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Full Length Research Paper

Vertical electrical sounding (VES) methods to delineate potential groundwater aquifers in Akobo area, Ibadan, South-western, Nigeria

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Vertical electrical resistivity soundings were conducted in order to delineate groundwater potential aquifers in Akobo area, Ibadan, South western, Nigeria. Twenty-one vertical electrical soundings were conducted using the Schlumberger configuration, covering the area. The data were interpreted with the help of Abaque (master) curve. The geoelectrical sections for the study area were: the topsoil, the clayey sand, sandy clayey, shale/clay basement and the fresh basement. The dominant rocks comprise suites of quartz schist and pegmatite. Interpretations of vertical electrical sounding (VES) were used to generate longitudinal conductance map. Isoresistivity contour map was prepared and interpreted in terms of resistivity and thickness of sub-surface layer at 56 m spacing using computer software (SURFER), and resistivity results were correlated with the existing lithology. Similarly, aquifer unit(s) thickness map was also prepared, in which good, moderate and poor zones are classified. The study reveals that the weathered and fractured horizons that occur in the easternmost part of the area constitute the productive water-bearing zones referred to as good groundwater potential aquifers with a thickness value greater than 20 m.

Key words: Electrical resistivity, fractured horizon, groundwater potential aquifers, vertical electrical soundings, weathered horizon.

INTRODUCTION

Groundwater exploration is gaining more and more importance in Nigeria owning to the ever increasing demand for water supplies, especially in areas with inadequate surface water supplies. Already, ten percent of the world's population is affected by chronic water scarcity and this is likely to rise to one-third by about 2025 (WHO, 1996).

The water scarcity experienced by the people, led to the search for surface water supply. Surface water, which mostly occurs as rivers are subjected to pollution. It is sad to say that most of the rivers in Nigeria are highly polluted, the pollutants being inadvertently introduced by man via industrial and petroleum exploration activities.

Despite the reported favorable ground water situations the world over, the Nigeria situation appears to be restricted by the fact that more than half of the country is underlain by sedimentary formations. These rocks comprise mainly sand stones, shales, clays and hard crystalline impervious rocks which are either igneous and limestone (Offodile, 1983).

The first alternative opened to man is ground water, which may be defined as "water in the zone of saturation and from which wells, springs and underground run off are supplied". This water is trapped by geological formations (Palacky et al., 1981). Many dug wells that were sunk in the study area without an initial proper investigation failed and so were abandoned. There are several reasons for the failure of boreholes and these include inadequate or lack of pre drilling investigation, lack of expertise on the part of personnel handling the drilling and sometimes lack of proper development of a successfully dug hole.

Hence, a systematic and scientific approach to the problem is therefore essential for the study area in order

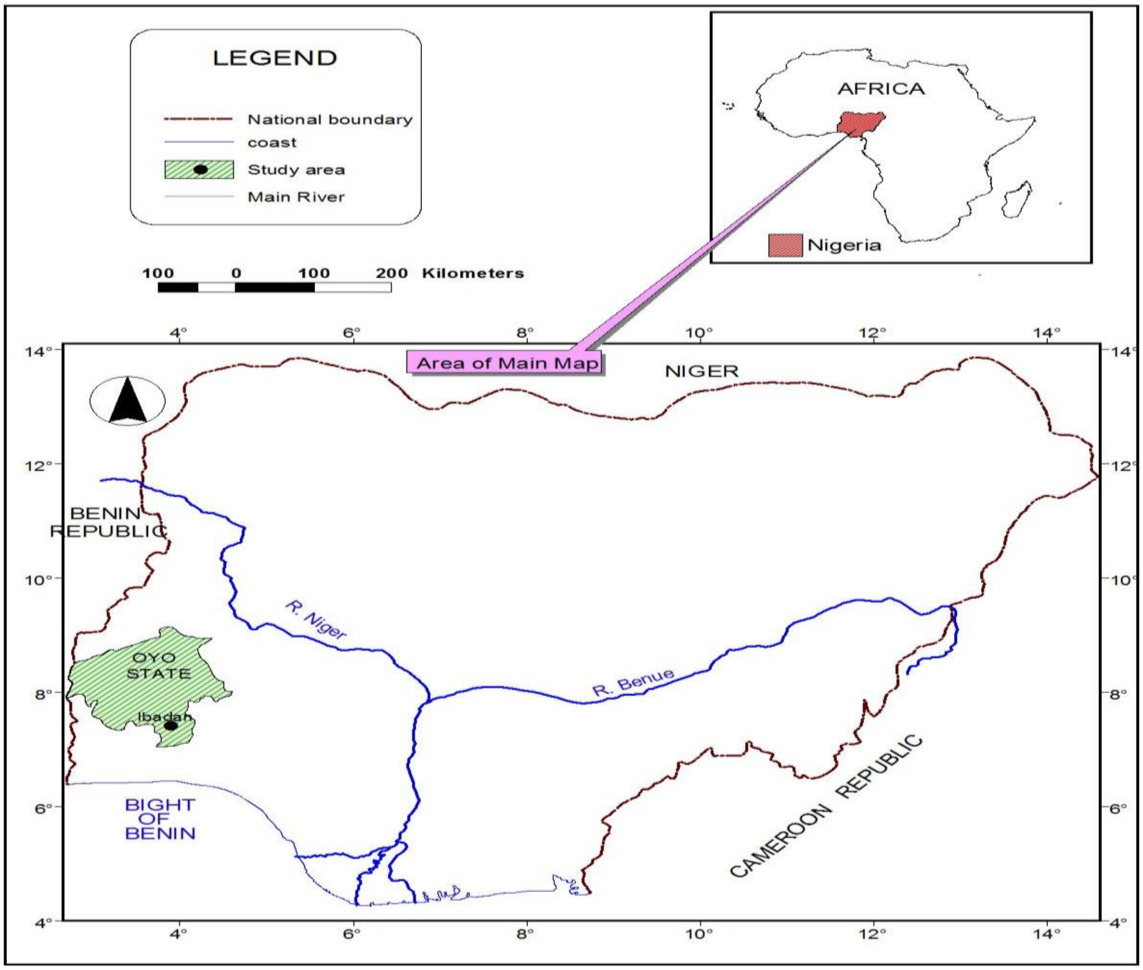


Figure 1. Map showing the location of Ibadan, Oyo State, Nigeria.

to overcome these problems. The quantity and disposition of ground water depends on the geological characteristics of the host rock formation. The search for ground water is faced with lots of uncertainties; to minimize or avoid failures altogether, it is pertinent that the right exploration techniques are utilized in the delineation of subsurface water-bearing formations (Coker et al., 2009). The objective of this study is to use the Schlumberger electrode configuration method to delineate the groundwater potential aquifers in the study area.

Ibadan, the largest city in sub-Sahara Africa and largest urban centre in West Africa (Olayinka et al., 1999) with several settlements (Figure 1), is not just large in area but equally thickly populated (Olayinka et al., 1999). The study area lies within the southwestern part of the Nigerian Precambrian basement complex and within latitudes 7^{o} 26.034' and 7^{o} 26.765'N and longitudes 3^{o} 57.197' E and 3^{o} 58.486'E.

Three major landform units, namely the hills, plains and river valleys, dominate the study area. The hills are the most striking feature, although they constitute less than 20% of the total surface area. The plains are the most extensive landform system in the area, with the elevation ranging between 218 and 269 m above sea level with an average elevation of 243 m above sea level which shows a positive correlation with ground water level elevation, that is the hydraulic gradient. Thus, the elevation of the study area is connected to the closeness of the basement complex rocks of the surface. The river valleys are the narrowest landform in the area. The river is a sluggish perennial stream in the dry season but a turbulent one during the wet season. This relief can be described as undulating and the drainage pattern is dendritic.

METHODS

Of all surface geophysical methods, the electrical resistivity method has been applied most widely for ground water investigations. Examples are the use of electrical resistivity profiling and vertical electrical sounding methods in delineation of various aquiferous units of south western Nigeria crystalline basement complex by

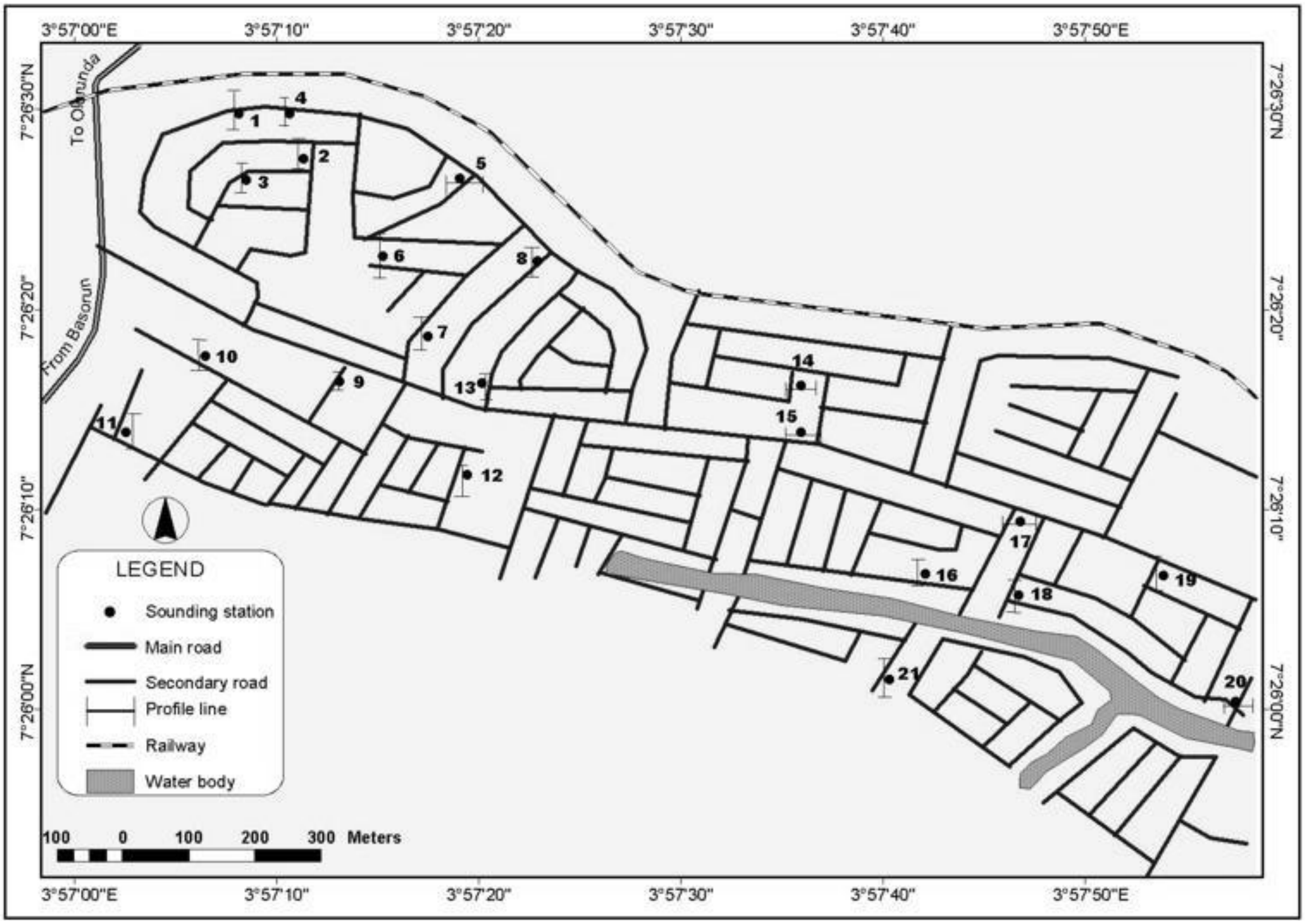


Figure 2. Location map of Oke-Badan Estate, Akobo, showing the sounding points.

Olorunfemi and Olorunniwo (1985), Olorunfemi and Opadokun (1986).

The literature available on electrical resistivity prospecting has been described in various books (Roy and Apparo, 1971; Todd, 1980; Zhdanov and Keller, 1994). The electrical resistivity method can be best employed to estimate the thickness of overburden and also the thickness of weathered/fractured zones with reasonable accuracy. Though both Wenner and Schlumberger electrode configuration methods are popularly employed, the Schlumberger electrode configuration method is more suited to the study area, ensuring better results. The method has practical, operational and interpretational advantages over other methods such as the Wenner method of electrode arrangement (Zohdy et al., 1974).

The four electrode Schlumberger array with a maximum current electrode spacing AB of 200 m was used for this survey. An ABEM SAS 2000 Terrameter was used to measure and record the resistance of the subsurface. For each electrode combination for which a sounding was made and reading of resistance R of the volume of earth material within the electrical space of the electrode configuration was obtained. The product of configuration factor K and R was then made to obtain the apparent resistivity of the said earth material.

This was subsequently done on all the point data obtained for each VES station to give the set of apparent resistivity values supplied for computer modeling using resist program for the iteration to obtain the geoelectrical parameters. The manner in which apparent resistivity values increase or decrease with each electrode separation forms the basis for quantitative interpretation of the electrical resistivity data.

Qualitative interpretation of the sub-surface resistivity distribution can be performed by observing the shape of the field curve. In the curve matching method, a curve is drawn by plotting apparent resistivity against electrode spacing, and this is interpreted by matching the field curve with master curve. Accordingly, the three layered earth can be classified into H, K, A and Q type curves, based on shape. The distribution of resistivities of different subsurface layers is described below: H-type, $\rho 1 > \rho 2 < \rho 3$; K-type, $\rho 1 < \rho 2 > \rho 3$; A-type, $\rho 1 < \rho 2 < \rho 3$; Q-type, $\rho 1 > \rho 2 > \rho 3$; KA, HQ-type, and so on, represent four layer curves.

RESULTS AND DISCUSSION

Twenty-one vertical electrical soundings, randomly distributed, were conducted in Akobo (Figure 2). The

Table 1. Results of interpretation of vertical electrical soundings and apparent resistivity at 56 m.

VES no/Curve type	p_1	h_1	p_2	h_2	p_3	h_3	P_4	Depth (H)	Aquifer thickness	Apparent resistivity at 56 m	Longitudinal conductance	Depth to
1 QH	794.7	1.10	438.3	6.32	224.5	8.44	1093	15.86	8.4	680	0.02	15.9
2 H	395.6	0.93	25.3	5.02	1337	-	-	5.95	5.0	309.4	0.1	6
3 QH	805.5	0.90	183.5	6.78	24.7	7.10	1320	14.78	7.10	233.9	0.1	14.8
4 H	2186	0.41	40.1	5.99	351.6	-	-	6.40	6	252.2	0.07	6.4
5 QH	1598.7	0.43	155.5	3.37	57.4	7.15	5038	10.95	7.15	2141.8	0.05	11
6 HA	1877.3	0.90	231.3	7.46	412.8	6.22	1523	14.58	13.7	853.6	0.02	14.6
7 HA	1457.3	0.48	385.8	3.62	764.3	8.23	5063	12.33	8.2	829.2	0.01	12.3
8 HA	1009.4	0.37	161.7	2.05	369.8	9.48	607.5	11.90	9.5	807.6	0.01	11.9
9 HA	1832.6	0.31	228.5	3.27	549.8	12.4	1198	15.9	12.4	929.6	0.03	15.9
10KH	173.3	1.82	859.5	3.75	182.4	19.8	858.2	25.4	19.8	413.1	0.04	25.4
11HA	592.6	2.37	47.8	10.1	239.5	2.06	497.7	14.6	12.2	266	0.06	14.6
12HA	264.4	1.03	156.4	11.9	782.8	20.4	1183	33.4	20.4	498.5	0.03	33.4
13KH	164.6	1.82	353.2	2.15	31.57	5.11	2624	9.08	5.1	436.7	0.06	9.1
14 H	213.6	1.35	82.9	23.7	1062	-	-	25.03	23.7	248.5	0.15	25
15KH	285.2	1.0	459.7	5.19	221.6	22.1	477.8	28.32	22.1	332.3	0.03	28.3
16QH	2985	0.21	107.6	9.85	25.9	17.3	1788	27.32	17.26	106.7	0.23	27.3
17QH	348	0.93	199.3	5.24	42.3	23.7	202.7	29.8	23.7	2107.3	0.14	29.8
18 H	195	1.10	83.6	18.2	498.1	-	-	19.3	18.2	227.6	0.11	19.3
19QH	634.7	0.73	172.9	6.25	31.5	22.2	385.7	29.2	22.2	84.9	0.24	29.2
20 H	206.3	1.0	30.1	12.8	908.6	-	-	13.8	12.8	131.1	0.24	13.8
21 H	44.5	1.0	23.9	13.7	989.2	-	-	14.8	13.7	124.9	0.28	

VES data are interpreted using the curve matching technique and the results and salient features of the subsurface parameters are given in Table 1.

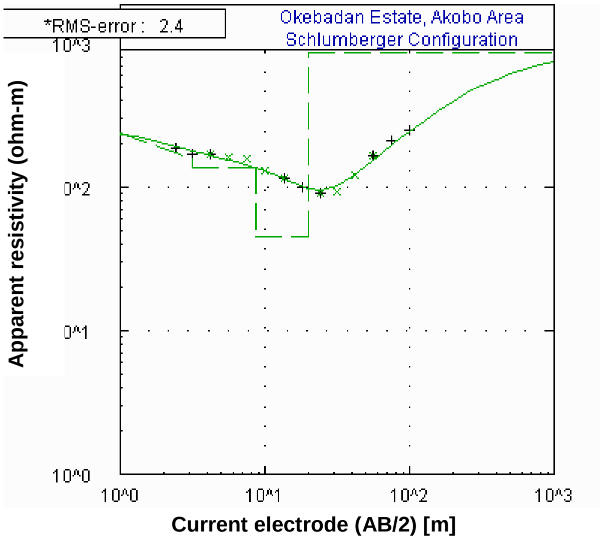
The only type of three-layer VES sounding curve obtained in this area is the H-type, however there also existed a number of four–layered type of VES curves namely QH, HA and KH (Figure 3). Thus, in the study area, the types of curves obtained are H-type, HA–type, QH–type and KH-type (which is the least). Apparent resistivity at 56 m depth is given in Table 1.

Iso-resistivity contour map at 56 m depth, as well as its 3-D map was prepared using the SURFER package and they were interpreted in terms of resistivities and thicknesses of various subsurface layers. Based on the VES interpretation results, longitudinal conductance map and aquifer thickness map were prepared.

Apparent resistivity at 56 m spacing

The apparent resistivity values for 56 m spacing range from 84.9 to 2141.8 Ωm and the corresponding contour map is given in Figure 4a, with a contour interval of 100 Ωm. The highest apparent resistivity value is 2141.8 Ωm as observed at the top north of the map (VES 5).

Figure 4b shows the 3D map which display two peaks representing the quartzite in the northwestern portion of the basin indicated by apparent resistivities 2107.3 and 2141.8 Ωm. The rest of the area are indicated by the lowest apparent resistivity occurred at VES 19 with a value of 84.9 Ωm is occupied by sandy clay.



No	Res	Thick	Depth
1	697.6	0.9	0.9
2	136.9	6.7	7.6
3	23.1	7.2	14.8
4	1061.6	--	--

Figure 3. Typical four layered VES curves.

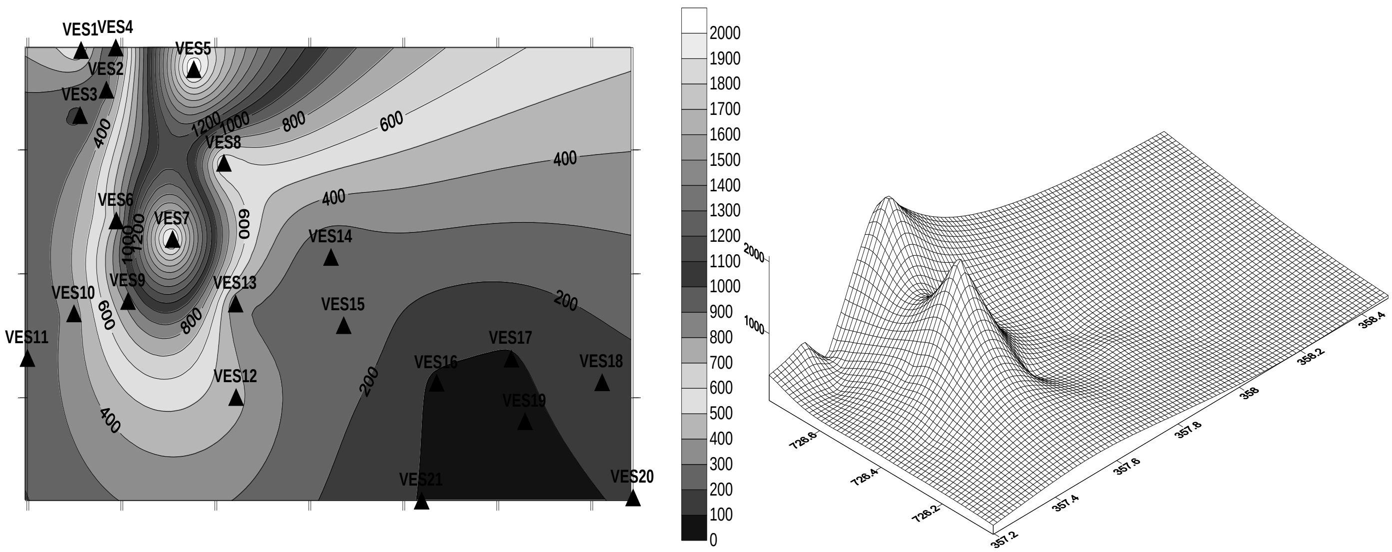


Figure 4. a) Apparent resistivity values at 56 m spacing. b) 3-D contour map displaying two peaks representing the quartzite in the northwestern portion of the basin indicated by apparent resistivities 2107.3 and 2141.8 Ωm.

Longitudinal conductance

The ratio of different layer to their respective resistivities is known as the longitudinal conductance. The properties of a thin conducting layer can be determined in terms of longitudinal conductance, and a resistive layer can be determined by transverse resistance (Yungul, 1996). Figure 4a depicts the total longitudinal conductance contour map. The conductance values vary from 0.01 to 0.28 with an average value of 0.095 Siemens. The conductance values increases towards the southeastern part of the contour map. As the conductance increases, the resistivity naturally decreases, pointing towards groundwater potential aquifers (Gowd, 2004). The 3-D view as shown in Figure 5b depicts a few peaks, with the prominent one seen in the southeastern portion.

Correlation of results of soundings with lithology

To assess the accuracy of the VES interpretations, sounding was carried out in close proximity of an existing well. The results of the VES soundings were then correlated with the existing borehole lithology.

Figure 6 represents the correlated geoelectric sections

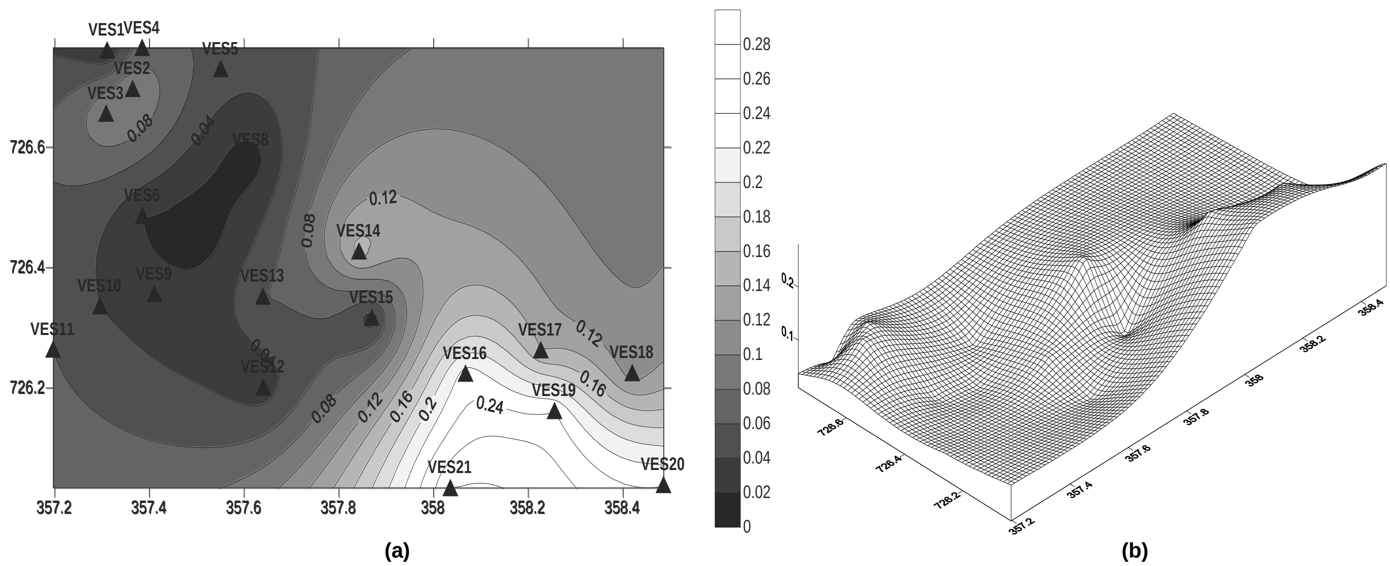


Figure 5. a) Total longitudinal conductance of 2-D contour map. b) Longitudinal conductance of 3-D map depicting a few peaks, with the prominent one seen in the southeastern portion.

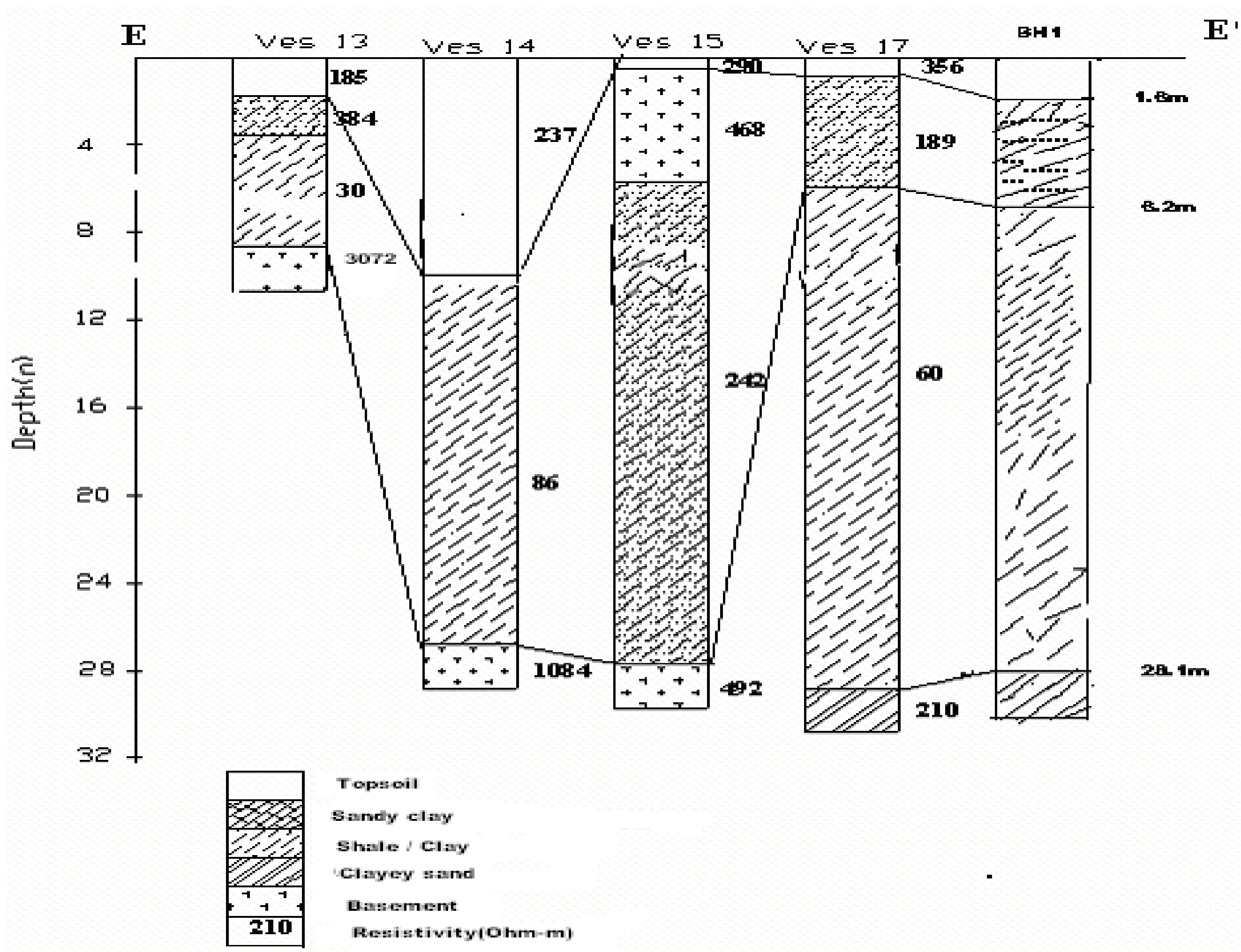


Figure 6. Correlation of resistivity results with borehole data.

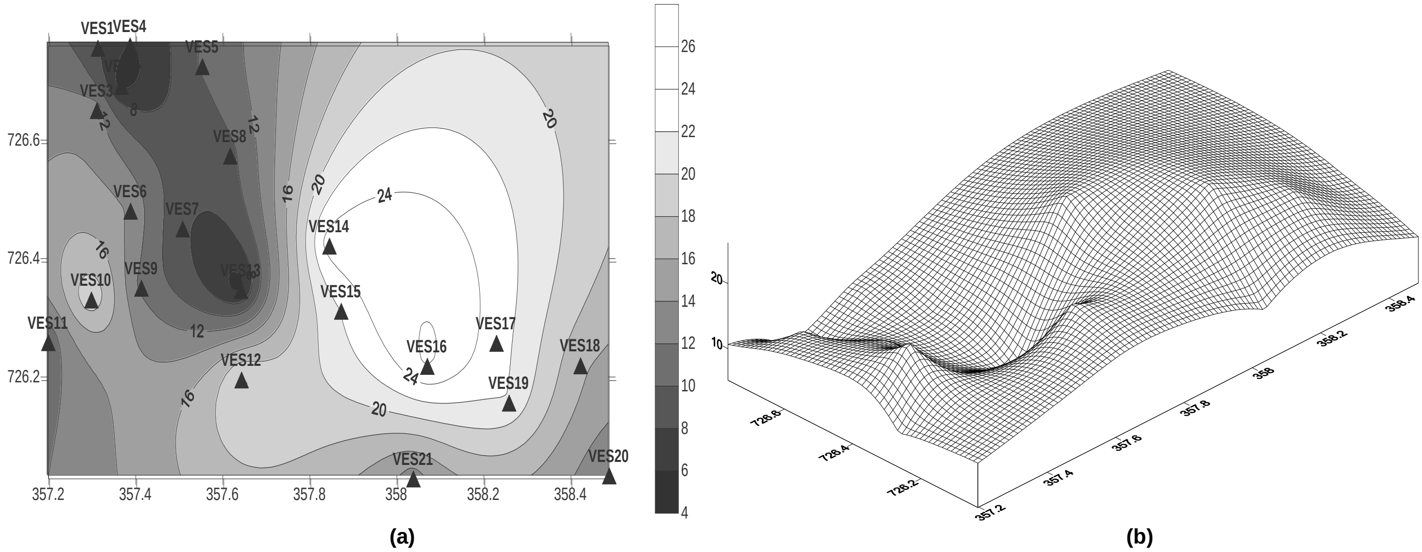


Figure 7. a, Aquifer unit(s) thickness for a) 2-D, and b) 3-D map contour maps.

beneath VES13, 14, 15 and VES 17 with available borehole logs BH1. The results from sounding no 17 located close to a successful borehole indicate four geoelectric layers with absolute resistivities of 355,189 and 60 ohm-m respectively, for the first three layers. The bottom-most layer has very low resistivity.

The top of the formation 355 ohm-m which extends down to a depth of 0.82 m from the surface correlates to the clayey sand of the available borehole logs with an overburden thickness of 1.6 m. The second geoelectric section is partly weathered with layer thickness of 5.12 m which corresponds to the borehole of thickness 6.2 m.

The third layer shows a decreasing trend in resistivity, indicating weathered layer exhibiting a low resistivity of 60 ohm-m up to a depth of 23 m which correlate with gravelly clay of an existing borehole of depth 22.1 m. The last layer has a very low resistivity value of 210 ohm-m thus, the layer is fractured. The results to a large extent show a degree of accuracy when compared with the lithological data of the existing bore-hole logs.

Aquifer unit(s) thickness map

The aquifer unit(s) thickness map shown in Figure 7 can be used in ranking geology formation because volume of water from each VES stations is a function of aquifer thickness.

The entire study area can be classified as good, moderate and poor groundwater potential zones. The study reveals that the productive water-bearing zone categorized as good potential zone occurs at the central eastern part of the study area with a thickness value greater than 20 m.

The moderate groundwater potential zone has a range of value of an aquifer thickness of 10 to 20 m. The remaining parts of the area were demarcated as the very low saturated zone with an aquifer thickness less than 10 m, classified as a poor potential water zone VES 1,2,4,7, 8, 13 as shown by the valley pattern displayed by 3-D map.

Conclusions

Groundwater potential aquifers producing zones have been delineated through investigation conducted by the electrical resistivity survey. Weathered and fractured horizons have been identified in the study area underlying VES stations, and all of these constitute the aquifer zones. Good prospects therefore exist for groundwater development in the study area where the depth to basement is relatively thick and has favourable low resistivity, while those with thin depth to bedrock and high resistivity value have a lower potential for an aquifer.

The productive groundwater potential zones are identified at the central eastern part, and as subordinately at the south western part of the study area. The electrical resistivity data therefore gives reasonably accurate results among other methods that can be used to understand the subsurface layers and basement configuration in groundwater prospecting.

REFERENCES

Coker JO, Makinde V, Olowofela JA (2009). Geophysical Investigation of Groundwater Potentials of Oke-Badan Estate, Ibadan, Southwestern, Nigeria. Proceedings of 3rd International Conference on Science and National Development University of Agric. Abeokuta, p. 119.

Gowd SS (2004). Electrical Resistivity Surveys to delineate Groundwater Potential Aquifers in Peddavanka Watershed, Anantapur District, Andhra Pradesh, India. J.Envir. Geol., 46: 118-131.
Offodile ME (1983). The occurrence and exploitation of groundwater in Nigeria basement complex rocks. J. Min. Geol., 20(1&2): 131-146.
Olayinka AI, Abimbola AF, Isibor RA, Rafiu AR (1999). A Geoeletrical – Hydrogeochemical investigation of shallow Groundwater occurrence in Ibadan Metropolis, Southwestern Nigeria. Environ. Geol., 3(1&2): 31-39.
Olorunfemi MO, Olorunniwo MA (1985). Geoelectric Parameters and Aquifer characteristics of some parts of Southwestern Nigeria. Geol. Appl. Hydrogeol., 20(1): 99-109.
Olorunfemi MO, Opadokun MA (1986). On the Application of surface Geophysical measurements in Geological Mapping - The Basement Complex of Southwestern Nigeria as a case study. J. Afr. Earth Sci., 6(3): 287-291.
Palacky GJ, Ritsema IL, De Long SJ (1981). Electromagnetic Prospecting for Groundwater in Precambrian Terrains in the Republic of Upper Volta. Geophys. Prospect., 29(3): 932–955.
Roy A, Apparao A (1971). Depth of investigation in direct current methods. Geophysics, 36: 943-959.
Todd DK (1980). Groundwater Hydrology, 2nd edition. John Wiley and Sons Inc., New York, p. 535.
WHO (World Health Organization) (1996). Guidelines for drinking water, Vol. 1, Recommendation. Geneva Switzerland.
Yungul SH (1996). Electrical methods in Geophysical Exploration of Sedimentary Basin. Chapman and Hill, U.K., p. 152.
Zhdanov SM, Keller GV (1994). The geoelectrical methods in geophysical exploration. Elsevier, Amsterdam, The Netherlands, p. 83.
Zohdy AAR, Eaton GP, Mabey DR (1974). Application of surface geophysics to groundwater investigations. Collection of Environmental data published by the Department of the Interior Geological Survey, Book 2, p. 9.