



Hydrogeophysical Investigation For Groundwater Potential In Kalgo Area, North Western Nigeria, Using Electrical Resistivity Method

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ABSTRACT

Hydrogeophysical Investigation was carried out in some selected parts of Kalgo area of North Western Nigeria, using Electrical resistivity method. Eight Vertical Electrical Soundings (VES) were carried out with Schlumberger configuration. The instrument used is ABEM SAS 300C Terrameter. The field data obtained were analyzed and interpreted using IPI2win and Surfer 12 which gave an automatic interpretation of the apparent resistivity data. Sounding curve obtained from the study area showed three geoelectrical layers which are the brown clay/ironstone (5 Ω m to 1500 Ω m), coarse sand (2400 Ω m to 10⁸ Ω m) and sandstone (9 Ω m to 968 Ω m). The results showed that the saturated groundwater bearing units (aquifer) lie within the intermediate (sandstone) geoelectric layers. However, the groundwater potential in the study area was classified into high and low groundwater zones. High groundwater potential zones were found at VES 02 and 03. The layer forms the aquifer due to its low resistivity 304 Ω m and thickness value of 47.7m at depth of 49.7m. These revealed the occurrence of groundwater in the environment due to largely occurrence of porosity and permeability resulting from sandstone of the rocks.

Key words: Geoelectric, Groundwater, Resistivity, Vertical, Electrical, Sounding.

INTRODUCTION

Water is considered as an important necessity for the sustenance life. This is why nature has bestowed the world with much of it. About two third of the total land space in the world is covered by it (Shiklomanov, 1993). Groundwater is another source of water supply but requires a lot of efforts and investment to harness and extract. Yet, less than 3 percent of fresh water available at any given moment on our planet earth occurs in streams and lakes, while the remaining percent is locked up in underground reservoir (Jayavel *et al.*, 2012). However, the availability of good quality water for drinking has been characterized with problem ranging from pollution to inadequate information to exploit it for use (Ishaku *et al.*, 2014). Groundwater exploration is a common practice in everywhere for fulfilling our domestic, agricultural and industrial requirements. It has inherent advantage over surface water as surface water, streams as well as lakes and tanks have gone dry in most of the seasons (Oseji, 2010). The advantage leads to groundwater depletion and put more stress on this precious natural resource (Lashkaripour *et al.*, 2005). The stress and demand for groundwater has been steadily increasing and making it necessary to intensify the exploration for more water resources (Issah *et al.*, 2018).

To identify groundwater resources, the electrical resistivity technique is widely used and it helps to understand the hydrological conditions (Anudu *et al.*, 2014). However, success of the method increases with prior background knowledge of hydrological parameters and electrical properties of the formations along with the geomorphological conditions of the area (Ruth, 2014). Besides, for identifying groundwater potential zones, it is necessary to adopt a systematic hydrologic and hydrogeomorphological investigation which provides information in planning the exploration and framing management strategies (Ishaku *et al.*, 2014).

In this study, the present attempt made with electrical resistivity method in view to locate suitable area of groundwater potential and also to evaluate the groundwater potential of the survey area and recommend optimal depth to drill for water at the chosen location.

In Electrical Resistivity surveying our goal is to measure the potential difference between two points (Fig. 1). Figure 1 illustrates two potential electrodes, P₁ and P₂ that are located on the surface with the current electrodes C₁ and C₂ (Augie *et al.*, 2019).

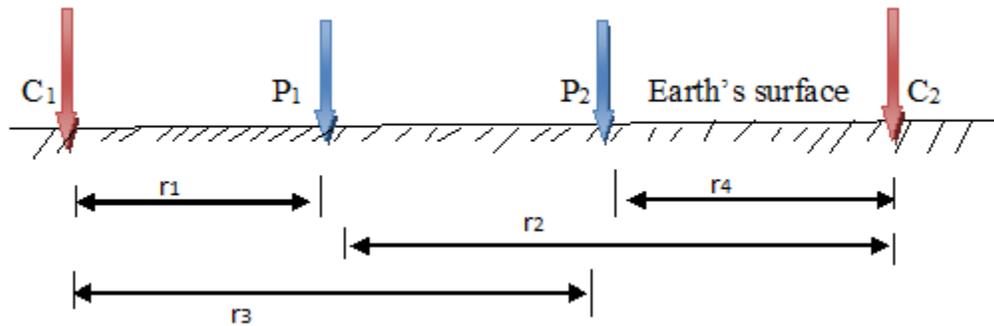


Figure 1: Diagram used to determine potential difference two points

Therefore, the potential difference ΔV equals

$$\Delta V = V_{P1} - V_{P2} \dots \dots \dots (1.1)$$

$$\Delta V = \left(\frac{I\rho}{2\pi r_1} - \frac{I\rho}{2\pi r_2} \right) - \left(\frac{I\rho}{2\pi r_3} - \frac{I\rho}{2\pi r_4} \right) \dots \dots \dots (1.2)$$

$$\Delta V = \frac{I\rho}{2\pi} \left(\frac{1}{r_1} - \frac{1}{r_2} - \frac{1}{r_3} + \frac{1}{r_4} \right) \dots \dots \dots (1.3)$$

In the resistivity method current is entered into the ground, potential difference is measured, and resistivity is determined. For ρ , equation 1.3 becomes.

$$\rho = \frac{2\pi\Delta V}{I} \left(\frac{1}{r_1} - \frac{1}{r_2} - \frac{1}{r_3} + \frac{1}{r_4} \right) \dots \dots \dots (1.4)$$

Resistivity ρ is thus given as

$$\rho = \frac{2\pi\Delta V}{I} \cdot G = RG \dots \dots \dots (1.5)$$

Where R is the measured resistance and G is the Geometric Constant which is a function of the electrode configuration employed during the survey.

Considering Schlumberger configuration which have been adopted in this study (Figure 2). All the four electrodes are

arranged collinearly and are symmetrically placed with respect to the centre. It is required that the distance between the current electrodes, A and B must never exceed 20 times of the spacing of the potential electrodes, M and N.

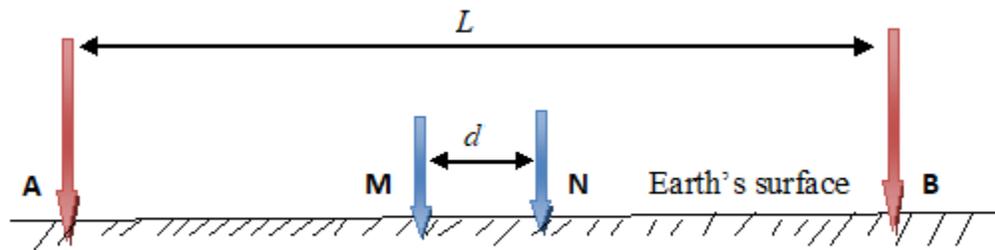


Figure 2: Electrode layout of Schlumberger configuration

The potential electrodes remain fixed while the current-electrodes spacing is expanded symmetrically about the Centre of the spread. When the ratio of the distance between the current electrodes to that between the potential electrodes becomes too large, the potential electrodes must also be displaced outwards otherwise the potential difference

becomes too small to be measured with sufficient accuracy. At this point, a new value for potential-electrode spacing, d is used, typically 2 to 4 times larger than the preceding value and the survey continues.

Comparing Figures 1. and 2;

$$r_1 = r_{AM} = \frac{L-d}{2}, r_2 = r_{MB} = \frac{L+d}{2}, r_3 = r_{AN} = \frac{L+d}{2} \text{ and } r_4 = r_{NB} = \frac{L-d}{2} \dots (1.6)$$

Equation for resistivity (equ. 1.4) becomes

$$\rho = \frac{2\pi\Delta V}{I \left\{ \left(\frac{1}{\frac{L-d}{2}} + \frac{1}{\frac{L+d}{2}} \right) - \left(\frac{1}{\frac{L+d}{2}} + \frac{1}{\frac{L-d}{2}} \right) \right\}} \dots (1.7)$$

$$\rho = 2\pi \frac{\Delta V}{I} \left\{ \left(\frac{2}{L-d} - \frac{2}{L+d} \right) - \left(\frac{2}{L+d} - \frac{2}{L-d} \right) \right\}^{-1} \dots (1.8)$$

The apparent resistivity ρ_a measured becomes:

$$\rho_a = \pi \left(\frac{L^2 - d^2}{4d} \right) \cdot \frac{\Delta V}{I} = G_s \cdot R \dots (1.9)$$

Where R and G_s are the measured resistance in Ohms and the Schlumberger array factor respectively. The depth of investigation is dependent on the current-electrodes separation, AB.

General Geology of the Study Area

Kebbi state falls within the Sokoto basin which is part of an extensive elongated sedimentary basin underlying most of the North-western Nigeria and eastern part of Niger Republic. Geologically, the Sokoto basin is divided into two groups, Sokoto group and Rima group. The later consist of Dukamaje formation, Kalambaina formation, Taloka formation, Illo formation and Gundumi formation, while the former group, consist of Gwandu formation, Dange formation and Wurno formation (Sa’adu and Sheik, 2012).

Study area falls within the Gwandu formation (Figure 4)

and this formation (Eocene-Miocene) which is one of the formations in Sokoto Basin. The sediments are made up of massive of clay interbedded with sandstone (Adelana *et al.*, 2006).

The area is bounded in the south by latitude of 12°20’0’’N to 12°20’40’’N and in the east by longitude of 4°11’0’’E to 4°11’40’’E (Figure 3). Kalgo lies in the southern part of Kebbi State, its headquarters are in town of Kalgo. Kalgo Local Government shares a west with Bunza LGA. Majority of the inhabitants of the town came from present day Niger Republic and others from other parts of Nigeria. Majority of the people of Kalgo town are Hausa speaking with a small fraction as Fulanis. The Bugajes and Adarawas also inhabit the town. The 2006 population census gave the population figure as 85,403 and it has an area of 1,173km². (Lawal, 2010).

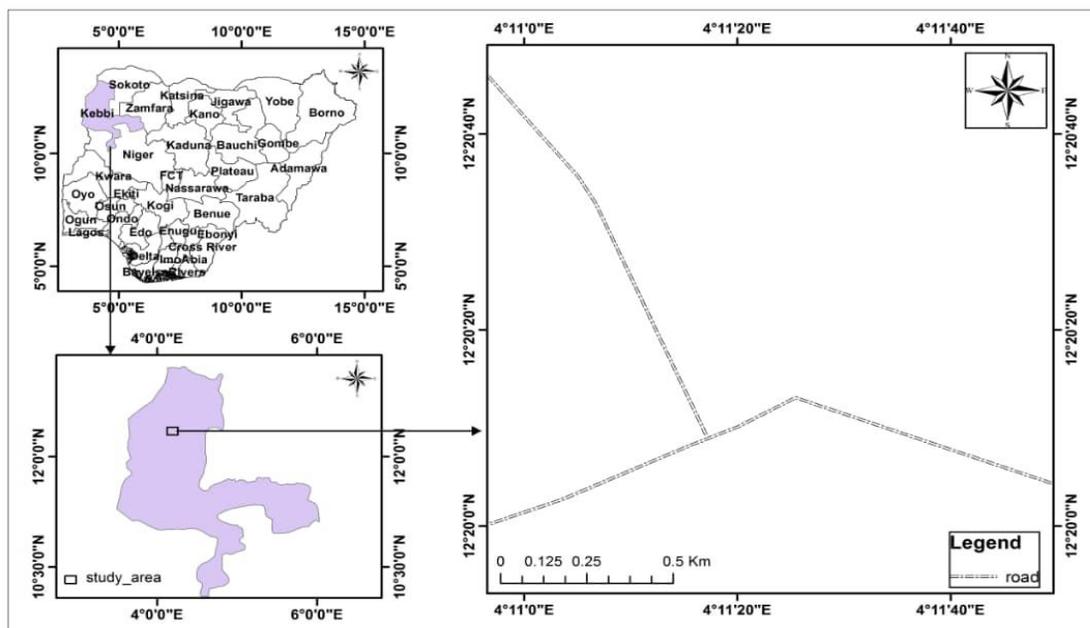


Fig. 3: Location Map of the Study Area

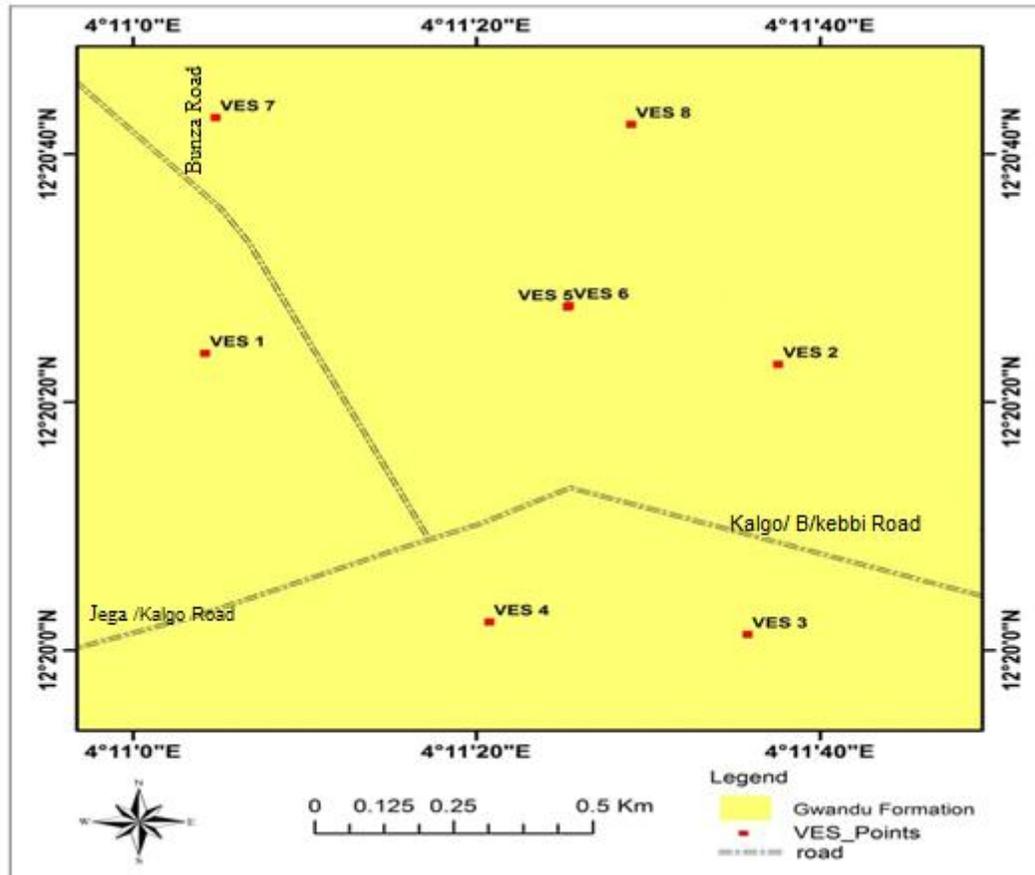


Fig. 4: Geological Map Showing all the VES points of the Study Area.

METHODOLOGY

Hydrogeophysical survey using electrical resistivity method was carried out in Kalgo area of Kebbi State. Method involved the use of specialized and precision instrument/equipment for the collection of data about the character and condition of the earth's surface materials. Eight sites (Figure 4) were selected and Vertical Electrical Soundings were conducted at these points using schlumberger array with a maximum current electrode (AB/2) spacing of 100m. At each measurement, the product of the resistance measured and the corresponding value of the geometric factor (Gw) gave the measured ground apparent resistivity.

RESULTS AND DISCUSSION

The results of the survey were correlated with a borehole log data near the study area (Figure 5) obtained from the Sokoto Agricultural and Rural development Agency, (SARDA 1988). Boreholes log data are a necessary and reliable source of primary data, and electrical resistivity sounding interpretations provide secondary information. Although borehole data provides a good sample for a six-inch diameter vertical cylindrical volume, it can be a poor representation of the several square meters surrounding the borehole. The log shows an overburden made up of three geologic layers.

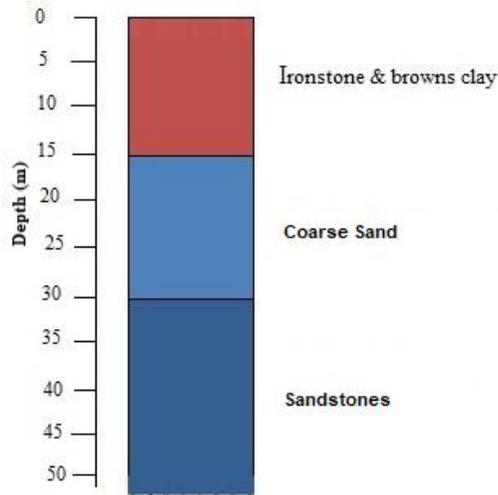


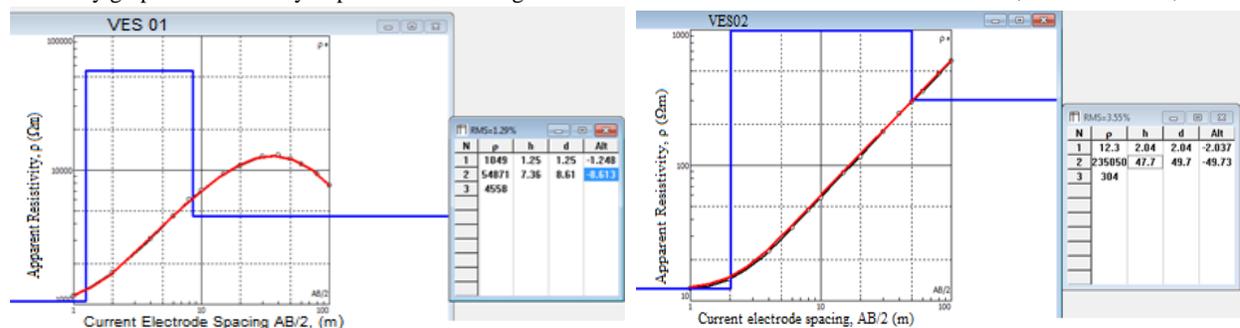
Figure 5: Borehole log data drilled near the study area (SARDA, 1988)

Table 1: Resistivity values of common rocks (Loke, 1999).

Rock type	Resistivity (Ωm)
Consolidated shale	20 – 2000
Argilites	10 – 800
Conglomerates	200 – 10000
Coarse sand	$2400 - 10^8$
Limestone	$50 - 10^7$
Dolomites	350 – 5000
Marls	3 – 70
Clays/Ironstone	5-100
Alluvium and sand	10 – 800
Oil sands	4 – 800
Top Soil	1 – 200
Sandstones	9 – 968

The computer inversion program IPI2WIN version 2.1 has been used to compute the geoelectric parameters of the study area. The output of sounding data is resistivity layer, log resistivity graph and resistivity-depth table. Sounding curve

obtained from the study area showed three geoelectrical layers Figure (6). They are the ironstone/brown clay (5 to 1500 ohm-m), sandstone/ coarse sand (2400 to 10^8 ohm-m) and weathered/fractured basement (9 to 968 ohm-m).



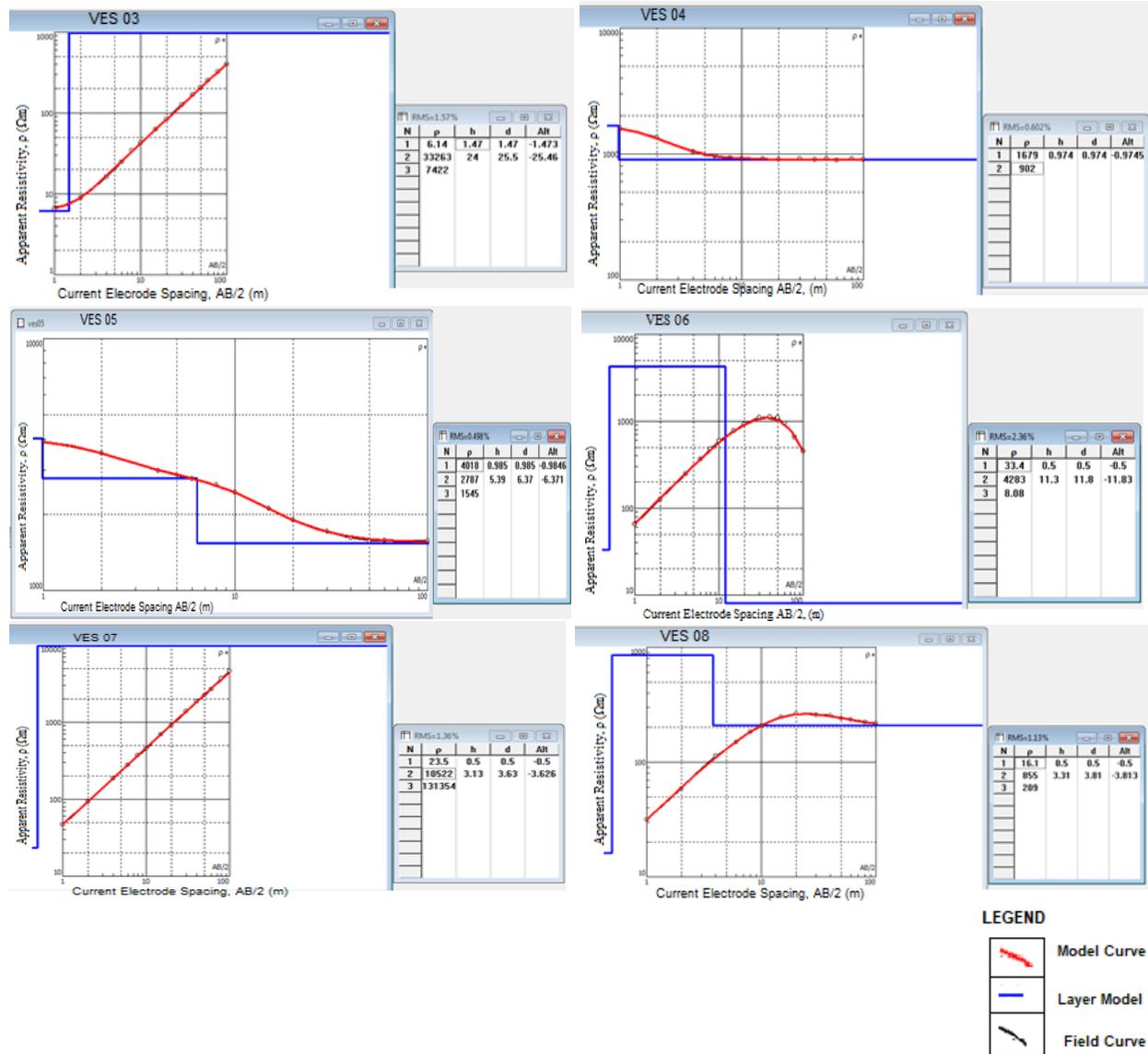


Fig.6: Plot of VES Obtained from the Study Area

Considered VES 02 (Figure 6). A total of three (3) layers were delineated at this point. The resistivity values range from 12Ωm to 235050Ωm while thickness values range from 2.04m to 49.7m. First layer composed of clay and ironstones with resistivity value of 12 Ωm and thickness 2.04m. Second

layer is inferred to be highly decomposed coarse sand with resistivity value of 235050Ωm. The third layer forms the aquifer due to its low resistivity 304 Ωm and thickness value of 47.7m. Its depth is 49.7m (Table 1 for summary of VES points).

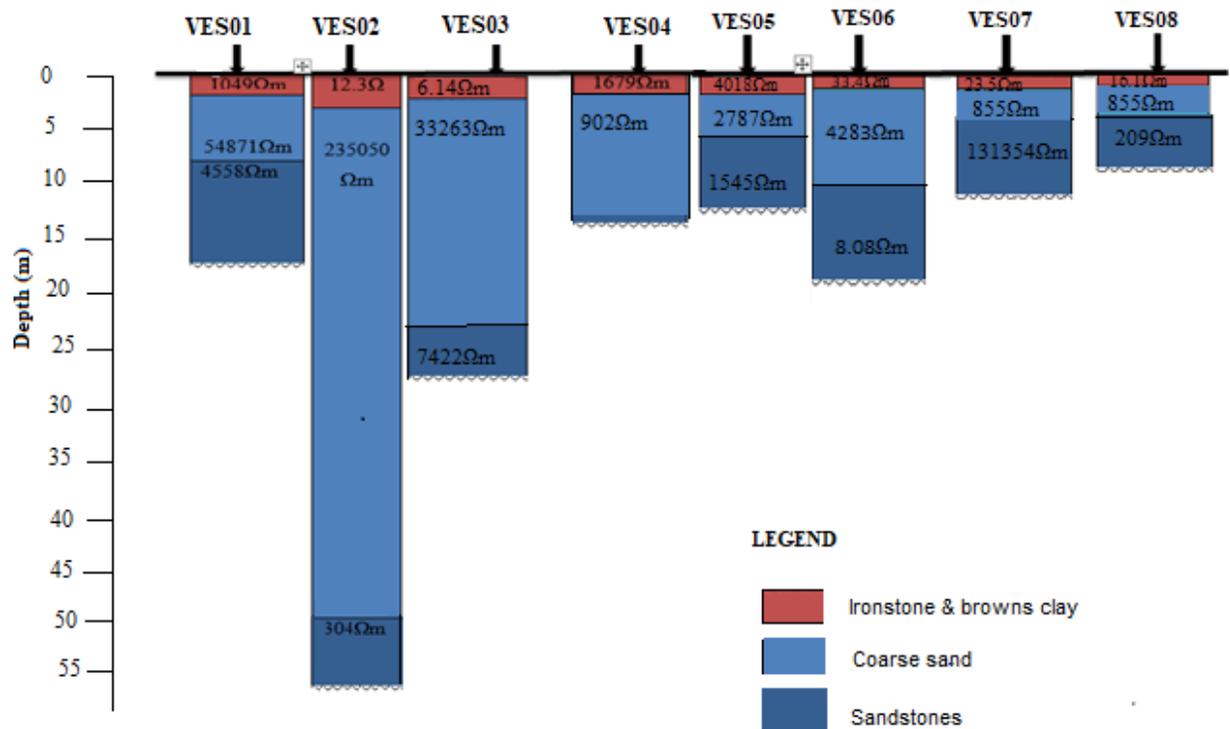


Fig. 7: Showing the Geoelectric Sections of VES Points

Table 1: Shows Summary of VES points; Numbers of layer, Resistivity, Thickness and depth of the subsurface.

VES POINTS	Layer 1			Layer 2			Layer 3		
	ρ_1 (Ωm)	d_1 (m)	h_1 (m)	ρ_2 (Ωm)	d_2 (m)	h_2 (m)	ρ_3 (Ωm)	d_3 (m)	h_3 (m)
01	1049	1.25	1.25	54871	8.91	7.36	4558	-	-
02	12.3	2.04	2.04	235050	49.7	47.7	304	-	-
03	6.14	1.47	1.47	33263	25.5	24	7422	-	-
04	1679	0.975	0.975	902	-	-	-	-	-
05	4018	0.985	0.985	2787	5.39	6.37	1545	-	-
06	33.4	0.5	0.5	4283	11.8	11.3	8.08	-	-
07	23.5	0.5	0.5	10522	3.63	3.13	131354	-	-
08	16.1	0.5	0.5	855	3.81	3.31	209	-	-

Based on the lithological logs from borehole (Figure 5 and Figure 7), the geological interpretation of the geoelectrical model for VES 01 is slightly thick ironstone and brown clay having resistivity value of 1049 Ωm with coarse sand/sandstones (54871 Ωm) underlin with thick sandstone. Also using borehole data, the geological interpretation of the geoelectric sections for VES 02 and VES 03 is slightly thick ironstone/brown clay having resistivity value of 12.3 Ωm (for VES 02) and 6.14 Ωm (for VES 03) with highly coarse sand having the resistivity value 235050 Ωm (VES 02) and 33263 Ωm (VES 03) underlin with sandstone basement having the resistivity value of 304 Ωm .

The third layer represents the deep seated aquiferous layer in the sandstone area. This layer is very important in groundwater accumulation (because it is a sandstone area

containing high porosity and permeability). In hard rock terrains composite aquifers of the weathered basement zone and fractured basement are known to give the highest groundwater yield.

CONCLUSION

Hydrogeophysical investigation using electrical resistivity method adopted in this study has given some insight in knowing groundwater condition in the study area with help of an aquifer dimensions especially its thickness and the depth to bedrock. The result from geophysical study revealed the occurrence of groundwater in this environment is largely due to occurrence of secondary porosity and permeability resulting from sandstone of the rocks. Thus the zones with high potentials for groundwater in the study area were identified. The nature and thickness of the overburden

also play important role on the availability of groundwater. High groundwater potential zones were found at VES 02 and 03. These regions revealed aquifer zones having thickness ranging from 02m to 47.7m. The siting of borehole should be done on VES 02 and VES 03 thereby having ability to retain and sustain portable water.

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