



CHARACTERIZATION OF AQUIFER POTENTIAL USING DAR-ZARROUK PARAMETERS IN A CRYSTALLINE BASEMENT, SOUTHWESTERN, NIGERIA.

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ABSTRACT

Potable groundwater is a rare resource in some part of Okeiho southwestern Nigeria, assessing and delineating its feasible zones of high potential using non-invasive geoelectric investigation is really vital so as to monitor the successful exploration of the underground water. The study area is underlain predominantly with coarse porphyritic granite and syenite including pyroxene diorite. Thirty six (36) Vertical electrical soundings (VES) were surveyed around built up areas using ABEM SAS 1000 Terrameter with potential and current electrode spacing varied from 0.5 to 15m and 1 to 160 m respectively with VES curves interpreted qualitatively and quantitatively using curve matching techniques. Geoelectrical properties such as weathered resistivity layer, Overburden thickness, weathered thickness layer, bedrock relief, basement resistivity, reflection coefficient and the Dar-Zarrouk parameters were determined from each VES point and contoured so as to distinguish the groundwater prospects within the studied area. Typical curves corresponding to VES data include 'A', 'H', 'HKH' and 'KH'. The most prevalent curve type is H-type, comprising of 67% curves observed while the 'A', 'KH' and 'HKH' types establish 22%, 8.3% and 2.7%. The thickness of the overburden ranges between 2.8 – 16.8 m; the weathered layer thickness range from 1.4 – 14.1 m; the basement resistivity ranges from 357 – 14760 Ωm ; the longitudinal conductance ranges from 0.022 – 0.39 Ω^{-1} ; the transverse resistance has values ranges from 53 – 4760 Ωm^2 , and the electrical anisotropy has values ranges from 1 to 1.8. The northern, eastern and central portion is described by decrease in overburden thickness, weathered resistivity layer, total longitudinal conductance, indicating low aquifer potential, transverse resistance unit, total longitudinal conductance unit, and electric anisotropy values increases towards the southwestern part, reflecting moderate aquifer prospects. In such manner, the southwestern part of the studied portions are categorized as moderate groundwater prospects; while the northern and eastern part are categorized as area with poor groundwater prospect.

Keywords: Crystalline Basement, Resistivity, Dar-Zarrouk Parameters, Aquifer Potential.

INTRODUCTION

Groundwater movement in fractured aquifers is very complex, and its accuracy is governed by the hydraulic performance (Singh, 2005). A detailed knowledge of groundwater exploration and exploitation is provided by the Electrical resistivity surveys as opined by Olayinka, 1992; Adewoye et al., (2018); Olayinka and Olorunfemi, 1992; Olayinka and Olayiwola, (2000). It provides exhaustive facts about groundwater repositories and hydrogeological settings .

Field logistics are simple , straightforward and easy (Sunmonu *et al.*,2012). This yields aquifer parameter that are essential for the description of aquifer dynamics and groundwater resource management as a whole this entails geometry of rock particles and pore spaces, secondary deposition and geologic processes such as folding and faulting. The effectiveness of geoelectric sounding in exploration and exploitation such as pollution indicator; dam siting and most especially assessing of aquifer prospects in basement complex have been reviewed and studied by many researchers viz: Adewoye et.,al (2017a and b); Mazac et al, 1990 ; Olayinka *et al* (1997) and Adewoye et.,al (2015). Malliet (1947) firstly initiated the concept of these parameters and later called them the Dazarrouk parameters. This have since been used in water yielding competences , thickness and depth of subsurface layers and the estimation of the hydraulic characteristics Oladunjoye, 2013 . The requisite for sustainable groundwater was stirred up the interest of this research as a result of failed/abortive boreholes , inadequate supply of pipe borne water and contamination of most water source. Groundwater is a rare resource endorsed for its chemical quality for most uses and

natural microbiological quality (McDonald *et al.*, 2000). Therefore, appraisal of groundwater potential of part of Okeiho was carried out so as to identify the aquifer dynamics which involves geoelectric and hydraulic potential with a view of classifying and planning a reliable and sustainable development . The studied area lies within the latitude $8^{\circ} 21' 11''$ and longitude $3^{\circ} 20' 51''$ in the Crystalline Basement Complex of Nigeria with an accessible road networks (Figure 1a). It is underlain by coarse porphyritic granite and Syenite including pyroxene diorite (Figure 1b). The average temperature during dry and wet season are 35°C and 28°C lasting between November to March and April to October respectively while Oguntoyinbo, 1978 estimated the annual mean rainfall to range between 1000 and 1200 mm with rainforest vegetation type .

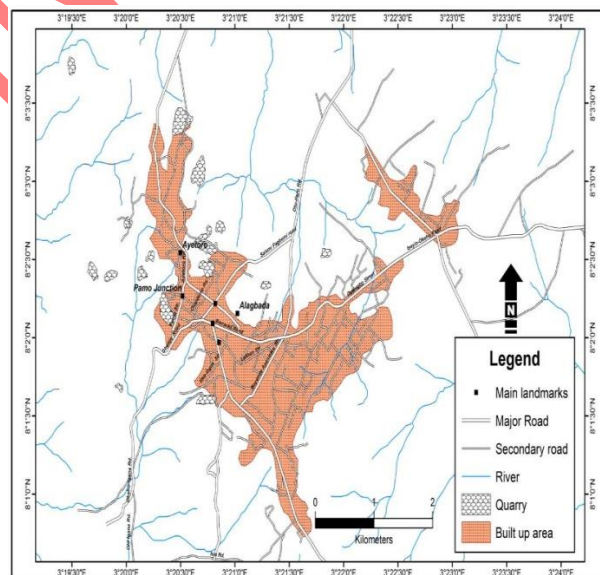


Fig. 1a: Topographic Map of part of Okeiho Township

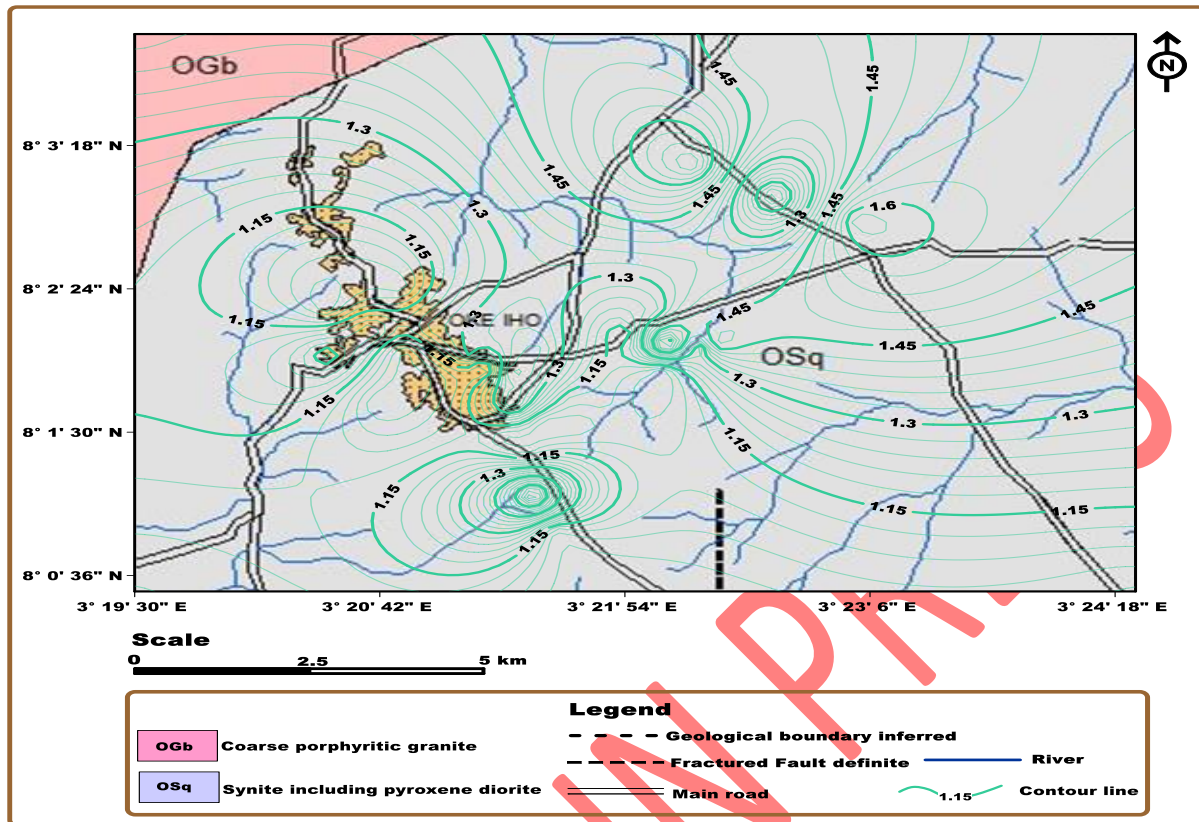


Fig. 1b: Local Geology Map of part of Okeiho Township

MATERIALS AND METHODS

Thirty six (36) VES traverses were carried out using ABEM SAS 1000 Terrameter. The resistivity of the subsurface sites were examined by applying electric current into the ground through two current electrodes and evaluating the resultant voltage variances amongst pair's potential electrodes. Measurements of current and potential difference were done repeatedly at these same points with a larger current electrode separation ($AB/2$) in each succeeding electrode probe to determine the depth to the basement rock. The current electrode ($AB/2$) spacing varied from 1 to 160 m and the potential electrode ($MN/2$) spacing varied from 0.5 to 15m. The values recorded were then plotted on a log-log paper as points with the resistivity values being on the vertical axis and the current

electrode spacing ($AB/2$) on the horizontal axis with all points joined together. All the field VES curves were interpreted qualitatively and quantitatively using curve matching techniques. The computer program used, follows the main ideas presented by Zodhy (1989) for automatic iterative interpretation so as to reduce the geo-electrical sounding curves into values number of layers (N), thickness (h) and resistivity of individual layers. The reflection coefficient of each station in the area was calculated using the method of, Olayinka (1996). The Dar-Zarrouk parameters are obtained from the first order geoelectric parameters (layer resistivities and thicknesses), these include the Total longitudinal unit conductance (S), Total transverse unit resistance (T), and coefficient of anisotropy (λ).

RESULTS AND DISCUSSION

The groundwater potential of Okeho and its environs were examined using electrical resistivity method. The area studied was delineated and the lineament (fractures) that

are within the area was also delineated. Lineaments exhibits a very vital role in draining groundwater in the basement complex rocks. Groundwater sustainability is much robust in lineament zones Figure 2.

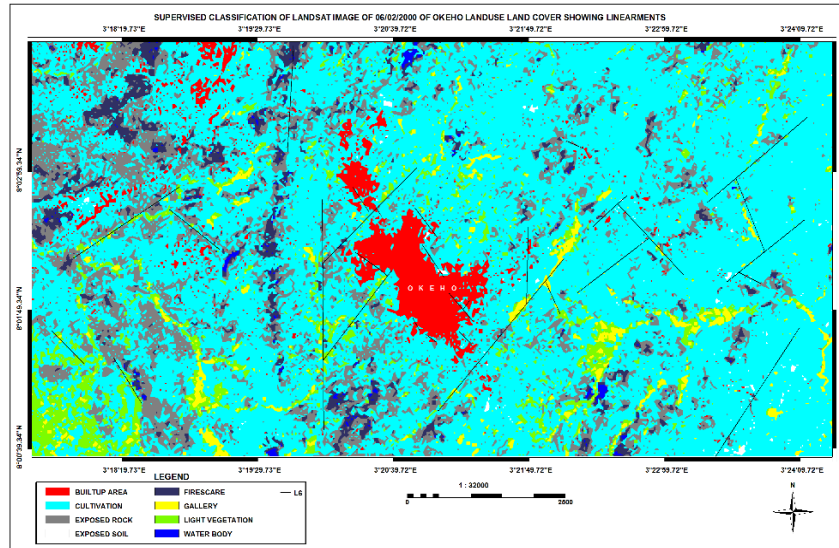


Figure 2: Okeiho Lineament Map

GEOELECTRICAL INVESTIGATION

Vertical electrical soundings method was adopted utilizing the convectional Schlumberger array as the array type adopted. From the information acquired from the field, geoelectrical properties of the area were determined from the resistivity value and the thickness of each layer. Weathered layer resistivity, Overburden thickness, weathered layer thickness, bedrock relief, reflection coefficient, basement resistivity, and the Dar-Zarrouk parameters were determined from each VES point and contoured so as to characterize the groundwater prospects in the study area. Results and salient highlights of sub surface parameters are given in Table 1. Figures 3(a-d) show typical sounding curves conforming to VES results include A', 'H', 'HKH' and 'KH'. The H-type is the most

prevalent, constituting 67% of the curves observed while the 'A', 'KH' and 'HKH' types establish 22%, 8.3% and 2.7% respectively. Figure 4 show the percentage distribution of the VES curves of the study area on the pie chart.

Table 1: Summary of Geoelectric Parameter of VES Curve Obtained

VES NO	LAYERS	RESISTIVITY (ohms-m)	LAYER THICKNESS (m)	DEPTH (m)	CURVE TYPES	PROBABLE LITHOLOGY
VES1	1	146	1.0	1.0	H	Topsoil
	2	12	3.7	4.7		Weathered Basement (Clayey)
	3	1119	-	-		Fresh Basement
VES2	1	350	3.7	3.7	H	Topsoil
	2	43	9.1	12.8		Weathered Basement (Clayey)
	3	1234	-	-		Fresh Basement
VES3	1	341	2.2	2.2	H	Topsoil
	2	59	6.6	8.8		Weathered Basement (Clayey)
	3	1130	-	-		Fresh Basement
VES4	1	81	1.6	1.6	A	Topsoil
	2	143	14.1	15.7		Weathered Basement
	3	762	-	-		Fresh Basement
VES5	1	195	2.5	2.5	H	Topsoil
	2	32	5.4	7.9		Weathered Basement (Clayey)
	3	1886	-	-		Fresh Basement
VES6	1	131	2.0	2.0	H	Topsoil
	2	12	4.0	6.0		Weathered Basement (Clayey)
	3	1824	-	-		Fresh Basement
VES7	1	312	2.8	2.8	H	Topsoil
	2	38	7.6	10.4		Weathered Basement (Clayey)
	3	1309	-	-		Fresh Basement
VES8	1	174	1.8	1.8	H	Topsoil
	2	22	7.7	9.5		Weathered Basement (Clayey)
	3	378	-	-		Fractured Basement
VES9	1	200	1.2	1.2	H	Topsoil
	2	47	2.5	3.7		Weathered Basement (Clayey)
	3	700	-	-		Fractured Basement
VES10	1	315	1.9	1.9	H	Topsoil
	2	29	4.5	6.4		Weathered Basement (Clayey)
	3	1927	-	-		Fresh Basement
VES11	1	410	2.0	2.0	H	Topsoil
	2	86	6.2	8.2		Weathered Basement (Clayey)
	3	7486	-	-		Fresh Basement
VES12	1	148	2.0	2.0	H	Topsoil
	2	78	10.6	12.6		Weathered Basement (Clayey)
	3	2740	-	-		Fractured Basement
VES13	1	126	1.6	1.6	H	Topsoil
	2	46	4.1	5.7		Weathered Basement (Clayey)
	3	1569	-	-		Fresh Basement
VES14	1	190	2.4	2.4	H	Topsoil
	2	64	7.5	9.9		Weathered Basement (Clayey)
	3	1363	-	-		Fresh Basement

VES15	1	156	1.1	1.1	H	Topsoil
	2	51	4.4	5.5		Weathered Basement (Clayey)
	3	2147	-	-		Fresh Basement
VES16	1	88	1.6	1.6	H	Topsoil
	2	30	3.4	5.0		Weathered Basement (Clayey)
	3	8388	-	-		Fresh Basement
VES17	1	128	2.0	2.0	H	Topsoil
	2	69	12.8	18.8		Weathered Basement (Clayey)
	3	8038	-	-		Fresh Basement
VES18	1	411	1.9	1.9	H	Topsoil
	2	164	7.3	9.2		Weathered Basement
	3	1448	-	-		Fresh Basement
VES19	1	69	1.4	1.4	A	Topsoil
	2	752	1.4	2.8		Fairly Weathered Basement
	3	14760	-	-		Fresh Basement
VES20	1	190	3.3	3.3	H	Topsoil
	2	99	9.3	12.6		Weathered Basement
	3	5732	-	-		Fresh Basement
VES21	1	167	1.5	1.5	A	Topsoil
	2	363	8.6	10.1		Fairly Weathered Basement
	3	2968	-	-		Fresh Basement
VES22	1	295	1.8	1.8	H	Topsoil
	2	41	5.9	7.7		Weathered Basement (Clayey)
	3	7121	-	-		Fresh Basement
VES23	1	78	1.0	1.0	KH	Topsoil
	2	504	4.7	5.7		Compacted Lateritic Clay
	3	71	10.8	16.5		Weathered Basement
	4	1596	-	-		Fresh Basement
VES24	1	121	0.6	0.6	KH	Topsoil
	2	702	2.2	2.8		Compacted Lateritic Clay
	3	89	6.3	9.1		Weathered Basement
	4	4643	-	-		Fresh Basement
VES25	1	134	1.2	1.2	H	Topsoil
	2	24	3.0	4.2		Weathered Basement (Clayey)
	3	8476	-	-		Fresh Basement
VES26	1	39	1.2	1.2	A	Topsoil
	2	89	8.5	9.7		Weathered Basement
	3	1287	-	-		Fresh Basement
VES27	1	63	1.7	1.7	A	Topsoil
	2	92	9.8	11.5		Weathered Basement
	3	1049	-	-		Fresh Basement
VES28	1	72	0.9	0.9	HKH	Topsoil
	2	24	2.0	2.9		Clayey Soil
	3	239	6.4	9.3		Lateritic Clay
	4	77	7.5	16.8		Weathered Basement
	5	818	-	-		Fractured Basement

VES29	1	153	1.9	1.9	H	Topsoil
	2	77	5.9	7.8		Weathered Basement
	3	581	-	-		Fractured Basement
VES30	1	186	3.2	3.2	H	Topsoil
	2	92	11.3	14.5		Weathered Basement
	3	2619	-	-		Fresh Basement
VES31	1	29	3.2	3.2	A	Topsoil
	2	1609	-	-		Fresh Basement
VES32	1	428	0.9	0.9	KH	Topsoil
	2	1031	2.6	3.5		Compacted Lateritic Clay
	3	197	8.6	12.1		Weathered Basement
	4	1459	-	-		Fractured Basement
VES33	1	115	1.7	1.7	H	Topsoil
	2	44	5.0	5.7		Weathered Basement
	3	357	-	-		Fractured Basement
VES34	1	47	1.6	1.6	H	Topsoil
	2	14	5.0	5.6		Weathered Basement (Clayey)
	3	2470	-	-		Fractured Basement
VES35	1	136	3.8	3.8	A	Topsoil
	2	3410	-	-		Fresh Basement
VES36	1	39	1.5	1.5	A	Topsoil
	2	81	7.9	9.4		Weathered Basement
	3	793	-	-		Fresh Basement

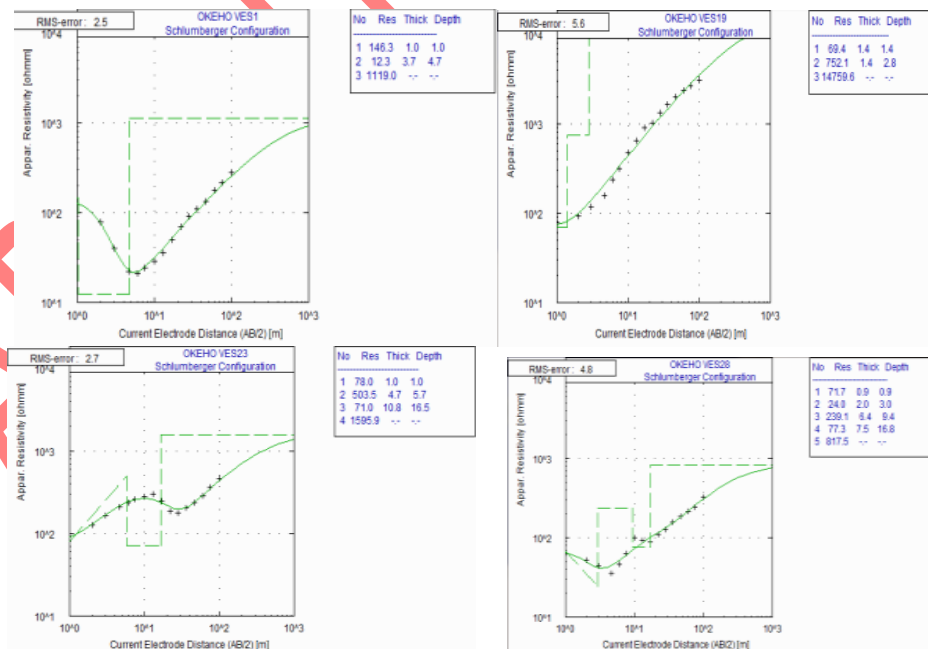


Figure 3: Showing the representative sample of the typical sounding curves of Okeho and environs. (a) H curve type (b) A curve type (c) KH curve type (d) HKH curve type

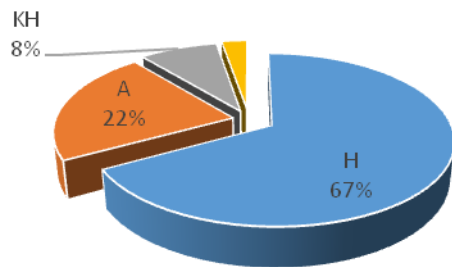


Figure 4: Percentage distribution of the available geoelectric curve types in Okeho and environs

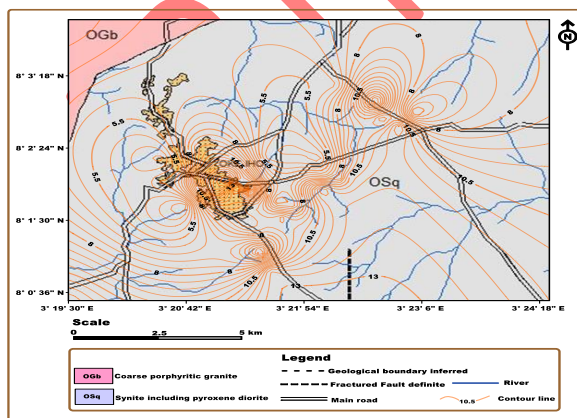
Overburden thickness is all formation/material overlaying the basement zone. The map displays the thickness of overburden varying from 2.8 m and 16.8 m with a mean thickness to be about 8.8 m Figure 5. The overburden in the central, southeastern and northeastern portion of the studied area is fairly thick and exceptionally thin respectively with the thickness varying from 10 – 13 m. Typically, this results coincide with the submissions of Omosuyi *et al.*, (2003) and Dan-Hassan and Olorunfemi (1999) on overburden thickness. The abstraction of groundwater may be relatively insignificant because of existence of shallow overburden leading to little or no occurrence of fractured zone within the studied area.

The map of the weathered basement resistivity displays some variation in the resistivity within the aquifer sections in the study area (Figure 6). The values of resistivity vary between 12 Ω m and 6752 Ω m; with an average of 90 Ω m. The resistivity is least at the Northern, Northwestern, Southeastern and northeastern part of the studied area exhibited resistivity values ranging between 30 Ω m and 75 Ω m. It rises around the southern part of the study area with values varying from 100 Ω m to 700 Ω m

and is highest towards southwestern part of the study area. In basement complex of Nigeria, Olayinka, (1992) opined that areas having weathered basement resistivity values varying between 100 Ω m to 800 Ω m may be a sustainable aquifer while Barker, (1980) observed highest yielding boreholes in the basement complex of Zimbabwe with weathered layers resistivity values ranging between 100 Ω m and 600 Ω m. This results agree with the findings of Olayinka, (1992); Barker, (1980) and Adiat *et al.*, (2009).

The thickness of weathered basement ranges from 1.4 m and 14.1 m with an average mean thickness of 6.7 m and the standard deviation is 2.8 m (Tables 1 and 2). The southeastern and southern part of the study area is fairly thick with thickness ranging from 8 m to 14.1 m while and the northern part is relatively thin with thickness ranging from 3 m to 7 m indicating minimal aquiferous zone (Figure 7). The study area is generally characterized by low weathered basement thickness between 3 m to 7 m. However, some areas have fairly thick weathered basement unit with thickness varying between 8 m and 12 m. The basement relief map clearly shows the structural resolution, degree of basement weathering and the basement topography (Figure 8). The hydrogeologic importance of this has been identified by Dan-Hassan and Olorunfemi, (1999). The relief of the area indicated that the subsurface depth varies over 2.8 m to greater than 16 m. The topography map considered shows the areas with geological formations such as trough and ridges which predicts the depth at which we can get good groundwater potential because troughs and ridges are good groundwater collecting zones. Ridges and topography depressions are shown in the bedrock relief map. The depression are described by the thick overburden as

realized in the central part of the study area indicating troughs for draining of groundwater while ridges are expressed as thin overburden as observed in the northwestern, southeastern and southwestern part of the study area. The bedrock resistivity values range from $357\Omega\text{m}$ – $14760\Omega\text{m}$. The bedrock resistivity contour map is shown in Figure 9. Olayinka and Olorunfemi (1999) opined that the resistivity values that are less than $1000\Omega\text{m}$ coincides with fractured basement rock while the basement resistivity values that exceed $1000\Omega\text{m}$ is of fresh basement rock. From the contour map generated, the presence of fresh bedrock ($>1000\Omega\text{m}$) is dominant within the study area with few occurrences of fractured bedrock ($<1000\Omega\text{m}$) which sparsely present in some part of the area. Generally, the fresh bedrock dominates the area as the resistivity value of the basement depicts that of fresh basement. Area with resistivity less or equal to $1000\Omega\text{m}$ can be found around the northeastern part of the map. It can be deduced that most of the areas with shallow overburden correspond with high bedrock resistivity values which invariably coincides with bedrock ridges portions. Results obtained from the computer iteration and their inferred lithologies Figure 10.



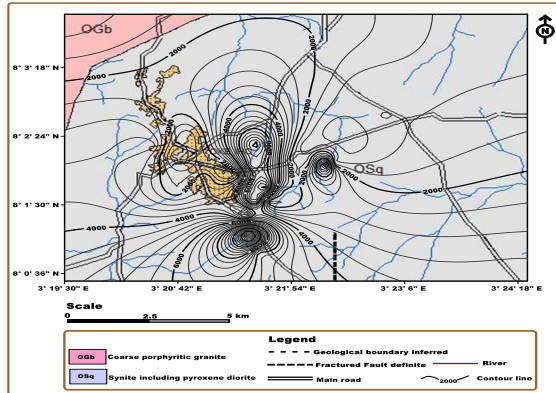


Figure 9: The Bedrock Resistivity Contour Map

The reflection coefficient value tends to increase maximally to a value of 1 as the freshness of the basement increases (Olayinka 1996). Degree of fracturing of the underlying basement and good aquiferous regions could be inferred from the basement resistivity and its reflection coefficient values. Better results were observed where the reflection coefficient is low and the overburden is relatively thick. The area which falls within this category is less than 20% of the area investigated. The value of the reflection coefficient ranges between 0.68 and 0.99 while it has average reflection coefficient of 0.91. The central part has reflection coefficient value less than 0.8 while the entire area has higher reflection coefficient.

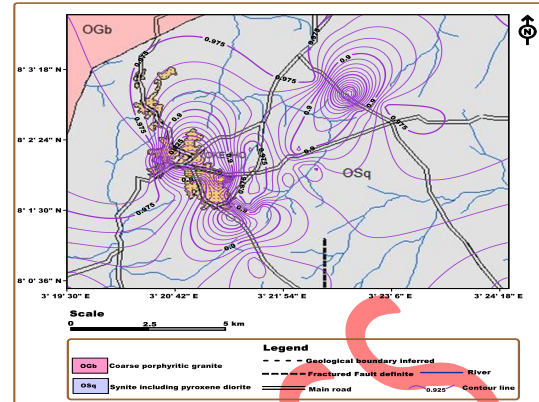


Figure 10: The Reflection Coefficient Contour Map

GEOELECTRIC (DAR-ZARROUK)

The electrical parameters such as transverse resistivity, longitudinal resistivity, longitudinal conductance and transverse resistance can be obtained for each layer from the respective thickness and resistivity. The sums of all the transverse resistances and of the longitudinal conductances for a layered ground is respectively known as Dar Zarrouk 'function' and 'variable', Table 2.

Table 2: Summary of Dar-Zarrouk Parameter from Geoelectric Data Obtained

	Latitude	Longitude	Longitudinal conductance	Transverse Resistance	Longitudinal Resistivity	Transverse Resistivity	Coefficient of Anisotropy
1	3.383722	8.047333	0.315183	190.4	14.91199	40.51064	1.648226
2	3.381278	8.044389	0.222199	1686.3	57.60593	131.7422	1.512268
3	3.378278	8.046056	0.118316	1139.6	74.37708	129.5	1.319518
4	3.377139	8.049667	0.118354	2145.9	132.6523	136.6815	1.015073
5	3.375389	8.064611	0.181571	660.3	43.50927	83.58228	1.38601
6	3.370667	8.053	0.348601	310	17.21168	51.66667	1.732581
7	3.372333	8.034139	0.208974	1162.4	49.76687	111.7692	1.498618
8	3.372778	8.040528	0.360345	482.6	26.36364	50.8	1.388127
9	3.367639	8.037639	0.061556	352.5	60.1083	95.27027	1.258959
10	3.368333	8.034167	0.161204	729	39.70121	113.9063	1.693838
11	3.371278	8.033861	0.076971	1353.2	106.5335	165.0244	1.244603
12	3.368111	8.031556	0.158719	1069.8	79.38558	84.90476	1.034178
13	3.365111	8.035222	0.101829	390.2	55.97628	68.45614	1.10587
14	3.365889	8.031778	0.129819	936	76.25998	94.54545	1.113453
15	3.36325	8.028111	0.093326	396	58.93333	72	1.105314
16	3.360306	8.028861	0.131515	242.8	38.01843	48.56	1.130166
17	3.358417	8.026	0.115625	732.1	76.97297	82.25843	1.033763
18	3.356833	8.022778	0.049135	1978.1	187.239	215.0109	1.071598
19	3.357556	8.018361	0.022152	1149.4	126.4019	410.5	1.802103
20	3.35925	8.014583	0.111308	1547.7	113.1996	122.8333	1.041683
21	3.355167	8.024417	0.032673	3372.3	309.119	333.8911	1.039297
22	3.358056	8.033639	0.150004	772.9	51.33192	100.3766	1.398371
23	3.355639	8.031278	0.174259	3213.6	94.68687	194.7636	1.434198
24	3.35575	8.027889	0.078879	2177.7	115.3664	239.3077	1.440252
25	3.358583	8.038278	0.133955	232.8	31.35376	55.42857	1.329603
26	3.361306	8.025722	0.126275	803.3	76.81656	82.81443	1.038307
27	3.346917	8.033389	0.133506	1008.7	86.13854	87.71304	1.009098
28	3.352222	8.033083	0.220014	2219.9	76.35872	132.1369	1.315475
29	3.353556	8.031722	0.089042	745	87.59943	95.51282	1.044192
30	3.349861	8.030889	0.140123	1631.6	103.4802	112.5241	1.042784
31	3.344611	8.028083	0.1	84.1	29	29	1
32	3.349056	8.035778	0.048279	4760	250.6242	393.3884	1.252851
33	3.344333	8.035694	0.128419	415.5	44.38596	72.89474	1.28152
34	3.340694	8.033028	0.391185	145.2	14.31546	25.92857	1.345819
35	3.340667	8.038	0.271429	53.2	14	14	1
36	3.346778	8.040194	0.135992	698.4	69.12151	74.29787	1.036768

The longitudinal conductance less than 0.1 S and above 0.7S were classified as poor and good protective capacity area respectively while longitudinal conductance values ranging between 0.1 S to 0.19 S were classified as zones of moderate and 0.2 S to 0.69 S as weak protective capacity Oladapo and Akintorinwa, (2007). It was observed that the central , northeastern cum northwestern and southern part of the study

area have moderate, weak and poor protective overburden capacity (Figure 11).Approximately it was observed that materials of weak/poor protective capacity underline the studied area.Groundwater potential in the study area was sectioned by transverse resistance unit (T).It varies from 53 to 4760 $\Omega \text{ m}^2$ with mean of 1164 $\Omega \text{ m}^2$. The maximum T value was noted at VES 32 while the minimum T

value was noted at VES 35(Fig.12). The southern , northern and the central part of the study area has values varying from 1000 $\Omega \text{ m}^2$ to 2000 $\Omega \text{ m}^2$, 500 $\Omega \text{ m}^2$ to 1000 $\Omega \text{ m}^2$ and 1000 $\Omega \text{ m}^2$ to 4 500 $\Omega \text{ m}^2$ respectively.

The map of total transverse conductance unit of the studied area was shown in Figure 12. Anisotropy coefficient varies from 1.0 to 1.8 in the study area. The minimum values are noted at VES 35 and VES 31 while the maximum values was noted at VES19 (Table 2). The lower the values of anisotropy coefficient ,the higher the aquifer potential Singh and Singh (1970) . High values anisotropy coefficient were noted around the eastern and northern part of the study area while decreasing values were recorded in the other parts indicating low aquifer potential zones (Figure 13). It was observed that the southern and central part of the study area is described by medium groundwater prospects .These areas agree with the regions with weak/poor protective layers which is the aquifer potential while total longitudinal conductance unit , transverse resistance unit and electric anisotropy values increases towards the southwestern part , reflecting moderate aquifer prospects. In such manner, the southwestern part of the studied portions are categorized as moderate groundwater prospects; while the northern and eastern part are categorized as area with poor groundwater prospect. groundwater-draining area.

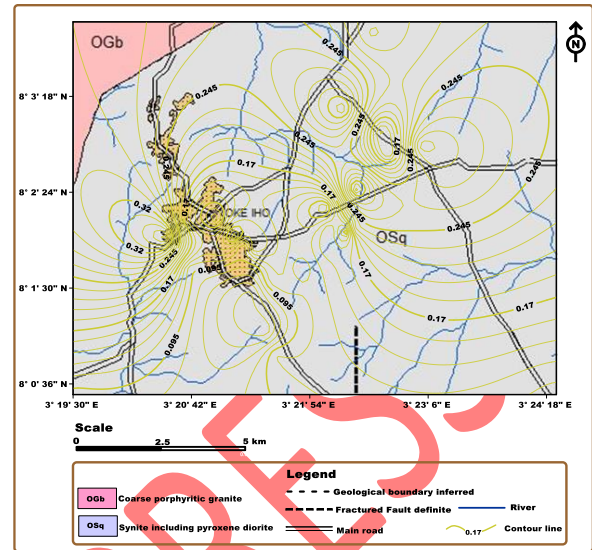


Figure 11: The Longitudinal Conductance Contour Map

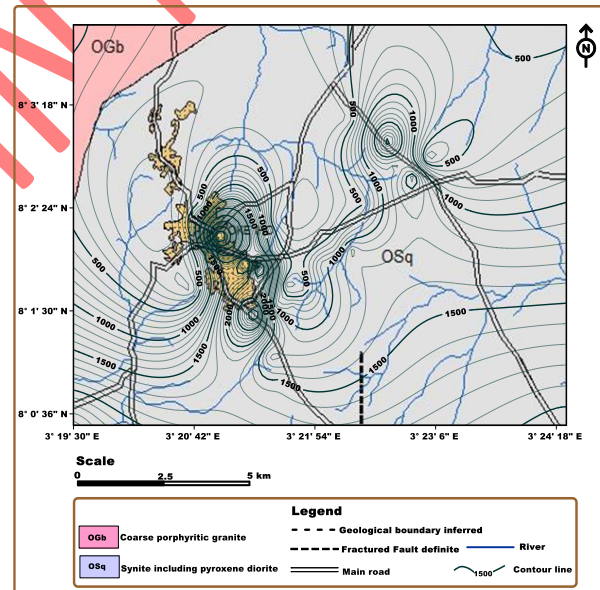


Figure 12: The Total Transverse Resistance Contour Map

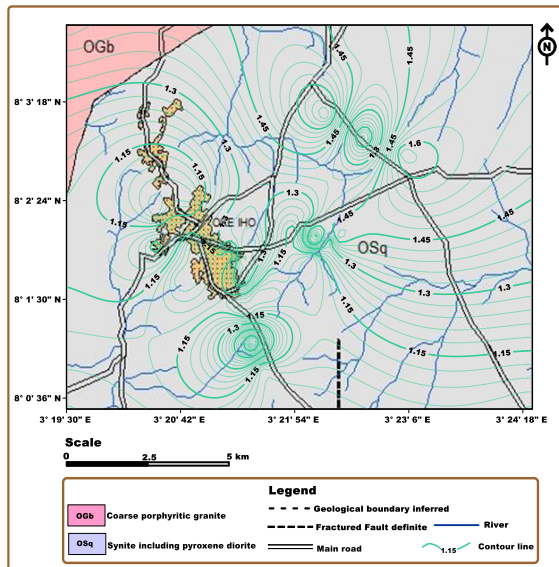


Figure 13: The Electrical Anisotropy Contour Map

CONCLUSIONS

Thirty six (36) vertical Electrical Sounding (VES) were surveyed in the built up areas of Okeiho town so as to monitor the successful exploration of groundwater. Typical curves corresponding to VES data include 'A', 'H', 'HKH' and 'KH'. The H-type is the most prevalent, constituting 67% of the curves observed while the 'A', 'KH' and 'HKH' types establish 22%, 8.3% and 2.7%. The thickness of the overburden ranges between 2.8 – 16.8 m; the weathered layer thickness range from 1.4 – 14.1 m; the basement resistivity ranges from 357 – 14760 Ωm ; the longitudinal conductance ranges from 0.022 – 0.39 Ω^{-1} ; the transverse resistance has values ranges from 53 – 4760 Ωm^2 , and the electrical anisotropy has values ranges from 1 to 1.8. The results of the analysis revealed the composition and nature of the subsurface lithologic units based on the integration of these aquifer parameters. The maps were combined to conclude generally that the northern, eastern and central portion are described by decrease in overburden

thickness, weathered resistivity layer, total longitudinal conductance, indicating low

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