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Geoelectrical Study of Groundwater Potential at Waziri Umaru Federal Polytechnic's Gesse Campus BirninKebbi, Kebbi State, Nigeria

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Abstract

Vertical Electrical Soundings (VES) are utilised in geophysical exploration to provide quick and cost-effective measurements. VES was utilised to explore groundwater at Waziri Umaru Federal Polytechnic's permanent campus in Birnin Kebbi. Eighteen (18) Vertical Electrical Soundings (Schlumberger array, maximum AB/2 spacing 100 m) were conducted, with data collected using an ABEM terameter (SAS 300c) to determine the geoelectric units in the subsurface strata and to delineate groundwater potential in the area. The acquired field data was evaluated using (IPI2win), which provides the interpretation of apparent resistivity in an ohm.meter. The resistivity and thickness of subsurface layers were used to analyse the data. Three to five (3-5) unique strata were identified in the research region, including topsoil, which is mostly sand, clayey sand/lose sand, sandy clay/fine sand, and clay unit. Water bearing aquifer exists at layer three in some identified VES locations, such as VES 3, VES5, VES13, and VES14, with thickness and associated resistivity values of 40.5 m, 37.5 m, 45.8 m, 60 m, and 173 ohm.m, 148 ohm.m, 222 ohm.m, and 432 ohm.m, respectively. As a result of the electrical resistivity data, acceptable accurate results may be obtained that can be used to comprehend stratigraphy.

Keywords: Free Open Source Software (FOSS), Geographic Information System (GIS), Web GIS, and Database Systems.

1. Introduction

Freshwater is highly a valuable resource often on which life depends, and its availability is critical to any community's long-term viability (Adagunodo *et al.,* 2018; Omosuyi *et al.,* 2021). There are different sources of water, such as streams, rivers, and ponds; none are as sanitary as groundwater, which is of great purity as well as appropriate chemical quality for numerous applications (Ventaka *et al*., 2014). Groundwater is found in diverse rock types and at various depths in variable proportions. Geophysical techniques are applied in the exploration of this portable freshwater source, which is a unique experience (Anomohanran *et al.,* 2020; Maxwell *et al.,* 2015). Among several methods used in groundwater exploration, the resistivity method is the most effective for locating productive wells, and VES provides information on the vertical variation in the ground's resistivity with depth (Al-Garni *et al.,* 2002). The resistivity method in geophysical exploration for groundwater in a sedimentary environment has proven reliable among other geophysical methods (Dahab, 2012). However, among different electrode arrays used for resistivity measurement, VES is the most popular (Abdulrazzaq *et al.,* 2020; Ekwok *et al.,* 2020; Raji & Abdulkadir, 2020) and is used to forecast the thickness and depth of aquifers (Rahajoeningroem & Indrajana, 2020).

This approach is reliable in finding layers with low resistivity values that may be a sign of saturated strata in a variety of geophysical terrains. The quality and quantity of groundwater resources are influenced by the climate and geology of an area. The climate maintains a consistent supply or recharge of groundwater resources through rainfall and surface water resources in a complicated hydrological cycle. The geology of the area determines the aquifer zones where exploitable groundwater may occur, as well as the geochemical features of the groundwater; human activities influence the geochemical aspects of the groundwater, among other things (Olasehinde *et al.,* 2015; Raji & Abdulkadir, 2020). In the sedimentary terrain, permeable and porous rock masks such as sandstone and lose sands, etc. are good indicators of the aquifer (Kola *et al*., 2013).

Due to the continual evacuation of students and staff from the temporary to the permanent campus of the institution, available water resources are threatened by an expanding population trend. However, it appears that groundwater research in Kebbi State is not keeping up with the state's high demand due to population increase, which is a major problem for the state's future groundwater development. The demand for groundwater has increased dramatically in recent years due to population growth, urbanisation, industrialisation, and intensive agricultural activities in the State in particular and Nigeria in general. However, surface water in Nigeria can easily be contaminated due to the failure of regulatory bodies to address water-related issues (Joel *et al*., 2020). This study aimed at using the electrical resistivity method to determine the groundwater potential at the permanent site of Waziri Umaru Federal Polytechnic, Birnin Kebbi with the following objectives: (i) determine the resistivity at earth's layers (ii) obtain the thickness of the earth's layers (iii) present the resistivity patterns at earth's layer (contour maps) and (iv) the depth to the confined aquifer. A thorough understanding of the geology of the area is required for

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successful groundwater investigation in sedimentary terrain. The exploration of groundwater has been easier in the study area because it is a sedimentary landscape (Abbey & Onyebueke, 2020).

2. Location, meteorology, and geology of the area

The area under study is within the sedimentary region of northern Nigeria between latitudes 12°27.454'N to 12°28.239'N and longitudes 004°13.624'E to 004°14.874'E in Birnin Kebbi metropolis of Kebbi State in north-western Nigeria (Figure 1).

Kebbi State belongs to the savanna climate where the rainy season and the dry season are clear. From May to October is the rainy season whereas from November to April is the dry season. Between December and March, it hardly rains with mean monthly precipitation of almost 0mm, though the annual mean precipitation is 835mm. The annual average minimum temperature is 22.2°C, and the annual average maximum temperature is 34.7°C (JICA, 2011).

Two formations dominate the study region Kebbi State: Prec. Gneiss is found in huge areas across the Basement Complex, while schist and granite are found in smaller areas. In the Cretaceous, argillaceous strata with intercalated sandstone layers predominate in the lower portion of the Cretaceous, whereas sandstone strata thicken in the upper section. The argillaceous strata predominate in the Tertiary's lower section, whereas sandstone layers are intercalated in the Tertiary's higher part. The Quaternary alluvial deposit is distributed over the lowlands along big rivers such as River Niger and Sokoto River, with a small thickness of the deposit (Figure 2). It is presumed that the aquifer consists of (i) the weathered and fractured part of the Basement Complex, (ii) the sandstone and the fractured part of the Cretaceous, and (iii) the sandstone layers of Tertiary (JICA, 2011).

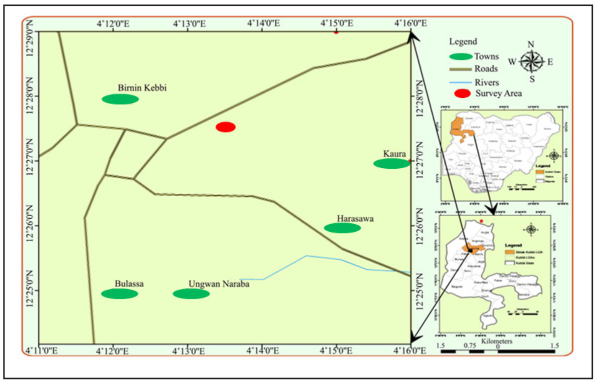

Figure 1. Location Map of Study Area

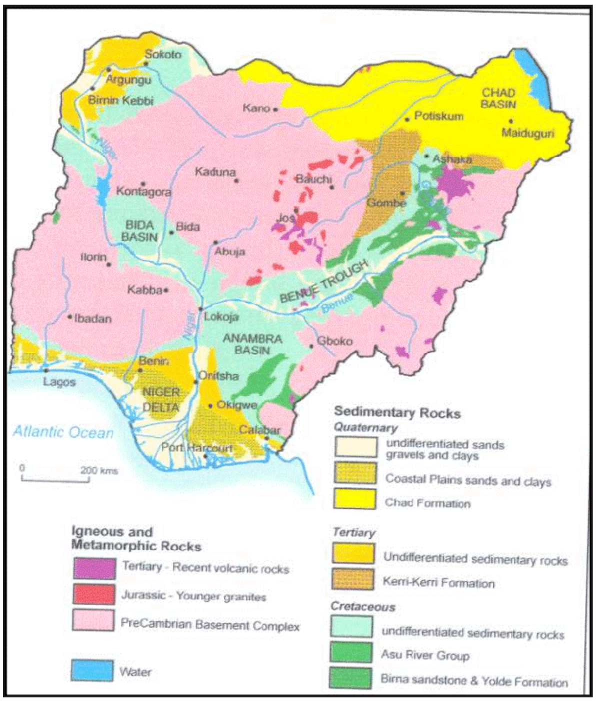

Figure 2. Geological Map of Nigeria showing Kebbi State

3. Materials and Method

Materials used include Global Positioning System (GPS), ABEM Terrameter (SAS 300c), connecting cables, four electrodes (steel rods), measuring tapes, and hammers. The IP2Win software (version 12.0) was used for analyzing geo-electrical data. 18 VES were conducted at different points using Schlumberger configuration with electrode spread at maximum AB/2 = 100m (Figure 3). Current electrodes (A and B) of equal distance on the opposite sides of the VES station and potential electrodes (M and N) were derived into the ground for proper contact to be made with the ground (Figure 4). With MN/2 fixed at its initial distance and AB/2 symmetrically expanded, the measurements were repeated and recorded. MN/2 was proportionately increased whenever the measured resistance became low. These pairs of electrodes were connected to the Terrameter through points AB and MN, which is referred to as the Schlumberger configuration.

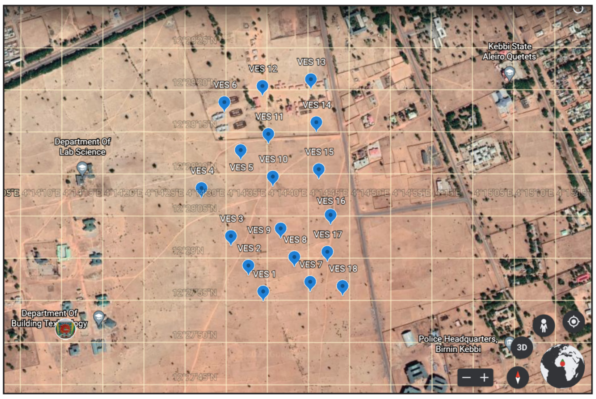

Figure 3. VES Points in the Area under Study (Google Earth).

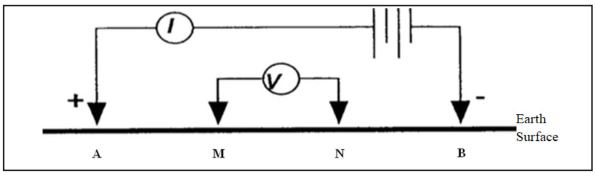

Figure 4. Schlumberger Array followed in this study.

4. Results and Discussion

The true resistivity model is determined by variations in the characteristics of subsurface materials (Hasan *et al.,* 2018). The results of the geoelectrical survey were presented in Tables 1, 2, and 3. Resistivity and thickness obtained from the analysis of the data (Figure 5) were used to adjudge the aquifer or non-aquifer layers and expected geologic formations (Bersi & Saibi, 2020; MO *et al*., 2020). The real resistivity-depth curve takes the shape of a sounding curve, with increasing electrode spacing, the perceived resistivity's rise (or drop) as the true resistivity's rise (or drop). This is especially true for layers whose thickness increases in direct proportion to their depth (Zohdy, 1989). Resistivity variations exist across lithologic interfaces or geo-electric boundaries in the subsurface. The interpreted result revealed 3 to 5 layers in which the top layer shows the diversity of resistivity and thickness ranging from (383 - 2089 ohm.m and 0.3 - 2.7 m). Resistivity values of layer 2 range between 1141 to 29558 ohm.m, thickness between 0.5 m to 13.4m and are interpreted as clayey sand/lose sand formation. Layer 3 with resistivity range of 60 to 1441 ohm.m and thickness varies from 7.9 to 67 m which was interpreted as sandy clay/fine sand. Layer 4 resistivity ranges between 1.23 ohm.m to 13389 ohm.m, thickness, from 2.1 to 39.7 m, and is interpreted as clay formation. The fifth layer exists in VES 1, 6, 8, 11, 12, 17, and 18 with unknown thickness, which indicates medium grain sand and sandstone formation. The fourth and fifth layers have very low resistivity values in some parts of the area which attribute to the saturated clay (Olasehinde *et al.,* 2015). Due to the decrease in resistivity values in layer 3 compared to layer 2 in some parts of the area, shows that layer 3 delineates a probable water saturation zone (Kola *et al*., 2013). The depth of the aquifer layer ranged between 9.7 m to 69 m in VES 17 and VES 14 respectively (Figure 6). These values are comparable to those of (JICA, 2011) and (Usman, 2020) and the result was also correlated with borehole log data obtained from drilled boreholes close to the study area (Figure 7). According to Omosuyi *et al.* 2007, high groundwater prospect zones are defined as those where the aquifer thickness exceeds 18 m, while medium and low groundwater prospective zones are defined as those where the aquifer thickness is between 10 and 18 m and below 10 m, respectively. The research area's relatively high aquifer thickness value makes it productive and desirable (Eugene-Okorie *et al*., 2020). Five separate subsurface layers were identified based on the quantitative interpretation and lithology of the locations, with their geoelectric curves denoted as K, KH, KQ, QQ, and HKH. It was observed that KQ is the dominant curve type in the study area (38.9%) followed by HKH (33.3%), KH (16.7%), and then K and QQ (5.5%) each (Figure 8).

The iso-resistivity analysis provides a qualitative assessment of the differences in resistivity at a certain depth, as well as the overall lateral changes in electrical characteristics in the surrounding area. The iso-resistivity and iso-depth contour maps of the aquifer layer are shown in Figures 9 and 10. Due to the significant values of thickness, the depth contour maps support the hypothesis that certain places may have a substantial groundwater yield. Figures 8 and 9 show that VES 3, VES 5, VES 13, and VES 14 are the ideal locations for groundwater exploration based.

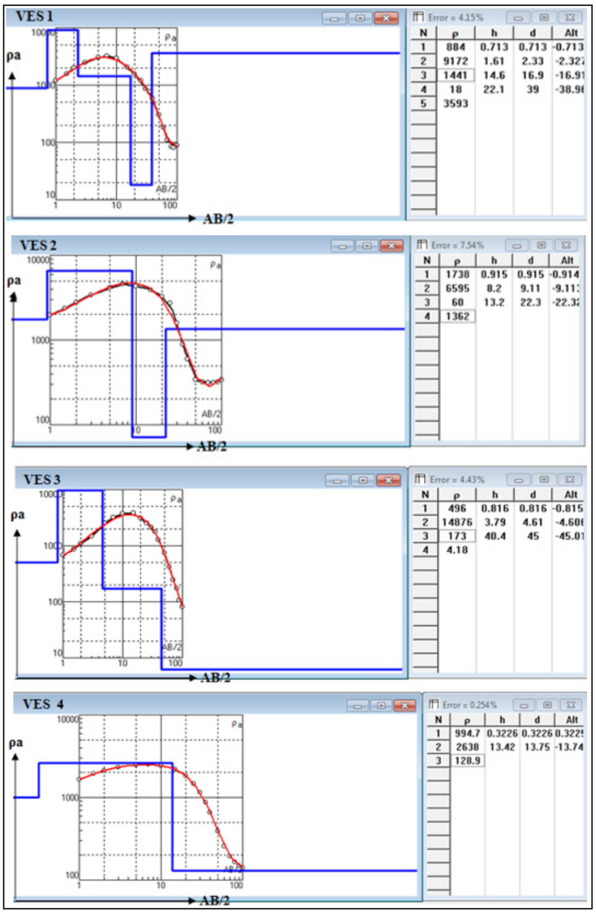

Figure 5. Model Curves and analysis.

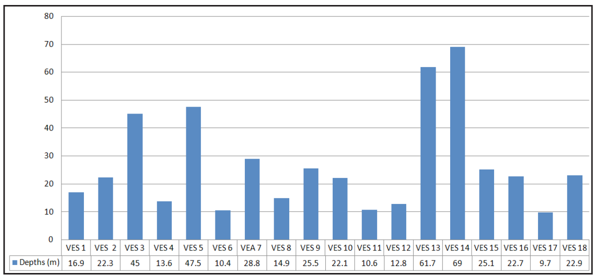

Figure 6. VES Depths of aquifer layer.

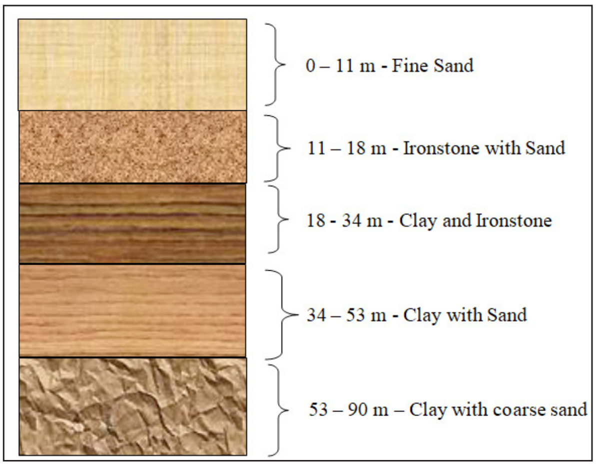

Figure 7. Borehole log close to the study area (SARDA, 1988).

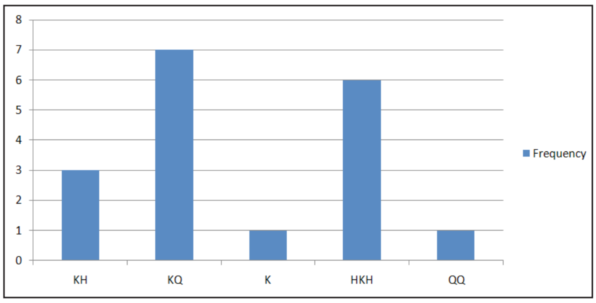

Figure 8. Frequency distribution of VES Curves.

Table 1. Geoelectric parameters of VES 1 to VES 6.

Coordinates	VES No.	Layer No.	Resistivity (ohm.m)	Thickness (m)	Depth (m)	Curve Types
$12^0$27.904'N $004^0$14.392'E Elevation:744	1	1	884	0.7	0.7	KH
		2	9172	1.6	2.3	
		3	1441	14.6	16.9	
		4	18	22.1	39	
		5	3593	…	…	
$12^0$27.952'N $004^0$14.365'E Elevation:734	2	1	1738	0.9	0.9	KH
		2	6595	8.2	9.1	
		3	60	13.2	22.3	
		4	1362	…	…	
$12^0$28.005'N $004^0$14.351'E Elevation: 734	3	1	496	0.8	0.8	KQ
		2	14876	3.7	4.6	
		3	173	40.4	45	
		4	4.18	…	…	
$12^0$28.058'N $004^0$14.351'E Elevation: 726	4	1	994.7	0.3	0.3	K
		2	2638	13.4	13.8	
		3	128.9	…	…	
$12^0$28.112'N $004^0$14.335'E Elevation: 704	5	1	782	0.5	0.5	KH
		2	2868	9.5	10	
		3	148	37.5	47.5	
		4	13389	…	…	
$12^0$28.167'N $004^0$14.337'E Elevation: 716	6	1	412	0.4	0.4	HKH
		2	9867	0.5	0.9	
		3	1247	9.6	10.4	
		4	289	31.7	42.2	
		5	0.69	…	…	

Table 2. Geoelectric parameters of VES 7 to VES 12.

Coordinates	VES No.	Layer No.	Resistivity (ohm.m)	Thickness (m)	Depth (m)	Curve types
12^{0}27.920'N 004^{0}14.445'E Elevation:726	7	1	513	0.7	0.7	KQ
		2	8505	1.1	1.8	
		3	950	27.1	28.8	
		4	1.23			
12^{0}27.971'N 004^{0}14.428'E Elevation: 731	8	1	884.7	0.5	O.5	HKH
		2	12292	0.6	1.1	
		3	1296	13.7	14.9	
		4	351.9	25.9	40.8	
		5	1.31			
12^{0}28.024'N 004^{0}14.409'E Elevation: 730	9	1	382	0.5	0.5	KQ
		2	1781	5.4	5.9	
		3	962	19.6	25.5	
		4	13			
12^{0}28.075'N 004^{0}14.396'E Elevation: 727	10	1	445	0.5	0.5	KQ
		2	2725	2.9	3.4	
		3	1194	18.7	22.1	
		4	33.3			
12^{0}28.132'N 004^{0}14.392'E Elevation: 720	11	1	775	1.1	1.1	HKH
		2	8312	1.5	2.5	
		3	1080	8.0	10.6	
		4	308	37.9	48.4	
		5	1.99			
12^{0}28.186'N 004^{0}14.389'E Elevation: 670	12	1	1307	1.0	1.0	HKH
		2	5633	0.5	1.4	
		3	1269	11.4	12.8	
		4	265	38.1	50.9	
		5	0.78			

Table 3. Geoelectric parameters of VES 13 to VES 18.

Coordinates	VES no	Layer	Resistivity (ohm.m)	Thickness (m)	Depth (m)	Curves
12^{0}28.188'N 004^{0}14.446'E Elevation: 718	13	1	2089	2.7	2.7	QQ
		2	1141	13.3	16	
		3	222	45.8	61.7	
		4	2.1			
12^{0}28.135'N 004^{0}14.457'E Elevation: 719	14	1	951	1.2	1.2	KQ
		2	7544	0.9	2.0	
		3	432	67	69	
		4	4.81			
12^{0}28.086'N 004^{0}14.457'E Elevation: 719	15	1	616	0.7	0.7	KQ
		2	6504	1.8	2.5	
		3	907	22.6	25.1	
		4	20.3			
12^{0}28.033'N 004^{0}14.468'E Elevation: 723	16	1	866	0.4	0.4	KQ
		2	29558	0.7	1.1	
		3	756	21.6	22.7	
		4	60.9			
12^{0}27.979'N 004^{0}14.474'E Elevation: 722	17	1	555	0.8	0.8	HKH
		2	3583	1.1	1.8	
		3	1006	7.9	9.7	
		4	411	24.4	34.2	
		5	0.849			
12^{0}27.926'N 004^{0}14.492'E Elevation: 738	18	1	970.4	1.0	1.0	HKH
		2	2578	3.4	4.4	
		3	637.9	18.5	22.9	
		4	114.4	39.7	62.5	
		5	2.76			

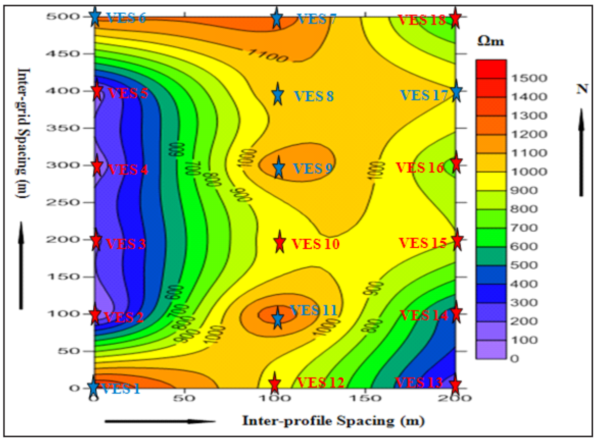

Figure 9. Resistivity Contour Map (Layer 3).

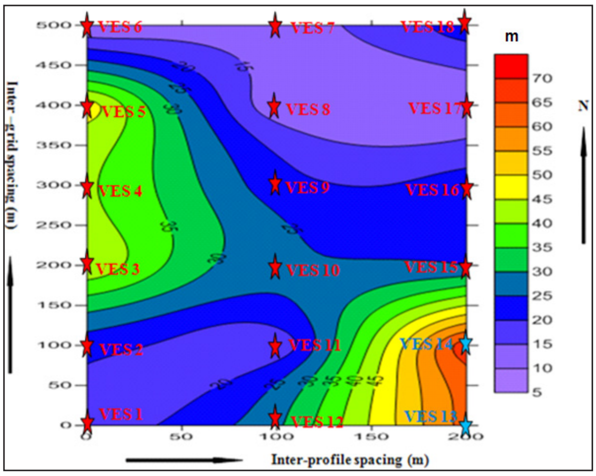

Figure 10. Depth Contour Map (Layer 3)

5. Conclusion

VES for groundwater exploration at the study area delineates a network of probable features, suspected to be groundwater occurrence. Different metrics, such as resistivity and the thickness of subsurface layers and their lithologic boundaries, were determined, and it was discovered that groundwater potential levels varied from one portion of the research region to the next. Within the research region, where the depth to bedrock is relatively deep and has a low resistivity value, there are good prospects for groundwater potential, whereas those with shallow depth to bedrock and a high resistivity value have a lesser potential for groundwater. The VES results for the entire area revealed a range of depths to strike the top of the water-bearing zones of 9.1 to 69 m. Using iso-resistivity and iso-depth contour maps of the aquifer layer it was observed that the optimum locations for groundwater investigation are within the soundings, VES 3, 5, 13, and 14. The geological formation in the study area consists of sand, clayey sand/lose sand, sandy clay/fine sand, and clay unit. Furthermore, the results obtained from the survey indicate the efficiency of VES techniques for the study of groundwater potential in the sedimentary region.

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References

Adagunodo, T. A., Akinloye, M. K., Sunmonu, L. A., Aizebeokhai, A. P., Oyeyemi, K. D., & Abodunrin, F. O., 2018. Groundwater exploration in aaba residential area of Akure, Nigeria. Frontiers in Earth Science, Pp. 1–12.

Abbey, M. E., & Onyebueke, D. E., 2020. Geoelectric evaluation of groundwater potential: a case study at Omuma local government area, Rivers State, Nigeria. Journal of Petroleum Exploration and Production Technology, 10(8), Pp. 3255–3261.

Abdulrazzaq, Z. T., Al-Ansari, N., Aziz, N. A., Agbasi, O. E., & Etuk, S. E., 2020. Estimation of main aquifer parameters using geoelectric measurements to select the suitable wells locations in Bahr Al-Najaf depression, Iraq. Groundwater for Sustainable Development, 11, 100437.

Al-Garni, M. A., Alisiobi, A. R., Ako, B. D., Andersen, K. R., Wan, L., Grombacher, D., Lin, T., Auken, E., Arefayne Shishaye, H., Abdi, S., Awad Sultan Araffa, S., Sabet, H. S., Dabour, A., Balasubramanian, A., Buursink, M. L., Jr, J. W. L., Survey, U. S. G., Clement, W. P., Knoll, M. D., Yaramanci, U., 2002. Groundwater Investigation Using Combined Geophysical Methods *. Journal of Applied Geophysics, 50(1–2), Pp. 1–8.

Anomohanran, O., Oseme, J. I., Iserhien-Emekeme, R. E., & Ofomola, M. O., 2020. Determination of groundwater potential and aquifer hydraulic characteristics in Agbor, Nigeria using geo-electric, geophysical well logging and pumping test techniques. Modeling Earth Systems and Environment, 0123456789.

Bersi, M., & Saibi, H., 2020. Groundwater potential zones identification using geoelectrical sounding and remote sensing in Wadi Touil plain, Northwestern Algeria. In Journal of African Earth Sciences (Vol. 172). Elsevier Ltd.

Dahab, M. A. H., Abbas, M. Y, and Abdelhakam, E. M, 2012. Geoelectric investigation of groundwater potential in Khor Abu Habil drainage basin. Journal of Science and Technology 13(2).

Ekwok, S. E., Akpan, A. E., Kudamnya, E. A., & Ebong, E. D., 2020. Assessment of groundwater potential using geophysical data: a case study in parts of Cross River State, south-eastern Nigeria. Applied Water Science, 10(6), Pp. 1–17.

Eugene-Okorie, J. O., Obiora, D. N., Ibuot, J. C., & Ugbor, D. O., 2020. Geoelectrical investigation of groundwater potential and vulnerability of Oraifite, Anambra State, Nigeria. Applied Water Science, 10(10), Pp. 1–14.

Hasan, M., Shang, Y., Akhter, G., & Jin, W., 2018. Geophysical Assessment of Groundwater Potential: A Case Study from Mian Channu Area, Pakistan. Groundwater, 56(5), Pp. 783–796.

Japan International Cooperation Agency (JICA), 2011, preparatory survey on the project for inprovement of rural water supply in the federal republic of nigeria. final report. Pp 11 - 046.

Joel, E. S., Olasehinde, P. I., Adagunodo, T. A., Omeje, M., Oha, I., Akinyemi, M. L., & Olawole, O. C., 2020. Geo-investigation on groundwater control in some parts of Ogun state using data from Shuttle Radar Topography Mission and vertical electrical soundings. Heliyon, 6(1).

Kola, O. R., Akinyem, L. P., Akinsegun, O., & Ijeoma, G. C., 2013. Application of Vertical Electrical Method in Groundwater Exploration at Remo North Local Government in Ogun State of Nigeria Corresponding Author : Akinyem L . P. 4(4), Pp. 672–678.

Maxwell, O., Ejike, E. J., & Ugwuoke, P. E., 2015. Geophysical Analysis of Basement Terrain Groundwater Using Vertical Electrical Sounding : A Case Study of Parts of Abuja North Central Nigeria. 2(4), Pp. 92–97.

MO, E., C, O., & AOI, S., 2020. Geoelectrical Parameters for the Estimation of Groundwater Potential in Fracture Aquifer at Sub-Urban Area of Abakaliki, SE Nigeria. International

Journal of Earth Science and Geophysics, 6(1).

Olasehinde, A., Sulaiman, A., Bute, S. I., & Hamza, Y. S., 2015. Hydro Geophysical Investigation of Kushi and its Environs , Northeastern , Nigeria. International Journal of Research in Geography 1(1), Pp. 13–21.

Omosuyi, G.O., Adeyemo, A., & Adegoke, A. O., 2007. Investigation of groundwater prospect using electromagnetic and geoelectric sounding at afunbiowo, near Akure, Southwestern Nigeria. Pacific J. Sci. Technol, 8(2), Pp. 172–182.

Omosuyi, Gregory Oluwole, Oshodi, D. R., Sanusi, S. O., & Adeyemo, I. A., 2021. Groundwater potential evaluation using geoelectrical and analytical hierarchy process modeling techniques in Akure-Owode, southwestern Nigeria. Modeling Earth Systems and Environment, 7(1), Pp.

Rahajoeningroem, T., & Indrajana, B., 2020. Groundwater Potential Investigation Using Geoelectric Method with Schlumberger Electrode Configuration in Catur Rahayu Village, Dendang District, Tanjung Jabung Timur Regency, Jambi Province. IOP Conference Series: Materials Science and Engineering, 879(1).

Raji, W. O., & Abdulkadir, K. A., 2020. Evaluation of groundwater potential of bedrock aquifers in Geological Sheet 223 Ilorin, Nigeria, using geo-electric sounding. Applied Water Science, 10(10), Pp.1–12.

Sokoto Agricultural and Rural Development Authority (SARDA), 1988. Sokoto Fadama Shallow Groundwater Study. Field Report Vol. II Ministry of Agriculture, Sokoto. Pp. 59 – 61.

Usman, Z. M., 2020. Geoelectric Survey For Groundwater Exploration At Birnin-Kebbi, Kebbi State, Nigeria, FUDMA Journal of Science, 3(1), Pp. 168-178.

Ventaka, R. G., 2014. Groundwater Investigation Using Geophysical Methods- a Case Study of Pydibhimavaram Industrial Area. International Journal of Research in Engineering and Technology, 03(28), Pp. 13–17.

Zohdy, A. A. R., 1989. A new method for the automatic interpretation of Schlumberger and Wenner sounding curves. Geophysics, 54(2), Pp.245–253.