HYDROGEOLOGICAL AND GEOPHYSICAL SURVEY REPORT

CARRIED OUT

AT ENDUATA AREA

ON TITLE NO. KAJIADO/DALALEKUTUK/6560

GEOGRAPHICAL LOCATION

ENDUATA VILLAGE, IMPIRO LOCATION, KAJIADO CENTRAL SUB-COUNTY KAJIADO COUNTY

CLIENT

EMPOWER AND SERVE KENYA

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REPORT NO. HDRG/24/01/31/1

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EXECUTIVE SUMMARY

BACKGROUND INFORMTION

This report presents the results of geophysical and hydrogeological investigations conducted for Empower and Serve on their property LR. No. Kajiado/kalalekutuk/6560 located in in Enduata Area, Impiro Location in Kajiado County. The study aimed at locating suitable site for drilling a productive borehole for domestic and minor irrigation use.

CURRENT WATER SUPPLY AND DEMAND

The survey area does not have a piped water supply system. The main source of water for the residents in the area is mainly from private boreholes. The sources are insufficient and unreliable especially during dry seasons and thus are. This project intends to ensure a continuous and reliable source of water for the client and community. The estimated water demand is approximately $20m^3$/day.

GEOLOGY

The survey site is mainly underlain by recent sediments comprising reddish brown sandy soils and alluvium. These soils are underlain by the metamorphic rocks of the Mozambique Belt Basement System including gneisses, migmatites, schists and crystalline limestones. Major intrusives include granites, pegmatites, quartz veins, meta-dolerites and granites.

HYDROGEOLOGY

Metamorphic rocks are generally compact and not water bearing because of their unfractured and impervious character and thus possess no primary porosity. Groundwater in metamorphic rocks is limited to weathered zones, fractures (cracks, joints, fissures) and faults. Groundwater occurrence in these rocks is likely to be localized, and limited to relatively small and isolated weathered and/or fractured pockets.

GEOPHYSICAL SURVEY

Electromagnetic (EM) Profiling and Resistivity sounding (Vertical Electrical Sounding-VES) were used to determine the horizontal and lithological changes with depth. One EM profile and one VES were carried out in the investigated area. The field survey phase of this project was carried out on 30th January 2024.

CONCLUSIONS

From the geological, geophysical and hydrogeological data analysis, the following conclusions are made: -

- The area is situated in a zone with low groundwater potential.
- The main aquifers are expected to be within the alluvial deposits and in weathered and/or fractured sections of the gneisses of the Basement system rocks.
- A borehole drilled in this area should target the maximum depth in order to tap all the local aquifers

RECOMMENDATIONS

From the survey findings and data, the following recommendations are made: -

a) *Drilling*

i. Drilling is recommended as follows:

Drilling Details (WGS 84)

DRILLING LOCATION on EM Profile	LONG& AND LATITUDES		UTM (ZONE 37 M)		Depth (m)	Diameter (mm)
	E	S	E	S		
8	36° 57.718'	1° 54.082'	273293	9789707	200	204

The site is benchmarked and known to the Martin Waithaka, phone no. 0721341866.

i. Geological rock samples should be collected at 2-meter intervals.
ii. Water struck and rest water levels and if possible, estimates of the yield of individual aquifers encountered should also be noted.
iii. To ensure proper drilling and construction of the borehole, it is recommended to have competent supervision by a qualified hydrogeologist.

a) *Drilling Permit*

Before drilling commences, a drilling permit must be obtained from the Water Resources Authority, Athi Area Regional office in Kibwezi Town in accordance with The Water Act 2016 and Water Resources Management 2007 (WRM) rule part II section 24.

b) *Borehole Construction*

Recommendations for borehole construction and completion methods are given in Chapter 6. To ensure proper drilling and construction of the borehole, it is recommended to have competent supervision by a qualified hydrogeologist.

c) *Test Pumping*

A proper Test pumping should be carried out for the borehole, this is a legal requirement and will aid in determining aquifer properties such as transmissivity and hydraulic conductivity. The test will also aid in choosing the right pump size as well as safe abstraction rates.

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ABBREVIATIONS: (NOTE: SI spellings used throughout).

EC	Electrical Conductivity (in micro-Siemens/centimeter)
Km	kilometers
m	meters
m amsl	metres above mean sea level
m bgl	metres below ground level
ppm	parts per million, equivalent to mg/l
SWL	static water level (in m bgl) (the piezometric level or water table,)
TDS	Total Dissolved Solids (ppm)
WSL	water struck level (in m bgl)
WRA	Water Resources Authority

GLOSSARY OF TERMS:

Aquifer	A geological formation or structure which transmits water and which may supply water to wells, boreholes or springs.
Catchment area	the area of land catching or collecting water draining into a river
Contamination	Addition of harmful substances; Pollution
Evapotranspiration:	the combine loose of moisture from the ground (evaporation) and the loss from green plants (transpiration)
Faults	a fracture in the earth crust with displacement in either side.
Fracture	breaking of something like rocks or bones.
Gravel Pack	well-sorted sand mostly made of silica
Infiltrated	to pass through by filtering gradually
Percolate	to pass or ooze through very small holes. It is also the gradual spreading.
Porosity	the percentage of open space in a rock formation
Recharge	The general term indicating the process of transport of water from surface sources (i.e., from rivers or rainfall) to groundwater storage.
Saturation	when it has had enough and cannot take any more of that substance
Screen	a filter to clean water from the earth into the well.
Topography	description of the surface of an area like its hills, rivers, valleys (landscape)

1 INTRODUCTION

1.1 Background Information

This report represents the results of the geophysical and hydrogeological survey conducted for Empower and Serve on their property LR. No. Kajiado/Kalalekutuk/6560 located in Enduata Area, Impiro Location in Kajiado County. The purpose of the study is to locate a suitable site for drilling of a productive borehole for domestic and minor irrigation uses by the client.

1.2 Scope of the Study

The groundwater resource assessment of this site entailed defining the mapped geological formation and conducting geological, hydrological, hydrogeological and geophysical surveys all aimed to establish the groundwater potential of the site and locating a suitable site for drilling.

1.3 Methodology and Approach by the Consultant

1. Data Inventory and Desk Study
   This involved compilation and inventory of existing borehole and aquifer data, reports and maps covering all aspects of water resources in the area within which the proposed site is located (Including meteorology, geology, hydrology, drainage, hydrogeology, soils, vegetation, and land use). The inventory also included an exhaustive literature review.
   The data sources consulted included:
2. Field Reconnaissance- inventory of existing water sources within the study area
3. Detailed Site Investigations using Electromagnetic horizontal profiling and electrical Resistivity method (Vertical Electrical Sounding)
4. Data analyses and Reporting

1.4 Survey Site Location

The site is located within Enduata Area, Impiro Location, Kajiado Central Sub-county in Kajiado County. The site is located about 20km southeast of Kajiado Town off the Kajiado-Mashuru Road at Enduata Shopping Center. The site is approximately defined by coordinates (**UTM Zone 37M) 0273294E and 9789707 S**.

1.5 Climate and Vegetation

The area is characterized by tropical savannah climate comprising low average annual rainfall and high average temperatures. Rainfall is low and bimodal; Long rains occur in April and May and the short rains fall in October and December. Mean annual rainfall varies between 500-600mm. The mean annual temperature is about 20.5^0 C (https://en.climate-data.org/).

The vegetation at the investigated area is characteristic of the climate mainly composed of acacia trees and short grass.

1.6 Physiography and Drainage

The site is located to the in a gently to moderately steep terrain generally sloping to the east. The local streams form a dendritic pattern flowing into the Mataraguesh River, which flows towards to the southeast.

1.7 Water Supply and Demand

The survey area does not have a piped water supply system. The main source of water for the residents in the area is mainly from private boreholes. The sources are not insufficient and unreliable especially during dry seasons. This project intends to ensure a continuous and reliable source of water for the client and community. The estimated water demand is approximately 20m^3/day.

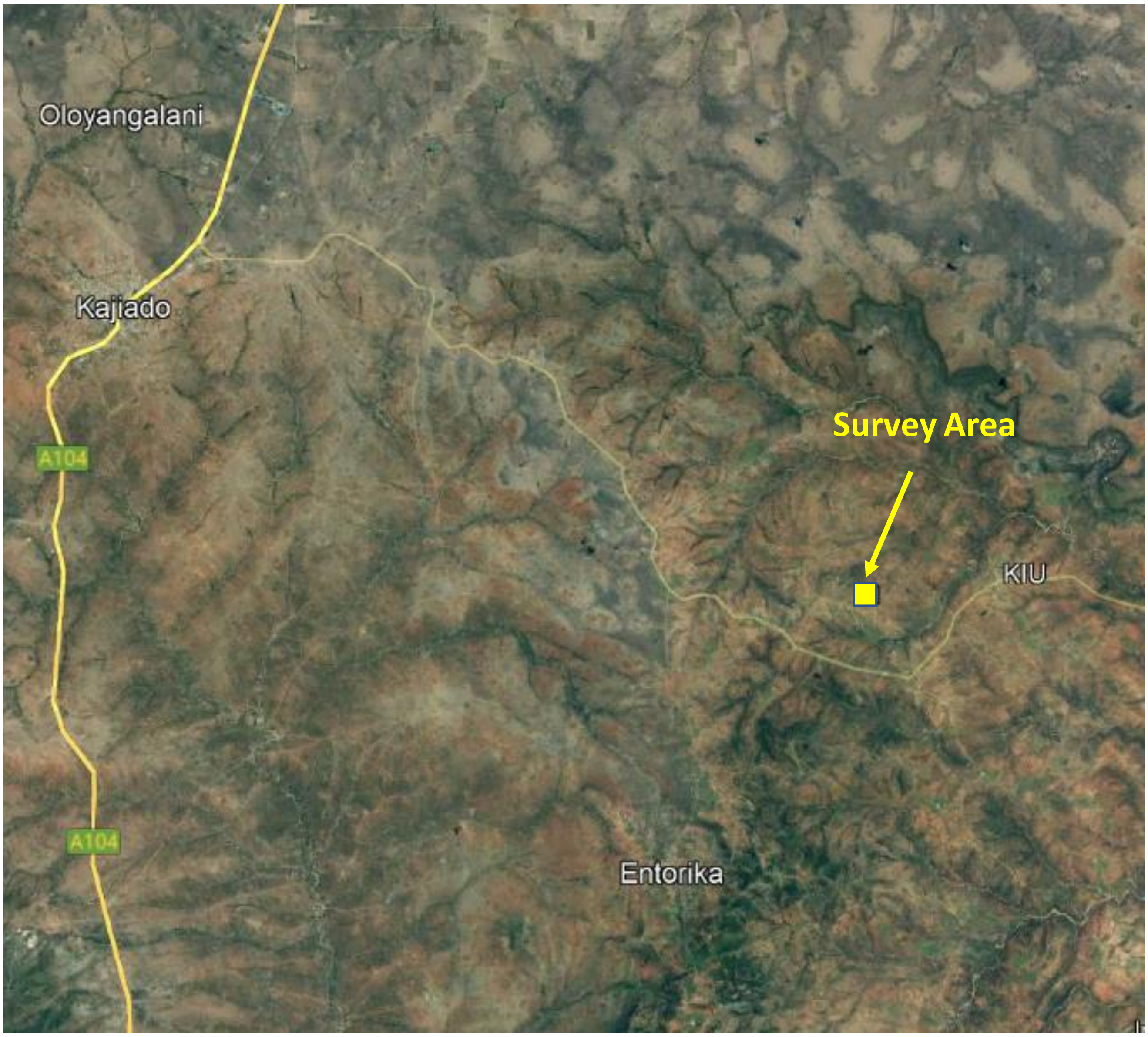

Figure 1: Site and Borehole Location Map (Courtesy of google earth)

2 GEOLOGY OF THE AREA

2.1 General Geology of the Area

Ground water presence and consequently the exploration techniques depend to a large extent on the geology of the area. The general area lies along the Mozambique Belt in Kenya comprising the low to high grade metamorphic rocks. The general geological succession and events are described in the Geology of the Kajiado Area (Matheson F.J., 1966).

2.2 Geology of the Study Area

The survey site is mainly underlain by Recent sediments comprising dark grey to black sandy soils and alluvium. These soils are underlain by metamorphic rocks of the Mozambique Belt Basement System including gneisses, migmatites, schists and crystalline limestones. Major intrusives include pegmatites and quartz veins.

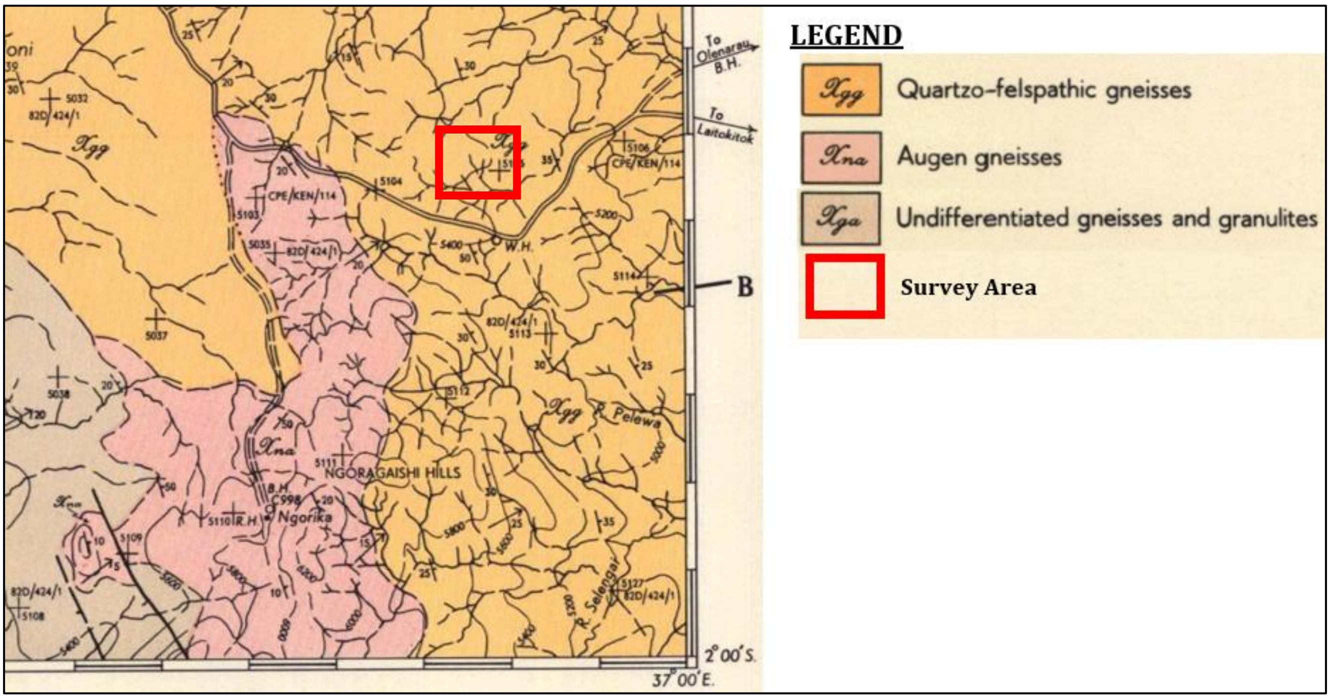

Figure 2: Geological Map of the Survey Area

3 HYDROGEOLOGY

3.1 General Hydrogeology

The occurrence of groundwater is dependent on the porosity and permeability rocks. These two parameters depend on the mode of formation of the rock (primary porosity) and processes that a rock has undergone since its formation (secondary porosity).

3.2 Aquifer Systems

The area consists of superficial deposits overlying Precambrian Metamorphic rocks of the Mozambique Belt. Metamorphic rocks are generally compact and not water bearing because of their unfractured and impervious character and thus possess no primary porosity. Groundwater in metamorphic rocks is limited to weathered zones, fractures (cracks, joints, fissures) and faults. Groundwater occurrence in these rocks is likely to be localized, and limited to relatively small and isolated weathered and/or fractured pockets.

3.3 Aquifer Hydraulic Characteristics

Ground water potential is described in terms of well yields or specific capacity. Where test data are available, the potential is also given in terms of hydraulic conductivity and transmissivity and storage coefficient. The following table is a summary of existing boreholes in located at a radius of 10km from the site:-

Table 1: Existing Boreholes in the Area

ID	Owner	Distance/ Bearing	Depth (m)	WSL (m)	WRL (m)	Yield (m^3/hr)	Drawdown (m)
1291	D.W.D	4.7km E	122	24	10.7	7.08	
4258	Emarti G.Ranch	5.8km N	150	106	11	10.2	127
3455	Kajiado C.Council	7.4km SW	167	49	38	1.5	21.3
1539	D.W.D	10.7km W	114	23	16	10.5	

3.3.1 Borehole Depths and Water Strike Levels

Borehole depths are highly variable in the area. Borehole depth range is estimated from borehole data to be between 100-167m bgl. From the data, water strike level range between 20 and 106m bgl.

3.3.2 Specific Capacity

Specific capacity is a crude indication of the efficiency of the borehole as an engineered structure, and is calculated by dividing the discharge rate (as m^3/day) by the total drawdown. High specific capacities generally indicate high transmissivity, low specific capacities the opposite. The aquifer specific capacity of the aquifer in the area averages at 1.81m^2/day.

Table 2: Aquifer Characteristics

BH ID	Yield (m^3/hr)	Drawdown (m)	Specific Capacity (m^2/day)	Transmissivity (m^2/day)
4258	10.2	127	1.927559	2.35
3455	1.5	21.3	1.690141	2.06
Average	***7.4***	***74.15***	***1.81***	***2.21***

3.3.3 Transmissivity

This is the rate of flow of water under a unit hydraulic gradient through a cross-section of unit width across the entire saturated section of an aquifer. Strictly speaking, transmissivity should be determined from the analysis of a well test, but the figures given bellow have been determined from past studies using Logan's method. Logan (1964) developed a relationship between specific capacity and transmissivity, 1.22 x Q/s, based on a reworking of Thiem's seminal steady-state groundwater flow equation (Thiem, 1906). The transmissivity from available borehole data averages at 2.21m^2/day).

3.3.4 Hydraulic Conductivity

This is defined as the volume of water that will move through a porous medium in unit hydraulic gradient through a unit area measured at right angles to the direction of flow.
The hydraulic Conductivity (K) is estimated as follows: -

K=T/Aquifer Thickness

Assuming an aquifer thickness of 20m, then the average hydraulic conductivity of the aquifer is given by;

K=2.21/20 = 1.1m/day

3.3.5 The Storage Coefficient

The storage coefficient of an aquifer is the volume of water released from or taken up per unit surface area per unit change in head. It is dimensionless. Empirical values of the storage coefficient cannot be determined from test data collected from previous drilling programmed in the area, as aquifer test data is inadequate. In an aquifer test, a borehole is pumped at a known discharge rate and water levels in one or more neighbouring observation boreholes, and the shape and type of drawdown curve in the observation borehole(s) is used to calculate the storage coefficient.

3.3.6 Recharge

The mechanism of recharge and the rate of replenishment of the aquifers which underlie area occurs through two possible recharge mechanisms; direct recharge at the surface and indirect recharge via faults and/or other aquifers. Direct recharge can only be to the shallow aquifers through infiltration of rain water. The major recharge processes of the deeper aquifers is through indirect recharge of surface and subsurface flow through faults and fractures. The metamorphic rocks are relatively impermeable and in their fresh state form poor aquifers. However, where these rocks have been fractured and jointed, and where weathering has occurred, conditions favourable to the transfer and storage of water are created. This mechanism is particularly important for recharge to the deep aquifers that provide more stable groundwater supplies.

3.3.7 Assessment of the Water Quality

Groundwater quality is generally determined by the type of rocks, residence time in rocks, recharge source and frequency and presence of groundwater contaminants. The water quality from the target aquifer in the area is expected to be vary from fresh to brackish.

3.3.8 Safe Yield

This should be determined from the specific capacity values obtained from test pumping data. If the specific yields are low, continuous over-pumping should be minimized to avoid over-pumping which may destroy the aquifer.

4 GEOPHYSICAL INVESTIGATION METHODS

4.1 Introduction

A variety of geophysical survey methods are available for groundwater investigation. The choice of the method to use depends on the kind of investigation one is carrying. In this case, the **Electro Magnetic** method was used for horizontal profiling to determine the highest potential site for drilling.

4.2 Electro Magnetic Method

4.2.1 Basic Principals

Electromagnetic (EM) methods make use of the response of the ground to the propagation of the electromagnetic fields which are composed of alternating electric intensity and magnetic force. The source field is naturally generated by variations in Earth's magnetic field, which provide a wide and continuous spectrum of EM field waves. These fields induce currents into the Earth, which are measured at the surface and contain information about subsurface resistivity structures. The natural magnetic and electric fields are due to electric currents flowing in the earth and the magnetic fields that induce these currents. The fields produced mainly by the interaction between solar winds and the magnetosphere and thunderstorms. The ratio of the electric field to magnetic field provides simple information about the surface conductivity. Different geological formations have different electric conductivities.

Data acquisition comprises simultaneous measurements of orthogonal components of magnetic and the induced electric field variations of the natural electromagnetic signal. The relationship between the orthogonal electric and magnetic components yields a measure of impedance over a frequency range. Impedance is usually expressed in terms of apparent resistivity and phase, and provides information about the subsurface conductivity distribution. A model for the subsurface geo-electric structure is obtained from analysis of the apparent resistivity and phase over a range of frequencies (and hence over a range of depths).

4.2.2 Instrumentation

The consultant used the **PQWT-TC300** geophysics machine for the EM profiling. The instrument works on the principle of electrical differences of natural earth magnetic field (frequency 0-30kHz) to solve the geological problem.

Figure 3: PQWT-TC300 Used for Electromagnetic Survey Profiling

The equipment has several characteristics that enable it to measure lithological differences with depth. These include discrete component design, circuit modular design, shielding technology to reduce circuit noise, high-precision, high-speed AD, 8-channel sampling, precision switching capacitor filter, high-speed CPU, multi-stage filter, two levels of power frequency and signal enhancement technology to counter interference. The equipment's programming uses digital filtering technology, including FFT digital filtering, FIR, IIR and other filtering technology with a frequency resolution up to 0.1Hz.

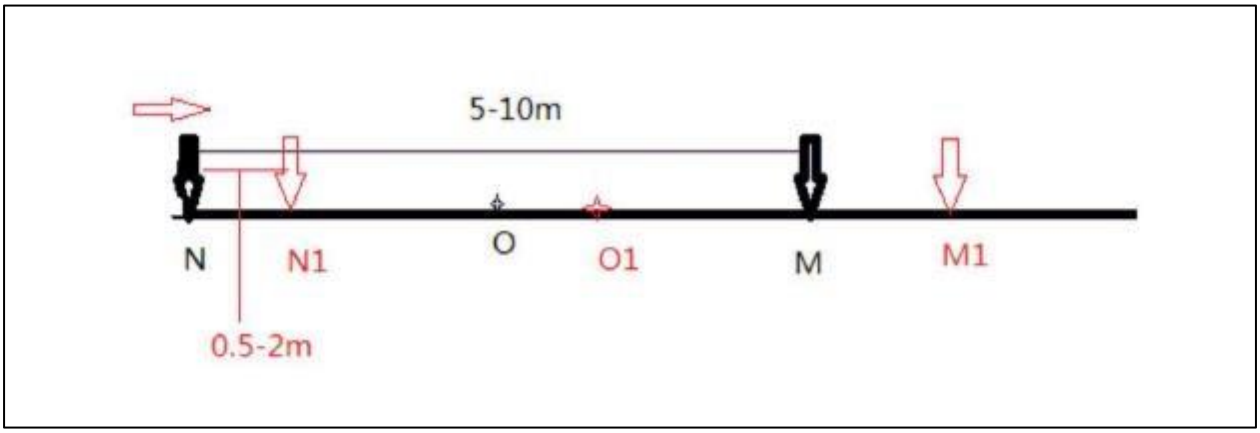

Figure 4: PQWT Electromagnetic Technique Survey Design

The user selects the desired operating frequency. The survey results are display in form of curves and 2D graphs on the user interface. The results are also stored in the device's memory for retrieval by the user.

4.3 Resistivity Method

Sometimes referred to as DC resistivity technique, this method measures the earth's resistivity by driving a direct current (DC) signal into the ground and measuring the resulting potentials (voltages) created in the earth. From the data obtained, the electrical properties of the earth (the geoelectric section) can be derived and thereby the geologic properties inferred. The diagram below illustrates the basic electrical array for that measurement.

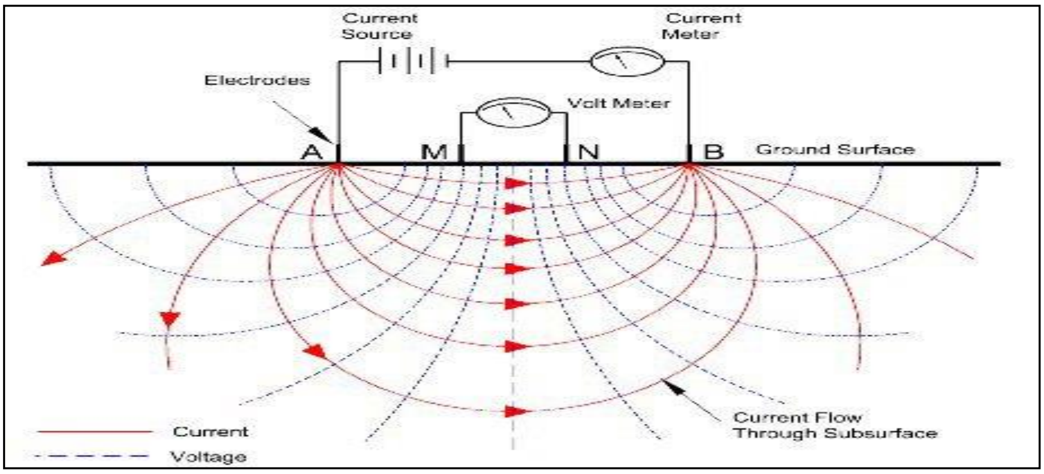

Figure 5: DC resistivity technique

The figure above is a schematic diagram showing the basic principle of DC resistivity measurements. Two short metallic stakes/current electrodes (AB) are driven about 1 foot into the earth to apply the current to the ground. Two additional potential electrodes (MN) are used to measure the earth voltage (or electrical potential) generated by the current. Depth of investigation is a function of the distance of current electrodes.

In the resistivity method, the spatial variation of resistivity (or conductivity the inverse) in the field is determined using four-electrode measurements AB and MN. Two (transmitter/current) electrodes (AB) are deployed to create an electrical circuit. Measurement of the potential difference (voltage) between the two other (potential) electrodes permits determination of an apparent resistivity (i.e., the resistivity a homogenous half space should have to give the actual measurement). Inverse methods may be applied to such measurements to determine an image of the subsurface structure Electrodes may be placed on the ground surface and/or in boreholes.

4.4 Basic Principles

The electrical properties of rocks in the upper part of the earth's crust are dependent upon the lithology, porosity, and the degree of pore space saturation and the salinity of the pore water. Saturated rocks have lower resistivity than unsaturated and dry rocks. The higher the porosity of the saturated rock is, the lower its resistivity, and the higher the salinity of the saturating fluids, the lower is the resistivity. The presence of clays and conductive minerals also reduces the resistivity of the rock.

The resistivity of earth materials can be studied by measuring the electrical potential distribution produced at the earth's surface by an electric current that is passed through the earth.
The resistance R of a certain material is directly proportional to its length L and cross-sectional area A, expressed as:

$$R = Rs * L/A \qquad \text{(Ohm)} \qquad (1)$$

Where; Rs is known as the specific resistivity which is a characteristic of the material and independent of its shape or size. With Ohm's Law,

$$R = dV/I \qquad \text{(Ohm)} \qquad (2)$$

Where dV is the potential difference across the resistor and I is the electric current through the resistor, the specific resistivity may be determined by:

$$Rs = (A/L) * (dV/I) \qquad \text{(Ohm.m)} \qquad (3)$$

4.4.1 Instrumentation

The consultant used the Chauvin Arnoux C.A 6472 Earth & Resistivity Tester for the vertical electrical soundings shown below.

Figure 6: C.A 6472 Earth & Resistivity Tester

5 FIELDWORK AND RESULTS

5.1 Fieldwork

Electromagnetic (EM) Profiling and Resistivity sounding (Vertical Electrical Sounding-VES) were used to unveil the hydro stratigraphy of the area and consequently the subsurface conditions. One EM profile and one VES were carried out in the investigated area. The field survey phase of this project was carried out on 31st January 2024.

5.2 Interpretation Results

The results of interpretation of the geophysical survey data are presented in the following sections.

The profiles generally show horizontal sedimentary sequences with varying resistivities. The resistivities vary with type of rock, water content, salinity of water and degree of weathering (where applicable). Very low resistivity values are indicative of clays and/or presence of saline water. Medium resistivity values indicate fresh to brackish water and/or sandy clays. High resistivity values indicate compact to slightly fractured rocks with little or no water. The profiles were used to select the most promising site for groundwater development.

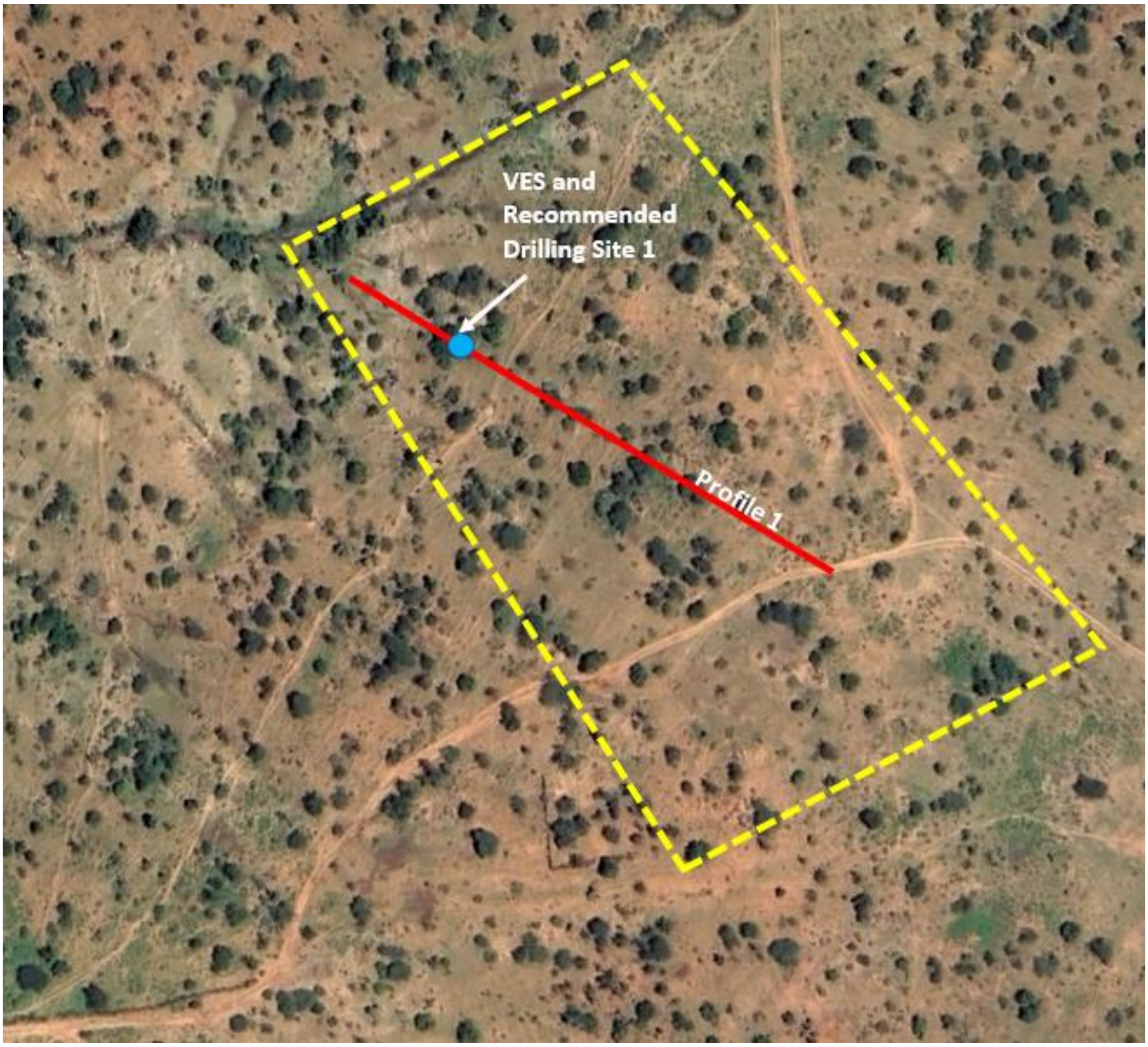

Figure 7: Profile Layout (Courtesy of google earth)

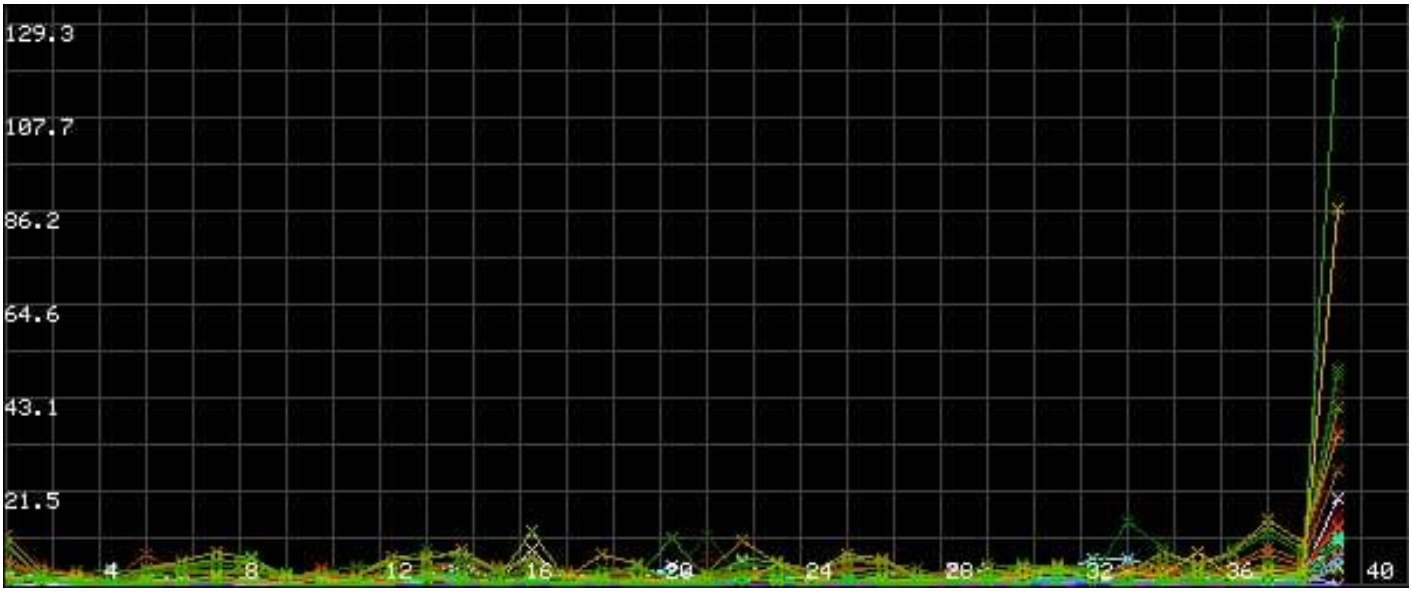

Figure 8: Profile 1 Raw Profile

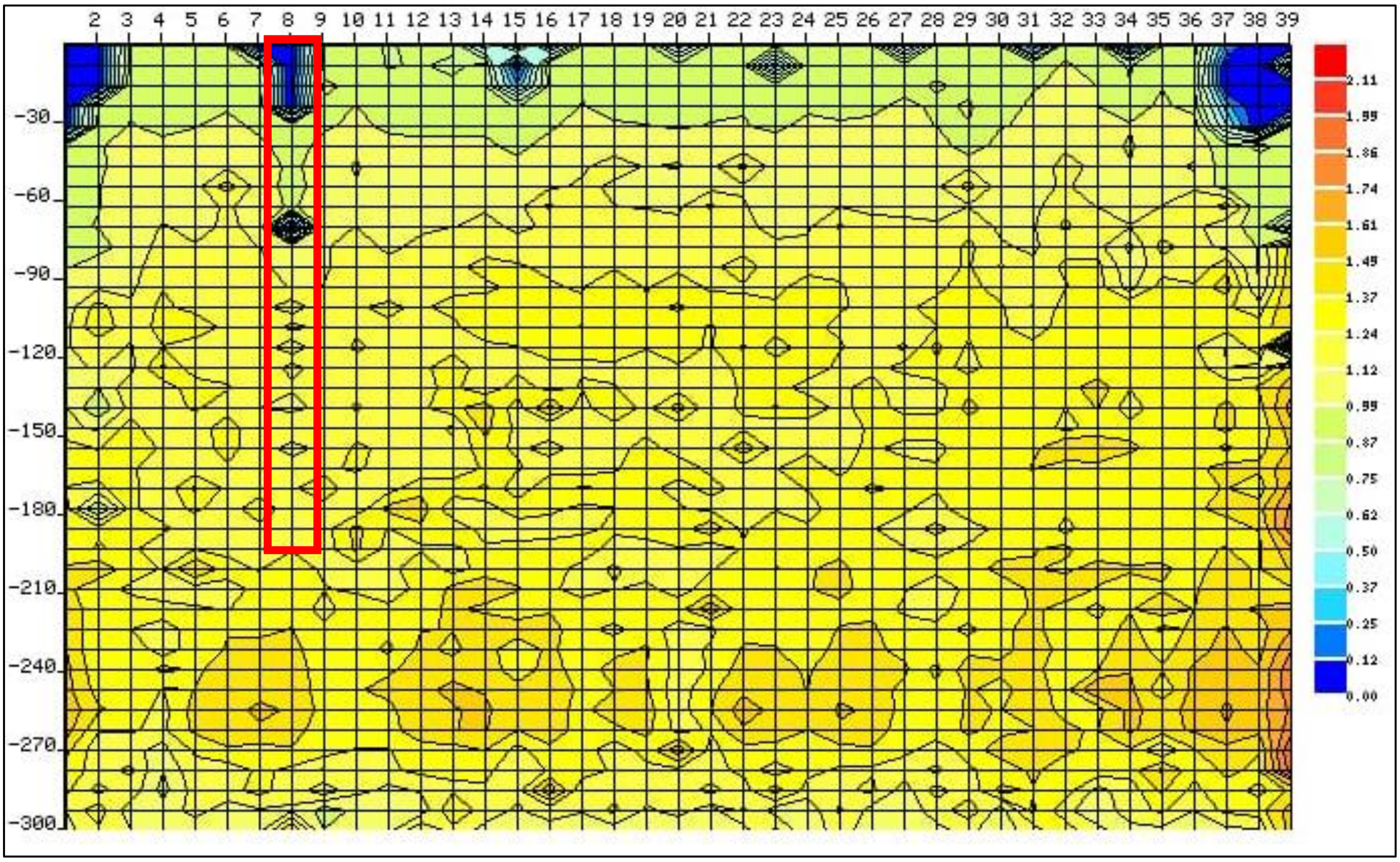

Figure 9: Profile 1 Raw Data Interpretation

Figure 10: Profile 1 Processed Data Interpretation

5.2.1 Vertical Electrical Soundings (VES)

The results and interpretation of the Vertical Electrical Sounding (VES) are as follows: -

AB/2	Resistivity (Ohm-m)
1.6	108.0
2	85.6
2.5	87.9
3.2	94.7
4	104.1
5	108.0
6.3	112.6
8	117.0
10	120.0
13	132.2
16	143.0
20	152.0
25	141.0
32	168.0
40	178.0
50	174.0
63	201.0
80	248.0
100	320.0
130	327.6
160	316.0
200	367.0
250	484.0

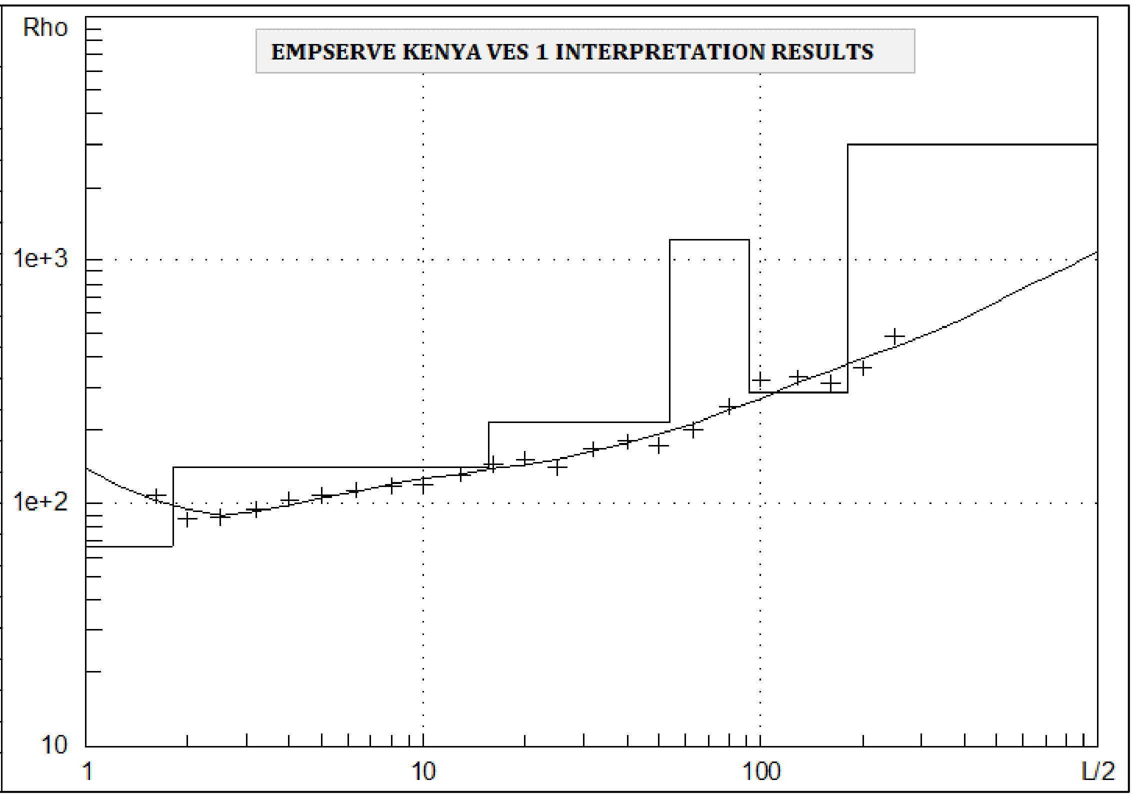

Figure 11: VES 1 Results

Table 3: VES Interpretation Results

VES No.	Layer no	Resistivity (ohm-m)	Depth (m)	Lithology	Hydrogeological Significance
VES 1	1	199.99	0.50	Superficial Deposits	Dry
	2	66.46	1.8	Sandy Soils	Dry
	3	141.30	15	Highly weathered Gneisses	Wet
	4	214.39	53	Weathered Gneisses	Aquiferous
	5	1206.78	92	Slightly Fractured Gneisses	Dry
	6	283.30	180	Weathered Gneisses	Aquiferous
	7	2975.35	>180	Compact Gneisses	Dry

From the data above, the shallow aquifer is expected at the depth between 10m up to about 50m while the deeper aquifer is expected at 100 to 180m within fractured and/or weathered metamorphic rocks.

6 CONCLUSION AND RECOMMENDATION

6.1 CONCLUSIONS

From the analysis of the available data, the following conclusions are made:

- The area is situated in a zone with low groundwater potential.
- The main aquifers are expected to be within the weathered and/or fractured sections of the metamorphic rocks of the Basement system rocks.
- A borehole drilled in this area should target the maximum depth in order to tap all the local aquifers

6.2 RECOMMENDATIONS

From the survey findings and data, the following recommendations are made: -

a) Drilling

i. Drilling is recommended as follows:

Table 4: Drilling Details (WGS 84)

DRILLING LOCATION on EM Profile	LONG& AND LATITUDES		UTM (ZONE 37 M)		Depth (m)	Diameter (mm)
	E	S	E	S		
8	36° 57.718'	1° 54.082'	273293	9789707	200	204

The site is benchmarked and known to the Martin Waithaka, phone no. 0721341866

ii. Geological rock samples should be collected at 2-meter intervals.

iii. Water struck and rest water levels and if possible, estimates of the yield of individual aquifers encountered should also be noted.

iv. During drilling, continuous monitoring of the EC should be carried after the first aquifer is struck. This will assist in assessing salinity with increase in depth.

v. To ensure proper drilling and construction of the borehole, it is recommended to have competent supervision by a qualified hydrogeologist.

b) Drilling Permit

Before drilling commences, a drilling permit must be obtained from the Water Resources Authority, Athi Catchment Area Regional office in Kibwezi Town in accordance with The Water Act 2016 and Water Resources Management 2007 (WRM) rule part II section 24.

c) Construction

i. Borehole Design

The design will be determined from the drilling observations. The design should ensure that screens are placed against the optimum aquifer zones.

ii. Casing and Screens

The borehole should be cased and screened with good quality uPVC casings. The slot size should be in the order of 1 mm.

iii. Gravel Pack

Gravel pack should be installed in the annular space of the borehole so as to prevent siltation from fine sands and silts of the borehole that can cause damage to the pump and borehole. An 8" diameter borehole screened at 6" will leave an annular space of approximately 1", which should be filled with gravel pack with a grain size of 2-4mm.

iv. *Borehole Construction*

The borehole design should be determined from the drilling observations i.e. aquifer locations, ground conditions (contaminants) etc.

v. *Well Development*

Development aims at repairing the damage done to the aquifer during the course of drilling by removing clays and other additives from the borehole walls. Secondly, it alters the physical characteristics of the aquifer around the screen and removes fine particles. Development should be done by use of air or water jetting.

vi. *Well Test Pumping*

Well tests give an indication of the quality of drilling, design and development; it also yields information on aquifer parameters, which are vital to the hydrogeologist to determine the design parameters of the accessories to be installed in the borehole.

The well test should include a step-drawdown test (preferably 1-hour step tests) and a continuous drawdown test (preferably 24hrs). Towards the end of the test, a 2-liter water sample should be collected for a full physical, chemical and bacteriological analysis before the water is put to any use. A copy of the analysis report must be sent to the WRA – Regional Office for record.

vii. *Well Monitoring*

The borehole must be installed with a Water Meter and an Airline/piezometer to monitor abstraction and to facilitate measurements of the water levels in the borehole.

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APPENDICES

Appendix 1: Drinking Water Quality Standards

	Symbol	Units	WHO (2011)	EU	KEBS KS EAS 12: 2014)
INORGANIC CONSTITUENTS OF HEALTH SIGNIFICANCE;					
Antimony	Sb	Mg/L	0.02	0.005	
Arsenic	As	Mg/L	0.01	0.01	0.01
Cadmium	Cd	Mg/L	0.003	0.005	0.003
Chromium	Cr	Mg/L	0.05	0.05	0.05
Cyanide	CN	Mg/L	0.07	0.05	0.01
Fluoride	F	Mg/L	1.5	1.5	1.5
Lead	Pb	Mg/L	0.01	0.01	0.01
Mercury	Hg	Mg/L	0.006	0.001	0.001
Nickel	Ni	Mg/L	0.07	0.02	0.02
Nitrates	NO_3	Mg/L	50	50	45
Selenium	Se	Mg/L	0.04	0.01	0.01
OTHER SUBSTANCES					
Aluminum	Al	Mg/L	0.1	0.2	0.2
Ammonium	NH_4	Mg/L	0.5	0.5	0.5
Barium	Ba	Mg/L	0.7		0.7
Boron	B	Mg/L	2.4	1.0	2.4
Calcium	Ca	Mg/L			150
Chloride	Cl	Mg/L	250	250	250
Copper	Cu	Mg/L	2	2	1.0
Iron	Fe	Mg/L	0.1		0.3
Magnesium	Mg	Mg/L			100
Manganese	Mn	Mg/L	0.05	0.05	0.1
Nitrite	NO_2	Mg/L	3	0.5	0.003
Phosphates	PO_4	Mg/L			2.2
Potassium	K	Mg/L			50
Silver	Ag	Mg/L			
Sodium	Na	Mg/L	200	200	200
Sulphate	SO_4	Mg/L	500	250	400
Zinc	Zn	Mg/L	3	-	5
Total Dissolved Solids	TDS	Mg/L	1000	1000	1500
Total Hardness as $CaCO_3$	$CaCO_3$	Mg/L			600
Colour		^{o} Hazen		5	50
Odour		-			Oduorless
Taste		-			Not Objectionable
Turbidity		NTU	1		<5
pH			8.2-8.8		6.5 – 8.5
Conductivity	EC	uS/cm	1500	1500	2500
Total Coliforms & E. coli (no./100mL)			0	0	0

Appendix 2: Sketch Map