The Processes Involved in The Acquisition, Processing and Interpretation of Geophysical Data for Borehole Drilling in North Central Basement Terrains of Nigeria with Case Study in (F.C.T.)

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Abstract- This paper presents elaborates on the methods involved in the acquisition, processing and interpretation of borehole geophysical data in Abuja (F. C. T) and its environs. The F.C.T is almost predominantly underlain by high grade metamorphism and igneous rocks of Precambrian age. The aim of the work is to delineate the subsurface geoelecteric sequence and its parameters, Identify the weathered or aquifer unit and determining the extent and Determining the depth of the borehole and the lithological sequence. Based on the field mapping and acquisition of resistivity data using the Omega resistivity meter otherwise known as the Terrameter, processing of the resistivity data using software such as IP2win or Interpex and interpretation, the depth to the fractured aquifer was determined to be between 50 m to 70 m. The geophysical survey was conducted using the electrical resistivity method and the schlumberger array was employed for VES to a total AB/2 separation of 100 m and MN/2 of 5 m. Recorded resistivity values are converted to apparent resistivity using standard conversion factors. The apparent resistivity values in this area range between 50 and 1000. The apparent resistivity curve types corresponding to the area are the K and H curve types which may suggest deep or shallow aquifers respectively.

Indexed Terms- Aquiclude 3, Aquifuge 3, Current electrode 5, Hydrological cycle 2, Potential electrodes 5, Terrameter 1.

I. INTRODUCTION

The main focus of this work is the detailed description of the methods involved in the acquisition, processing and interpretation of borehole geophysical data in Abuja (F. C. T) and its environs which covers an area of approximately 1769 km^2. The study area consists of metamorphic and igneous rocks. Equipment used in the field includes; Omega resistivity meter, Cable wires, Electrodes, Pegs, GPS, Tape with software applications such as Interpex and IP2win.

- HYDROLOGY AND HYDROLOGIC CYCLE - Hydrology is the science, which deals with the occurrence, distribution and disposal of water on the planet earth; it is the science which deals with the various phases of the hydrologic cycle. Hydrologic cycle is the water transfer cycle, which occurs continuously in nature; the three important phases of the hydrologic cycle are: (*a*) Evaporation and evapotranspiration (*b*) precipitation and (*c*) runoff. The globe has One-third land and Two-thirds Ocean. Evaporation from the surfaces of ponds, lakes, reservoirs, ocean surfaces and transpiration from surface vegetation *i.e.,* from plant leaves of cropped land and forests etc. take place. These vapours rise to the sky and are condensed at higher altitudes by condensation nuclei and form clouds, resulting in droplet growth. The clouds melt and sometimes burst resulting in precipitation of different forms like rain, snow, hail, sleet, mist, dew and frost. A part of this precipitation flows over the land called runoff and the rest filters into the soil which builds up the ground water table. The surface runoff joins the streams and the water is stored in reservoirs. A portion of surface runoff and ground water flows back to ocean, again evaporation starts from the surfaces of lakes, reservoirs and ocean, and the cycle repeats.

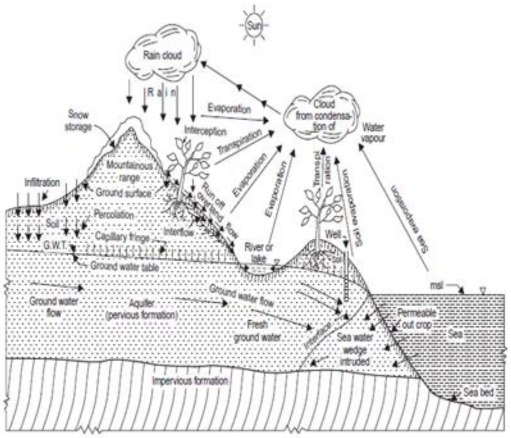

Figure 1: Hydrological cycle (Raghunath, 2006)

Ground water is widely distributed under the ground and is a replenishable resource unlike other resources of the earth. The problems in Ground Water Investigation are the zones of occurrence and recharge. The modern trends are to create more opportunity for recharge of ground water from natural sources like rain, percolation dams, etc. The ground water is free from pollution and the ground water storage is free from atomic attacks. Ground water can be developed at a small capital cost in least possible time, and intensive irrigation can be practiced with double and triple cropping including commercial crops; ground water can be used for supplemental irrigation during periods of deficient surface supply, for the year-round irrigation practice.

Water bearing geologic formation or stratum capable of transmitting water through its pores at a rate sufficient for economic extraction by wells is called 'Aquifer'. A geologic formation, which can absorb water but cannot transmit significant amounts, is called an 'Aquiclude'. A geologic formation with no interconnected pores and hence can neither absorb nor transmit water is called an 'Aquifuge'. A geologic formation of rather impervious nature, which transmits water at a slow rate compared to an aquifer (insufficient for pumping from wells), is called an 'Aquitard'. (Raghunath, 1985).

GEOLOGY OF THE CASE STUDY AREA- The study area lies within the southern part of the "roughly rounded" north-Central basement complex of Nigeria. The F.C.T is almost predominantly underlain by high grade metamorphism and igneous rocks of Precambrian age generally trending NNE-SSW with rocks consisting of gneiss, migmatites, granites and schist belts.

LOCATION AND ACCESSIBILITY - The study area lies between latitudes 8°25'- 9°20'N and longitudes 6°45'- 7°39'E. It is geographically located in the center of the country with a landmass of approximately 7,315km².

RELIEF- The lowest elevation in the Federal Capital Territory (Abuja) is found in the extreme southwest where the flood plain of the river Guraja is at an elevation of about 10 m above sea level from there, the land rises irregularly eastward, northwards and north westwards. The highest part of the territory is in the northeast where there are many peaks over 760m above sea level. Hills occurs either as clusters or form long ranges. The most prominent of these include the Gawa range in the northeast, the Guarfata range southwest of Suleja; the Bwari-Aso range in the northeast, the Idon-Kasa range north-west of Kuje and the Wuna range north of Gwagwalada. Elsewhere in the territory, there are many rather roundish isolated hills usually called ISELBERGS in between the major hills are extensive plains, the most important of which are the Gwagwa plains and the Rubochi plains. Indeed about 50% of the Federal Capital Territory (Abuja) consists of plains. Out of these plains, the Gwagwa plain was selected for the building of the Federal Capital Territory City (F.C.T).

II. GEOPHYSICAL SURVEY

Geophysical survey involves a relatively rapid and cost-effective means of deriving aerially, information of the subsurface geology. Many geophysical methods find application in locating subsurface water and they include:

I. Electrical resistivity method
II. Seismic refraction
III. Electromagnetic (EM)

Electrical resistivity method is used in the delineation of electrical properties of the ground, where artificially generated currents are introduced into the ground through two current electrodes and the resulting potential differences are measured across two other potential electrodes which is displayed by the resistivity meter as resistance. A deviation from the pattern of potential differences expected from a homogeneous ground provides information on the form and properties of the sub-surface material.

Two main types of procedures are employed in Electrical resistivity survey

I. Vertical Electrical Sounding
II. Horizontal Profiling

In this technique, vertical variations in the ground apparent resistivity are measured with respect to a fixed array. The survey is carried out by gradually expanding or increasing the electrode spacing from a fixed centre. Information like the resistivity value, thickness, depth of the study area are revealed and based on these Geo-electric parameters recommendations is made.

- PRINCIPLES OF ELECTRICAL RESISTIVITY METHOD - The electrical resistivity method involves the passage of electricity current using D.C into the subsurface, through two electrodes (the current electrodes). The potential difference measured across another pair of electrodes (the potential electrodes) is displayed as resistance by the omega resistivity meter, which may or may not be within the current electrodes depending on the electrode array in use.

- ARRAY METHOD – The Schlumberger array method was used in the geophysical borehole survey.

- SCHLUMBERGER CONFIGURATION - In this array, all the four electrodes are placed along a common line as with the Werner array but they are not spaced equally where the distance between the inner two, which are used to measure voltage is kept less than one fifth the distance between the other electrodes are used to apply current to ground. In making depth sounding, the other electrodes are moved in steps, but the inner electrodes are not moved unless the voltage observed between them become too small to measure (http://appliedgeophysics.berkeley.edu/dc/index.html).

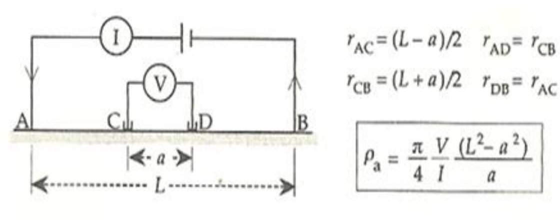

Figure 2: Typical schlumberger configuration, Audson, 2016.

Note that electric resistivity is determined as a function of the electrode separation. Continually increasing the electrode spacing alters the resistivity from successively deeper layers. VES is used in hydrogeology for determining the thickness of overburden earth layers in the basement terrain. The basic concept in VES is that as the distance between the current and potential electrodes is increased, the current passing across the current electrodes carries a current fraction that returned to the surface from increasingly deeper sections.

Where:
ρa = apparent resistivity, AB = Current electrode
V/I = resistance, MN = potential difference electrodes,
a = Electrode spacing, X = Point of investigation

- FIELD WORK – After mobilization to the site, the geo-physicist must do a quick reconnaissance to get acquainted with the terrain, mark outcrops and understand the topography of the site. The survey equipment is connected and a transverse is then chosen along which the survey will be carried out. A geophysical survey should be carried out by two or more individuals for better efficiency and proper time management.

Figure 3: Picture of an Omega resistivity meter, electric cables and electrodes.

INSTRUMENTS - *The omega resistivity meter/ terrameter:* This is an instrument used in carrying out electrical resistivity survey of any area in the sedimentary and basement complex. It is used to read the resistivity of the rock or any viable material in the subsurface when a direct current is sent into the earth. The OMEGA RESISTIVITY MERTER was used during my training.

Cable wires: These are used for connecting the electrodes to the terrameter. Usually four cable wires are used, two for current and the other two for potential difference. The current cables are blue in colour while the potential cables are red in colour. They are reeled around a wheel of steel and fitted with crocodile clips for easy connection.

Electrodes: These are rods which are about 45cm to 55cm long made of metal. They are four, two for current and the other two for the potential. They have a very sharp pointed end for easy penetration with the other end flat. The electrodes are placed strategically during geophysical survey depending on the array used.

Tape rule: It consists of plastic fabric with linear measurements markings, which is used for measurement, each type rule is about 50cm long.

Hammer: A tool consisting of a solid, heavy metal which is used in driving electrodes into ground.

Figure 4: Picture of an Omega resistivity meter showing its interface.

RELEVANCE OF ELECTRICAL RESISTIVITY METHOD IN GROUNDWATER EXPLORATION - Location of subsurface water through mapping of the water table, indirect location of a potential aquifer such as weathered zone, porous and permeable sandstones. Mapping of geological structures that are favourable to groundwater accumulation, such as fractures.

LIMITATIONS, FIELD OPERATIONAL PROBLEMS ENCOUNTERED DURING SURVEY.

- Instruments malfunction
- Cable leakage
- Buried pipes and buried power lines
- Inconsistency in readings at particular points at different time or seasons.

DATA INTERPRETATION TECHNIQUE – A graph data sheet is used to fill in resistivity values and also plot graphs of apparent resistivity values against current electrode spacing values to determine the thickness of the overburden, depth of the aquifer, lithology variations and fresh/weathered basement. We use the Interpex 1-D Sounding Inversion Application which for a long period of time has proven effective, accurate and suitable for borehole siting to plot resistivity values and mark lithology changes with depth to determine if the borehole will be economical.

CASE STUDY: APPLICATION OF ELECTRICAL RESISTIVITY METHOD TO INVESTIGATE GEOLOGIC STRUCTURES FAVOURABLE FOR BOREHOLE SITING AT ASO HILLS, KARU LOCAL GOVERNMENT AREA, F C T.

General information -
Located on a flat land terrain with no visible outcrop, however the area is underlain by the basement complex rocks where water prospects depend on fractures and weathered zone.

Field work: The field work comprised of a geological reconnaissance of the site for the survey followed by the Geophysical survey.

Geophysical survey - A total of 2 (VES) points were investigated using the Schlumberger electrode configuration along a traverse of 0/180° for both VES 1 and VES 2 with maximum current electrode spacing of 100 meters and maximum potential spacing of 5 meters. The apparent resistivity values of the underlying layers at different depths were acquired during the sounding exercise. The delineation of a good, clean and confined aquifer for industrial use is of great importance for quality water supply to neighbouring homes in the area.

Materials used:
The equipment used in carrying out the survey includes:

- Omega Resistivity Meter.
- Electrodes.
- Hammer.
- Measuring Tape.
- Current and potential cables.

INTERPRETATION METHOD
The data obtained from the conducted geophysical electric sounding was plotted on a VES graph data sheet. The graph was then interpreted by curve margin based on the resistivity.

VES 1

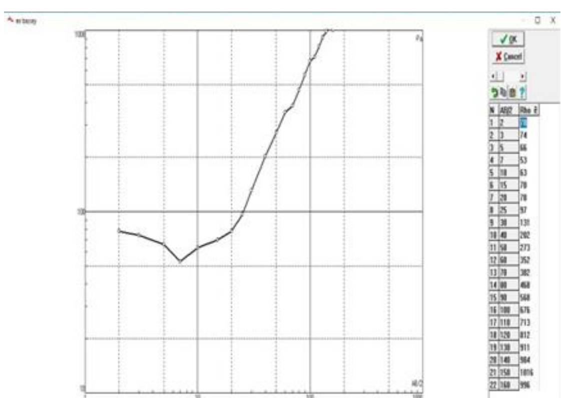

Figure 5: IP2win sounding inversion software for VES 1 showing the H type curve.

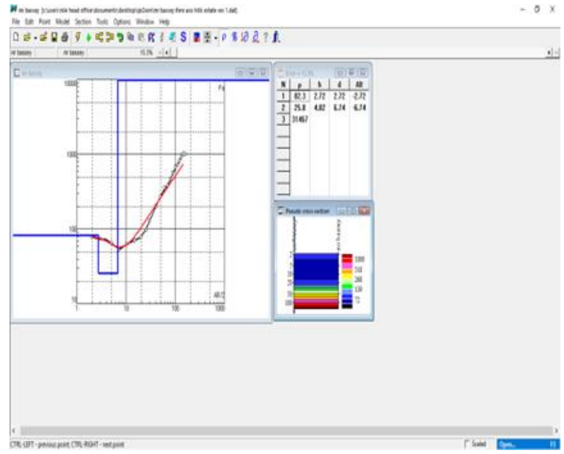

Figure 6: Pseudo cross section of the subsurface showing as colour codes for VES 1

VES 2

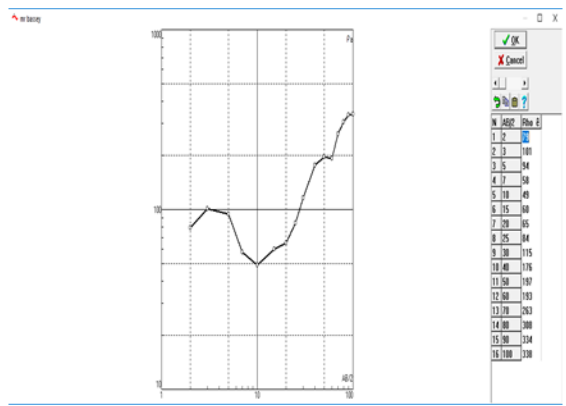

Figure 7: IP2win sounding inversion software for VES 2 showing the H type curve.

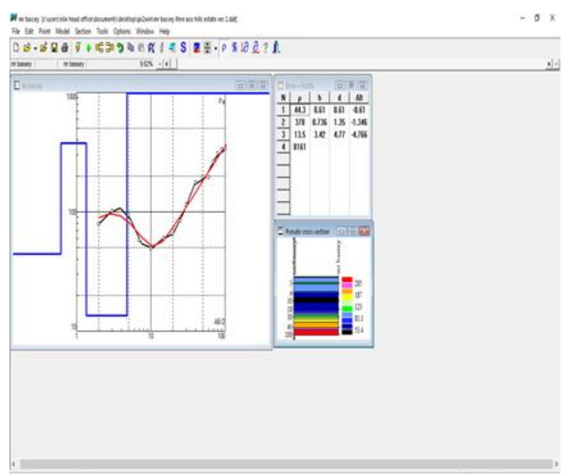

Figure 8: Pseudo cross section of the subsurface showing as colour codes for VES 2

RECOMMENDATION

- Overburden is 15 - 20 meters
- Total drill depth is 70 ± 10 meters
- Yield of borehole is expected to be low to moderate according to the IP2win software
- Therefore, VES 1 is recommended for drilling.

Note, the IP2win software provides the thickness of the lithologies that are infused, therefore calculating the yield of the borehole since we know that the lithology where the aquifer is found is the weathered and fractured basement.

CHALLENGES ENCOUNTERED -

- Mechanical problems from the Terrameter.
- As seen from the failed borehole on this plot, it is clear that this area is difficult in terms of getting water. The main limitation of any geophysical investigation is that it doesn't show the object of interest (such as water, hydrocarbon or any mineral deposit) directly. Thus, there is no geophysical investigation technique that completely shows the occurrence of the target resource.

CONCLUSION

From qualitative and quantitative analysis, four geo-electric layers are identified. The layers identified include (but are not restricted to) the first layer which indicates the top soil, the second layer which indicates the weathered basement (comprising of clay/mica), the third layer represent the highly weathered/ fractured basement (water bearing section) and finally the fourth layer represents the fresh basement.

ACKNOWLEDGEMENT

I am greatly indebted to Mr. William Kamale and his family for his intervention by offering me a placement and feeding in his company, when all hope was lost. I am also grateful to all my lecturers in the Department of Geology for preparing me academically for the challenges I encountered during the duration of the training.

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