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Geoelectric investigation for mapping subsurface groundwater potential in Umutu and environs in delta state, Nigeria

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ABSTRACT

Eighteen Vertical Electrical Sounding (VES) using Schlumberger configuration with a maximum current electrode separation varying from 200m to 650m were carried out at Umutu and environs in Delta State Nigeria. The aim of survey was to determine the underlying lithology, determination of area of corrosive groundwater as well as computing the transmissivity of the aquifer in the area to determine the best location for sitting borehole of high quality in terms of high output. The results have shown that VES 7 has the lowest corrosive groundwater and highest aquifer transmissivity value of 357.0m^2/day. With the computation of aquifer transmissivity value resulting from the values obtained it becomes possible to demarcate regions of high groundwater in the area.

Introduction

Groundwater is water in porous rocks beneath the surface of the earth within saturated zones where the hydrostatic pressure is equal to or greater than atmospheric pressure. It has been observed that a good deal of rainfall runs off over the surface of the ground in rills and streams. Finally, some part of it sinks underground and becomes the groundwater responsible for springs, caves and wells (Egbai, 2011).

In Nigeria, groundwater form a significant part of the water considering the fact that very large tropical rainfall occurs in about 55% of the country of relatively permeable rock formations that do transmit and store large quantities of water (Offodile, 1992).

Factors such as low capital cost required for the development of groundwater resources, convenient availability "close" to where water is needed and its natural quality (adequate for portable needs with little or no treatment) are influencing many developed and developing nations, in changing to subsurface source of water, for both domestic and industrial purposes (Tods, 1980).

In Nigeria, access to portable water supplies (Government sources) in major cities across the country has been ever-increasingly difficult. More than 70% of the population lack access to improved water sources (Abdulirafiu et al; 2011), hence, population would only but rely on hand dug shallow wells and some few boreholes (deep wells) with motorized pump. Since, the area is developing and human habitation is springing up, the study is aimed at providing good portable water for human and industrial use, hence knowing the best possible location for sinking borehole in order to access the quantity and quality of groundwater supply will be an added advantage.

The provision of water for domestic and other uses in rural and urban centres is one of the most intractable problems in Nigeria today. Access to adequate water of good quality is essential to health, food production and sustainable development (Oliver and Ismalia, 2011).

Every human use of water, whether for drinking, irrigation, and industrial processes or for recreation has some quality requirements in order to make it acceptable. This quality criterion can be described in terms of physical, chemical and biological properties of such water.

The increasing industrial development in Umutu, umuaja and environs has led to the demand for portable water to cater for the need of the people which has prompted the present search for favourable subsurface ground water potential zones in the area. A few boreholes were drilled in different places in the areas, and some of them have become abortive because of lack of poor systematic scientific investigation.

The aims of the study are to ascertain the general water level of Umutu, Umuaja and environs using vertical electrical soundings (VES), to determine the corrosiveness of the groundwater in the area. This research will provide a useful tool on the possible sites for subsurface groundwater boreholes for sustainable water development and supply which will supplement the unproductive borehole from government. In this work, VES soundings were used for the estimation of transmissivity of the aquifer in the areas surveyed. This is a measure of how much water can be transmitted horizontally, such as to a pumping well. Applying average hydraulic conductivity of 10m/d (MWT1974) for the existing boreholes in the areas, the transmissivities are estimated from the relationship established by Niwas and Singhal (1981).

$$T_r = K\delta R \frac{KL}{\delta}$$

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where T_r is transmissivity, K is the hydraulic conductivity, δ is the electrical conductivity, R is the transverse resistance and L the longitudinal conductance.

The electrical resistivity method could be considered one of the most useful geophysical methods employed in groundwater exploration in the Basement Complex area (Olurunfemi and Fasuyi, 1993; Ako and Olurunfemi,1989). This is so because of the usually pronounced resistivity contrast between the weathered and or fractured zone, which is commonly the zone of saturation and the fresh bedrock (Casmir,2006). The method has also proved to be quick, economic and effective means of solving groundwater problems in different regions of the country (Ekine and Osobonye,1996; Mbipom et al., 1996; Mbonu et all,1991).

Geomorphology, geology and hydrogeology of the area

River Ethiope took its source from Umuaja a town in Ukwani Local Government Area of Delta State. Umutu is the closest town to Umuaja the river spreads through major towns flowing through Obiaruku, Abraka, Sapele and empties its waster into the Atlantic Ocean.

This area of Delta state enjoys heavy rainfall during the rainy season. Some parts get flooded during the rainy season and then remain dry during summer (Akpokodye and Eru-Efeotor, 1987).

The source of River Ethiope is generally in an upland region, where precipitation is heaviest and where these is a slope down from which the run-off can flow, with the fact that shows a dendritic drainage pattern (Goncheng, 1992). The area is made of a relatively flat terrain which is low and average land rising on the average of 26.80m elevation (Lagos datum) on the land and about 19.0m towards river Ethiope. It experiences the equatorial hot and wet climate with almost uniform temperature throughout the year. The relative humidity is consistently high, about 85% and annual rainfall ranges from 25.4mm to 457.2mm.

The communities obtain water for domestic use from the Ethiope River about 500m to 2km from the towns depending on the location. They practice subsistence farming.

The Niger Delta consists of three main tertiary stratigraphic units overlain by quaternary deposit (Short and Stauble, 1967).

The base is the Akata Formation comprising mainly of marine shales and sand beds. The Agbada formation is the intermediate parallel square consisting of interbedded sand and shale. The Benin formation is comprise of fluviatile gravels and sands. Agbada and Benin formations sediments were deposited during the late tertiary – early quaternary period (Mbonu et al, 1991). The major source of groundwater in the area is from rainfall which is drained into nearby River Ethiope and swamps.

Location

The study areas Umutu and Environs are in Ukwani Local Government Area (L.G.A) of Delta State. The area lies within latitude 5^0 40'N and 5^0 56'N and between longitude 6^0 12'E and 6^0 14'E. It covers a total area of about 250km^2. It is surrounded by some neighbouring villages and towns like Obi – Obite, Egedei, Obiaruku, Obinomba etc. This is shown in Figure 1.

The VES locations are:

Location 1: Obeti Primary School VES 1
Location 2: Obeti Secondary School VES 2
Location 3: Umuaja 50m from River Ethiope VES 3
Location 4: Source of River Ethiope Umuaja VES 4
Location 5: Opposite Street Umutu near River Ethiope Umuaja VES 5
Location 6: Imala Street Umutu near River Ethiope VES 6
Location 7: Imala Street Umutu 1km away from R.Ethiope VES 7
Location 8: Market Square Ebedei VES 8
Location 9: New Agbor – Sapele Road Ebedei VES 9
Location 10: New Agbor – Sapele Road Obinomba VES 10
Location 11: Old Agbor – Sapele Road Obinomba VES 11
Location 12: Amai Road Obiaruku VES 12
Location 13: Wire Road Obiaruku VES 13
Location 14: Ghana Quarter Obiaruku VES 14
Location 15: Opposite the secretariat VES 15
Location 16: Michelin Road Umutu VES 16
Location 17: Obinomba Grammer School Obinomba VES 17
Location 18: Ebedei Primary School, Ebedei VES 18

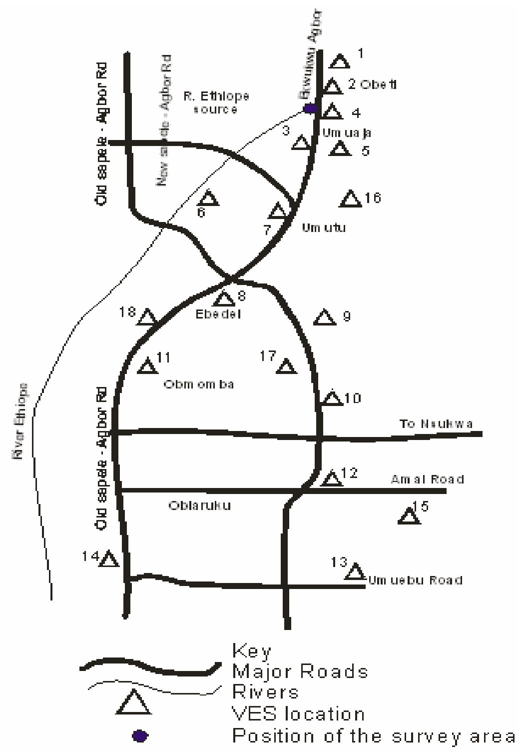

Fig 1: Map of the study Area showing VES locations

Analysis

The instruments used for the survey are cables, steel electrodes, D.C. battery, hammers, GPS, measuring tape, Umbrella, rain boots ABEM SAS 1000 Terrameter with an inbuilt booster which helps in injecting more current for greater depth penetration.

The Schlumberger electrode configuration was utilized for the purpose of data acquisition. A total of 18 vertical electrical soundings were carried out with the total maximum current spread varying from 200m to 650m within the area of survey.

The field survey in the Schlumberger electrode array system is to expand the current electrodes successively while the potential electrodes remain fixed. This process yields a rapidly decreasing potential difference across the potential electrodes which ultimately exceeds the measuring capabilities of the instrument (Egbai and Asokhai, 1998). At this point, a new value for the potential electrode separation is selected, typically 2 to 4 times larger than the proceeding value and survey is continued. The distance between the potential electrodes must never exceed 2/5 of AB/2 where AB is the current electrode distance, that is, CD ≤ AB/2 where CD is the potential electrode distance.

The data obtained from the various locations within the studied area were carefully recorded and smoothed. Quantitative analysis was carried out using the method of smoothing of raw data collected from the field by means of curve matching and curve fitting. The data obtained from the electrical resistivity survey were plotted on a leg – log graph paper with the electrode separation (AB/2) on the abscissa and apparent resistivity (ℓ) values as the ordinate. The thickness and resistivity values obtained from the partial curve matching were used for a quantitative computer iteration using the Resist Software Vander Velphen, 1998.

A summary of VES interpretation as well as results of the computation of the aquifer transmissivities for all the VES locations are as shown in Table I and II. Figures 3A to 3E show the VES curves.

The geoelectric section of the study area is equally shown in Table 1.

The corrosivity ratio propounded by Ryzner 1944 was used to evaluate the corrosive nature of the subsurface groundwater in the area of study. The ratio is of the form as:

$$\text{Corrosivity Ratio (CR)} = \frac{0.028CL + 0.021SO_4}{0.02(HCO_3 + CO_3)}$$

(measured in ppm)

This equation was applied in the determination of the corrosivity ratio of the area of study. Geochemical method was adopted where water samples were collected from the area of study and the major ion characteristics of water sample are analysed. Water samples were collected within the area of survey and analysed.

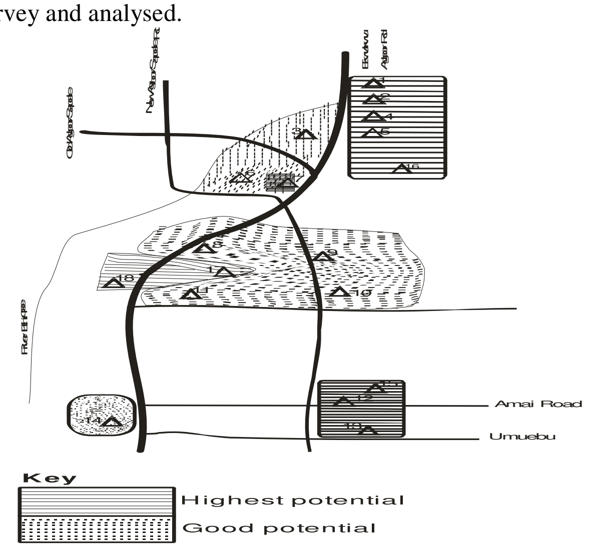

Fig 2: Map showing levels of groundwater potential in the study area

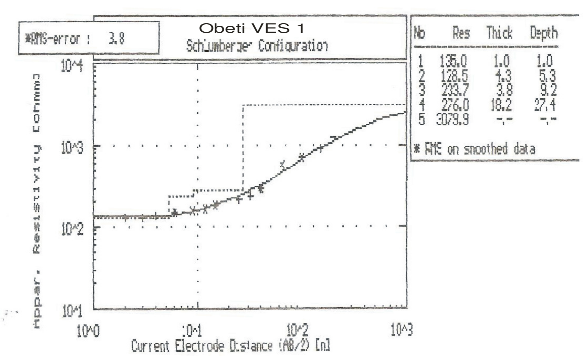

Figure 3A: VES 1 for Obeti

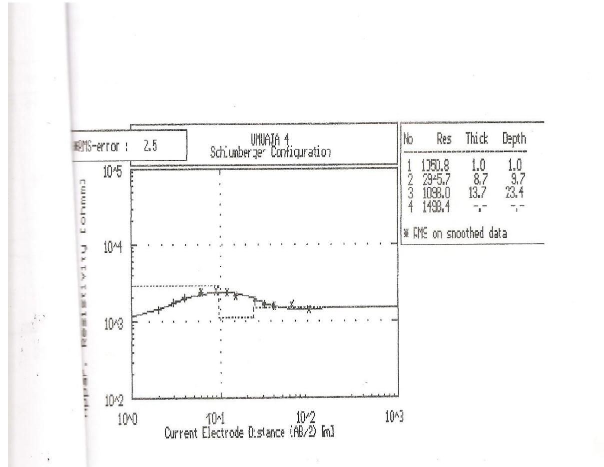

Figure 3B: Umuaja VES

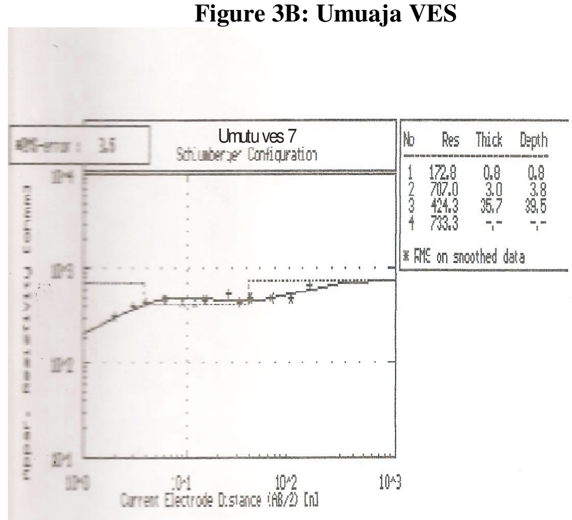

Figure 3C: Umutu VES 7

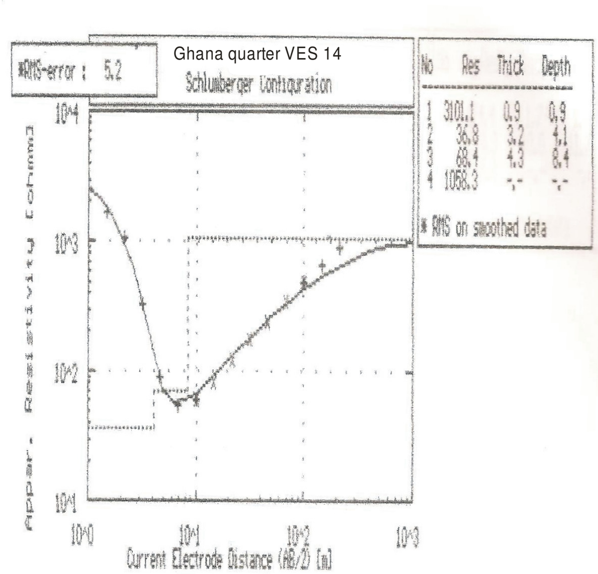

Figure 3D: Ghana Quarters VES 14

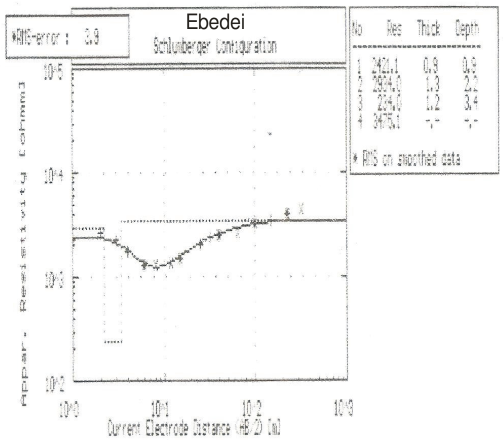

Figure 3E: Ebedei VES 9

Results And Discussion

Interpretation of the vertical electrical soundings (VES) suggests that there exist 3 to 5 layers underlie the surveyed areas. VES 6, 11 and 17 are of three layer earth, while VES 1, 3 and 15 are of 5 layer earth. The rest are 4 layer earth having the highest number. The VES curves were dominated by the KH type. Some of the typical field sounding curves are shown in Figure 3A to 3E.

The VES data shows that there is a topmost thin layer of thickness ranging from 0.9m to 1.7m and underlying this layer in most cases is the lateritic varying layer of thickness between 0.2m to 11.2m while underlying the topsoil is the fine smooth sand, coase sand or clay. Next to these layers are other associated layer which include white smooth sand, clay, silty sand and gravel of varying quantities and thickness in the area of VES.

The aquiferous layer lies in the fourth layer of VES 1, 3 and 15 of 5 – layer locations. The resistivities of the areas vary from 276.0 – 3529.5Ωm having thickness which ranges from 2.6 – 20.5m. In the 4 – layer locations, the aquiferous layer lies in the third layer with resistivities in the range of 68.4 – 3603.5Ωm and thickness within 1.3 – 35.7m. The only exception here is VES 8 having aquifer in the second layer with resistivity of 243.4Ωm and thickness 10.3m with RMS% error of 8.9. Similarly, VES 6, 11 and 17 have their aquifer in the second layer. The resistivities of these locations vary between 204.3 - 4000Ωm. The thickness of these aquiferous layer ranges between 4.0 – 11.8m. These areas are extensively sandy formation. The aquifer within these areas are unconfined.

The low resistivity recorded in VES 1, 2, 3, 7, 8, 9, 10, 11, 13, 14 and 16 of Obeti, 50m from River Ethiope, Umuaja and others show that the aquifer within these locations are highly contaminated due to gulley erosion. These areas are very close to River Ethiope and refuse brought from the hill top are deposited around here while some are dumped into the river. These refuse dump results in low resistivity of the aquifer and consequently resulting in high corrosive ground water (Egbai, 2011). Water samples collected from boreholes within these VES locations shows brownish colouration when exposed for about two to three days in a container. On the other hand, VES 4, 5, 6, 12, 15, 17 and 18 have high resistivities which vary from 1098 - 4000Ωm. These high resistivities result in very low corrosive groundwater and boreholes within these VES locations remain colourless when exposed for two to three days in a container.

The data in Table 2 show a summary of aquifer electrical properties for all VES stations. VES 1, 2, 4, 5, 7, 12, 13, 15, 16, 17 and 18 have very high transmissivity ranging from 118 – 357m^2/day while others have low transmissivity ranging from 13 – 103m^2/day. VES 7 has the highest transmissivity of 357m^2/day while VES 9 has the lowest transmissivity of 13m^2/day. The average transmissivity value of 153.055m^2/day was obtained for this area of research. This is good for sedimentary area close to River Ethiope. Based on the aquifer transmissivity values computed, the areas in Figure 2 have been demarcated as having good groundwater potential and as such any groundwater project in the area should be concentrated within these locations.

Conclusion

Eighteen Vertical Electrical Sounding (VES) were carried out in Umutu and environs in Delta State, Nigeria. The results reveal that Umutu and environs as an extensive sandy zone. The study have revealed three, four and five geoelectric layers namely topsoil, laterite, sand (Smooth to coarse), clay, clayey sand and gravel. The resistivity values obtained from the geoelectric section have enabled us to demarcate the zones of corrosive groundwater hence area of high corrosive values were identified. An average transmissivity value of 153.055m^2/day was obtained for the area studied with VES 7 (Imata Street Umutu, 1km away from River Ethiope) having the lowest corrosive groundwater and highest transmissivity value of 357m^2/day while VES 9 (New Agbor – Sapele Road, Ebedei) has the lowest transmissivity value of 13.0m^2/day. Hence, VES 7 has been demarcated as having the best groundwater potential and as such any groundwater project in the area should be concentrated more within this region.

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References

Abdulrafiu O.M; Adelek A; and Laleef, O.G; 2011, Adv. Applied Sc. Res. Vol 2(1), 289 – 298.

Ako, B.D and Olarunfemi, M.O; 1989, Geoelectric Survey for groundwater in the newer Basalts of Vom, Plateau State, Nigeria J. Mining. Geol. 25,142, 247 – 250

Akpokudje, E.E; 1987 The occurance and Economic potential of clean sand deposits of the Niger Delta. Journal of Africa. Earth Sc vol 6 p: 61 – 65

Casmir Akaolisa, 2006, Aquifer transmissivity and Basement Structure determination using resistivity sounding at Jos Plateau State Nigeria. Environmental Monitoring and Assessment Vol 114: 27 – 34

Egbai, J.C and Asokhai, M.B. 1998 correlation between Resistivity Survey and well logging in Delta State, Nigeria. J of NAMP, Vol.2 pp. 163 – 175

Egbai, J.C. 2011, Resistivity method: A tool for identification of Areas of Corrosive groundwater in Agbor, Delta State, Nigeria JE TE AS 2(2)

Ekine, A.S and Osobonye, G.T. 1996, Surface Geoelectric sounding for the determination of aquifer characteristics in parts of Bonny local government area, River State, Nigeria, Nig.J. Physics 85, 93 – 99.

Goncheng Leong, 1992, Certificate Physical and Human geography. University press, Ibadan, p 50 – 51.

Mbonu, P.D.C; Ebeniro, J.O, Ofoegbu, C.O. and Ekine, A.S, 1991, Geoelectric sounding for determination of aquifer characteristics in parts of Umuahia area of Nigeria, Geophysics 56, 284 – 291

Mbipom, E.W; Okwueze, E.E and Onwuegduche, A.A, 1996, Estimation of transmissivity using AES data from the Mbaise area of Nigeria, Nig.J. Physics 8, 28 – 32

MWT (Ministry Of Work and Transport), 1974, Atlas of Imo State, Owerri, Nigeria.

Niwas, S. and Singhal, D.C. 1981, Estimation of aquifer transmissivity for Dar – Zarrouk parameters in porous media, J. Hydrology 50, 393 – 399

Offodile, M.E; 1992, An Approach to Groundwater Study and Development in Nigeria Mecom Services Limited, Jos, Nigeria. P 138 – 148

Oliver, N.M. and Ismaila, Y.S. 2011, An assessment of total coliform levels of some portion of River Gongola in Adamawa State, Nigeria, Adv in App Sc. Res. 2(3), 191 – 197

Olorun femi, M.O. and Fasuyi, S.A, 1993, Aquifer types and the geoelectric/hydrogeologic characteristics of part of the central Basement terrain of Nigeria (Niger State). J.Africa Earth Science 3(3), 309 – 317

Ryzner, J.W, 1944, A new index for determining amount of Calcium Carbonate scale formed by water, Jour. Amer. W.W Assn. 36, pp 472 – 486.

Short, K.C. and Stauble, A.J. 1967, Outline of Geology of Niger Delta, American Ass of Petroleum Geologist, Vol. 51, No 5, p. 761 – 779

Todds D.K. 1980, Groundwater hydrology. 2nd ed. New York, John Wiley, America.

Vander Velpen, B.P.A, 1988, Resist Version 1.0 M.S.c Research Project ITC, Deft, Netherlands.

Table 2: Summary of Electrical properties of aquifer for all VES stations

VES	RESISTIVITY (Ωm)	THICKNESS (m)	CONDUCTIVITY (Ωm)	LONGITUDE CONDUCTANCE	TRANSMISSIVITY (m2/day)
1	276.0	18.2	3.6×10^{-3}	0.0655	182.0
2	347.8	20.1	2.9×10^{-3}	0.0580	201.0
3	928.3	2.6	1.07×10^{-3}	0.0028	26.0
4	1098.0	13.7	9.1×10^{-4}	0.0124	137.0
5	1574.4	14.1	6.35×10^{-4}	0.0089	141.0
6	1697.8	4.0	5.89×10^{-4}	0.0023	40.0
7	424.3	35.7	2.36×10^{-3}	0.0842	357.0
8	243.4	10.3	4.11×10^{-3}	0.0423	103.0
9	234.0	1.3	4.27×10^{-3}	0.0056	13.0
10	851.2	7.6	1.17×10^{-3}	0.0089	76.0
11	204.3	10.0	4.89×10^{-3}	0.0489	100.0
12	3603.5	22.5	2.77×10^{-4}	0.0062	225.0
13	218.9	13.6	4.57×10^{-3}	0.0622	136.0
14	68.4	4.3	14.6×10^{-3}	0.0628	43.0
15	3529.5	20.5	2.83×10^{-4}	0.0058	205.0
16	655.1	34.7	1.53×10^{-3}	0.0531	347.0
17	4000.0	11.8	2.5×10^{-4}	0.0029	118.0
18	1363.8	30.5	7.33×10^{-4}	0.0224	305.0

Table I: A summary of the VES interpretation and Model Parameters and Lithology

VES	LAYERS	RESISTIVITY (Ωm)	THICKNESS (m)	DEPTH (m)	LITHOLOGY	CURVE TYPE	RMS% ERROR
1	1	135.0	1.0	1.0	Topsoil	$\rho_1 > \rho_2 < \rho_3 < \rho_4 < \rho_5$ HKA	3.8
	2	128.5	4.3	5.3	Laterite		
	3	233.7	3.8	9.1	Clay		
	4	276.0	18.2	27.3	White Sand		
	5	3079.9	—	—	Coarse Sand		
2	1	531.2	1.0	1.0	Topsoil Laterite	$\rho_1 > \rho_2 > \rho_3 < \rho_4$ QH	2.9
	2	348.9	3.9	4.9	White smooth		
	3	347.8	20.1	25.0	sand		
	4	3218.9	—	—	Coarse sand		
3	1	1143.5	0.9	0.9	Top soil	$\rho_1 < \rho_2 > \rho_3 > \rho_4 < \rho_5$ KQH	5.6
	2	3726.6	0.8	1.7	Fine smooth sand		
	3	2871.4	0,9	2.6	Fine coarse sand		
	4	928.3	2.6	5.2	Smooth sand		
	5	1735.0	—	—	Coarse sand		
4	1	1050.8	1.0	1.0	Top soil	$\rho_1 < \rho_2 > \rho_3 < \rho_4$ KH	2.5
	2	2945.7	8.7	9.7	Fine coarse sand		
	3	1098.0	13.7	23.4	Smooth sand		
	4	1367.4	—	—	Coarse sand		
5	1	2289.7	1.0	1.0	Top soil	$\rho_1 < \rho_2 > \rho_3 < \rho_4$ KH	4.0
	2	4728.9	4.9	4.9	Fine coarse sand		
	3	1574.4	14.0	19.0	Smooth sand		
	4	2035.9	—	—	Coarse sand		
6	1	917.8	1.0	1.0	Top soil	$\rho_1 < \rho_2 > \rho_3$ K	3.0
	2	1697.8	4.0	5.0	Sand		
	3	714.4	—	—	Clayey sand		
7	1	172.8	0.8	0.8	Top soil	$\rho_1 > \rho_2 < \rho_3 > \rho_4$ HK	3.5
	2	707.0	3.0	3.8	Laterite		
	3	424.3	35.7	39.5	Sand		
	4	733.3	—	—	Coarse sand		
8	1	299.2	1.1	1.1	Top soil	$\rho_1 > \rho_2 < \rho_3 > \rho_4$ HK	8.9
	2	243.4	10.3	11.4	Sand		
	3	8817.2	228.8	240.2	Coarse sand		
	4	3285.0	—	—	Gravel		
9	1	2421.1	0.9	0.9	Top soil	$\rho_1 < \rho_2 > \rho_3 < \rho_4$ KH	3.9
	2	2934.0	1.3	2.2	Coarse sand		
	3	234.0	1.3	3.5	Clayey sand		
	4	3475.1	—	—	Gravel		
10	1	1078.3	1.0	1.0	Top soil	$\rho_1 > \rho_2 < \rho_3 < \rho_4$ HA	2.2
	2	482.8	0.2	1.2	Laterite		
	3	851.2	7.6	8.8	Sand		
	4	4094.5	—	—	Fine coarses sand		
11	1	124.4	1.7	1.7	Top soil	$\rho_1 < \rho_2 < \rho_3$ A	5.3
	2	204.3	10.0	11.7	Clayey sand		
	3	906.9	—	—	Sand		
12	1	1514.3	0.8	0.8	Top soil	$\rho_1 < \rho_2 > \rho_3 > \rho_4$ KQ	7.8
	2	3864.8	9.4	10.2	Coarse sand		
	3	3603.5	22.5	32.7	Smooth sand		
	4	1839.6	—	—	Clayey sand		
13	1	115.6	1.0	1.0	Top soil	$\rho_1 < \rho_2 > \rho_3 > \rho_4$ KQ	5.4
	2	435.0	7.5	8.5	Silty sand		
	3	218.9	13.6	22.1	Clayey sand		
	4	1448.8	—	—	Coarse sand		
14	1	3101.1	0.9	0.9	Top soil	$\rho_1 > \rho_2 < \rho_3 < \rho_4$ HA	5.2
	2	36.8	3.2	4.1	Laterite		
	3	68.4	4.3	8.4	Sand		
	4	1058.3	—	—	Clayey sand		
15	1	2529.0	1.4	1.4	Top soil	$\rho_1 > \rho_2 > \rho_3 < \rho_4 < \rho_5$ QA	2.7
	2	2220.7	1.0	2.4	Laterite		
	3	679.4	4.1	6.5	Clayey sand		
	4	3529.5	20.5	27.0	Coarse sand		
	5	4321.1	—	—	Gravel		
16	1	131.0	1.0	1.0	Top soil	$\rho_1 < \rho_2 < \rho_3 < \rho_4$ AA	5.9
	2	598.5	4.0	5.0	Laterite		
	3	655.1	34.7	39.7	Fine sand		
	4	978.8	—	—	Coarse sand		
17	1	300.0	1.0	1.0	Top soil	$\rho_1 < \rho_2 > \rho_3$ K	8.5
	2	4000.0	11.8	12.8	Coarse sand		
	3	831.7	—	—	Clayey sand		
18	1	346.2	1.0	1.0	Top soil	$\rho_1 < \rho_2 < \rho_3 > \rho_4$ AK	18.7
	2	478.1	10.2	11.2	Laterite		
	3	1363.8	30.5	41.7	Coarse sand		
	4	333.9	—	—	Clayey sand		