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Full Length Research Paper

Geoelectric investigation of the effect of heavy clay deposits on aquifer potential in Okpara waterside Delta State, Nigeria

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Groundwater is a valuable natural resource that is of immense importance to life. It is naturally stored in the pore spaces within soil compartments and between unconsolidated formations. Its availability and characteristics are greatly determined by the properties of the immediate geologic formations, landfills, toxic wastes and running surface waters etc. Surface geologic presentation of formations in Okpara waterside greatly suggests heavy clay deposits. It is therefore important to investigate the formation strata and its effect of heavy clay deposits on existing aquifer in Okpara waterside. Hence, eight vertical electrical sounds (VES) were made using Schlumberger array to empirically delineate the formation strata and ascertain its effect on existing aquifers. The results show that the formations in Okpara waterside have low resistivities with A, HA and K – curve types and are predominantly compact clay to a depth of 17 m. Viable aquifer is confined and within 27 to 35 m. Its bed consists of medium grain sand, sandy clay and impermeable clay. There is also clear evidence of patched aquifers and water bearing formations at about 10 m and near surface. The aquifer at Okpara Waterside is relatively of good quality due to high level of filtering from compact clay and low levels of domestic and industrial activities and so highly recommended for domestic, commercial and industrial utilities.

Key words: Schlumberger, Okpara Waterside, aquifer characteristic, heavy clay, geologic formations.

INTRODUCTION

Groundwater is a natural resource that is of immense importance to life. Its characteristics are greatly determined by the properties of the immediate geologic formations Milsom (1992). This is evident in the fact that groundwater is naturally stored in the pore spaces within soil compartments and between unconsolidated formations. Okpara Waterside is a town with heavy clay deposits probably because of its nearness to the course of continuously flowing River Ethiope. Aquifer characteristics are greatly influenced by formation strata and terrain type (Akpokodje and Etu-Efeotor (1987).

Hence, the acquisition of viable deep water wells is mainly dependent on adequate and reliable empirical knowledge of the geology of the area and the depth of aquifer Okolie et al. (2005). Since the demand for potable water for both domestic and commercial use is remarkably on the increase in Okpara Waterside it is important that a geophysical study of the formation of Okpara Waterside be made to ascertain its formation strata and aquifer characteristics for the purpose of determining the aquifer characteristics and sitting viable wells. Thus, eight sounding sites were randomly selected in Okpara Waterside where vertical electrical sounds (VES) were made using signal averaging system (SAS) 1000 terrameter which is capable of displaying the computed resistivity of the formation under investigation.

LOCATION OF STUDY AREA

Okpara is situated near Eku. It is about seven kilometres west of Eku in Ethiope East Local Government Area. It is within Latitude 5°42'N and 5°48'N and Longitude 5°42'E and 5°45'E (Figure 1). It stretches from the bank of River

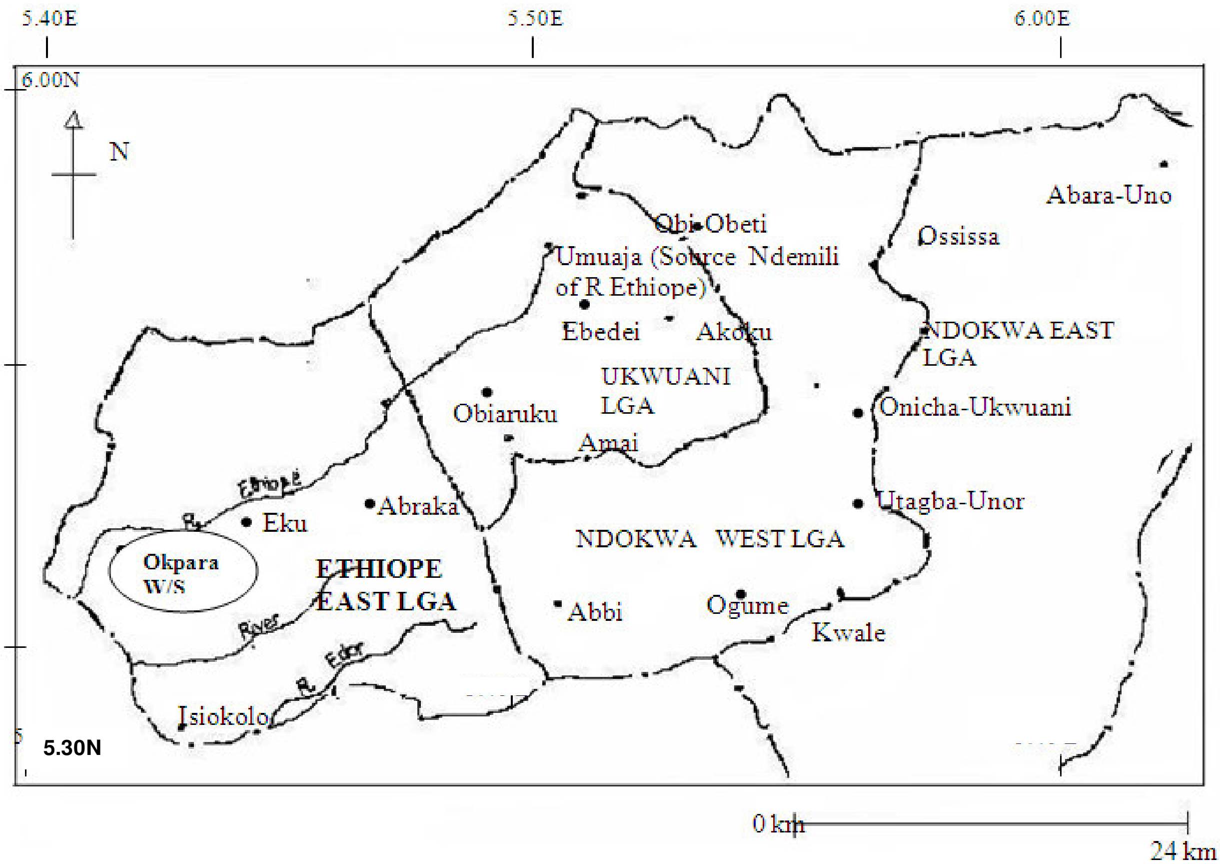


Figure 1. Location map of Okpara Waterside.

Ethiope to a few kilometres into the inter-land. It is within the thick forest region of the country as it experiences heavy rainfall for over eight months of the year. There exist a number of hand dug wells that fill to the brim for most parts of the year. This is indicative of the presence of heavy clay deposits. Its geological presentation shows that it is in the Bini formation.

MATERIALS AND METHODS

A general survey of the area of study was first made from which stations and sites choices were determined. Eight sites were chosen and sounded in Okpara Waterside using VES and applying Schlumberger array. Schlumberger array was a choice array for the study because of its high degree of penetration, accuracy, reliability and the use of limited work force Okwueze et al. (1991). In using the Schlumberger array, four electrodes were spread linearly with the potential electrodes positioned closed to the station and the current electrodes at the end of spread. Each station was located at the centre of the spread so that one of the electrodes acts as the current source while the other acts as the sink Rehinhard (1974). Each station was sounded using a Signal Averaging System (SAS) 1000 terrameter which recorded both voltage and current values of the subsurface, stacked the results automatically, computed the apparent resistivities of the subsurface under investigation in real time and displayed the mean resistivity value digitally. Each mean resistivity value was then recorded as the apparent resistivity. In each station several apparent resistivity values were obtained by expanding the current electrodes spacing progressively from (1.00 m to 681) x 2 and tabulated as in (Table 1). The current electrodes spacing was increased after each reading while the potential electrodes spacing was increased only when deemed necessary and controlled by the relation $^{AB}/_{2} \geq {}^{5MN}/_{2}$ as required by Schlumberger array Okolie et al. (2010).

The theory obtain from first principle holds that a potential difference is established between the two inner electrodes in Figure 2 (Dobrin, 1960). Thus, by Atakpo, (2009), the potential difference ($V_c - V_D$) between the two inner electrodes measured by the in built terrameteric voltmeter connected between electrode C and D is:

$$\nabla V = (V_c - V_D) = \varrho \frac{I}{2\pi}\left\{\left(\frac{1}{r_1} - \frac{1}{r_2}\right) - \{\frac{1}{R_1} - \frac{1}{R_2}\}\right\} \qquad \text{..................... ....1}$$

and the subsurface resistivity is

$$\Rightarrow \varrho = 2\pi r\left\{\frac{1}{\left({}^{1}/_{r_1} - {}^{1}/_{r_2} \right) - \left(\frac{1}{R_1} - \frac{1}{R_2}\right)}\right\} \qquad \text{..2}$$

Table 1. Sample field data (apparent resistivities in Okpara Waterside).

MN/2 (m)	AB/2 (m)	VES 1 (Ωm)	VES 2 (Ωm)	VES 3 (Ωm)	VES 4 (Ωm)
0.2	1.00	194	182	188	297
	1.47	196	219	127	120
	2.15	156	212	167	147
	3.16	120	215	192	175
2/1.0	4.64	135	211	194	190
	6.81	129	197	198	210
1.0/3.0	10.00	148	226	214	264
	14.70	158	224	263	319
	21.50	160	213	283	338
	31.60	189	267	327	358
3.0/8.0	46.40	230	302	361	389
	68.10	266	349	386	410
8/16	100.00	271	397	417	429
	147.00	401	402	438	461
16/30	215.00	553	510	480	380
30/50	316.00	512	496	773	391
60	464.00	479	421	581	364
60/80	681.00	360	372	537	268

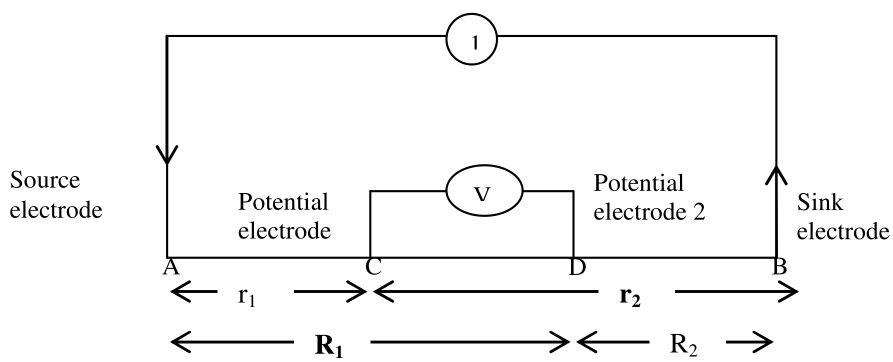


Figure 2. General four-electrode configuration for VES survey.

Applying Schlumberger array (Figure 3), the potential difference between the inner electrodes P_1 and P_2 by Okolie et al. (2005) will be given as:

$$dV = V_{P1} - V_{P2} = \frac{\varrho}{2\pi}\left\{\frac{1}{a - \frac{b}{2}} - \frac{2}{a + \frac{b}{2}} + \frac{1}{a - \frac{b}{2}}\right\} \quad \ldots\ldots\ldots\ldots \quad 3$$

$$= \varrho\frac{I}{2\pi}\left\{\frac{2}{a - \frac{b}{2}} - \frac{2}{a + \frac{b}{2}}\right\} \quad \ldots\ldots\ldots\ldots \quad 4$$

$$= \varrho\frac{I}{2\pi}\left(\frac{8b}{4a^2 - b^2}\right) \quad \ldots\ldots\ldots\ldots \quad 5$$

And by Okolie (2009) Schlumberger array geometric factor, is given as:

$$G_s = \frac{2\pi}{8b}\left(4a^2 - b\right) \quad \ldots\ldots\ldots\ldots \quad 6$$

An increase in the current electrode spacing makes for deeper penetration of current into the earth and consequently deeper structural responses and investigation while an increase in the potential electrode spacing often increases the potential difference of the subsurface material under investigation. By increasing the potential electrodes spacing, the resistance recorded by the terramenter may change. This observed change in resistance does not actually change the resistivity of the particular structure because of the moderating Geometric Factor.

With the ABEM (SAS) 1000 terrameter, the generated geometric factor is instrumentally computed and applied to obtain the displayed apparent resistivity. The interpretation of resistivity field data was done by both qualitative and quantitative analyses. The apparent resistivity values were then plotted against half electrode spacing in a 3- decade bi-log graph (Figures 4 to 7) and used to determine the curve types qualitatively and estimate the approximate number of layers which are based on the subsurface resistivity combinations Ujuanbi and Asokhia (2000).

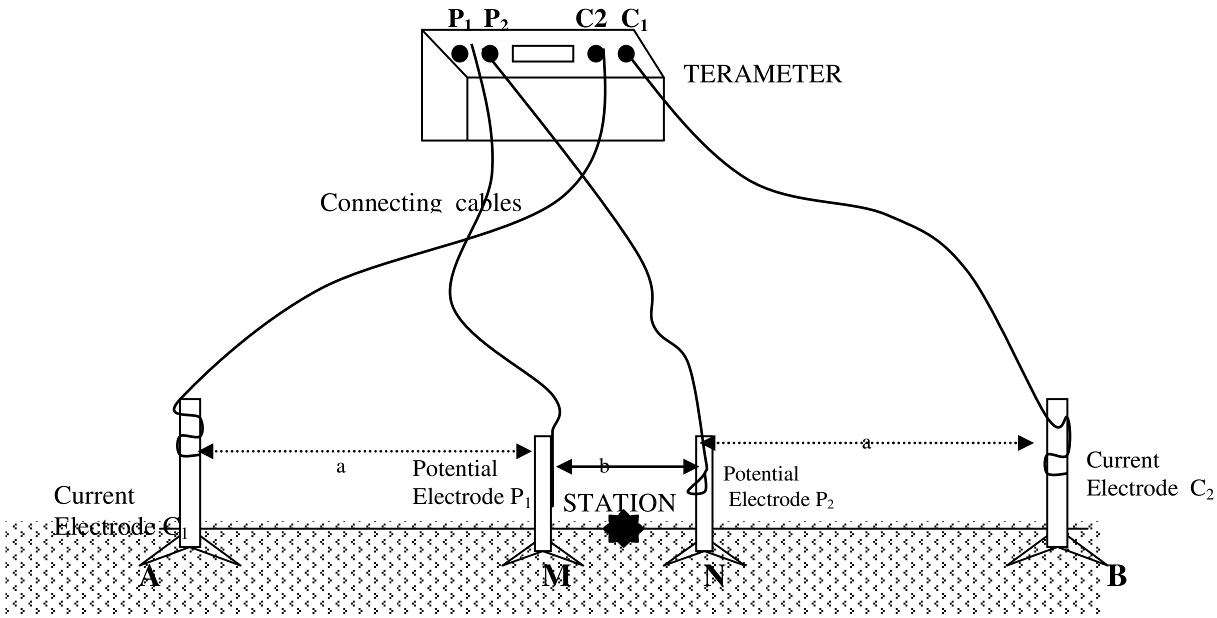


Figure 3. VES field layout for Schlumberger array.

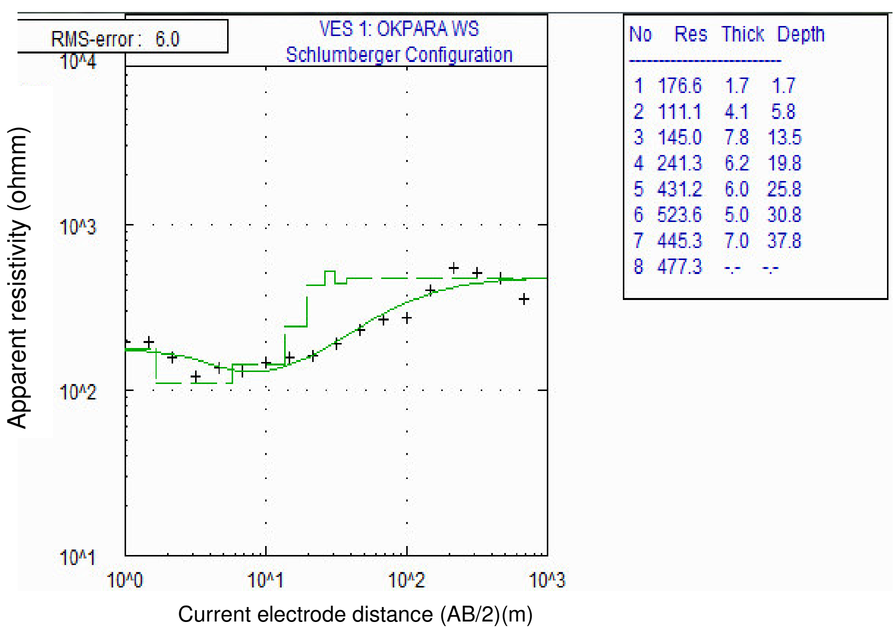


Figure 4. VES 1: Sample site with HA- type curve in Okpara Waterside.

RESULTS AND DISCUSSION

The results of qualitative analysis shows that A, HA, and K- curve types exist in Okpara Waterside with marked evidence of low resistive zones (Figures 4 to 7). The implication of these existing curve types in the study area is that resistivity increases with increasing depth (Okwueze, 1996). Clay has naturally high conductivity. Thus, the analysis of the obtained low resistivities of 150 to 250 ohm-m indicate that subsurface geologic profile in Okpara Waterside consists of heavy clay deposits. The analysis shows that the subsurface presentation at Okpara is predominantly compact clay from near surface to about 17 m (Figure 8). This clay prevents water and

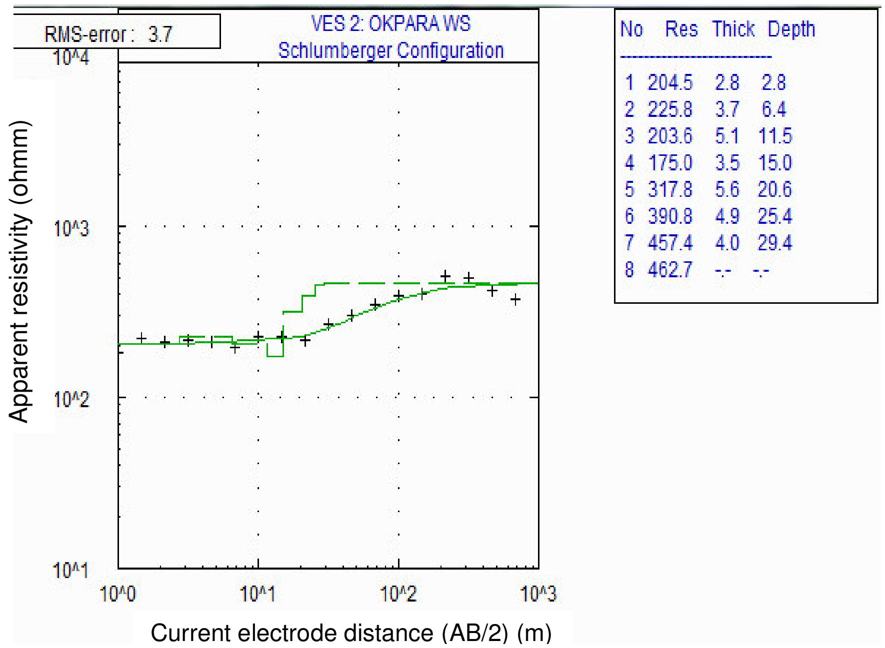


Figure 5. VES 2: Sample site with A-curve type in Okpara Waterside.

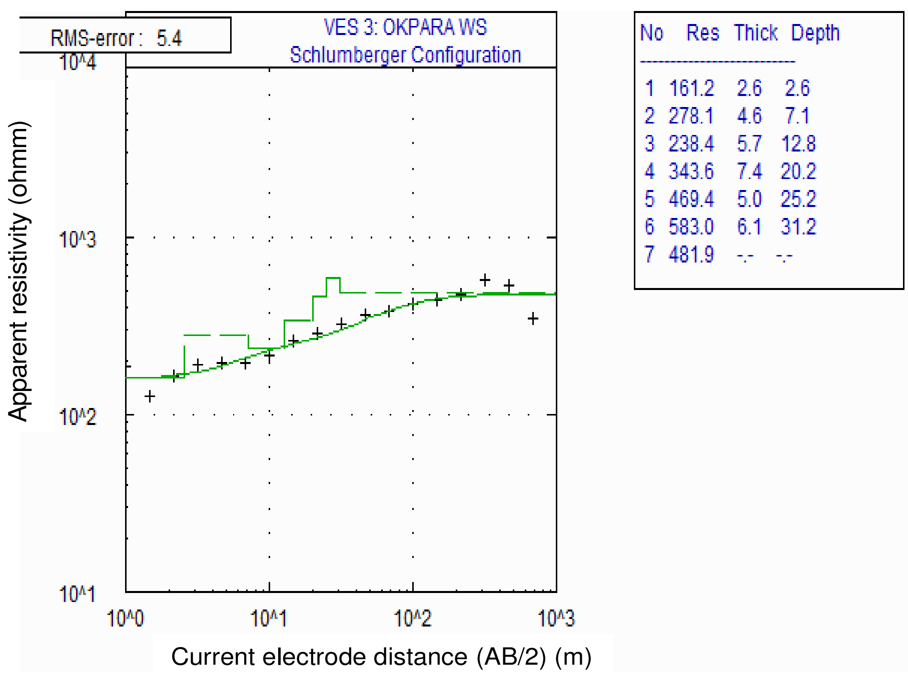


Figure 6. VES 3: Sample site with A-curve type in Okpara Waterside.

waste peculations through it. Thus, for most part of the year the low land areas are water logged with evidence of patches of ponds and slow running streams. This explains the existence of numerous hand-dug wells in Okpara Waterside. Most of these wells are filled to brim almost all the year round as their beds are cemented with thick clay deposits. Similarly, the aquifer is confined since its bed consists of medium grain sand, sandy clay and

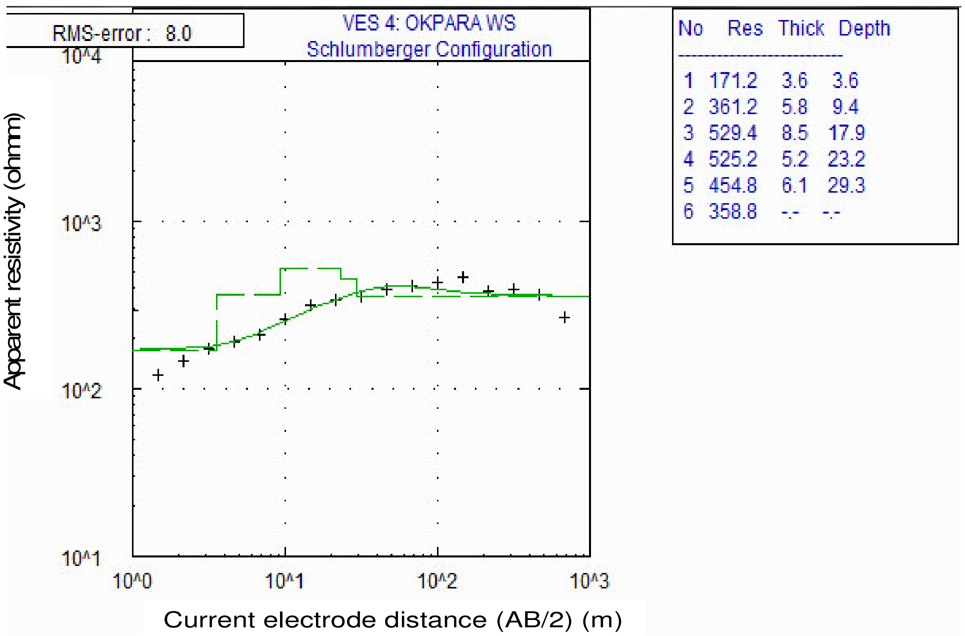
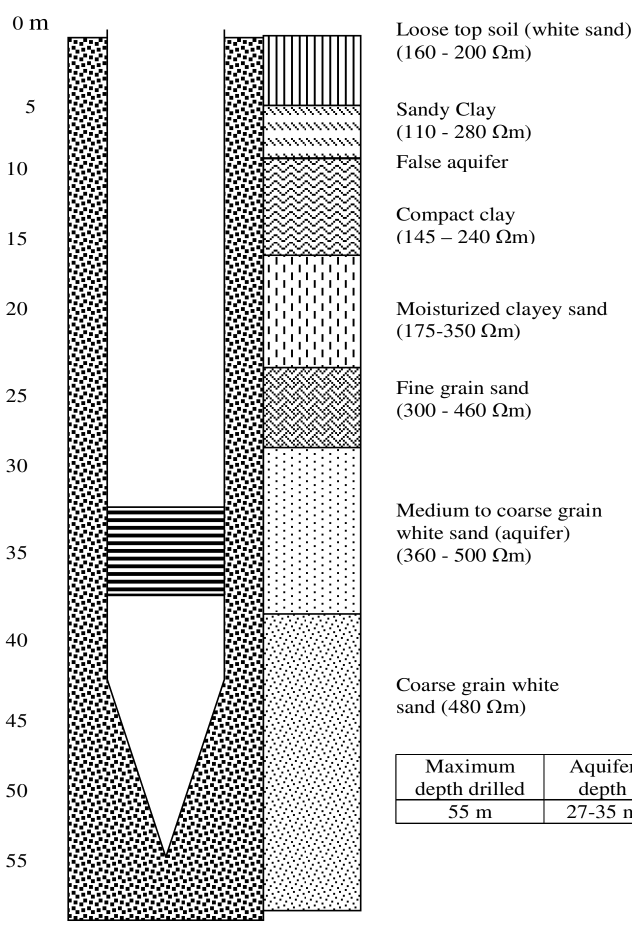


Figure 7. VES 4: Sample site with K-curve type in Okpara Waterside.



Maximum depth drilled	Aquifer depth	Static water level
55 m	27-35 m	20 m

Figure 8. Formation strata and well lithology of Okpara Waterside.

impermeable clay. The aquifer is within 27 to 35 m (Figure 8). There is however, evidence of patch aquifers and water bearing formations at near surface and static water level is within 20 m in the study town. The study shows that the aquifer at Okpara is relatively of good quality due to high level of filtering from compact clay and low levels of domestic and industrial activities. Moreover, the presence of the swift flowing River Ethiope does not allow peculation of toxic and other forms of waste into the subsurface and aquifer. The analysis and results are in consonance with direct well logs of existing wells.

Conclusion

In conclusion, Okpara Waterside is a town with heavy clay deposits probably because of its nearness to the course of River Ethiope, presence of thick forest heavy rainfall for most part of the year and existence of patches of low land. Viable aquifer is confined and within 27 to 35 m. Its bed consists of medium grain sand, sandy clay and impermeable clay. There is also clear evidence of patched aquifers and water bearing formations at about 10 m and near surface. Static water level is about 20 m. The aquifer at Okpara is relatively of good quality due to high level filtering from compact clay and low levels of domestic and industrial activities. It is therefore highly recommended for domestic, commercial and industrial utilities. The derived lithology of Okpara Waterside is in consonance with direct well log of existing wells.

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