GSJ: Volume 6, Issue 4, April 2018, Online: ISSN 2320-9186
www.globalscientificjournal.com

VERTICAL ELECTRICAL SOUNDING INVESTIGATION FOR GROUNDWATER DEVELOPMENT IN A CRYSTALLINE BASEMENT COMPLEX TERRAIN; A CASE STUDY OF IDI-ORO APETE, SOUTHWESTERN NIGERIA.

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ABSTRACT

A geophysical survey involving sixteen vertical electrical sounding (VES) was carried out at Idi -oro Apete in the neighbourhood of The Polytechnic, Ibadan, Nigeria in order to delineate potential subsurface water bearing zones for groundwater development in the area. The study area is underlain by Precambrian basement complex of Southwestern, Nigeria. The schlumberger array with a maximum half current electrode spread (AB/2m) of 75m was employed. The field data obtained were plotted on bi-logarithm graph and quantitatively interpreted by partial curve matching technique and computer iteration using WinResist Software. The interpretation of VES data revealed a maximum of five geoelectric layers in the subsurface from which the aquiferous units were delineated. These are topsoil, compacted lateritic clay/ clay formation, weathered basement, fractured basement and presumably fresh bedrock. The weathered and fractured basements constitute the aquifer units. The resistivity and thickness of the weathered basement ranges from 52-470Ωm and 4.5 and 35.1m respectively while the resistivity of the fractured basement ranges from 156-979 Ωm. Depth to the fractured basement in about 94% of the surveyed area varied between 5.9-17.7m.The fractured basement is significant in enhancing the ground water potential in this area due to its relatively low resistivity resulting from its high fracture frequency. The results obtained from this study indicated that the subsurface within the area is generally characterised by the presence of water bearing units. Hence, the groundwater occurrence potential of the area is considered high. A sustainable Groundwater development program is therefore feasible in the area.

Keywords: Geophysical survey, groundwater, Vertical Electrical Sounding, aquiferous units, subsurface

INTRODUCTION

The population of Apete township in Ido local Government area of Oyo state in Nigeria has rapidly increased as a result of its proximity to the only state owned tertiary institution, The Polytechnic, Ibadan in the state capital. This increament is mainly due to large number of students recently admitted to the institution . A suburb of Apete, Idi oro community, in the neighbourhood of this institution witnessed more of the influx of students and staffs from this citadel of learning and technological innovation, being nearer since the available hall of residences in the institution had full beyond capacity and this has led to increased demand for potable water in the area. Safe water is a basic necessity of life. It could have serious public health implications, ranging from diseases to outbreak of epidemics when it is not available and/or contaminated. One of the necessary conditions for the eradication/reduction of water borne diseases such as typhoid fever, cholera and guinea worm in Nigeria is the supply of potable water to rural communities. Groundwater obtained from wells, boreholes and springs may not undergo considerable treatment before becoming potable due to the natural filtration process it has undergone through the soil horizons [1]Because groundwater is widely known to be more hygienic than surface water, the possibility of utilizing it as a source of water supply for public use is always attractive. The need for good quality water and readily available potable groundwater in this community to cope with the ever increasing demands for water necessitates the present work. In the basement complex terrain of Nigeria, the occurrence of groundwater is highly unpredictable and hence requires a combination of hydrologic, geophysical and geologic surveys to achieve success in groundwater development programs [2].Therefore, detailed pre-drilling geophysical investigations become inevitable. In this study, we relied solely on the geophysical survey technique using the electrical resistivity method to locate zones of high potential for groundwater yield. Vertical electrical sounding has been found suitable for groundwater exploration in the basement complex areas of Nigeria [3],[4] [5],[6],[7], and [8]). The method amongst other is capable of delineating the depth to potential aquifer, depth to bedrock and cost effective. This study was aimed at unravel the subsurface geology and its associated features that are favourable for groundwater development at Idi-oro Apete, Southwestern Nigeria, for the purpose of serving as a working guide for future groundwater development in the area.

SITE DESCRIPTION, GEOLOGY AND HYDROGEOLOGY

The study area, idi-oro community is a suburb of Apete township in Ido local Government area of Oyo state, Nigeria. It is bounded by latitudes 7°27' and 7°27'10 north of the equator and longitudes 3°52'30'' and 3°52'40'' east of the Greenwich Meridian (fig.1). The southern part of the area is bounded by North Campus of The Polytechnic, Ibadan while at the western part, it is bounded by Apete Central Market. Topographically, the area is gentle, with surface elevation ranging from 197m to 220m above sea level. The area is underlain by the Precambrian basement complex rocks of Southwestern Nigeria [9] (fig.2). These rocks are inherently characterized by low porosity and permeability. The highest groundwater yield in basement terrain is found in areas where thick overburden overlies fracture zones; these zones are often characterized by relatively low resistivity value [10]. The basement aquifers are often limited in extent both laterally and vertically [11]. Basement aquifers are developed within the weathered overburden and fractured bedrock of crystalline rocks of intrusive and/or metamorphic origin which are mainly of Precambrian age [12]. Viable aquifers wholly within the fractured bedrock are of rare occurrence because of the typically low storativity of fracture systems [13].The localized nature of the basement aquifer system makes detail knowledge of the subsurface geology, its extent of weathering and structural disposition through geological and geophysical investigation inevitable.

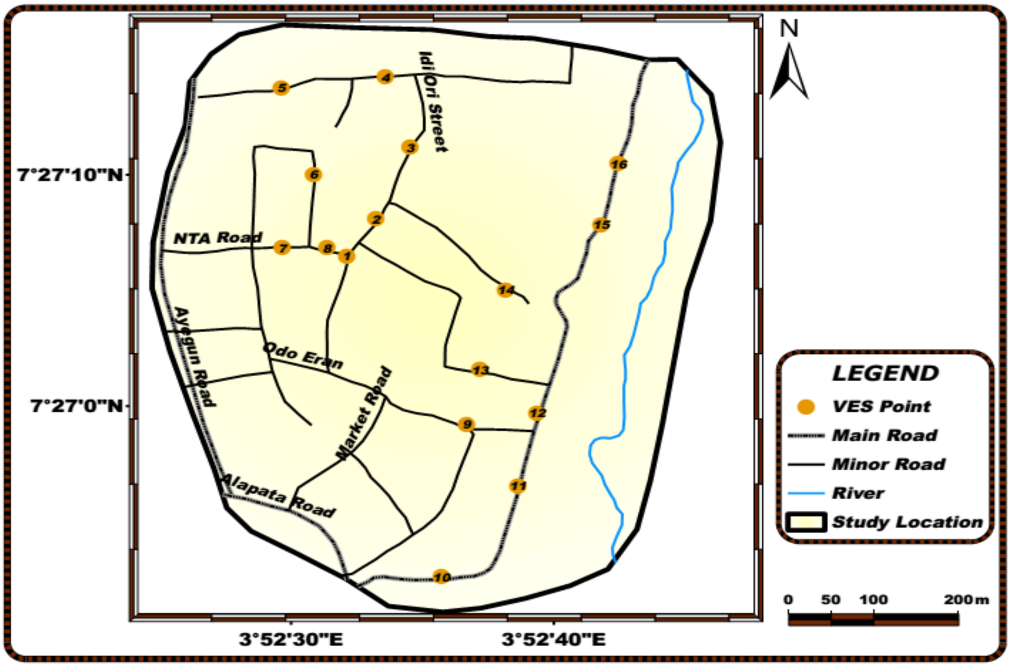

Fig.1: Location map of the study area showing the VES points

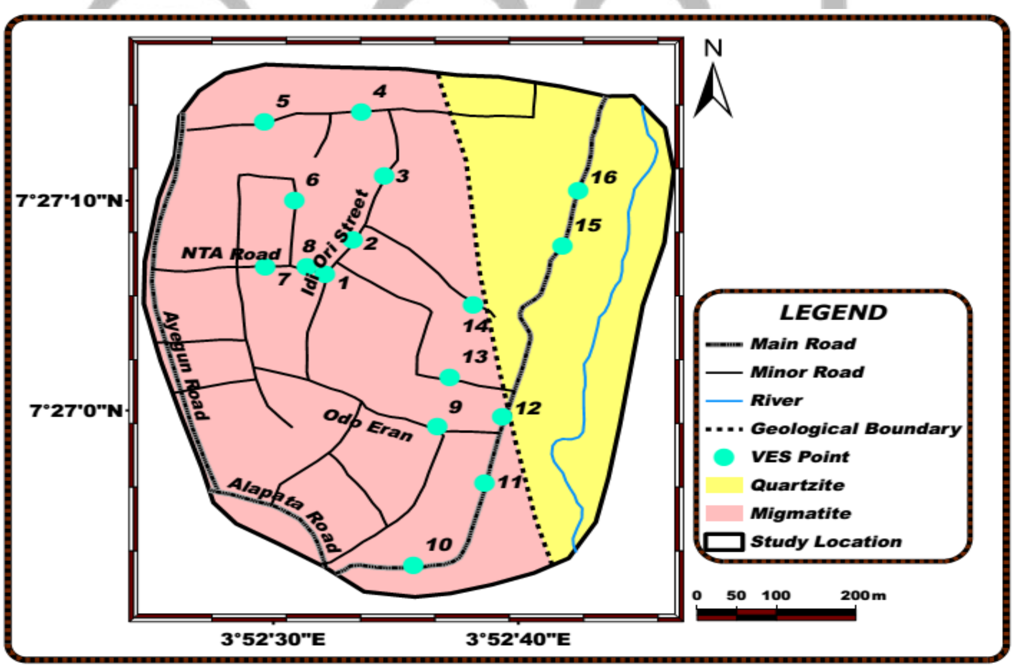

Fig.2 Geological map of Ibadan showing the study area

MATERIAL AND METHOD

The geophysical method adopted for this study is the Electrical resistivity prospecting method. Sixteen Vertical Electrical Soundings (VES) were conducted across the study area using Schlumberger electrode array, with half electrode spacing (AB/2) varying from 1-100m. The Omega resistivity meter was used for the data acquisition. The readings of ground resistance as obtained from the resistivity meter at each observatory point were multiplied by the corresponding geometric factor (K) in order to obtain the apparent resistivity (ρa) at each point. The apparent resistivities obtained is then plotted against corresponding (AB/2m) on bi-log graph paper. The field curve were manually interpreted [14] using Master curves [15] and auxiliary point charts [16], [17].
The resistivities and thickness of the VESes obtained from manual interpretation were later used as an initial model for computer-assisted interpretation [18] which is input by the interpreter into a computer program. Through an iterative process, the program varies the thickness and electrical resistivity of each layer until it finds a final geoelectric model that satisfactorily best fits the data.

RESULTS AND DISCUSSION

Resistivity Sounding Curves

Typical resistivity sounding curves obtained from the survey area are shown in fig 3, these include the H, KH, HA ,A, HK, AA and AK type with three to four geoelectric layer combination. H-type curve is the most dominant (Table 3), accounting for 44% of the total. The KH, HA and A type constitute 19,12,5,12.5% respectively while HK, AA and AK type have 6% occurrences each .The 3 layer predominate with 56.5 % occurrences. [19]showed that field curves often mirror image geo-electrically the nature of the successive lithologic sequence in an area and hence can be used qualitatively to assess the groundwater prospect of an area .The H and KH curves which are often associated with groundwater possibilities [20] are the major types in the area . The results summary of the VES interpretation is shown in Table 1.

Table: 2. Results summary of the VES interpretation for the study area.

VES NO	NO OF LAYERS	APPARENT RESISTIVITY (ΩM)	THICKNESS (M)	DEPTH (M)	CURVE TYPE	PROBABLE LITHOLOGY
1	1	62	0.7	0.7	KA	Top soil
	2	52	1.4	2.1		Clayey formation
	3	101	18.2	20.3		Weathered basement
	4	504				Fractured basement
2	1	65	0.7	0.7	AK	Top soil
	2	80	9.6	10.3		Clayey formation
	3	470	12.9	23.3		Weathered basement
	4	156				Fractured basement
3	1	31	1.0	1.0	AA	Top soil
	2	70	1.0	1.9		Clay formation
	3	104	35.1	37.0		Weathered basement
	4	3988				Fresh basement
4	1	83	0.8	0.8	H	Top soil
	2	26	8.5	9.3		Clayey formation
	3	979				Fractured basement
5	1	63	0.7	0.7	A	Top soil
	2	86	5.1	5.9		Clayey formation
	3	586				Fractured basement
6	1	82	0.6	0.6	KH	Top soil
	2	223	0.9	1.5		Lateritic clay
	3	108	8.2	9.8		Weathered basement
	4	250				Fractured basement
7	1	277	1.0	1.0	H	Top soil
	2	52	6.7	7.7		Weathered basement
	3	220				Fractured basement
8	1	96	2.7	2.7	KH	Top soil
	2	261	1.9	4.6		Lateritic clay
	3	72	13.4	18.1		Weathered basement
	4	835				Fractured basement
9	1	25	0.8	0.8	KH	Top soil
	2	153	4.8	5.6		Lateritic clay
	3	72	11.2	16.8		Weathered basement
	4	846				Fractured basement
10	1	63	1.6	1.6	H	Top soil
	2	27	4.5	6.0		Weathered basement
	3	254				Fractured basement
11	1	65	0.6	0.6	A	Top soil
	2	81	16.0	17.7		Weathered basement
	3	284				Fractured basement
12	1	143	1.4	1.4	H	Top soil
	2	74	16.1	17.5		Weathered basement
	3	538				Fractured basement
13	1	546	0.4	0.4	H	Top soil
	2	113	6.3	6.7		Weathered basement
	3	311				Fractured basement
14	1	321	0.7	0.7	H	Top soil
	2	74	5.3	5.9		Weathered basement
	3	599				Fractured basement
15	1	82	0.5	0.5	HA	Top soil
	2	52	2.5	2.0		Clay formation.
	3	101	17.5	20.5		Weathered basement
	4	504				Fractured basement
16	1	260	0.7	0.7	H	Top soil
	2	148	2.5	4.2		Weathered basement
	3	785				Fractured basement

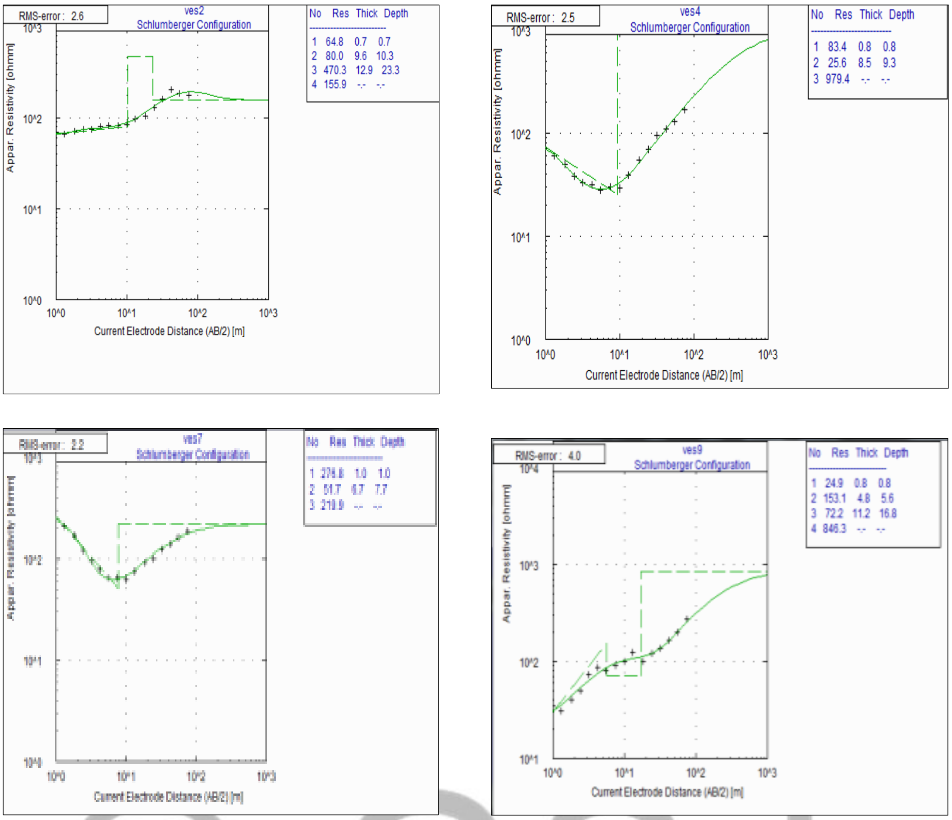

Fig. 3: Typical resistivity sounding curves obtained for VES 2, VES4, VES 7, and VES 9 from the survey area.

Geo-electric Sections

The resistivity and thickness values obtained as geoelectric parameters from the inversion of the Vertical Electrical Sounding data were used to prepare 2-D geoelectric sections displayed in Figures 4a- d. These sections give an insight into the structural disposition of subsurface rock units in the area. Figure 4a is a geoelectric section drawn through VES location 5,6,1,9 and 11 in the north western to south eastern direction of the study area. The cross section presented as profile AA' shows four geo- electrical layers in all the five locations across the profile. The top soil which is relatively thin is characterized by the resistivity value between 25 and 63 ohm-m with a thickness that ranges from 0.6 to 2.7m and predominantly clayey. Underlying the top soil at locations around VES 8, 1, 9 is compacted lateritic clay with resistivity value between 52 and 223ohm-m and thickness ranging from 1.9 to 5.1m except at VES 5 and 11 where it is found absent .This layer confines the underlying weathered basement aquiferous unit with resistivity values between 72 and 108ohm-m and thickness that varies from 11.2 to 18.2m. This upper aquiferous unit at all the VES across the profile overlies fractured basement that has resistivity ranges from 250 to 846 Ohm-m. These last two layers depict an aquiferous unit along the profile.

Fig 4b below shows the geo- electrical section for profile BB' across North South direction of the study area cutting across VES point 14, 13, 9 and 10. The interpretation of four VES data along this section reveals three to four geo-electric layers. The top soil has resistivity values ranging from 25 to 546 Ohm-m and thickness between 0.6 to 0.8m characteristic of clay to sandy top soil. Beneath the top soil at VES 9 is compacted lateritic clay material with resistivity values of 153 Ohm-m confining the underlying upper weathered basement which is absent at VES 14,13 and 10. The weathered basement has resistivity value that ranges from 27 to 113ohm-m. and a thickness that varies from 4.5 to 11.2m. This layer at all the VES across the profile overlies fractured basement that has resistivity value ranging from 254 to 848 Ohm-m. These last two layers depict an aquiferous unit along the profile.

Fig 4c is a geo- electrical section drawn through VES location 16, 15, 12, and 11 in North South direction of the study area. The section presented as profile CC' shows three to four geo- electrical layers. The top soil has resistivity values ranging from 62 to 280ohm-m and thickness between 0.6 to 1.4m characteristic of clay to clayey sand/sand. Beneath the top soil in the vicinity of VES 15 is the presence of a clayey formation with resistivity values of 52 Ohm-m. This layer confines the underlying weathered basement except at VES 16, 12 and 11. The weathered basement has resistivity values between 74 to 148ohm-m and a thickness that varies from 2.5 to 18.2m. This layer at all the VES across the profile overlies fractured basement that has resistivity ranges from 284 to 785 Ohm-m. These last two layers across the profile depict aquiferous units.

Fig 4d shows geoelectric section for profile DD' across North east-South west direction of the study area which is made up of data from VES 3, 2 and 1.The section delineates four geoelectric layers. The top soil has resistivity values ranging from 31 to 65 Ohm-m and thickness varying between 0.7 to 1.0m representing clayey /sandy clay top soil. Beneath the top soil across the profile is a clay formation with resistivity value ranging from 52 to 80 and a thickness between 1.0 to 35.1m.This layer confines the underlying weathered basement upper aquiferious unit with resistivity values between 101 to 470 Ohm-m and thickness of 20.2m to 37m.This upper aquiferous unit in turns overlies the fractured basement at VES 2 and 1 except in VES 3 that has presumably fresh basement.

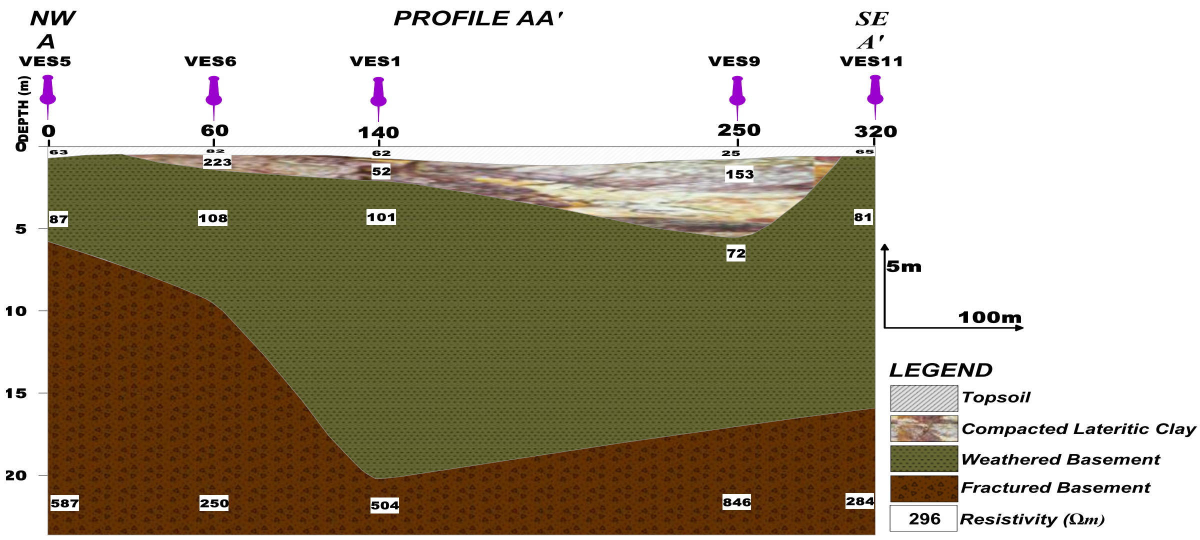

Fig 4a :Geoelectric section across VES 5,6,1,9 and 11

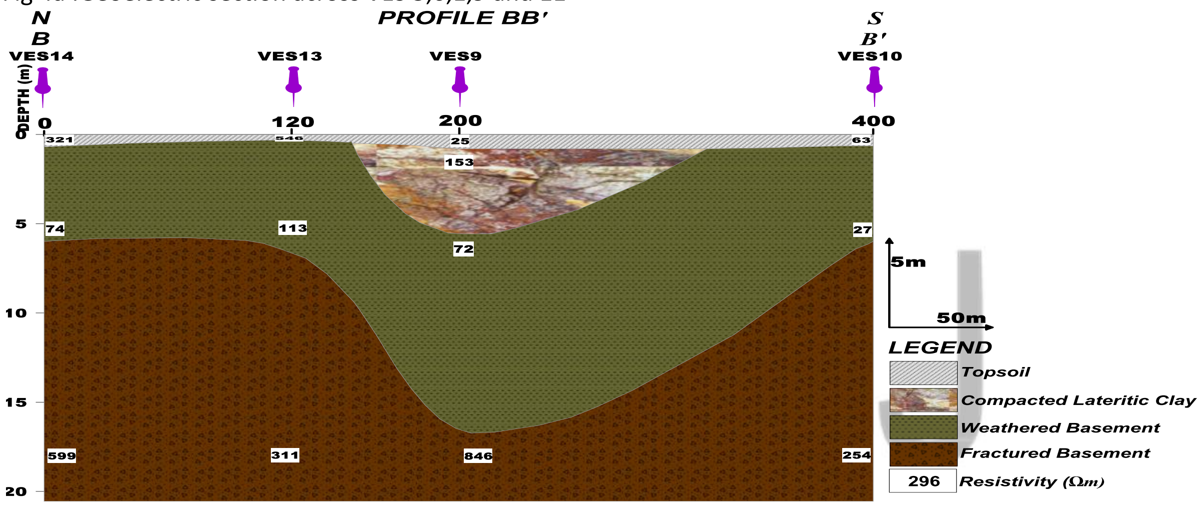

Fig 4b :Geoelectric section across VES 14,13,9 and 10

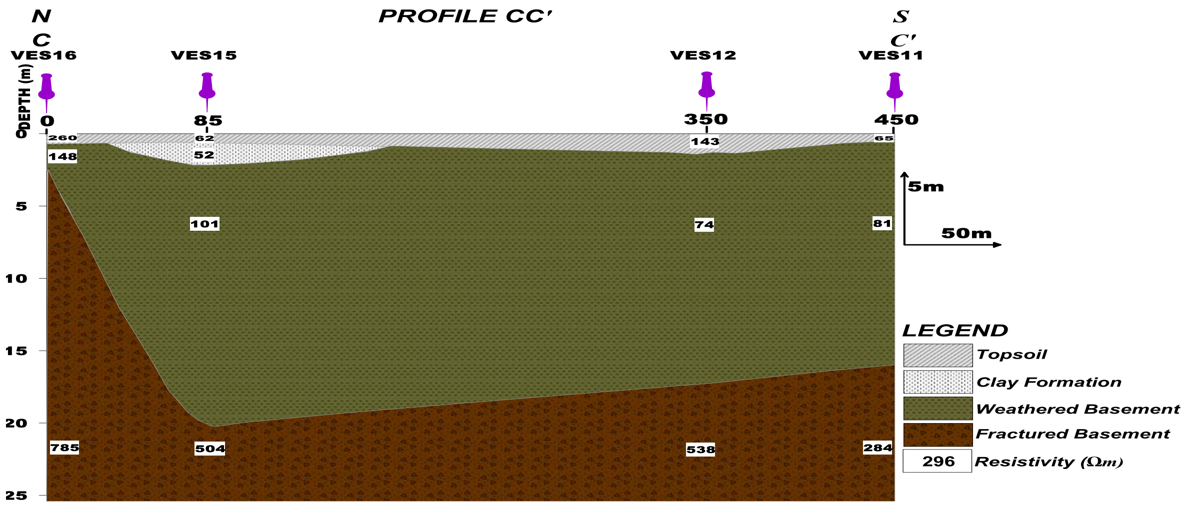

Fig 4c :Geoelectric section across VES 16,15,12 and 11

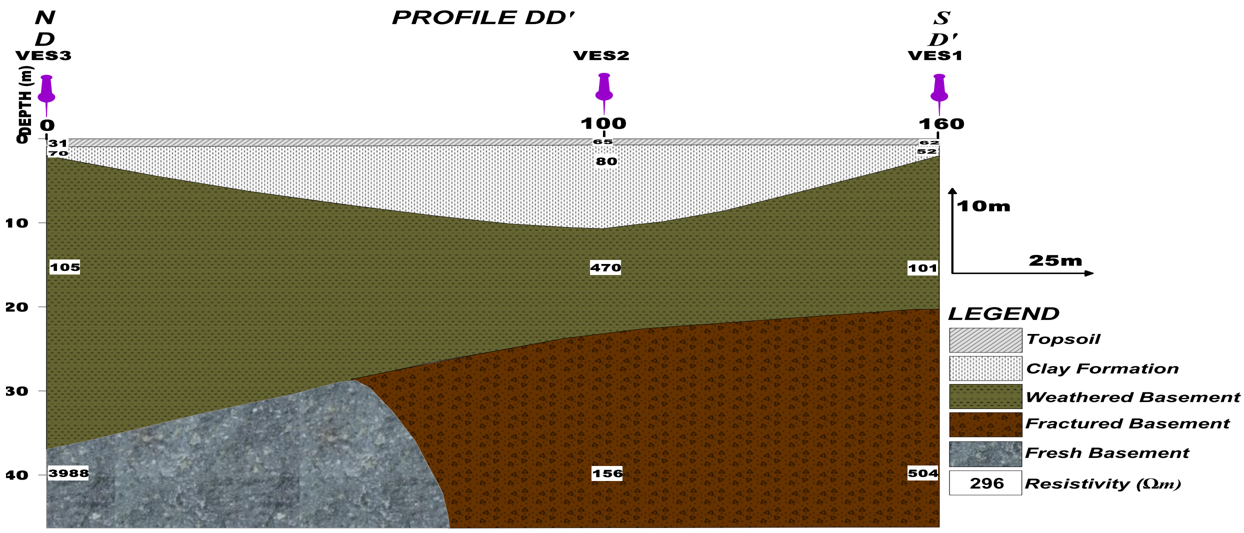

Fig 4d: Geoelectric section across VES 3, 2 and 1.

CONCLUSION

The geophysical investigation conducted at Idi-oro Apete community, Southwestern Nigeria has revealed five geologic units in the subsurface across the area from which the water bearing units (aquifer) were identified. The weathered and fractured basements constitute the aquiferous units. The weathered basement is relatively thick and predominantly clayey sand in a little above half of the surveyed area. This indicates medium groundwater discharge capacity and fairly proctective capacity. The fractured basement in about 94% of the area occurred at depth range of 5.9-17.7m. Although this lower aquiferous unit is fairly protected but highly permeable and has high groundwater discharge capacity. Drilling for groundwater borehole in this area is achievable but to a minimum depth of 45 meters in order to allow large reservoir within these aquifers and for ensuring that the lower aquifer is fully penetrated. Generally, sustainable groundwater development program in the area feasible. The study has also shown that there is the need for adequate geophysical investigation to assess the groundwater potential of basement complex terrain in order to have a sustainable groundwater development project.

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