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Full Length Research Paper

Estimation of aquifer characteristics using vertical electrical soundings (VES) data from Enugu State University of Science and Technology, Agbani, Nigeria

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Vertical electrical soundings (VES) were carried out in order to determine the groundwater potential of the Enugu State University of Science and Technology, Agbani, Nigeria. The instrument used was the ABEM Terrameter SAS 300B, employing the Schlumberger electrode configuration. Interpretation of the VES data by partial curve matching technique aided by computer modeling showed that the sampled earth subsurface can be described mainly in terms of four geoelectric layers. Estimate of aquifer characteristics showed that the thickness is highly variable and ranges from 20 to 45 m while the transmissivity ranges from 7 to 16.5 m^2/day. Fine-medium-coarse grained sands constitute the aquifer in the area. The inferred transmissivity of the aquiferous layer enabled the delineation of the best portion of the study area for groundwater development programme.

Key words: Groundwater, aquifer, thickness, transmissivity, resistivity.

INTRODUCTION

On relocation of the Enugu State University of Science and Technology (ESUT) to its permanent site at Agbani in 2006, the problem of portable water supply to the university, especially the students in the hostels, was one of the teething problems of the university. The students in and around the university had to grapple with this problem by resorting to all sorts of unhygienic or unsafe water. Early attempts made towards solving this water problem by sinking three boreholes at different locations in the university could not give the needed solution as only one borehole was functional; the other two were unproductive. This presents the dire need for planning for a sustainable development of the groundwater resources of the area. Effective water development programme of an area must include a carefully conducted geophysical investigation. Hence, the needs for a geophysical study of the groundwater potentials of the area.

The vertical electrical sounding (VES) method has been chosen for this study in order to provide a geophysical database for exploration of the university groundwater resources. VES has proved to be effective in solving groundwater problems in most places in Nigeria (Onuoha and Mbazi, 1988; Mbonu et al., 1991; Mbipom et al., 1996; Ekine and Osobonye, 1996; Eze and Ugwu, 2010).

In the present study, an attempt had been made to establish the aquifer characteristics of the studied area and hence delineate the best area for drilling productive boreholes in the university. This is important, considering the large costs (up to one Million Naira and above) of drilling boreholes in Nigeria.

Geology and hydrogeology of the study area

The study area lies between latitude 6°18lN and 6°19lN and longitude 7°32lN and 7°33lE in Nkanu West Local Government Area of Enugu State, Nigeria and covers an area of about 3.46 km^2 (Figure 1). The study area is within the southern portion of the Benue Trough of Nigeria and is underlain by four main geologic formations: the Asu River Group, Eze-Aku Shales, Agwu-Ndeaboh

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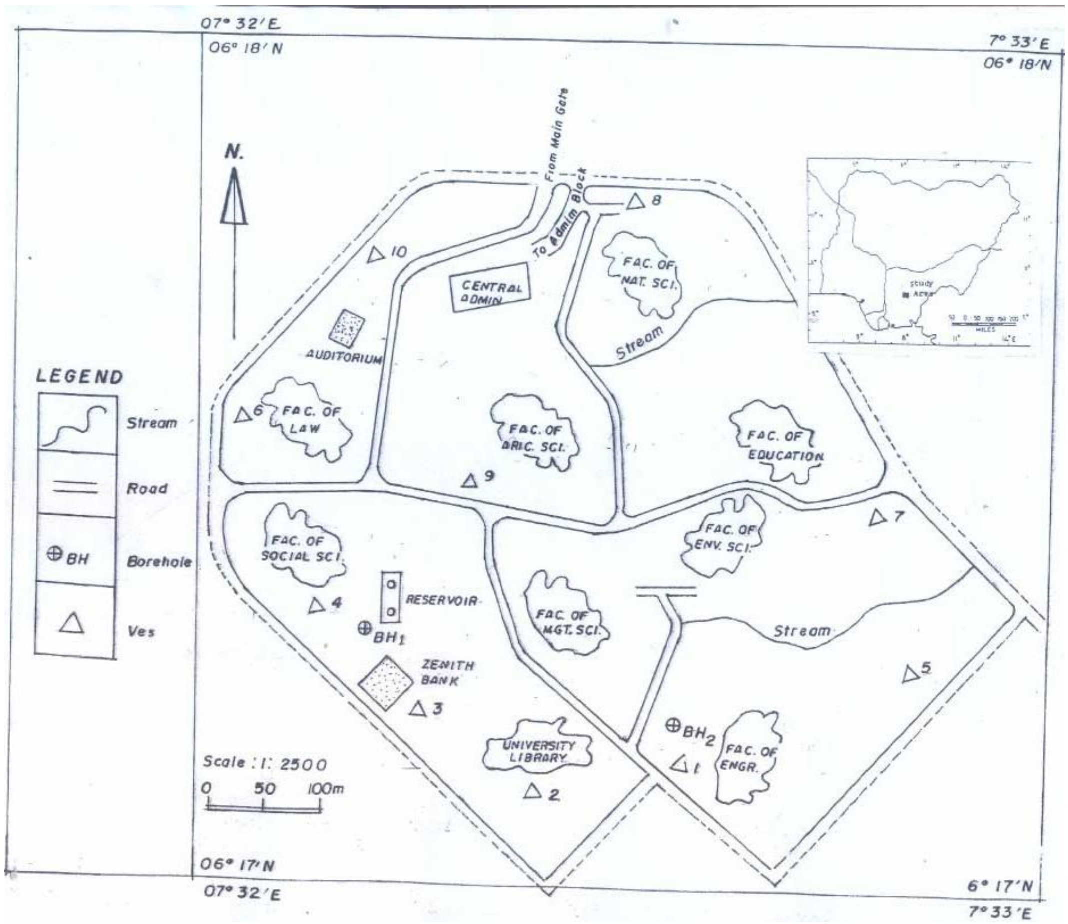

Figure 1. Location map of the study area showing sounding stations.

Shales, and Enugu Shales (Reyment, 1965; Murat, 1972; Nwachukwu, 1972; Hoque, 1977). The shales and limestone of the Albian Asu River Group (Lower Cretaceous) are the oldest sediments in the area (Figure 2). Overlying the Asu River Group sediments are the Upper Cretaceous sediments, comprising mostly the Eze-Aku Shales. The Eze-Aku Shales consist of nearly 1000 m of calcareous flaggy shales and siltstones, thin sandy and shaly limestone, and calcareous sandstones (Reyment, 1965). They are of Turonian age and are overlain by younger sediments of the Agwu-Ndeaboh Shales. The Conanian Agwu-Ndeaboh Shales consist mainly of marine fossilferous bluish grey well bedded shales with intercalations of yellow limestone and fine grained yellow calcareous sandstones.

Study area

The sandstone bodies are consolidated due to long lasting over-burden pressure exerted by the younger overlying materials. They are overlain by the Enugu or Nkporo Shales (Campanian) which are also mainly marine in character, with some sandstone (Agbani sandstone) intercalations. Hydrologically speaking, the Agbani Sandstone is aquiferous. The recharge of the aquifer is copious judging from the rainfall pattern of the region. The existence of springs in the area confirm the presence of the water bearing sands whose exposure due to erosion leak water to the surface.

Physiography and drainage

The study area is low-lying, about 137 m above sea level. This result in the swamping of some areas by small rivers formed from the springs issuing from the exposed Agbani Sandstone bodies. The existing rivers are tributaries of the Asu River which constitutes the major drainage basin in the area.

MATERIALS AND METHODS

Data acquisition and interpretation

Ten vertical electrical soundings (VES) were carried out at various locations within the university as shown in Figure 1. The instrument

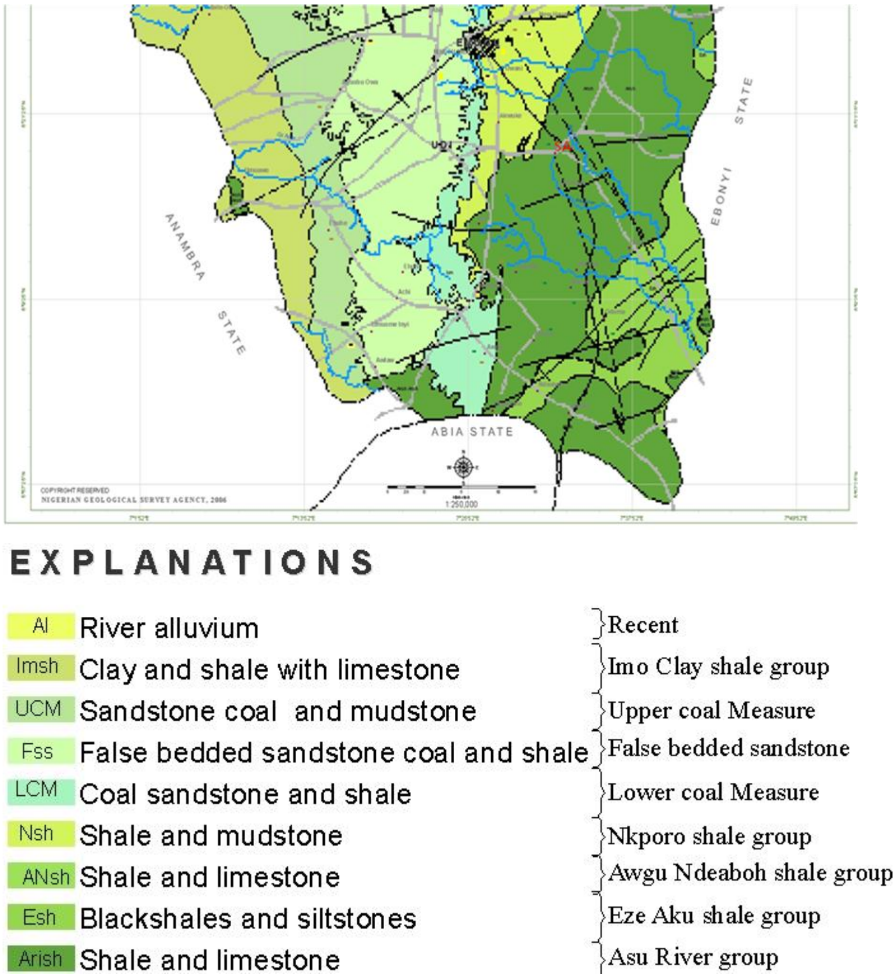

Figure 2. Geological and mineral resources map of the southern portion of Enugu State, Nigeria (NGSA, 2006) showing the study area.

used was the ABEM Terrameter SAS 300B, employing the Schlumberger electrode configuration. The instrument measures the resistance of the subsurface earth structure sampled by the survey. Resistance of the earth subsurface measured by the instrument was used to calculate the apparent resistivity of the earth model using the geometric factor of the Schlumberger configuration. The maximum current electrode separation (AB) achieved in the field ranged from 600 to 800 m, depending on the accessibility along each profile.

Values of apparent resistivity obtained from the field measurements at each sounding station were plotted as ordinate against half-current electrode separation (AB/2) as abscissa on log-log graphs. The field curves were first interpreted by partial curve matching technique in order to estimate the true resistivity and thickness of the layers using the two-layer curves of Orellena and Mooney (1966). These initial estimates were then used as the starting parameters for the computer iteration process of RESIST Version1 (Vander, 1988) software. This was used to obtain better estimates of the true resistivity values of the geoelectric layers and their corresponding thicknesses after several iterations. Results obtained from the VES data interpretation were used to compute the aquifer transmissivity, T, using the analytical relationship of Niwas and Singhal (1981):

$$T = K\sigma R = \frac{KS}{\sigma}$$

Where k, σ, R and S are the hydraulic conductivity, electrical conductivity, transverse resistance, and longitudinal conductance of the aquiferous layer, respectively. The transverse resistance, R, and longitudinal conductance, S, were obtained from the VES interpretation results using the equations of Maillet (1947) given by:

$$R = h_i \rho_i$$

and

$$S = h_i / \rho_i$$

Where h_i and ρ_i are the thickness and resistivity of the aquiferous layer for each VES station, respectively, (Marlum Nig. Limited, personal communication) gave K = 0.37 m/day from a pumping test on ESUT BH.2. The three parameters (R, S, and K)

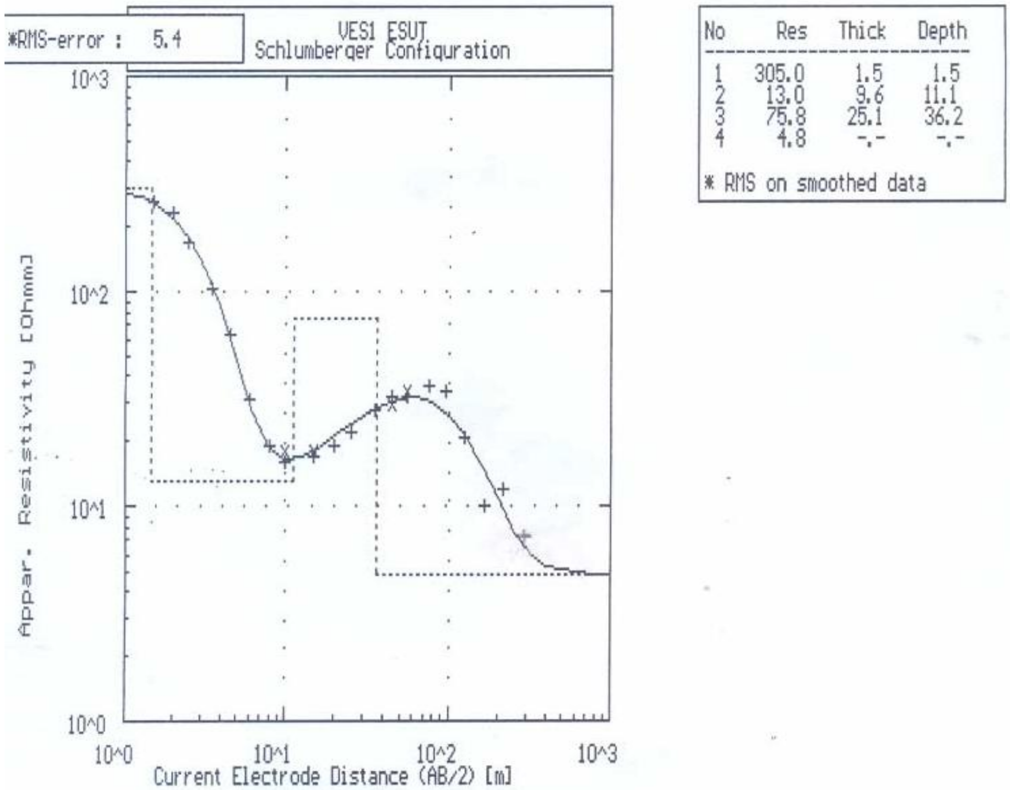

Figure 3. Interpretation result of VES 1 data.

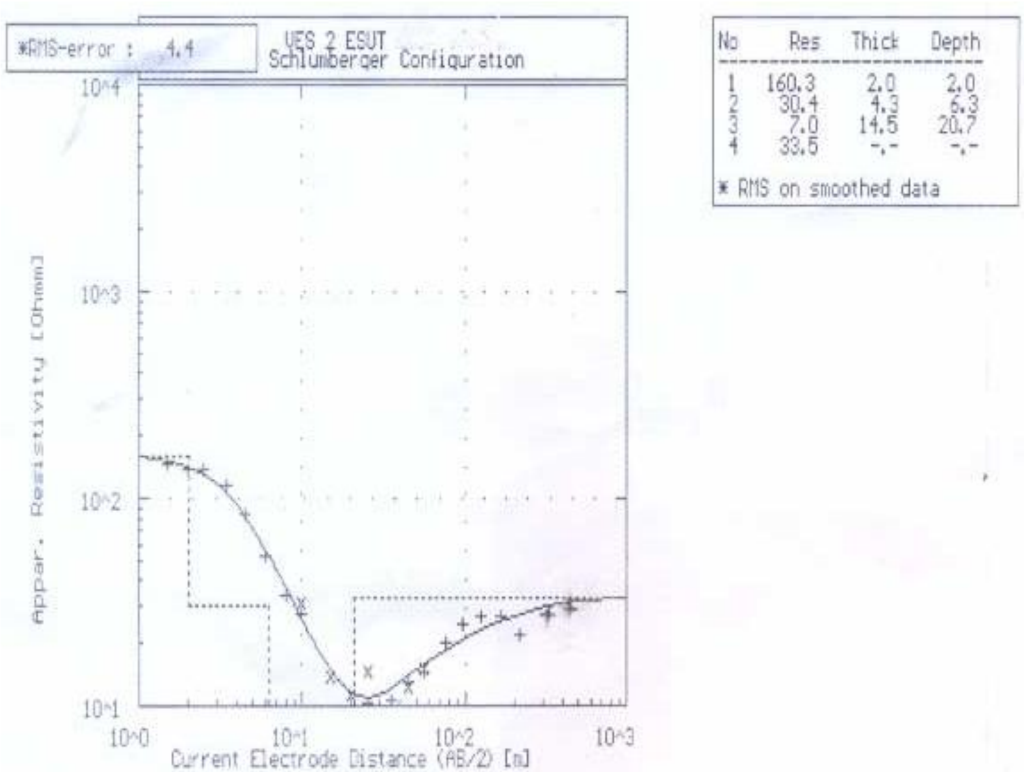

Figure 4. Interpretation result of VES 2 data.

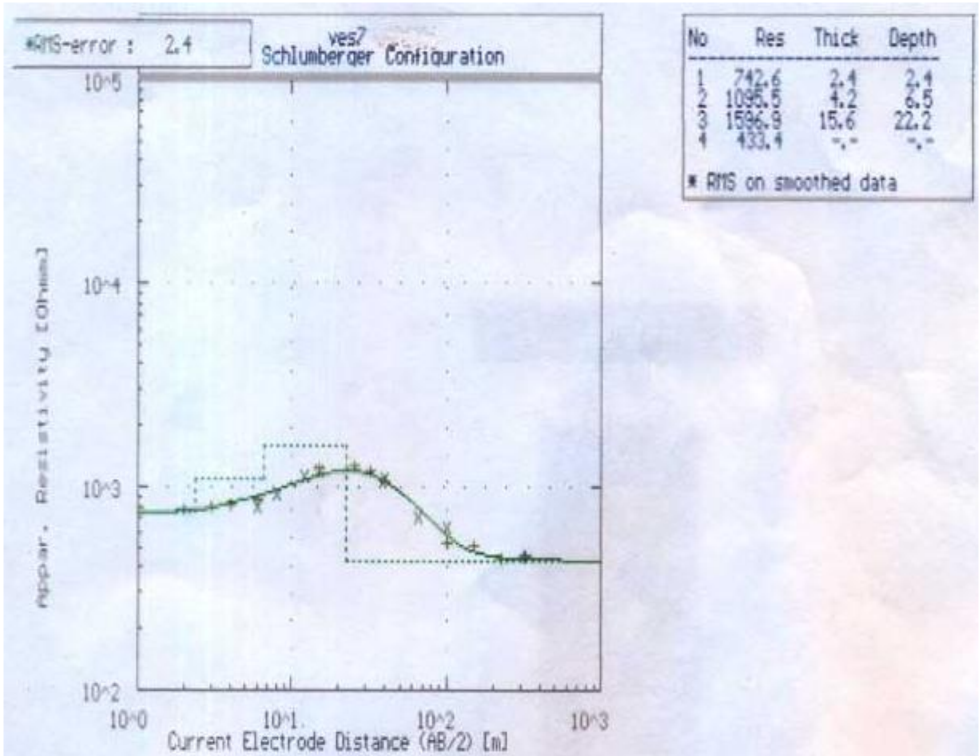

Figure 5. Interpretation result of VES 4 data.

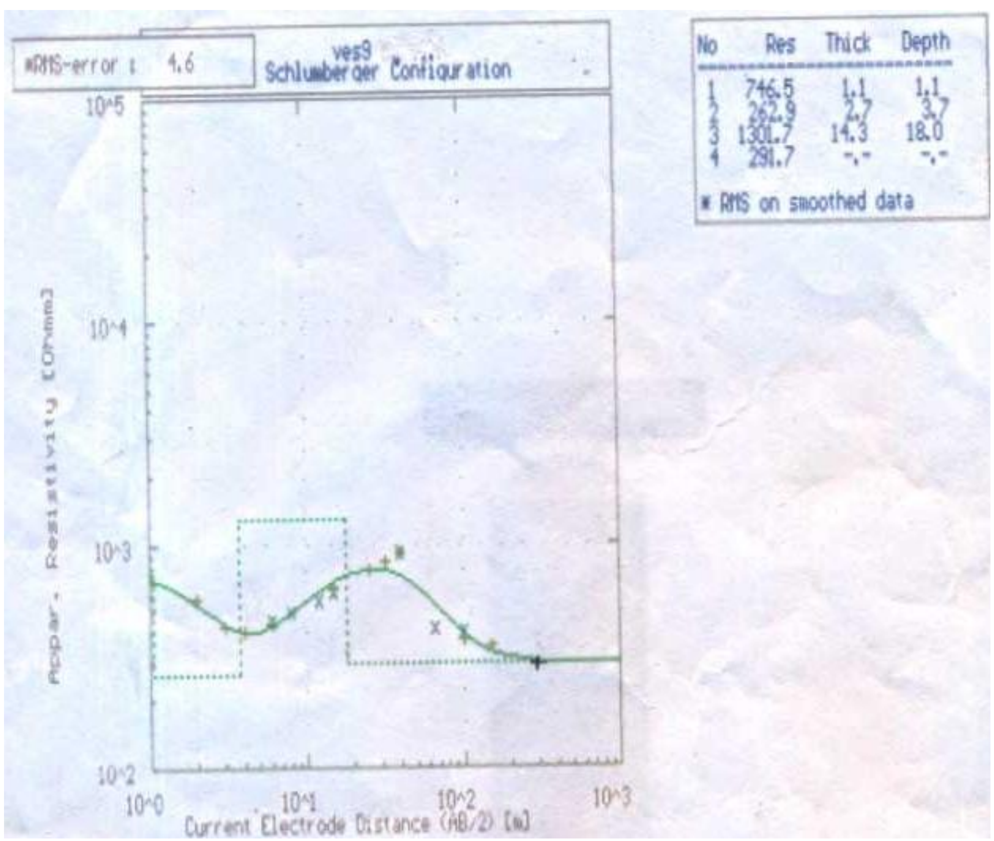

Figure 6. Interpretation result of VES 9 data.

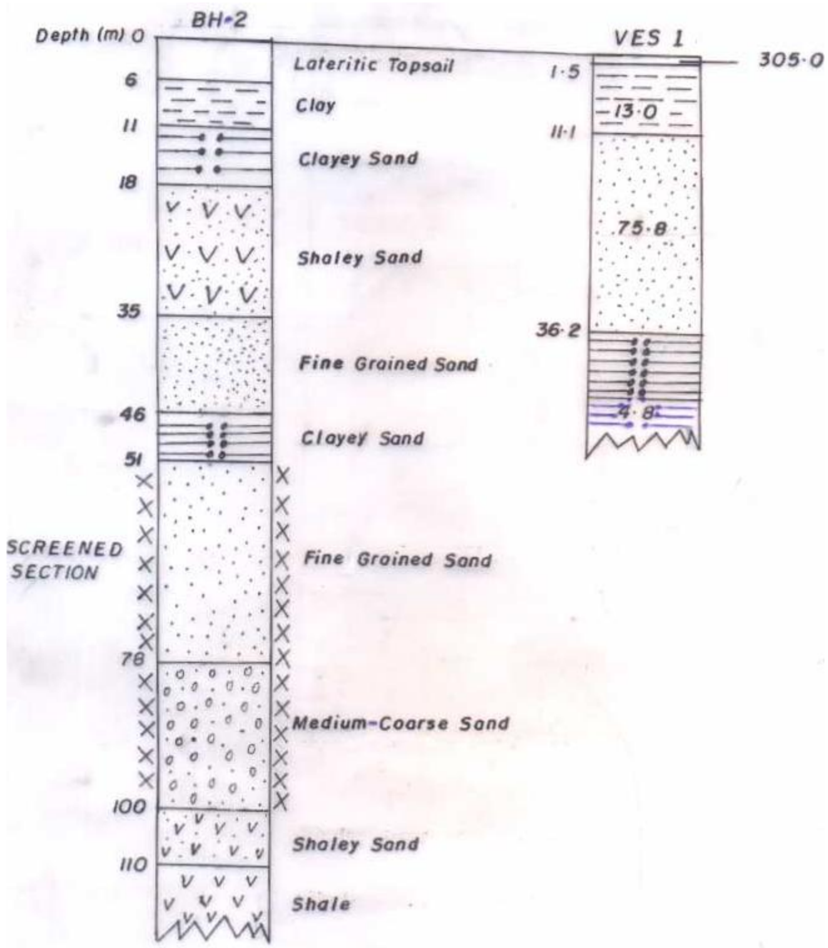

Figure 7. Correlation between lithologic log of ESUT borehole 2 and VES 1 result.

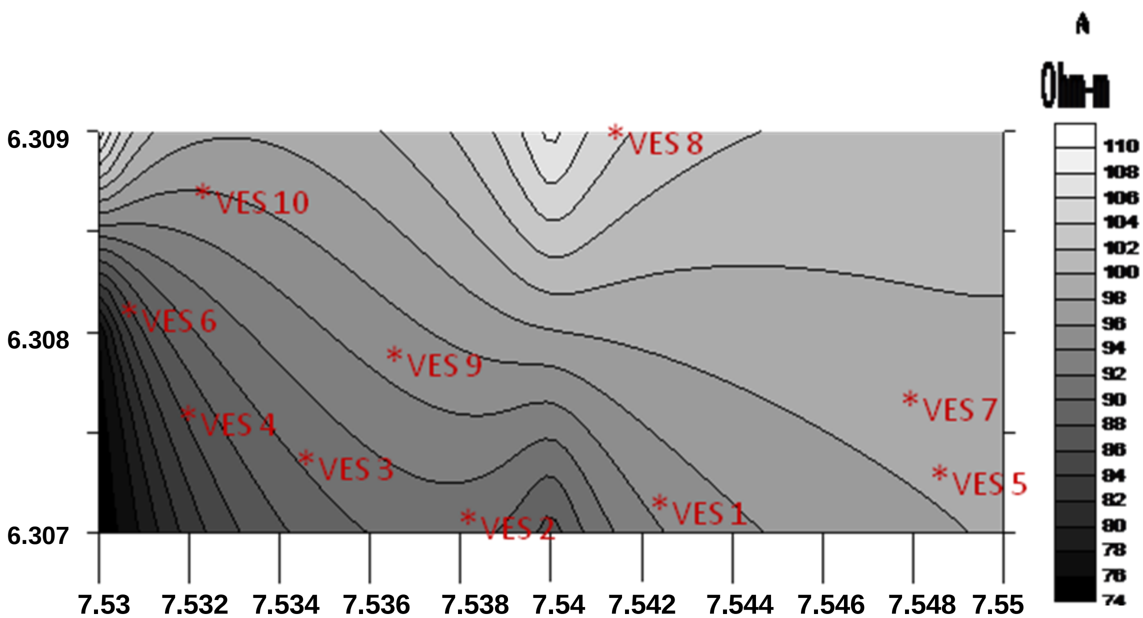

Figure 8. Contour map showing the aquifer resistivity in the study area.

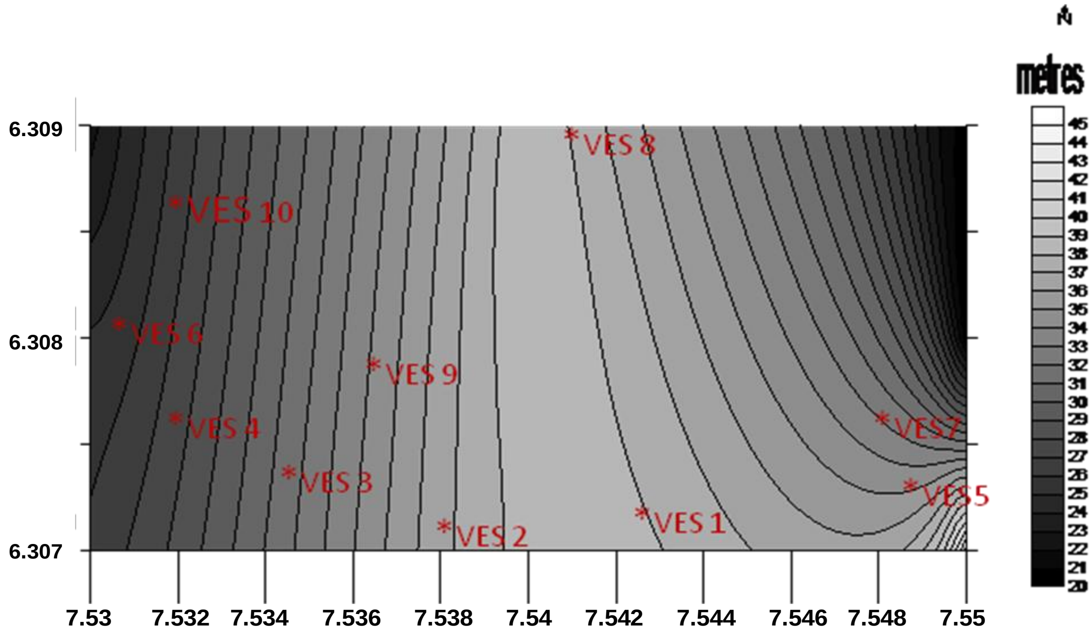

Figure 9. Isopach map of the aquifer in the study area.

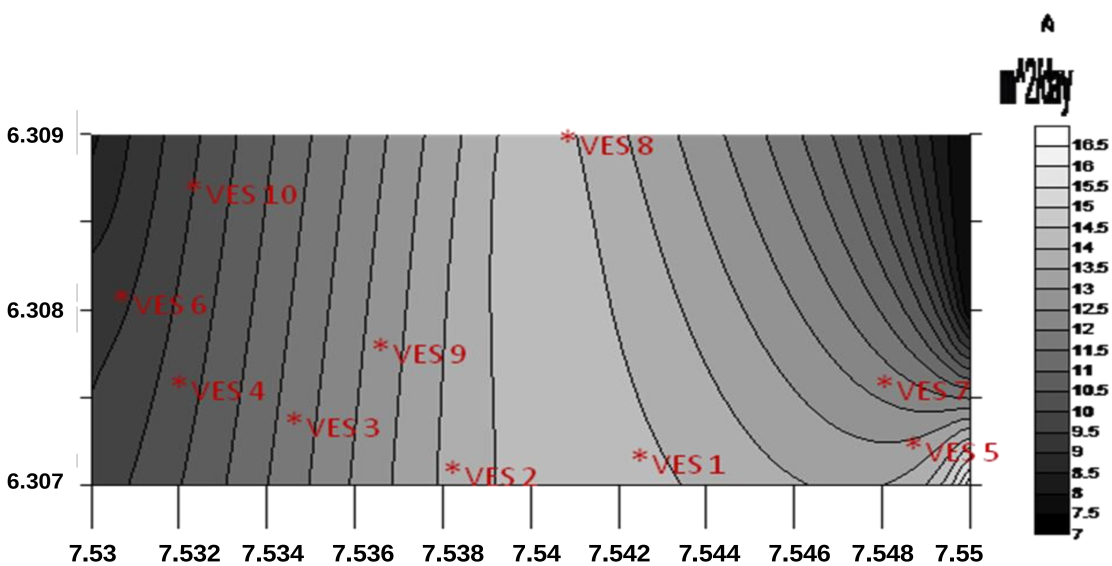

Figure 10. Contour map of aquifer transmissivity in the study area.

were subsequently used to calculate the aquifer transmissivity, T, for each VES station.

RESULTS AND DISCUSSION

The apparent resistivity curves of the interpreted VES data predominantly suggested the existence of four geoelectric layers. Representative curves of the interpreted results are shown in Figures 3 to 6. The first layer resistivity ranges from 160.0 to 1448.0 Ωm while the thickness varies from 1.1 to 2.2 m. The second layer resistivity ranges from 13.0 to 262.9 Ωm with the thickness varying from 2.7 to 9.6 m. The resistivity of the third layer ranges from 7.0 to 1301.7 Ωm with the thickness varying from 14.3 to 38.2 m while the fourth layer has resistivity range of 4.8 to 291.7 Ωm.

A correlation between the VES 1 result and the lithologic log of the only functional borehole (ESUT BH. 2) located about 30 m away from VES 1 station is shown in

Figure 7. This correlation was used to infer the lithology of the VES results. The first layer was inferred to be lateritic sand while the second layer was inferred to be clay. The third layer (which is fairly thick) was inferred to be fine-medium-coarse sands and constitutes the aquifer in the area. This aquiferous layer is followed by the next layer constituting of clayey or shaly sand.

From the resistivity, thickness, and transmissivity of the aquiferous layer obtained for each sounding station, contour maps of the aquifer resistivity, thickness, and transmissivity of the study area were obtained using Surfer 8 (Golden Software Inc., 2002) as shown in Figures 8 to 10.

The aquifer thickness from the VES results is highly variable as is the electrical resistivity with depth. The isopach map (Figure 9), showed that the aquifer is more developed around the centre of the study area in the north-south direction, up to a maximum of 45 m. The transmissivity map (Figure 10) also showed the same trend, ranging from 7.0 to 16.5 m^2/day. This is an expected result because of the direct relationship between aquifer thickness and transmissivity. High aquifer transmissivity and reasonable aquifer thickness are favourable conditions for drilling productive boreholes. This explains why ESUT BH.2 sited at the southern portion of the study area is productive while ESUT BH.1 sited at the western part of the study area is unproductive.

Conclusion

Application of VES technique has enabled the delineation of the area with good prospect for groundwater development programme in the University. The aquifer in the area comprises of fine-medium-coarse grained sands. The aquifer thickness is variable and ranges from 20 to 45 m while the transmissivity ranges from 7 to 16.5 m^2/day. The result of this study has provided additional baseline data on the aquifer characteristics of the area. This will no doubt guide borehole programme in the University with a view to drilling productive boreholes.

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