

Groundwater Investigation in a Fadama Terrain: A Geophysical Appraisal of Jebba-North, Nigeria

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Abstract

Hydro-geophysical study was carried out in the Fadama terrain overlying the basement complex area of Jebba-North Nigeria using Vertical Electrical Resistivity sounding to determine the groundwater potential of the subsurface layers. A total of eight vertical electrical sounding locations were probed. The sounding data were processed and interpreted using WINRESIST interpretation software. The Vertical Electrical sounding curves revealed that the area is generally characterized by three geo-electric layers. The underlying geo-electric section comprising topsoil, weathered basement and fresh basement was established. The top soil (laterite) is a highly resistive layer with resistivity ranging from 2.6 Ω m to 1068.0 Ω m and thickness ranging from 0.6 m to 9.5 m. The weathered basement layer has resistivity ranging from 7.2 Ω m to 408.7 Ω m and the thickness varies from 5.3 m to 62.6 m while the fresh basement has resistivity values ranging from 132.6 Ω m to 5438.8 Ω m and depth to basement varies between 6.0 m and 63.2 m. Two types of aquifers, which are the weathered basement and fractured basement aquifers, have been delineated in this study. These aquifer units may have significant groundwater potential having a range of depths from 5m to 65m.

1. Introduction

Fadamas are formed on the flood-plains of paleo-channels of streams which may or may not be abandoned by such rivers. Fadamas are characterized by alluvial deposits with sediments depicting the flow regimes of ancient rivers. The energy of flow may be inferred from the specific textural parameters of the clastic fragments which constitute the fluvial sediments found in the flood plains, centres of large scale agricultural activities involving dry season farming supported by irrigation. Waters (surficial or subterranean) are derived from flowing streams within the alluvial plains or drawn from tube wells and bore-holes, sunk into the alluvial deposits. The energy condition of alluvial deposits is inferred from the grain-size composition of sedimentary units found in the stratigraphic section of the flood plain deposits. Previous workers on Fadamas have reported litho-facies (lithological units) of varying textural characteristics, mineralogy, form and physical appearance (Leeder, 1982).

Where Fadamas support irrigation farming there is no sufficient information about the groundwater availability and the storage capacity of aquifers within the flood plain deposits that constitute the Fadama land. This research therefore uses available equipment and systematic approach to obtain pertinent information about the structure (layering) and the textural characteristics of the lithology that constitute Fadama land. Data collections involved the use of both geological and geophysical techniques.

2. Materials and Methods

The study area, Jebba-North, Nigeria, falls within longitude 4°48'E and 4°51'E and latitude 9°7'N and 9°12'N. It makes the western part of sheet 181 Jebba South-east. The study area also lies within the North Central Nigeria, (Figures 1 and 2).

The climatic condition of the study area is dry and wet with two distinct seasons: the rainy and dry seasons. The rainy season runs from April to November, while the dry season extends from November to April. The field work was carried out in the dry season, around November. The average annual temperature ranges between 35°C during the day and 25°C at night. The annual range of rainfall in the wet season is about 1500 mm. The area lies within the Guinea Savannah vegetation belt of Nigeria, characterized by scanty trees, shrubs and grasses due to the moderate annual rainfall.

The study area consists of four rock types: migmatite gneiss, quartzite complex, the Pan African granitoids and the minor acid dykes.

The geophysical investigation involved the electrical resistivity measurements in the accessible areas of the Fadama terrain. The survey engaged the Schlumberger vertical electrical sounding. In this method, current is introduced artificially into the earth through a pair of electrode pinned to the ground (current electrode) and the resulting potential difference due to the current is measured through another pair of electrode (potential electrode) that is also pinned to the ground, any subsurface variation in conductivity alters the current flow; which in turn affects the

distribution of electric potential at the surface (Chukwurah, 1992; Etu-Efeotor, 1981; Dobrin and King, 1976; 1988 and Parasins, 1966; 1972 and 1986).

A total of 8 stations, spaced some kilometers apart, were established and surveyed for 159 vertical electrical soundings using a method whereby readings were taken automatically and the results were averaged continuously with an ABEM SAS 300C terrameter and a maximum half current electrode spacing of 100 m since it is a near surface investigation. Two measuring electrodes were closely placed mid-way between the two widely spaced current electrodes. Separation of the inner potential electrode was fixed with 0.5 m, 1.0 m, 2.5 m and 7.5 m while the other current electrodes were moved in the following succession 10 m, 20 m, 30 m, 40 m, 50 m, 60 m, 70 m, 80 m, 90m and 100m. The electrodes were firmly inserted into the ground at required separation mentioned above as measurements were being taken. The cables were then connected to the electrode and the meter and the main instrument was switched on. The various resistivity values obtained were then observed and recorded and their corresponding resistance values obtained.

3. Results and Interpretations

The statistical summary of the results is shown in Table 1. Eight (8) vertical electrical soundings were conducted at Jebba-North. The Schlumberger electrode configuration was used. The apparent resistivity values at each station along the axis were obtained by multiplying the value of the resistance at each depth with corresponding geometric factor. The data were interpreted by Partial Curve Matching Technique, Table 2 and Fig. 4.1 to 4.8. The resistivity and thickness obtained from the partial curve matching were improved upon by using an automatic iterative computer program. A close study of the VES curves showed that most of them depict a three layer section characterized by H-curve-type which covers almost 95% of the study area and A-curve-type (Table 2). The type of curves (Selemo et al, 1995) and the resistivity of the material (Oyedele, 2001) were used as guides in the interpretation and analysis of the geo-electric parameters in terms of probable, potable and sustainable water supply.

3.1.1 Curve type A: This curve shows three geo-electric layers. This curve type is typical of a poor site for ground water accumulation. The only exception is the occurrence of fracture(s) within the layers. VES 8 has this kind of curve.

3.1.2 Curve type H: This VES curve shows three geo-electric layers. This curve type is typical of a good site for ground water accumulation especially if the second layer is thick sand/gravel. The only exception is when the second layer is very thin but the last layer is impermeable, (Identified from exceptionally high resistivity). VES 4, 5, 6, 7, 12, 13 and 14 have this kind of curve.

3.2 Interpretation of the geo- electric section

The geo-electric section shows the lateral and vertical relationship between subsurface layers as obtainable from the variation of the apparent resistivity values with depth within the study area. It is a quick guide to studying the changes in the rock types and structures with depth.

Three sections of the geo-electric layers taken in different direction have been established in this research.

3.2.1 VES 5, 6, 8, 14 (Fig.3.1)

It has three (3) layers i.e the top soil, the weathered basement and the fresh basement which has been delineated by electrical resistivity. The top soil has resistivity value ranging between 2.6 Ω m-964.7 Ω m with a thickness in the range of 0.6m-9.5m. The weathered basement has range of resistivity between 29.7 Ω m-408.7 Ω m and range of thickness between 18.2m-62.6m, while the fresh basement has a range of resistivity between 132.6 Ω m-5438.8 Ω m.

3.2.2 VES 4, 8, 12 (Fig. 3.2)

It has three layers i.e the top soil, the weathered basement and the fresh basement which have been delineated by electrical resistivity. The top soil has resistivity values ranging from 2.6 Ω m to 1068.0 Ω m with a thickness in the range of 0.6 m - 3.5 m. The weathered basement has range of resistivity between 7.2 Ω m - 408.7 Ω m and range of thickness between 15.0 m - 62.6 m, while the fresh basement has a range of resistivity between 395.9 Ω m - 5270.0 Ω m.

3.2.3 VES 4, 5, 7 (Fig. 3.3)

It has three layers i.e the top soil, the weathered basement and the fresh basement which have been delineated by electrical resistivity. The top soil has resistivity value ranging from 321.4 Ω m to 1068.0 Ω m with thickness in the range of 0.9 m to 9.5 m. The weathered basement has range of resistivity between 7.2 Ω m and 88.1 Ω m and range of thickness between 16.0 m - 19.8 m, while the fresh basement has a range of resistivity from 3539.7 Ω m to 5438.8 Ω m.

3.3 Assessment of groundwater prospect and aquifer delineation

Electrical resistivity contrasts exist across interfaces of lithologic units in the subsurface. These contrasts are often adequate to delineate discrete geo-electric layers and identify aquiferous layers (Schwarz, 1988).

Generally, the interpretation of the 8 VES conducted in the study area reveals the presence of 3 geo-electric layers and they are of varying characteristics both in composition and lithology. These layers fall into three groups and these are topsoil, the weathered layer (which can be sandy, clayey sand, or clayey) and the fractured/fresh basement rock. The resistivity of earth material is strongly affected by water saturation and water quality (Lucius et al., 2001). The resistivity parameter is an important factor in appraising an aquifer.

The topmost layer (top soil) is exposed at the surface and its high resistivity value has been interpreted to be due to the presence of sand and pebbles in ground mass of lateritic matrix. The resistivity of the topsoil ranges between 2.6 Ω m to 1068.0 Ω m while the thickness varies between 0.6 m and 9.5 m.

The resistivity and thickness of the weathered layer ranged between 7.2 Ω m to 408.7 Ω m and 5.3 m to 62.6 m respectively. Its low resistivity value suggest possible seepage conduits of water flow. Weathering must have taken place to a great extent in the layer thereby increasing its water retention ability and porosity.

The fresh basement rock has resistivity values which range from 132.6 Ω m to 5438.8 Ω m and depth to basement varies between 6.0 m and 63.2 m. The fresh basement is made up of granitic bodies with little or no fracture. It is as such very poor in conductivity implying its very high resistivity value. This is expected in non-permeable or highly compacted rock types.

High resistive values close to the surface forming a crest or doming up corresponds to fresh basement close to the surface and this implies shallow weathering. Low resistivity values close to the surface or high resistivity values forming a trough corresponds to deep weathering. The thick zones of weathered and fractured rock are favorable for construction of bore wells. VES 14, VES 4, VES 5, VES 6, VES 7, VES 13 and VES 12 have fractures with low resistivity values below 100 Ohm-m.

4. Discussion and Conclusion

On the basis of all the available information obtained from the interpretation of vertical Electrical Sounding data, it is observed that the geo-electric sections of the study area include the top soil layer, weathered basement layer, and the fresh basement.

The topsoil is the first geo-electric layer. It is a thin, highly resistive layer with resistivity ranging from 2.6 Ω m to 1068.0 Ω m. It is composed of sand and pebbles in ground mass of lateritic matrix occurring in various proportions. This probably accounts for the difference in the resistivity values. The thickness of the top soil layer ranges from 0.6 m to 9.5 m.

The weathered basement layer which is a low resistive layer with resistivity values ranging from 7.2 Ω m to 408.7 Ω m. A low resistivity value also indicates substantial clay content. Higher resistivity implies lower clay proportions and increased permeability. The thickness of this layer varies from 5.3 m to 62.6 m, and it is dependent on the degree of bedrock weathering.

Fresh Basement rock is characterized by high resistivity values which exceeds 1000 Ω m in almost all the locations. Depth to fresh rocks from the interpretation of sounding curves is found to range between 6.0 m and 63.2 m.

Based on all the information obtained from the interpretation of the VES data, 7 VES stations have been chosen as the most viable locations for the development of groundwater resources in the study area. These include VES

stations 14, 4, 5, 6, 7, 13 and 12. The thickness and resistivity of the aquifers at these VES stations indicates a very good potential for groundwater. It can be concluded that the possibility of tapping groundwater resources in this study area is bright. The resistivity data/information from this research to a great extent proved to be reliable for groundwater exploration in the basement complex terrain particularly when using the Schlumberger configuration.

Acknowledgement

We acknowledge the effort of Mr. A.D. Adedoyin of the Department of Geology and Mineral Sciences, University of Ilorin, Ilorin, Nigeria, for his contributions during the field exercise. Others are some members of the Jebba Team (project students) of 2009 and 2010; namely, Funsho Taiwo, Yinka Adeoye, Morakinyo Ebunoluwa, Tititola, Adesina Obarehin, Arisekola Banke and others who assisted with data collection.

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Table1: Statistical summary of the VES Data

Resistivity ($\square$ m)	Thickness (m)	Resistivity ($\square$ m)	Thickness (m)	Resistivity ($\square$ m)	Thickness (m)
14		4		5	
588.0	5.7	1068.0	3.5	321.4	9.5
29.7	18.2	7.2	16.0	42.0	19.8
4558.5		5270.0		5438.8	
Resistivity ($\square$ m)	Thickness (m)	Resistivity ($\square$ m)	Thickness (m)	Resistivity ($\square$ m)	Thickness (m)
6		7		8	
964.7	2.5	452.9	0.9	2.6	0.6
53.8	25.4	88.1	19.4	408.7	62.6
132.6		3539.7		4856.0	
Resistivity ($\square$ m)	Thickness (m)	Resistivity ($\square$ m)	Thickness (m)		
13		12			
441.7	0.7	381.3	1.4		
53.8	5.3	44.7	15.9		
2095.7		395.9			

Table2: showing types of the interpreted curves

VES NO.	CURVE TYPE	CURVE-CHARACTERISTICS	NO OF GEO ELECTRIC LAYERS
4	H	$\rho_1 > \rho_2 < \rho_3$	3
5	H	$\rho_1 > \rho_2 < \rho_3$	3
6	H	$\rho_1 > \rho_2 < \rho_3$	3
7	H	$\rho_1 > \rho_2 < \rho_3$	3
8	A	$\rho_1 < \rho_2 < \rho_3$	3
12	H	$\rho_1 > \rho_2 < \rho_3$	3
13	H	$\rho_1 > \rho_2 < \rho_3$	3
14	H	$\rho_1 > \rho_2 < \rho_3$	3

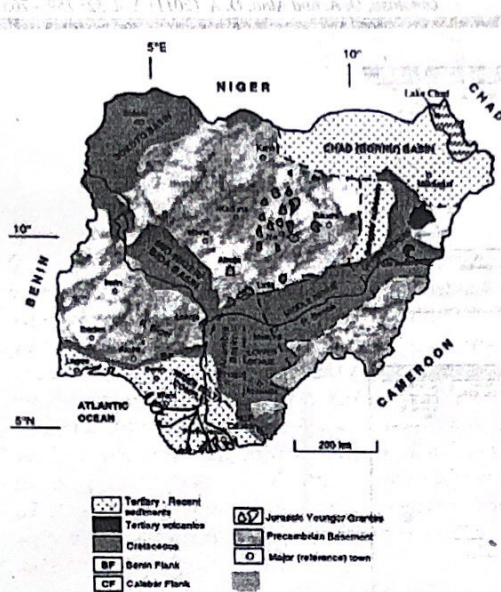


Fig. 1: Geological map of Nigeria Showing the Study area (Ohaie et al., 2004)

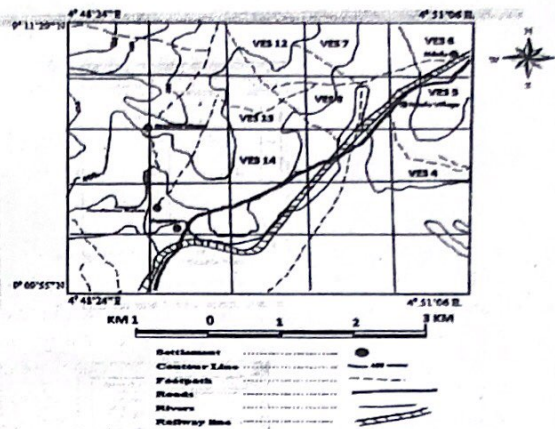


Fig. 2: Topographical Map of Jebba-North, Nigeria Showing the Study Area.

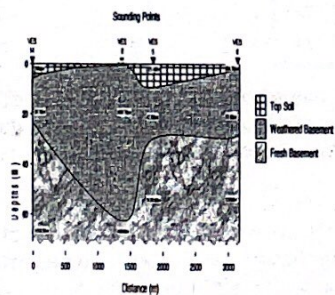


Fig. 3.1: Geo-electric section of VES 14, 8, 5 and 6

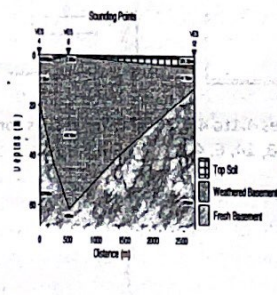


Fig3.2: Geo-electric section of VES 4, 8 and 12

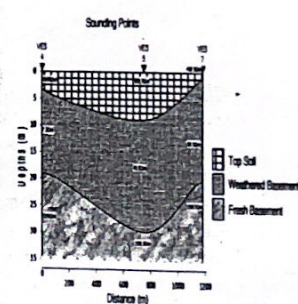
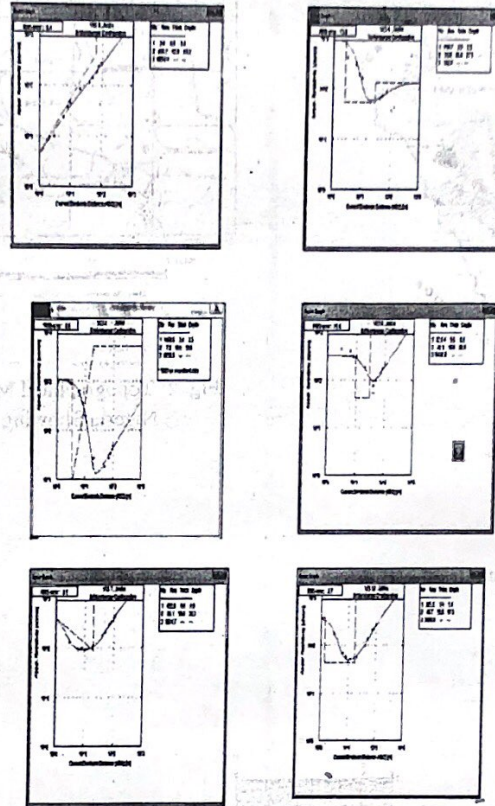


Fig3.3: Geo-electric section of VES 4, 5 and 7



Figures 4.1 to 4.4: Resistivity curves for VES 13, 14, 6, 4, and 6 respectively