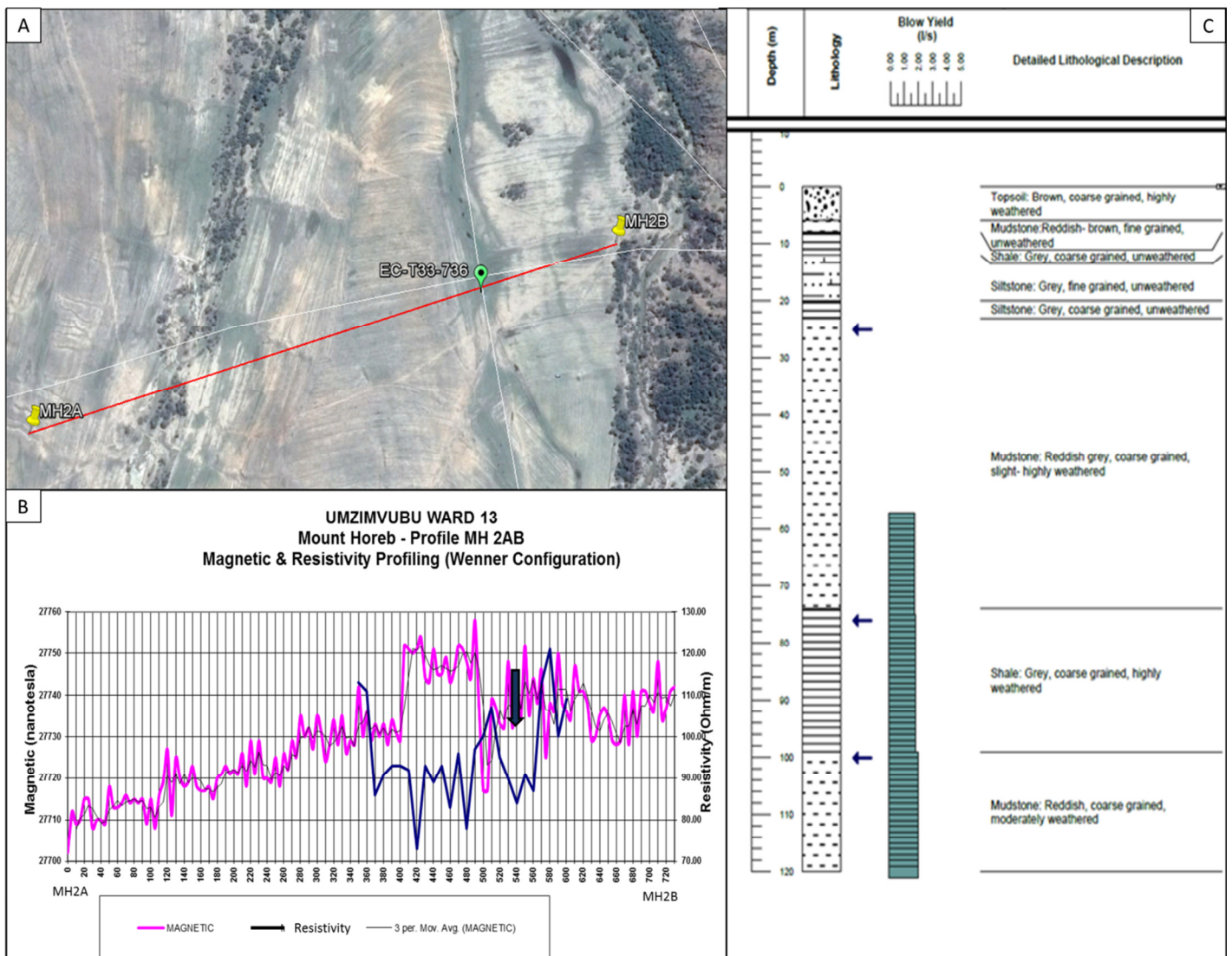


Figure 48 A) The physical and structural setting of the geophysical profile and exploration drilling site. B) The geophysical data collected from profile MH2, which was completed in a NE direction and the exploration drilling site chosen for development indicated by the arrow. C) Exploration drilling log of borehole EC-T33-736 as well as the depth and yield of water strikes intercepted.

During the desktop study, a lineament with a north-north easterly trend was identified for geophysical surveying. The lineament appears to be cross cut by a second lineament, which has an east – west trend becoming south-west westward along its strike direction (Figure 48).

A magnetic anomaly, as well as two resistivity anomalies, was detected during the survey process. It was decided to target the broader of the two resistivity

anomalies, which also appeared to fall directly on the northerly trending lineament.

This was the deepest borehole drilled within Ward 13. The borehole yielded 4.5 l/s in total. A water strike was intercepted in a highly weathered mudstone formation at 25 mbgl, which yielded 2 l/s. A second strike, which produced approximately 0.5 l/s, was intercepted in a weathered shale formation. At 101 mbgl, a third water strike yielding 2 l/s was intercepted in a weathered mudstone formation.

EC-T33- 737

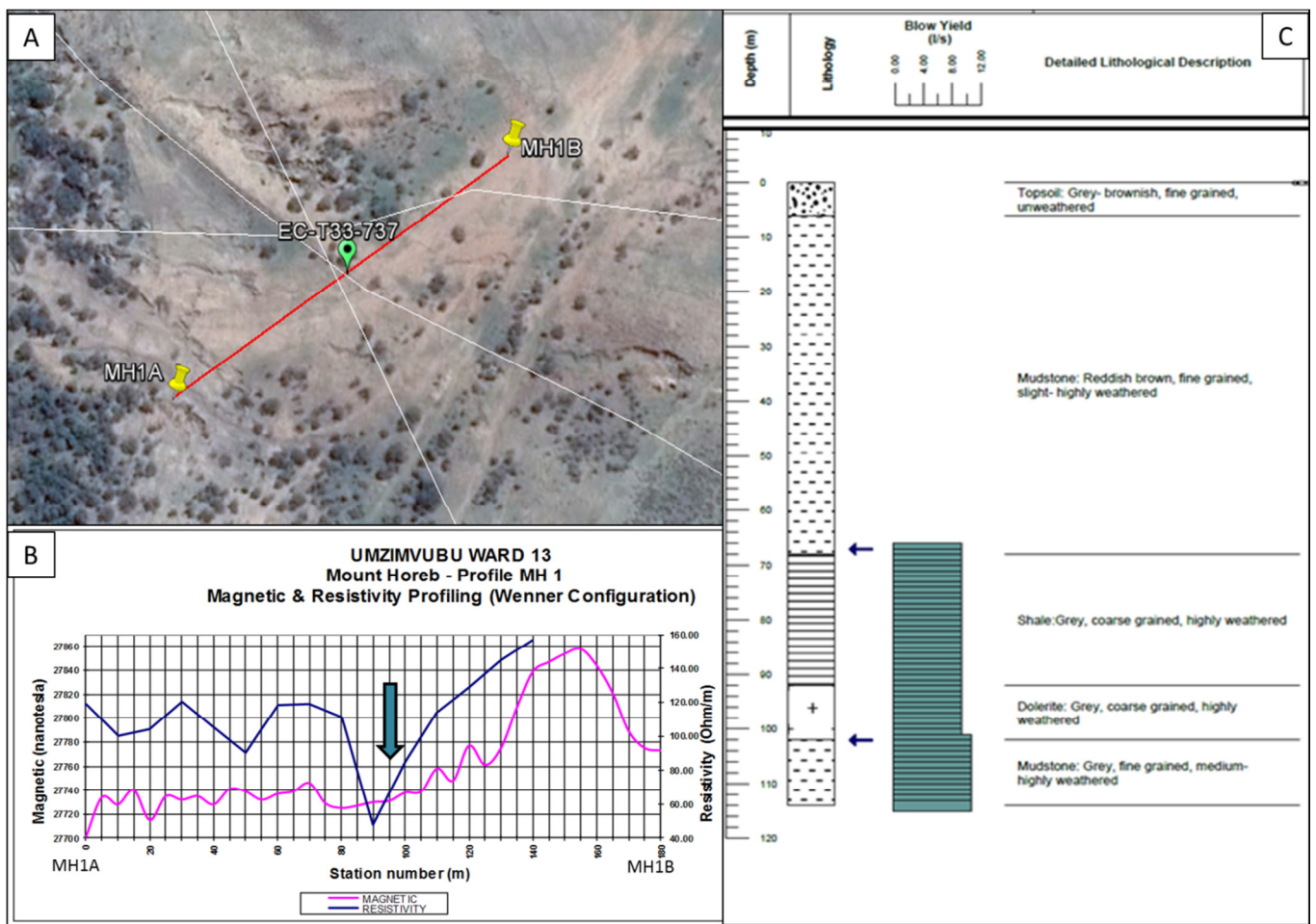


Figure 49 A) The interpretation of the structural setting and geophysical profile performed (MH1) in a NE direction. B) The geophysical data collected and the data station selected for exploration drilling indicated with an arrow. C) The borehole drilling log as well as the depth and yield of the water strikes intercepted.

From the desktop phase of the project, three linear structures were identified. A geophysical profile (MH1) was performed crossing all three lineaments. A prominent magnetic anomaly as well as an electrical resistivity anomaly was detected (Figure 49).

The resistivity anomaly, which also appeared to fall on one of the lineaments in the area, was selected for exploration drilling. Two water strikes were intercepted during the drilling of the borehole, down to a final depth of 114 mbgl, with a final blow yield of 11.75 l/s. The first strike was intercepted in a horizontal fracture between a mudstone and a shale formation, which yielded 9 l/s. The borehole was then drilled through a dolerite dyke formation and at its lower contact with a

mudstone formation, an additional 2.75 l/s water strike was intercepted. The evidence from the borehole log confirms that the lineament is a dolerite dyke.

EC-T33- 738

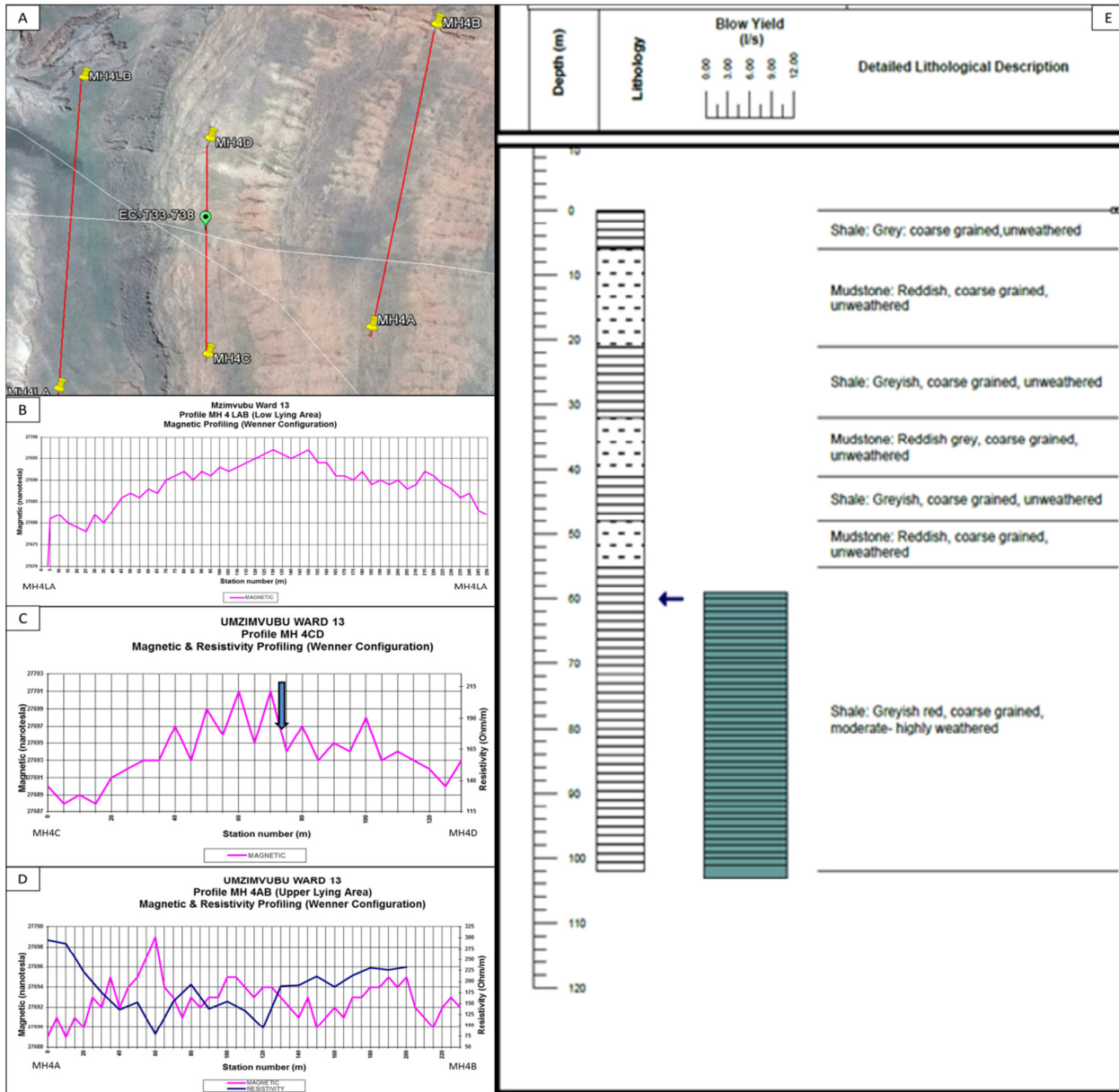


Figure 50 A) The structural and physical setting of borehole EC-T33-738 as well as the geophysical profiles conducted in the area. B) A display of the data collected from profile MH4L AB (the lower lying area). C) The data collected from profile MH4 CD and the data station that was selected for the drilling operation. D) The geophysical data that was collected from profile MH4AB (the upper profile). E) The visual display of the formations that were intercepted during the drilling operation and the depth and yield of the water strike.

The east – west lineament within the area was identified during the desktop study. Profile MH AB was the first of the three geophysical profiles performed within the area. A prominent magnetic as well as electric resistivity anomaly was detected on the profile; it was, however, in a relatively high lying topographical area. Profile MH LAB was then performed. However no magnetic anomaly was detected on the profile and the profile was inaccessible for the drill rig. Profile MH CD was then performed in an area that was accessible to the drill rig and where a visible change in soil colour was present. The resulting data did not deliver a standard magnetic anomaly; instead a section of magnetic noise was detected over the perceived structure (Figure 50).

After drilling to a final depth of 102 mbgl, borehole EC-T33-738 had a final blow yield of 11.3 l/s from a singular water strike at 63 mbgl in a highly weathered shale formation. The target structure was confirmed to be a dolerite dyke, because of the linear dolerite outcrop present on site. It was, however, a fractured zone associated with the dolerite dyke which yielded the water strike, as no dolerite formations were intercepted during the drilling process.

5.3.2 Ward 15 Boreholes

EC-T33-750

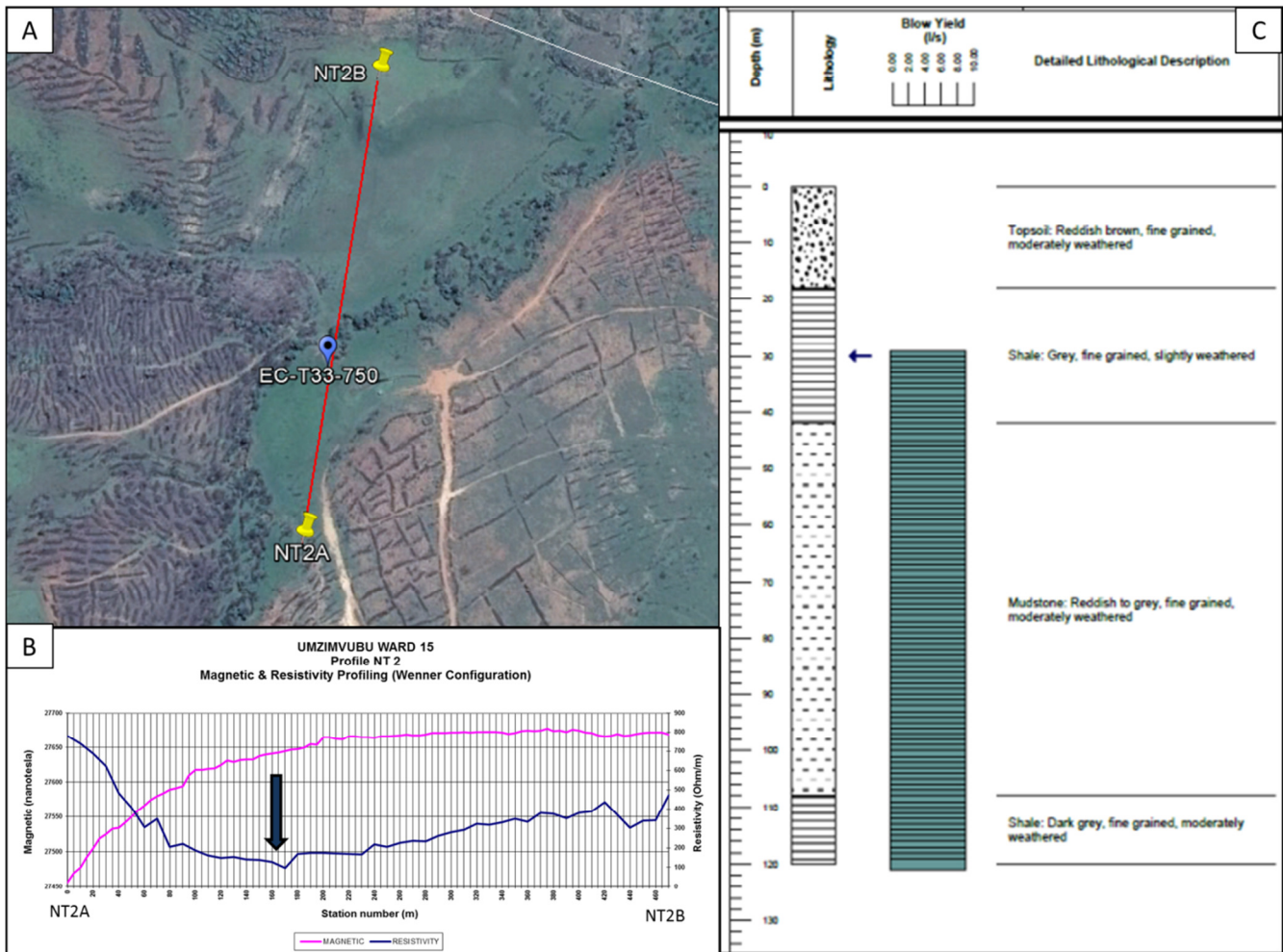


Figure 51 A) The spatial setting of geophysical profile NT2, borehole EC-T33-750 and the lineaments in the area. B) A graphical presentation of the data collected from profile NT2 as well as the data station selected for exploration drilling. C) The drilling log of borehole EC-T33-750 and the depth of the water strike and yield obtained from the strike.

During the desktop investigation, a dry surface water drainage line in a flat lying area was observed to change direction by approximately 45° to the east. This pronounced change, coupled with changes in soil colour, prompted a geophysical profile (Figure 51) to be carried out over the dried drainage line. The resulting data appeared to resemble a gradual change in lithological formation. A slight anomaly was detected on the resistivity data and was accordingly selected for exploration drilling.

The borehole was drilled to a final depth of 120 mbgl and produced a total blow yield of 8.5 l/s. A water strike was intercepted at 30 mbgl in a fractured shale formation. From the geophysical and drilling data obtained, it appears that the target structure was a horizontal fracture zone within the upper shale formation and not a geological contact zone.

EC-T33-755

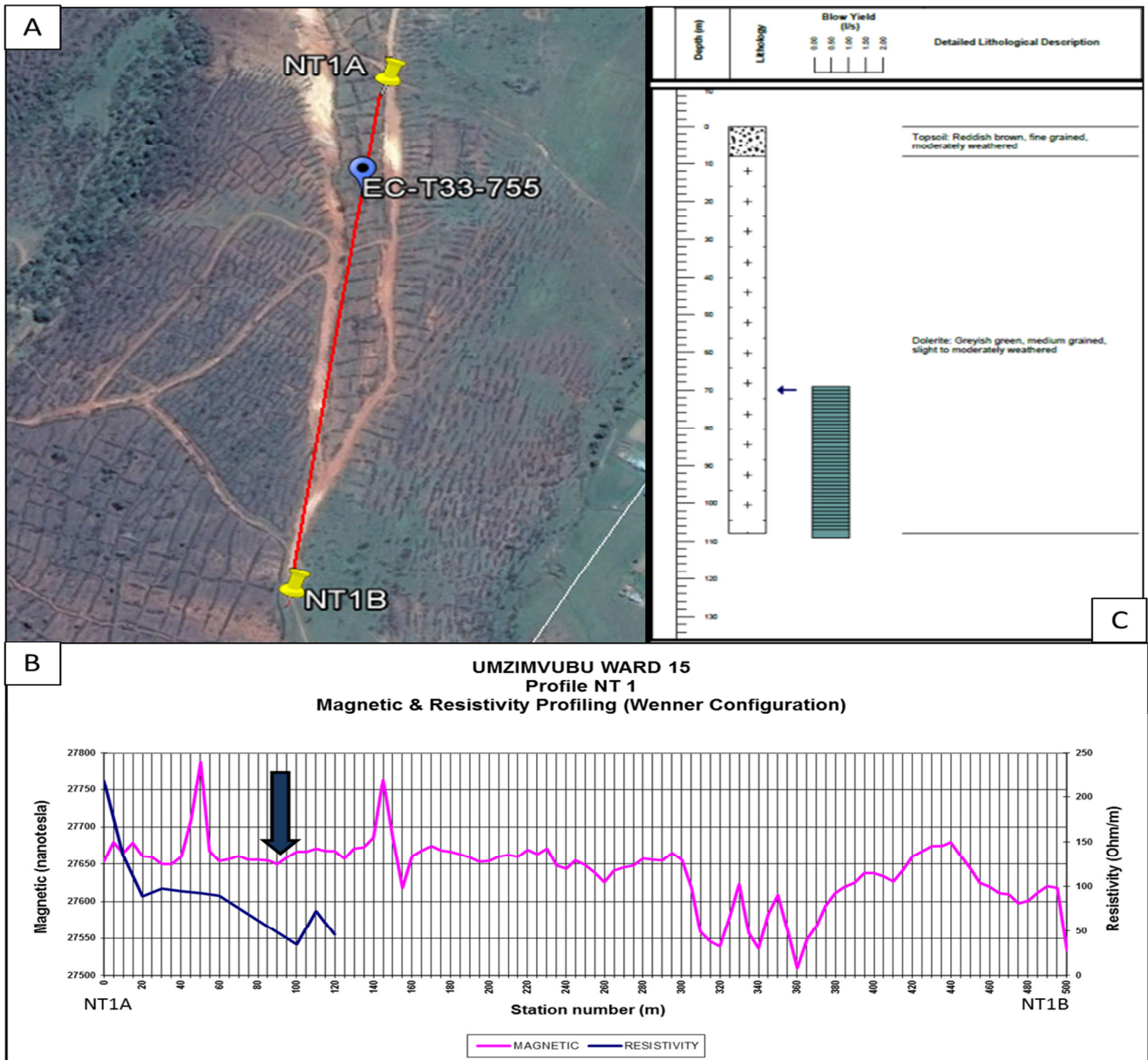


Figure 52 A) The spatial setting of profile NT1 as well as borehole EC-T33-755 and the lineaments in the area. B) The data collected from profile NT1 represented graphically and the data station selected for exploration drilling. C) The drilling log for borehole EC-T33-755 as well as the depth of the water strikes intercepted and the yield obtained from the water strike.

During the on-site investigation, a prominent change in soil colour, from brown to deep red, was observed. The geological outcrops within the red soil zone all appeared to be doleritic in origin and appeared to originate from a dolerite sill. A geophysical survey was carried out over the area of soil colour change (Figure 52). Two positive magnetic anomalies were detected, along with a negative electrical resistivity anomaly. It was decided to drill an exploration borehole on the resistivity anomaly.

At a completed depth of 108 mbgl, the borehole (EC-T33-755) was considered successful, yielding 0.5 l/s. A singular strike was intercepted at 70 mbgl in a dolerite formation, which was the only hard rock geological formation intercepted during the drilling process.

EC-T33-846

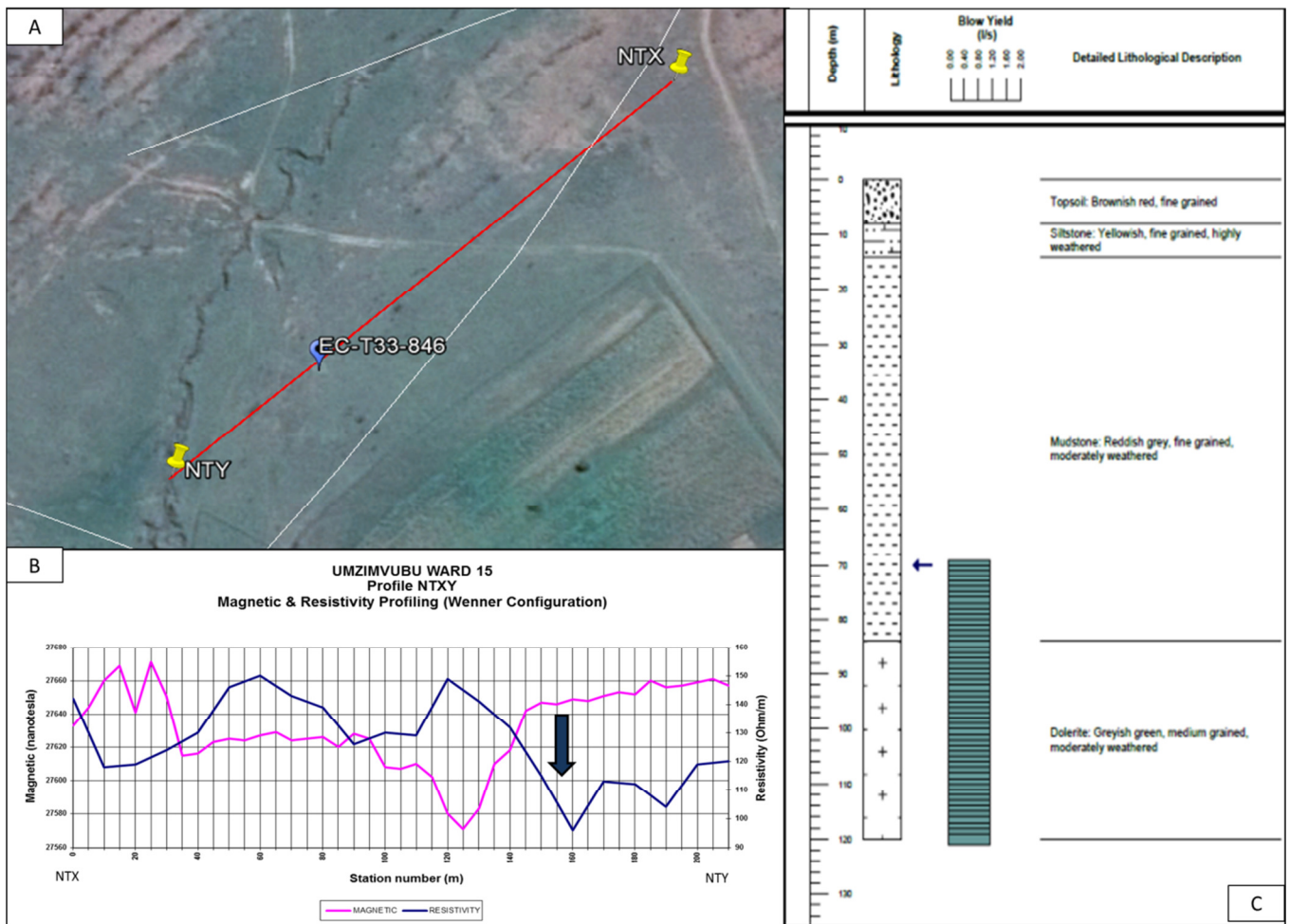


Figure 53 A) The spatial setting of the geophysical profile NT X-Y and borehole EC-T33-846. B) The geophysical data collected at profile NT X-Y as well as the data station selected for exploration drilling. C) The drilling log as well as the depth and yield of the water strike intercepted during drilling.

While the site was investigated, a soil colour change was spotted close to small surface water drainage. The site was further investigated and a north-westerly trending dyke was identified, which was not identified during the remote sensing section of the desktop study. A geophysical profile was carried out over the identified structure. From the data collected during the profile, a positive and negative magnetic anomaly was detected and a broad negative anomaly was detected on the resistivity, resembling a geological contact zone (Figure 53).

A decision was made to site an exploration borehole on the negative anomaly, near the dolerite dyke. The final blow yield of borehole EC-T33-846 amounted to 1.8 l/s when drilling was halted at a final depth of 120 mbgl. The water strike

intercepted at 70 mbgl in weathered and fractured mudstone formation, which was intercepted above a dolerite contact zone.

EC-T33-740

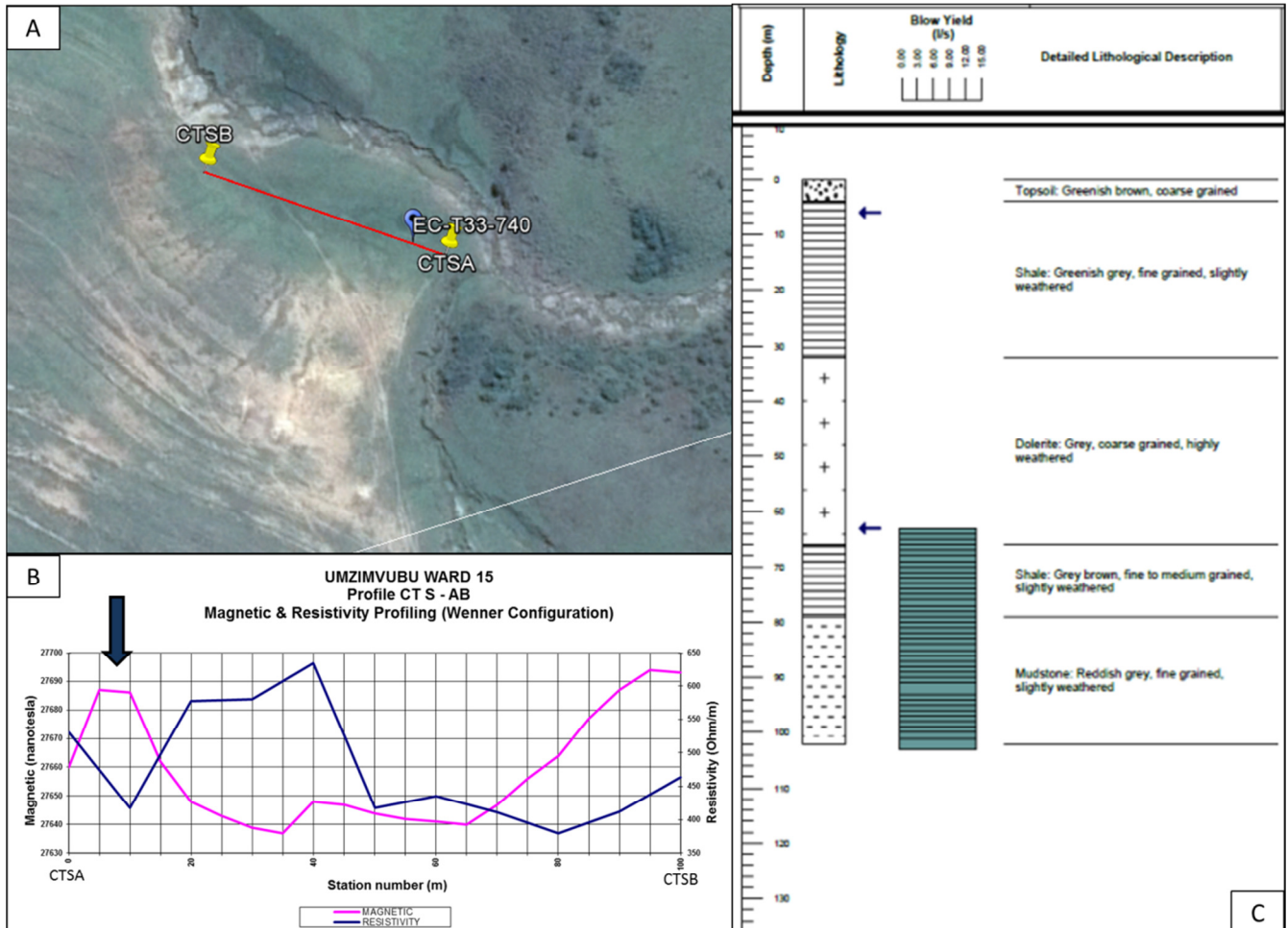


Figure 54 A) The spatial setting of borehole EC-T33-740, geophysical profile CTS and the lineaments in the area. B) A graphic display of the data collected from profile CTS. C) The drilling log, as well as depth and yield of water strikes intercepted during the drilling process.

Upon the completion of the on-site investigation, a dolerite dyke was identified, which cross cut a surface drainage. The dyke was crossed near the start of the profile and a positive magnetic and negative resistivity anomaly was produced. An exploration borehole was sited on the anomaly on the upstream side of the dolerite dyke (Figure 54).

The borehole (EC-T33-740) produced a final blow yield of 15 l/s after drilling it down to its completed depth of 115 mbgl. Two water strikes were intercepted

during the drilling process; a seepage strike was intercepted at 6 mbgl, with the main strike being intercepted at 66 mbgl in a well-weathered dolerite formation.

EC-T33-741

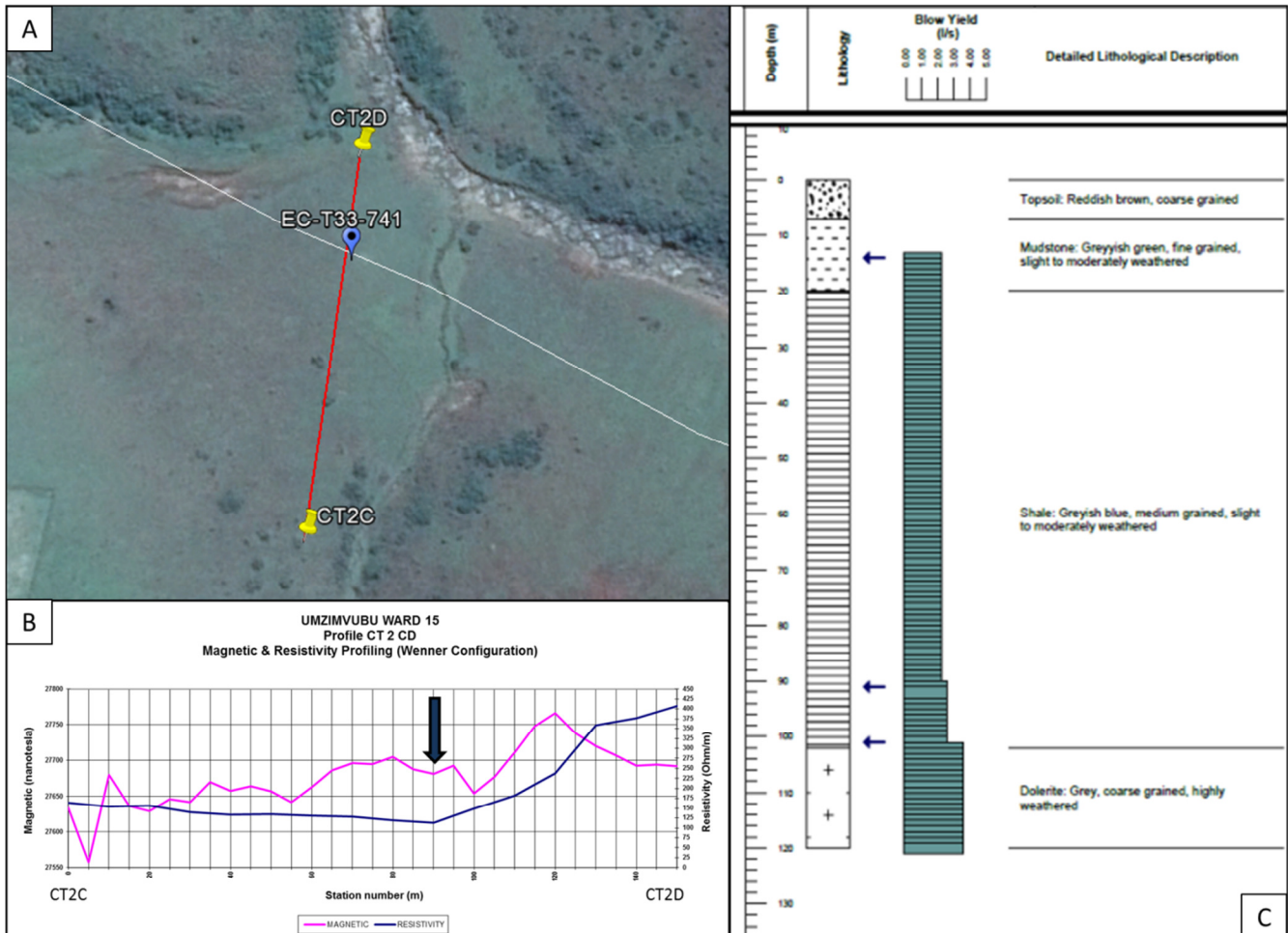


Figure 55 A) The spatial setting of Borehole EC-T33-741 and geophysical profile CT2 CD as well as the lineaments in the area. B) The data collected from profile CT2 CD as well as the data station selected for exploration drilling. C) The drilling log and yield obtained from the water strikes during the drilling process.

A north-westerly trending lineament was identified during the desktop study, nearby a surface water drainage line. A geophysical profile performed over the lineament resulted in a lithological contact being detected. An exploration drilling site was sited on the lowest data point on the electrical resistivity profile (Figure 55).

Borehole EC-T33-741 was drilled to a final depth of 120 mbgl and produced a final blow yield of 4.0 l/s after three water strikes were intercepted during the drilling operation. The first strike was intercepted at 14 mbgl and produced 0.1 l/s from a weathered mudstone formation. The second strike was intercepted at 90 mbgl and produced 1.3 l/s from a fractured shale formation. A third water strike was intercepted at 102 mbgl, which produced 2.6 l/s from a fractured dolerite formation.

EC-T33-742 and EC-T33-746

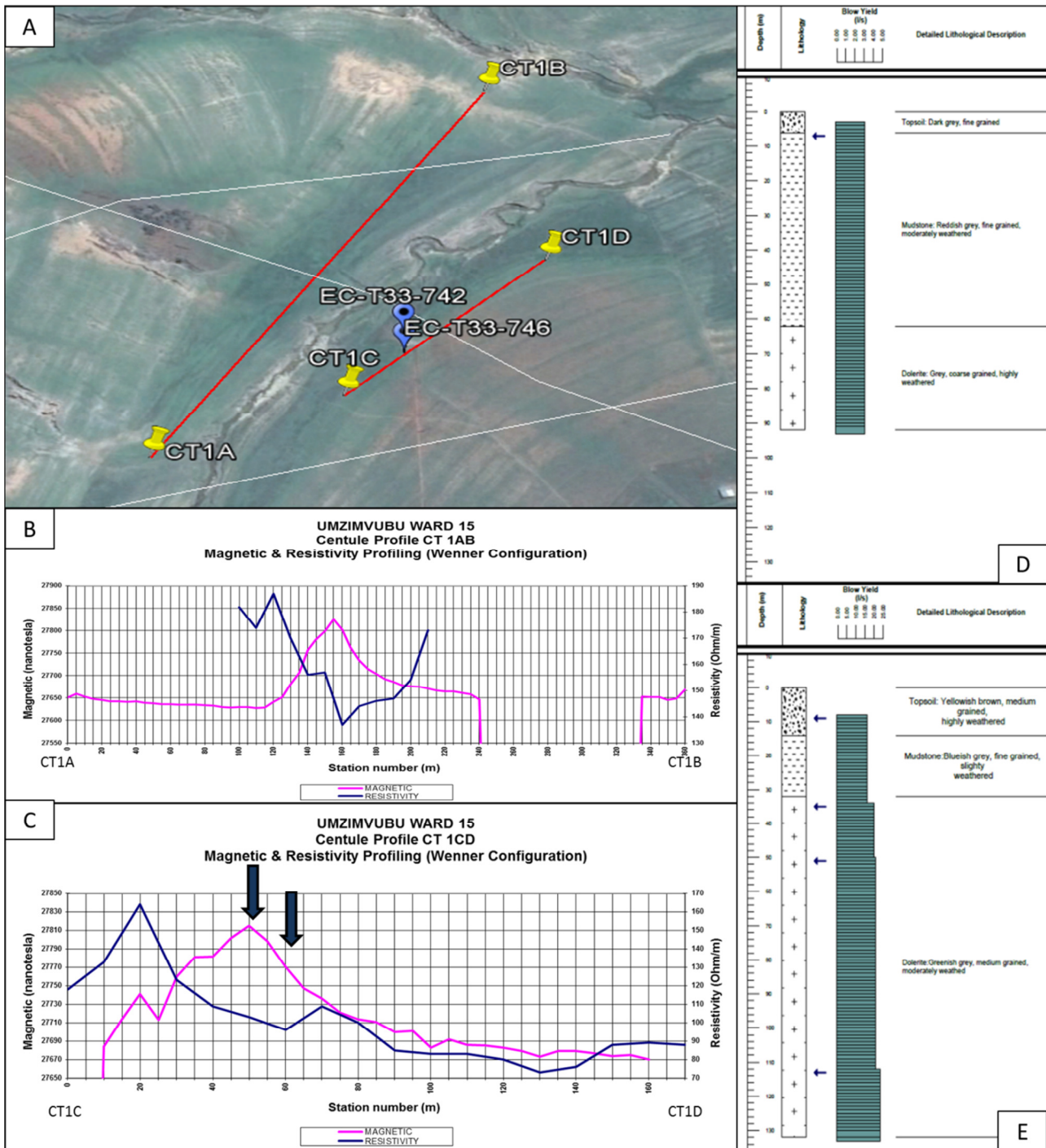


Figure 56 A) The spatial setting of geophysical profiles CT1 AC and CT1 CD, as well as boreholes EC-T33-742 and EC-T33-746, and the lineaments in the area. B) A graphical representation of the data collected on profile CT1AB. C) The data collected on profile CT1CD represented graphically. D) The drilling log of borehole EC-T33-742 as well as the depth and yield of the water strikes intercepted during the drilling process. E) The drilling log of borehole EC-T33-746, with water strike depths and yields indicated.

A section of the project area with two north-easterly lineaments and one north westerly trending lineament was detected from the desktop study. Profile CT1AB was set out to cross both the north westerly and the northern north easterly trending lineament, where the north westerly trending lineament was found to be both magnetic and weathered. To simplify the water use licence application of a potential borehole it was decided to carry out a second profile on the opposite side of the surface water drainage line (Figure 56).

Two exploration boreholes were drilled as the first, borehole EC-T33-742, did not meet the required yield for the project area. Borehole EC-T33-742 produced 2.6 l/s from the contact between a weathered dolerite sill structure and the upper residual weathered material. The three following water strikes were all intercepted in the same weathered and fractured dolerite sill formation at 35, 51 and 113 mbgl respectively, which produced 5.5, 6.5 and 11.6 l/s respectively.

Thereafter, borehole EC-T33-746 was drilled and produced a final blow yield of 26.2 l/s and has an artesian water level, from four water strikes that were intercepted during the drilling operation. Drilling was halted at a final drilling depth of 132 mbgl.

EC-T33-748

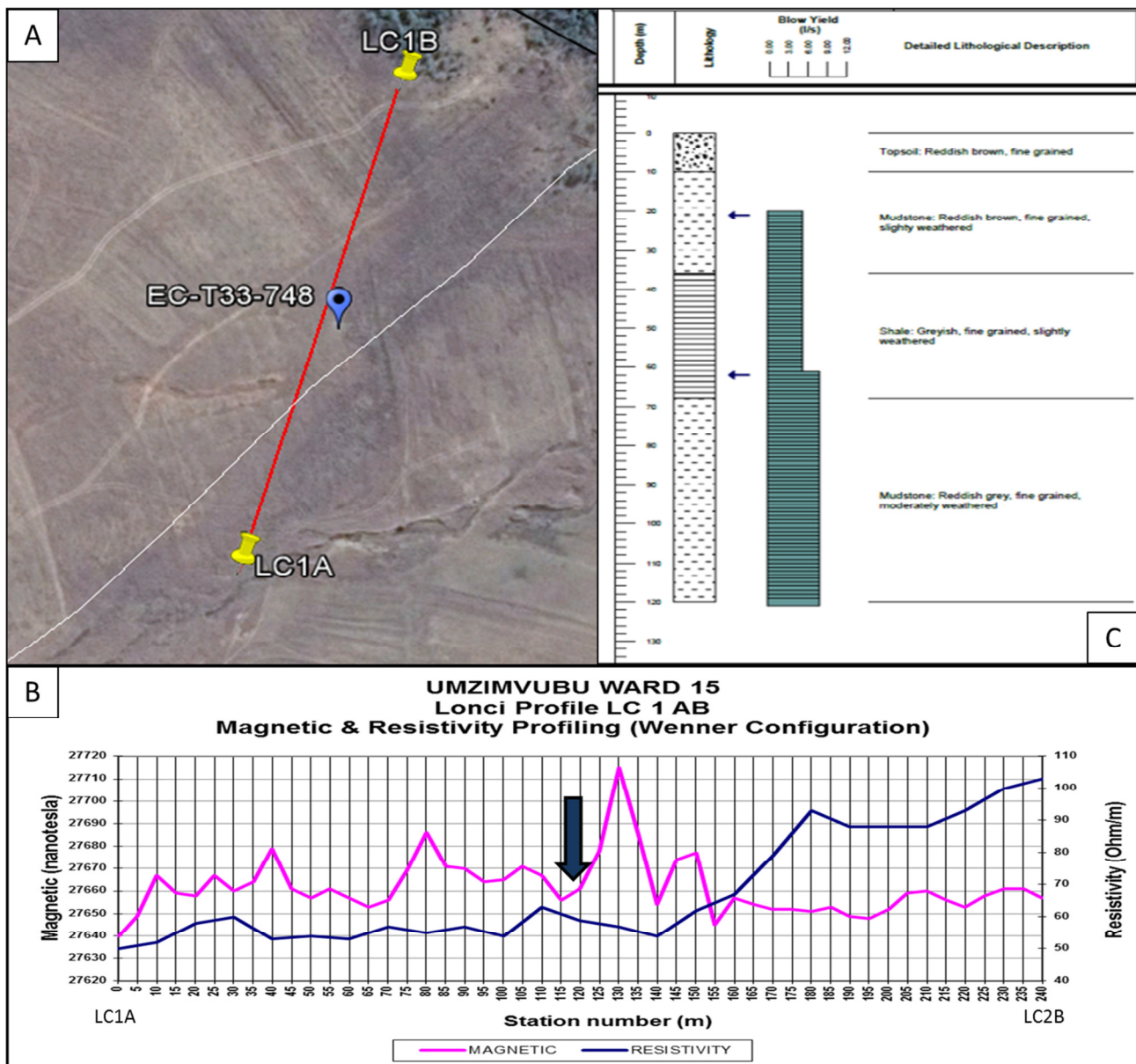


Figure 57 A) The spatial setting of geophysical profile LC1 as well as borehole EC-T33-748 and the lineament in the area. B) The geophysical data collected from profile LC1 as well as the data station selected for exploration drilling. C) The drilling log as well as water strike depths and yields intercepted during exploration drilling.

During the desktop investigation, a north-easterly trending lineament was detected and was identified for geophysical investigation. A broad positive magnetic anomaly was detected as well as a contact zone on the electrical resistivity data. An exploration borehole was adjacent to the magnetic anomaly and the borehole (EC-T33-748) was drilled down to a final depth of 120 mbgl. The borehole produced a final blow yield of 10.9 l/s from two water strikes. The

upper water strike was intercepted at 22mbgl and produced 1 l/s from a weathered mudstone formation. The lower strike produced 9.9 l/s from a fractured shale formation at a depth of 62 mbgl (Figure 57).

EC-T33-754

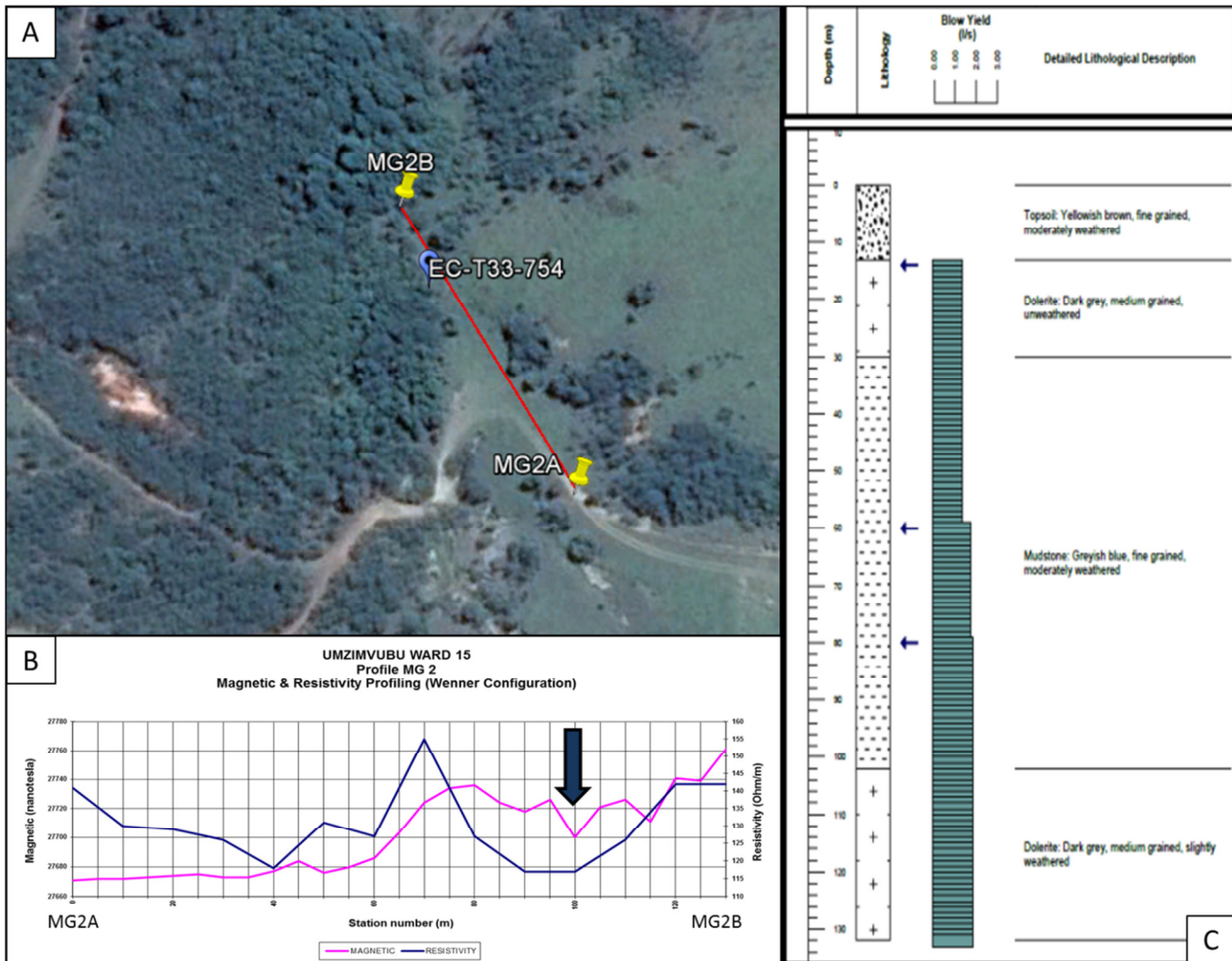


Figure 58 A) The spatial setting of the geophysical profile MG2 and borehole EC-T33-754. B) A graphical display of the geophysical data collected from profile MG2. C) The borehole drilling log as well as the strike depth and yield data for borehole EC-T33-754.

During the on-site investigation, a pronounced change in soil colour was detected adjacent to a densely forested area. A geophysical profile (MG2) was executed over the apparent contact zone (Figure 58). The lowest electrical resistivity data reading nearest to the magnetic contact zone was selected for exploration drilling.

The borehole (EC-T33-754) was drilled down to a depth of 132 mbgl and produced a blow yield of 3 l/s from three water strikes. The first strike, which yielded 1 l/s, was intercepted at a depth of 14 mbgl in a weathered dolerite formation. The second and third strikes were both intercepted in a weathered mudstone formation at 60 and 80 mbgl respectively. The upper strike yielded 0.8 l/s and the lower strike yielded 1.2 l/s.

EC-T33-751 and EC-T33-752

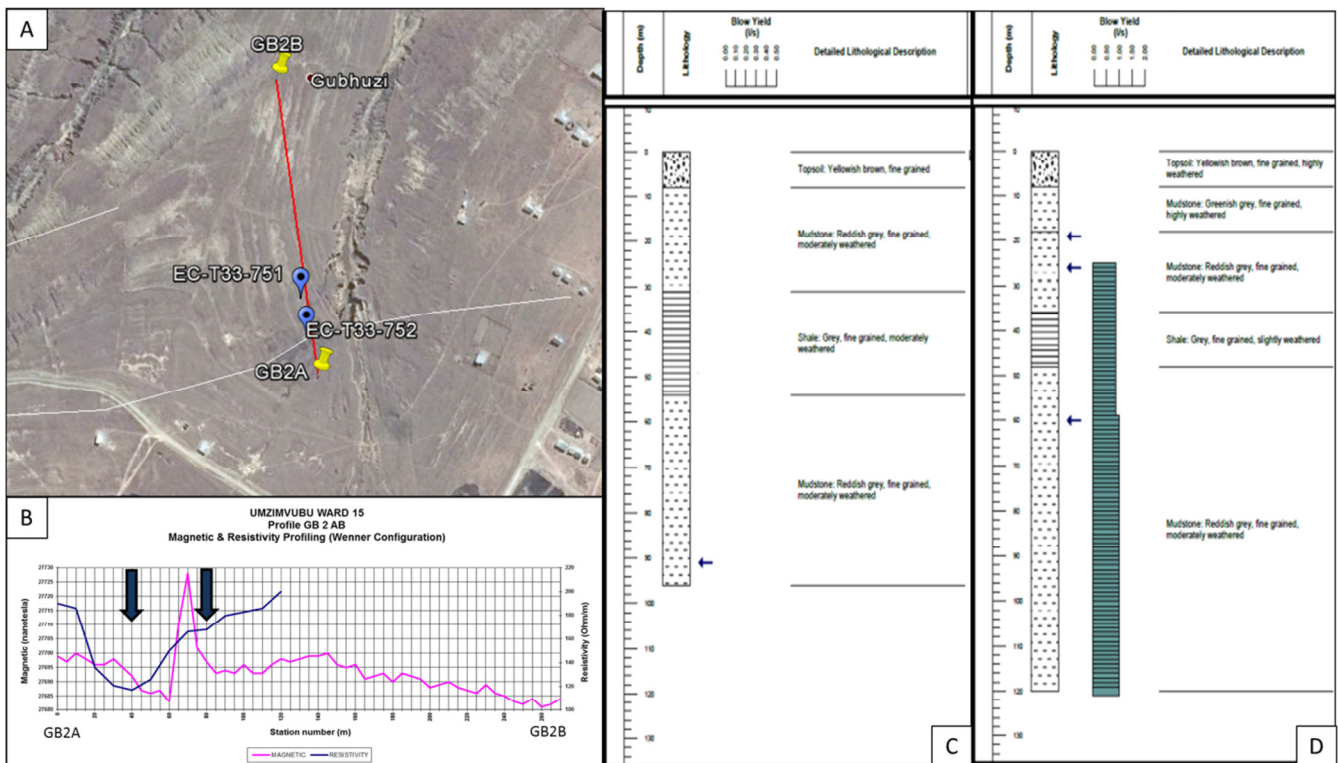


Figure 59 A) The spatial setting of geophysical profile GB2 and boreholes EC-T33-751 and EC-T33-752, as well as the location of the lineaments in the area. B) A graphical display of the geophysical data collected at profile GB2 and the two data stations selected for exploration drilling. C) The drilling log for borehole EC-T33-751. D) The drilling log and depths and yields of water strikes intercepted during the drilling of borehole EC-T33-752.

After identifying an E-W striking lineament during the remote sensing section of the desktop study, the lineament was selected for geophysical investigation. A prominent magnetic anomaly was detected along with a section of low electrical resistivity (Figure 59).

The structure was first targeted on its dip side, or the furthest side of the magnetic structure in an attempt to drill through it. Borehole EC-T33-751 did not, however, produce any water strikes.

It was then decided to target the low resistivity area closer to the start of the profile, and after being drilled down to a final depth of 120 mbgl, the borehole produced 1.5 l/s from three water strikes intercepted during the drilling operation. A strike yielding approximately 0.1 l/s was intercepted at a depth of 19 mbgl. The second water strike was intercepted in a weathered shale formation and yielded 0.8 l/s at a depth of 26 mbgl. The third water strike was intercepted in weathered mudstone layer, which yielded 0.6 l/s from a weathered mudstone formation, at a depth of 60 mbgl.

EC-T33-756

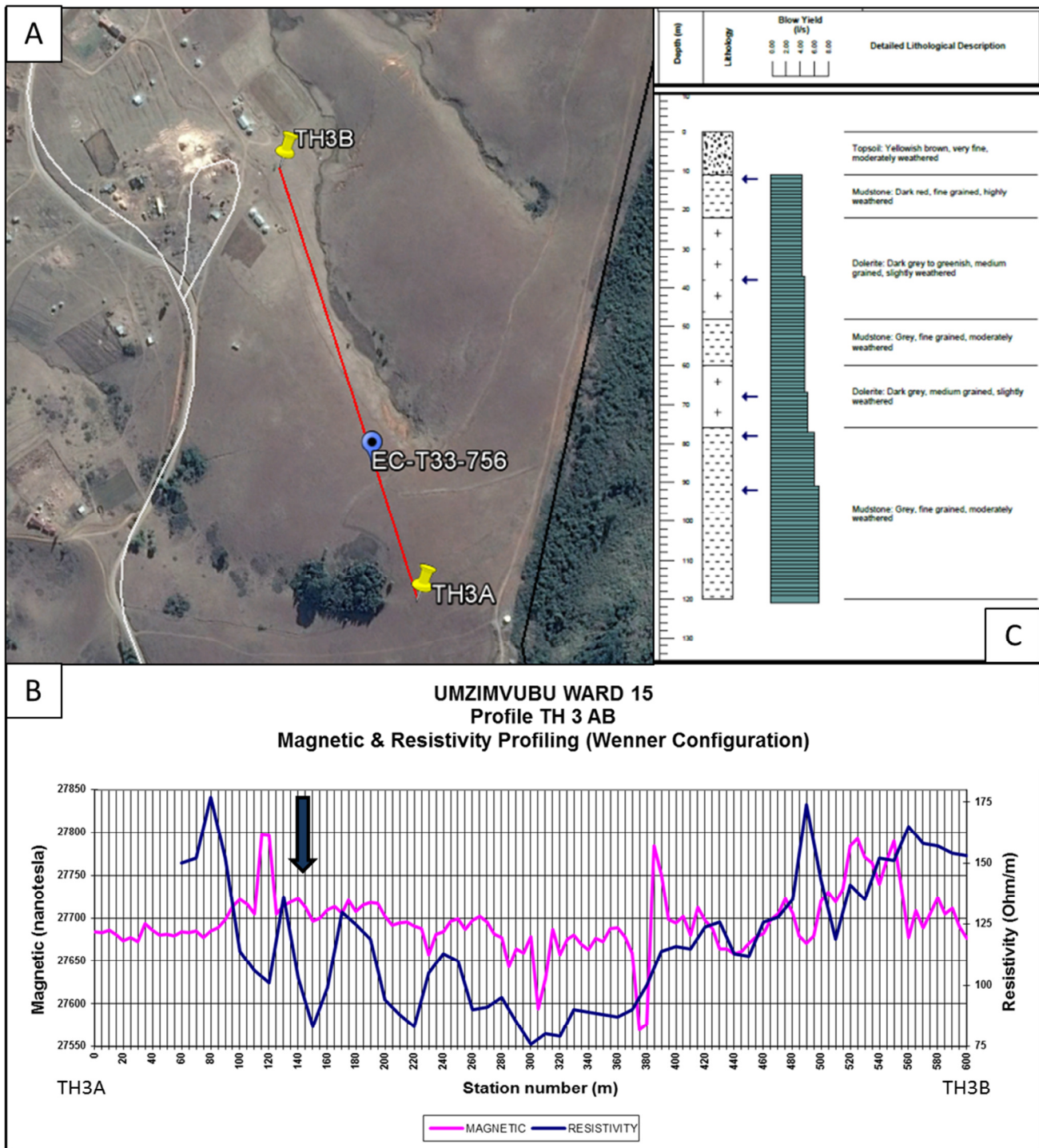


Figure 60 A) The spatial setting of geophysical profile TH3 and borehole EC-T33-756. B) A graphical display of the data collected from profile TH3 as well as the data station selected for exploration drilling. C) The drilling log for borehole EC-T33-756, as well as the depths and yields obtained from water strikes.

During the on-site investigation, an area of deep red soil was sighted adjacent to a surface water drainage line, which appeared to be fed by a groundwater spring. A geophysical profile was then executed along the drainage line over the area of soil colour variation (Figure 60). Two positive magnetic anomalies were detected, the first of which was detected adjacent to the area of soil colouration. The resistivity data indicated an area of low resistivity along the margins of the magnetic anomaly. This area of low resistivity was selected for exploration drilling.

After being drilled to a final depth of 120 mbgl, a total of 5 water strikes were intercepted to produce a final blow yield of 6.4 l/s. The first water strike was intercepted at a depth of 12 mbgl and produced 1.4 l/s from a fractured mudstone formation. Thereafter two strikes were intercepted a weathered and fractured dolerite dyke formation, at 38 and 68 mbgl yielding 0.5 and 0.4 l/s respectively. The two lower strikes were intercepted in a fractured and weathered mudstone formation at depths of 78 and 92 mbgl, yielding 1.9 and 2.2 l/s.

EC-T33-757

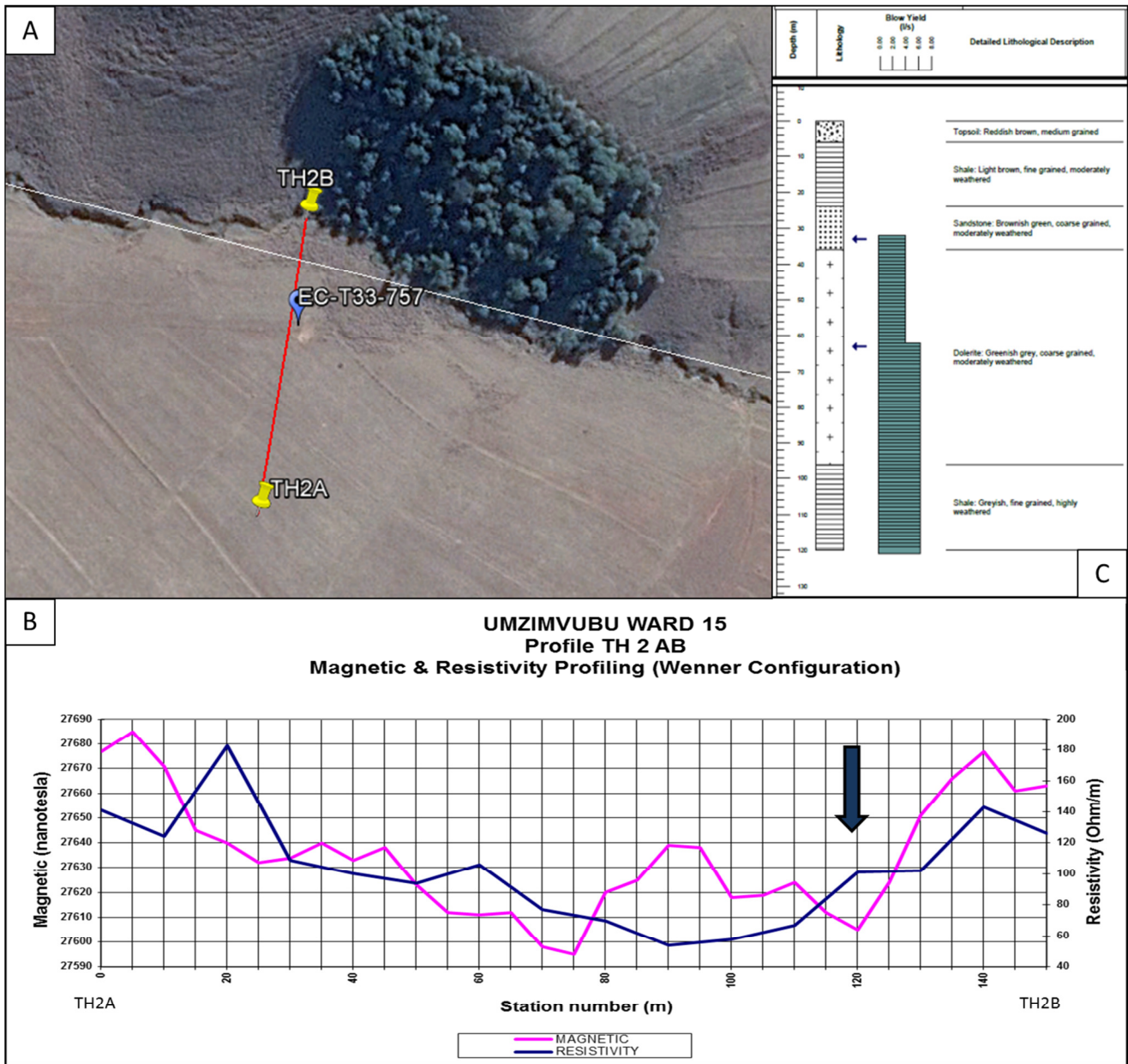


Figure 61 A) The spatial setting of geophysical profile TH1 and borehole EC-T33-757. B) The data collected from profile TH2 as well as the data station selected for exploration drilling. C) The drilling log for borehole EC-T33-757, as well as the depths and yields obtained from water strikes.

A NW striking lineament detected during the remote sensing section of the project, was selected for geophysical investigation. Profile TH2 produced a magnetic contact zone near the end of the profile as well as an area of low electrical resistivity around the middle of the profile. The contact zone was

selected for exploration drilling (Figure 61). At its final depth of 120 mbgl, borehole EC-T33-757 produced a blow yield of 6 l/s from two water strikes. The first water strike was intercepted at a depth of 33 mbgl, producing 1.6 l/s from a weathered sandstone formation. The second water strike was intercepted in a weathered dolerite formation and produced 5 l/s.

EC-T33-275

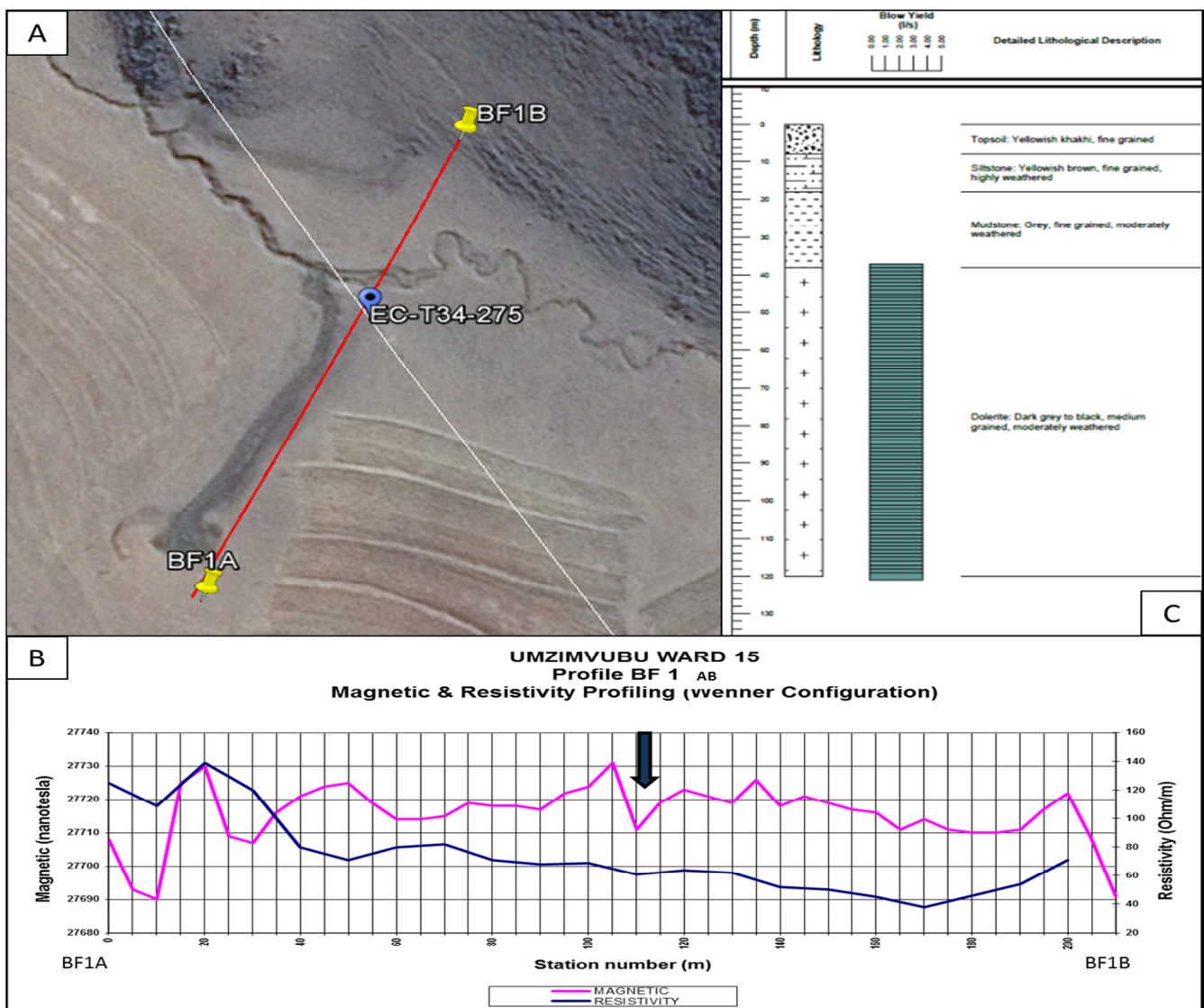


Figure 62 A) The spatial setting of geophysical profile BF1 and borehole EC-T34-275. B) The data collected from profile BF1 as well as the data station selected for exploration drilling. C) The drilling log for borehole EC-T34-275, as well as the depths and yields obtained from water strikes.

After a NW striking lineament was detected adjacent to a groundwater drainage zone and below a groundwater spring, it was selected for geophysical investigation. A small positive magnetic anomaly was detected near the middle of the profile along with a low general electrical resistivity trend (Figure 62). The anomaly was selected for exploration drilling. After the borehole (EC-T34-275) was drilled to a final depth of 120 mbgl, it yielded a final blow yield of 3.9 l/s. The yield was produced from a singular water strike that was intercepted at a depth of 38 mbgl on a weathered and fractured mudstone/dolerite contact zone.

5.4 Drilling Results Summary

Figures 63 and 64 show the localities of all the successful boreholes drilled on linear structures in Ward 13 and 15 respectively.

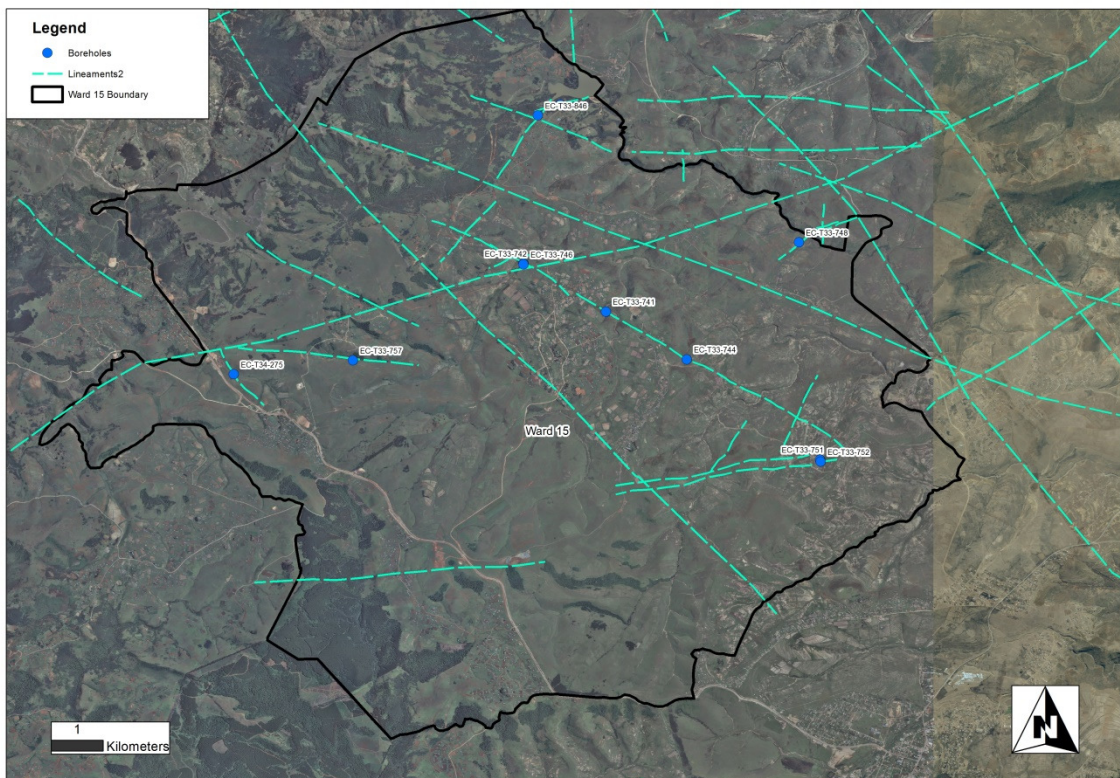


Figure 63 Ward 15 borehole localities

Tables 5 and 6 provide the target structure strike and groundwater strike yield data for all boreholes in Ward 13 and 15 drilled on linear structures.

Table 5 The drilling results of the boreholes drilled on linear structures in Ward 15 of the project area.

Ward 15 Borehole Target Structure Strike Analysis							
Borehole Number	Structure strike direction	Angle (°)	Lineament Length (km)	Lineament Width (m)	Distance from Lineament (m)	Lithology (Main Strike)	Yield(l/s)
EC-T34-275	NW	332	1.27	8.4	1.6	Dolerite	3.9
EC-T33-757	E-W	278	2.95	23.4	32.6	Dolerite	5.6
EC-T33-751	E-W	82	3.52	9.2	44.1	-	0
EC-T33-752	E-W	82	3.52	9.2	2.8	Shale	1.5
EC-T33-741	NW	304	5.38	15.9	3.7	Shale/Dolerite Contact	4
EC-T33-742	NW	312	1.68	5.6	30.3	Mudstone	2.6
EC-T33-746	NW	312	1.68	5.6	17.4	Dolerite	26.2
EC-T33-846	NE	32	1.87	6.5	25.4	Mudstone	1.8
EC-T33-748	NE	57	1.62	16.3	14.5	Shale	10.9

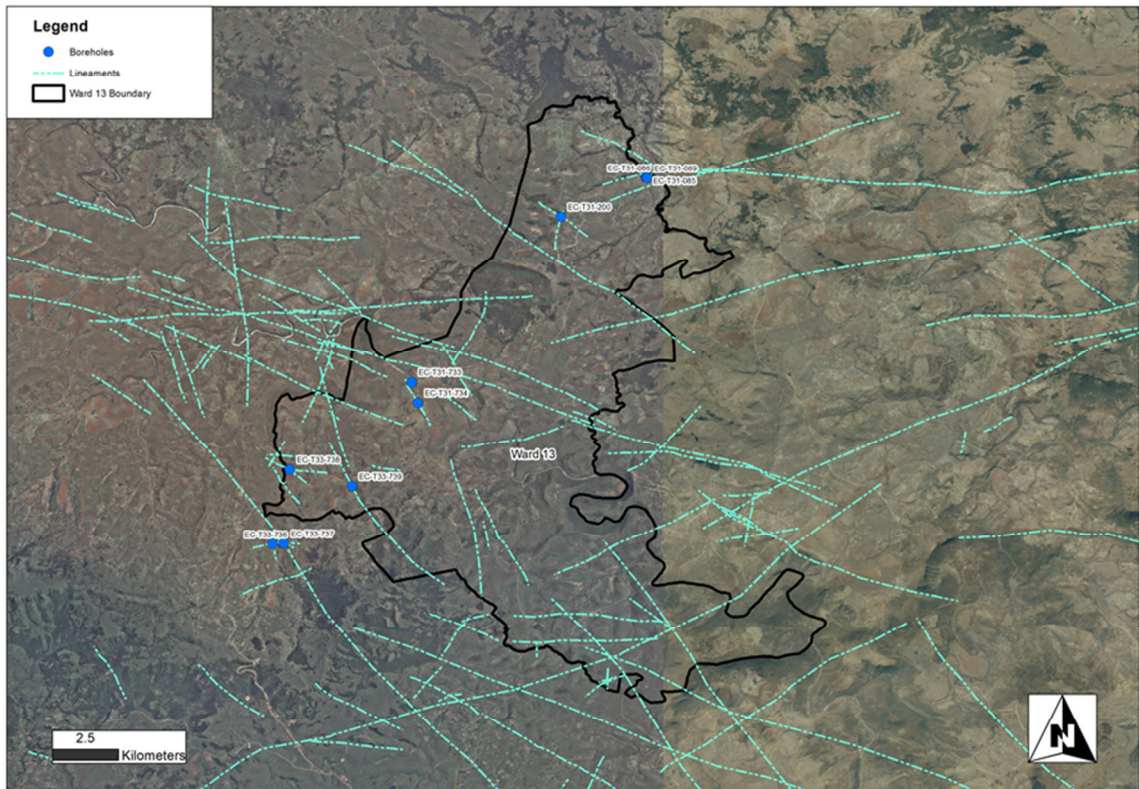


Figure 64 Ward 13 borehole localities

Table 6 The drilling results of the boreholes drilled on linear structures in Ward 15 of the project area.

Ward 13 Borehole Target Structure Strike Analysis							
Borehole Number	Structure strike direction	Angle (°)	Lineament Length	Lineament Width	Distance from Lineament	Lithology (Main Strike)	Yield(l/s)
EC-T33-736	N-S	359	1.02	11.4	1.6	Mudstone	4.45
EC-T33-737	NW	168	1.71	3.8	7.4	Mudstone/Shale contact	11.75
EC-T33-738	E-W	276	1.44	9.3	5.4	Shale	11.3
EC-T33-734	NW	331	1.67	13.9	41	Dolerite	20
EC-T33-733	NW	293	0.49	11.9	6.7	Mudstone	10
EC-T31-198	NW	287	2.81	11.3	74.8	Sandstone	10.8
EC-T31-200	NNE	15	2.29	12.6	24.3	Mudstone	16.1
EC-T31-085	NE	302	5.71	83.2	15.6	Dolerite	0.1
EC-T31-086	NE	302	5.71	83.2	5.7	Dolerite	0.1
EC-T31-089	NE	302	5.71	83.2	31.4	Dolerite	0.1

Of the 21 boreholes drilled on linear structures, a total of nine were sited on NW striking lineaments, four were sited on E-W striking lineaments, five were sited on NE striking lineaments. One borehole was also sited on an N-S, one on a NNE and one on a ENE striking structure.

The highest average yield was produced from NW striking structures (290-340 degrees) at an average of 12.63 l/s per successful site. An average yield of 8.4 l/s was produced from NE/NNE (10-70 degrees) striking structures. The average yield produced from E-W (80-100 degrees) striking structures was calculated at 6.1 l/s. The only N-S (350-10 degrees) structure targeted during the study produced 4.45 l/s. All complete drilling construction logs are attached in Appendix B, Sections 9.21 and 9.2.2.

The average yield from borehole that have water strikes within dolerite formations is 7.0 l/s, however the average is the product of a variety of blow yields. Three of the boreholes drilled on dolerite were practically dry yielding only 0.1 l/s each. Two very high yielding boreholes were also drilled on dolerite formations yielding 20 and 26.2 l/s respectively.

The most consistent successful drilling target was linear structures in sedimentary rocks; strikes were intercepted in mudstone, sandstone, shale and at the contact points between sedimentary formations. The average yield from a borehole where the main water strike was intercepted in sedimentary rocks was

9.36 l/s. During drilling at many of the boreholes with main strikes in sedimentary rocks, dolerite was encountered at some point throughout the drilling process. This then indicates that fracturing brought on by the intrusion of the dolerites transpired into the adjacent sedimentary rocks.

A single main water strike was intercepted at the contact point of a dolerite and shale formation.

In Ward 13 the average distance from the borehole to the nearest linear structure was 21.8 meters. The average lineament width was 32.3 meters; this stat is skewed as the three boreholes (EC-T33-085, EC-T33-086 and EC-T33-089) that had the lowest blow yields were all drilled on an 83 meter wide regional structure. The average lineament length was 2.83 km, this stat is also skewed by the three unsuccessful boreholes that were drilled on a 5.71 km long lineament. The higher yielding boreholes were drilled on lineaments that are 9-13 meters wide and are no longer than 2.30 km.

At Ward 15 the average distance from a borehole to the nearest lineament is 19.5 meters. The average estimated lineament width is 11.22 meters, the widest of which is approximately 23.4 m wide. An average lineament length of 2.61 km was measured, with the longest being 5.38 km long, the single borehole drilled on this lineament yielded 4 l/s. the highest yielding borehole in this ward was drilled on a 1.62 km long dolerite dyke that is approximately 5.6 m wide and the borehole position is approximately 17.4 m from the dyke.

5.5 Aquifer Testing Results

The most informative way to determine the physical nature and behaviour of an aquifer is by performing a hydraulic aquifer test (Kruseman and De Ridder, 1991).

A constant rate test, consists of pumping a borehole at a constant rate. Because of time and budget limits, all constant rate tests were conducted for a 24 hour period. The test is designed to stress the aquifer and also monitor the recovery rate when the test is complete. The constant rate test is preceded by a calibration test of sorts, such as a step test.

It is also possible to determine between the flow from a fracture network and the aquifer that feeds the fracture network. During an aquifer test, the water level will tend to stabilise around a fracture until it has been emptied and it is only the water from an aquifer entering the pump inlet. If the water level continues to stay at the particular level of the fracture, it can be accepted that the aquifer yield is very close to that of the yield test being performed (Chevalier *et al.*, 2001).

The opposite of a good fracture network can also be present in a borehole in the form of no-flow boundaries. No flow boundaries are very prevalent when targeting dolerite intrusions, as it is possible that the fracture may be cut off from the borehole at the point where, for example, a dyke is intersected. This then will not allow water to flow radially into the borehole and is common in dolerite intrusions that show low levels of weathering (Anderson and Woessner, 1992).

As can be seen from Table 7, significant variances between the blow yield and the recommended sustainable yield calculated by the FC software are a common occurrence. These variances are visually displayed in Figure 65. The presence of no-flow boundaries, the general transmissivities and storativities according to the Cooper-Jacob and Hantush methods as indicated by the FC software has been summarized in Table 7. Storativity values were taken from the FC program.

It is apparent from Table 7 that only approximately 33% of successful boreholes which intercepted dolerite formations contained no-flow boundaries. This accounts for approximately half of all the no-flow boundaries detected during the pump testing data collection phase. All analytical plots are shown in Appendix C, Sections 9.3.1 and 9.3.2.

Table 7 Summary of Aquifer data as well as dolerite presence per successful borehole. Note boreholes EC-T33-735 and EC-T33-742 were selected for monitoring purposes and were therefore not pump tested.

Borehole No.	Dolerite Present (Y/N)	Blow Yield (l/s)	Transmissivity CJ (m ² /d)	Transmissivity H (m ² /d)	Storativity CJ	Storativity H	Sustainable 24h Yield (l/s)	No flow boundaries
EC-T31-198	N	6	10.9	10	4.59E-05	1.74E-04	4.6	0
EC-T31-199	N	5	1.3	0	1.23E-01	7.30E-03	1.19	2
EC-T31-200	Y	16.1	24.8	21	1.34E-03	3.48E-04	4.59	0
EC-T33-733	N	10	12.4	8.2	6.57E-01	7.67E-02	5.2	0
EC-T33-734	Y	20	52.4	50.3	2.75E-04	6.29E-05	15.17	0
EC-T33-736	Y	4.45	0.4	0.4	1.56E-01	8.62E-03	0.14	1
EC-T33-737	Y	11.75	0.4	0.1	1.52E-01	6.78E-03	0.14	1
EC-T33-738	N	11.3	7.1	2.3	4.64E+00	5.91E-04	2.63	0
EC-T33-740	Y	15	4.9	0.3	1.35E-01	4.47E-03	3.35	0
EC-T33-741	Y	4	2.4	2.2	1.87E-03	1.97E-04	2.4	0
EC-T33-746	Y	26.2	9.6	7.4	1.01E-01	1.23E-02	5.82	0
EC-T33-748	N	10.9	3.1	2.2	2.85E-01	2.44E-02	1.14	1
EC-T33-750	N	8.5	2.8	1.1	6.00E-01	6.94E-02	0.87	2
EC-T33-752	N	1.5	2.1	1.3	4.78E-02	7.74E-03	0.16	2
EC-T33-754	Y	3	3.4	3.1	3.30E-04	8.86E-05	1.98	0
EC-T33-756	Y	1.5	2.3	0.3	9.43E-01	4.25E-02	0.43	2
EC-T33-757	Y	5.6	1.5	0.9	2.13E-02	2.21E-03	0.51	1
EC-T33-846	Y	1.8	23.6	22.9	3.22E-06	2.28E-06	2.51	0
EC-T34-275	Y	3.9	7.1	7	1.24E-05	4.82E-06	2.38	0

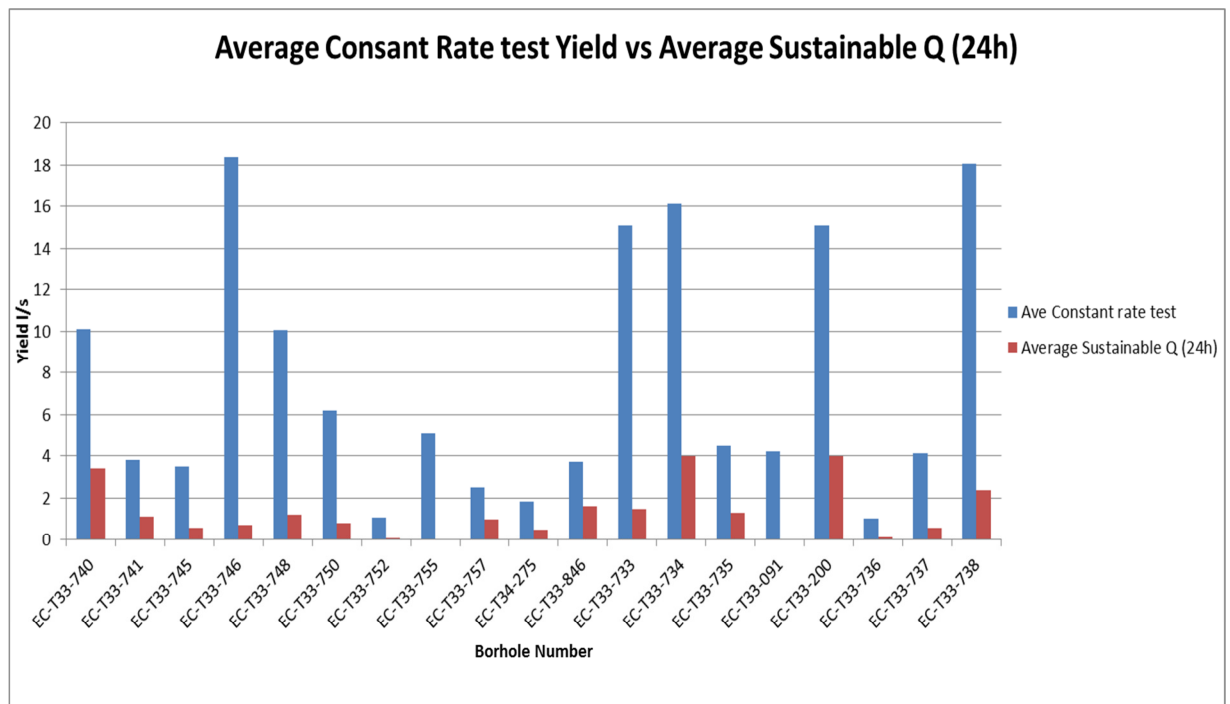


Figure 65 Constant rate pumping test yield and recommended 24 hour production pumping rate.

As can be seen from Figure 65, the constant rate yield is on average significantly higher than the sustainable yield over 24 hours as prescribed by the FC program. The total yield of the 19 tested boreholes during the constant abstraction rate test was 144.54 l/s, whilst the total yield prescribed over 24 hours is 55.21 l/s. Thus the average sustainable yield of a borehole drilled in the study area is only 38.2% of the constant rate abstraction test yield. The average sustainable 24 hour yields of the boreholes tested in the study area are calculated at 2.9 l/s which compares favourably to the previously reported study area average of 0.5-2 l/s (King 2002).

5.6 Groundwater Chemistry Results

Samples collected during the testing phase, were sent off to an independent and approved laboratory for hydrochemical analysis in accordance with the South African National Standards guidelines (SANS 241-1:2015). The resultant data is then classified and compared to the South African national standards for domestic supply as put forward by DWAF (1998). The chemical results for all boreholes recommended for production are summarised in Table 8.

Table 8 Chemical grouping of borehole samples in terms of DWAF (1998) Domestic Water Supply classification.

Class	0-Blue	1-Green	2-Yellow	3-Red	4-Purple
Description	Ideal	Good	Marginal	Poor	Unacceptable
No. of Samples	0	7	11	3	4
% of Samples	0%	28%	44%	12%	16%

It has been indicated on the groundwater resource maps that the study area predominantly has Ca^{2+} and Mg^{2+} as the major cations and HCO_3^- as the dominant anion in the project area. The general water quality of the study area expressed in terms of total dissolved solids (TDS) can be generally expected to be < 500ppm.

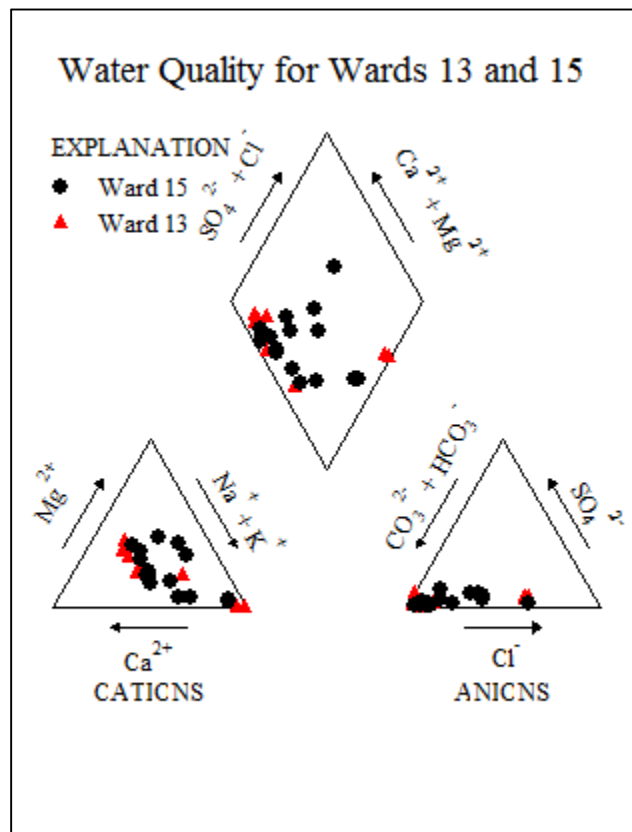


Figure 66 Piper Diagram displaying the resultant chemistries from the boreholes drilled in ward 13 and 15

Figure 66 shows the Piper Diagram of the groundwater chemistry data derived from the samples taken from the newly drilled production boreholes in Wards 13 and 15. The Piper Plot was selected to display the data, as it is the same technique used by King (2002) to display the data in the explanation booklet of the 1:500 000 hydrogeological map of Durban.

The majority of the boreholes plot in the $\text{CO}_3^{2-} + \text{HCO}_3^-$ and $\text{Na}^+ + \text{K}^+$ sectors of the plot. This is generally an indication of recent recharge. Chloride isotopic relationships investigated in the Bedford area (Hughes and Sami, 1992) revealed that the chloride ions are meteoric in origin. After a period of evaporative enrichment of meteoric salts near or on the soil surface, the meteoric salts would then leach into the groundwater table during a recharge event.

The more alkaline groundwater chemical compositions could accelerate the mobilisation of fluorite out of minerals such as apatite [$\text{Ca}_5(\text{PO}_4)_3(\text{F}, \text{Cl}, \text{OH})$] and biotite mica [$\text{K}(\text{Mg}, \text{Fe})_3(\text{AlSi}_3\text{O}_{10})(\text{F}, \text{OH})_2$]. Both apatite and biotite are minerals that are abundant in the mineral make up of dolerites (Banjaree, 2014).

6. Discussion

The study area has a unique setting, as it falls within a small basin area north of the town of Mount Frere. The understanding of the groundwater occurrence within igneous and sedimentary formations and the hydrogeological interaction between the two rock types is a major research goal for this study. The three major interactions that will be discussed are the geophysical nature, the dynamic hydrogeological interaction and the hydro-geochemical interaction.

6.1 Geophysical Discussion

The success of the geophysical survey is dependent on the drilling results of the study. This will attest to the correct method of borehole siting, by using the available data collected during the survey. The survey localities are again decided upon based on onsite observations of environmental and geological features as well as the observations of the remote sensing process during the desktop study. Therefore, site characterisation plays an integral part in the process of laying out geophysical surveys.

The crossing of geophysical anomalies during the survey is not the sole purpose of the survey; sufficient background data has to be collected so that the shape and orientation of the anomaly can be interpreted. This is also why a combination of multiple geophysical methods is advantageous to better interpretation of geophysical anomalies and to deciding on precise drilling targets.

The majority of the structures targeted for geophysical analysis proved to be anomalous in some way, showing either both positive magnetic and negative resistivity anomalies, or either of the two.

6.2 Drilling Discussion

The results of the drilling operation confirmed the knowledge that the minimum drilling depth of a borehole should be between 30->70 mbgl, as the majority of water strikes encountered were between 30-70 mbgl. However, high yielding water strikes can be found down to a depth of 110 mbgl and therefore drilling to such a depth should be considered if the necessary yield is not yet achieved with in the first 70 meters of drilling.

In terms of the drilling success rate, it compares well to previous studies in the area (Smart (1998) and Chevalier and Woodford (2002) and Vegter (2001)) albeit with a much smaller empirical study and the highest potential sites selected for development. An average 70% success rate and an average yield of 7.3 l/s per successful borehole were achieved.

The approach followed therefore makes it possible for the party that executes the exploration drilling to give more accurate cost estimation when a specific feasible drilling depth can be used to cost the project.

The frequency of water strike interception and the total yield are indicated in Figure 67 in adherence to the method followed by Vegter (2001). It is apparent that the majority of water strikes are encountered between 60-70 mbgl, and a deeper area of weathering and/or fracturing is present at 100-110 mbgl. However, this is not necessarily an indication of major weathered zones throughout the entire project area. This can also be attributed to the way that a borehole is sited in terms of the target structure. If, for instance, the specific target being developed is a dolerite dyke intrusion with a specific dip orientation that can be calculated from mapping the outcrop of the structure or drawing such a conclusion from geophysical data, a borehole can be drilled to intercept the said structure at a specific depth.

When drilling on a budget, it is important to enter the dolerite at such a depth that the borehole has the highest chance of success whilst being able to stop drilling at such a depth that is economically viable to the parties involved.

The static water levels measured at successfully developed boreholes had an average depth of approximately 16 mbgl which then indicates the possibility of relatively consistent hydraulic gradient conditions existing within the project boundaries. This then also supports the knowledge that the hydraulic gradient will generally mimic the topographical conditions in unconfined to semi confined conditions, as generally steep gradients occur in sloped areas within the project boundaries.

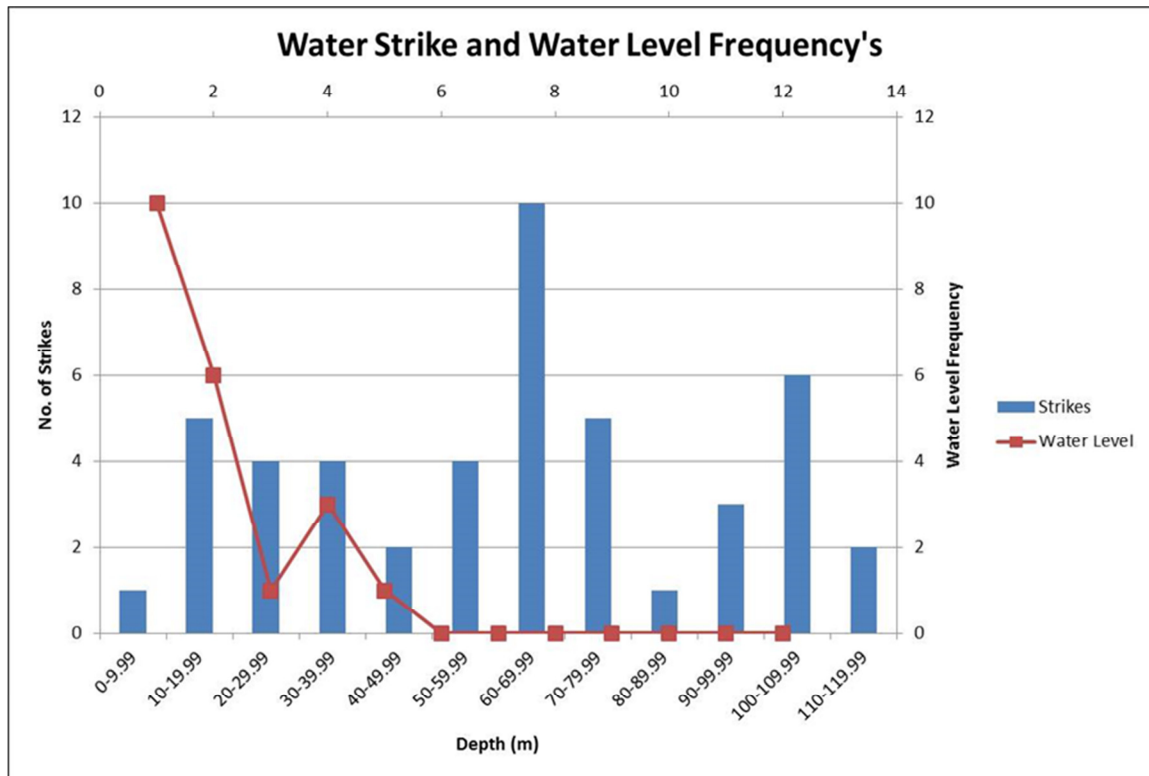


Figure 67 Water strike frequency and cumulative water levels.

Figure 68 again displays the strike frequency along with the total, median, upper and lower quartile values in terms of actual yields produced from the water strikes. This indicates that the single strike intercepted between 0-10 mbgl is the only strike depth that has a higher median strike value than 60-70 mbgl, which is the depth range in terms of strike frequency and total yield where the highest frequencies and yields were logged. Figure 68 also indicates that there are upper quartile outliers which are responsible for the relatively high total yield values at 60-70 and at 100-110 mbgl depth ranges. The median strike value, however, for the 100-110 strike range indicates that water strikes from this depth range may be relatively low yielding in comparison to shallower depth ranges.

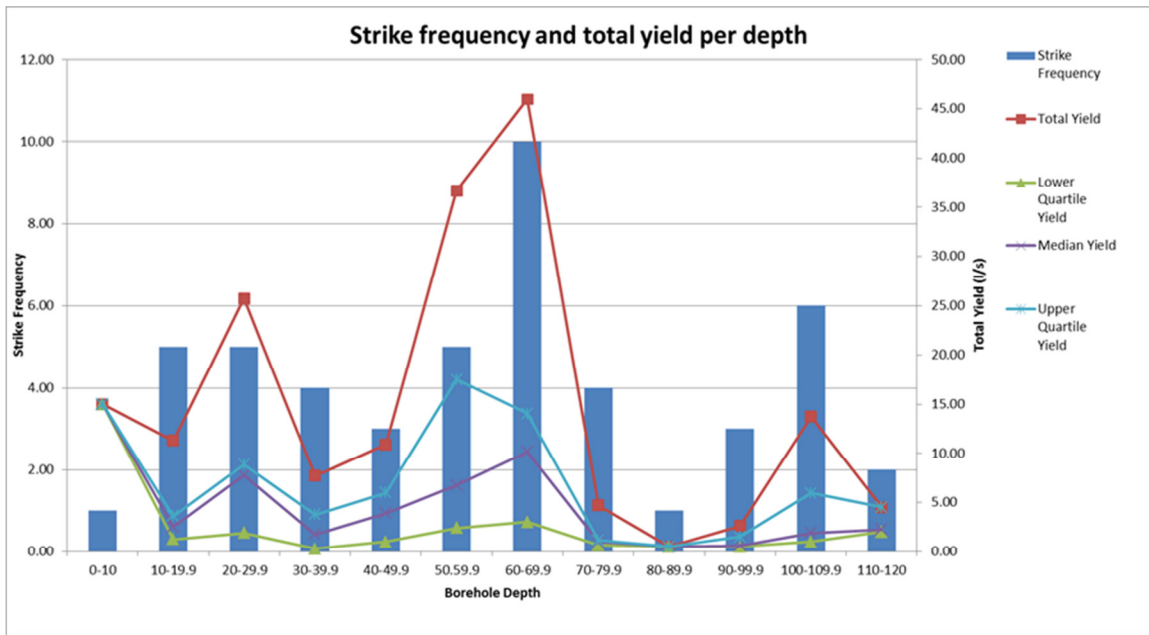


Figure 68 The water strike frequency as well as the total strike yield per depth and the yield quartile information.

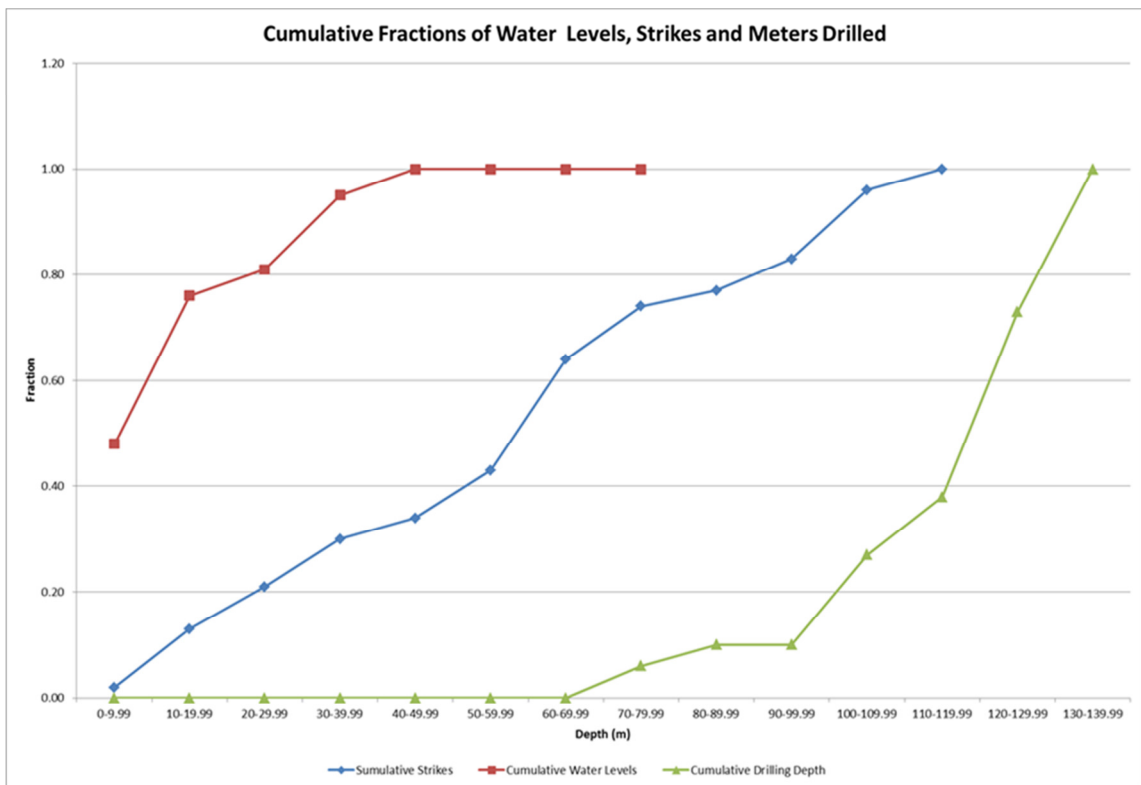


Figure 69 The fractional comparison of static water levels, water strike depths and final drilling depths of successful boreholes.

From Figure 69 it can be accepted that approximately 80% of all newly drilled successful boreholes within the project area have static water levels between 0-30 mbgl. The majority (+/- 50%) of the static water levels within this depth zone, however, had static levels of 10 mbgl and less. The two artesian boreholes drilled during the project development phase were not included in the graph.

Although water strikes were intercepted throughout the entire Karoo Supergroup aquifer, 35% of all successful exploration drilling sites definitively intercepted water strikes between 50-70 mbgl. A secondary strike zone, so to speak, was also experienced between 90-100 mbgl, with 15% of all successful exploration boreholes experiencing water strikes at this depth.

The shallowest successful borehole drilled within the project area was drilled to a final depth of 60 mbgl. However, the majority of the sites (60%) were drilled to depths of 110-140 mbgl.

In terms of the distance of the borehole to the linear structure targeted, in the cases where linear structures were the drilling targets, an average distance of approximately 20.3 meters was found. This however is a variable result as some boreholes were drilled as close as 1.6 meters to the lineament, where the furthest was drilled 74.8 meters from the nearest lineament.

In terms of boreholes that produced above average blow yields (> 8 l/s), drilled on linear structures, it was found that the majority of the boreholes were drilled in the presence of linear structures that were no longer than 2.5 km in measurable surface length. Boreholes that were drilled on more regional structures and fell into the same yield class were found to be much less common. This is depicted on the map on Figure 70.

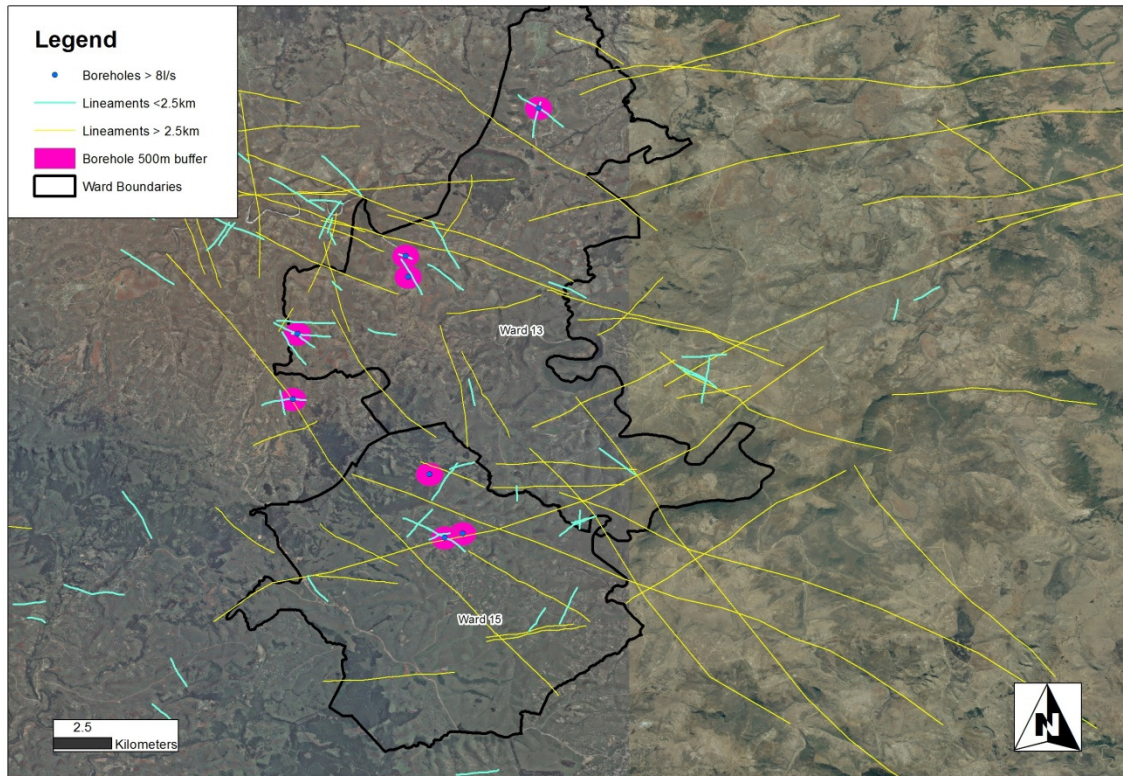


Figure 70: Drilling map, boreholes with blow yields > 8 l/s and linear structures.

6.3 Borehole Testing Discussion.

Specifically, in terms of targeting dolerite intrusions for drilling purposes, the presence of no-flow boundaries must be taken into account. In total 8 boreholes in aquifers containing no-flow boundaries were detected during the testing of the boreholes in Wards 13 and 15. Of the total number of no-flow boundaries, 50% of the detected no-flow boundaries were found in boreholes that targeted dolerite dyke intrusions. Based on this statistic, lineaments in country rock, such as faults or master joints where radial flow patterns are more likely to exist, should be deemed equal in terms of potential groundwater supply targets to dolerite intrusions.

The relatively low sustainable yield (2.9 l/s) can be attributed to the low relative transmissivities of the Karoo Supergroup sediments in general, when compared to the dolomitic aquifers of the Transvaal Group where much higher transmissivities are often encountered (Vegter and Foster, 1989). A calculated transmissivity of 440 m²/d was measured over the Kuruman dyke (Smit, 1970).

Though the aquifers have low general transmissivities, the transmissivities of the boreholes drilled in Wards 13 and 15 compare well to other areas within a similar geological setting. A study was undertaken that analysed the horizontal transmissivities of boreholes in the Beaufort West area in the western Karoo Basin, where the general average transmissivity of a successful borehole yielding more than 5 l/s was no less than 100 m²/d (Van Wyk and Witthueser, 2011). In comparison, borehole EC-T33-734 that has a transmissivity, of 52.4 m²/d is recommended for a sustainable yield of more than 15 l/s. This could be due to the fact that the Karoo aquifers lack the homogenous make up that the Theis equation assumes.

As in the drilling discussion, it was found that the general recovery from boreholes drilled on linear structures with a surface length of no more than 2.5km, were greater than those drilled on more regional structures. This would then allow for the allocation of a greater yield/duty cycle recommendation per borehole. Depicted on Figure 71 is the locality of the boreholes with 24 hour duty cycle yields that are >2.5 l/s and the linear structures they are drilled on.

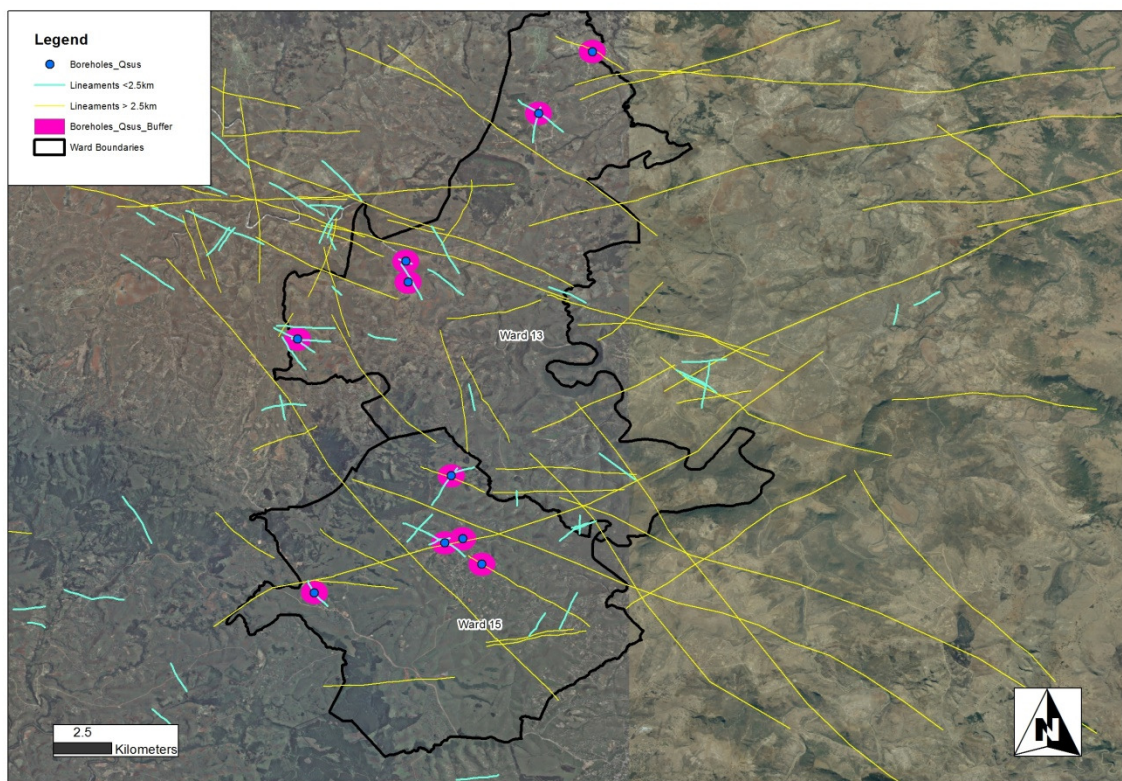


Figure 71: Analysis map, boreholes with a duty cycle yield > 2.5 l/s.

6.4 Hydro-Chemical Discussion

The quality of groundwater is generally very good, as it is removed from direct surface pollution sources. Groundwater, is however, exposed to various geological formations in various stages of weathering and in various reaction conditions, such as aerobic and anaerobic, saline or brack, acidic or alkaline. The reaction condition of the water can have a catalytic effect on the water's saturation of certain trace elements that can be advantageous in certain concentrations to the end user, or dangerous at higher concentrations.

Therefore two major factors should be taken into account when making assumptions about groundwater chemistry before it is analysed by a laboratory, namely the depth of the aquifer and the lithologies the water has been in contact with (Vrba, 2002).

In terms of the depth at which water strikes were intercepted and water quality there is a clear relation, which is summarised in Tables 9 and 10. Three of the four boreholes (EC-T33-736, EC-T33-741 and EC-T33-746) with water quality (Class 3 and 4) not fit for human consumption, had water strikes that were intercepted beyond 90 mbgl. The two other boreholes (EC-T33-737 and EC-T31-200) with water strikes beyond 90 mbgl produced class 1 water qualities.

Table 9 The target structure characteristics, blow yield and DWA chemical classification for Ward 13.

Ward 13 Borehole Target Structure Strike Analysis				
Borehole Number	Structure Strike Direction	Blow Yield(l/s)	Strike Depth (mbgl)	Human Consumption Classification (DWA)
EC-T33-736	N-S	4.45	58,76,102	3
EC-T33-737	NW	11.75	68,102	1
EC-T33-738	E-W	11.3	60	1
EC-T33-734	NW	20	19,52	3
EC-T33-733	NW	10	54	1
EC-T31-200	NNE	16.1	24,61,107	1
EC-T31-085	NE	0.1	31	2

Table 10 The target structure characteristics, blow yield and DWA chemical classification for Ward 15.

Ward 15 Borehole Target Structure Strike Analysis				
Borehole Number	Structure Strike Direction	Blow Yield(l/s)	Strike Depth (mbgl)	Human Consumption Classification
EC-T34-275	NW	3.9	40	2
EC-T33-757	E-W	5.6	33,64	2
EC-T33-752	E-W	1.4	27,60	2
EC-T33-741	NW	4	15,90,100	4
EC-T33-740	NE	15	61	2
EC-T33-746	NW	26.1	9,31,54,113	4
EC-T33-846	NE	1.8	69	1
EC-T33-748	NE	10.9	4,63	2

It could possibly be stated, from the data summarised in Table 9 and 10, that it appears to be the highest yielding boreholes which have the highest potential for poor groundwater quality results. Both boreholes that yielded 20 l/s and higher had class 4 quality classifications, rendering the source unsuitable for human consumption. The best quality groundwater seemingly emanates from boreholes yielding less than 10 l/s from water strikes shallower than 90 mbgl.

It appears that water samples with higher fluoride values generally have more alkaline pHs. This, however, is from a very small data set and no time series data is available on the sites. This was also the conclusion of Kumar (2011) and the process of natural fluoride enrichment of groundwater was explained by Banjaree (2014) through the weathering and dissolution of fluorite rich minerals.

7. Conclusion and Recommendations

7.1 Conclusion

In conclusion, the study could not prove out right that there is a direct link between the physical characteristics of dolerite intrusions as the study was based on a water supply project which was completed on a limiting budget. Good results however were generally received; this speaks to the value of having a trained groundwater professional on-site during the borehole siting process. It was however apparent that the Karoo Supergroup in the study area can produce high yielding boreholes with relatively good quality, which exceeded the perceived norms for Karoo aquifers.

When approaching a characterisation study, a multi-scale approach can produce results which may alter the original thought process of working in a specific area and ties work done on site to that done in the desktop phase of a study. The process where by a regional study is first performed, followed by an in depth site assessment, which should then be validated against the regional norms to prove or disprove the credibility thereof. The success of the project validates the necessity for trained groundwater exploration personnel to be present on site.

Geophysical data, though essential to the success of a borehole, should not be used as the only reference point for drill site selection. The geophysical data collected from an area should rather be used in conjunction with the conceptual picture formed by the groundwater specialist on site. That being said, it is necessary to perform the profile with multiple geophysical methods, analysing various parameters of the target structure. A magnetometer, for instance, is an ideal method to use for rapidly identifying target structures. However, it does not allow for much insight into the amount of weathering or fracturing around a target structure. This is where a method such as the electrical resistivity can be used to pinpoint the most weathered/fractured sections of the target structure, with great success.

The majority of successful boreholes drilled during the course of this project were sited on linear structures that have NW strike directions. This is partly due to NW striking structures being some of the most abundant in the project area. The NW striking lineaments also produced the highest average yield 12.63 l/s.

This very high average is due to two of the boreholes successfully drilled being on NW striking structures yielding more than 20 l/s. Thus although good average yields of 8.4 l/s were encountered from NE/NNE striking structures, 6.1 l/s were produced from E-W structures and 4.45 l/s from the N-S structure that was explored. It appears therefore from the data collected during this study, NW striking structures may be the better groundwater production sites, however more data will need to be collected to confirm this.

Large regional structures may not necessarily make the best drilling targets. The most successful boreholes in terms of yield, for the best part were drilled on lineaments with a surface extension of no more than 2.5 km. the boreholes drilled on the shorter less regional structures, more often produced blow yields of more than 8 l/s and 24 hour duty cycle yields of more than 2.5 l/s.

The depth at which water strikes are intercepted affects not only on the yield, but also the quality of the water that can be expected to be produced from the borehole. In terms of yield and strike frequency, it appears that water strikes between 60-70 mbgl are not only the most frequently occurring, but also the highest yielding with a 2.2 l/s average yield.

None of the water strikes within the 60-70 mbgl depth range produced water qualities above DWAf class 2. Poor water quality was generally encountered above 60 mbgl and below 90 mbgl. It is possible that there is a correlation between the pH value of a water sample and its iron and fluoride contents.

From the testing data outputs calculated by the FC software, it is apparent that there is no definitive correlation between the presence of dolerite intrusions and the presence of no-flow boundaries in the vicinities of the boreholes drilled during the project. Of the 20 successful boreholes drilled during the project, 60% contained dolerite. There is, however, no definitive difference in yield or groundwater quality between boreholes that contained dolerite or those which did not.

Dolerite containing boreholes also group along with other boreholes on the Piper Diagram. This then would indicate that groundwater around dolerite intrusions is also regularly recharged, thus indicating the possibility of dolerite intrusions

being part of an open aquifer system when weathered/fractured and that they may act less frequently as confining features than expected.

7.2 Recommendations

From the data and results produced during this project, the following is recommended:

- A multi-scale approach should be followed when characterising an area, whereby regional data should be tied in with site specific work to credit or discredit the validity thereof.
- Geophysical data should be used to confirm or discredit the conceptual site picture formed by the on-site specialist. The magnetic method was used to great success in conjunction with the Wenner array electrical resistivity method during the project.
- Further research can be conducted on the yield potential of specific linear structural orientations. From the results produced by this study, it appears to be advantageous to target NW striking linear structures.
- It may be beneficial for production yield purposes to target linear structures that are shorter and less regional in presence.
- In terms of yield and number of confining barriers or no-flow boundaries detected during the borehole testing phase of the project, it is apparent that there is not a significant difference in targeting dolerite dykes or non doleritic linear structures. This could be validated by performing long constant rate pumping tests on boreholes which have dolerite intrusions present.
- It is apparent from the dolerite outcrops investigated within the project area that the fracture network alongside certain dolerite intrusions propagates well into the country rock. Thus it is not necessarily best to drill directly into a dolerite structure, but rather move away from the structure to the fractured country rock. From the resultant drilling data it is expected that the best possible drilling targets, based on onsite observations are linear structures that are less than 2.3 km long and are 9-13 meters wide.

- Drilling deeper than 90 mbgl should be considered only if no other targets are present.
- If a relatively high yielding water strike is intercepted below 60 mbgl, drilling should be stopped 20 m below the strike, for production purposes. This will allow enough space for the development of the borehole and the installation of the test and production pump, along with ensuring that the groundwater quality will not be affected by deep water strikes.
- During the drilling operation, basic chemical indicators should be measured on site such as pH, EC and TDS each time a water strike is intercepted. Samples from the same boreholes should then be tested at later points in time to allow for the development of a time series data base. This will allow the specialist on site to make predictions on possible fluoride and iron constituent issues and should be investigated for future research.

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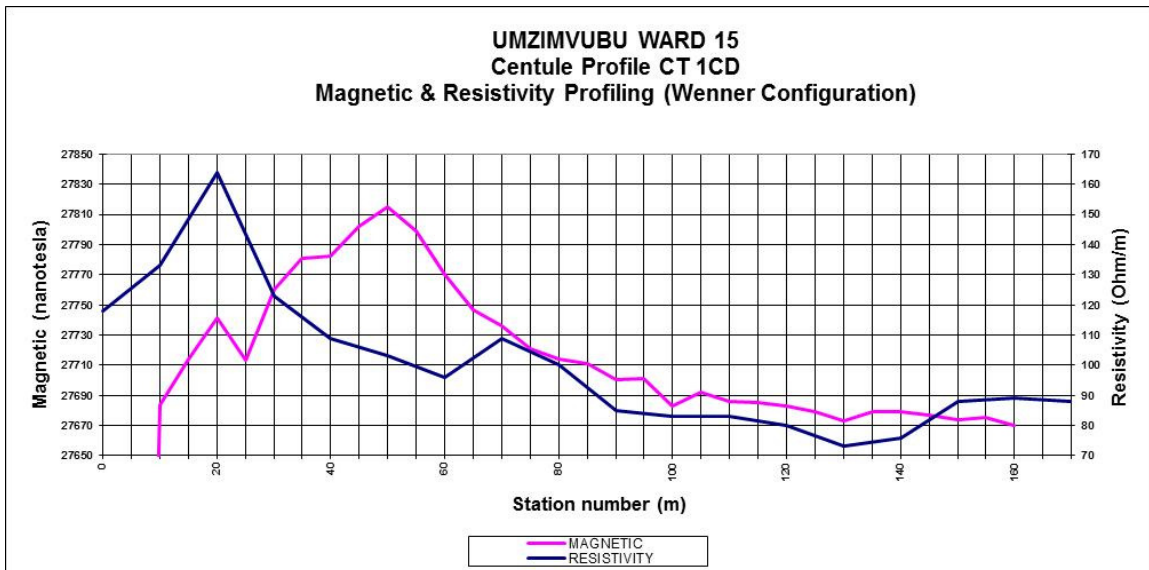
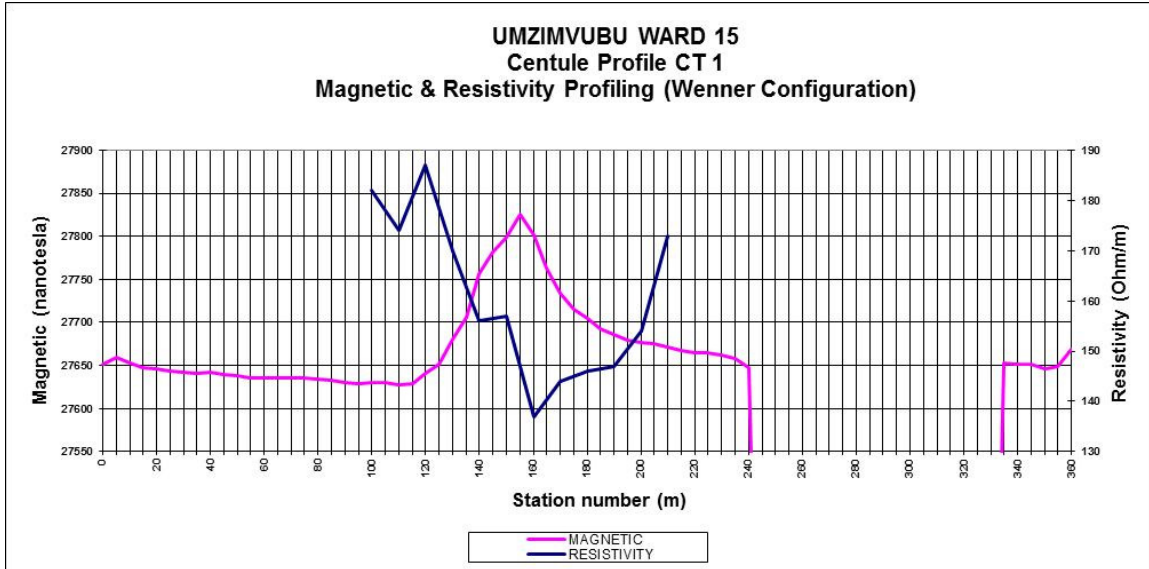
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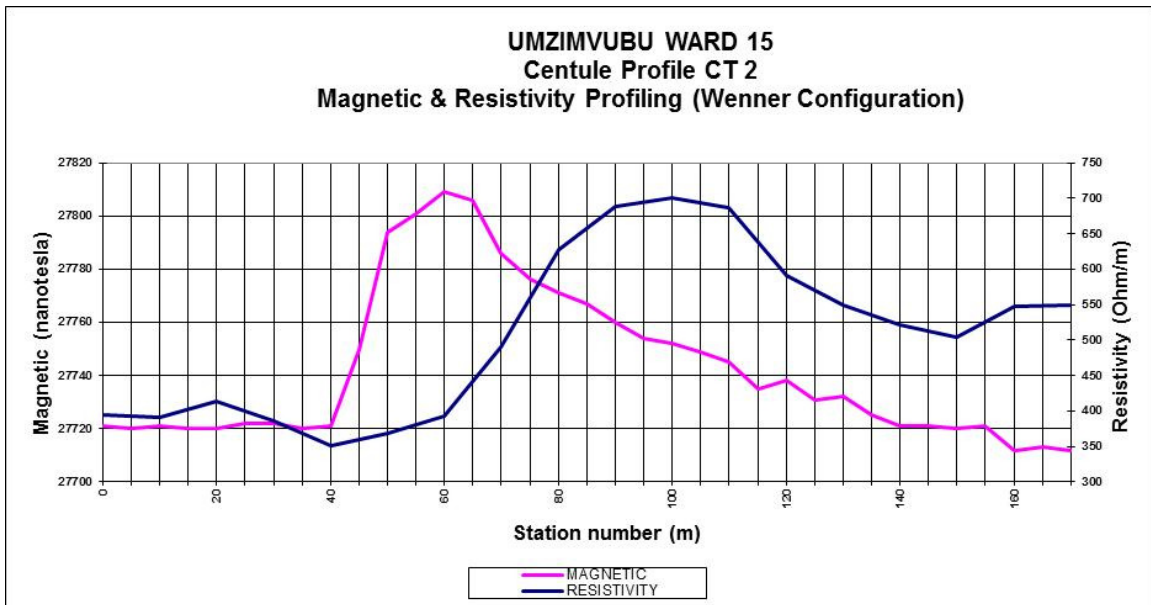
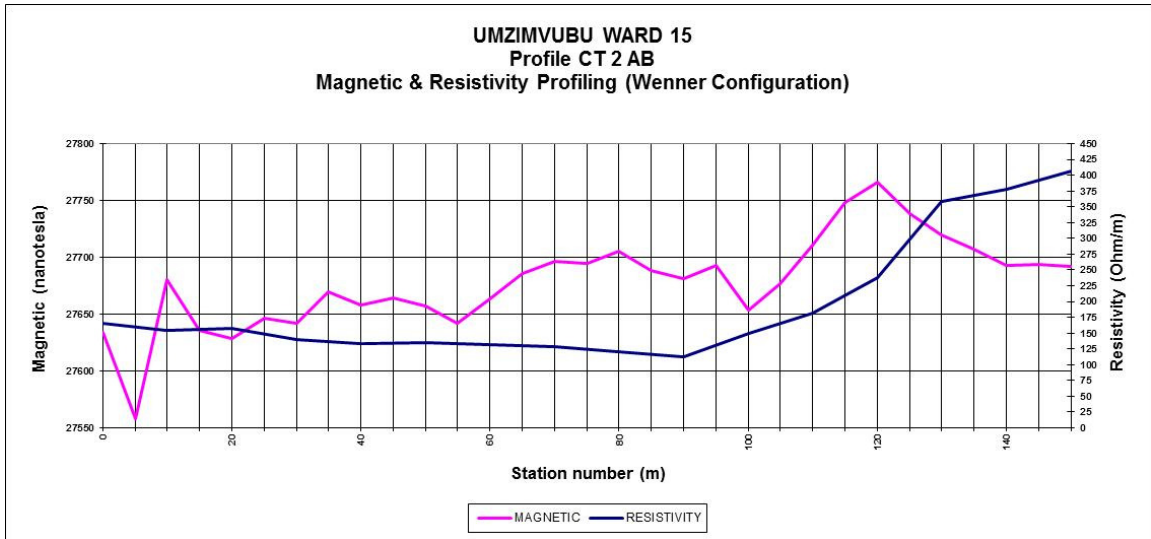
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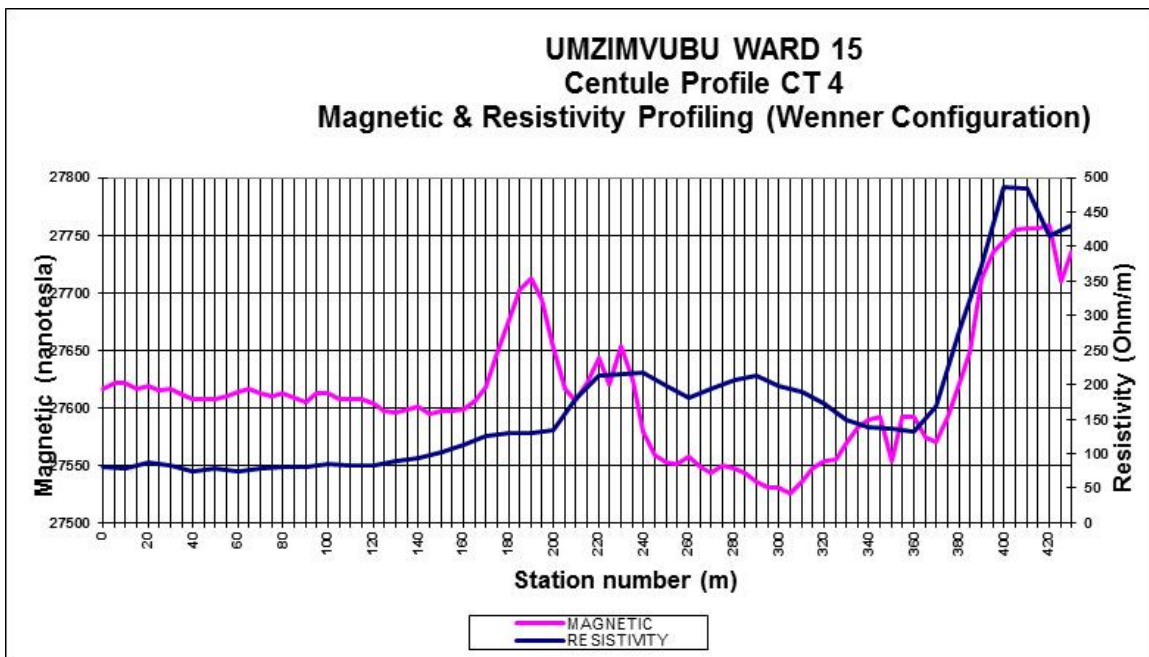
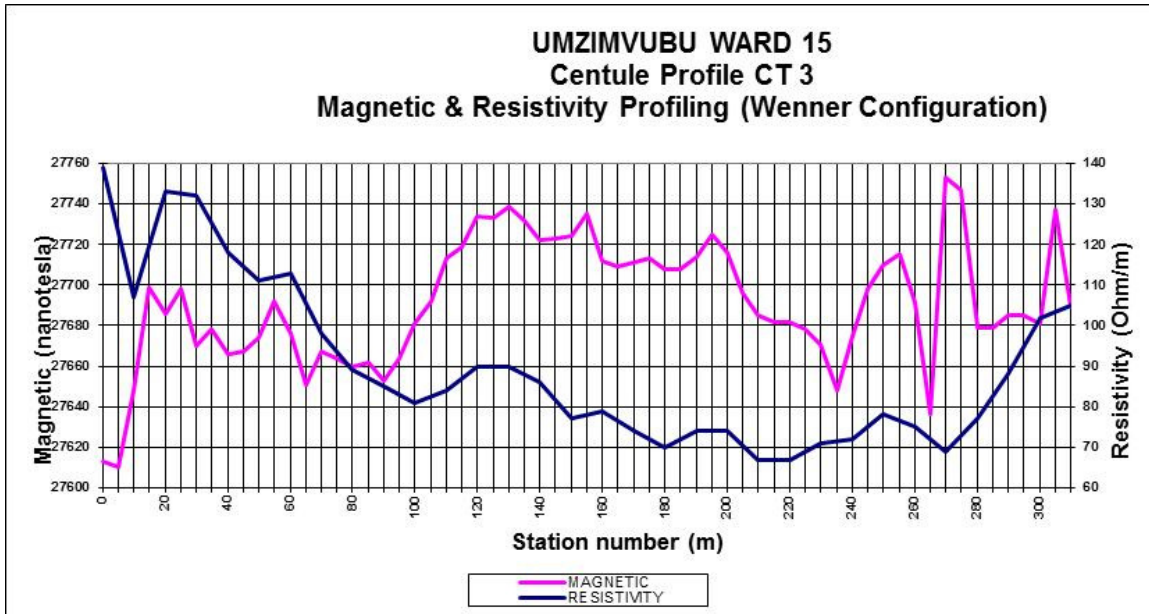
9. Appendices

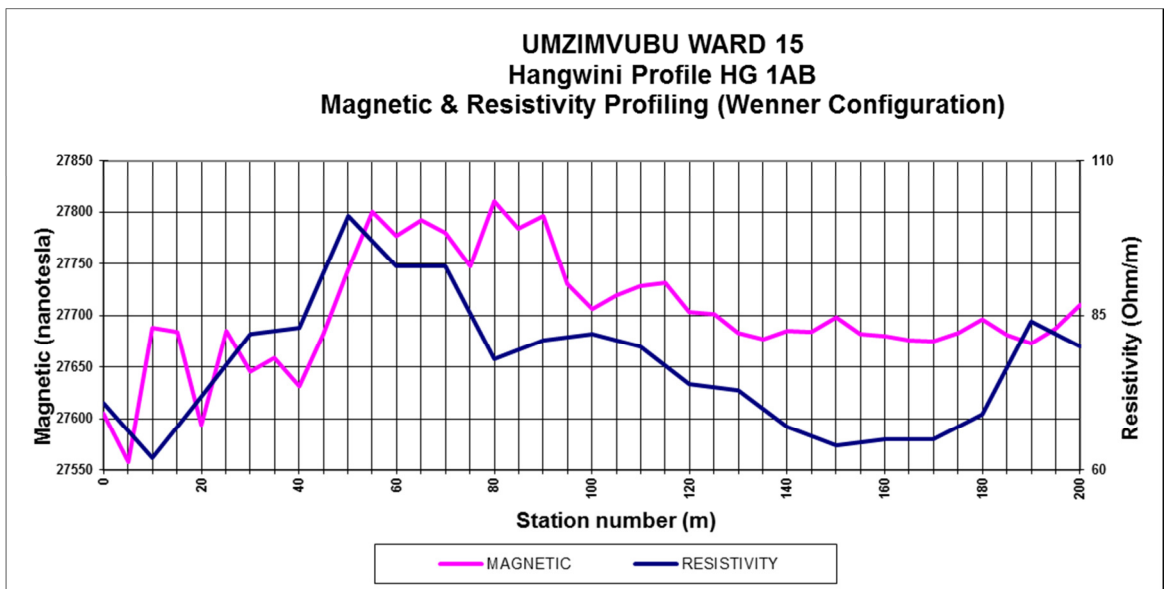
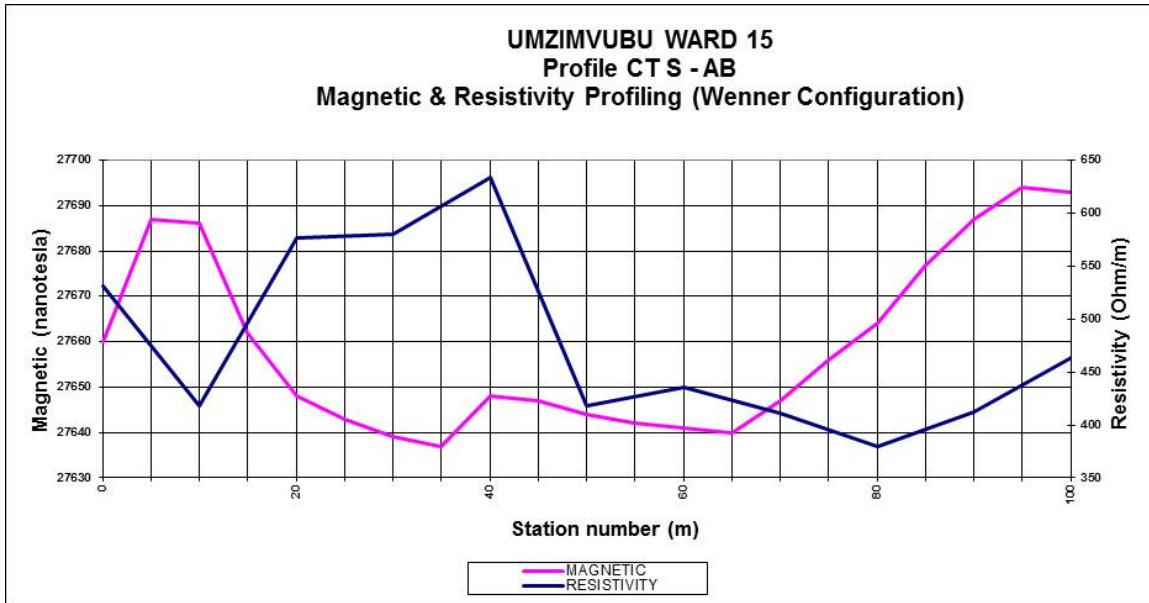
9.1 Appendix A: Geophysical Data

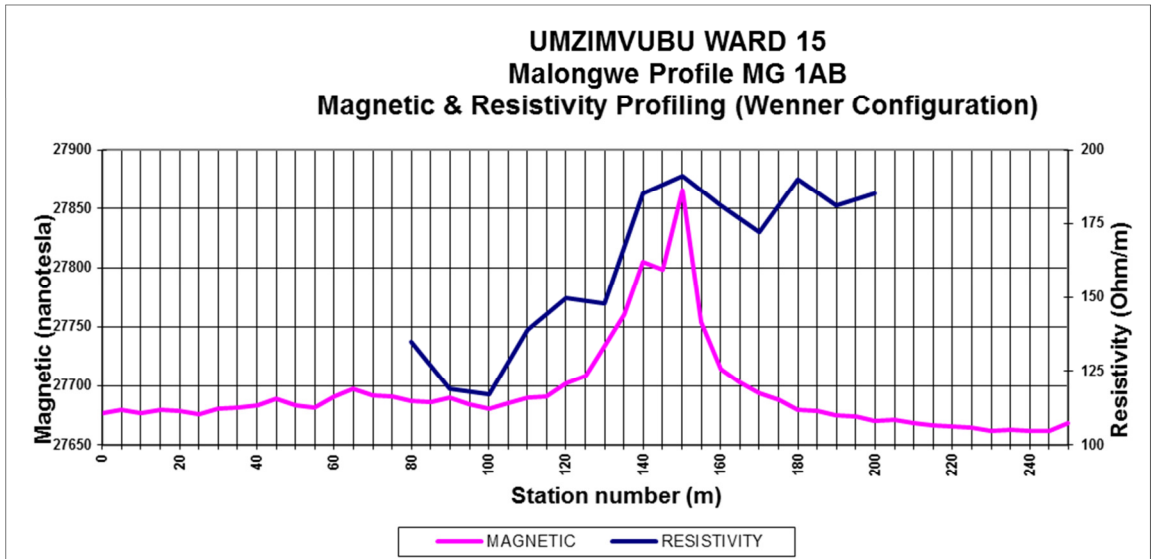
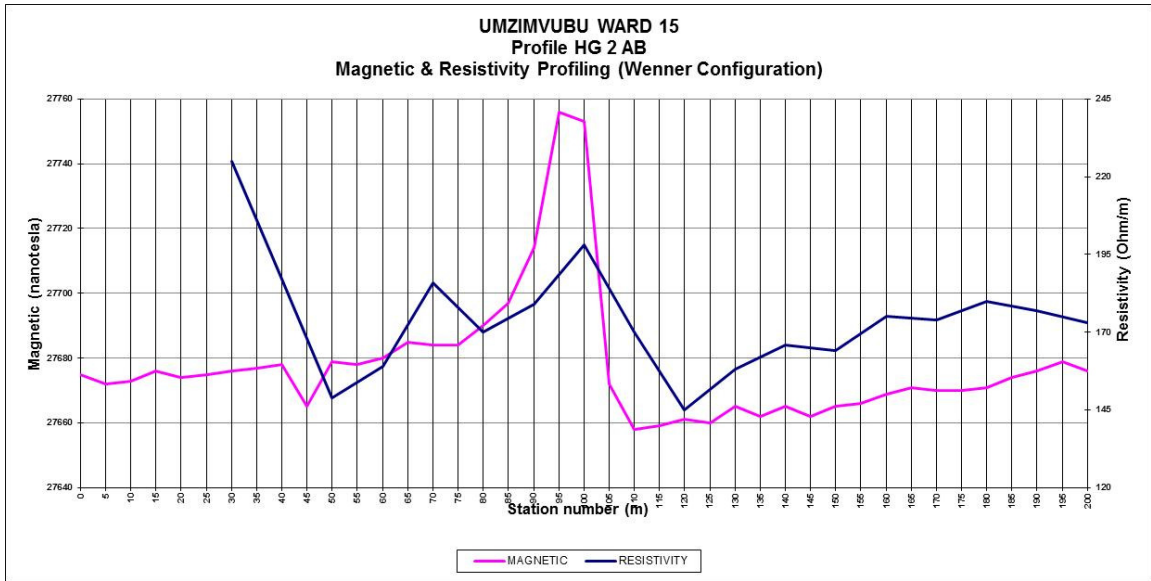
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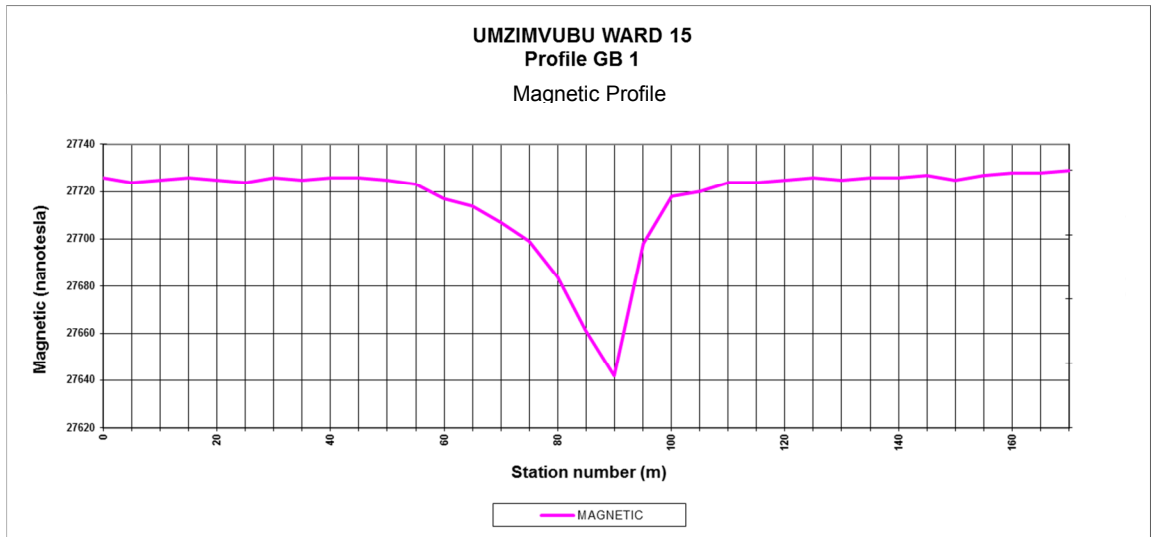
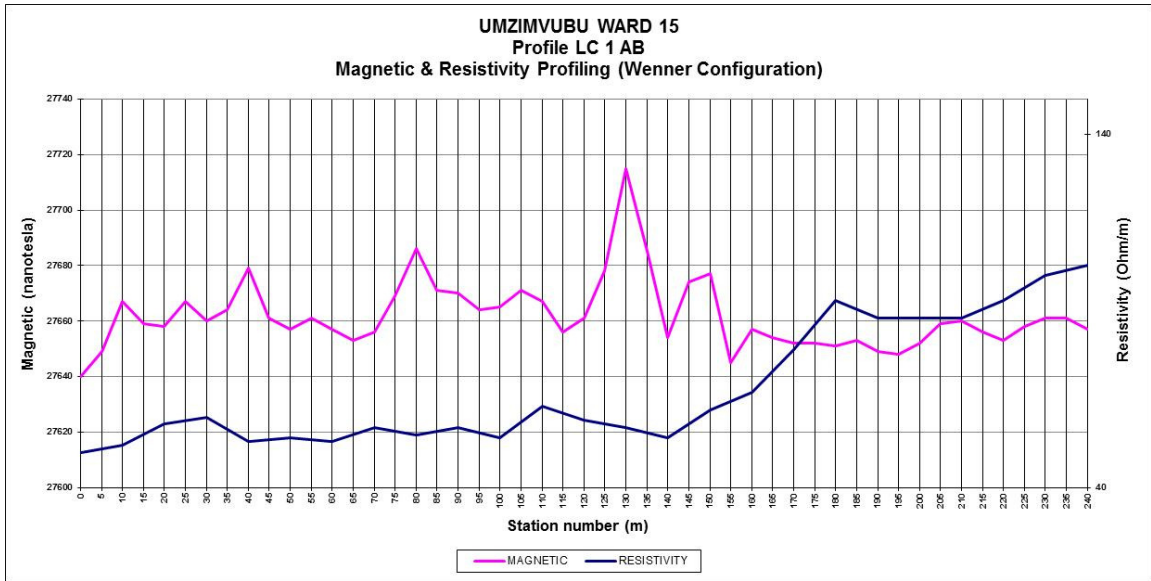


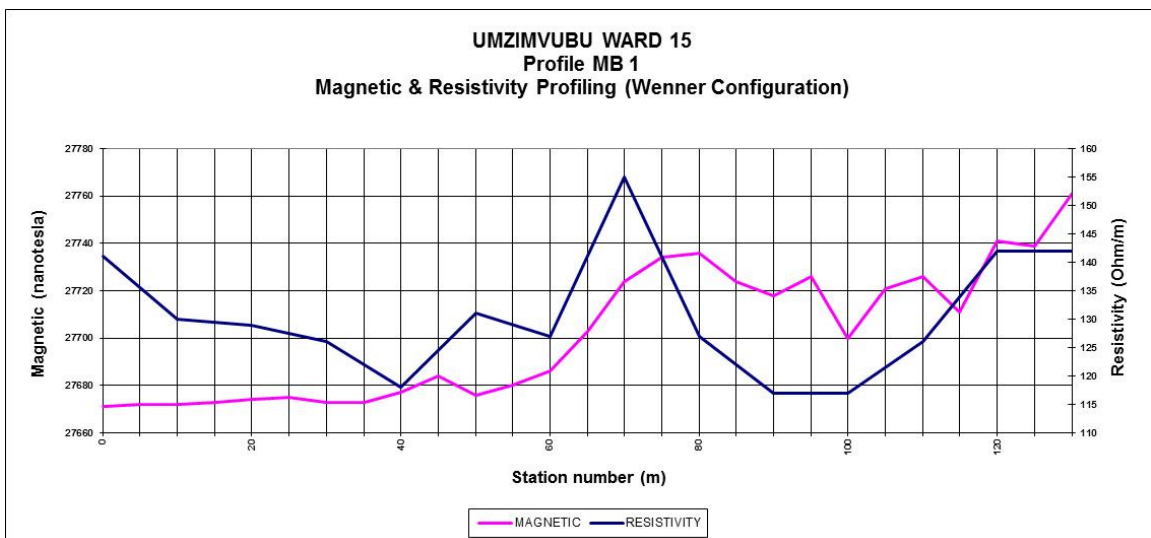
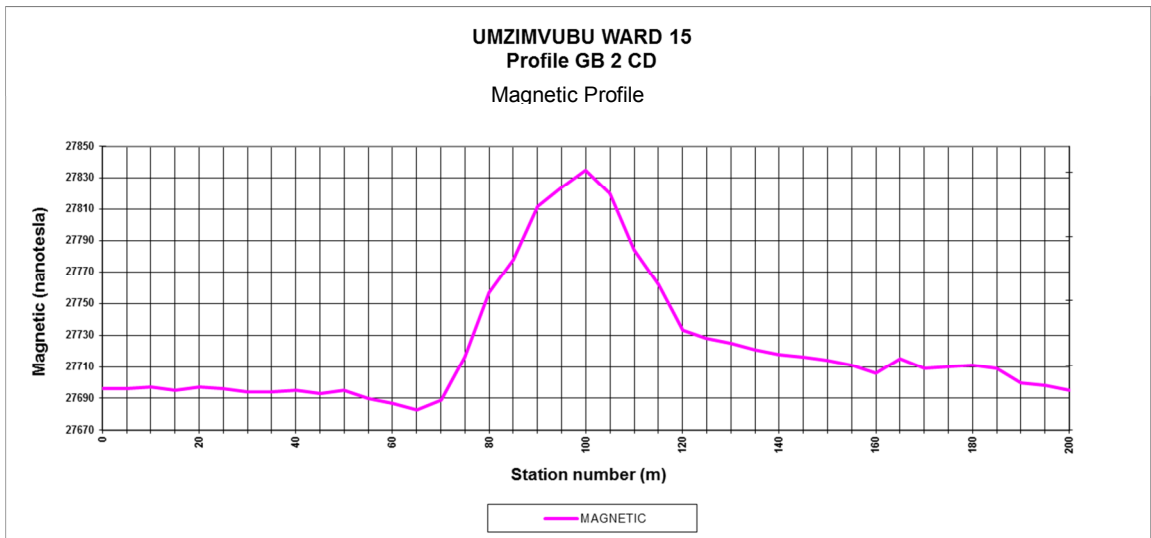
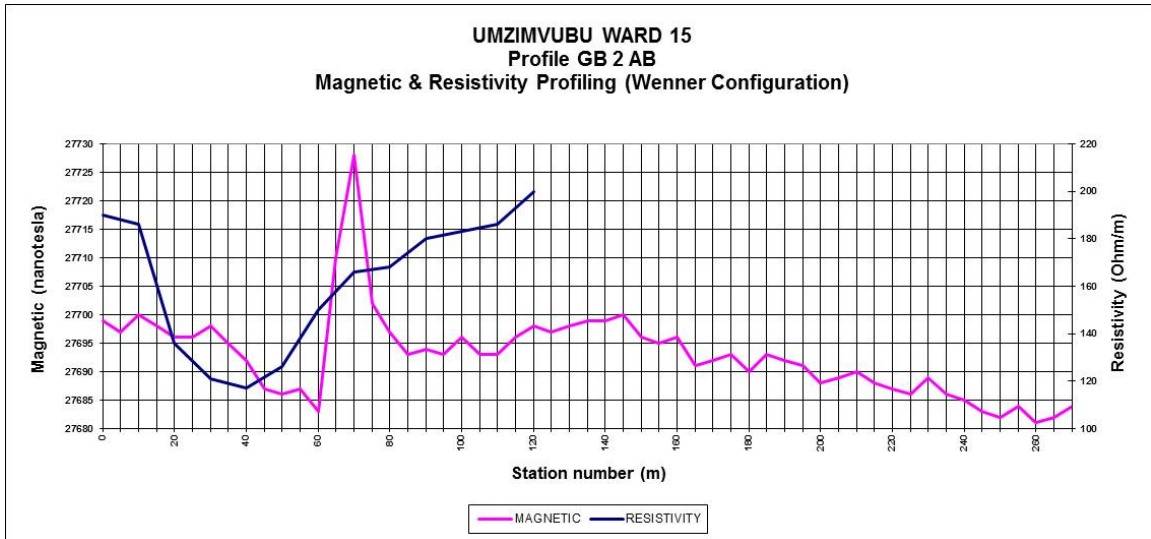


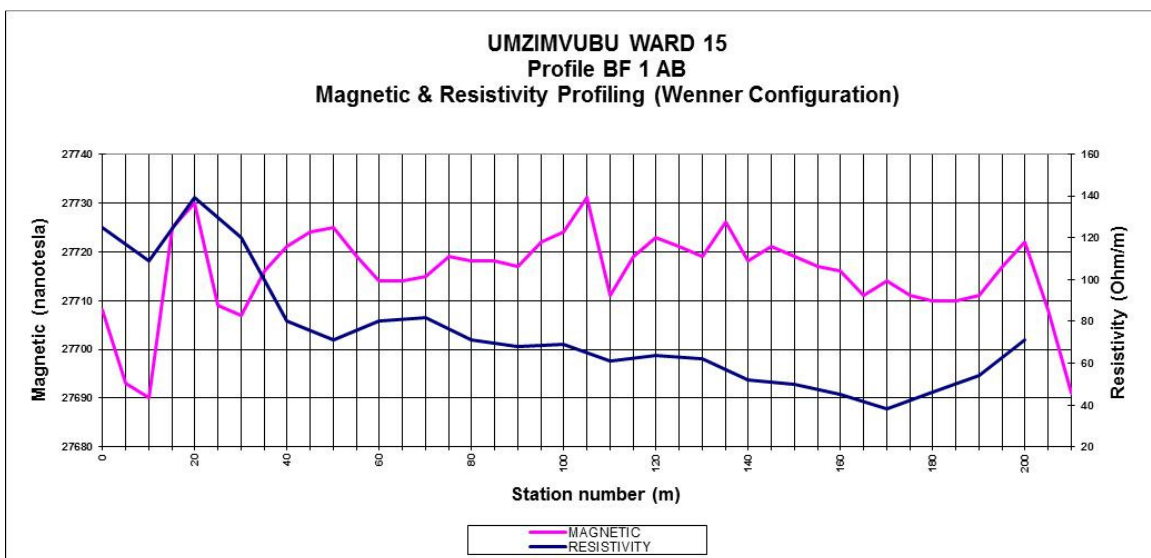
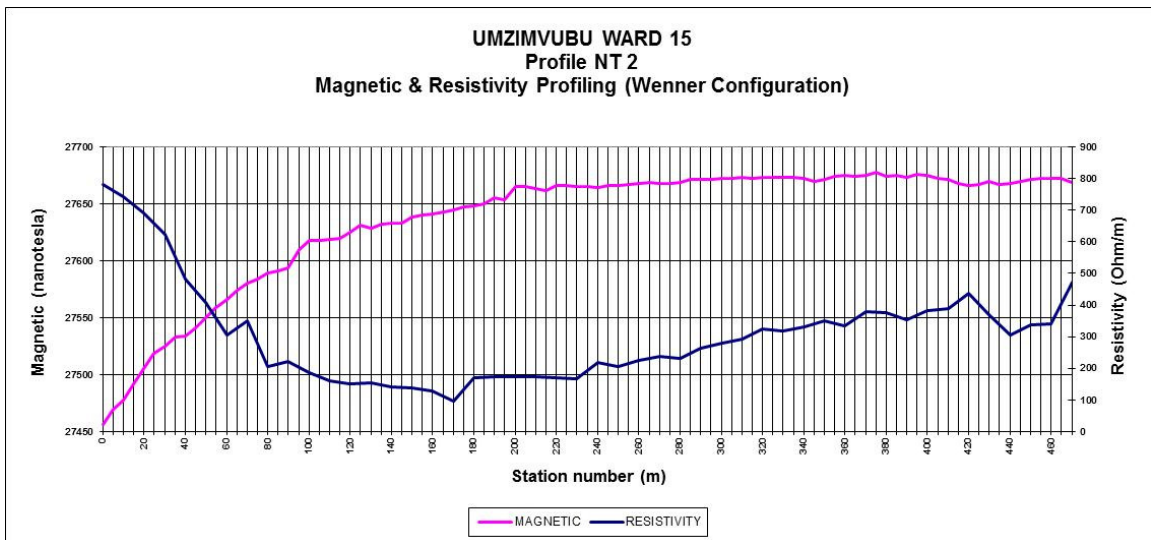
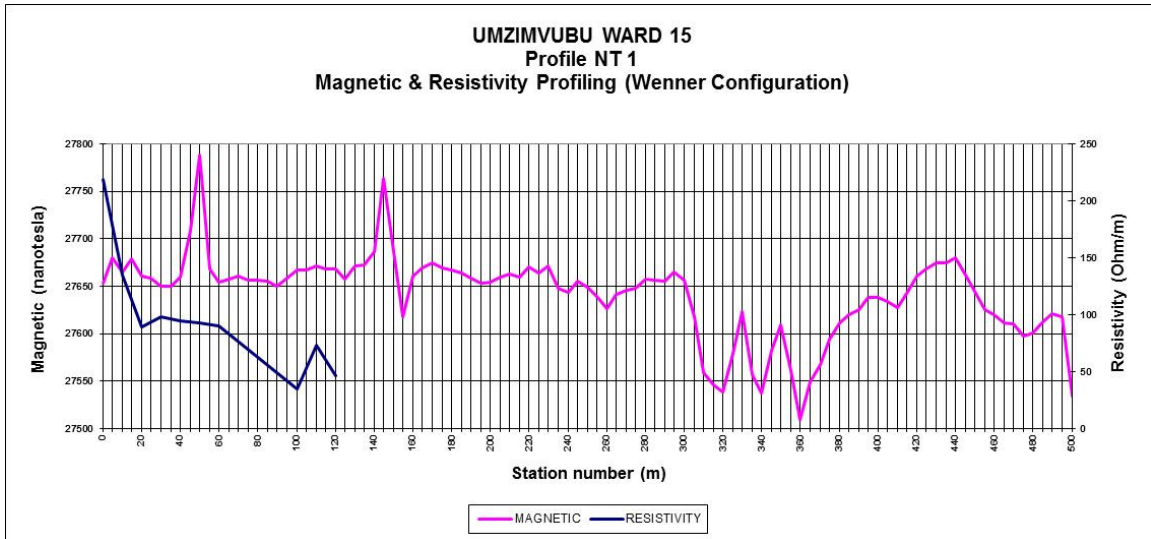


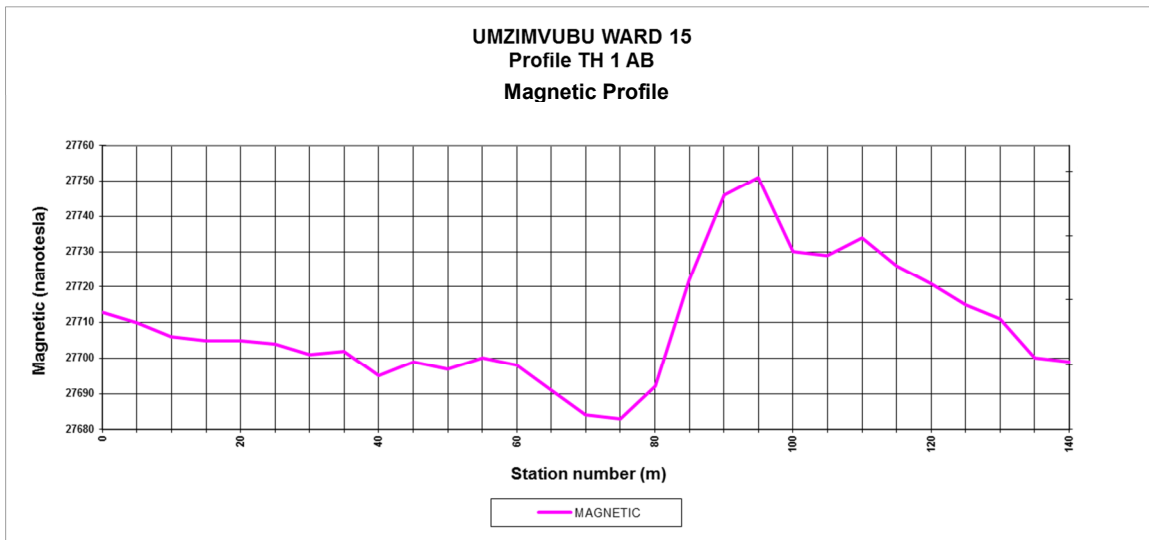
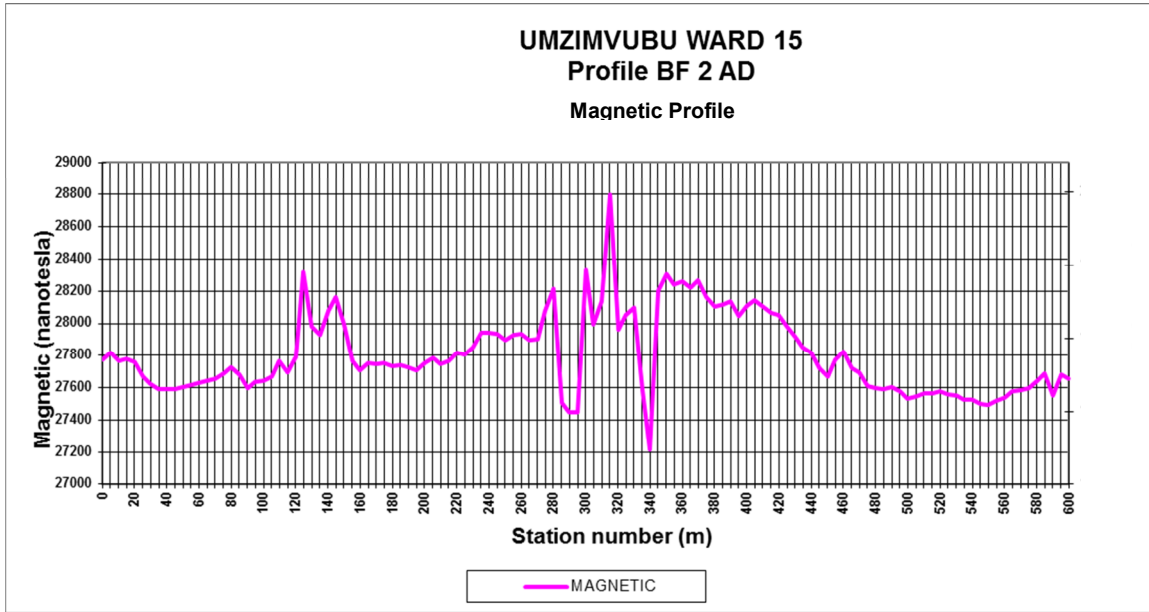


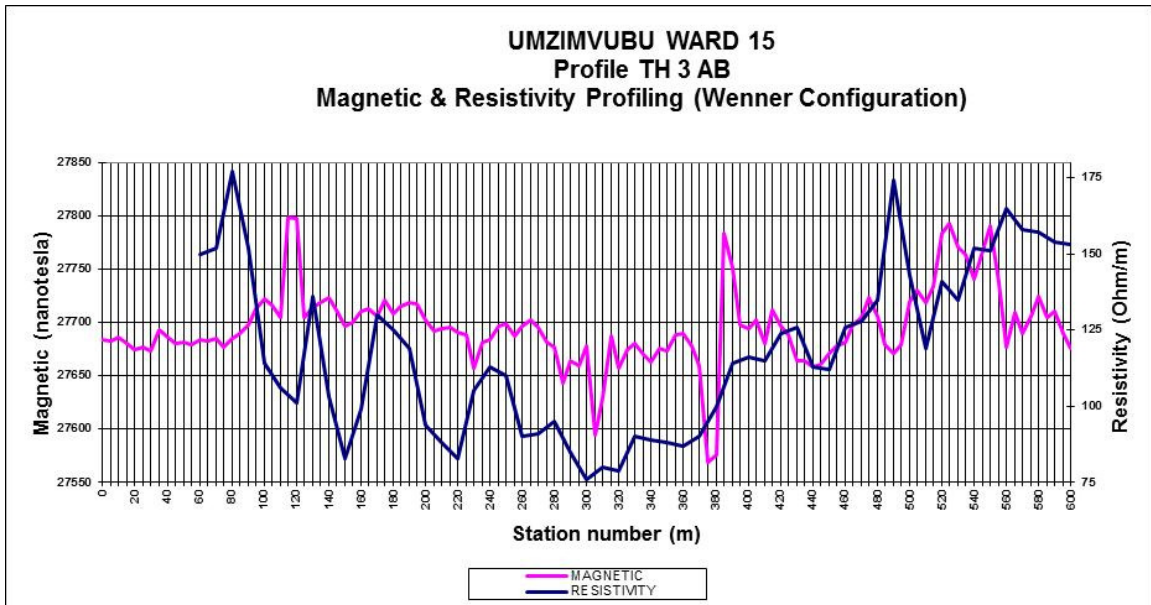
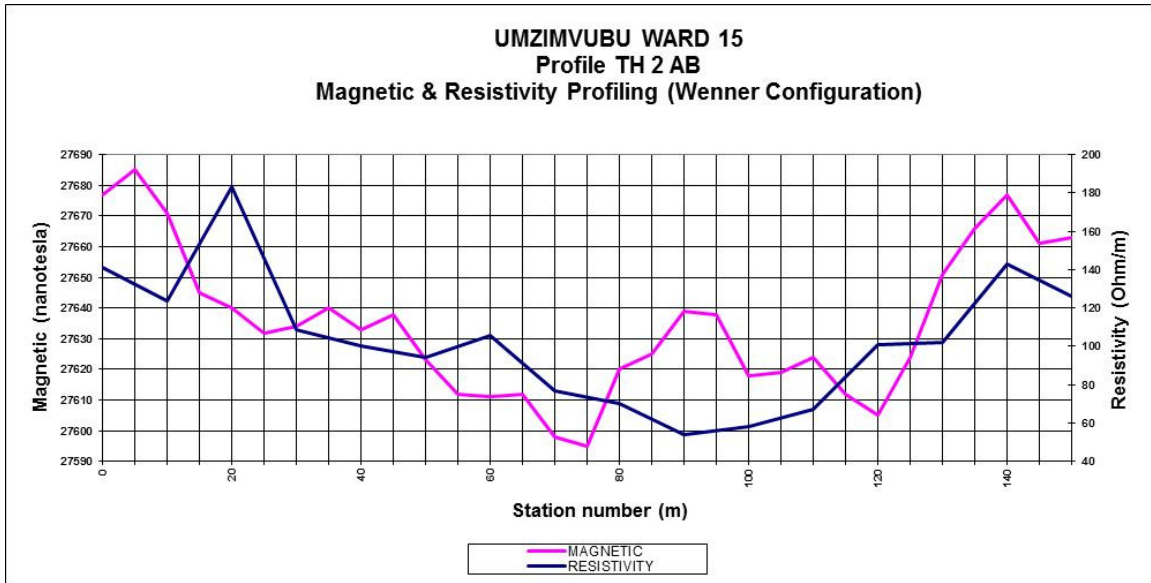


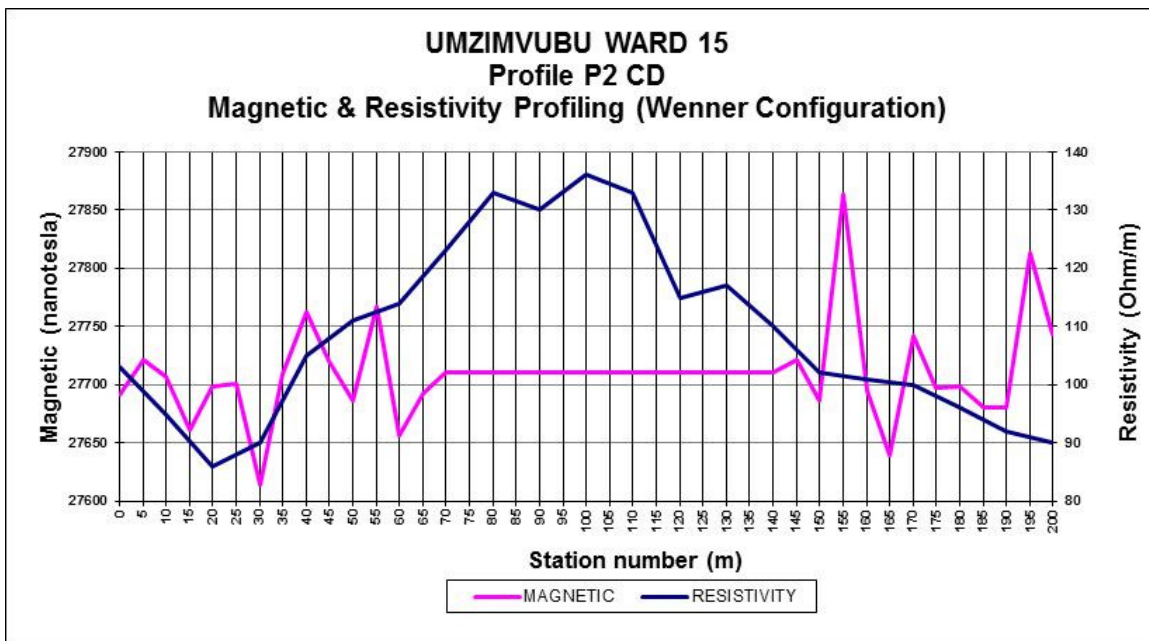
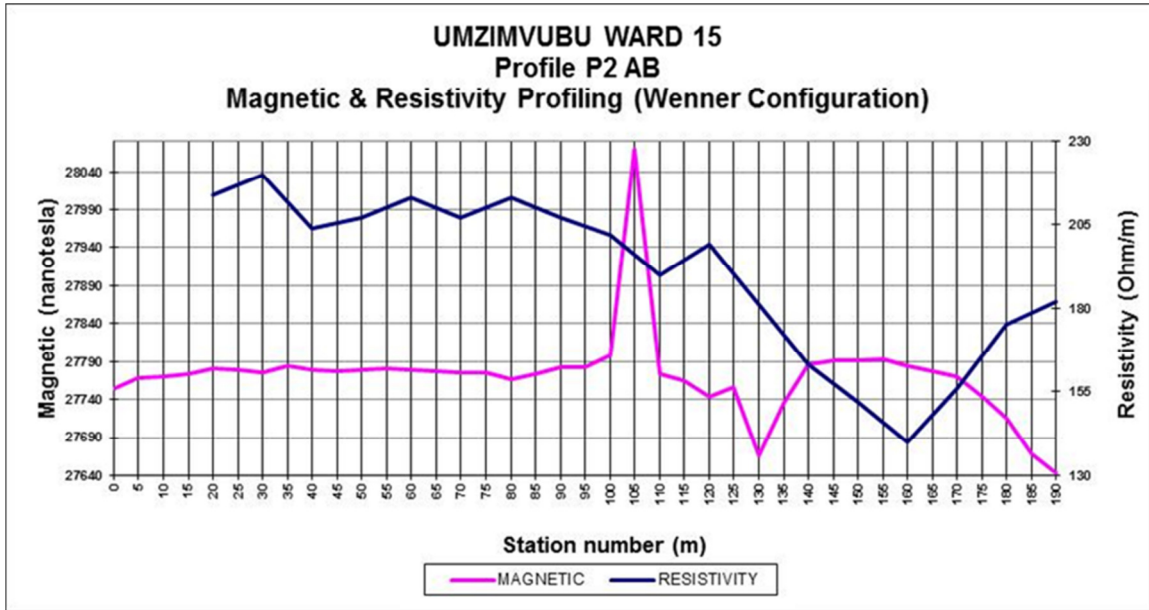


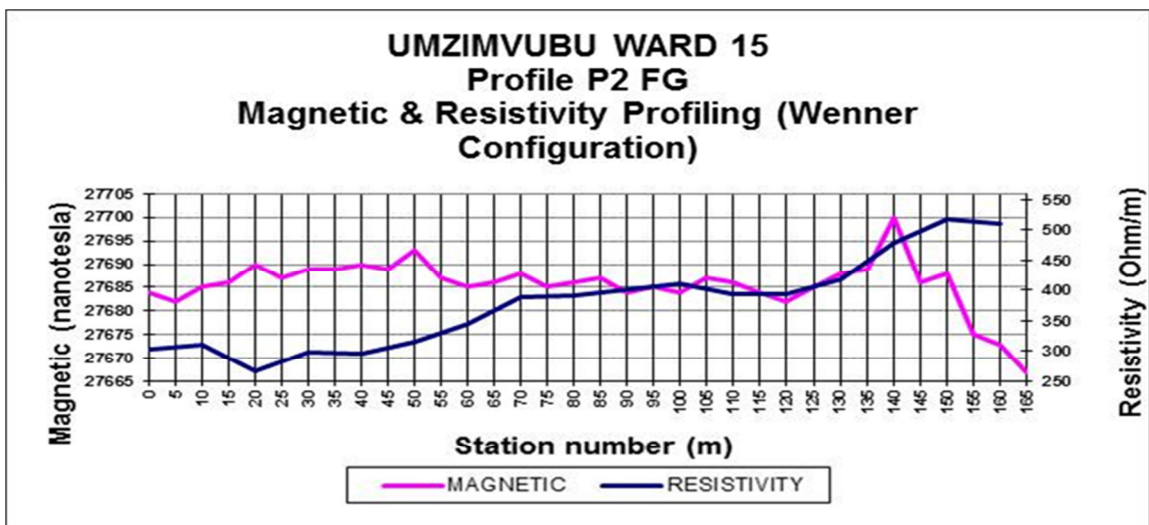
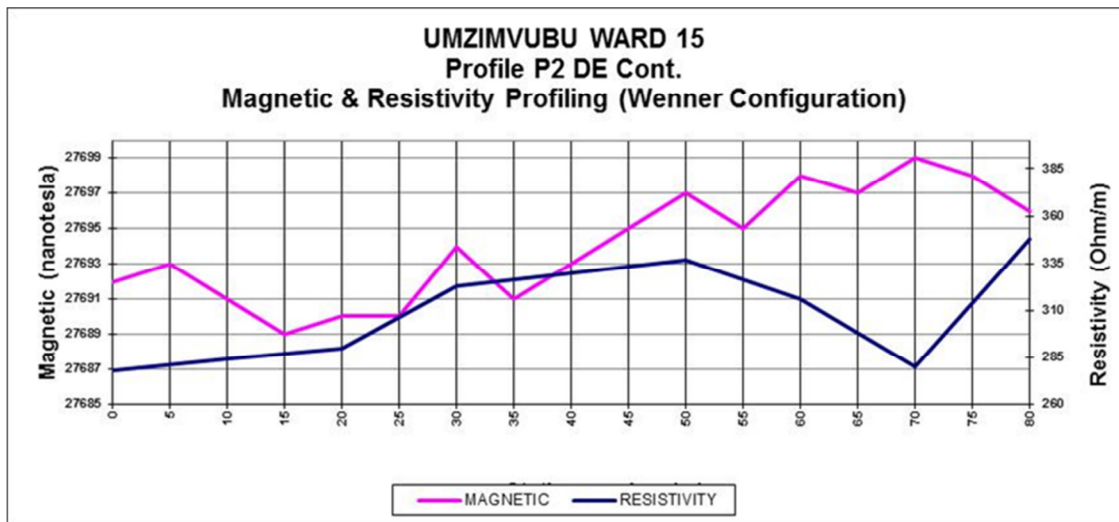
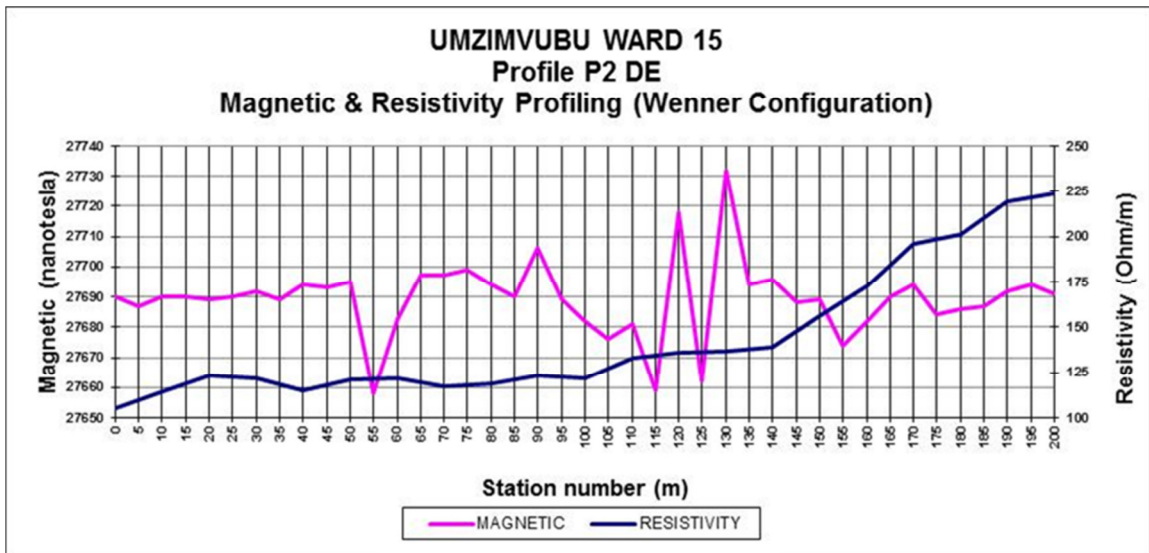


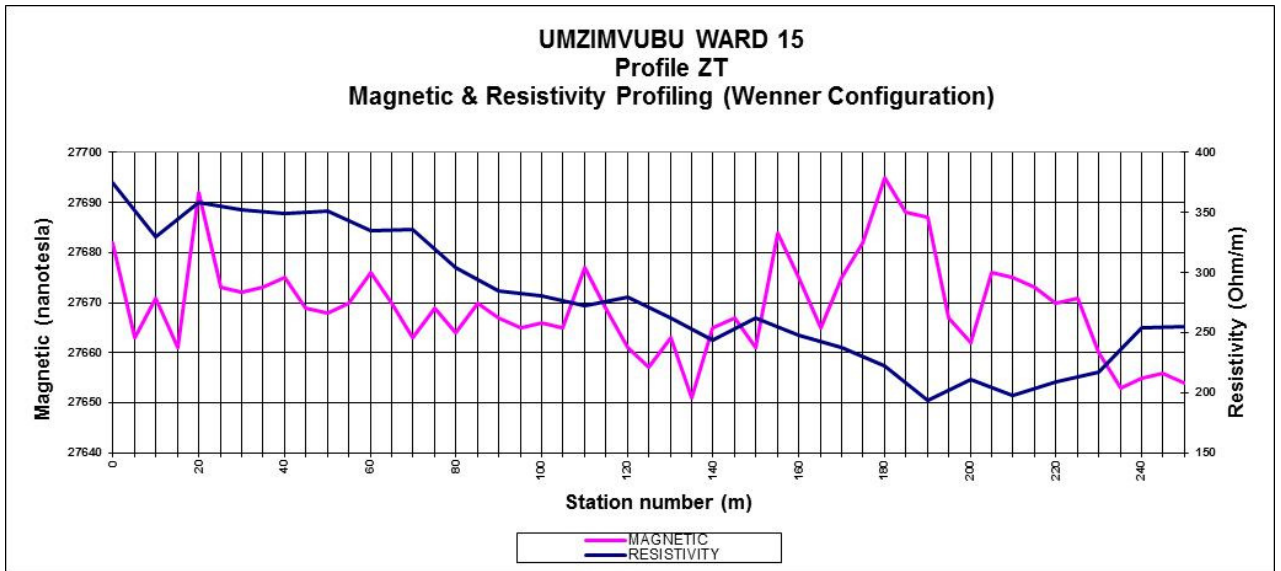
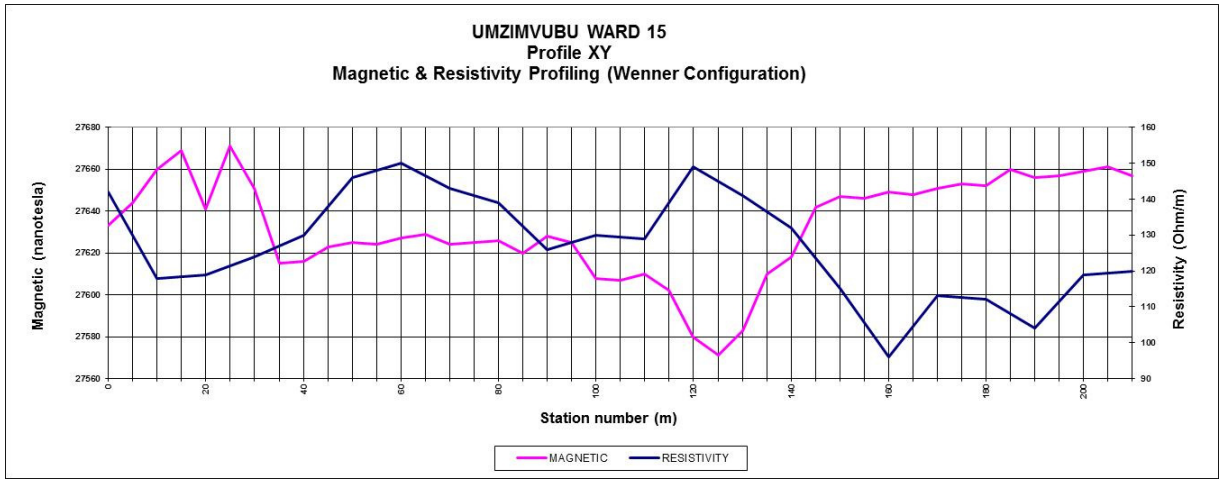


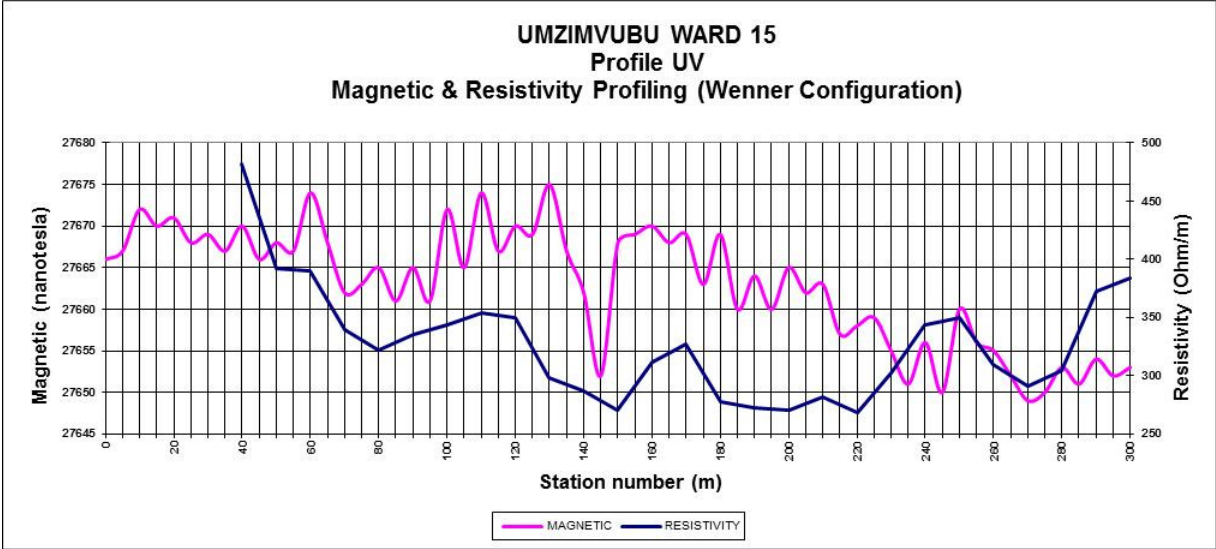




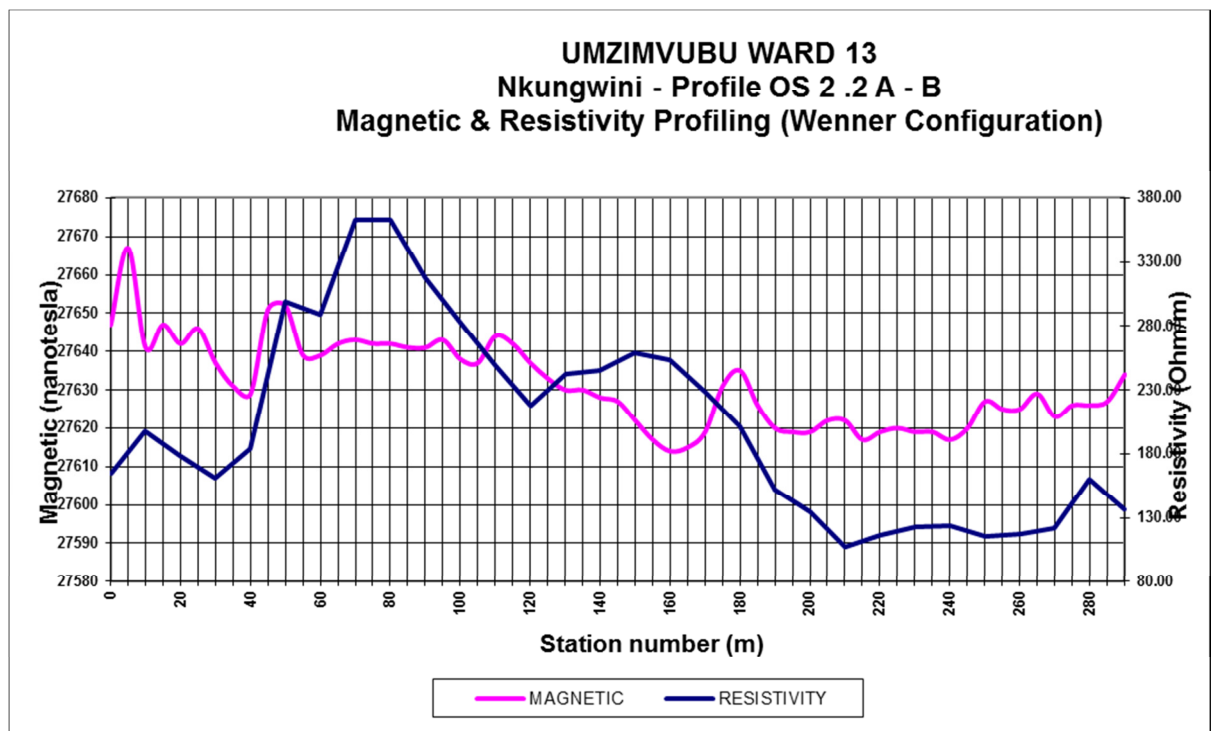
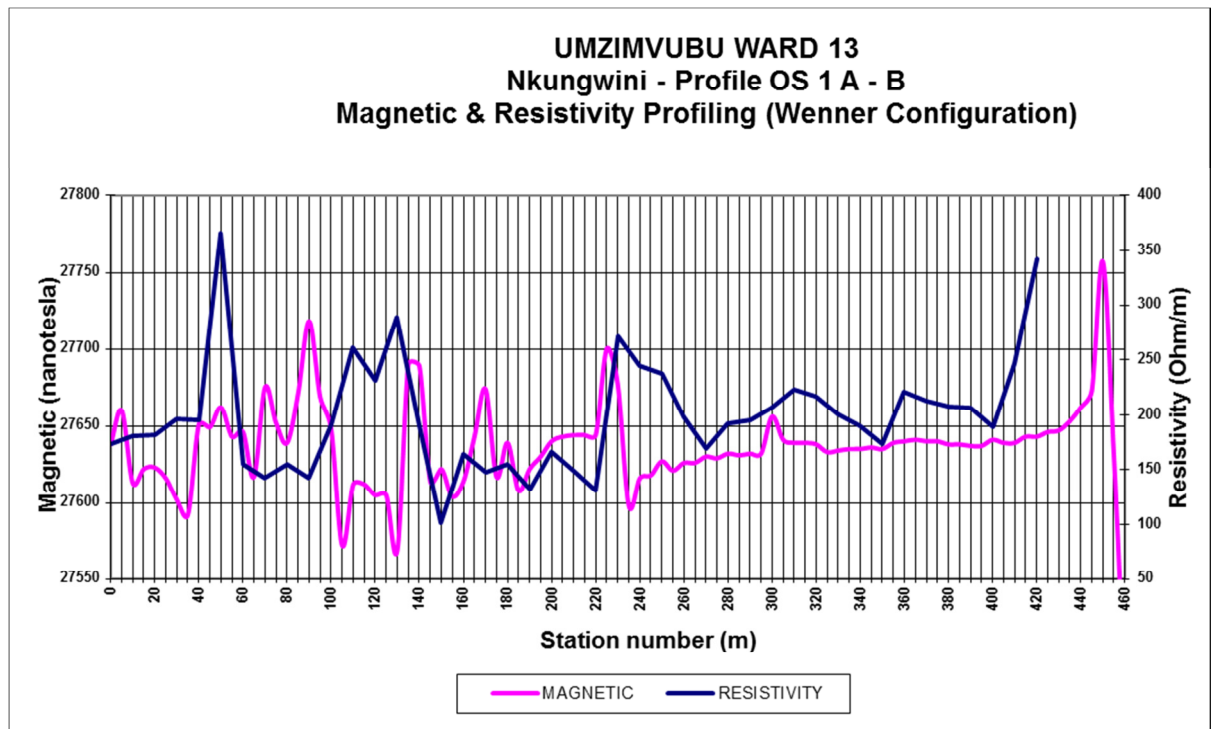


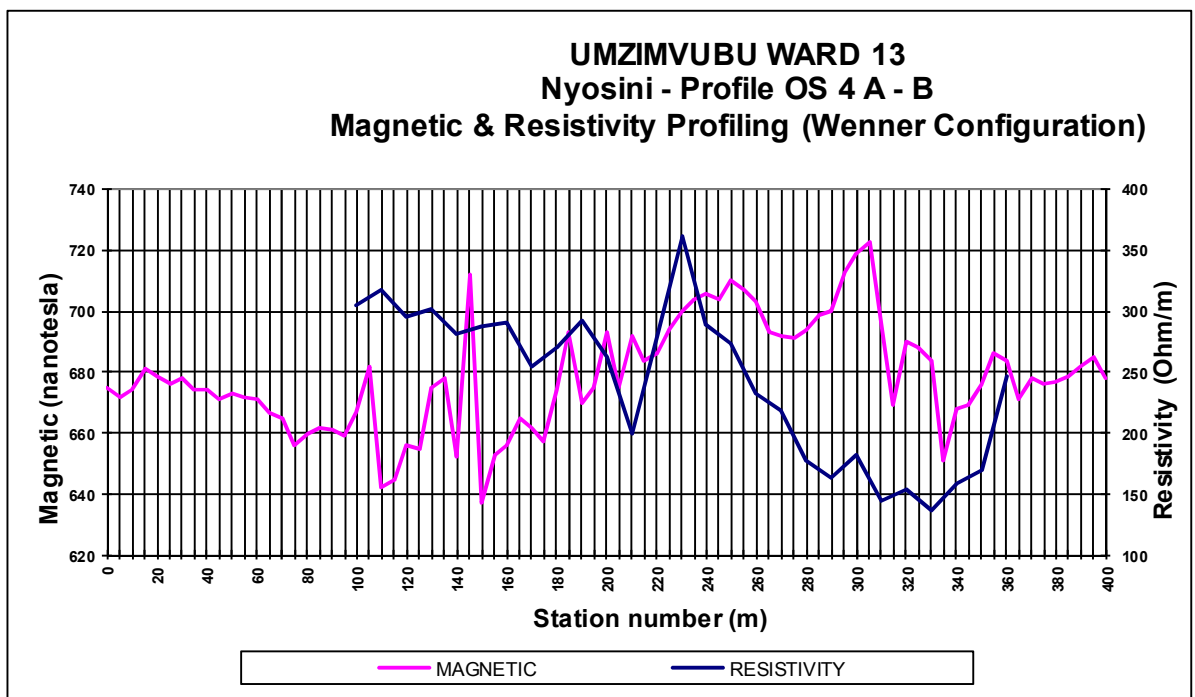
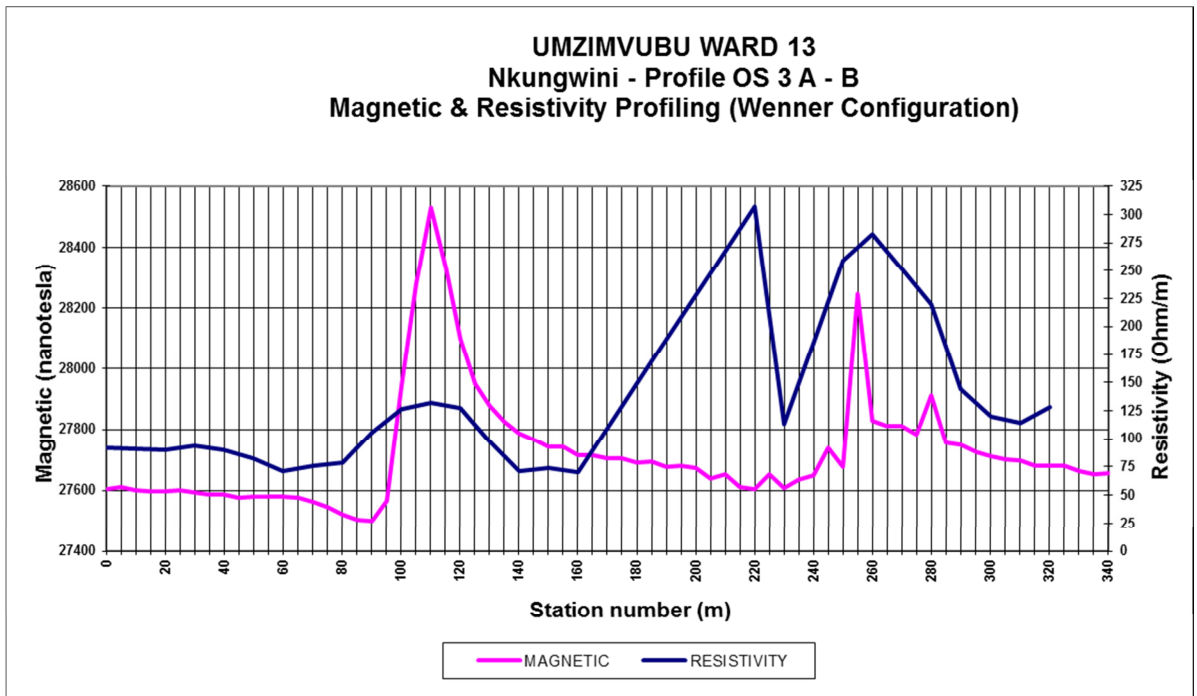


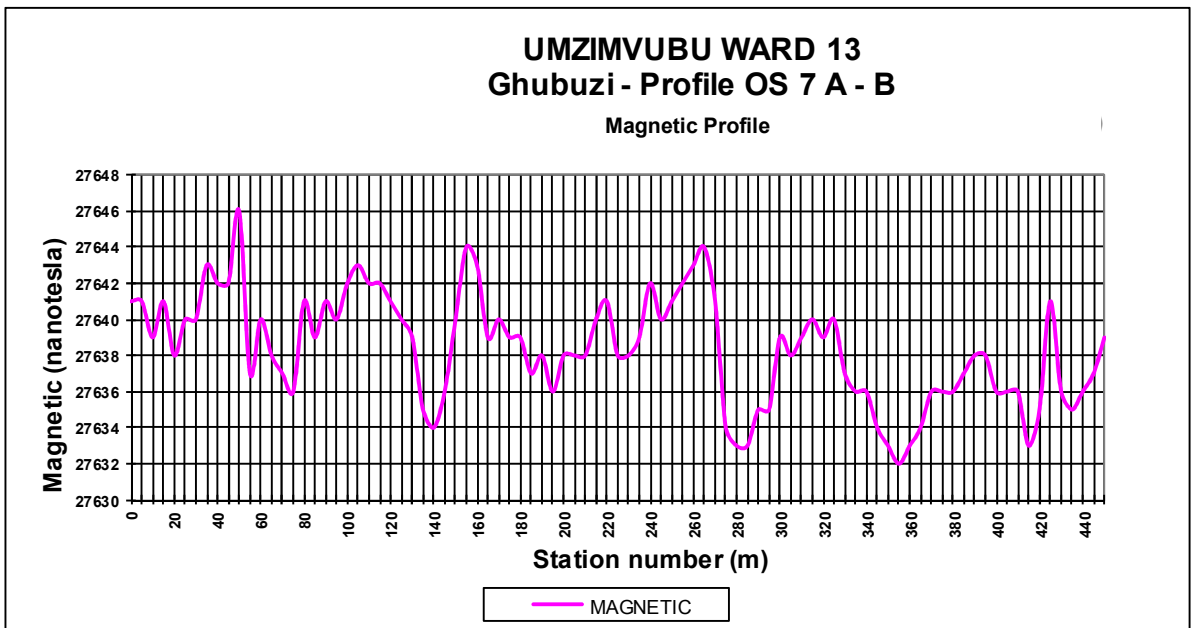
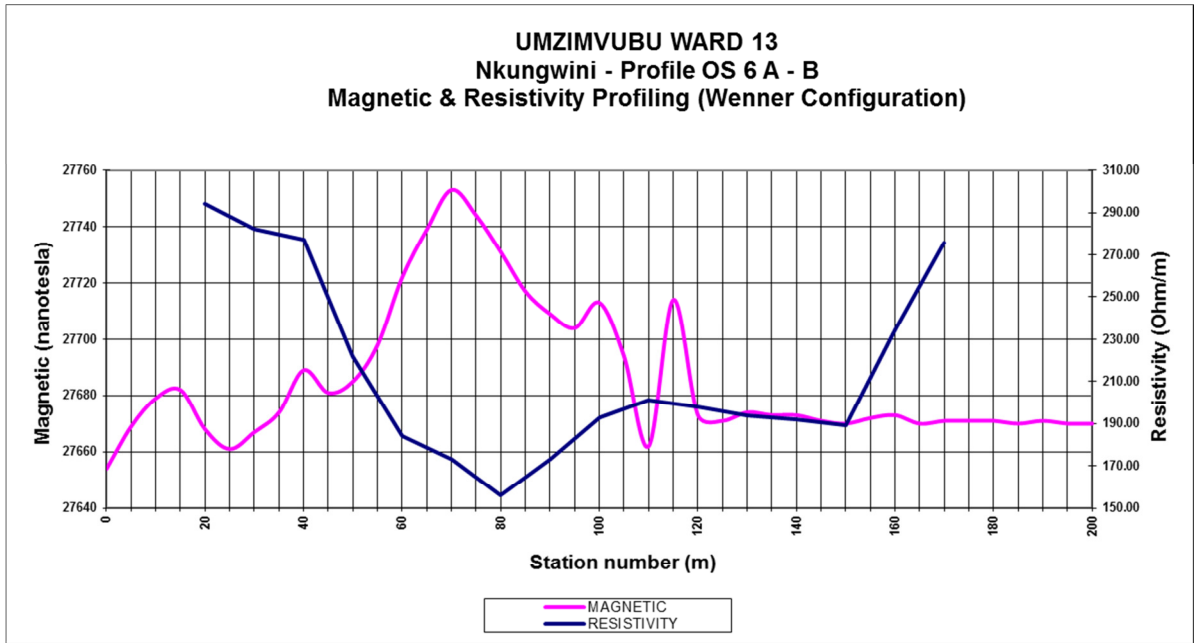


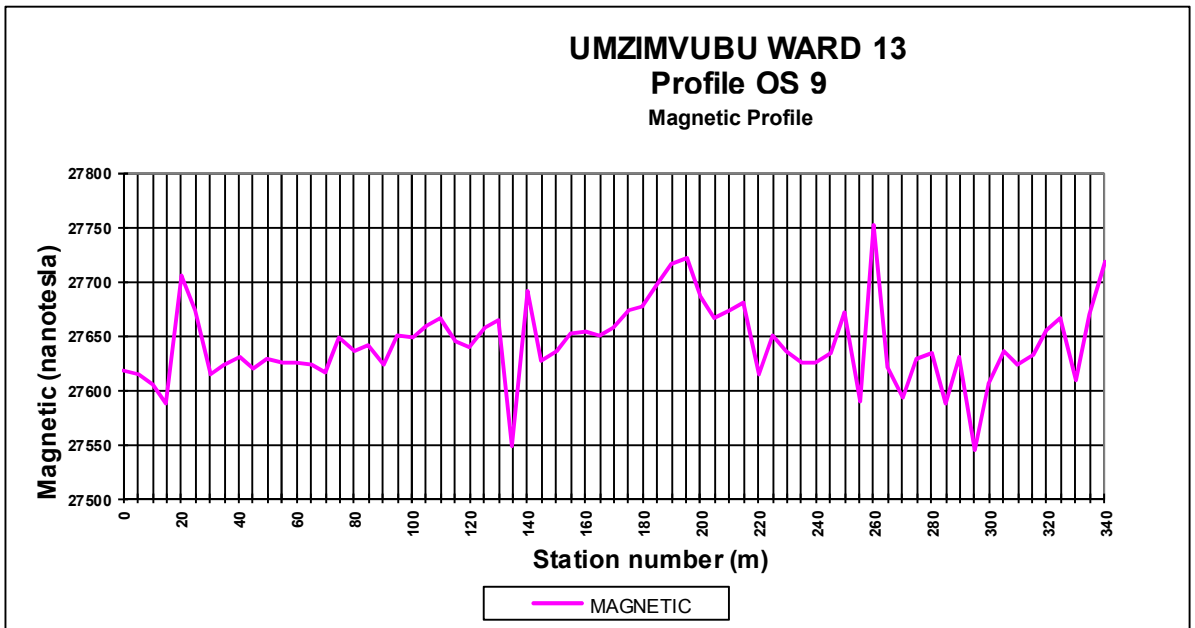
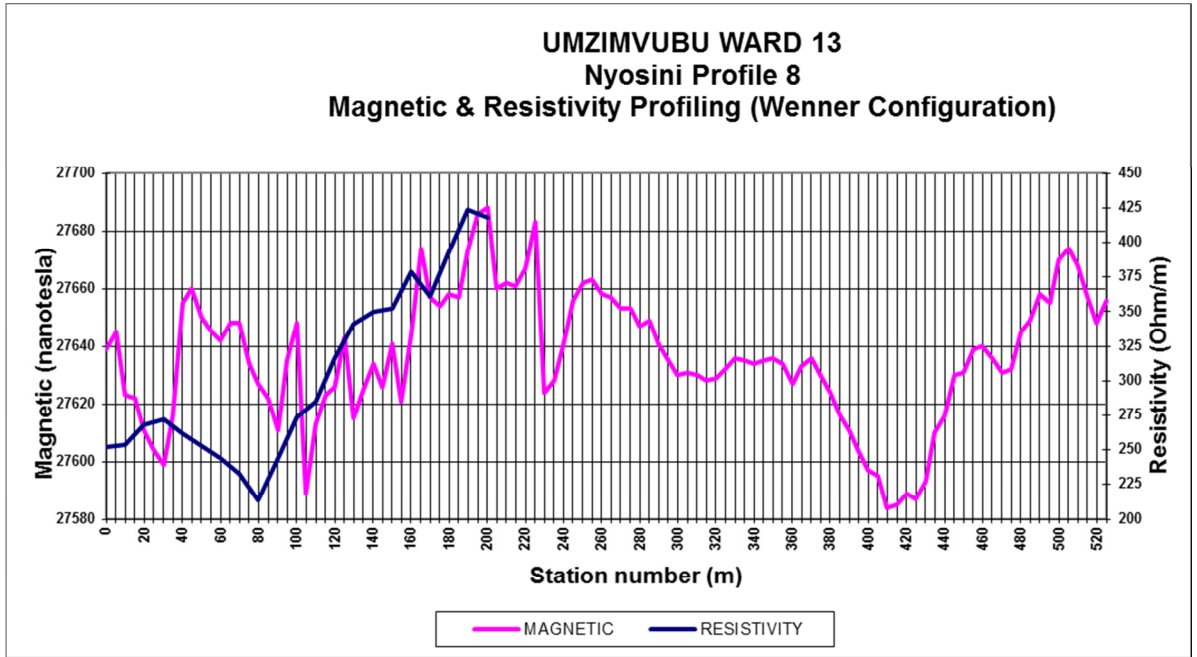


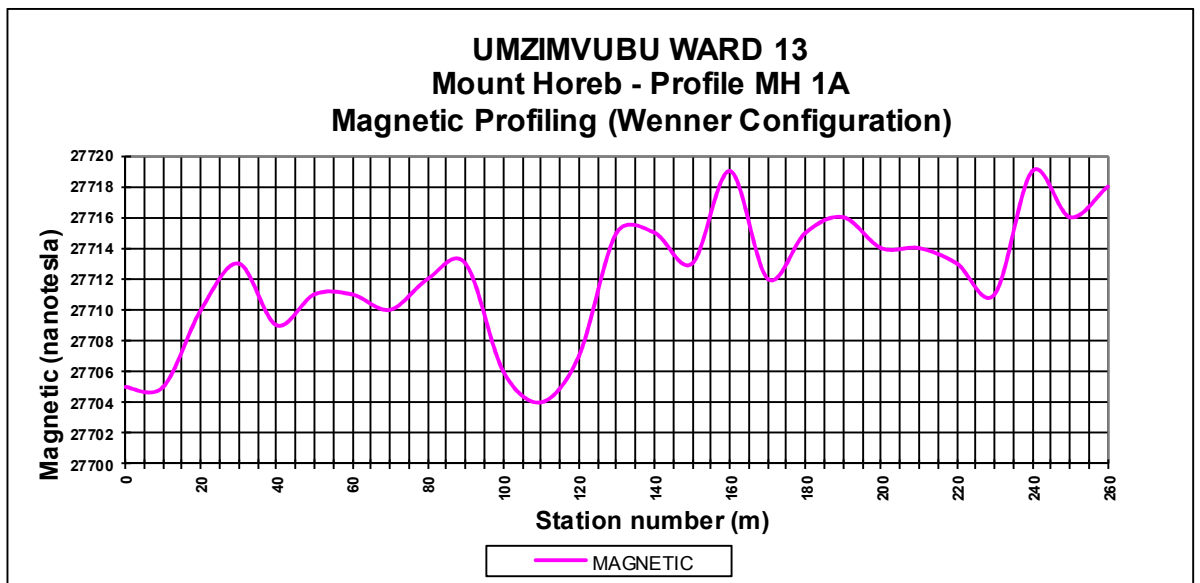
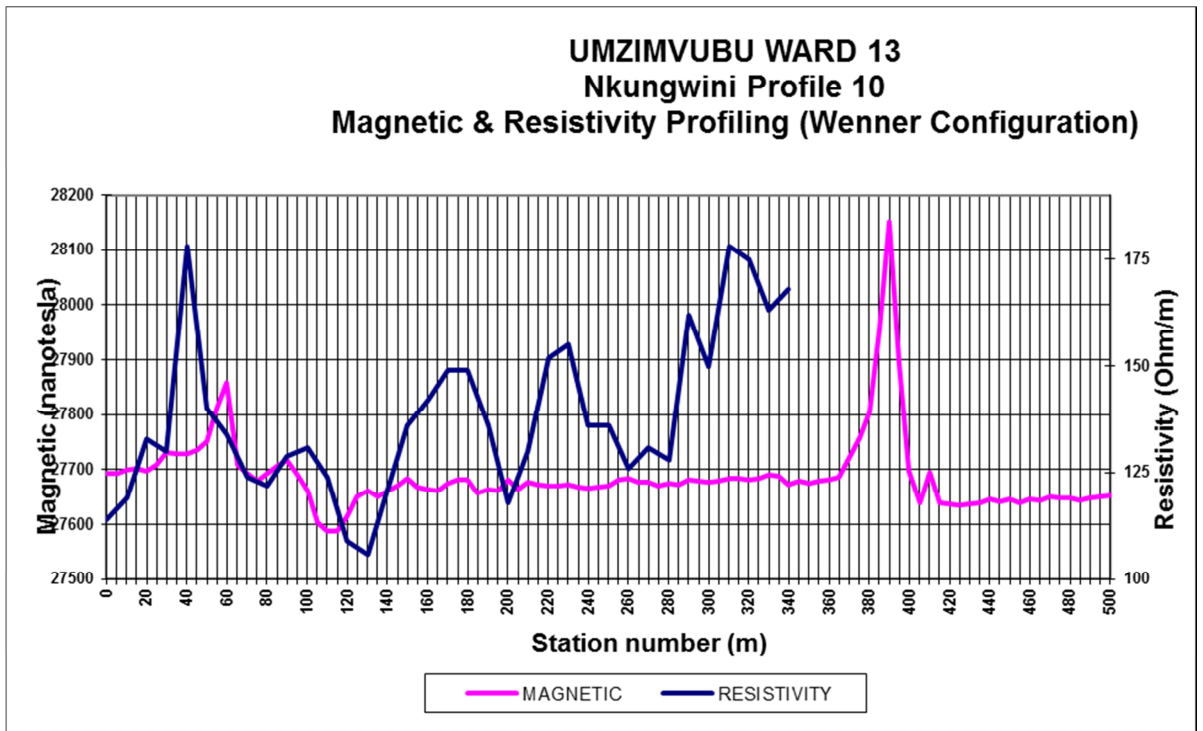
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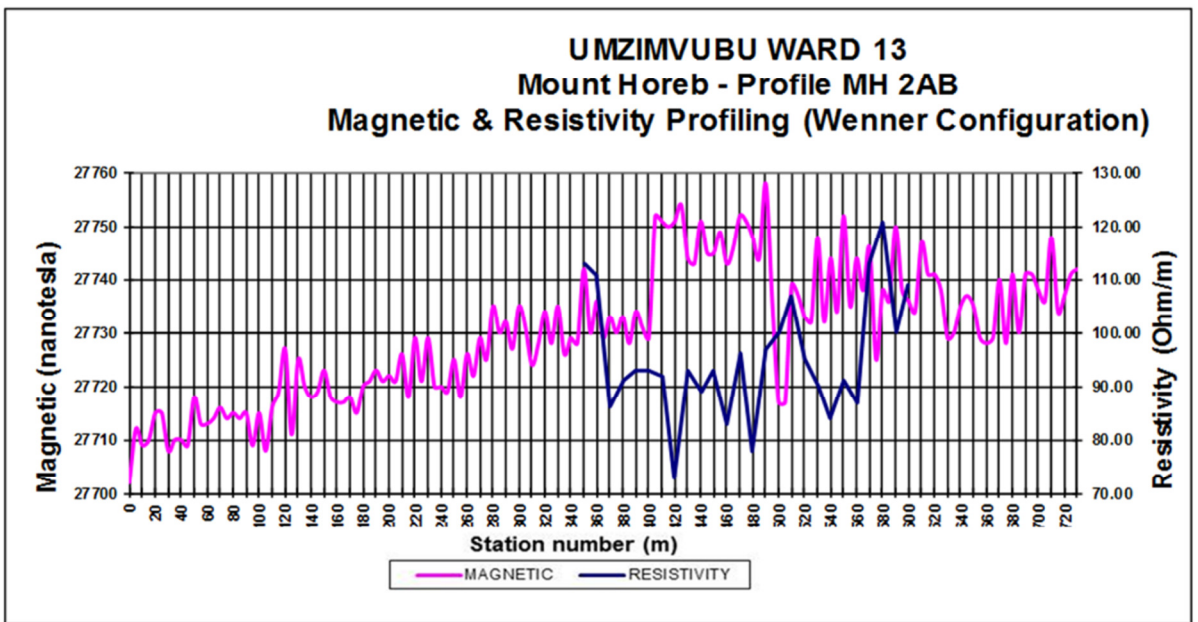
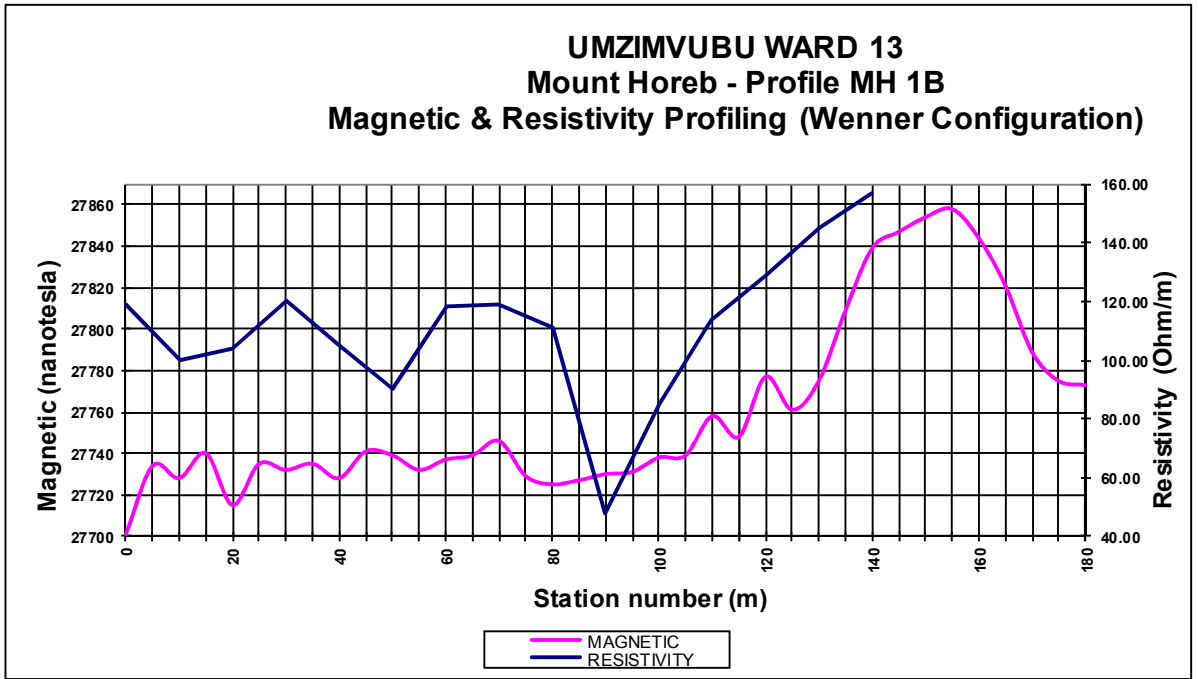


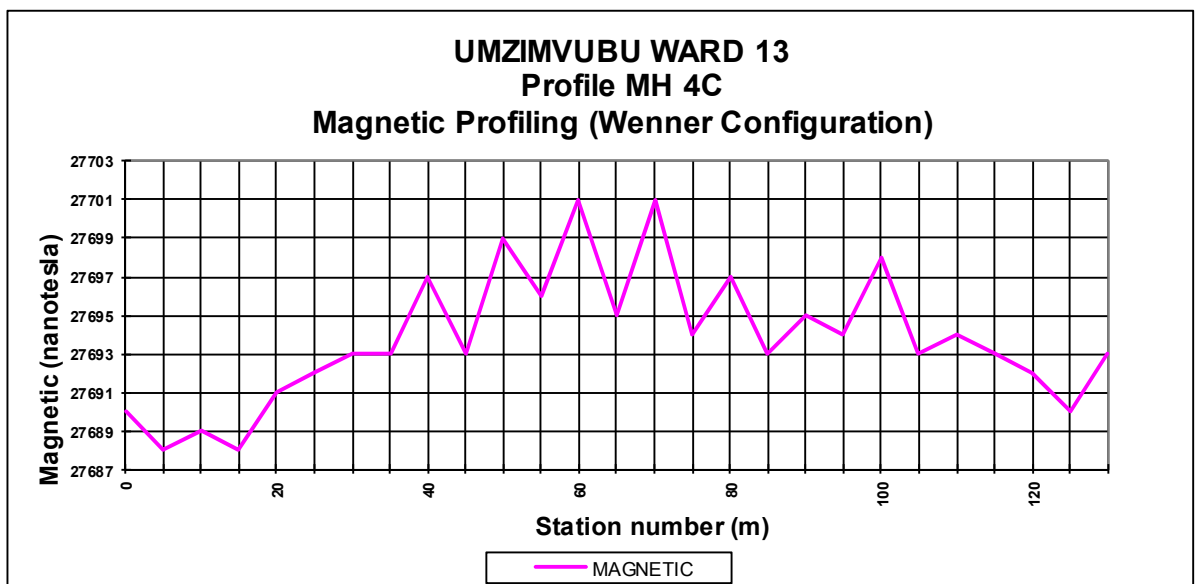
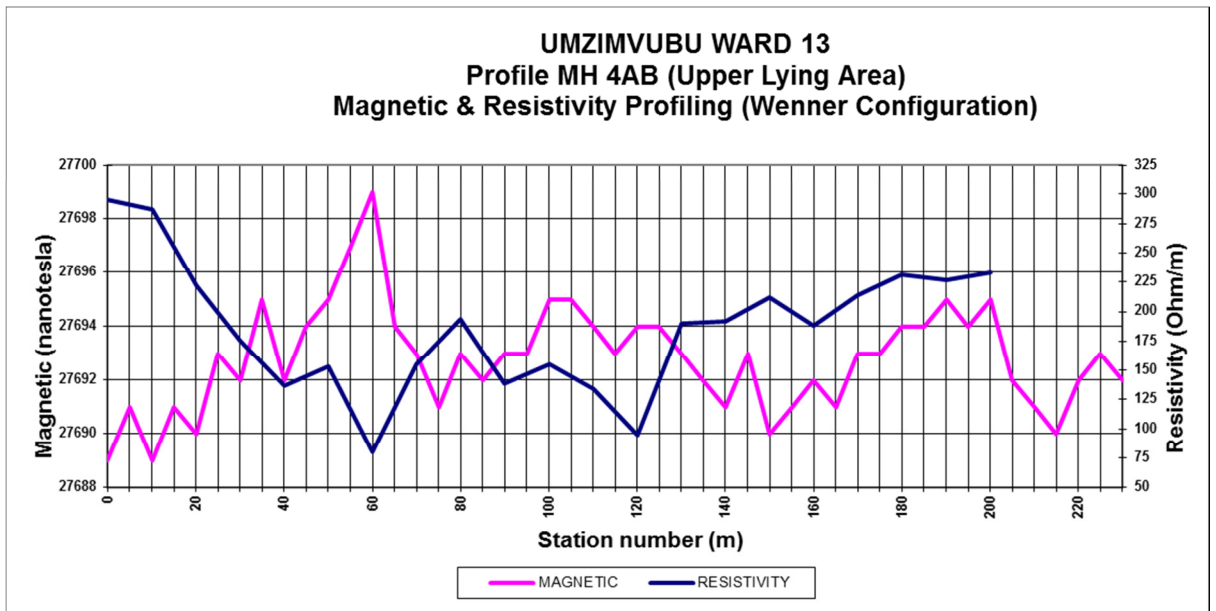
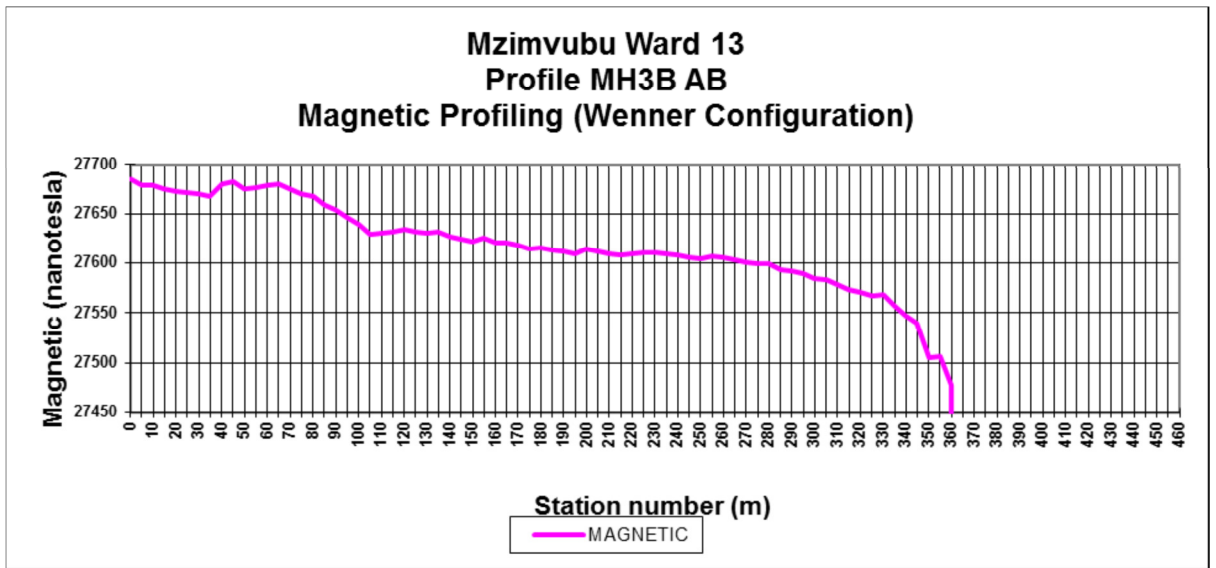


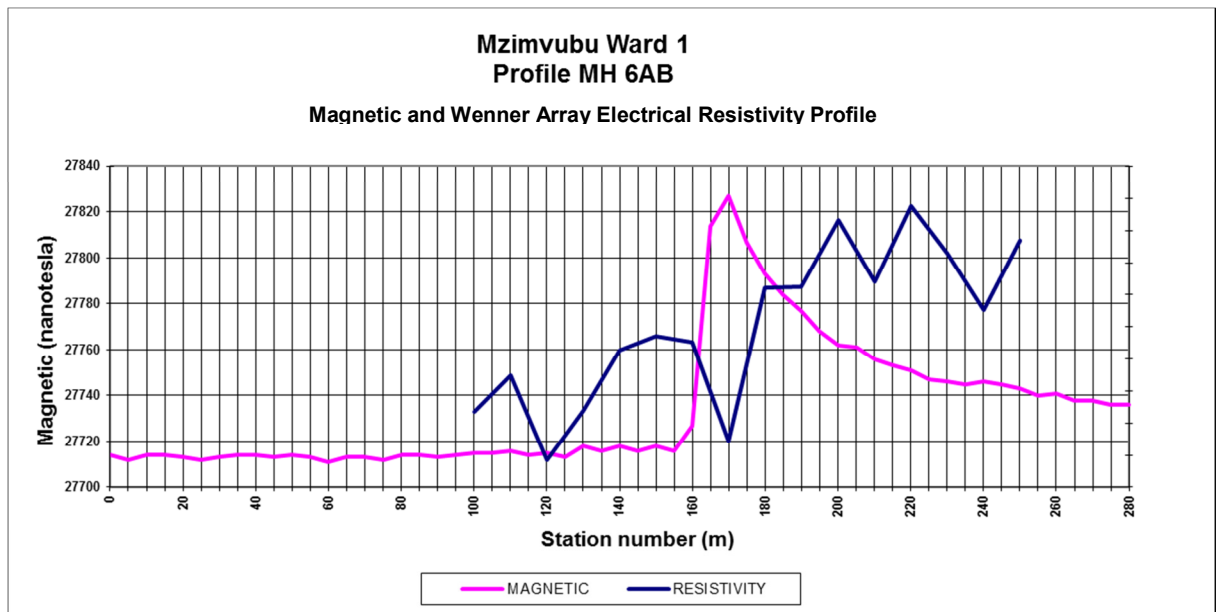
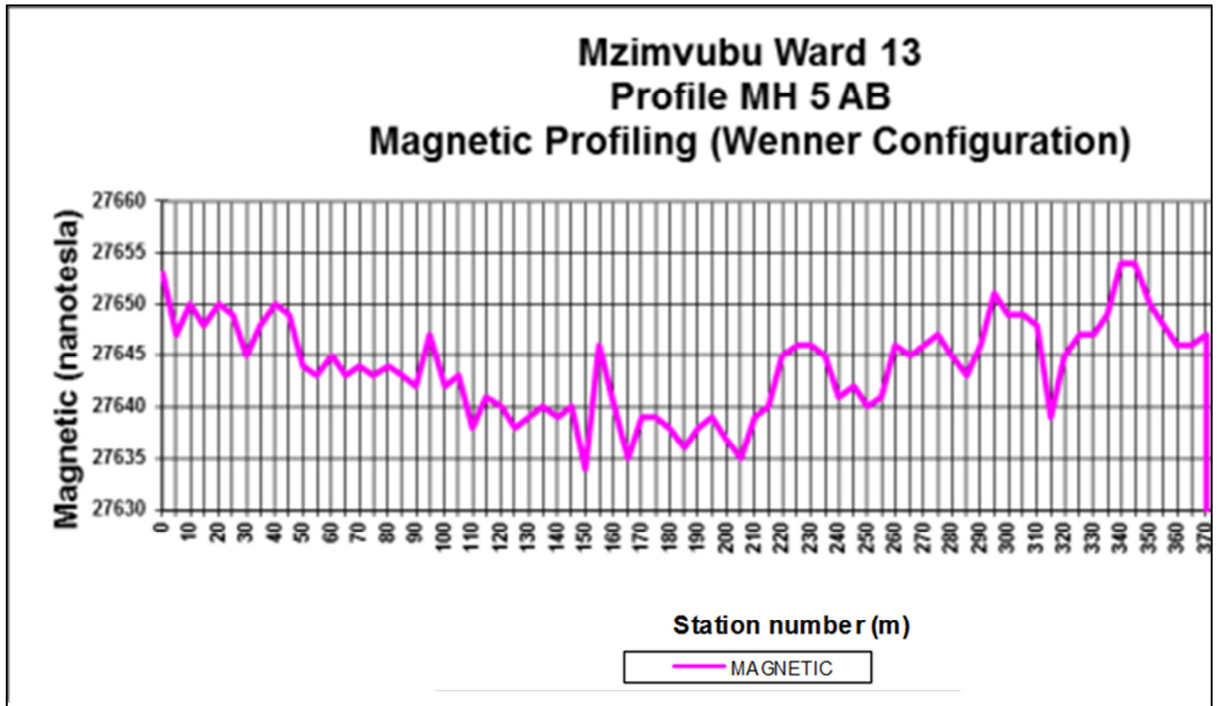


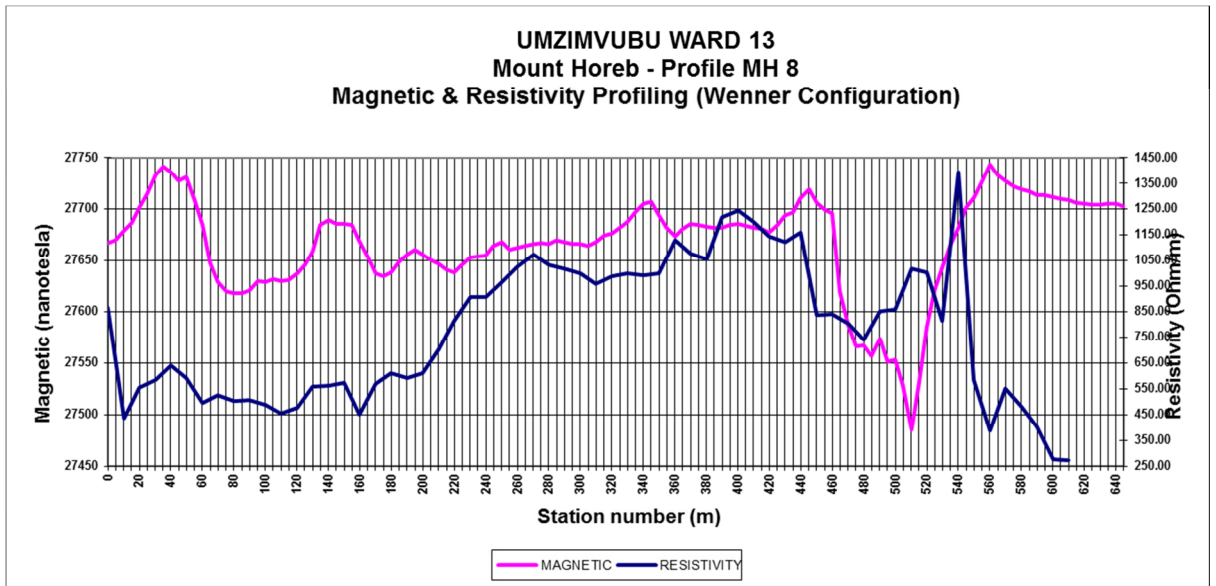
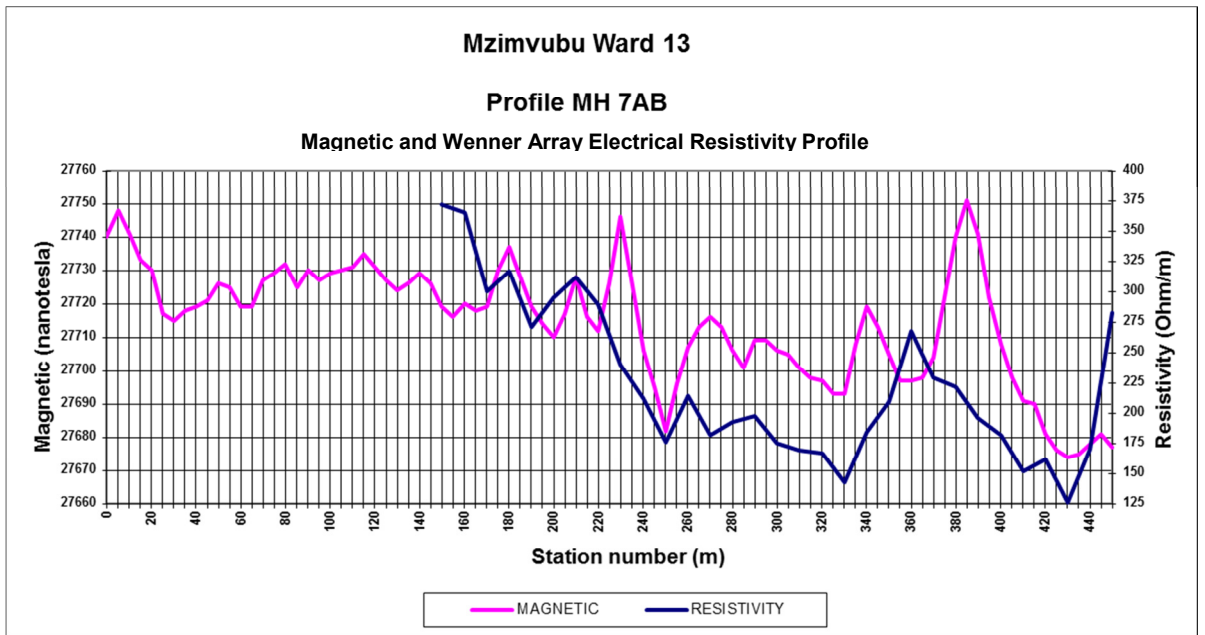


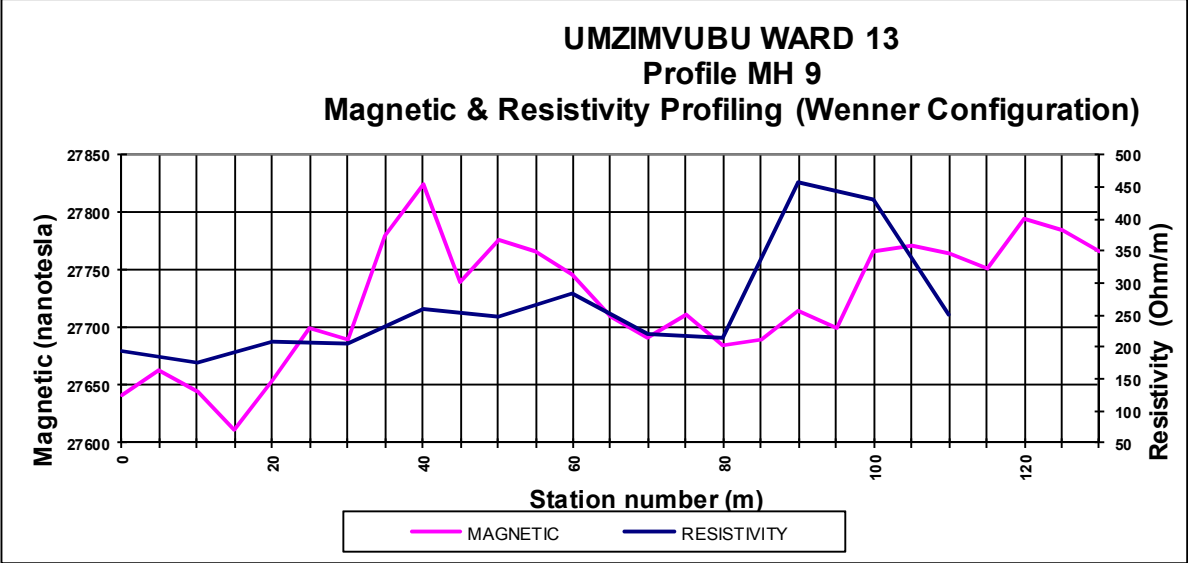






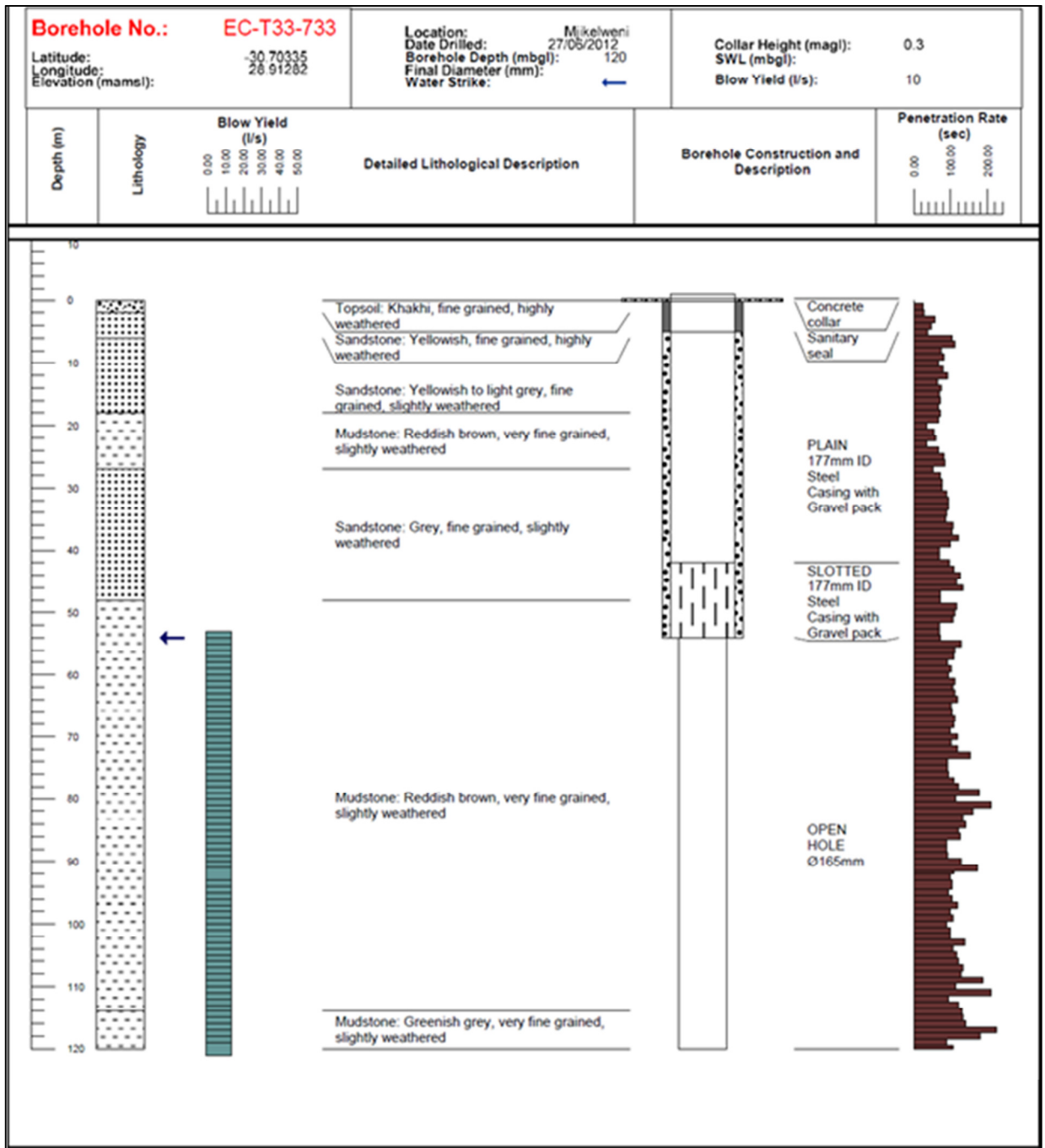


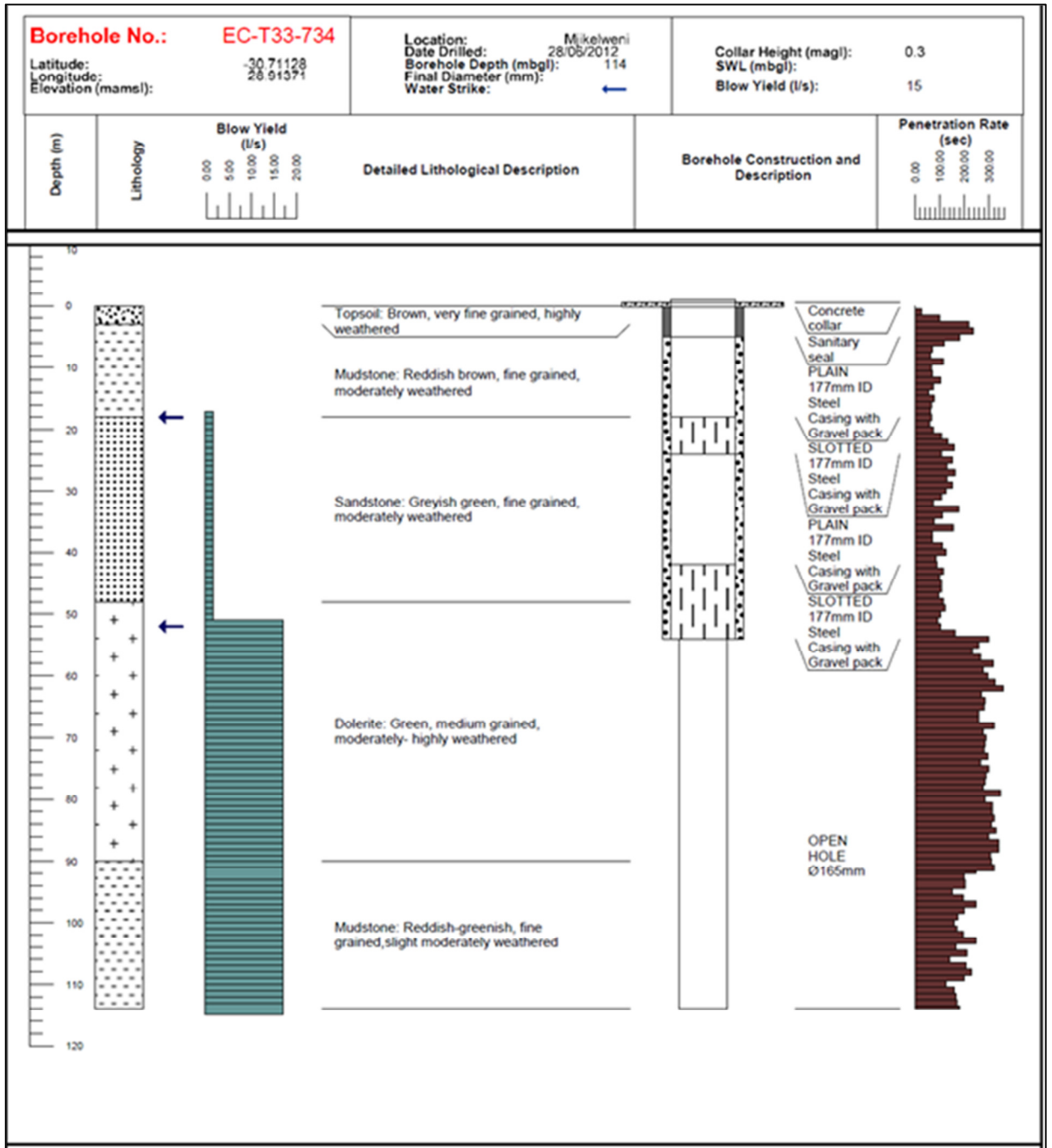


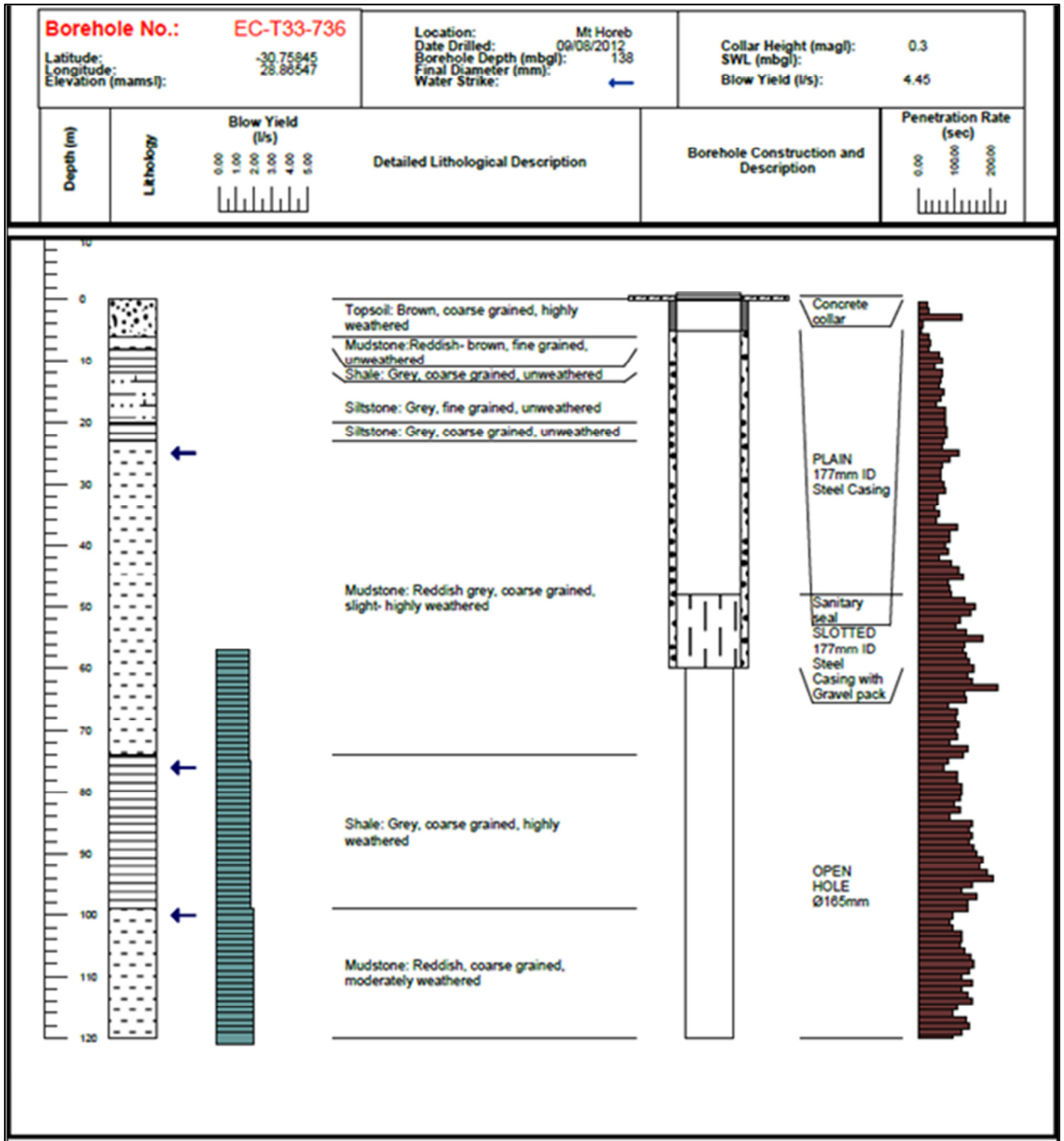


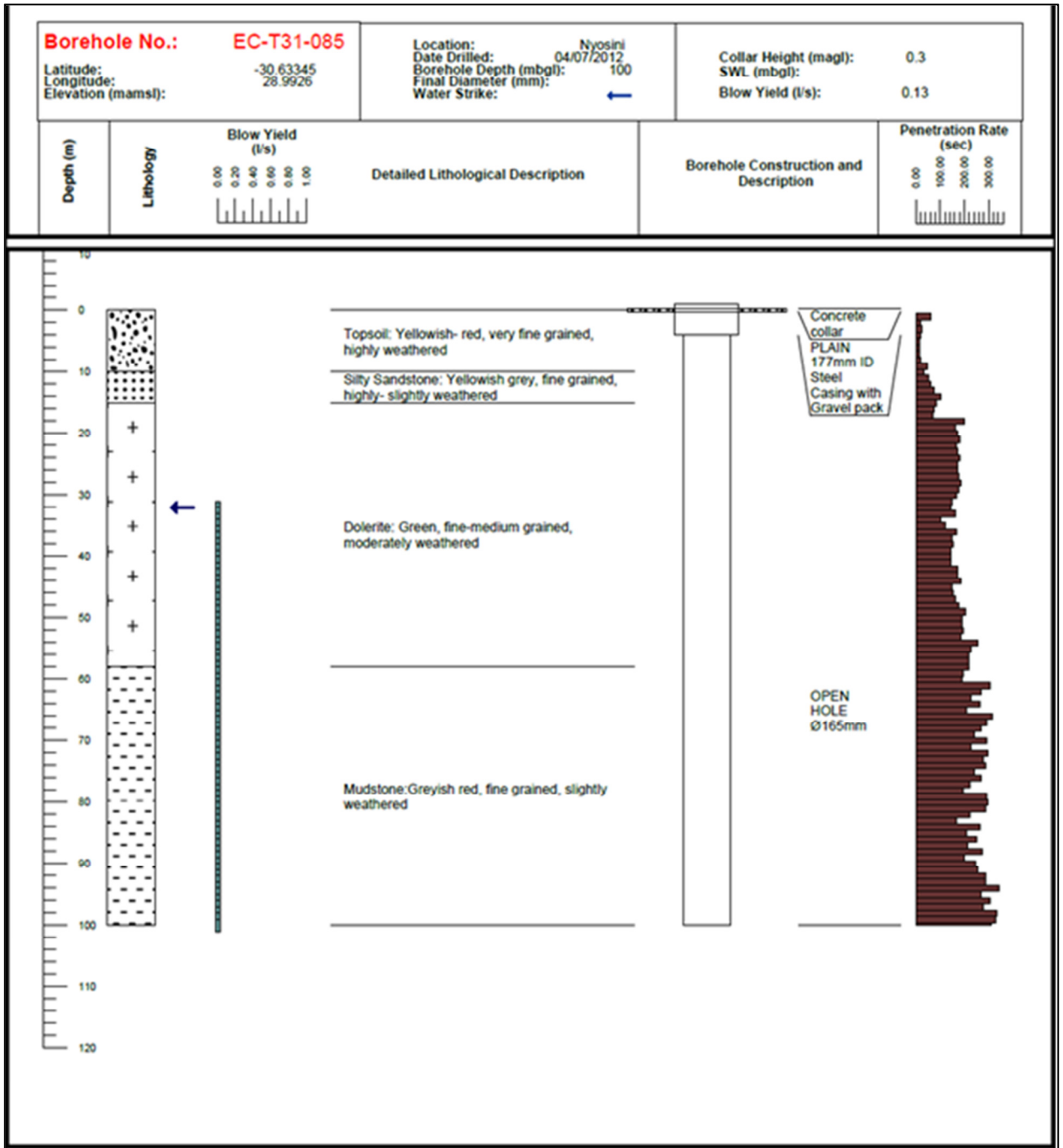
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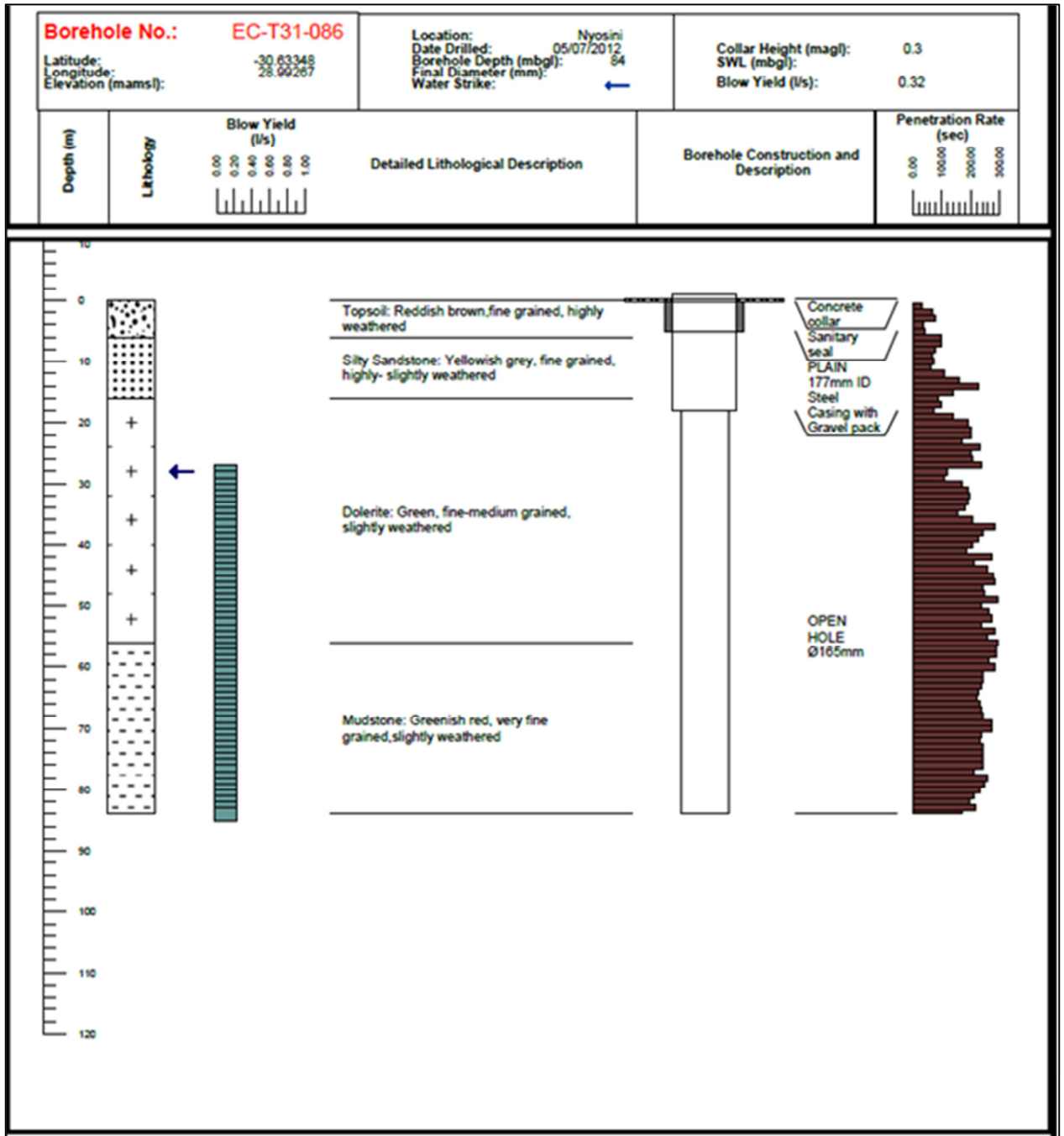
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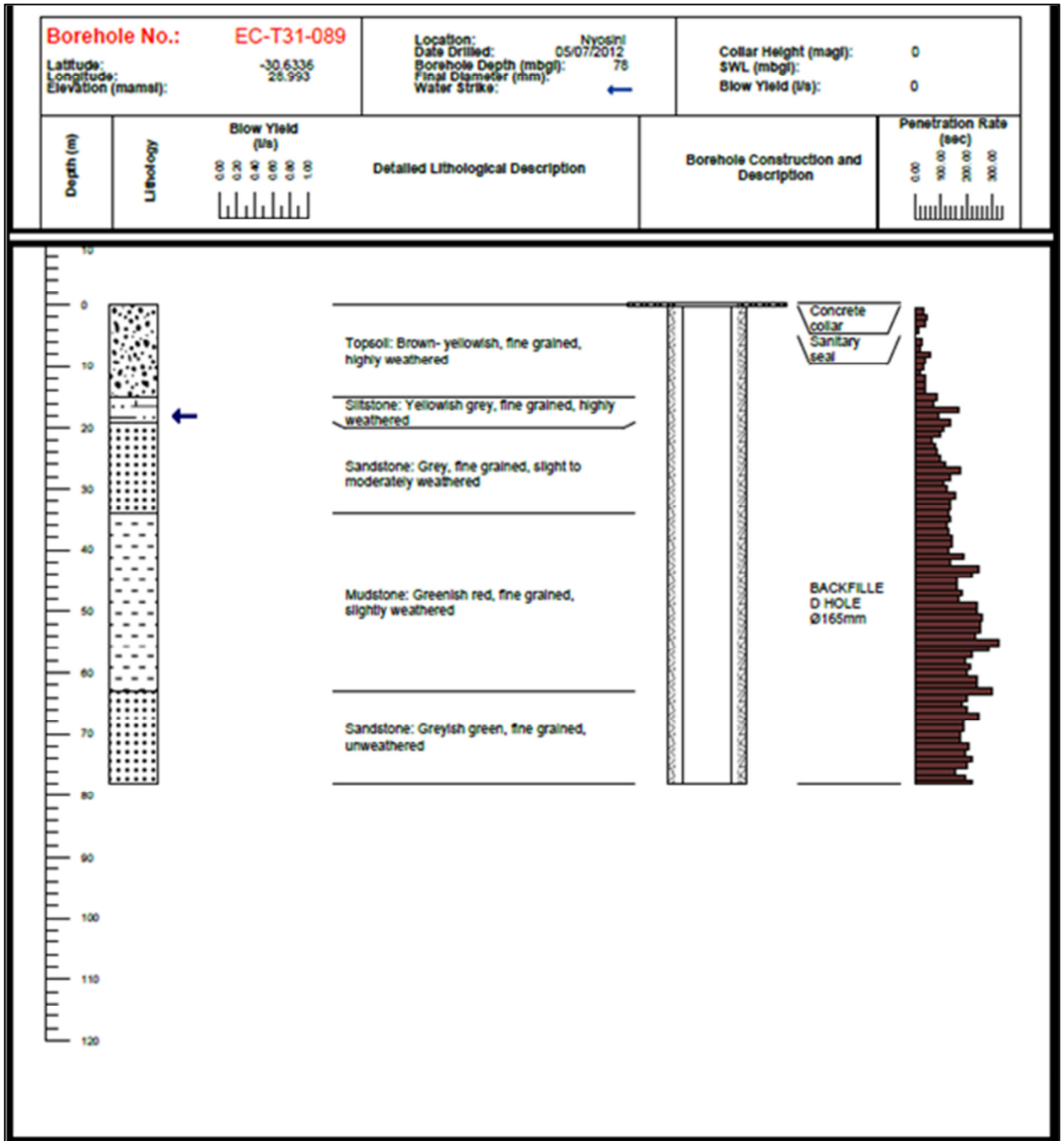


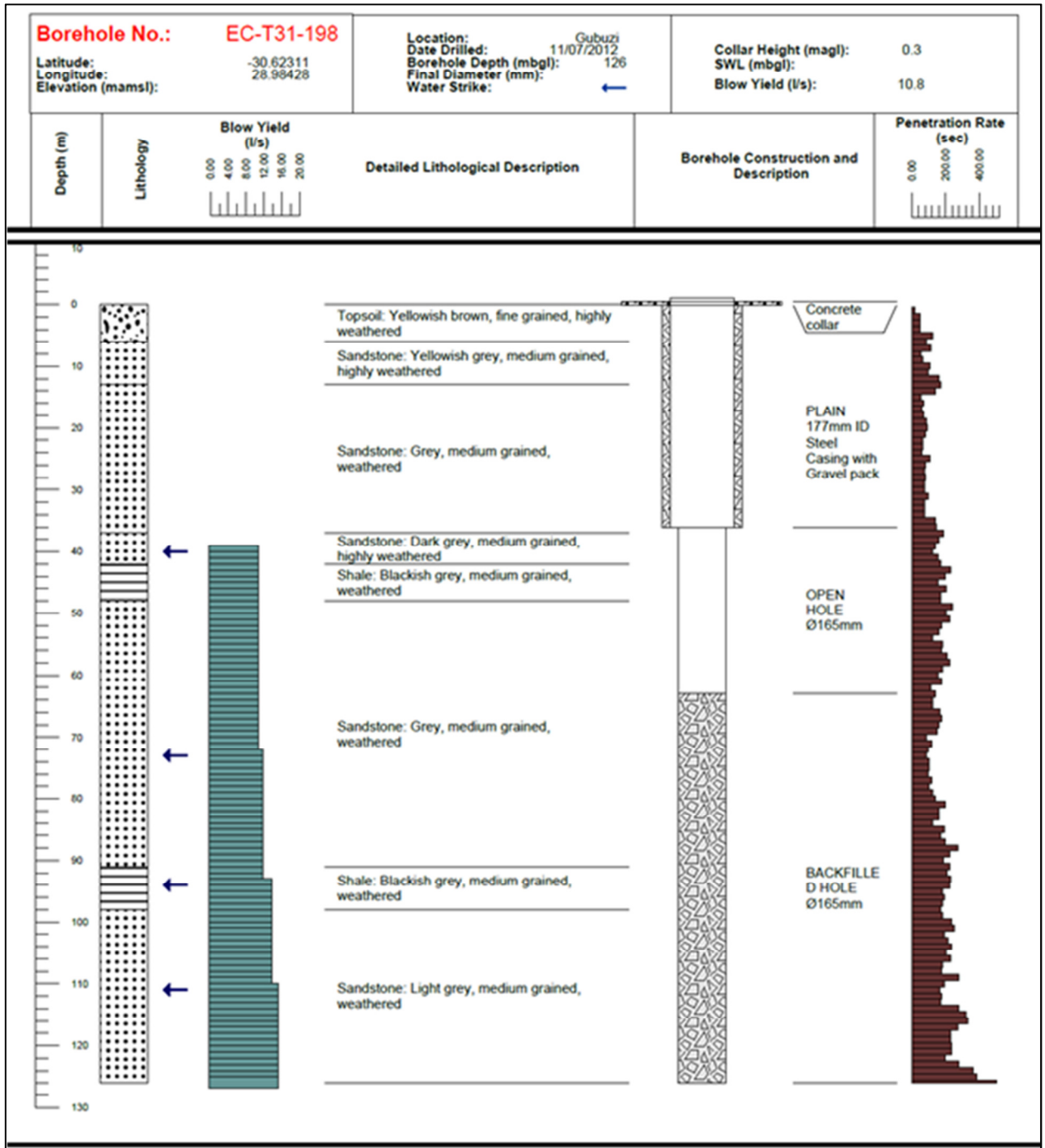


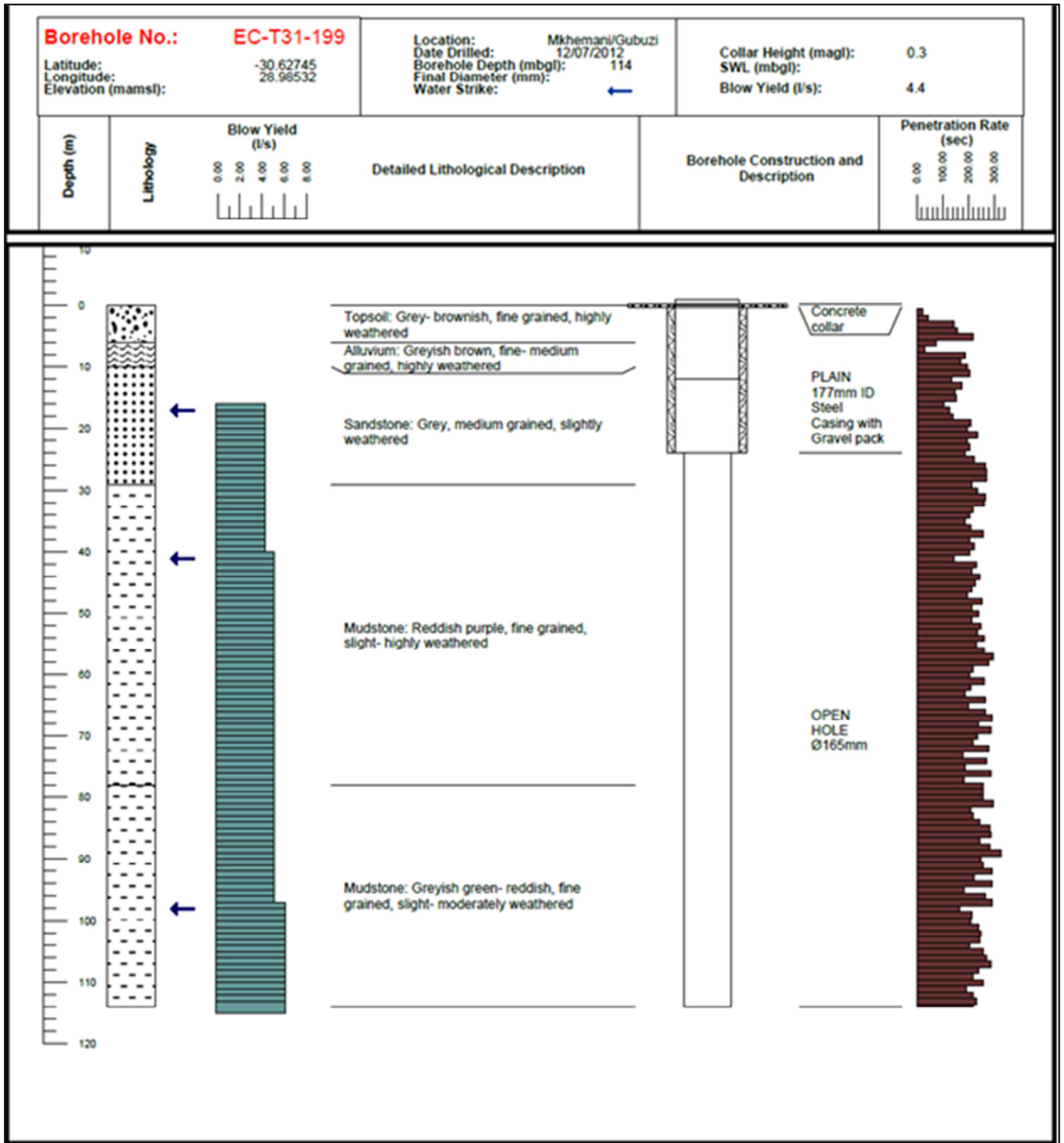


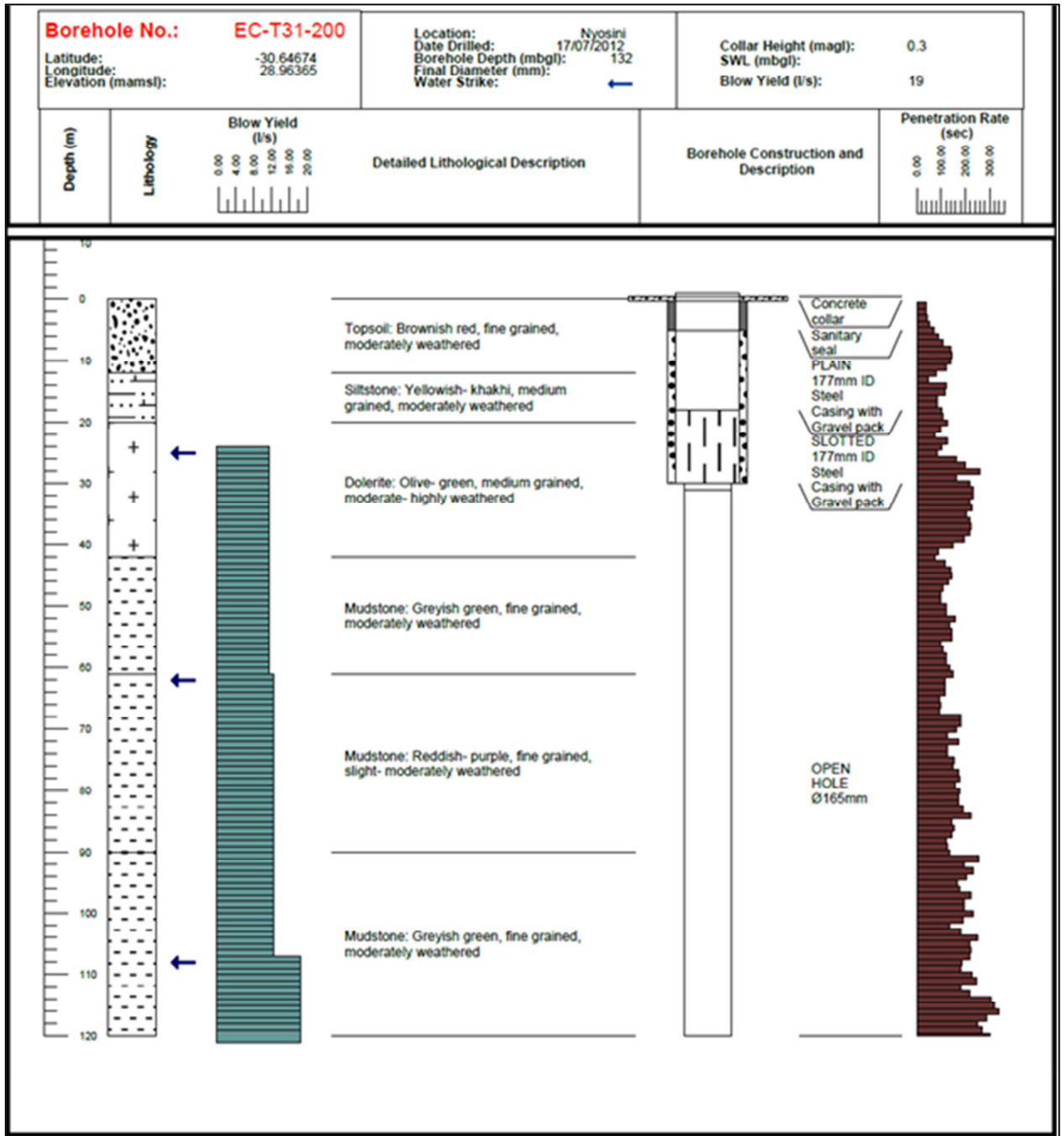


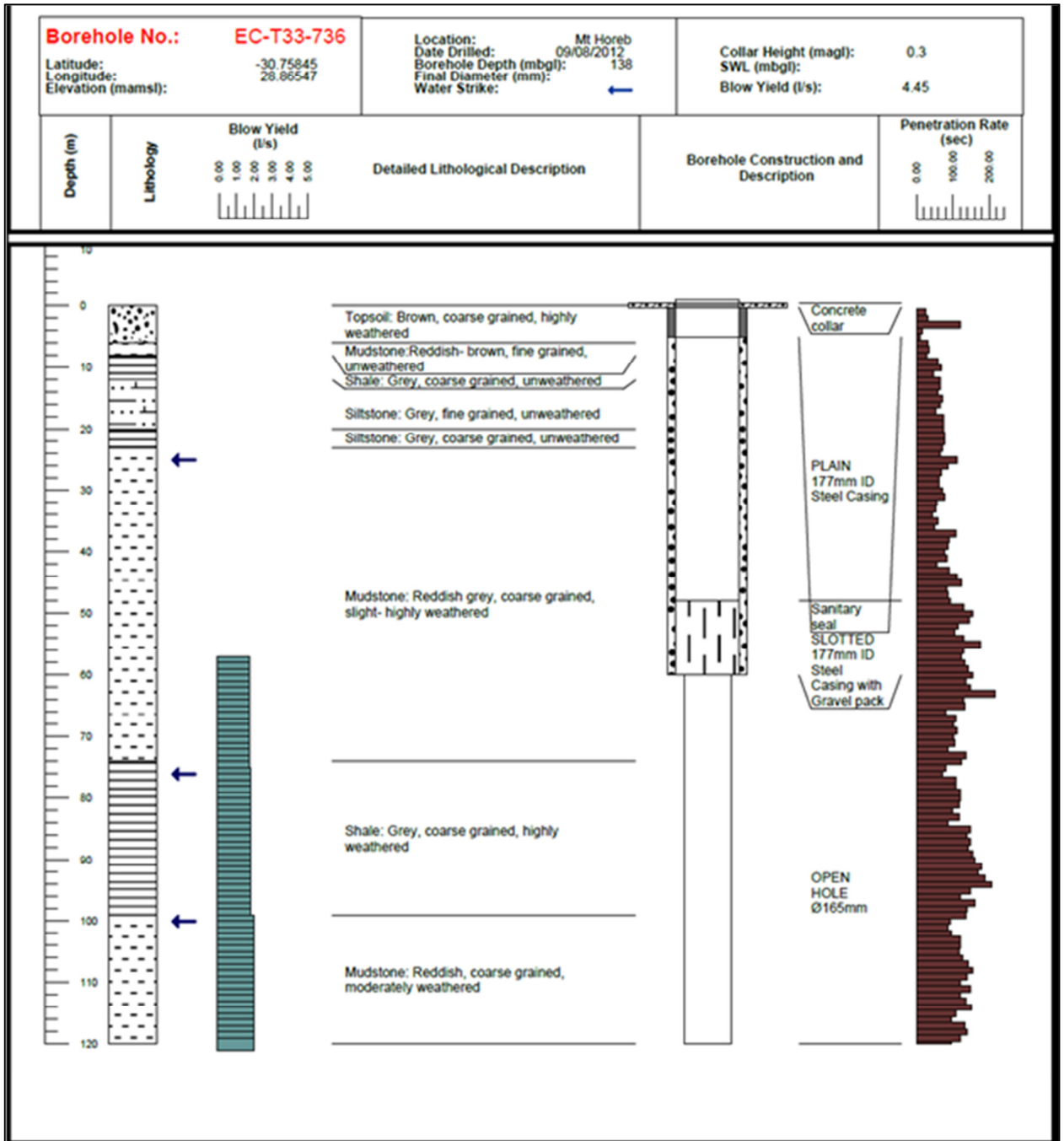


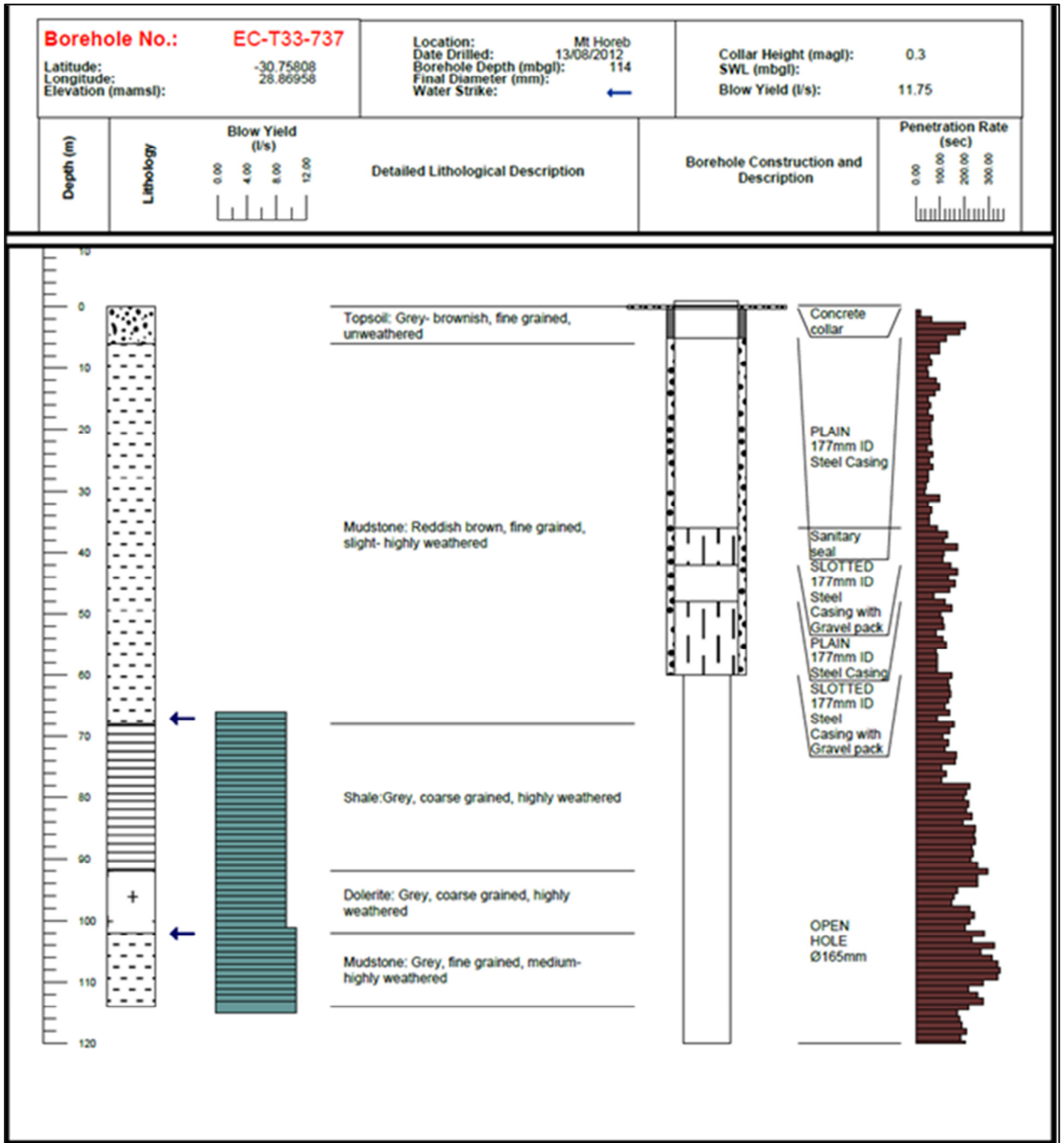


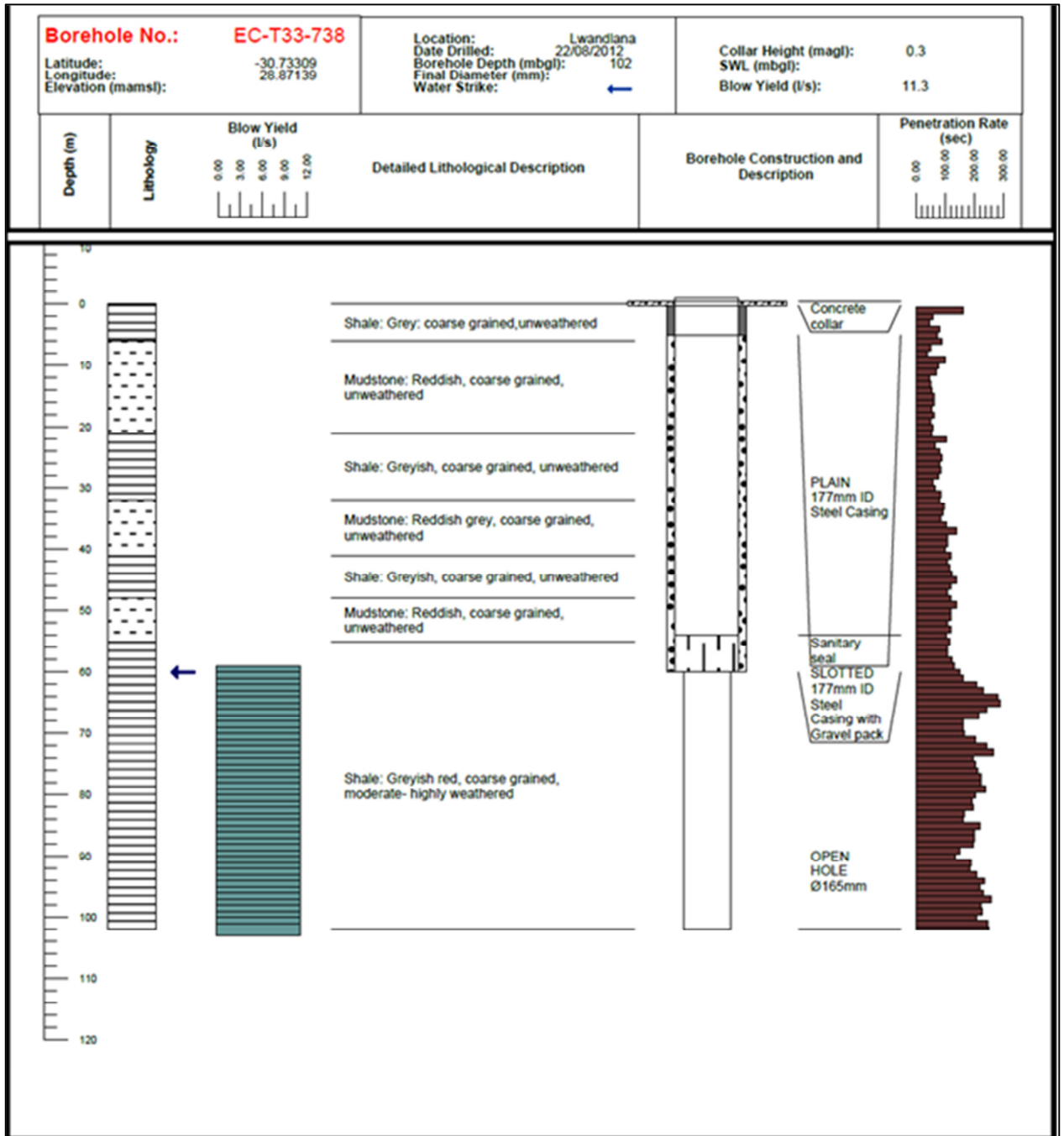


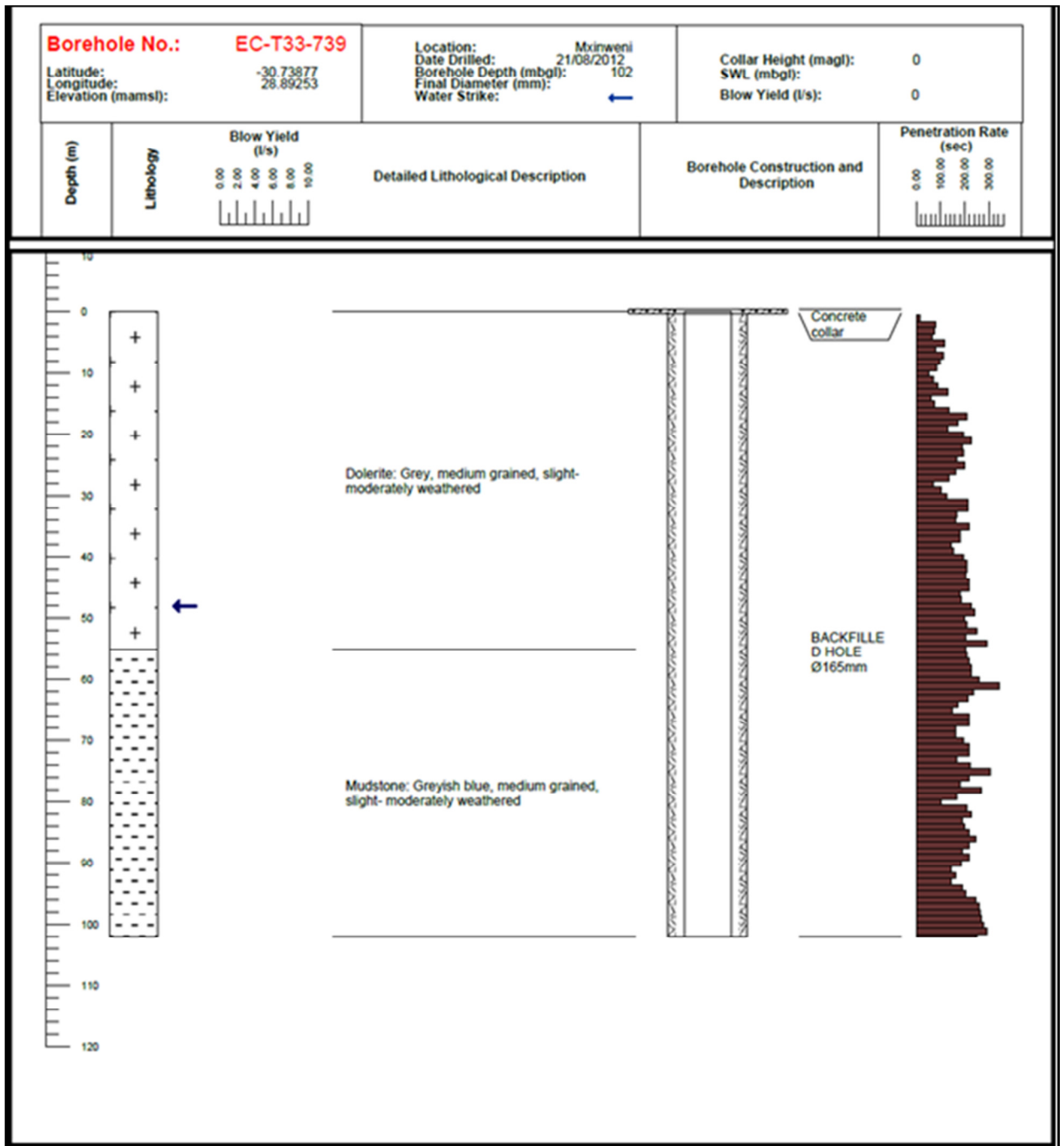




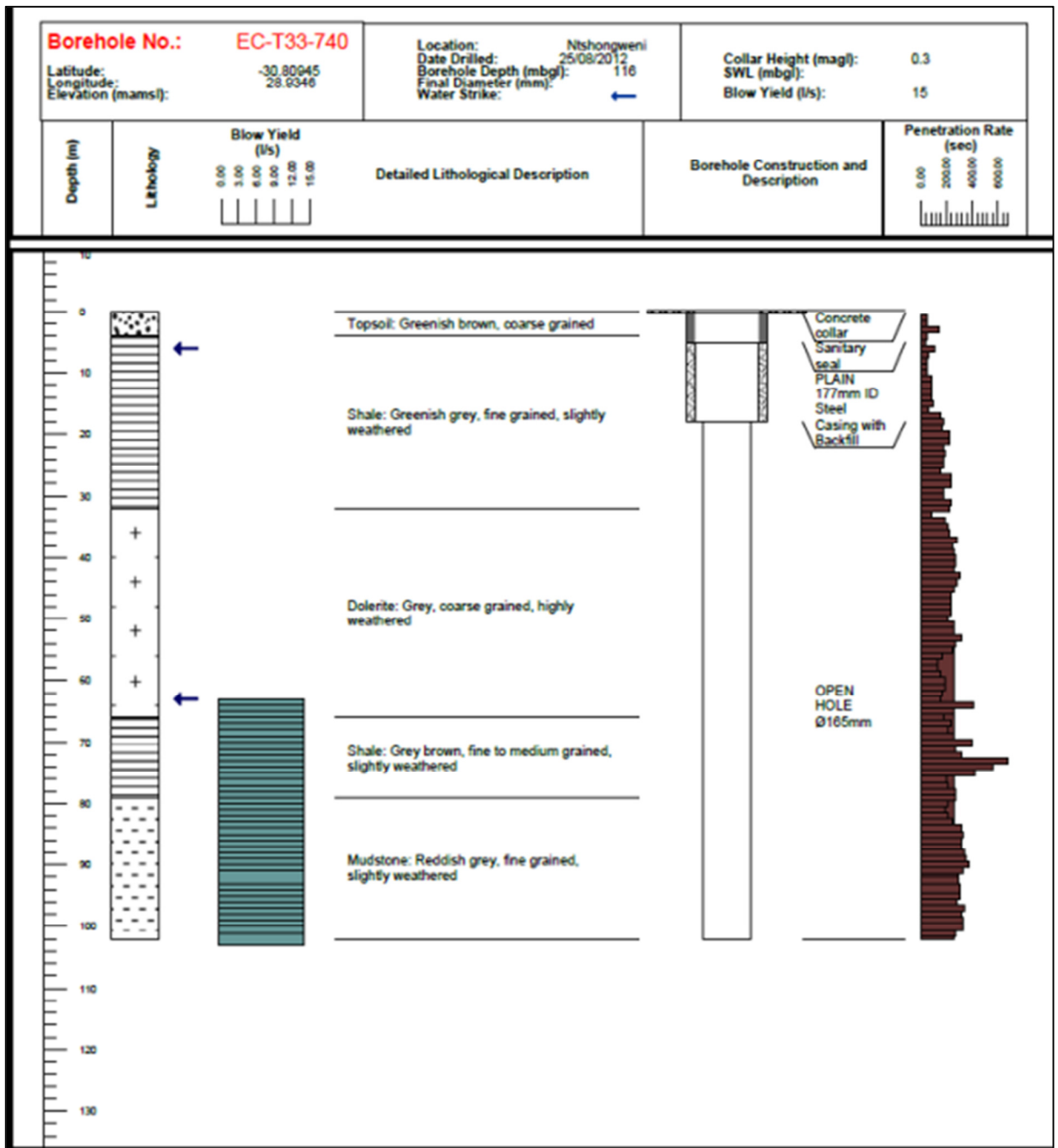


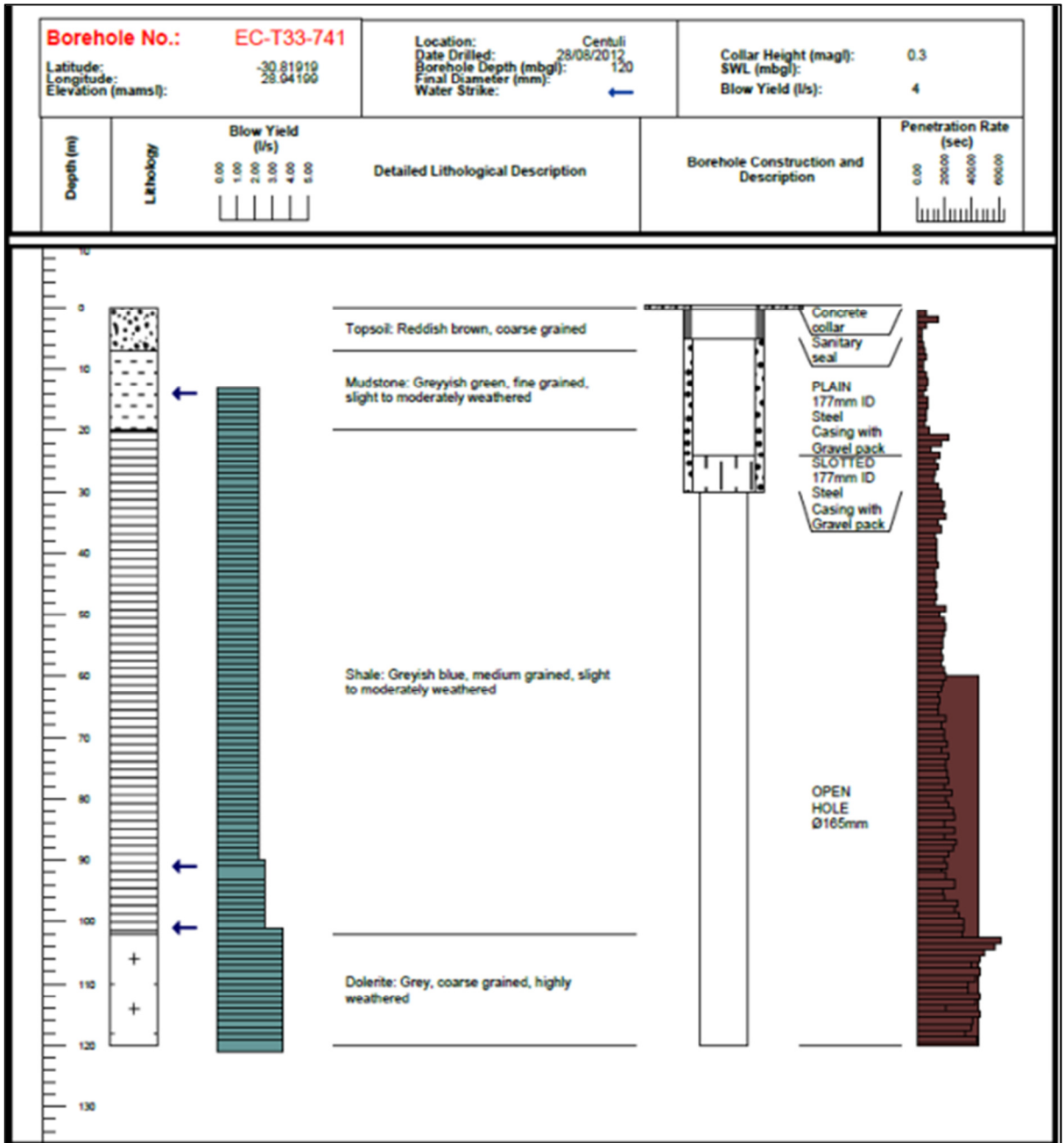


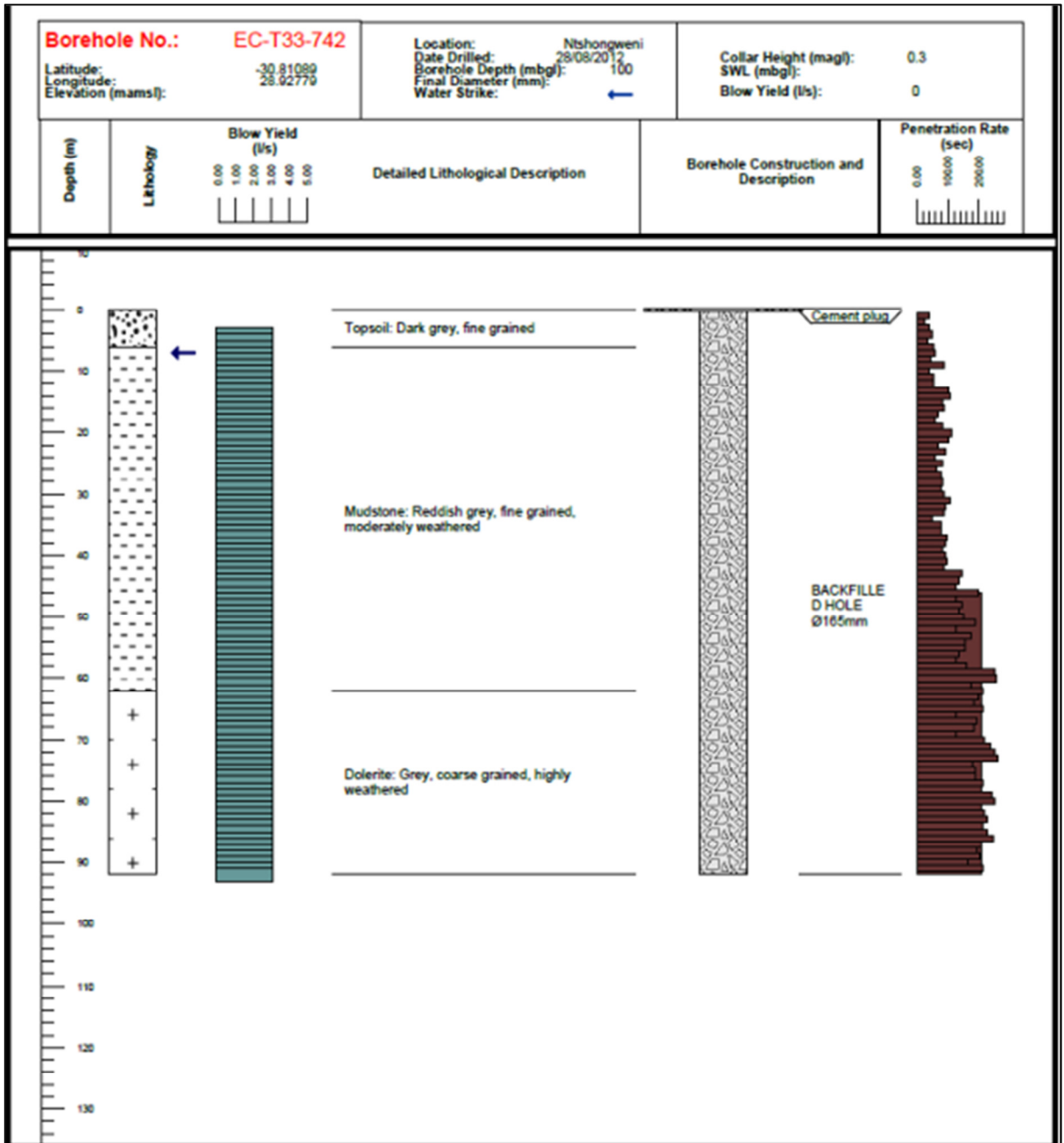


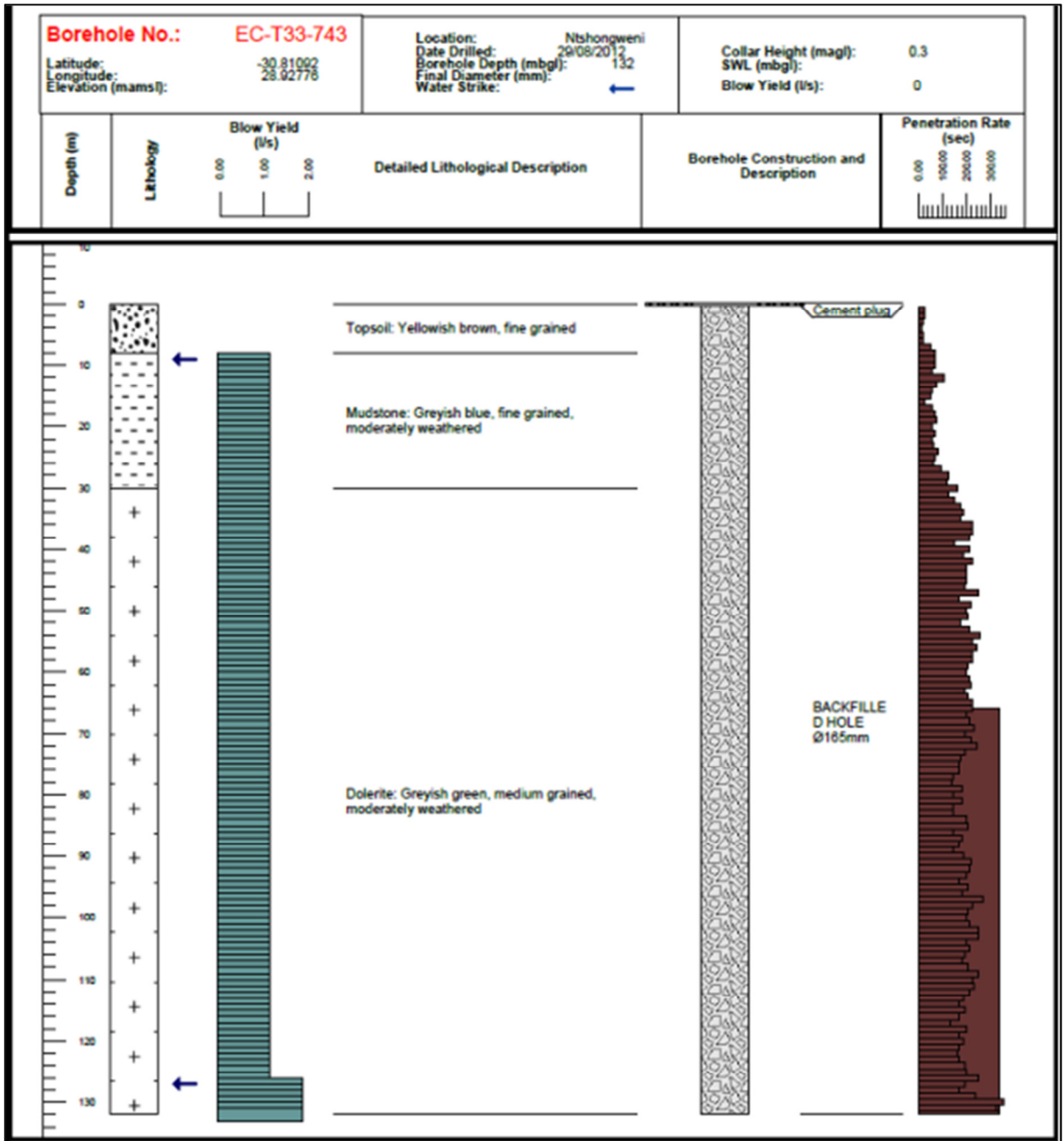


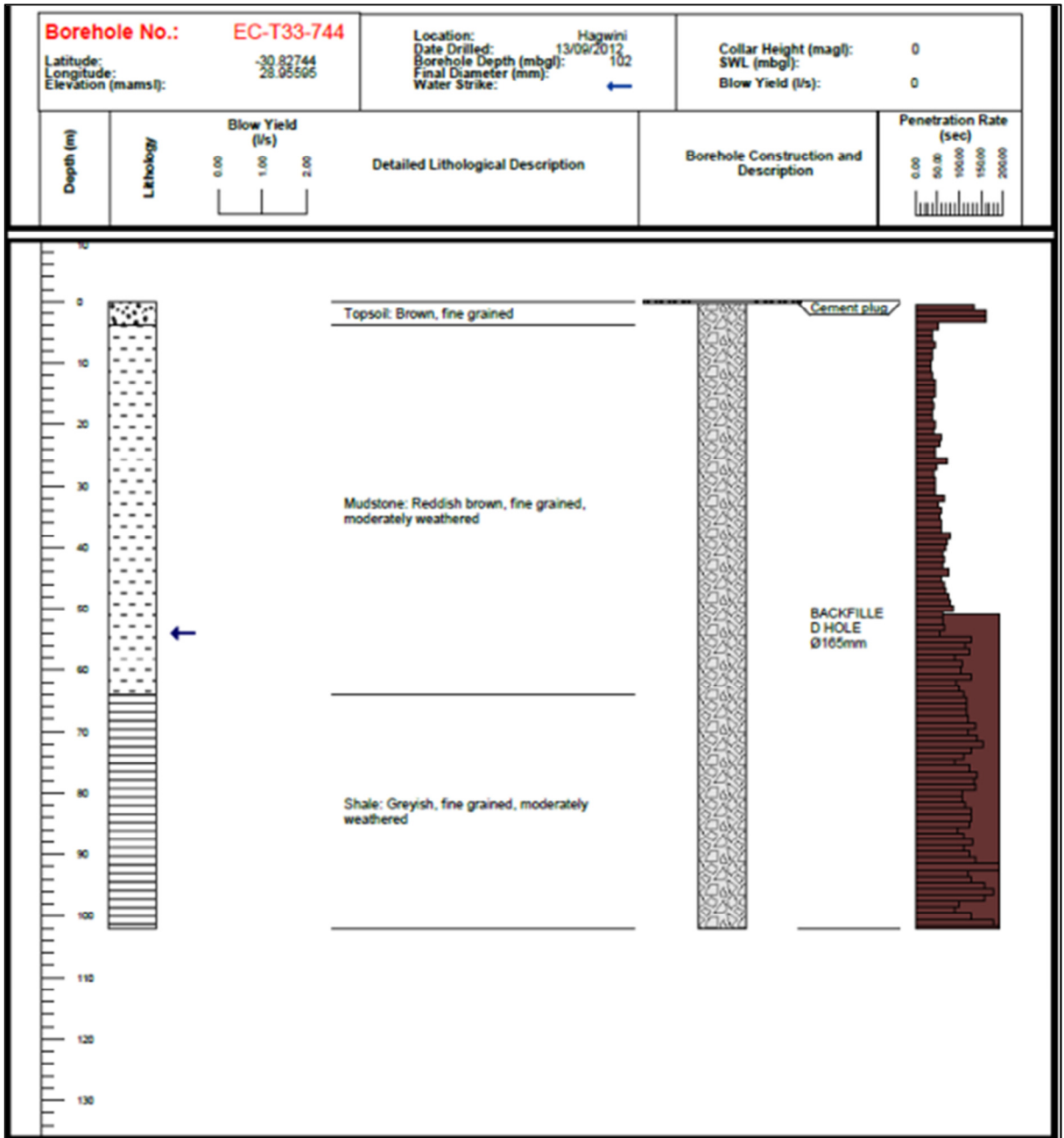
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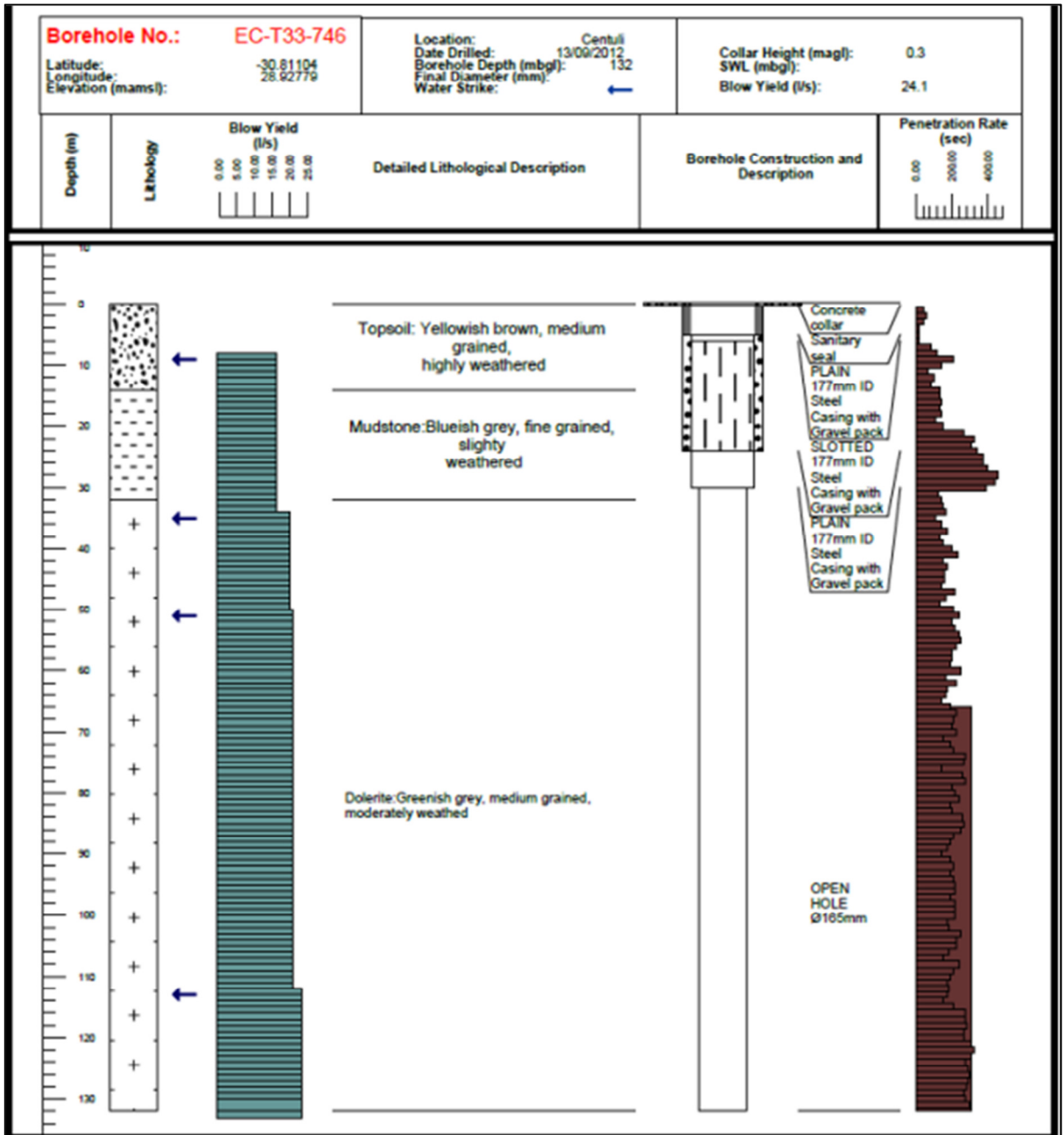


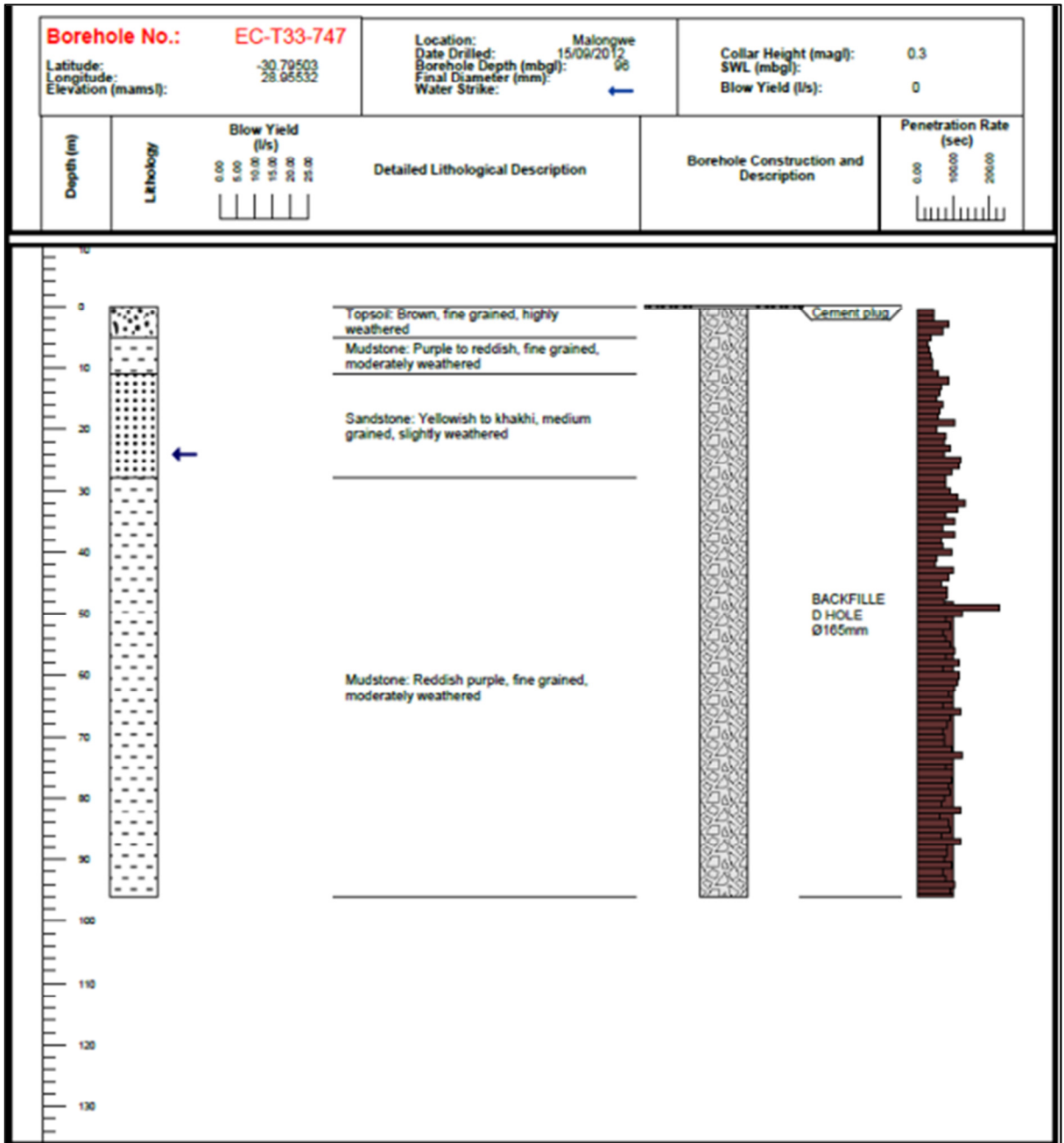


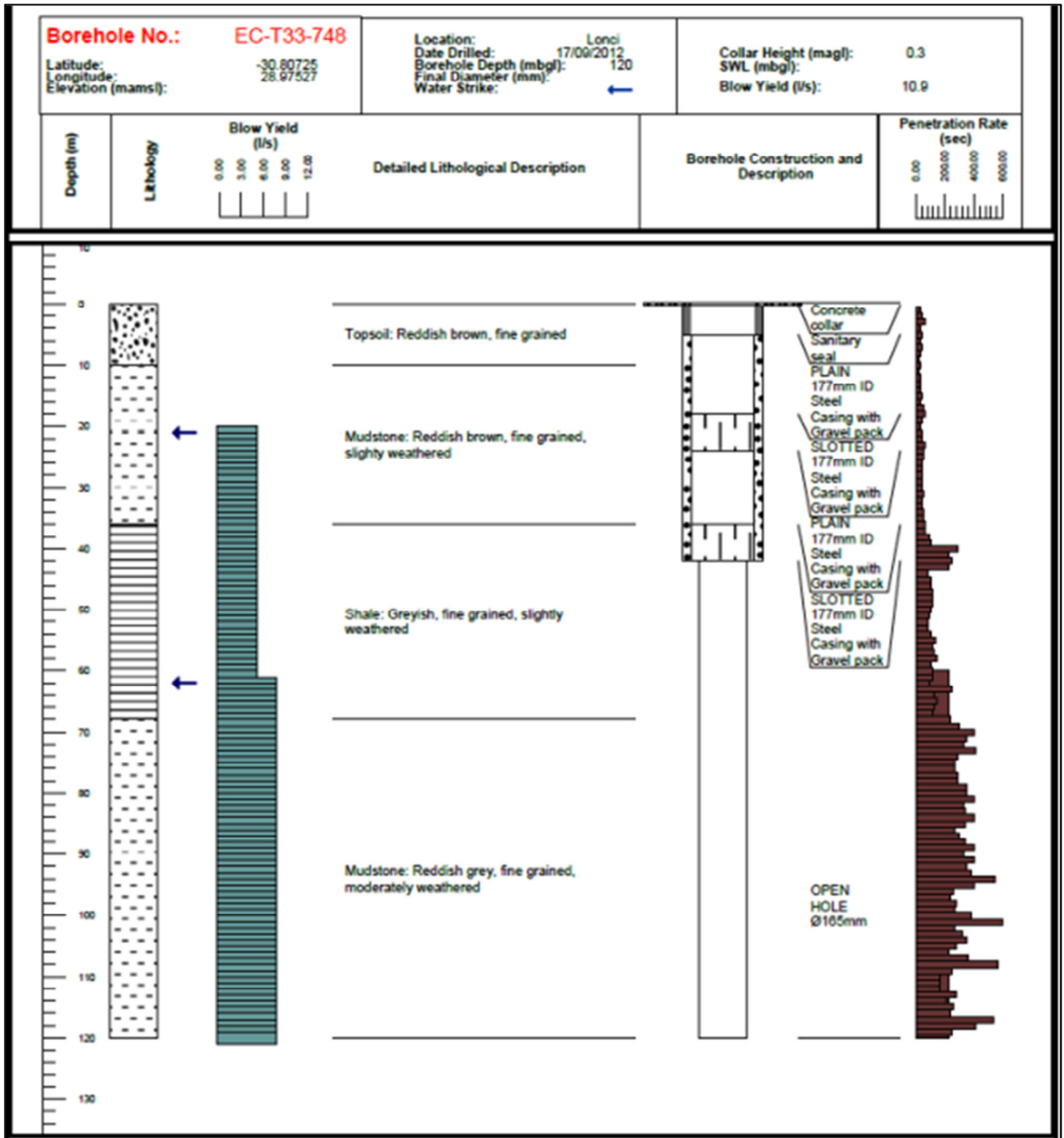


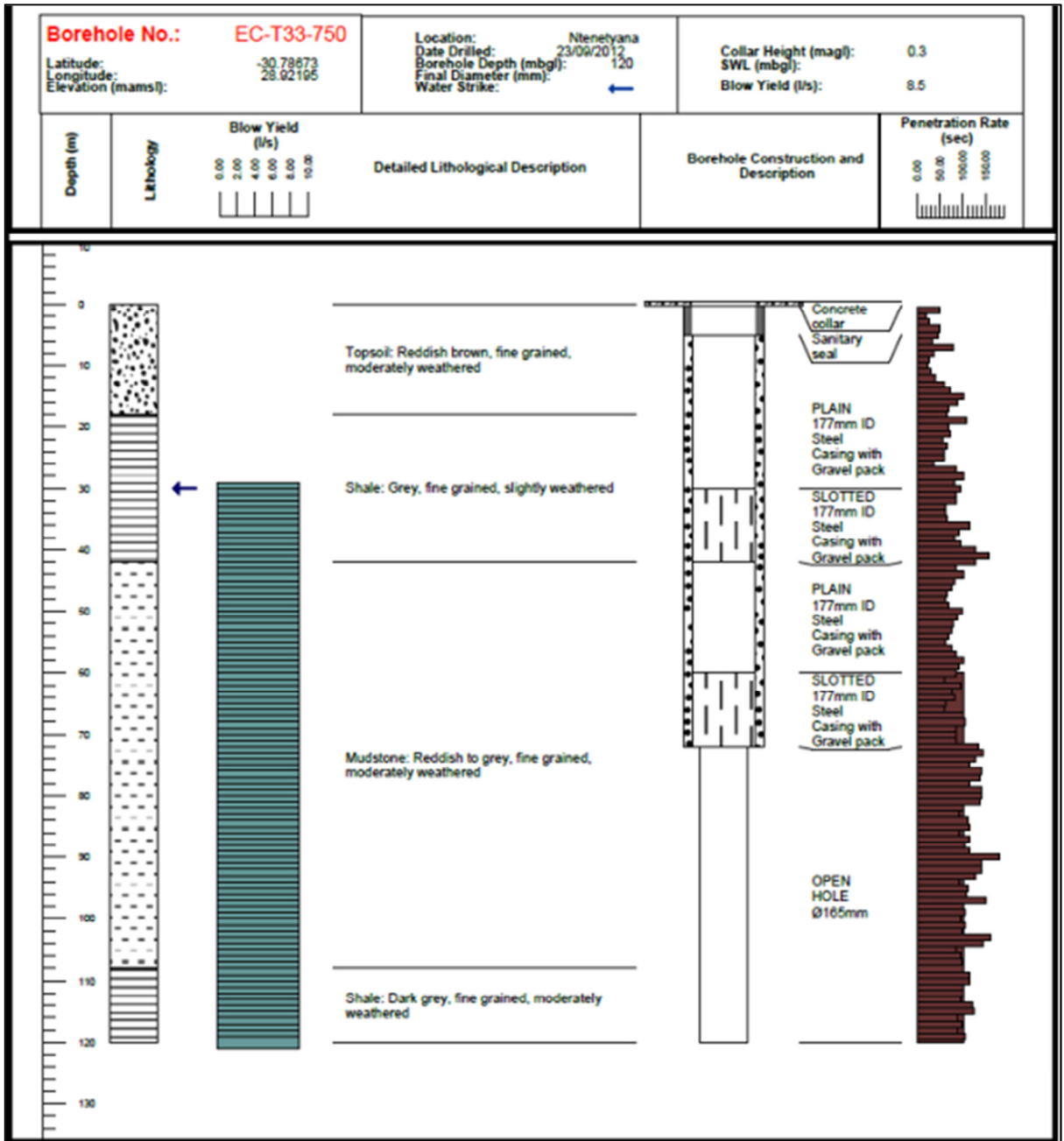


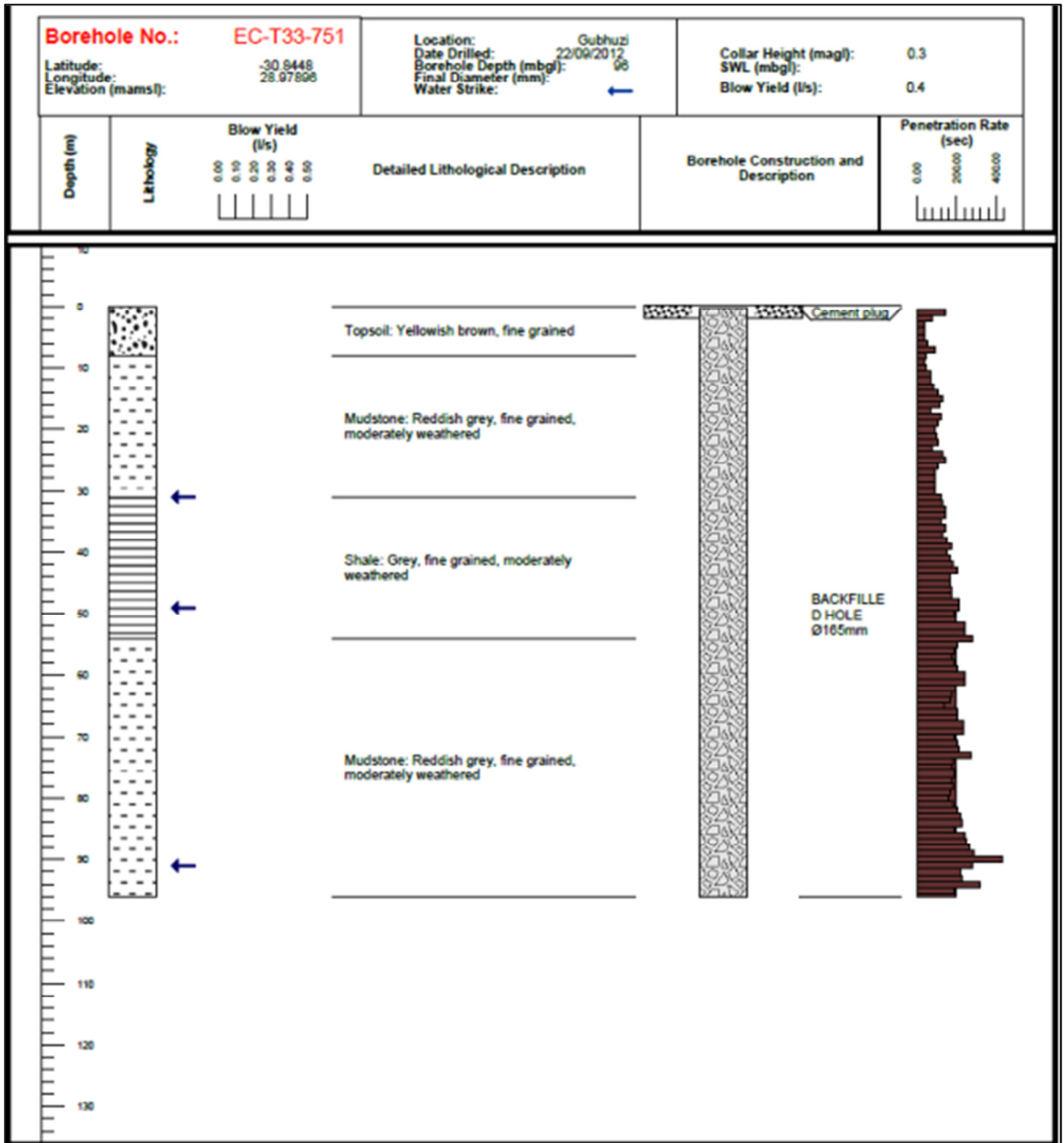


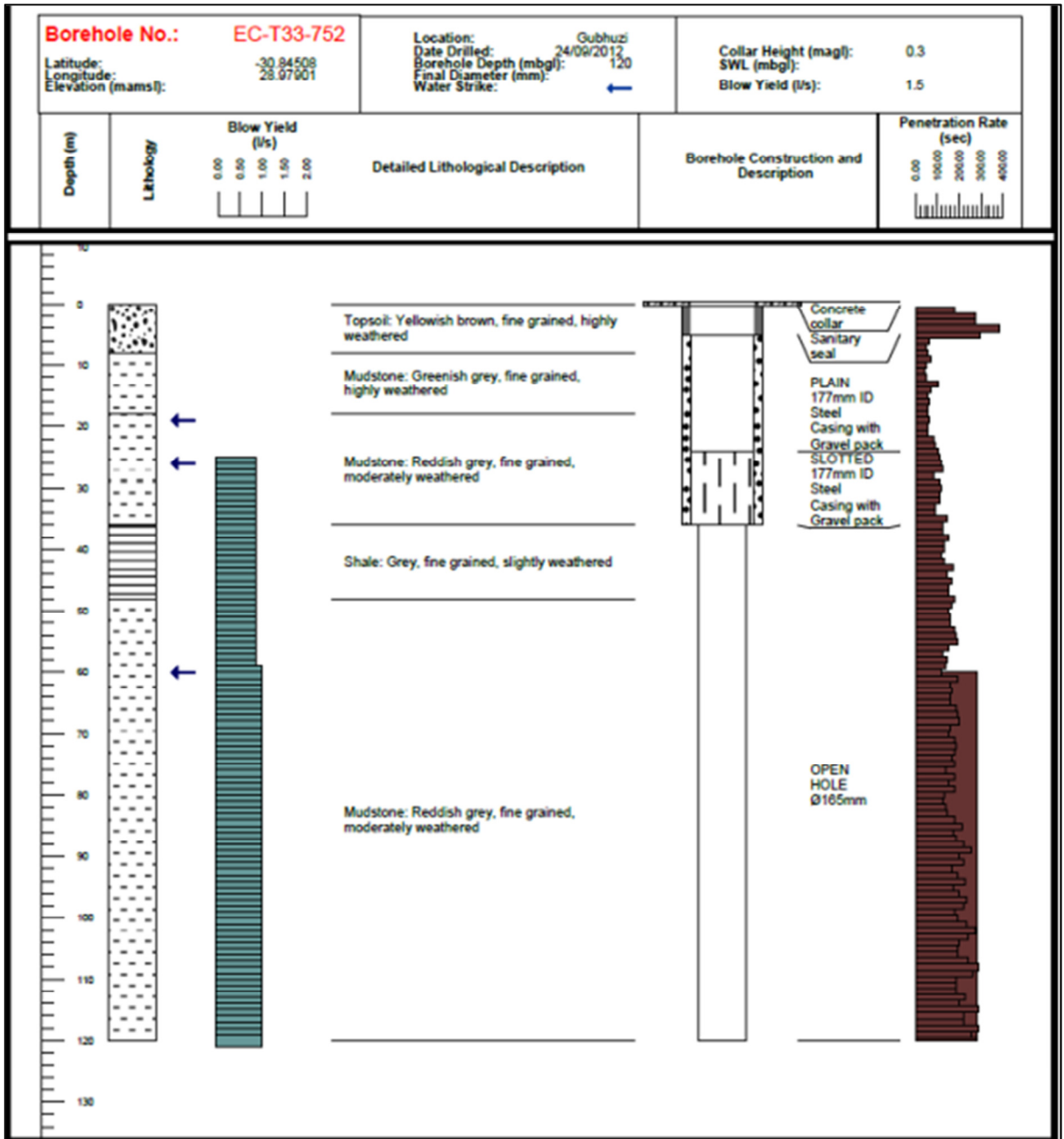


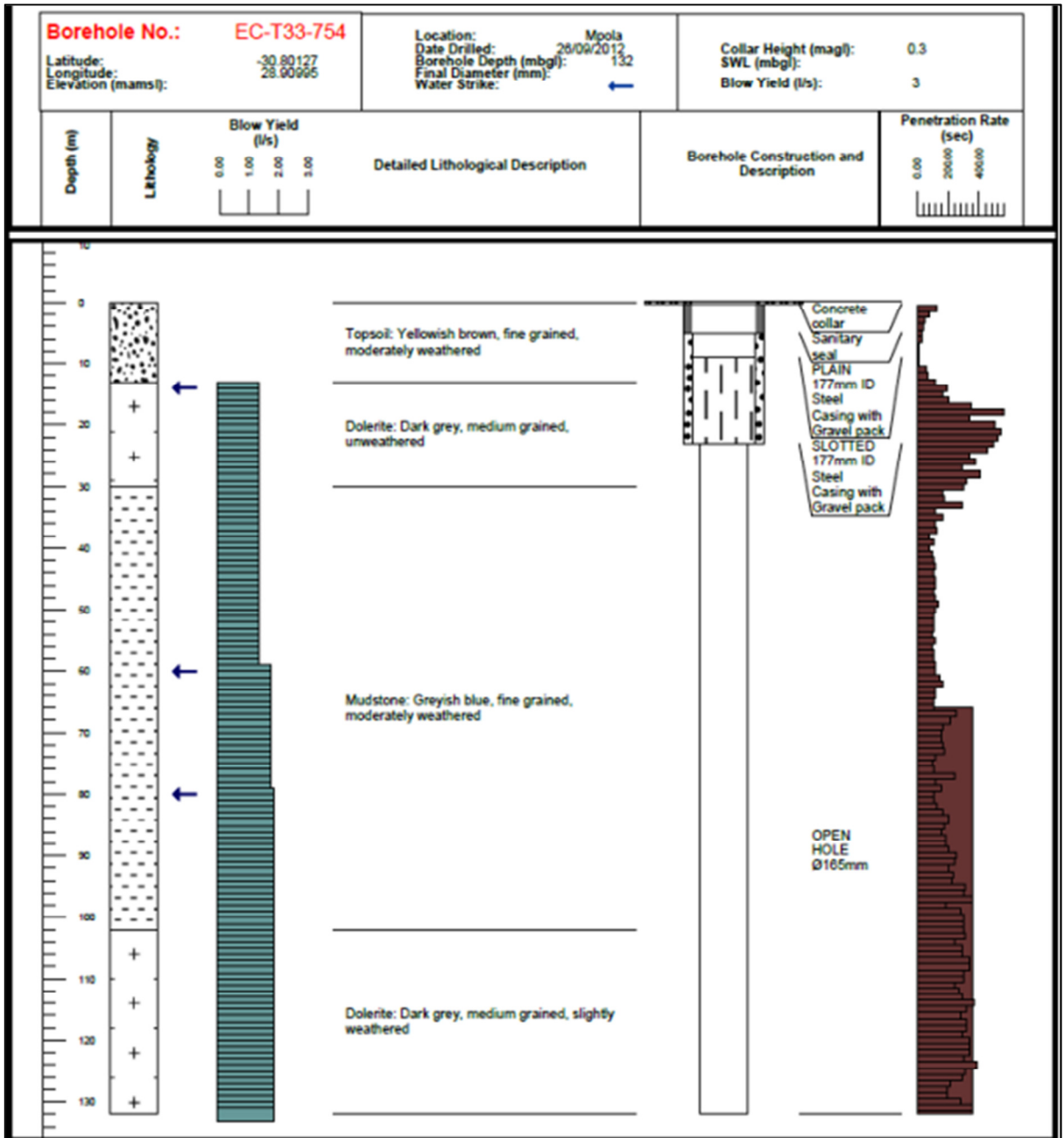


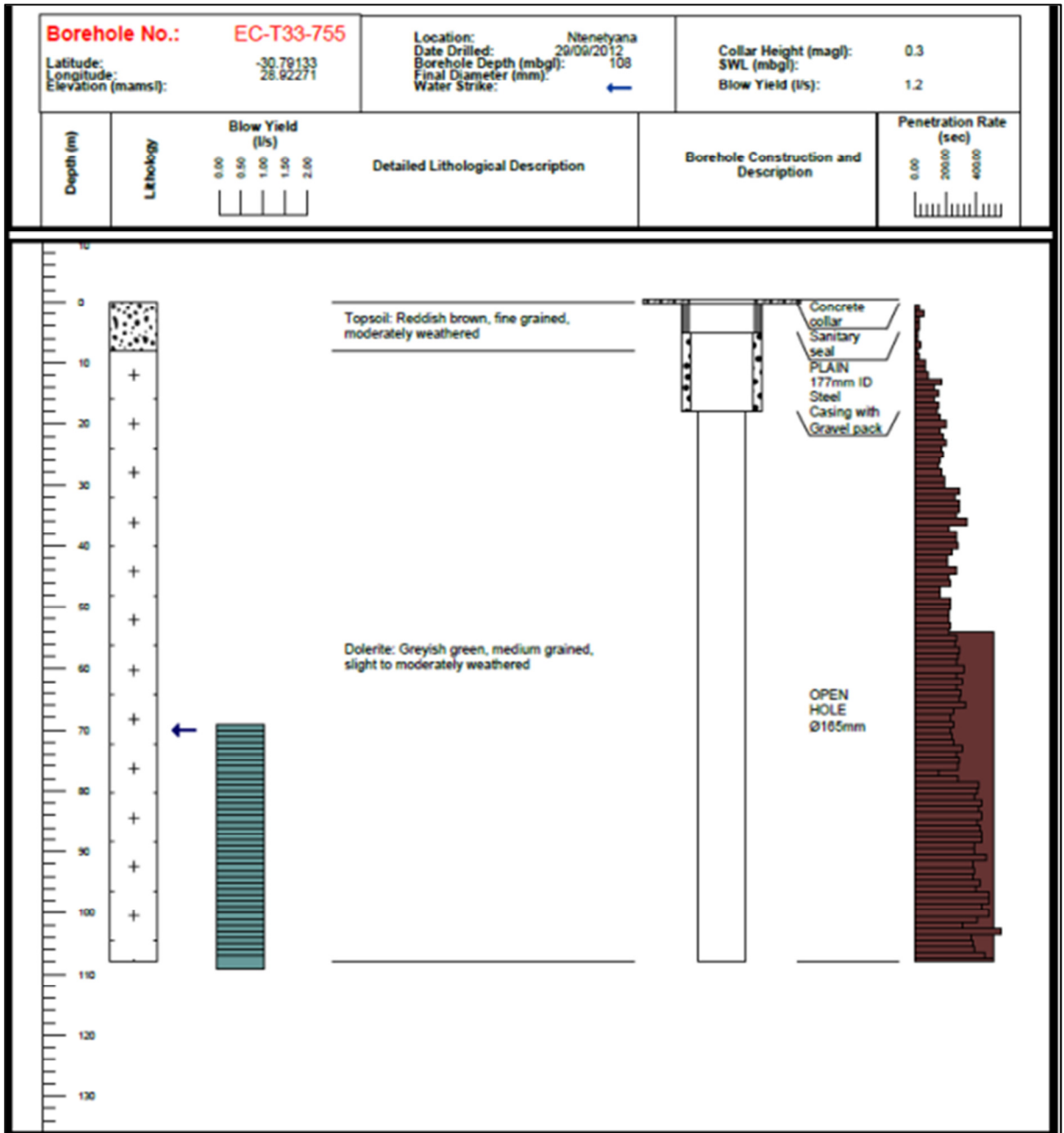


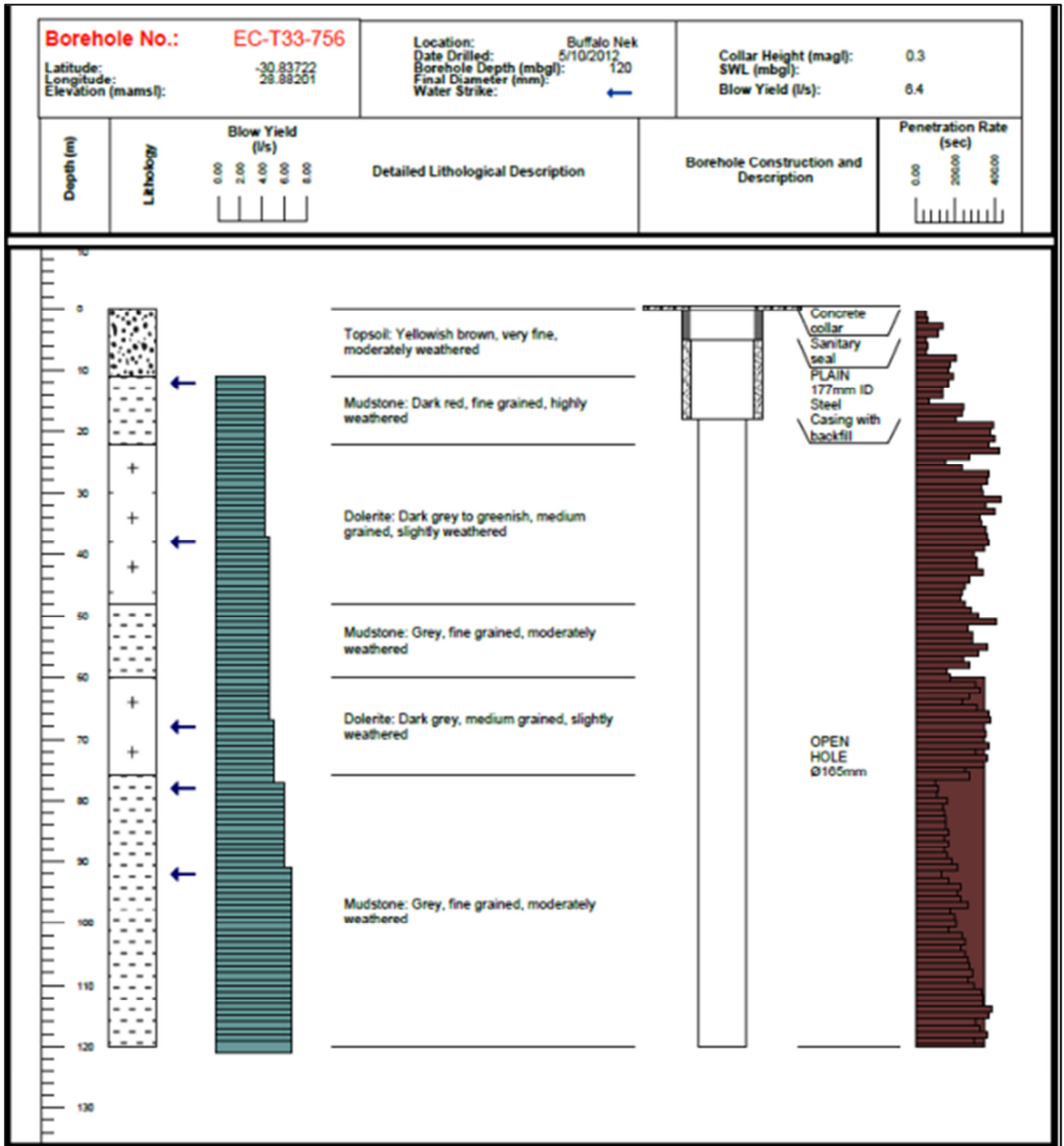


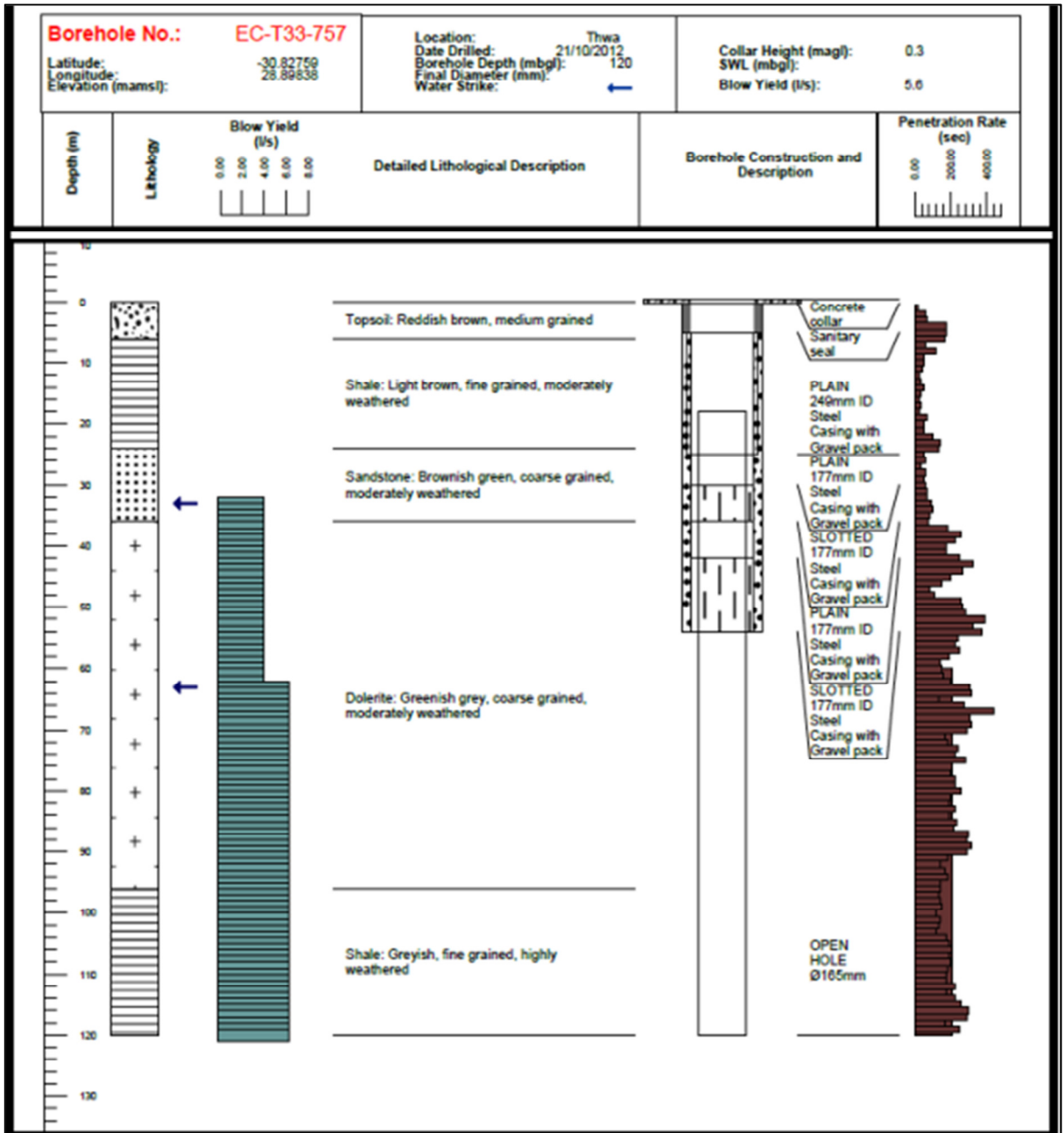


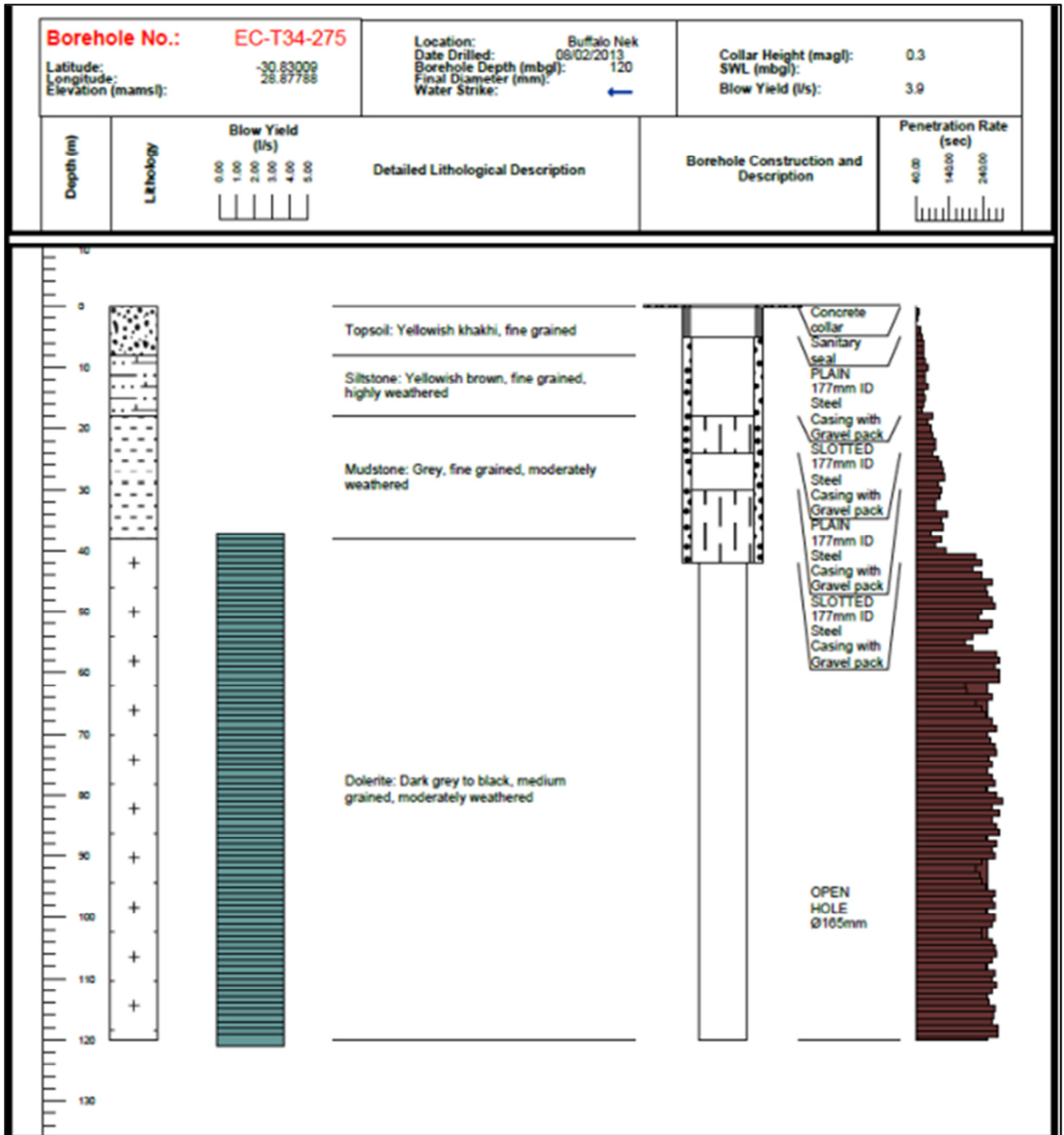


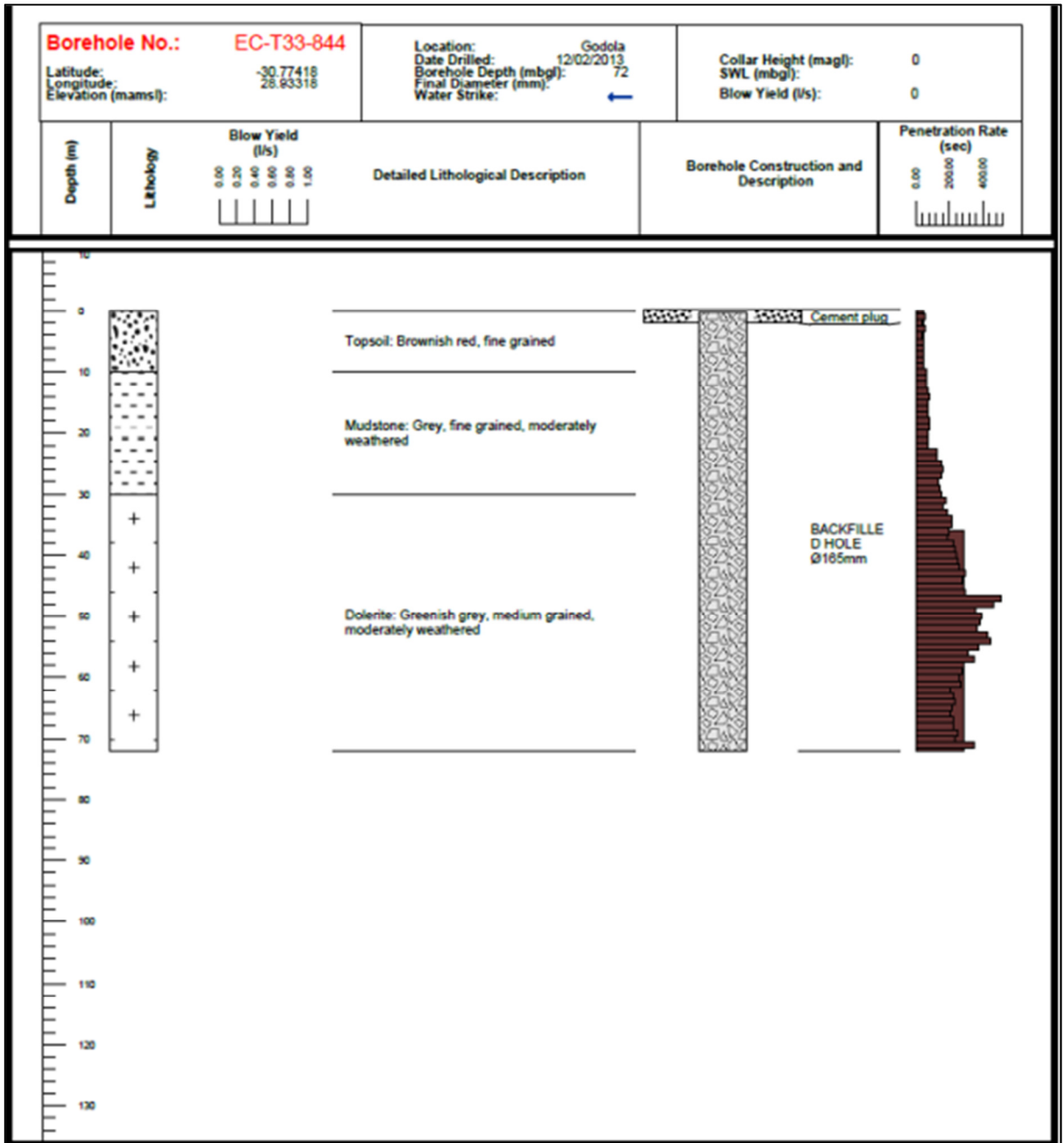


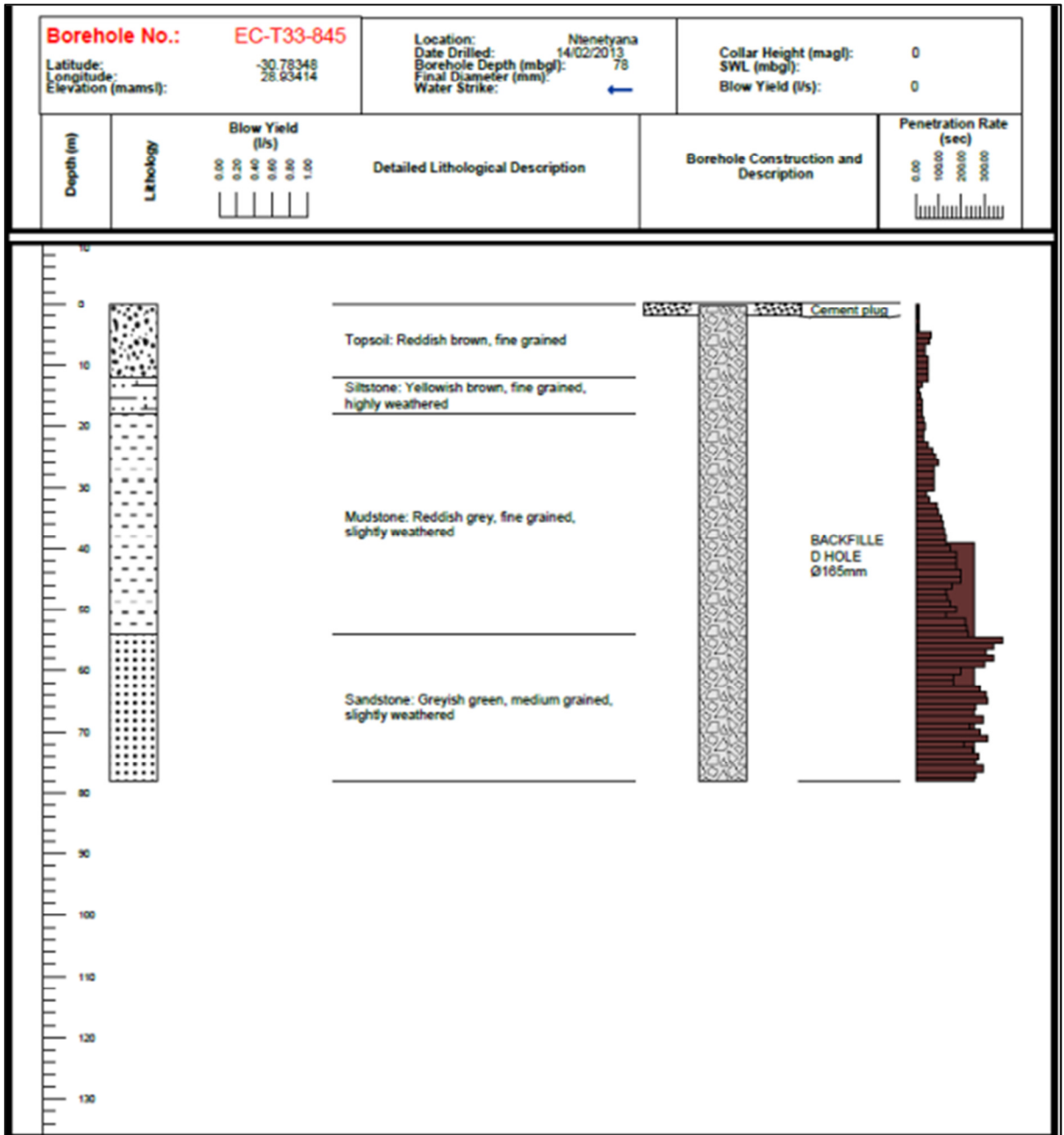


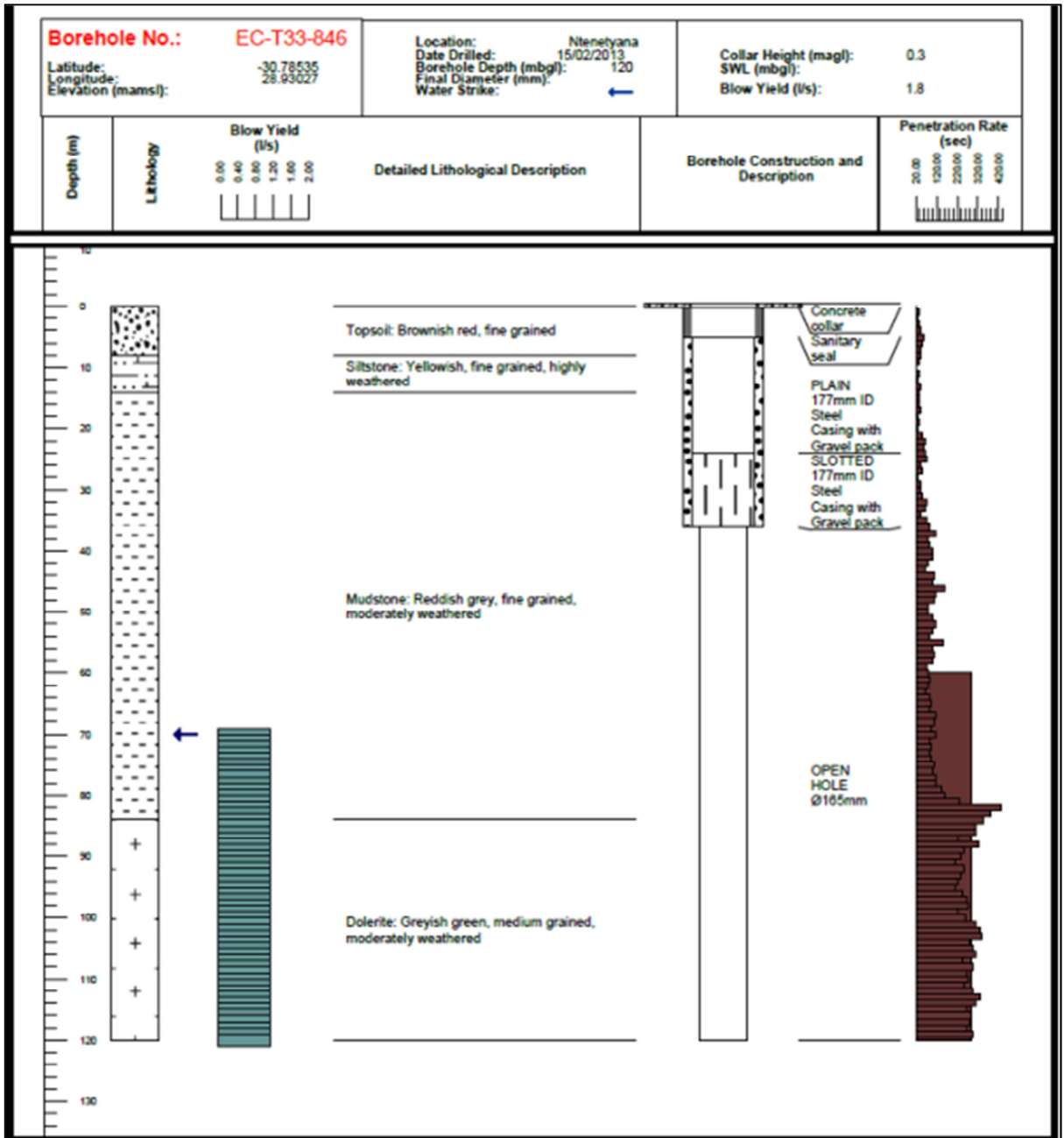


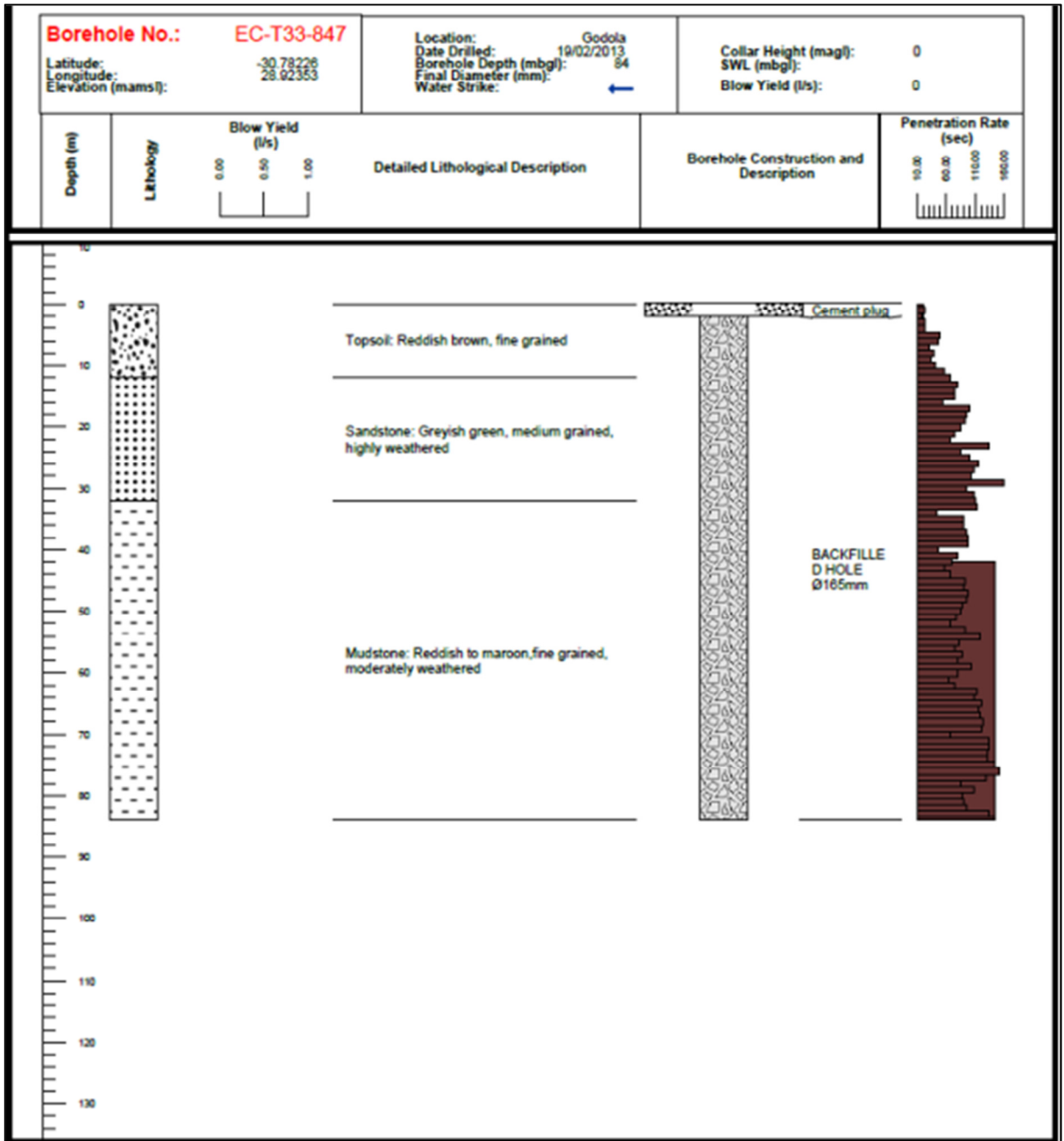




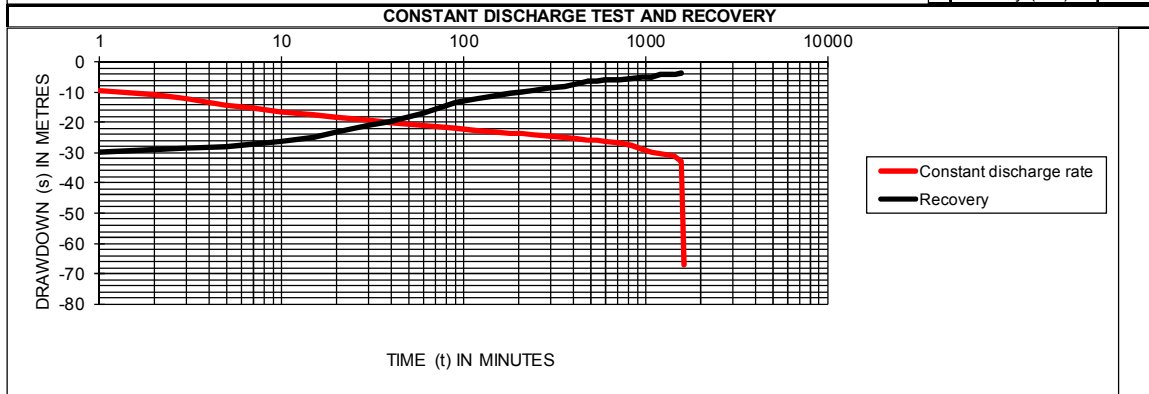
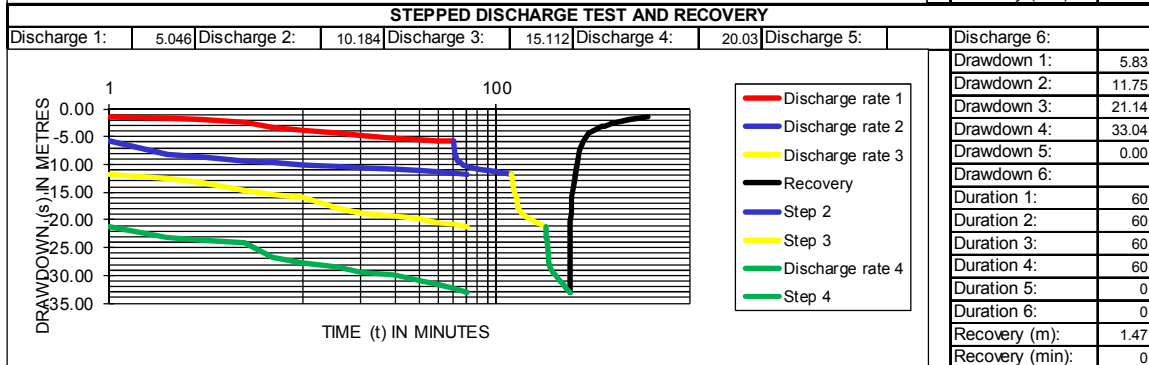
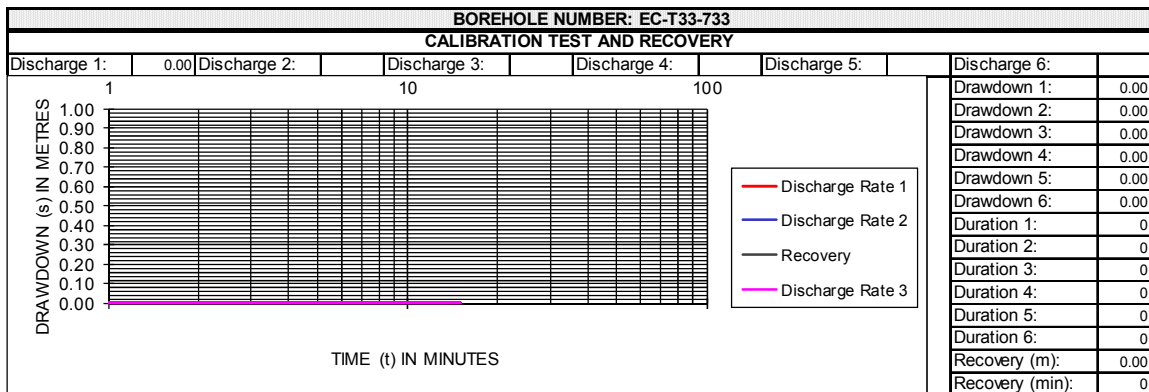




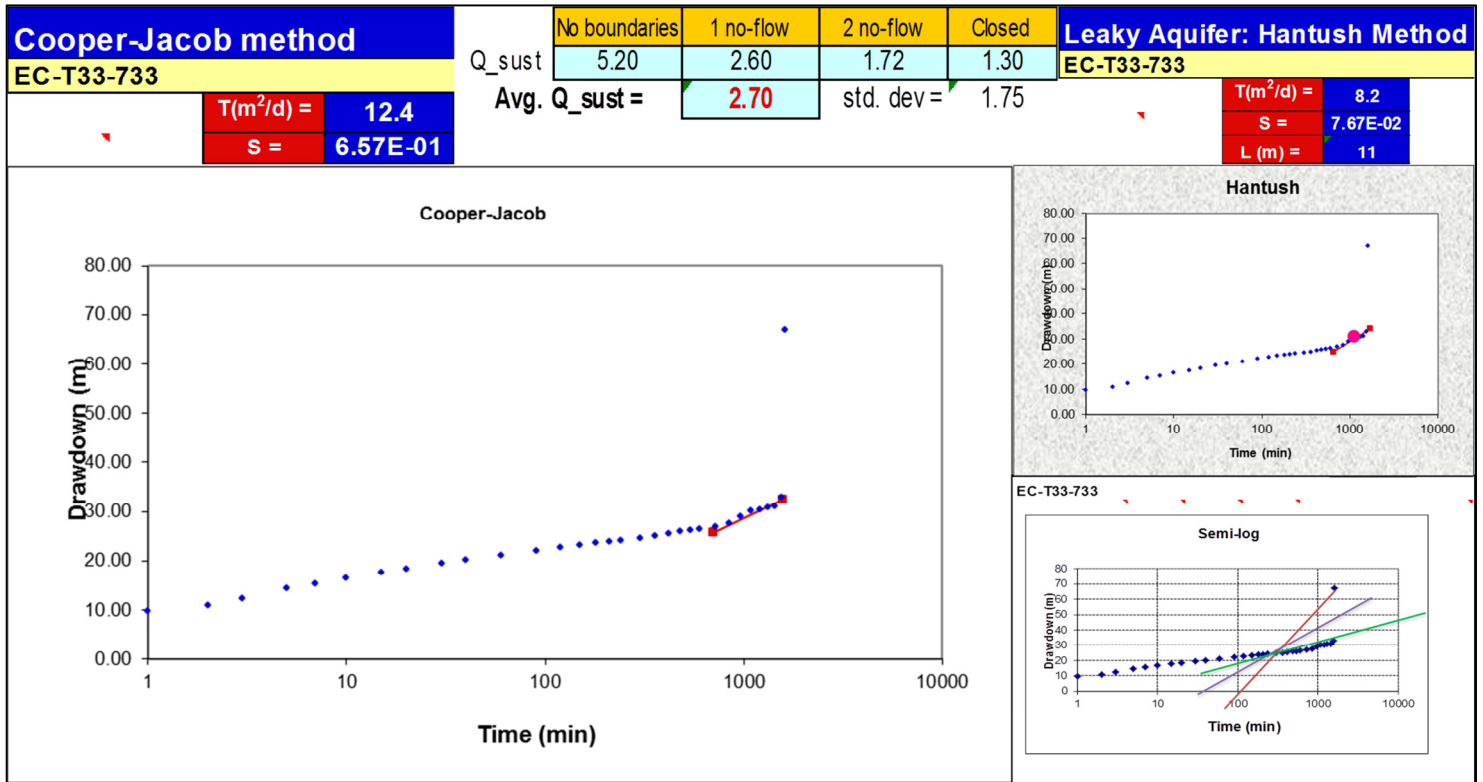




TEST DESCRIPTION	STEP	1	2	3	4	5	6	TOTAL:	RECOVERY:	RECOVERY TEST			
CALIBRATION TEST:								(min) (hrs)	(m) (min)	TIME TOTAL (hrs): 32.00			
TEST DURATION (Minutes)								0 0.00	0.00	Cal	Steps	CD Total	
TEST YIELD (l/s)								MAXIMUM (l/s)	0.0	360	1560	1920	
DRAWDOWN (m)								MAXIMUM (m)		DRAWDOWN TOTALS (CD):			
MULTI-RATE / STEP DRAWDOWN:										AVAILABLE	UTIL-	%	
TEST DURATION (Minutes)	60	60	60	60				240 4.00	1.47	ISED			
TEST YIELD (l/s)	5.05	10.18	15.11	20.03				MAXIMUM (l/s)	20.0	72.4	67.00	92.57	
DRAWDOWN (m)	5.8	11.75	21.14	33.04				MAXIMUM (m)	33.0				
CONSTANT DISCHARGE TEST		TEST DURATION		TEST YIELD		DRAWDOWN		RECOVERY:					
	(min)	(hrs)	(l/s)	(m)	(m)	%	(min)	(hrs)					
	1621	27.02	14.97	67.00	3.74	94.42	1560	26.00					
OBSERVATION BOREHOLES:		No. of boreholes		720		1440		2880		>2880 (min)		TOTAL:	
			(min)	(min)	(min)	nr.	Time	(min)	(hrs)				
								0	0.00				



TEST INFORMATION					
Date tested	13-Jul-12	Water level (mbgl)	17.62	Depth of pump (mbgl)	90
CD duration	1621	CD discharge rate	14.97	CD drawdown	67
Available drawdown (m)	72.38	% Recovery after CD	94	% after	1560 min

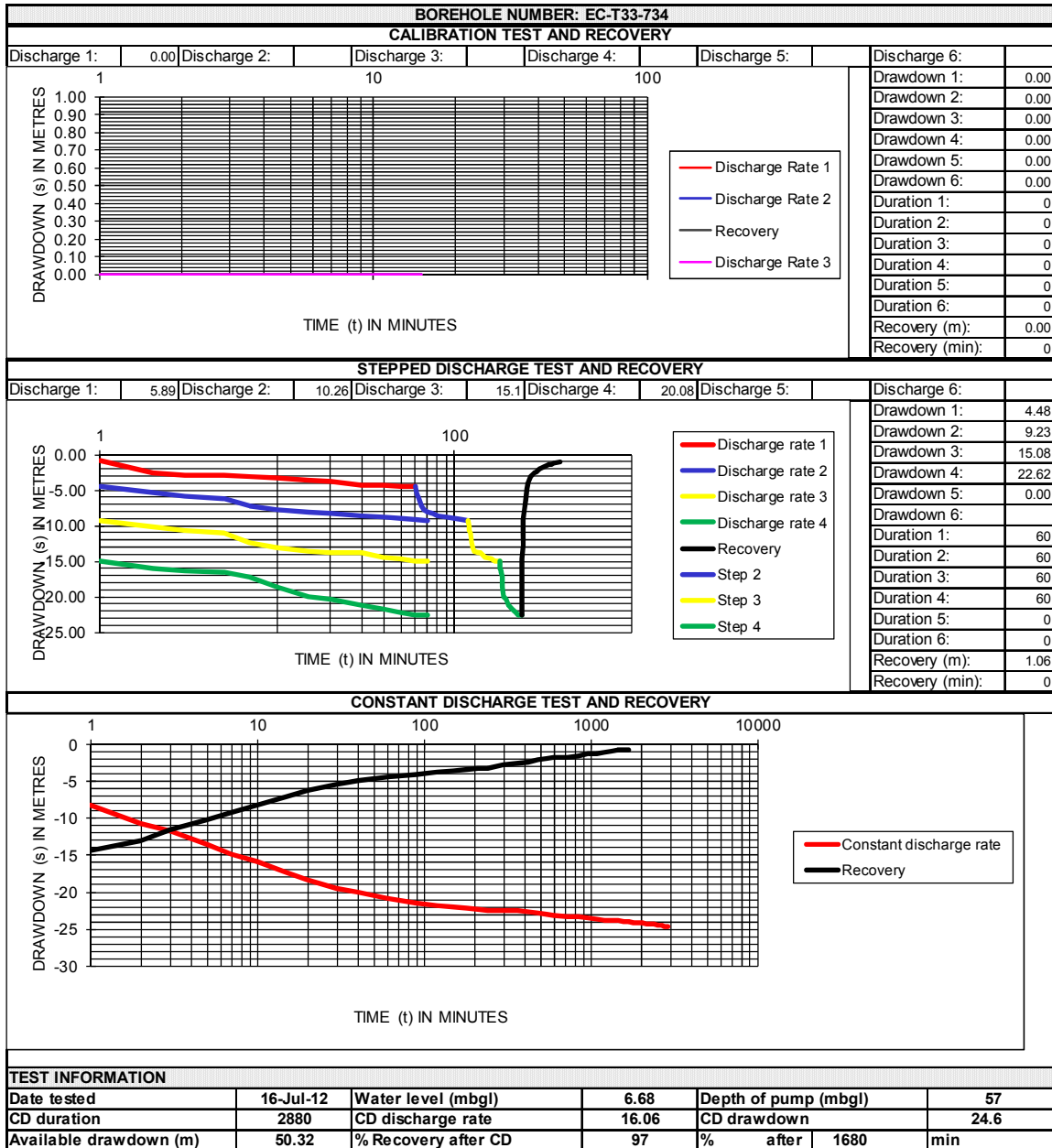


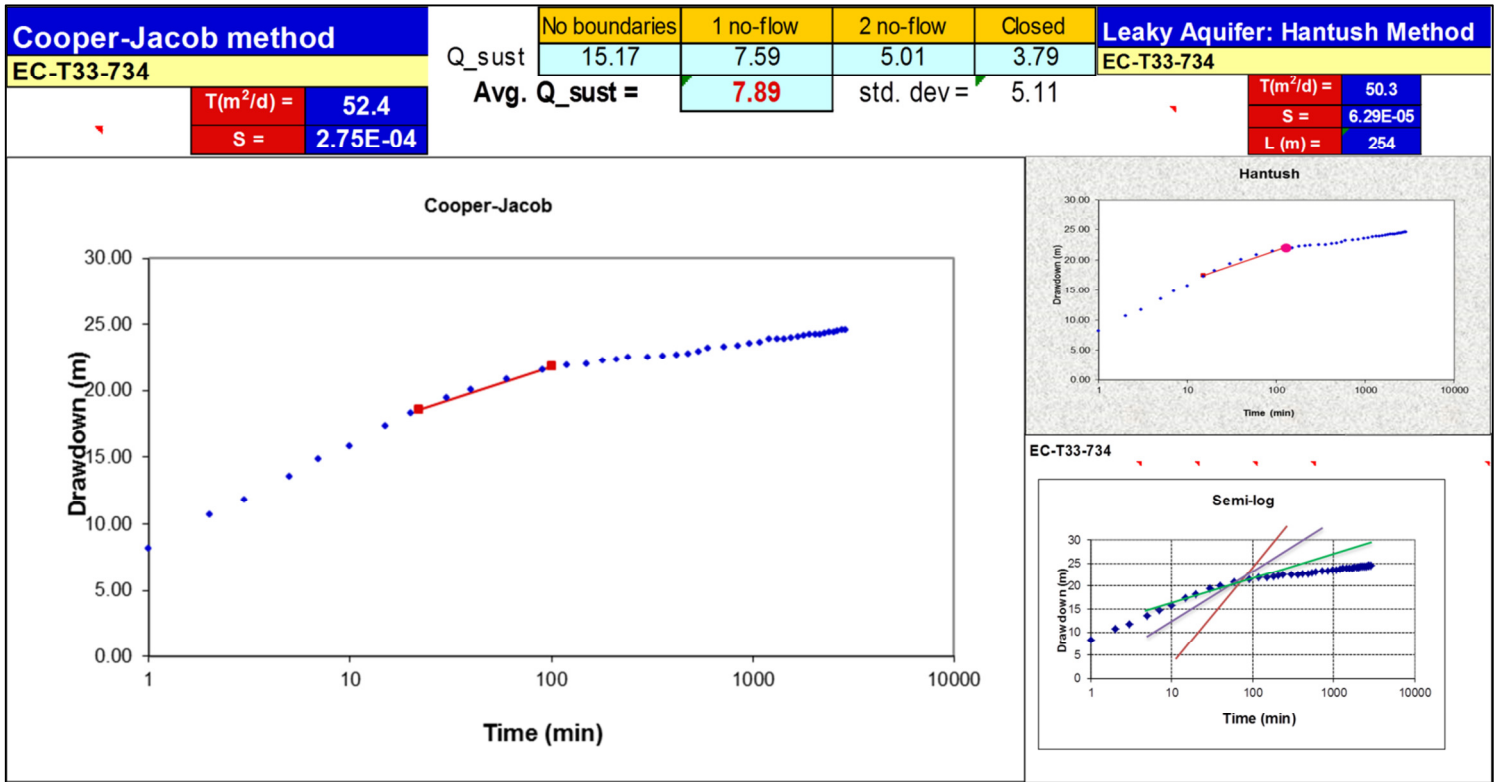
STEPPED DISCHARGE TEST AND RECOVERY															
BOREHOLE NO. :		EC-T33-734			PROJECT:		Umzimwubu Ward 13								
ALTERNATIVE NO. :		0			SITE NAME:		0								
ALTERNATIVE NO. :		0			CLIENT:		0								
BOREHOLE DEPTH (mbgl):		112.70		CASING DEPTH (mbgl):		7.00		PUMP TYPE USED: GW 9002							
DEPTH OF PUMP (mbgl):		57.00		CASING HEIGHT (magl):		0.54		OPERATOR: Yellow Cap, Stanley, Thomas, Lusanda							
PUMP INLET DIAMETER (mm):		170.000		CASING ID (mm):		0.000		CONTRACTOR: Welltek Services							
STATIC WATER LEVEL (mbgl):		6.68		DATUM LEVEL (magl):		0.74									
DISCHARGE RATE 1			Time	Recovery 1	DISCHARGE RATE 2			Time	Recovery 2	DISCHARGE RATE 3			Time	Recovery 3	
DATE:		16-Jul-12		(min)	(m)	DATE:		16-Jul-12		(min)	(m)	DATE:		16-Jul-12	
TIME:		08:00 AM		1		TIME:		09:00 AM		1		TIME:		10:00 AM	
Time	Drawdown	Yield	2		Time	Drawdown	Yield	2		Time	Drawdown	Yield	2		
(min)	(m)	(l/s)	3		(min)	(m)	(l/s)	3		(min)	(m)	(l/s)	3		
1	0.90		5		1	5.27		5		1	10.23	15.100	5		
2	2.55		7		2	5.78	10.260	7		2	10.69		7		
3	2.90	5.890	10		3	6.15		10		3	10.98		10		
5	2.92		15		5	7.16		15		5	12.35	15.100	15		
7	3.15		20		7	7.83	10.260	20		7	13.02		20		
10	3.33		30		10	8.03		30		10	13.59		30		
15	3.58	5.890	40		15	8.33	10.260	40		15	13.75	15.100	40		
20	3.78		50		20	8.58		50		20	13.82		50		
30	4.30		60		30	8.83		60		30	14.40		60		
40	4.32		70		40	9.02	10.260	70		40	14.71	15.100	70		
50	4.41	5.890	80		50	9.11		80		50	14.95		80		
60	4.48		90		60	9.23		90		60	15.08		90		
70			100		70			100		70			100		
80			110		80			110		80			110		
90			120		90			120		90			120		
100			150		100			150		100			150		
110			180		110			180		110			180		
120			210		120			210		120			210		
Average yield: 5.89			(l/s)		Average yield: 10.26					Average yield: 15.1					
DISCHARGE RATE 4			Time	Recovery 4	DISCHARGE RATE 5			Time	Recovery 5	DISCHARGE RATE 6			Time	Recovery	
DATE:		16-Jul-12		(min)	(m)	DATE:		16-Jul-12		(min)	(m)	DATE:		16-Jul-12	
TIME:		11:00 AM		1		TIME:		11:00 AM		1		TIME:		11:00 AM	
Time	Drawdown	Yield	2		Time	Drawdown	Yield	2		Time	Drawdown	Yield	2	12.68	
(min)	(m)	(l/s)	3		(min)	(m)	(l/s)	3		(min)	(m)	(l/s)	3	11.22	
1	16.07		5		1			5		1			5	9.07	
2	16.36	20.08	7		2			7		2			7	7.70	
3	16.60		10		3			10		3			10	6.29	
5	17.23		15		5			15		5			15	4.75	
7	18.64	20.08	20		7			20		7			20	3.88	
10	19.93		30		10			30		10			30	3.07	
15	20.42		40		15			40		15			40	2.65	
20	21.20	20.08	50		20			50		20			50	2.33	
30	21.75		60		30			60		30			60	2.10	
40	22.19		70		40			70		40			70	1.84	
50	22.58		80		50			80		50			80	1.70	
60	22.62	20.08	90		60			90		60			90	1.58	
70			100		70			100		70			100	1.45	
80			110		80			110		80			110	1.38	
90			120		90			120		90			120	1.28	
100			150		100			150		100			150	1.06	
110			180		110			180		110			180		
120			210		120			210		120			210		
Average yield: 20.08															
COMMENTS:										300	180		300		
										360	210		360		
										420	240		420		
										480	300		480		
										540	360		540		
										600	420		600		
										660	480		660		
										720					
										780					
												Average yield:	720		

DISCHARGE BOREHOLE				OBSERVATION BOREHOLE 1			OBSERVATION BOREHOLE 2			OBSERVATION BOREHOLE 3		
Time	Draw down	Yield	Recovery	Time	Drawdown	Recovery	Time	Drawdown	Recovery	Time	Draw down	Recovery
(min)	(m)	(l/s)	(m)	(min)	(m)	(m)	(min)	(m)	(m)	(min)	(m)	(m)
2400	24.38	16.02		1500			1500			1500		
2520	24.40			1560			1560			1560		
2640	24.50	16.08		1620			1620			1620		
2760	24.57			1680			1680			1680		
2880	24.60	16.08		1740			1740			1740		
1800				1800			1800			1800		
1860				1860			1860			1860		
1920				1920			1920			1920		
1980				1980			1980			1980		
2040				2040			2040			2040		
2100				2100			2100			2100		
2160				2160			2160			2160		
2220				2220			2220			2220		
2280				2280			2280			2280		
2340				2340			2340			2340		
2400				2400			2400			2400		
2460				2460			2460			2460		
2520				2520			2520			2520		
2580				2580			2580			2580		
2640				2640			2640			2640		
2700				2700			2700			2700		
2760				2760			2760			2760		
2820				2820			2820			2820		
2880				2880			2880			2880		

DESCRIPTION:	QUANTITY:	UNIT:	S U M M A R Y	DESCRIPTION:	QUANTITY:	UNIT:	
ESTABLISHMENT		Sum			STRAIGHTNESS TEST:		No.
INTER HOLE MOVE > 10 km		Km.			VERTICALITY TEST:		No.
FROM: SITE NAME:					CASING DETECTION:		No.
BOREHOLE No:					STEEL BOREHOLE COVER:		No.
INTER HOLE MOVE < 10 km:		No.			BOREHOLE MARKING:		No.
REMOVAL AND RE-ERECTION OF PUMP HOUSE:		No.			SITE CLEANING / FINISHING:		No.
REMOVAL OF EXISTING EQUIPMENT:		No.			REPORTING & DATA RECORDING:		No.
RE-INSTALLATION OF EXISTING EQUIPMENT:		No.			SLUG TEST:		No.
WORK TIME RATE (REPAIRS):		Hour			LAYFLAT (m):		m
STANDING TIME:		Hour			BOREHOLE DEPTH AFTER TEST:		m
LATITUDE: -30.7112	LONGITUDE: 28.91362				BOREHOLE WATERLEVEL AFTER TEST:		m

TEST DESCRIPTION	STEP	1	2	3	4	5	6	TOTAL:	RECOVERY:	RECOVERY TEST			
CALIBRATION TEST:								(min) (hrs)	(m) (min)	TIME TOTAL (hrs): 30.50			
TEST DURATION (Minutes)								0 0.00	0.00	Cal	Steps	CD	Total
TEST YIELD (l/s)								MAXIMUM (l/s)	0.0	0	150	1680	1830
DRAWDOWN (m)								MAXIMUM (m)		DRAWDOWN TOTALS (CD):			
MULTI-RATE / STEP DRAWDOWN:										AVAILABLE	UTIL-	%	
TEST DURATION (Minutes)	60	60	60	60				240 4.00	1.06	ISED			
TEST YIELD (l/s)	5.89	10.26	15.10	20.08				MAXIMUM (l/s)	20.1	50.3	24.60	48.89	
DRAWDOWN (m)	4.48	9.23	15.08	22.62				MAXIMUM (m)	22.6				
CONSTANT DISCHARGE TEST	TEST DURATION		TEST YIELD		DRAWDOWN		RECOVERY:						
	(min)	(hrs)	(l/s)		(m)		(m)	%	(min)	(hrs)			
	2880	48.00	16.06		24.60		0.70	97.15	1680	28.00			
OBSERVATION BOREHOLES:	No.	720	1440		2880		>2880 (min)		TOTAL:				
	of boreholes	(min)	(min)		(min)		nr.	Time	(min)	(hrs)			
									0	0.00			



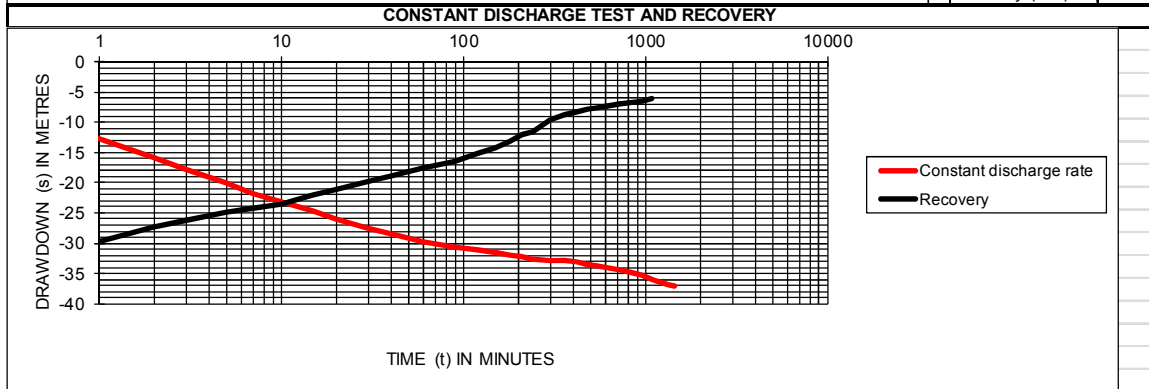
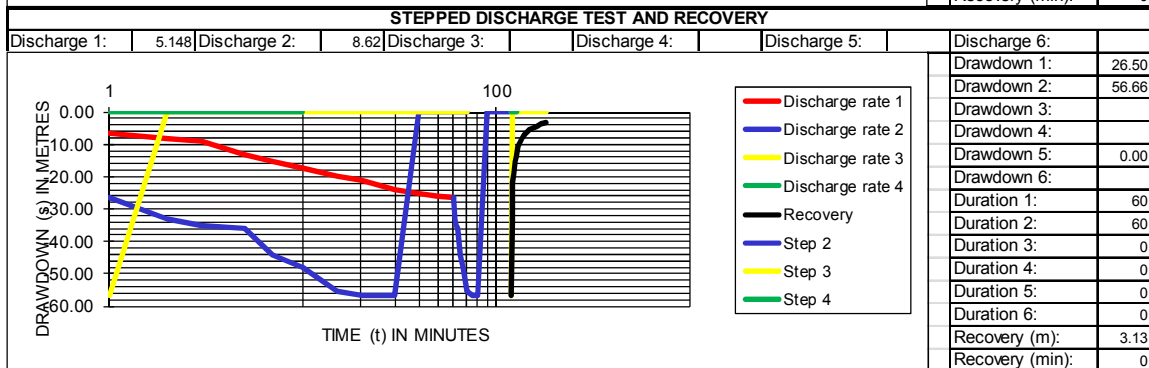
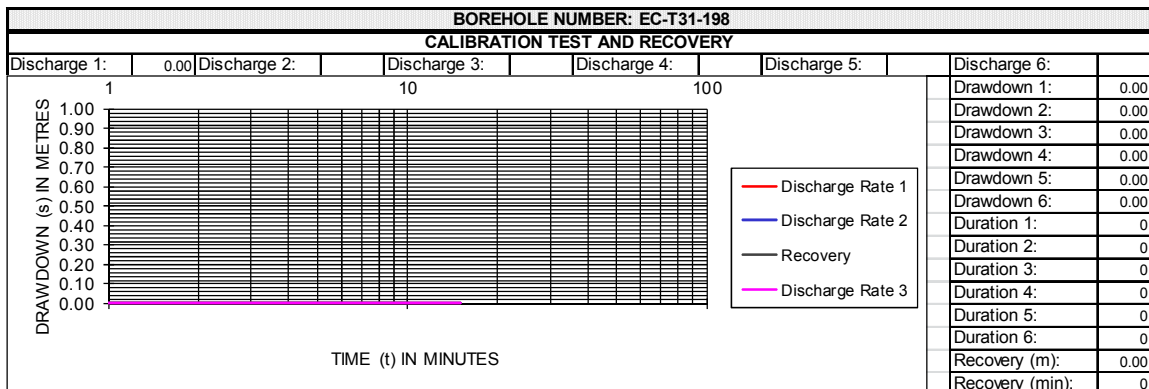


STEPPED DISCHARGE TEST AND RECOVERY															
BOREHOLE NO. :		EC-T31-198		PROJECT:		Umzimwubu Ward 13									
ALTERNATIVE NO. :		0		SITE NAME:		0									
ALTERNATIVE NO. :		0		CLIENT:		0									
BOREHOLE DEPTH (mbgl):		62.80		CASING DEPTH (mbgl):		0.00		PUMP TYPE USED:				P 150			
DEPTH OF PUMP (mbgl):		59.00		CASING HEIGHT (magl):		0.36		OPERATOR:				Stanley, Yellow Cap, Lusanda, Thomas			
PUMP INLET DIAMETER (mm):		170.000		CASING ID (mm):		0.000		CONTRACTOR:				Welltek Services			
STATIC WATER LEVEL (mbgl):		1.60		DATUM LEVEL (magl):		0.45									
DISCHARGE RATE 1			Time	Recovery 1	DISCHARGE RATE 2			Time	Recovery 2	DISCHARGE RATE 3			Time	Recovery 3	
DATE:		21-Jul-12		(min)	(m)	DATE:		21-Jul-12		(min)	(m)	DATE:		(min)	(m)
TIME:		4:50 AM		1		TIME:		5:50 AM		1		TIME:		1	
Time	Drawdown	Yield	2		Time	Drawdown	Yield	2		Time	Drawdown	Yield	2		
(min)	(m)	(l/s)	3		(min)	(m)	(l/s)	3		(min)	(m)	(l/s)	3		
1	6.53		5		1	33.21		5		1			5		
2	8.12	0.910	7		2	35.35		7		2			7		
3	9.26		10		3	36.19		10		3			10		
5	13.07		15		5	44.24		15		5			15		
7	15.49	0.910	20		7	48.04		20		7			20		
10	17.42	2.360	30		10	55.46		30		10			30		
15	19.72		40		15	56.66		40		15			40		
20	21.16		50		20	56.66		50		20			50		
30	23.84	2.360	60		30			60		30			60		
40	25.22		70		40			70		40			70		
50	26.00		80		50			80		50			80		
60	26.50	2.360	90		60			90		60			90		
70			100		70			100		70			100		
80			110		80			110		80			110		
90			120		90			120		90			120		
100			150		100			150		100			150		
110			180		110			180		110			180		
120			210		120			210		120			210		
Average yield: 1.78			(l/s)		Average yield: #DIV/0!					Average yield: #DIV/0!					
DISCHARGE RATE 4			Time	Recovery 4	DISCHARGE RATE 5			Time	Recovery 5	DISCHARGE RATE 6			Time	Recovery	
DATE:				(min)	(m)	DATE:		21-Jul-12		(min)	(m)	DATE:		21-Jul-12	
TIME:				1		TIME:				1		TIME:		1	33.69
Time	Drawdown	Yield	2		Time	Drawdown	Yield	2		Time	Drawdown	Yield	2	22.06	
(min)	(m)	(l/s)	3		(min)	(m)	(l/s)	3		(min)	(m)	(l/s)	3	18.89	
1			5		1			5		1			5	15.34	
2			7		2			7		2			7	13.58	
3			10		3			10		3			10	10.79	
5			15		5			15		5			15	8.33	
7			20		7			20		7			20	7.10	
10			30		10			30		10			30	5.38	
11			40		15			40		15			40	4.35	
12			50		20			50		20			50	3.77	
30			60		30			60		30			60	3.13	
40			70		40			70		40			70		
50			80		50			80		50			80		
60			90		60			90		60			90		
70			100		70			100		70			100		
80			110		80			110		80			110		
90			120		90			120		90			120		
100			150		100			150		100			150		
110			180		110			180		110			180		
120			210		120			210		120			210		
Average yield: #DIV/0!										Average yield: #DIV/0!					
COMMENTS:								300		180		300			
								360		210		360			
								420		240		420			
								480		300		480			
								540		360		540			
								600		420		600			
								660		480		660			
								720							
								780		Average yield:			720		

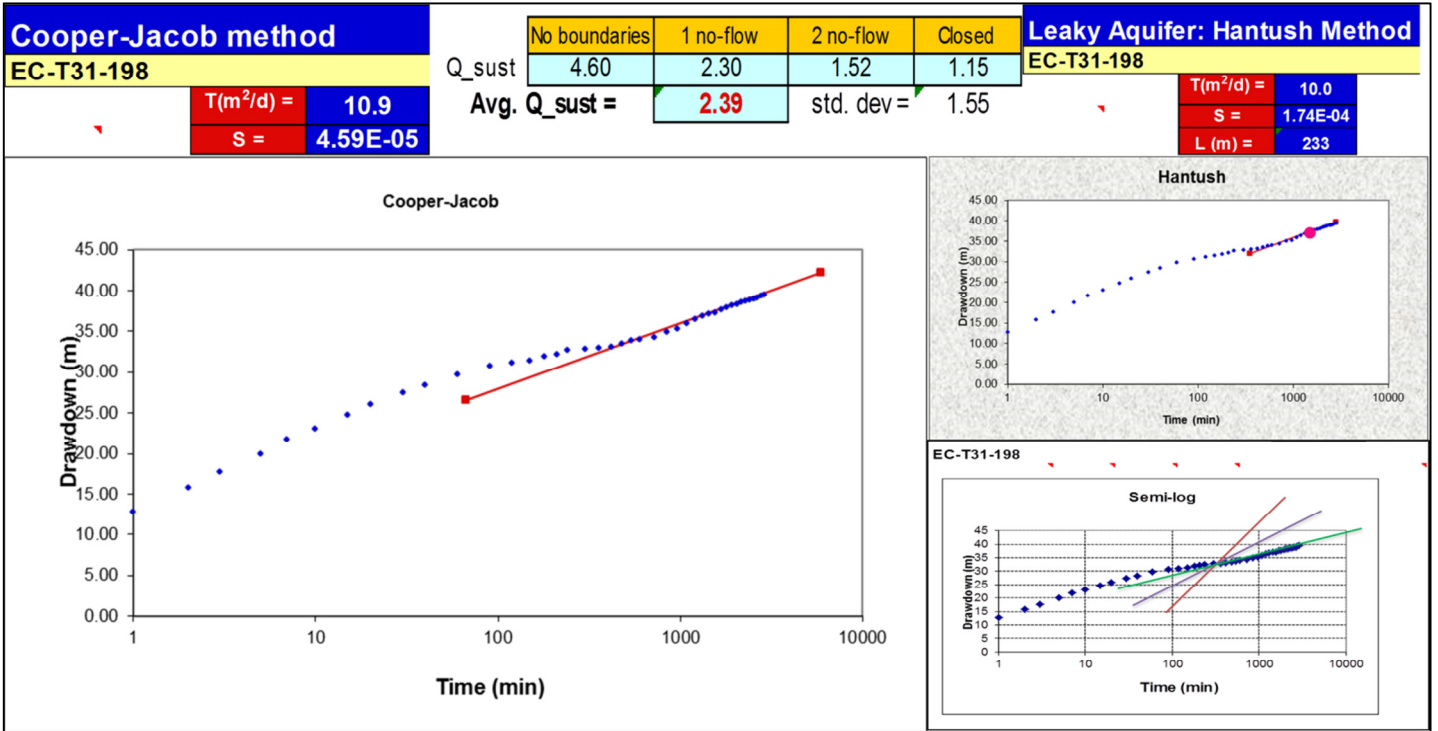
CONSTANT DISCHARGE TEST AND RECOVERY																	
BOREHOLE NO. :			EC-T31-198			PROJECT:			Umzimvubu Ward 13			CLIENT: 0					
ALTERNATIVE NO. :			0			SITE NAME:			0								
DEPTH OF PUMP (m bdl):			59.00			PUMP TYPE USED:			P 150			OPERATOR:			Stanley, Yellow Cap, Lusanda, Thomas		
INLET DIAMETER (mm):			170			EXISTING EQUIPMENT:			0			CONTRACTOR:			Welltek Services		
TEST DATE:		13/10/2012		TEST DATE:		17/10/2012		TOTAL TIME - PUMPED (min):			2880		TOTAL TEST TIME (min):		5760		
TEST STARTED TIME:		2:00 PM		TEST COMPLETED TIME:		8:00 AM		TOTAL TIME-RECOVERY(min):			2880		AVERAGE YIELD (l/s):		5.51		
DISCHARGE BOREHOLE				OBSERVATION BOREHOLE 1				OBSERVATION BOREHOLE 2				OBSERVATION BOREHOLE 3					
CASING HEIGHT (magl):				0.36				No. :				No. :					
CASING DEPTH (m bdl):				0.00				DATUM LEVEL (magl):				DATUM LEVEL (magl):					
CASING ID (mm):				0.00				CASING DEPTH (m bgl):				CASING DEPTH (m bgl):					
BOREHOLE DEPTH (m bgl):				62.80				BOREHOLE DEPTH :				BOREHOLE DEPTH :					
WATER LEVEL (m bgl):				1.60				WATER LEVEL:				WATER LEVEL:					
DATUM LEVEL (magl):				0.45				DISTANCE (m):				DISTANCE (m):					
Time	Drawdown	Yield	Recovery	Time	Drawdown	Recovery	Time	Drawdown	Recovery	Time	Drawdown	Recovery					
(min)	(m)	(l/s)	(m)	(min)	(m)	(m)	(min)	(m)	(m)	(min)	(m)	(m)					
1	12.78		29.80	1			1			1							
2	15.84	5.51	27.30	2			2			2							
3	17.73		26.25	3			3			3							
5	20.00		25.00	5			5			5							
7	21.78	5.51	24.30	7			7			7							
10	23.13		23.54	10			10			10							
15	24.73	5.51	22.08	15			15			15							
20	26.00	5.51	21.18	20			20			20							
30	27.51		19.90	30			30			30							
40	28.45		18.96	40			40			40							
60	29.75	5.51	17.53	60			60			60							
90	30.70		16.48	90			90			90							
120	31.08	5.51	15.26	120			120			120							
150	31.45		14.18	150			150			150							
180	31.90		13.16	180			180			180							
210	32.18	5.51	12.00	210			210			210							
240	32.65		11.57	240			240			240							
300	32.82		9.56	300			300			300							
360	32.94	5.51	8.78	360			360			360							
420	33.15		8.34	420			420			420							
480	33.44		7.87	480			480			480							
540	33.84	5.51	7.60	540			540			540							
600	34.06		7.36	600			600			600							
720	34.32		7.01	720			720			720							
840	34.94	5.51	6.78	840			840			840							
960	35.26		6.57	960			960			960							
1080	35.92		6.18	1080			1080			1080							
1200	36.42	5.51	5.50	1200			1200			1200							
1320	36.89		5.35	1320			1320			1320							
1440	37.10		4.90	1440			1440			1440							
1560	37.24		4.77	1800			1800			1800							
1680	37.65	5.51	4.68	2280			2280			2280							
1800	37.86		4.41	2880			2880			2880							
1920	38.12		4.30														
2040	38.34		4.00														
2160	38.52	5.51	3.85														
2280	38.70		3.58														

DISCHARGE BOREHOLE				OBSERVATION BOREHOLE 1			OBSERVATION BOREHOLE 2			OBSERVATION BOREHOLE 3		
Time	Drawdown	Yield	Recovery	Time	Drawdown	Recovery	Time	Drawdown	Recovery	Time	Drawdown	Recovery
(min)	(m)	(l/s)	(m)	(min)	(m)	(m)	(min)	(m)	(m)	(min)	(m)	(m)
2400	38.82		3.37	1500			1500			1500		
2520	38.92	5.51	3.06	1560			1560			1560		
2640	39.06		2.84	1620			1620			1620		
2760	39.35		2.44	1680			1680			1680		
2880	39.47		2.28	1740			1740			1740		

TEST DESCRIPTION	STEP	1	2	3	4	5	6	TOTAL:	RECOVERY:	RECOVERY TEST					
CALIBRATION TEST:								(min)	(hrs)	(m)	(min)	TIME TOTAL (hrs): 19.00			
TEST DURATION (Minutes)								0	0.00	0.00		Cal	Steps	CD	Total
TEST YIELD (l/s)								MAXIMUM (l/s)	0.0			0	60	1080	1140
DRAWDOWN (m)								MAXIMUM (m)				DRAWDOWN TOTALS (CD):			
MULTI-RATE / STEP DRAWDOWN:												AVAILABLE	UTIL-	%	
TEST DURATION (Minutes)		60	60					120	2.00	3.13		ISED			
TEST YIELD (l/s)		5.15	8.62					MAXIMUM (l/s)	8.6			57.4	39.47	68.76	
DRAWDOWN (m)		26.50	56.66					MAXIMUM (m)	56.7						
CONSTANT DISCHARGE TEST		TEST DURATION		TEST YIELD		DRAWDOWN		RECOVERY:							
		(min)	(hrs)	(l/s)		(m)		(m)		%	(min)	(hrs)			
		1440	24.00	5.51		39.47		2.28		94.22	2880	48.00			

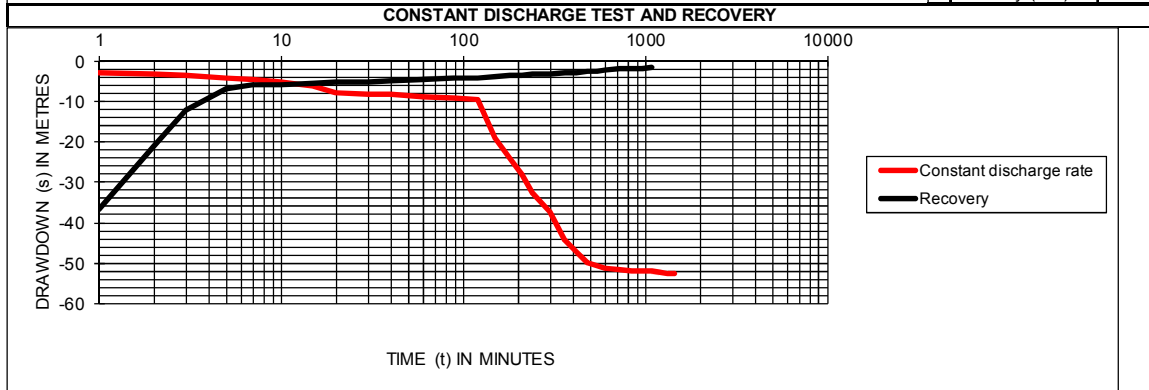
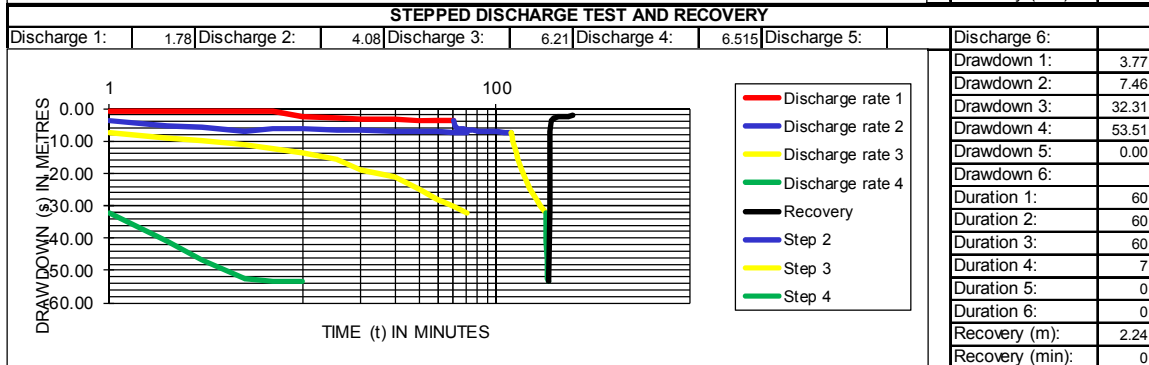
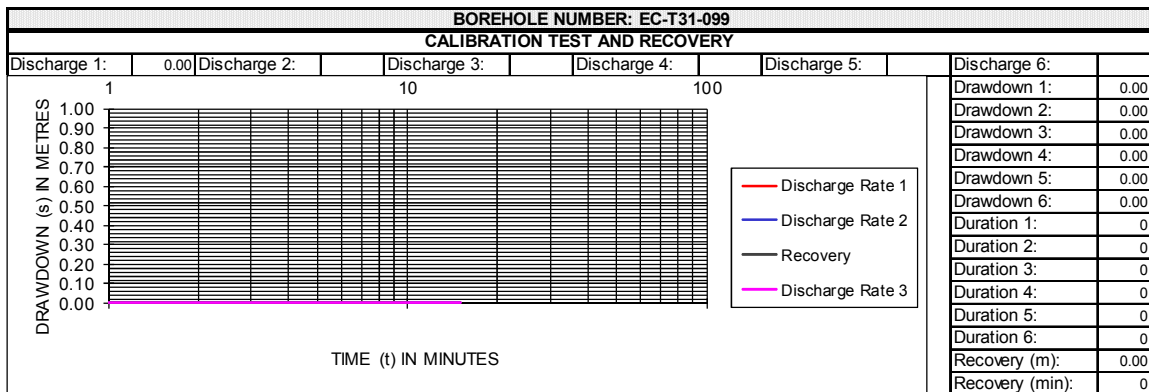


TEST INFORMATION					
Date tested	13-Oct-12	Water level (mbgl)	1.60	Depth of pump (mbgl)	59
CD duration	2880	CD discharge rate	5.51	CD drawdown	39.47
Available drawdown (m)	57.4	% Recovery after CD	94	% after	2880 min



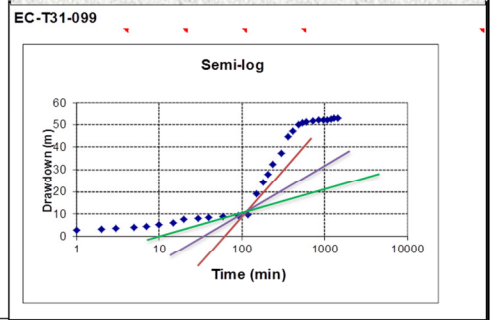
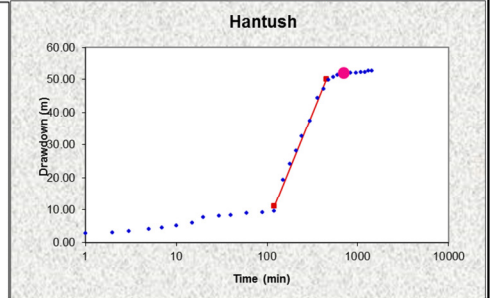
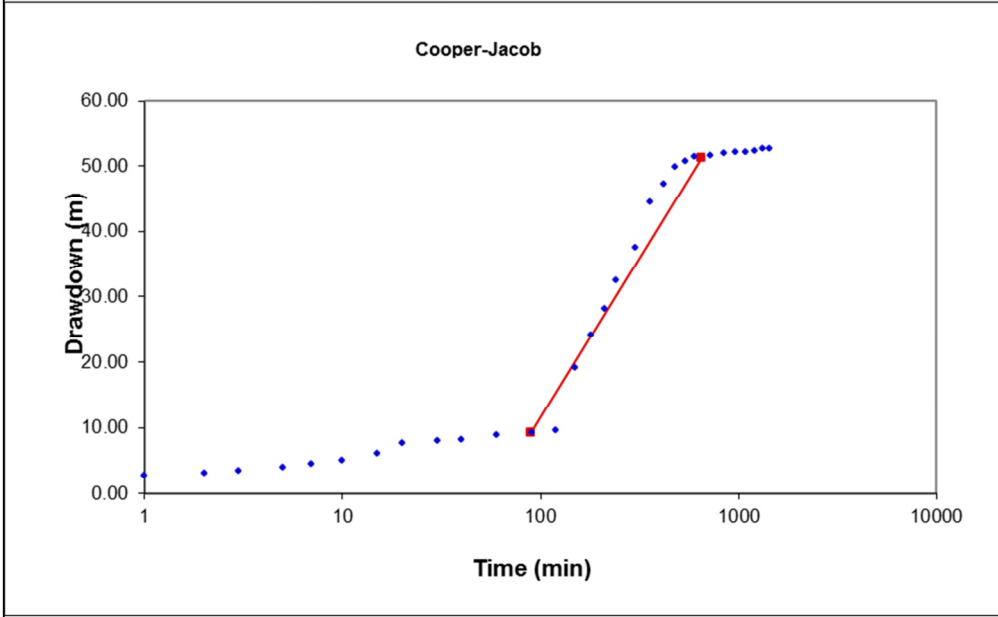
STEPPED DISCHARGE TEST AND RECOVERY														
BOREHOLE NO. :		EC-T31-099			PROJECT:		Umzimwubu Ward 13							
ALTERNATIVE NO. :		0			SITE NAME:		0							
ALTERNATIVE NO. :		0			CLIENT:		0							
BOREHOLE DEPTH (mbgl):		116.88		CASING DEPTH (mbgl):		0.00		PUMP TYPE USED: P 150						
DEPTH OF PUMP (mbgl):		60.00		CASING HEIGHT (magl):		0.48		OPERATOR: Stanley, Yellow Cap, Lusanda, Thomas						
PUMP INLET DIAMETER (mm):		170.000		CASING ID (mm):		0.000		CONTRACTOR: Welltek Services						
STATIC WATER LEVEL (mbgl):		4.88		DATUM LEVEL (magl):		0.45								
DISCHARGE RATE 1			Time	Recovery 1	DISCHARGE RATE 2			Time	Recovery 2	DISCHARGE RATE 3			Time	Recovery 3
DATE:		21-Jul-12			DATE:		21-Jul-12			DATE:		21-Jul-12		
TIME:		04:50 AM			TIME:		05:50 AM			TIME:		06:50 AM		
Time	Drawdown	Yield	2		Time	Drawdown	Yield	2		Time	Drawdown	Yield	2	
(min)	(m)	(l/s)	3		(min)	(m)	(l/s)	3		(min)	(m)	(l/s)	3	
1	0.64		5		1	5.46		5		1	9.00		5	
2	0.75	0.910	7		2	5.86		7		2	9.82	6.210	7	
3	0.79		10		3	6.83		10		3	11.07		10	
5	0.84		15		5	6.14	4.080	15		5	12.55		15	
7	0.89	0.910	20		7	6.20		20		7	13.46	6.210	20	
10	2.60	2.360	30		10	6.52		30		10	15.65		30	
15	2.94		40		15	6.74		40		15	18.92		40	
20	3.16		50		20	6.85	4.080	50		20	21.15	6.210	50	
30	3.33	2.360	60		30	7.01		60		30	24.95		60	
40	3.53		70		40	7.19		70		40	28.28		70	
50	3.66		80		50	7.46		80		50	30.10		80	
60	3.77	2.360	90		60	7.30	4.080	90		60	32.31		90	
70			100		70			100		70			100	
80			110		80			110		80			110	
90			120		90			120		90			120	
100			150		100			150		100			150	
110			180		110			180		110			180	
120			210		120			210		120			210	
Average yield: 1.78			(l/s)		Average yield: 4.08					Average yield: 6.21				
DISCHARGE RATE 4			Time	Recovery 4	DISCHARGE RATE 5			Time	Recovery 5	DISCHARGE RATE 6			Time	Recovery
DATE:		21-Jul-12			DATE:		21-Jul-12			DATE:		21-Jul-12		
TIME:		07:50 AM			TIME:		1			TIME:		1		
Time	Drawdown	Yield	2		Time	Drawdown	Yield	2		Time	Drawdown	Yield	2	
(min)	(m)	(l/s)	3		(min)	(m)	(l/s)	3		(min)	(m)	(l/s)	3	
1	40.86		5		1			5		1			5	31.33
2	46.63	8.02	7		2			7		2			7	12.25
3	52.74		10		3			10		3			10	6.92
5	53.51		15		5			15		5			15	3.81
7	53.51	5.01	20		7			20		7			20	3.22
10			30		10			30		10			30	3.00
11			40		15			40		15			40	2.81
12			50		20			50		20			50	2.66
30			60		30			60		30			60	2.56
40			70		40			70		40			70	2.46
50			80		50			80		50			80	2.32
60			90		60			90		60			90	2.24
70			100		70			100		70			100	
80			110		80			110		80			110	
90			120		90			120		90			120	
100			150		100			150		100			150	
110			180		110			180		110			180	
120			210		120			210		120			210	
Average yield: 6.515														
COMMENTS:										300	180		300	
										360	210		360	
										420	240		420	
										480	300		480	
										540	360		540	
										600	420		600	
										660	480		660	
										720				
										780				
										Average yield:			720	

TEST DESCRIPTION	STEP	1	2	3	4	5	6	TOTAL:	RECOVERY:	RECOVERY TEST			
CALIBRATION TEST:								(min) (hrs)	(m) (min)	TIME TOTAL (hrs): 19.00			
TEST DURATION (Minutes)								0 0.00	0.00	Cal	Steps	CD	Total
TEST YIELD (l/s)								MAXIMUM (l/s)	0.0	0	60	1080	1140
DRAWDOWN (m)								MAXIMUM (m)		DRAWDOWN TOTALS (CD):			
MULTI-RATE / STEP DRAWDOWN:										AVAILABLE	UTIL-	%	
TEST DURATION (Minutes)	60	60	60	7				187 3.12	2.24	ISED			
TEST YIELD (l/s)	1.78	4.08	6.21	6.52				MAXIMUM (l/s)	6.5	55.1	52.70	95.61	
DRAWDOWN (m)	3.77	7.46	32.31	53.51				MAXIMUM (m)	53.5				
CONSTANT DISCHARGE TEST		TEST DURATION		TEST YIELD		DRAWDOWN		RECOVERY:					
	(min)	(hrs)	(l/s)	(m)	(m)	(m)	(m)	%	(min)	(hrs)			
	1440	24.00	4.03	52.70	1.62	96.93	1080	18.00					
OBSERVATION BOREHOLES:		No.		720		1440		2880		>2880 (min)		TOTAL:	
	of boreholes	(min)	(min)	(min)	(min)	nr.	Time	(min)	(hrs)				
								0	0.00				



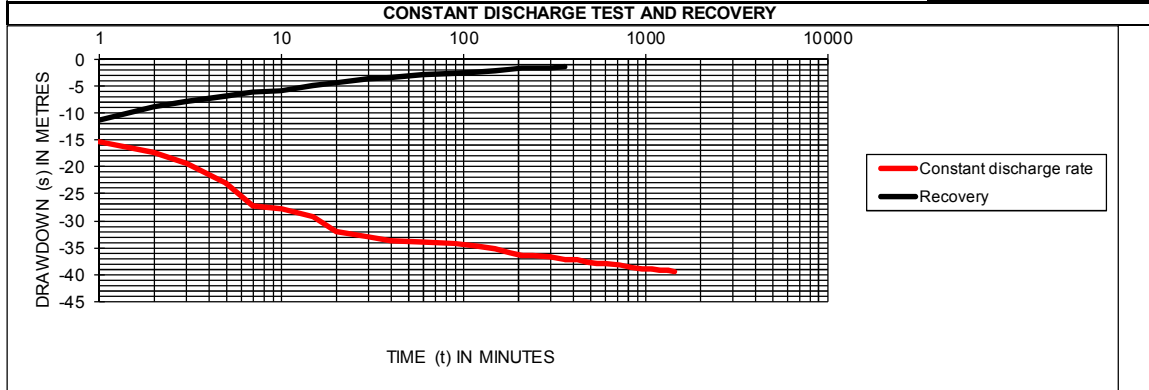
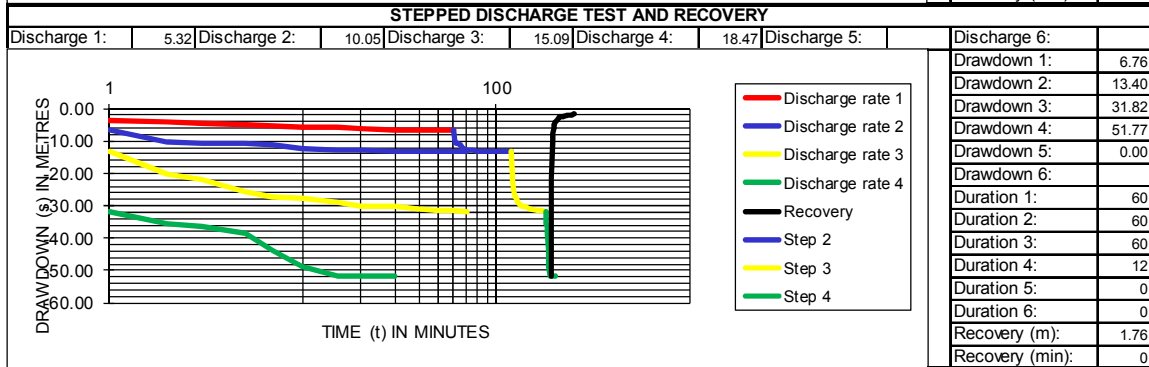
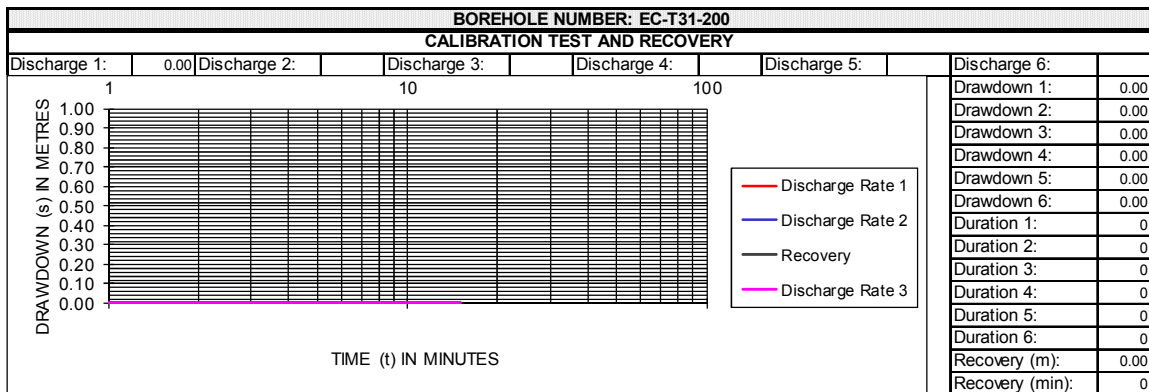
TEST INFORMATION					
Date tested	21-Jul-12	Water level (mbgl)	4.88	Depth of pump (mbgl)	60
CD duration	1440	CD discharge rate	4.03	CD drawdown	52.7
Available drawdown (m)	55.12	% Recovery after CD	97	% after	1080 min

Cooper-Jacob method		Q _{sust}	No boundaries	1 no-flow	2 no-flow	Closed	Leaky Aquifer: Hantush Method	
EC-T31-199			3.61	1.81	1.19	0.90	EC-T31-199	
		Avg. Q _{sust} =	1.88	std. dev =		1.22	T(m ² /d) =	0.2
		T(m ² /d) =	1.3				S =	7.30E-03
		S =	1.23E-01				L (m) =	2

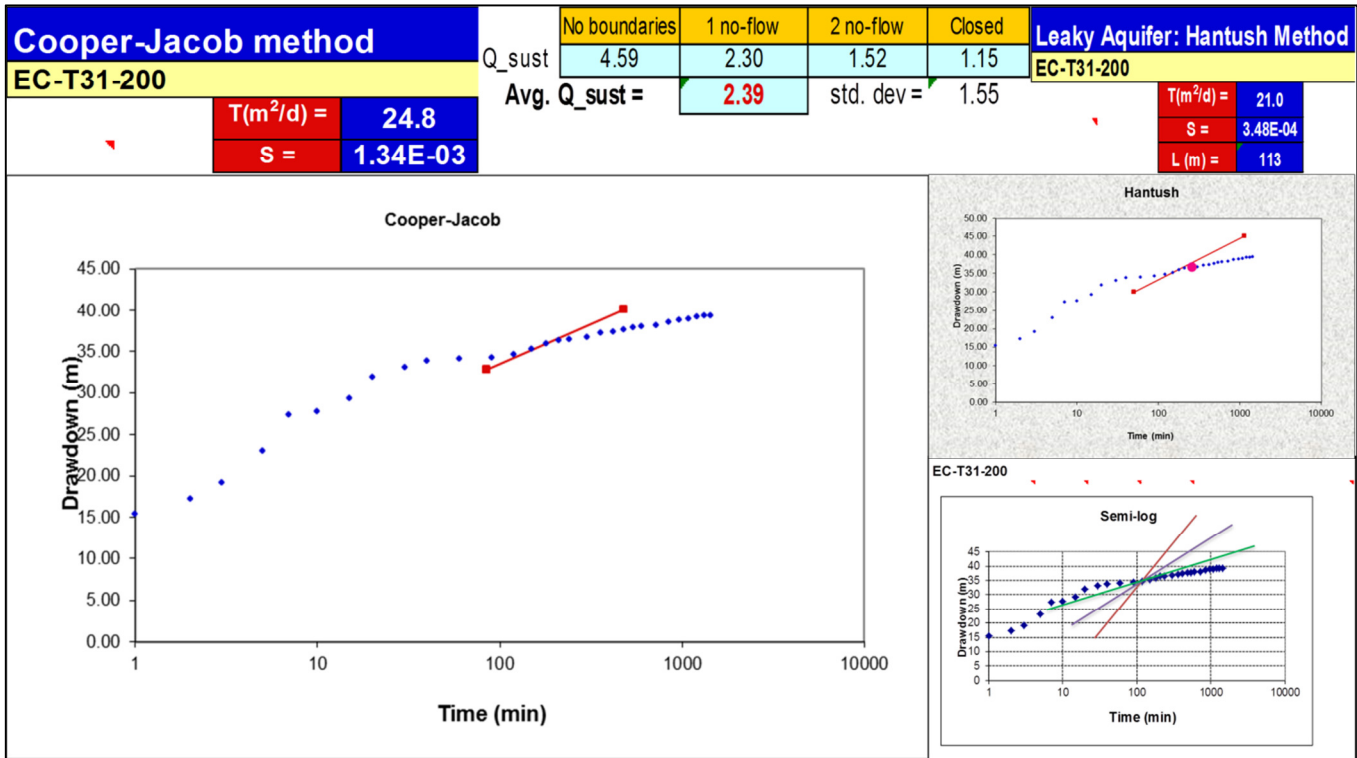


STEPPED DISCHARGE TEST AND RECOVERY																	
BOREHOLE NO. :		EC-T31-200			PROJECT:		Umzimwubu Ward 13										
ALTERNATIVE NO. :		0			SITE NAME:		0										
ALTERNATIVE NO. :		0			CLIENT:		0										
BOREHOLE DEPTH (mbgl):		132.00		CASING DEPTH (mbgl):		29.67		PUMP TYPE USED:				GW 9002					
DEPTH OF PUMP (mbgl):		93.00		CASING HEIGHT (magl):		0.51		OPERATOR:				Stanley, Yellow Cap, Thomas					
PUMP INLET DIAMETER (mm):		118.000		CASING ID (mm):		0.000		CONTRACTOR:				Welltek Services					
STATIC WATER LEVEL (mbgl):		37.79		DATUM LEVEL (magl):		0.85											
DISCHARGE RATE 1			Time	Recovery 1	DISCHARGE RATE 2			Time	Recovery 2	DISCHARGE RATE 3			Time	Recovery 3			
DATE:		08-May-12		(min)	(m)	DATE:		08-May-12		(min)	(m)	DATE:		08-May-12		(min)	(m)
TIME:		06:00 PM		1		TIME:		07:00 PM		1		TIME:		08:00 PM		1	
Time	Drawdown	Yield	2		Time	Drawdown	Yield	2		Time	Drawdown	Yield	2				
(min)	(m)	(l/s)	3		(min)	(m)	(l/s)	3		(min)	(m)	(l/s)	3				
1	3.73		5		1	10.16		5		1	20.46		5				
2	4.18	5.320	7		2	10.64	10.050	7		2	22.02		7				
3	4.54		10		3	10.86		10		3	25.76	15.090	10				
5	5.00		15		5	11.10		15		5	27.24		15				
7	5.24	5.320	20		7	12.46	10.050	20		7	27.90		20				
10	5.57		30		10	12.78		30		10	28.82	15.090	30				
15	5.93		40		15	12.90		40		15	30.02		40				
20	6.15	5.320	50		20	13.12	10.050	50		20	30.36		50				
30	6.44		60		30	13.20		60		30	30.95	15.090	60				
40	6.60		70		40	13.28		70		40	31.52		70				
50	6.65		80		50	13.32		80		50	31.61		80				
60	6.76		90		60	13.40		90		60	31.82		90				
70			100		70			100		70			100				
80			110		80			110		80			110				
90			120		90			120		90			120				
100			150		100			150		100			150				
110			180		110			180		110			180				
120			210		120			210		120			210				
Average yield: 5.32			(l/s)		Average yield: 10.05					Average yield: 15.09							
DISCHARGE RATE 4			Time	Recovery 4	DISCHARGE RATE 5			Time	Recovery 5	DISCHARGE RATE 6			Time	Recovery			
DATE:		08-May-12		(min)	(m)	DATE:		08-May-12		(min)	(m)	DATE:		08-May-12		(min)	(m)
TIME:		09:00 PM		1		TIME:		1			TIME:		1		21.56		
Time	Drawdown	Yield	2		Time	Drawdown	Yield	2		Time	Drawdown	Yield	2	10.00			
(min)	(m)	(l/s)	3		(min)	(m)	(l/s)	3		(min)	(m)	(l/s)	3	7.94			
1	35.60		5		1			5		1			5	6.10			
2	36.42	20.13	7		2			7		2			7	4.77			
3	38.30		10		3			10		3			10	4.06			
5	43.76	20.15	15		5			15		5			15	3.15			
7	48.92		20		7			20		7			20	2.48			
10	51.77		30		10			30		10			30	2.32			
11	51.77	16.86	40		15			40		15			40	2.02			
12	51.77	16.75	50		20			50		20			50	1.89			
30			60		30			60		30			60	1.76			
40			70		40			70		40			70				
50			80		50			80		50			80				
60			90		60			90		60			90				
70			100		70			100		70			100				
80			110		80			110		80			110				
90			120		90			120		90			120				
100			150		100			150		100			150				
110			180		110			180		110			180				
120			210		120			210		120			210				
Average yield: 18.4725										Average yield: 18.4725							
COMMENTS:													300		300		
													360		360		
													420		420		
													480		480		
													540		540		
													600		600		
													660		660		
													720		720		
													780		780		
													Average yield:		720		

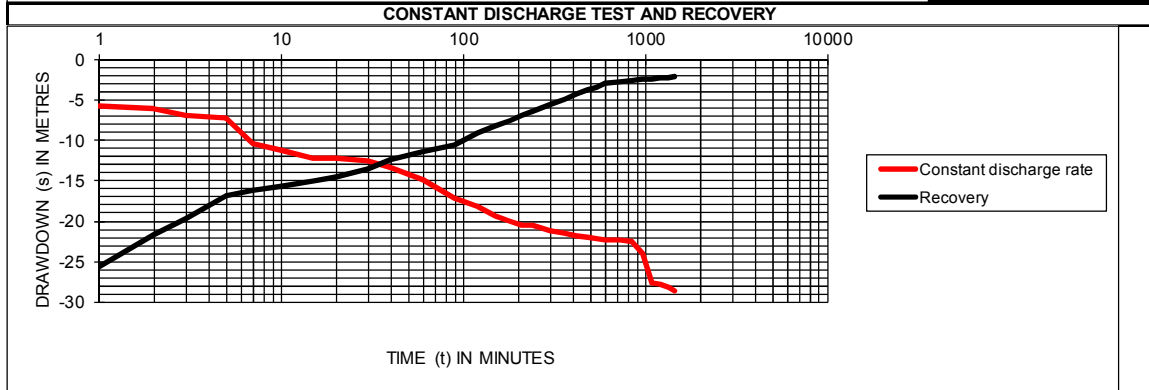
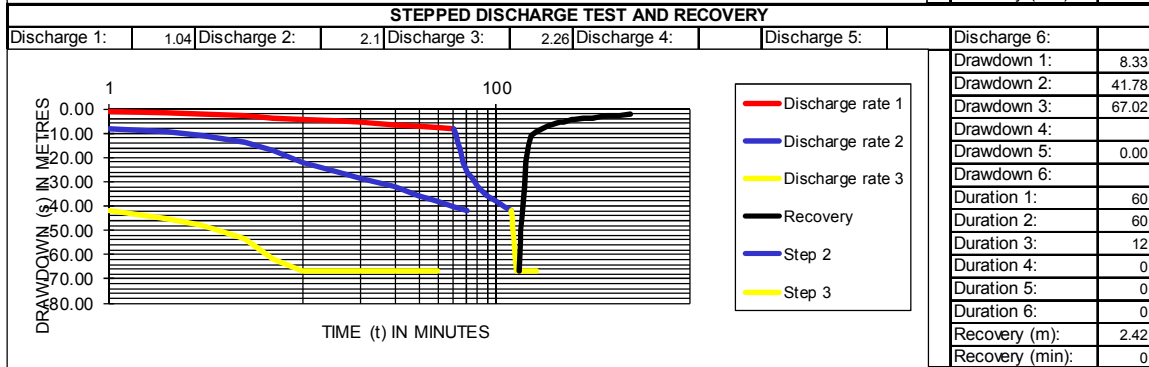
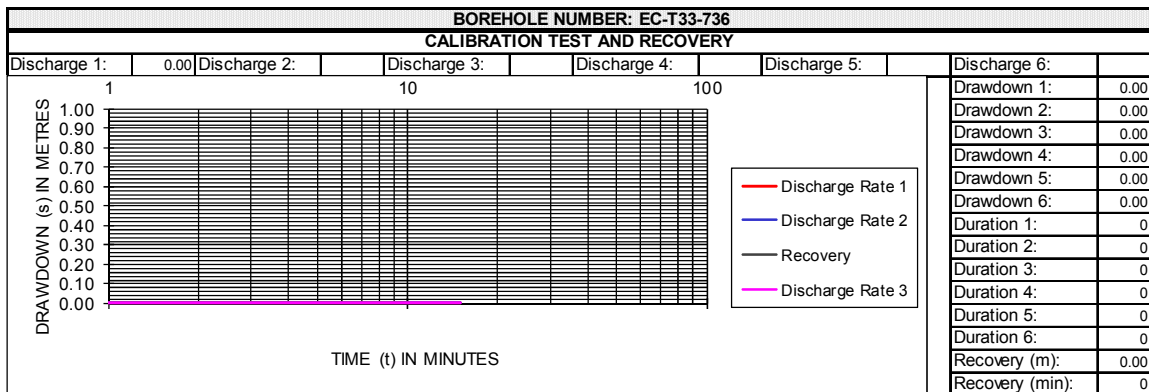
TEST DESCRIPTION	STEP	1	2	3	4	5	6	TOTAL:	RECOVERY:	RECOVERY TEST					
CALIBRATION TEST:								(min)	(hrs)	(m)	(min)	TIME TOTAL (hrs): 7.00			
TEST DURATION (Minutes)								0	0.00	0.00		Cal	Steps	CD	Total
TEST YIELD (l/s)								MAXIMUM (l/s) 0.0			0	60	360	420	
DRAWDOWN (m)								MAXIMUM (m)			DRAWDOWN TOTALS (CD):				
MULTI-RATE / STEP DRAWDOWN:												AVAILABLE	UTIL-	%	
TEST DURATION (Minutes)	60	60	60	12				192	3.20	1.76		ISED			
TEST YIELD (l/s)	5.32	10.05	15.09	18.47				MAXIMUM (l/s) 18.5			55.2	39.36	71.29		
DRAWDOWN (m)	6.8	13.40	31.82	51.77				MAXIMUM (m) 51.8							
CONSTANT DISCHARGE TEST	TEST DURATION		TEST YIELD		DRAWDOWN		RECOVERY:								
	(min)	(hrs)	(l/s)	(m)	(m)	%	(min)	(hrs)							
	1440	24.00	15.09	39.36	1.48	96.24	360	6.00							
OBSERVATION BOREHOLES:	No.	720	1440	2880	>2880 (min)		TOTAL:								
	of boreholes	(min)	(min)	(min)	nr.	Time	(min)	(hrs)							
							0	0.00							



TEST INFORMATION					
Date tested	08-May-12	Water level (mbgl)	37.79	Depth of pump (mbgl)	93
CD duration	1440	CD discharge rate	15.09	CD drawdown	39.36
Available drawdown (m)	55.21	% Recovery after CD	96	% after	360 min

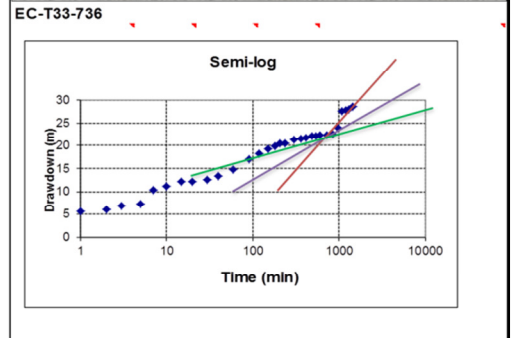
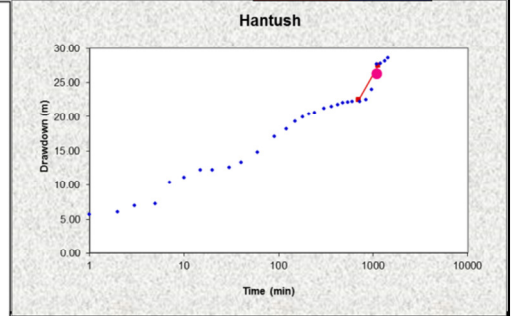
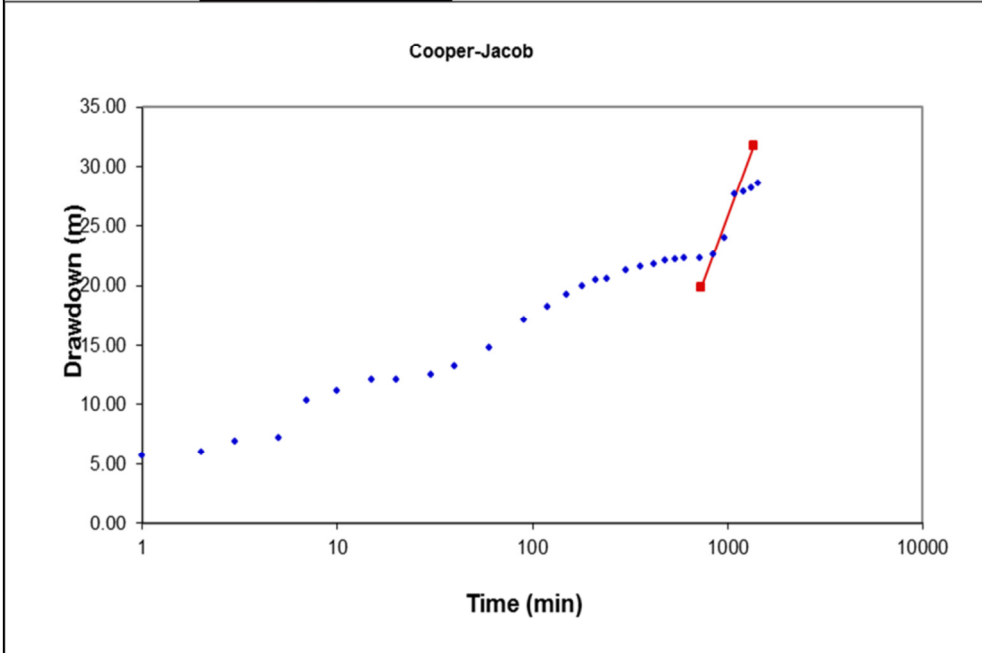


TEST DESCRIPTION	STEP	1	2	3	4	5	6	TOTAL:	RECOVERY:	RECOVERY TEST		
CALIBRATION TEST:								(min) (hrs)	(m) (min)	TIME TOTAL (hrs): 30.00		
TEST DURATION (Minutes)								0 0.00	0.00	Cal	Steps	CD Total
TEST YIELD (l/s)								MAXIMUM (l/s)	0.0	0	360	1440 1800
DRAWDOWN (m)								MAXIMUM (m)		DRAWDOWN TOTALS (CD):		
MULTI-RATE / STEP DRAWDOWN:										AVAILABLE	UTIL-	%
TEST DURATION (Minutes)	60	60	12					132 2.20	2.42	ISED		
TEST YIELD (l/s)	1.04	2.10	2.26					MAXIMUM (l/s)	2.3	67.4	28.56	42.37
DRAWDOWN (m)	8.33	41.78	67.02					MAXIMUM (m)	67.0			
CONSTANT DISCHARGE TEST	TEST DURATION		TEST YIELD		DRAWDOWN		RECOVERY:					
	(min)	(hrs)	(l/s)	(m)	(m)	%	(min)	(hrs)				
	1440	24.00	1.03	28.56	2.06	92.79	1440	24.00				
OBSERVATION BOREHOLES:	No.	720	1440	2880	>2880 (min)		TOTAL:					
	of boreholes	(min)	(min)	(min)	nr.	Time	(min)	(hrs)				
							0	0.00				



TEST INFORMATION					
Date tested	13-Aug-12	Water level (mbgl)	12.60	Depth of pump (mbgl)	80
CD duration	1440	CD discharge rate	1.03	CD drawdown	28.56
Available drawdown (m)	67.4	% Recovery after CD	93	% after	1440 min

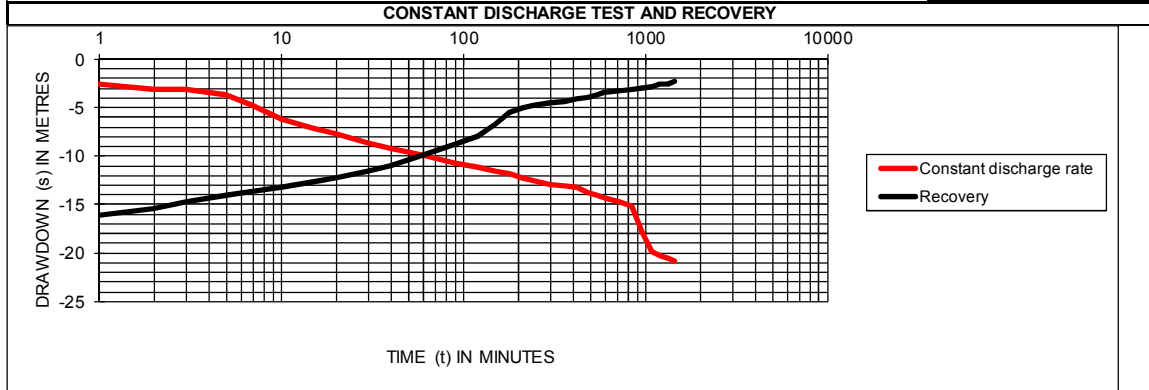
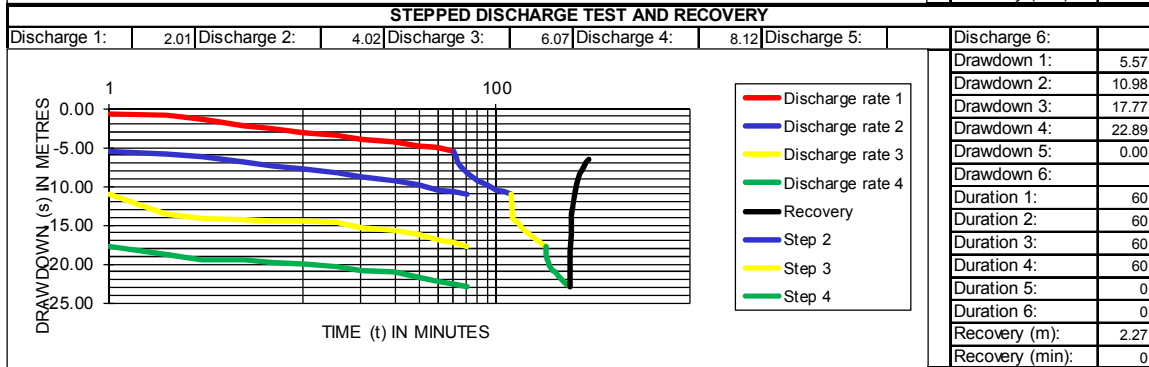
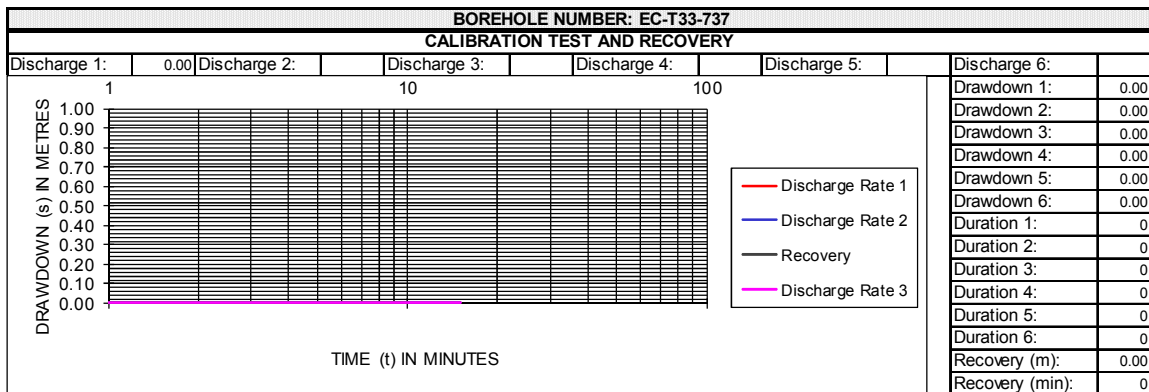
Cooper-Jacob method						Leaky Aquifer: Hantush Method	
EC-T33-736		Q_sust	No boundaries 0.28	1 no-flow 0.14	2 no-flow 0.09	Closed 0.07	EC-T33-736
		Avg. Q_sust =	0.15		std. dev = 0.09		
		T(m ² /d) =	0.4				T(m ² /d) = 0.4
		S =	1.56E-01				S = 8.62E-03
						L (m) =	5



STEPPED DISCHARGE TEST AND RECOVERY																	
BOREHOLE NO. :		EC-T33-737			PROJECT:		Umzimwubu Ward 13										
ALTERNATIVE NO. :		0			SITE NAME:		0										
ALTERNATIVE NO. :		0			CLIENT:		0										
BOREHOLE DEPTH (mbgl):		119.23		CASING DEPTH (mbgl):		0.00		PUMP TYPE USED:				BP 40					
DEPTH OF PUMP (mbgl):		80.00		CASING HEIGHT (magl):		0.17		OPERATOR:				Stanley, Yellow Cap, Thomas, Popeye, Junior					
PUMP INLET DIAMETER (mm):		165.000		CASING ID (mm):		0.000		CONTRACTOR:				Welltek Services					
STATIC WATER LEVEL (mbgl):		32.06		DATUM LEVEL (magl):		0.62											
DISCHARGE RATE 1			Time	Recovery 1	DISCHARGE RATE 2			Time	Recovery 2	DISCHARGE RATE 3			Time	Recovery 3			
DATE:		22-Aug-12		(min)	(m)	DATE:		22-Aug-12		(min)	(m)	DATE:		22-Aug-12		(min)	(m)
TIME:		07:00 AM		1		TIME:		08:00 AM		1		TIME:		09:00 AM		1	
Time	Drawdown	Yield	2		Time	Drawdown	Yield	2		Time	Drawdown	Yield	2				
(min)	(m)	(l/s)	3		(min)	(m)	(l/s)	3		(min)	(m)	(l/s)	3				
1	0.67		5		1	5.91		5		1	13.65		5				
2	0.89		7		2	6.15	4.020	7		2	14.17		7				
3	1.45	2.010	10		3	6.81		10		3	14.30	6.070	10				
5	2.18		15		5	7.40		15		5	14.52		15				
7	2.61	2.010	20		7	7.77		20		7	14.54		20				
10	3.02		30		10	8.23		30		10	14.72		30				
15	3.49	2.010	40		15	8.81		40		15	15.28		40				
20	3.88		50		20	9.26	4.020	50		20	15.63	6.070	50				
30	4.35		60		30	9.83		60		30	16.27		60				
40	4.79		70		40	10.53		70		40	16.97		70				
50	5.03	2.010	80		50	10.70		80		50	17.20		80				
60	5.57		90		60	10.98		90		60	17.77		90				
70			100		70			100		70			100				
80			110		80			110		80			110				
90			120		90			120		90			120				
100			150		100			150		100			150				
110			180		110			180		110			180				
120			210		120			210		120			210				
Average yield: 2.01			(l/s)		Average yield: 4.02					Average yield: 6.07							
DISCHARGE RATE 4			Time	Recovery 4	DISCHARGE RATE 5			Time	Recovery 5	DISCHARGE RATE 6			Time	Recovery			
DATE:		22-Aug-12		(min)	(m)	DATE:		22-Aug-12		(min)	(m)	DATE:		22-Aug-12		(min)	(m)
TIME:		10:00 AM		1		TIME:				1		TIME:				1	18.50
Time	Drawdown	Yield	2		Time	Drawdown	Yield	2		Time	Drawdown	Yield	2				
(min)	(m)	(l/s)	3		(min)	(m)	(l/s)	3		(min)	(m)	(l/s)	3				
1	18.74		5		1			5		1			5	13.54			
2	19.44		7		2			7		2			7	12.54			
3	19.55	8.12	10		3			10		3			10	11.63			
5	19.86		15		5			15		5			15	10.54			
7	20.05		20		7			20		7			20	9.64			
10	20.32		30		10			30		10			30	8.47			
15	20.84	8.12	40		15			40		15			40	7.61			
20	21.08		50		20			50		20			50	6.95			
30	21.67		60		30			60		30			60	6.53			
40	22.17	8.12	70		40			70		40			70	6.12			
50	22.52		80		50			80		50			80	5.66			
60	22.89		90		60			90		60			90	5.20			
70			100		70			100		70			100	5.03			
80			110		80			110		80			110	4.67			
90			120		90			120		90			120	4.60			
100			150		100			150		100			150	3.96			
110			180		110			180		110			180	3.55			
120			210		120			210		120			210	3.12			
Average yield: 8.12																	
COMMENTS:									300		180		300	2.27			
									360		210		360				
									420		240		420				
									480		300		480				
									540		360		540				
									600		420		600				
									660		480		660				
									720								
									780				720				
									Average yield:			720					

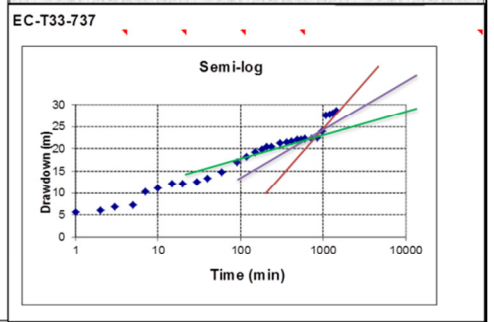
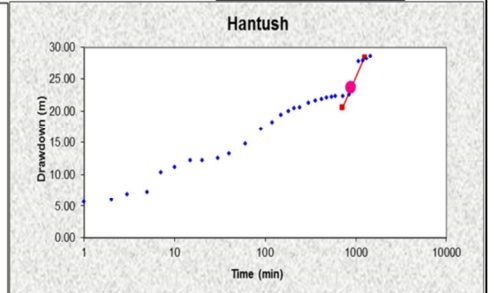
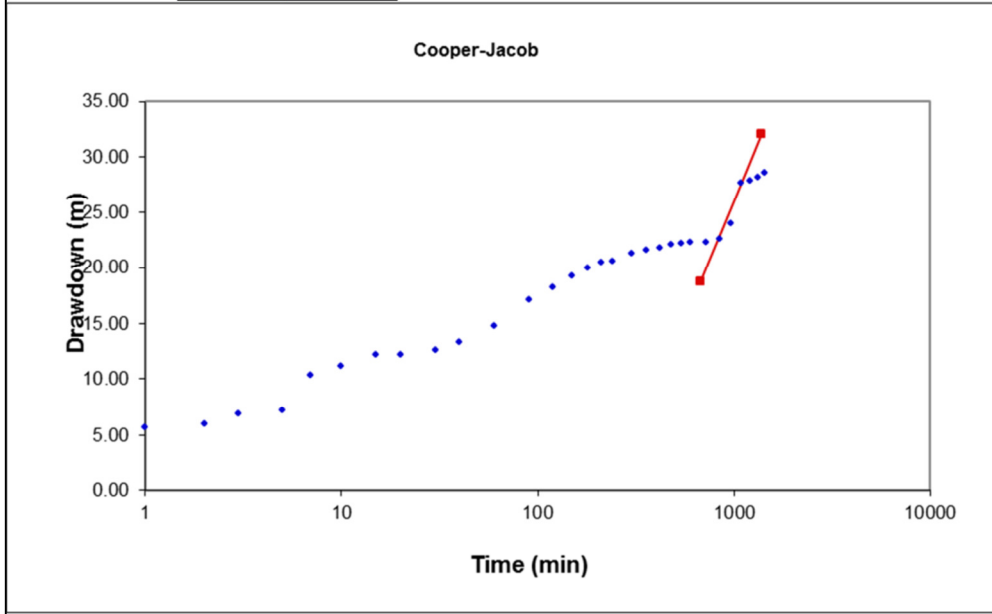
TEST DESCRIPTION	STEP	1	2	3	4	5	6	TOTAL:	RECOVERY:
CALIBRATION TEST:								(min) (hrs)	(m) (min)
TEST DURATION (Minutes)								0 0.00	0.00
TEST YIELD (l/s)								MAXIMUM (l/s)	0.0
DRAWDOWN (m)								MAXIMUM (m)	
MULTI-RATE / STEP DRAWDOWN:									
TEST DURATION (Minutes)	60	60	60	60				240 4.00	2.27
TEST YIELD (l/s)	2.01	4.02	6.07	8.12				MAXIMUM (l/s)	8.1
DRAWDOWN (m)	5.57	10.98	17.77	22.89				MAXIMUM (m)	22.9
CONSTANT DISCHARGE TEST								RECOVERY:	
		TEST DURATION		TEST YIELD		DRAWDOWN			
		(min)	(hrs)	(l/s)		(m)		(m)	%
		1440	24.00	4.15		20.87		2.32	88.88
								(min)	(hrs)
								1440	24.00
OBSERVATION BOREHOLES:								TOTAL:	
		No.	720	1440		2880		>2880 (min)	
		of boreholes	(min)	(min)		(min)		nr.	Time
								(min)	(hrs)
								0	0.00

RECOVERY TEST			
TIME TOTAL (hrs): 29.00			
Cal	Steps	CD	Total
0	300	1440	1740
DRAWDOWN TOTALS (CD):			
AVAILABLE	UTIL-	% ISED	
47.9	20.87	43.53	



TEST INFORMATION					
Date tested	22-Aug-12	Water level (mbgl)	32.06	Depth of pump (mbgl)	80
CD duration	1440	CD discharge rate	4.15	CD drawdown	20.87
Available drawdown (m)	47.94	% Recovery after CD	89	% after	1440 min

Cooper-Jacob method		Q_sust	No boundaries	1 no-flow	2 no-flow	Closed	Leaky Aquifer: Hantush Method	
EC-T33-737			0.29	0.14	0.10	0.07	EC-T33-737	
		Avg. Q_sust =	0.15		std. dev =	0.10		T(m ² /d) = 0.1
		T(m ² /d) =	0.4				S =	6.78E-03
		S =	1.52E-01				L (m) =	2

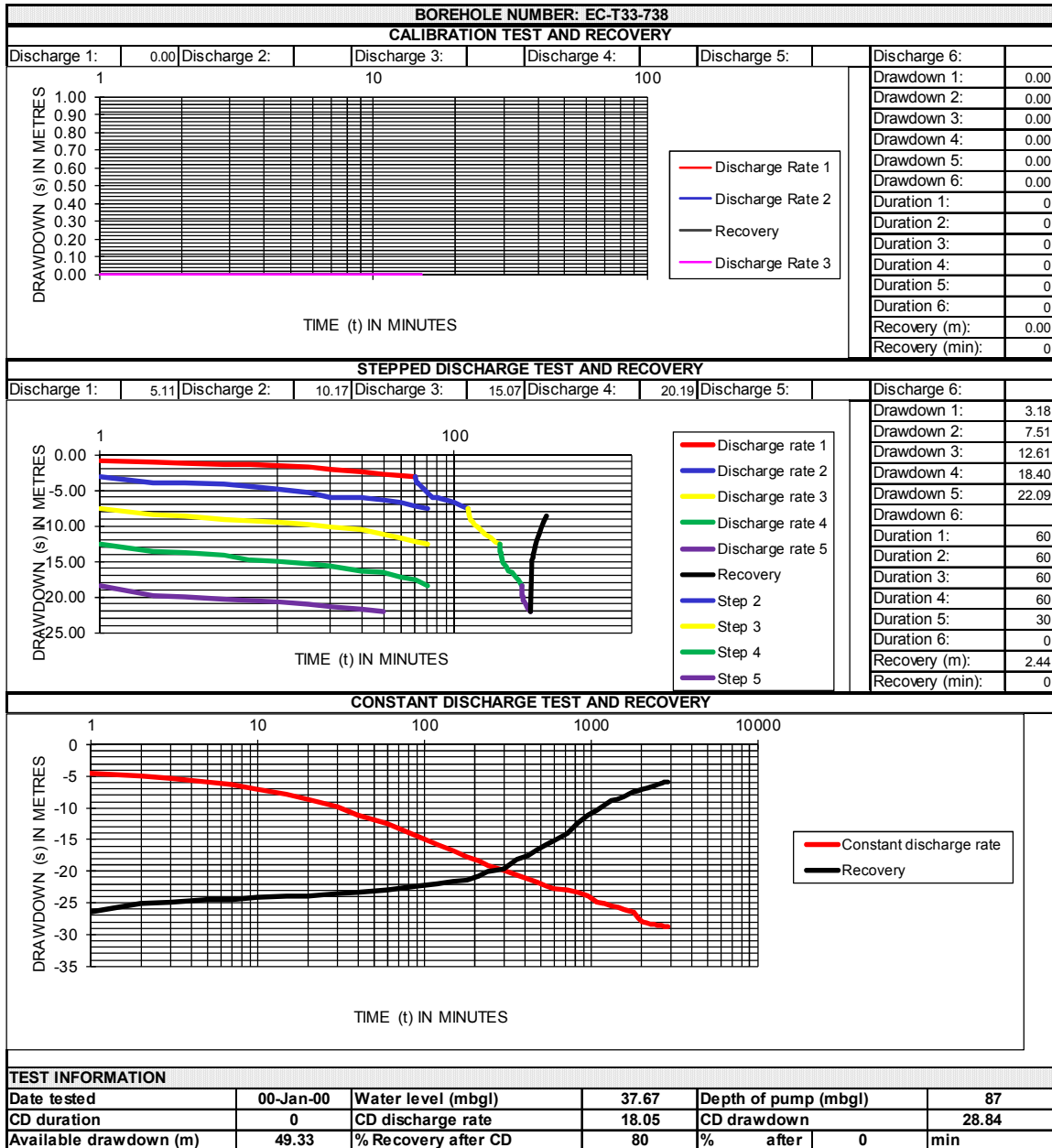


STEPPED DISCHARGE TEST AND RECOVERY																	
BOREHOLE NO. :		EC-T33-738		PROJECT:		Umzimwubu Ward 13											
ALTERNATIVE NO. :		0		SITE NAME:		0											
ALTERNATIVE NO. :		0		CLIENT:		0											
BOREHOLE DEPTH (mbgl):		102.52		CASING DEPTH (mbgl):		0.00		PUMP TYPE USED:				GW 9002					
DEPTH OF PUMP (mbgl):		87.00		CASING HEIGHT (magl):		0.48		OPERATOR:				Thomas, Stanley, Yellow Cap					
PUMP INLET DIAMETER (mm):		170.000		CASING ID (mm):		0.000		CONTRACTOR:				Welltek Services					
STATIC WATER LEVEL (mbgl):		37.67		DATUM LEVEL (magl):		0.47											
DISCHARGE RATE 1			Time	Recovery 1	DISCHARGE RATE 2			Time	Recovery 2	DISCHARGE RATE 3			Time	Recovery 3			
DATE:		23-Aug-12		(min)	(m)	DATE:		23-Aug-12		(min)	(m)	DATE:		23-Aug-12		(min)	(m)
TIME:		11:45 AM		1		TIME:		12:45 PM		1		TIME:		01:45 PM		1	
Time	Drawdown	Yield	2		Time	Drawdown	Yield	2		Time	Drawdown	Yield	2				
(min)	(m)	(l/s)	3		(min)	(m)	(l/s)	3		(min)	(m)	(l/s)	3				
1	0.83		5		1	3.92		5		1	8.47		5				
2	1.03	5.110	7		2	4.04	10.170	7		2	8.69	15.070	7				
3	1.19		10		3	4.14		10		3	9.15		10				
5	1.37		15		5	4.47		15		5	9.37		15				
7	1.41	5.110	20		7	4.84	10.170	20		7	9.56	15.070	20				
10	1.49		30		10	5.42		30		10	9.86		30				
15	1.76		40		15	5.95		40		15	10.24		40				
20	1.99	5.110	50		20	5.99	10.170	50		20	10.59	15.070	50				
30	2.37		60		30	6.34		60		30	11.22		60				
40	2.69		70		40	6.80		70		40	11.76		70				
50	2.95	5.110	80		50	7.17	10.170	80		50	12.17	15.070	80				
60	3.18		90		60	7.51		90		60	12.61		90				
70			100		70			100		70			100				
80			110		80			110		80			110				
90			120		90			120		90			120				
100			150		100			150		100			150				
110			180		110			180		110			180				
120			210		120			210		120			210				
Average yield: 5.11			(l/s)		Average yield: 10.17					Average yield: 15.07							
DISCHARGE RATE 4			Time	Recovery 4	DISCHARGE RATE 5			Time	Recovery 5	DISCHARGE RATE 6			Time	Recovery			
DATE:		23-Aug-12		(min)	(m)	DATE:		23-Aug-12		(min)	(m)	DATE:		23-Aug-12		(min)	(m)
TIME:		02:45 PM		1		TIME:		15:45		1		TIME:				1	15.70
Time	Drawdown	Yield	2		Time	Drawdown	Yield	2		Time	Drawdown	Yield	2		15.10		
(min)	(m)	(l/s)	3		(min)	(m)	(l/s)	3		(min)	(m)	(l/s)	3		14.82		
1	13.59		5		1	19.80		5		1			5		14.44		
2	13.82	20.19	7		2	20.07		7		2			7		14.10		
3	14.21		10		3	20.38		10		3			10		13.54		
5	14.77		15		5	20.60	26.31	15		5			15		12.76		
7	15.00	20.19	20		7	20.77		20		7			20		12.13		
10	15.26		30		10	21.06		30		10			30		11.20		
11	15.66		40		15	21.35	26.31	40		15			40		10.13		
12	16.30		50		20	21.68		50		20			50		9.31		
30	16.63	20.19	60		30	22.09		60		30			60		8.62		
40	17.16		70		40			70		40			70		8.05		
50	17.61		80		50			80		50			80		7.49		
60	18.40	20.19	90		60			90		60			90		7.05		
70			100		70			100		70			100		6.59		
80			110		80			110		80			110		6.21		
90			120		90			120		90			120		5.82		
100			150		100			150		100			150		5.09		
110			180		110			180		110			180		4.37		
120			210		120			210		120			210		3.84		
Average yield: 20.19																	
COMMENTS:									300	180			300	2.9			
									360	210			360	2.44			
									420	240			420				
									480	300			480				
									540	360			540				
									600	420			600				
									660	480			660				
									720								
									780				780				
									Average yield:			720					

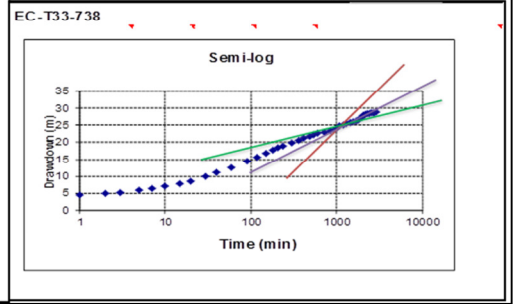
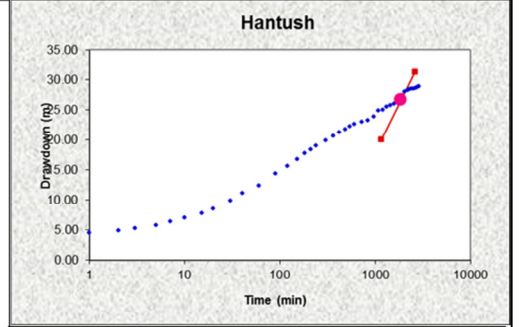
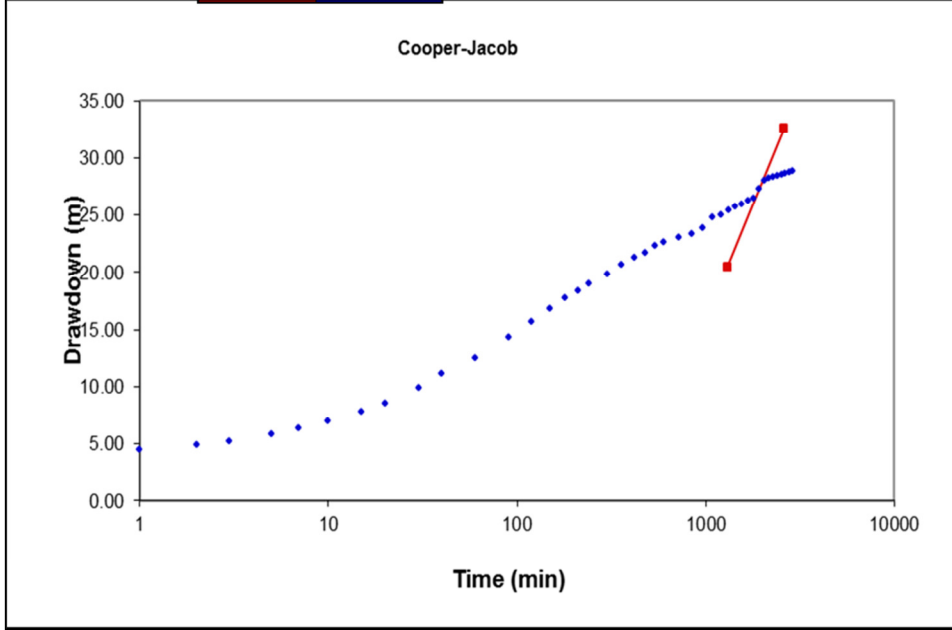
DISCHARGE BOREHOLE				OBSERVATION BOREHOLE 1			OBSERVATION BOREHOLE 2			OBSERVATION BOREHOLE 3		
Time	Draw down	Yield	Recovery	Time	Drawdown	Recovery	Time	Drawdown	Recovery	Time	Draw down	Recovery
(min)	(m)	(l/s)	(m)	(min)	(m)	(m)	(min)	(m)	(m)	(min)	(m)	(m)
2400	28.46	18.05	6.50	1500			1500			1500		
2520	28.54		6.22	1560			1560			1560		
2640	28.62		6.08	1620			1620			1620		
2760	28.70	18.05	5.96	1680			1680			1680		
2880	28.84		5.82	1740			1740			1740		
1800				1800			1800			1800		
1860				1860			1860			1860		
1920				1920			1920			1920		
1980				1980			1980			1980		
2040				2040			2040			2040		
2100				2100			2100			2100		
2160				2160			2160			2160		
2220				2220			2220			2220		
2280				2280			2280			2280		
2340				2340			2340			2340		
2400				2400			2400			2400		
2460				2460			2460			2460		
2520				2520			2520			2520		
2580				2580			2580			2580		
2640				2640			2640			2640		
2700				2700			2700			2700		
2760				2760			2760			2760		
2820				2820			2820			2820		
2880				2880			2880			2880		

DESCRIPTION:	QUANTITY:	UNIT:	S U M M A R Y	DESCRIPTION:	QUANTITY:	UNIT	
ESTABLISHMENT		Sum			STRAIGHTNESS TEST:		No.
INTER HOLE MOVE > 10 km		Km.			VERTICALITY TEST:		No.
FROM: SITE NAME:					CASING DETECTION:		No.
BOREHOLE No:					STEEL BOREHOLE COVER:		No.
INTER HOLE MOVE < 10 km:		No.			BOREHOLE MARKING:		No.
REMOVAL AND RE-ERECTION OF PUMP HOUSE:		No.			SITE CLEANING / FINISHING:		No.
REMOVAL OF EXISTING EQUIPMENT:		No.			REPORTING & DATA RECORDING:		No.
RE-INSTALLATION OF EXISTING EQUIPMENT:		No.			SLUG TEST:		No.
WORK TIME RATE (REPAIRS):		Hour			LAYFLAT (m):		m
STANDING TIME:		Hour			BOREHOLE DEPTH AFTER TEST:		m
LATITUDE: -30.73309	LONGITUDE: 28.87139				BOREHOLE WATERLEVEL AFTER TEST:		m

TEST DESCRIPTION	STEP	1	2	3	4	5	6	TOTAL:	RECOVERY:	RECOVERY TEST				
CALIBRATION TEST:								(min) (hrs)	(m) (min)	TIME TOTAL (hrs): 54.00				
TEST DURATION (Minutes)								0	0.00	0.00	Cal	Steps	CD	Total
TEST YIELD (l/s)								MAXIMUM (l/s) 0.0			0	360	2880	3240
DRAWDOWN (m)								MAXIMUM (m)			DRAWDOWN TOTALS (CD):			
MULTI-RATE / STEP DRAWDOWN:											AVAILABLE	UTIL-	%	
TEST DURATION (Minutes)	60	60	60	60	30			270	4.50	2.44	ISED			
TEST YIELD (l/s)	5.11	10.17	15.07	20.19	26.31			MAXIMUM (l/s) 26.3			49.3	28.84	58.46	
DRAWDOWN (m)	3.18	7.51	12.61	18.40	22.09			MAXIMUM (m) 22.1						
CONSTANT DISCHARGE TEST	TEST DURATION		TEST YIELD		DRAWDOWN		RECOVERY:							
	(min)	(hrs)	(l/s)		(m)		(m)	%	(min)	(hrs)				
	2880	48.00	18.05		28.84		5.82	79.82	0	0.00				
OBSERVATION BOREHOLES:	No.	720	1440	2880	>2880 (min)		TOTAL:							
	of boreholes	(min)	(min)	(min)	nr.	Time	(min)	(hrs)						
							0	0.00						



Cooper-Jacob method		No boundaries	1 no-flow	2 no-flow	Closed	Leaky Aquifer: Hantush Method	
EC-T33-738		Q _{sust} = 2.64	1.32	0.87	0.66	EC-T33-738	
T(m ² /d) = 7.1		Avg. Q _{sust} = 1.37		std. dev = 0.89		T(m ² /d) = 2.3	
S = 4.64E+00						S = 2.90E-01	
						L (m) = 2	

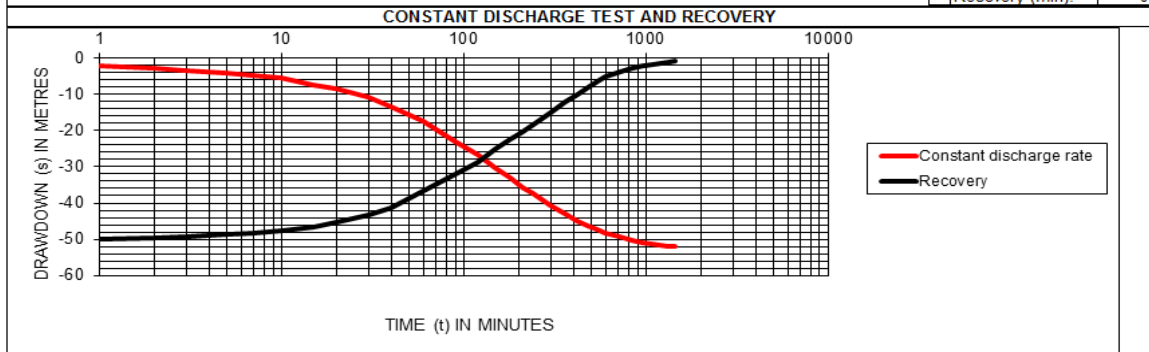
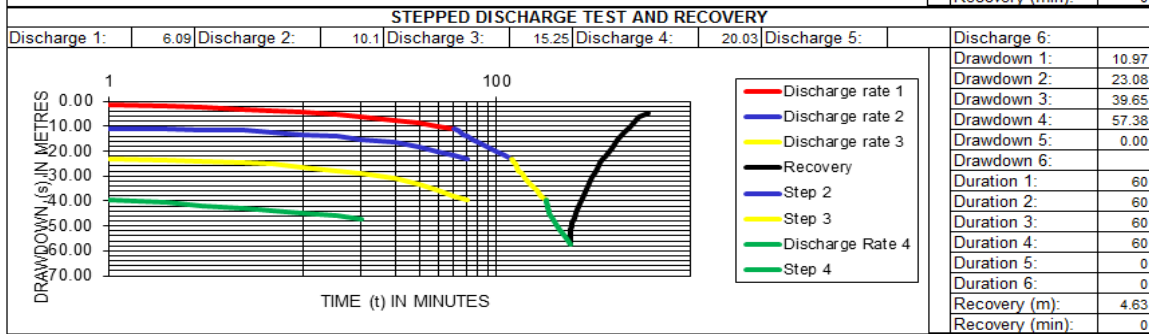
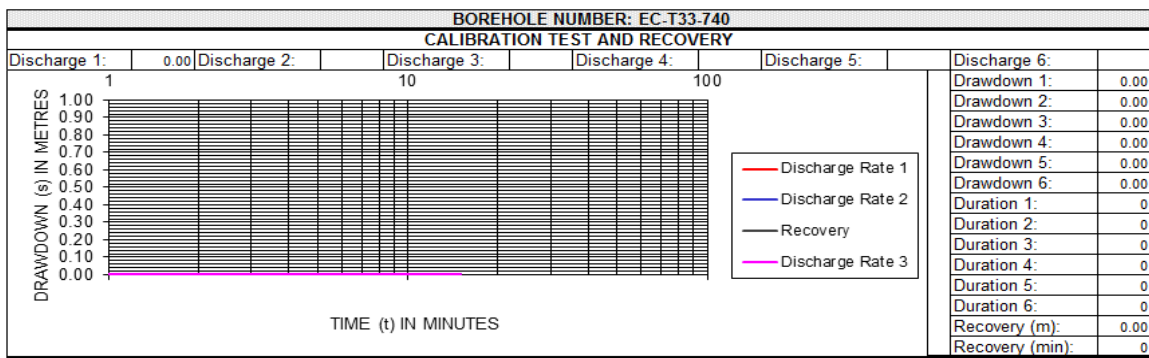


9.3.2 Ward 15 Testing Data (Step and Constant)

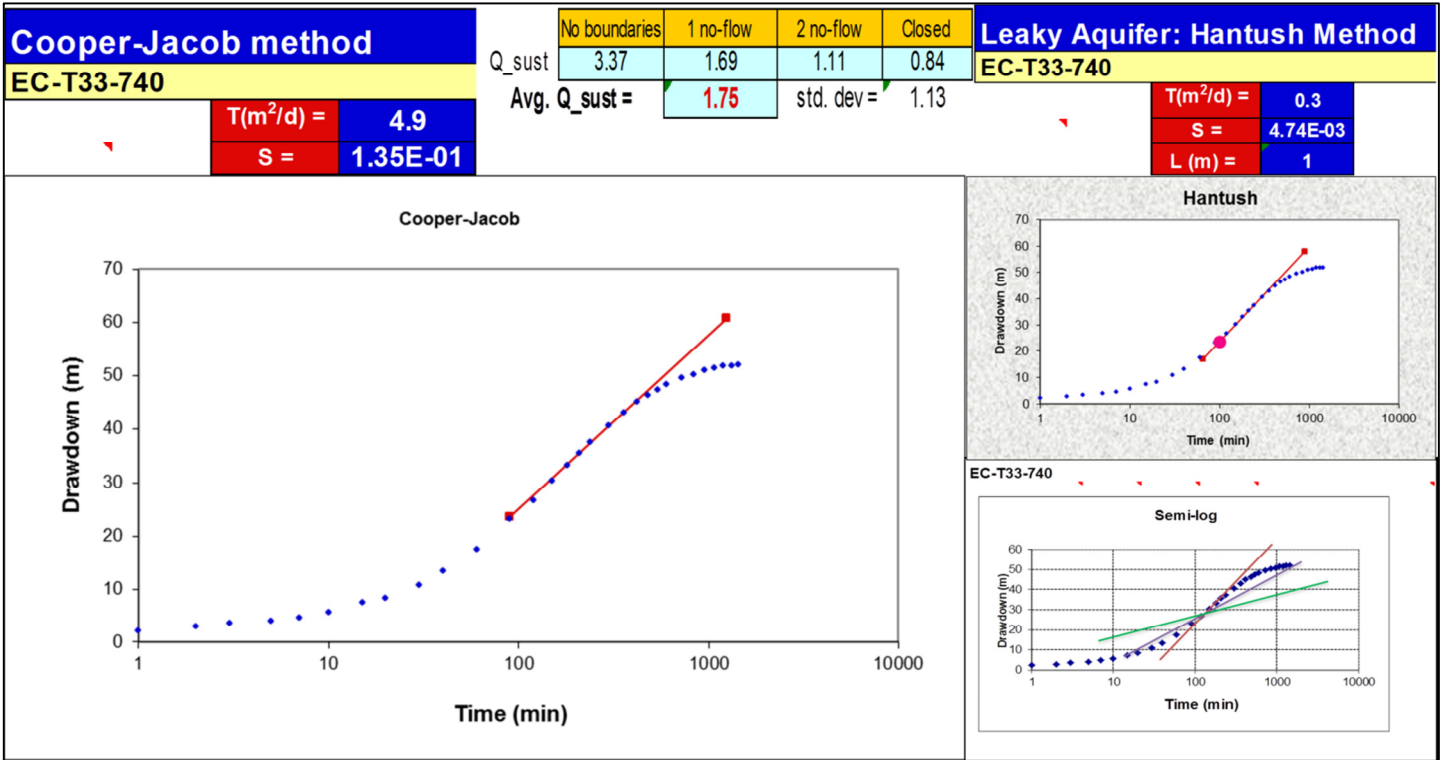
STEPPED DISCHARGE TEST AND RECOVERY														
BOREHOLE NO. :		EC-T33-740			PROJECT:		Umzimvubu Ward 15							
ALTERNATIVE NO. :		0			SITE NAME:		0							
ALTERNATIVE NO. :		0			CLIENT:		0							
BOREHOLE DEPTH (mbgl):		116.00		CASING DEPTH (mbgl):		0.00		PUMP TYPE USED: GW 9002						
DEPTH OF PUMP (mbgl):		69.00		CASING HEIGHT (magl):		0.44		OPERATOR: Yellow Cap, Thomas, Pop Eye, Junior						
PUMP INLET DIAMETER (mm):		170.000		CASING ID (mm):		0.000		CONTRACTOR: Welltek Services						
STATIC WATER LEVEL (mbgl):		0.00		DATUM LEVEL (magl):		0.88								
DISCHARGE RATE 1			Time	Recovery 1	DISCHARGE RATE 2			Time	Recovery 2	DISCHARGE RATE 3		Time	Recovery 3	
DATE:		12-Aug-12			DATE:		12-Aug-12			DATE:		12-Aug-12		
TIME:		07:00 AM			TIME:		08:00 AM			TIME:		09:00 AM		
Time	Drawdown	Yield		Time	Drawdown	Yield		Time	Drawdown	Yield		Time	Recovery	
(min)	(m)	(l/s)		(min)	(m)	(l/s)		(min)	(m)	(l/s)		(min)	(m)	
1	1.44	5		1	11.11	5		1	23.79	5		1		
2	2.07	7		2	11.40	10.100		2	24.22	15.250		2		
3	2.59	10		3	11.73			3	24.42			3		
5	3.17	15		5	12.33			5	25.12			5		
7	3.61	20		7	13.30	10.100		7	26.48	15.250		7		
10	4.20	30		10	14.00			10	27.75			10		
15	5.25	40		15	15.27			15	29.18			15		
20	6.07	50		20	16.31	10.100		20	30.71	15.250		20		
30	7.46	60		30	18.24			30	33.24			30		
40	8.71	70		40	20.02			40	35.65			40		
50	9.93	80		50	21.52	10.100		50	37.95	15.250		50		
60	10.97	90		60	23.08			60	39.65			60		
70		100		70				70				70		
80		110		80				80				80		
90		120		90				90				90		
100		150		100				100				100		
110		180		110				110				110		
120		210		120				120				120		
Average yield:		6.09		Average yield:		10.1		Average yield:		15.25				
DISCHARGE RATE 4			Time	Recovery 4	DISCHARGE RATE 5			Time	Recovery 5	DISCHARGE RATE 6		Time	Recovery	
DATE:		12-Aug-12			DATE:		12-Aug-12			DATE:		12-Aug-12		
TIME:		10:00			TIME:					TIME:				
Time	Drawdown	Yield		Time	Drawdown	Yield		Time	Drawdown	Yield		Time	Recovery	
(min)	(m)	(l/s)		(min)	(m)	(l/s)		(min)	(m)	(l/s)		(min)	(m)	
1	40.63	5		1		5		1		5		1	50.93	
2	42.04	20.03		2		7		2		7		2	50.31	
3	42.77	10		3		10		3		10		3	49.74	
5	44.15	15		5		15		5		15		5	48.72	
7	44.69	20.03		7		20		7		20		7	47.88	
10	45.82	30		10		30		10		30		10	46.96	
11	47.53	40		15		40		15		40		15	44.81	
20	49.12	20.03		20		50		20		50		20	43.67	
30	51.41	60		30		60		30		60		30	40.81	
40	53.53	70		40		70		40		70		40	37.87	
50	55.05	20.03		50		80		50		80		50	35.20	
60	57.38	90		60		90		60		90		60	32.93	
70		100		70		100		70		100		70	30.54	
80		110		80		110		80		110		80	28.87	
90		120		90		120		90		120		90	27.05	
100		150		100		150		100		150		100	24.77	
110		180		110		180		110		180		110	23.34	
120		210		120		210		120		210		120	22.33	
Average yield:		20.03										240		
COMMENTS:												240		
												300		
												360		
												420		
												480		
												540		
												600		
												660		
												720		
												780		
										Average yield:		720		

DESCRIPTION:	QUANTITY:	UNIT:	SUMMARY	DESCRIPTION:	QUANTITY:	UNIT:
ESTABLISHMENT		Sum		STRAIGHTNESS TEST:		No.
INTER HOLE MOVE > 10 km		Km.		VERTICALITY TEST:		No.
FROM: SITE NAME:				CASING DETECTION:		No.
BOREHOLE No:				STEEL BOREHOLE COVER:		No.
INTER HOLE MOVE < 10 km:		No.		BOREHOLE MARKING:		No.
REMOVAL AND RE-ERECTION OF PUMP HOUSE:		No.		SITE CLEANING / FINISHING:		No.
REMOVAL OF EXISTING EQUIPMENT:		No.		REPORTING & DATA RECORDING:		No.
RE-INSTALLATION OF EXISTING EQUIPMENT:		No.		SLUG TEST:		No.
WORK TIME RATE (REPAIRS):		Hour		LAYFLAT (m):		m
STANDING TIME:		Hour	BOREHOLE DEPTH AFTER TEST:		m	
LATITUDE:			BOREHOLE WATERLEVEL AFTER TEST:		m	
	LONGITUDE:					

TEST DESCRIPTION	STEP	1	2	3	4	5	6	TOTAL:	RECOVERY:	RECOVERY TEST					
CALIBRATION TEST:								(min) (hrs)	(m) (min)	TIME TOTAL (hrs): 30.00					
TEST DURATION (Minutes)								0	0.00	0.00	0.00	Cal	Steps	CD	Total
TEST YIELD (l/s)								MAXIMUM (l/s)	0.0			0	360	1440	1800
DRAWDOWN (m)								MAXIMUM (m)				DRAWDOWN TOTALS (CD):			
MULTI-RATE / STEP DRAWDOWN:												AVAILABLE	UTIL-	%	
TEST DURATION (Minutes)	60	60	60	60				240	4.00	4.63		USED			
TEST YIELD (l/s)	6.09	10.10	15.25	20.03				MAXIMUM (l/s)	20.0			69.0	51.97	75.32	
DRAWDOWN (m)	11.0	23.08	39.65	57.38				MAXIMUM (m)	57.4						
CONSTANT DISCHARGE TEST	TEST DURATION		TEST YIELD		DRAWDOWN		RECOVERY:								
	(min)	(hrs)	(l/s)	(m)	(m)	(m)	%	(min)	(hrs)						
	1440	24.00	10.09	51.97	0.90	98.27	1440	24.00							
OBSERVATION BOREHOLES:	No.	720	1440	2880	>2880 (min)	TOTAL:									
	of boreholes	(min)	(min)	(min)	nr.	Time	(min)	(hrs)							
							0	0.00							

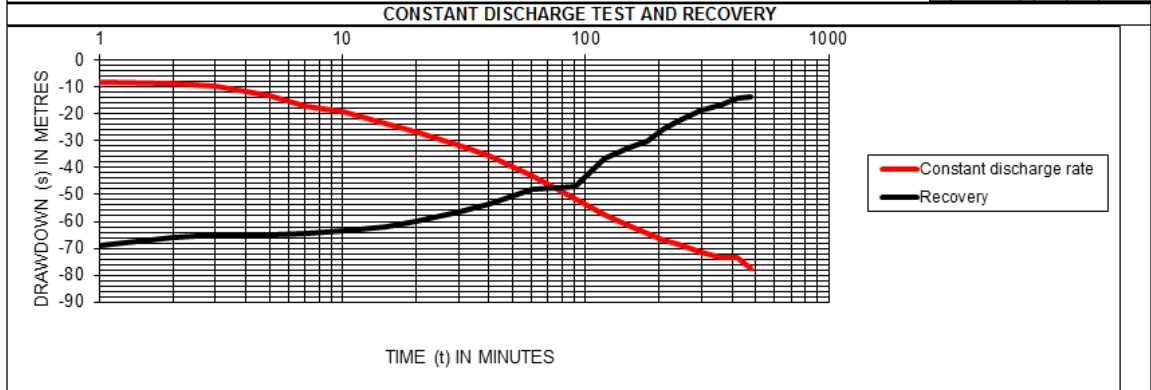
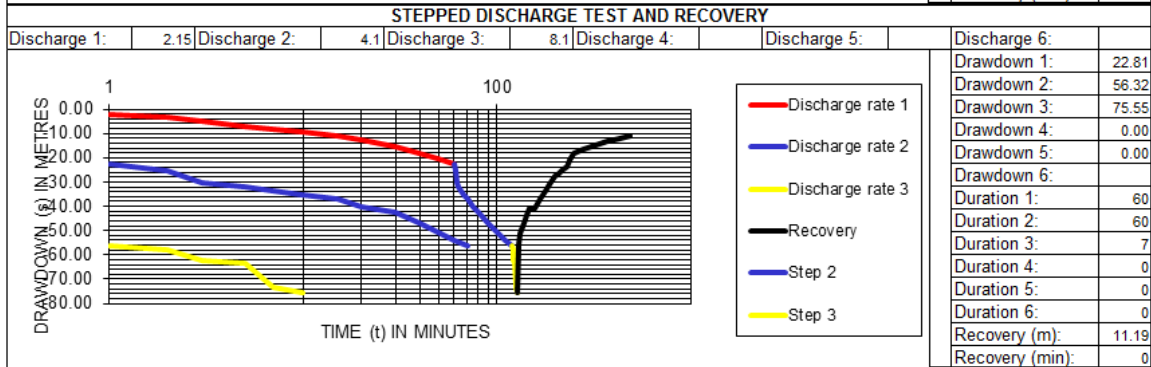
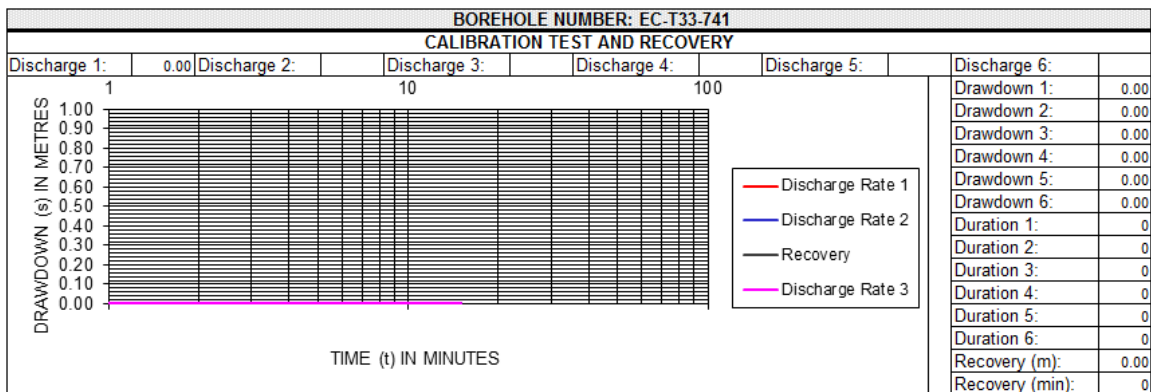


TEST INFORMATION					
Date tested	30-Aug-12	Water level (mbgl)	0.00	Depth of pump (mbgl)	69
CD duration	1440	CD discharge rate	10.09	CD drawdown	51.97
Available drawdown (m)	69	% Recovery after CD	98	% after	1440 min



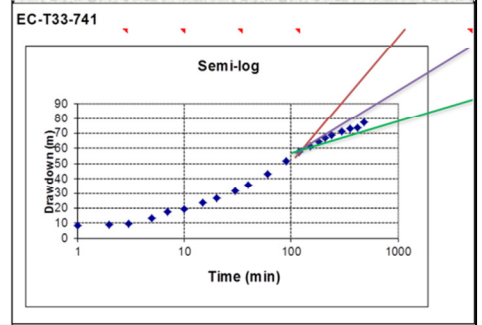
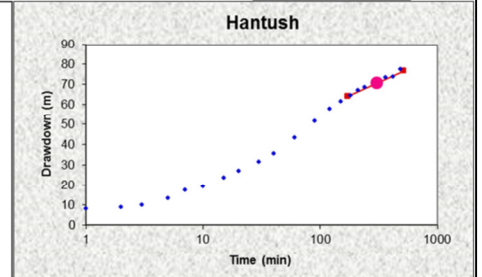
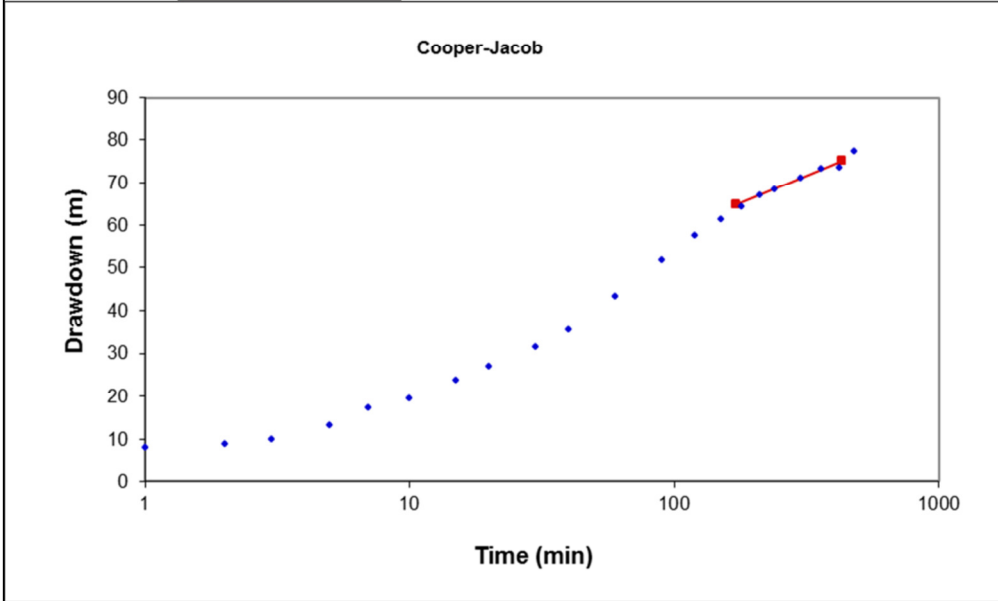
STEPPED DISCHARGE TEST AND RECOVERY																	
BOREHOLE NO. :		EC-T33-741			PROJECT:		Umzimwubu Ward 15										
ALTERNATIVE NO. :		0			SITE NAME:		0										
ALTERNATIVE NO. :		0			CLIENT:		0										
BOREHOLE DEPTH (mbgl):		119.56		CASING DEPTH (mbgl):		0.00		PUMP TYPE USED:		BP 40							
DEPTH OF PUMP (mbgl):		90.00		CASING HEIGHT (magl):		0.38		OPERATOR:		Stanley, Phillip, Junior							
PUMP INLET DIAMETER (mm):		170.000		CASING ID (mm):		0.000		CONTRACTOR:		Welltek Services							
STATIC WATER LEVEL (mbgl):		14.13		DATUM LEVEL (magl):		0.36											
DISCHARGE RATE 1			Time	Recovery 1	DISCHARGE RATE 2			Time	Recovery 2	DISCHARGE RATE 3			Time	Recovery 3			
DATE:		29-Aug-12		(min)	(m)	DATE:		29-Aug-12		(min)	(m)	DATE:		29-Aug-12		(min)	(m)
TIME:		02:00 PM		1		TIME:		03:00 PM		1		TIME:		04:00 PM		1	
Time	Drawdown	Yield	2		Time	Drawdown	Yield	2		Time	Drawdown	Yield	2				
(min)	(m)	(l/s)	3		(min)	(m)	(l/s)	3		(min)	(m)	(l/s)	3				
1	2.28		5		1	25.45		5		1	58.05	8.100	5				
2	3.28		7		2	30.12		7		2	62.35		7				
3	5.01	2.150	10		3	32.16		10		3	63.44		10				
5	6.95		15		5	33.85	4.100	15		5	73.10	8.100	15				
7	8.35		20		7	35.31		20		7	75.55		20				
10	9.30		30		10	37.08		30		10			30				
15	10.82		40		15	40.15		40		15			40				
20	12.53	2.150	50		20	42.48	4.100	50		20			50				
30	15.52		60		30	46.79		60		30			60				
40	18.16		70		40	50.87		70		31			70				
50	20.58		80		50	53.95		80		50			80				
60	22.81		90		60	56.32		90		60			90				
70			100		70			100		70			100				
80			110		80			110		80			110				
90			120		90			120		90			120				
100			150		100			150		100			150				
110			180		110			180		110			180				
120			210		120			210		120			210				
Average yield: 2.15			(l/s)		Average yield: 4.1					Average yield: 8.1							
DISCHARGE RATE 4			Time	Recovery 4	DISCHARGE RATE 5			Time	Recovery 5	DISCHARGE RATE 6			Time	Recovery			
DATE:		29-Aug-12		(min)	(m)	DATE:		29-Aug-12		(min)	(m)	DATE:		29-Aug-12		(min)	(m)
TIME:				1		TIME:				1		TIME:				1	56.03
Time	Drawdown	Yield	2		Time	Drawdown	Yield	2		Time	Drawdown	Yield	2	55.90			
(min)	(m)	(l/s)	3		(min)	(m)	(l/s)	3		(min)	(m)	(l/s)	3	55.50			
1			5		1			5		1			5	51.20			
2			7		2			7		2			7	49.40			
3			10		3			10		3			10	46.91			
5			15		5			15		5			15	43.50			
7			20		7			20		7			20	41.01			
10			30		10			30		10			30	40.69			
15			40		15			40		15			40	36.88			
20			50		20			50		20			50	33.70			
30			60		30			60		30			60	31.06			
40			70		40			70		40			70	27.73			
50			80		50			80		50			80	26.40			
60			90		60			90		60			90	24.61			
70			100		70			100		70			100	23.97			
80			110		80			110		80			110	20.94			
90			120		90			120		90			120	18.23			
100			150		100			150		100			150	16.56			
110			180		110			180		110			180	15.4			
120			210		120			210		120			210	14.1			
Average yield: #DIV/0!										Average yield:							
COMMENTS:												240		240	13.21		
												300		300	12.25		
												360		360	11.19		
												420		420			
												480		480			
												540		540			
												600		600			
												660		660			
												720					
												780		Average yield:	720		

TEST DESCRIPTION	STEP	1	2	3	4	5	6	TOTAL:	RECOVERY:	RECOVERY TEST					
CALIBRATION TEST:								(min)	(hrs)	(m)	(min)	TIME TOTAL (hrs): 14.00			
TEST DURATION (Minutes)								0	0.00	0.00		Cal	Steps	CD	Total
TEST YIELD (l/s)								MAXIMUM (l/s) 0.0			0	360	480	840	
DRAWDOWN (m)								MAXIMUM (m)			DRAWDOWN TOTALS (CD):				
MULTI-RATE / STEP DRAWDOWN:												AVAILABLE	UTIL-	%	
TEST DURATION (Minutes)		60	60	7				127	2.12	11.19			ISED		
TEST YIELD (l/s)		2.15	4.10	8.10				MAXIMUM (l/s) 8.1			75.9	77.30	101.88		
DRAWDOWN (m)		22.8	56.32	75.55				MAXIMUM (m) 75.6							
CONSTANT DISCHARGE TEST		TEST DURATION		TEST YIELD		DRAWDOWN		RECOVERY:							
		(min)	(hrs)	(l/s)		(m)		(m)	%	(min)	(hrs)				
		480	8.00	3.79		77.30		13.90	82.02	480	8.00				
OBSERVATION BOREHOLES:		No.	720	1440		2880		>2880 (min)				TOTAL:			
		of boreholes	(min)	(min)		(min)		nr.	Time	(min)	(hrs)				
										0	0.00				



TEST INFORMATION					
Date tested	30-Aug-12	Water level (mbgl)	14.13	Depth of pump (mbgl)	90
CD duration	480	CD discharge rate	3.79	CD drawdown	77.3
Available drawdown (m)	75.87	% Recovery after CD	82	% after	480 min

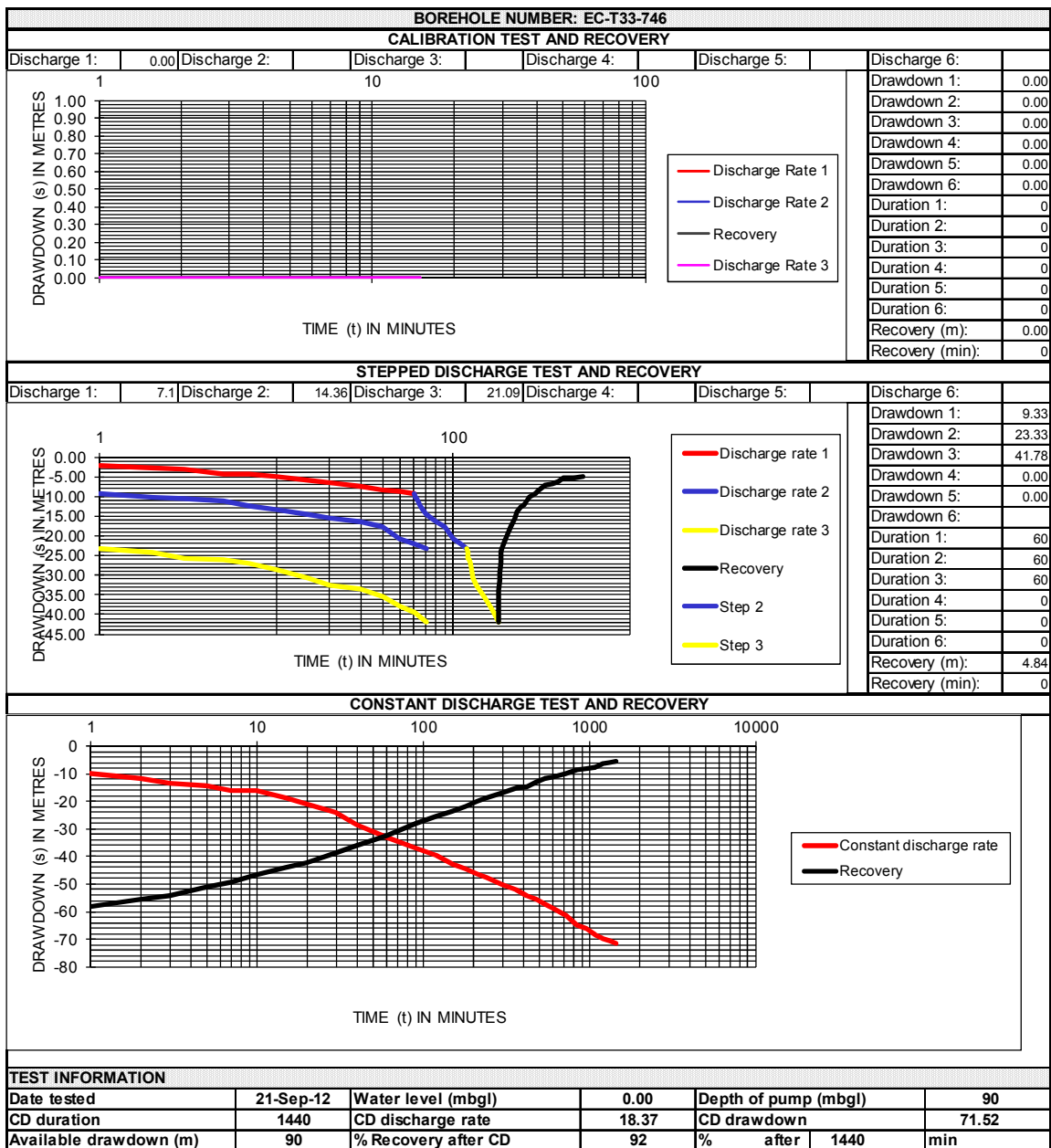
Cooper-Jacob method		<table border="1"> <tr> <td>No boundaries</td> <td>1 no-flow</td> <td>2 no-flow</td> <td>Closed</td> </tr> <tr> <td>1.83</td> <td>0.91</td> <td>0.60</td> <td>0.46</td> </tr> </table>				No boundaries	1 no-flow	2 no-flow	Closed	1.83	0.91	0.60	0.46	Leaky Aquifer: Hantush Method	
No boundaries	1 no-flow	2 no-flow	Closed												
1.83	0.91	0.60	0.46												
EC-T33-741		Q _{sust}	Avg. Q _{sust} =		std. dev =	EC-T33-741									
	T(m ² /d) =	2.4	0.95		0.61	T(m ² /d) =	2.2								
	S =	1.87E-03				S =	1.97E-04								
						L (m) =	64								



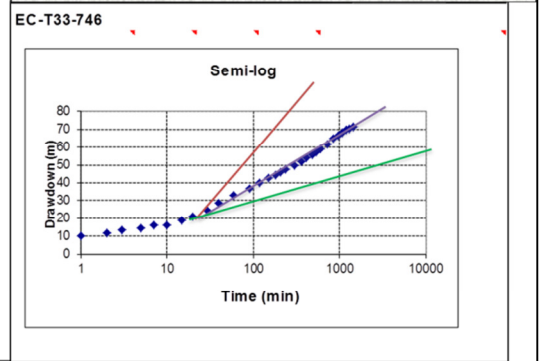
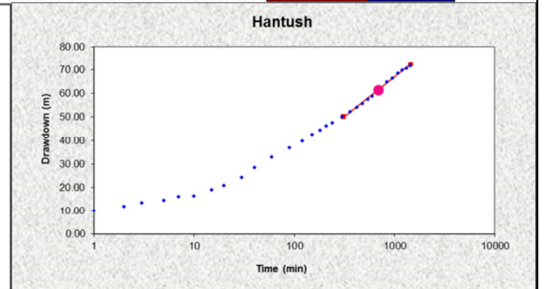
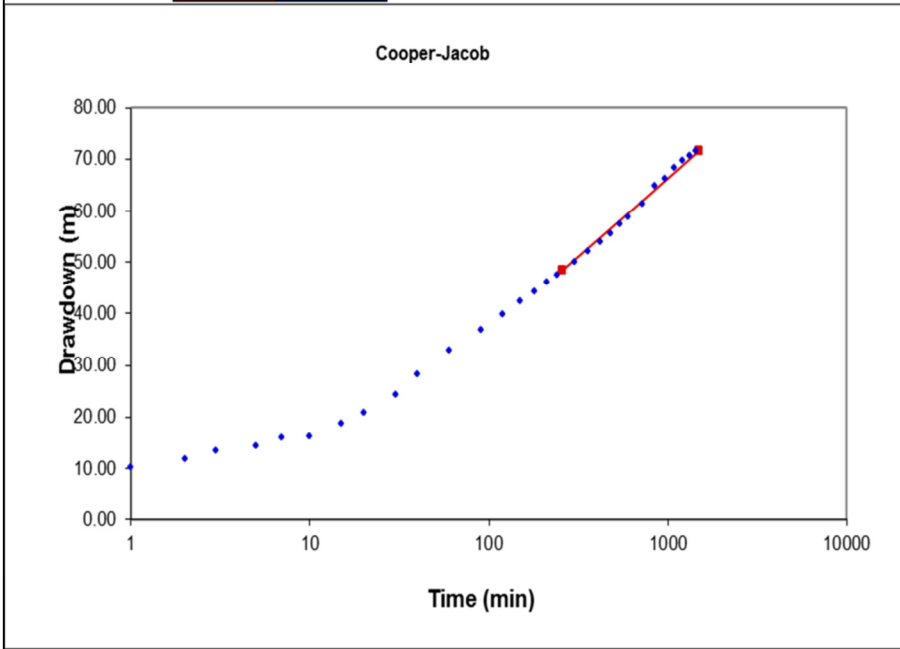
STEPPED DISCHARGE TEST AND RECOVERY																	
BOREHOLE NO. :		EC-T33-746			PROJECT:		Umzimwubu Ward 15										
ALTERNATIVE NO. :		0			SITE NAME:		0										
ALTERNATIVE NO. :		0			CLIENT:		0										
BOREHOLE DEPTH (mbgl):		128.54		CASING DEPTH (mbgl):		0.00		PUMP TYPE USED:				GW 9002					
DEPTH OF PUMP (mbgl):		90.00		CASING HEIGHT (magl):		0.28		OPERATOR:				Yellow, Junior					
PUMP INLET DIAMETER (mm):		170.000		CASING ID (mm):		0.000		CONTRACTOR:				Welltek Services					
STATIC WATER LEVEL (mbgl):		0.00		DATUM LEVEL (magl):		0.86											
DISCHARGE RATE 1			Time	Recovery 1	DISCHARGE RATE 2			Time	Recovery 2	DISCHARGE RATE 3			Time	Recovery 3			
DATE:		20-Sep-12		(min)	(m)	DATE:		20-Sep-12		(min)	(m)	DATE:		20-Sep-12		(min)	(m)
TIME:		11:45 AM		1		TIME:		12:45 PM		1		TIME:		01:45 PM		1	
Time	Drawdown	Yield	2		Time	Drawdown	Yield	2		Time	Drawdown	Yield	2				
(min)	(m)	(l/s)	3		(min)	(m)	(l/s)	3		(min)	(m)	(l/s)	3				
1	2.16		5		1	10.32		5		1	24.09		5				
2	2.70	7.100	7		2	10.61	14.360	7		2	25.63	21.090	7				
3	3.12		10		3	11.04		10		3	26.12		10				
5	4.24		15		5	12.52	14.360	15		5	27.04		15				
7	4.46	7.100	20		7	13.40		20		7	28.44	21.090	20				
10	5.03		30		10	14.44		30		10	30.71		30				
15	5.84		40		15	15.50		40		15	32.53		40				
20	6.60	7.100	50		20	16.36	14.360	50		20	33.54	21.090	50				
30	7.48		60		30	17.61		60		30	35.24		60				
40	8.36		70		40	20.78		70		40	37.75		70				
50	8.71	7.100	80		50	22.04	14.360	80		50	39.49	21.090	80				
60	9.33		90		60	23.33		90		60	41.78		90				
70			100		70			100		70			100				
80			110		80			110		80			110				
90			120		90			120		90			120				
100			150		100			150		100			150				
110			180		110			180		110			180				
120			210		120			210		120			210				
Average yield: 7.1			(l/s)		Average yield: 14.36					Average yield: 21.09							
DISCHARGE RATE 4			Time	Recovery 4	DISCHARGE RATE 5			Time	Recovery 5	DISCHARGE RATE 6			Time	Recovery			
DATE:		20-Sep-12		(min)	(m)	DATE:		20-Sep-12		(min)	(m)	DATE:		20-Sep-12		(min)	(m)
TIME:				1		TIME:				1		TIME:				1	33.75
Time	Drawdown	Yield	2		Time	Drawdown	Yield	2		Time	Drawdown	Yield	2				
(min)	(m)	(l/s)	3		(min)	(m)	(l/s)	3		(min)	(m)	(l/s)	3				
1			5		1			5		1			5	26.64			
2			7		2			7		2			7	24.04			
3			10		3			10		3			10	22.93			
5			15		5			15		5			15	21.54			
7			20		7			20		7			20	19.80			
10			30		10			30		10			30	17.76			
15			40		15			40		15			40	15.74			
20			50		20			50		20			50	14.00			
30			60		30			60		30			60	12.75			
40			70		40			70		40			70	12.15			
50			80		50			80		50			80	11.24			
60			90		60			90		60			90	10.28			
70			100		70			100		70			100	9.76			
80			110		80			110		80			110	9.27			
90			120		90			120		90			120	8.82			
100			150		100			150		100			150	7.14			
110			180		110			180		110			180	6.68			
120			210		120			210		120			210	6.12			
Average yield: #DIV/0!										Average yield: 5.4							
COMMENTS:									300		180		300	5.13			
									360		210		360	4.84			
									420		240		420				
									480		300		480				
									540		360		540				
									600		420		600				
									660		480		660				
									720								
									780		Average yield:			720			

TEST DESCRIPTION	STEP	1	2	3	4	5	6	TOTAL:	RECOVERY:
CALIBRATION TEST:								(min) (hrs)	(m) (min)
TEST DURATION (Minutes)								0 0.00	0.00
TEST YIELD (l/s)								MAXIMUM (l/s)	0.0
DRAWDOWN (m)								MAXIMUM (m)	
MULTI-RATE / STEP DRAWDOWN:									
TEST DURATION (Minutes)	60	60	60					180 3.00	4.84
TEST YIELD (l/s)	7.10	14.36	21.09					MAXIMUM (l/s)	21.1
DRAWDOWN (m)	9.3	23.33	41.78					MAXIMUM (m)	41.8
CONSTANT DISCHARGE TEST		TEST DURATION		TEST YIELD		DRAWDOWN		RECOVERY:	
		(min)	(hrs)	(l/s)		(m)		(m)	%
		1440	24.00	18.37		71.52		5.70	92.03
OBSERVATION BOREHOLES:		No. of boreholes		720		1440		2880	
								>2880 (min)	
								nr. Time	
								TOTAL:	
								(min) (hrs)	
								0 0.00	

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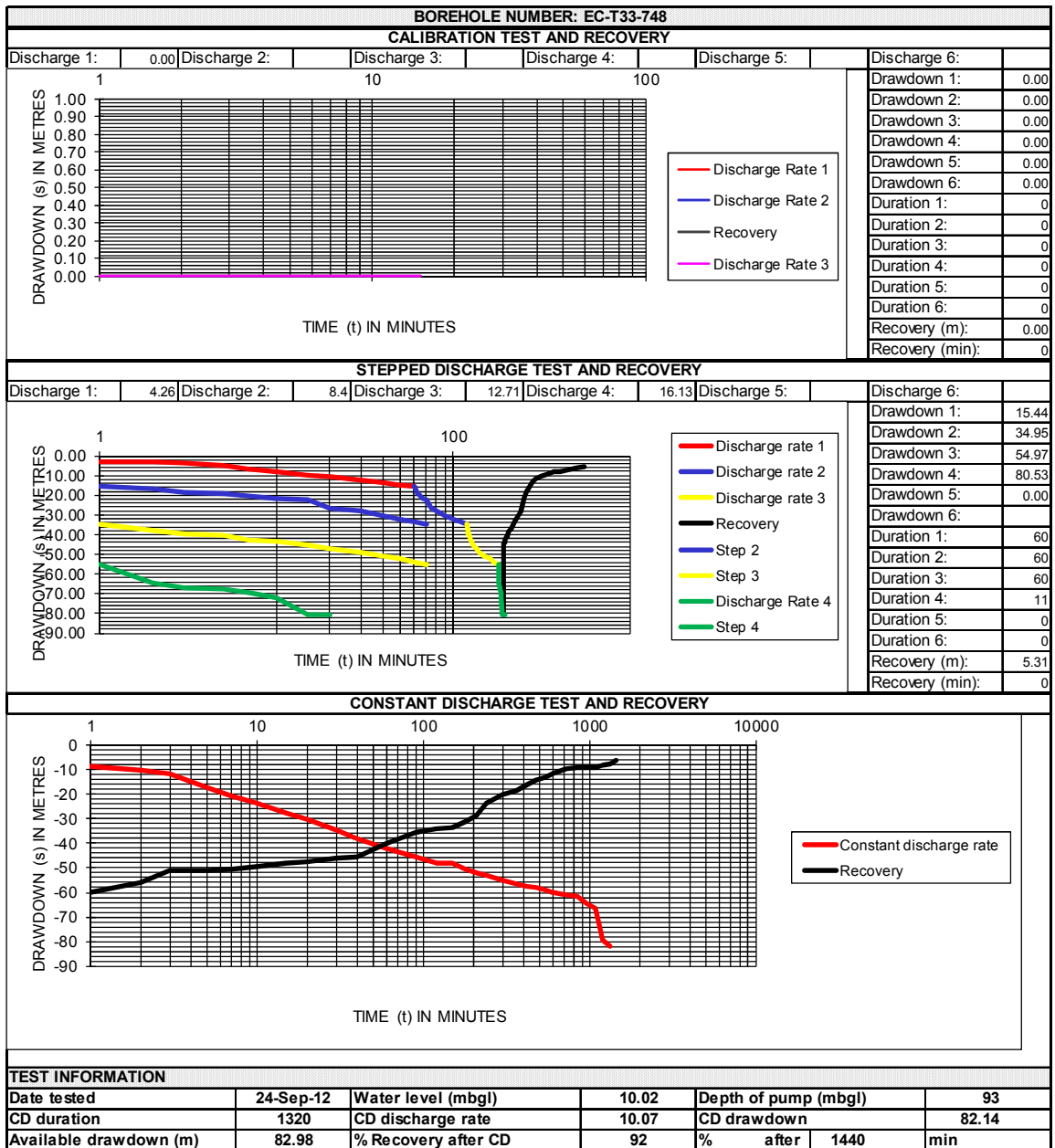
Cooper-Jacob method		Q_sust	No boundaries	1 no-flow	2 no-flow	Closed	Leaky Aquifer: Hantush Method	
EC-T33-746			5.82	2.91	1.92	1.46	EC-T33-746	
		Avg. Q_sust =	3.03		std. dev = 1.96		T(m ² /d) =	7.4
		T(m ² /d) =	9.6				S =	1.23E-02
		S =	1.01E-01				L (m) =	21



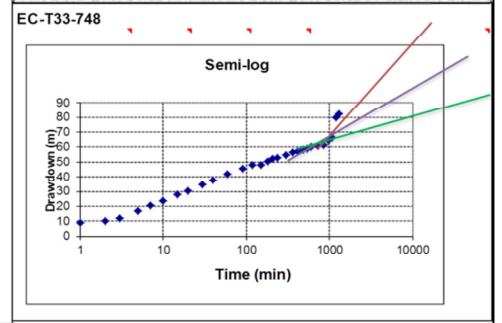
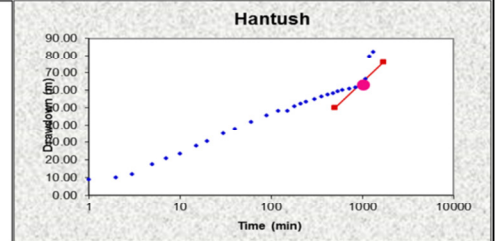
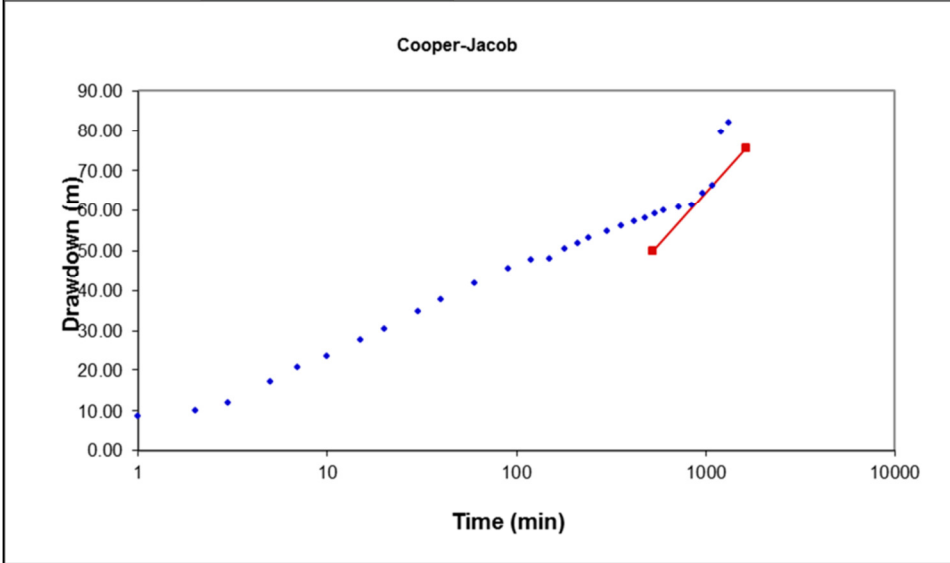
STEPPED DISCHARGE TEST AND RECOVERY																	
BOREHOLE NO. :		EC-T33-748			PROJECT:		Umzimwubu Ward 15										
ALTERNATIVE NO. :		0			SITE NAME:		0										
ALTERNATIVE NO. :		0			CLIENT:		0										
BOREHOLE DEPTH (mbgl):		120.62		CASING DEPTH (mbgl):		0.00		PUMP TYPE USED:				GW 9002					
DEPTH OF PUMP (mbgl):		93.00		CASING HEIGHT (magl):		0.18		OPERATOR:				Stanley, Yellow & Junior					
PUMP INLET DIAMETER (mm):		170.000		CASING ID (mm):		0.000		CONTRACTOR:				Welltek Services					
STATIC WATER LEVEL (mbgl):		10.02		DATUM LEVEL (magl):		0.63											
DISCHARGE RATE 1			Time	Recovery 1	DISCHARGE RATE 2			Time	Recovery 2	DISCHARGE RATE 3			Time	Recovery 3			
DATE:		24-Sep-12		(min)	(m)	DATE:		24-Sep-12		(min)	(m)	DATE:		24-Sep-12		(min)	(m)
TIME:		07:00 AM		1		TIME:		08:00 AM		1		TIME:		09:00 AM		1	
Time	Drawdown	Yield	2		Time	Drawdown	Yield	2		Time	Drawdown	Yield	2				
(min)	(m)	(l/s)	3		(min)	(m)	(l/s)	3		(min)	(m)	(l/s)	3				
1	2.90		5		1	16.52		5		1	37.94	12.710	5				
2	3.37		7		2	18.37		7		2	39.72		7				
3	3.90		10		3	19.02		10		3	40.52		10				
5	5.03		15		5	20.37		15		5	42.54	12.710	15				
7	7.09	4.260	20		7	21.59		20		7	43.54		20				
10	8.18		30		10	22.40		30		10	45.50		30				
15	9.97		40		15	26.82	8.400	40		15	47.21	12.710	40				
20	10.35		50		20	28.18		50		20	49.24		50				
30	12.45	4.260	60		30	30.39		60		30	50.67		60				
40	13.72		70		40	32.27		70		40	52.33	12.710	70				
50	14.58		80		50	33.55	8.400	80		50	53.77		80				
60	15.44		90		60	34.95		90		60	54.97		90				
70			100		70			100		70			100				
80			110		80			110		80			110				
90			120		90			120		90			120				
100			150		100			150		100			150				
110			180		110			180		110			180				
120			210		120			210		120			210				
Average yield: 4.26			(l/s)		Average yield: 8.4					Average yield: 12.71							
DISCHARGE RATE 4			Time	Recovery 4	DISCHARGE RATE 5			Time	Recovery 5	DISCHARGE RATE 6			Time	Recovery			
DATE:		24-Sep-12		(min)	(m)	DATE:		24-Sep-12		(min)	(m)	DATE:		24-Sep-12		(min)	(m)
TIME:		10:00		1		TIME:		1		TIME:		1		46.95			
Time	Drawdown	Yield	2		Time	Drawdown	Yield	2		Time	Drawdown	Yield	2				
(min)	(m)	(l/s)	3		(min)	(m)	(l/s)	3		(min)	(m)	(l/s)	3				
1	64.53		5		1			5		1			5				
2	66.95		7		2			7		2			7				
3	67.90		10		3			10		3			10				
5	69.66	16.13	15		5			15		5			15				
7	72.08		20		7			20		7			20				
10	80.53		30		10			30		10			30				
11	80.53		40		15			40		15			40				
20			50		20			50		20			50				
30			60		30			60		30			60				
40			70		40			70		40			70				
50			80		50			80		50			80				
60			90		60			90		60			90				
70			100		70			100		70			100				
80			110		80			110		80			110				
90			120		90			120		90			120				
100			150		100			150		100			150				
110			180		110			180		110			180				
120			210		120			210		120			210				
Average yield: 16.13										Average yield: 7.46							
COMMENTS:										300			300				
										360			360				
										420			420				
										480			480				
										540			540				
										600			600				
										660			660				
										720							
										780			Average yield:		720		

TEST DESCRIPTION	STEP	1	2	3	4	5	6	TOTAL:	RECOVERY:
CALIBRATION TEST:								(min) (hrs)	(m) (min)
TEST DURATION (Minutes)								0 0.00	0.00
TEST YIELD (l/s)								MAXIMUM (l/s)	0.0
DRAWDOWN (m)								MAXIMUM (m)	
MULTI-RATE / STEP DRAWDOWN:									
TEST DURATION (Minutes)	60	60	60	11				191 3.18	5.31
TEST YIELD (l/s)	4.26	8.40	12.71	16.13				MAXIMUM (l/s)	16.1
DRAWDOWN (m)	15.4	34.95	54.97	80.53				MAXIMUM (m)	80.5
CONSTANT DISCHARGE TEST	TEST DURATION		TEST YIELD		DRAWDOWN		RECOVERY:		
	(min)	(hrs)	(l/s)	(m)	(m)	%	(min)	(hrs)	
	1320	22.00	10.07	82.14	6.31	92.32	1440	24.00	
OBSERVATION BOREHOLES:	No.	720	1440	2880	>2880 (min)		TOTAL:		
	of boreholes	(min)	(min)	(min)	nr.	Time	(min)	(hrs)	
							0	0.00	

::



Cooper-Jacob method		No boundaries	1 no-flow	2 no-flow	Closed	Leaky Aquifer: Hantush Method	
EC-T33-748		Q_sust = 2.27	1.14	0.75	0.57	EC-T33-748	
		Avg. Q_sust = 1.18		std. dev = 0.77		T(m ² /d) = 2.2	
						S = 2.44E-02	
						L (m) = 8	
		T(m ² /d) = 3.1					
		S = 2.85E-01					

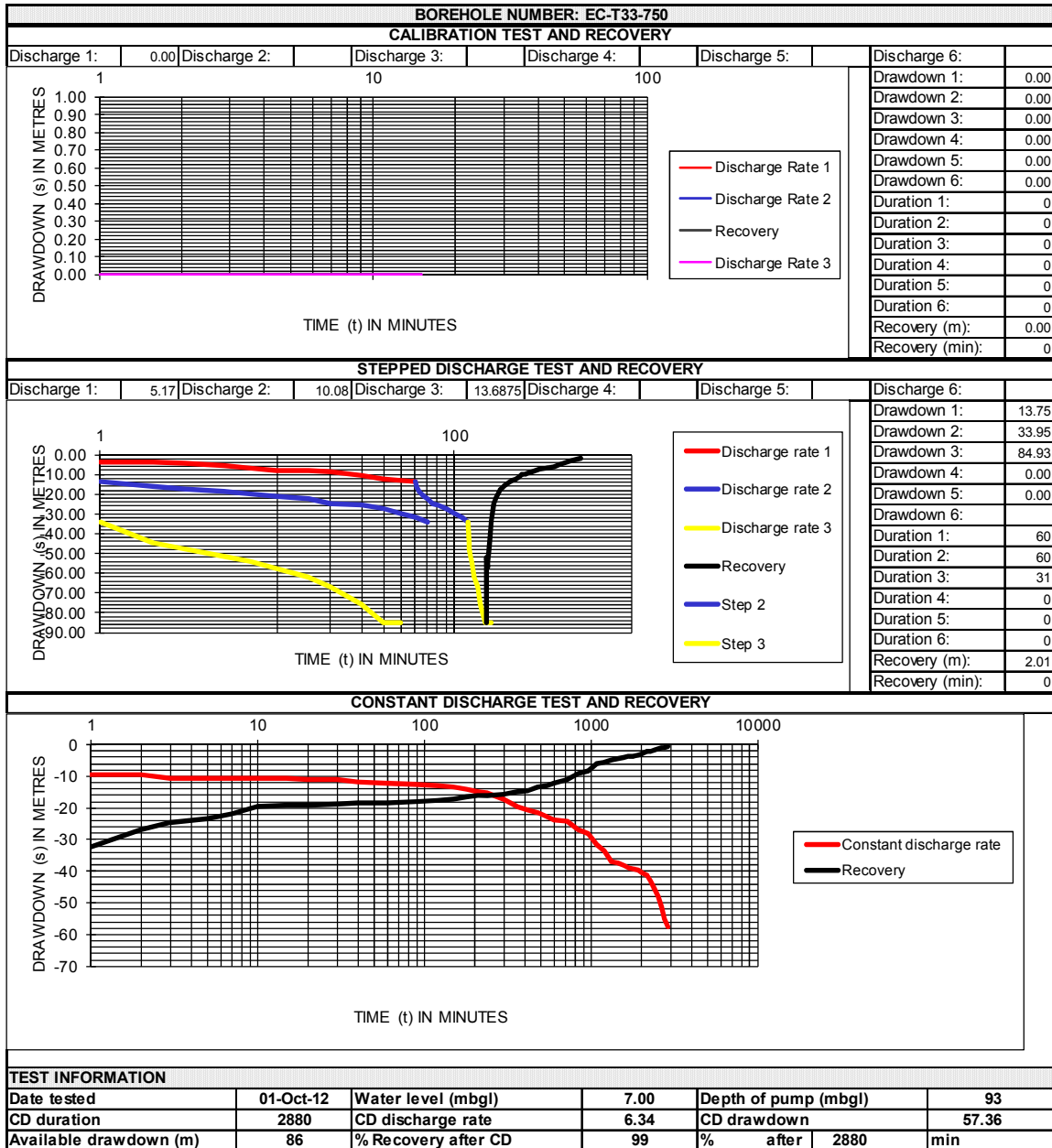


STEPPED DISCHARGE TEST AND RECOVERY																	
BOREHOLE NO. :		EC-T33-750			PROJECT:		Umzimvubu Ward 15										
ALTERNATIVE NO. :		0			SITE NAME:		0										
ALTERNATIVE NO. :		0			CLIENT:		0										
BOREHOLE DEPTH (mbgl):		140.00		CASING DEPTH (mbgl):		0.00		PUMP TYPE USED: GW 9002									
DEPTH OF PUMP (mbgl):		93.00		CASING HEIGHT (magl):		0.21		OPERATOR: Yellow Cap, Junior									
PUMP INLET DIAMETER (mm):		170.000		CASING ID (mm):		0.000		CONTRACTOR: Welltek Services									
STATIC WATER LEVEL (mbgl):		7.00		DATUM LEVEL (magl):		0.51											
DISCHARGE RATE 1			Time	Recovery 1	DISCHARGE RATE 2			Time	Recovery 2	DISCHARGE RATE 3			Time	Recovery 3			
DATE:		30-Sep-12		(min)	(m)	DATE:		30-Sep-12		(min)	(m)	DATE:		30-Sep-12		(min)	(m)
TIME:		08:00 AM		1		TIME:		09:00 AM		1		TIME:		10:00 AM		1	
Time	Draw down	Yield	2		Time	Draw down	Yield	2		Time	Draw down	Yield	2				
(min)	(m)	(l/s)	3		(min)	(m)	(l/s)	3		(min)	(m)	(l/s)	3				
1	3.42		5		1	16.22		5		1	44.61		5				
2	3.76		7		2	17.47		7		2	47.84		7				
3	4.07	5.170	10		3	18.63	10.080	10		3	51.26	15.420	10				
5	5.71		15		5	20.09		15		5	54.03		15				
7	6.94		20		7	21.32		20		7	57.77		20				
10	7.77	5.170	30		10	22.48	10.080	30		10	62.31	15.420	30				
15	8.06		40		15	24.66		40		15	67.22		40				
20	8.94		50		20	25.32		50		20	75.64		50				
30	10.80	5.170	60		30	27.19	10.080	60		30	84.93	15.420	60				
40	12.34		70		40	29.74		70		31	84.93	8.490	70				
50	13.00		80		50	31.34		80		50			80				
60	13.75	5.170	90		60	33.95	10.080	90		60			90				
70			100		70			100		70			100				
80			110		80			110		80			110				
90			120		90			120		90			120				
100			150		100			150		100			150				
110			180		110			180		110			180				
120			210		120			210		120			210				
Average yield: 5.17			(l/s)		Average yield: 10.08					Average yield: 13.6875							
DISCHARGE RATE 4			Time	Recovery 4	DISCHARGE RATE 5			Time	Recovery 5	DISCHARGE RATE 6			Time	Recovery			
DATE:		30-Sep-12		(min)	(m)	DATE:		30-Sep-12		(min)	(m)	DATE:		30-Sep-12		(min)	(m)
TIME:				1		TIME:				1		TIME:				1	52.37
Time	Draw down	Yield	2		Time	Draw down	Yield	2		Time	Draw down	Yield	2				
(min)	(m)	(l/s)	3		(min)	(m)	(l/s)	3		(min)	(m)	(l/s)	3				
1			5		1			5		1			5	49.27			
2			7		2			7		2			7	42.06			
3			10		3			10		3			10	33.39			
5			15		5			15		5			15	24.95			
7			20		7			20		7			20	21.87			
10			30		10			30		10			30	17.76			
15			40		15			40		15			40	15.74			
20			50		20			50		20			50	13.96			
30			60		30			60		30			60	12.75			
40			70		40			70		40			70	12.14			
50			80		50			80		50			80	11.28			
60			90		60			90		60			90	10.15			
70			100		70			100		70			100	9.76			
80			110		80			110		80			110	9.27			
90			120		90			120		90			120	8.85			
100			150		100			150		100			150	7.17			
110			180		110			180		110			180	6.54			
120			210		120			210		120			210	6.12			
Average yield: #DIV/0!										240							
COMMENTS:										150							
										300							
										180							
										360							
										210							
										420							
										240							
										480							
										300							
										540							
										360							
										600							
										420							
										660							
										480							
										720							
										780							
										Average yield:							
										720							

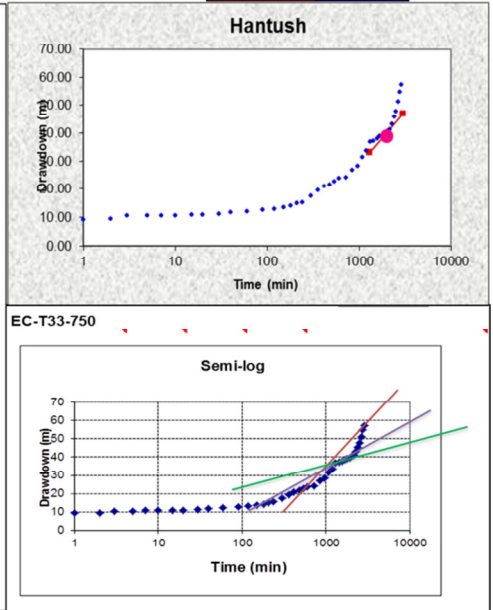
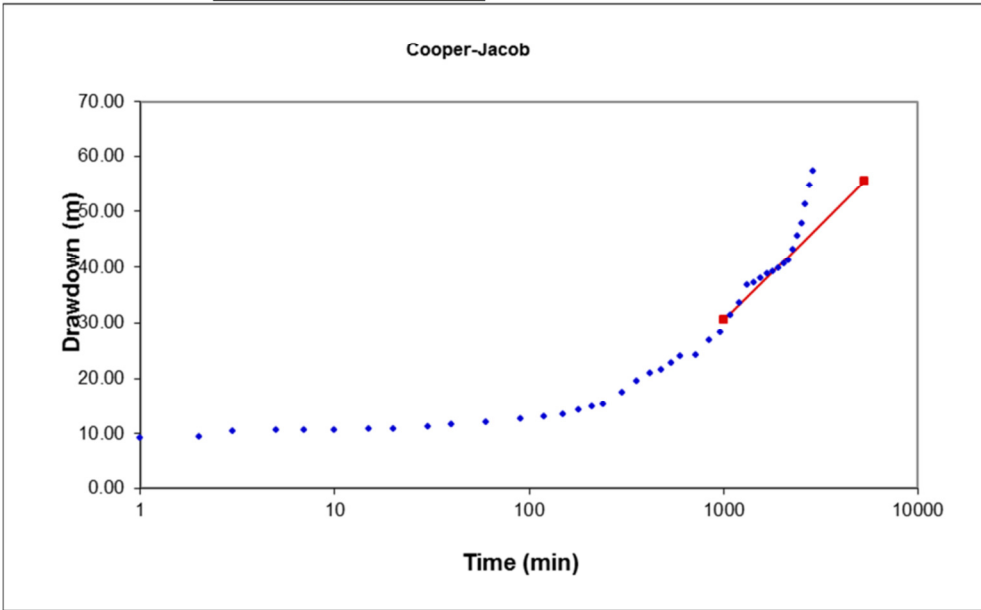
DISCHARGE BOREHOLE				OBSERVATION BOREHOLE 1			OBSERVATION BOREHOLE 2			OBSERVATION BOREHOLE 3		
Time	Draw down	Yield	Recovery	Time	Drawdown	Recovery	Time	Drawdown	Recovery	Time	Draw down	Recovery
(min)	(m)	(l/s)	(m)	(min)	(m)	(m)	(min)	(m)	(m)	(min)	(m)	(m)
2400	45.66		1.87	1500			1500			1500		
2520	47.92	6.18	1.52	1560			1560			1560		
2640	51.24		1.11	1620			1620			1620		
2760	54.80		0.91	1680			1680			1680		
2880	57.36		0.72	1740			1740			1740		
1800				1800			1800			1800		
1860				1860			1860			1860		
1920				1920			1920			1920		
1980				1980			1980			1980		
2040				2040			2040			2040		
2100				2100			2100			2100		
2160				2160			2160			2160		
2220				2220			2220			2220		
2280				2280			2280			2280		
2340				2340			2340			2340		
2400				2400			2400			2400		
2460				2460			2460			2460		
2520				2520			2520			2520		
2580				2580			2580			2580		
2640				2640			2640			2640		
2700				2700			2700			2700		
2760				2760			2760			2760		
2820				2820			2820			2820		
2880				2880			2880			2880		

DESCRIPTION:	QUANTITY:	UNIT:	S U M M A R Y	DESCRIPTION:	QUANTITY:	UNIT	
ESTABLISHMENT		Sum			STRAIGHTNESS TEST:		No.
INTER HOLE MOVE > 10 km		Km.			VERTICALITY TEST:		No.
FROM: SITE NAME:					CASING DETECTION:		No.
BOREHOLE No:					STEEL BOREHOLE COVER:		No.
INTER HOLE MOVE < 10 km:		No.			BOREHOLE MARKING:		No.
REMOVAL AND RE-ERECTION OF PUMP HOUSE:		No.			SITE CLEANING / FINISHING:		No.
REMOVAL OF EXISTING EQUIPMENT:		No.			REPORTING & DATA RECORDING:		No.
RE-INSTALLATION OF EXISTING EQUIPMENT:		No.			SLUG TEST:		No.
WORK TIME RATE (REPAIRS):		Hour			LAYFLAT (m):		m
STANDING TIME:		Hour			BOREHOLE DEPTH AFTER TEST:		m
LATITUDE:	LONGITUDE:				BOREHOLE WATERLEVEL AFTER TEST:		m

TEST DESCRIPTION	STEP	1	2	3	4	5	6	TOTAL:	RECOVERY:	RECOVERY TEST				
CALIBRATION TEST:								(min) (hrs)	(m) (min)	TIME TOTAL (hrs): 96.00				
TEST DURATION (Minutes)								0	0.00	0.00	Cal	Steps	CD	Total
TEST YIELD (l/s)								MAXIMUM (l/s) 0.0			0	2880	2880	5760
DRAWDOWN (m)								MAXIMUM (m)			DRAWDOWN TOTALS (CD):			
MULTI-RATE / STEP DRAWDOWN:											AVAILABLE	UTIL-	%	
TEST DURATION (Minutes)		60	60	31				151	2.52	2.01	ISED			
TEST YIELD (l/s)		5.17	10.08	13.69				MAXIMUM (l/s) 13.7			86.0	57.36	66.70	
DRAWDOWN (m)		13.8	33.95	84.93				MAXIMUM (m) 84.9						
CONSTANT DISCHARGE TEST	TEST DURATION		TEST YIELD		DRAWDOWN		RECOVERY:							
	(min)	(hrs)	(l/s)		(m)		(m)	%	(min)	(hrs)				
	2880	48.00	6.34		57.36		0.72	98.74	2880	48.00				
OBSERVATION BOREHOLES:	No.	720	1440		2880		>2880 (min)		TOTAL:					
	of boreholes	(min)	(min)		(min)		nr.	Time	(min)	(hrs)				
									0	0.00				



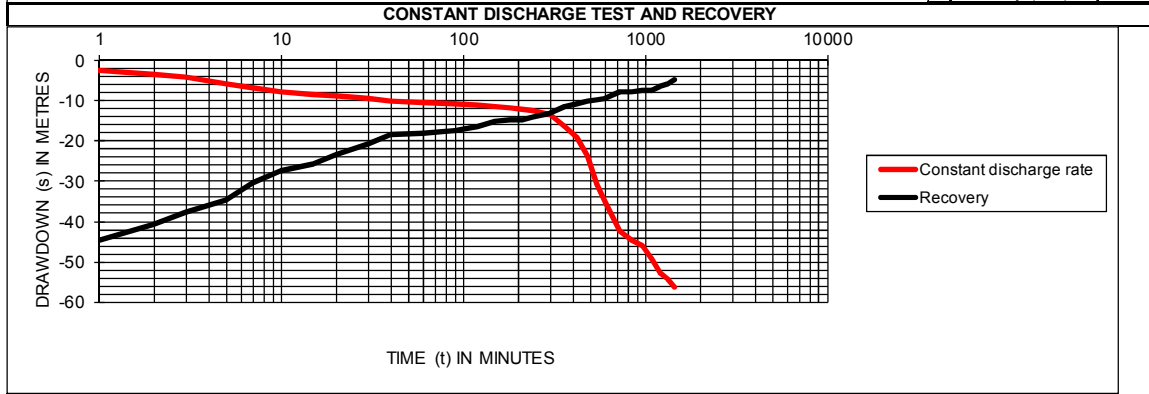
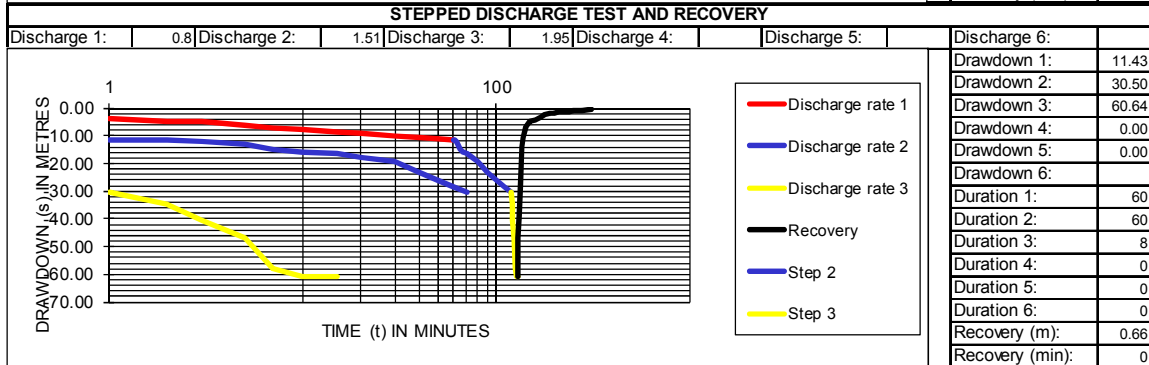
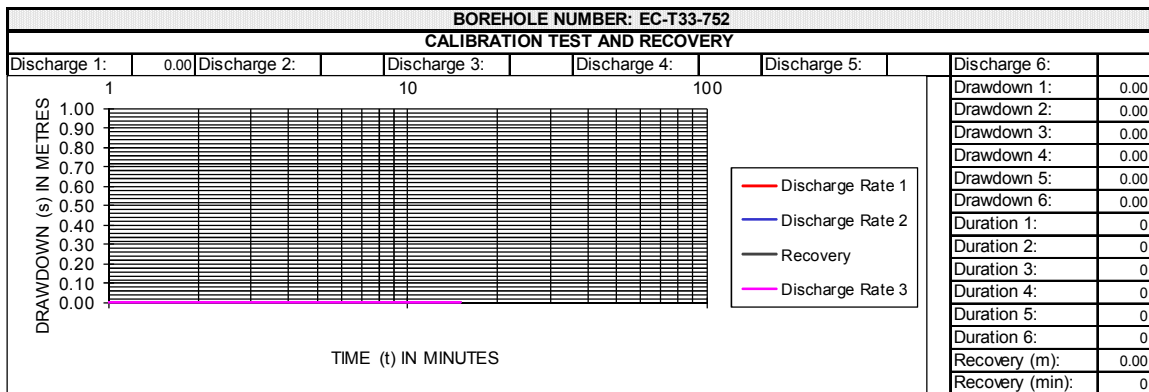
Cooper-Jacob method						Leaky Aquifer: Hantush Method	
EC-T33-750		Q_sust	No boundaries	1 no-flow	2 no-flow	Closed	EC-T33-750
		Avg. Q_sust =	2.62	1.31	0.87	0.66	
				1.36	std. dev =	0.88	
		T(m ² /d) =					T(m ² /d) =
		S =					S =
							L (m) =



CONSTANT DISCHARGE TEST AND RECOVERY															
LE NO. :		EC-T33-752		PROJECT:		Umzimvubu Ward 15			CLIENT:		0				
ACTIVE NO. :		0		SITE NAME:		0									
PUMP (mbdl):		69.00		PUMP TYPE USED:		BP 40			OPERATOR:		Thomas and Phillip				
METER (mm):		170		EXISTING EQUIPMENT:		0			CONTRACTOR:		Welltek Services				
DATE:		2012/09/29		TEST DATE:		2012/10/01		TOTAL TIME - PUMPED (min):		1440		TOTAL TEST TIME (min):		2880	
TIME:		08:00 AM		COMPLETED TIME:		08:00 AM		TOTAL TIME-RECOVERY(min):		1440		AVERAGE YIELD (l/s):		1.09	
DISCHARGE BOREHOLE			OBSERVATION BOREHOLE 1				OBSERVATION BOREHOLE 2				OBSERVATION BOREHOLE 3				
No. :			No. :				No. :				No. :				
DEPTH (mbdl):			DATUM LEVEL (magl):				DATUM LEVEL (magl):				DATUM LEVEL (magl):				
ID (m):			CASING DEPTH (mbgl):				CASING DEPTH (mbgl):				CASING DEPTH (mbgl):				
LE DEPTH (mbgl):			BOREHOLE DEPTH :				BOREHOLE DEPTH :				BOREHOLE DEPTH :				
LEVEL (mbgl):			WATER LEVEL:				WATER LEVEL:				WATER LEVEL:				
LEVEL (magl):			DISTANCE (m):				DISTANCE (m):				DISTANCE (m):				
Draw down	Yield	Recovery	Time	Draw down	Recovery	Time	Draw down	Recovery	Time	Draw down	Recovery				
(m)	(l/s)	(m)	(min)	(m)	(m)	(min)	(m)	(m)	(min)	(m)	(m)				
2.46		44.80	1			1			1						
3.52		40.50	2			2			2						
4.18	1.09	37.54	3			3			3						
5.73		34.80	5			5			5						
6.89		30.40	7			7			7						
7.90		27.50	10			10			10						
8.46	1.09	25.62	15			15			15						
8.94		23.44	20			20			20						
9.34		20.80	30			30			30						
9.96	1.08	18.32	40			40			40						
10.44		18.02	60			60			60						
10.83		17.56	90			90			90						
11.02		16.50	120			120			120						
11.46	1.08	15.15	150			150			150						
11.86		14.80	180			180			180						
12.08		14.65	210			210			210						
12.52		14.20	240			240			240						
13.44	1.09	12.98	300			300			300						
16.45		11.28	360			360			360						
18.97		10.80	420			420			420						
23.80		10.00	480			480			480						
30.70	1.09	9.89	540			540			540						
35.06		9.50	600			600			600						
42.30		7.91	720			720			720						
44.70		7.88	840			840			840						
46.08		7.50	960			960			960						
49.30		7.40	1080			1080			1080						
52.60	1.09	6.37	1200			1200			1200						
54.38		5.84	1320			1320			1320						
56.42		4.82	1440			1440			1440						
			1800			1800			1800						
			2280			2280			2280						
			2880			2880			2880						

TEST DESCRIPTION	STEP	1	2	3	4	5	6	TOTAL:	RECOVERY:
CALIBRATION TEST:								(min) (hrs)	(m) (min)
TEST DURATION (Minutes)								0 0.00	0.00
TEST YIELD (l/s)								MAXIMUM (l/s)	0.0
DRAWDOWN (m)								MAXIMUM (m)	
MULTI-RATE / STEP DRAWDOWN:									
TEST DURATION (Minutes)	60	60	8					128 2.13	0.66
TEST YIELD (l/s)	0.80	1.51	1.95					MAXIMUM (l/s)	2.0
DRAWDOWN (m)	11.4	30.50	60.64					MAXIMUM (m)	60.6
CONSTANT DISCHARGE TEST		TEST DURATION		TEST YIELD		DRAWDOWN		RECOVERY:	
	(min)	(hrs)	(l/s)	(m)	(m)	(m)	%	(min)	(hrs)
	1440	24.00	1.09	56.42	4.82	91.46		1440	24.00
OBSERVATION BOREHOLES:		No. of boreholes		720		1440		2880	
		(min)	(min)	(min)	(min)	>2880 (min)	nr.	Time	TOTAL: (min) (hrs)
									0 0.00

RECOVERY TEST			
TIME TOTAL (hrs): 27.00			
Cal	Steps	CD	Total
0	180	1440	1620
DRAWDOWN TOTALS (CD):			
AVAILABLE	UTIL-	% ISED	
61.5	56.42	91.74	

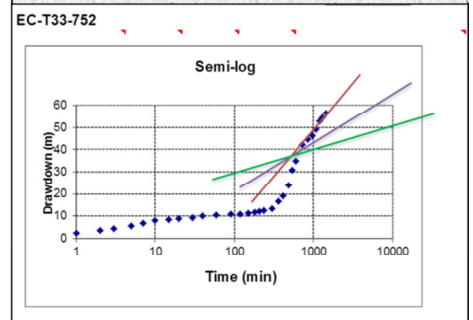
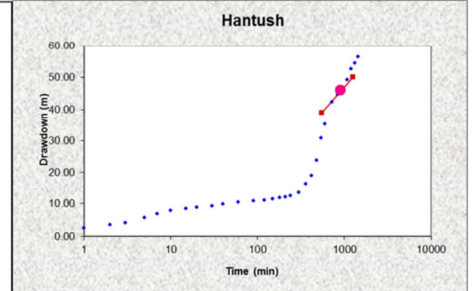
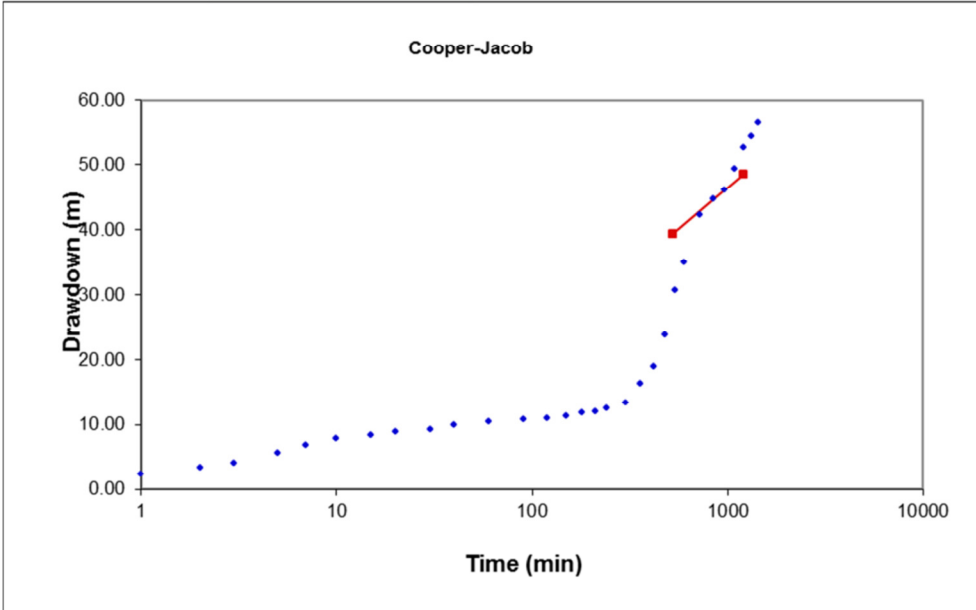


TEST INFORMATION					
Date tested	29-Sep-12	Water level (mbgl)	7.50	Depth of pump (mbgl)	69
CD duration	1440	CD discharge rate	1.09	CD drawdown	56.42
Available drawdown (m)	61.5	% Recovery after CD	91	% after	1440 min

Cooper-Jacob method	
EC-T33-752	
$T(m^2/d) =$	2.1
$S =$	4.78E-02

	No boundaries	1 no-flow	2 no-flow	Closed
Q_{sust}	0.16	0.08	0.05	0.04
Avg. $Q_{sust} =$	0.09		std. dev = 0.06	

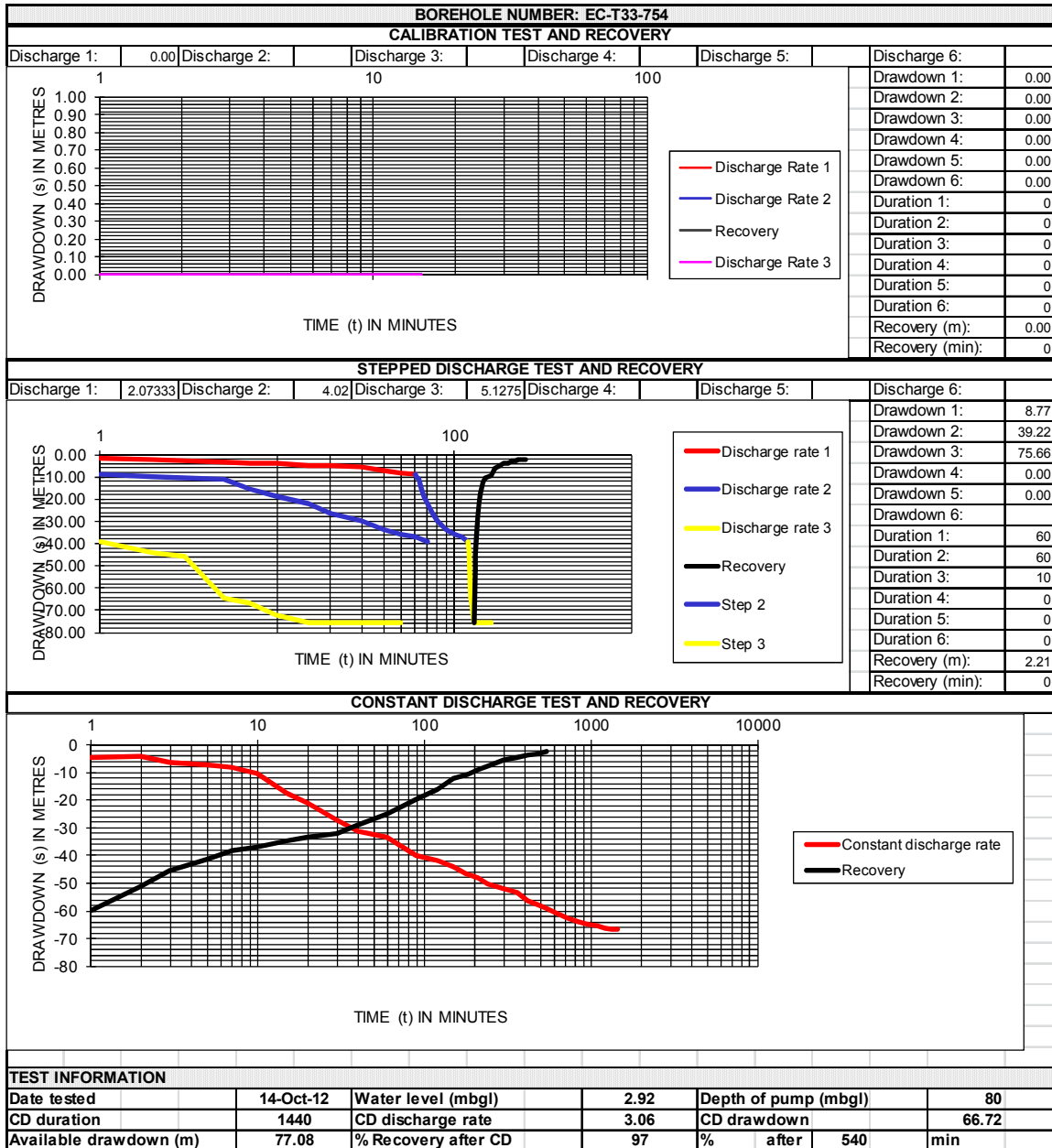
Leaky Aquifer: Hantush Method	
EC-T33-752	
$T(m^2/d) =$	1.3
$S =$	7.74E-03
$L (m) =$	12

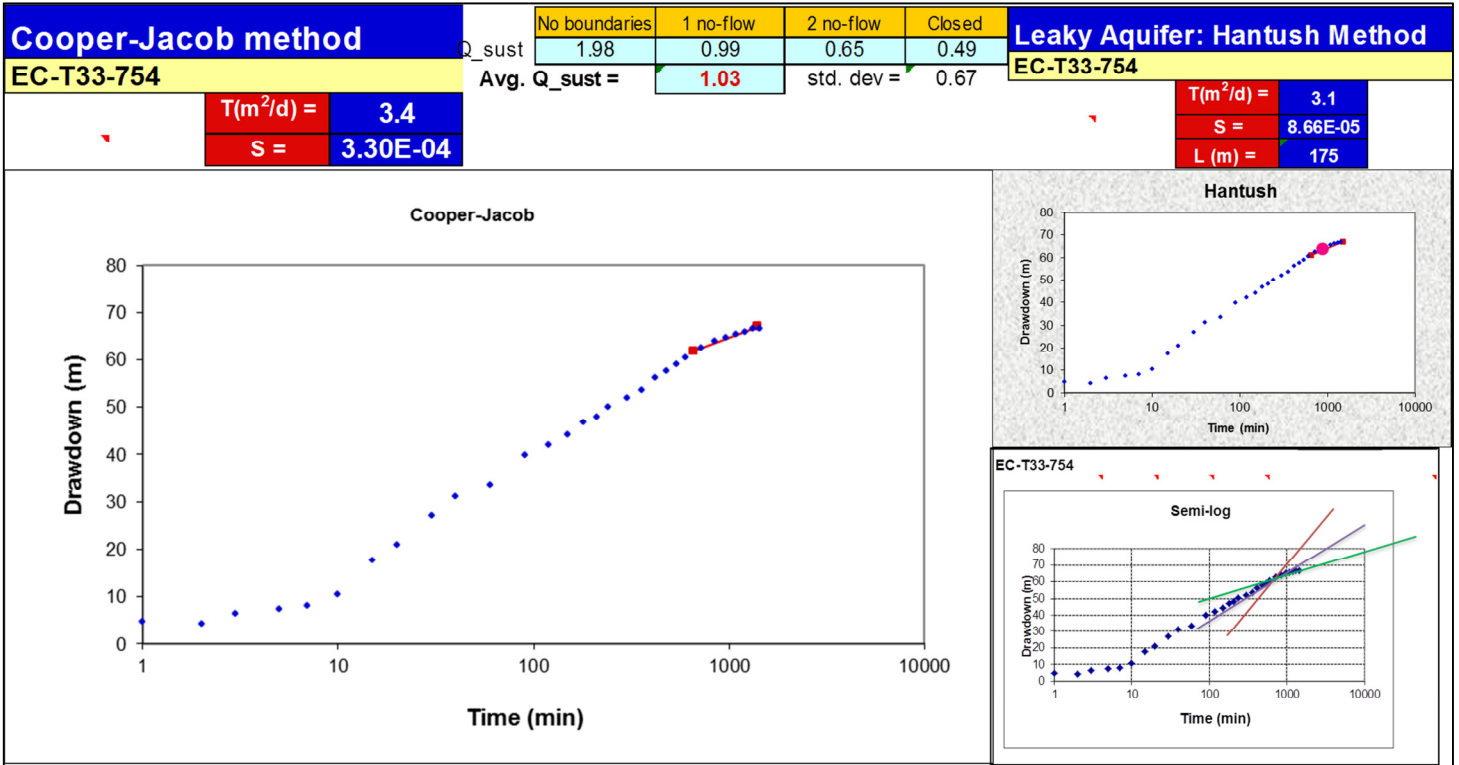


STEPPED DISCHARGE TEST AND RECOVERY																		
BOREHOLE NO. :		EC-T33-754			PROJECT:		Umzimwubu Ward 15											
ALTERNATIVE NO. :		0			SITE NAME:		0											
ALTERNATIVE NO. :		0			CLIENT:		0											
BOREHOLE DEPTH (mbgl):		129.85		CASING DEPTH (mbgl):		0.00		PUMP TYPE USED:				BP 40						
DEPTH OF PUMP (mbgl):		80.00		CASING HEIGHT (magl):		0.35		OPERATOR:				Stanley, Junior						
PUMP INLET DIAMETER (mm):		170.000		CASING ID (mm):		0.000		CONTRACTOR:				Welltek Services						
STATIC WATER LEVEL (mbgl):		2.92		DATUM LEVEL (magl):		0.25												
DISCHARGE RATE 1			Time	Recovery 1	DISCHARGE RATE 2			Time	Recovery 2	DISCHARGE RATE 3			Time	Recovery 3				
DATE:		14-Oct-12		(min)	(m)	DATE:		14-Oct-12		(min)	(m)	DATE:		14-Oct-12		(min)	(m)	
TIME:		7:00 AM		1		TIME:		8:00 AM		1		TIME:		9:00 AM		1		
Time	Drawdown	Yield	2		Time	Drawdown	Yield	2		Time	Drawdown	Yield	2					
(min)	(m)	(l/s)	3		(min)	(m)	(l/s)	3		(min)	(m)	(l/s)	3					
1	1.49		5		1	9.75	4.020	5		1	44.14		5					
2	2.16		7		2	10.38		7		2	45.56	6.240	7					
3	2.54		10		3	11.21		10		3	64.55		10					
5	3.32	2.090	15		5	15.19	4.020	15		4	66.69	6.250	15					
7	3.66		20		7	18.48		20		5	72.45		20					
10	3.92		30		10	22.15		30		6	75.66		30					
15	4.89	2.090	40		15	26.68	4.020	40		7	75.66	4.250	40					
20	5.02		50		20	29.90		50		8	75.66		50					
30	5.43		60		30	33.43		60		9	75.66		60					
40	6.97	2.040	70		40	35.67		70		10	75.66	3.770	70					
50	8.00		80		50	37.08		80		50			80					
60	8.77		90		60	39.22	4.020	90		60			90					
70			100		70			100		70			100					
80			110		80			110		80			110					
90			120		90			120		90			120					
100			150		100			150		100			150					
110			180		110			180		110			180					
120			210		120			210		120			210					
Average yield: 2.0733333			(l/s)		Average yield: 4.02					Average yield: 5.1275								
DISCHARGE RATE 4			Time	Recovery 4	DISCHARGE RATE 5			Time	Recovery 5	DISCHARGE RATE 6			Time	Recovery				
DATE:		14-Oct-12		(min)	(m)	DATE:		14-Oct-12		(min)	(m)	DATE:		14-Oct-12		(min)	(m)	
TIME:				1		TIME:				1		TIME:				1	51.91	
Time	Drawdown	Yield	2		Time	Drawdown	Yield	2		Time	Drawdown	Yield	2			45.35		
(min)	(m)	(l/s)	3		(min)	(m)	(l/s)	3		(min)	(m)	(l/s)	3			36.17		
1			5		1			5		1			5			27.70		
2			7		2			7		2			7			22.24		
3			10		3			10		3			10			17.44		
5			15		5			15		5			15			12.64		
7			20		7			20		7			20			10.56		
10			30		10			30		10			30			9.51		
15			40		15			40		15			40			6.27		
20			50		20			50		20			50			4.89		
30			60		30			60		30			60			3.90		
40			70		40			70		40			70			3.76		
50			80		50			80		50			80			3.00		
60			90		60			90		60			90			2.65		
70			100		70			100		70			100			2.43		
80			110		80			110		80			110			2.36		
90			120		90			120		90			120			2.21		
100			150		100			150		100			150					
110			180		110			180		110			180					
120			210		120			210		120			210					
Average yield: #DIV/0!										240						240		
COMMENTS:									300			180			300			
									360			210			360			
									420			240			420			
									480			300			480			
									540			360			540			
									600			420			600			
									660			480			660			
									720									
									780						Average yield:			720

CONSTANT DISCHARGE TEST AND RECOVERY															
BOREHOLE NO. :		EC-T33-754			PROJECT:		Umzimvubu Ward 15			CLIENT:		0			
ALTERNATIVE NO. :		0			SITE NAME:		0								
DEPTH OF PUMP (m bdl):		80.00			PUMP TYPE USED:		BP 40			OPERATOR:		Stanley, Junior			
INLET DIAMETER (mm):		170			EXISTING EQUIPMENT:		0			CONTRACTOR:		Welltek Services			
TEST STARTED	DATE:	14/10/2012			TEST COMPLETED	DATE:	15/10/2012			TOTAL TIME - PUMPED (min):	1440	TOTAL TEST TIME (min):	1980		
	TIME:	11:00 AM				TIME:	8:00 PM			TOTAL TIME-RECOVERY(m in):	540	AVERAGE YIELD (l/s):	3.06		
DISCHARGE BOREHOLE				OBSERVATION BOREHOLE 1				OBSERVATION BOREHOLE 2			OBSERVATION BOREHOLE 3				
CASING HEIGHT (magl):		0.35		No. :				No. :				No. :			
CASING DEPTH (m bdl):		0.00		DATUM LEVEL (magl):				DATUM LEVEL (magl):				DATUM LEVEL (magl):			
CASING ID (mm):		0.00		CASING DEPTH (m bgl):				CASING DEPTH (m bgl):				CASING DEPTH (m bgl):			
BOREHOLE DEPTH (m bgl):		129.85		BOREHOLE DEPTH :				BOREHOLE DEPTH :				BOREHOLE DEPTH :			
WATER LEVEL (m bgl):		2.92		WATER LEVEL:				WATER LEVEL:				WATER LEVEL:			
DATUM LEVEL (magl):		0.25		DISTANCE (m):				DISTANCE (m):				DISTANCE (m):			
Time	Draw down	Yield	Recovery	Time	Draw down	Recovery	Time	Draw down	Recovery	Time	Draw down	Recovery			
(min)	(m)	(l/s)	(m)	(min)	(m)	(m)	(min)	(m)	(m)	(min)	(m)	(m)			
1	4.85		60.01	1			1			1					
2	4.30	3.05	50.97	2			2			2					
3	6.41		45.50	3			3			3					
5	7.42		41.22	5			5			5					
7	8.07	3.03	38.33	7			7			7					
10	10.49		37.07	10			10			10					
15	17.53		34.85	15			15			15					
20	20.91		33.32	20			20			20					
30	27.08	3.05	31.97	30			30			30					
40	31.20		28.93	40			40			40					
60	33.63		25.18	60			60			60					
90	39.98		19.65	90			90			90					
120	41.98		15.99	120			120			120					
150	44.25	3.08	12.23	150			150			150					
180	46.80		10.69	180			180			180					
210	47.99		8.93	210			210			210					
240	50.17		7.64	240			240			240					
300	51.85	3.08	5.36	300			300			300					
360	53.53		4.66	360			360			360					
420	56.32		3.90	420			420			420					
480	57.75		3.30	480			480			480					
540	59.09	3.05	2.27	540			540			540					
600	60.49			600			600			600					
720	62.53			720			720			720					
840	63.92			840			840			840					
960	64.71	3.05		960			960			960					
1080	65.45			1080			1080			1080					
1200	66.04			1200			1200			1200					
1320	66.58			1320			1320			1320					
1440	66.72	3.05		1440			1440			1440					

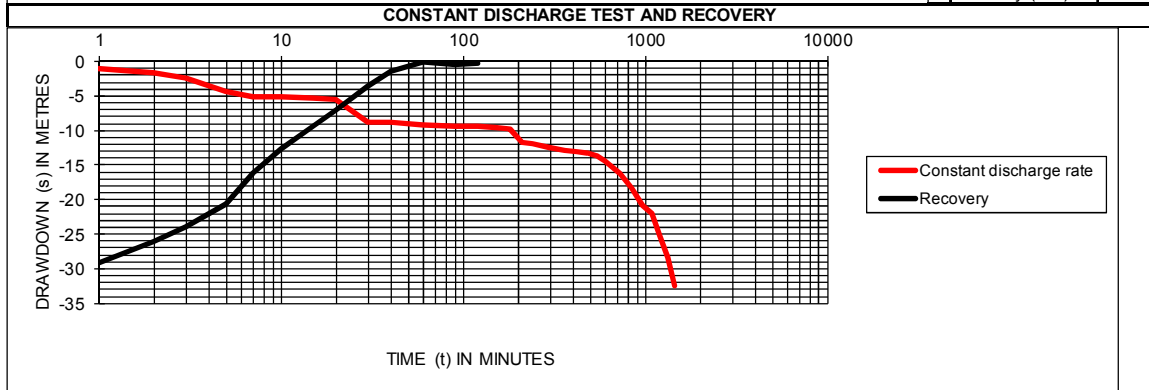
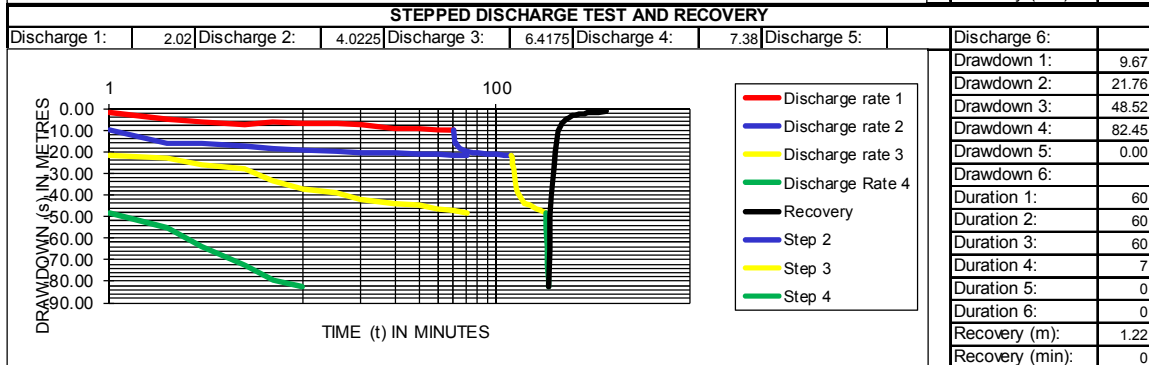
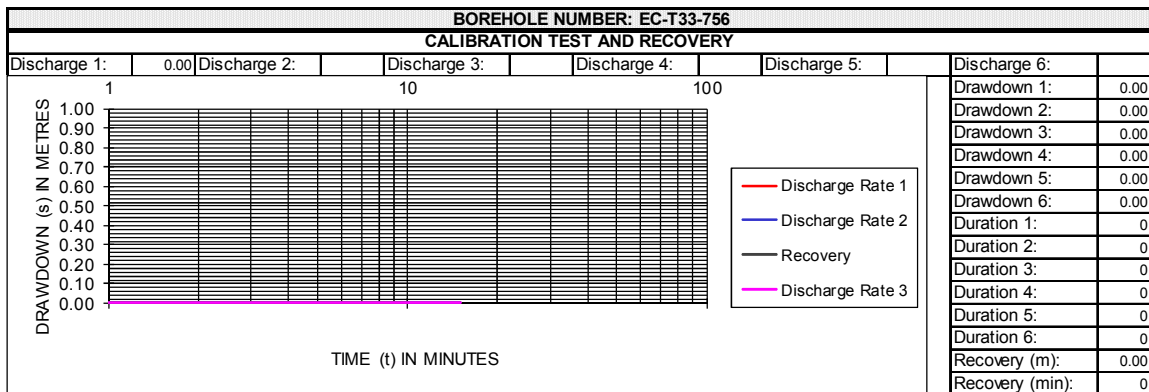
TEST DESCRIPTION	STEP	1	2	3	4	5	6	TOTAL:	RECOVERY:	RECOVERY TEST					
CALIBRATION TEST:								(min)	(hrs)	(m)	(min)	TIME TOTAL (hrs): 11.00			
TEST DURATION (Minutes)								0	0.00	0.00		Cal	Steps	CD	Total
TEST YIELD (l/s)								MAXIMUM (l/s)	0.0			0	120	540	660
DRAWDOWN (m)								MAXIMUM (m)				DRAWDOWN TOTALS (CD):			
MULTI-RATE / STEP DRAWDOWN:												AVAILABLE	UTIL-	%	
TEST DURATION (Minutes)		60	60	10				130	2.17	2.21		ISED			
TEST YIELD (l/s)		2.07	4.02	5.13				MAXIMUM (l/s)	5.1			77.1	66.72	86.56	
DRAWDOWN (m)		8.8	39.22	75.66				MAXIMUM (m)	75.7						
CONSTANT DISCHARGE TEST		TEST DURATION		TEST YIELD	DRAWDOWN		RECOVERY:								
		(min)	(hrs)	(l/s)	(m)		(m)	%	(min)	(hrs)					
		1440	24.00	3.06	66.72		2.27	96.60	540	9.00					





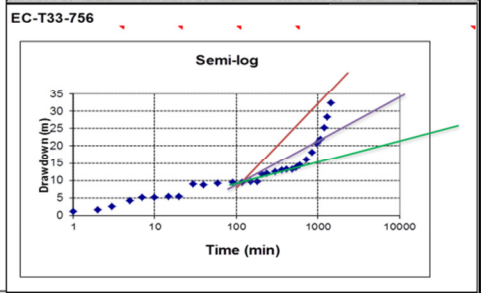
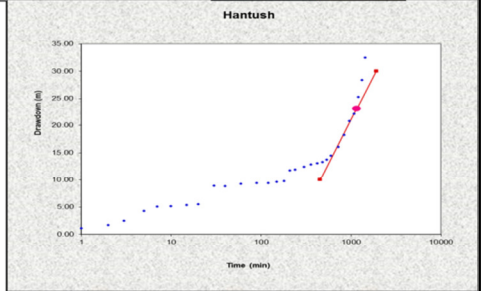
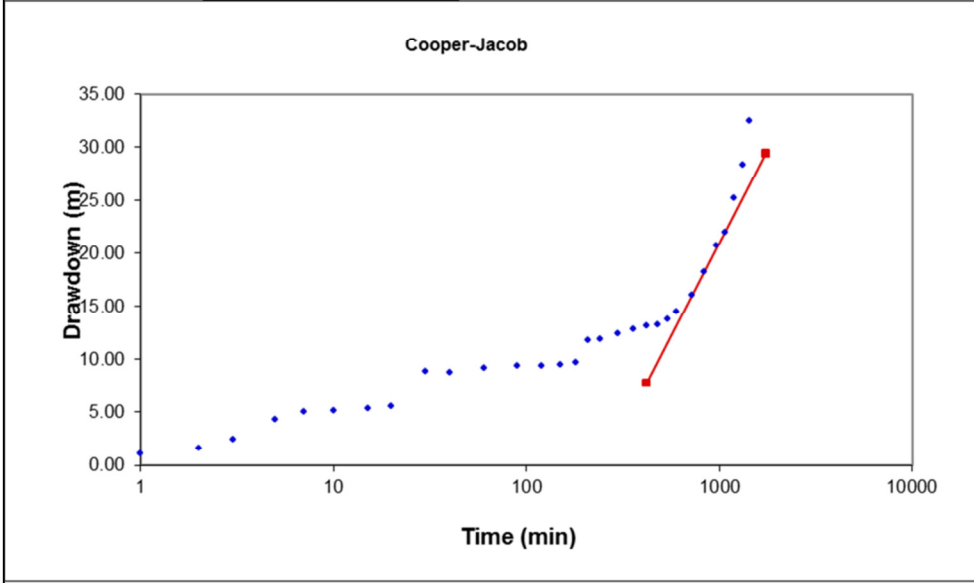
STEPPED DISCHARGE TEST AND RECOVERY																	
BOREHOLE NO. :		EC-T33-756			PROJECT:		Umzimwubu Ward 15										
ALTERNATIVE NO. :		0			SITE NAME:		0										
ALTERNATIVE NO. :		0			CLIENT:		0										
BOREHOLE DEPTH (mbgl):		119.81		CASING DEPTH (mbgl):		0.25		PUMP TYPE USED:				BP 30					
DEPTH OF PUMP (mbgl):		93.00		CASING HEIGHT (magl):		0.00		OPERATOR:				Stanley, Junior					
PUMP INLET DIAMETER (mm):		170.000		CASING ID (mm):		0.000		CONTRACTOR:				Welltek Services					
STATIC WATER LEVEL (mbgl):		10.08		DATUM LEVEL (magl):		0.58											
DISCHARGE RATE 1			Time	Recovery 1	DISCHARGE RATE 2			Time	Recovery 2	DISCHARGE RATE 3			Time	Recovery 3			
DATE:		21-Oct-12		(min)	(m)	DATE:		21-Oct-12		(min)	(m)	DATE:		21-Oct-12		(min)	(m)
TIME:		02:00 PM		1		TIME:		03:00 PM		1		TIME:		04:00 PM		1	
Time	Drawdown	Yield	2		Time	Drawdown	Yield	2		Time	Drawdown	Yield	2				
(min)	(m)	(l/s)	3		(min)	(m)	(l/s)	3		(min)	(m)	(l/s)	3				
1	2.01	2.020	5		1	15.97		5		1	23.05		5				
2	5.06		7		2	16.00	4.030	7		2	25.96	6.410	7				
3	6.36		10		3	17.65		10		4	28.05		10				
5	7.34	2.030	15		5	18.72		15		5	33.56		15				
7	6.23		20		7	19.44		20		6	37.25	6.420	20				
10	6.56		30		10	19.95	4.010	30		7	39.33		30				
15	6.72		40		15	20.38		40		8	42.11		40				
20	7.70	2.010	50		20	20.50		50		9	43.95	6.430	50				
30	9.51		60		30	21.08	4.020	60		10	44.79		60				
40	9.58		70		40	21.35		70		40	46.25		70				
50	9.61	2.020	80		50	21.61		80		50	47.33	6.410	80				
60	9.67		90		60	21.76	4.030	90		60	48.52		90				
70			100		70			100		70			100				
80			110		80			110		80			110				
90			120		90			120		90			120				
100			150		100			150		100			150				
110			180		110			180		110			180				
120			210		120			210		120			210				
Average yield: 2.02			(l/s)		Average yield: 4.0225					Average yield: 6.4175							
DISCHARGE RATE 4			Time	Recovery 4	DISCHARGE RATE 5			Time	Recovery 5	DISCHARGE RATE 6			Time	Recovery			
DATE:		21-Oct-12		(min)	(m)	DATE:		21-Oct-12		(min)	(m)	DATE:		21-Oct-12		(min)	(m)
TIME:		17:00		1		TIME:		17:00		1		TIME:		17:00		1	65.23
Time	Drawdown	Yield	2		Time	Drawdown	Yield	2		Time	Drawdown	Yield	2				
(min)	(m)	(l/s)	3		(min)	(m)	(l/s)	3		(min)	(m)	(l/s)	3				
1	55.36		5		1			5		1			5	40.45			
2	63.78	8.02	7		2			7		2			7	34.21			
3	72.55		10		3			10		3			10	27.03			
5	79.21		15		5			15		5			15	19.78			
7	82.45	6.73	20		7			20		7			20	10.57			
10			30		10			30		10			30	6.59			
15			40		15			40		15			40	5.21			
20			50		20			50		20			50	4.03			
30			60		30			60		30			60	3.27			
40			70		40			70		40			70	2.92			
50			80		50			80		50			80	2.35			
60			90		60			90		60			90	2.30			
70			100		70			100		70			100	2.29			
80			110		80			110		80			110	2.01			
90			120		90			120		90			120	1.65			
100			150		100			150		100			150	1.58			
110			180		110			180		110			180	1.22			
120			210		120			210		120			210				
Average yield: 7.375																	
COMMENTS:										300			300				
										360			360				
										420			420				
										480			480				
										540			540				
										600			600				
										660			660				
										720			720				
										780			780				
										Average yield:			720				

TEST DESCRIPTION	STEP	1	2	3	4	5	6	TOTAL:	RECOVERY:	RECOVERY TEST				
CALIBRATION TEST:								(min) (hrs)	(m) (min)	TIME TOTAL (hrs): 5.00				
TEST DURATION (Minutes)								0	0.00	0.00	Cal	Steps	CD	Total
TEST YIELD (l/s)								MAXIMUM (l/s)	0.0		0	180	120	300
DRAWDOWN (m)								MAXIMUM (m)			DRAWDOWN TOTALS (CD):			
MULTI-RATE / STEP DRAWDOWN:											AVAILABLE	UTIL-	%	
TEST DURATION (Minutes)	60	60	60	7				187	3.12	1.22	ISED			
TEST YIELD (l/s)	2.02	4.02	6.42	7.38				MAXIMUM (l/s)	7.4		82.9	32.45	39.13	
DRAWDOWN (m)	9.7	21.76	48.52	82.45				MAXIMUM (m)	82.5					
CONSTANT DISCHARGE TEST		TEST DURATION		TEST YIELD		DRAWDOWN		RECOVERY:						
	(min)	(hrs)	(l/s)	(m)	(m)	%	(min)	(hrs)						
	1440	24.00	5.10	32.45	0.08	99.75	120	2.00						
OBSERVATION BOREHOLES:		No.	720	1440	2880	>2880 (min)	TOTAL:							
											0	0.00		



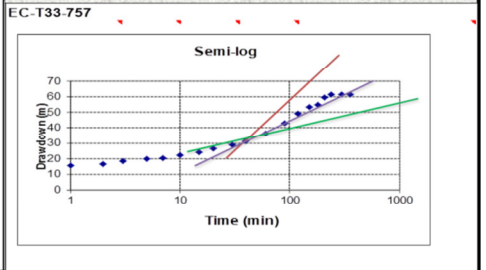
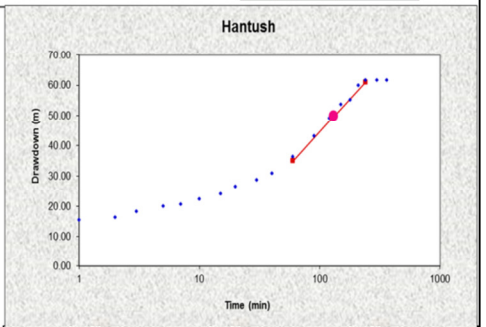
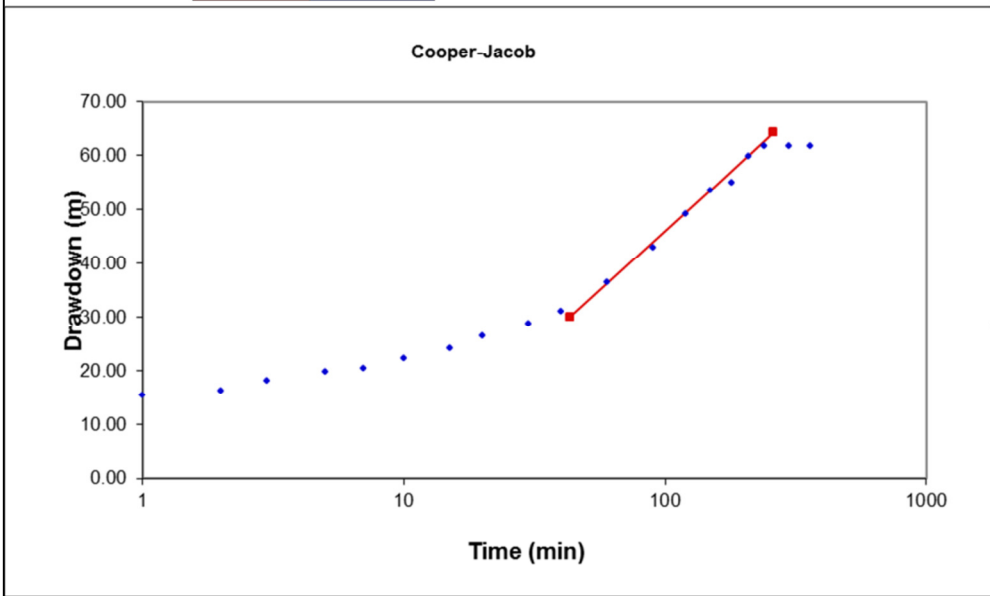
TEST INFORMATION					
Date tested	22-Oct-12	Water level (mbgl)	10.08	Depth of pump (mbgl)	93
CD duration	1440	CD discharge rate	5.10	CD drawdown	32.45
Available drawdown (m)	82.92	% Recovery after CD	100	% after	120 min

Cooper-Jacob method						Leaky Aquifer: Hantush Method	
EC-T33-756		Q _{sust}	No boundaries	1 no-flow	2 no-flow	Closed	EC-T33-756
			1.31	0.65	0.43	0.33	
		Avg. Q _{sust} =	0.68		std. dev = 0.44		
T(m ² /d) = 2.3						T(m ² /d) = 0.3	
S = 9.43E-01						S = 4.25E-02	
						L (m) = 2	



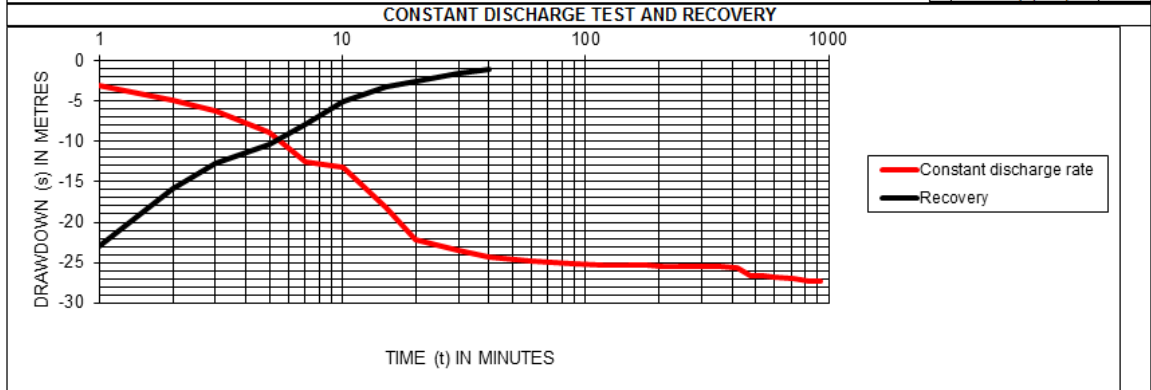
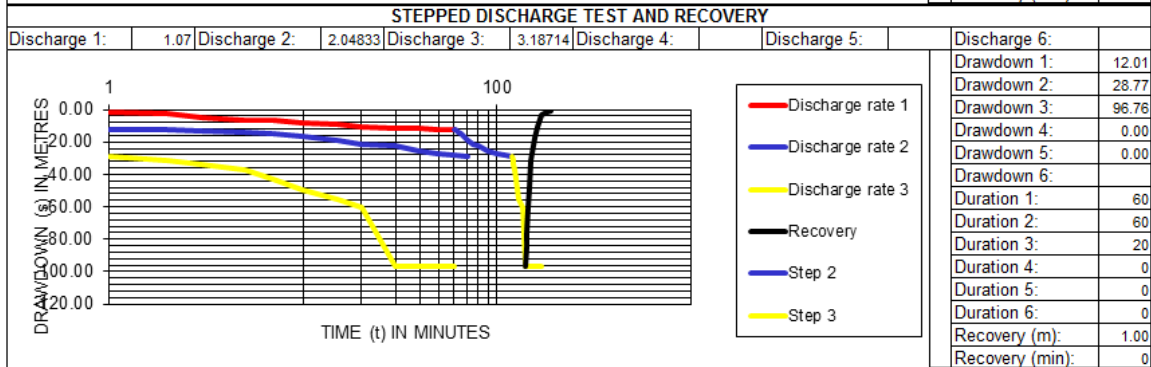
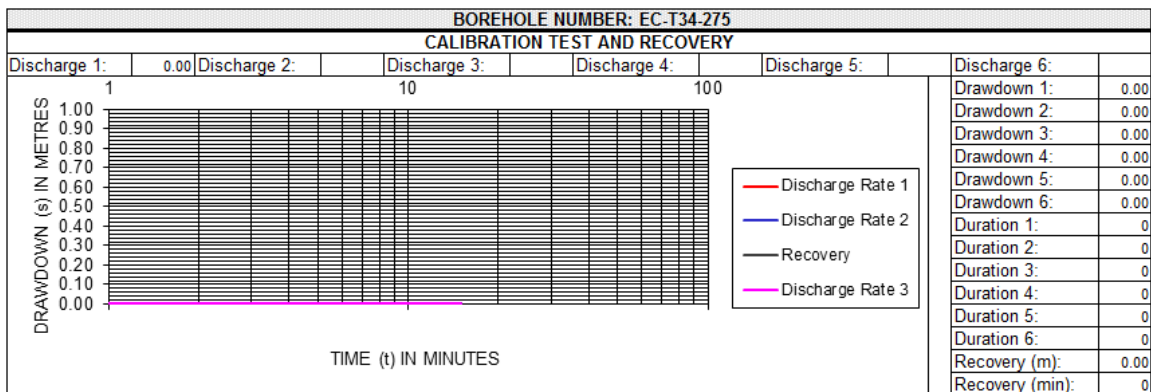
STEPPED DISCHARGE TEST AND RECOVERY																	
BOREHOLE NO. :		EC-T33-757			PROJECT:		Umzimwubu Ward 15										
ALTERNATIVE NO. :		0			SITE NAME:		0										
ALTERNATIVE NO. :		0			CLIENT:		0										
BOREHOLE DEPTH (mbgl):		121.44		CASING DEPTH (mbgl):		0.00		PUMP TYPE USED: BP 30 M									
DEPTH OF PUMP (mbgl):		69.00		CASING HEIGHT (magl):		0.48		OPERATOR: Stanley, Junior, Philip, Thomas									
PUMP INLET DIAMETER (mm):		170.000		CASING ID (mm):		0.000		CONTRACTOR: Welltek Services									
STATIC WATER LEVEL (mbgl):		7.10		DATUM LEVEL (magl):		0.52											
DISCHARGE RATE 1			Time	Recovery 1	DISCHARGE RATE 2			Time	Recovery 2	DISCHARGE RATE 3			Time	Recovery 3			
DATE:		24-Oct-12		(min)	(m)	DATE:		24-Oct-12		(min)	(m)	DATE:		24-Oct-12		(min)	(m)
TIME:		02:00 PM		1		TIME:		03:00 PM		1		TIME:		04:00 PM		1	
Time	Drawdown	Yield	2		Time	Drawdown	Yield	2		Time	Drawdown	Yield	2				
(min)	(m)	(l/s)	3		(min)	(m)	(l/s)	3		(min)	(m)	(l/s)	3				
1	3.12		5		1	12.50		5		1	32.10		5				
2	4.12		7		2	15.90		7		2	33.81		7				
3	4.15	2.150	10		3	17.96	4.100	10		4	36.85		10				
5	4.54		15		5	18.75		15		5	38.45	6.140	15				
7	4.85		20		7	19.56		20		6	40.93		20				
10	5.32	2.150	30		10	20.07		30		7	42.25		30				
15	5.39		40		15	21.61	4.100	40		8	42.61		40				
20	6.45		50		20	22.75		50		9	49.33	6.140	50				
30	7.05		60		30	24.92		60		10	53.30		60				
40	8.28	2.150	70		40	25.56		70		40	54.36		70				
50	9.02		80		50	28.55	4.100	80		50	59.97	6.140	80				
60	10.17		90		60	30.70		90		60	62.40		90				
70			100		70			100		61	62.40		100				
80			110		80			110		62	62.40		110				
90			120		90			120		63	62.40		120				
100			150		100			150		64	62.40		150				
110			180		110			180		65	62.40		180				
120			210		120			210		66	4.73		210				
Average yield: 2.15			(l/s)		Average yield: 4.1					Average yield: 6.14							
DISCHARGE RATE 4			Time	Recovery 4	DISCHARGE RATE 5			Time	Recovery 5	DISCHARGE RATE 6			Time	Recovery			
DATE:		24-Oct-12		(min)	(m)	DATE:		24-Oct-12		(min)	(m)	DATE:		24-Oct-12		(min)	(m)
TIME:				1		TIME:				1		TIME:				1	42.12
Time	Drawdown	Yield	2		Time	Drawdown	Yield	2		Time	Drawdown	Yield	2				
(min)	(m)	(l/s)	3		(min)	(m)	(l/s)	3		(min)	(m)	(l/s)	3				
1			5		1			5		1			5	37.59			
2			7		2			7		2			7	36.74			
3			10		3			10		3			10	35.74			
5			15		5			15		5			15	34.39			
7			20		7			20		7			20	33.54			
10			30		10			30		10			30	31.24			
20			50		20			50		20			50	28.31			
30			60		30			60		30			60	27.60			
40			70		40			70		40			70	25.15			
50			80		50			80		50			80	23.29			
60			90		60			90		60			90	22.78			
70			100		70			100		70			100	21.45			
80			110		80			110		80			110	20.02			
90			120		90			120		90			120	15.62			
100			150		100			150		100			150	14.04			
110			180		110			180		110			180	12.62			
120			210		120			210		120			210	10.58			
Average yield: #DIV/0!										Average yield: #DIV/0!							
COMMENTS:										300			300				
										360			360				
										420			420				
										480			480				
										540			540				
										600			600				
										660			660				
										720			720				
										780			780				
										Average yield:			720				

Cooper-Jacob method		Q_sust				Leaky Aquifer: Hantush Method	
EC-T33-757		No boundaries	1 no-flow	2 no-flow	Closed	EC-T33-757	
		1.02	0.51	0.34	0.25		
		Avg. Q_sust = 0.53		std. dev = 0.34			
		T(m ² /d) = 1.5		T(m ² /d) = 0.9			
		s = 2.13E-02		S = 2.21E-03			
				L (m) = 6			

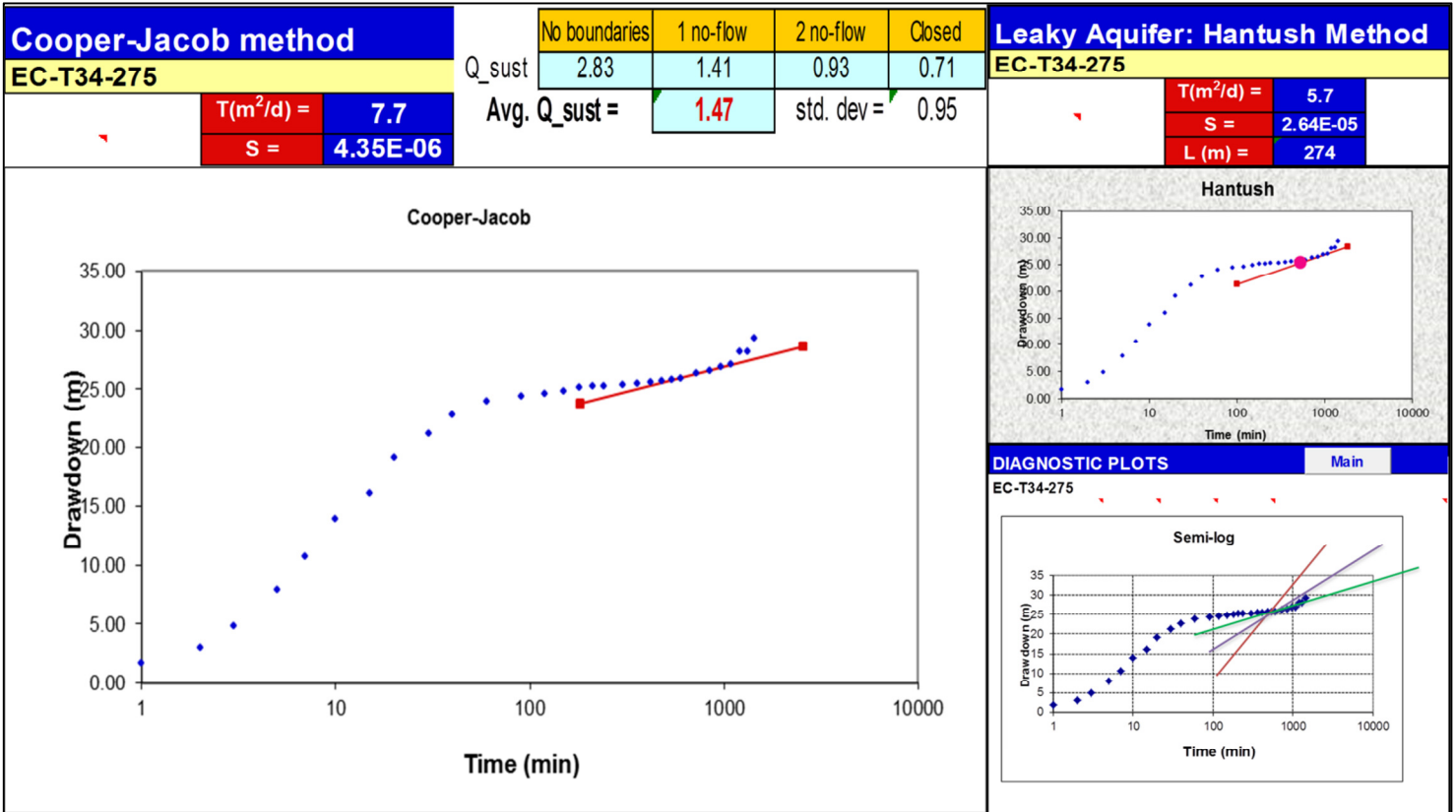


STEPPED DISCHARGE TEST AND RECOVERY															
BOREHOLE NO. :		EC-T34-275		PROJECT:		Umzimvubu Ward 15									
ALTERNATIVE NO. :		0		SITE NAME:		0									
ALTERNATIVE NO. :		0		CLIENT:		0									
BOREHOLE DEPTH (mbgl):		120.05		CASING DEPTH (mbgl):		0.00		PUMP TYPE USED:				GW1302			
DEPTH OF PUMP (mbgl):		99.50		CASING HEIGHT (magl):		0.33		OPERATOR:				0			
PUMP INLET DIAMETER (mm):		170.000		CASING ID (mm):		0.000		CONTRACTOR:				AB Pumps			
STATIC WATER LEVEL (mbgl):		2.24		DATUM LEVEL (magl):		0.41									
DISCHARGE RATE 1			Time	Recovery 1	DISCHARGE RATE 2			Time	Recovery 2	DISCHARGE RATE 3			Time	Recovery 3	
DATE:		24-Feb-13		(min)	(m)	DATE:		24-Feb-13		(min)	(m)	DATE:		24-Feb-13	
TIME:		09:20 AM		1		TIME:		10:20 AM		1		TIME:		11:20 AM	
Time	Drawdown	Yield	2		Time	Drawdown	Yield	2		Time	Drawdown	Yield	2		
(min)	(m)	(l/s)	3		(min)	(m)	(l/s)	3		(min)	(m)	(l/s)	3		
1	1.81		5		1	12.31		5		1	31.81	3.81	5		
2	2.63		7		2	13.02	2.02	7		2	34.12		7		
3	4.92	1.06	10		3	13.87		10		3	37.60	4.10	10		
5	6.47		15		5	14.96	2.04	15		5	42.67		15		
7	6.99	1.05	20		7	16.82		20		7	49.99	4.11	20		
10	7.88		30		10	19.02	2.05	30		10	55.13		30		
15	9.40	1.07	40		15	21.65		40		11	60.71	4.09	40		
20	10.61		50		20	22.39	2.06	50		13	96.76		50		
30	11.24	1.08	60		30	25.60		60		14	96.76	2.09	60		
40	11.55		70		40	27.40	2.07	70		16	96.76	2.06	70		
50	11.96		80		50	28.17		80		20	96.76	2.05	80		
60	12.01	1.09	90		60	28.77	2.05	90		60			90		
70			100		70			100		61			100		
80			110		80			110		62			110		
90			120		90			120		63			120		
100			150		100			150		64			150		
110			180		110			180		65			180		
120			210		120			210		66			210		
Average yield: 1.07			(l/s)		Average yield: 2.0483333					Average yield: 3.1871429					
DISCHARGE RATE 4			Time	Recovery 4	DISCHARGE RATE 5			Time	Recovery 5	DISCHARGE RATE 6			Time	Recovery	
DATE:		24-Feb-13		(min)	(m)	DATE:		24-Feb-13		(min)	(m)	DATE:		24-Feb-13	
TIME:				1		TIME:				1		TIME:		84.64	
Time	Drawdown	Yield	2		Time	Drawdown	Yield	2		Time	Drawdown	Yield	2	80.67	
(min)	(m)	(l/s)	3		(min)	(m)	(l/s)	3		(min)	(m)	(l/s)	3	76.08	
1			5		1			5		1			5	60.07	
2			7		2			7		2			7	48.35	
3			10		3			10		3			10	31.00	
5			15		5			15		5			15	17.37	
7			20		7			20		7			20	10.40	
10			30		10			30		10			30	3.10	
15			40		15			40		15			40	1.97	
20			50		20			50		20			50	1.00	
30			60		30			60		30			60		
40			70		40			70		40			70		
50			80		50			80		50			80		
60			90		60			90		60			90		
70			100		70			100		70			100		
80			110		80			110		80			110		
90			120		90			120		90			120		
100			150		100			150		100			150		
110			180		110			180		110			180		
120			210		120			210		120			210		
Average yield: #DIV/0!															
COMMENTS:								300		180		300			
								360		210		360			
								420		240		420			
								480		300		480			
								540		360		540			
								600		420		600			
								660		480		660			
								720							
								780		Average yield:		720			

TEST DESCRIPTION	STEP	1	2	3	4	5	6	TOTAL:	RECOVERY:	RECOVERY TEST				
CALIBRATION TEST:								(min) (hrs)	(m) (min)	TIME TOTAL (hrs): 1.60				
TEST DURATION (Minutes)								0	0.00	0.00	Cal	Steps	CD	Total
TEST YIELD (l/s)								MAXIMUM (l/s) 0.0			0	50	40	90
DRAWDOWN (m)								MAXIMUM (m)			DRAWDOWN TOTALS (CD):			
MULTI-RATE / STEP DRAWDOWN:											AVAILABLE	UTIL-	%	
TEST DURATION (Minutes)	60	60	20					140	2.33	1.00	ISED			
TEST YIELD (l/s)	1.07	2.05	3.19					MAXIMUM (l/s) 3.2			97.3	27.37	28.14	
DRAWDOWN (m)	12.0	28.77	96.76					MAXIMUM (m) 96.8						
CONSTANT DISCHARGE TEST	TEST DURATION		TEST YIELD		DRAWDOWN		RECOVERY:							
	(min)	(hrs)	(l/s)	(m)	(m)	%	(min)	(hrs)						
	930	15.50	1.83	27.37	1.01	96.31	40	0.67						
OBSERVATION BOREHOLES:	No.	720	1440	2880	>2880 (min)		TOTAL:							
	of boreholes	(min)	(min)	(min)	nr.	Time	(min)	(hrs)						
							0	0.00						



TEST INFORMATION					
Date tested	24-Feb-13	Water level (mbgl)	2.24	Depth of pump (mbgl)	99.5
CD duration	930	CD discharge rate	1.83	CD drawdown	27.37
Available drawdown (m)	97.26	% Recovery after CD	96	% after	40 min



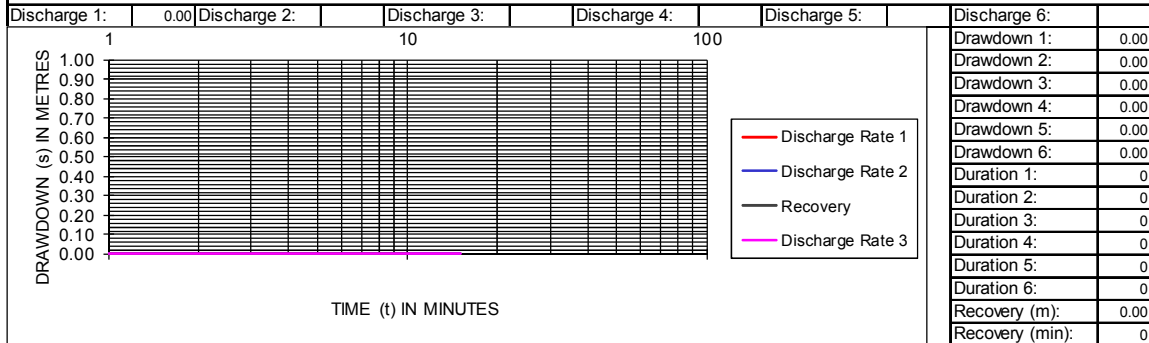
STEPPED DISCHARGE TEST AND RECOVERY																	
BOREHOLE NO. :		EC-T33-846			PROJECT:		Umzimwubu Ward 15										
ALTERNATIVE NO. :		0			SITE NAME:		0										
ALTERNATIVE NO. :		0			CLIENT:		0										
BOREHOLE DEPTH (mbgl):		120.00		CASING DEPTH (mbgl):		0.00		PUMP TYPE USED:				GW1302					
DEPTH OF PUMP (mbgl):		99.50		CASING HEIGHT (magl):		0.27		OPERATOR:				0					
PUMP INLET DIAMETER (mm):		170.000		CASING ID (mm):		0.000		CONTRACTOR:				AB Pumps					
STATIC WATER LEVEL (mbgl):		41.69		DATUM LEVEL (magl):		0.42											
DISCHARGE RATE 1			Time	Recovery 1	DISCHARGE RATE 2			Time	Recovery 2	DISCHARGE RATE 3			Time	Recovery 3			
DATE:		27-Feb-13		(min)	(m)	DATE:		27-Feb-13		(min)	(m)	DATE:		27-Feb-13		(min)	(m)
TIME:		02:00 PM		1		TIME:		03:00 PM		1		TIME:		04:00 PM		1	
Time	Draw down	Yield	2		Time	Drawdown	Yield	2		Time	Drawdown	Yield	2				
(min)	(m)	(l/s)	3		(min)	(m)	(l/s)	3		(min)	(m)	(l/s)	3				
1	0.60		5		1	4.80		5		1	6.18	2.04	5				
2	1.00	0.48	7		2	4.81	0.95	7		2	7.19		7				
3	1.26		10		3	4.82		10		4	7.59	2.05	10				
5	2.29	0.50	15		5	4.82	1.04	15		5	8.32		15				
7	2.80		20		7	4.85		20		6	9.40	2.03	20				
10	3.27	0.52	30		10	4.87	1.01	30		7	9.46		30				
15	3.77		40		15	4.90		40		8	9.72	2.01	40				
20	4.00	0.51	50		20	4.96	1.02	50		9	10.13		50				
30	4.44		60		30	5.05		60		10	10.49	2.00	60				
40	4.53	0.55	70		40	5.06	1.03	70		40	10.62		70				
50	4.66		80		50	5.08		80		50	10.77	2.02	80				
60	4.77	0.52	90		60	5.12	1.04	90		60	10.89		90				
70			100		70			100		70			100				
80			110		80			110		80			110				
90			120		90			120		90			120				
100			150		100			150		100			150				
110			180		110			180		110			180				
120			210		120			210		120			210				
Average yield: 0.5133333			(l/s)		Average yield: 1.015					Average yield: 2.025							
DISCHARGE RATE 4			Time	Recovery 4	DISCHARGE RATE 5			Time	Recovery 5	DISCHARGE RATE 6			Time	Recovery			
DATE:		27-Feb-13		(min)	(m)	DATE:				DATE:				(min)	(m)		
TIME:		05:00 PM		1		TIME:				TIME:				1	40.01		
Time	Draw down	Yield	2		Time	Drawdown	Yield	2		Time	Drawdown	Yield	2	26.24			
(min)	(m)	(l/s)	3		(min)	(m)	(l/s)	3		(min)	(m)	(l/s)	3	16.58			
1	11.08	3.50	5		1			5		1			5	8.69			
2	12.90		7		2			7		2			7	6.16			
3	15.80	4.10	10		3			10		3			10	5.04			
5	19.73		15		5			15		5			15	3.90			
7	22.30	4.09	20		7			20		7			20	3.18			
10	24.47		30		10			30		10			30	2.40			
15	29.60	4.07	40		15			40		15			40				
20	34.45		50		20			50		20			50				
30	43.94	4.10	60		30			60		30			60				
40	52.30		70		40			70		40			70				
50	57.81	4.08	80		50			80		50			80				
51	57.81	3.88	90		60			90		60			90				
52	57.81	3.87	100		70			100		70			100				
55	57.81	3.74	110		80			110		80			110				
90			120		90			120		90			120				
100			150		100			150		100			150				
110			180		110			180		110			180				
120			210		120			210		120			210				
Average yield: 3.9366667																	
COMMENTS:								300		180		300					
								360		210		360					
								420		240		420					
								480		300		480					
								540		360		540					
								600		420		600					
								660		480		660					
								720									
								780		Average yield:			720				

TEST DESCRIPTION	STEP	1	2	3	4	5	6	TOTAL:	RECOVERY:		
CALIBRATION TEST:								(min) (hrs)	(m) (min)		
TEST DURATION (Minutes)								0 0.00	0.00		
TEST YIELD (l/s)								MAXIMUM (l/s)	0.0		
DRAWDOWN (m)								MAXIMUM (m)			
MULTI-RATE / STEP DRAWDOWN:											
TEST DURATION (Minutes)	60	60	60	55				235 3.92	2.40		
TEST YIELD (l/s)	0.51	1.02	2.03	3.94				MAXIMUM (l/s)	3.9		
DRAWDOWN (m)	4.8	5.12	10.89	57.81				MAXIMUM (m)	57.8		
CONSTANT DISCHARGE TEST		TEST DURATION		TEST YIELD		DRAWDOWN		RECOVERY:			
		(min)	(hrs)	(l/s)		(m)		(m)	%	(min)	(hrs)
		1440	24.00	3.67		17.14		0.78	95.45	210	3.50
OBSERVATION BOREHOLES:		No. of boreholes		720		1440		2880		>2880 (min)	
				(min)		(min)		(min)		nr.	Time
										TOTAL: (min) (hrs)	
										0 0.00	

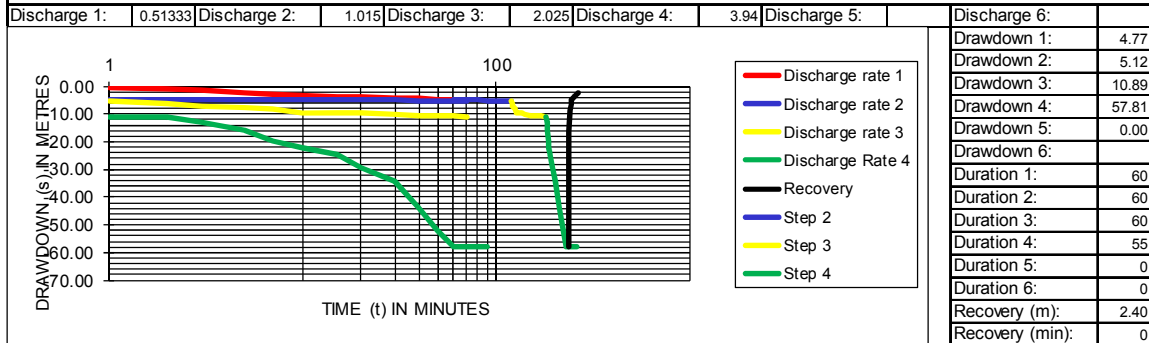
RECOVERY TEST			
TIME TOTAL (hrs): 4.00			
Cal	Steps	CD	Total
0	30	210	240
DRAWDOWN TOTALS (CD):			
AVAILABLE	UTIL-	% ISED	
57.8	17.14	29.65	

BOREHOLE NUMBER: EC-T33-846

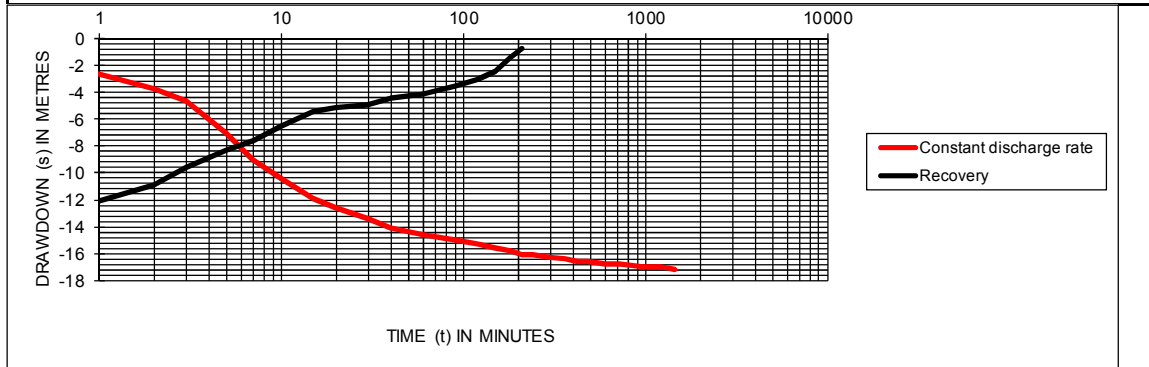
CALIBRATION TEST AND RECOVERY



STEPPED DISCHARGE TEST AND RECOVERY



CONSTANT DISCHARGE TEST AND RECOVERY



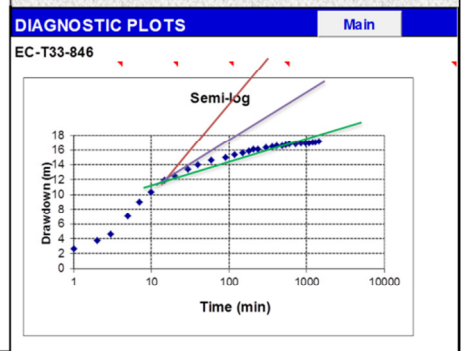
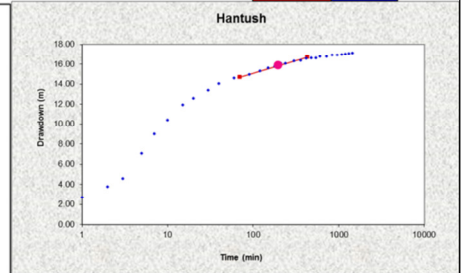
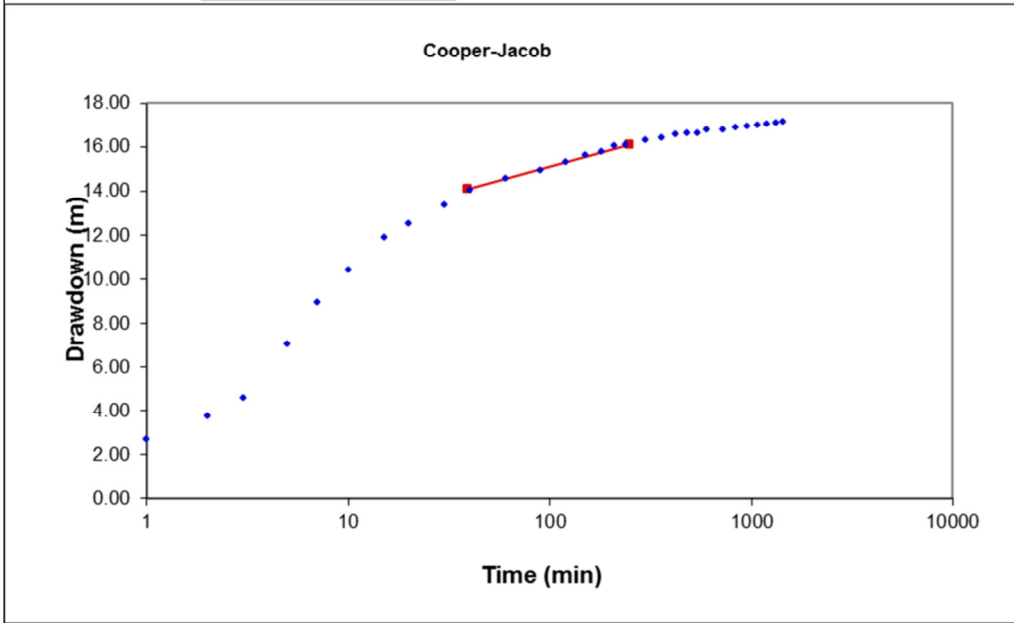
TEST INFORMATION

Date tested	28-Feb-13	Water level (mbgl)	41.69	Depth of pump (mbgl)	99.5
CD duration	1440	CD discharge rate	3.67	CD drawdown	17.14
Available drawdown (m)	57.81	% Recovery after CD	95	% after	210 min

Cooper-Jacob method	Q _{sust}	No boundaries	1 no-flow	2 no-flow	Closed	Leaky Aquifer: Hantush Method
		2.51	1.26	0.83	0.63	
EC-T33-846	Avg. Q _{sust} =		1.31	std. dev =	0.85	EC-T33-846

T(m ² /d) =	23.6
s =	3.22E-06

T(m ² /d) =	23.4
S =	3.03E-06
L (m) =	790



9.4 Appendix D: Hydro-Chemical Data

9.4.1 Ward 13 Hydro-Chemical Data

Umzimvubu Ward 13					
Borehole Id		EC-T33-733			
Date Sampled		13-Jul-12			
Drinking water class		1			
Sample Number		12029/12			
					Class
Micro-biological properties	Viable organisms				0
	Faecal coliforms				0
	Total coliforms				0
Physical Properties	Electrical Conductivity	EC	mS / m	59.00	0
	Total Dissolved Salts	TDS	mg / l	320.00	0
	pH Value	pH		7.40	0
	Turbidity		NTU	0.80	1
Chemical properties	Arsenic	As	mg / l		0
	Cadmium	Cd	mg / l		0
	Calcium	Ca	mg / l	50.00	0
	Chloride	Cl	mg / l	34.00	0
	Copper	Cu	mg / l		0
	Fluoride	F	mg / l	0.21	0
	Iron	Fe	mg / l	0.06	1
	Total Hardness	CaCO ₃	mg / l	207.00	1
	Magnesium	Mg	mg / l	20.00	0
	Manganese	Mn	mg / l		0
	Nitrate	N	mg / l	6.45	1
	Nitrate	NO ₃	mg / l		0
	Potassium	K	mg / l	1.40	0
	Sodium	Na	mg / l	29.00	0
	Sulphate	SO ₄	mg / l	7.01	0
Zinc	Zn	mg / l		0	
Chemical properties (not required for the classification of domestic drinking water supply)	Ammonia	NH ₄	mg / l	0.08	
	P - Alkalinity	CaCO ₃	mg / l	10.00	
	M - Alkalinity	CaCO ₃	mg / l	206.00	
	Calcium Hardness	CaCO ₃	mg / l	125.00	
	Magnesium Hardness	CaCO ₃	mg / l	82.00	
	Carbonate	CaCO ₃	mg / l		
	Bicarbonate	HCO ₃	mg / l		
	Silica	Si	mg / l		
Phosphor	PO ₄ as P	mg / l			

Umzimvubu Ward 13

Borehole Id	EC-T33-734
Date Sampled	26-Jul-12
Drinking water class	3
Sample Number	8503

			Class
Micro-biological properties	Viable organisms		0
	Faecal coliforms	0.00	1
	Total coliforms	0.00	1

Physical Properties	Electrical Conductivity	EC	mS / m	51.00	0
	Total Dissolved Salts	TDS	mg / l	320.00	0
	pH Value	pH		7.60	0
	Turbidity		NTU	0.40	1

Chemical properties	Arsenic	As	mg / l		0
	Cadmium	Cd	mg / l		0
	Calcium	Ca	mg / l	67.00	0
	Chloride	Cl	mg / l	23.00	0
	Copper	Cu	mg / l		0
	Fluoride	F	mg / l	2.40	3
	Iron	Fe	mg / l	0.03	1
	Total Hardness	CaCO ₃	mg / l	307.00	2
	Magnesium	Mg	mg / l	34.00	1
	Manganese	Mn	mg / l		0
	Nitrate	N	mg / l	0.01	0
	Nitrate	NO ₃	mg / l		0
	Potassium	K	mg / l	3.90	0
	Sodium	Na	mg / l	195.00	1
	Sulphate	SO ₄	mg / l	2.06	0
Zinc	Zn	mg / l		0	

Chemical properties (not required for the classification of domestic drinking water supply)	Ammonia	NH ₄	mg / l	0.08	
	P - Alkalinity	CaCO ₃	mg / l	10.00	
	M - Alkalinity	CaCO ₃	mg / l	215.00	
	Calcium Hardness	CaCO ₃	mg / l	167.00	
	Magnesium Hardness	CaCO ₃	mg / l	140.00	
	Carbonate	CaCO ₃	mg / l		
	Bicarbonate	HCO ₃	mg / l		
	Phosphor	PO ₄ as P	mg / l		

Umzimvubu Ward 13

Borehole Id	EC-T33-735
Date Sampled	08-Jul-12
Drinking water class	1
Sample Number	11867/12

		Class
Micro-biological properties	Viable organisms	0
	Faecal coliforms	0
	Total coliforms	0

Physical Properties	Electrical Conductivity	EC	mS / m	35.00	0
	Total Dissolved Salts	TDS	mg / l	242.00	0
	pH Value	pH		7.50	0
	Turbidity		NTU	0.70	1

Chemical properties	Arsenic	As	mg / l		0
	Cadmium	Cd	mg / l		0
	Calcium	Ca	mg / l	31.00	0
	Chloride	Cl	mg / l	10.00	0
	Copper	Cu	mg / l		0
	Fluoride	F	mg / l	0.12	0
	Iron	Fe	mg / l	0.08	1
	Total Hardness	CaCO ₃	mg / l	131.00	0
	Magnesium	Mg	mg / l	13.00	0
	Manganese	Mn	mg / l		0
	Nitrate	N	mg / l	1.52	0
	Nitrate	NO ₃	mg / l		0
	Potassium	K	mg / l	1.20	0
	Sodium	Na	mg / l	14.00	0
	Sulphate	SO ₄	mg / l	1.17	0
Zinc	Zn	mg / l		0	

Chemical properties (not required for the classification of domestic drinking water supply)	Ammonia	NH ₄	mg / l	0.18	
	P - Alkalinity	CaCO ₃	mg / l	10.00	
	M - Alkalinity	CaCO ₃	mg / l	152.00	
	Calcium Hardness	CaCO ₃	mg / l	77.00	
	Magnesium Hardness	CaCO ₃	mg / l	54.00	
	Carbonate	CaCO ₃	mg / l		
	Bicarbonate	HCO ₃	mg / l		
	Silica	Si	mg / l		
Phosphor	PO ₄ as P	mg / l			

Umzimvubu Ward 13

Borehole Id	EC-T31-086
Date Sampled	26-Jul-12
Drinking water class	2
Sample Number	8504

			Class
Micro-biological properties	Viable organisms		0
	Faecal coliforms	0.00	1
	Total coliforms	0.00	1

Physical Properties	Electrical Conductivity	EC	mS / m	31.00	0
	Total Dissolved Salts	TDS	mg / l	250.00	0
	pH Value	pH		7.70	0
	Turbidity		NTU	8.80	2

Chemical properties	Arsenic	As	mg / l		0
	Cadmium	Cd	mg / l		0
	Calcium	Ca	mg / l	28.00	0
	Chloride	Cl	mg / l	5.00	0
	Copper	Cu	mg / l		0
	Fluoride	F	mg / l	0.18	0
	Iron	Fe	mg / l	0.02	1
	Total Hardness	CaCO ₃	mg / l	110.00	0
	Magnesium	Mg	mg / l	9.70	0
	Manganese	Mn	mg / l		0
	Nitrate	N	mg / l	1.00	0
	Nitrate	NO ₃	mg / l		0
	Potassium	K	mg / l	1.90	0
	Sodium	Na	mg / l	26.00	0
	Sulphate	SO ₄	mg / l	2.63	0
Zinc	Zn	mg / l		0	

Chemical properties (not required for the classification of domestic drinking water supply)	Ammonia	NH ₄	mg / l	0.08	
	P - Alkalinity	CaCO ₃	mg / l	10.00	
	M - Alkalinity	CaCO ₃	mg / l	147.00	
	Calcium Hardness	CaCO ₃	mg / l	70.00	
	Magnesium Hardness	CaCO ₃	mg / l	40.00	
	Carbonate	CaCO ₃	mg / l		
	Bicarbonate	HCO ₃	mg / l		
	Silica	Si	mg / l		
Phosphor	PO ₄ as P	mg / l			

Umzimvubu Ward 13

Borehole Id EC-T31-198 AT
 Date Sampled
 Drinking water class **4**
 Sample Number 18832/12

			Class
Micro-biological properties	Viable organisms		0
	Faecal coliforms	0.00	1
	Total coliforms	0.00	1

Physical Properties	Electrical Conductivity	EC	mS / m	30.00	0
	Total Dissolved Salts	TDS	mg / l	169.00	0
	pH Value	pH		8.80	0
	Turbidity		NTU	11.40	2

Chemical properties	Arsenic	As	mg / l		0
	Cadmium	Cd	mg / l		0
	Calcium	Ca	mg / l	2.70	0
	Chloride	Cl	mg / l	14.00	0
	Copper	Cu	mg / l		0
	Fluoride	F	mg / l	7.10	4
	Iron	Fe	mg / l	0.01	0
	Total Hardness	CaCO ₃	mg / l	7.00	0
	Magnesium	Mg	mg / l	0.20	0
	Manganese	Mn	mg / l		0
	Nitrate	N	mg / l	0.06	0
	Nitrate	NO ₃	mg / l		0
	Potassium	K	mg / l	0.20	0
	Sodium	Na	mg / l	69.00	0
	Sulphate	SO ₄	mg / l	2.02	0
Zinc	Zn	mg / l		0	

Chemical properties (not required for the classification of domestic drinking water supply)	Ammonia	NH ₄	mg / l	0.08	
	P - Alkalinity	CaCO ₃	mg / l	14.00	
	M - Alkalinity	CaCO ₃	mg / l	90.00	
	Calcium Hardness	CaCO ₃	mg / l	7.00	
	Magnesium Hardness	CaCO ₃	mg / l	1.00	
	Carbonate	CaCO ₃	mg / l		
	Bicarbonate	HCO ₃	mg / l		
	Phosphor	PO ₄ as P	mg / l		

Umzimvubu Ward 13

Borehole Id	EC-T31-199
Date Sampled	26-Jul-12
Drinking water class	2
Sample Number	8502

			Class
Micro-biological properties	Viable organisms		0
	Faecal coliforms	0.00	1
	Total coliforms	0.00	1

Physical Properties	Electrical Conductivity	EC	mS / m	35.00	0
	Total Dissolved Salts	TDS	mg / l	438.00	0
	pH Value	pH		7.50	0
	Turbidity		NTU	1.20	2

Chemical properties	Arsenic	As	mg / l		0
	Cadmium	Cd	mg / l		0
	Calcium	Ca	mg / l	37.00	0
	Chloride	Cl	mg / l	5.00	0
	Copper	Cu	mg / l		0
	Fluoride	F	mg / l	0.41	0
	Iron	Fe	mg / l	0.01	1
	Total Hardness	CaCO ₃	mg / l	134.00	0
	Magnesium	Mg	mg / l	10.00	0
	Manganese	Mn	mg / l		0
	Nitrate	N	mg / l	0.43	0
	Nitrate	NO ₃	mg / l		0
	Potassium	K	mg / l	0.70	0
	Sodium	Na	mg / l	30.00	0
	Sulphate	SO ₄	mg / l	2.06	0
Zinc	Zn	mg / l		0	

Chemical properties (not required for the classification of domestic drinking water supply)	Ammonia	NH ₄	mg / l	0.08	
	P - Alkalinity	CaCO ₃	mg / l	10.00	
	M - Alkalinity	CaCO ₃	mg / l	173.00	
	Calcium Hardness	CaCO ₃	mg / l	92.00	
	Magnesium Hardness	CaCO ₃	mg / l	41.00	
	Carbonate	CaCO ₃	mg / l		
	Bicarbonate	HCO ₃	mg / l		
	Silica	Si	mg / l		
Phosphor	PO ₄ as P	mg / l			

Umzimvubu Ward 13

Borehole Id	EC-T31-200
Date Sampled	16-Aug-12
Drinking water class	1
Sample Number	8795

				Class
Micro-biological properties	Viability organisms			0
	Faecal coliforms		0.00	1
	Total coliforms		0.00	1
Physical Properties	Electrical Conductivity <i>EC</i>	mS / m	31.00	0
	Total Dissolved Salts <i>TDS</i>	mg / l	222.00	0
	pH Value <i>pH</i>		7.50	0
	Turbidity	NTU	0.30	1
Chemical properties	Arsenic <i>As</i>	mg / l		0
	Cadmium <i>Cd</i>	mg / l		0
	Calcium <i>Ca</i>	mg / l	24.00	0
	Chloride <i>Cl</i>	mg / l	12.00	0
	Copper <i>Cu</i>	mg / l		0
	Fluoride <i>F</i>	mg / l	0.05	0
	Iron <i>Fe</i>	mg / l	0.01	1
	Total Hardness <i>CaCO₃</i>	mg / l	113.00	0
	Magnesium <i>Mg</i>	mg / l	13.00	0
	Manganese <i>Mn</i>	mg / l		0
	Nitrate <i>N</i>	mg / l	1.92	0
	Nitrate <i>NO₃</i>	mg / l		0
	Potassium <i>K</i>	mg / l	0.40	0
	Sodium <i>Na</i>	mg / l	11.00	0
	Sulphate <i>SO₄</i>	mg / l	1.94	0
Zinc <i>Zn</i>	mg / l		0	
Chemical properties (not required for the classification of domestic drinking water supply)	Ammonia <i>NH₄</i>	mg / l	0.08	
	P - Alkalinity <i>CaCO₃</i>	mg / l	10.00	
	M - Alkalinity <i>CaCO₃</i>	mg / l	131.00	
	Calcium Hardness <i>CaCO₃</i>	mg / l	60.00	
	Magnesium Hardness <i>CaCO₃</i>	mg / l	54.00	
	Carbonate <i>CaCO₃</i>	mg / l		
	Bicarbonate <i>HCO₃</i>	mg / l		
	Silica <i>Si</i>	mg / l		
Phosphor <i>PO₄ as P</i>	mg / l			

Umzimvubu Ward 13

Borehole Id	EC-T33-736
Date Sampled	16-Aug-12
Drinking water class	3
Sample Number	8794

			Class
Micro-biological properties	Viable organisms		0
	Faecal coliforms	0.00	1
	Total coliforms	0.00	1

Physical Properties	Electrical Conductivity	EC	mS / m	64.00	0
	Total Dissolved Salts	TDS	mg / l	262.00	0
	pH Value	pH		6.70	0
	Turbidity		NTU	8.60	2

Chemical properties	Arsenic	As	mg / l		0
	Cadmium	Cd	mg / l		0
	Calcium	Ca	mg / l	1.00	0
	Chloride	Cl	mg / l	7.00	0
	Copper	Cu	mg / l		0
	Fluoride	F	mg / l	1.51	3
	Iron	Fe	mg / l	0.16	1
	Total Hardness	CaCO ₃	mg / l	3.00	0
	Magnesium	Mg	mg / l	0.20	0
	Manganese	Mn	mg / l		0
	Nitrate	N	mg / l	0.05	0
	Nitrate	NO ₃	mg / l		0
	Potassium	K	mg / l	0.30	0
	Sodium	Na	mg / l	101.00	1
	Sulphate	SO ₄	mg / l	0.88	0
Zinc	Zn	mg / l		0	

Chemical properties (not required for the classification of domestic drinking water supply)	Ammonia	NH ₄	mg / l	0.08	
	P - Alkalinity	CaCO ₃	mg / l	10.00	
	M - Alkalinity	CaCO ₃	mg / l	175.00	
	Calcium Hardness	CaCO ₃	mg / l	2.00	
	Magnesium Hardness	CaCO ₃	mg / l	1.00	
	Carbonate	CaCO ₃	mg / l		
	Bicarbonate	HCO ₃	mg / l		
	Phosphor	PO ₄ as P	mg / l		

9.4.2 *Ward 15 Hydro-Chemical Data*

Umzimvubu Ward 15

Borehole Id	EC-T33-740
Date Sampled	30-Aug-12
Drinking water class	2
Sample Number	9003

		Class	
Micro-biological properties	Viable organisms		0
	Faecal coliforms	0.00	1
	Total coliforms	0.00	1

Physical Properties	Electrical Conductivity	EC	mS / m	19.00	0
	Total Dissolved Salts	TDS	mg / l	146.00	0
	pH Value	pH		8.10	0
	Turbidity		NTU	6.30	2

Chemical properties	Arsenic	As	mg / l		0
	Cadmium	Cd	mg / l		0
	Calcium	Ca	mg / l	12.00	0
	Chloride	Cl	mg / l	5.00	0
	Copper	Cu	mg / l		0
	Fluoride	F	mg / l	0.37	0
	Iron	Fe	mg / l	0.05	1
	Total Hardness	CaCO ₃	mg / l	36.00	0
	Magnesium	Mg	mg / l	1.40	0
	Manganese	Mn	mg / l		0
	Nitrate	N	mg / l	0.09	0
	Nitrate	NO ₃	mg / l		0
	Potassium	K	mg / l	0.20	0
	Sodium	Na	mg / l	26.00	0
	Sulphate	SO ₄	mg / l	1.81	0
Zinc	Zn	mg / l		0	

Chemical properties (not required for the classification of domestic drinking water supply)	Ammonia	NH ₄	mg / l	0.08	
	P - Alkalinity	CaCO ₃	mg / l	10.00	
	M - Alkalinity	CaCO ₃	mg / l	89.00	
	Calcium Hardness	CaCO ₃	mg / l	30.00	
	Magnesium Hardness	CaCO ₃	mg / l	6.00	
	Carbonate	CaCO ₃	mg / l		
	Bicarbonate	HCO ₃	mg / l		
	Silica	Si	mg / l		
Phosphor	PO ₄ as P	mg / l			

Umzimvubu Ward 15

Borehole Id	EC-T33-741
Date Sampled	30-Aug-12
Drinking water class	4
Sample Number	9004

			Class
Micro-biological properties	Viable organisms		0
	Faecal coliforms	0.00	1
	Total coliforms	0.00	1

Physical Properties	Electrical Conductivity	EC	mS / m	22.00	0
	Total Dissolved Salts	TDS	mg / l	154.00	0
	pH Value	pH		9.50	2
	Turbidity		NTU	2.10	2

Chemical properties	Arsenic	As	mg / l		0
	Cadmium	Cd	mg / l		0
	Calcium	Ca	mg / l	2.20	0
	Chloride	Cl	mg / l	25.00	0
	Copper	Cu	mg / l		0
	Fluoride	F	mg / l	5.40	4
	Iron	Fe	mg / l	0.06	1
	Total Hardness	CaCO ₃	mg / l	7.00	0
	Magnesium	Mg	mg / l	0.40	0
	Manganese	Mn	mg / l		0
	Nitrate	N	mg / l	0.15	0
	Nitrate	NO ₃	mg / l		0
	Potassium	K	mg / l	0.20	0
	Sodium	Na	mg / l	40.00	0
	Sulphate	SO ₄	mg / l	1.73	0
Zinc	Zn	mg / l		0	

Chemical properties (not required for the classification of domestic drinking water supply)	Ammonia	NH ₄	mg / l	0.08	
	P - Alkalinity	CaCO ₃	mg / l	18.00	
	M - Alkalinity	CaCO ₃	mg / l	35.00	
	Calcium Hardness	CaCO ₃	mg / l	5.00	
	Magnesium Hardness	CaCO ₃	mg / l	2.00	
	Carbonate	CaCO ₃	mg / l		
	Bicarbonate	HCO ₃	mg / l		
	Phosphor	PO ₄ as P	mg / l		

Umzimvubu Ward 15

Borehole Id	EC-T33-745
Date Sampled	01-Oct-12
Drinking water class	1
Sample Number	9289

			Class
Micro-biological properties	Viable organisms		0
	Faecal coliforms	0.00	1
	Total coliforms	0.00	1

Physical Properties	Electrical Conductivity	EC	mS / m	39.00	0
	Total Dissolved Salts	TDS	mg / l	228.00	0
	pH Value	pH		7.30	0
	Turbidity		NTU	0.30	1

Chemical properties	Arsenic	As	mg / l		0
	Cadmium	Cd	mg / l		0
	Calcium	Ca	mg / l	29.00	0
	Chloride	Cl	mg / l	12.00	0
	Copper	Cu	mg / l		0
	Fluoride	F	mg / l	0.12	0
	Iron	Fe	mg / l		0
	Total Hardness	CaCO ₃	mg / l	138.00	0
	Magnesium	Mg	mg / l	16.00	0
	Manganese	Mn	mg / l		0
	Nitrate	N	mg / l	1.06	0
	Nitrate	NO ₃	mg / l		0
	Potassium	K	mg / l	0.90	0
	Sodium	Na	mg / l	19.00	0
	Sulphate	SO ₄	mg / l	2.02	0
Zinc	Zn	mg / l		0	

Chemical properties (not required for the classification of domestic drinking water supply)	Ammonia	NH ₄	mg / l	0.29	
	P - Alkalinity	CaCO ₃	mg / l	10.00	
	M - Alkalinity	CaCO ₃	mg / l	166.00	
	Calcium Hardness	CaCO ₃	mg / l	72.00	
	Magnesium Hardness	CaCO ₃	mg / l	66.00	
	Carbonate	CaCO ₃	mg / l		
	Bicarbonate	HCO ₃	mg / l		
	Silica	Si	mg / l		
Phosphor	PO ₄ as P	mg / l			

Umzimvubu Ward 15

Borehole Id	EC-T33-746
Date Sampled	01-Oct-12
Drinking water class	4
Sample Number	9288

			Class
Micro-biological properties	Viable organisms		0
	Faecal coliforms	0.00	1
	Total coliforms	0.00	1

Physical Properties	Electrical Conductivity	EC	mS / m	26.00	0
	Total Dissolved Salts	TDS	mg / l	176.00	0
	pH Value	pH		9.20	1
	Turbidity		NTU	3.70	2

Chemical properties	Arsenic	As	mg / l		0
	Cadmium	Cd	mg / l		0
	Calcium	Ca	mg / l	3.30	0
	Chloride	Cl	mg / l	11.00	0
	Copper	Cu	mg / l		0
	Fluoride	F	mg / l	4.70	4
	Iron	Fe	mg / l		0
	Total Hardness	CaCO ₃	mg / l	14.00	0
	Magnesium	Mg	mg / l	1.40	0
	Manganese	Mn	mg / l		0
	Nitrate	N	mg / l	0.45	0
	Nitrate	NO ₃	mg / l		0
	Potassium	K	mg / l	0.50	0
	Sodium	Na	mg / l	48.00	0
	Sulphate	SO ₄	mg / l	1.70	0
Zinc	Zn	mg / l		0	

Chemical properties (not required for the classification of domestic drinking water supply)	Ammonia	NH ₄	mg / l	0.28	
	P - Alkalinity	CaCO ₃	mg / l	28.00	
	M - Alkalinity	CaCO ₃	mg / l	62.00	
	Calcium Hardness	CaCO ₃	mg / l	8.00	
	Magnesium Hardness	CaCO ₃	mg / l	6.00	
	Carbonate	CaCO ₃	mg / l		
	Bicarbonate	HCO ₃	mg / l		
	Phosphor	PO ₄ as P	mg / l		

Umzimvubu Ward 15

Borehole Id	EC-T33-748
Date Sampled	01-Oct-12
Drinking water class	2
Sample Number	9290

			Class
Micro-biological properties	Viable organisms		0
	Faecal coliforms	0.00	1
	Total coliforms	0.00	1

Physical Properties	Electrical Conductivity	EC	mS / m	37.00	0
	Total Dissolved Salts	TDS	mg / l	234.00	0
	pH Value	pH		7.50	0
	Turbidity		NTU	9.40	2

Chemical properties	Arsenic	As	mg / l		0
	Cadmium	Cd	mg / l		0
	Calcium	Ca	mg / l	27.00	0
	Chloride	Cl	mg / l	6.00	0
	Copper	Cu	mg / l		0
	Fluoride	F	mg / l	0.15	0
	Iron	Fe	mg / l		0
	Total Hardness	CaCO ₃	mg / l	125.00	0
	Magnesium	Mg	mg / l	14.00	0
	Manganese	Mn	mg / l		0
	Nitrate	N	mg / l	1.97	0
	Nitrate	NO ₃	mg / l		0
	Potassium	K	mg / l	0.90	0
	Sodium	Na	mg / l	22.00	0
	Sulphate	SO ₄	mg / l	1.84	0
Zinc	Zn	mg / l		0	

Chemical properties (not required for the classification of domestic drinking water supply)	Ammonia	NH ₄	mg / l	0.14	
	P - Alkalinity	CaCO ₃	mg / l	10.00	
	M - Alkalinity	CaCO ₃	mg / l	154.00	
	Calcium Hardness	CaCO ₃	mg / l	67.00	
	Magnesium Hardness	CaCO ₃	mg / l	58.00	
	Carbonate	CaCO ₃	mg / l		
	Bicarbonate	HCO ₃	mg / l		
	Phosphor	PO ₄ as P	mg / l		

Umzimvubu Ward 15

Borehole Id	EC-T33-750
Date Sampled	09-Oct-12
Drinking water class	3
Sample Number	9518

			Class
Micro-biological properties	Viable organisms		0
	Faecal coliforms	0.00	1
	Total coliforms	0.00	1

Physical Properties	Electrical Conductivity	EC	mS / m	20.00	0
	Total Dissolved Salts	TDS	mg / l	162.00	0
	pH Value	pH		7.90	0
	Turbidity		NTU	35.80	3

Chemical properties	Arsenic	As	mg / l		0
	Cadmium	Cd	mg / l		0
	Calcium	Ca	mg / l	16.00	0
	Chloride	Cl	mg / l	5.00	0
	Copper	Cu	mg / l		0
	Fluoride	F	mg / l	0.50	0
	Iron	Fe	mg / l	0.01	1
	Total Hardness	CaCO ₃	mg / l	58.00	0
	Magnesium	Mg	mg / l	4.40	0
	Manganese	Mn	mg / l		0
	Nitrate	N	mg / l	0.90	0
	Nitrate	NO ₃	mg / l		0
	Potassium	K	mg / l	0.40	0
	Sodium	Na	mg / l	17.00	0
	Sulphate	SO ₄	mg / l	1.59	0
Zinc	Zn	mg / l		0	

Chemical properties (not required for the classification of domestic drinking water supply)	Ammonia	NH ₄	mg / l	0.60	
	P - Alkalinity	CaCO ₃	mg / l	10.00	
	M - Alkalinity	CaCO ₃	mg / l	78.00	
	Calcium Hardness	CaCO ₃	mg / l	40.00	
	Magnesium Hardness	CaCO ₃	mg / l	18.00	
	Carbonate	CaCO ₃	mg / l		
	Bicarbonate	HCO ₃	mg / l		
	Phosphor	PO ₄ as P	mg / l		

Umzimvubu Ward 15

Borehole Id	EC-T33-752
Date Sampled	09-Oct-12
Drinking water class	2
Sample Number	9519

			Class
Micro-biological properties	Viable organisms		0
	Faecal coliforms	0.00	1
	Total coliforms	0.00	1

Physical Properties	Electrical Conductivity	EC	mS / m	48.00	0
	Total Dissolved Salts	TDS	mg / l	350.00	0
	pH Value	pH		7.20	0
	Turbidity		NTU	1.50	2

Chemical properties	Arsenic	As	mg / l		0
	Cadmium	Cd	mg / l		0
	Calcium	Ca	mg / l	37.00	0
	Chloride	Cl	mg / l	19.00	0
	Copper	Cu	mg / l		0
	Fluoride	F	mg / l	0.09	0
	Iron	Fe	mg / l	0.01	1
	Total Hardness	CaCO ₃	mg / l	142.00	0
	Magnesium	Mg	mg / l	12.00	0
	Manganese	Mn	mg / l		0
	Nitrate	N	mg / l	0.08	0
	Nitrate	NO ₃	mg / l		0
	Potassium	K	mg / l	0.90	0
	Sodium	Na	mg / l	41.00	0
	Sulphate	SO ₄	mg / l	2.48	0
Zinc	Zn	mg / l		0	

Chemical properties (not required for the classification of domestic drinking water supply)	Ammonia	NH ₄	mg / l	0.23	
	P - Alkalinity	CaCO ₃	mg / l	10.00	
	M - Alkalinity	CaCO ₃	mg / l	196.00	
	Calcium Hardness	CaCO ₃	mg / l	92.00	
	Magnesium Hardness	CaCO ₃	mg / l	49.00	
	Carbonate	CaCO ₃	mg / l		
	Bicarbonate	HCO ₃	mg / l		
	Silica	Si	mg / l		
Phosphor	PO ₄ as P	mg / l			

Umzimvubu Ward 15

Borehole Id	EC-T33-754
Date Sampled	15-Oct-12
Drinking water class	2
Sample Number	9581

			Class
Micro-biological properties	Viable organisms		0
	Faecal coliforms	0.00	1
	Total coliforms	0.00	1

Physical Properties	Electrical Conductivity	EC	mS / m	13.00	0
	Total Dissolved Salts	TDS	mg / l	109.00	0
	pH Value	pH		8.50	0
	Turbidity		NTU	2.00	2

Chemical properties	Arsenic	As	mg / l		0
	Cadmium	Cd	mg / l		0
	Calcium	Ca	mg / l		0
	Chloride	Cl	mg / l	5.00	0
	Copper	Cu	mg / l		0
	Fluoride	F	mg / l	1.00	2
	Iron	Fe	mg / l		0
	Total Hardness	CaCO ₃	mg / l		0
	Magnesium	Mg	mg / l		0
	Manganese	Mn	mg / l		0
	Nitrate	N	mg / l		0
	Nitrate	NO ₃	mg / l		0
	Potassium	K	mg / l		0
	Sodium	Na	mg / l		0
	Sulphate	SO ₄	mg / l		0
Zinc	Zn	mg / l		0	

Chemical properties (not required for the classification of domestic drinking water supply)	Ammonia	NH ₄	mg / l		
	P - Alkalinity	CaCO ₃	mg / l	10.00	
	M - Alkalinity	CaCO ₃	mg / l	56.00	
	Calcium Hardness	CaCO ₃	mg / l		
	Magnesium Hardness	CaCO ₃	mg / l		
	Carbonate	CaCO ₃	mg / l		
	Bicarbonate	HCO ₃	mg / l		
	Phosphor	PO ₄ as P	mg / l		

Umzimvubu Ward 15

Borehole Id	EC-T33-756
Date Sampled	
Drinking water class	2
Sample Number	9791

		Class
Micro-biological properties	Viable organisms	0
	Faecal coliforms	0.00 1
	Total coliforms	0.00 1

Physical Properties	Electrical Conductivity	EC	mS / m	14.00	0
	Total Dissolved Salts	TDS	mg / l	97.00	0
	pH Value	pH		7.40	0
	Turbidity		NTU	5.20	2

Chemical properties	Arsenic	As	mg / l		0
	Cadmium	Cd	mg / l		0
	Calcium	Ca	mg / l	11.00	0
	Chloride	Cl	mg / l	5.00	0
	Copper	Cu	mg / l		0
	Fluoride	F	mg / l	0.16	0
	Iron	Fe	mg / l	0.01	0
	Total Hardness	CaCO ₃	mg / l	47.00	0
	Magnesium	Mg	mg / l	4.70	0
	Manganese	Mn	mg / l		0
	Nitrate	N	mg / l	0.31	0
	Nitrate	NO ₃	mg / l		0
	Potassium	K	mg / l	5.00	0
	Sodium	Na	mg / l	7.10	0
	Sulphate	SO ₄	mg / l	1.84	0
Zinc	Zn	mg / l		0	

Chemical properties (not required for the classification of domestic drinking water supply)	Ammonia	NH ₄	mg / l	0.14	
	P - Alkalinity	CaCO ₃	mg / l	10.00	
	M - Alkalinity	CaCO ₃	mg / l	64.00	
	Calcium Hardness	CaCO ₃	mg / l	27.00	
	Magnesium Hardness	CaCO ₃	mg / l	19.00	
	Carbonate	CaCO ₃	mg / l		
	Bicarbonate	HCO ₃	mg / l		
	Silica	Si	mg / l		
	Phosphor	PO ₄ as P	mg / l		

Umzimvubu Ward 15

Borehole Id	EC-T33-757
Date Sampled	
Drinking water class	2
Sample Number	9793

		Class
Micro-biological properties	Viable organisms	0
	Faecal coliforms	0.00 1
	Total coliforms	0.00 1

Physical Properties	Electrical Conductivity	EC	mS / m	15.00	0
	Total Dissolved Salts	TDS	mg / l	95.00	0
	pH Value	pH		8.50	0
	Turbidity		NTU	2.50	2

Chemical properties	Arsenic	As	mg / l		0
	Cadmium	Cd	mg / l		0
	Calcium	Ca	mg / l	7.20	0
	Chloride	Cl	mg / l	5.00	0
	Copper	Cu	mg / l		0
	Fluoride	F	mg / l	0.54	0
	Iron	Fe	mg / l	0.01	0
	Total Hardness	CaCO ₃	mg / l	22.00	0
	Magnesium	Mg	mg / l	0.90	0
	Manganese	Mn	mg / l		0
	Nitrate	N	mg / l	0.16	0
	Nitrate	NO ₃	mg / l		0
	Potassium	K	mg / l	0.40	0
	Sodium	Na	mg / l	21.00	0
	Sulphate	SO ₄	mg / l	2.42	0
Zinc	Zn	mg / l		0	

Chemical properties (not required for the classification of domestic drinking water supply)	Ammonia	NH ₄	mg / l	0.08	
	P - Alkalinity	CaCO ₃	mg / l	10.00	
	M - Alkalinity	CaCO ₃	mg / l	66.00	
	Calcium Hardness	CaCO ₃	mg / l	18.00	
	Magnesium Hardness	CaCO ₃	mg / l	4.00	
	Carbonate	CaCO ₃	mg / l		
	Bicarbonate	HCO ₃	mg / l		
	Phosphor	PO ₄ as P	mg / l		

Umzimvubu Ward 15

Borehole Id	EC-T34-275
Date Sampled	26-Feb-13
Drinking water class	2
Sample Number	298

		Class
Micro-biological properties	Viable organisms	0
	Faecal coliforms	0.00 1
	Total coliforms	0.00 1

Physical Properties	Electrical Conductivity	EC	mS / m	13.00	0
	Total Dissolved Salts	TDS	mg / l	93.00	0
	pH Value	pH		7.50	0
	Turbidity		NTU	2.40	2

Chemical properties	Arsenic	As	mg / l		0
	Cadmium	Cd	mg / l		0
	Calcium	Ca	mg / l	8.30	0
	Chloride	Cl	mg / l	60.00	0
	Copper	Cu	mg / l		0
	Fluoride	F	mg / l	0.60	0
	Iron	Fe	mg / l	0.01	0
	Total Hardness	CaCO ₃	mg / l	28.00	0
	Magnesium	Mg	mg / l	1.80	0
	Manganese	Mn	mg / l		0
	Nitrate	N	mg / l	0.35	0
	Nitrate	NO ₃	mg / l		0
	Potassium	K	mg / l	0.50	0
	Sodium	Na	mg / l	9.80	0
	Sulphate	SO ₄	mg / l	2.42	0
Zinc	Zn	mg / l		0	

Chemical properties (not required for the classification of domestic drinking water supply)	Ammonia	NH ₄	mg / l	0.08	
	P - Alkalinity	CaCO ₃	mg / l	10.00	
	M - Alkalinity	CaCO ₃	mg / l	56.00	
	Calcium Hardness	CaCO ₃	mg / l	21.00	
	Magnesium Hardness	CaCO ₃	mg / l	7.00	
	Carbonate	CaCO ₃	mg / l		
	Bicarbonate	HCO ₃	mg / l		
	Silica	Si	mg / l		
Phosphor	PO ₄ as P	mg / l			

Umzimvubu Ward 15

Borehole Id	EC-T33-846
Date Sampled	01-Mar-13
Drinking water class	1
Sample Number	299

			Class
Micro-biological properties	Viable organisms		0
	Faecal coliforms	0.00	1
	Total coliforms	0.00	1

Physical Properties	Electrical Conductivity	EC	mS / m	20.00	0
	Total Dissolved Salts	TDS	mg / l	129.00	0
	pH Value	pH		7.70	0
	Turbidity		NTU	0.80	1

Chemical properties	Arsenic	As	mg / l		0
	Cadmium	Cd	mg / l		0
	Calcium	Ca	mg / l	14.00	0
	Chloride	Cl	mg / l	5.00	0
	Copper	Cu	mg / l		0
	Fluoride	F	mg / l	0.18	0
	Iron	Fe	mg / l	0.02	1
	Total Hardness	CaCO ₃	mg / l	53.00	0
	Magnesium	Mg	mg / l	4.30	0
	Manganese	Mn	mg / l		0
	Nitrate	N	mg / l	0.55	0
	Nitrate	NO ₃	mg / l		0
	Potassium	K	mg / l	0.50	0
	Sodium	Na	mg / l	15.00	0
Sulphate	SO ₄	mg / l	2.85	0	
Zinc	Zn	mg / l		0	

Chemical properties (not required for the classification of domestic drinking water supply)	Ammonia	NH ₄	mg / l	0.08	
	P - Alkalinity	CaCO ₃	mg / l	10.00	
	M - Alkalinity	CaCO ₃	mg / l	90.00	
	Calcium Hardness	CaCO ₃	mg / l	35.00	
	Magnesium Hardness	CaCO ₃	mg / l	18.00	
	Carbonate	CaCO ₃	mg / l		
	Bicarbonate	HCO ₃	mg / l		
	Phosphor	PO ₄ as P	mg / l		