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GROUNDWATER POTENTIAL INVESTIGATION USING 1-D ELECTRICAL RESISTIVITY TECHNIQUE AT NIGER STATE POLYTECHNIC ZUNGERU, ZUNGERU MAIN CAMPUS, NIGER STATE, NIGERIA

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ABSTRACT

Electrical resistivity method employing vertical electrical sounding was carried out with aim to investigate groundwater potential at Niger State Polytechnic, Zungeru, Niger State. Ten points were selected at different locations within the campus for vertical electrical sounding (VES), using Schlumberger protocol. Maximum current electrodes separation (AB) of 120m was used. The investigation was carried out using Terrameter PE 02 SAS 300 system. The survey was able to investigate groundwater potential of the area. The IPI2win software was used for data analysis. The geologic section derived from geoelectric parameters revealed three subsurface layers. The first layer is interpreted as topsoil, the second layer is inferred to be weathered rock, while the third layer probably could be fresh basement rock. The thickness of the superficial cover is averagely 2.49m, and the depth to the basement is between 5.2m to 22.9m, the aquifer thickness ranges between 1.67 to 21.1m. The laterite in the second layer shown in some locations is of great importance as it reduces surface run off and aids infiltration into the underlying aquifer. The thickness of the aquifer component in the north-southern half of the study area is large enough to harbour substantial quantity of water. Areas around ZUN 01 and ZUN 05 could be potential areas for groundwater exploration. In this research, the depth to bedrock and aquifer thickness were determined, lithological formations within the overburden were delineated and approximate depths were estimated in order to establish suitable sites for borehole construction. A correlation of the borehole log data with the VES was made and is in agreement.

Keywords: Aquifer, Electrode, Groundwater, Resistivity

INTRODUCTION

Water is essential for development of different season's irrigation, industry and domestic purpose. Groundwater is the main source for portable water supply, domestic, industrial and agricultural uses. The scarcity of groundwater increases day by day due to rapid increase in population, urbanization, industrial and agricultural related activities. Groundwater is more advantageous than the surface water due to its lesser extent of evaporation and pollution. Water scarcity problem affects the human chain and other living things. The rapid rural development in and around the study area and the associated activities have resulted in the increase of population demands leading to excesses utilization of groundwater.

Geophysics has played a useful role for groundwater exploration for many years and improvements in instruments and the development of better methods is resulting in a widening of its applications. It measures the physical properties of the subsurface, specifically related to the position of water and its quality, and the position and properties of geological units.

The electrical resistivity method primarily allows measurement of the potential differences on the surface due to the current flow within the ground. This method employs a phenomenon which makes possible the delineation and fluid content determination of various subsurface geologic units by the analysis of their electrical resistance response. Since there exists a close relationship between the electrical conductivity and some hydrogeological properties of an aquifer system, the electrical resistivity method has widely been used for quantitative estimation of water transmitting properties of aquifers, aquifer zone delineation and evaluation of the geophysical properties of the aquifer zone in several locations (De Lima and Niwas, 2000; Chand *et al*., 2004; Louis *et al*., 2004; Mufid Al-Hadithi *et al*., 2006; Niwas and de Lima 2003; Dhakate and Singh 2005; Khalil, 2006).

This work is aim at using the electrical resistivity technique to delineate the subsurface lithology and assessment of groundwater potential of the area under study, in order to guide the borehole drilling to minimize the drilling of the dry borehole outcome in the study area (Keary and Brooks, 1992; Telford et al, 1990).

LOCATION OF THE STUDY AREA

Zungeru is a town in Niger State, Nigeria. It was the capital of the British protectorate of Northern Nigeria from 1902 until 1916.Zungeruharbours the site of the study area, Niger StatePolytechnic is located along Zungeru-Bida Road beside the RiverKaduna.The study area is bounded by latitude

9^{0}44’45.46” N, 9^{0}45’26.60” N and longitude 6^{0}7’55.25” E, 6^{0}8’39.07” E with an average of 131m above sea level.

Fig. 1. Location map of the study area, the arrowed lines represent the VES positions. Map adopted from Google earth.

MATERIAL AND METHOD

A. Theory

The geophysical instruments used in this study include the following: Terrameter PE 02 SAS 300, electrodes (current electrodes and potential electrode), reels of connecting cables, battery and hammer. A total of 10 VES points were occupied on the study area with maximum electrode spacing of 120m.The Vertical Electrical Sounding which is a 1-D resistivity approach is used to measure the vertical variations in electrical properties beneath the earth surface using the Schlumberger electrode protocol. It involves the use of a pair of current electrodes and a pair of potential electrodes to measure the resultant potential difference within the subsurface (Fig. 2). Data are obtained by increasing the electrode spacing linearly about a central position whose vertical resistivity variation is sought.

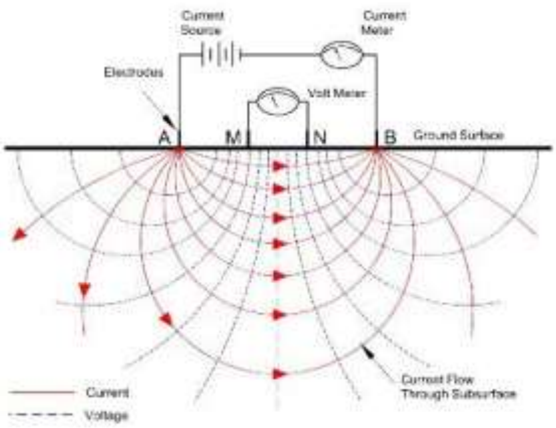


Fig. 2. Schematic illustration of Basic Concept of Electrical Resistivity Measurement (Muchingami, *et all.*, 2013)

Resistance measurements are made at each expansion and multiplied by the respective geometric factor (K) to give the apparent resistivity of the point using the equation;

$$\rho_a = \frac{K\Delta V}{I} = KR$$

Where

$$K = \frac{\frac{\pi}{2}\left[\left(\frac{AB}{2}\right)^2 - \left(\frac{MN}{2}\right)^2\right]}{\left(\frac{MN}{2}\right)}$$

$\rho_a =$ Apparent resistivity, K = Geometric Factor, V = Voltage, I = Current, R = Resistance, AB is the Current Electrode Separation and MN is potential electrode separation.

During data acquisition the electrodes were connected appropriately to their respective terminals on the Terameter through cables and hammered to make good contact with the earth. During the sounding, the instrument sends down direct current into the earth subsurface through the pair of steel current electrodes, while the established subsurface potential difference across the subsurface under investigation was measured by the Terameter through the steel potential electrodes. For each sounding, the Terameter computes and displays a mean digital value of the apparent resistivity of the subsurface under investigation.

B. Field Procedures and Data Collection

Measurements were taken along profiles following the technique outlined by (Telford, *et all.*, 1990). The Schlumberger electrode configuration was used, with maximum current electrode separation (AB/2) of 60.0 m to establish various sounding points. Measurements were taken at each VES point by expanding the current electrodes symmetrically about the center of the spread. The maximum exploration depth (also known as depth of penetration) of the AMNB method is 1/3 to 1/4 of the maximum distance of AB (Frohlich, *et all.*, 1996). That is, for AB = 120m the depth probed is about 40m to 30m. This depth is considered enough for groundwater study and other parameters of interest. Measurements were taken starting from AB/2 = 1.5m, 2.5m, 4.0m, 6.0m, 8.0m, 10.0m, 15.0m, 20.0m, 25.0m, 32.0m, 40.0m, to 60.0m. At a distance when the potential difference between the potential electrodes becomes too small for the potential to be measured accurately, the potential electrodes (MN) spacing was also increased from 1.0m to 5.0m to obtain a measurable potential. Measurement then continue to next AB/2, using the new potential electrodes position, and then to the next, until to a distance of 60.0m, then the equipment was moved to the next VES point and repeated the same procedure until the whole profiles were covered. Readings were taken at five different points.

RESULTS AND DISCUSSIONS

A. Data Interpretation

The results collected from the field were used to generate a profile of the points of soundings. The software used was the IPI2win software, which plotted the apparent resistivity against the electrode spacing. The resistivity values generated the soil profile which gave information on the different soil types within the subsurface formation. The Vertical Electrical Sounding (VES) for ZUN 01 and 02 displayed simple A-type curve, ZUN 04 displayed HA-type while ZUN 03, 05, 06, 07, 08, 09 and 10 displayed simple H-type curve Table I.

B. **DISCUSSION**

The summary of the results of the VES data are presented on Table I. This table comprises the coordinates and the elevation above mean sea level of each VES points. Also, the thickness and the resistivity of the observed layers and the curve type of each VES point is presented. The interpreted VES data revealed that the area is characterised by three geoelectric layers with varied thickness and resistivity values (Table I). The lithology of the subsurface were inferred from the geoelectric sections bearing in mind the surficial geology and the subsurface geology obtained from nearby borehole log Fig. 7. The inferred lithologies from top to bottom are lateritic clay soil, weathered basement rock and fresh competent basement rock. Groundwater potential was evaluated based on the thickness of the overburden, the thickness and the resistivity of the weathered layer. From Table I, the overburden thickness ranges from 1.27 m to 5.2 m (Table I), the weathered layer thickness ranges from 1.67 m to 21.1 m and with the varied resistivity values as shown on Table I. VES stations ZUN 02, 03, 04, 05, 07, 08, 09 and 10 are non aquiferous as there is no indication of weathering or fracturing that will serve as conduit for water storage and its passage. VES ZUN 01 and 06 revealed a prolific aquifer potential as there is indication of productive fracturing within the weathered basement and the very thick overburden which is most likely to store water (Table I). Groundwater extraction can be achieved by drilling to a depth of about 45 to 52m based on the acquired borehole log available of the surveyed area.

Table I. Summary of the results of interpreted VES data

STATION	COORDINATES LATITUDE/ LONGITUDE	ELEVATION (m)	LAYER NUMBER	RESISTIVITY (Ωm)	THICKNESS (m)	DEPTH (m)	LITHOLOGY	CURVE TYPE
ZUN 01	09⁰44.677'N 006⁰07.962'E	117	1	28.2	1.72	0.00	Sandy, clay & silt	**A**
			2	72.9	21.1	1.72	Weathered basement	
			3	2804	Infinity	22.9	Fresh basement	
ZUN 02	09⁰44.644'N 006⁰08.076'E	116	1	215	1.66	0.00	Lateritic soil	**A**
			2	379	4.47	1.66	Weather basement	
			3	6358	Infinity	6.12	Fresh Basement	
ZUN 03	09⁰44.677'N 006⁰07.962'E	113	1	284	1.52	0.00	Lateritic soil	**H**
			2	39	2.30	1.52	Sandy, clay & silt	
			3	2265	Infinity	3.82	Fresh basement	
ZUN 04	09⁰44.911'N 006⁰08.005'E	113	1	140.3	2.44	0.00	Lateritic, clayey & silty soil	**HA**
			2	47.5	2.34	2.44	Clay-fresh water	
			3	78.1	Infinity	4.78	Clay soil	
ZUN 05	09⁰44.737'N 006⁰08.917'E	116	1	141.9	1.78	0.00	Lateritic, clayey & silty soil	**H**
			2	35.1	3.12	1.78	Clay-fresh water	
			3	1055	Infinity	4.90	Fresh basement	
ZUN 06	09⁰45.031'N 006⁰07.896'E	120	1	255	5.2	0.00	Sand and Gravel	**H**
			2	172	15.9	5.2	Weather basement	
			3	4642	Infinity	21.1	Fresh Basement	
ZUN 07	09⁰44.921'N 006⁰87.090'E	119	1	230	1.82	0.00	Lateritic soil	**H**
			2	114	4.09	1.82	Sand and Gravel	
			3	3757	Infinity	5.91	Fresh Basement	
ZUN 08	09⁰44.890'N 006⁰08.037'E	112	1	272	2.05	0.00	Lateritic soil	**H**
			2	51	7.48	2.05	Clay soil	
			3	1896	Infinity	9.53	Fresh Basement	
ZUN 09	09⁰44.688'N 006⁰07.859'E	113	1	57.4	1.27	0.00	Sandy, clay & silt	**H**
			2	125.5	4.24	1.27	Weather basement	
			3	467.5	Infinity	5.51	Weather basement	
ZUN 10	09⁰44.784'N 006⁰07.896'E	115	1	128.4	2.33	0.00	Lateritic, clayey & silty soil	**H**
			2	72.5	1.67	2.33	Clay soil	
			3	426.2	Infinity	4.00	Weather basement	

N	ρ	h	d	Alt
1	215	1.66	1.66	-1.655
2	379	4.47	6.12	-6.123
3	6358			

Fig. 3. A typical resistivity curves and interpreted model for VES station ZUN 01 STATION: ZUN 01, AZIMUTH : N/S COORDINATES: N09^{0}44.677' E 006^{0}07.962'

N	ρ	h	d	Alt
1	255	5.2	5.2	-5.199
2	172	15.9	21.1	-21.06
3	4642			

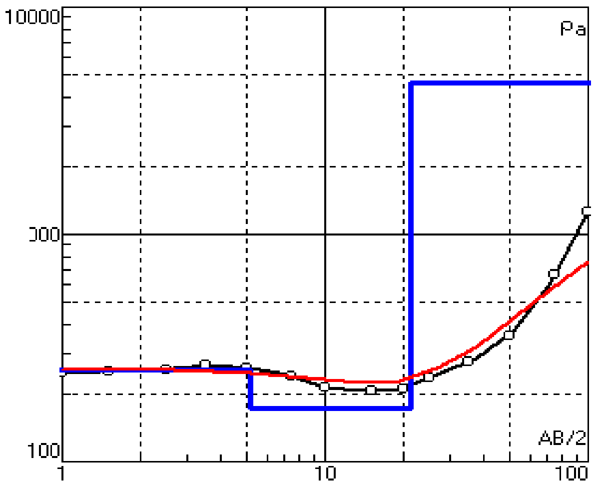


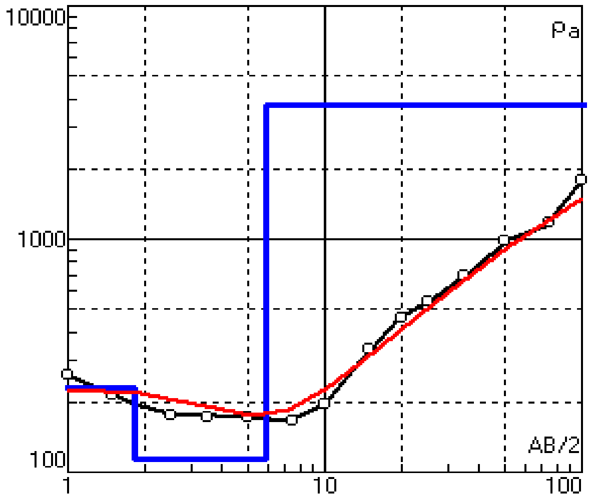
Fig. 4. A typical resistivity curves and interpreted model for VES station ZUN 06 STATION: ZUN 06, AZIMUTH : NW/SE COORDINATES: N09^{0}45.031' E006^{0}07.896'

N = Layer Number, ρ = Resistivity (ohm-m), h = Thickness (m), d = Depth (m)

Field curve

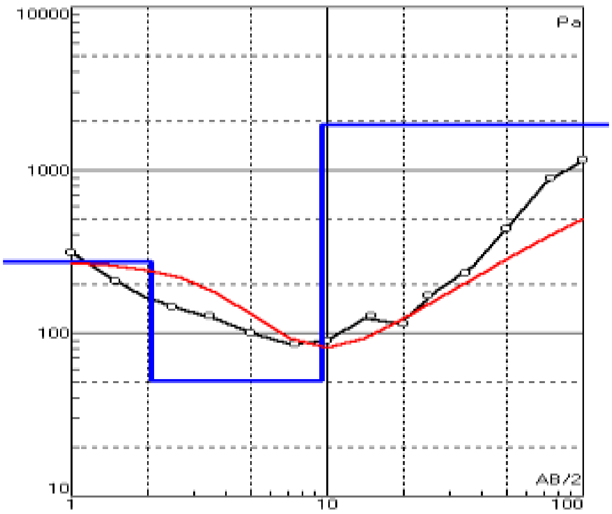
Digitized curve

Layer model



N	ρ	h	d	Alt
1	230	1.82	1.82	-1.819
2	114	4.09	5.91	-5.911
3	3757			

Fig. 5. A typical resistivity curves and interpreted model for VES station ZUN 07 STATION: ZUN 07, AZIMUTH : NE/SW COORDINATES: N09^{0}44.921' E006^{0}87.090'



N	ρ	h	d	Alt
1	272	2.05	2.05	-2.054
2	51	7.48	9.53	-9.532
3	1896			

Fig. 6. A typical resistivity curves and interpreted model for VES station ZUN 08 STATION: ZUN 08, AZIMUTH :NW/SE COORDINATES: N09^{0}44.890' E006^{0}08.037'

N = Layer Number, ρ = Resistivity (ohm-m), h = Thickness (m), d = Depth (m)

-.-.-.-.- Field curve

Digitized curve

Layer model

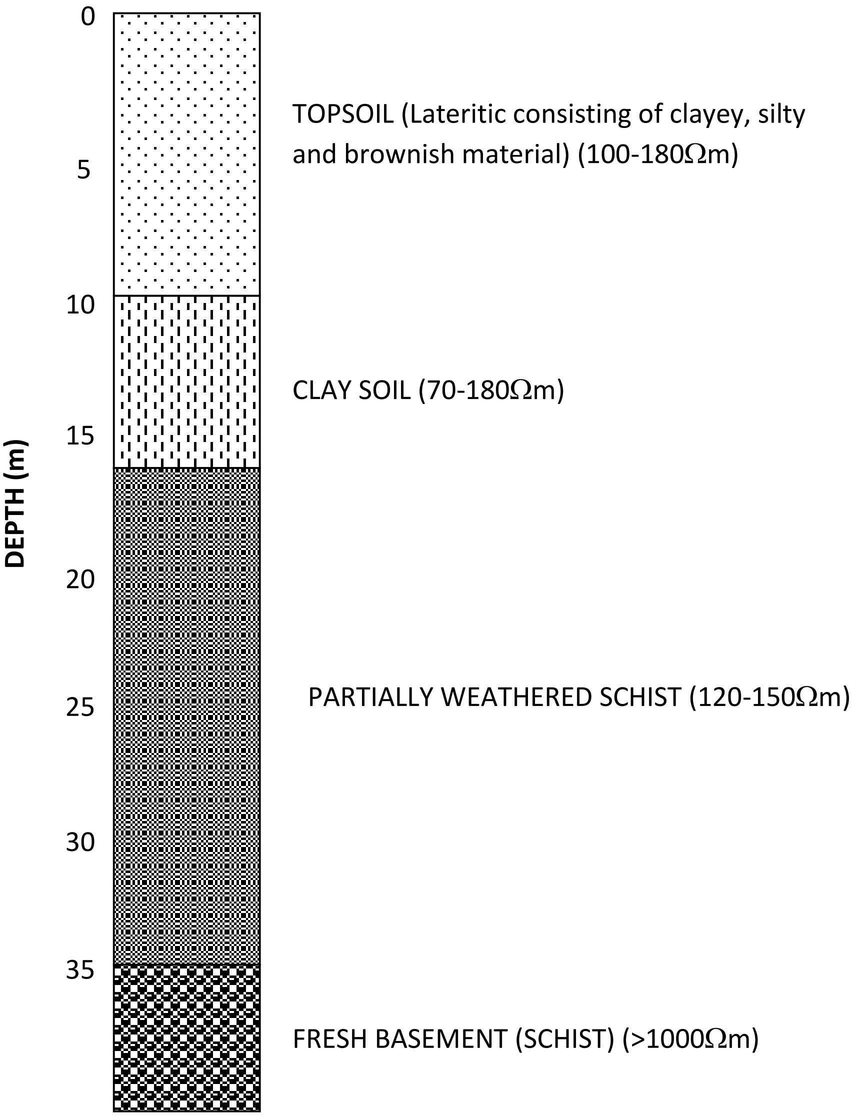


Fig. 7. Geological Well-Log obtained from Demont Drilling Company Limited, Minna (Drilling Engineers, 2010).

CONCLUSION

The survey was able to investigate groundwater potential of the area. The geologic section derived from geoelectric parameters suggests three subsurface layers. The first layer is interpreted as topsoil, the second layer is inferred to be weathered rock, while the third layer probably could be fresh basement rock. The thickness of the superficial cover is averagely 2.49m, and the depth to the basement is between 5.2m to 22.9m, the aquifer thickness ranges between 4.09 to 21.1m. The laterite in the second layer shown in some locations is of great importance as it reduces surface run off and aids infiltration into the underlying aquifer. The thickness of the aquifer component in the north-southern half of the study area is large enough to harbour substantial quantity of water. Areas around ZUN 01 and ZUN 06 could be potential areas for groundwater exploration. It is recommended that a borehole be drilled at VES station ZUN 01 and 06, both stations to a depth of about 23 m. The fracture in both traverses may also extend to any area parallel but close to these traverses. Such location can also be drilled. Other geophysical methods like the Electromagnetic (VLF) Method and Dipole-dipole electrical resistivity survey can be used to complement the methods used for this study.

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