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RESEARCH ARTICLE

HYDROGEOPHYSICAL DELINEATION OF PROLIFIC GROUNDWATER AQUIFER AROUND STUDENTS' HOSTELS IN FUPRE CAMPUS, NIGERIA

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ABSTRACT

Electrical resistivity survey was conducted around Students' Hostels in FUPRE to delineate prolific aquifer for potable water to serve the teeming population of staff and students. Five vertical electrical soundings (VES) using Schlumberger electrode configuration with a maximum current electrode spread of 300m were employed for data acquisition. WINRESIST software was employed to execute the iteration and inversion processes of computing resistivities, depths and thicknesses of the various layers and the curve types. Results indicate that the area is characterized by 4 distinct geoelectric layers inferred differently at the VES locations. Two potential groundwater aquifer zones are delineated. The unconfined shallow aquifer zones found at VES 1, 3, 4 and 5 locations have shallow overburden depth ranging between 3.7-19.3m and coarse-grained sand columns with thicknesses ranging between 2.8-17.7m while the confined deep aquifer zone found at VES 2 location coincides with deep overburden layer at a depth of 42.6m and coarse-grained sand column with appreciable thickness of 19.1m. These results suggest that boreholes for sustainable groundwater supply around the Students' Hostels should be sited at VES 2 location and screened at a depth ≥40.0m. However, aquifers at VES 1, 3, 4 and 5 have potentials for groundwater but are vulnerable to contamination. It is recommenced that electrical resistivity and hydrogeological surveys should be conducted at different locations in FUPRE, before any borehole(s) are drilled, to delineate the appropriate aquifer for potable groundwater supply and to avoid possible contamination.

KEYWORDS

Vertical electrical sounding, aquifer, coarse-grained sand, groundwater, students' hostels, FUPRE campus.

1. INTRODUCTION

The rapid expansion in infrastructure and increase in population of staff and students witnessed by the Federal University of Petroleum Resources Effurun (FUPRE) and its proximity to surrounding communities such as Ugbomro, Iteregbi, Ebrumede, Okuatata, Okuokoko, Okorikpere and Agbarho where most staff and students reside have led to the growing high demands for potable water to serve the teeming population. Hence, the aim of this research is to delineate prolific groundwater aquifer with the objectives of determining the appropriate lithology for quality groundwater without mineralization and contamination, depth to the prolific aquifer and thickness to provide the maximum yield at all seasons of the year to meet this growing demands for potable water in the absence of public water utility system.

The water table regime in FUPRE Campus is very shallow as it is located within the relatively low terrain with porous and permeable sand that support groundwater percolation and retention. Most groundwater boreholes in this vicinity are bottomed at shallow depth (less than 40m deep) and assumed to be very suitable for domestic and industrial uses but the mineralization level and dissolved salts reduce the quality as observed by Amadi, 2009 and Akpoborie, et. al. 2014. The availability of potable water basically depends on the soil composition, depth and thickness of aquifer and environmental factors such as content of dissolved salts, mineralization of rocks, among others. These factors control the groundwater potential and quality in any area and electrical resistivity survey, which involves introducing electrical current into the ground by electrodes and measuring the potential differences between layers at certain depths in the ground, has over time proven to be one of the easiest methods of determining the factors above for cheap access to good quality groundwater in aquifers. This is because the instrumentation and field logistics are easy to implement and data analysis is less tedious and economical to handle. Vertical electrical sounding (VES) is an electrical resistivity method for measuring vertical variations of electrical resistance in the ground is employed in this study.

Vertical electrical sounding (VES) has been recognized to be more suitable for hydrogeological surveys in sedimentary basin as shown by several researchers among others: Alaminiokuma and Chaanda, 2020 studied the groundwater potential of Mando, Kaduna, Crystalline Basement Complex, Nigeria using VES. The results show that the area is characterized by four to five geoelectric subsurface layers inferred differently at the VES traverses. An unconfined shallow aquifer zone was delineated. The potential groundwater aquifer zone found at all the VES locations has shallow overburden depth ranging between 7.1–10.9m with coarse-grained sand columns having thicknesses ranging between 6.0–9.6m suggesting that groundwater occurrence in Mando lies within the weathered overburden (WO) composed of coarse-grained sands which forms a level below the loose clayey laterite. Mgbolu et al., 2019 studied the groundwater potential, aquifer hydraulic characterization and

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vulnerability using VES in parts of Ndokwa, Niger Delta Basin, Nigeria. Results revealed five to six geo-electric layers/units across the study area. The subsurface lithology is predominantly sandstone intercalated, in some cases, with clay, sandy clay, and clayey sand. The average depth to aquifer as 71.91 m (10.33–173.97 m); average aquifer thickness as 42.52 m (4.7–149.7 m) and average aquifer resistivity value as 1289 Ωm (470.84–2697.7 Ωm). Average overburden thickness was estimated to be 28.53 m (4.28–62.44 m). Aquifer characteristics derived from the VES results gave average calculated aquifer transmissivity value as 1162.31 m^2/day (129.54–4181.31 m^2/day), and average calculated aquifer hydraulic conductivity as 27.28 m/day (25.69–28.92 m/day). Longitudinal conductance values range of 0.006–0.137 were recorded from geo-electric field survey data in the area, indicating dominance of sand and sparse distribution of clay; and suggesting that the Aquifer Protective Capacity APC of the overburden above the aquifers in the study area is mostly poor to weak and prone to contamination from infiltration. Nwokocha et al., 2018 delineated aquifer in Omuma Local Government Area of Rivers State, Nigeria using VES. Results show that the resistivity range of the area lies between 25 and 7356.5Ωm and a maximum depth of 70m was penetrated. The quantitative and qualitative analysis delineates 4 to 5 distinct subsurface geo-electric layers and total of six different geo-electric curve types were obtained; AKQ, KQQ, AK, HQ, KHK, and HK. The aquifer thickness and iso-Resistivity maps delineated the area of study into grade I, grade II and grade III groundwater potential zones based on the aquifer thickness and resistivity values derived from the survey. The entire southern region and few parts of the west show good prospect of underground water with aquifer thickness of 56m and above. Iserhien-Emekeme et. al., 2017 identified lithology and underground water conditions of Jeddo using geophysical and geochemical methods. Results of the resistivity sounding revealed that the formation is made up of clay, clayey sand, and fine to coarse-grained sand. The mean depth of the aquifer was obtained as 12.7 m while the aquifer resistivity ranged from 161 to 1728 Ωm. The mean value of transmissivity obtained for the aquifer is 169 m^2day^{-1} while analysis of the transmissivity revealed that about 6% of the study area has greatest potential for a productive aquifer. The study also revealed that the underground water flows in the northeast–southwest direction.

Consequently, this research will serve as a model for the delineation of prolific aquifer suitable for the location of groundwater boreholes to serve as sources of potable water for the University Community and its environs. It is significant for the measurement of resistivities, thicknesses, depths and lithological structure of the study area.

2. LOCATION, GEOGRAPHY, GEOLOGY AND HDROGEOLOGY OF THE STUDY AREA

2.1 Location

The study area is located around the Students' Hostels within the campus of Federal university of Petroleum Resources Effurun, Nigeria (Figure 1).

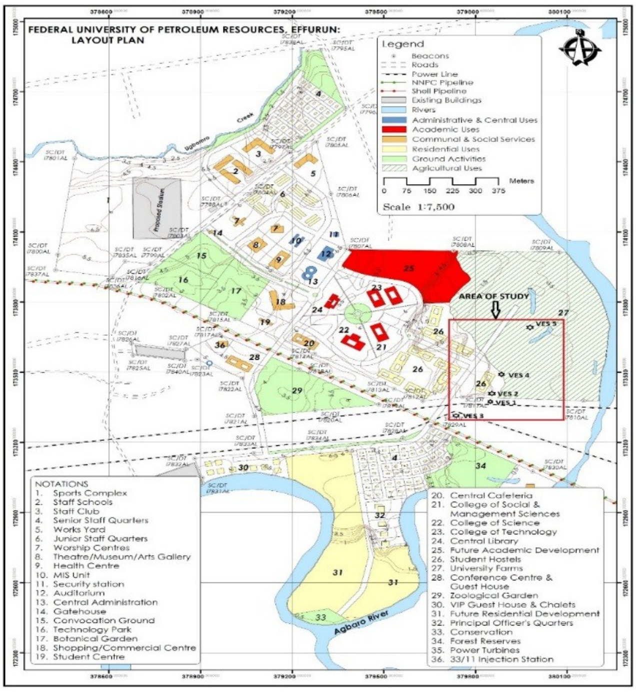

Figure 1: Map of FUPRE campus showing the study area

2.2 Geography

FUPRE is located between Ugbomro and Iteregbi Communities in Uvwie local Government Area of Delta State. These communities are surrounded by Okuatata, Okuokoko, Okorikpere and Agbarho communities. The area is a lowland with elevation not greater than 15m above sea level. It is a relatively flat terrain and the area is drained by the Agbarho and Ugbomro Rivers.

The area is a hot/wet equatorial climate region made of two main seasons: the wet and dry seasons. The climate is tropical equatorial type with mean annual rainfall greater than 300m and mean temperature of about 28°C (Iloeje, 1981). The wet season begins from April and ends in September while dry season begins from October and ends in March. The study area has a direct recharge from rainfall, the rate of infiltration and percolation is very high. The area belongs to the freshwater vegetation belt of rainforest and swamp forest which is thickly vegetated with grass, trees and creeping plants.

2.3 Geology

The area of study is located within the Niger Delta which is the largest Basin in West Africa and the most prolific delta in Africa. The Niger Delta is situated on the continental margin of the Gulf of Guinea in equatorial West Africa between latitude 4°N to 7°N and longitude 5°E to 8°E covering an area of about 108900km^2 (Whiteman, 1982). It extends from the Calabar flank and the Abakaliki Trough in eastern Nigeria to the Benin flank in the west and it opens to the Atlantic Ocean in the south. The development of the Niger Delta resulted from the formation of the Benue trough as a failed arm of a triple junction associated with the separation of the Africa and South American Plates and subsequent opening of the South Atlantic (Whiteman, 1982).

The Benue-Abakaliki trough was filled with sediments during the early Cretaceous time, which later underwent folding, faulting and uplift with subsidence of the adjacent Anambra basin to the west and Afikpo syncline to the east during the Santonian. The Niger Delta consists of three diachronous units, namely from bottom, Akata, Agbada and Benin Formations (Weber and Daukoru, l975).

2.4 Hydrogeology

The study area is underlain by the Quaternary Warri deltaic sand (Etu-Efeotor and Akpokodje, 1990). The sediment overlies the Coastal Plain sand. It is characterized by yellowish colour and consists of silt, sand and clay. The sands are generally loose, porous, poorly sorted and lateritic. Small proportions of gravels and limited number of thin clay horizons are sometimes present at greater depths (Avbovbo, 1978). According to Amadi (2009), two main aquiferous units have been identified in the study area. The shallowest aquifer of 2-5m depth occurs within the unconfined superficial alluvium comprising of sandy/silty layers. Hand dug wells exploit water from this aquifer. Deeper, confined and prolific aquifers are encountered at about 55rn.

This aquifer consists of medium-to-coarse grained sand and gravel. Industrial and public boreholes derive their source from the second aquifer. Water level in this area fluctuates in response to climatic conditions, Average water level in the dry season is 3.0m while it rises to the ground level during the rainy season (Amadi, 2009).

3. METHODOLOGY

3.1 Field Data Acquisition

Ohmega 1000 Resistivity Meter was employed in acquiring the Vertical Electrical Sounding data along 5 traverses. The Schlumberger configuration (Figure 2) with a maximum current electrodes separation of 300m was employed. Two current electrodes were placed linearly at the same mid-point with two potential electrodes but at different distances from one another. The current electrodes were placed at equal distances, ***s*** from the mid-point of the array while the potential electrodes were similarly placed at equal distances but at a distance, $a/2 < s$. Different spreads of current electrodes, AB were achieved, thereby resulting in different probe depths (Table 1). The measurements were repeated 4 times at each point and the average was recorded to ensure accuracy of the results.

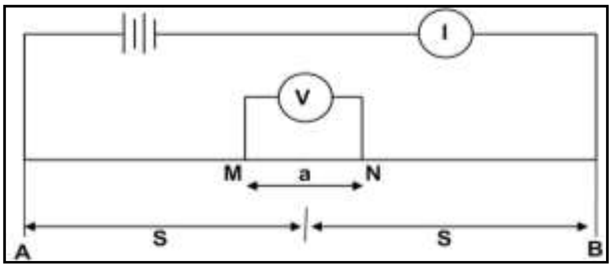

Figure 2: Schlumberger array for data acquisition

3.2 Computation of Soil Apparent Resistivity, ρ_a

Apparent resistivities were obtained from field resistance values using the equation:

$$\rho_a = \frac{2\pi R}{\left[\frac{1}{AM} - \frac{1}{AN} - \frac{1}{BM} + \frac{1}{BN}\right]} \qquad (1)$$

Where ρ_a is apparent resistivity, R is the measured resistance, AB= Distance between current electrodes, MN=Distance between potential electrodes and $\left[\frac{1}{AM} - \frac{1}{AN} - \frac{1}{BM} + \frac{1}{BN}\right]$ is the geometric factor, K.

4. DATA INTERPRETATION

The apparent resistivity, ρ_a values were plotted against half current electrode spread, AB/2 employing WINRESIST software. For each VES station, the iteration process was conducted until the root mean square (RMS) error of ≤ 3.7% was obtained. The resistivities, thicknesses and depth of the various layers were computed and the curve types were determined.

5. RESULTS AND DISCUSSION

5.1 Results

Table 1 shows the VES data acquired around the students' hostels while figures 3 - 7 show the geoelectric sections for the five VES stations. Generally, the KQ type curve except VES 1 with AQ type curve were observed in the study area.

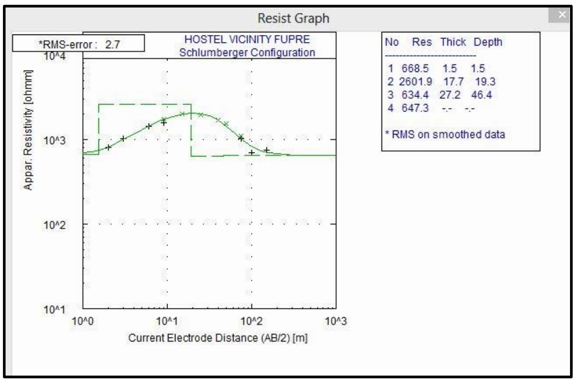

Figure 3: Geoelectric section for VES 1

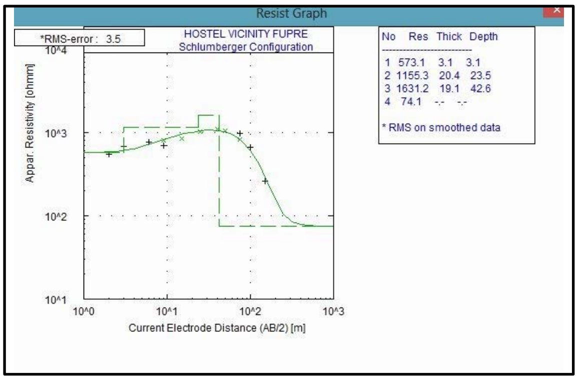

Figure 4: Geoelectric section for VES 2

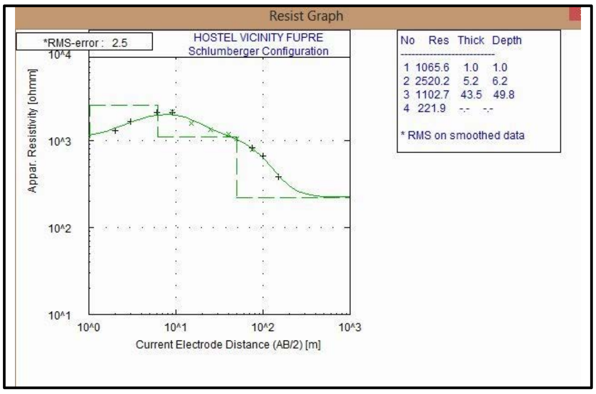

Figure 5: Geoelectric section for VES 3

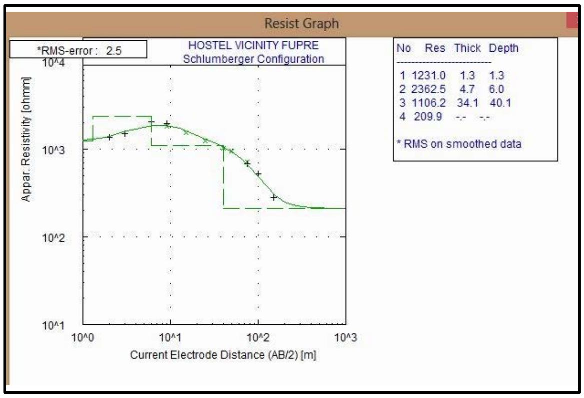

Figure 6: Geoelectric section for VES 4

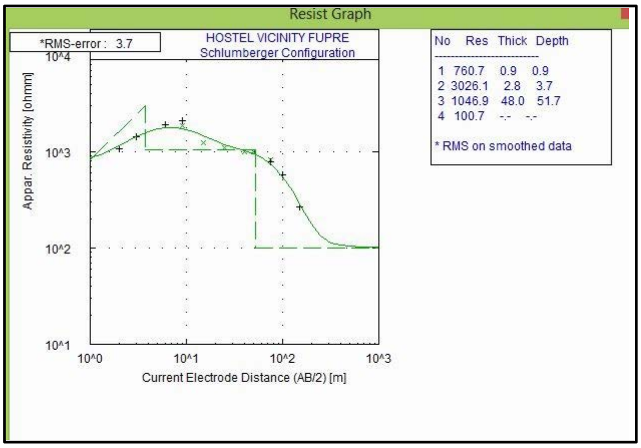

Figure 7: Geoelectric section for VES 5

Table 1: Vertical electrical sounding data acquired around students' hostels

ELECTRODE CONFIGURATION		GEOELECTRIC FACTOR, K	TRAVERSES									
			VES 1 Lat. 05°34'05.1" N; Long. 005°50'30.6" E; Elevation 13m		VES 2 Lat. 05°34'07.7" N; Long. 005°50'35.7" E; Elevation 12m		VES 3 Lat. 05°34'04.3" N; Long. 005°50'38.2" E; Elevation 12m		VES 4 Lat. 05°34'09.1" N; Long. 005°50'38.6" E; Elevation 14m		VES 5 Lat. 05°34'22.2" N; Long. 005°50'35.2" E; Elevation 11m	
AB/2 (m)	MN/2 (m)		R (Ω)	ρ_a (Ωm)	R (Ω)	ρ_a (Ωm)	R (Ω)	ρ_a (Ωm)	R (Ω)	ρ_a (Ωm)	R (Ω)	ρ_a (Ωm)
2	0.5	11.78	68.09	802.1	46.87	552.129	109.6	1291.1	116.7	1374.7	90.62	1067.5
3	0.5	27.5	37.51	1031.53	24.64	677.6	60.24	1656.6	55.01	1512.8	52.2	1435.5
6	0.5	112.36	12.77	1434.84	6.758	759.329	18.7	2101.1	18.2	2045	17.09	1920.2
9	0.5	253.79	6.143	1559.03	2.72	690.309	8.327	2113.3	7.667	1945.8	8.358	2121.2
9	2	60.5	28.36	1715.78	13.47	814.935	35.3	2135.7	30.37	1837.4	31.07	1879.7
15	2	173.64	11.67	2026.38	4.854	842.849	8.987	1560.5	8.966	1556.9	7.231	1255.6
25	2	487.93	3.980	1941.96	2.102	1025.63	2.741	1337.4	2.538	1238.4	2.264	1104.7
40	2	1250	1.350	1687.5	0.8845	1105.63	0.9362	1170.3	0.8256	1032	0.8083	1010.4
50	2	1961.14	0.787	1543.42	0.53	1039.4	0.53	1039.4	0.4884	957.82	0.505	990.38
75	2	4416.5	0.251	1108.54	0.1878	829.419	0.1787	789.23	0.1604	708.41	0.1878	829.42
75	10	868.21	1.167	1013.2	1.117	969.791	0.9616	834.87	0.7839	680.59	0.9068	787.29
100	10	1555.71	0.451	701.625	0.4285	666.622	0.4315	671.29	0.3401	529.1	0.3747	582.92
150	10	3520	0.2152	757.504	0.07462	262.662	0.1096	385.79	0.07941	279.52	0.07599	267.50

Table 2 is a summary of the interpretation of the results of the Vertical Electrical Sounding in the study area. The results show that the area is characterized by four geoelectric subsurface layers. Figure 8 shows the lithologic cross-section for the study area as deduced from the inferred lithology in Table 2.

Table 2: VES data interpretation results in the study area

Sounding Locations	Geoelectric Layers	Resistivity, ρ(Ωm)	Thickness, *h*(m)	Depth, D(m)	Inferred Lithology	Curve Type
VES 1	I	668.5	1.5	1.5	Clayey Topsoil	AQ
	II	2601.9	17.7	19.3	Coarse-grained sand	
	III	634.4	27.2	46.4	Clayey sand	
	IV	647.3	-	-	Clayey sand	
VES 2	I	573.1	3.1	3.1	Clayey Topsoil	KQ
	II	1155.3	20.4	23.4	Medium-grained sand	
	III	1631.2	19.1	42.6	Coarse-grained sand	
	IV	74.1	-	-	Wet clay	
VES 3	I	1065.6	1.0	1.0	Silty Topsoil	KQ
	II	2520.2	5.2	6.2	Coarse-grained sand	
	III	1102.7	43.5	49.8	Medium-grained sand	
	IV	221.9	-	-	Clay	
VES 4	I	1231.0	1.3	1.3	Silty Topsoil	KQ
	II	2362.5	4.7	6.0	Coarse-grained sand	
	III	1106.2	34.1	40.1	Medium-grained sand	
	IV	209.9	-	-	Clay	
VES 5	I	760.7	0.9	0.9	Clayey Topsoil	KQ
	II	3026.1	2.8	3.7	Coarse-grained sand	
	III	1046.9	48.0	51.7	Medium-grained sand	
	IV	100.7	-	-	Clay	

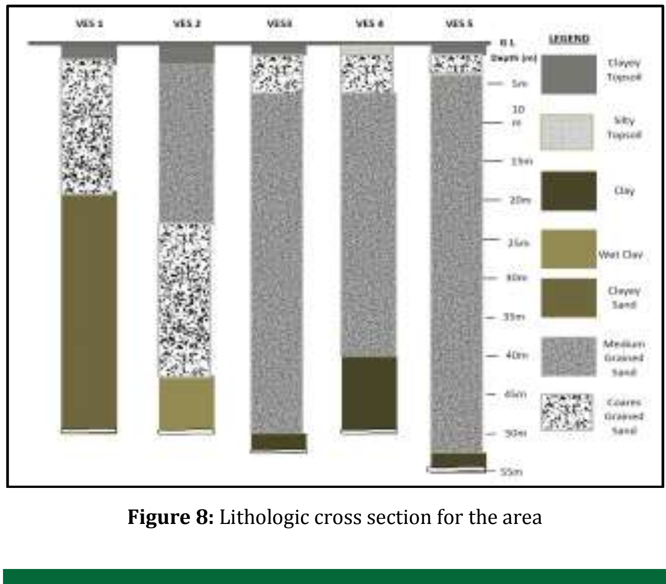

Figure 8: Lithologic cross section for the area

5.2 Discussion

VES 1: Four geoelectric layers of AQ curve type are delineated at this location. Inferred lithologies are characterized by a 1.5m thick topsoil that is composed of clayey sand with resistivity of 668.5 Ωm to a depth of 1.5m. Below this formation is a 17.7m thick coarse-grained sand to a depth of 19.3m. This is a *shallow aquifer zone* with resistivity value of 2601.9Ωm. This is followed by two layers of clayey sand formations with resistivity values of 634.4Ωm and 647.3 Ωm respectively with undetermined thicknesses and depths since they make up the last layers.

VES 2: Four geoelectric layers of KQ curve type are delineated at this location. The 3.1m thick topmost sediment to a depth of 3.1m is characterized by clayey topsoil materials with resistivity of 573.1 Ωm. Underlying this layer are a 20.4m thick medium-grained sand to a depth of 23.4m with resistivity of 1155.3 Ωm and a 19.1m thick coarse-grained sand to a depth of 42.6m with resistivity of 1631.2Ωm. The third layer constitutes the *deep aquifer zone*. Below this zone is a layer of wet clay with resistivity of 74.1Ωm and undetermined thickness and depth.

VES 3: Four geoelectric layers of KQ curve type are delineated at this location. Soil layers here are characterized by a porous and permeable 1.0m thick silty topsoil with resistivity of 1065.6 Ωm and depth of 1.0m.

Below this layer is a 4.7m thick coarse-grained sand to a depth of 6.0m. This is a *shallow aquifer zone* with resistivity value of 2520.2Ωm. However, this is followed by a 43.5m thick aquiferous medium-grained sand formation with resistivity values of 1102.7Ωm to a depth of 49.8m. Below this zone is a layer of clay with resistivity of 221.9Ωm and undetermined thickness and depth.

VES 4: Four geoelectric layers of KQ curve type are delineated at this location. Similar to VES 3, lithologies here are also characterized by a porous and permeable 1.3m thick silty topsoil with resistivity of 1231.0 Ωm to a depth of 1.3m. Underlying this layer is a 5.2m thick coarse-grained sand to a depth of 6.2m. This is a *shallow aquifer zone* with resistivity value of 2362.5Ωm. However, this is followed by a 34.1m thick aquiferous medium-grained sand formation with resistivity value of 1106.2Ωm to a depth of 40.1m. Beneath this zone is a layer of clay with resistivity of 209.9Ωm and undetermined thickness and depth.

VES 5: Four geoelectric layers of KQ curve type are delineated at this location. The 0.9m thick uppermost layer to a depth of 0.9m is characterized by clayey topsoil materials with resistivity of 760.7Ωm. Underlying this layer are a 2.8m thick coarse-grained sand to a depth of 3.7m with resistivity of 3026.1Ωm and a 48.0m thick medium-grained sand to a depth of 51.7m with resistivity of 1046.9Ωm. The second layer constitutes the *shallow aquifer zone*. Below the third layer is a layer of clay with resistivity of 100.7Ωm and undetermined thickness and depth.

6. CONCLUSION

The study reveals that the aquifer characteristics (depth, thickness, resistivity and lithology) vary laterally and vertically from one VES location to another around the students' hostels in FUPRE. This may be due to the difference in mineralogical compositions of the rock types that make up the soil. This non-uniformity in aquifer characteristics implies that prolific groundwater will not occur under the same conditions in different parts of FUPRE hence, the need for this study. The low resistivity values obtained are observed to be prevalent in zones with high clay rock-forming minerals which bound the aquifer top and bottom while the high resistivities are observed to be dominant in zones with medium-grained and especially coarse-grained sands which constitute the potential aquifer materials.

Two potential groundwater aquifer zones are delineated in the study area. The *unconfined shallow aquifer* ***zones*** found at VES 1, 3, 4 and 5 locations have shallow overburden depth ranging between 3.7-19.3m and coarse-grained sand columns with thicknesses ranging between 2.8-17.7m and the *confined deep aquifer zone* found at VES 2 location coinciding with deep overburden layer at a depth of 42.6m and coarse-grained sand column with appreciable thickness of 19.1m.

7. RECOMMENDATION

Sequel to the findings of this study, it is recommended that boreholes for sustainable groundwater supply around the Students' Hostels should be drilled and screened at a depth ≥40.0m at VES 2 location. However, aquifers at VES 1, 3, 4 and 5 have potentials for groundwater but are vulnerable to contamination since they are unconfined. Unconfined aquifer zones have higher tendency of allowing the permeation of contaminant fluids into the groundwater such that in any event of contamination such water becomes unsafe for both domestic and industrial uses.

It is also recommended that electrical resistivity and hydrogeological surveys should be conducted at different locations in FUPRE to delineate the appropriate deep aquifer zones before any borehole(s) are drilled for potable groundwater supply to avoid possible contamination.

REFERENCES

Akpoborie, I.A., Aweto, K.E., Ohwoghere-Asuma, O., 2014. Urbanization and Major Ion Hydrogeochemistry of the Shallow Aquifer at the Effurun - Warri Metropolis, Nigeria. Environment and Pollution. 4(1), 37-46.

Alaminiokuma, G. I. and Chaanda, M. S. (2020). Groundwater Potential of Mando, Kaduna, Crystalline Basement Complex, Nigeria, Journal of Earth Sciences and Geotechnical Engineering. 10(2), 15-26.

Amadi, A.N., 2009. Aquifer Characteristics and Groundwater Vulnerability in parts of Warri, Delta State, Nigeria. Journal of Science, Technology and Mathematics Education (JOSTMED). 6(I), 108-123.

Atakpo, E.A., 2013. Geoelectric Investigation of Deghele Community in Warri South West L.G.A, Delta State, Nigeria. Journal of Applied Physics. (1), 46-51.

Avbovbo, A.A., 1978. Tertiary lithostratigraphy of Niger Delta: Bull. Amer. Assoc. Pet. Geol.,62, pp. 291-306.

Etu-Efeotor, J.O., Akpokodje, G.E., 1990. Aquifer systems of the Niger Delta. Journal of Mining and Geolog1. 26 (2), 264-266.

Iloeje, N.P., 1981. A new geography of Nigeria (A new revised edition), published in Great Britain by B. Williams Colwes Ltd, London, pp. 85–120.

Iserhien-Emekeme, R.E., Ofomola, M.O., Bawallah, M., Anomohanran, O., 2017. Lithological Identification and Underground Water Conditions in Jeddo Using Geophysical and Geochemical Methods. Hydrology. 4(42), 1-15.

MgboluI, C.C., Obiadi, I., Obiadi, C.M., Okolo, C.M., Irumhe, P.E. 2019. Integrated groundwater potentials studies, aquifer hydraulic characterization and vulnerability investigations of parts of Ndokwa, Niger Delta Basin, Nigeria. Solid Earth Sciences. 4(3), 102-112.

Nwokocha, C., Uko, E.D., Ngah, S.A., 2018. Aquifer Delineation in Omuma Local Government Area of Rivers State, Nigeria Using Vertical Electrical Sounding Techniques. Journal of Applied Physics. 10(2), 65-70.

Weber, K.J., Daukoru, E.M., 1975. Petroleurn Geology of the Niger Delta. 9th World Petroleum Congr. Tokyo, Proc.2, pp. 209-222.

Whiteman, A., 1982. Nigeria: its Petroleum Geology, Resources and Potential. London: Graham and Trotman Publishers, pp. 301-310