MINISTRY OF WATER & ENVIRONMENT

WATER SUPPLY AND SANITATION PROGRAMME

MANUAL FOR BOREHOLE CONSTRUCTION AND SUPERVISION

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GUIDELINES FOR BOREHOLE SITING

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1.0 INTRODUCTION

There is large and growing demand for safe water. Groundwater is one of the best sources of drinking water. Besides being generally free from bacteriological pollution, it has an almost constant quality and temperature and it is available in large quantities. Groundwater is a major clean water source and if properly developed and managed can help increase water supply, thereby minimizing the county's water problems.

Groundwater sources are found within certain underground geological formations called "aquifers". The various strata of soil, sand, and gravel found underground filter out most disease-causing organisms and harmful chemicals as the water infiltrates through them. This is why groundwater can be considered a clean water source.

It is only recently that borehole siting has become more important to water supply projects. In the past the location of borehole sites did not need detailed hydrogeological investigations of groundwater occurrence. Rural communities usually settled near a known supply of surface or shallow groundwater. However, with increased population pressures, increased settlement in areas where water cannot easily be accessed, pollution of existing surface water supplies and the expansion of economic activities, available water resources in many areas have become inadequate. New and often much deeper, potable water supplies have to be tapped.

One of the most effective and possible ways of developing groundwater is through borehole drilling and borehole construction. In order for borehole construction in Uganda to be in line with good international practices and standards, certain guidelines/procedures, some of which should be mandatory, must be followed and adhered to by all stakeholders operating in the country. One of these procedures is **BOREHOLE SITING.**

The proper locating or siting of a well, provides foundational and long-term success of any groundwater based water supply program. It also significantly increases the success and reduces the costs of such a program. A systematic hydrogeological investigation of a proposed project area provides a foundation for success, longterm water-supply sustainability, helps to avoid unsuccessful boreholes and minimizes the depth of required drilling.

The prevailing geology and available groundwater resources are fundamental as they determine what is possible. Particularly where the only option is to use expensive machine drilling, well-carried-out investigations can lead to substantial savings in the drilling cost, which in turn more than covers the cost of the site-investigation procedures and thus reduces the overall cost per well.
Deciding on the need for and method*(s)* of site investigation*(s)* requires careful consideration. Depending on the local circumstances, mainly geological, detailed groundwater exploration methods may be unnecessary and costly; while in other situations, the use of expensive and sophisticated equipment may lead to considerable savings for the overall project or programme, in terms of time, effort, and cost per wells.

Ideally, all groundwater development should be preceded by proper hydrogeological exploration work to locate the optimum amount of groundwater. In many areas the construction of wells has proceeded without detailed insight into the hydrogeological conditions which determine the presence and location of groundwater and has mainly been based on user convenience *(distance to site, ownership of plot, etc.)*. In good groundwater-potential areas, water has often been struck despite the lack of proper investigations. However, expanding water demand, especially in difficult areas, increasingly necessitates the application and proper use of groundwater investigation techniques.

The objective of any of these methods is to give some understanding of what is going on under the ground; the potential depth-to, location and type of aquifers, direction of groundwater flow and the relative position to possible sources of contamination.

This guideline proposes a systematic approach to groundwater investigations, so as to place water-well siting within the reach of the users at low cost. In addition, these guidelines have been developed by consulting numerous organizations in addition to the consultant’s inputs. Based on the experiences these organisation and the consultants, the methods to use and the ones to avoid have also been incorporated in this guideline. These guidelines were further reviewed and contrasted with the relevant, already established, literature and documents: The following documents were part of the review:

- Groundwater Management in Integrated Water Resources Management (IWRM).
- Borehole siting and drilling supervision tender documents.

- Simple methods for assessing groundwater resources in low permeability areas of Africa.
- RWSN - A Guide to Drilling Supervisors.
- RWSN - Siting of drilled wells.
- ICRC - Practical guideline for test pumping water wells.

The main focus was on reviewing the existing guidelines of Borehole Siting and the Socio Technical Manual for Siting of Boreholes *(A guide for Hydrogeologists Involved in Siting, May 2000)*

Groundwater exploration is a cumulative process of gathering data on the presence of groundwater in an area and can be described as various levels of investigations:-

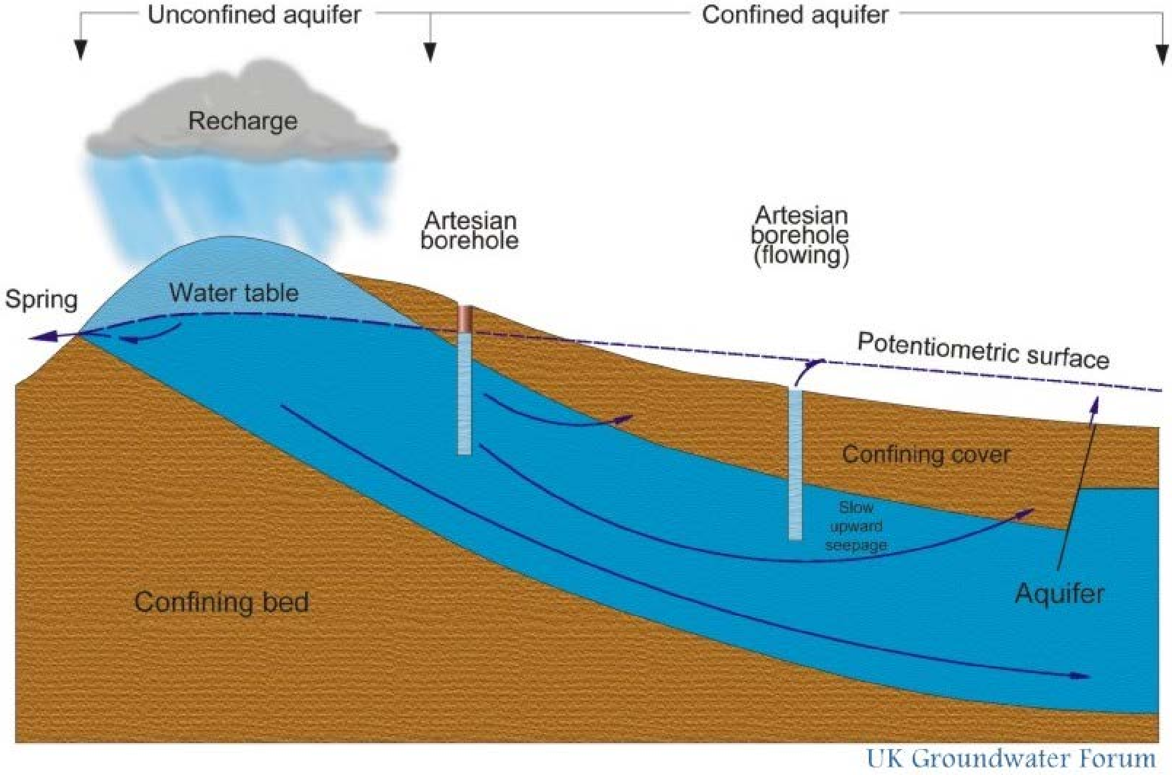
Level 1: Inventory of existing data *(Geological Data, Topographical data, Hydrological and Climatic Data Analysis, Analysis of Existing Well Data, etc.).*
Level 2: Remote sensing data interpretation *(Satellite Imagery, Aerial Photography, Airborne geophysical data, etc.)*
Level 3: Hydrogeological fieldwork Level *(Geomorphological Analysis, Water Points Inventory and Monitoring, Hydro-Climatic Monitoring, etc.)*
Level 4: Geophysical survey level *(Electrical Resistivity, Seismic Refraction, Electromagnetic Profiling (EM) and VLF Profiling).*
Level 5: Exploratory drilling *(Hand Drilling, Machine Drilling, Geological Logging, Geophysical Logging, Test Pumping, Water Sampling, etc..)*

Each level builds on the information obtained at the previous level and provides additional detail on the local hydrogeological situation. The level of investigation required in a proposed project area depends on the data which is obtained at the initial levels. Often the inventory of existing information can give a good impression and additional detail needed for successful borehole siting.
Evidently, more detailed information and investigation is required in an area where previous borehole success rates have been low than where plentiful of groundwater at shallow depth appears to be present.

2.0 GROUNDWATER OCCURRENCE

A proper understanding of the occurrence of groundwater in a project area is needed from the planning stages so that adequate water-well siting capacity can be built into the programmes from the beginning. This knowledge will always enhance successful boreholes siting and provide a basis for obtaining adequate and sustainable yield.

Groundwater is held in the pore spaces or natural openings in rock formations. In unconsolidated rocks and sediments groundwater is held in spaces between grains, known as the intergranular pores. In consolidated and cemented hard rocks *(igneous and metamorphic)*, Groundwater can occur in fractures or cracks which may or may not be interconnected. Groundwater in intergranular pores does not require complex siting details, while groundwater in only fractures requires specific techniques; and failing to locate fractures can mean failure to find water and expensive dry wells. A water bearing rock is called an aquifer. Aquifers provide storage, filtration and distribution of groundwater and a useful aquifer is one that can store water and release it when needed e.g. sand deposits. The objective of groundwater investigations / boreholes siting, is to locate those geological formations which host aquifers *(or which are aquifers in themselves)*.



Groundwater occurrence

2.1 Aquifers

A preferable aquifer for borehole is a geologic formation that contains sufficient saturated permeable material to yield significant quantities of water to a well. An aquifer is an underground layer of water-bearing permeable rock or unconsolidated materials *(gravel, sand, silt, or clay)* from which groundwater can be usefully extracted using a well. Aquifers are typically saturated regions of the subsurface and can occur at various depths.

Aquifers can be divided into three main types as follows:

i) porous like in river sands;

ii) fractured like in crystalline bedrock; and

iii) fractured/porous like in sedimentary rocks like limestone, sandstones, etc.

Either porous or fractured systems may be dominant in a given area depending on the local geological conditions prevailing in the area. In a good aquifer, the water-bearing rock or soil matrix has open spaces or pores large enough to transmit water toward the well at the required rate of abstraction; though not all geological formations which are saturated with water are aquifers. Generally, the water yielding capacity of an aquifer is identified by three characteristics of the rock matrix: porosity, permeability and specific yield. Aquifers can be porous like in river sands, fractured like in crystalline bedrock or fractured and porous like in sedimentary rocks, for example limestone and sandstones.

Typically, aquifers are classified according to their boundary conditions including confined and unconfined aquifers.

In unconfined aquifers *(also referred to as phreatic aquifers)* the upper boundary is the water table or phreatic surface. Unconfined aquifers are of limited lateral extent and thickness and are known as perched aquifers. They have limited storage and are prone to drying up. Unconfined aquifers usually receive recharge water directly from the surface, from precipitation or from a body of surface water *(e.g., a river, stream, or lake)* which is in hydraulic connection with it. They are prone to contamination from the surface *(e.g from pit latrines, pesticides, industrial waste, etc)*. They are usually shallow, productive and therefore relatively cheap and attractive to develop.

Confined aquifers are covered by impermeable materials such as clay and may hold water under pressure. When water is struck, during drilling into a confined aquifer, the water level will rise under pressure and in some cases even overflow. These aquifers, in the latter case, are sometimes referred to as artesian aquifers. An artesian aquifer is a specific condition of a confined aquifer where the hydraulic grade line *(potential free surface)* of the aquifer is higher than the confining stratum. Not all confined aquifers are artesian at all points. An artesian well is one such that water will flow from the well at the ground surface without pumping because the hydraulic grade line for the aquifer is higher than the ground surface.

3.0 BOREHOLE SITING

3.1 Purpose and Scope

The purpose of this activity is to identify one or more drilling targets which offer the best possibility of locating a groundwater resource capable of supporting a successful borehole for the intended purpose of use. It is not sufficient to be satisfied with meeting the minimum yield required for a borehole to be deemed successful. Every effort must be made to identify a target which offers the greatest chance of success also in terms of borehole yield. This task falls squarely on the shoulders of the Hydrogeologist.

The scope of activities related to this task extends from a pre-fieldwork assessment of the groundwater resource potential in the project area to field based exploration efforts. The key to successful borehole siting is an understanding in detail in detail of, amongst others, the geology, structural geology, geohydrology and geomorphology *(in particular weathering patterns and profiles)* of a specific site. Geophysics is only one of the tools available with which to obtain a better understanding of these aspects. It is important that borehole sites are chosen principally on hydrogeological grounds to have the greatest chance of obtaining an adequate yield and water quality that satisfy the needs of a particular project.

Generally proper borehole sites should be:-

-free from pollution of animal and human waste;
- protected from the risk of flooding;
- protected from erosion that may be causes by surface runoff after precipitation
- within easy access to the local community *(and for the drilling rig).*
- have minimized hydraulic interference with boreholes located nearby.

Since the well will usually be under the care of the local community, the users' full agreement should be sought for the site location. This requires proper communication with the beneficiary local community and involvement of the respective local leaders/councils about the new borehole. The investigation process should avoid potential conflicts regarding ownership, operation and maintenance of the new borehole(s). More information on the process is in the (Rural Water Supply and Sanitation Handbook, second edition, Vol 1, Community Management).

Briefing community members before siting begins

3.2 Approach

The siting of a potential water supply borehole must follow a carefully considered and planned approach aimed at maximising the success rate in the most cost effective and sustainable manner. The siting activity must not to be rushed because of the imminent arrival of a drilling rig on site. Rushing of the siting activity may lead to rough and shoddy work which does not serve the aims of the project in that it may result in fewer successful boreholes being established. Since lower success rates impact unfavourably on the financial viability of a groundwater development project, the maximisation of exploration efforts within acceptable project fiscal limits should be encouraged. In some huge projects, the siting activity may be carried out jointly by an exploration team of the Hydrogeological Consultant comprising of at least: (1) a hydrogeologist, (2) a geophysicist and (3) a social worker. While a fully competent team is expected to be involved with borehole siting, it does not necessarily mean that all three members of the exploration team have to be on site at the same time. Local conditions will determine who is best suited or most needed to define the correct drilling position.

3.3 Techniques for Groundwater Resources Exploration

It is not within the scope of this document to provide a detailed exposition of all the possible techniques *(especially those involving geophysics)* and their application in the exploration for groundwater resources. A technique that may give success in one geological environment may be worse in another. No technique or piece of equipment is consistently useful in all environments. Different hydrogeological environments also demand different levels of siting. In other areas where groundwater potential is poor, siting methods that are well established and standard techniques can be used. However, there are many hydrogeological environments which are complex and no standard techniques are available for siting wells and boreholes. In these areas, geophysical and other techniques must be tested to provide new rules of thumb that are appropriate for that environment.

Locating groundwater is a science and an art. It requires a basic knowledge of hydrogeology, as well as, observation and inquiry. Overall, the so called “geological triangulation” which is the application of the combination of: 1) maps, 2) observation and 3) geophysics should be used. For an accurate assessment of the potential for groundwater in an area, it is important not to rely on just one technique or approach. Maps can often be wrong; community discussions can be misleading and geophysical surveys cannot be interpreted properly unless the geological environment is known first. An approach that has been used successfully in many groundwater projects is to use a combination of maps, observations and geophysics (DFID).

In order to plan and implement effective well siting, it is essential to gather available knowledge of local groundwater occurrence and conditions. Field mapping and geological observation often holds the key to any successful water borehole drilling project. For example, are the existing boreholes in an area drilled on visible targets or on satellite image identified lineaments? The location and assessment of "dry" *(unsuccessful)* borehole positions also can provide invaluable information when siting new boreholes. Communication with owners, community leaders and water committees who often have vital information regarding water sources in the area should not be ignored.

Field observations should entail at least detailed mapping of rock outcrops, particularly along drainage channels where exposed outcrops and potential targets/non-targets may be visible. The production of a map at a scale of 1:50,000 should ideally show satellite image lineaments, fracture zones, dykes, lithological changes and any associated relevant attributes such as dip and strike. Such a map will also serve to plan geophysical surveys more optimally. It should be emphasized that activities in this regard should aim at maximising exploration efforts within the financial framework budgeted for this work. Generally, the Hydrogeologist is expected to employ a combination of available data, observational and geophysical techniques.

3.4 Familiarisation with the Project Area/ Reconnaissance Surveys

This activity must take the form of a reconnaissance survey and can provide considerable information from the community on groundwater resources. It is aimed at assessing aspects such as:-

(1) the nature of the terrain especially in regard to the execution of geophysical surveys and its accessibility for heavy machinery,
(2) the spatial distribution of communities within the project area,
(3) the geology within the project area as it might relate to groundwater occurrence,
(4) the status regarding existing water supply facilities and infrastructure and
(5) an assessment of the possible influence of sanitation structures on the positioning of boreholes.

The reconnaissance survey should be undertaken jointly with a representative of the client.

3.4.1 Observations Data during Reconnaissance

1. Where are people presently getting their water?
2. Hand dug wells found nearby will show the depth to groundwater and the type of sediment in the area.

3. Are there drilled wells in the area? Perhaps the village or responsible government agency has useful information on the well, such as its depth and the sediment or rock types encountered when the well was drilled.

4. Groundwater can often be found in sand or gravel layers in the bottom of a valley, even if those layers are covered by layers of silt or clay. Groundwater in valleys or low-lying areas is often closer to the surface than in steep or relatively high areas.

5. Are there springs in the area? Groundwater can usually be found nearby. If a spring flows all year, it is likely to come from a productive aquifer. If the spring dries up, then it might be overflow from a perched aquifer, but still worth exploring.

6. Are there streams in the area? Carefully observe stream flow, looking for sections where flow is greater and sections where flow is less. Where it is greater, groundwater may be discharging into the stream, indicating a good area to drill. Even dry stream beds often have shallow groundwater underneath.

7. Trees or shrubs that remain green in the dry season may have roots that reach into the groundwater at a relatively shallow depth. Greener patches of grass may reveal places where groundwater is close to the surface.

8. Pay attention to where animals go to find water. Bees and pigs are very good at finding water.

9. Look for deposits of salt or other minerals – usually visible as a white “crust” on the surface of the ground. These may be caused by the evaporation of groundwater, which leaves the minerals behind. A large surface deposit might indicate that the ground water has a very high mineral content.

10. Look for “outcrops” of tilted layers of rock on hills or ridges; groundwater will flow downhill along the direction of tilt.

11. Some rock layers, like sandstone or limestone, have many cracks. These may produce acceptable quantities of water.

12. Examine any outcrops of marble or limestone that are being used for building materials. Some can be good aquifers. But remember that not all drilling techniques can penetrate rock.

13. Do not limit your investigation to a small area. It is desirable for a well to be as close as possible to where people live, but it is more important that it produces a sufficient quantity of water.

3.4.2 Plotting of the project area/ Villages on the Maps

Locating the project area / village on the map is an important part of the planning phase of a project. After plotting of the project area or village on various maps, an understanding of what geology underlies the project area or village can be got. At the reconnaissance stage, this gives a good idea of the proportion of the project area that is underlain by each geological unit. In addition, each improved water source *(such as borehole or improved well)* can be located on maps, and each abandoned borehole. This will help assess which areas are easy to find groundwater in and which ones are difficult. With the advent of the GPS *(global positioning system)* it is now very easy to locate wells and villages on maps. For greatest accuracy they should be set up to the same grid system as the maps on which the information will be plotted. ***(This stage may be simplified by using the existing groundwater maps).***

3.5 Experience of the Project Area

It is always helpful to find someone who has worked in the area before. Not only can they give their own opinion of the area, but they can help point one in the direction of other projects in the area or maps and reports that might have been written. However, all advice and information given should be treated cautiously and always checked in the field. Since people can often give misleading information in their enthusiasm to be helpful.

3.6 Maps and Reports

For most areas it should be possible to gather basic information, such as topographic maps, aerial photographs, geological maps, hydrogeological maps, aeromagnetic maps, databases of boreholes, reports of previous projects and local research in the area, local NGOs/ local government databases of boreholes and consultant’s reports. Topographic maps at appropriate scales provide the most basic information for undertaking a well siting programme. They provide the correct terrain and rivers and indication on land and accessibility. Geological and hydrogeological maps present and summarise a great deal of complex information in a visual form. Maps on groundwater development potential and quality are also vital.

A variety of documents including project reports, driller's and consultant's reports, NGO project documents, academic studies, etc., can provide useful information about the areas where groundwater development is proposed. Drilling records and databases are often most reliable with regard to local geology and hydrogeology. Drilling logs, records and databases can be extremely useful sources of information.

3.7 Geographical Information Systems *(GIS)*

GIS are excellent tools for water supply projects. They allow map information to be combined, analysed and presented in many different ways. This means that tailor made maps can be easily created for different project stakeholders. However, to set up a GIS demands specific expertise and considerable effort to get all the data in the appropriate format. To create a GIS for an area available data are put into digital form. That means digitising topographic and geological maps and making sure they are in the same map registration. Once this is done other information, such as village locations can be added and plotted on top. Once some investigations have been done, preliminary groundwater potential maps could be drawn up and printed for use in the field. It is recommended to use compatible data format with common GIS software.

4.0 REMOTE SENSING INTERPRETATION TECHNIQUE

Satellite imagery and Aerial photography interpretation provide useful information to help create a base map for the area and is used for narrowing down targets for groundwater investigation. This is a specialised technique and will require the input of a good consultant. A satellite image contains information from the light spectrum and is interpreted to help give an indication of changing conditions on the ground. Under good conditions, changes in geology can sometimes be observed. Fracture zones, rivers and roads are interpretable with experience. Information from satellite images can be presented on maps at about 1:50 000 scale. These tools are useful both during reconnaissance, scaling down to the area of interest, and identifying geological boundaries and hydrologically significant features which may not be visible on the ground.

5.0 HYDROGEOLOGICAL FIELD SURVEYS AND AQUIFER CORRELATION

The objective of hydrogeological field surveys is to assess the potential / presence of groundwater in the underlying rock by an evaluation of ground surface characteristics. A number of useful characteristics may already have become evident from the earlier level of investigations described above. The hydrogeological surveys provide the opportunity, where possible, to check the findings of the inventory of existing data and of the remote sensing interpretation in the field. Based upon the field investigations and the previous levels of investigation, the project area can be divided into water availability zones *(high, medium and low potential)* according to the expected availability of ground water.

The basic elements to be checked during hydrogeological field surveys are:-

- Check the information collected from the desk study.
  - Check rock outcrops to confirm geology.
  - Check the topography - lower grounds as areas of groundwater accumulation and potential recharge areas.
  - Check existing water supply – functionality, fluctuations, quality.
  - Acquire the GPS location of existing boreholes – for aquifer correlation.
  - Sketch a map of the location with all the information collected.
  - Is a geophysical survey required or the borehole can be sited on the basis of the assessment?
  - On the basement complex and on the consolidated sediments geophysics will be required.
  - In the unconsolidated sediments existing borehole records may be sufficient to site boreholes.

It is not always that geophysics is required to site a borehole. If the survey finds sound evidence of groundwater potential, then sites can be selected without additional investigations using geophysics. This is especially true for areas with simple hydrogeological environments such that of the ubiquitous presence unconsolidated sedimentary materials and shallow groundwater. It should be done only where it will provide useful information. In situations where additional investigations are required, hydrogeological fieldwork serves as the basis for selection of sites for detailed geophysical surveys. It is generally too time consuming and expensive to cover the whole project area systematically with geophysical measurements.

6.0 GEOPHYSICAL TECHNIQUES/ INVESTIGATION

6.1 Introduction

Geophysical surveys are by far the most commonly used techniques in detailed water well siting. The techniques measure the physical properties of rocks such as resistivity, conductivity, magnetic fields and sonic properties. Most cannot directly detect the presence of water. Instead the contrast in subsurface *(water and rock)* properties are interpreted in relation to geological features that are expected to facilitate groundwater storage and movement. To increase the possibility of successful boreholes, proper geophysical investigations must be carried out using the appropriate and standard geophysical equipment.

Geophysical surveys can be undertaken at sites based upon geological observations made within the area of investigations. The type of geophysical survey depends on the rock types present. The survey results should support the observation data, confirming the type of rock present. The survey results can then be collated with observed data to identify targets for boreholes or wells.

The Hydrogeologist should identify potential targets with the geophysics serving as a backup to identify optimal positions and/or to move drilling positions to more accessible or favourable places. No geophysics should be done until targets are identified. Specific targets should be identified from existing geological maps, satellite images/ airphotos and field mapping as required. Geophysical techniques include: (1) magnetic surveys, (2) frequency domain electromagnetic surveys, (3) electrical resistivity surveys, (4) gravimetric surveys and (5) seismic refraction surveys. The most commonly and widely employed of these techniques are the electromagnetic and electrical resistivity techniques. Techniques considered appropriate for specific geological environments should also be identified preferably in the initial stages of a project.

6.2 Geophysical Theory – Resistivity Method

The resistivity method has been used for many years and can be employed in two distinct ways. The first is a vertical electric sounding *(VES)* in which depth variations in subsurface resistivity at a fixed point can be interpreted in terms of a sequence of geological layers. The electrodes are expanded in an array about a central point. as detailed below. The measurements are done to identify low resistivity zones or conductors that may be caused by water bearing layers or aquifers. Two types of aquifers are targeted:

1. near-vertical zones in fractured or faulted rock and
2. areas with substantial thickness of the regolith (weathered bedrock).

Resistivity profiles are carried out to identify the lateral variation in resistivity at one target depth *(usually target depth is approximately 40-60m)*. The actual target depth should be informed by local drilling history and experience, if functioning wells exist in the area for comparison. The zones are identified through anomalies on the profiles. The interpretation of the profile is both qualitative and quantitative. The shape and the lowest resistivity value of the anomaly are considered. Parallel profiling is mainly carried out in areas where anomalies have been detected that had not been identified during the API. The results of the parallel profiling are used to establish the orientation of the anticipated fractured zone.

A Vertical Electrical Sounding is carried out at the anomaly to identify the vertical variation in resistivity at that particular spot. The VES gives resistivity values of the layers down to ½ AB=120 m which corresponds to approximately 75-90 m. When the bedrock is shallow, ½AB values of 83 m suffice and sometimes ½ AB values have to be extended to 160m or 200 m.

Set up of Resistivity surveys using Vertical Electrical Technique

Preliminary interpretation of resistivity soundings is based on experience. Interpretation of the sounding curve is based on the convolution method of Ghosh *(1971)* a mathematical curve fitting procedure. Without any additional data for correlation it can easily lead to a fitting solution that does not quite correspond to reality.

The layered earth model is actually very much a simplification of the many different layers which may be present. The various equivalent solutions that can be generated by a computer programme should therefore be carefully analysed. In general, a single resistivity sounding should never be interpreted in isolation as this leads to a meaningless result. Also, the fact that a clay layer *(not water producing)* has the same resistivity as a water bearing sand layer; and the fact that some specific minerals present in the rock may also be highly conductive and show up as an anomaly on the resistivity profile, makes the interpretation a delicate activity.

When interpreting the VES with computer software it is important to realize the following effects:-

1. ***Equivalence:*** equivalence is the problem of having different interpreted computer models for the same resistivity curve. This is the result of the fact that usually more than one solution is possible e.g. a relatively thin layer with a low resistivity may give the same result as a thick layer with a slightly higher resistivity.

2. ***Suppression:*** when the thickness of a layer intercalated within a sedimentary sequence is relatively small it may not be noticed in the resistivity graph and is 'suppressed' and therefore not sensitive to the computer interpretation. Nevertheless, where *justified (e.g. when it is known to exist from borehole data)* this 'invisible' layer may be introduced in the interpreted model.

3. ***Masking:*** when a low resistivity layer *(10 ohmm or less),* like heavy clay / black cotton soils , is found at the surface, all layers below it will likely create 45 degrees because the resistivity increase at this shallow depth on a logarithmic scale will give the maximum angle which is 45 degrees. Hence the distinction of the underlying layers is made impossible *(a 100 ohmm and a 1,000 ohmm layer below the clay layer will create the same curve).*

In view of the above it is clear that no Consultant can give a 100% guarantee for productive boreholes. It is also impossible to give accurate estimates of a borehole yield, or water quality, based on the geophysical measurements only. The results of an analysis of many rural water supply projects however indicate that the above discussed methodology is likely to increase success rates up to 70 to 100% depending on the hydrogeological conditions of the area.

6.3 Geophysical Surveying Protocols

Geophysical exploration is generally carried out along measured survey lines *(traverses).* These survey lines often follow roads or tracks which provide ready pedestrian accessibility within the area of investigation. In some instances, geophysical surveys lines may form a rectilinear grid. The geographic position of the survey lines/grids must in all instances be determined as accurately as possible. This can be achieved by using a combination of coordinates obtained from a global positioning system instrument and the identification and plotting of the line*(s)* or grid on a map of a suitable scale. The smallest acceptable map scale is that provided by the published 1:50 000 scale topocadastral maps. The 1:10 000 scale orthophoto maps, if available, provide a more convenient, accurate and therefore preferred scale for this purpose. The survey lines as plotted on a map must indicate the start and end points as well as the direction of the geophysical surveys carried out along each traverse. The latter information is, for example, critical when it comes to the interpretation of magnetic survey data. Survey station intervals along each traverse must be set out accurately using a measuring tape or similar distance-calibrated tool. The pacing out of the survey lines must be avoided. All geophysical survey lines must be clearly marked in the field such that these can be located at any stage within the period it is expected drilling will take place

Calibration sounding at an existing borehole

6.4 Equipment and set-up

The geophysical surveys can be done by means of resistivity measurements, in the form of profiles and vertical electrical soundings *(VESes),* with the use of any resistivity meter *(an ABEM Terrameter SAS300/1000, SuperSting etc.).* There are different electrode configurations available for carrying out VESes. The three most common are Schlumberger, Wenner and Offset Wenner. For VES, the electrodes are moved to set distances on either side of a midpoint. The resistivity profiles may be run with a ½AB distance of 90 m and a station interval of 10 m. The VESes should be carried out at promising anomalous zones as identified through the profiling exercise to get an insight in the depth and type of the overburden and depth to the bedrock.

Field execution of geophysical investigations is based on the results of a desk study on geology, hydrogeology and borehole data; and the results of a detailed aerial photograph interpretation focused on lineaments. Within the target sites selected for geophysical investigations: -

- Coordinates of the start and end of the profiles as well as the points for the VESes should be recorded with GPS, as well as the altitude on the VES location forms. The orientation of the profiles should be measured with a compass and recorded.

- The geophysical profiling should be carried out perpendicular to major lineaments marked during the aerial photograph interpretation. The resistivity profiling will be done using a station interval of 10 m.

- In case significant anomalies are recorded, sometimes, a short (100-200 m) parallel profile at a lateral distance of 20 – 100 m, may be carried out to verify the existence and direction of an anomalous zone coinciding with the mapped lineament.

- In the center of the most significant anomaly that can be related to an anomalous zone, a resistivity sounding is carried out. The array of the sounding is extended until sufficient data are available to define the 45 degrees slope indicating fresh (dry) bedrock.

- Finally, an analysis of all soundings carried out on the significant anomalies, should be carried out to select the sites which are most favorable in terms of groundwater, these being a suitable pre- bedrock resistivity and sufficient depth of weathering.

- It is required that where a potential drilling target is identified on the basis of horizontal profiling by the electrical resistivity method, a minimum of three vertical soundings must be conducted at the anomaly of the profile. **Under no circumstances**

will a single vertical sounding be viewed as sufficient, or acceptable, irrespective of whether it is supported by another geophysical exploration technique.

6.5 Field Note along Survey Line

The collection of geophysical data must be accompanied by field notes regarding the occurrence of natural and unnatural features which are observable along the survey line. Such notes must be recorded opposite the station nearest to these features. Natural features might include: (1) rock outcrop, (2) gullies and surface water drainages, (3) visible changes in soil cover and (4) sudden marked changes in terrain slopes. Unnatural features would include: (1) existing boreholes with an indication of their assessed yield, (2) fences, (3) telephone lines and powerlines, (4) gates and gateposts and (5) building structures and dwellings.

The interpretation of the geophysical data must be undertaken as soon as possible after the data have been collected. This activity should seek to identify as many potential drilling targets as might be indicated by the data. The targets should be ranked firstly according to their scientifically adjudged potential for success and secondly according to the convenience of their location in respect of the service area.

6.6 Interpretation of measurements

Resistivity data is interpreted with specialized interpretation software for instance WINSEV or any appropriate software. The interpretation of the survey data should be undertaken by using fixed resistivity values of the bedrock and the pre bedrock layer of 5000m and 150m, respectively. The subsequent Report should provide a site location map with the detailed results of the geophysical surveys and their interpretation.

6.7 Analysis of measurement

During the field survey, potential sites have to be surveyed using the resistivity profiling and VES methods. Afterwards these sites are evaluated on their ground water potential in order to select the most promising site. The hydrogeologist may develop a scoring system to rank the potential sites comprising the main evaluation criteria, their weight factor, and scoring *(source WE Consult).*

6.8 Marking of Borehole Site(s)

The actual marking of the prospective borehole site(s) must be undertaken as soon as possible after the survey data have been interpreted. This task is the responsibility of the exploration team. The site and its identification number must be marked clearly in the field. It is preferable that more than one method of marking be used, e.g. a whitewashed cairn of rocks packed around or over a tagged one-metre long steel peg hammered at least two-thirds of its length *(if possible)* into the ground. If the use of a metal peg is not considered suitable, then the planting of a concrete block with dimensions approximately 200 mm x 200 mm x 200 mm *(and bearing the assigned number of the borehole)* in the ground a distance of five metres to the north of the borehole must be considered. It is important that each such site be pointed out to at least one, and preferably more than one of the contact persons responsible for water supply matters within the community. The preservation of the marked prospective borehole site*(s)* must form part of the collective responsibility of the community.

Marking site using a wooden peg

6.9 Documentation of Geophysical Data

Raw geophysical field data must be recorded on appropriate data sheets. On these must be indicated basic information such as: (1) the 1:50 000 scale topo cadastral map sheet number, (2) the drainage basin number at tertiary level, (3) the date of the survey, (4) the unique identifying number assigned to the survey line, (5) the direction of the survey line, (6) the coordinates of the start and end points of the survey line, (7) the name of the community within which the survey is carried out, (8) the name of the district within which the community is located and (9) coordinates according to which the geographic position of the community can be identified on a map. It is further required of the Hydrogeological Consultant to present the geophysical field data in a neatly documented graphical format. The positions and identification numbers of marked borehole sites must: (1) be indicated on these graphs against their true positions along the survey line and (2) be cross-referenced to the locality map*(s).* A brief interpretation of the geophysical data leading to the choice of each marked borehole site must be provided in the final technical report compiled by the Hydrogeologist.

7.0 OTHER FACTORS TO BE CONSIDERED IN LOCATING BOREHOLE SITES

7.1 Groundwater Flow Direction

If the groundwater flow direction is known, it is best to place the well up-gradient from a latrine or potential source of pollution, so that contamination moves away from the well. It may be difficult to know the direction of flow. But, groundwater in an unconfined aquifer tends to follow topography and it flows from a recharge area to a discharge point. Knowing this, it will usually be better to locate a well uphill from a source of pollution than downhill from one.

7.2 Environmental Factors

The following environmental issues should be considered when siting boreholes:

1) The direction that groundwater flows, as noted above, is a very important environmental factor to know. A borehole should be located so that pollution from any source moves away from the well and not toward it.

2) The type of soil near the surface is also important. As mentioned, clay, silt, and fine sand can keep contaminants from reaching the groundwater.

3) Surface waters, like streams, rivers, and ponds, may contain biological, agricultural, or industrial contamination. So wells should be located at least 50 meters away from them.

4) Avoid areas that get flooded, since people cannot get to the well to the well during times of high water and the well may be contaminated by floodwaters overflowing and seeping into the well.

5) The well site should be elevated enough to direct surface runoff away from it.

6) Naturally-occurring chemicals, like arsenic, boron, and selenium can affect groundwater quality, so water should be tested in areas where this may be a problem.

7.3 Minimum Distances *(m)* from Threats to Borehole

Sn.	Existing Structures	Minimum Distance from Borehole (m)
1	Existing production wells/boreholes)	500
2	Hand pump water wells or boreholes	100
3	Latrines, septic tanks, soakaways	30
4	Streams, canals, irrigation ditches	50
5	Buildings	10
6	Approved or informal solid dumps, burial ground/Graveyard	500
7	Main roads/Municipal roads	20m
8	Lake/River	100

Limitations: These suggested distances are broad estimates; specific minimum distances should vary with the knowledge of the Geology of the project area.

7.4 Cultural Factors

Cultural factors can be thought of as anything related to human activity that should be considered when locating a well site. Examples of some cultural factors might include:-

1. Proximity to where people live. Convenience is a very important factor to consider when locating a well. Studies have shown that when a water point is located less than 200 meters from a home, people tend to use more water than when the source is farther away. They drink more water and wash more often, which con tributes to better health.

2. If there are more people who want to use the well than the well can support, people will not have enough water for good health. One borehole for every 300 people is an

appropriate goal. A large village may need several hand pump boreholes, or a production well, in order to experience all the benefits of clean water.

3. Are there areas in or around the community that are considered sacred? It is wise to respect the “spiritual landscape” of the area as viewed by those who live there. You may not share the community’s beliefs, but it is a demonstration of love to be sensitive to theirs. Asking about these things with gentleness can help build good relationships.

4. A cemetery is an especially sensitive cultural issue. In some places, people have refused to drink water that comes from the ground because people were buried in the ground. There is no real risk of contamination if a well is located a safe distance up-gradient from a cemetery. However, the perception that people have is a more important consideration when choosing a well site.
5. Even a small village may have a well thought-out plan for growth. So, consider what future development may take place in the village and locate the well in a place that will not conflict with that growth.

6. Some communities have cesspools, or large seepage pits, that receive much more human waste than a family latrine. A well should be placed at least 50 meters away from such a concentrated contamination source.

7. Animal pens concentrate waste in a small space and are similar to a latrine in their potential to contaminate groundwater. Use the “safe separation distance” criteria as you would for a latrine.

8. Industrial facilities, or garbage dumps, may discharge harmful chemicals into the soil and groundwater, so wells should be located at least 500 meters up-gradient of them.

9. A well shall not be closer than 20 meters, if feasible, from an overhead power line, because the lines could be touched when installing or repairing the hand pump.

10. Before drilling, identify any underground pipes that might run near the well site.

11. If a new well is placed too close to another well that is still being used, they may interfere with each other. This can reduce the amount of water that each well is able to produce. The appropriate separation distance depends on the pumping rate of the wells and the characteristics of the aquifer.

1. 12. An abandoned well may be filled with trash. Since it probably reaches to the water table, this can be a serious source of groundwater contamination. In such a situation, the "safe separation distance" criteria for a latrine that contacts the groundwater, should be used.

7.5 Property Ownership

Property ownership is a cultural factor that deserves special consideration. Wherever there are people living and working, there will be some sense of property. Ownership might be individual, collective, a mix of these, or something entirely different. In any case, it is not likely that property ownership will be evident to an outsider, even an outsider from within that culture. If you are involved in surveying and walking around trying to find the best location for a well, it is always important to ask permission before walking around and looking at things. It is best to be accompanied by a local leader, so no suspicion will arise among those who may not know the purpose of your visit.

8.0 MAKING A SITE LOCATION SKETCH MAP

In these cases, making a simple map helps identify the most important factors to consider. Starting from the preferred site, a site map should be made considering major features such as access roads, schools, shops, etc, indicating distances from the preferred well site location.

Make a simple sketch of what you find. The map does not have to be exact. Measure distances from the well site for each source of contamination you find. Take topography into account because it influences the direction of groundwater flow.

If the source of contamination is too close to the proposed well site, then the problem should be discussed with WUC/. Help them consider a better well site. Work with them to find the best place for the new well, given the restrictions of the environmental and cultural factors. Remember that finding the best well site often requires tact and compromise.

9.0 REPORTING

All aspects pertaining to the borehole siting must be documented with evidence in a technical report. The compilation of this report is the responsibility of the Hydrogeologist. The emphasis in the report should be explain the methods used and the activities carried out during siting, with wherever possible evidence in terms of tables of data used during desk studies, calibration data, google maps, topographic maps, geological maps, and pictures of some of the activities. A proposed format for the siting report is indicated below.

1.0 INTRODUCTION (Including purpose of consultancy)

2.0 GENERAL INFORMATION

2.1 Location

2.2 Physiography and Climate

2.3 General geology (geological map of the area with details for the site where possible)

2.4 Hydrogeology (groundwater occurrence and potential)

3.0 HYDROGEOLOGICAL INVESTIGATIONS

3.1 Desk Studies (include data used, topographic map analysis, Google maps, etc)

3.2 Reconnaissance surveys (include data from reconnaissance surveys, calibrations etc)

3.3 Borehole Siting

3.3.1 Introduction

3.3.2 Siting Method (brief background of method used and how it works)

4.0 RESULTS OF THE INVESTIGATIONS

4.1 Resistivity profiling (explanation of the technique and interpretation of results)

4.2 Resistivity Vertical Electrical Soundings (explanation of the technique and interpretation of results)

4.3 Site Selection and Ranking of Sites (basis/ criteria for site selection)

5.0 COMMUNITY PARTICIPATION/INVOLVEMENT

6.0 GENERAL CONCLUSIONS AND RECOMMENDATIONS

6.1 CONCLUSIONS

6.2 RECOMMENDATIONS

10.0 Case Studies

10.1 Case Study of Hydrogeological Survey Steps by WE Consult

Location village	• Administrative,	
	• Location in District / Country map	
	• Coordinates	
Preferred sites	• Coordinates	
Topography	• General	Absolute height (MAMSL)
	• Topographic profile N-S Google Earth 2-5 km length	Elevation preferred site bottom valley 1
	• Topographic profile E-W Google Earth 2-5 km length	Elevation preferred site bottom valley 2
	• Topographic map	
	• DEM map	
	• Hillshade map	
Geological map	• Geology preferred site	
	• Geology surroundings	
	• Faults fractures	
	• Geological Report Uganda	
Source / Borehole data	• Water Source location map	Watsup data
	• Groundwater mapping maps • Water quality • Success rate • DTB	
	• Borehole yield map	TGS / MWE / WE
	• Borehole characteristics table per admin unit	Include neighbouring units

	• Borehole characteristics per geological unit	Include neighbouring units
	• Static Water Level expected depth? SWL not too deep?	
	• Calibration BH nearby for geophysical measurements	
Geophysical data nearby	• Earlier survey results dry and successful, check anomaly and VES and compare later with results	
Lineament analysis	• Aerial Photos 1:39,000 and 1:60,000 from EBB, show more than Google Earth, digitize lineaments in GIS • DEM Contours • Topomap • Rivers • Google Earth • Hillshade • Fractures faults geological map	
Target sites for geophysics	• In sediments no profiling, VES only. High resistivities are target. • For handpump borehole in flat areas 2 profiles perpendicular. Otherwise target lineman or valleys if less than 1000 m from preferred site • For production boreholes, target lineaments and valleys only. Cross in different places	
Reconnaissance survey	• Verify the sites in field on location accessibility • Check results earlier drilling programmes,	
Fieldwork	• Profiles as per location indicated in desk study:	

	• Mark the locations of any feature the profile is crossing in accuracy in meter. Station 21.5 is 215 meter from start and 5 m from 21. If necessary, mark when ABMN electrodes are crossing something (when you expect conductor in underground, high voltage line, bridge etc. • On anomaly take coordinates	
	• Do parallel profile if necessary	
Interpretation	• Interprete the VES using model based on existing borehole data If no data use realistic models and depths (not DTB of 200m for example)	
Prioritisation of drill Sites	Use scoring table, example below	

Criteria	Explanation	Specific criteria		Classification
Topography (20%)	The topography of a location is determining for the groundwater potential. The potential depends on the location on a slope; the highest potential is the bottom of a valley and the lowest is at the top of a high hill.	Ridge / hill top		0
		Upper slope		5
		Flat area / head of valley		10
		Saddle / lower slope		15
		valley / foot lower slope		20
Lineament (20%)	Lineaments often have a high groundwater potential. The presence and quality of a lineament is acquired from analyses of aerial photos, topographical maps, or field	Lineament present	Very clear	20
			Clear	10
		No lineament present	Vague	5
			No lineament	0

	observation.			
Anomaly (30%)	Experience shows that the anomaly is the most reliable indicator for high potential areas. Because a ½ AB distance of 90 m is used, the anomalies become more pronounced and deeply weathered zones or cracks are more precisely indicated. The potential is amongst others based on the general shape, resistivity and width of the anomaly.	Contrast (shoulder/ lowest anomaly value)	< 1.5 or > 4	0
			2 - 4	10
		Width (shoulder to shoulder)	< 19 m and > 80 m	0
			20 – 60	5
		Shape of anomaly and trend of profile	Minor anomaly in sloping trend	2
			Major anomaly in horizontal trend`	7
		Confirmation of anomaly (shape and value)	None	0
			Little	3
			Shape and value	8
VES (15%)	The VES is usually carried out on an anomaly and indicates the resistance of different layers. The aspects of importance are general shape, resistivity at depth and width of trough. The VES interpretations are the most reliable when the geology is well known.	VES dip	> 200 Ωm	0
			10 - 100 Ωm	7
		Depth to bedrock	45 º is < 27m or > 120	0
			45 º is 40m - 83m	8
Similarity (15%)	Confirmation profiles and VES near existing high	Anomaly	Low-high similarity	10

	yielding boreholes, and survey results of earlier projects, have resulted in types of VES and anomaly. If the actual VEs or anomaly shows good similarity a higher score is attributed	VES	Low-high similarity	5

10.2 Case Study of Hydrogeological Survey Steps by Aquatech Enterprises (U) Ltd

Aquatech Enterprises (U) Ltd, in Uganda follows the following siting procedures: -

Phase 1 is a planning and reconnaissance study which includes mobilisation of equipment and personnel, collection and interpretation of existing data and preliminary selection of target areas for detailed investigations. It normally also includes field data collection, site-specific data analysis and verification of results of desk studies and preliminary site selection. Activities to be carried out during this phase are as follows: -

- Liaise with client;
- Collect and review hydrogeological reports and literature for the areas of interest;
- Collect and study maps – (topographic, geological and hydrogeological).
- Collect and study drilling information and records;
- Visit field to determine field conditions, accessibility to preferred sites and community readiness to participate;
- Use a GPS to locate sites on a topographic map. This will provide information on where to expect to find water and whether the quality is expected to be good.

Phase 2 comprises the hydrogeological investigations, including topographic map analysis and detailed geophysical surveys of the areas of interest. These mainly use the resistivity technique to characterise the different formations. Since most of Uganda is underlain by hard rocks, the approach uses an ABEM Terrameter 300C or SAS 1000 for traversing and vertical electrical soundings. These methods provide a) an estimation of the thickness of the regolith,

b) an indication of horizontal changes in aquifer properties and c) the locations of any vertical geological boundaries.

Existing data for nearby water sources are collected and used for calibration. Where data are not available, calibration resistivity soundings are made at existing drilled water wells to characterise the underlying geology in terms of resistivity and groundwater potential. The results of the calibration measurements guide final interpretation of the data. Traversing is carried out to assess lateral variation whenever this is found to be necessary based on the local hydrogeological environment. The anomalies identified from the profiling are further investigated by soundings to ascertain hydrogeological variation with depth. Initial resistivity profiles are always run perpendicular to the inferred fracture zone.

11.0 BILLS OF QUANTIES (BOQS)

As we have seen, a good hydrogeological survey has a number of inputs. In puts include manpower, equipment, maps, data, and transport. Each of these items has a cost attached. Some items are lump sum while the majority of inputs are time based. The time taken to undertake a survey depends on the groundwater potential, and it may vary from half a day to several days of studies and field investigations. The overall time is also affected by the location of the site from Kampala, knowing that nearly all groundwater consultants have offices in Kampala. Therefore, the cost of siting and supervision is a range of cost, based on the inputs. The minimum costs for all geophysical investigations for borehole locations/sites within Uganda, the Bill of Quantity (BoQ) is given below:

Siting of boreholes, Handpump **-1 day**

Description	**Time taken unit**	**Rate (USD)**	**Amount USD**
Purchase of Maps/Data		15	15.0
Desk studies	0.2	80	16.0
Siting	1	80	80.0
Transport	1	50	50.0
Equipment	1	50	50.0
Documentation and Reporting	0.2	80	16.0
Total			**227.0**
Add 10% overheads			22.7
Sub total			**249.7**
Add 20% Profit			24.9
Sub total			**274.6**
Add 18% VAT			49.43
Total			**324.03**
Total in Uganda Shillings (1USD=3700			**1, 198,911**

Minimum cost for Siting of hand pump is approximately 1.2m

Supervision of Drilling hand pump- 3 days

Item	Time taken	Rate	Amount
Supervision of Drilling	3	80	240
Transport	3	20	60.0
Supervision of test pumping, casting and Installation	2	35	70.0
Documentation and reporting	0.25	80	20.0
Sub-total			400.0
Add 10% overheads			40.0
Sub-total			440.0
Add 20% Profit			80.0
Sub Total 1			528.0
Add 18% VAT			95.04
Total Cost			498.44
			1,844,228

Siting and supervision of a hand pump. 3,000,000/= – 3,600,000/=

Siting of boreholes, Production Borehole – 2.5 days

Item	Time taken	Rate (USD)	Amount
Purchase of maps/Data		30	30.0
Desk studies	0.5	120	60.0
Siting	2.5	120	300.0
Transport	3	50	150.0
Equipment	3	50	150.0
Documentation and reporting	0.5	120	60.0
Total			750.0
Add 10% overheads			75.0
Sub total			825.0
Add 20% Profit			165.0
Sub total			990.0
Add 18% VAT			178.2
Total cost			1,168.2
		Total plus VAT	4,322,340

Siting production boreholes ranges between 4.5m to 6.5m

Supervision of drilling 8 days

Item	Time taken	Rate	Amount
Supervision of drilling	4	100	400.0
Transport	4	20	160.0
Test pumping supervision	4	50	200
Documentation and reporting	0.5	100	50.0
Sub-total			810.0
Add 10% overheads			81.0
Sub -total			891.0
Add 20% Profit			178.2
Sub -total			1,069.2
Add 18% VAT			192.46
Total Cost			1,261.66
Total Plus VAT			4,668,142

The cost supervision of production boreholes ranges between is about 3.50m to 4.70m

RESISTIVITY PROFILING

Location/Village	
Parish	
Sub-County	
County	
District	

Project No./ name			Profile		Parallel Y/N	
			Orientation		Parallel to pr.	
Date			UTM Datum	(WGS84)	UTM Zone	
Time start		Time end	UTM X start		UTM Y start	
Target and orientation (lineament, valley, dyke) or no specific target			UTM X end		UTM Y end	
			Configuration			
Remarks			½ AB		½ MN	
			C :		Station Int.	
Name of Geophysicist / Hydrogeologist						

Station	**Reading (Ω)**	**Remarks:** *Note (marked) trees, valleys, etc and coordinates anomalies and end profile*	**Station**	**Reading (Ω)**	**Remarks**: *Note* (marked) trees, valleys, etc and coordinates anomalies and end profile
0			16		
1			17		
2			18		
3			19		
4			20		
5			21		
6			22		
7			23		
8			24		
9			25		

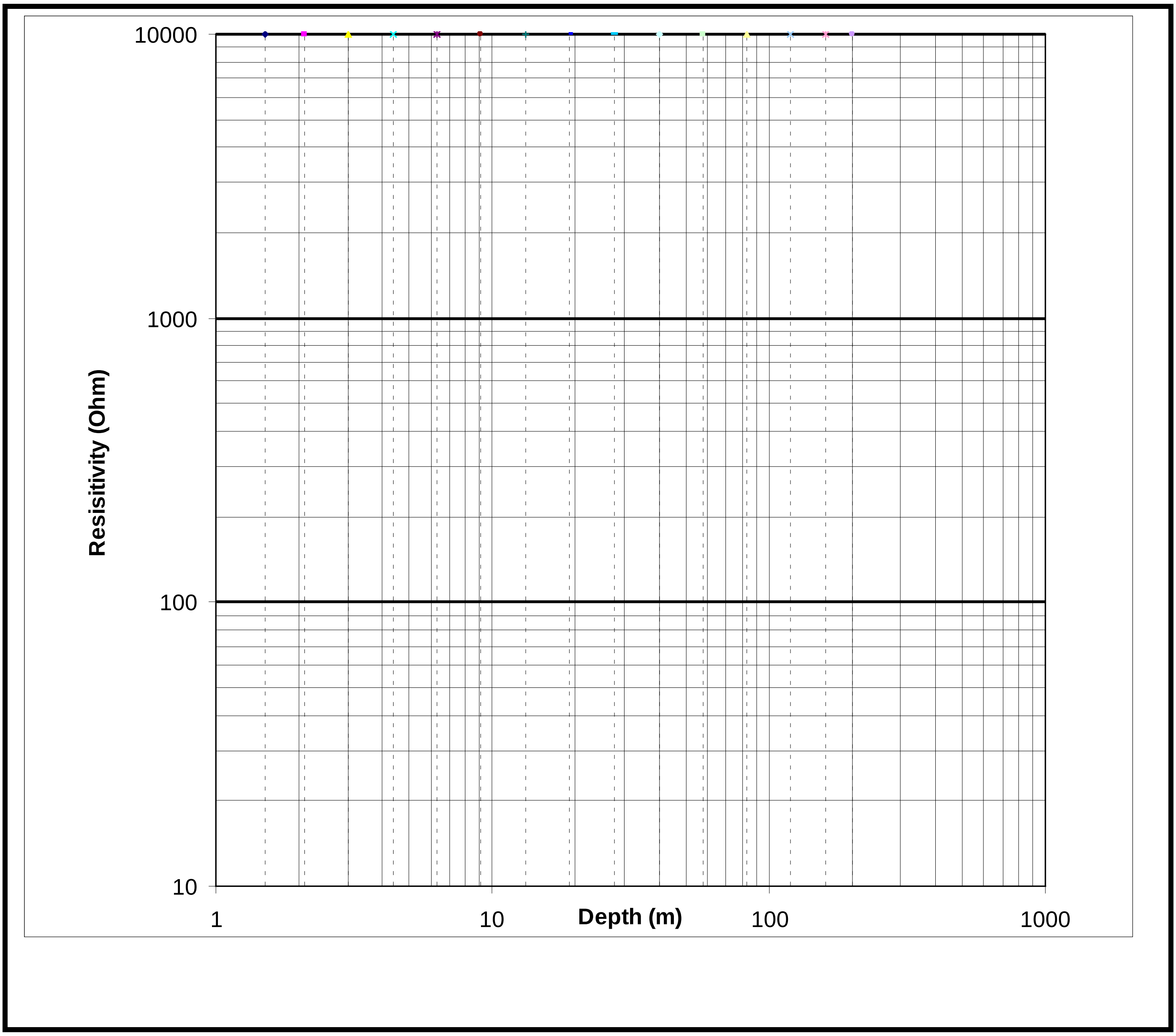
10			26		
11			27		
12			28		
13			29		
14			30		
15			31		

VERTICAL ELECTRICAL SOUNDING

Location/Village	
Parish	
Sub-County	
County	
District	

Project no.		Client/project name				UTM Datum	(WGS84)
VES		Date		UTM X		UTM Zone	
Profile/station		Time start		UTM Y		Orientation	
Profile/station		Time end		UTM Z		Elevation map	

station	AB/2	MN/2	C	Reading (Ω)	App.Res. (Ωm)		AB/2	MN /2	C	Reading (Ω)	App.Res. (Ωm)
1	1.5	0.5	6.28			10	40	5	495		
2	2.1	0.5	13.1				40	0.5	5026		
3	3.0	0.5	27.5			11	58	5	1049		
4	4.4	0.5	60.0					20	233		
5	6.3	0.5	124			12	83	20	510		
6	9.1	0.5	259					5	2156		
7	13.2	0.5	546			13	120	5	4516		
		5	46.9					20	1100		
8	19.0	5	106			14	160	20	1979		
		0.5	1133			15	200	20	3110		
9	27.5	0.5	2375								
		5	230								


10000
1000
100
10
Resisitivity (Ohm)
1
10
Depth (m)
100
1000

	RECONNAISANCE SURVEY	

Project name:		Location:		Page 1	of 2
Project No:		Parish:		Borehole No:	
Date:		Sub-County:		Altitude:	
Team / Unit:		County:		Map No:	
Source Name:		District:		Aerial photos:	

PREFERRED SITES				
Information from (name & function e.g. LC1):				
Village site 1	UTM x		UTM y	
Comments:				
Village site 2	UTM x		UTM y	
Comments:				
Village site 3	UTM x		UTM y	
Comments:				

EXISTING WATER SOURCES

Source name	Type	ID. No.	UTM x	UTM y	Yield (m^3/hr)	Quality	Present situation

INCEPTION			
Topography: (hills, valleys, steep slopes)		Catchment: (size, distance to river, gradient)	
Geology: (Unit, type, outcrops)		Vegetation: (type, presence of lush vegetation)	
Latrines: (depth, water strike, lithology`)		Accessibility: (roads, bridges, seasonal variations)	

ANTICIPATED LINEAMENTS FROM API			
Direction	Extent (km)	Lineament crossings (GPS or description with distances from features)	Remarks (faint, outspoken, ridge, valley)
/			
/			
/			
/			
/			

REMARKS:

	RECONNAISANCE SURVEY	

Project name:		Location:		Page 2 of 2

PROPOSED SURVEY				
Profile	Direction	Start (description or GPS)	Length (m)	Purpose
1	/			
2	/			
3	/			
4	/			

Check Sounding:	yes / no	Proposed ½ AB (m):	
Location:		Cutting / slashing:	
Remarks:			

LOCATION MAP

N