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Research Article

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Application of Earth Resistivity Measurement in the North Eastern Rivers State (a Geoelectric based study)

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Abstract Earth resistivity investigation was conducted in parts of the North East region of Rivers State, comprising Etche, Omuma and Oyigbo Local Government areas. Eighteen geoelectric surveys were carried out in the area under review using the Schlumberger configuration aimed at delineating the subsurface and layer thicknesses. Maximum current electrode spread of 500m, and an Abem 300B terrameter was used to acquire the field data. The area consists of medium coarse to coarse unconsolidated sands with groundwater at the water table atmospheric pressure. The top sediments are aerated unconsolidated and highly variable thickness throughout the area. Data acquired were qualitatively and quantitatively interpreted using IP12Win resistivity inversion software which generated the layer resistivities and thicknesses. The overburden thickness varies from 0.2 to 304.4m across the study area. This was used to prepare the groundwater potential and Isoresistivity/Isopach maps which assisted in the zoning of the area into low, medium and high groundwater potential zones. Groundwater potential is very high throughout the area investigate, hence, the groundwater potential rating of the area is considered generally high. The geolctric section revealed the sequence of the area lithology as top soil, various grades of sand and medium coarse sand. The general thickness of is quite enough for prolific aquifer yield at long pumpage. Contour maps of the Isoresistivity and Isopach are also presented.

Keywords Isoresistivity, Isopach, IP12Win, Geoelectric, permeability, Homogeneities

Introduction

The North Eastern part referred to in this study is made up Etche, Omuma and Oyigbo Local Government areas of Rivers State. The area lies within the coastal plain of North East, Rivers State, comprising Etche, Omuma and Oyigbo LGAs. The earth resistivity measurement applied here is one of the cheapest geoelectric methods for groundwater and subsurface investigations [1]. Earth resistivity techniques are extensively used in engineering surveys to locate subsurface cavities, faults and fissures, mineral shafts, overburden thickness and formations. High prolific aquifer yield has been identified in the following information on existing wells in the area. Schlumberger electrode arrangement is adopted here following its advantages over the other geoelectric methods. A total electrode spread, AB is applied.

The aim of this study is to apply earth resistivity for the identification of subsurface formations with respect to its lithological features and determination of the subsurface resistivity values relative to freshwater potentials of the area. A total of twenty vertical electrical soundings (VES) were conducted along four geoelectric profiles in other to evaluate the geologic setting of the area. Many authors [2-4] have extensively discussed the quantitative and qualitative interpretation of the earth resistivity measurements. The interpretation of the apparent resistivity data was achieved using the IP12win software which reveals the layer resistivities and thicknesses of the formation. The results obtained were subjected to quantitative interpretations of the Isoresistivity, isopach, geoelectric sections and distribution of longitudinal conductance representation of the study area [5].

Physiography and Hydrogeology of the Area

The study area is the North Eastern Rivers State covering the area enclosed by latitudes $5^0$15'30''N and $4^0$46'45''N, and longitudes $7^0$32'E and $7^0$25'E. (fig.1). The area features a tropical wet climate with lengthy and heavy rainy season of annual rainfall of 2300mm and very short dry seasons. The entire area is drained by two major rivers, the Otamiri and Imo Rivers flowing southwards to the Atlantic Ocean.

Basically, the area consists of medium coarse to coarse unconsolidated sands with groundwater at the water table atmospheric pressure. The top sediments are aerated unconsolidated and highly variable thickness throughout the area [6-7]. The subsurface geology of the Niger Delta consists of three lithostratigraphic units (Benin, Agbada and Akata Formations) which are in turn overlain by quaternary sediments. The Benin formation is about 2100m thick and is made up of over 90% massive, porous and coarse sands. [8]. The high permeability of Benin formation, the overlying lateritic red sand and weathered top of the formation provide the hydrologic condition favouring aquifer formation in the area [9]. Groundwater potentials are very high due to the high permeability, high recharge potential and considerable aquifer thickness [10]. The water in most of the area has high iron content and water table varying between 1.0m to 15.0m inland. The aquifer here is usually unconfirmed and is encountered at varying depths. Locally, a multi-storey aquifer is formed by the localized fine sands and clayey which separate the coastal plain sands. The high rainfall ensures adequate groundwater recharge [11].

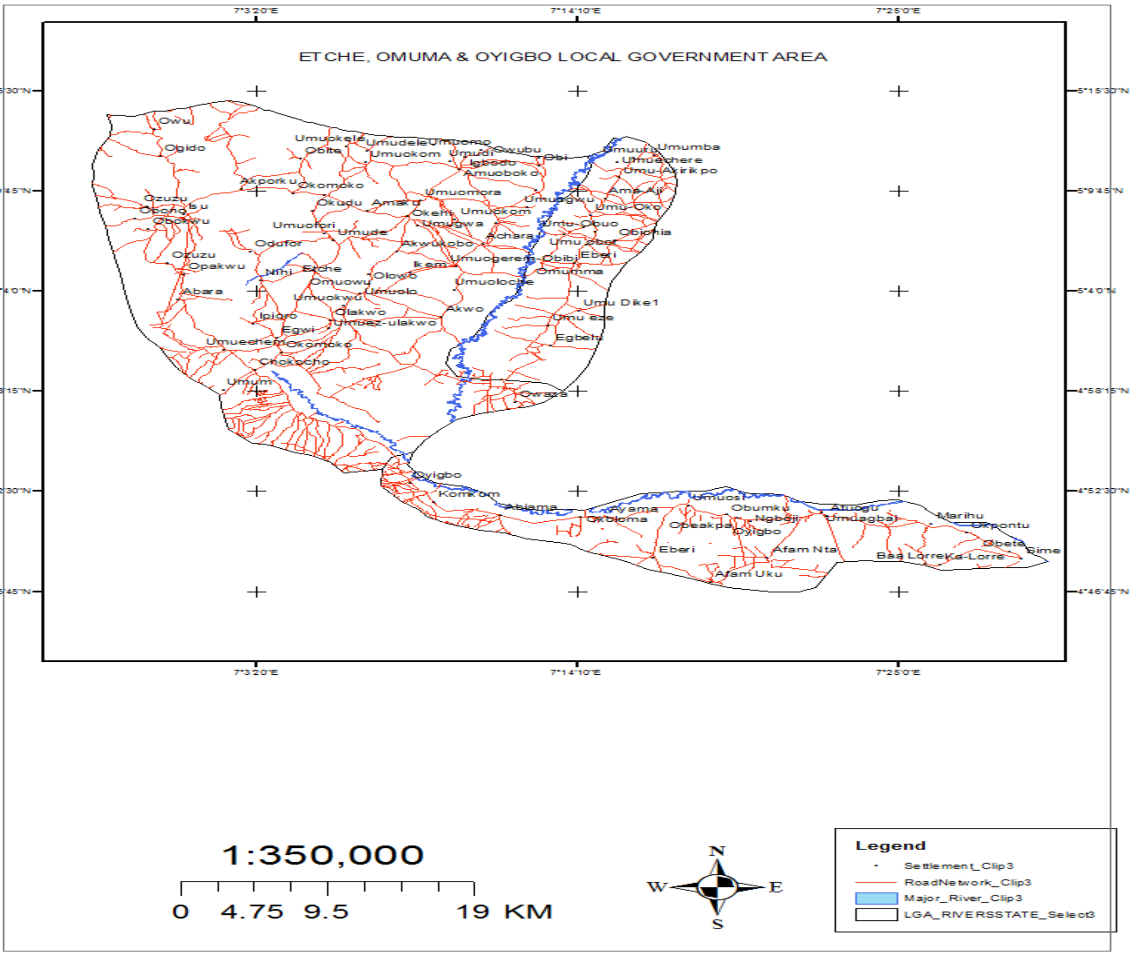

Figure 1: Map of the study area showing towns and road network

Materials and Method

The earth resistivity (ER) survey was conducted using Schlumberger configuration for data acquisition. Schlumberger array used in the field survey is found to be more suitable for this study. This is because the potential electrodes can be rapidly located on the apparent resistivity curves and theoretical computation can be performed with less assumption than similar computations for the Wenner array. Besides compensating for the effects of local shallow in homogeneities, the method is quick, cheap and current penetration is at greater depth. The field data were recorded using an Abem SAS 300B terameter which allows filtering and self-potential of the earth. It has the special characteristics of the ability to display the resistivity, portability and ability to automatically compensate for Polarization at the electrodes, induced polarization of the earth materials and instrument drift effects. Accordingly, it possible to measure the resistance at each electrode spread. The instrument is powered by external 12V battery while the four stainless metal electrodes were used to mark the current and potential spacing along the stride. The current spacing (AB/2) begins with a distance 1.0m and extends up to 200m. The ratio between MN distance and AB distance ranges from $\frac{1}{3}$ to about $\frac{1}{10}$. The layer parameters (apparent resistivity & thickness) obtained using the software IP12Win gave the quantitative interpretation of the subsurface.

Results and Discussions

The Table 1 below presents the layer parameters (resistivies, thicknesses, depth) for the VES points conducted in the study area, which were compared and integrated to the existing geological information to construct geological maps and picture of the study area.

Table 1: Layer parameters for the VES points conducted in the study

VES no	Resistivity of layers (Ω-m)					Thickness of layers (m)				Total Depth (m) (Actual drill Depth)	Eastings	Northings
	ρ_1	ρ_2	ρ_3	ρ_4	ρ_5	t_1	t_2	t_3	t_4	h		
1	1712.4	5458.4	582.5	3879.8	-	3.9	20.3	59.0	-	83.2	520748	110518
2	510.5	2318.1	478.7	7195.6	-	0.7	16.9	37.7	-	55.3	500841	134222
3	3849.1	1125.1	3986.5	395.2	-	0.3	5.9	59.4	-	65.6	520210	125717
4	644.3	2607.0	921.8	3240.9	-	2.0	19.6	37.8	-	59.7	509704	128847
5	98.6	288.8	2419.3	782.2	-	0.2	22.2	77.6	-	100	514818	126240
6	693.5	6798.1	405.9	-	-	2.2	44.2	-	-	46.4	514114	102820
7	2454.5	1838.8	5481.0	335.5	-	3.5	7.4	77.6	-	88.5	504490	134095
8	371.2	309.6	1602.1	1104.7	-	2.6	15.2	204.9	-	222.7	530776	115952
9	1263.4	778.3	2515.7	984.6	1136.9	2.3	4.0	54.9	104.4	165.6	528549	115468
10	85.1	2433.5	2504.1	-	-	0.5	54.3	-	-	54.8	505325	120650
11	458.6	6204.8	795.6	4241.0	-	1.5	20.9	26.2	-	48.6	508894	126213
12	608.4	4843.7	1253.8	0.001	-	0.8	5.3	124.6	-	130.7	516141	116814
13	314.6	7924.6	1984.5	6781.6	-	0.2	5.3	31.1	-	36.6	511758	112492
14	788.4	409.6	4311.8	454.4	-	2.0	7.2	87.6	-	96.8	521710	136587
15	2183.5	1186.6	7445.6	317.9	-	3.1	3.2	25.9	-	32.2	517678	104599
16	33.3	207	1670	45.2	505	0.9	1.7	6.9	36.8	46.3	549079	92509
17	99	980	513	960	172	0.5	3.5	32.5	98.6	135.1	545792	98201
18	37.6	16..2	520.0	99.0	138	0.7	2.4	15.6	84.3	103	549125	92709
19	578.4	777.4	2710.4	10126	-	2.8	11.8	44.5	-	59.1	526420	118619
20	34.3	1897.5	409.4	224	5158.4	1.3	10.9	12.7	40	64.9	526625	117200

ρ = resistivity t=thickness

Geoelectric section maps

A careful examination of the subsurface sections can provide useful information about the subsurface lithology, structure and zones of groundwater occurrences. These sections show the vertical distribution of resistivities within a particular volume of the earth. The sections consist of a sequence of uniform horizontal or slightly inclined layers. The layer's resistivity is noted on each one for each VES sounding, after which several sections for VES points on a certain traverse can be linked together to show a cross sectional view of the traverse. Each layer in a geoelectric section is completely characterise by the thickness and apparent resistivity of the section. The interpretive geo-electric section AB which runs across NW-NE direction of the study area is made up of data from VES 3, 4, 5, 7 & 8 (Fig 2). The interpretative cross section shows mainly four geo-electric layers. The topsoil which is relatively thin is characterized by resistivity values ranging from 96.6 ohm-m to 3849.1 ohm-meter with a thickness that varies from 0.3m to 3.5m, and composed of predominantly lateritic, and clayey sand towards the northeastern part. The second layer has resistivity values that vary from 288.8 Ohm-m to 6798.1 Ohm-m comprising mainly grained/fine sands. The highest thickness in this layer is 22.2m at the vicinity of VES 5. These layers (First and Second) are very poor for groundwater potential, because they very shallow and clayey. The fresh water zone is found in third layer which s made up of medium coarse sands with thickness that range from 37.8m to 204.9m at VES 8 (Umudike) in Omuma LGA, Rivers State. The fourth layer is the infinite layer with no information on the layer thickness. Available well data from the area are very comparable to the vertical Electrical sounding (VES) data obtained in this survey.

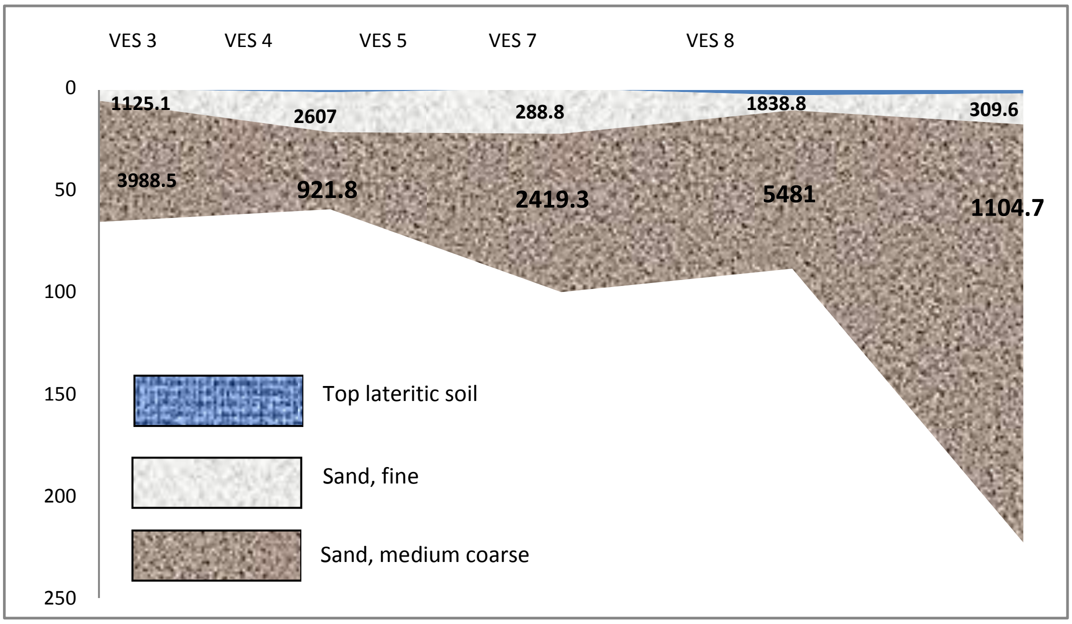

Figure 2: Interpretive Geoelectric Section for the Profile NW-NE direction

The profile CD runs from the West to South Eastern part of the study area with VES 6, 11, 13, 15, 16 & 17. (Fig.3). Again the topsoil constitutes the first layer in this profile with reistivity values ranging from 99.0 to 2183.5 Ohm-m. The highest layer thickness here is 3.1m at vicinity of VES 15. This layer is very poor for groundwater potential. The second layer reveal dry surface layer of average thickness of 13m and layer resistivity which varies from 207 to 7924.6 Ωm at the vicinity of VES 13. The zone is consist dry grained sand which contain little or no water for any meaningful purpose. The third layer is predominantly wet and identified as the aquifer unit characterized by resistivity values between 405.9 to 5481.0 Ohm-m and thickness values of 16.4m to 6.9 to 124.6m. Groundwater potential here is very high. The last layer with resistivity values that vary from 45.2 to 6871.6 ohm-m with infinite thickness is suggestive of yet another fresh water zone according to the area geology.

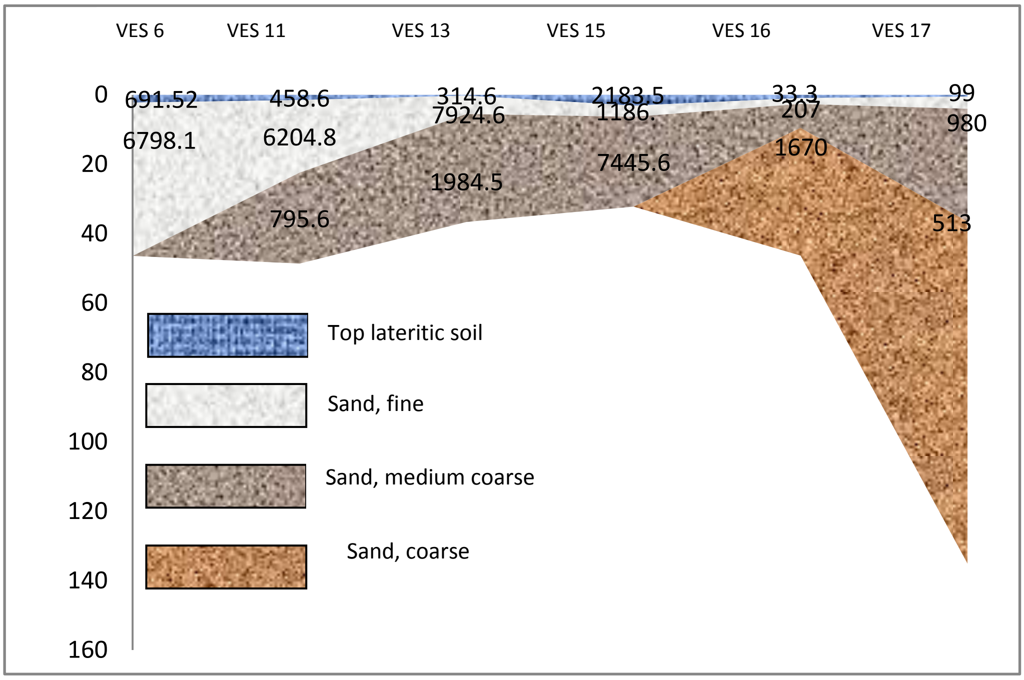

Figure 3: Interpretive Geoelectric Section for the Profile W-SE direction

Profile E-F is located to the SW to NE, with the geoelectric section constructed according to the quantitative interpretation results of VES 1, 9, 12, and 19. The top layer consists of lateritic topsoil with thickness variation from 0.8 to 3.9m, and resistivity range of 578.4 to 1712.4 Ohm-m at VES 1. This layer is very poor for groundwater potential. The next geoelectric layer consist of resistivity values which vary from 309.6 to 5458.4 Ohm-m, and variable thickness of 5.3 to 20.3m. This layer is predominantly dry sand. The third later constitutes the water-bearing layer believed to be saturated with fresh water according to the area geology. The aquifer is saturated by the adjoining Otamiri, Ogochie and Imo rivers criss-crossing the study area. The fourth layer which is not completely resolved because of short profile spacing may represent another saturated fresh water zone. This profile agrees with the figures 2 and 3 above.

Isoresistivity and Isopach maps of the aquiferous zones

The isoresistivity maps are constructed at $\frac{AB}{2}$ = 50m and 100m, (Figs. 5a & 5b). The choice of the spacing is dependent on the variability between them. These maps reflect the lateral variation of the electric resistivity at the depth of penetration. The isoresistivity, $\frac{AB}{2}$ = 50m shows resistivity values in Northern part which range from 500Ωm at VES 5 (Umuaturu) to 2500Ωm at VES near Egwi. The Southern half, on the other hand is underlain with relatively higher resistive values from 3500Ωm to 4500Ωm in the vicinity of VES 6 (Ikwerrengwo) near the Imo River. The isoresistivity, $\frac{AB}{2}$ = 100m indicates similar characteristics with resistivity values at the Eestern part as 1000Ωm to 150Ωm at VES 18 (Okasagu) and resistivity above 4000Ωm at the Western part of the study area.

The isopach contour map was exclusively constructed with the third layer thickness where freshwater aquifer was delineated, (Fig. 6). To access the actual groundwater potential, it is also necessary to have knowledge of thickness of the geologic soil profile of the sedimentary basin; hence the contours of the thickness of the aquiferous zones are displayed. It can be observed that almost all the aquiferous zone along the layer appear thick enough for drilling of prolific boreholes over the entire area (Table.1). However, the isopach map constructed from the survey above shows that this shallow unconsolidated aquifers are highly variable in thickness, from 15.6m to at VES 18 to 204.6m at the VES 8 (Umudike, Omuma LGA), except VES 16 and 20 which indicated thickness of 6.9m and 12.7m respectively.

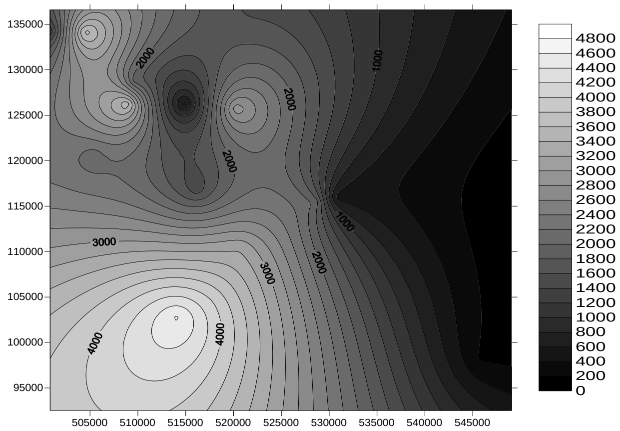

Figure 4(a): Isoresistivity map at $\frac{AB}{2}$ *= 50m*

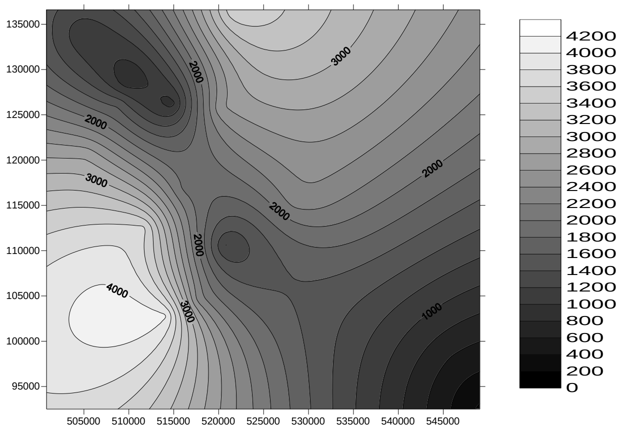

Figure 4(b): Isoresistivity map at $\frac{AB}{2}$ *= 100m*

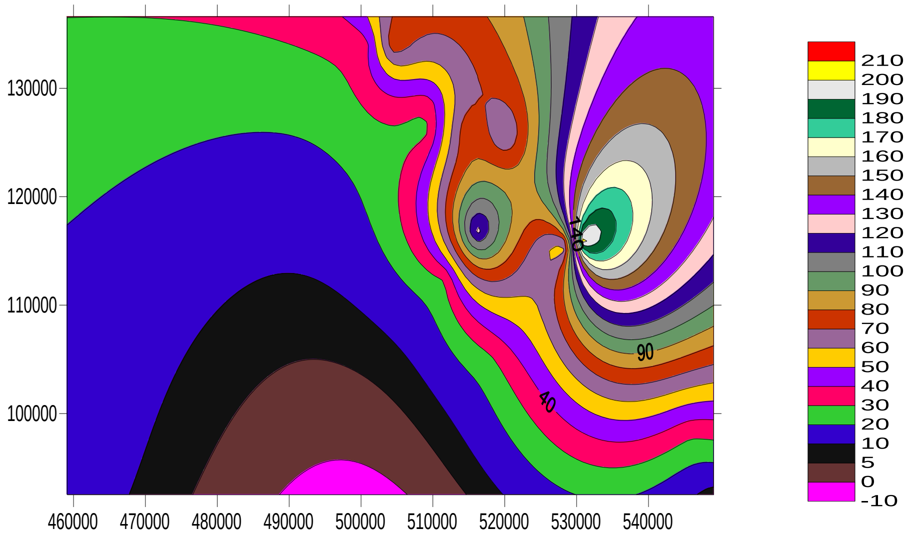

Figure 5: Isopach map of the fresh water depth of the study area

Conclusion

The result of this study has revealed precisely the aquiferous zone of the area. The characteristic geoelectric parameters of the delineated aquifer at each sounding point were elaborately used to produce the groundwater potential maps presented in this report. The computer iterated sounding interpretations revealed mainly three distinct layers comprising the lateritic top soil, fine/grained sand and the medium to coarse sand identified as the fresh water aquifer with appreciable thicknesses that sustain long term yield. The aquifer in this area varies in thickness from place to place. Groundwater potential is very high in the area following the resistivity values encountered in the survey. Well depth of 36.6m – 230m can be achieved with high yield following the high recharge as well as the aquifer thicknesses.

The results of this study have also provided reliable information and data for an elaborate groundwater abstraction in the area.

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