GEOELECTRIC INVESTIGATION OF THE SUBSURFACE FOR THE DETERMINATION OF SUITABLE SITE FOR SINKING OF BOREHOLE AT MODOJI, KATSINA LOCAL GOVERNMENT KATSINA STATE.

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Abstract: Geophysical investigation was carried out with the aim of determining favorable site for erecting a yield borehole which will serve as a source of water supply in Modoji, Katsina Local Government of Katsina State, Nigeria. In order to study the groundwater potential in the area. Vertical Electrical Sounding (VES) using Schlumberger array was carried out at twelve (12) stations. The field data obtained has been analyzed using Computer Software *(ipi2win*) which gives an automatic interpretation of apparent resistivity. The VES result revealed the heterogeneous nature of the subsurface geologic sequence. The geologic sequence beneath the study area is composed of topsoil (sandy-clay and sandy-lateritic), weathered basement, fracture basement layer and fresh basement. However, fracture basement and fresh basement do not show lateral variation in the basement resistivity. The result aim is to determine a favorable site for erecting a yield borehole which will serve as a source of water supply in some parts of Modoji Katsina local government. The result of the investigation revealed the various resistivity sound curves of the VES points which clearly identify the depth of the aquifer layer of this research to be from 10.8m to 57.8m. The high yielding areas are based on the high thickness of the aquiferous layer.

Keywords: Vertical electrical sounding (VES), Groundwater, Depth, Fracture, Aquifer and Borehole

Introduction

In the discipline of numerical analysis, there are two types of Groundwater is the water that lies beneath the ground surface filling the pore spaces between grains in the bodies of sedimentary rocks (Okwueze, 1978). The availability of quality water resources has always been the primary concern of every community. Despite the abundance of rainfall, the problem of obtaining an adequate quality water is generally becoming a problem due to the increase in population and industrialization. As a result of this, surface water such as streams, hand dug wells and rivers cannot be dependable throughout the year. Hence, the need to look for other alternatives to supply water. The world is made to depend on the most reliable source of fresh water which lies beneath the earth surface known as groundwater. In consideration of the availability of water, one must first address three question: where it comes from? Where does it go to? And where to be found? (Foster 1991).

As stated earlier, groundwater is gotten from rain in West Africa that percolates into the ground. If the rainfall is not heavy, the water quickly evaporates and during heavier downfall, the volume of water infiltrating the surface exceeds that which can be absorbed or held in the soil above the groundwater water table. This excess may then flow laterally to a stream or ponds or may continue to infiltrate downwards to the groundwater table (Foster, 1991). Water bearing formations capable of yielding water in sufficient quality for economic usefulness are known as aquifers. Almost all formations will produce water, but those not capable of meeting even modest supply demands are called aquitards.

Potable water is one of the major resources that a human being of any nation can benefit from (Alile *et al*, 2008). This is because water is a free gift of nature to mankind. This wonderful resource has surpassed so many generations because of its value to human life. Water is very important in all human endeavors such as home usage and also in manufacturing, transportation, construction and most importantly agriculture. Because of the importance of water and the continuous demand for a sufficient and steady supply of water to meet up with the demand of the increasing population and industrialization. People have shifted the search of water from surface to groundwater exploration leading to the development of many geophysical techniques for the detection and mapping of groundwater (Shemang, 1990).

Geophysics is not only concern about the study of the earth and its surrounding but also deals with the various ways of exploiting earth's resources. Since the majority of mineral deposits are beneath the earth surface, their detection depends on those characteristics which differentiate them from the surrounding media (Fristchknecht and Keller, 1997). Parameters such as conductivity, porosity, permeability and transmissibility characterized groundwater and distinguished it from the surrounding media. In this research, Vertical Electrical Sounding (VES) using Schlumberger array has been adopted because of its high penetrating ability in locating groundwater aquifer.

Location of the Study Area

The location of the study area falls between Latitude 13° 02′ 54.0″**N** and 12°58′51.3″**N** and Longitude 007°37′01.6″**E** and 007°36′06.2″**E** Modoji, Katsina State, Nigeria.

Geology and Hydrogeology

The formation consists of hard underrate ferruginous sandstone, grits, arkoses, breccia and basal conglomerate, lying unconformable on the basement complex of Nigeria.

The upper part of the terrain is underlain by soft friable ferruginous Sandstone, arkoses, breccia and basal conglomerate of Ilo/Gundumi formation.

There are two auriferous layers in this area, the soft friable and hard underrated ferruginous sandstone in the overburden of the basement complex.

In the basement rocks, groundwater occurs either in the weathered mantle or in joints and fractured systems in the weathered\fresh rocks. The presence of ground water in any given area is therefore dependent upon whether sufficient thickness and lateral extent of weathered materials are present with high hydraulic characteristics to provide the reservoir or joint and fractures are available in the decomposed rocks.

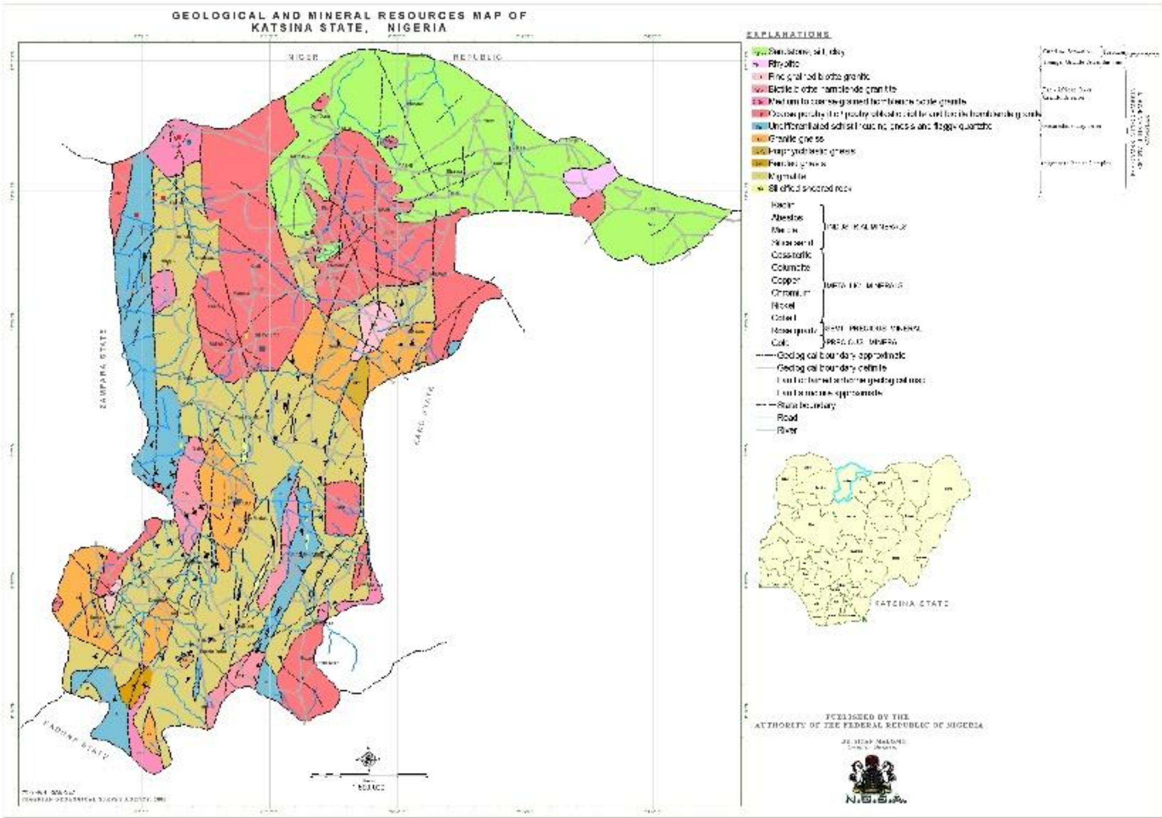


Figure 1: Geological map of Katsina state with the location of the study area.

Principle of the Resistivity Method

In electrical resistivity method anomalies of the subsurface conduction depend on electrical conductivity contrast between the conductor and the host rock. Details on conductivity (electrical property) of earth material can be found in Telford *et al* (1976), Keller and Frischnecht (1977). There are many methods of observing these anomalies in electrical surveying some of this material make use of naturally occurring field within the earth while others require the introduction of artificially generated source into the ground. The resistivity method uses artificial source field. Artificially generated electric current are driven into the ground. Any variation in the subsurface resistivity (conductivity) alters the distribution of the electric potential. The resulting potential differences are measured at the surface. Any variation observed from the pattern of potential differences expected from uniform earth are deviation from the uniform earth, these deviations represent the geological target of resistivity exploration.

Generally, four electrode arrays are used at the surface, one pair for introducing current into the earth and the potential difference establish in the earth by the current is measured in the vicinity of current flow with the second pair.

A great number of electrode arrangements have been used for resistivity exploration. The most used electrode arrangement is warner and Schlumberger, three-point speed, lee-partition spread and dipole-dipole spread method (Telford *et al* 1976). Any of these electrode arrangements may be used to study lateral variation of resistivity or variation in resistivity with depth (keller and Frischnecht 1977). In studying lateral variation such as those associated with dyke-like structures of faults a fixed separation is maintained between the various electrodes and the array is moved as a whole along the transverse line this is called a horizontal profiling or trenching. In studying the variation of resistivity with depth as in case of layered medium, the center of electrodes spread is often kept fixed while the electrode spacing is changed. This is called the vertical electrical sounding (VES) the electrical resistivity method employed in this work is the VES a brief description of the theoretical basis of the method is given below

Theory of D.C resistivity method.

The simplest approach to theoretical study of the earth resistivity method is to consider first the case of completely homogenous isotropic earth. The equation which give a potential due to a single point source of current at surface is developed according to Keller and Frischnecht (1977) from two basic considerations.

1-Ohms law

$E = \rho j$ ………………………………………………………….. (1)

Where

E= potential gradient

J= current density

P= resistivity of the medium and

2- Divergence condition

$\nabla \cdot j = 0$…………………………………………………. (2)

This states that all current going into a chunk material must leave the other side unless there is a source or sink current.

Within the chunk, the divergence of the current density vector must be zero at every place but at the current source.

Thus the Laplace equation can thus be obtained from these two equations

$j = \sigma E$ ……………………………………………..…..(3)

But $\sigma = {}^{1}/_{\rho}$

Hence $j = {}^{1}/_{\rho} E$ ……………………………………………… (4)

Where j=current density.

σ=conductivity.

ρ =resistivity.

E=electric field.

The component of electric field in any direction is the negative of the value of change of the potential in that direction

$E = -\nabla v$ ………………………………………………… (5)

Put equation (5) into (4)

$j = -\sigma \nabla v$ …………………………………..……….. (6)

$j = -{}^{1}/_{\rho}\, \nabla v$ ………………………………………………..(7)

The divergence of current density

$\nabla \cdot j = 0$ …………………………………………………………… (8)

Put equation (6) into (8)

$$\nabla . j = \nabla(\sigma \nabla v)$$

$(\nabla v)\nabla\sigma + \sigma\nabla^2 v = 0$ …………………………………... (9)

Since σ is constant the first term varnishes

$\sigma\nabla^2 v = {}^{1}/_{\rho}\, \nabla^2 v = 0$ ………………………………… (10)

In spherical polar coordinate, Laplace equation can be expressed assin$^2\,\theta$

$\nabla^2 V = {}^{1}/_{r^2}\, \frac{\partial}{\partial r}(r^2 \frac{\partial v}{\partial r}) + \frac{1}{r^2 \sin\theta}\frac{\partial}{\partial \theta}(\sin\theta \frac{\partial v}{\partial \theta}) + \frac{1}{r^2 \sin^2\theta}\frac{\partial^2 v}{\partial \varphi^2} = 0$ …………… (11)

Where

θ = zenithal polar coordinate

φ = azimuthal angle

For the single current electrode source placed at the surface, there is complete symmetry of current flow with respect to θ and ϕ direction and the derivative with respect to this direction are zero.thus

$\nabla^2 V = {}^{1}/_{r^2}\, \frac{\partial}{\partial r}(r^2 \frac{\partial v}{\partial r}) = 0$ since $r \neq 0$

$= \frac{\partial}{\partial r}(r^2 \frac{\partial v}{\partial r}) = 0$ …………………………………………………………… (12)

The equation can be integrated directly, thus

$r^2 \frac{\partial v}{\partial r} = C$ …………………………………………………………… (13)

$V = -\frac{C}{r} + D$

Where C and D are constant and r is the distance from the current electrode

V = 0 when $r \to \infty$

Then D = 0

Thus

$V = -\frac{C}{r}$ …………………………………………………… (14)

The current flows azimuthally through a hemisphere surface in the lower medium

$I = 2\pi r^2 j$ ……………………………………… (15a)

$j = -\frac{1}{\rho}\nabla V = -\frac{1}{\rho}\frac{\partial v}{\partial r}$ ………………………… (15b)

Combining 15a and 15b we have

$I = -\frac{2\pi r^2}{\rho}\frac{\partial v}{\partial r}$

$I = -\frac{2\pi}{\rho} r^2 \frac{\partial v}{\partial r}$

But

$r^2 \frac{\partial v}{\partial r} = C$

$I = -\frac{2\pi}{\rho} C$

$C = -\frac{I\rho}{2\pi}$ ……………………………………………… (16)

Put (16) in (14)

$V = \frac{I\rho}{2\pi r}$ …………………………………………………(17)

Equation 17 is the potential at distance r from single current electrode placed at surface. Application of (17) to general four electrodes configuration is shown below.

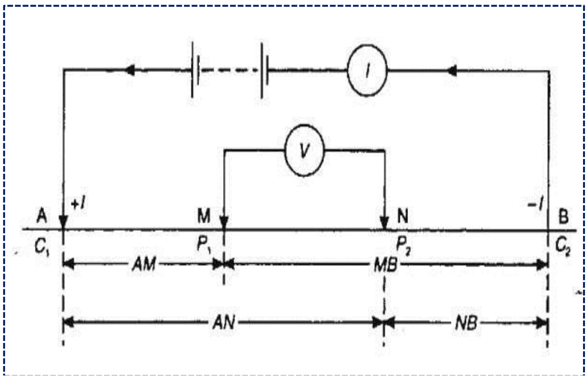


Figure 3; four-electrode configuration for resistivity measurement, with current electrodes (C_1 and C_2) and potential electrodes (P_1 and P_2) (P. Keary and M. Brook, 2002)

From figure 6 above, let r_1 = AM, r_2 = MB, r_3 = AN and r_4 = NB

Hence, the potential P_1 due to current at C_1 is: $v_{AM} = \frac{I\rho}{2\pi r_1}$

And the potential P_2 due to current at C_2 is: $v_{MB} = -\frac{I\rho}{2\pi r_2}$

$V_1 = \frac{I\rho}{2\pi}(\frac{1}{r1} - \frac{1}{r2})$ …………………………………… (18)

Since the current at the two current electrodes are equal and opposite in direction (one current electrode act as source and the other sink)

Where B_1 is distance from P_1 to C_1

B_2 is the distance from C_2 to P_1

Similarly, the potential at p_2 due to C_1 and C_2 is

$V_2 = \frac{I\rho}{2\pi}(\frac{1}{r3} - \frac{1}{r4})$

Where is the distance of C_1 from P_2

The potential difference between P_1 and P_2 is

$$V1 - V2 = \frac{I\rho}{2\pi}((\frac{1}{r1} - \frac{1}{r2}) - (\frac{1}{r3} - \frac{1}{r4})) = \nabla V$$

$$\rho = \frac{2\pi}{((\frac{1}{r1} - \frac{1}{r2}) - (\frac{1}{r3} - \frac{1}{r4}))}\frac{\nabla V}{I}$$

$\rho = K(\frac{\nabla V}{I})$ …………………………………… (19)

Where $k = \frac{2\pi}{((\frac{1}{r1} - \frac{1}{r2}) - (\frac{1}{r3} - \frac{1}{r4}))}$ ……………………… (20)

Equation (16) is an expression for an ideal case of an isotropic homogeneous uniform earth. When the earth is uniform, resistivity calculated with (18) should be constant and independent of electrode spacing.

In real situation the earth is in homogeneous (not uniform). In homogeneous earth, the resistivity will vary with the relative position of the electrodes. Any computed value of resistivity is then known as the apparent resistivity and will be as a function of the homogeneity equation (18) is the basic relation for calculating the apparent resistivity (ρ_a) of any electrode configuration and can be used to define ρ_a as

$\rho_a = K(\frac{\nabla V}{I})$ ……………………………………………… (21)

Where k is the geometric factor in both (18) and (20) and depends on electrode configuration used for field measurement. For this study's objective Schlumberger electrode configuration was used for field measurement. Schlumberger configuration is convenient to use in this field and the potential electrodes are not usually moved or when moved they are moved in a minimum number of times during a given sounding compared to frequent movement of other electrode configuration this configuration is therefore cost effective since it saves time and man power (Aboh, 2011).

Material and Method

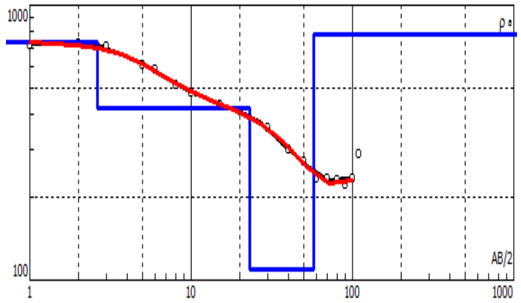
The Terrameter SAS system consist of a basic unit called terrameter SAS 300. The SAS 300 (basic Unit) can be used for self-potential and resistivity surveys. In general, the SAS 300 contains the three units, all houses in a single casing, the transmitter, the receiver and microprocessor. The electrically isolated transmitters send out well defined and regulated signal current. The receiver discriminate noise and measures voltages correlated with the transmitted signal current (resistivity survey mode) and also measures uncorrelated D.C potential with same discrimination and noise rejection (voltage measuring mode). The microprocessor monitors and controls operation and calculated results in depth.

In geophysical survey, the SAS 300 permits natural or induced signal to be measured at extremely low levels, with excellent penetration and low power, consumption. Moreover, it can also be used in a wide variety of application where effective signal/noise discrimination is needed. It can also be used to determine the ground resistance of grounding arrangement at the power plants and along power levels.

The Schlumberger method is used in this research in the Schlumberger array; the current electrodes are spaced much further apart than the potential electrode. Schlumberger array data were acquired using SAS 300 Terrameter along with other accessories-cables.

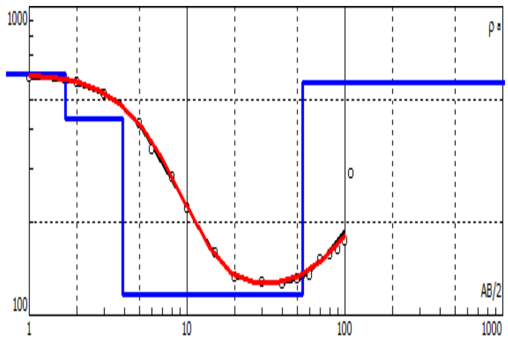
Result and Discussion

The Schlumberger array method of electrical resistivity was used to investigate the ground water potential of Modoji, Katsina Local Government of Katsina State. Twelve Vertical electrical sounding (VES) were carried out at different location within the study area. The VES point were interpreted using the IPI2WIN as follows.



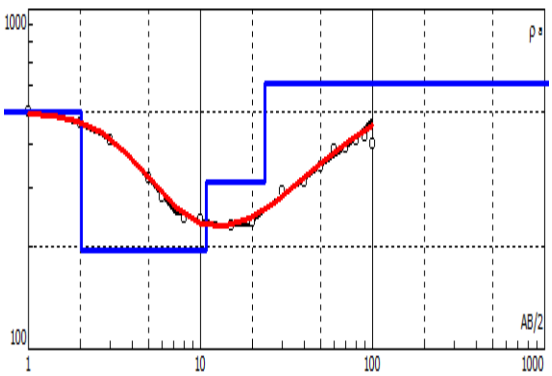
N	ρ	h	d	Alt
1	605	1.69	1.69	-1.695
2	436	2.22	3.91	-3.91
3	117	50.2	54.1	-54.14
4	568			

FIGURE 2: Digitized model of interpreted VES 1



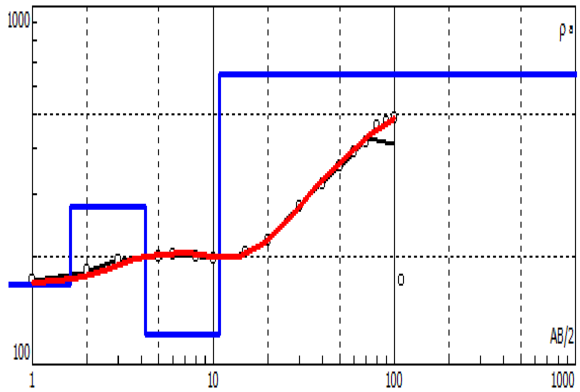
N	ρ	h	d	Alt
1	735	2.61	2.61	-2.609
2	422	20.5	23.1	-23.12
3	109	34.7	57.8	-57.8
4	783			

FIGURE 2: Digitized model of interpreted VES 2



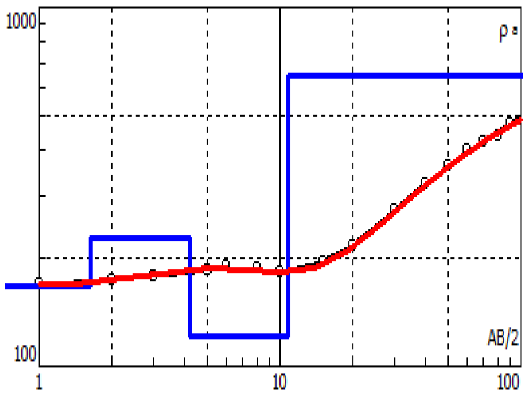
N	ρ	h	d	Alt
1	499	2.03	2.03	-2.029
2	195	8.77	10.8	-10.8
3	310	12.9	23.7	-23.68
4	606			

FIGURE 4: Digitized model of interpreted VES 3



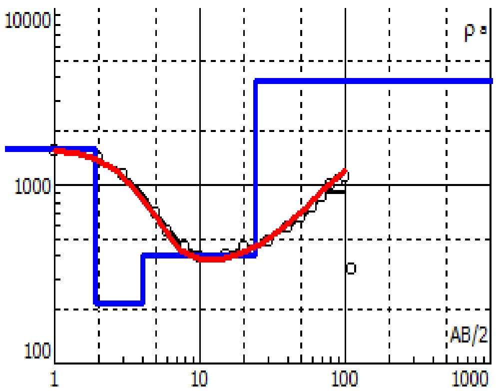
N	ρ	h	d	Alt
1	167	1.63	1.63	-1.63
2	276	2.59	4.22	-4.224
3	121	6.58	10.8	-10.8
4	646			

FIGURE 5: Digitized model of interpreted VES 4



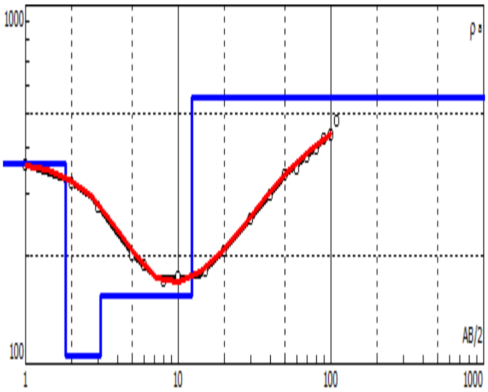
N	ρ	h	d	Alt
1	167	1.63	1.63	-1.63
2	228	2.59	4.22	-4.224
3	121	6.58	10.8	-10.8
4	646			

FIGURE 6: Digitized model of interpreted VES 5



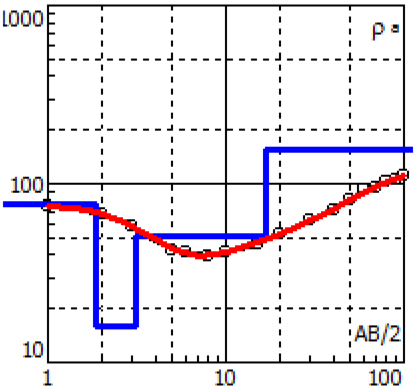
N	ρ	h	d	Alt
1	1593	1.91	1.91	-1.909
2	216	2.13	4.04	-4.043
3	404	20.1	24.1	-24.1
4	3840			

FIGURE 7: Digitized model of interpreted VES 6



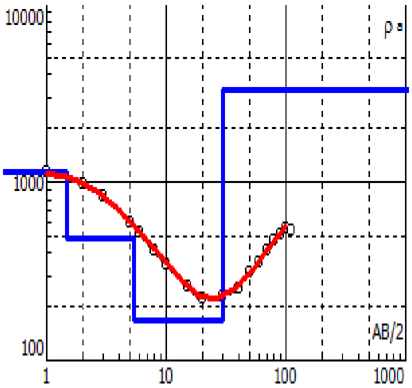
N	ρ	h	d	Alt
1	362	1.84	1.84	-1.84
2	105	1.26	3.1	-3.1
3	155	9.19	12.3	-12.29
4	553			

FIGURE 8: Digitized model of interpreted VES 7



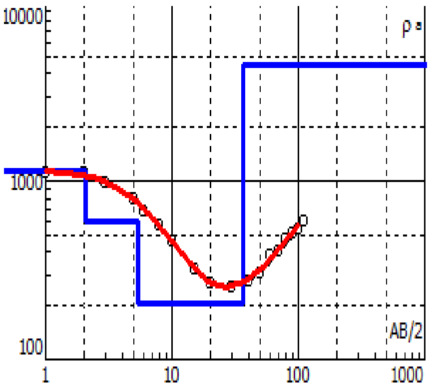
N	ρ	h	d	Alt
1	77.2	1.84	1.84	-1.84
2	15.9	1.26	3.1	-3.1
3	51	13.9	17	-16.99
4	155			

FIGURE 9: Digitized model of interpreted VES 8



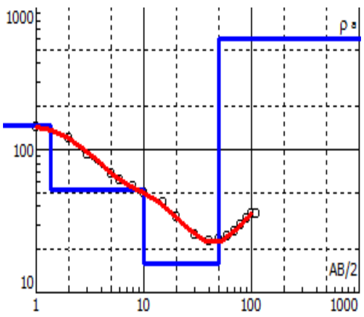
N	ρ	h	d	Alt
1	1138	1.47	1.47	-1.474
2	485	3.9	5.38	-5.376
3	168	24	29.4	-29.38
4	3287			

FIGURE 10: Digitized model of interpreted VES 9



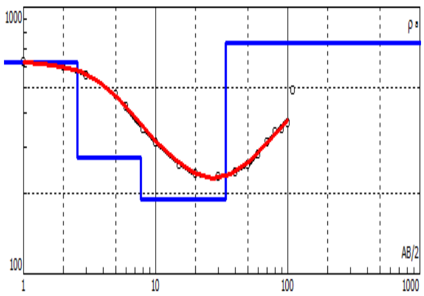
N	ρ	h	d	Alt
1	1138	2.06	2.06	-2.064
2	596	3.31	5.38	-5.376
3	206	31.1	36.5	-36.46
4	4484			

FIGURE 11: Digitized model of interpreted VES 10



N	ρ	h	d	Alt
1	621	2.56	2.56	-2.558
2	273	5.17	7.73	-7.732
3	190	26.2	33.9	-33.94
4	734			

FIGURE 12: Digitized model of interpreted VES 11



N	ρ	h	d	Alt
1	147	1.35	1.35	-1.352
2	52.4	8.65	10	-10
3	15.9	39.7	49.7	-49.73
4	596			

FIGURE 13: Digitized model of interpreted VES 12

From characteristics of resistivity of weathered and fracture basement layers of the VES points, this shows that the weathered and the fractured basement are believed to be the major component of the aquifer in this study area where fresh groundwater is expected to be in abundance. The fracture basement could contribute to the aquifer system where fracture density is high and its thickness is considerably large (Zume, 1999). In determining areas with suitable and exploitable ground water with the resistivity of the subsurface, a low resistivity indicates a highly conductive formation and usually groundwater zones are very conductive (Ajayi and Hassan, 1988). In this research the layer of interest is the weathered and fracture basement which are layers that possibly contain the groundwater as indicated by its high conductivity value. The VES points identify the subsurface layers to the maximum of four layers, which are the top soil, weathered basement, fractured basement and fresh basement. The resistivity sound curves of the VES points clearly identify the depth of the aquifer layer of this research to be from 10.8m to 57.8m. Therefore, from the model interpretation of the VES points it is clearly seen that the depth to the basement rock, the aquiferous layer and areas for erecting boreholes are clearly identified.

Conclusion

The vertical electrical sounding was used to investigate the ground water potential of the study area. From the VES model interpretation of the study area, all the VES point have tendency of producing yielding borehole for domestic and commercial uses of the people around the area. But VES1, VES2, VES7, VES9, VES10, VES11 and VES12 are the most suitable VES point for drilling high yielding borehole.

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