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Geo-Electrical Survey for Groundwater Exploration in a Part of the Basement Complex Terrain, Ilorin Metropolis Northcentral Nigeria

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ABSTRACT

Investigation and determination of groundwater potential is an important procedure for addressing the problem of acute water shortage. In order to achieve this purpose, a geo-electrical resistivity survey involving vertical electrical sounding (VES) technique for groundwater exploration was carried out at Oke-Adini area, Ilorin. A total of twelve (12) VES stations with the current electrode maximum separation of 100 m were completed. The field data obtained was first subjected to a conventional partial curve matching before being interpreted with the computer iteration techniques using the WinGlink and WinResist software. The results revealed four layers comprising of the top soil with resitivity values ranging from 190 to 900 Ωm while the thickness ranges from 0.44 to 1.15 m. The weathered basement has resistivity values ranging from 54.1 to 150 Ωm while the thickness ranges from 2.0 to 17 m. The fractured basement resistivity values ranges from 5.7 to 503.4 Ωm with 1.51 to 50.8m in thickness. The resistivities of the fresh basement is above 700 Ωm. The obtained resistivity analysis and pseudo section curves shows that VES station 3, 6, and 7 exhibited low resistivities value and high overburden thickness in the weathered rock layer from all survey conducted and therefore, recommended has being most suitable target for borehole tube drilling.

Keywords:
Geo-electrical,
Investigation,
Resistivity,
Aquifer,
Basement Complex,
Ilorin.

INTRODUCTION

Oke-Adini community is a fast growing and densely populated settlement in Ilorin metropolis (Ahmed, 2019). This is as a result of migration from north to south partly due to insecurity, economic activities, proximity to numerous companies, quarries, schools and other government owned establishments (Olasehinde, 2010; Ajayi *et al*., 2021). The high demand for potable and consistent water supply by the inhabitants for both domestic and industrial usage has led to acute water shortage in many parts of this area. The importance of water as a valuable natural resources vital to the existence of human society cannot be overemphasized (Olasehinde and Awojobi, 2004; Ibrahim *et al.*, 2012; Olawepo *et al*., 2013; Ajayi *et al*., 2021). Studies had earlier confirmed that the water level in most area underlain by the crystalline basement rock of Precambrian era has been restricted and falling rapidly due to an increase in extraction (Kazeem, 2007; Abiola *et al*., 2009; Jeff, 2008; Olawuyi and Abolarin, 2013; Olatunji *et al.*, 2020). This is due to the number of wells drilled for domestic and industrial purpose has rapidly and indiscriminately increased due to poor understanding of the geology and groundwater occurrence in the area (Olatunji *et al*., 2017). In many cases, the yields of the boreholes sunk into such zones are low (Olanrewaju *et al.*, 1996). In order to pursue large scale development and extraction of groundwater, it is essential to have a reliable estimate of groundwater potential (Fawale and Ojo, 2017; Nwankwo, 2011; Ogundana and Talabi, 2014; Ariyo, 2007). In view of this, a comprehensive geophysical survey was carried out in the area with the aim of locating site where groundwater can be extracted for a long-term steady water supply wherever possible. Olorunfemi and Fasuyi, (1996), Amadi and Olasehinde, (2010) both affirmed that the occurrence of groundwater in recoverable quantity as well as its circulation are controlled by geological factors.

Several literatures have also describe electrical resistivity survey as the most effective means of exploring groundwater especially in the basement complex and hard rock terrains (Barongo, and Palacky, 1991; Olayinka and Olorunfemi, 1992; Olorunfemi and

Fasuyi, 1993; Olorunfemi, *et al.*, 1999; Olasehinde *et al.*, 1999; Alile *et al*., 2008; Nwankwo, 2011; Olayinka and Oyedele, 2012). Previous work has been carried out around the study area while utilizing electrical resistivity technique. Three to four geo-electric sections with varied thickness and resistivity values involving poor productive fractures serving as a conduit for water passage was elucidated (Lawal *et al*., 2014; Olatunji *et al.*, 2017; Fawale *et al.*, 2020). Lawal et al. (2012) also evaluated the impact of delineating groundwater distribution and exploration while Ashaolu and Omotosho (2015) performed an assessment of the static water level and overburden thickness for groundwater development and management using electrical resistivity sounding around the area with great success.
This study of groundwater condition in Oke-Adini using the vertical electrical soundings method was carried out to empirically ascertain areas or sites where viable boreholes for long term steady supply can be achieved could be located.

Location and Geology of the Study Area
The study area is located along the Kwara Polytechnic/Old Jebba road and it lies between the Longitude 4°36’0"and 4°37’0"E and Latuitude 4°31’0" and 4°32’0" N. The area is underlain by the Precambrian Crystalline Basements complex of Kwara State, North Central part of Nigeria ranging from Precambrian to Paleozoic age (Olawuyi and Abolarin, 2013) (Fig.1). The granite types and the granodiorite together form part of the older granite which are parts of migmatite-gneisses, granitic gneisses and metasediments such as quartzites (Rahman, 1988).The structural fabrics is majorly a North-South fracture trending sequence characterised by Southernly plunging (6º-10º) anticlinorium with a limb of gentle westernly dipping is observed (Olasehinde, 1999; Olasehinde *et al*., 1986). High-grade metamorphic rocks in form of gneisis migmatites and Granite suites are found occasionally. The basement complex rocks within the South-West was classified into groups of five which includes: Migmatite- Gneiss complex which comprises gneisses, quartzite, calc silicate rocks, biotite hornblende schist, and amphibolites; slightly migmatised to unmagmatised Para-schist and meta-igneous rocks; charnockitic rocks; older granites and unmetamorphosed dolerite dyke, which comprises pegmatite, quartz veins and doleritic dykes (Rahaman,1973, Nwankwo, 2011). Also basement rocks are undifferential which are made up of granites, gneisses, migmatite, quartzite, calc silicates, biotites hornblended schist and amphibolies rocks. There are also unmetamorphosed delorite dykes which comprises of pegmatite, quartz veins and delorite dykes (Lawal *et al.*, 2017). The obtained minerals from the few specimens around the area are feldspars, quartz, muscovite and biotite (Ajayi *et al.*, 2021).

Figure 1: Geological Map of Ilorin Showing the Area of Study (Ahmed, 2019).

Drainage and Topography

The major rivers and streams draining the area and acting as a tributary to River Niger includes Oyun River and river Ile-Apa (Fig. 2). The trellis nature of the drainage seems to suggest a fracture controlled drainage system (Olasehinde, 1986). The drainage pattern of the area does not seem to be controlled by structures of the underlying bedrock (Nwankwo, 2011).

Generally the study area has an undulating topography, having elevation of about 1250 m above sea level (Olasehinde, 2010). The centre part is remarkably identified due to its ridges, with certain parts occupied by former tin tailing sands. In majority parts of the area of study, the ground is characterized by rough rugged troughs and crest due to erosions which characterized the topography of the area (Nwankwo, 2011) and quartzite, which explains the low level nature of the topography.

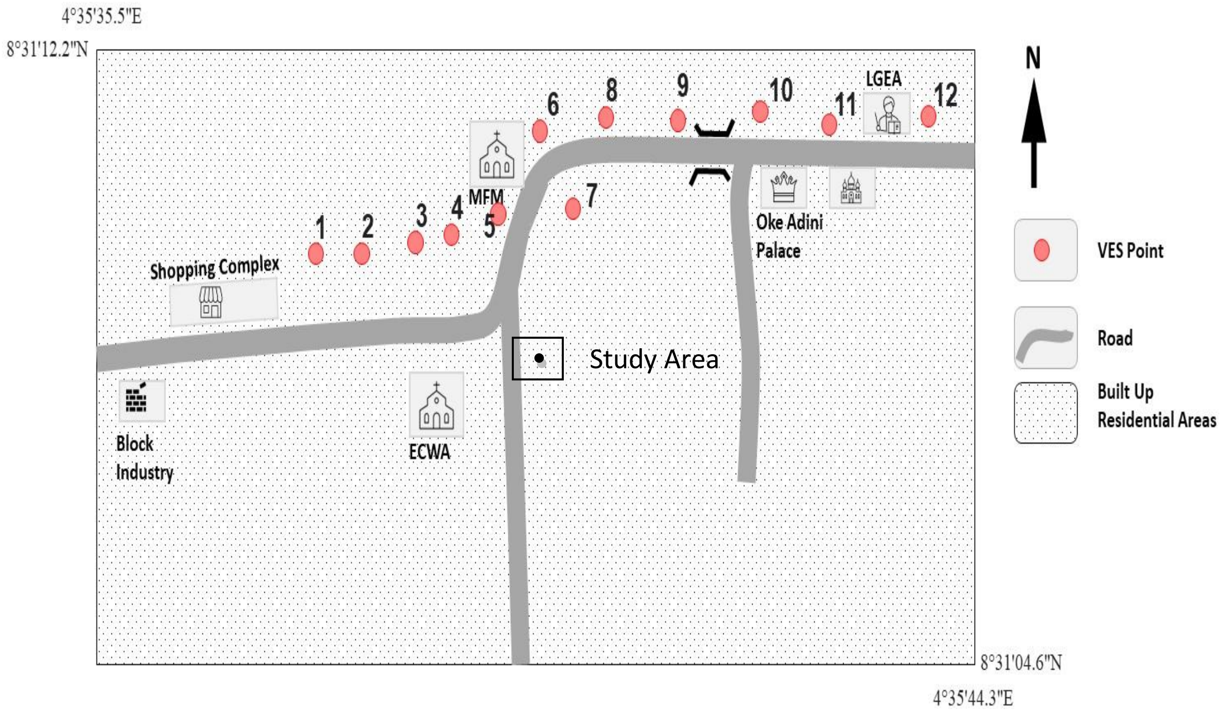

Figure 2: Location Map of the Study Area showing the VES stations.

MATERIALS AND METHODS

In this study, VES was carried out at the study area with a PELI 1300 portable terameter. Other materials include: two metallic current and potential electrodes, two reels of calibrated rope, hammers, compass for finding the orientation of the traverses, cutlass for cutting traverses and field data sheet. Olasehinde et al. 2015 affirmed that groundwater is economically and effectively investigated while using electrical resistivity survey. It is also more popular and mostly adopted for groundwater exploration than any other geophysical techniques (Osemeikhian and Asokhia, 1994; Olorunfemi *et al*., 1999; Hago, 2000; Afolayan *et al*., 2004; Lashkaripour and Nakhaei, 2005; Ariyo, 2007). VES technique was adopted for the acquisition of field data because it has been used to determine the subsurface resistivity distribution, aquifer characteristics and depth of the sub-surface layers (Fawale *et al*., 2011; Sing, 1984 Ajayi *et al*., 2020). It was also adopted to locate areas with thick weathered zone and fractured containing groundwater (Oladunjoye, 2011; Nwankwo, 2011; Eluwole and Ademilua, 2014). In a conventional Schlumberger electrode configuration, the distance between current electrode is increase from the fixed point of array representing actual point being investigated (Olasehinde and Taiwo, 2000). The potential electrodes separations are kept constant until the attenuated current upon where they were expanded to make the current penetrate deeper (Ologe and Augie, 2020). The wider the current electrode separation the deeper the penetration or depth of investigation (Alile *et al*., 2008). Grant and West (1965) defined an apparent resistivity ρa computed during field survey as the product of the geometric factor (G) and the resistance (R) recorded in the electrical resistivity meter and resistivity the earth ($\rho = GR$) (Fig. 3).

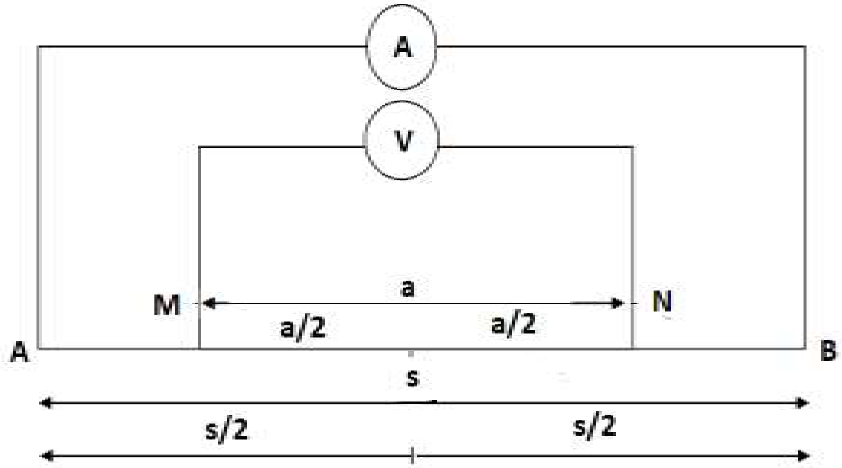

Figure 3: Schlumberger Electrode Configuration Arrangement.

Where G is the geometric Factor of the electrode arrangement in case of Schlumberger electrode configuration, which is given by:

From Fig. 3 the potential of M from A is given by

$$V_M = \frac{I\rho}{2\pi}\left\{\frac{1}{s-{}^{a}/_{2}} - \frac{1}{s+{}^{a}/_{2}}\right\} \quad (1)$$

Where s is the current electrode spacing from the midpoint

a is the potential electrodes separation distance

ρ is taken as the resistivity of different layers

The potential at N due to A is therefore given by

$$V_N = \frac{I\rho}{2\pi}\left\{\frac{1}{s+{}^{a}/_{2}} - \frac{1}{s-{}^{a}/_{2}}\right\} \quad (2)$$

The potential difference ΔV between the two potential electrodes is given by

$$\Delta V = V_M - V_N \quad (3)$$

$$\Delta V = \frac{I\rho}{\pi}\left\{\frac{4a}{4s^2-a^2}\right\} \quad (4)$$

The resistivity ρ obtained is equal to the true resistivity only if the geologic medium is homogeneous and isotropic (Abiola *et al*., 2009).

$$\rho = R\pi\left\{\frac{4\left(\frac{AB}{2}\right)^2-(MN)^2}{4(MN)}\right\} \quad (5)$$

In the Schlumberger electrode configuration the wider the current electrode separation the deeper the penetration or depth of investigation (McCann *et al*., 1997; Osemeikhian and Asokhia, 1994). The geometric factor for configuration involving schlumberger electrode array is given by:

$$G = \pi\left\{\frac{\left(\frac{AB}{2}\right)^2-\left(\frac{MN}{2}\right)^2}{2\left(\frac{MN}{2}\right)}\right\} \quad (6)$$

Where AB is the two current electrodes spacing from each other while MN is the two potential electrodes separating distance between them.

RESULTS AND DISCUSSION

The resistivity field data collected were processed and subjected to both qualitative and quantitative detailed interpretation (Fig. 3.0 – 10.0) involving different computer iteration techniques aimed at unravelling the subsurface resistivity distribution for groundwater potential and exploration in the study area. The qualitative interpretation of the resistivity data was studied in terms of forms and character depleted in terms of resistivity forms and pattern with depth (Okwueze *et al.,* 1988). This was done by plotting apparent resistivities obtained from the field against the corresponding half Schlumberger electrode spacing$\left(\frac{AB}{2}\right)$ using the Winresist (Fig. 4 – 9). The field resistivity analysis shows that the area comprises of four geo-electrical layers. The field data obtained was thereafter developed into a pseudosection map (Fig. 10). These maps are resistivity distribution of station involving subsurface layers with depth of the survey in the area. The purpose of interpreting resistivity distributions of the entire VES station was to locate anomalous regions, convert multiple layers by distinguishing units of different lithology, thereafter convert the values of obtained resistivity to a reasonable subsurface geological picture (Nwankwo *et al.,* 2004; Nwankwo, 2011).

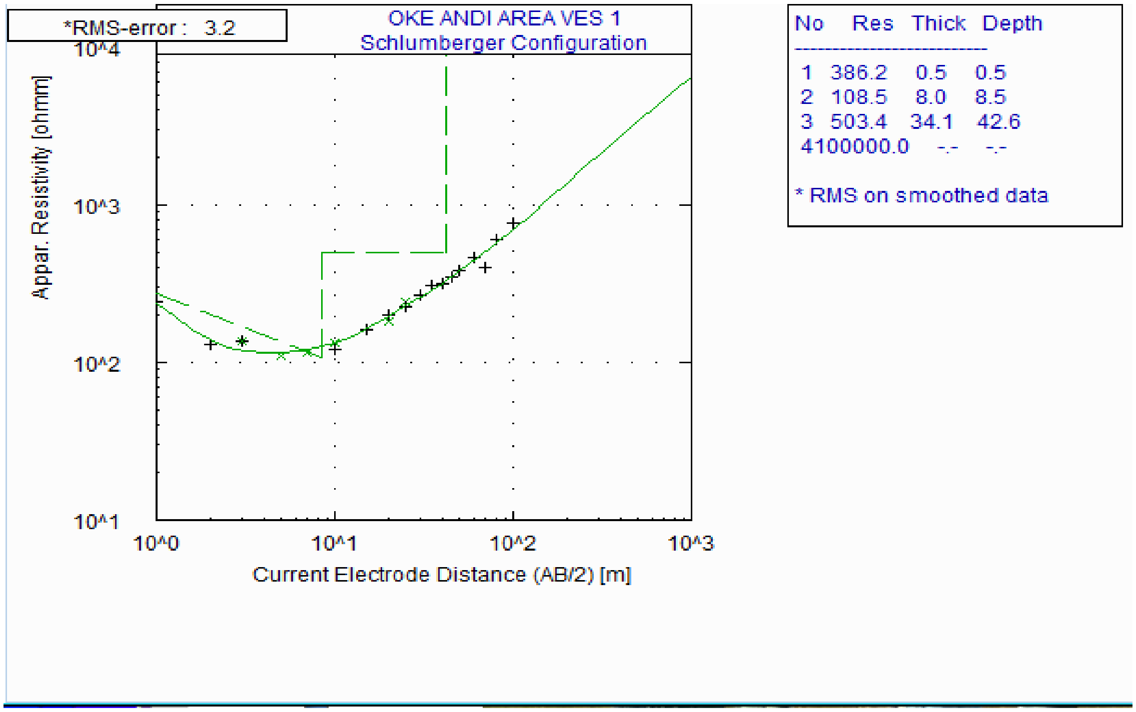

Figure 4: Resistivity Sounding Plot for VES 1.

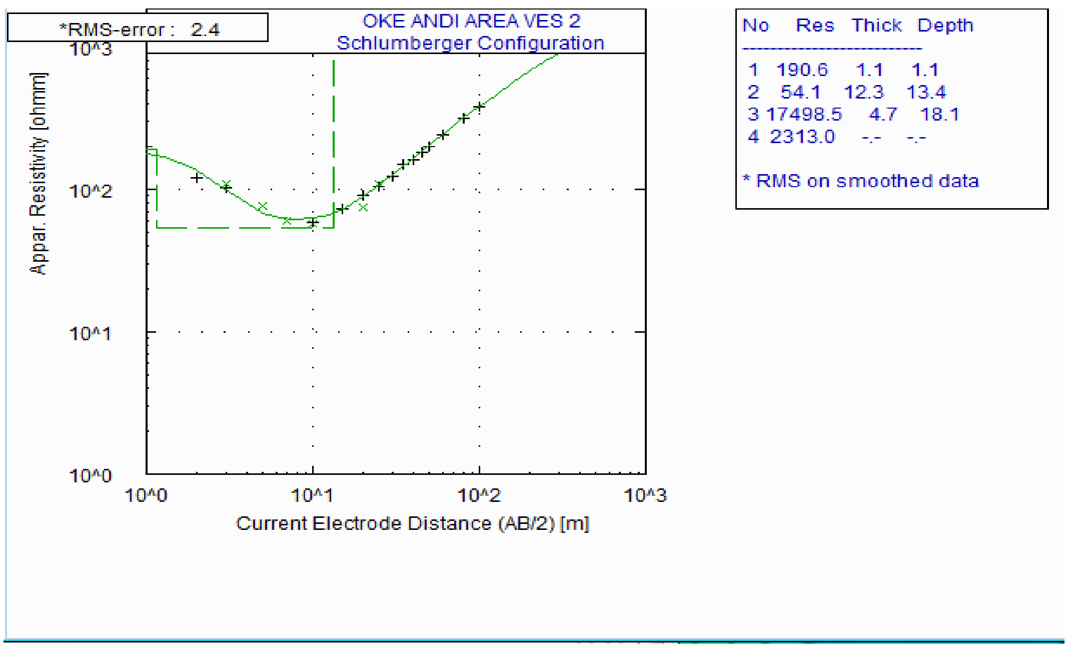

Figure 5: Resistivity Sounding Plot for VES 2.

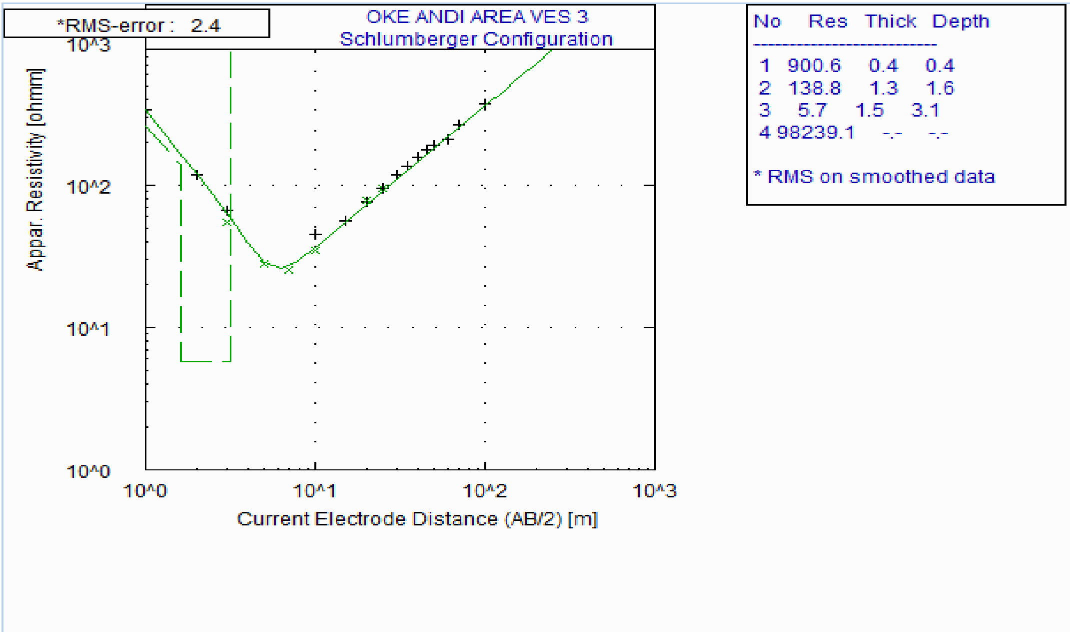

Figure 6: Resistivity Sounding Plot for VES 3.

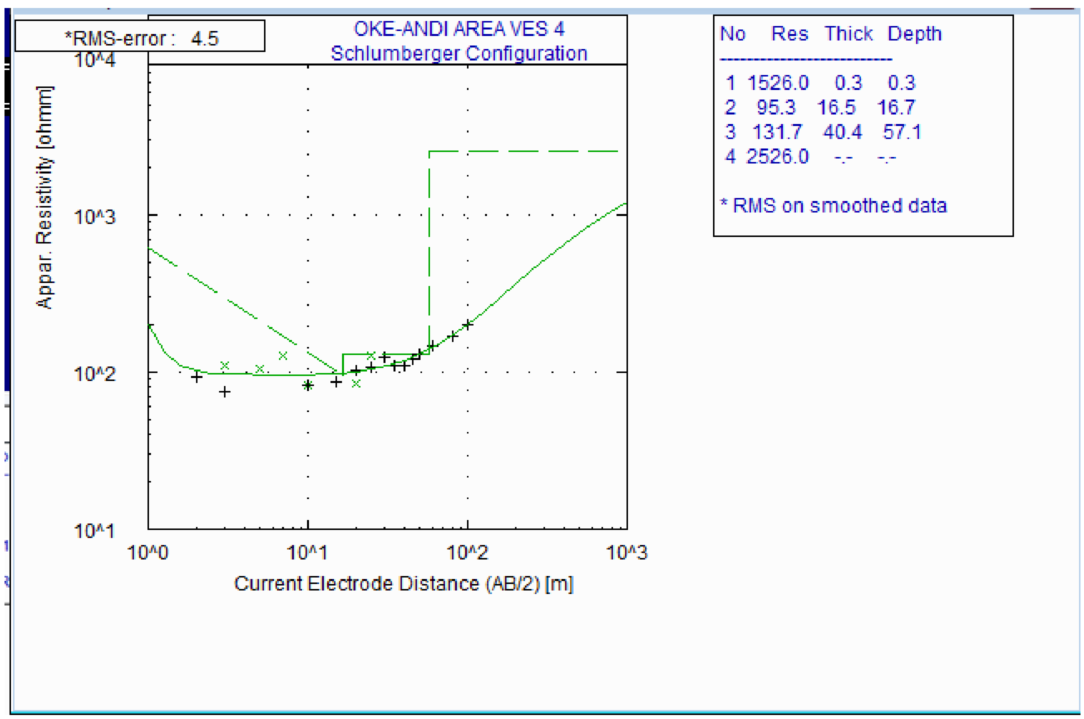

Figure 7: Resistivity Sounding Plot for VES 4

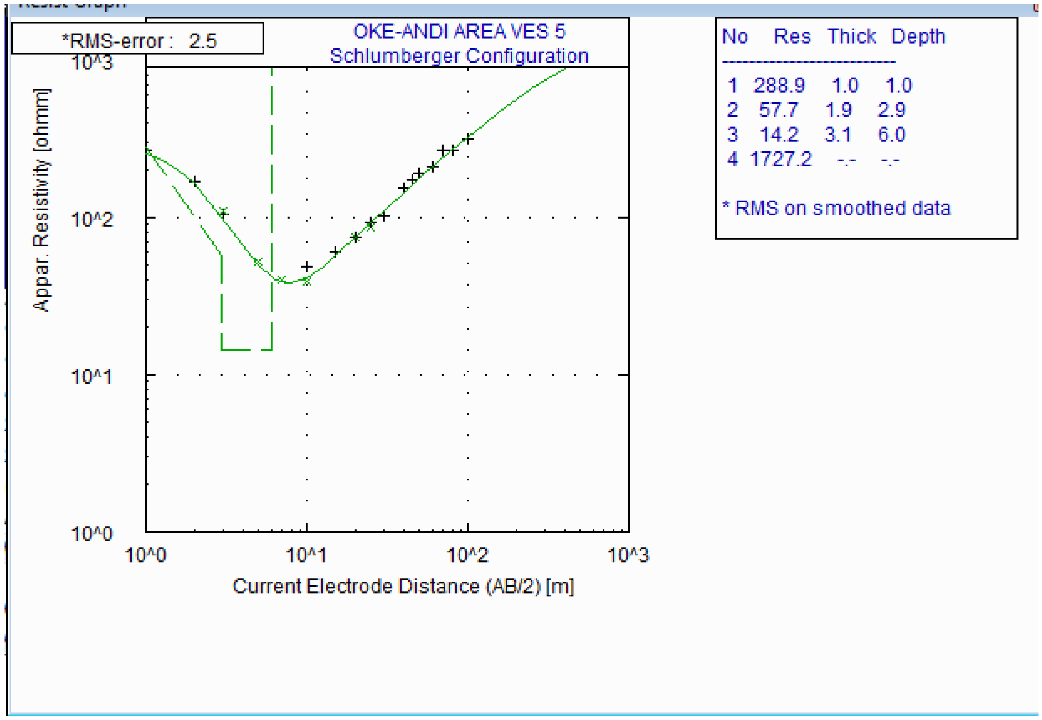

Figure 8: Resistivity Sounding Plot for VES 5.

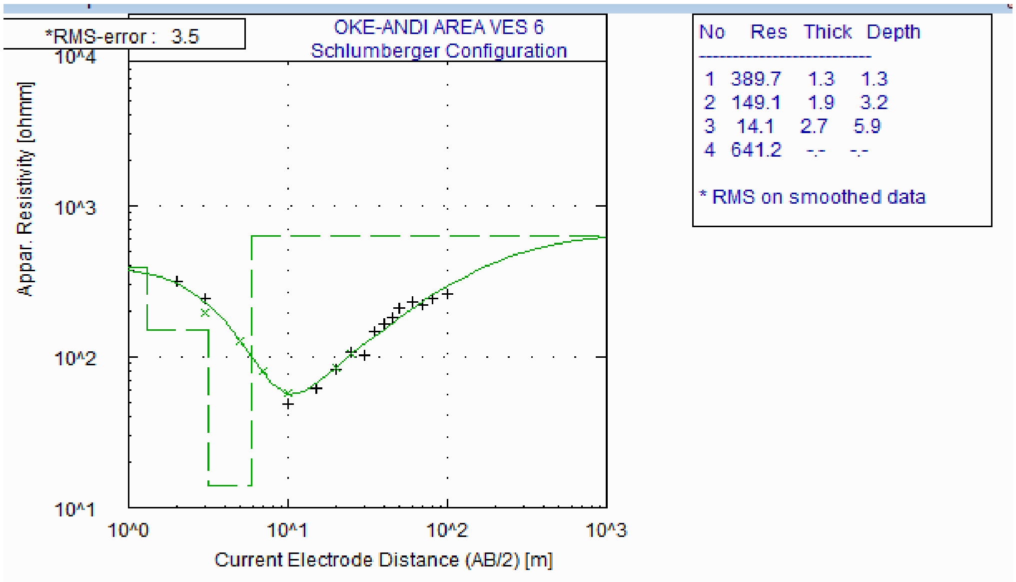

Figure 9: Resistivity Sounding Plot for VES 6.

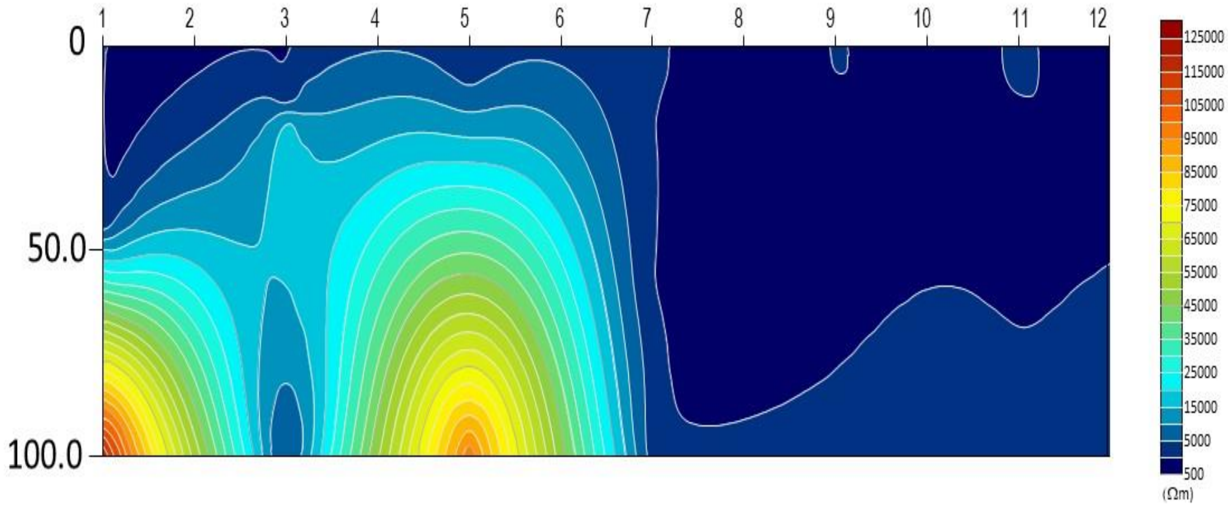

Figure 10: Resistivity Distribution Map of the entire VES stations.

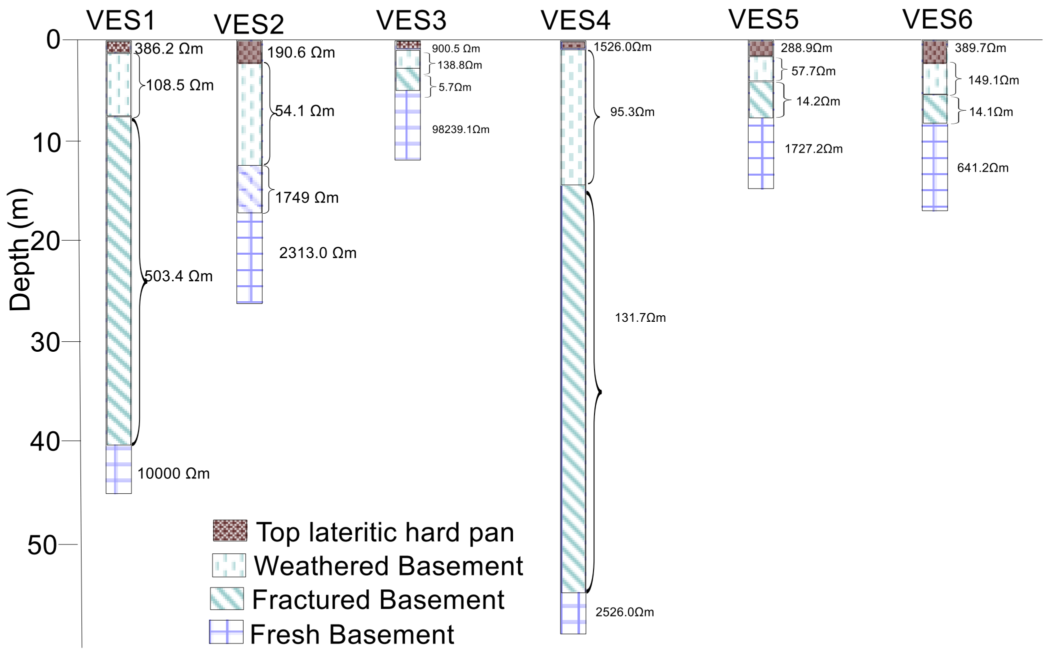

Figure 11: Geo electrical resistivity log.

The immediate underlying resistivity layer depth zone corresponds with the existing saturated aquifer of the study area. Multiple layers were selected to differentiate different lithological units and geo-section and also convert the field resistivity value into a reasonable geological picture. The first layer is interpreted as the top lateritic soil layer and is basically composed of rock units. The top most as seen from the section is made up of mostly sand and clay with thickness ranging from 0.44 to 1.15 m and resistivity values varying from 190 to 900 Ωm representing about 20% of the entire formation within this section. The second layer interpreted as the weathered basement has a resistivity ranging from 54.1 to 150 Ωm with thickness varying from 2.0 to 17 m. The third layer is the fractured basement with the resistivity value from 5.7 to 503.4 Ωm while the thickness ranges from 1.51 to 50.82 m. The fourth layer, fresh basement has resistivity value above 700 Ωm.

The field resistivity interpretation has the fracture which occurs after the second layers of the area. Since the presence of fracture in an aquifer is generally and usually accompanied by high fluid streaming potential and substantial water which can be collected through the fractures therefore providing a high yield groundwater resources. In view of this, the low resistivity areas, weak zones, delineated by the geoelectric curves and maps from the six VES stations will present a high level of groundwater yield and considered the most favorable target for sitting borehole or well tube around the study area. The pressure of the ever-growing population of inhabitants of the area of study has grown beyond the capacity of the existing boreholes, storage facilities and reticulation network. There is a need for proper completion and maintenance of borehole and expansion of storage and reticulation facilities. In view of this, an average depth of 40 m to 50 m boreholes drilling is recommended for in this area.

CONCLUSION

The groundwater potential and protective capacity evaluation of the rock units around Oke – Adini area in Ilorin, North-Central, Nigeria was undertaken using twelve (12) vertical electrical soundings stations. The computer iteration interpretation technique revealed that the area is characterized by four (4) underlying layers earth model which comprises of topsoil with limited hydrologic significance, weathered layer, fractured basement and the fresh basement. The most promising aquifers where groundwater could be tapped are within and closed to VES 3, 6 and 7 with low resistivity values due to aquifer thickness and proximity to the river. These VES stations located by the river bank depict an indicative of high water bearing region. Majority of these areas characterised by zones of appreciable overburden thickness with clayey columns is found and observed to be thick enough to protect the aquifer in the area from the surface polluting fluid.

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