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Groundwater Potential Evaluation Using Electrical Resistivity Method at Laniba, Ibadan, Southwestern Nigeria

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Abstract

A geophysical investigation involving an electrical resistivity method using Vertical Electrical Sounding technique has been carried out at Laniba, Ibadan, falling within the Precambrian basement complex of Southwestern Nigeria. This was aimed at characterizing the subsurface geoelectric sequences and evaluating the groundwater potential of the area for groundwater development. A total of Ten (10) Vertical Electrical Sounding (VES) was conducted out across the area using Schlumberger array with a maximum half- current electrode separation of 100m using Ohmega Resistivity Meter. The field data obtained was plotted using bi-logarithm graph and interpreted quantitatively by partial curve matching technique and computer iteration using WinResist Software. The interpretation of the VES data reveals three to four geo-electric layers, based on characteristic resistivity ranges, comprising of topsoil, lateritic soil/clayey soil / Quartzite and Quartz- Schist formation, weathered basement and fractured basement with resistivity of 46-1024 Ohm-m, 91-3369 Ohm-m, 55-365 Ohm-m and 338-886 Ohm-m respectively. Their thickness respectively varies from 2.2-16.6m, 0.6-14.4m and 14.7-46.5m. Two probable aquiferous units namely; weathered basement and fractured basement have been delineated based on the observed resistivity values. The groundwater potential map produced by integrating various categories of aquifer maps classified the area into poor, fair, moderate and good groundwater potential zones with about 60% of the area characterized by moderate to high groundwater discharge. Hence, groundwater development is feasible in the area; mostly where both aquiferous units delineated exists. The Vertical electrical sounding technique of electrical resistivity method employed has been efficient in evaluating the groundwater potential of the area.

Keywords: *Geophysical investigation, Groundwater potential, Vertical Electrical Sounding (VES), Geo-electric layers, Aquiferous units*

Introduction

The growing Population both in rural and urban areas usually raises the demand for potable water and other infrastructures in many parts of the world. The situation is not different in the ancient city of Ibadan in Nigeria, particularly the developing areas as a result of relocation of most dwellers in the core and /or old areas to new sites of the city. This has particularly led to overcongestion in the new areas which in turn continue to pose more pressure on the existing insufficient groundwater sources. The case of Laniba community in the neighborhood of International Institute of Tropical Agriculture (IITA) and University of

Ibadan, Ibadan is becoming worst as more people including staff of the institute as well as academics and non academics staff from University of Ibadan are shifting to the place due its proximity to these two institutions and relatively lower cost of land purchase in the region. The sporadic population growth this area is witnessing has increased the water demand in the community. Hence, there is need for ground water development program in the area. Safe water is a basic necessity of life and when it is not available and/or contaminated, it could have serious public health implications, ranging from diseases to outbreak of epidemics (Abiola et al, 2013). Rain water, streams, and lakes were in the past the major sources of water to humans. However, all are unsuitable sources of drinkable water due to pollution and contamination as result of human activities (Olorunfemi et al,1999).That portion of water beneath the surface of the Earth i.e Groundwater is considered to be the best form of water and as the only reliable alternative means of water supply to the city (Auwalu ,L Yand Abubakar ,Y L,2012). Many communities in the world depend on groundwater extracted from weathered/fractured zones through water wells/boreholes (Clark, 1985; Olasehinde *et al*., 1998). Due to the natural filtration process it has undergone through the soil horizons, groundwater obtained from wells, boreholes and springs may not undergo considerable treatment before becoming potable (Abdullahi *et al*., 2005). The possibility of utilizing it as a source of water supply for public use is always attractive because groundwater is widely known to be more hygienic than surface water, (Abdullahi *et al*., 2005). However groundwater occurrence in an area is largely controlled by by various geological factors that includes structure, geological sequences and stratigraphic distributions of hydrological units (Diat *et al*., 2013). Groundwater distribution in basement complex areas varies from place to place due to the localized nature of basement aquifers (Dan-Hassan and Olorunfemi.,1999, Meli'i et al., 2011, 2012; Teikeu et al. 2012;Ekoro et al., 2012).The spatial variation of the aquifer parameters such as porosity, permeability, conductivity and transmisivity can be attributed to, tectonic set-up and degree of weathering of near-surface rocks ,among other causes (Baker et al., 2001).Currently ,various geophysical techniques are being employed to explore for groundwater. Electrical resistivity method however, has been proved to be the most effective technique in mapping groundwater resource as groundwater movement and existence are largely localized and hard to determine (Metwaly, 2012). This is due to the close relationships between the electrical properties and some of hydrogeological properties of the aquifer (Diat *et al*., 2013). High resistivity contrasts usually occur between solid rocks and saturated fracture zones (Leroux et al., 2007). Electrical resistivity method had been employed in the present study in other to effectively delineate the possible aquiferiuos unit in the study area with a view to evaluating its groundwater potentials for groundwater development thereby paving way for provision of adequate and potable water all year round for the people of this community.

SITE DESCRIPTION AND GEOLOGY SETTING

The study area, Laniba lies between longitude 3^{o}52'30"E to 3^{o}52'55"E of the Greenwich Meridian and latitude 7^{o}28'35"N to 7^{o}28'55"N in Akinyele Local Government area Oyo State. (Figure 1). It is bounded by International Institute of Tropical Agriculture (IITA) in the North, University of Ibadan and Ajibode community in the East, Balogun in the West and Lakoto in the South. The topography is gentle, with surface elevation ranging from 196m to 221m above sea level. Geologically, the area fall within the Precambrian basement complex rocks of Southwestern Nigeria (Rahaman,1976) and underlain by two major petrologic units: the Quartzite and quartz schist, and undifferentiated migmatite gneisses rocks which generally strike NW-SE and dip to the east (Figure 2). Quartzite and quartz schist which dominated the area occur as elongated ridges striking NW-SE (Olorunfemi et al.,1999) while Gneisses are migmatized in places and are characterized by predominantly medium-sized grains. Hydrogeologically, these rocks are inherently characterized by low porosity and permeability (Abiola et al.,2013). 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 (Olayinka,1990)

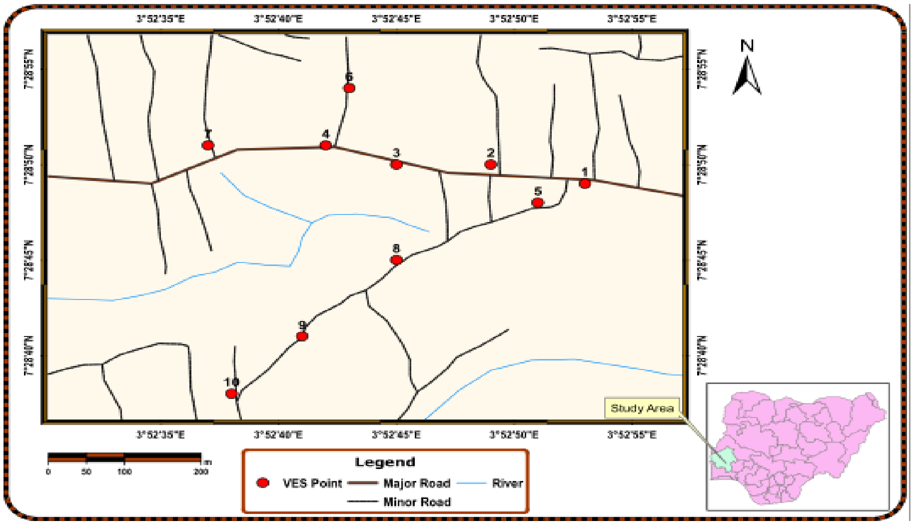


Figure 1 : Location map of the study area showing the VES points

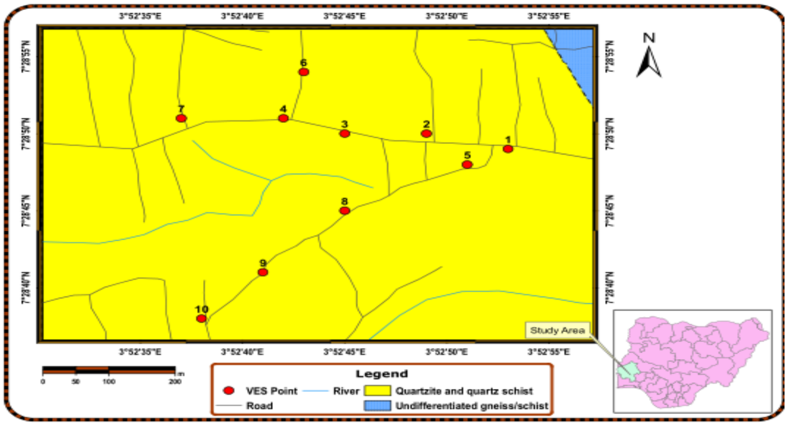


Figure 2: Geological map of the study area

MATERIAL AND METHOD

Electrical resistivity method of geophysical prospecting was solely adopted for this study. Ten(10) Vertical Electrical Soundings (VES) were carried out across the study area using Schlumberger electrode configuration(Zhody et al., 1974), with half current electrode spacing (AB/2) varying from 1-100m. The co-ordinate of each of the sounding stations was recorded with the aid of the “GARMIN 12” channel personnel navigation geographical position system (GPS) unit. The Allied Omega resistivity meter was used for the for resistance measurement. To obtain the apparent resistivity (ρa) at each observatory point, the readings of the resistance as obtained from the resistivity meter at each point were then multiplied by the corresponding geometric factor (K) . The obtained apparent resistivities is then plotted against corresponding AB/2 on log-log graph paper to produce depth sounding curves. After being visually inspected for curve type identification, the fields curve, were then subjected to manual interpretation using partial curve matching technique (Olorunfemi and Okhue,1992). The resistivities and thickness of the VESes obtained from initial (manual) interpretation were later used as an initial model for computer-assisted interpretation (Vander, 1988) which is input into a computer program by the interpreter. Through an iterative process, the program varies the electrical resistivity and thickness of each layer until it finds a final geoelectric model that satisfactorily best fits the data.

RESULTS AND DISCUSSIONS

Resistivity Sounding Curves

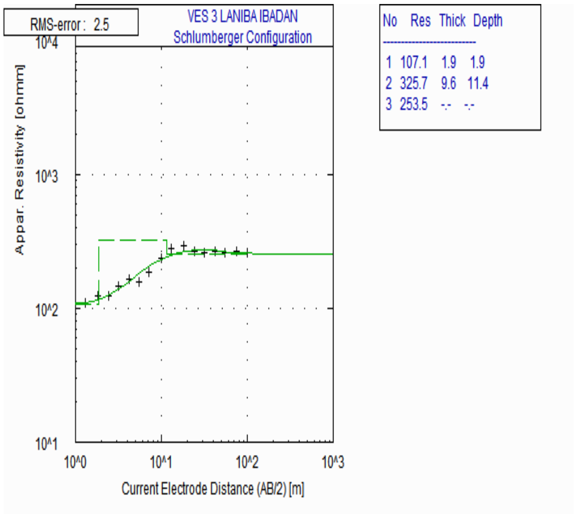
The Vertical Electrical Soundings data interpreted produced a short range of depth sounding curves: three-layer case (K and A- type) and four-layer case (KH and AK –type) .The K curve type predominates with 40% occurrence while KH,AK and A constitute 30%, 20% and 10% of the total respectively(Table 1). Typical sounding curves obtained for the area are shown in Fig 3, these include K, A KH and AK.. Field curves often mirror-image (geoelectrically) the nature of the successive lithologic sequence in a place and hence can be used, in qualitative sense for groundwater prospect assessment of an area (Worthington, 1977).The H and KH curves types are often associated with groundwater possibilities while type A may typify a rapid resistivity progression, indicative of shallow, resistive bedrock. KH which is one of the curve type that often associated with groundwater possibilities is also prominent in the study area

TABLE 1: Result Summary of VES interpretation in the area

VES NO.	LAYER	RESISTIVITY (ohms – m)	LAYER THICKNESS (m)	DEPTH (m)	CURVE TYPE	PROBABLE LITHOLOGY
1	1	190	0.7	0.7	AK	Top Soil (Clayey Sand)
	2	270	2.2	2.9		Sandy Sub Soil
	3	1136	5.2	8.0		Lateritic Soil
	4	102	-	-		Weathered Basement
2	1	73	0.8	0.8	KH	Top Soil (Clay)
	2	231	4.9	5.7		Lateritic Soil
	3	82	14.7	20.4		Weathered Basement (Clayey)
	4	338	-	-		Fractured Basement
3	1	107	1.9	1.9	K	Top Soil (Sandy Clay)
	2	326	9.6	11.4		Lateritic Soil

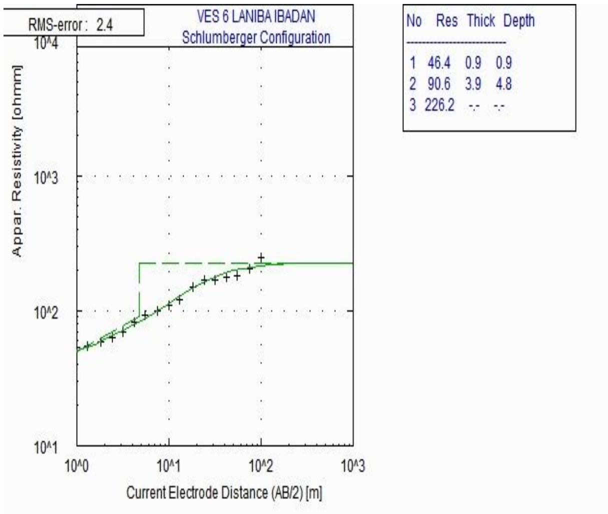
	3	254	-	-		Weathered Basement
4	1	60	0.7	0.7	K	Top Soil (Clay)
	2	353	8.1	8.8		Lateritic Soil
	3	282	-	-		Weathered Basement
5	1	185	2.1	2.1	K	Top Soil
	2	265	12.7	14.8		Lateritic Soil
	3	179	-	-		Weathered Basement
6	1	46	0.9	0.9	A	Top Soil(clayey)
	2	91	3.9	4.8		Clayey Formation (Sub Soil)
	3	226	-	-		Lateritic Soil
7	1	48	0.4	0.4	AK	Top Soil (clayey)
	2	115	6.8	7.2		Sandy Clay Sub Soil
	3	521	9.3	16.5		Lateritic Soil
	4	55	-	-		Weathered Basement (Clayey)
8	1	110	0.7	0.7	KH	Top Soil (Clayey Sand)
	2	447	7.2	8.0		Lateritic Soil
	3	103	21.3	29.3		Weathered Basement
	4	728	-	-		Fractured Basement
9	1	226	0.5	0.5	KH	Top Soil (Sandy)
	2	646	7.9	8.4		Lateritic Soil
	3	149	46.5	54.9		Weathered Basement
	4	886	-	-		Fractured Basement
10	1	1024	2.3	2.3	K	Top Soil (Lateritic Soil)

	2	3369	14.3	16.6		Quartz -Schist Formation
	3	365	-	-		Weathered Basement



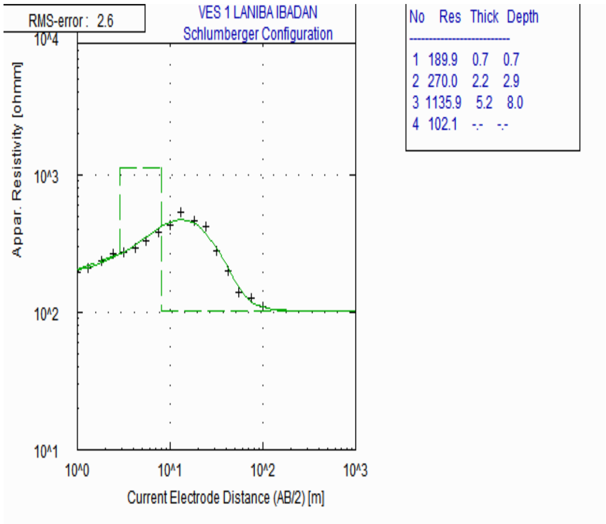
No	Res	Thick	Depth
1	107.1	1.9	1.9
2	325.7	9.6	11.4
3	253.5	-.-	-.-

Figure 3a: K-type



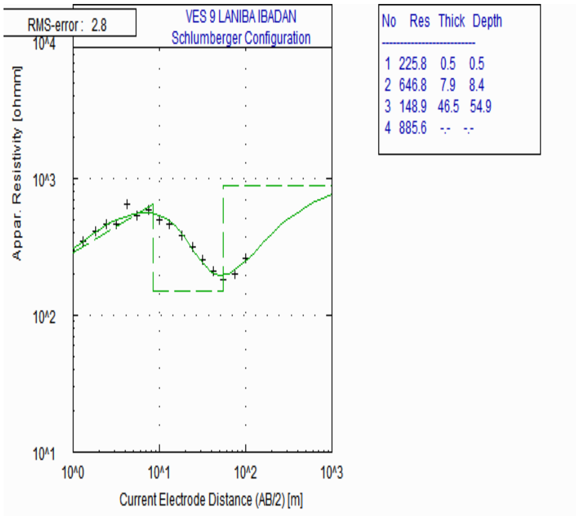
No	Res	Thick	Depth
1	46.4	0.9	0.9
2	90.6	3.9	4.8
3	226.2	-.-	-.-

Figure 3b: A-type



No	Res	Thick	Depth
1	189.9	0.7	0.7
2	270.0	2.2	2.9
3	1135.9	5.2	8.0
4	102.1	-.-	-.-

Figure 3c: AK- type



No	Res	Thick	Depth
1	225.8	0.5	0.5
2	646.8	7.9	8.4
3	148.9	46.5	54.9
4	885.6	-.-	-.-

Figure 3d: KH -type

Geoelectric Section

The geoelectric parameters (resistivitiy and thickness) obtained from the inversion of the Vertical Electric Sounding data are presented as geoelectric section and maps. Fig 4a is a geoelectric section drawn through VES 1, 2, 3 and 4 in the East-West direction of the study area. Along this section presented as profile 1, the interpretation of these four VES reveals three (3) – four (4) geoelectric layer. The top soil which is relatively

thin is characterized by the resistivity value of between 60 Ohm-m - 190 Ohm-m with a thickness value ranging from 0.7 m - 1.9 m and composed predominantly clay, clayey sand and sandy clay . Beneath the top soil at VES 1 is sandy sub soil which has resistivity value of 270 Ohm-m and thickness of 2.2 m. Underlying this subsoil and the top soil at other VES location along the profile is occurence of lateritic soil with resistivity value which varies between 231 Ohm-m - 1136 Ohm-m and thickness ranging from 4.9 m - 9.6 m.This layer confines the underlying weathered basement aquiferous unit with resistivity values varying between 82 Ohm-m – 282 Ohm-m across the profile. The weathered aquiferous unit at VES 2 which is 14.7 m thick overlies fractured basement with resistivity value of 338Ohm-m. This fractured basement is identified as major aquifer unit at that location based on resistivity value.
Figure 4b shows geo–electric section for profile 2 across North – South direction of the study area which is cutting across VES points 5, 8, 9, and 10. The interpretation of four VES data along this section also reveals three (3) to four (4) geoelectric layers. The top soil has resistivity values ranging from 120 Ohm-m – 1024 Ohm-m characteristic of clayey sand, sandy clay and laterite with a thickness of 0.5 m – 2.3 m. Beneath the top soil at VES 5, 8 and 9 along the profile, is a lateritic soil with resistivity value ranging from 265 Ohm-m – 646 Ohm-m and thickness between 7.2 m – 12.7 m while the top soil at VES 10 is underlain by 14.3 thick Quartzite schist formation with resistivity value of 3369 Ohm-m forming the second layer. The next layer which is recognized as aquifer unit with resistivity range of 103 – 365 Ohm-m and thickness of between 21.3 – 46.5 m is presumed weathered basement. In crystalline basement terrain, the thickness and resistivity value of unconsolidated materials overlying the basement is important factor in evaluating groundwater potential (Vanderberghe,1982).The last layer at VES 8 and 9 with resistivity value of between 728 – 886 Ohm-m with infinite thickness is suggestive of fractured basement and recognized as major aquiferous unit

Figure 4c is a geo–electric section orienting N-S cutting across VES 3, 6 and 8. The cross section shows three (3) - four(4) geoelectric layers. The top soil has resistivity values ranging from 46 Ohm-m – 110 Ohm-m with thickness that range from 0.7m – 1.9m characteristic of clayey sand and sandy clay.. Beneath the top soil at VES 6 is clayey formation subsoil with resistivity value of 91 Ohm-m and thickness of 3.9 m. The next layer across the profile is a lateritic soil with resistivity value ranging from 226 Ohm-m – 447 Ohm-m with a thickness that varies from 7.2 m – 9.6 m. This layer confined the underlying presumed weathered basement with resistivity values of between 103 Ohm-m – 253 Ohm-m and thickness of 21.3 m, an aquiferous unit across the profile. The weathered layer at VES 8 overlies fractured basement with resistivity value of 592 Ohm-m. This layer is recognized as major aquiferous unit across the section

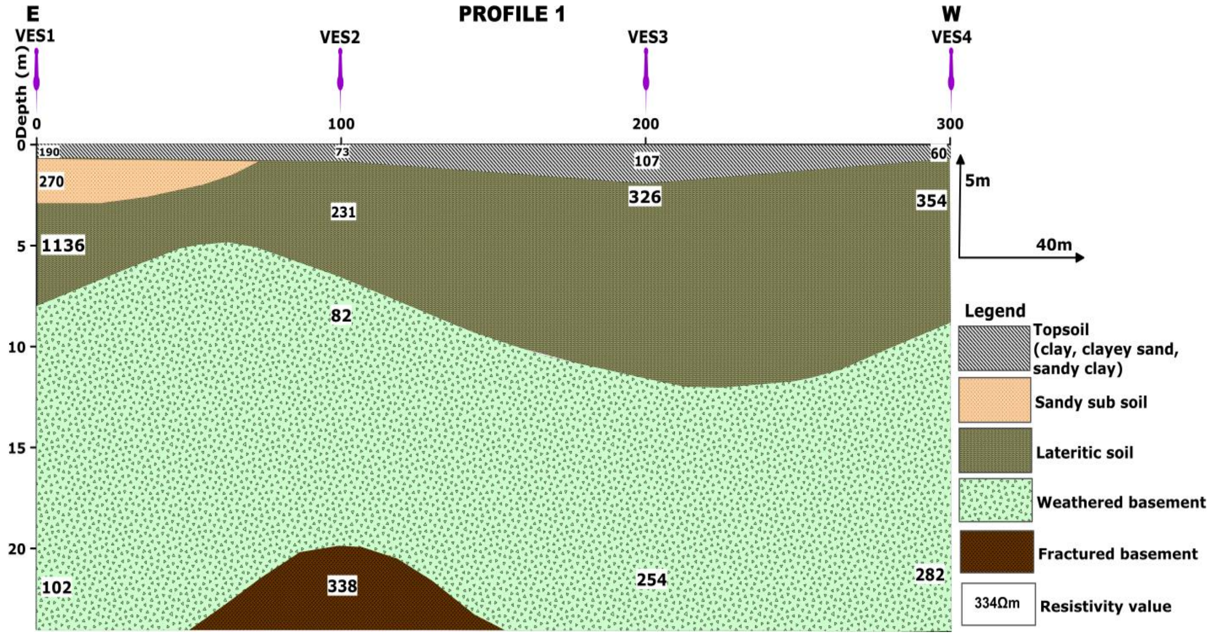


Figure 4a: Geoelectric section across VES 1, 2, 3, 4

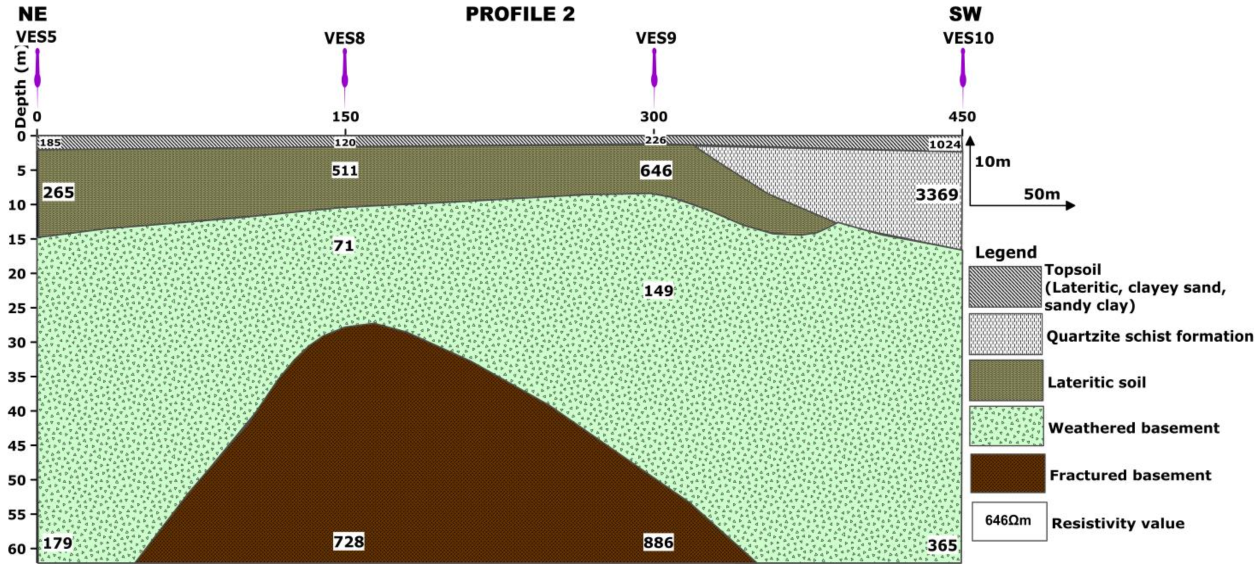


Figure 4b: Geoelectric section across VES 5, 8,9, 10

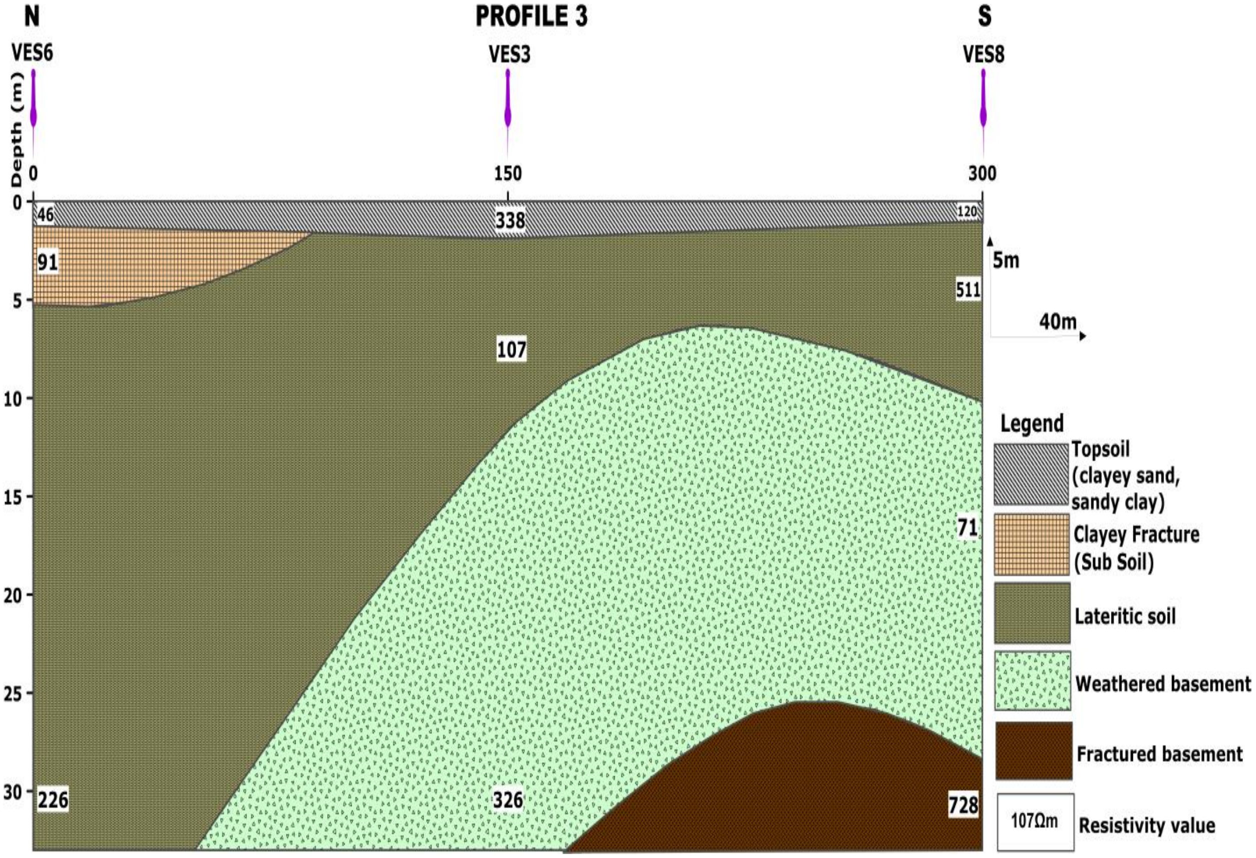


Figure 4c: Geoelectric section across VES 6, 3, 8

Isoresistivity and Isopach map of the Weathered Basement.

The Isoresistivity map of the weathered basement of the study area is as shown in figure 5. This layer which occurs in about 90% of the investigated locations is considered as upper aquiferous unit in the area. It is characterized by resistivity value that range from 55 Ohm-m to 365 Ohm-m having an average value of 175 Ohm-m. As revealed by the map only 20% of the study area has resistivity value typical of clay while the remaining parts are sandy and The location around VES points with resistivity value less than 133 Ohm-m are clayey / clayey sand which could be regarded as fairly pervious formation which implies that groundwater potential in this zone is low. These are found in the north, northeastern, and northwestern part of the study area, while the area with resistivity that range from 134 – 210 Ohm-m are found in the southeastern part of the study area. The area with resistivity value ranging from 211 – 288 Ohm-m are found in the central part of the study area characterized by sand, which is relatively pervious while the area with resistivity value of greater than 289 Ohm-m is found in the south/Southwestern part of the area. This is also clay free sandy geomaterial which could serve as upper aquiferous layer. Area characterized by resistivity value of 211Ohm-m and above is a fair to good aquiferous unit.

Isopach map of the weathered basement

The Isopach map of the weathered basement is shown in fig 6 and it represent the variation in thickness of this layer in the study area .Locations around VES at the north, northeastern and northwestern part of the study area have a thickness value less than 14.6 m while locations in the vicinity of VES at the southeastern and southwestern part of the area have a thickness range from 14.7 – 25.2 m. The southern part the area is characterized by thickness value that range from 25.3 to greater than 35.9 m. Based on this, they are of moderate to good aquifer yield

Isoresistivity map of the fractured basement

The isoresistivity map of the fractured basement is shown in figure 7. The fractured basement is the major and lower aquiferous unit in the area. In the study area, VES around locations with resistivity value of between 263 and 471Ohm-m covers the northern, northeastern, northwestern and southwestern part of the study area. This indicates areas with high ground water yield. Locations in the vicinity of VES with resistivity value that range from 472Ohm-m and above are found in the southern part of the study area. This is an indication of moderate groundwater potential. Generally the area is characterized by moderate to good fractured aquiferous unit.

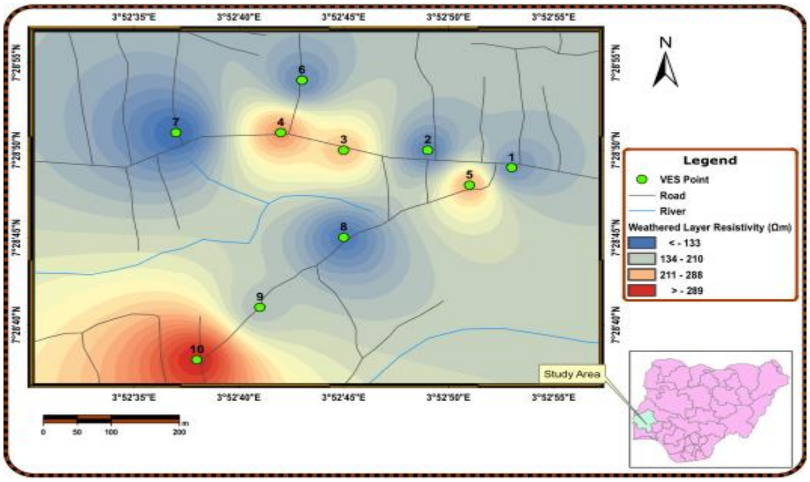


Figure 5: Isoresistivity map of the weathered basement

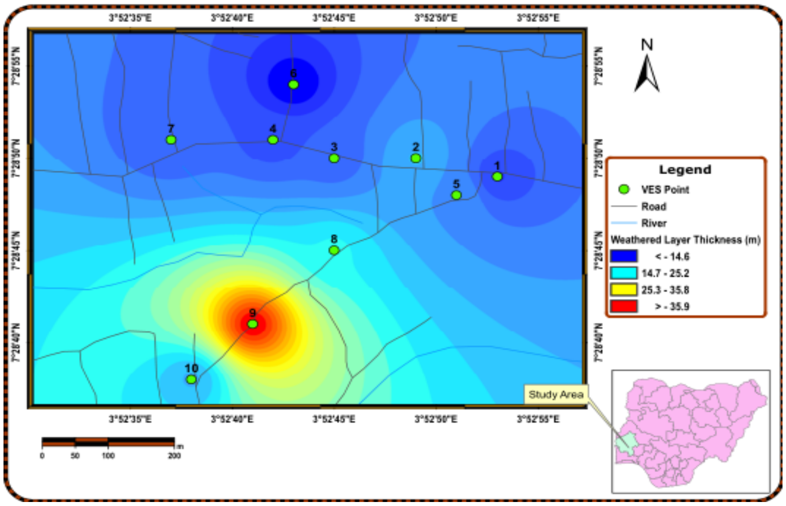


Figure 6: Isopach map of the weathered basement

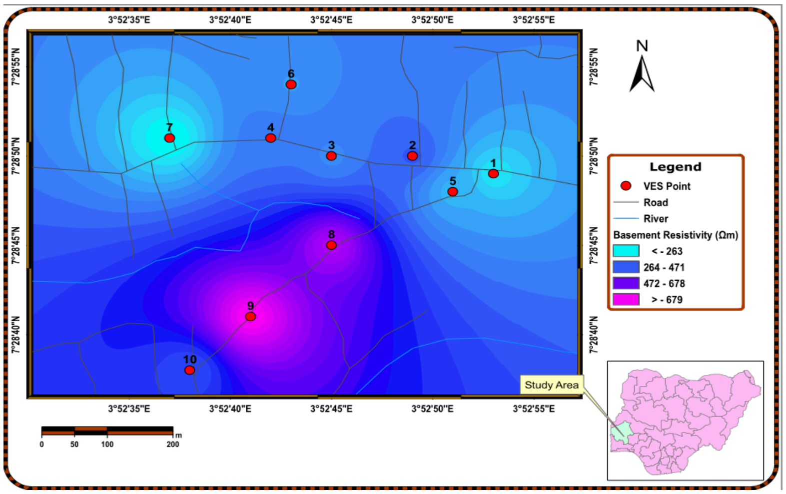


Figure 7: Isoresistivity map of fractured basement

Groundwater Potential Evaluation of the study area

The groundwater potential of a basement complex area is determined by a complex inter-relationship between the geology, weathering process and depth, post emplacement tectonic history, nature of weathered layer, groundwater flow pattern, recharge and discharge processes (Olorunfemi et al., 2004). For the present work, the groundwater potential evaluation of the study area has been based on the various categories of aquifer maps including weathered basement isoresistivity, fractured basement isoresistivity and isopach maps as deduced from the geoelectrical layer parameters obtained from the VES interpretation result. The groundwater potential map of the study area is as shown in fig 8. It reveals the groundwater potential of different region across the area. The aforementioned aquifer resistivity and aquifer thickness maps were synthesized, integrated and correlated to produce the groundwater potential map of the area. The map generally categorized the area into poor, moderate, fair and good zones. The northern region of the area covering locations around VES 4, 6 and 7 are considered to be of poor aquiferous yield hence categorized as poor groundwater potential zone while locations around VES 2 and 3 at central the region of the study area are categorized as fair groundwater potential zone being characterized by subsurface sequence of fair aquiferous yield. The Eastern and southeastern part having considered to be characterized by moderate aquiferous yield are classified as moderate groundwater potential zone while the Southern region covering locations around VES 8,9and 10 are rated good groundwater potential zone having characterized by subsurface lithology of good aquiferous.

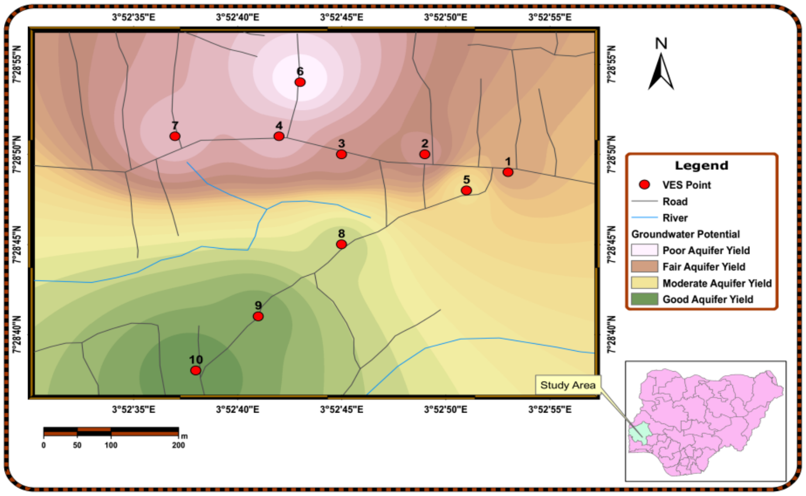


Figure 8: Groundwater potential map of the study area.

Conclusion

An evaluation of groundwater potential of Laniba, Ibadan, Southwestern Nigeria was carried out using Electrical Resistivity geophysical prospecting method. Three (3) to four (4) subsurface geoelectric layers comprising of top soil (mostly clayey sand), Lateritic soil/ clayey soil/ Quartzite and Quartz- Schist formation, weathered basement and fractured/ fresh bedrock were delineated using Vertical Electrical Sounding technique. The weathered and fractured basement constitute the aquifer units. The weathered basement in most places across the investigated area are relatively thick and sandy making it fairly promising due to its fair to moderate discharge. The fracture basement, although very scanty in the area is highly permeable and has high groundwater discharge owing to its observed low resistivity. The weathered layer and fractured basement iso- resistivity as well as weathered basement iso-pach maps were integrated, synthesized and correlated to produce groundwater potential map which classified the area into poor, fair , moderate and good potential zones. This map shows a very reliable agreement with the groundwater discharge of the existing deep water well within the study area. Despite the limitations of Electrical resistivity method, the Vertical Electrical Sounding technique adopted in this study has been found to be reliable for groundwater exploration in the basement complex terrain to which the study area belong in particular when combined with geologic mapping.

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