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GEOPHYSICAL INVESTIGATION FOR AQUIFER VULNERABILITYIN UVWIE, DELTA STATE

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Abstract

Due to the fact that most groundwater in the Uvwie and its environ are not portable, it is necessary to employ the electrical prospecting method to delineate the aquifer levels and the protective capacities of the overlying layers in the locality. Selected locations were surveyed using the Schlumberger configuration with maximum current spread of 120m. A total of 10 VES were carried out, 2 VES per location. The 2D electrical resistivity imaging (ERI) data obtained showed that greater proportion of data obtained from field investigation revealed high resistivity images values, which are proxy for freshwater. The high resistivity images values were interpreted as sand, low resistivity values clays and silty sand saturated with freshwater. Results from acquired data showed that while aquifers in the study area are poorly protected, aquifers at Ugboroke, Refinery road and FUPRE area relatively less vulnerable. Five layers was delineated except for VES3 which have four layers. The apparent resistivity of the aquifers range from 598.2Ωm-1401.1.6Ωm, at depth range of 15.6m-41.0m. Delineated Lithologies are made up of clay and sandstone sequence which corresponds to the Niger Delta formation.

***Keywords*: Groundwater, Aquifer, Delineate, Lithology, Apparent resistivity.

1.0 Introduction

Ground water is stored, and moves through layers of sand and rock called aquifer. The porosity of the rocks and how well the pore space are connected determines the speed at which ground water flows. An aquifer is an underground layer of water bearing permeable rock, rock fractures or unconsolidated sand [1].Aquifer occurs at various depth. When it is close to the surface it is called shallow aquifer.

Shallow aquifers which are used for domestic water supply and irrigation are prone to contamination from both industrial and domestic waste. The key expression for quantifying an aquifer protection is its vulnerability [2,3].Hence an aquifer protection is essential for a sustainable use of the ground water resources, protection of the dependent ecosystems, and a central part of spatial planning and action plans [4]. Aquifers varies with the season as they are more likely to be topped by local rainfalls, intruding surrounding lakes and rivers, etc. Aquifers can be confined and unconfined. It is confined when it is bounded by overlying impermeable rock layer (Aquitard) and unconfined when there is no impermeable layer separating it from the surface.Depth to aquifer studies are so important that they give detail statistics as a guide to both water borehole and sewage pit construction in residential housing area.

Hydrogeophysical aquifer studies has helped to give statistics of clear aquifer depth and thickness, salt water intrusion, ground water contamination, etc. This research is done in Uvwie local government area at strategic locations with the objective to determine aquifer bed thickness, depth and vulnerability in the area. Uvwie local government area which is approximately 100 square kilometers lies between longitudes 5.40’ and 5.50’East of Latitudes 5.30 and 5.50 North. It comprise of several communities (Ekpan, Effurun, Ugboroke, Enerhen, etc.) which host major oil cooperations. As such it is a core transition zone with complexity of oil pipes network. It is the gate way to Warri city.

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Due to the heavy industrialization and continuum population surge, the need for portable and sustainable drinking water is on a steady and high increase. Hence the objective of this research is to provide detail statistics of bed (aquifer) thickness and depth for industrial and domestic consumption.

2.0 THEORY AND METHOD

Resistivity techniques rely on the response of the earth to the flow of electric current[2,5]. Usually, with the VES technique, when an electric current is drilled into the ground via two current electrode, and the resulting potential difference is measured by the two potential electrodes, we can obtain a response that is a direct measure of the electrical impedance of the subsurface according to the equation below.

$$\mathbf{R}=\frac{V}{I} \qquad (1)$$

Where R is the response called resistance, V is the potential difference and I the current.
The resistivity therefore is a measure of the response and the electrode geometric factor,k, as shown in the equations below.

$$\rho_{a}=KR \qquad (2)$$

Where,

$$K=\frac{\pi s^2}{a}\left[1-\frac{a^2}{4s^2}\right] \qquad (3)$$

ρ_a= Apparent resistivity, k=geometric factor for schlumber array,a=MN, and s=AB/2[3].
In the shallow subsurface, the presence of water controls most of the conductivity variation.Generally, measurement of resistivity is a measure of water saturation and connectivity of the pore space of rock bodies [2].
A total of 10 VES were conducted in five different locations (2 VES per location) using the schlumberger configuration with a maximum current spread of 120m (fig 1, Table 1). The schlumberger technique was used because is easier, effective, more economic and most appropriate in sedimentary environment. An Omega Terrameter was used to obtain the Resistance (the earth response) at each VES point which was later used to compute the apparent resistivity(Table3-12). The apparent resistivity was in turn used as an input data in a computer iteration inversion program to give the true resistivity, depth and thickness of the layers. (fig 4 - 5).

Table1: showing location and coordinates of VES points in the study area.

Location	Latitude	Longitude	Elevation (m)	VES number
JFK field (refineryroad)	N 05◦ 34’ 03.2”	E 005◦ 45’ 39.8”	6	1
	N 05◦ 34’ 03.8”	E 005◦ 45’ 46.6”	6	2
Okugbe Primary school(Ekpan)	N 05◦ 33’ 41.9”	E 005◦ 44’ 39.8”	5	3
	N 05◦ 33’ 41.1”	E 005◦ 44’ 46.3”	5	4
College of Education(Ugboroke)	N 05◦ 32’ 34.3”	E 005◦ 44’ 34.9”	3	5
	N 05◦ 32’ 34.8”	E 005◦ 44’ 35.5”	4	6
Urhoboh college (Effurun)	N 05◦ 31’ 59.9”	E 005◦ 46’ 43.9”	7	7
	N 05◦ 31’ 59.0”	E 005◦ 46’ 43.8”	8	8
Federal University of petroleum resources (Ugbomron)	N 05◦ 34’ 14.0”	E 005◦ 50’ 31.4”	9	9
	N 05◦ 34’ 07.9”	E 005◦ 50’ 23.3”	10	10

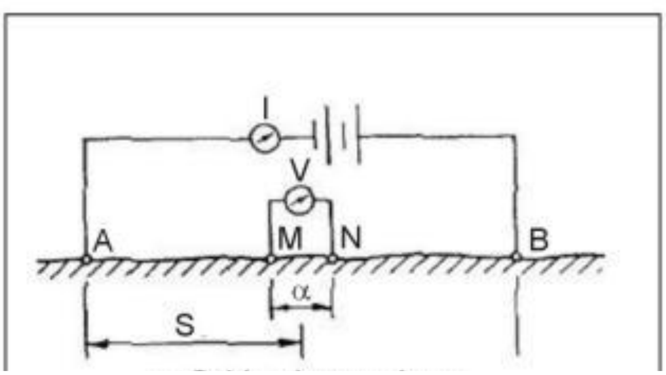


Fig 1. showing the schlumber array

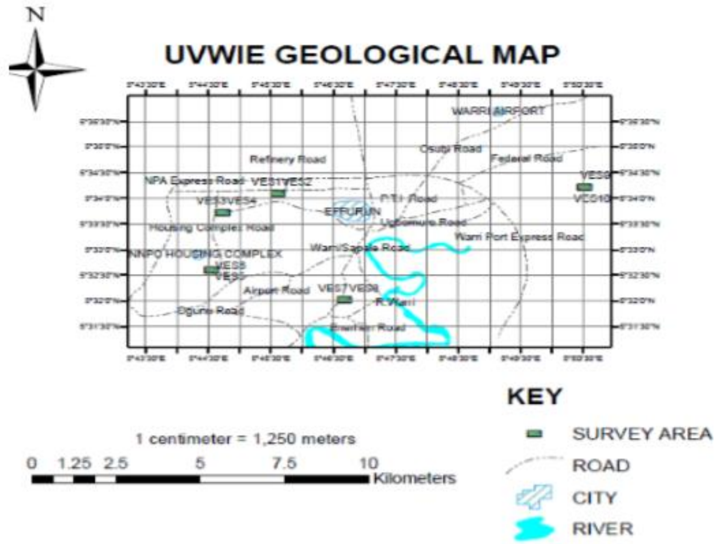


Fig 2. Location map of the study area, showing VES locations.

The data obtained from the resistivity survey was interpreted quantitatively by computer iteration software based on the work of Vander Velpen [6] to obtain the true resistivity, depth and thickness of the layers delineated. These first order geoelectric parameters (resistivity and thickness) were used to derive the total longitudinal unit conductance (Lc), which is a second order geoelectric parameter or the Dar Zarrouk parameter [4], as shown by the equation below.

$$\mathbf{Lc} = \frac{h}{\rho} \text{---------------- (4)[5]}$$

Hence the overburden protective capacity, which is the core factor of the underlain aquifer vulnerability, was evaluated using the total longitudinal unit conductance in the equation, [7]. The Longitudinal unit conductance (mhos)/protective capacity rating as modified by Olusegun, [8], was used to rate the aquifer vulnerability (Table 2).

Table2: Showing Aquifer protective Capacity rating [8].

Rating	**Remark**
Greater than 10	Excellent
5 – 10	Very good
0.2 – 4.9	Moderate
0.1 – 0.19	Weak
Less than 0.1	Poor

2.1 GEOELECTRIC PROPERTIES OBTAINED AND COMPUTED IN THE STUDY AREA

Table3: Acquired and computed data for VES 1.

AB/2	RESISTANCE	APPRERENT RESISTIVITY
1	798.6	2509.2
1.5	315.8	2231.92
2	167.5	2105.14
2.5	100.3	1969.64
3	66.41	1877.942
5	17.66	1387.193
8	4.72	949.14
11	1.939	737.173
14	1.137	700.20
18	593.0	603.68
18	1.411	718.21
22	844.8	642.36
26	588.9	625.41
26	1.147	609.06
30	881.4	623.11
35	693.5	667.312
35	988.0	633.79
40	775.8	650.02
45	629.6	667.644
50	412.2	539.64
55	3354.4	561.40
60	282.3	532.192

Table 4: Acquired and computed data for VES 2.

AB/2	RESISTANCE	APPRERENT RESISTIVITY
1	818.7	2572.36
1.5	301.7	2132.87
2	174.6	2194.37
2.5	104.5	2052.12
3	66.51	1880.77
5	17.66	1387.19
8	4.458	896.45
11	1.838	698.78
14	1.035	637.39
18	567.6	577.82
18	1.198	609.79
22	864.1	657.031
26	569.6	604.913
26	1.188	630.8
30	1.008	712.61
35	789.0	759.21
35	1.136	728.74
40	771.7	646.582
45	602.1	638.482
50	226.4	296.40
55	385.8	611.143
60	249.8	470.923

Table5: Acquired and computed data for VES 3

AB/2	RESISTANCE	APPRERENT RESISTIVITY
1	219.3	689.04
1.5	81.95	579.35
2	38.69	486.26
2.5	19.70	386.86
3	10.96	309.93
5	2.213	428.74
8	467.1	454.11
11	228.4	451.74
14	122.8	448.00
18	49.75	439.68
18	245.4	464.43
22	107.6	450.07
26	58.69	443.57
26	95.35	439.67
30	100.3	446.43
35	37.917	434.98
35	243.4	474.84
40	20.31	428.61
45	18.88	429.47
50	23.05	432.86

Table 6: Acquired and computed data for VES 4

AB/2	RESISTANCE	APPRERENT RESISTIVITY
1	279.6	878.50
1.5	122.8	868.13
2	59.30	745.28
2.5	31.88	626.04
3	19.29	545.48
5	4.234	693.07
8	850.9	639.25
11	301.6	620.43
14	138.1	610.56
18	80.93	609.67
18	35.74	642.83
22	36.72	604.19
26	56.76	602.30
26	105.6	600.90
30	87.73	602.88
35	55.04	599.86
35	89.77	601.41
40	33.611	591.60
45	28.84	592.40

Table7: Acquired and computed data for VES 5

AB/2	RESISTANCE	APPRERENT RESISTIVITY
1	184.8	580.642
1.5	69.86	493.74
2	39.90	501.46
2.5	25.69	504.487
3	18.17	513.81
5	7.240	568.702
8	2.843	571.69
11	1.472	559.28
14	919.0	565.95
18	634.6	646.03
18	1.086	552.78
22	645.7	491.04
26	502.6	533.76
26	1.011	536.84
30	837.7	592.21
35	580.6	558.68
35	935.3	599.99
40	671.2	562.38
45	561.1	595.005
50	435.6	570.27
55	328.0	519.56
60	297.5	560.85

Table 8:Acquired and computed data for VES 6

AB/2	RESISTANCE	APPRERENT RESISTIVITY
1	136.0	427.31
1.5	73.62	520.31
2	29.85	375.16
2.5	32.49	638.02
3	15.02	424.74
5	6.346	498.48
8	2.914	585.97
11	1.746	663.80
14	1.066	656.48
18	550.4	560.312
18	1.127	573.65
22	725.0	551.26
26	594.0	630.83
26	1.136	603.214
30	921.3	651.31
35	703.7	677.13
35	1.740	687.833
40	865.9	725.51
45	5.920	6277.76
50	4.747	6214.62

Table9: Acquired and computed data for VES 7

AB/2	RESISTANCE	APPRERENT RESISTIVITY
1	86.01	270.24
1.5	44.78	316.48
2	26.40	331.79
2.5	17.66	346.80
3	12.69	358.85
5	4.915	385.07
8	2.619	526.65
11	1.655	629.20
14	1.096	6774.95
18	613.3	684.34
18	1.309	666.29
22	806.3	613.08
26	541.2	574.75
26	1.106	587.28
30	827.6	585.07
35	601.1	578.40
35	920.0	590.17
40	676.3	566.65
45	516.8	548.03
50	415.3	543.70
55	302.6	478.74
60	240.6	453.58

Table 10:Acquired and computed data for VES 8

AB/2	RESISTANCE	APPRERENT RESISTIVITY
1	62.15	195.28
1.5	28.84	203.88
2	18.88	237.28
2.5	14.01	274.93
3	11.17	315.87
5	6.021	472.95
8	2.650	532.88
11	1.624	617.42
14	1.025	631.23
18	630.6	641.96
18	1.370	697.3
22	843.8	641.60
26	599.1	636.24
26	1.137	603.74
30	885.5	626.664
35	671.2	511.61
35	977.9	627.32
40	681.4	570.92
45	500.6	530.85
50	364.5	477.19
55	289.4	458.44
60	216.3	407.77

Table11: Acquired and computed data for VES 9

AB/2	RESISTANCE	APPRERENT RESISTIVITY
1	127.900	401.810
2	37.370	469.605
3	18.170	513.745
5	6.8240	535.956
8	2.9440	591.726
11	1.736	659.910
14	1.188	731.514
18	733.1	746.205
18	1.502	764.425
22	1.066	810.443
26	777.8	825.913
26	1.706	905.765
30	1.132	800.164
35	909.8	875.330
35	1.401	898.615
40	1.066	893.051
45	785.9	833.280
45	1.000	795.216
50	912.9	896.237
55	568.6	675.448

Table 12:Acquired and computed data for VES 10

AB/2	RESISTANCE	APPRERENT RESISTIVITY
1	257.40	808.646
2	75.750	951.903
3	42.340	1197.137
5	19.490	1530.741
8	8.895	1788.446
11	4.915	1868.352
14	2.416	1487.657
18	1.401	1426.044
18	3.198	1627.584
22	1.949	1481.757
26	1.238	1314.581
26	737.1	1034.982
30	1.736	1227.106
30	1.309	1257.406
35	925.1	1162.515
40	1.106	1111.872
45	862.1	1096.889
45	995.1	1055.092
50	757.5	991.573

3.0 RESULT AND DISCUSSION

The study area lie within the sombriero Warri deltaic plain deposit characterized with mangrove forest. The curve types are QHK for VES1 and VES2 in JFK field of refinery road, AK and QQ for VES 3 and 4 in Okugbe primary school ground of Ekpan, AKQ and KQH for VES (5 and 6) in College of education, KQ and AK for VES (7 and 8) in Urhobo college ground of Effurun, and QH, KH for VES (9 and 10) in Federal university of petroleum resources ground at Ugbomro.

The geoelectric section revealed 4 – 5 delineated layers in the study area. VES1 has 5 layers of loamy top soil with resistivity 2652.7Ωm and 1.1m thick. This was underlain with a 3.1m thick lateritic sand layer of resistivity 1319.3Ωm followed by a 6.5m thick clay layer of resistivity 518.1Ωm. This layer is impermeable and gives a confinement but poor protection of 0.013 to the underlying aquiferous coarsive sand bed of 731.4Ωm at a depth of 18.9m. This aquiferous layer overlain a clayey layer of infinite depth and thickness.
VES2 show a trend similar to VES1, with a confined sand bed (aquifer) of resistivity 1401.1 Ωm at 18.1m depth. This aquiferous layer is overlain with an aquitard (clay) of resistivity 392.5 Ωm ,5.6m thick, and poor aquifer protection of 0.0 14.

Table 13:Table of Results in the study area

S/N	Layers	Resistivity(ρ)(Ωm)	Thickness(h) (m)	Depth (m)	h/ρ	Curve type	Probable lithology
VES1	I	2652.7	1.1	1.1	0.00041	P1>p2>p3<p4<p5	Top soil
	II	1319.3	3.1	4.2	0.0023	QHK	Lateritic sand
	III	518.1	6.5	10.7	0.013		clay
	IV	731.4	8.2	18.9			sand
	V	533.8					clay
VES 2	I	2481.7	1.3	1.3	0.00052	P1>p2>p3<p4<p5 QHK	Top soil
	II	1593.1	2.1	3.4	0.0013		Lateritic sand
	III	392.5	5.6	9.0	0.014		Clay
	IV	1401.1	9.2	18.1			Sand
	V	231.2					Shale
VES 3	I	947.5	0.6	0.6	0.00063	P1>p2<p3>p4>p5 AK	Top soil
	II	281.4	1.7	2.3	0.0060		Clay
	III	497.3	17.7	20.0			Sand
	IV	351.4					Clay
VES 4	I	1076.1	0.6	0.6	0.00043	P1>p2>p3<p4>p5 QQQ	Top soil
	II	548.1	2.3	3.0	0.0017		Clay
	III	680.2	8.2	11.1			sand
	IV	520.8	11.3	22.5			Clay
	V	604.0					Fine sand
VES 5	I	522.1	0.7	0.7	0.0013	P1<p2<p3>p4>p5 AKQ	Top soil
	II	535.0	5.1	5.8	0.0095		Clay
	III	586.1	11.9	17.7	0.02		Clayey sand
	IV	598.2	23.3	41.0			Sand
	V	534.9					Clay
VES 6	I	405.1	0.9	0.9	0.0022	P1<p2<p3<p4>p5 KQH	Top soil
	II	622.2	5.9	6.8	0.0095		Lateritic sand
	III	386.7	7.3	14.1	0.019		Shale
	IV	807.6	8.2	22.3	0.011		Sand
	V	4548.6					sand
VES 7	I	277.8	1.6	1.6	0.0057	P1<p2>p3>p4>p5 KQQ	Top soil
	II	726.6	11.1	12.7	0.015		Lateritic Sand
	III	663.6	5.2	18.0	0.0078		Coarsive Sand
	IV	571.2	5.9	23.8	0.010		Fine Sand
	V	316.8					clay
VES 8	I	150.8	0.8	0.8	0.0053	P1<p2>p3>p4<p5 AKH	Top soil
	II	641.3	2.8	3.6	0.0044		Sandy clay
	III	842.6	12.0	15.6	0.014		Sand
	IV	326.0	22.6	38.2	0.069		Clay
	V	327.1					Clay
VES 9	I	388.2	1.0	1.0	0.0026	P1>p2>p3<p4>p4 QHQ	Top soil
	II	617.0	7.4	8.3	0.012		Clay
	III	1497.0	5.5	13.9	0.0037		Sand
	IV	1046.7	9.9	23.9	0.0095		Sand
	V	528.8					clay
VES 10	I	680.7	0.9	0.9	0.0013	P1<p2>p3<p4>p5 KHK	Top soil
	II	2147.3	6.8	7.7	0.0032		Sand
	III	957.3	7.7	15.4	0.008		clay
	IV	1031.4	5.9	21.3			Sand
	V	857.5					clay

VES3 and VES 4 showed vulnerable and shallow aquifer sand beds depth of 20.0m and 11.1m with lithology ranging from loamy top soil,lateritic sand to very fine sand and clay.These aquifers of VES3 and VES4 of Ekpan area, enjoy a relatively poorer respective protection 0.006 and 0.0017 from their overlying layers, VES5 of the Ugboroke area showed an aquiferous layer of 598.2Ωm at 41.0m deep with overlaying aquitard of cumulative protection of 0.0295.VES 6 showed a potential aquifer bed of coarsive sand bed at a depth of 22.3m underlying 7.7m thick aquitard at a depth of 14.4m which gives a protection of 0.019. The lithology from top to bottom are loamy top soil, lateritic sand clay, sand and fresh basement.

VES7 of Urhobo college ground of Effurun area showed a coarsive sand bed of 663.6Ωm at a subsurface depth of 18.0m underlying protective layer of 0.014 capacity.

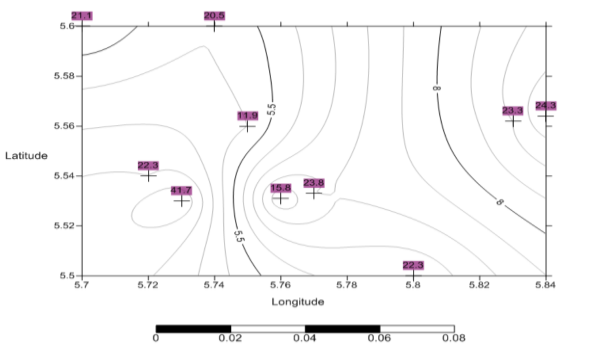
VES8 also of Urhobo college ground of Effurun area showed similar trend to VES7, with aquiferous sand bed of 842.6Ωm at shallower depth of 15.0m underlying a protective layer of 0.014 capacity.

VES 9 and 10 showed confined aquifer beds of 1046.7Ωm and 1031.4Ωm at respective depth of 23.9m and21.3m underlying protective layers of 0.0095 and 0.0032 respective protection capacity.

Clearly from the table of result, the aquifer at a subsurface depth of 41.0m of VES5 of college of education of Ugboroke area, enjoy the highest protection of 0.02 capacity from the overlain protective layer.

However the aquifers in the study area may be vulnerable to contamination over a period of residential time. The protecting overburden impermeable layers (aquitard) are not thick enough. Usually, aquifers are protected by overburden impermeable geologic barriers with enough thickness to offer sufficient protection to the aquifer from percolating fluid [2]. Very fine sand and clay are suitable protective layers and when they are thick enough and overly an aquifer bed, they form a protective cover [8]. This is however not the case with the study area.

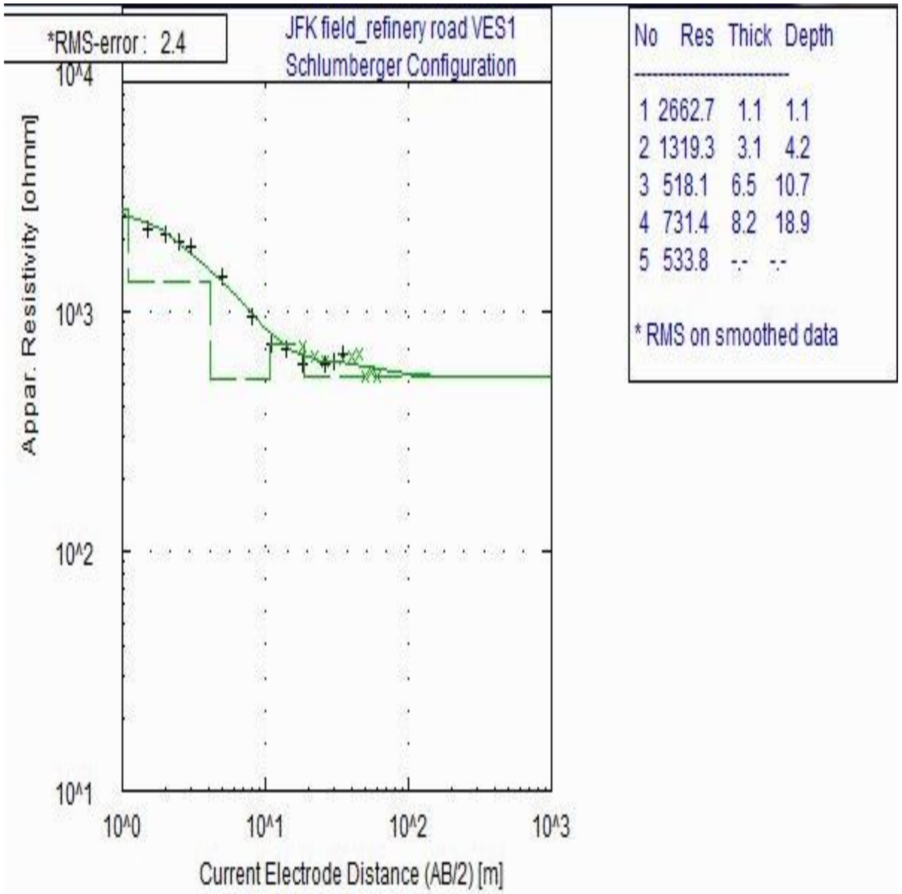
A map of the aquifer depth of the study area was created using the SURFER12 software (fig 3).



KEY

■	Aquifer depth
+	VES point

Fig 3: Map showing Aquifer depths at VES points of the area.


*RMS-error : 2.4
JFK field_refinery road VES1
Schlumberger Configuration
No Res Thick Depth
1 2662.7 1.1 1.1
2 1319.3 3.1 4.2
3 518.1 6.5 10.7
4 731.4 8.2 18.9
5 533.8 -.- -.-
* RMS on smoothed data
Appar. Resistivity [ohmm]
10^4
10^3
10^2
10^1
10^0
10^1
10^2
10^3
Current Electrode Distance (AB/2) [m]

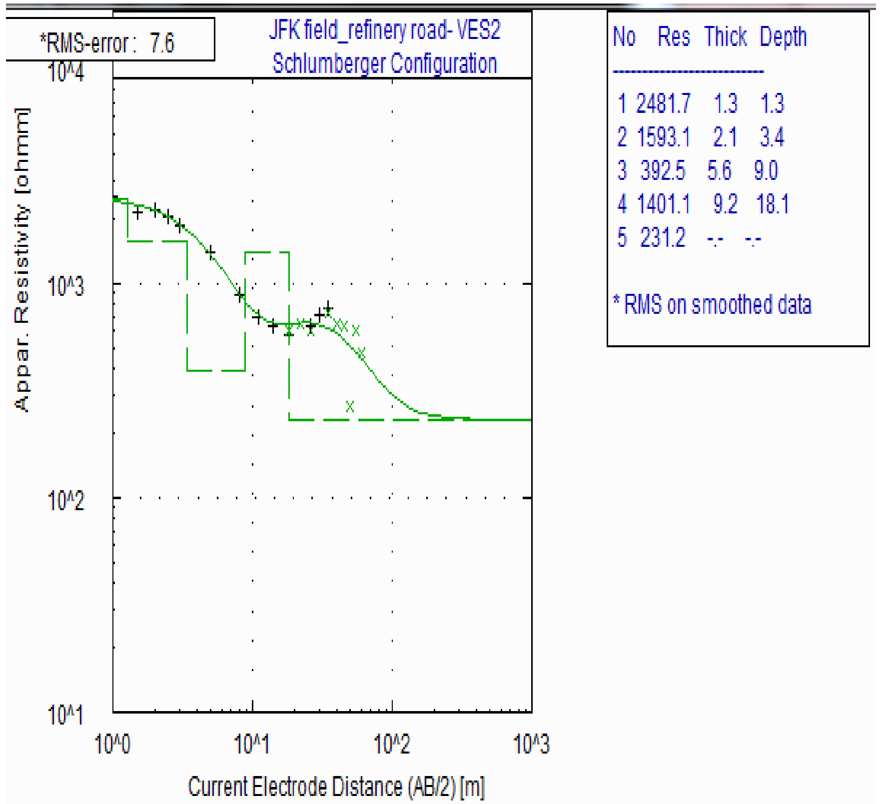
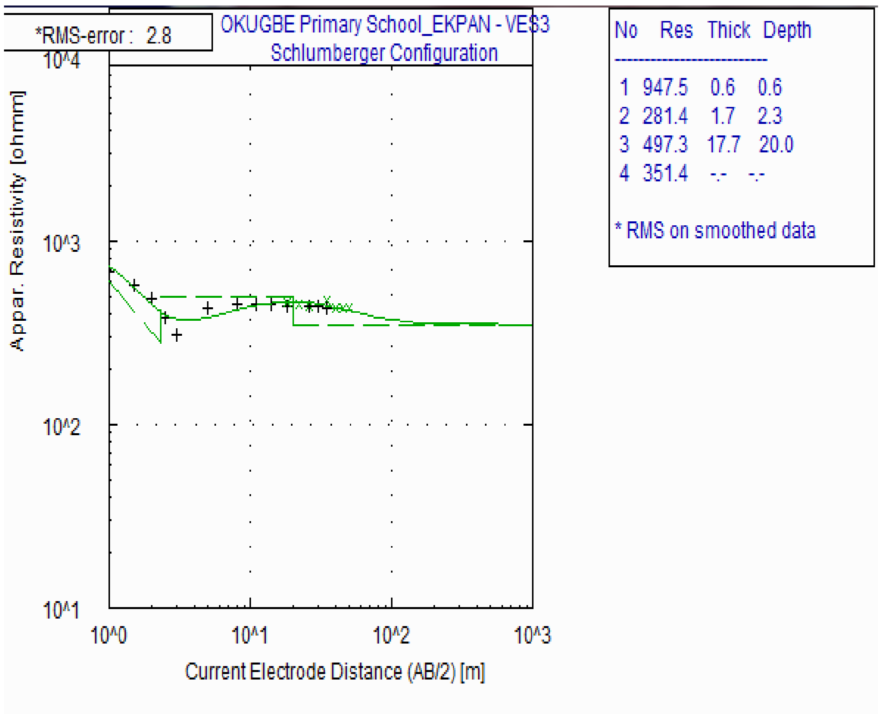

*RMS-error : 7.6
JFK field_refinery road- VES2
Schlumberger Configuration
No Res Thick Depth
1 2481.7 1.3 1.3
2 1593.1 2.1 3.4
3 392.5 5.6 9.0
4 1401.1 9.2 18.1
5 231.2 -.- -.-
* RMS on smoothed data
Appar. Resistivity [ohmm]
10^4
10^3
10^2
10^1
10^0
10^1
10^2
10^3
Current Electrode Distance (AB/2) [m]

Fig. 4a



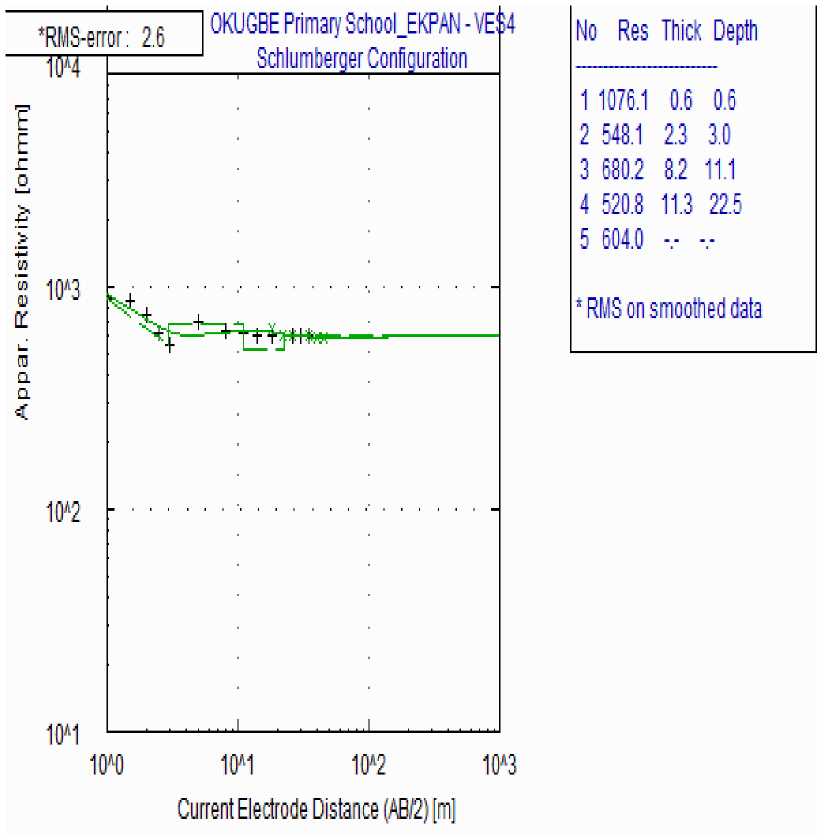


Fig 4b. Resistivity interpretation resulting from the display of WinResist iteration program VES1, VES2, VES3 and VES4

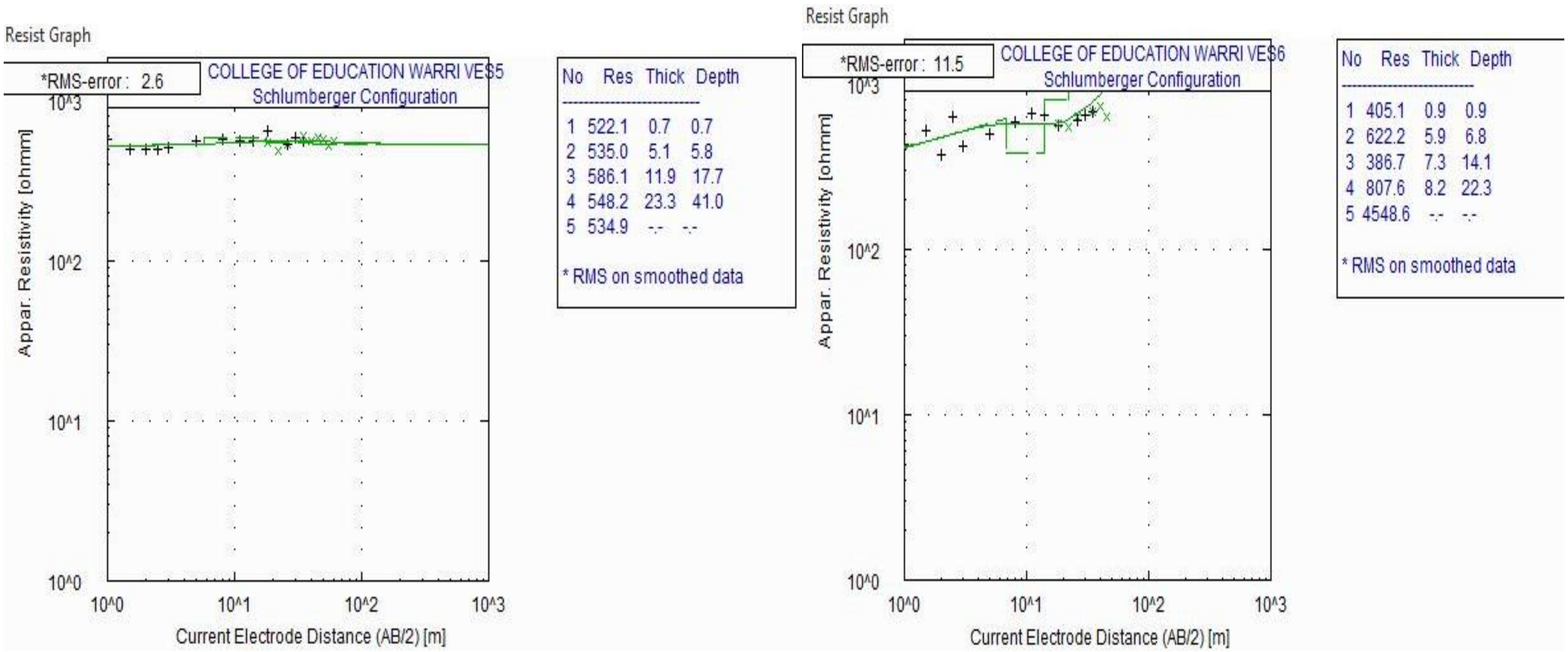

Resist Graph
*RMS-error : 2.6
COLLEGE OF EDUCATION WARRI VES5
Schlumberger Configuration
Appar. Resistivity [ohmm]
Current Electrode Distance (AB/2) [m]
No Res Thick Depth
1 522.1 0.7 0.7
2 535.0 5.1 5.8
3 586.1 11.9 17.7
4 548.2 23.3 41.0
5 534.9 -.- -.-
* RMS on smoothed data
Resist Graph
*RMS-error : 11.5
COLLEGE OF EDUCATION WARRI VES6
Schlumberger Configuration
Appar. Resistivity [ohmm]
Current Electrode Distance (AB/2) [m]
No Res Thick Depth
1 405.1 0.9 0.9
2 622.2 5.9 6.8
3 386.7 7.3 14.1
4 807.6 8.2 22.3
5 4548.6 -.- -.-
* RMS on smoothed data

Fig. 4c

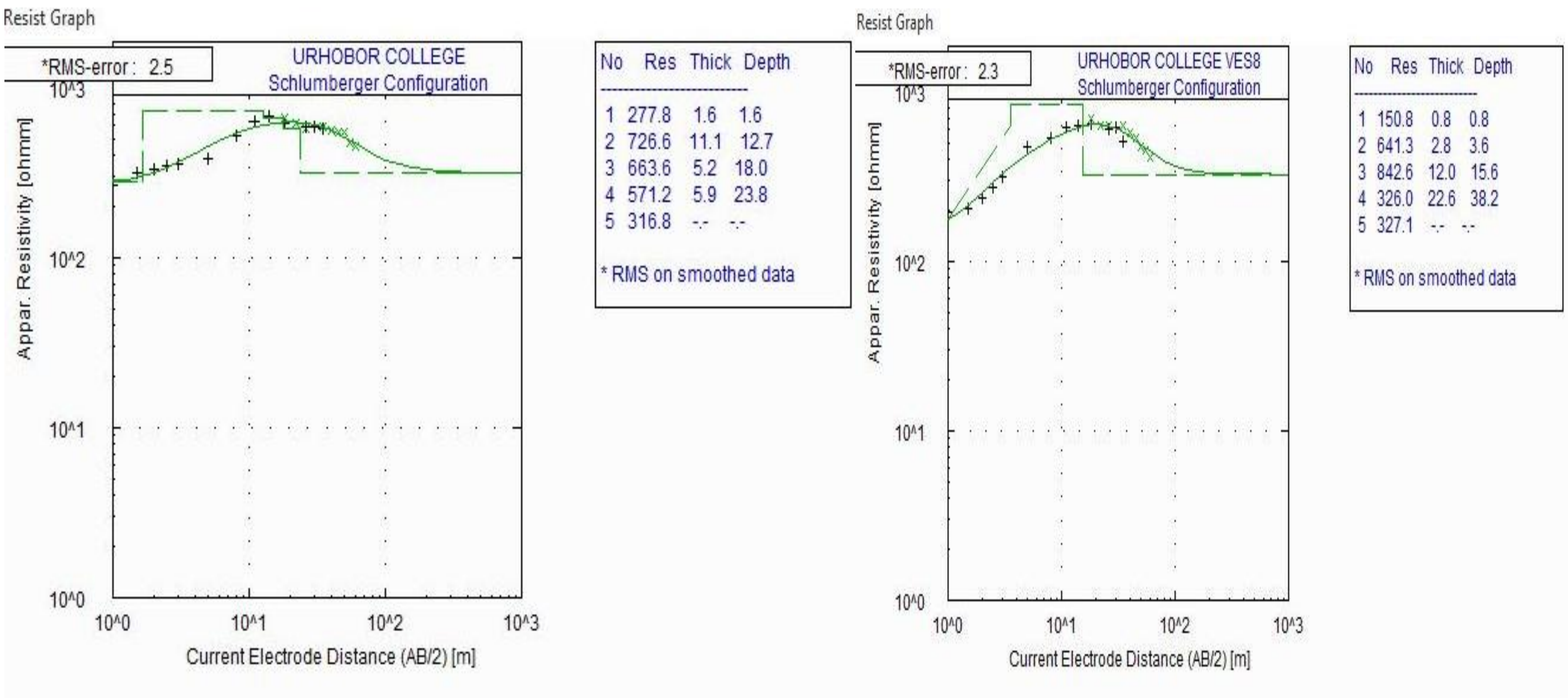

Resist Graph
*RMS-error : 2.5
URHOBOR COLLEGE
Schlumberger Configuration
Appar. Resistivity [ohmm]
10^3
10^2
10^1
10^0
10^0 10^1 10^2 10^3
Current Electrode Distance (AB/2) [m]
No Res Thick Depth
1 277.8 1.6 1.6
2 726.6 11.1 12.7
3 663.6 5.2 18.0
4 571.2 5.9 23.8
5 316.8 -.- -.-
* RMS on smoothed data
Resist Graph
*RMS-error : 2.3
URHOBOR COLLEGE VES8
Schlumberger Configuration
Appar. Resistivity [ohmm]
10^3
10^2
10^1
10^0
10^0 10^1 10^2 10^3
Current Electrode Distance (AB/2) [m]
No Res Thick Depth
1 150.8 0.8 0.8
2 641.3 2.8 3.6
3 842.6 12.0 15.6
4 326.0 22.6 38.2
5 327.1 -.- -.-
* RMS on smoothed data

Fig. 4d

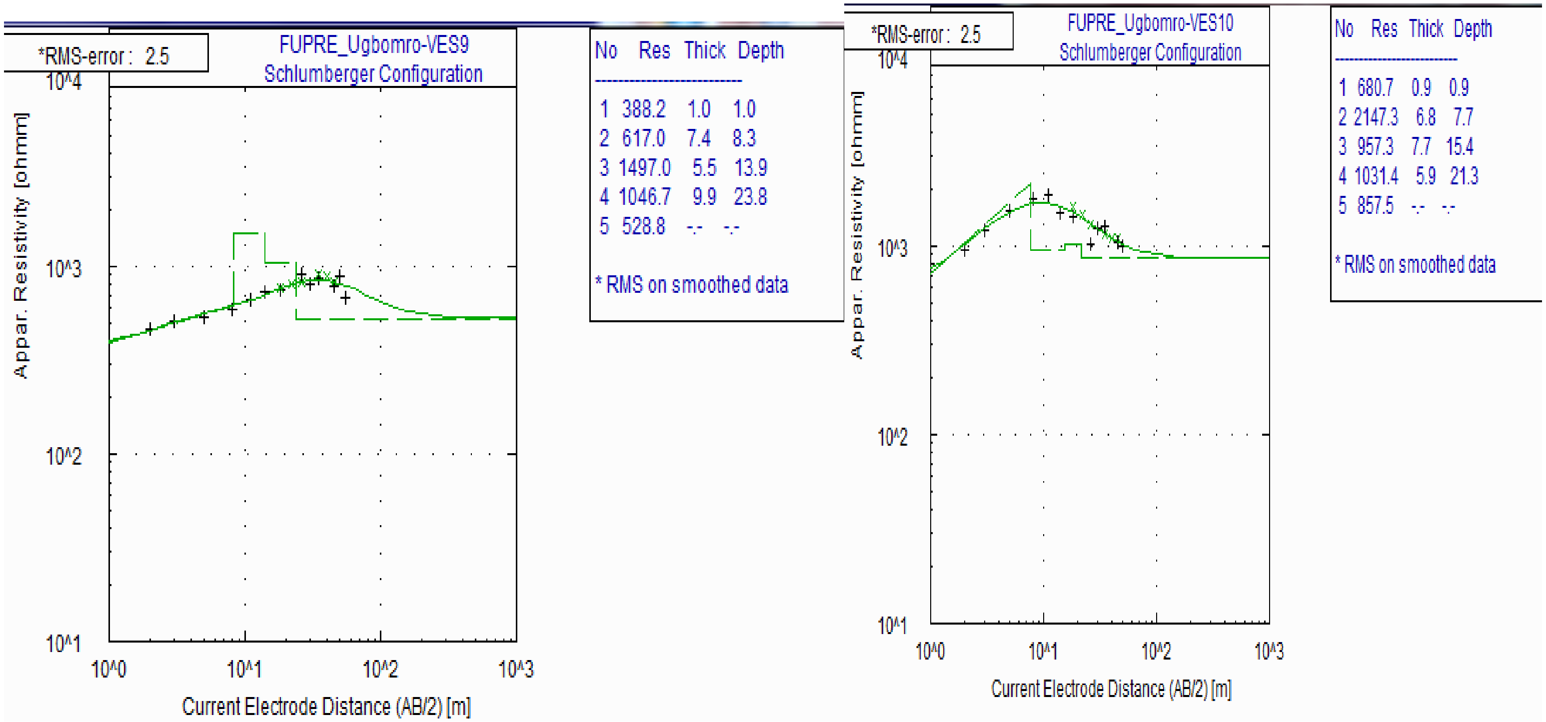


Fig 5.Resistivity interpretation resulting from the display of WinResist iteration programVES5, VES6,VES7, VES8, VES9 and VES10

4.0 CONCLUSION

Five locations in Uvwie Local Government Area were investigated for ground water potentials. A total of 10 VES data set were acquired using the schlumberger configuration. Results from analyzed acquired data from the study area showed that the aquifers in the study area are shallow. It also showed good potentials for ground water exploration, especially with VES1, VES2 in refinery road area, VES4 in Ekpan area, VES5 in Ugboroke area, VES9 and VES 10 in FUPRE, as the aquifers at these VES points are confined by impermeable overlying rock bodies (clay).

While all the aquifers in the study area are poorly protected due to the low thickness of overlying aquitards, the aquifers in Ugboroke, refinery road and Ugbomro area have relatively good protection in an increasing order, in the study area. However, it is therefore strongly recommended that ground water development should consider good water treatment measures to make it safer for domestic consumption

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