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Comparison of underground resistivity in parts of Odi- Sagbama Local Government and Eastern parts of Yenagoa, Bayelsa State, Niger Delta, Nigeria

Isaac OludayoAdedokun [1,*] and Jonathan EyireOsang [2]

[1] *Department of Physics, Faculty of Science, Niger Delta University, Wilberforce Island, Bayelsa State, Nigeria.*
[2] *Department of Physics, Faculty of Physical Science, University of Cross River State, Nigeria.*

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Abstract

The need to compare the underground Resistivity in Odi-Sagbama Local Government area and eastern parts of Yenagoa, Bayelsa State, Nigeria, to help individual, government or private agency to make a choice of location for the infrastructural developmental stride of the area necessitated this research. A total of eight Vertical Electrical Soundings (VES) were conducted in each side of the study area using Schlumberger array and Abem Terrameter (SAS 1000) to acquire the data. Maximum electrode spread of 1000m was used in all the sixteen VES stations occupied and then a RESIT computer program employed to process the acquired resistivity sounding data. Seven HA resistivity curves (VES 1-6 and 8) and one QH in VES 7 were observed in Odi-Sagbama side while at eastern side of Yenagoa, the curves vary significantly: HA (VES 9), KHA (VES 10), AHK (VES 11), QKH (VES 12), HA(14), HK (VES 13, 15), and HKA (VES 16).This indicates more stratification in eastern parts of Yenagoa. In each side, the topsoil resistivity is less than 100Ωm in five stations and above100 Ωm in three. The resistivities encountered are lower in Odi-Sagabama than eastern parts of Yenagoa as the lowest and the highest are 5.2 Ωm and 542.4 Ωm in the former and 10.2 Ωm and 922.1 Ωm in the latter.The average resistivity of the Aquifers and average depth of Water Tablein the area (Odi-Sagbama)are 265.2 Ωm and 71.06m respectively while they are 266.46 Ωm and 42.76m respectively in eastern Yenagoa. Generally, lithologyen countered are Clay and Sand which are present in all the layers in different forms and at different depths, Clay being the dominant. Except in layer four, the lithology are the same on the two sides of the study area but are at different depths and thicknesses.

Keywords: Lithology; RESIT; Resistivity; Terrameter; VES

1. Introduction

The study area for the comparison of subsurface resistivity could be divided into two sides: Odi-Sagabama local government and eastern parts of Yenagoa (the capital of the state) local government (Fig.1). The two sides have witnessed tremendous increase in human activities though more in parts of Yenagoa, which is the state capital. Consequently, noteworthy pressure on land and its resources has become inevitable and is directed towards economic expansion and improved standard of living. Thus more buildings for living and for industries are being built, sinking of boreholes, construction of roads are all necessity which call for geological, geophysical and hydro-geological investigation in the area. This research presents good knowledge of information on the substratum lithology/resistivity in the area that can guide individuals or industry or government agencies, to make appropriate decision on either side of the study area. It is also aimed at providing adequate geological data base and a systematic and scientific basis for the development in the area. The wide use of resistivity survey in groundwater investigations, engineering foundation problems and environmental studies has given electrical methods of geophysical prospecting a good song of ode. Recently a lot has been put into studying of environment than before [1].

*Corresponding author: Isaac Oludayo Adedokun

For this research, Schlumberger Vertical Electrical Sounding (VES) method of geophysical investigation was employed. It is a non-invasive, relatively cheap and quantitative evaluation technique used for locating sites/depths. Resistivity values are significantly influenced by the grain size of geo-materials. Soils with a greater proportion of fines like silt and clay tend to exhibit lower resistivity values while soils composed of comparatively coarser sediments like sand and gravel result in higher resistivity measurements. On account of the above, geoelectric surveys can thus assist in delineating subsoil boundaries based on differences in their textural grain sizes [2]. Geophysical resistivity techniques are based on the response of the earth to the flow of electrical current. In these methods, an electrical current is passed through the ground and two potential electrodes allow us to record the resultant potential difference between them, giving us a way to measure the electrical impedance of the subsurface material. The apparent resistivity is then a function of the measured impedance (ratio of potential to current) and the geometry of the electrode array. Resistivity measurements are associated with varying depths depending on the separation of the current and potential electrodes in the survey, and can be interpreted in terms of a lithologic and/or geo-hydrologic model of the subsurface [3]

1.1. Description and Geology of the study area:

The study area, (Figure 1), is in Bayelsa State which lies between Latitudes 4^0 15’North and 5^0 23’North; and Longitudes 5^0 15’East and $6^0$45’ East at the core of Niger Delta region. Geographically, the state is situated within the coastal area of the Niger Delta sedimentary basin. The average elevation is about 10.3m with the ground surface relatively flat andslopes gently towards the Atlantic Ocean in the South. The area is drained by tributaries of River Num, Orashi River and Talyor Epie Creek even though all emptied their waters into the Atlantic Ocean. The Niger Deltais characterized by nearly flat topography sloping slightly seawards [4]. The area lies within the tropical Equitorial climate with an annual mean rainfall of 3000 mm which serves as the major source of groundwater recharge [5,6]

The geology and geomorphology of the Niger Delta have been extensively described by various authors [7]Its geologic sequencecomprises three main tertiary subsurface litho-stratigraphic units which are overlain by various types of quaternary deposits [8]The subsurface geology of the Niger Delta consists of three litho-stratigraphic units (Benin, Agbada and Akata Formations) in a top- to-bottom sequence [9,10].The base of the unit is the Akata formation; it is comprised mainly of marine shales with some sand beds.

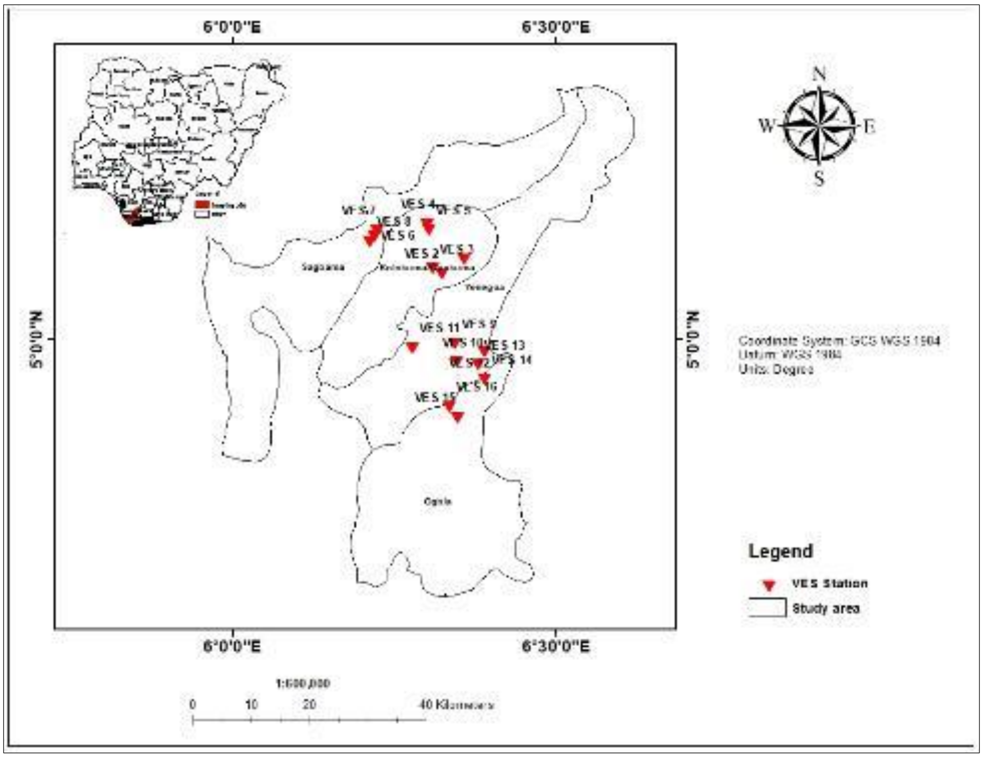


Figure 1 The study area showing the positions of Vertical electrical soundings (VES)

The formation ranges in thickness from about 550 m to over 6,000 m. The Agbada formation is the overlying paralic sequence which consists of inter-bedded sands and shale with a thickness of 300 m to about 4,500 m, thinning both seawards and towards the Delta margin. The topmost unit is the Benin formation; it is comprised of over 90% sandstone with shale intercalations. It is coarse grained, gravely, locally fine grained, poorly sorted, sub angular to well-rounded and bears lignite streaks and wood fragments The Benin formation is about 2100 m thick and is made up of over 90% massive, porous, coarse sands with localized clay/shale inter-beds [7]. The unit is thickest in the central area of the Delta. The contact with the underlying Agbada formation is defined by the base of sandstones which also corresponds to the base of the fresh water bearing strata

2. Material and methods

Actually all electrical methods employ an artificial source of current, which is introduced into the ground through point electrodes. The procedure is to measure potentials at other electrodes in the vicinity of the current flow. As the current is measured as well, it is possible to determine an effective or apparent resistivity of the subsurface [11]. Abem Terrameter (SAS 1000) resistivity equipment was used for a maximum current electrode (AB) of 1000.00m for all the sixteen VES stations occupied. Schlumberger vertical electrical sounding (VES) method was adopted for the survey. In this arrangement, the four electrodes A, M, N andB were placed on a straight line and at equal distance from each other (Figure 2). The outer electrodes A and B are current electrodes which are being moved away on either side of the stationary equipment while the two inner potential electrodes, M and N remain fixed for a while. The arrangement was such that the distance between potential electrodes M N never exceeded 2/5 of AB/2. As the current electrodes were being expanded, the process yielded a rapidly decreasing potential difference across MN which eventually exceeded the measuring capabilities of the instrument. Then, at that point, a new value of MN was used, typically two to four times larger than the preceding value [11].The values of AB/2 started with: 1.00, 1.5, 2…50, 60, .350,400 and 500mwhile MN commenced from 0.025, 0.25……..0.05, 1.00…..10.00, 20.00m.The depth of investigation is of the order of 0.1 to 0.3 times the AB length [12] and so the depth under consideration here is between 100 and 300m. The resistivity sounding data acquired was processed using RESIT computer program

Therefore the depth for which information is required determines the current electrode separation. Each time the current or potential or both electrodes were expanded, the value of the resistance R measured by the Terrameter was recorded. This was done for all the sixteen stations occupied. The value of the Geometric factor K each time the electrodes were expanded was calculated using the equation below [13]

$$K = 2\pi\left[\frac{1}{r_{AM}} - \frac{1}{r_{MB}} - \frac{1}{r_{AN}} + \frac{1}{r_{NB}}\right]^{-1}$$

Where r_{AM} = AM , r_{MB} = MB, r_{AN} = AN, ,r_{NB} = NB.

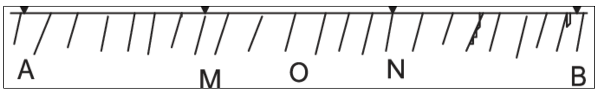


Figure 2 Arrangement of the electrodes for Schlumberger configuration field survey.

The product of the resistance R and the geometric factor K gives the apparent resistivity $\rho_{a.}$ The RESIT computer software programme, was employed to plot the apparent resistivity $\rho_{a.}$ against the half current electrodes (AB/2) spacing and curves obtained were interpreted.

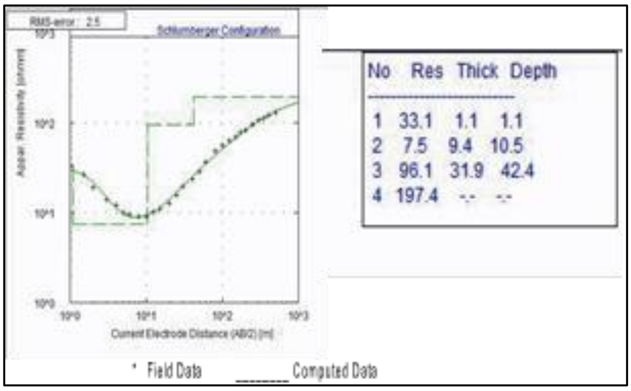
3. Results and discussion

The results in the study areas are considered separately and then compared: Odi-Sagbama where eight VES stations (VES 1-VES 8), whose geoelectirc layers and lithology are presented respectively in Figures 3 and 4, were occupied and eastern parts of Yenagoa where eight VES stations (VES 9 – VES 16) were sampled and displayed in Figures 5 and 6 for geoeletric layers and lithology respectively. The results of the geo-electric layers and lithology from these two sections are compared and the summary of Aquifer resistivity against depth (Figure 7), lithology, aquifer and water table shown on Table 1 and 2.

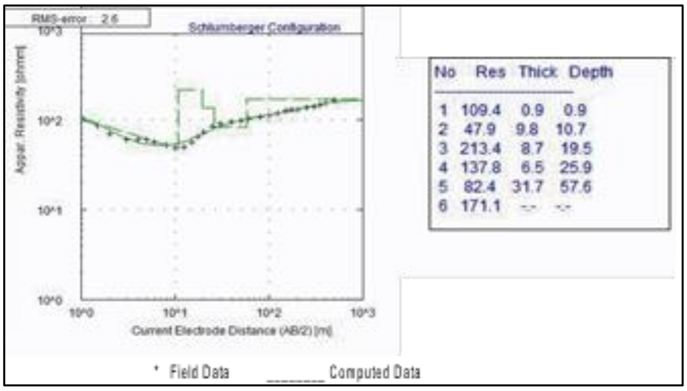
In Odi-Sagbama area, VES 1- VES 8 occupied and the geoelectric layers shown (Figure 3).For VES 1 the resistivity curve identified, using computer assisted programme, was HA curve and a four layer stratified location. The topsoil resistivity (33.1 Ωm) is underlain by wet Clay of lowest resistivity (7.5 Ωm) of the station 1.1m and below the surface up to a depth of 10.5m.Resistivity increases from here down to the substratum. Clayey layer three overlies an Aquifer, of resistivity 197.4 Ωm , in this location which can be found in the last layer four at a depth of 42.4 m from the surface. VES 2. is a six-layer stratification with QHA resistivity curve identified. The topsoil is underlain by a lower resistivity of 47.9 Ωm which overlies the aquifer of 213.4 Ωm resistivity at 19.5m depth in the third layer. The resistivity decreases (82.4 Ωm)down through to the Clay fifth layer and then rises to 171,1 Ωmin the substratum, that could be interpreted as fine sand at 57.6 m below the surface. The computer interpretation technique identified four layers giving HA resistivity curve in VES 3. The first layer,1.7m deep, is the topsoil and overlies a wet Clay of very low resistivity (6.3 Ωm) that is 9.4m deep. Resistivity increases in the third layer to 422.4 Ωm, providing the aquifer of this location at 76.5m beneath the surface. The last layer, having a resistivity of 277.2 Ωm, could be fine sand underlain the aquifer.Four layers and HA resistivity curve were revealed in VES 4. The resistivity in this station is generally low, being 106.6 Ωm in the substratum where the aquifer, 56.9m deep, could be considered to be located. The subsoil and the third layers are Clay of resistivity values5.2 Ωm and 55.0 Ωm respectively.

The fifth location, VES 5 is a four-layer stratified earth and HA resistivity curve type. Its topsoil has the lowest resistivity (8.3 Ωm). The subsoil fine sand, 32.5m deep, has higher resistivity of 352.6 Ωm. This is underlain by a lower resistive fine sandformation (195.1 Ωm) that sits on top of aquifer of 547.4 Ωm in the substratum that is 120.7m deep. The last layer accommodates the aquifer. HA resistivity curve type of five-layer stratification were observed in VES 6. The topsoil resistivity (47 Ωm) lies on top of wet Clay of low resistivity (13.3 Ωm) 54m deep. From this the resistivity increases downward in the third (45.4 Ωm), fourth(106.5 Ωm)and the substratum (336.5 Ωm) layers where the aquifer is located at 66.6m deep. In VES 7, the geo-electric layer, using computer assisted interpretation method , revealed five layer of QH resistivity curve type. The topsoil, 1.5m deep, has the highest resistivity (2111. 0Ωm). The underneath layer, which could be fine sandhas a reduced resistivity of 494.8 Ωm. Resistivity decreases down to the fourth layer, (70.1 Ωm) which could be Clay at 142.0m depth. From this the resistivity increases to 181.8 Ωm, in the fine sand substratum.

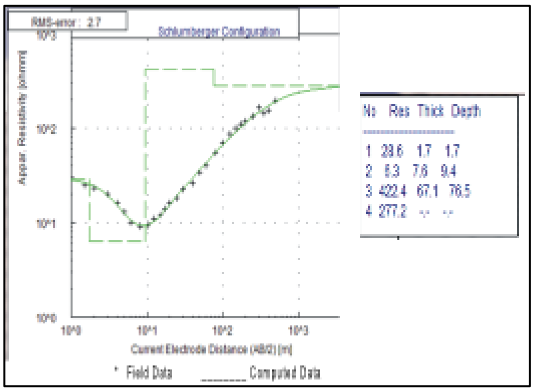
The last sounding in this area was VES 8. Computer interpretation technique identified five -layer stratification of QHA resistivity curve type. The topsoil is a dry sand and possesses the highest resistivity (1089.1 Ωm) of the location. The resistivity continues to decrease up to 78.8 Ωm in the third layer, which is Clay that is situated 80.8m below the surface. It then rises in the fourth layer (109.8 Ωm) to 16.6 Ωm in the last year four. This layer accommodates the aquifer at a depth 119.8m.The Geo-electric layers, field and theoretical curves for each of the stations VES 1-8 are shown in Figure 3 while Figure 4 represents the Lithology for the corresponding VES stations.



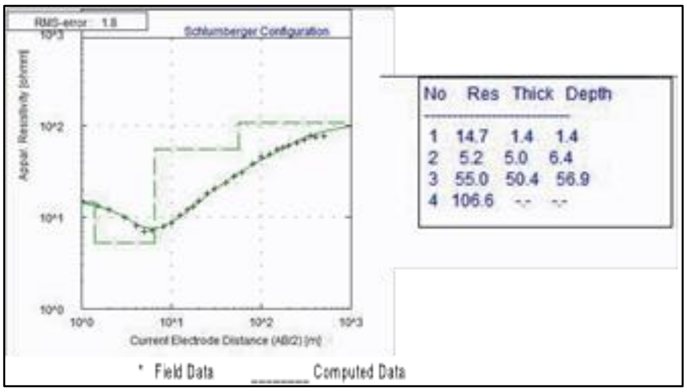
Geo-electric layers, Field and theoretical curves for VES 1



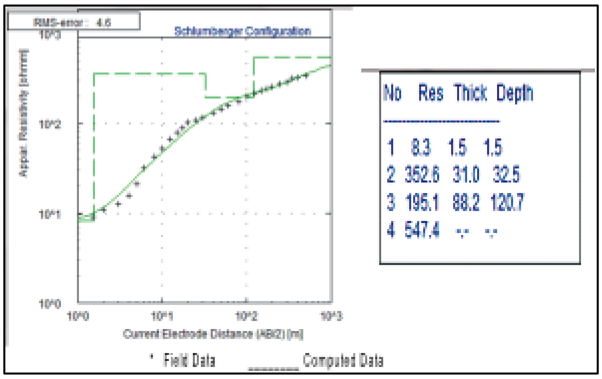
Geo-electric layers, Field and theoretical curves for VES 2



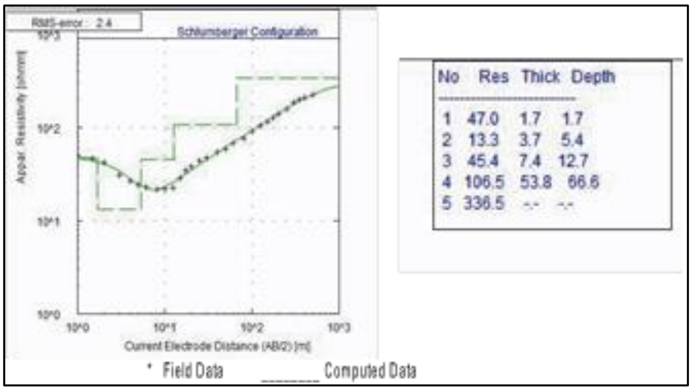
Geo-electric layers, Field and theoretical curves for VES 3



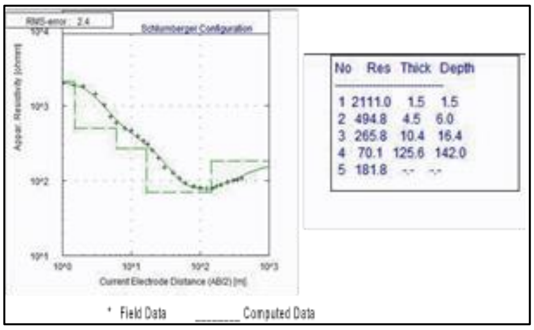
Geo-electric layers, Field and theoretical curves for VES 4



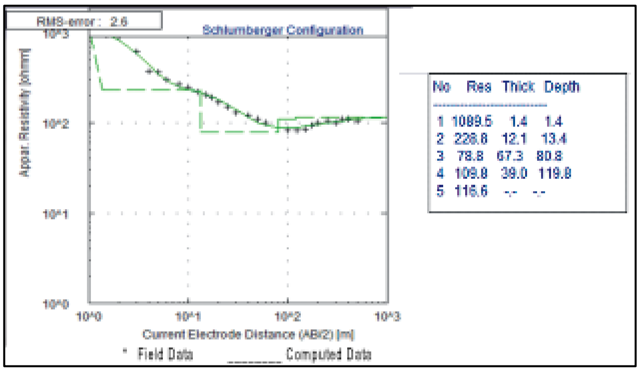
Geo-electric layers, Field and theoretical curves for VES 5



Geo-electric layers, Field and theoretical curves for VES 6

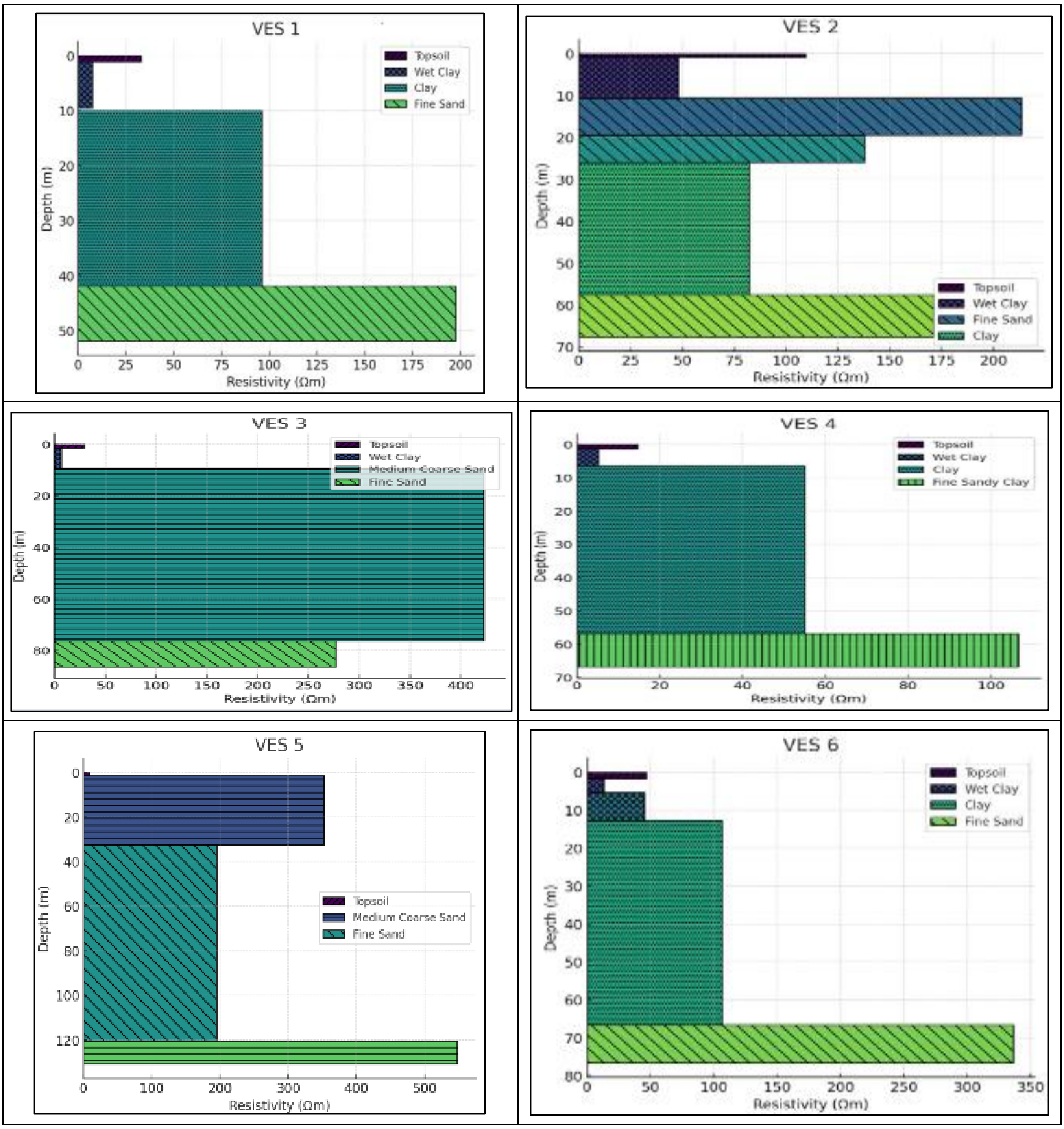


Geo-electric layers, Field and theoretical curves for VES 7



Geo-electric layers, Field and theoretical curves for VES 8

Figure 3 The plots of resistivity against half-electrode spread (AB/2) for Odi-Sagbama area


VES 1
Topsoil
Wet Clay
Clay
Fine Sand
Depth (m)
Resistivity (Ωm)
VES 2
Topsoil
Wet Clay
Fine Sand
Clay
Depth (m)
Resistivity (Ωm)
VES 3
Topsoil
Wet Clay
Medium Coarse Sand
Fine Sand
Depth (m)
Resistivity (Ωm)
VES 4
Topsoil
Wet Clay
Clay
Fine Sandy Clay
Depth (m)
Resistivity (Ωm)
VES 5
Topsoil
Medium Coarse Sand
Fine Sand
Depth (m)
Resistivity (Ωm)
VES 6
Topsoil
Wet Clay
Clay
Fine Sand
Depth (m)
Resistivity (Ωm)

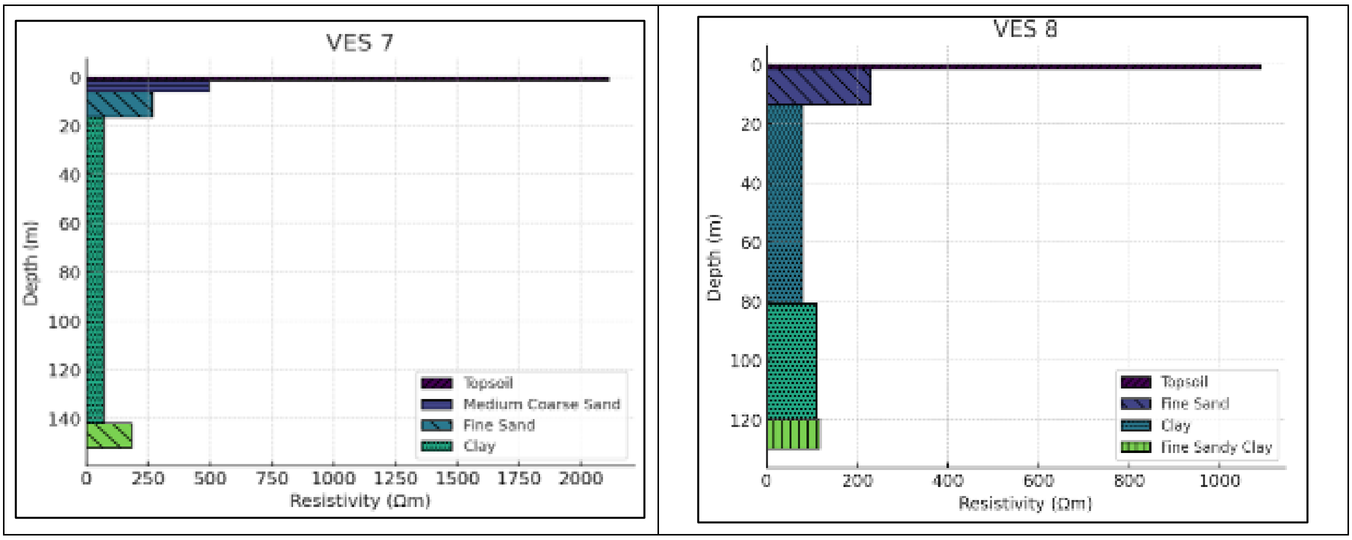
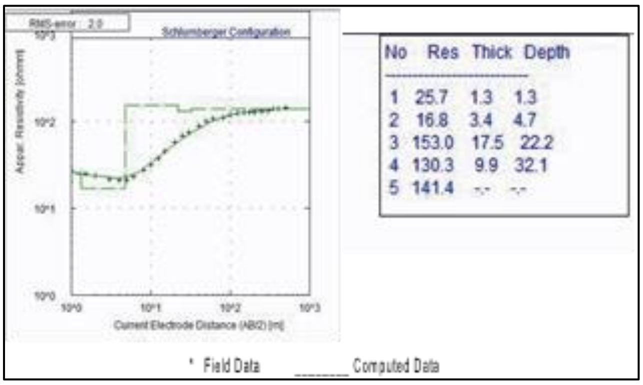


Figure 4 Lithology obtained from Odi-Sagbama area

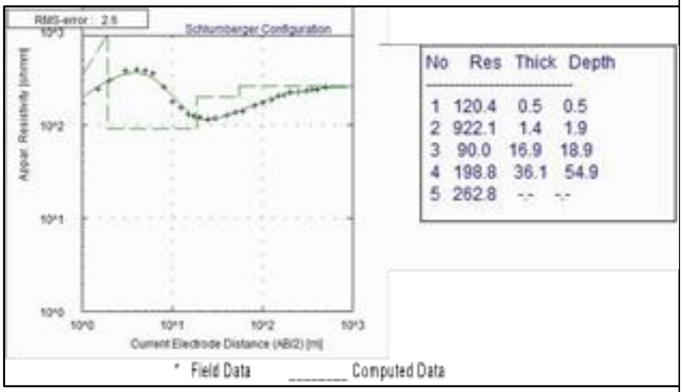
VES 9 – VES 16 were obtained in eastern parts of Yenagoa (Figure 5). The geo-electric layer and resistivity curve revealed in VES 9 are five and HA respectively. The location is generally of low resistivity ranging from 25.7 Ωm at the topsoil to 153.0 Ωm in the third layer. Resistivity increases and decreases alternately from the topsoil to the substratum. The third layer, 22.2 m deep, is where the aquifer could be found. It overlies a sandy clay of resistivity 130.3 Ωm, which is 32.1m below the surface. Resistivity increases in the substratum, at 32.1m, to 141.4 Ωm. The VES 10 location is a five-layer stratification having KHA resistivity curve. The topsoil (120.4 Ωm) is underlain by a much higher resistive medium coarse sand(922.1 Ωm), 1.9m deep. This overlies a 90.0 Ωm Clay in the third layer; the resistivity increases through the fourth (198.8 Ωm) to the fine sand fifth layer (262.8 Ωm) which is the last layer. The aquifer in this location is situated 50.4mdeep at this substratum. The interpretation of VES 11 gave five-layer stratification of alternating low and high resistivity down to the last layer, revealing AHK resistivity curve. The subsoil, which could be fine sand, has the highest resistivity (292.7 Ωm) and at 7.6m depth. It lies on Clay (91.5 Ωm) in the third layer, which in turn overlies a relatively higher resistivity layer (246.2 Ωm) that accommodates the aquifer, 31.4 m deep, in the fourth layer. The clay substratum has a reduced resistivity of 73.9 Ωm at 67.7m below the surface. In VES 12, the resistivity curve encountered in this location was QKH with five-layer stratification. The topsoil, which could be mainly dry fine sand, has the highest resistivity value of 549.1 Ωm. The resistivity decreases down the layer up to the fourth one where a value of 29.4. The underneath layer two, three and four are all Clays of various water compositions. The last layer five, of resistivity 143.2 Ωm, at 103.8m depth could be aquifer in this location.

VES 13 is a five-layer stratification of HK resistivity curve type. The topsoil (149.7 Ωm) is underlain by a much lower resistive (19.0 Ωm) wet Clay layer. The third layer of 841.3 Ωm, at 16.4 m depth accommodates the aquifer. The resistivity decreases through the sandy Clay(130.9 Ωm) in the fourth layer to the Clay substratum (102.9 Ωm) which is 34.4m deep. Five layers of HA resistivity curve were identified in VES 14. The topsoil overlies a wet Clay of lower resistivity (13.7 Ωm located 4.9m below the surface. Resistivity increases from this through the third (65.8 Ωm), fourth (68.5 Ωm) and the last year (116.6 Ωm), which is 69.3m below the surface and bears the aquifer. The geo-electric layer, using computer assisted interpretation method revealed four layers of HK resistivity curve in VES 15. The first two layers-topsoil and subsoil- are of very low resistivity, being 38.0 and 10.2 Ωm respectively. The aquifer is locate d in layer three, 23.4m below the surface and 239.5 Ωm resistive. This overlies Clay sandy (149.3 Ωm) in the subtratum and situated26.5m from the surface. Six layers of HKA resistivity curve have been revealed in VES 16. The resistivity in this location is generally low, from the lowest in the subsoil (18.1 Ωm) to the highest in (129.2 Ωm) in the substratum layer located at 66.1m down the surface. The aquifer of this station can be found in this last layer at a depth of 66.1m.

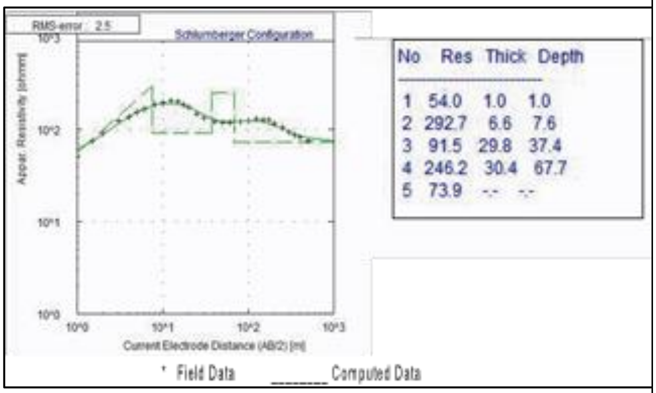
The observations from the study area revealed four 4 layers, three 5 layers and 1 six layers in Odi-Sagbama section. In the eastern parts of Yenagoa. Seven5 layers and 1 Six layer stratifications were encountered. There are remarkable variations in the electrical resistivity underneath which is an indication of its heterogeneity. The geoelectric layers and lithology for this side of the study area are shown in Figure 5 and Figure 6 respectively.



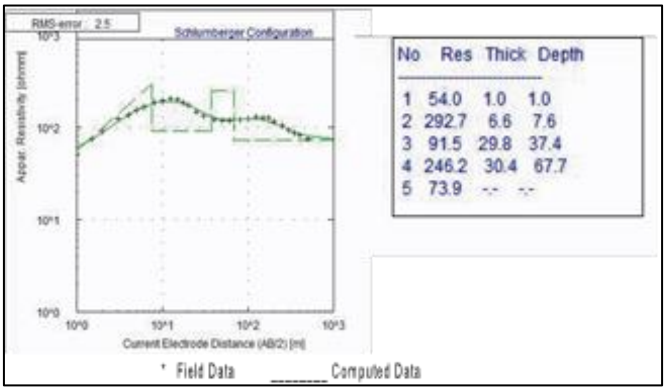
Geo-electric layers, Field and theoretical curves for VES 9



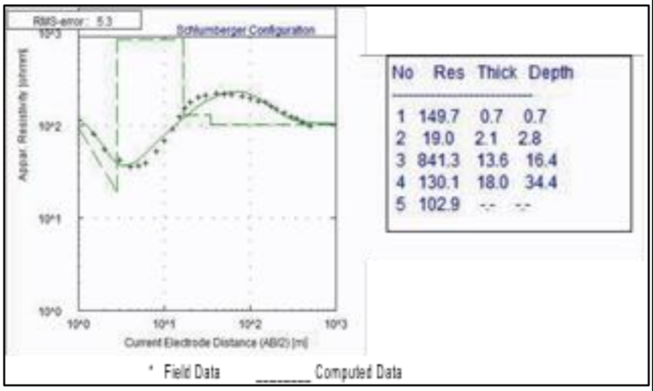
Geo-electric layers, Field and theoretical curves for VES 10



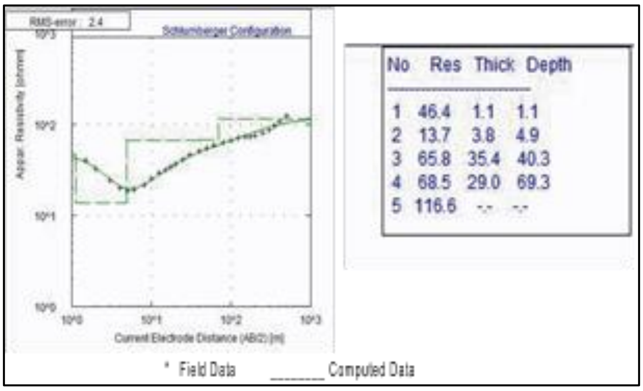
Geo-electric layers, Field and theoretical curves for VES 11



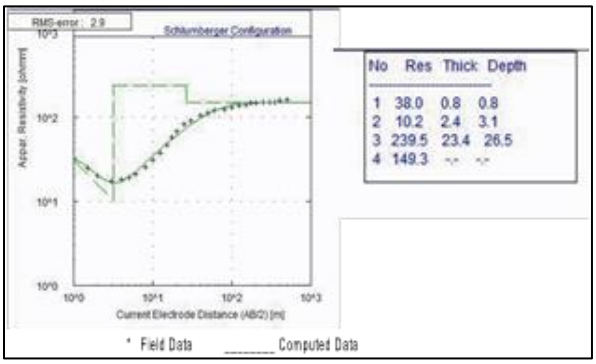
Geo-electric layers, Field and theoretical curves for VES 12



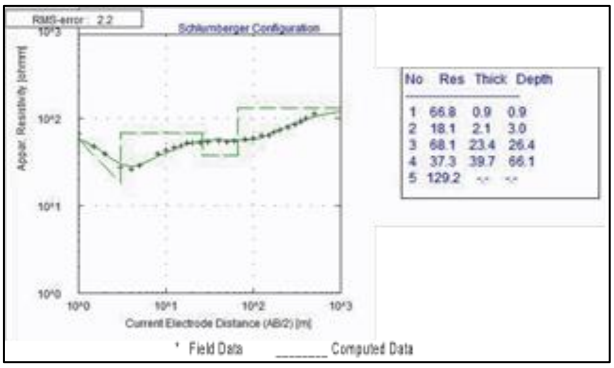
Geo-electric layers, Field and theoretical curves for VES13



Geo-electric layers, Field and theoretical curves for VES 14

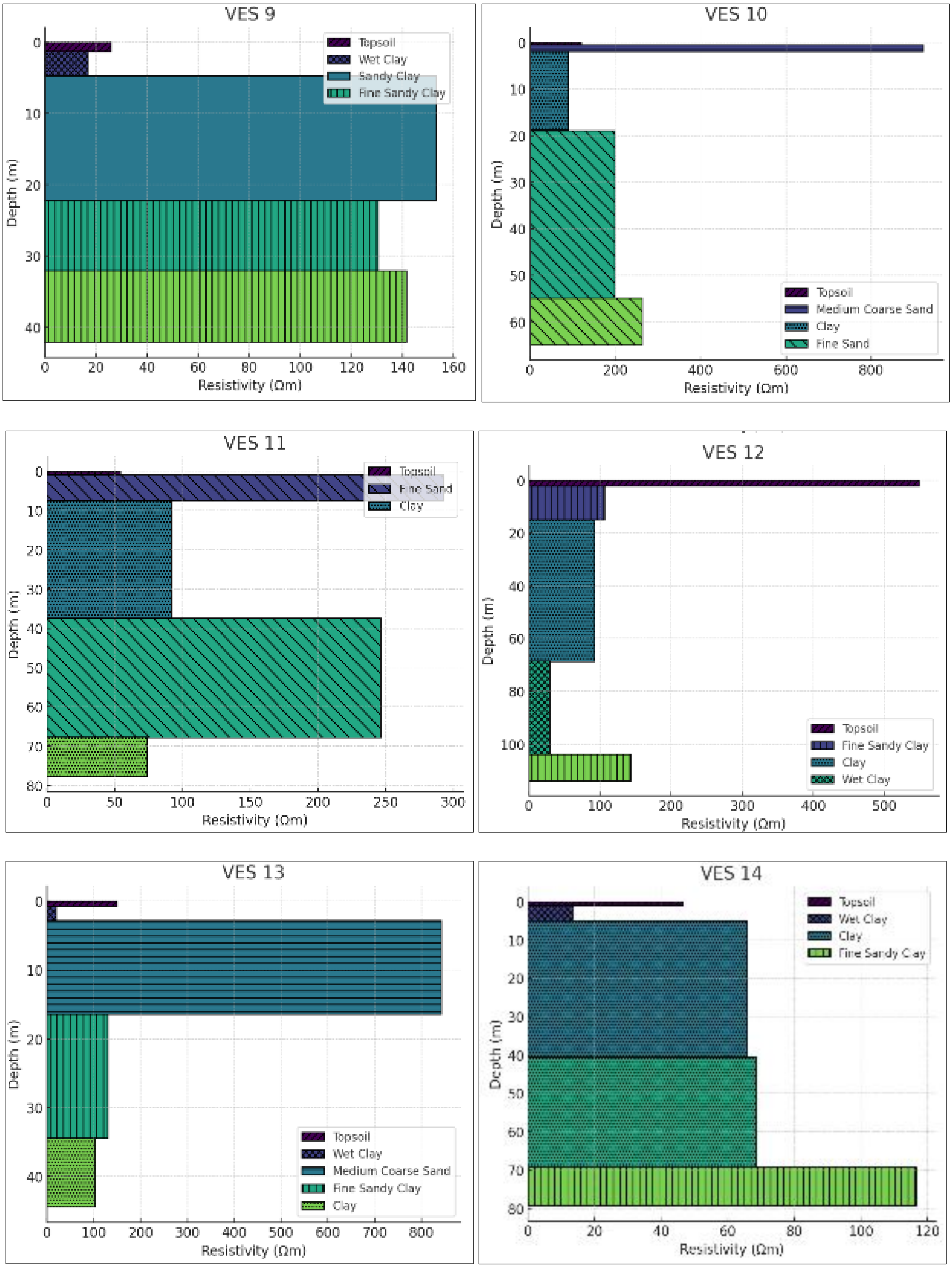


Geo-electric layers, Field and theoretical curves for VES 15



Geo-electric layers, Field and theoretical curves for VES 16

Figure 5 The plots of resistivity against half-electrode spread (AB/2) for eastern parts of Yenagoa


VES 9
Topsoil
Wet Clay
Sandy Clay
Fine Sandy Clay
Depth (m)
Resistivity (Ωm)
VES 10
Topsoil
Medium Coarse Sand
Clay
Fine Sand
Depth (m)
Resistivity (Ωm)
VES 11
Topsoil
Fine Sand
Clay
Depth (m)
Resistivity (Ωm)
VES 12
Topsoil
Fine Sandy Clay
Clay
Wet Clay
Depth (m)
Resistivity (Ωm)
VES 13
Topsoil
Wet Clay
Medium Coarse Sand
Fine Sandy Clay
Clay
Depth (m)
Resistivity (Ωm)
VES 14
Topsoil
Wet Clay
Clay
Fine Sandy Clay
Depth (m)
Resistivity (Ωm)

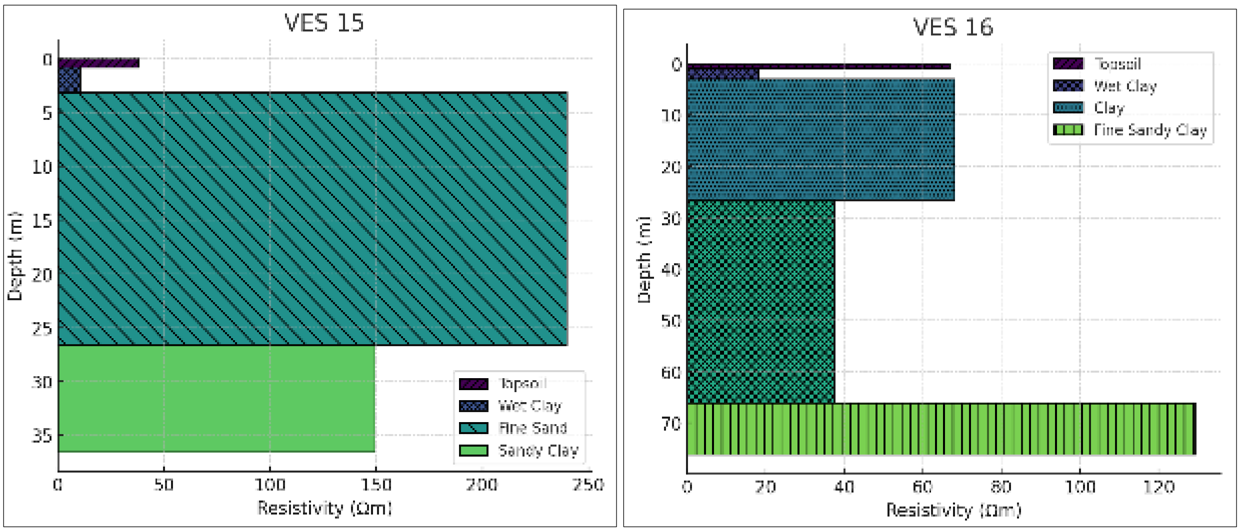


Figure 6 Lithology obtained from eastern parts of Yenagoa

3.1. Comparison of results from the two sides of the study area

Odi-Sagbama area: The resistivity curves encountered here indicated that resistivity increases down to substratum layer in all except in VES 7. Three 5-layer, four 4-layer and one6-layer earth were observed in this area. The resistivity curves are HA (VES 1,2, 3,4,5, 6 and 8) and QH (VES 7). The lowest and highest resistivities in the subsurface are 5.2Ωm in the second layer of VES 4and 542.4 Ωm in the substratum of VES 5 respectively. The average resistivity of the Aquifers in the area is 265.2 Ωm. The shallowest and deepest Water tables recorded are 9.4m in VES 3 and 120.7m in VES5 respectively, with an average of 71.0625m.Elevation ranges between 6 and 16m with an average of 11m in this area (Tables 1 and 2).

At the Eastern parts of Yenagoa, consisting of VES 9,10, 11, 12, 13, 14 15 and 15, Seven 5-layer and One 4-layer stratification were observed. Resistivity curves in this area are HA (VES 9), KHA (VES 10), AHK (VES 11), QKH (VES 12), HK (VES 13), HA (VES 14), HK VES 15 and HKH (VES 16).These indicate that resistivity is increasing down the substratum layers in VES (9, 10, 12, 14 and 16) and decreasing in VES (11, 13 and 15). The lowest and highest resistivities in the subsurface are 10.2Ωm in the second layer of VES 15and 922.1 Ωm in the second layer of VES 10 respectively. The average resistivity of the Aquifers in the area is 266.462 Ωm. The shallowest and deepest Water tables recorded are 2.8m in VES 13 and 103.8m in VES12 respectively, with an average depth of 42.7625m. Elevationranges between 7 and 13m with an average of9.125m in this area (Tables 1 and 2).

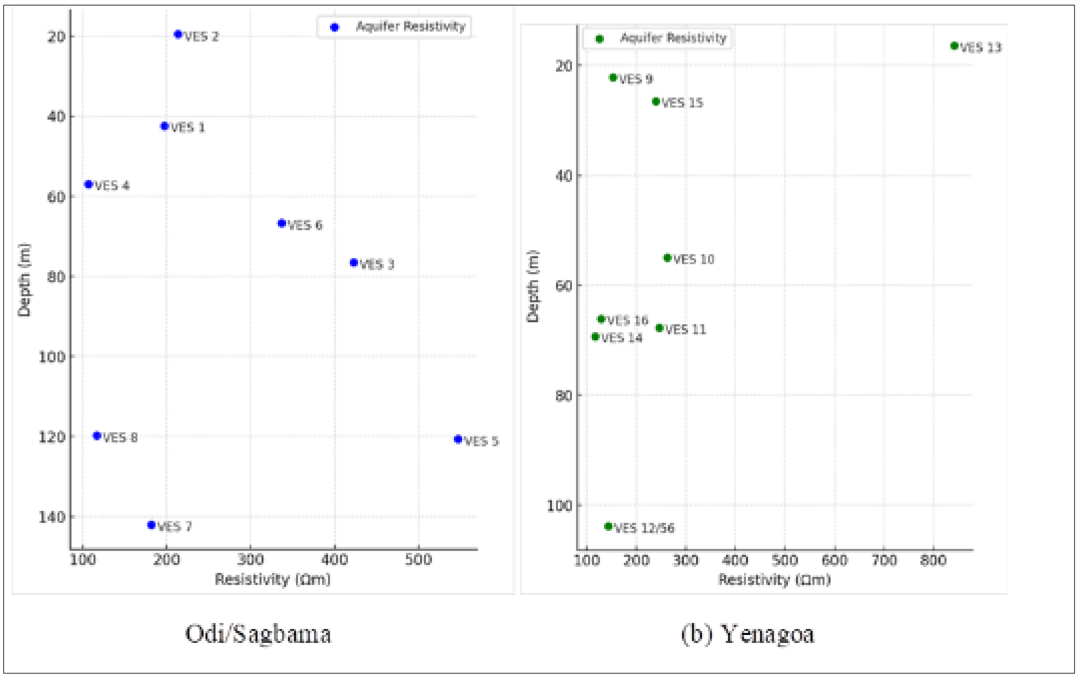


Figure 7 The plots of depth of Aquiferagainst resistivity values in Odi/Sagbama (a) and eastern parts of Yenagoa (b)

Table 1 Summary of Aquifer resistivity, water table, depth and thickness

Odi-Sagbama area				
VES	**Aquifer Resistivity/Ωm**	**Water Table/m**	**Depth/m**	**Thickness/m**
1	197.4	42.40	42.40	∞
2	213.4	10.70	19.50	8.70
3	422.4	9.40	76.50	67.10
4	106.6	56.90	56.90	∞
5	547.4	120.70	120.70	∞
6	336.5	66.60	66.60	∞
7	181.8	142.00	142.00	∞
8	116.6	119.80	119,80	∞
Eastern parts of Yenagoa				
VES	**Aquifer Resistivity/Ωm**	**Water Table/m**	**Depth/m**	**Thickness/m**
9	153.0	4.70	22.20	17.50
10	262.8	54.90	54.90	∞
11	246.2	37.40	67.70	30.40
12	143.2	103.80	103.80	∞
13	841.3	2.80	16.40	13.60
14	116.6	69.30	69.30	∞
15	239.5	3.10	26.50	23.40
16	129.2	66.10	66.10	∞

Table 2 Summary of results of geo-electric layers

Odi/ Sagbama area						
VES 1						
Layer	1	2	3	4	5	6
Resistivity/ Ωm	33.1	7.5	96.1	197.4		
Lithology	Topsoil	WetClay	Clay	Fine Sand		
Depth/m	1.1	10.5	42.4	--		
Thickness/m	1.1	8.4	31.9	--		
VES 2						
Layer	1	2	3	4	5	
Resistivity/ Ωm	109.4	47.9	213.4	137.8	82.4	171.1
Lithology	Topsoil	Wet Clay	Fine Sand	Fine Sand	Clay	Fine Sand
Depth/m	0.9	10.7	19.5	25.9	57.6	--
Thickness/m	0.9	9.8	8.7	6.5	31.7	--
VES 3						
Layer	1	2	3	4		
Resistivity/ Ωm	28.6	6.3	422.4	277.2		
Lithology	Topsoil	Wet Clay	Medium coarse Sand	Fine Sand		
Depth/m	1.7	9.4	76.5	--		
Thickness/m	1.7	7.6	67.1	--		
VES 4						
Layer	1	2	3	4		
Resistivity/ Ωm	14.7	5.2	55.0	106.6		
Lithology	Topsoil	Wet Clay	Clay	Fine sandy Clay		
Depth/m	1.4	6.4	56.9			
Thickness/m	1.4	5.0	50.4			
VES 5						
Layer	1	2	3	4		
Resistivity/ Ωm	8.3	352.6	195.1	547.4		
Lithology	Topsoil	Medium coarse Sand	Fine Sand	Medium coarse Sand		
Depth/m	1.5i	32.5	120.7	--		
Thickness/m	1.5	31.0	88.2	--		
VES 6						
Layer	1	2	3	4	5	
Resistivity/ Ωm	47.0	13.3	45.4	106.5	336.5	
Lithology	Topsoil	Wet Clay	Wet Clay	Clay	Fine sand	

Depth/m	1.7	5.4	12.7	66.6	--	
Thickness/m	1.7	3.7	7.4	53.8	--	
VES 7						
Layer	1	2	3	4	5	
Resistivity/ Ωm	2111.0	494.8	265.8	70.1	181.8	
Lithology	Topsoil	Medium coarse sand	Fine Sand	Clay	Fine sand	
Depth/m	1.5	6.0	16.4	142.0	--	
Thickness/m	1.5	4.5	10.4	125.6	--	
VES 8						
Layer	1	2	3	4	5	
Resistivity/ Ωm	1089.5	228.8	78.8	109.8	116.6	
Lithology	Topsoil	Fine Sand	Clay	Clay	Fine sandy Clay	
Depth/m	1.4	13.4	80.8	119.8	--	
Thickness/m	1.4	12.1	67.3	39.0	--	
Eastern parts of Yenagoa						
VES 9						
Layer	1	2	3	4	5	
Resistivity/ Ωm	25.7	16.8	153.0	130.3	141.4	
Lithology	Topsoil	Wet Clay	Sandy Clay	Fine sandy Clay	Fine sandy Clay	
Depth/m	1.3	4.7	22.2	32.1	--	
Thickness/m	1.3	3.4	17.5	9.9	--	
VES 10						
Layer	1	2	3	4	5	
Resistivity/ Ωm	120.4	922.1	90.0	198.8	262.8	
Lithology	Topsoil	Medium coarse Sand	Clay	Fine Sand	Fine Sand	
Depth/m	0.5	1.9	18.9	54.9	--	
Thickness/m	0.5	1.4	16.9	36.1	--	
VES 11						
Layer	1	2	3	4	5	
Resistivity/ Ωm	54.0	292.7	91.5	246.2	73.9	
Lithology	Topsoil	Fine Sand	Clay	Fine Sand	Clay	
Depth/m	1.0	7.6	37.4	67.7	--	
Thickness/m	1.0	6.6	29.8	30.4	--	
VES 12						
Layer	1	2	3	4	5	
Resistivity/ Ωm	549.1	106.4	92.6	29.4	143.2	

Lithology	Topsoil	Fine sandy Clay	Clay	Wet Clay	Fine sandy Clay
Depth/m	2.2	14.9	68.5	103.8	--
Thickness/m	2.2	12.7	53.7	35.3	--
VES 13					
Layer	1	2	3	4	5
Resistivity/ Ωm	149.7	19.0	841.3	130.1	102.9
Lithology	Topsoil	Wet Clay	Medium coarseSand	Fine sandy Clay	Clay
Depth/m	0.7	2.8	16.4	34.4	--
Thickness/m	0.7	2.1	13.6	18.0	--
VES 14					
Layer	1	2	3	4	5
Resistivity/ Ωm	46.4	13.7	65.8	68.5	116.6
Lithology	Topsoil	Wet Clay	Clay	Clay	Fine sandy Clay
Depth/m	1.1	4.9	40.9	69.3	--
Thickness/m	1.1	3.8	35.4	29.0	--
VES 15					
Layer	1	2	3	4	5
Resistivity/ Ωm	38.0	10.2	239.5	149.3	
Lithology	Topsoil	Wet Clay	Fine Sand	Sandy Clay	
Depth/m	0.8	3.1	26.5	--	
Thickness/m	0.8	2.4	23.4	--	
VES 16					
Layer	1	2	3	4	
Resistivity/ Ωm	66.8	18.1	68.1	37.3	129.2
Lithology	Topsoil	Wet Clay	Clay	Wet Clay	Fine sandy Clay
Depth/m	0.9	3.0	26.4	66.1	--
Thickness/m	0.9	2.1	23.4	39.7	--

4. Conclusion

The observations in these two areas are that in Odi-Sagbama, the lowest water table (9.4m) and deepest (120.7m)are higher than the lowest (2,8m) and the deepest (103.8m)in the eastern parts ofYenagoa . The average depth of water table is 265.2m and 266.4m in Odi-Sagbama and Yenagoa parts respectively. Resistivity recorded is lower in Odi-Sagabma with the lowest and highest values being 5.2 Ωm and 542.4 Ωm, than in Yenagoa side, where lowest 10.2 Ωm and highest 922.1 Ωm resistivity values were observed.

Generally in Odi-Sagbma, the topsoil resistivity is less than 100 Ωm in five VES locations and above 100 Ωm in three VES locations. The topsoil resistivity is higher than the subsoil in seven VES locations except VES 5. At eastern Yenagoa, the same trend was observed; five VES stations have topsoil resistivity less than100 Ωm and three higher than 100 Ωm . The topsoil resistivity is higher than the subsoil in six VES locations in Yenagoa, except in VES 10 and 11. The subsurface in the area is essentially made up of Clay (of very low resistivity), Sandy Clay, Fine Sand, mediumcoarse sand and coarse sand. The outcome of this research will help individual, government or private agency to make a choice of location for the infrastructural developmental stride in response to the increase in the number of people making a living in the area.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

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