SUBSURFACE GEOELECTRICAL INVESTIGATION OF GROUNDWATER POTENTIAL IN IGIEDUMA, SOUTH – SOUTHERN NIGERIA.

BY

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Abstract

Geoelectrical survey involving the use of resistivity sounding method was recently carried out to investigate the groundwater potential in *Igieduma.* Geographically the study area lies within latitude $5^0 55' N$ and $7^0 00' N$ and longitude $5^0 00' E$ and $6^0 40' E$. Three vertical electrical sounding (VES) locations were visited in the study area, VES 22(A, B & C). The study was carried out using the ABEM SAS 1000 terrameter. Vertical Electrical Sounding was carried out using the Schlumberger electrode configuration and the WinResist method of interpretation was adopted. The interpretation of the resistivity curves over the study area within geologic terrain often referred to as sedimentary environment indicates that the area have groundwater potential. A correlation of the results with the lithologic log from boreholes showed a total depth of 250.90m, 272.49m and 239.50m respectively at VES 22A,VES 22B and VES 22C.

Keywords: geoelectrical method, resistivity, subsurface, groundwater potential, Igieduma

1.0 Introduction

Groundwater is characterized by a certain number of parameters which are determined by geophysical methods such as electrical resistivity methods, seismic methods, magnetic methods, gravity methods etc. But for this research work, the application of electrical resistivity survey method was used. The most usual parameters are the porosity, the permeability, the transmissivity and the conductivity. Electrical resistivity method in geophysical exploration for groundwater in a sedimentary environment has proven reliable [1]. Records show that the depths of aquifers differ from place to place because of variation in geo-thermal and geo-structural occurrence [2, 3].

The geology of the study area reveals that the entire area is underlain by sedimentary rocks. These rocks are of ages between Paleocene to recent. The sedimentary rock contains about 90 percent of sandstone and shale intercalation. It is coarse grained locally, fine grained in some areas, poorly sorted, sub- angular to well rounded and bears lignite streaks and wood fragment [4]. The sedimentary rock of the study area constitutes the Benin formation. This has an important groundwater reservoir. Asokhia [5], used a simple computer iteration technique for the interpretation of vertical electrical sounding. A preliminary finding of the groundwater resource potentials from a regional geoelectric survey of the Obudu basement area of Nigeria has been done [3]. Oyedele, [6] carried out a hydrogeophysical and hydrogeochemical investigation of groundwater quality in some parts of Lagos, Nigeria.

Reinhard, [7] carried out a combined geo-electrical and Drill-hole investigation for detecting fresh-water aquifers in Northern Western Missouri. Application of surface geophysics to groundwater investigation has been carried out by Zohdy et al [8]. Zohdy [9] did some work on automatic interpretation of Schlumberger sounding curves. Alile [10] carried out geophysical investigation for underground water in the Southern and Central Senatorial Districts of Edo State of Nigeria. This was done using the Vertical Electrical Sounding (VES) and seismic refraction methods. In this work, subsurface geoelectrical investigation of groundwater potential in Igieduma was carried out so as to provide geophysical information of the subsurface on the depth to the aquifer layer. The subsurface information will be relevant in the development of an effective water scheme for the area and other areas underlain by the formation.

2.0 Resistivity Theory

The electrical resistivity method is one of the most useful techniques in ground water hydrology exploration because the resistivity of a rock is very sensitive to its water content. In turn, the resistivity of water is very sensitive to its ionic content. In general, it is able to map different stratigraphic units in a geologic section as long as the units have a resistivity contrast. This is also connected to rock porosity and fraction of water saturation of the pore spaces.

Essentially, the basis of all resistivity sounding is a differential equation in electric potential that reduces to Laplace's equation for isotropic media. Hence, particular solution for electric potential and apparent resistivity may be derived for a number of model representations of the earth. The most common model is a horizontally stratified earth of homogenous and isotropic layers

The inverse problem of converting field measurement into a geoelectric section is invariably solved in terms of an earth model of horizontal layers. Sometimes, however, a field sounding suggests departures from such a simple model and allowances, usually qualitative may be made during interpretation. Traditional methods of qualitative interpretation are examined and are shown to be outdated; emphasis is placed on computer based methods of analysis.

Maillet [11], expounded the fundamental theory behind the resistivity method and the theory has been adequately covered in the literature [12, 13 and 14]. Feynman et al [15] expressed the Maxwell's equations for earth materials having dielectric and magnetic properties as:

$\nabla \times \underline{H} = \underline{J} + \partial D / \partial t$ -- (1)

$\nabla \times E = -\partial B / \partial t$ --- (2)

$\nabla \cdot \underline{B} = 0$ -- (3)

$\nabla \cdot \underline{D} = Q$ -- (4)

Where H = magnetic field strength.

$$\therefore H = \frac{\underline{B} - \mu_0 \underline{M}}{\mu_0}$$

$\underline{B}$ = Magnetic flux density, μ_0 = Permeability of free space, $\underline{M}$ = Magnetization, $\underline{J}$ = Current density, $\underline{D}$ = Electric displacement = $\varepsilon_0 \underline{E} + \underline{P}$,
ε_0 = Permittivity of free space, $\underline{E}$ = Electric field strength, $\underline{P}$ = Polarization, t = time and Q = electric charge density.

The equation of continuity is obtained by taking the divergence of equation (1)

i.e. $\nabla \cdot \nabla \times H = \nabla \cdot J + \nabla \cdot \partial D / \partial t$

But the divergence of a curl is zero

$$\nabla \cdot J = -\nabla \cdot \partial D / \partial t$$

$\Rightarrow \nabla \cdot J = -\frac{\partial}{\partial t} \nabla \cdot D$ -- (5)

This is so because the order of derivatives with respect to co-ordinate and time can be reversed. Substituting equation (4) into equation (5) we have

$\nabla \cdot \underline{J} = -\frac{\partial}{\partial t} Q$ --- (6)

The resistivity method operates in the absence of a field of induction and is based on observations of an electric field maintained by direct current. However, for source free regions of the earth, equation (2) and (6) becomes:

$\nabla \times \underline{E} = 0$ -- (7)

$\nabla \cdot \underline{J} = 0$ -- (8)

However, Ohm's law provides the relationship between E and J and it states that the current density is proportional to the electric field strength:

$J = \sigma E$

This proportionality constant is called conductivity.

Equation (7) suggests that the electric field strength may be expressed as the gradient of a scalar potential (V):

$\underline{E} = -\nabla V$ --- (9)

It must be noted that for an isotropic medium, the conductivity will be a scalar quantity so that J and E will be in the same direction. In general, J and E are not in the same direction because conduction might be easier in one direction rather than another.

Such a medium is said to be anisotropic and the conductivity is a tensor of second rank, the subscripts i and j may be any of the x, y or z spatial directions in a rectangular co-ordinate system. Ohm's law becomes:

$\underline{J} = \sigma_{rj}\underline{E}$ Or, more fully:

$$\begin{bmatrix} J_x \\ J_y \\ J_z \end{bmatrix} = \begin{bmatrix} \sigma_{xx} & \sigma_{xy} & \sigma_{xz} \\ \sigma_{yx} & \sigma_{yy} & \sigma_{yz} \\ \sigma_{zx} & \sigma_{zy} & \sigma_{zz} \end{bmatrix} \begin{bmatrix} E_x \\ E_y \\ E_z \end{bmatrix} \text{-- (10)}$$

Combining equations (8), (9) and (10) gives a differential equation which is basis of all resistivity prospecting with direct current:

$\nabla \sigma_{rj} \nabla V = 0$ -- (11)

In this isotropic case where the conductivity at a point in the ground is independent of direction, equation (11) reduces to Laplace's equation:

$\nabla^2 \nabla V = 0$ --- (12)

Solution to equations (11) and (12) may be developed for a particular model of the earth by selecting a co-ordinate system to match the geometry of the model and by imposing appropriate boundary conditions; several popular models will be considered in the following section.

3.0 Methodology

In this research work, the Schlumberger array configuration was adopted. The method responds more favourably to measurable parameters that can easily distinguish the aquifer from other formations. The field equipment for this study is the ABEM Terrameter SAS 1000. In interpreting the data we have that first, to classify the observed apparent resistivity curves into types. This classification was primarily made on the basis of the shapes of the curves, but at the same time it was related to the geological situation in the subsurface. The shapes of a VES curve depend on the number of layers in the subsurface and the thickness of each layer. Model parameters estimated from the data were used for computer iterative operations to interpret the data. In the iterative interpretation method used in this research, the field data were compared with the data derived from a layer model obtained by curve matching. The agreement between the two sets of data was unsatisfactory, then the parameters of the layer model were adjusted been a standard way of carrying it out. This procedure was repeated until a sufficient agreement between the model data and the field data were obtained.

4.0 Results, Analysis and Discussion

The results are presented as VES 22A, VES 22B and VES 22C as in Figure 4.1 and Figure 4.2 respectively. They represent the respective VES locations in the study area.

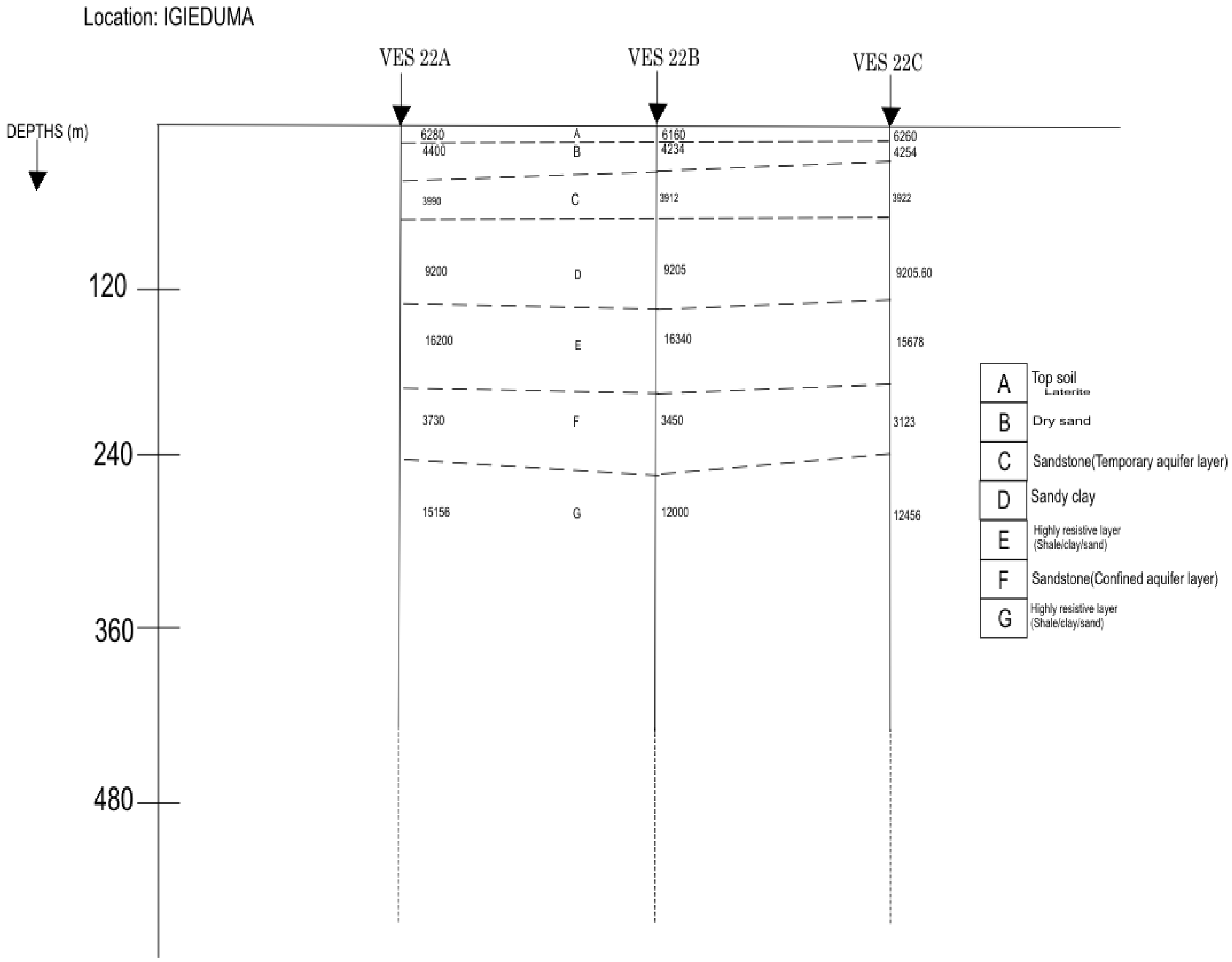

Figure 4.1: Geoelectric sections of the location at *Igieduma.*

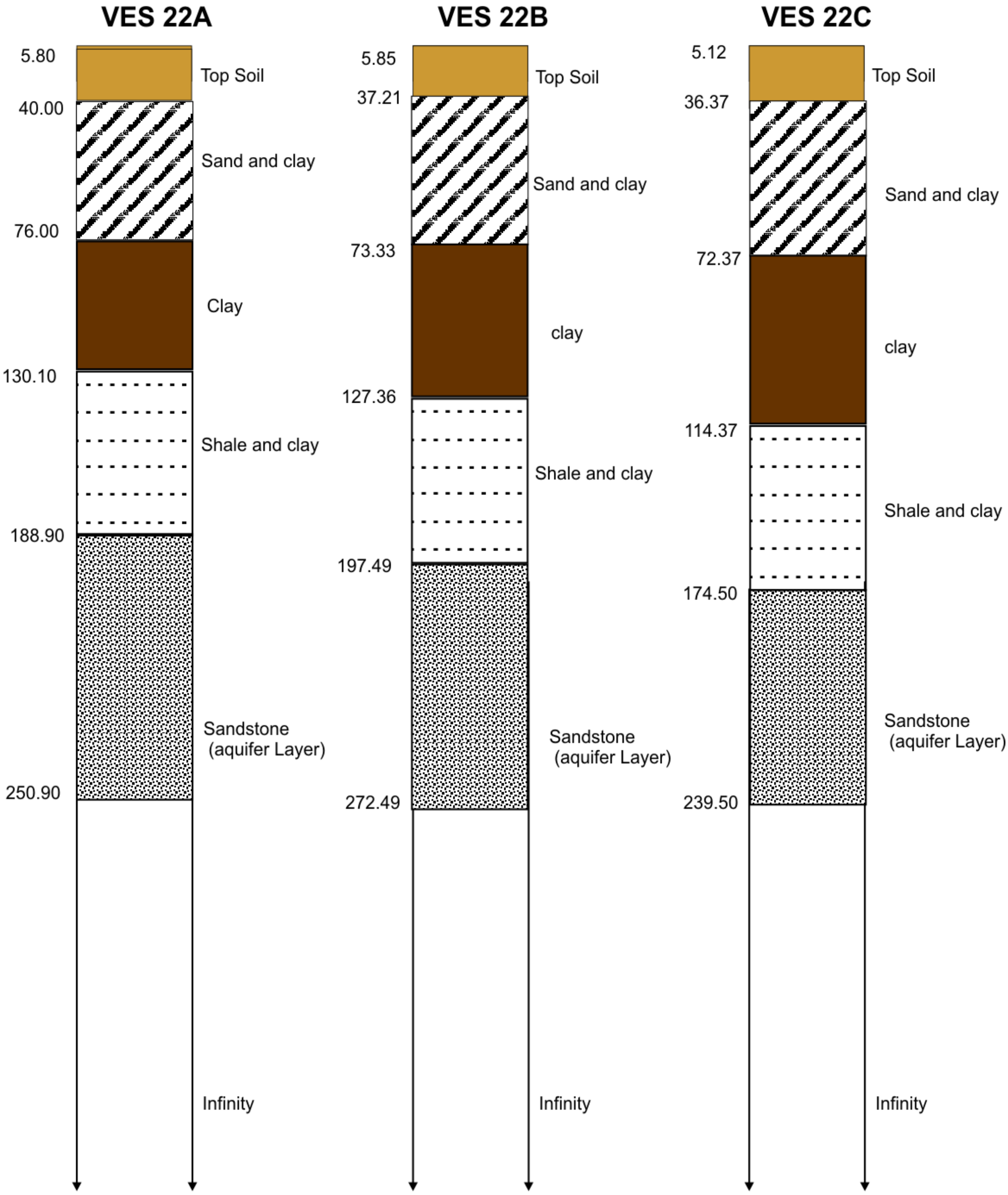

Figure 4.2: Geologic sections of the location at *Igieduma*.

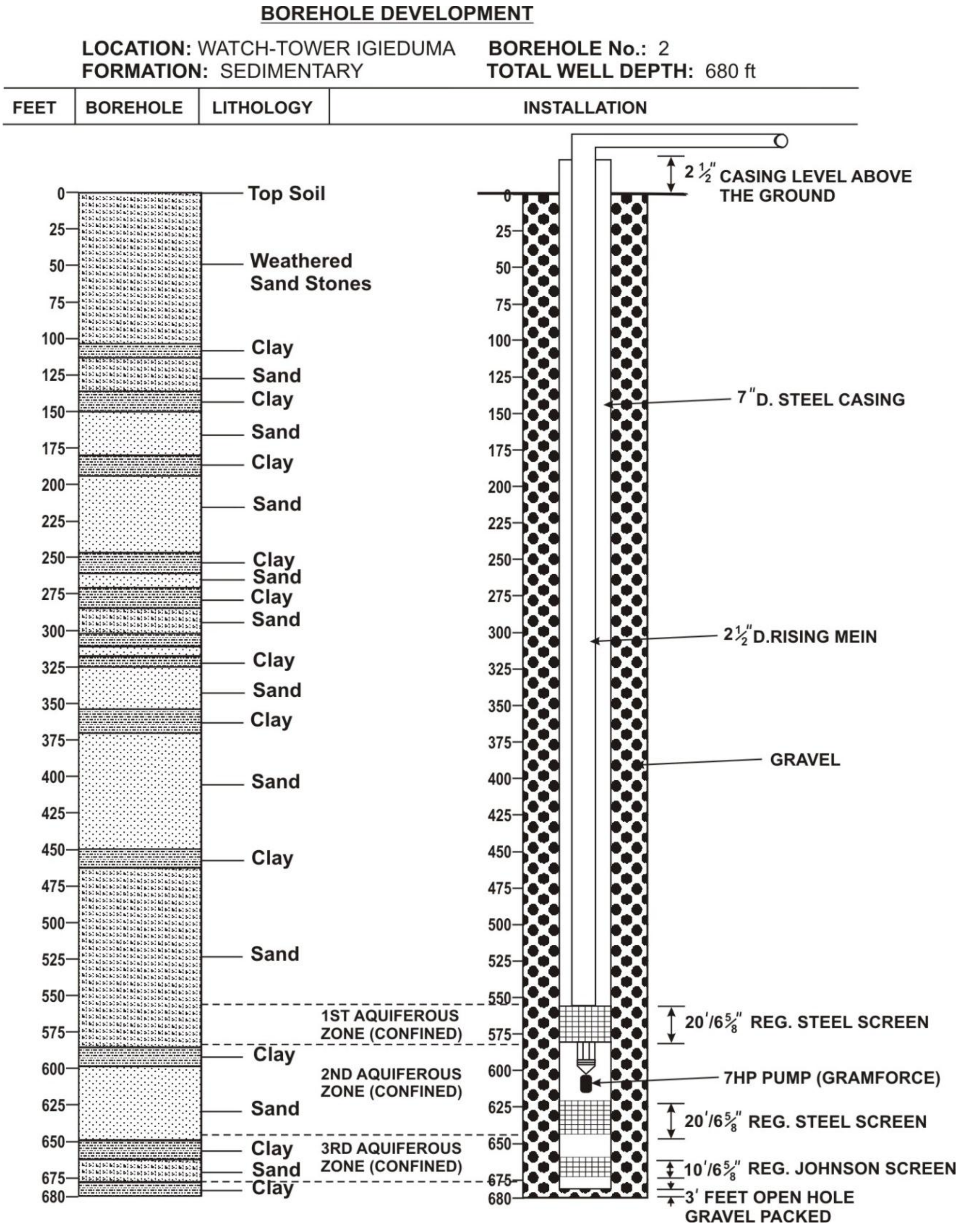

Figure 4.3: *Igieduma* Borehole Section

VES 22(A, B and C) located at *Igieduma* exhibited the **AHAKQ-CURVE TYPE ($\rho_1 < \rho_2 < \rho_3 < \rho_4 < \rho_5 > \rho_6 > \rho_7$).** In this VES 22(A, B and C) the computer interpretation resolved seven geoelectric layers. The geoelectrical sections and the geologic sections are showed in Figure 4.1 and Figure 4.2. A total depth of 250.90m, 272.49m and 239.50m were obtained from the analysis of the curves. This agrees with the borehole development at the *Igieduma* Watch-Tower in Figure 4.3. The colours used in the geologic sections to display the lithology are not peculiar to the geologic materials but were used to identify and to differentiate the materials.

5.0 Conclusion

This research provides geophysical information of the subsurface on the depth to the aquifer layer as it correlated very well with the borehole section at *Igieduma* (Figure 4.3). This information is going to be relevant to the development of an effective water scheme for the area and possibly beyond other areas underlain by the formation. The subsurface geologic materials in the study area are mainly sand, sandstone and shale/clay (Figure 4.2).

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