HYDROGEOLOGICAL SURVEY REPORT

FOR

KANJALU GIRL'S SECONADRY SCHOOL P. O. BOX 933, MERU.

LOCATED

IN

KIANJALU AREA,MIATHENE LOCATION,MIATHENE SUB LOCATION, TIGANIA WEST SUB COUNTY,MERU COUNTY

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SUMMARY

This report documents the findings of hydro-geological and geophysical borehole site surveys - carried out at the **Clients’** Farm with the sole intention to provide a water supply supplement for domestic use.

The Clients’ mailing address details for the purpose of specific reference:

Kanjalu Girl’s Seconday School,
P.O. Box 933,
Meru,.

The objective of this study is to develop a borehole for domestic water supply for the school; in view of the inadequate supply within the area. The above survey program was envisaged and commissioned by school management.

The Project area is generally underlain by the Tertiary and Quaternary volcanic flows known as Nyambene Volcanic Series with minor patches of quaternary Sediments. The volcanic rocks associated by this series comprises of tuffs, basalts, trachytes, phonolites and agglomeratic constituents of the above rocks.

For successive execution of the program, the survey baseline data has to rely heavily on the fundamental borehole data that covers the underground hydrography of the wider Kabuitu area; To give an insight, groundwater occurrence in the Ewaso Ngiro, Catchment basin is a complex interplay of recharge in the forest zone (Mt Kenya Forest), structural controls on the surface drainage, and geology and known results from previous boreholes in the area.

Based on the assessment findings, the report is detailed and includes amongst others quantifiable recharge, discharge groundwater flux evaluations, statistical aquifer data evaluations, and computed values of aquifer transmissivities and the typical specific capacities of the aquifers based on available test data. At least **20m^3/day** of water is required as part of this water augment exercise, which is to be obtained from groundwater sources; in the absence of any other source.

Summary of the proposed site

Site coordinates	VES No. & ranking in Yield Potential	Recommended depth in meters	Construction Requirements.	Anticipated Yield m^3/hr
N 365141.917E E 16176.367N Elev. 1420m	Line Point 8	150m	216mm/153mm	10-20

In addition to the hydro geologic assessment outlined above, a detailed coordinated planning with the Government Authorities [Water Resources Authority} - must be implemented to obtain relevant permits and consent for the project implementation.

1.0 INTRODUCTION

1.1 General Site Details

The proposed borehole site is located in Kianjalu area ,Miathiene Location, Miathene Sub Location,Tigania West in Meru County. The site coordinates for the investigated site falls on the coordinates – **N 16176.367 E365141.367, Elev1420asl WGS 1984** on the topographical **map sheet 109/3** – of the ***Meru Area***- Survey of Kenya.

At the site, geophysical measurements were carried out to confirm the hydro-geological conditions and identify optimum and suitable site locations. This was done through resistivity application where one vertical Electrical Sounding (VES) was carried.

1.2 Climate, Drainage & Topography

The project area has bi modal rainfall distribution with two rainy seasons between March to May and Mid December. Temperatures are highest in the Months of January to Mid March before the rains season and lowest in the months of July to August. The Climatic conditions vary with topography variety of the area. This site is located in flat topography sloping southeastwards.

Rainfall is fairly in this area with annual average of more than 600mm.The area is drained mainly by Kindani Stream that has many seasonal tributaries.

2.0 TERMS OF REFERENCE

Under the specific Terms of reference, the client **Kanjalu Girls Seconady School** commissioned Amicus Boreholes, to undertake Hydro-geological assessments/ Borehole site investigations within his farm in Kanjalu Area. The requirement to construct a borehole in the area is necessitated by the obvious - shortfalls in piped water supply – from the city Council mains. The proposed facility is intended for the provision of water supply at the client's premises for domestic utility.

The client issued the Terms of Reference for the execution of the Hydro-geological assessments/ Borehole site investigations within the premises, and subsequently presents a hydro-geological report under the following Terms of Reference:

(i) ***Undertake comprehensive feasibility study of the groundwater occurrence within the site.***

(ii) ***Optimize an ideal –survey location for the proposed borehole project,***

(iii) ***Integrate reconnaissance survey data with Geophysical borehole data obtained in the conduct of the surveys and assimilate the borehole data to define the recharge/discharge boundaries for the project site. I.e. calibrate the exploration data against known geological settings.***

(iv) ***Undertake comprehensive assessments of the existing borehole facilities located in the neighboring areas with a view to quantify the inherent potential; and confirm the actual development of other boreholes subsequent to development of the borehole.***

(v) ***Compilation/documentation of all the additional available hydro-geological, geological, geophysical, hydrological data and the subsequent provision of a comprehensive report on the groundwater exploration program for the project area.***

The specific Terms of Reference, calls for the need to establish the baseline conditions that control the groundwater dynamics in the general aquifer systems; as a way to quantify and optimize borehole outputs.

The entire study will be contained in a detailed report on the investigations and recommendations. The current study further lays emphasis on the client's specific water requirements and is geared towards attaining a sustainable water supply component of about **20m^3/day.**

3.0 DETAILS OF GEOLOGY.

3.1 Regional Geology

Generally, the area lies on the eastern edge of the East African Rift Valley. It's bounded to the south and south west by the volcanic edifices of the Mount Kenya and to the North by Nyambene Ranges. The rocks in the higher parts of the area are mainly volcanic comprising phonolites, basalts, trachytes and tuff. In the lower areas the Metamorphic rocks of the Basement System Predominate.

The geological history of the area can be followed from the Precambrian era which is represented by the metamorphic Basement System. Successive stages stages of uplift and erosion lasting until the beginning of tertiary have resulted in removal of upper layers of the basement system and any other overlying younger layers which might have ever been deposited. This is the erosion surface underlying the Tertiary and Quaternary volcanics.

Subsequently, lava sheets consisting of phonolites and basalts flooded out from the area which at present the rift valley towards which the whole series thickens. The eastern limit of these lavas coincides with the present ewaso ngiro river course.

This was followed by a prolonged period of relative stability as evidence by the remnants of an erosion surface in Ewaso Ngiro basin which represent the end tertiary peneplain. In the following stage eruptive canters, mainly in the south, became active. Mount Kenya and Nyambene erupted and most of the other parts in the south were covered with lava flows

3.2 Localized Geology of the Area.

Generally the area geology associated with Nyambene volcanic lava which technically controls the geological setting of this area. The volcanic rocks associated with this series comprise tuff, basalts, trachytes, phonolites, and agglomeritic constituents of the above rocks.

It is implicit in the account of Stratigraphy that the volcanic structures are complex, especially in the latter stages of the history of the eruptions, due to the alternative quiescence, erosions and eruptions, with the younger lava effusions are often scattered and confined in widely separated valleys. At the project area the surface is covered by mainly dark black cotton soil, ashy volcanic soils with clayey loams and clayey sub-soils particularly along the valleys.

These soils are underlain by the lower Nyambene basalts. These lavas are composed of various thin type of lava flows intercalated with tuffs and old land surface deposits. The lavas are underlain by rocks of Basement system. The Nyambene volcanic series consist of;

i. The lower Nyambene Basaltic lava Flows.
ii. The upper Nyambene Basaltic Lava.
iii. The Quaternary Basaltic with intercalations of phonolites, ashes and tuffs of parasitic vents.

3.1.1 Quaternary volcanics and sediments

The main event during the Pleistocene was the origin of Mount Kenya. The sequence of volcanic deposit is Mount Kenya suite which is divided into the volcanics of the main eruptive episode and the volcanics of the satellite events Rocks from the first episode are mainly basalt, trachytes and agglomerates.

The most important representative of the main volcanic episode are the porphyritic phonolites and agglomerates while the basaltic lava on the northern slopes of mount Kenya and the nyambene hills are the most important representatives of the second episode.

3.1.2 Tertiary volcanics and sediments

These volcanic rocks are products of eruption which started in the middle Miocene. The lower layers are basaltic while the upper layers are more phonolitic and trachytic. The lava originated in many separate flows which are usually interbedded with tuffs and sediments.

3.1.3 Basement System Rocks

The pre- Cambrian Basement rock are the oldest in the area. They comprise various types of sediments which were transformed by regional metamorphism into gneisses, schists and quartzites. These rocks outcrop in most of the north- eastern and south eastern parts of the area

4. HYDROGEOLOGY

The hydrogeology of the area is determined by the nature of the parent rock, structural features, weathering processes and precipitation patterns. Within volcanic rocks, groundwater primarily occurs within fissure zones, sediment beds, Lithological contacts and Old Land surfaces (O.L.S).

Lava flows rarely possess significant pore spaces. The inherent porosity of the lava suite is dependent upon these secondary fissures, such as cracks and joints. The volcanic rocks associated with this series comprise tuff, basalts, trachytes, phonolites, and agglomeratic constituents of the above rocks.

It is implicit in the account of Stratigraphy that the volcanic structures are complex, especially in the latter stages of the history of the eruptions, due to the alternative quiescence, erosions and eruptions, with the younger lava effusions are often scattered and confined in widely separated valleys.

The weathered zones, Old Land Surfaces’ (OLS), which characterize and indicate periods of erosion between volcanic eruptions and subsequent lava flows, are potential aquifers.

4.1 Surface Water Resources

The project site is located in an area that is moderately drained by surface water resources. There is a moderately flowing ***Kindani River*** that lies South of the site flowing in a North East to South West direction.These River systems are marked by moderate flows as part of their perennial flows. The rivers may be clear in their upper courses occasionally getting muddy in their watercourses as a result of effluent discharge into their courses.

4.2 Ground Water Resources.

Groundwater can be obtained from four types of aquifers in this area.

Contact zone: Contact zones between various lava flows forms the most common aquifer in this area. These aquifers are generally confined.

Fault zones and fracture zones: The areas have numerous faults crossing it and are normally encountered as highly fractured zones. This would be one source of ground water, since fault zones form very important aquifers in other words impermeable rocks. The fault also plays an important role in ground water recharge system. Deeply weathered and fracture zones in volcanic rocks are also good aquifers as long as the catchment in large.

Old land surfaces: Old land surfaces, sometimes consisting of gravels and sand. Forms very good aquifers as old the lateral extent of these materials is usually very yield are occasionally very high. **Sand and sediments:** These where trapped between impermeable rocks can form a very good storage zones hence very good aquifers. These are normally found in the old land surface deposits.

4.3 Existing Boreholes

The area has few boreholes drilled that are successful. These boreholes have yields that varied due the difference in conditions of the underlying rocks and structural conditions. Good yields are struck within down throw sides of faults or near zones areas where fracturing and weathering of underlying rocks extends to great depth.

The quality of water is expected to be god but may be mineralized with fluoride content being lower than WHO standard of 1.5 parts per million.

Table showing existing boreholes in the area

Borehole serial number C-& owners name	**Distance/ bearing from site(kilometers)**	**Total depth (mbgl)**	**WSL (mbgl)**	**WRL (mbgl)**	**PWL(meters)**	**Tested yield ($M^{3/HOURS)}$**
7757-Kabwito Pri School	1.4/NE	124	15	9.5	14	3.06
7250 Matyandui Pri School	2.64/NNW	190	56	40.5	40	9
9681-Nkumari Pri School	2.7/S	31	-	-	-	-
7249-Mangala Village	4.6/NE	140	27	17	22	7.9
7252Muthucine Pri School	14.7/N	100	50	38.8	61.8	6

M bgl meters below the ground

These boreholes have been drilled to depths ranging between 90 metres to 200 metres below ground level. Water struck levels range between 50 to 90 metres, water rest levels between 9.5 to 40 metres below ground level and tested yield range from 3,060 to 9,000 litres per hour.

These boreholes have varied yields due to the fact that most of them falls in rocks with different weathered and fractured depths. Those within similar zone of fractured and weathered have similar yields. The project area has medium to high groundwater potential.

4.4. Aquifer Properties

Aquifer characteristics: Transmissivities (T) and specific yield / storage coefficients. Borehole specific capacities have been calculated using the formula S=Q/s (Driscoll, 1986) where Q is the yield during pump test and s is the drawdown that is represented by pumping water level less static water level (PWL–SWL).

Transmissivity is calculated using the formula T=0.183Q/s. This formula has a limitation because borehole completion data from Ministry of Water and Irrigation Services gives the summary of pump test. It is ideal if the test pump data is in log scale.

Logan's formula T=1.22 Q/s is the best for estimating transmissivity.

The area does not have aquifer tests and it is difficult to ascertain specific yields, storage coefficients of existing boreholes in the project area. From Driscoll 1986 the following summary of Specific Yield ranges for earth materials.

Hydraulic conductivity (K) and Groundwater Flux

Locations laboratory investigations and Isotope methods are very expensive methods and are the best for determining hydraulic conductivity and groundwater flux correctly. The results are confined to few locations, and they depend on the scale of the investigation method. Rock sample measurements in laboratory vary from well test results. Ministry of Water and Irrigation Services data is also not very reliable.

Hydraulic conductivity is calculated using the formula k=T/D where k is the hydraulic conductivity, T is the transmissivity and D is aquifer thickness. In the Ministry of Water and Irrigation Services data the start of the aquifer is the one recorded and most of the time the thickness is not given.

4.5. Recharge

Although the rate of recharge in the area cannot be accurately quantified, the mechanism by which recharge occurs can only be postulated. The two possible recharge mechanisms are direct recharge at the surface and indirect recharge via faults or lateral water movement through the homogenous aquifer beds.

Direct recharge at the surface is dependent on the climate, geology, topography and surface cover characterizing the type area. The fore-mentioned factors are closely related and cannot be considered in isolation.

Both the topographical and surface vegetation cover aspect determines the flow characteristics of the surface water, i.e. presence of relatively flat areas and dense vegetation cover will retard the rates of flow of the surface water, thus enhancing the infiltration and vice versa.

Indirect recharge is facilitated by the presence of geological structures such as faults. The structures have a substantial effect on the groundwater flow systems at times impeding flow due to hydraulic discontinuities. Faults may facilitate flow by providing channels of high permeability or may be barriers by offsetting zones of high permeability. Higher hydraulic gradients may develop down slope with the resultant effect of the main faults acting as zones of low permeability.

The overall effect of these faults is to channel flow along the axis of the faults, conduits or if they are in filled, they act as barriers to the lateral flow.

4.6. Groundwater Quality

Generally, groundwater chemistry from the volcanic terrain varies from place to place due to mode of recharge and how long water has interacted with rocks. Water quality from the proposed borehole is expected to meet the WHO standards but with some slight modification due to the increased amounts of minerals.

Consumption by humans of waters with concentrations somewhat above the standard limits is not necessarily harmful. Still, the best possible quality should be targeted, and the identified sources should have chemical properties within and/ or to the WHO norms. Appropriate technological solutions must be considered in areas where adverse types of water are likely to have hazardous effects on man and livestock. However, for toxic substances, a maximum permissible concentration limit has been established. The constituents for which these standards have been set (e.g. heavy metals, pesticides, bacteria) all have a significant health hazard potential at concentrations above the specified limits. Hence, the specified limits should not be exceeded in public water supplies.

Table 4.2: Maximum dissolved constituent limits as per WHO/EU standard

Parameter	**WHO/EU Guideline**
Cations (mg/l)	
Iron	0.2
Manganese	0.5
Calcium	No Guideline
Magnesium	No Guideline
Sodium	200
Potassium	No Guideline
Anions (mg/l)	
Chloride	250
Fluoride	1.5
Nitrate	50
Nitrite	0.50
Sulphate	250
Total Hardness $CaCO_3$ (mg/l)	Desirable:150-500
Total Alkalinity $CaCO_3$ (mg/l)	No Guideline
Physical Parameters	
PH	Desirable:6.5-8.5
Colour(Pt mg/l)	Desirable:15
Turbidity(NTU)	Desirable:<5
Conductivity(S/cm)	250microS/cm
Total Dissolved Solids(mg/l)	No Guideline

5. Field Exploration Program

5.5. Prospecting Methods

5.5.1. Resistivity (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, the lower is its resistivity, and the higher the salinity of the saturating fluids, the lower the resistivity. The presence of clays and conductive minerals also reduces the resistivity of the rock. The resistivity of the 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:

$$R = \rho * L.A \qquad (1)$$

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

$$R = \Delta V/I \qquad (2)$$

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

$$\rho = (A/L)\,\Delta\,V/I) \qquad (3)$$

5.6. Survey Design

Two categories of field techniques exist for conventional resistivity analysis of the subsurface. These techniques are vertical electric sounding (VES), and Horizontal Electrical Profiling (HEP).

5.6.1. Vertical Electrical Sounding (VES) .

The object of VES is to deduce the variation of resistivity with depth below a given point on the ground surface and to correlate it with the available geological information in order to infer the depths and resistivities of the layers present.

In VES, with wenner configuration, the array spacing "a" is increased by steps, keeping the midpoint fixed (a = 2 , 6, 18, 54…….) .

In VES, with schlumberger, the potential electrodes are moved only occasionally, and current electrode are systematically moved outwards in steps

$$AB > 5\ MN$$

5.6.2. Horizontal Electrical profiling (HEP)

The object of HEP is to detect lateral variations in the resistivity of the ground, such as lithological changes, near- surface fault.

In the wenner procedure of HEP, the four electrodes with a definite array spacing "a" is moved as a whole in suitable steps, say 10-20 m. four electrodes are moving after each measurement.

In the schlumberger method of HEP, the current electrodes remain fixed at a relatively large distance, for instance, a few hundred meters, and the potential electrode with a small constant separation (MN) are moved between A and B.

5.7. Field Work

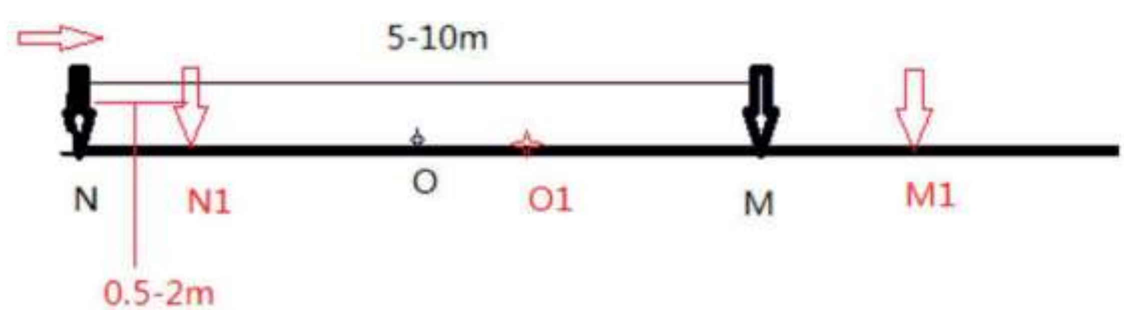
A detailed exploration program was carried out on the **22nd January 2025,** and it entailed both reconnaissance and hydro geological and geophysical surveys.

Geophysical line point 5 were arranged perpendicular to Dowsing point in order to detect tectonic crushed zone on both sides of the border and its different physical characteristics.

Setup

Use a measuring tape and mark with paint the start of a line perpendicular to your abnormal/anomaly point. Measure position according to the test results of drawing later.

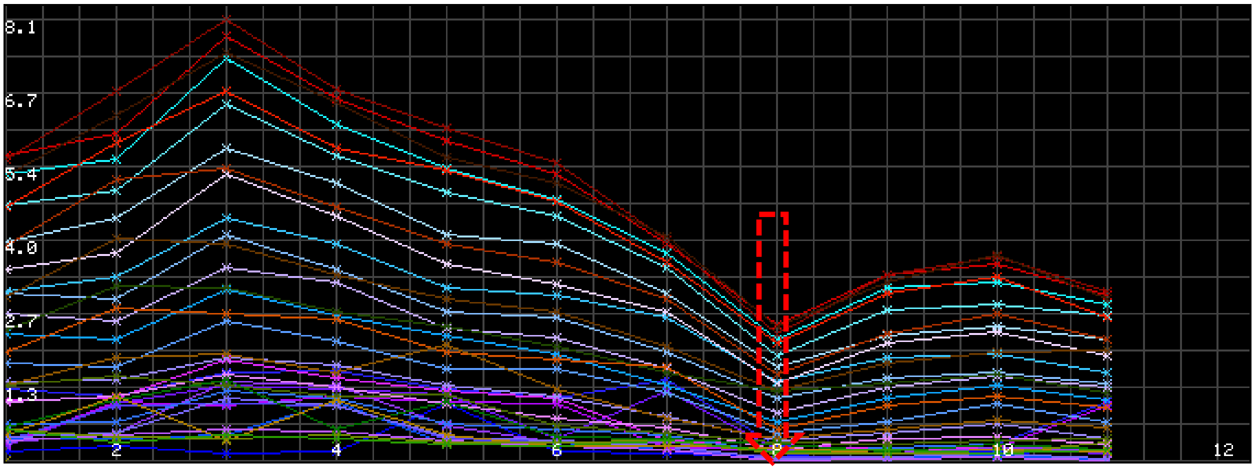
The collected data each time is the data of midpoint between two electrode data, the point O is the first set of data as shown by the figure below. Electrode spacing is generally 5-10m (Choose 6/8/10…m according to your actual situation), dot spacing is generally about 0.5-2m, and electrode spacing and dot spacing must keep the same distance for one measuring line.



The Survey Results

The results of the fieldwork geophysical measurements are as shown below. Underground geological changes are displayed through automatic mapping curves and profiles, and analyze specific information such as aquifers, fractures, faults, and caves.

Line 2



PROFILE 1

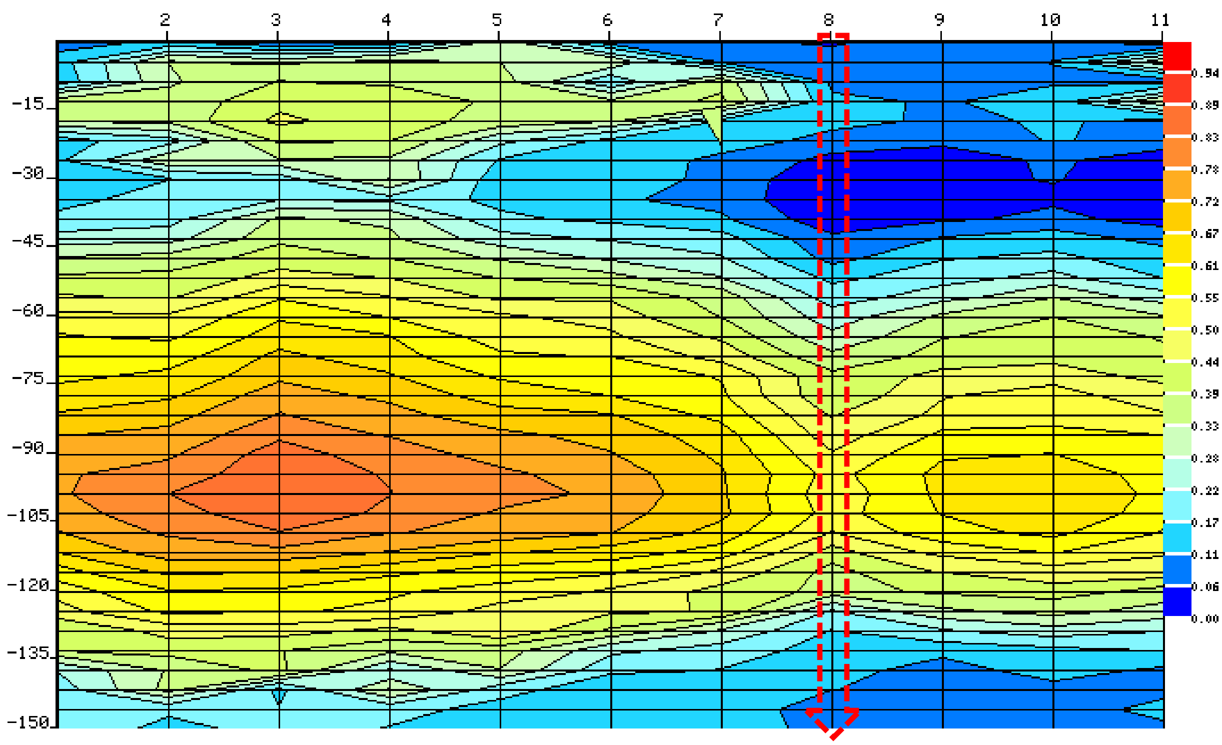


Figure 1: Subsurface profile

The results above show that the surveyed site consists of a fractured and weathered aquifers beneath the surface. We have selected/recommended ***point 5 of line 1*** as the most suitable location for the drilling of a water supply borehole**.**

6.Impacts of Proposed Drilling Activity

The area is characterized by a low density of boreholes as can be referenced from the table of neighboring boreholes in section 3. The boreholes are generally moderately yielding and the proposed borehole will not have any significant effect to the aquifer if drilled. Water abstraction from the borehole will have to be controlled.

The proposed borehole water will be used mainly for domestic applications. For this kind of abstraction, the effects to aquifer will be quite minimal as the aquifer is ample with an excellent recharge owing to its large recharge area and huge storage capacity.

Pumping this facility will unlikely cause any adverse effects to cone of depression hence there shall be no hydraulic interference to other boreholes in the neighbourhood of the proposed site.

Groundwater contamination will be controlled by construction input where use of bentonite clay seal is proposed together with an 8" surface casing of at least 5m long. A 1x1x1 m slab must be constructed around the protruding 6" casing to limit surface water intrusion. Any water struck above 10 metres must be sealed off during construction for fear of pathogens from pit latrines.

Water discharged during drilling process will however be discharged into a soak pit. Waste water has also one advantage as it can be reused during drilling in case need for water arises during drilling process.

The proposed borehole should be installed with the following devices to allow routine measurements of groundwater abstraction and water levels:-

i. Water master meter for monitoring groundwater abstraction.
ii. Airline for monitoring water table fluctuation.

However, all conditions given by Water Resources Authority should be adhered to and they include pumping 60% of the tested yield for a period of 10 hours a day.

6. Conclusions and Recommendations for Borehole Development

Conclusions

Based on the discussions in the previous chapters on hydrogeology, geophysics and existing boreholes, it has been concluded that a water supply borehole is to be developed on the proposed project site to a recommended depth of **150 m** below ground level. This depth is considered ideal considering the thickness of the aquifer that will be penetrated.

Based on the available information on geology and existing boreholes, combined with the hydro geological assessments, the following conclusions can be drawn: -

a) The maximum yield that can be obtained from a borehole which fully penetrates the formation is likely to be above 10 m^3/hr.

b) The required depth of a fully penetrating hole would be at least 150 metres

The location is shown in the site sketch – (Back pocket map extract of Leopard Area; Topographical map sheet No.109/3). Below is a tabulation of the construction summary to be adopted to realize the project objectives: -

Table 6.1: Borehole Construction Recommendations

Site coordinates	VES No. & ranking in Yield Potential	Recommended depth in meters	Construction Requirements.	Anticipated Yield m^3/hr
N 16176.367 E 365141.917 Elev. 1420m	Line 1 Point 5	150m	216mm/153mm	10-20

Recommendations

i. The drilling should ideally be carried out with a Rotary drilling plant rotary in order to attain the maximum recommended drill depth of **150 m** below ground level unless enough water has been struck or the formation is complicated to continue drilling.
ii. A monitoring tube is to be installed in the drilled intake to allow regular measurements of the water levels in the intake wells. This is a requirement for the final pumping equipment installation.
iii. In case shallow aquifers are encountered it is recommended to seal these off within the upper 10 metres, in order to avoid any risk of cone of depression coalescence and contamination by surface water.
iv. The recommendations on well construction cannot be considered complete without the mention of the requirement to test pump the water supply bore to British standards BS 6316 (1992), which is an industry standard. At least 10hours of the step test at –2-hour interval followed by a CRT test for 30 hours is recommended. Recovery must be carried out to full Static Water Levels. In order to maximize yields in this part of the aquifer systems, the proposed borehole will have to be drilled to the recommended depth, very carefully constructed and developed.

Appendix 1: Drilling Techniques

Drilling Methodology

Drilling should be carried out with an appropriate tool – comprised of a high-powered rotary machine, which is considerably faster. Geological rock samples should be collected at 2 meter intervals. Struck and rest water levels and if possible, estimates of the yield of individual aquifers encountered, should also be noted.

Well Design

The design of the well should ensure that screens are placed against the optimum aquifer zones. An experienced works drilling consultant/hydro-geologist should make the final design; and should make the main decision on the screen settings.

Casing and Screens

The well should be cased and screened with good quality screens; considering the depth of the borehole it is recommended to use steel casing and screens of 6” diameter. Slots should be maximum 1mm in size. We strongly advise against the use of torch-cut steel well casing as screen. In general, its use will reduce well efficiency (which leads to lower yield), increase pumping costs through greater drawdown, increase maintenance costs, and eventually reduction of the potential effective life of the well.

Gravel Pack

The use of a gravel pack is recommended within the aquifer zone, because the aquifer could contain sands or silts which are finer than the screen slot size. An 8” (203mm) diameter borehole screened at 6” (153mm) will leave an annular space of approximately 1”, which should be sufficient. Should the slot size chosen be too large, the well will pump sand, thus damaging the pumping plant and leading to gradual ‘siltation’ of the well. The grain size of the gravel pack should be an average 2-4mm.

Well Construction

Once the design has been agreed, construction can proceed. In installing screen and casing, centralizers at 6 meter intervals should be used to ensure centrality within the borehole. This is particularly important to insert the artificial gravel pack all around the screen. If installed, gravel packed sections should be sealed off top and bottom with clay (2m).

The remaining annular space should be backfilled with an inert material and the top five meters grouted with cement to ensure that no surface water at the wellhead can enter the well bore and thus prevent contamination.

Well Development

Once screen, gravel pack, seals and backfill have been installed, the well should be developed. 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.

We do not advocate the use of over pumping as means of development since it only increases permeability in zones, which are already permeable. Instead, we would recommend the use of air or water jetting, or the use of the mechanical plunger, which physically agitates the gravel pack and adjacent aquifer material. This is an extremely efficient method of developing and cleaning wells.

Well development is an expensive element in the completion of a well, but is usually justified in longer well-life, greater efficiencies, lower operational and maintenance costs and a more constant yield. Within this frame the pump should be installed at least 2m above the screen, certainly not at the same depth as the screen.

Well Testing

After development and preliminary tests, a long-duration well test should be carried out on all newly-completed wells, because from giving an indication of the quality of drilling, design and development, it also yields information on aquifer parameters which are vital to the hydro-geologist. A well test consist of pumping a well from a measured start level Water Rest Level-(WRL) at a known or measured yield, and simultaneously recording the discharge rate and the resulting draw downs as a function of time. Once a dynamic water level (DWL) is reached, the rate of inflow to the well equals the rate of pumping. Usually the rate of pumping is increased stepwise during the test each time equilibrium has been reached (Step Draw-Down Test). Towards the end of the test a water sample of 2 liters should be collected for chemical analysis. The duration of the test should be 48 hours, followed by a recovery test for a further 24 hours, or alternatively until the initial WRL has been reached (during which the rate of recovery to WRL is recorded). The results of the test will enable the project design consultant to calculate the optimum pumping rate, the installation depth, and the draw-down for a given discharge rate.