

*Full Length Research Paper*

# Application of linear schlumberger configuration in delineation of formation strata and groundwater distribution in Ifon Ondo State, Nigeria

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**Linear Schlumberger configuration was employed to delineate the formation strata and groundwater distribution in Ifon Edo State, Nigeria with a view to identifying suitable sites for sitting viable boreholes for long term supply of potable water in the town and nearby communities. Ten vertical electrical soundings (VES) were made using Schlumberger array. Six soundings were made along Orin-Oyih river road and four around the quarry. The obtained field data were subjected to analysis and interpretation by conventional curve matching and computer iteration techniques, "the Resist" The results reveal that stations exhibit A, H and KH curve types mainly. Also sites along the river road have their fifth and sixth layers consisting of medium to coarse grain and gravely sand which is indicative of high water bearing media (aquifer) within 30 - 25 m while sites around the quarry consist of rocks that are far depth with no distinct aquifer. Moreover, while most sites along Orin-Oyih river road have formations of relatively high resistivities, the formations of sites very close to the river and around the quarry exhibit low resistivities.**

**Key words:** Schlumberger, Ifon, formation, computer, iteration, aquifer.

## INTRODUCTION

Ifon is a fast growing economic town because of its strategic position as a link town between the south and North and the emergence of numerous industries and manufacturing companies. It is therefore obvious that the demand for reliable and consistent water supply is high. Certainly the use of water is beyond mere domestic as virtually all the industries, companies and governmental establishments are in dire need of water. Such high demand can only be achieved through viable boreholes. The drilling of viable boreholes can be obtained by carrying out adequate geophysical studies to empirically ascertain areas or sites where long term steady supply can be achieved. The study in Ifon was therefore made using Schlumberger tool to determine high yield sites to ensure successful borehole sitting.

## GEOLOGY AND LOCATION OF STUDY AREA

Ondo State is located in the South-Western part of Nigeria. It lies between longitudes 4.00E and 6.00E and latitudes 5.45N and 8.15N. It covers an area of over 14, 600 square kilometres. It is bounded by Kwara, Kogi and Ekiti State in the North, Edo and Delta in the east, Ogun, Oyo and Oshun States in the west and in the South by the Atlantic Ocean. Over 60% of the State is underlain by basement migmatites, gneisses and granites which form rugged hills and rolling plains. Ondo State is blessed with natural resources which need to be explored. With moderate average temperature range of (25 - 30)°C almost all round the year and an array of exploitable economic mineral resources such as kaolin, bitumen, dimension stones, oil and gas, glass sand and limestone among others, it is a viable state for varieties of minerals. The area of study, Ifon is located in Ose local government area of Ondo State. It is within the southern 40% of

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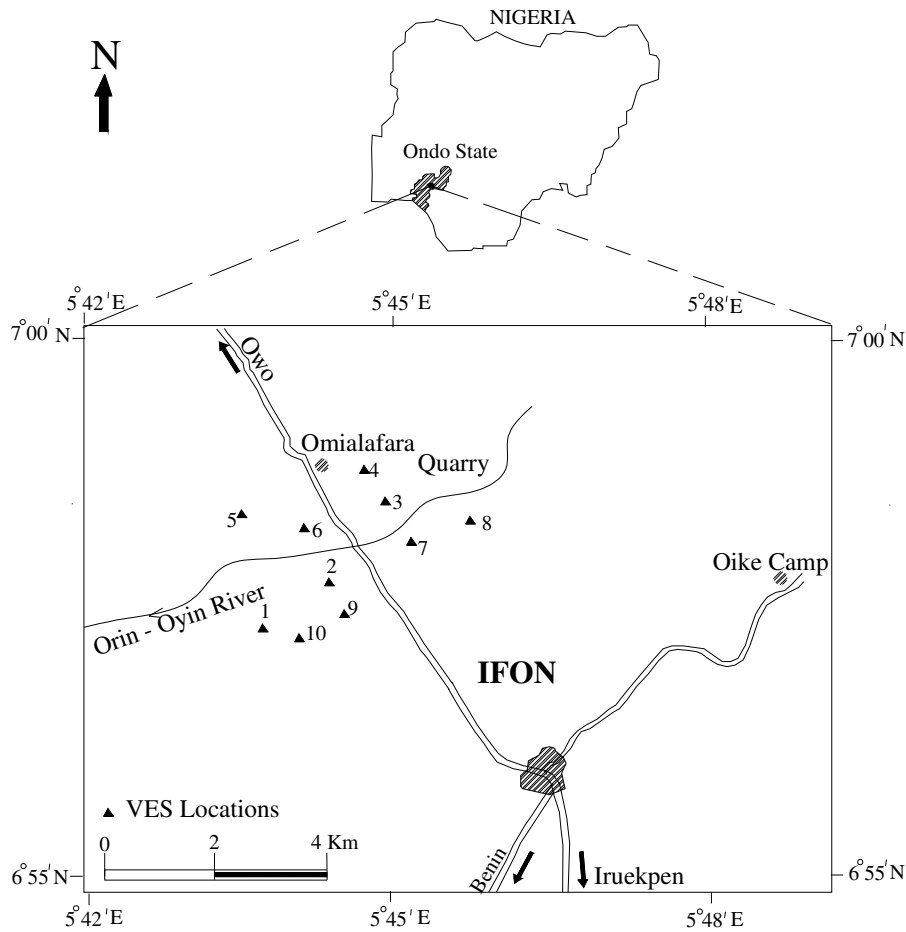


Figure 1. Map of IFON in Nigeria showing study locations.

the state underlain by flat lying sedimentary rocks consisting of sand, sandstones, shale, clays and limestone. It lies on the eastern end of the Dahomey sedimentary basin and particularly within latitude 5°40'E – 5°48'E and longitude 6°55'N – 7°00'N (Figure 1).

**MATERIALS AND METHODS**

The vertical electrical sounding was used to determine the electrical resistivities and depths of the subsurface layers with the aid of a sensitive ABEM Self Averaging System (SAS) 1000 terrameter. The Schlumberger array of electrical resistivity method was applied because of its relatively low cost of field operation, reduced logistics man power and reliability on application to formation and groundwater investigations. Ten VES stations were established and surveyed. Six along the Orin-Oyih River road, four around the Orin-Oyih quarry.

The resistivities of the different layers were measured using the terrameter which is capable of sending current into the earth subsurface through a pair of conducting electrodes, auto-matically computing and displaying the apparent resistivity of the subsurface structure under investigation Dobrin (1976). In the Wenner array the electrode spacing are equal (Figure 2) so that the potential

difference between the inner electrodes is computed using equation 1 from which the apparent resistivity of the formation is obtained (equation 2 and 3) (Keary and Brooks, 1991).

$$\nabla V = (V_c - V_D) = \frac{I}{2\pi} \left\{ \left( \frac{1}{r_1} - \frac{1}{r_2} \right) - \left( \frac{1}{R_1} - \frac{1}{R_2} \right) \right\} \dots \quad (1)$$

So that the resistivity of the formation by Griffith and King (1976) is

$$\rho = 2\pi \frac{\Delta V}{I} \left\{ \frac{1}{\left( \frac{1}{r_1} - \frac{1}{r_2} \right) - \left( \frac{1}{R_1} - \frac{1}{R_2} \right)} \right\} \dots \quad (2)$$

$$\rho \Rightarrow = 2\pi r \left\{ \frac{1}{\left( \frac{1}{r_1} - \frac{1}{r_2} \right) - \left( \frac{1}{R_1} - \frac{1}{R_2} \right)} \right\} \dots \quad (3)$$

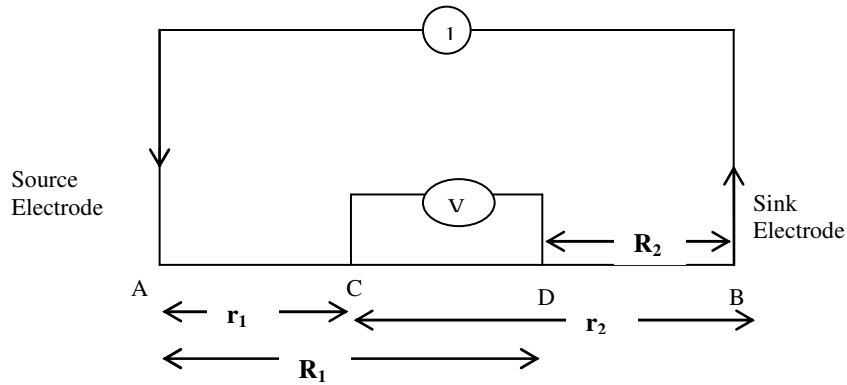


Figure 2. General four-electrode configuration for resistivity survey.

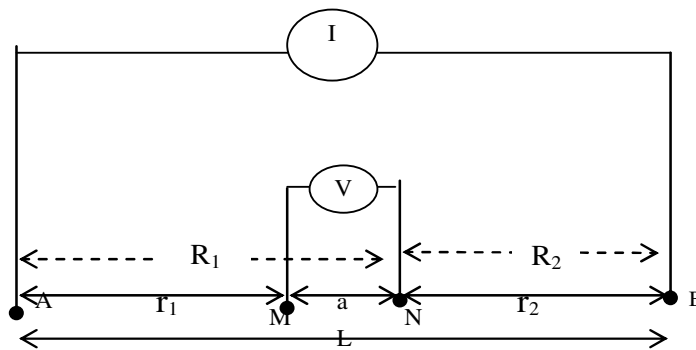


Figure 3. Schlumberger Field Electrode Configuration. Where “a” is the distance between the potential electrodes, L is the distance between current electrodes Okwueze and Ezeanyim (1985), Zohdy (1988).

In this study, however, the terrameter was connected to four linearly arranged electrodes which were hammered into the earth at appropriate intervals to ensure that current electrodes separation is much greater than the potential electrodes spacing as required in the Schlumberger array (Figure 3) Okolie et al. (2005).

Thus, in the Schlumberger array in which  $L \gg a$  equations 4 to 8 hold

$$r_1 = R_2 = \frac{L - a}{2} \dots\dots\dots(4a)$$

$$r_2 = R_1 = \frac{L + a}{2} \dots\dots\dots(4b)$$

Substituting into equation 2.47, we have

$$\rho_a = \frac{2\pi V}{I \left[ \frac{2}{L-a} - \frac{2}{L+a} - \left( \frac{2}{L+a} - \frac{2}{L-a} \right) \right]} \dots\dots\dots(5)$$

Therefore, apparent resistivity of the formation becomes

$$\rho_a = \frac{\pi V}{4I} \left[ \frac{L^2 - a^2}{a} \right] \dots\dots\dots(6)$$

With a Geometric factor, G given by

$$G = \frac{\pi}{4} \left[ \frac{L^2 - a^2}{a} \right] \dots\dots\dots(7)$$

This array was used to ensure deep penetration as the current electrodes separation increases geometrically for each successive reading with respect to the potential electrode spacing and for logistics of limited manpower and time management since the potential electrodes are seldom moved Okolie et al. (2007).

The apparent resistivity values obtained from the ABEM terrameter (Table 1) were plotted against the corresponding half current electrode spacing from which qualitative analysis of the subsurface was made Ako et al. (1986). This first stage analysis gave the resistivity of the top layer, the depth replacement of each formation and the curve type of each site. Lowrie (1997), showed that current penetration to a depth, Z is achieved with a total current spread L, as

$$L = [3Z] \dots\dots\dots(8a)$$

**Table 1.** Sample field data obtained in study area.

Current Electrode Separation AB/2 (m)	Potential Electrode Separation MN/2 (m)	Geometric factor (K) $K = \frac{\pi L^2}{2a}$	Smoothened Apparent Resistivity ( $\Omega$ m) VES 1	Smoothened Apparent resistivity ( $\Omega$ m) VES 2	Smoothened Apparent Resistivity ( $\Omega$ m) VES 3	Smoothened Apparent Resistivity ( $\Omega$ m) VES 4
1	0.5	6.28	200	222	410	185
2	0.5	25.13	296	256	386	160
3	0.5	56.55	348	357	371	138
4	0.5	100.53	400	482	330	120
6	0.5	226.19	480	627	250	102
6	1.0	113.10	480	611	250	102
9	1.0	201.06	550	925	222	110
12	1.0	452.39	631	1242	218	128
15	1.0	706.86	650	1652	230	149
15	2.0	353.43	650	1678	230	149
25	2.0	981.75	685	2974	320	255
32	2.0	1608.50	575	2556	380	330
40	2.0	2513.31	551	4463	440	400
40	5.0	1005.31	551	3372	440	400
65	5.0	2654.65	528	4997	660	600
100	5.0	6283.19	520	8386	800	800
100	10.0	3141.59	520	7186	600	895
150	10.0	7068.59	580		1000	895
200	10.0	12566.37	640		1200	
200	20.0	6283.19	640		1200	
250	20.0	9817.48	750		1400	
300	20.0	14137.17	900		1500	
350	20.0	19242.26			1600	

So that

$$z = \left[ \frac{L}{3} \right] \dots \dots \dots (8b)$$

**DATA ANALYSIS AND RESULTS**

The field data obtained were analyzed using qualitative and quantitative analysis.

The apparent resistivities from the field were plotted against half current electrode spacing ( $^{AB}/_2$ ) in the log-log graph and the curves obtained from the resistivity data were studied qualitatively in terms of their forms and character depicted in the pattern of resistivity variation with depth and attributed to the presence or absence of conducting bodies below the surface at the points of the observation of the anomalies Okwueze et al. (1988). The quantitative interpretations were made using partial curve matching technique in which the field curves are matched segment by segment with the appropriate master curve and corresponding auxiliary curves to obtain the resistivity replacement and the Depth Index (DI) and the reflection coefficient, Okolie et al. (2008). The apparent

resistivities and layer thicknesses of each location were then calculated from Equations 9 and 10.

$$\ell_n = \ell_{n-1} \times K_{n-1} \dots \dots \dots (9)$$

Where n = number of layers

$$h + \frac{1}{h_n} = DI_n \dots \dots \dots (10)$$

Where  $DI_n$  = depth index of  $n^{th}$  layer

$h_n$  = thickness of the  $n^{th}$  layer (Lowrie, 1997).

These obtained apparent resistivity and thickness values from equations 9 and 10 were used to carry out computer iteration to obtain final smoothened iterated field curves as in Figure 4 to 7.

**DISCUSSION**

The results reveal that stations along the river road

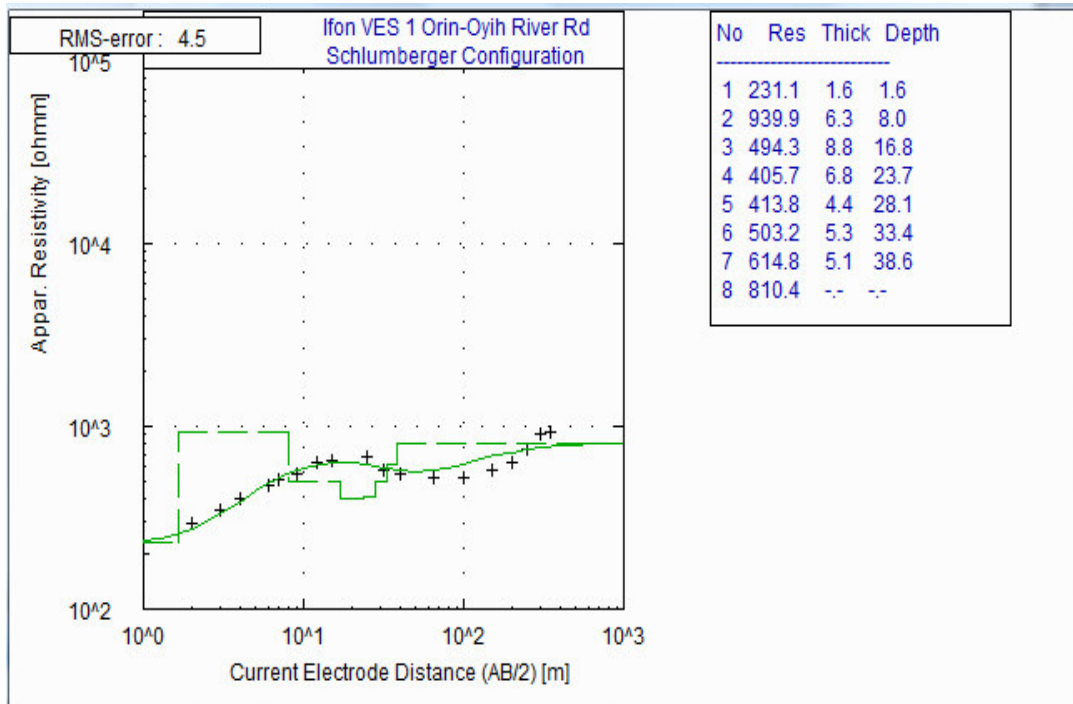


Figure 4. VES 1 Orin-Oyih River Road. KH- Curve.

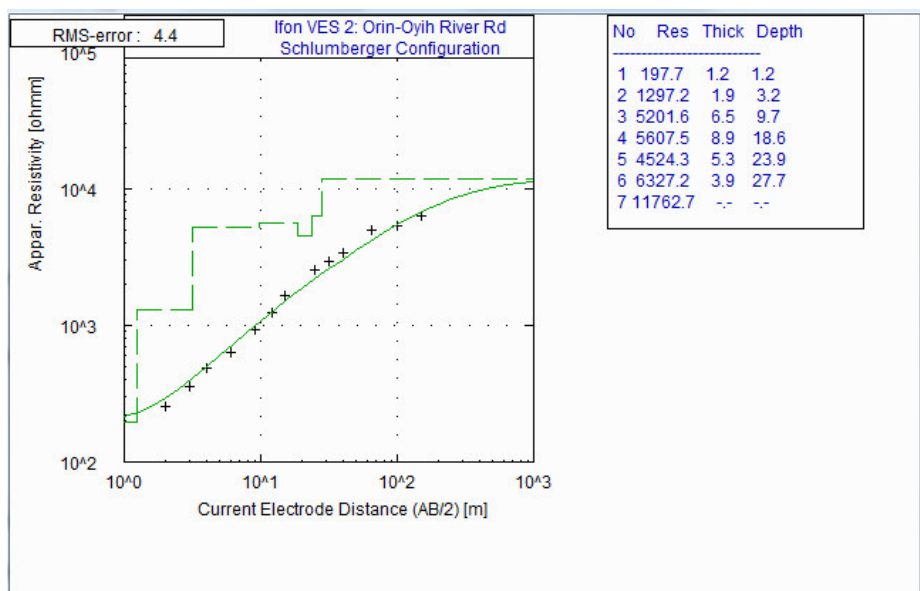


Figure 5. VES 2 Orin-Oyih River Road. A – Curve.

exhibit A and KH curve types while those around the quarry are H-curve type mainly Okwueze et al. (1988). Also sites along the river road have their fifth and sixth layers consisting of medium to coarse grain and gravely sand which is indicative of high water bearing media (aquifer) Oseji et al. (2005) while sites around the quarry consist of rocks that are far depth with no distinct aquifer.

There are cases of weathered rock overlying basement rock. Moreover, most sites along Orin-Oyih river road have formations of relatively high resistivities, while the formations of sites very close to the river and around the quarry exhibit low resistivities. In general, 6 to 8 layers were empirically distinguished and used to generate the geoelectric sections and borehole lithologies of the study

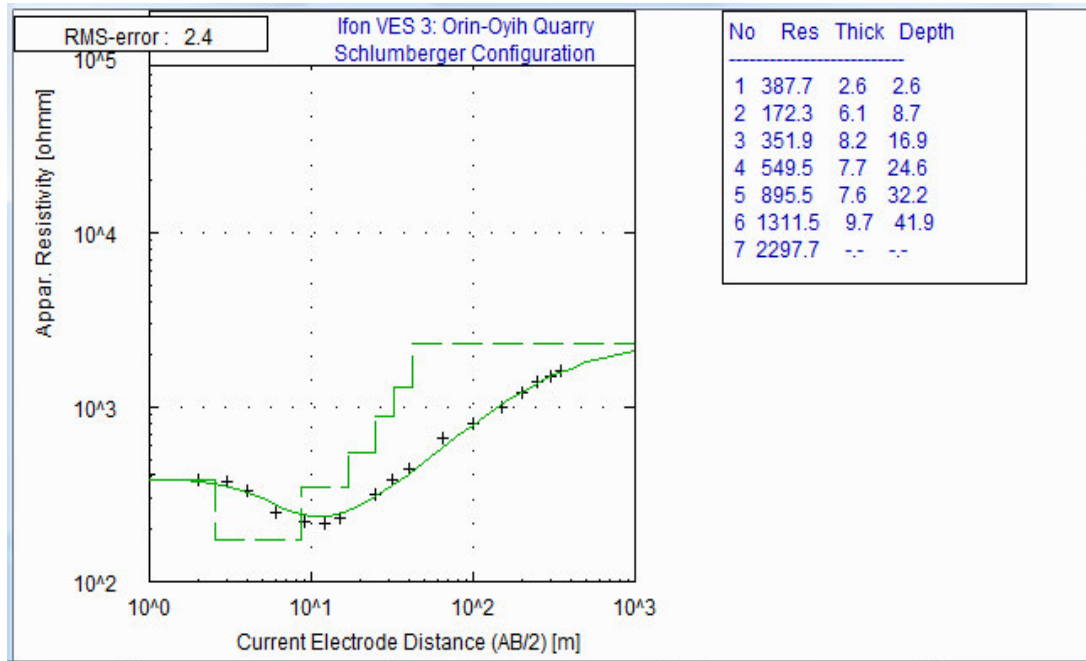


Figure 6. VES 3 Orin-Oyih Quarry. H – curve.

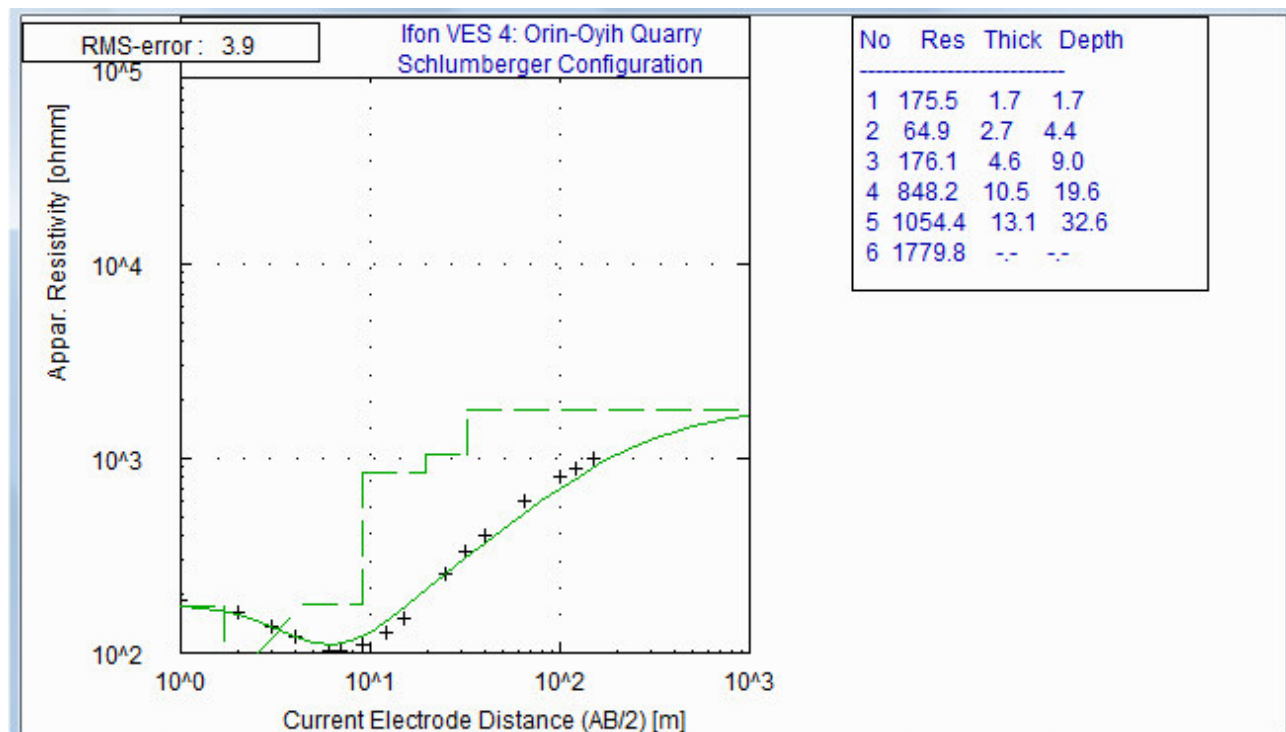
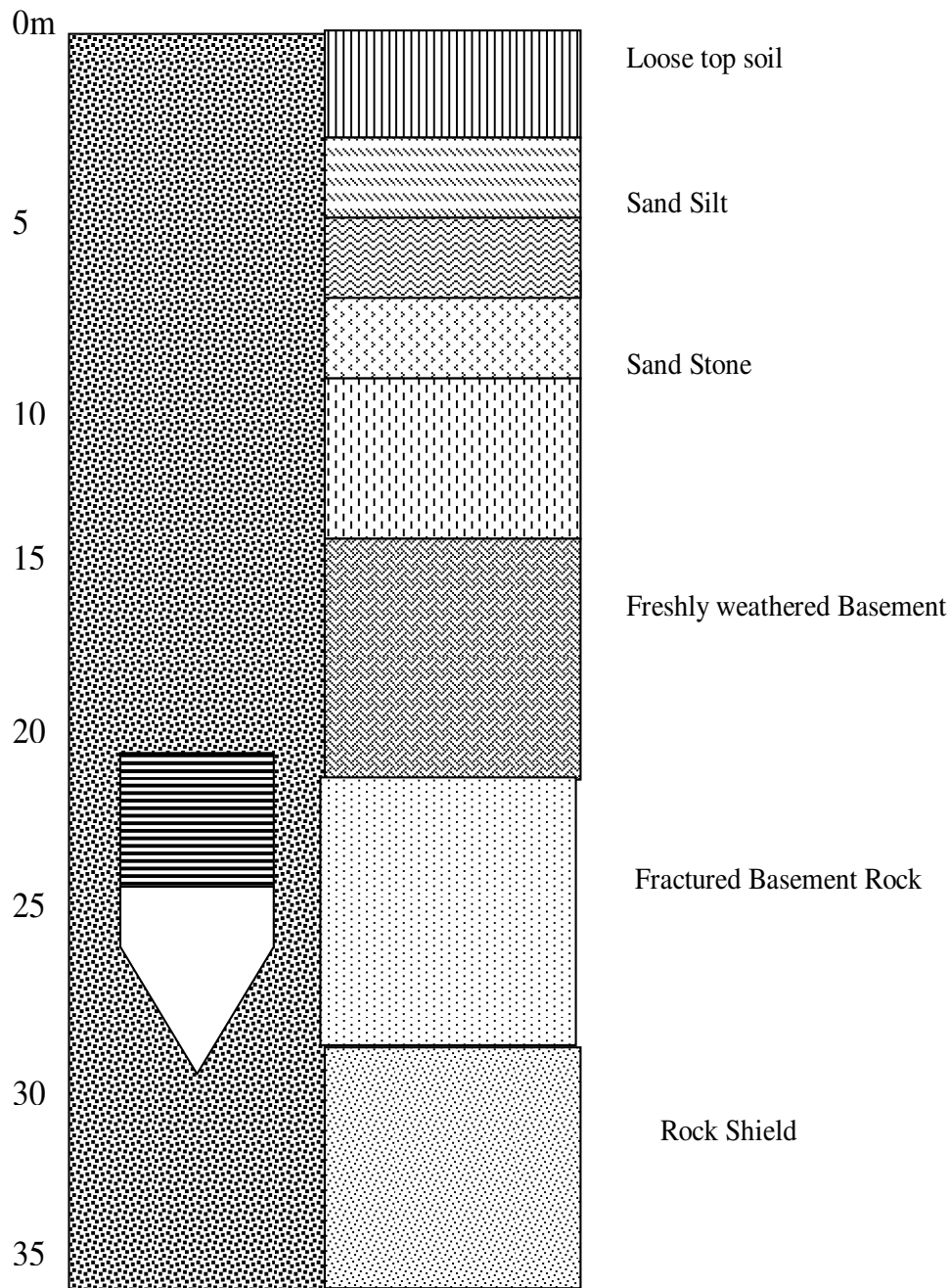


Figure 7. VES 4 Orin-Oyih Quarry. H-curve.

area (Figures 8 and 9). They were matched with existing wells and were found to be consistent. Table 2 shows the results from the analysis of sample sites in the study area.

**Conclusion**

Subsurface formation at Ifon is a blend of basement complex and sedimentary terrain. Three main curve types



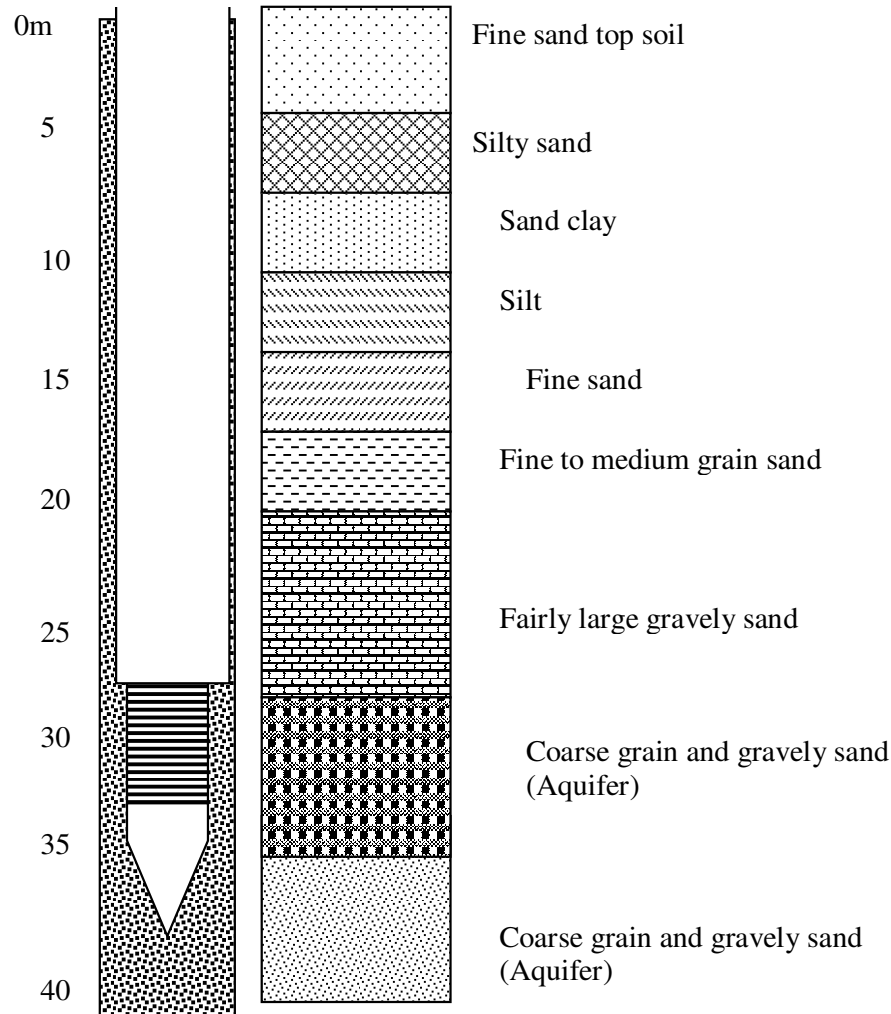
**Figure 8.** Goelectric section and Borehole Lithology for sites on Orin-Oyih Quarry, Ifon.

KH, H and A, are prominent. Sites along the river road have KH and A curve types while sites around the quarry exhibit H- curve type mainly. The most promising aquifers are within and closed to VES 1 with low resistivity due to the presence of clay and closeness to the river. These sites on the river road are indicative of high water bearing medium (aquifer) with medium to coarse grain sand at 30 – 35 m depth. Sites around the quarry consist of low resistive rocks that are far depth characteristic of basement complex with no distinct aquifer. It is therefore

recommended that for effective bore hole sitting in Ifon sites along and close to river Orin-Oyih should be the target.

#### **ACKNOWLEDGEMENT**

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**Figure 9.** Geoelectric section and Borehole Lithology for sites on Orin-Oyih river Road, Ifon.

**Table 2.** Interpretation of Results (Sample Sites).

VES Site	Layer	Resistivity ( $\Omega$ m)	Thickness (m)	Depth (m)	Formation Lithology	Curve Type
1	1	231	1.6	1.6	Fine top soil	KH
	2	940	6.3	8.0	Loose sand	
	3	494	8.8	16.8	Clayey sand	
	4	406	6.8	23.7	silty sand	
	5	414	4.4	28.1	Fine	
	6	503	5.3	33.4	Fine to medium grain sand	
	7	615	5.1	38.6	Coarse grained sand (Aquifer)	
	8	810	-----	-----	Gravely sand (Aquifer)	
2	1	198	1.2	1.2	Clayey top soil	A
	2	1297	1.9	3.2	Loose sand	
	3	5202	6.5	9.7	Fine grained sand	
	4	5608	8.9	18.6	Fine grained sand	
	5	4524	5.3	23.9	Basement rock	
	6	6327	3.9	27.7	Coarse grained sand (Aquifer)	
	7	11763	-----	-----	Gravely sand	

Table 2. Contd.

3	1	388	2.6	2.6	Loose top sand	
	2	172	6.1	8.7	Silty sand	
	3	352	8.2	16.9	Sand Stone	
	4	550	7.7	24.6	Freshly weathered basement	H
	5	896	7.6	32.2	Fractured basement rock	
	6	1312	9.7	41.9	Basement rock	
	7	2298	-----	-----	Unfractured Rock Shield	
4	1	176	1.7	1.7	Top clayey sand	
	2	65	2.7	4.4	Clay	
	3	176	4.6	9.0	Clayey sand	
	4	848	10.5	19.6	Medium to coarse grain sand	H
	5	1054	13.1	32.6	Fine crystalline basement	
	6	1780	-----	-----	Basement rock	

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