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Geoelectrical Investigation of Groundwater Potential At Riol Farm, Owode, Abeokuta, Ogun State

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Abstract

Geoelectrical investigation was carried out in order to solve the problem of drilling unproductive boreholes in RIOL Farm situated at Owode, Abeokuta in Ogun State. Fifteen (15) Schlumberger Vertical Electrical Sounding (VES) with current electrode spacing (AB) ranging from 2 m to 1000 m were acquired using PASI resistivity meter. The VES data were processed and interpreted using partial curve matching and computer iteration technique using WinRESIST software. The qualitative analysis reveals that the rising curves are dry sand devoid of groundwater while the descending parts of the VES curves are indicative of wet sands which could serve as potential aquifer. Four geoelectric sections generated from the interpreted VES results show four to six geo-electrical layers which correspond to topsoil with resistivity ranging between 45.0-993.9 ohm-m and thickness range between 0.5-1.0 m, lateritic clayey sand with resistivity ranging between 61.8-2328.0 ohm-m and thickness range between 1.2-5.5 m, sand/sandstone having resistivity range of between 1003.4-9575.9 ohm-m and thickness range between 4.2-114.8 m, sand with resistivity value ranging from 318.9-1581.2 ohm-m and thickness range between 5.1-78.9 m and consolidated sandstone / ironstone with resistivity value between 23245.5-4388.7 ohm-m. The quantitative analysis reveals that sands at the upper layer are dry within the depth of 2.2 – 69.8 m and appear to be unsaturated while sands at the depth not less than 80 m in VES 2, VES 9 and VES 15 are wet (saturated) and recommended for drilling. Thus, the wet sands denote aquifer units in the study area. Based on our recommendation, the location of VES 15 was drilled and yielded a productive borehole within a depth of 110m..

Keyword: Schlumberger Array; Aquifer; Geoelectric Section; Resistivity; Borehole Log

1.0 Introduction

One of the most important resources needed for sustainable development of any part of the world today is water [1]. Water is an essential natural resource, which is available both on surface as well as in various other suitable water reservoir formations/structures in the surface. Groundwater is often withdrawn for agricultural, municipal and industrial use by constructing and operating extraction wells. Groundwater is also largely used as a source for drinking and irrigation purposes [2].

The fact that numerous unsuccessful boreholes have been drilled in the Basement Complex terrain of Nigeria necessitates the scientific investigation of the groundwater potential of a proposed site prior to drilling [3]. The high failure rate in most groundwater project experienced in Basement Complex aquifers has contributed to the general acceptance of a geophysical survey as a compulsory prerequisite to any successful water well drilling project [4].

The basic application of geophysical methods is to measure the physical properties contrast between a target and its environment. Therefore, better contrast/anomaly informs better geophysical responses and the identification. So, the efficiency of any geophysical technique lies in its ability to detect and image the subsurface hydrogeological heterogeneities or variations. Hence, in groundwater exploration, a judicious application or integration of techniques is required for success in the exploration, technologically as well as economically [5].

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The application of geoelectrical method for groundwater investigation has been a method of choice and has enjoyed a lot of success. To mention a few of such applications, groundwater quality of a coastal aquifer lying south of Chennai City, Madras, India was successfully carried out using geo-electrical techniques [6]. The study detected fresh water ridge of good groundwater quality in the central portion of the coastal aquifer while the Eastern and Western margins of the aquifer contained groundwater of poor quality. Vertical Electrical Sounding and Horizontal Electrical Profiling (HEP) were applied to determine the potential groundwater in the Cretaceous-Tertiary sedimentary sequence, East of Jeddah, Saudi Arabia [7]. The groundwater potential within the vicinity of Federal College of Agriculture, Akure was evaluated using an integrated approach involving Electrical resistivity and Electromagnetic methods along four traverses [8]. The study showed high and medium groundwater potential zones under the North-Eastern part of the survey area. The investigation of groundwater potential of Alegongo around Oke-badan Estate, Ibadan, South-Western Nigeria was carried out using Electrical resistivity method [9]. The interpreted resistivity data were used to prepare different maps which were used to evaluate the groundwater potential as well as groundwater protective capacity rating of the study area.
The area under study is both residential and majorly agricultural centre with inadequate supply of portable water. Five boreholes were drilled in that area at shallow depth which proved abortive. Hence, the study was aimed to proffer a lasting solution to this problem by searching for more reliable aquifers at deeper depths using a wider spread of Schlumberger Vertical Electrical Sounding.

1.1 Basic Theory

The resistivity method is based on the principle of Ohm's law which establishes a relationship between the electric current ***I*** in a conducting wire, and the potential difference ***V*** across it [10] as expressed by the equation

$$V = IR \qquad (1.1)$$

Equation 1.1 governs the flow of current in the ground.

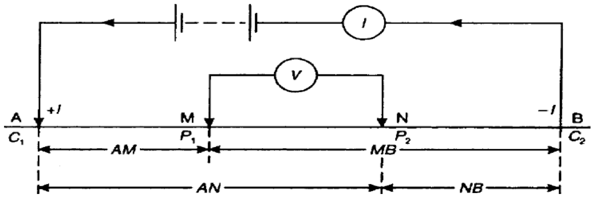

Figure 1: Diagram showing basic concept of resistivity measurement.
Consider a continuous current injected into the ground through the current electrodes (C_1 and C_2) as shown in Figure 1. The potential difference measured at M is given as

$$V_M = \frac{\rho I}{2\pi}\left(\frac{1}{AM} - \frac{1}{MB}\right) \qquad (1.2)$$

Similarly, the resultant potential at N is

$$V_N = \frac{\rho I}{2\pi}\left(\frac{1}{AN} - \frac{1}{NB}\right) \qquad (1.3)$$

The potential difference measured by the voltmeter connected between M and N is given as

$$V = \frac{\rho I}{2\pi}\left[\left(\frac{1}{AM} - \frac{1}{MB}\right) - \left(\frac{1}{AN} - \frac{1}{NB}\right)\right] \qquad (1.4)$$

Therefore,

$$\rho = 2\pi \frac{V}{I}\left[\left(\frac{1}{AM} - \frac{1}{MB}\right) - \left(\frac{1}{AN} - \frac{1}{NB}\right)\right]^{-1} \qquad (1.5)$$

$$\boldsymbol{\rho} = k\frac{\mathrm{V}}{\mathrm{I}} \qquad (1.6)$$

Where,

$$k = \frac{2\pi}{\left(\frac{1}{AM} - \frac{1}{MB}\right) - \left(\frac{1}{AN} - \frac{1}{NB}\right)} \qquad (1.7)$$

ρ is the resistivity of the conductor measured in ohm-m (Ωm) and ***k*** is called the geometric factor of the electrode arrangement.

1.2 Geology of the Study Area

The geology of the study area as shown in Figure 2 belongs to the Ise Formation of the Cretaceous Abeokuta group, the oldest group of sediment in the basin unconformably overlying the basement [11]. Three formations were recognized within the Dahomey basin belonging to the Abeokuta group based on lithologic homogeneity and similarity of origin [12]. This group is the thickest sedimentary unit within the basin. The formations from oldest to youngest are Ise, Afowo and Araromi Formation. Ise formation unconformably overlies the basement complex of Southwestern Nigeria, consisting of conglomerates and grits at the base which is in turn overlain by coarse to medium grained sands with interbeded kaolinite. The conglomerates are imbricated and at some locations ironstones occur [13]. An age range of Neocomian-Albian is assigned to this formation based on paleontological assemblages. Afowo formation overlies the Ise formation, and composed of coarse to medium grained sandstone with variable but thick interbedded shale, siltstone and claystone. The sandy facies are tar-bearing while shales are organic-rich [14]. Using palynological assemblage, a Turonian age is assigned to the Lower part of this formation, while the upper part ranges into Maastrichtian. The youngest Cretaceous formation in the group is Araromi formation, which conformably overlies the Afowo formation. It is composed of fine-medium grained sandstone at the base, overlain by shales, silt-stone with interbedded limestones, marl and lignite. A Maastrichtian to Paleocene age to this formation was assigned based on faunal content [12]. The study area (Figure 3) is at RIOL Farm, Owode, Abeokuta, Southwestern, Nigeria within longitudes $03^0 31'44.3''$ East to $03^0 31'50.4''$ East and latitudes $06^0 31'44.3''$ North to $06^0 59'04.6''$ North.

The area of investigation is located along Abeokuta – Ishagamu Expressway, in Isoba village,Owode Egba, Obafemi Owode Local Government Area, Ogun State. It is accessible through Abeokuta/Sagamu Express road. At the time of investigation, the site (farm) had been cleared of obstructions. The farm site is plain all through from the entrance (gate). At the North-West bordered with farm 5, at the south-East and South-West by Isoba village, bordered at the East by Abeokuta-Sagamu Express road respectively.

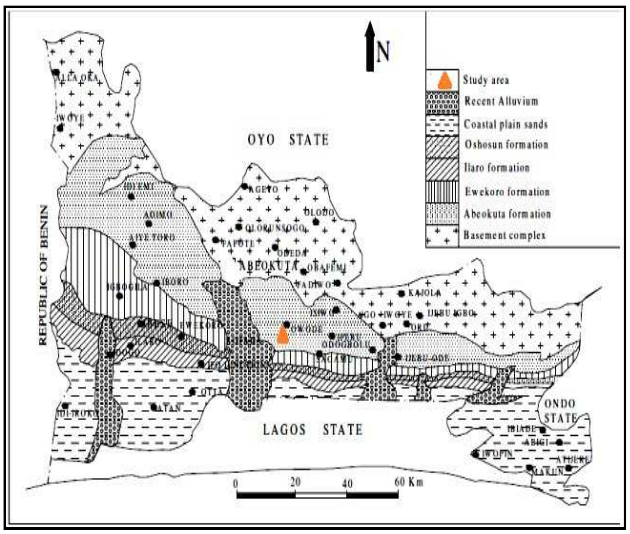

Figure 2: Geology of Ogun State [15].

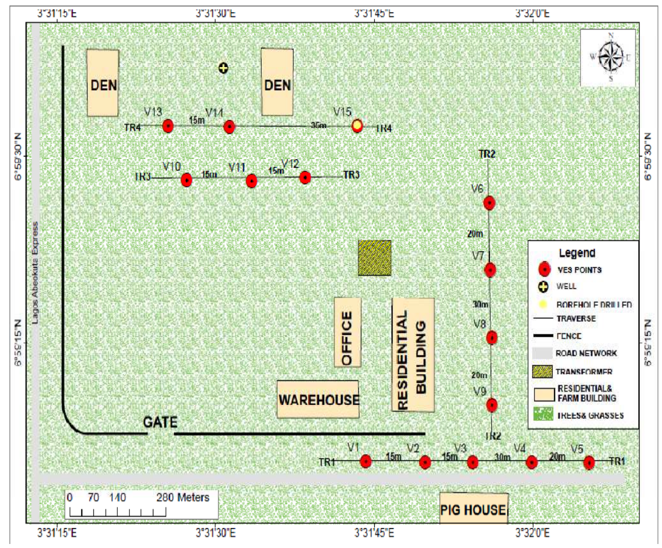

Figure 3: Base Map of the Study Area.

2.0 Materials and Methodology

2.1 Data Acquisition

The electrical resistivity survey was carried out along four traverses using Vertical Electrical Sounding (VES) using Schlumberger electrode array configuration. A total of fifteen (15) vertical electrical soundings were carried out along those traverses with current electrode spacing (AB) ranging from 2 m to 1000 m as shown in Figure 3. The data was acquired using the PASI Terrameter (16-GL) and also Global Positioning System (GPS) for finding the position and elevation of the survey point.

2.2 Data Processing

The qualitative interpretation of the depth sounding curves were carried out based on distinctive geo-electric characteristics and the number of layers using the primary auxiliary curves (H, K, A and Q).The quantitative interpretation of the depth sounding was first processed manually by plotting the apparent resistivity values against half the distance of electrode spacing (AB/2) on a transparent paper superimposed on a log-log graph paper. The graph obtained for each VES profile was correlated with theoretical curves to obtain points of coincidence to get layer parameters and these were used to derive resistivity, thickness and depth values for each layer. The VES data were further processed using the computer software Win RESIST 1.0 [16] to obtain a final model that best fits the observed data. The final model parameters (resistivity, thickness and depth) generated by the processing software were used to infer the lithology of the study area.

3.0 Results and Discussion

A sample of A curve which dominated the study area is presented in Figure 4a while a sample of AK curve is shown in Figure 4b. The geo-electric sections as shown in Figures 5 (a – d) were generated from the interpreted VES results and are subsequently discussed as below.

3.1 Qualitative Implications of VES Curves

VES curves 1, 3, 4, 5, 6, 7, 8, 10, 11, 12, 13, and 14 are classified as A curves arising from their rising nature. They are indicative of dry sands which are devoid of groundwater based on our knowledge of the geology of the environment. A sample of the VES curves is shown in Figure 4a. In contrast, VES 2, 9, and 15 curves show two AK and AKA curves respectively. These type curves reveal inflections along their rising segments which could be diagnostic of saturated / wet sands where groundwater could be tapped. Its sample curve is shown in Figure 4b. The observed VES type curves correspond to that expected based on the geology of Ise formation of the Abeokuta Group.

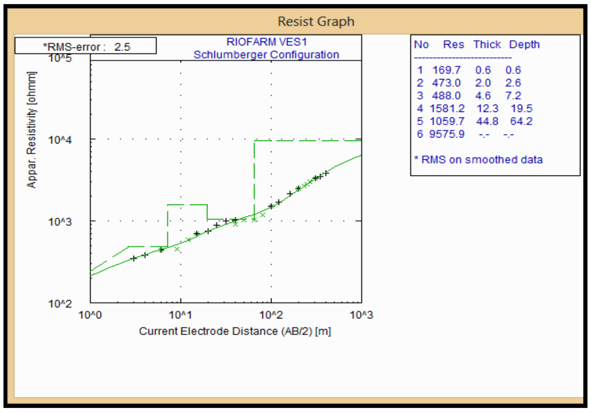

Figure 4a: A Sample of A-type VES Curve obtained in the study area

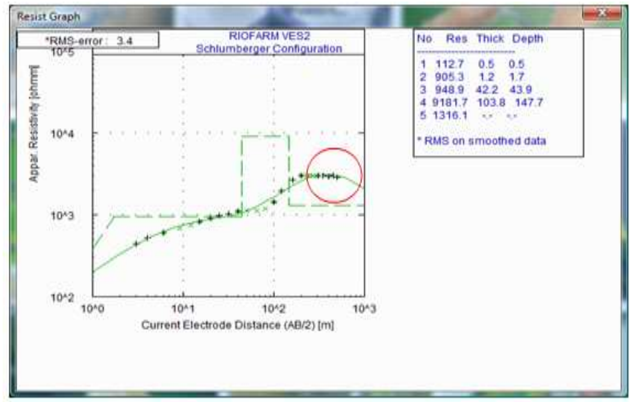

Figure 4b: A Sample of AK-type VES Curve obtained in the study area

3.2 Quantitative Implications of VES Curves

Figure 5a consists of VES 1-5 which has five to six geo-electric layers which correspond to the topsoil, lateritic clayey sand, sand, sandstone and consolidated sandstone/ ironstone. The topsoil is characterized by resistivity values ranging from 112.7 to 998.3 ohm-m and layer thickness of 0.5-0.7 m. The second layer denotes lateritic clayey sand with resistivity values ranging from 473.0 to 2328.0 ohm-m and layer thickness of 1.0-2.8 m. The third stratum represents lateritic clayey sand with resistivity values ranging from 488.0 to 948.9 ohm-m along the VES (1-5), while the third stratum in VES 3 signifies sand with resistivity value of 873.9 ohm-m and thickness of 6.3 m. The fourth horizon represents sand with resistivity value of 1581.2 ohm-m and layer thickness of 12.3 m along VES 1 while in VES (2-5), the geologic unit along the VES depicts sand/ sandstone with resistivity values ranging from 2053.2 to 9181.7 ohm-m and layer thickness of 4.2 to 103.8 m. The fifth horizon connotes sand having resistivity values ranging from 781.4 to 1316.1 ohm-m and layer thickness of 32.2 to 56.6 m along VES (1- 5). The sixth geoelectric unit denotes the consolidated sandstone/ ironstone along VES 3, VES 4 and VES 5 with resistivity values ranging from 8609.9 to 29357.1 ohm-m. The layer thickness could not be determined because the current terminated within this horizon. In VES 1, the geologic unit along the VES is representative of sand/sandstone with resistivity value 9575.9 ohm-m. The thickness could not be determined because the current terminated within the horizon.

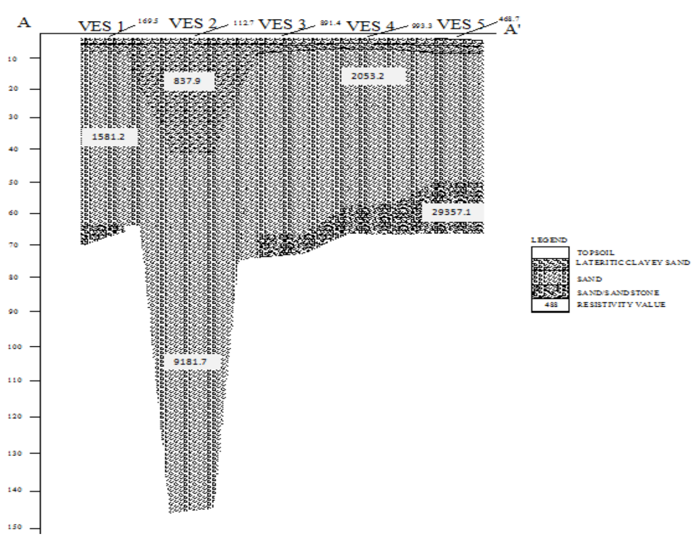

Figure 5a: Geoelectric Section along AA′ (VES 1-5).

Figure 5b comprises VES 6-9 which has five to six geo-electric layers. These are representative of topsoil, lateritic clayey sand, sand, sand/ sandstone and consolidated sandstone. The topsoil is characterized by resistivity values ranging from 68.7 to 468.7 ohm-m with layer thickness of 0.5 to 1.0 m. The second horizon depicts lateritic clayey sand with resistivity values ranging from 476.2 to 1026.1 ohm-m and layer thickness of 1.7 to 3.4 m. The third stratum represents lateritic clayey sand with resistivity values ranging from 341.8 to 1253.7 ohm-m and layer thickness ranging from 4.1 to 10.9 m in VES (7-9) but in VES 6, the geologic unit is sand which has a resistivity value of 874.1 ohm-m and layer thickness of 5.1 m. The fourth geoelectric represents sand / sandstone with resistivity values ranging from 1238.0 to 2131.9 ohm-m and layer thickness of 55.5 to 69.4 m in VES 6 and VES 7 but in VES 8, the geologic stratum is indicative of sand having resistivity value of 711 ohm-m and thickness value of 37.6 m. While in VES 9, the geologic unit is representative of consolidated sandstone / ironstone with resistivity value of 2744.6 ohm-m and thickness of 51.2 m. The fifth stratum denotes consolidated sandstone in VES 6 and VES 8 with resistivity values ranging from 4670.4 to 22179.5 ohm-m, but the thickness could not be determined due to the termination of current within that zone. The fifth stratum in VES 7 and VES 9 depicts sand / sandstone and sand respectively with resistivity values of 2131.9 and 869.1 ohm-m and the layer thickness of VES 7 is 55.5 m while the thickness in VES 9 could not be determined due to the current terminating within the region. The sixth geoelectric unit represents consolidated sandstone which has resistivity value of 21581.5 ohm-m in VES 7. The layer thickness could not be determined due to the current terminating within the region.

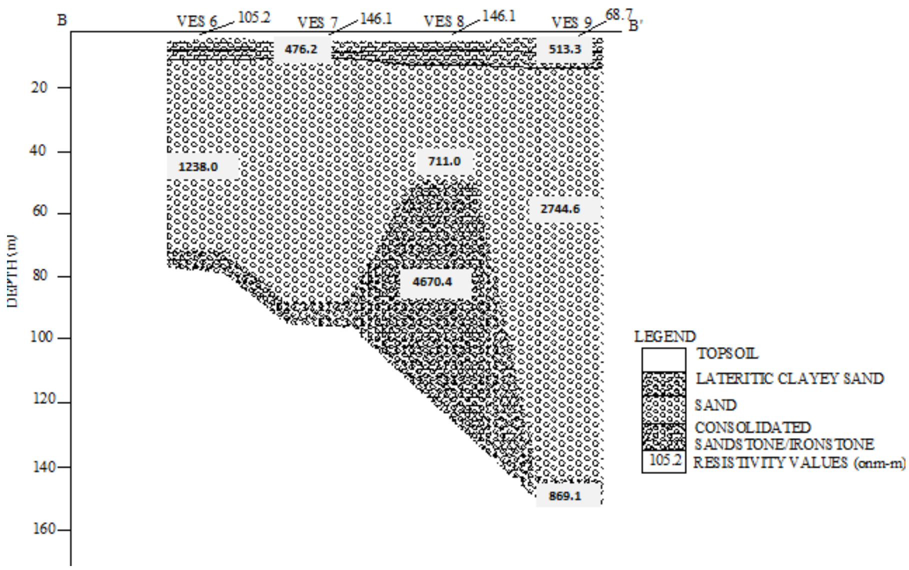

Figure 5b: Geo-electric Section along BB′ (VES 6-9).

Figure 5c represents geoelectric section along CC′ generated from VES 10-12. This section shows four to five geoelectric layers corresponding to topsoil, lateritic clayey sand, sand, sandstone and fresh basement. The topsoil is has resistivity values ranging from 71.2 to 76.7 ohm-m with thickness of layer between 0.7 to 0.9 m. The second layer depicts lateritic clayey sand having resistivity values in the range from 151.7 to 247.1 ohm-m and thickness of layer between 1.2 to 3.0 m. The third stratum depicts sand with resistivity values ranging from 318.9 to 496.1 ohm-m with layer thickness of 14.4 to 16.7 m in VES 11 and VES 12 but in VES 10, the geologic unit represents lateritic clayey sand with resistivity value of 160.5 ohm-m and layer thickness of 13.6 m. This region composes of dry sand and therefore groundwater cannot be found from this zone. The forth stratum denotes sand/ sandstone with resistivity values ranging from 2670.9 to 2852.5 ohm-m with layer thickness of 22.0 m to where the current is being terminated. While in VES 10, the geoelectric unit is diagnostic of consolidated sandstone/ironstone with resistivity value of 4392.8 ohm-m but the thickness value could not be determined because the current was terminated within the region. The fifth layer depicts the consolidated sandstone with resistivity value of 13059.1 ohm-m but the layer thickness could not be determined due to the termination of current in this zone.

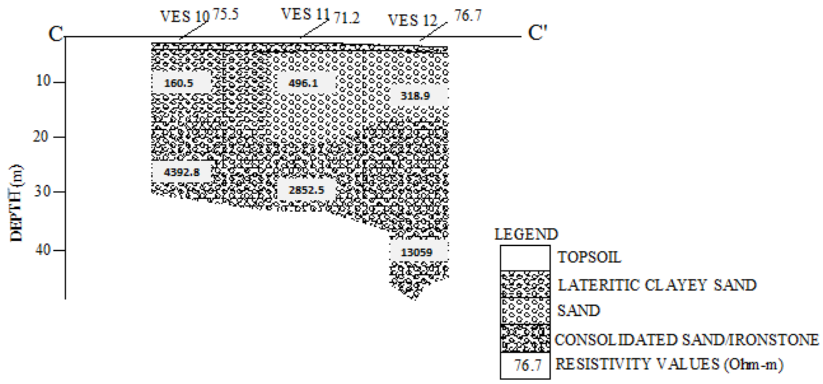

Figure 5c: Geo-electric Section along CC′ (VES 10 -12).

Figure 5d composes of VES 13-15 which has four to six geo- electric layers. The section corresponds to topsoil, lateritic clayey sand, sand/sandstone, sand and consolidated sandstone. The topsoil is characterized by resistivity values ranging from 45.0 to 174.9 ohm-m with layer thickness of 0.5 to 0.7 m. The second layer depicts lateritic clayey sand with resistivity values ranging from 61.8 to 429.9 ohm-m and layer thickness of 1.5-5.5 m. The third horizon denotes lateritic clayey sand with resistivity values ranging from 211.0 to 885.9 ohm-m and layer thickness of 3.3 to 24.8 m. The fourth geoelectric unit is representative of lateritic clayey sand in VES 14 having resistivity value of 71.2 ohm-m with layer thickness of 14.3 m while in VES 15, the geologic unit is sand/sandstone which has a resistivity value of 2633.5 ohm-m and layer thickness of 114.5 m. The fourth stratum in VES 13 is indicative of consolidated sandstone with resistivity value of 5885.5 ohm-m and thickness values could not be determined due to the current terminating within the region. The fifth geologic unit represents sand in VES 15 with resistivity value of 492.1ohm-m and layer thickness of 78.9 m, in this region, ground water could be tapped. While in VES 14 the geologic unit represents sand/ sandstone with resistivity value of 5188.4 ohm-m but the layer thickness could not be determined due to the current being terminated within the region. The sixth horizon represents the consolidated sandstone in VES 15 with resistivity value of 4388.7 ohm-m, the layer thickness could not be determined due to the current being terminated.

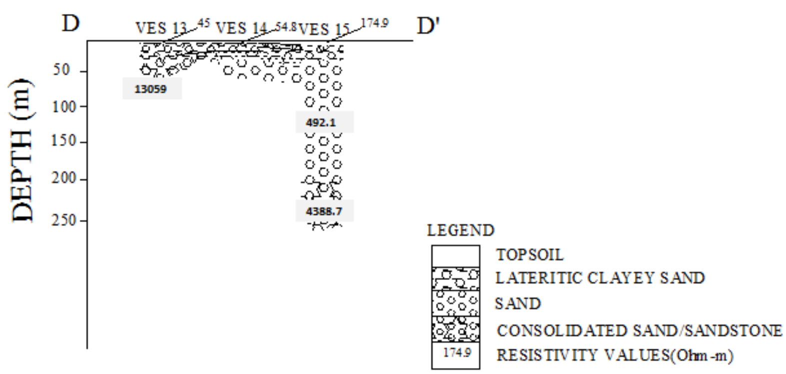

Figure 5d: Geo-electric Section along DD′ (VES13-15).

4.0 Conclusion

The investigation of groundwater potential was carried out at RIOL Farm, Owode, Abeokuta, Ogun state, Southwestern, Nigeria using fifteen (15) Vertical Electrical Soundings (VES) via Schlumberger array.

The qualitative analysis reveals that the A-type rising curves indicate dry sand devoid of groundwater while parts of the VES curves with inflections are suggestive of wet sands which could serve as potential aquifer for ground water development in the study area. Four geoelectric sections generated from the interpreted VES results show four to six geo-electrical layers which correspond to topsoil, lateritic clayey sand, sand/sandstone, sand and consolidated sandstone/ ironstone. The topsoil with thickness ranging from 0.5 – 1.0 m and resistivity values ranging from 45.0 – 993.0 ohm-m, while the lateritic clayey sand has thickness values ranging from 1.0 – 24.8 m with resistivity values ranging from 61.8 – 2328 ohm-m. The sand/ sandstone have thickness values ranging from 4.2 m to where the current terminated and resistivity values ranging from 1003.4 – 9575.9 ohm-m. Also the sand has thickness values ranging from 5.1 m to where the current terminated and

resistivity values ranging from 318.9 -1581.0 ohm-m while the consolidated sandstone/ ironstone has resistivity values ranging from 2744.6 to 29357.1ohm-m and thickness ranging from 134.1 m to where the current was terminated.
The quantitative analysis reveals that sands at the upper layer are dry within the depth of 2.2 – 69.8 m and appear to be unproductive of groundwater while sands at the depth not less than 80 m are saturated / wet as indicated in VES 2, VES 9 and VES 15. Thus, the wet sands denote aquifer units where groundwater could be tapped within the study area. The study also shows that most of the failed boreholes terminated within the dry sand zone. A productive borehole at depth of 110 m was sunk within the study area based on the result of the VES 15.

5.0 References

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