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Geoelectrical Resistivity Approach to Groundwater Potential Mapping: A Case Study of Ginti Community, Ikorodu, Lagos

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ABSTRACT
Groundwater potential of Ginti community was investigated using geophysical electrical resistivity method. Both the two dimensional (2D) electrical resistivity measurements and Vertical Electrical Soundings were carried out to delineate and identify fresh water aquifers in the area. In order to achieve these objectives, the 2-D electrical resistivity measurements using the Wenner-Schlumberger array along four traverses, each of length 200 m, and twenty-nine VES using the Schlumberger configuration with maximum (AB/2)in the range of 350 to 500 m, were manually carried out. The results of the 2-D resistivity measurements as inverted resistivity models (IRM) showed that three zones were delineated in terms of resistivity distributions. They were the high resistivity zones, the intermediate and the low resistivity zones represented. The VES results presented as geoelectric sections revealed that between four to six layers were delineated. Interpretation of the results was constrained using available borehole data obtained from the area. The lithology units delineated were topsoil (lateritic), lateritic clayey sand, clayey sand and sand with variations in their resistivity. Two aquifer types were identified; a shallow aquifer units which occurred between depths of about 2 to 45 m with thicknesses ranging from 2 to 44 m throughout the study area, and the second regarded as the deep aquifer units, it occurred between depths of about 53 to 176 m. The DarZarouk parameters computed in order to zone the aquifer characteristics for the groundwater potential suggested that three potential zones namely; the poor, low and moderate groundwater zones were classified.

Keywords:
Groundwater,
Inverted Resistivity section,
Dazarouk parameters,
Aquifer units,
Lithology.

INTRODUCTION

Fresh water is crucial for the well-being of human societies and the fervent demand for it especially in urban settlement cannot be over emphasized. Groundwater serves as the most viable source of water for both domestic and industrial uses, hence the need for locating zones of sustainable groundwater supply and good quality is crucial. The use of water ranges from drinking, washing clothes, cooking to generating electricity in thermo-electric power plants as well as irrigation for agriculture

According to Rao (2006) and Chowdhury *et al.,* (2009), groundwater is said to be a more dynamic renewable natural resource and plays important role in drinking, agricultural and industrial needs as a timely assured source compared with surface water. However, availability with good quality and quantity in appropriate time and space is also important. Some notable researchers have shown that the reality of poor economic situation and challenges of expansion of many essential infrastructural facilities to meet the increasing demand on the parts of the government necessitate the need for individuals and local communities to look for alternative to the conventional public water supply (Aggarwal *et al.,* 2009; Chawla *et al.,* 2010; Rodell *et al.,* 2009).

Surface geophysical methods, as veritable tools in groundwater exploration, have the basic advantage of saving cost in borehole construction by locating target aquifers before drilling is embarked upon (Obiora and Onwuka, 2005). This can be achieved to a certain level of precision, when the results are interpreted with adequate knowledge of the geology of the area. In this present study, the use of 2-D electrical resistivity method using the Wenner-Schlumberger configuration and the Vertical Electrical Soundings (VES) using the Schlumberger array were deployed. Electrical resistivity surveys mainly aim at determining subsurface resistivity distribution by making measurements on the ground surface. From these measurements, the true resistivity of the subsurface can be estimated and by extension the geological unit responsible for such estimated true resistivity. The ground resistivity is related to various geological parameters such as the mineral and fluid content, porosity and degree of water saturation in the rock. The VES is a very viable technique in investigating the variation of resistivity with depth which is an important parameter in delineating aquifers (Keary and Brooks, 2002). This technique has proven over time to be cost effective and viable in delineating groundwater potential zones, mapping aquifer units and an approach worthy of consideration before drilling of borehole is embarked upon (Obiora and Onwuka, 2005, Salami and Olorunfemi, 2014, Kamaldeen *et al.,* 2013, Ojo *et al.,* 2007 and Anizoba *et al.,* 2015). The 2-D Electrical Resistivity Imaging is very sensitive in probing the lateral variation of resistivity of the subsurface (Keary and Brooks, 2002).

The study area, Ginti community is in Ikorodu axis of Lagos, Nigeria. It spans within a geographical coordinates of 6.57^0 to 6.61^0 North of the equator and 3.57^0 to 3.62^0 East of the Greenwich Meridian, covering a total area of about 4.05 square kilometer. The area is a fast developing community with several economic activities taking place daily. It is accessible by Igbe road off Ijede road. The closest towns and places to the area are Oke-Eletu, Igbopa, Ikorodu, and Ijede.

The study area is characterized by a wet equatorial climate with mean annual rainfall above 1800 mm. There are two main seasons, namely; the rainy season and dry season, which usually lasts from April to October and October to March respectively. It experiences an average temperature of 27^0C. Vegetation is dominated by swamp forest wetlands and tropical swamp forest comprising of fresh waters and mangrove. Generally, the pattern of relief in Lagos reflects the coastal location of the state. Water is the most significant topographical feature in Lagos State. Water and wetlands cover over 40% of the total land area within the state and an additional 12% is subject to seasonal flooding (Iwugo et al., 2003).

Geologically, the study area is directly underlain by the Benin formation which consists largely of sands/sandstones with lenses of shales and clays mostly in the northern part (Omatshola and Adegoke, 1981; Enu, 1985 and Nton, 2001). Owing to the thinness of this formation, favourable aquifer is difficult to locate (Offodile, 2002). The Ewekoro/Akinbo/Oshosun Formations, consist of a sequence of sandstones, shales, limestones and clays (Adegoke,1980). All of the formations are multi-aquiferous, but the relatively high depths of the aquiferous zones of both the Ewekoro and Abeokuta Formations at lkorodu make them economically unattractive for water prospecting through boreholes. Furthermore, the work of (Offodile, 2002) showed that the Ewekoro Formation has poor groundwater potential majorly because of the argillaceous nature of the rock.

The Abeokuta Formation consists of arkosic sandstones and grits, tending to be carbonaceous towards the base. The formation has good potential for ground water except that the bituminous materials associated with the sands could affect the quality of the water.

The llaro Formation consists of fine to coarse sands alternating with shales and clays. The geological studies of its outer appearance suggested that it could be a good aquifer that can yield a substantial amount of water (Offodile, 2002). However, Hydro (1993) suggested that most of the boreholes in the area tap water from the Akinbo Formation. Although locating these multi-aquifers is very tasking, it must however be done in order to make borehole construction in lkorodu economically less distressful.

The area is under development with settlement not exceeding 600 buildings, and because it is a fast growing one, the need for fresh and clean water is of utmost importance to meet domestic and industrial need not only in the present but also in the future. About two shallow boreholes and few hand dug wells exist in the community but these could not meet up with the demand for water in the area. This is because the wells and boreholes sometimes run out of water needed for both domestic and industrial needs, hence the need for prospecting for groundwater potential zones in the area.

For this purpose, the geo-electrical method involving the 2-D Electrical Resistivity Tomography (ERT) and Vertical Electrical Sounding were employed. This present study is aimed at locating the groundwater potential zones in Ginti Community, Ijede, Ikorodu, Southwestern, Nigeria.

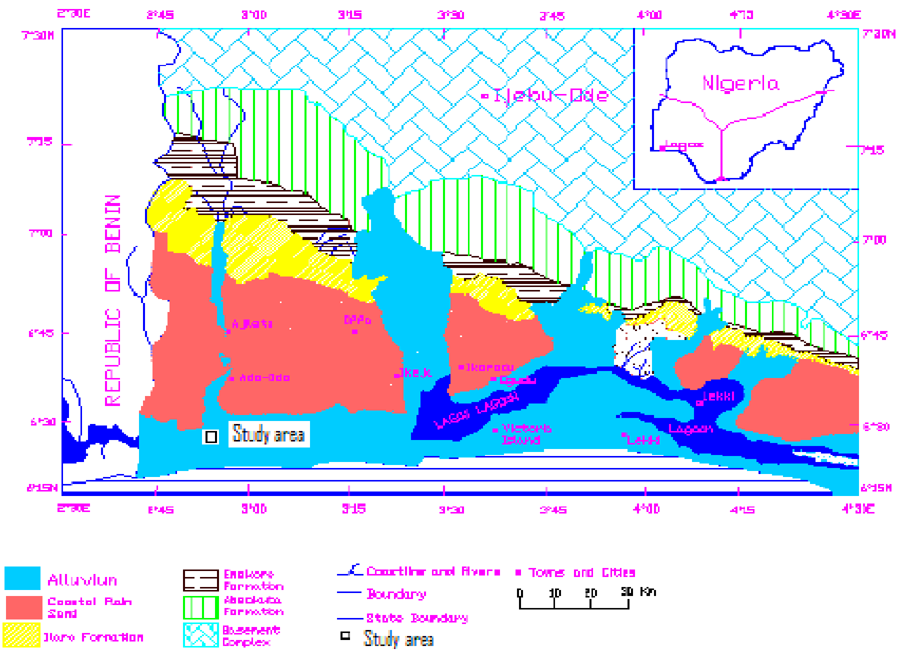

Figure 1: Geological map of Lagos State (Badmus et al, 2011)

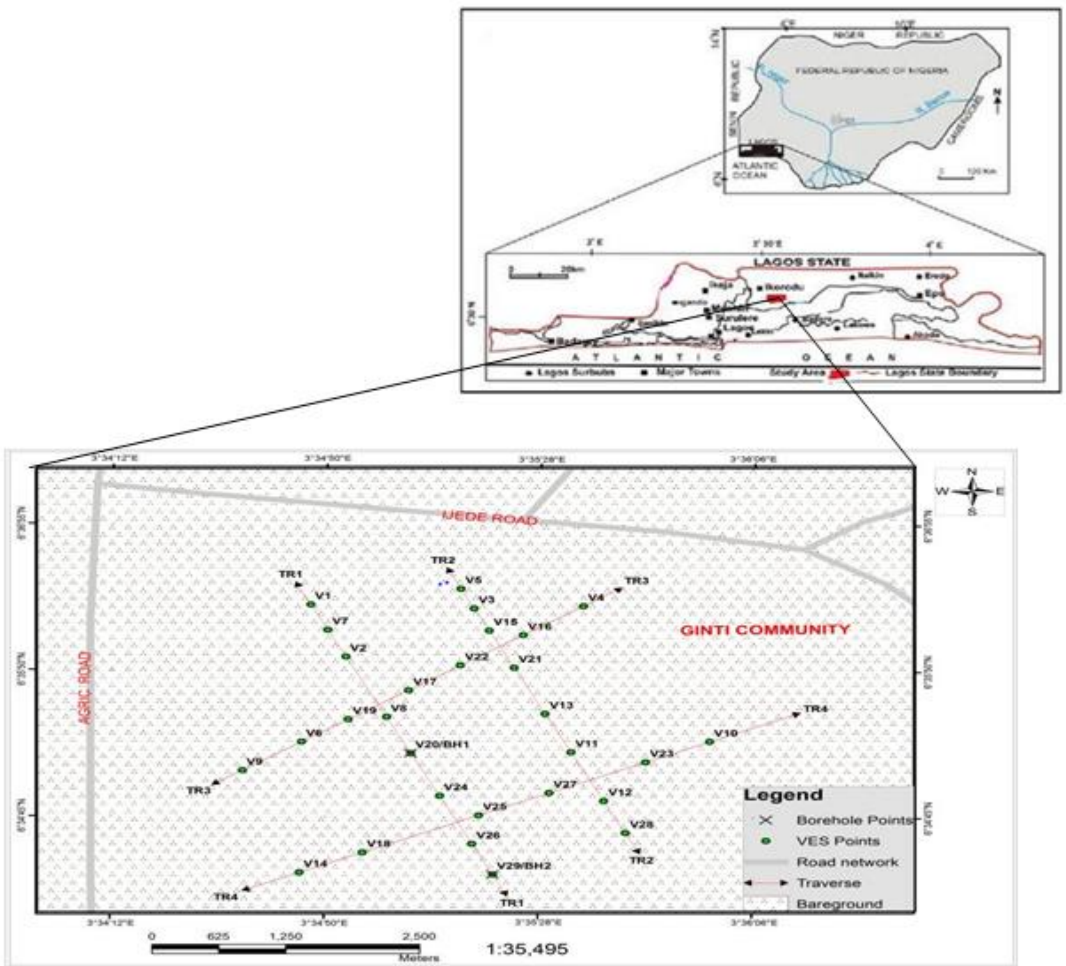

Figure 2: Location map of the study area

MATERIALS AND METHODS

2-D Electrical Resistivity measurements

The 2-D electrical resistivity data were collected using PASI resistivity meter with four electrodes of length about 40 cm partially driven into the ground using hammers. The four electrodes with two as current electrodes and the other two as potential electrodes were connected through multichannel cables to the resistivity meter, using the Wenner-Schlumberger array configuration. This type of electrode arrangement is hybrid between the Wenner and Schlumberger arrays. During the acquisition, the wiring is continuously changed so that the spacing, a between the 'potential electrodes' remains constant, while the spacing between the 'current electrodes' increases as a multiple of a. The potential electrode spacing, a, was initially set at a = 10 m, and n = 1. This means that the separation between C1 and P1 and that between P2 and C2 was 10 m, each. The whole array was moved along the traverse while apparent resistance readings were taken until a distance of 200 m was covered. The n was consequently set at n=2,3,4….9 while "a" remained at 10 m.

The resistance values recorded were converted to apparent resistivity using equation1.

$$\rho_a = \pi n(n+1)aR \quad (1)$$

Where a is the potential electrode spacing, n, the integral multiple of a, and R the resistance recorded at the field. The factor $G = \pi n(n+1)a$ is the geometric factor of the configuration. The values of the apparent resistivity obtained, electrode spacing and x-locations were entered into a text file for processing using a DIPRO version 4.0 for the inversion of the resistivity data.

VES measurements

Twenty-nine VES were acquired in the study area using the Schlumberger configuration. The maximum AB/2 (m) for the VES spanned between 350 m and 500 m based on available space. The potential electrodes P1and P2 were kept fixed initially at 0.25m separation and current electrodes C1 and C2 were moved outwards symmetrically in steps while resistance readings were taken progressively starting from AB/2 of 1m. The resistance values recorded were converted to apparent resistivity using equation 2.

$$\rho_a = \frac{\pi L^2 R}{2l} \quad (2)$$

Where L is the mid-point value of the current electrode spacing, i.e. AB/2, l, the mid-point value of the potential electrode spacing, i.e. MN/2, and R, the resistance values obtained on the field. The factor $G = \frac{\pi L^2}{2l}$ is the geometric factor of the configuration.

Thereafter, the apparent resistivity values for each VES point were plotted against the half of the current electrode spacing (AB/2) on a tracing paper while placing a log-log graph sheet underneath through a process called partial curve-matching technique. The electrode spacing at which inflection occurs on the graph provides an idea of the depth to the interface. The data alongside the resistivities and thicknesses of the manually-modeled layers through forward modeling were further processed by computer iteration inversion technique using WinResist program. Two boreholes data available were used for constraining the resistivity data interpretation.

Estimation of Aquifer parameters characteristics

The DarZarrouk parameters: the hydraulic conductivity, aquifer protective capacity and transmissivity were calculated from the primary geoelectric parameters. These aquifer parameters are particularly important when describing the geoelectric sections that are made up of several layers (Zhody *et al.,* 1974). They were relevant in the characterization of the various aquifers and by extension the zoning of the groundwater potential of the study area.

Hydraulic conductivity

Hydraulic conductivity is a measure of the rate of flow of water in an aquifer system. According to (Chachadi and João, 2005), the aquifer hydraulic conductivity is its ability to transmit water due to the presence of interconnected pores (effective porosity) in the sediments and fractures in the consolidated rocks.

The hydraulic conductivity (m/day) of the aquiferous units according to (Chachadi and João, 2005) is given in equation 3. $K = \frac{10^{-5} \times 86400 \times \rho_a{}^{1.195}}{97.5}$ (3)

The ratings of the aquifer hydraulic parameter, modified from Aller *et al* (1987), are given in Table 1.

Table 1: Aquifer hydraulic conductivity ratings modified after Aller *et al* (1987)

Indicator	Indicator variables		Importance rating
	Class	Range	
Hydraulic conductivity (m/day)	High	> 40	10
	Medium	10 - 40	7.5
	Low	5 - 10	5
	Very low/Poor	<5	2.5

Aquifer protective capacity

The Aquifer Protective Capacity (APC) is the ability of the overburden units to retard and filter penetrating ground surface polluting fluid into the aquifer units (Fatoba *et al.,* 2014; Salami and Olorunfemi, 2014). This is usually evaluated for a study area using the longitudinal conductance measured in mhos for each VES station. According to Oladapo and Akintorinwa (2007), the protective capacity of an aquifer compares directly with the sum of the longitudinal unit conductance of all the layers above the aquifer. The protective capacity of a unit or layer is given by Niwas and Singhal (1981) in equation 4.

$$P_c = \sum_1^n S_{Li} \quad (4)$$

Where Pc is the protective capacity of the aquifer, and S_{Li}, the longitudinal conductance of the layers above the aquifer given in equation 5.

$$S_{Li} = \frac{h_i}{\rho_i} \quad (5)$$

Where h_i is the thicknessesof the layers overlying the aquifer, and ρ_i, their resistivity values.

Transmissivity

The Transmissivity is a major property of an aquifer which helps in characterization of rocks as water conducting media (Fatoba *et al.,* 2014). It is the product of the hydraulic conductivity (K) and the aquifer layer thickness in equation 6.

$$T = Kh \quad (6)$$

where T is the Transmissivity, K, the hydraulic conductivity and h, the layer thickness.

This implies that the transmissivity of any aquifer unit depends on its thickness and hydraulic conductivity. An aquifer with a high hydraulic conductivity and thickness is rated 'very good' in terms of transmissivity. Aquifer units with very low hydraulic conductivity values and high thickness are regarded as moderately good (Todd, 1980).

RESULTS AND DISCUSSION

Results of the 2-D Electrical Resistivity measurements

Generally, the 2-D inverted resistivity models revealed that three resistivity anomalous zones are mapped at different depths due to the variations in current distribution in the subsurface (Figures 3 a-d). These are the high resistivity, medium resistivity and low resistivity zones. The delineated zones were the topsoil (lateritic) with resistivity values that range from 94 to 939 Ωm and thickness ranging from 0.6 to 4 m, clayey sand/sandy clay with resistivity values that range from 200 to 842 Ωm and thickness ranging from 2 to 9 m, lateritic clayey sand with resistivity values that range from 939 to 3200 Ωm and thickness ranging from14 to 46 m, and sand with resistivity values that range from 185 to 1189 Ωm and thickness ranging from 12 to 44 m. A depth below 10 m is generally characterized with clayey sand/sandy clay, lateritic clayey sand and sand with resistivity values ranging from 139 to 2000 Ωm along the profile. Depth above 10 m is made up of clay, clayey sand/sandy clay, lateritic clayey sand and sand with resistivity values that range from 100 to 3200 Ωm. The sandy layer serves as the potential aquifer where groundwater could be tapped and is more pronounced at depths of about 8 to 50 m from a lateral distance of about 50 to 90 m.

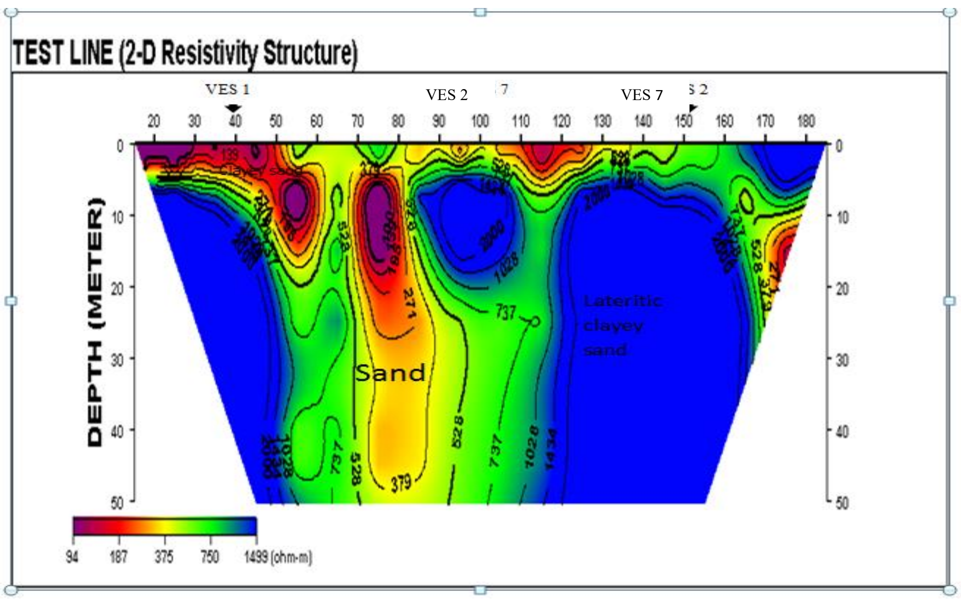

Figure 3a: 2-D resistivity section along traverse One

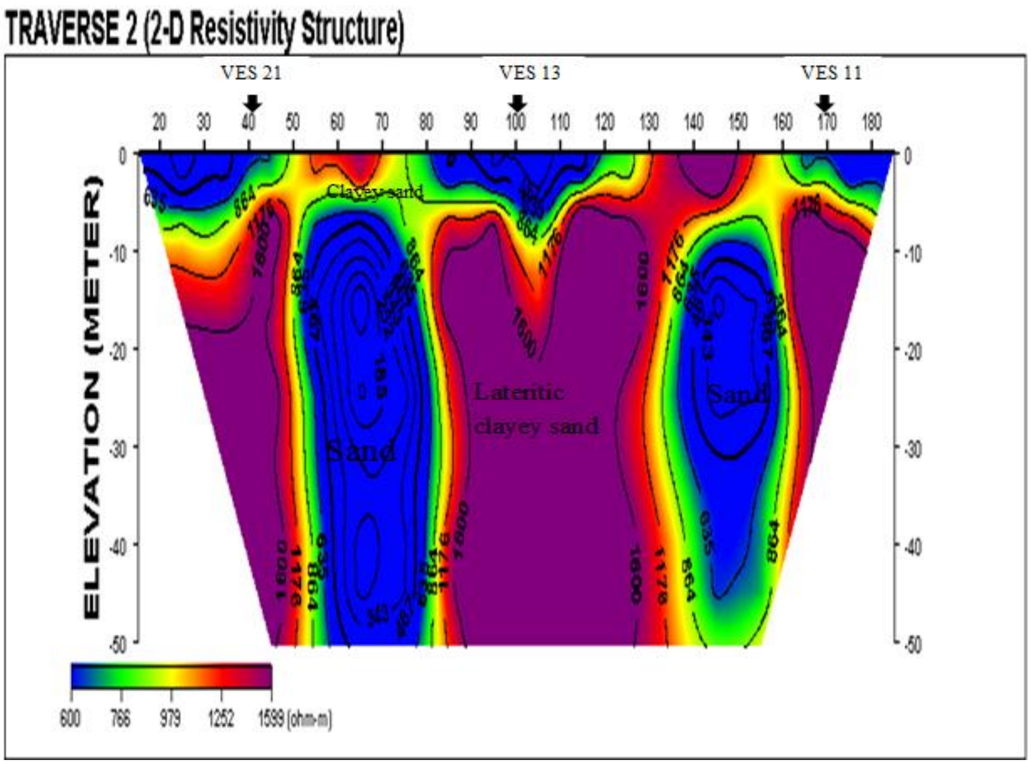

Figure 3b: 2-D resistivity section along traverse two

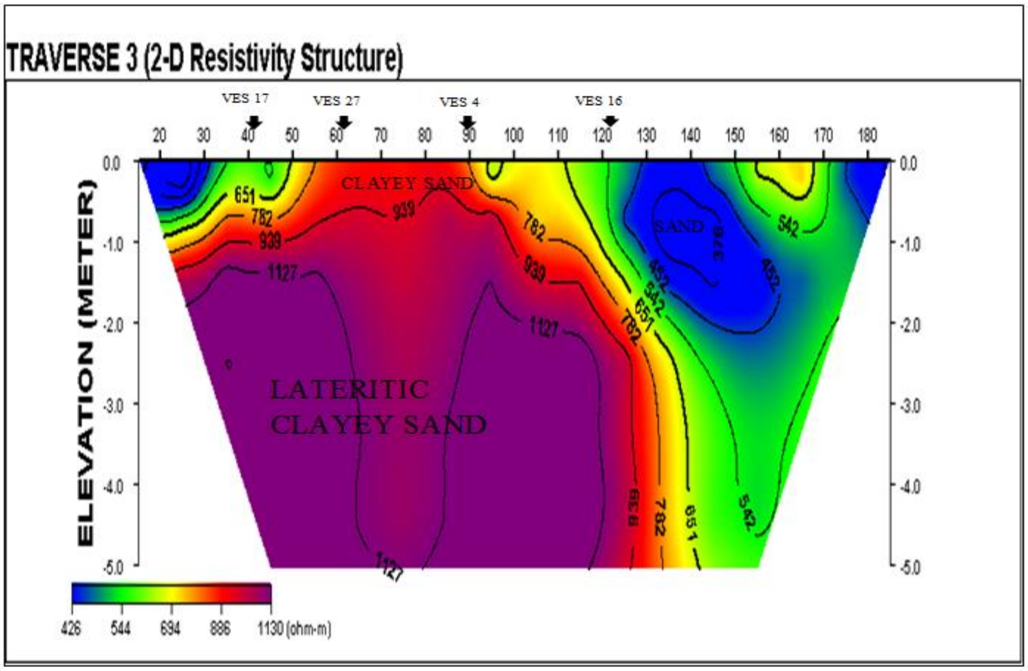

Figure 3c: 2-D resistivity section along traverse three

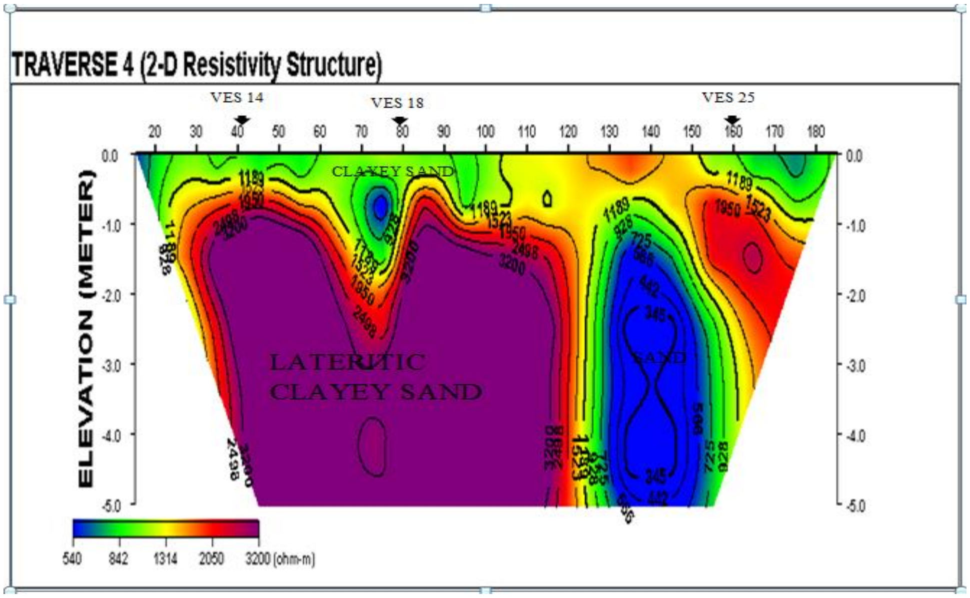

Figure 3d: 2-D resistivity section along traverse four

Results of the Vertical Electrical Sounding

Representative inverted VES curve types of the computer iteration process for VES 1 and VES 2 are presented in figure 4. The curve types are AK showing a four layer model and KHK showing a five layer earth model for figure 4a and figure 4b respectively.

The geo-electric sections generated revealed that three to seven geoelectric earth layer models are delineated from the interpreted VES data for all the sounded locations as shown in figure 5. The four layer model is most prevalent; it is followed by the five layer model and the three layer models. The six layer models and the seven layers are least. Generally, the geo-electric sections reveal four geoelectric layers namely; the topsoil (lateritic) with resistivity values ranging from 45 to 672 Ωm, and thickness that ranges from 0.5 to 1.9 m, the clayey sand layer with resistivity values ranging from 261 to 852 Ωm, and thickness that ranges from 1.1 to 20.3 m, the lateritic clayey sand layer with resistivity values that range from 891 to 6050 Ωm, and thickness that ranges from1.0 to 167.7 m, and sandy layer with resistivity values that range from 104 to 992 Ωm. The layer of sand represents potential aquifer where groundwater could be tapped. Two aquifer units are delineated; the first aquifer unit with resistivity values ranging from 113 to 992 Ωm occurs at a depth range of about 2 to 45.4 m with thickness ranging from 1.7 to 38.4 m, and the second, deep aquifer unit with resistivity values ranging from 104 to 934 Ωm occurs at a depth of about 53.1 to 176.4 m. The first or shallow aquifer unit is characterized by poor protective capacity due to its poor protective capacity values which range from 0.002 to 0.060 mhos implying that it is highly vulnerable to surface contamination. The conductivity of the aquifer ranges from very low to moderate, with hydraulic conductivity values ranging from 3 to 34 m/day, while its transmissivity ranges from fairly good to very good transmissivity, with transmissivity values ranging from 44 to 572 m^2/day. The thickness of this aquifer ranges from 1.7 to 38.4 m and could be employed for shallow groundwater development. The second or deep aquifer unit is characterized by overburden thickness values which range from 53.1 to 176.4 m, poor to moderate protective capacity with protective capacity values ranging from 0.029 to 0.204 mhos, and very low to moderate hydraulic conductivity with hydraulic conductivity values ranging from 2 to 31 m/day. The aquifer could be employed for deep boreholes in the study area.

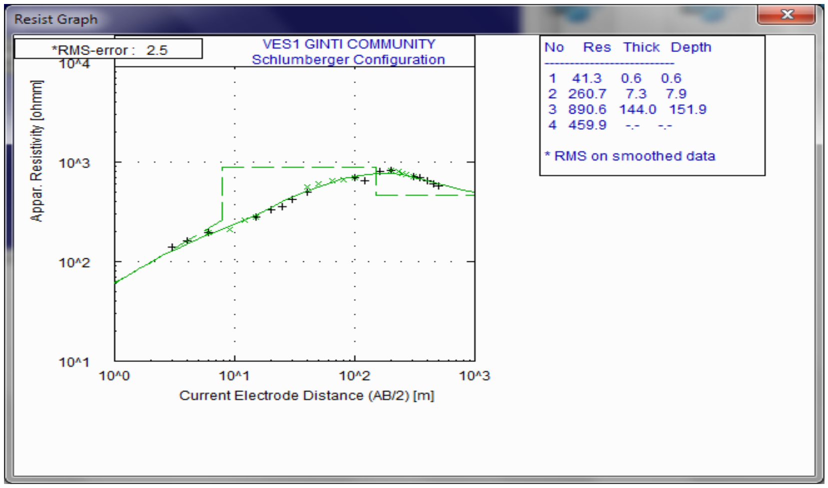

Figure 4a: Representative Inverted Field Sounding curves

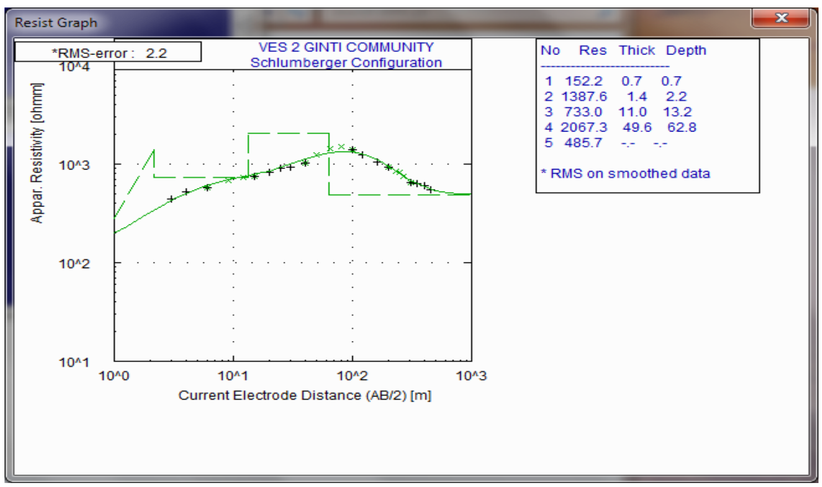

Figure 4b: Representative Inverted Field Sounding curves

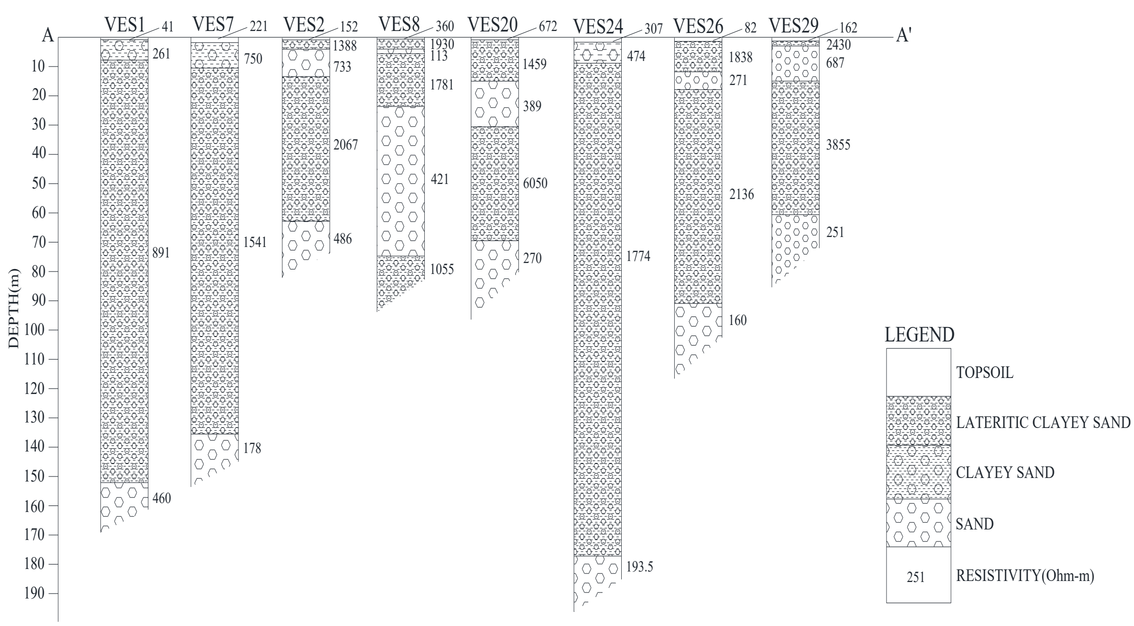

Figure 5a: Geoelectric section along AA'

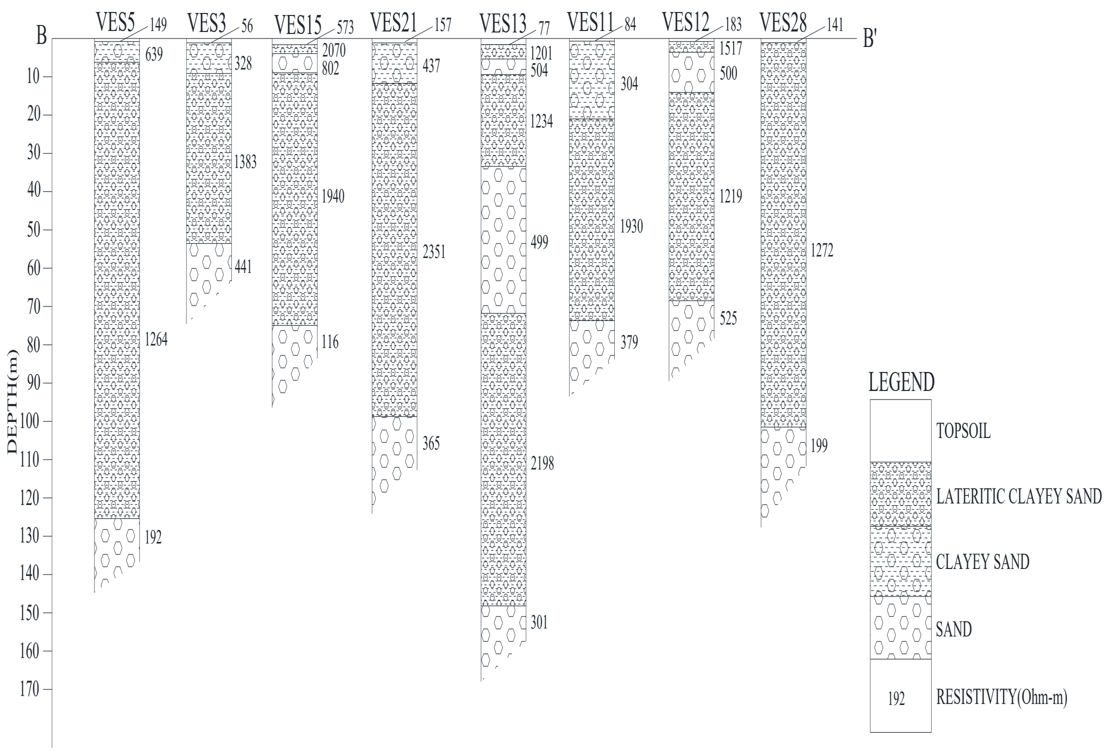

Figure 5b: Geoelectric section along BB'

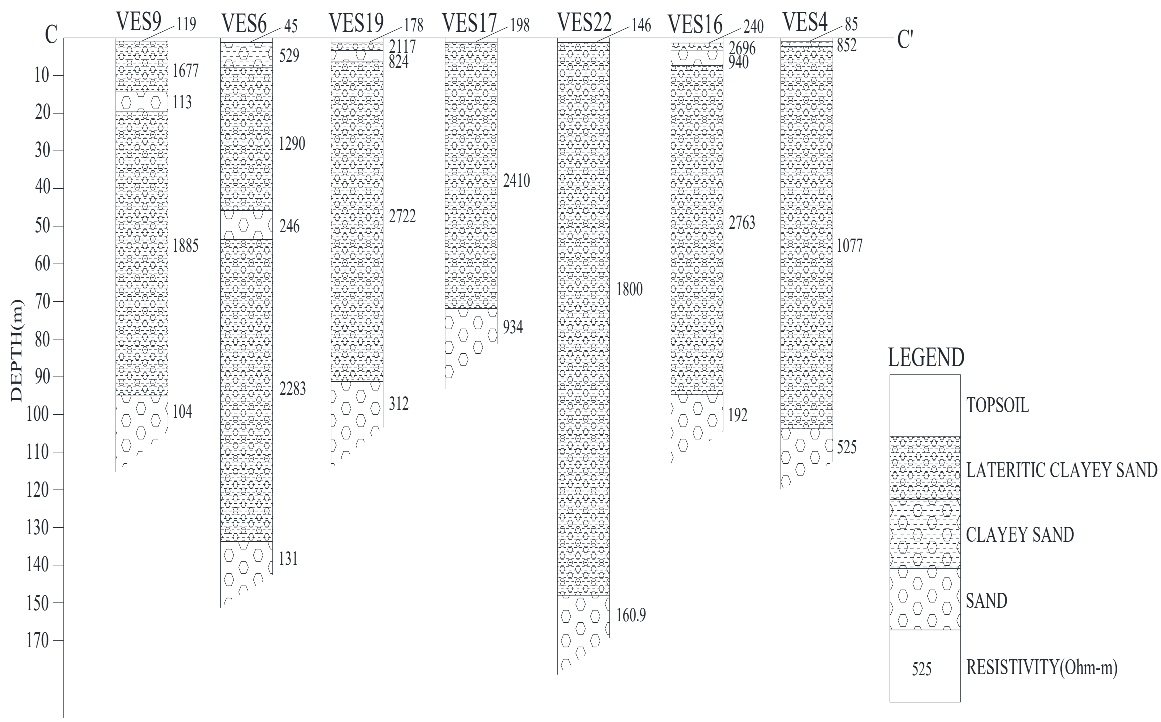

Figure 5c: Geoelectric section along CC'

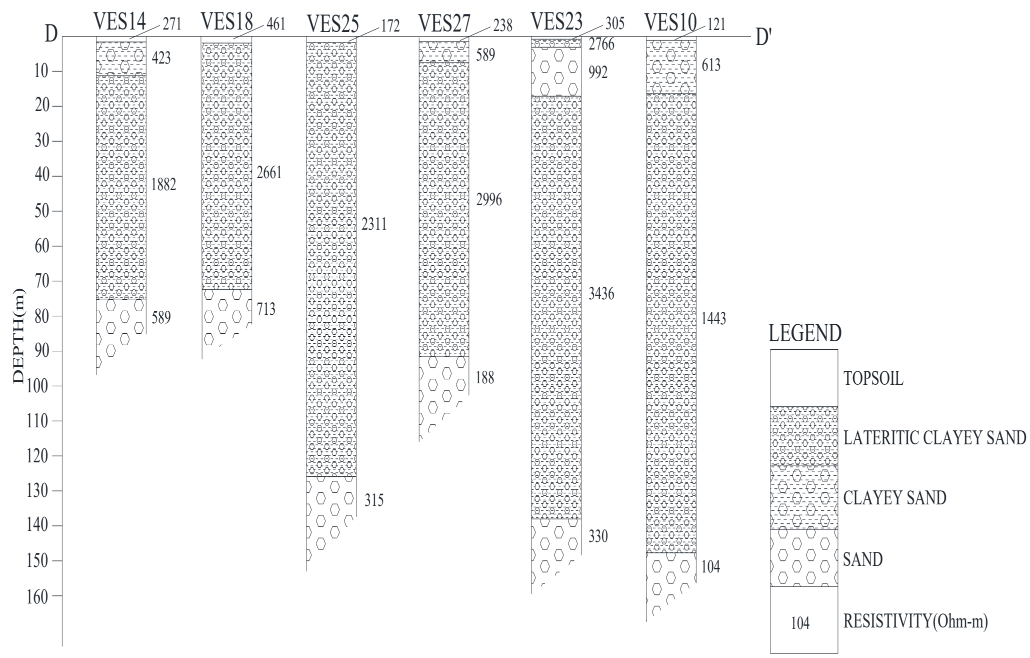

Figure 5d: Geoelectric section along DD'

Borehole data

Two hand-dug borehole data were obtained before embarking on the survey in order to have an idea of the lithological conditions of the environment as well as the depth to water table or aquifer. The result of the hand-dug well data is shown in figure 6.

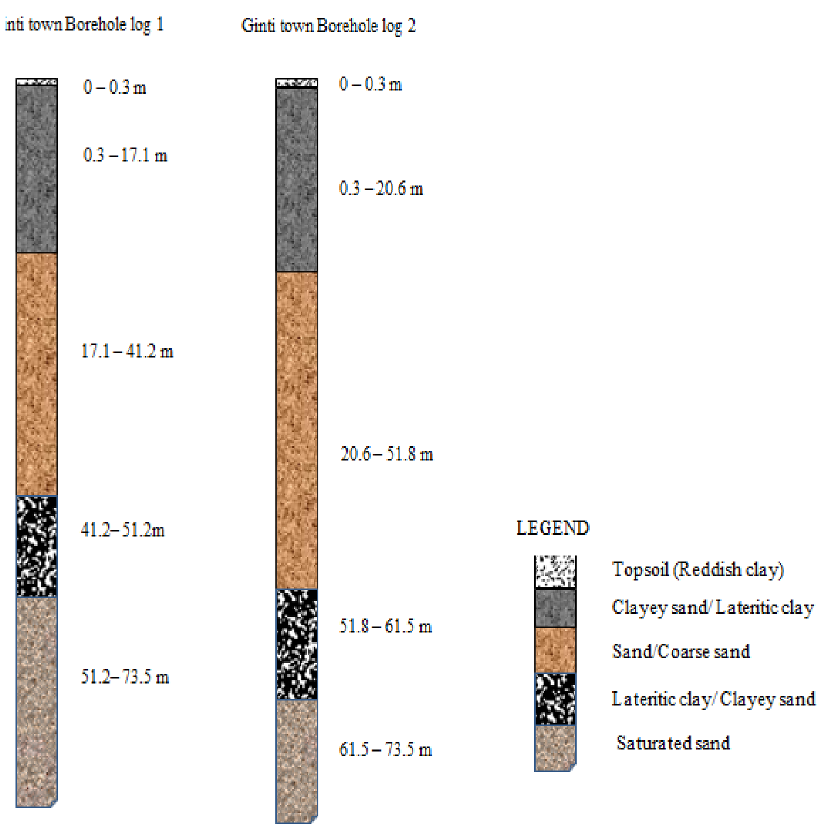

Figure 6: Column borehole logs for correlation

Aquifer Characteristics Maps of the first aquifer

The hydraulic conductivity characteristic of an aquifer is an important property for both groundwater exploration and contaminant plumes assessment (Singh, 2005; Anizoba *et al.,* 2015). Figure 7a is the map of the computed hydraulic conductivity values for the shallow aquifer unit using equation 3. It shows hydraulic conductivity values that range from 3 to about 34 m/day. The hydraulic conductivity depends on the intrinsic permeability of the material and on the degree of saturation. From this map, the aquifer is characterized as having very low/poor to moderate/medium hydraulic conductivity towards the north and south of the study area. The area zoned as moderate has hydraulic conductivity values ranging from 11 to 34 m/day. This region includes VES 2, VES 12, VES 13, VES 15, VES 16, VES19, VES 20, VES 23 and VES 29. The region of low conductivity values range from 6 to 7 m/day. This area includes VES 6 and VES 26. The poor or very low conductivity region is characterized with hydraulic conductivity value of about 3 m/day, and this area includes VES 8 and VES 9.

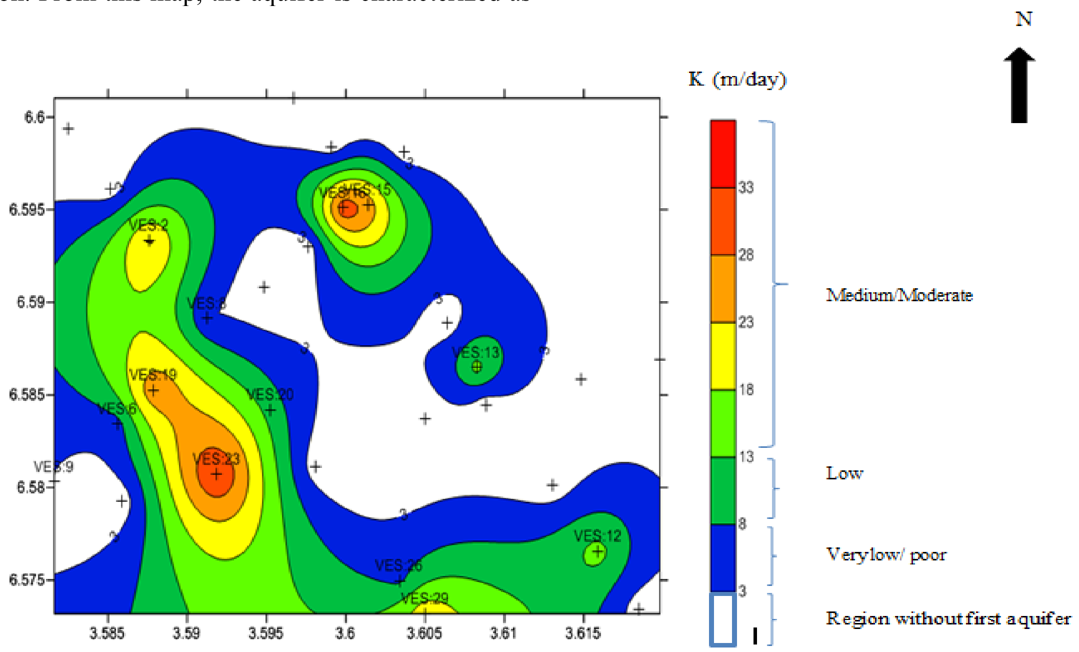

Figure 7a: Hydraulic conductivity map of the first aquiferous units.

Figure 7b is the transmissivity map for the shallow aquifer with values that range from 4 to 572 m^2/day. An aquifer with a high hydraulic conductivity and thickness is rated 'very good' since the ease with which the aquifer can release water is high. From the map, the aquifer transmissivity is classified as very low/poor to very good with good transmissivity towards the east and south of the study areas. The area with very good transmissivity comprises VES 13 and VES 23 with transmissivity values ranging from 521-572 m^2/day. The good transmissivity area comprises VES 2, VES 12, VES 20 and VES 29 with transmissivity values ranging from 173 to 262 m^2/day while moderately good transmissivity comprises VES 15, VES 16, and VES 19 with transmissivity values ranging from 95 to 141 m^2/day. Furthermore, low or fairly good transmissivity area comprises VES 6, VES 9 and VES 26 with transmissivity values ranging from 13 to 49 m^2/day, while only VES 8 falls within the very low/poor transmissivity region of the aquifer with hydraulic conductivity values ranging from 11 to 34 m/day. This region includes VES 2, VES 12, VES 13, VES 15, VES 16, VES 19, VES 20, VES 23 and VES 29. The region of low hydraulic conductivity ranges from 6 to 7 m/day. This area includes VES 6 and VES 26. The very low hydraulic conductivity region has value of about 3 m/day, and this area includes VES 8 and VES 9.

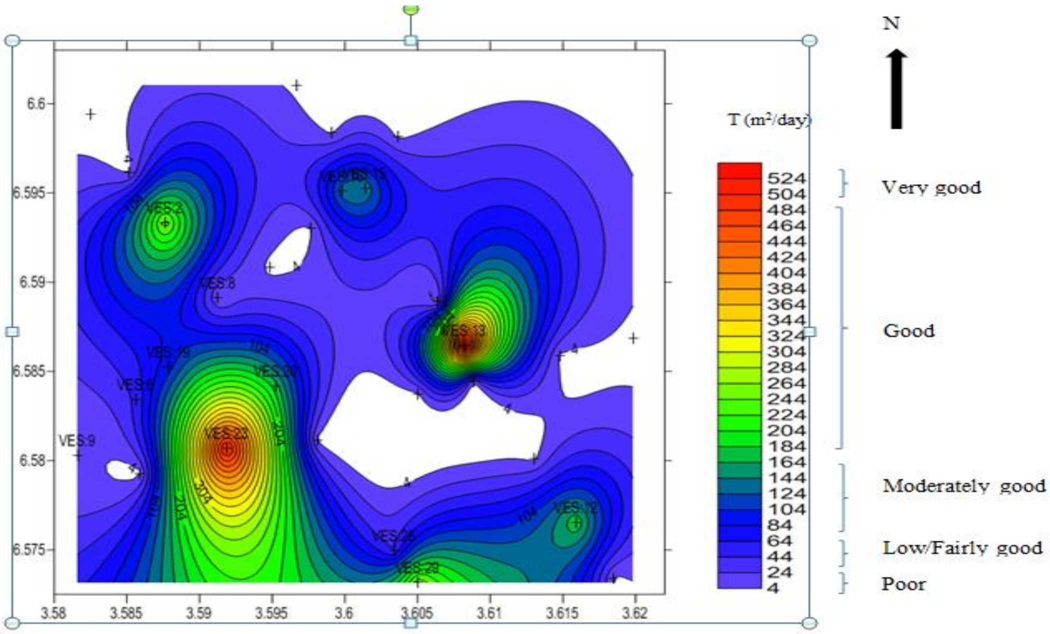

Figure 7b: Transmissivity map of the first or shallow aquiferous unit.

Aquifer Protective Capacity (APC) is a measure of the ability of the overburden units to retard and filter penetrating ground surface polluting fluid into the aquiferous unit. APC is evaluated for the study area using the longitudinal conductance measured in mhos for each VES station. Oladapo and Akintorinwa (2007) opined that the protective capacity of an aquifer compares directly with the sum of the longitudinal unit conductance of all the layers above the aquifer. The estimated APC values for the first or shallow aquifer span between 0.0014 and 0.06 mhos (Figure 7c). Protective capacity depends on the thickness and resistivity of the overburden layers. From the aquifer protective capacity map, this aquifer is rated poor and is more vulnerable to surface contamination due to its relative thinness, closeness to the surface and unavailability of a very good retarding overburden layer (clay).

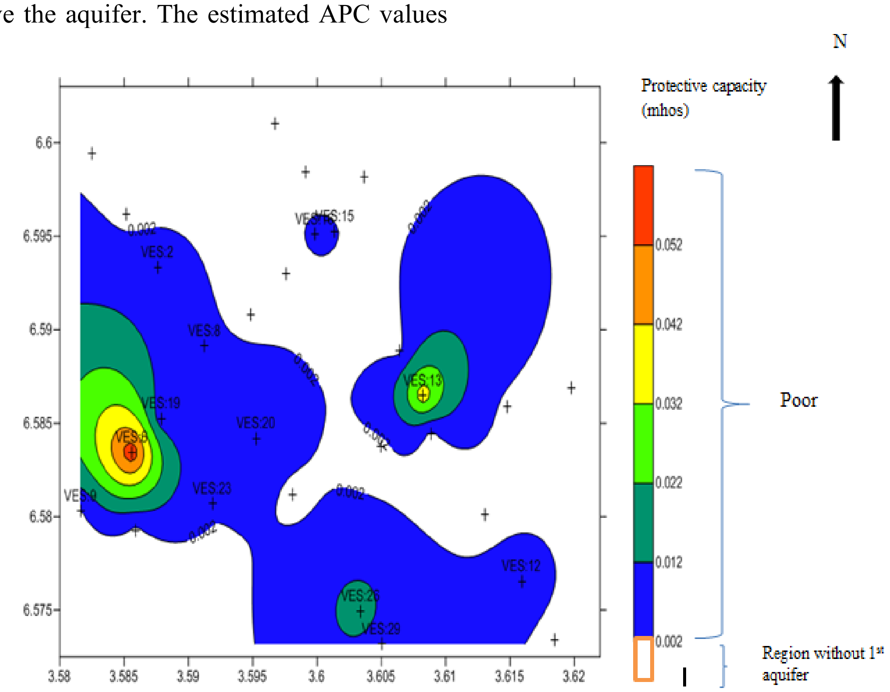

Figure 7c: Protective capacity map of the first or shallow aquiferous units

Aquifer Characteristics Maps of the second aquifer

The estimated hydraulic conductivity values of the VES results for the second or deep aquifer range from 3 to about 31 m/day (Figure 7d). The map shows that moderate hydraulic conductivity with values ranging from 12 to 31 m/day are observed at the central and north-eastern part of the investigated area. This region includes VES 1, VES 2, VES 4, VES 14, VES 18 and VES 12. The north-eastern and most of the central part of the investigated area are characterized by low hydraulic conductivity values which range from 5 to 12 m/day. This area includes VES 3, VES 5, VES 8, VES 11, VES 13, VES 16, VES 19, VES 20, VES 21, VES 22, VES 23, VES 24, VES 25, VES 27, VES 28 and VES 29. The south-eastern and the central part of the investigated area are characterized by poor hydraulic conductivity with very low hydraulic conductivity values ranging from 1 to 5 m/day. This area includes VES 6, VES 7, VES 9, VES 10, VES 15, and VES 26.

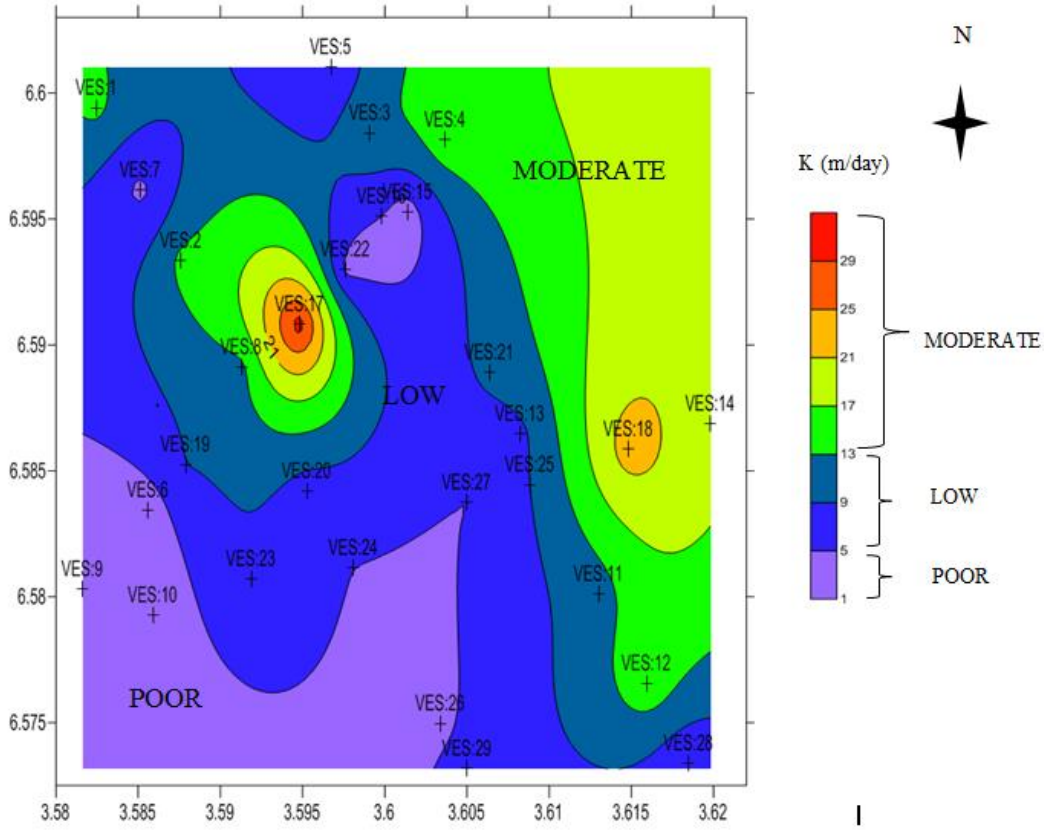

Figure 7d: Hydraulic conductivity map of the second aquiferous unit.

The estimated Aquifer Protective Capacity values of the VES results for the second or deep aquifer range from 0.029 to about 0.204 mhos (Figure 7e). The map revealed that most of the eastern part of the sounded points is rated weak with APC values ranging from 0.1 to 0.18 mhos. This area covers seven locations including VES 4, VES 5, VES 6, VES 9, VES 10, VES 13 and VES 24. The remaining part of the investigated area except VES 1 is characterized by poor protective capacity with protective capacity values which range from 0.02 to 0.1 mhos. This area includes VES 2, VES 3, VES 7, VES 8, VES 11, VES 12, VES 14, VES 15, VES 16, VES 17, VES 18, VES 19, VES 20, VES 21, VES 22, VES 23, VES 25, VES 26, VES 27, VES 28 and VES 29. This indicates that the aquifer could be vulnerable to surface contamination due to unavailability of very good retarding overburden layers.

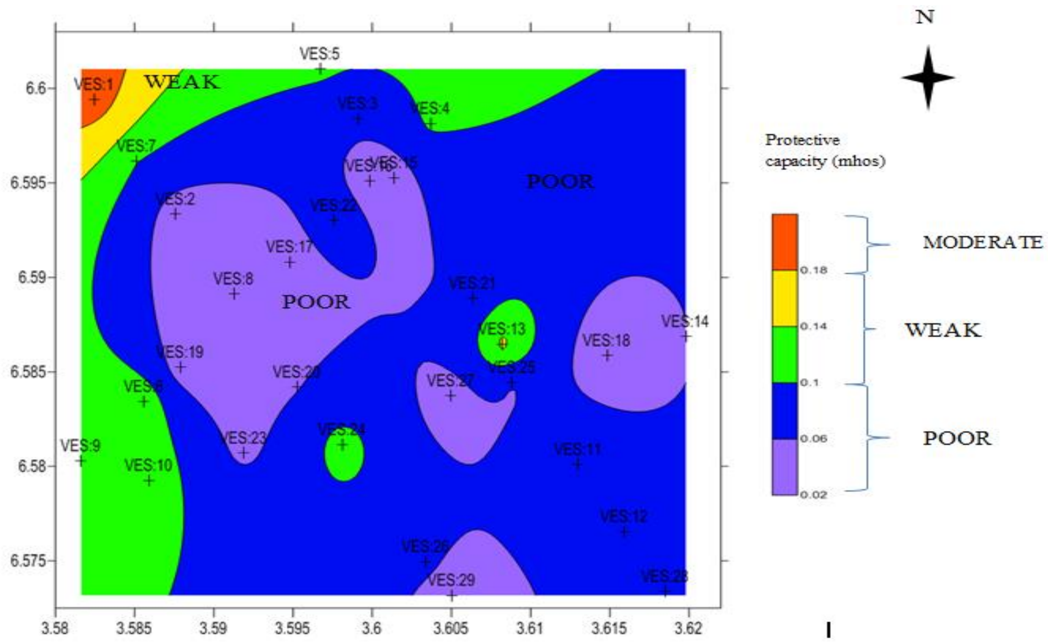

Figure 7e: Aquifer protective capacity map of the second aquiferous units.

Groundwater potential evaluation of the study area

The groundwater potential assessment of the study area was based on the DarZarrouk parameters. This involves picking the zones of moderate hydraulic conductivity values that correspond with moderate, weak or poor protective capacity values in order to draw conclusion from the zones revealed by each map. It can be seen from the aquifer protective capacity and the hydraulic conductivity maps that VES 1, VES 4 and VES 11 have moderate conductivity values ranging from 11 to 16 m/day as well as moderate to weak protective capacity values in the range of 0.106 to 0.204 mhos and are therefore considered as areas of moderate groundwater potentials, occupying majorly the north-eastern part.

The area of low groundwater potentials comprises three zones; zones of moderate hydraulic conductivity but poor protective capacity with conductivity and protective capacity values ranging from 10 to 31 m/day and 0.029 to 0.074 mhos respectively; zones of low hydraulic conductivity and weak protective capacity with conductivity and protective capacity values ranging from 5 to 8 m/day and 0.107 to 0.151 mhos respectively and zones of low hydraulic conductivity and poor protective capacity with conductivity and protective capacity values ranging from 5 to 9 m/day and 0.035 to 0.085 mhos respectively. This area which covers the central and eastern part of the investigated area includes VES 2, VES 3, VES 5, VES 8, VES 12, VES 14, VES 17, VES 18, VES 19, VES 20, VES 21, VES 23, VES 24, VES 25, VES 27, VES 28 and VES 29.

The area of poor or very low groundwater potential comprises zones of poor hydraulic conductivity and weak protective capacity with conductivity and protective capacity values ranging from 2 to 4 m/day and 0.101 to 0.126 mhos respectively, as well as zones of poor hydraulic conductivity and poor protective capacity with conductivity and protective capacity values ranging from 3 to 5 m/day and 0.039 to 0.088 mhos respectively. This zone which covers the south-western part of the investigated area includes VES 6, VES 7, VES 9, VES 10, VES 15, VES 16, VES 22 and VES 26. Figure 7f shows the groundwater evaluation map of the study area.

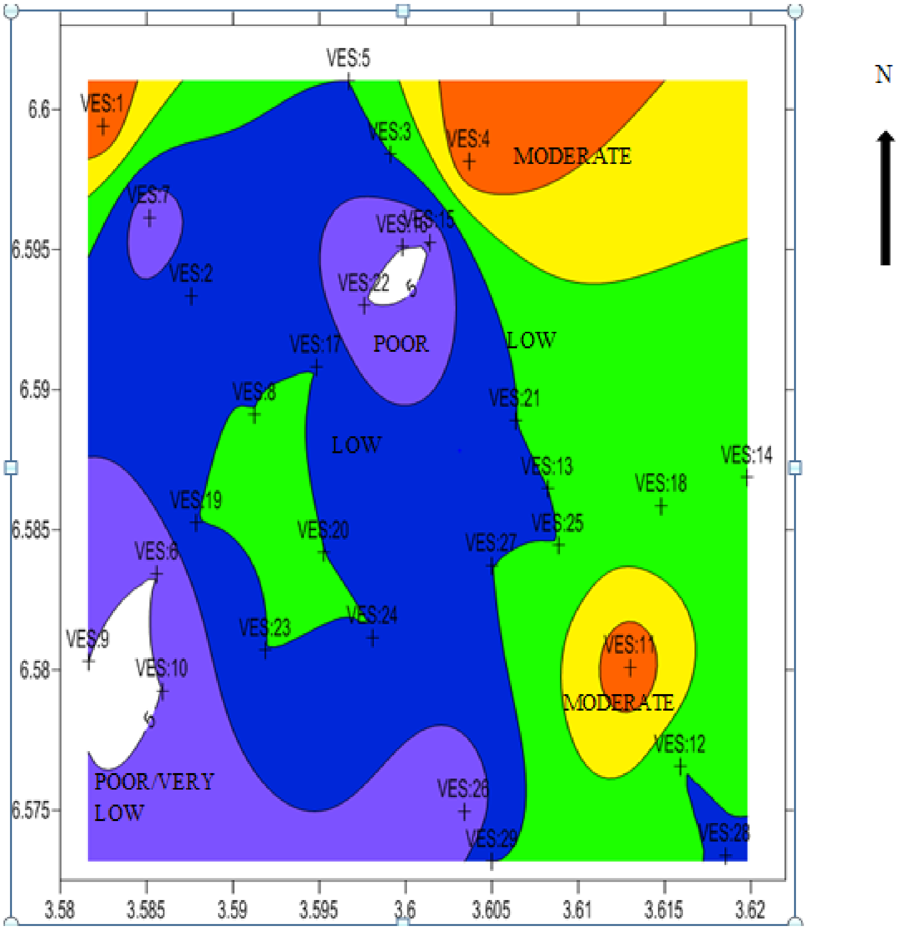

Figure 7f: Groundwater evaluation map of the study area.

CONCLUSION

The results of the 2-D electrical resistivity measurements and the Vertical Electrical Sounding revealed complexity in the geology of the study area which comprises clay, clayey sand, lateritic clayey sand, and sand. The two geophysical techniques displayed effectiveness in delineating the study area as two aquiferous units corresponding to the first or shallow aquiferous units and the second or deep aquiferous units are identified in this study. The shallow aquifer units characterized are more vulnerable to contamination due to its poor protective capacity. The weak to poor natures of the protective capacity of these aquiferous units are probably due to their relative thinness, closeness to the surface and unavailability of a very good retarding overburden layer. Generally, this present study provided a detailed assessment of secondary geoelectric factors influencing groundwater potential in the study area and the necessity to integrate these factors in prospecting for groundwater.

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