

GEOPHYSICAL INVESTIGATION FOR GROUNDWATER DEVELOPMENT AROUND CHAPEL OF LIGHT HOSTEL AREA, UNIVERSITY OF ILORIN

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ABSTRACT

This research was carried out to map underground water systems in the study area that can serve as additional water source because the school population is increasing. A total of twenty-seven vertical electrical sounding (VES) data was acquired along five profiles using the Schlumberger electrode configuration with half current electrode separation ($AB/2$) varying from 1m to 100m. VES data interpretation was done by plotting the apparent resistivity against $AB/2$ and using Moore's cumulative method to obtain initial model parameters. This was subsequently followed by computer iterations which helped to produce 1D resistivity curves. Resistivity pseudo-cross sections were obtained from the curves. The pseudo section gave a rough estimation of the true subsurface resistivity distribution and thickness map, was subsequently produced. The result of data interpretation revealed three geo-electric layers which correspond to the topsoil, weathered/fractured basement, and the fresh basement. The top soil (having some lateritic units in some areas) with relatively high resistivity values (600-2000 ohm-m) are observed across the entire study area. The weathered/fractured layer is usually regarded as the aquifer in basement terrains. The resistivity of the layer varies from 60.8 ohm-m to 390.5 ohm-m and the thickness ranges between 3.5m and 12.5m. The fresh basement was characterized by resistivity values that range from 1826 ohm-m to 67907 ohm-m. The isopach map shows that the thickness of the weathered layer is decent enough for groundwater accumulation and ranges from 3.5m to 12.5m. As observed on the map, the thickness of the aquifer layer is appreciable in the south eastern part of the study area. The result of this study has proved that there are significant underground water systems which can be harnessed as additional source of water for the school populace. The geophysical results presented here can be supported by borehole data if they are available.

Keywords: Resistivity, groundwater, aquifer, geo electric layer, vertical electrical sounding.

Introduction

Geophysical investigations are an integral part of pre-planning and design of any water resource project. As physical development gets to different sections of the university, it is presumed that new

structures will spring up around the study area because it is an enormous vacant land. However, around the area, already, is a chapel and a hostel. The University of Ilorin has a robust water system,

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sourced from the university dam. Nevertheless, this study was conducted to investigate the possibility of harnessing underground water systems in the future as population increases. Since water is considered an important necessity in the sustenance of life, and a lot of farms are found around the area, the availability of good quality water for domestic and agricultural use is very important. This is even more important because groundwater happens to be a more reliable source of water for more than half of the world's population (Alabi *et al.*, 2010; Anomohanran, 2011).

According to Otutu and Oviri (2010) groundwater is the water found in the saturated layers of soils and rocks. This water is usually below the water table and is held in the sub-surface within the saturated zone under hydrostatic pressure. Such groundwater systems can be found in the sedimentary terrain or in the basement complex environment (Fadele *et al.*, 2013).

In other to explore this natural resource, various geophysical methods can be employed. These methods include electrical resistivity method, seismic refraction method, and many others (Karami *et al.*, 2009). The choice of method depends largely on the depth of investigation and many times the cost (Todd, 2004). Despite the fact that different geophysical methods can be used, the electrical resistivity remains the most commonly used method (Molua and Emagbetere, 2005). One of the reasons for that is that the ground resistivity is related to various geological parameters, such as, the mineral and fluid content, porosity and degree of water saturation in the rock. Anomalous conditions within the subsurface, such as electrically better or poorer conducting layers, are inferred from electrical resistivity studies (Sharma, 2012). In addition, the field operation is quite easy and data processing is less cumbersome. Also, it is nondestructive and economical (Iserhien-Emekeme *et al.*, 2004; Atakpo and Ofomola, 2012). The electrical resistivity method can be used to estimate different layer resistivities, the depths

to various subsurface geoelectric layers and their thicknesses. This method provides a very reliable means of locating weathered/fractured zones in the basement complex environment. Once this is mapped, productive boreholes that can provide potable water all year round can be recommended. This paper is an attempt to describe the various geoelectric layers that can be found and the thickness of the producing aquifer in the area. This will help in the design and preplanning of any water resource project in the area. Also, by combining results of hydrogeological features and geology with this geophysical information, one may be able to describe subsurface structural features and aquifer geometry.

Materials and Methods

The project site is located in the southern part of the University of Ilorin (Permanent Site), Kwara State. The University Campus is situated about 12km east of Ilorin Township and it occupies a total area of about 15,000 hectares of land. The campus lies within longitudes 4°39'-4°E and latitude 8°28' – 8°30'N. It falls within the basement complex of Nigeria. (Olasehinde and Raji, 2007). The area can be accessed by major roads as well as footpaths that are interconnected. The geophysical survey conducted covers an area of approximately 94Km². Vertical electrical sounding were conducted along 6 profiles with station interval of 50m and an approximate profile separation of 100m. Features around the study area include a church, farms, and chapel of light hostel. Figure 1 is a base map of the study area showing these features as well as the VES points along each profile.

An earth resistivity meter was used to acquire the electrical data by injecting electrical current into the ground using two pair of current electrodes and measuring the resulting potential difference created within the earth. The half current electrode distance (AB/2) was varied between 1 and 100m. The principle of Ohms law ($R=IV$) was used to determine the resistance and the resistance was

further converted to apparent resistivity using the geometric factor of the Schlumberger array. Apparent resistivities of each corresponding data point were hence calculated by taking the product of resistance and the geometric factor at each depth of study. The apparent resistivities obtained on the field were then plotted on a log-log graph to generate 1D resistivity curves for each sounding. The sounding curves were compared with model curves in order to determine the true layer resistivity and thickness of each geo-electric layer in the study area using model parameters from Moore's cumulative approach (1945). This was needed as input in the computer iteration process using WIN- RESIST software (version 1.0). Interpretation is considered satisfactory when the R.M.S (error) is less than or equal to 10%.

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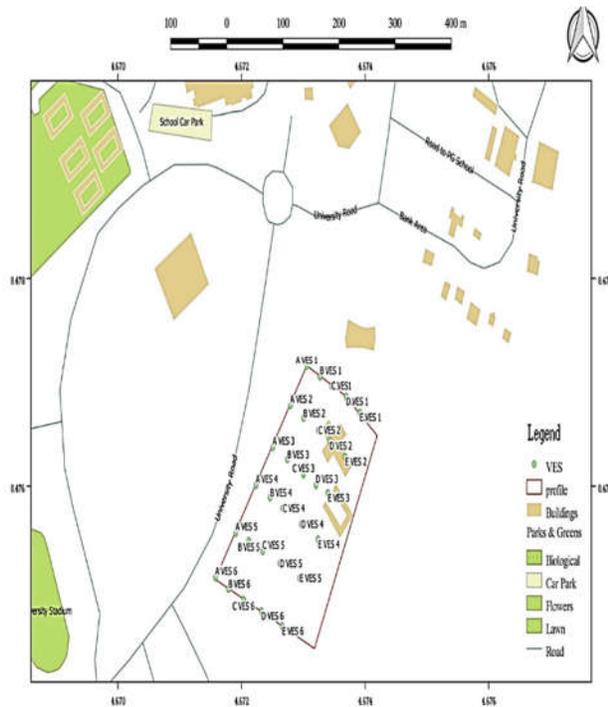


Fig 1: The Map of the Study Area

Pseudo-resistivity sections were produced using IPI2WIN (version 3.0.1). Even though an approximate image of the true subsurface resistivity is displayed on a resistivity pseudo section, the type of array used will determine the shape of the contours (Loke, 2001). This may or may not affect

the results obtained. The Pseudo-cross sections in this project showed the cumulative resistivity along the VES points. Pseudo sections were generated by joining resistivity of layers along a profile guided by least value fitting error.

Twenty-seven (27) Vertical Electric Sounding (VES) were conducted in all, with current electrode spreading ranging from 1m to 100m. At the end of the exercise, an isopach map of the aquifer layer was generated by contouring the top and bottom depths of the aquifer layer and taking the difference.

Results and Discussion

Interpretation of VES Data and Resistivity Sounding Curves.

The VES data are presented as sounding curves (i.e. plots of apparent resistivity against half electrode spacing). This was used to determine the subsurface geo electric layers. The sounding curves and the resultant geo-electric parameters of resistivity and depth are shown in Figs. 2- 4. The curves revealed three geo-electric layers comprising the lateritic topsoil/sandy topsoil whose resistivity varies from 513.3 ohm-m to 1489 Ohm-m and thickness range from 0.5m to 3.3m; the second layer, interpreted as the weathered layer, with resistivity ranging from 60.8 ohm-m to 390.5 Ohm-m and thickness ranging from 3.6 to 12.6m; and the basement layer with resistivity value of 1826 Ohm-m to 67,907 ohm-m. Table i and ii summarizes the overall sounding results obtained from the field. From the tables, the subsurface lithological characterization shows that the aquifer in the study area are defined by the weathered/fractured layer. This is in agreement with earlier studies carried out in other parts of university of Ilorin for example, the research work by Olasehinde and Raji (2007) revealed that there are predominantly three geo electric layers in the area that they investigated. However four layer models were also included in their results. The average depth to the low resistivity aquifer layer around chapel of light hostel area is layers is 8.9m.

Pseudo Resistivity section interpretation.

A total of five resistivity pseudo sections were generated from five profiles and are displayed in Fig. 5-11. They were obtained from the correlation of VES data results along the profile.

In Figure 5, the profile is made up of resistivity values from VES 1, 2, 3, 4, 5 and 6. VES points 1 to 6 are labelled as Point a1 (pa1) – Point a6 (pa6). Three geoelectric layers are interpreted to underlie this profile, represented by different ranges of resistivity values. The resistivity values and depth to different resistivity zones are highlighted on the vertical axis. According to Milsom (2003), various rocks and sub-surface layers can be classified based on their resistivity values. Using this approach, the first layer is interpreted as the top soil with resistivity values ranging from 500ohm-m to 900 ohm-m. The top layer has relatively high resistivity values, which means it can be lateritic or sandy in nature. In addition, there are outcrops close to the study area. It is speculated that the high resistivity may be influenced by the resistivity of the shallow basement around the area. The intermediate layer is probably the aquifer unit and is therefore interpreted as the weathered layer/fractured basement. It has resistivity values ranging from 196 ohm-m to 380 ohm-m. VES 1, 2, 3, 4, 5 and 6 are good locations for groundwater amassing based on the consistent low resistivity values along the profile at the depth range of 7.2m to 37.3m.

In Figure 6, the results obtained are similar to that of profile one. The resistivity values are classified into 3 different ranges. The top layer is identified with resistivity values ranging from 420ohm-m to 1200 ohm-m. The next layer is characterized by low resistivity values and is also interpreted as the fractured basement. It has resistivity ranging from 110 ohm-m to 331 ohm-m. Therefore, there are probable spots beneath these VES points (except at VES point 2) where groundwater can accumulate at the following depths: 7.2m, 13.9m and 20.0m respectively. Nwankwo (2011) obtained a similar result and demarcated three geo electric layers

around MAGDAS observatory unit area, in university of Ilorin. His own results showed that the thickness of the weathered layer is usually more than 25m whereas generally, the thickness of the weathered layer in this study ranges between 3.5m to 12.5m.

Figure 7 is showing correlated resistivity values from VES pc1, to pc6. At VES station 1, the low resistivity layer is too shallow to be interpreted as an aquifer. Below VES station 2, low resistivity zones are not observed. Three geoelectric layers are interpreted to underlie the area. The top layer is interpreted as a lateritic soil and depicts a highly inhomogeneous soil with resistivity values ranging from 160ohm-m to 1300 ohm-m. This soil can be observed visually with the physical eyes around the area. The intermediate layer is the interpreted unit for groundwater accumulation because the range of resistivity values is low. The resistivity value is between 100 ohm-m and 300 ohm-m. VES stations pc3-pc6 are probable locations for groundwater amassing on this profile. The depth to the aquifer unit ranges from 7.2m to 37.3m.

VES point d2 (pd2) and part of point d3 represents the location of the chapel of light hostel. In Figure 8, even though, the hostel posed as an obstruction to data acquisition, resistivity values were correlated across VES point d1, d3, d4, d5 and d6. From observation, the resistivity of the top layer is very low in some areas and highly variable ranging from 250ohm-m to 700 ohm-m. VES point d1 – point d3 shows the presence of low resistivity layers at shallow depths. This may represent top soil that is not composed of either sand or laterite. It is underlain by a low resistivity layer interpreted as weathered layer or fractured basement. This layer has resistivity values ranging from 110 ohm-m to 251 ohm-m. VES pd4 to pd6, are recommended locations for groundwater amassing based on the resistivity values and thicknesses of the weathered layer. The depth to such the aquifer unit ranges between 10m and 20m.

The last Pseudo section in Figure 9 is also separated into three resistivity sections; the first geo electric layer with a high resistivity values limited to soundings point e1 and point e2. This top layer is also characterized by low resistivity values that ranges between 180ohm- and 500 ohm-m at VES stations pe3-pe6. The second layer has low resistivity values limited VES pe3 to pe6. This ranges between 139ohm-m and 290 ohm-m. The deeper portion of the pseudo section is interpreted as the bed rock and has resistivity values ranging from 924 ohm-m to 3034 ohm-m.

Isopach map interpretation

Figure 10 shows the Isopach map of the weathered/fractured layer. The isopach map of

weathered/fractured, shows thickness of interpreted aquifer units in the range of 3.5m to 12.5m. Areas with thick aquifers are marked C Q and E. The aquifer thickness is high and decent for groundwater build-up particularly within the areas where the thickness is above 6.5m. The area marked C in the southern part of the study area has the highest thickness observed. It is expected that the overburden, covering the fresh basement is thick enough to collect adequate water for groundwater exploitation in the area. VES stations pa3, pc1, pd1, pd4-pd6, pe4-pe6, and pe3-pe5 fall among the area and are recommended as drilling sites for groundwater development.

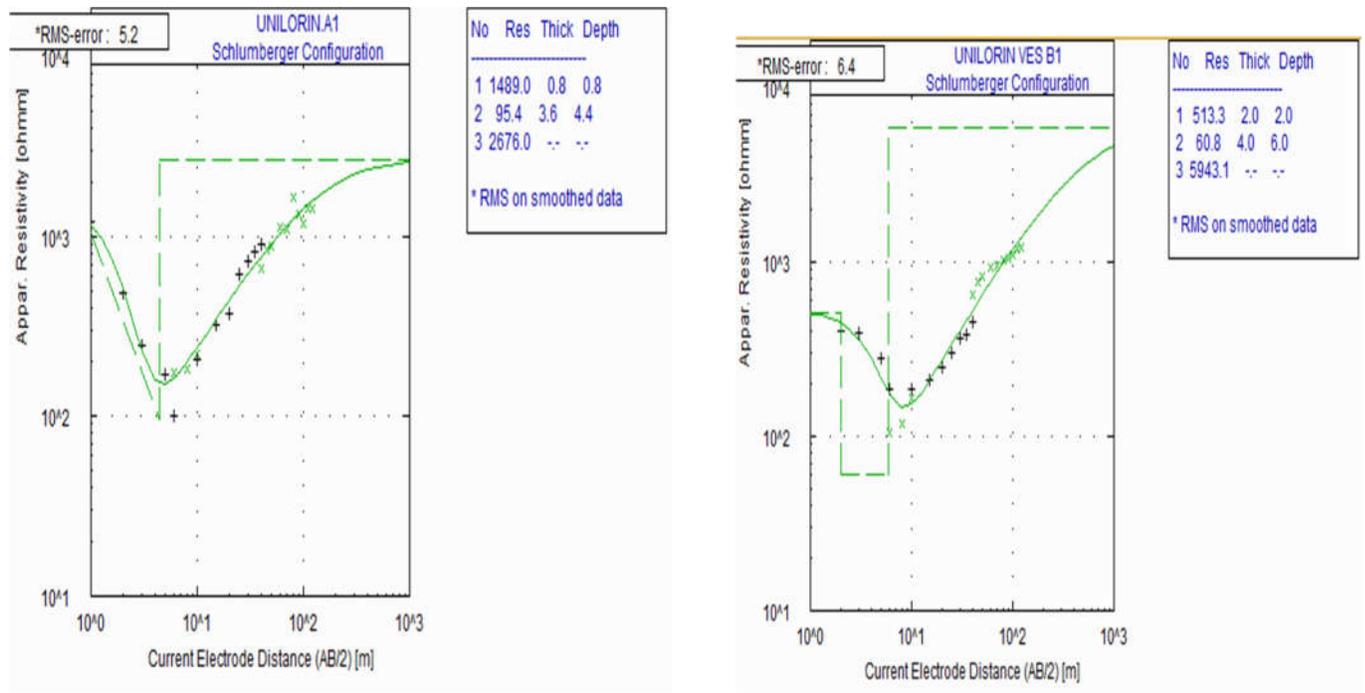


Fig. 2a & 2b: Resistivity sounding curve for location A1 and B1

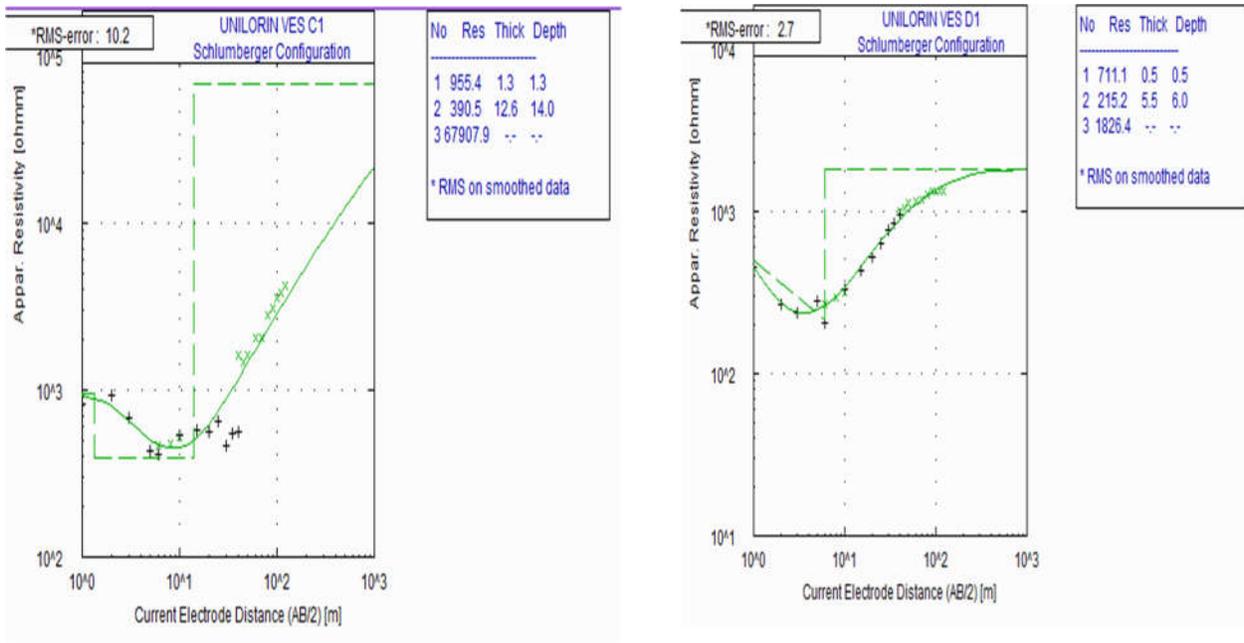


Fig. 3a&3b: Resistivity sounding curve for location C1 and D1

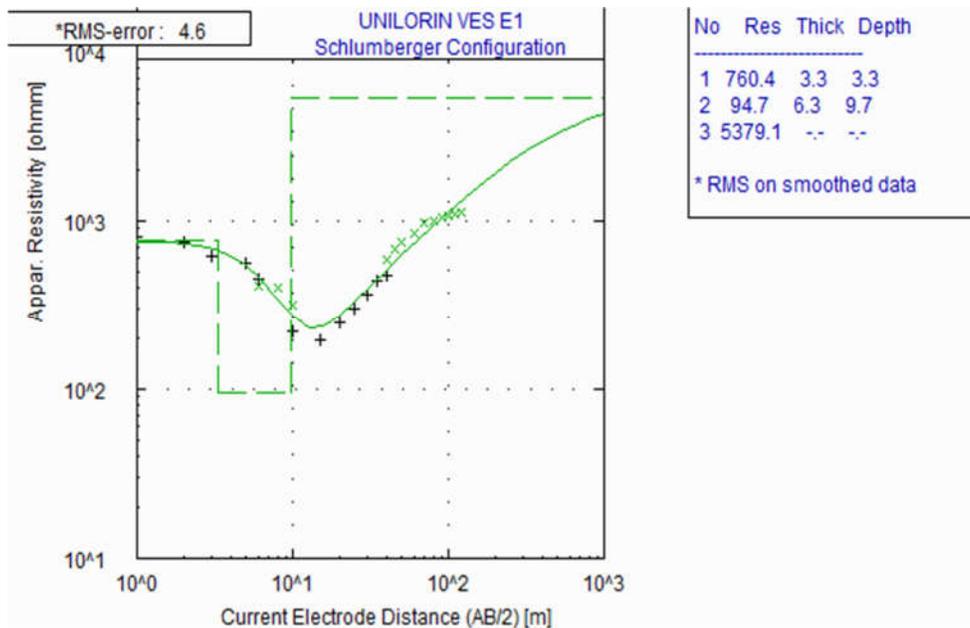


Fig. 4: Resistivity sounding curve for location E1.

Table i: Summary of obtained geo electric parameters (Profile A-C).

| Ves no | P1 (ohm-m) | P2(ohm-m) | P3(ohm-m) | h1(m) | h2(m) | h3(m) |
|--------|------------|-----------|-----------|-------|-------|----------|
| pa1 | 200 | 95.4 | 2675 | 0.8 | 3.6 | ∞ |
| pa2 | 967 | 110.4 | 3061 | 2.1 | 3.6 | ∞ |
| pa 3 | 1104 | 130.0 | 8101 | 0.8 | 8.1 | ∞ |
| pa 4 | 955.5 | 64.5 | 7575.4 | 2.9 | 4.0 | ∞ |
| pa 5 | 729.5 | 47.4 | 29642 | 2.7 | 6.3 | ∞ |
| pa 6 | 980.6 | 73.6 | 2668 | 2.5 | 4.8 | ∞ |
| pb1 | 513.3 | 60.8 | 5943.1 | 2.0 | 4.0 | ∞ |
| pb 2 | 1093.7 | 81.9 | 3629.6 | 3.4 | 4.7 | ∞ |
| pb 3 | 954.7 | 80.3 | 7149.1 | 2.8 | 5.8 | ∞ |
| pb 4 | 667.8 | 67.8 | 4103.0 | 2.2 | 5.4 | ∞ |
| pb 5 | 481.9 | 48.2 | 8436.9 | 2.5 | 6.8 | ∞ |
| pb 6 | 471.3 | 88.9 | 6977.6 | 0.9 | 7.4 | ∞ |
| pc1 | 955.4 | 390.5 | 67907 | 1.3 | 12.6 | ∞ |
| pc 2 | 937.8 | 102.1 | 3309.3 | 3.4 | 5.9 | ∞ |
| pc 3 | 724.5 | 72.8 | 2326.5 | 2.3 | 3.8 | ∞ |
| pc 4 | 339.0 | 93.9 | 8764.6 | 2.0 | 6.5 | ∞ |
| pc 5 | 998.8 | 72.4 | 1186.8 | 3.6 | 7.0 | ∞ |
| pc 6 | 505.6 | 97.6 | 5521.4 | 1.3 | 7.4 | ∞ |

Table ii: Summary of obtained geo electric parameters (Profile D-E).

| Ves no | P1 (ohm-m) | P2(ohm-m) | P3(ohm-m) | h1(m) | h2(m) | h3(m) |
|--------|---|-----------|-----------|-------|-------|----------|
| pd1 | 711 | 215.2 | 1826.4 | 0.5 | 5.5 | ∞ |
| pd2 | 912.2 | 86.2 | 4918.9 | 3.2 | 7.2 | ∞ |
| pd3 | Survey not carried out due to obstruction: Hostel | | | | | |
| pd4 | 957.5 | 113.3 | 10290.0 | 3.7 | 9.8 | ∞ |
| pd5 | 354.3 | 97.4 | 3243.5 | 2.6 | 12.7 | ∞ |
| pd6 | 786.4 | 88.8 | 5934.6 | 3.3 | 7.5 | ∞ |
| pe1 | 760.4 | 74.7 | 5379.1 | 3.3 | 6.3 | ∞ |
| pe2 | Obstruction: Hostel | | | | | |
| pe3 | 292.3 | 54.7 | 16044.7 | 2.7 | 4.1 | ∞ |
| pe4 | 456.8 | 49.5 | 28,828.8 | 3.3 | 5.1 | ∞ |
| pe5 | 989.6 | 56.4 | 17123 | 3.3 | 4.4 | ∞ |
| pe6 | Obstruction: farm | | | | | |

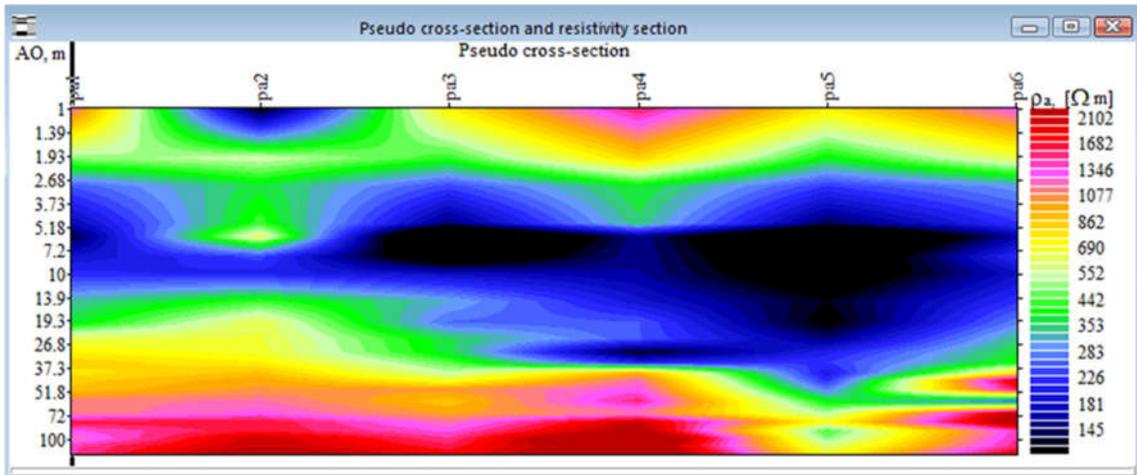


Fig. 5: Resistivity Pseudo section of profile A

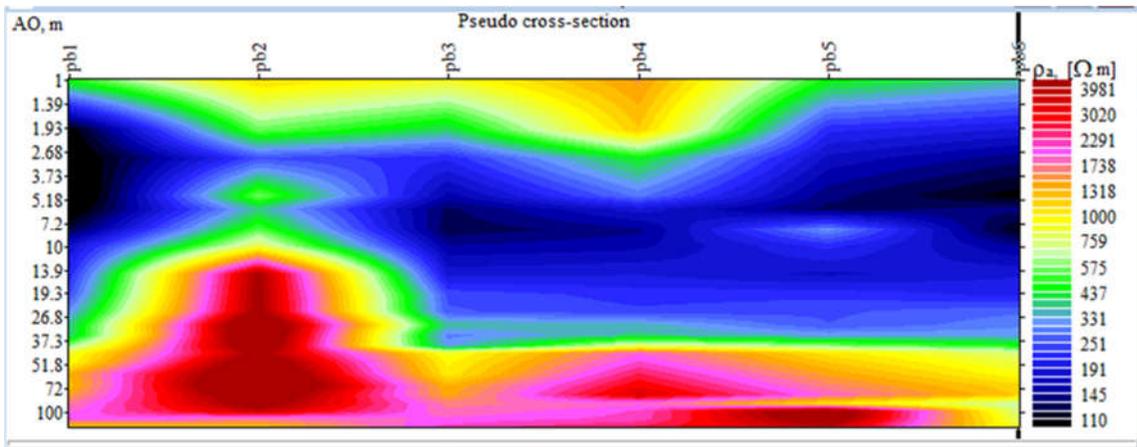


Fig. 6: Resistivity Pseudo section of profile B

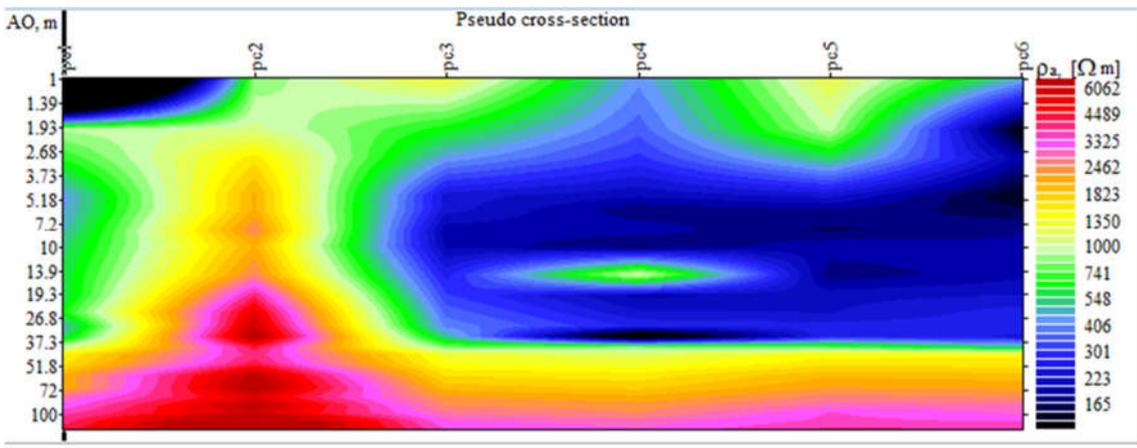


Fig. 7: Resistivity Pseudo section of profile C

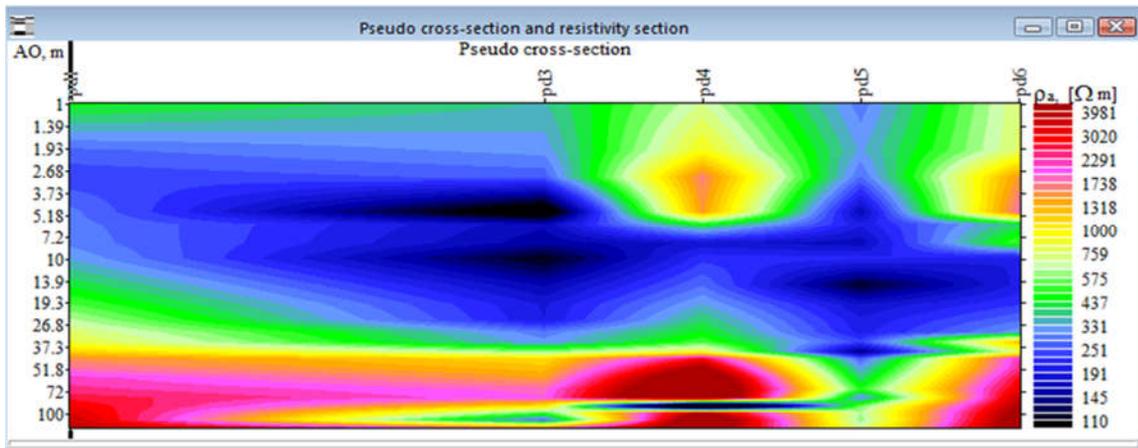


Fig. 8: Resistivity Pseudo section of profile D

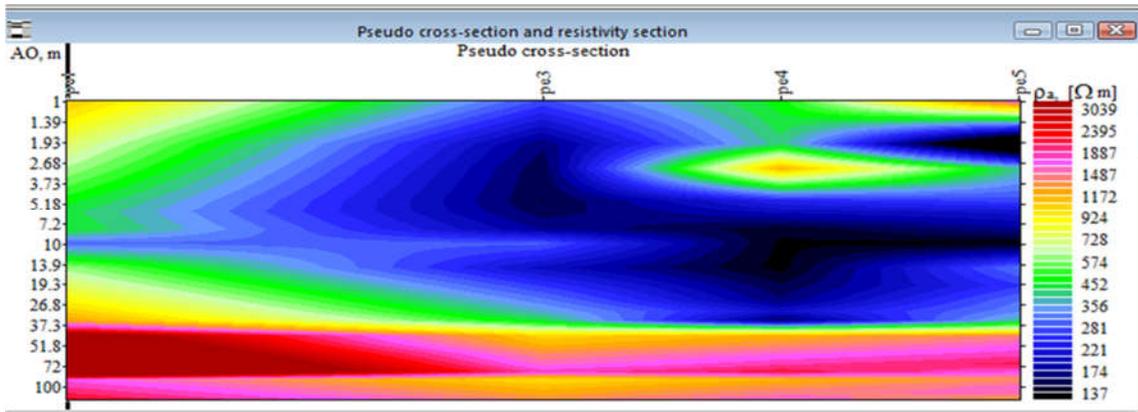


Fig. 9: Resistivity Pseudo section of profile E

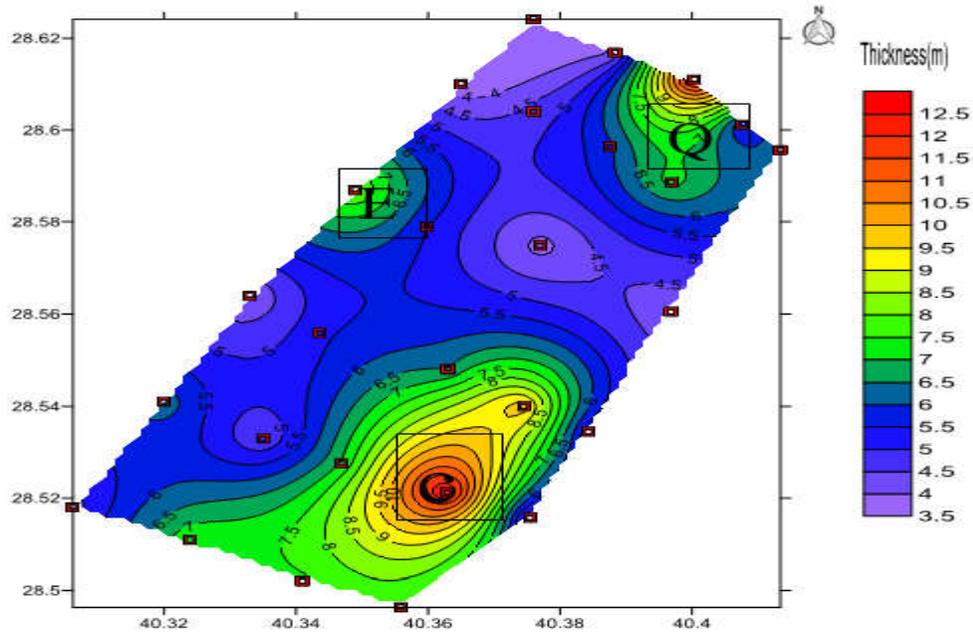


Fig. 10: The isopach map of the weathered basement

Conclusion

The study has demonstrated the usefulness of the VES method in the exploration of groundwater in the Basement Complex Terrain of UNILORIN. In general, the VES curves obtained exhibited a three-layer curve type, showing that the first layer is highly resistive in most cases. This was followed by the next layer which is observed to be less resistive and is interpreted as the weathered basement and finally, the highly resistive fresh basement. The weathered basement was earmarked as the aquifer unit. The thickness of this unit as seen on the isopach map ranges between 3.5m and 12.5m. This thickness is higher in the southern part of the study area. The implications presented by this study is that groundwater aquifer exist in the study area especially in the southern part of the study area and can be exploited as an additional source of water for residents and the teeming population of university of Ilorin. The geophysical results presented here can be supported by borehole data in the nearest future.

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