Communication in Physical Sciences 2020, 5(3):281-290

Evaluation of Groundwater Potential in Gashua Northeast Nigeria, Using Electrical Resistivity Method.

Agada Livinus Emeka, Adetola Sunday Oniku, and Osita Meludu
Received 25 April 2020/Accepted 17 June 2020/Published online: 20 June 2020

Abstract *Electrical resistivity method was used to evaluate the groundwater potential of Gashua, Northeast Nigeria. A total of ten (10) vertical electrical sounding (VES) using Schlumberger electrode configuration were carried out. The field data was interpreted using Winresist version 1. The results of the electrical resistivity survey indicated that the study area is composed of five geoelectrical layers namely; the topsoil (which is a mixture of sand and clay materials), clay, sand, sandy clay and sand. The resistivity of the first layer range from 42.7 to 199.7 Ωm and its thickness range from 0.6 to 1.9 m, the second layer had resistivity ranging from 16.5 to 37.9 Ωm with a thickness ranging from 4.1 to 10.7 m. The resistivity of the third layer ranged from 101.2 to 288.2 Ωm and the thickness ranged from 38.9 to 99.7 m, this was the first aquifer in the study area. The resistivity of the fourth layer ranged from 100.7 to 214.3 Ωm and its thickness from 28.5 to 94 m. The fifth layer is the second aquifer and its resistivity ranged from 254 to 350 Ωm. The aquifer resistivity ranged from 101.2 to 288.2 Ωm and from 253.8 to 350.1 Ωm for the first and second aquifers respectively. The study area is composed of two potential aquifers that are capable of producing groundwater, the first aquifer is unconfined and it highly susceptible to contamination. The second aquifer is confined and it is capable of yielding high volume and quality groundwater for both domestic and industrial consumption. It is advisable to drill boreholes in the study area to a depth beyond 120 m in order to have sustainable and quality groundwater supply for consumption.*

Key Words: *Gashua, groundwater potential, resistivity, aquifer, layer, Geoelectric, thickness.*

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1.0 Introduction

Increase in population growth alongside with industrialization had given rise to intensive exploitation of groundwater in Gashua area. Groundwater is used for domestic, industrial and agricultural purposes in the study area. Base on the importance of groundwater to human existence in the area, it is important to explore the groundwater potential in the study area. Detailed evaluation of groundwater potential is essential because it can provide information on the depth, thickness of the aquifer and the overburden that will guide the abstraction of quality groundwater in any given locality. There are several boreholes and hand dug well that were drilled without proper information and most of them have ceased to function because they were not properly guided. Therefore, the consequence was dryness or inadequate supply of water by boreholes and wells during dry season (Agada *et al*., 2020). Groundwater is the water which occurs beneath the earth's surface and it is stored in the aquifer (Agada *et al*., 2020). An aquifer is a geologic formation which stores and transmits groundwater (Agada *et al*., 2020). The nature and thickness of an aquifer determine the quality of the groundwater it contains and its yielding capacity. An aquifer could be confined or unconfined. A confined aquifer is an aquifer that is overlain by a relative impermeable layer of rock. Unconfined aquifer is an aquifer whose water table is at atmospheric pressure. It is recharged by rain or stream water infiltrating directly through the overlying soil.

Groundwater constitute about thirty percent of the world fresh water supply. Ninety-five percent of the population of the study area depends on groundwater for their domestic, industrial and agricultural activities. Groundwater is naturally replenished by surface water from rainfall, streams and rivers. The study area is located in the fringe of Chad basin. The Chad basin consists of sands, clays, and silts, with interbedded discontinuous clay lenses (Agada *et al*., 2020).

George *et al*. (2017) carried out surface conductivity of residual argillaceous bands in the groundwater repositories of coastal sediments of EOLGA. The analysis of the data shows that the aquifer systems composing of fine sands, siltstones and coarse sand have bulk and pore-water resistivities ranging from 40.1–2049.4 Ω m (average = 995.18 Ω m) to 2.7–256.9 Ω m (average = 91.2 Ω m) respectively. Anomohanran (2011) carried out geophysical investigation of Oleh, Nigeria to determine the groundwater potential and the geological structure of the area. He used vertical electrical sounding method and reported that the first aquifer is unconfined and prone to pollution and had resistivity ranging from 347.4 to 1137 Ωm and depth ranging between 2.0 and 3.7 m. The second aquifer was however described as viable source of portable water and recommended borehole within the fourth layer because of its quality and viability. Little has been reported on the status of groundwater in the zone and yet water supply is limited. Acquisition of such knowledge can provide a background information that can serve as a guide for geological exploration of groundwater. Hence the present study is aimed at exploring underground water potential in Gashua, Northeast Nigeria. Geophysical exploration methods such as electrical resistivity, seismic refraction, magnetic, electromagnetic and gravity methods have proven to be effective in groundwater exploration. But in this study, electrical resistivity method was adopted using Schlumberger array because of its efficiency and depth of investigation. The objective of this study is to understand the overall groundwater conditions of the study area with emphasis on the nature, thickness and the types of aquifers in the study area. The results of this study will help in providing useful information that will help in identifying potential boreholes and well sites that could produce quality groundwater and optimal yield.

1.1 Study Area

Gashua is a town in Yobe State, northeastern Nigeria, situated close to the convergence of Hadeija and Jama'are rivers in the Chad Basin. It is located on latitude 12^0 $52^{'}$ North and Longitude 11^0 $2^{'}$ East. The Chad consist of three water bearing horizons i.e. the upper, middle, and the lower zones (Matheis, 1976). Lithologically, the upper zone is composed of layers of clayed grits, sands and sandy clay of varying thickness (Makinde *et al*., 2010). It has a population of about 125, 000 according to 2006 national population census result. The climate is characterized by short wet season (June – September) and long dry season (October – May), with high temperatures of about 39^0C to 45^0C. During the raining season, temperatures fall to 25 ^{0}C with annual rainfall of about 500 to 1000 mm.

1.2 Geology of the Study Area

Gashua is located within the Chad basin. The Chad basin extends to five countries in Africa, namely, Chad, Nigeria, Cameroon, Central Africa Republic, and Niger. The Basin lies between latitudes 11^0 N and 14^0 N and longitude 9^0 E and 14^0 E, covering Borno State, parts of Yobe and Jigawa States in Nigeria. About ten percent of the Chad Basin lies in the Northeastern part of Nigeria (Agada *et al*, 2020). The Chad basin resulted from plate divergence along the West Africa continental margin (Yikarebogha *et al.,* 2013). The various process which led to the plate divergence started with regional thermal doming, volcanism, rifting, formation of oceanic crust, marine incursion and subsequent widening and deepening of young oceans (Yikarebogha *et al*., 2013). Sedimentation in the Chad basin started in Albian times, the basal sedimentary sequence is the Bima sandstone, which was deposited unconformably over the Precambrian crystalline basement rock (Yikarebogha *et al*., 2013). Deposition of the Bima sandstone continued up to the Cenomania. The Turonian was characterized by extensive transgression during which the Gongila Formation was deposited as a transitional sea deposit (Avbovbo *et al*., 1986).

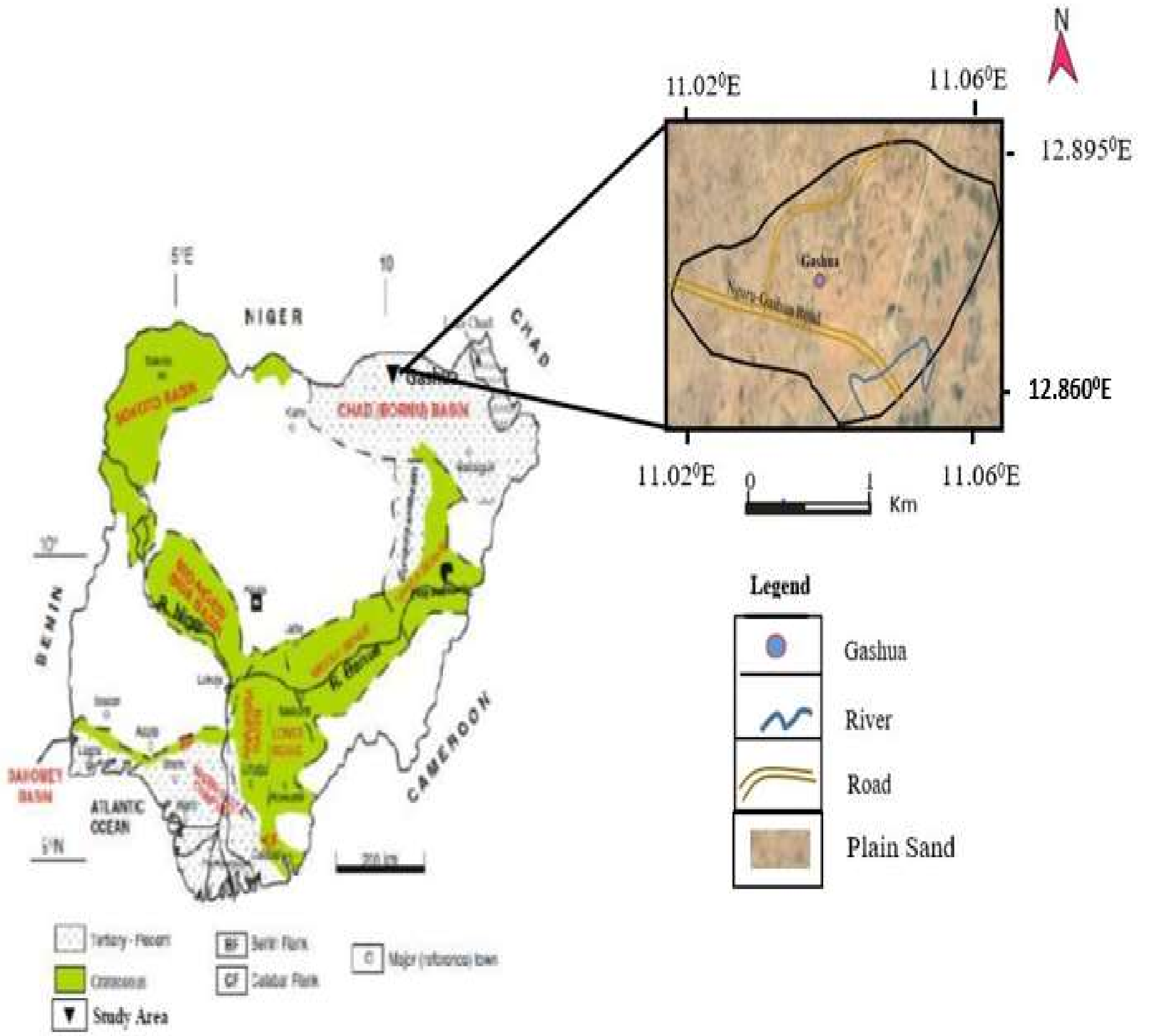


Fig. 1: Geological map of Nigeria (modified after Adebanji, 2012) showing sedimentary basins and the study area

The Fika shale was deposited during the transgression which began in the Turonian and continued up to the senonian period (Matheis, 1976). Towards the end of the Cretaceous, during the Maastrichtian time, an estuarine deltaic environment prevailed in the basin and the Gombe sandstone, shale and limestone were deposited (Yikarebogha *et al*., 2013). The Keri-Keri Formation was deposited unconformably on the eroded surface of the Gombe sandstone in the Pleistocene (Matheis, 1976). An unconformable Pleistocene deposit of the Chad formation was deposited on the Keri-Keri Formation (Matheis, 1976). The Keri-Keri formation is Eocene in age (Ola-Buraimo and Boboye, 2011).

2.0 Materials and Method

2.1 Materials

The following instruments were used for the data acquisition ABEM SAS1000 digital Terrameter, Personal computer, Global Positioning System (GPS), Hammers, Measuring tape, UPS Battery and Charger, pegs, ABEM SAS external Battery Adapter (EBA), Electrodes, Reels of Cables and Jumpers. The VES stations that were used for the study are indicated in Fig. 1.

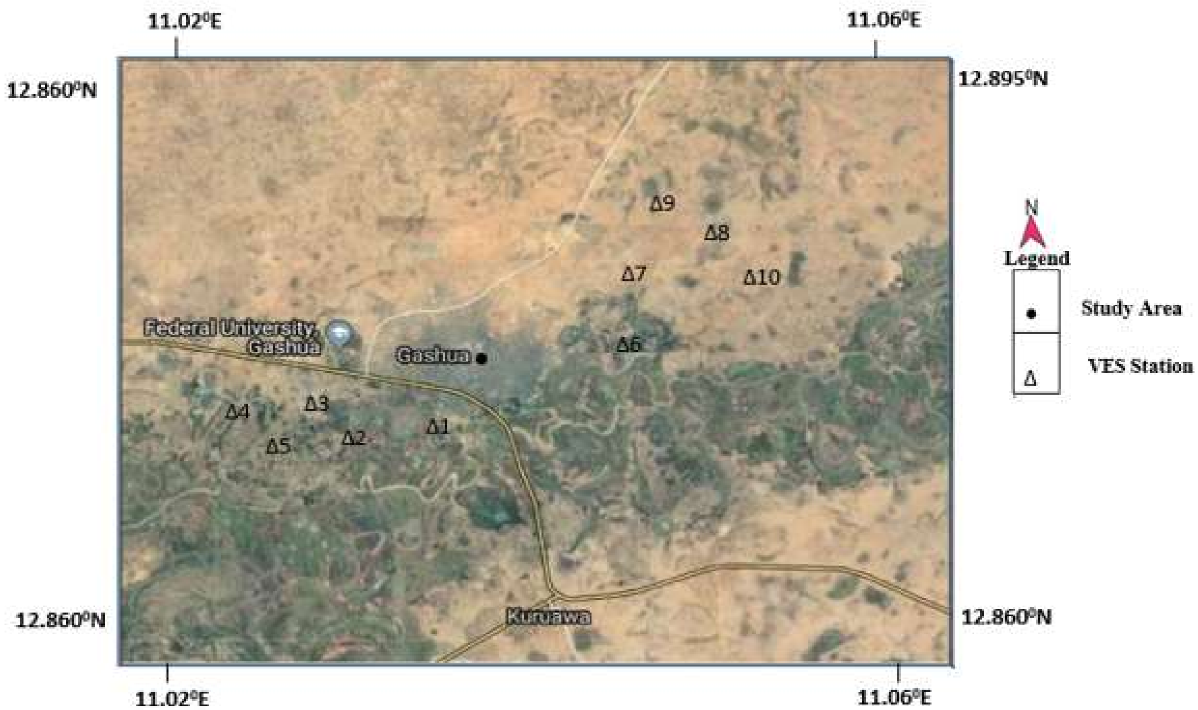


Fig. 2: Sketched Map of the Study area showing the VES stations

2.2 Methodology

Electrical resistivity method using Schlumberger array was used for this study, it involves the placing of four (4) electrodes collinearly. The VES stations were carefully selected (Fig. 2) and the electrical cables were laid along the profile, they were then linked to the ground using the electrodes through the sets of cable jumpers. The contact between the electrode cables, electrode take-outs and cable jumpers were checked for proper connections. The electrode test was performed to ensure that current was flowing through all the electrodes. The inner electrodes are the potential electrodes and the outer electrodes are the current electrodes. Ten (10) vertical electrical resistivity soundings were carried out in the study area with the aim of delineating the depth to the groundwater, aquifer thickness and lithology of the study area. The Terrameter measures the resistance, voltage and current. The apparent resistivity values were obtained by multiplying the resistance by the geometric factor (*K*), that is, (*R* x *K*). *K* was determined by using the following,

$$K = \frac{\left[\left(\frac{AB}{2}\right)^2 - \left(\frac{MN}{2}\right)^2\right] X\ 3.142}{\left(\frac{MN}{2}\right) X\ 2} \qquad (1)$$

where AB is the current electrode spacing and MN is the potential electrode spacing. During sounding, apparent resistivity of the subsurface material was measured as a function of depth. The progressive increase in the distance between the current electrodes causes the current lines to penetrate to greater depths. The acquired vertical electrical sounding (VES) data was processed using WINRESIST version 1.0 software.

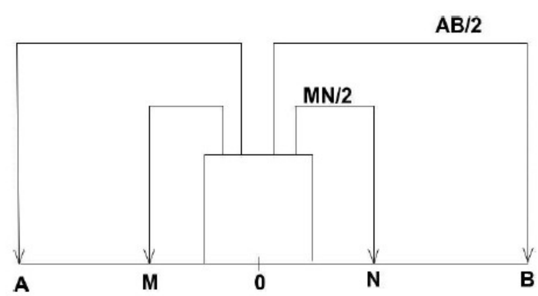


Fig. 3: Schlumberger Array
(AB = Current electrodes, MN = Potential electrodes)

The results from the graph drawn by the processing software shows the thickness, depth and resistivity values of the various soil layers. In the graph, the apparent resistivity values were plotted against the current electrode spacing

($^{AB}/_{2}$) (m) and an iterative process was carried out until a good fit was obtained (Loke and Barkar, 1996).

4.0 Results and Discussion

The results of the electrical resistivity survey showed that the topsoil has resistivity ranging from 42.7 to 189.3 Ωm and 0.6 to 1.9 m thickness, the second layer is a clay formation which has resistivity that ranged from 15.9 to 37.9 Ωm and thickness ranging from 4.1 to 10.7 m (Table 1). The clay content in the second layer is minimal and the thickness of the layer in all the VES stations is generally small (Figs. 4 and 5), thus providing little or no protection for the aquifer beneath them.

Table 1. Geoelectric and Lithologic Parameters of the Study Area

S/N	Layers	Resistivity (Ωm)	Thickness (m)	Depth (m)	Lithology
	1	91.1	0.8	0.8	Topsoil
	2	26.7	6.7	7.5	Clay
VES 1	3	213.4	44.4	51.9	Sand
	4	104.8	58.6	110.5	Sandy Clay
	5	260.6	---	---	Sand
	1	109.4	1.4	1.4	Topsoil
	2	19.9	5.5	6.9	Clay
VES 2	3	288.2	38.9	45.8	Sand
	4	100.7	66.7	112.5	Sandy Clay
	5	314.8	----	-----	Sand
	1	111.3	1.0	1.0	Topsoil
	2	31.7	5.0	6.0	Clay
	3	101.2	46.5	52.5	Sand
VES 3	4	214.3	49.0	101.5	Sandy Clay
	5	281.4	----	---	Sand
	1	107.5	1.4	1.4	Topsoil
	2	16.5	4.5	5.9	Clay
VES 4	3	189.7	99.7	105.6	Sand
	4	136.5	37.6	143.2	Sandy Clay
	5	350.1	----	----	Sand
VES 5	1	189.3	0.6	0.6	Topsoil
	2	29.9	7.0	7.6	Clay
	3	196.0	50.5	58.1	Sand
	4	184.4	94.0	152.1	Sandy Clay
	5	307.4	----	----	Sand
	1	42.7	1.1	1.1	Topsoil
	2	30.1	4.3	5.4	Clay
VES 6	3	101.4	58.6	64.0	Sand
	4	171.4	28.5	92.5	Sandy Clay
	5	318.7	----	-----	Sand
	1	59.9	1.6	1.6	Topsoil
	2	15.9	4.1	5.7	Clay
VES 7	3	266.9	73.4	79.1	Sand
	4	125.3	47.5	126.6	Sandy Clay

	5	291.8	----	----	Sand
	1	169.3	1.1	1.1	Topsoil
	2	25.1	7.0	8.1	Clay
VES 8	3	242.0	44.1	52.2	Sand
	4	118.1	30.5	87.3	Sandy Clay
	5	253.8	---	----	Sand
	1	113.3	1.9	1.9	Topsoil
	2	32.4	10.3	12.2	Clay
VES 9	3	194.8	45.6	57.8	Sand
	4	149.7	29.5	87.3	Sandy Clay
	5	306.3	----	----	Sand
	1	99.7	0.8	0.8	Topsoil
	2	37.9	10.7	11.5	Clay
'EVES 10	3	274.1	46.9	58.4	Sand
	4	132.8	69.4	127.8	Sandy Clay
	5	326.8	----	----	

The sand formation was the third layer and its resistivity ranged from 101.2 to 288.2 Ωm with thickness ranging from 38.9 to 99.7 m (Table 1). It is the first aquifer in the study area where most of the hand dug wells and shallow boreholes take their root. It could be vulnerable to pollution by contaminant plume considering its shallow nature, porosity, permeability and dominance of sand formation in the study area, it is an unconfined aquifer (Figs 4 and 5). The fourth layer is made up of sandy-clay which has resistivity values that ranged from 100.7 to 214.3 Ωm and thickness ranging from 28.5 to 94 m (Table 1). The fifth layer is under confined condition provided by the fourth layer. This layer is the most important groundwater unit in the study area and its resistivity value range from 254 to 350 Ωm. It is a sandy aquifer with great thickness. Expected depths of boreholes in the study area were found to range from 60 to 120 m while the expected average depth of hand dug wells in the study area is 20 m (Makinde *et al*., 2010).

The geoelectric sections (Figs. 4 and 5) were obtained from the results of the vertical electrical resistivity sounding survey using Schlumberger array.

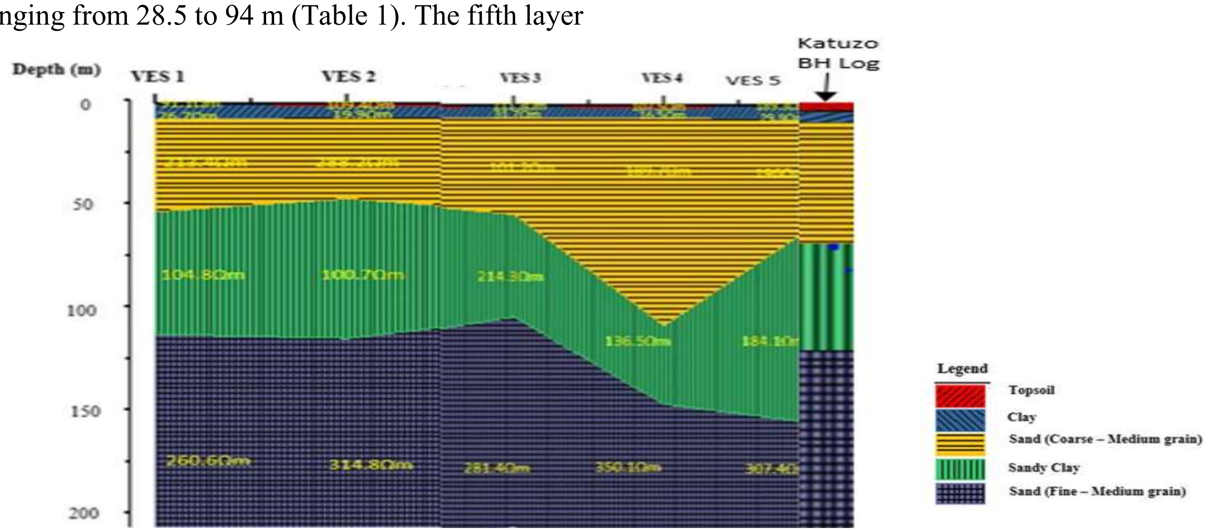


Fig. 4: Correlation of the geoelectric sections of VES 1-5 with an existing Borehole from Katuzo area of the study area

The results showed good correlation in terms of layers when compared with an existing borehole log from Katuzo area of the study area. The results obtained also indicated that the study area has two potential aquifers that are capable of producing groundwater. The first aquifer is not confined and it is susceptible to contamination by leachate. The second aquifer is confined by a thick sandy clay and it is capable of yielding quality groundwater with high degree of sustainability. All of the hand dug wells and some of the boreholes were drilled to the first aquifer which is unconfined. Groundwater in these wells and boreholes fluctuate due to seasonal changes. At the peak of the dry season (February to May) most of the hand dug wells get dried and the shallow boreholes become incapacitated due to groundwater fluctuation.

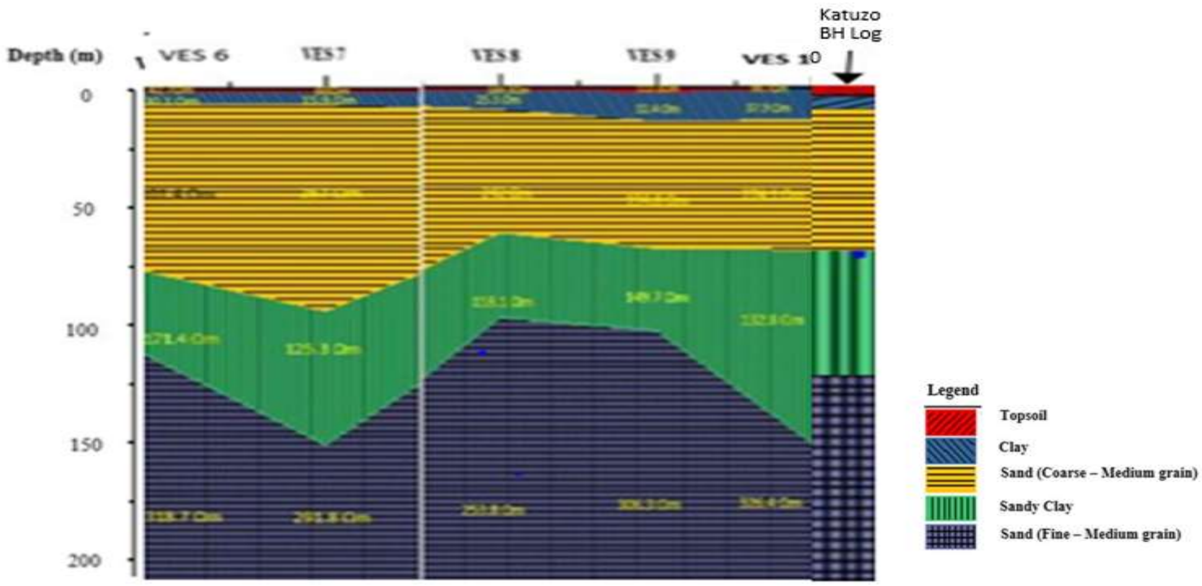
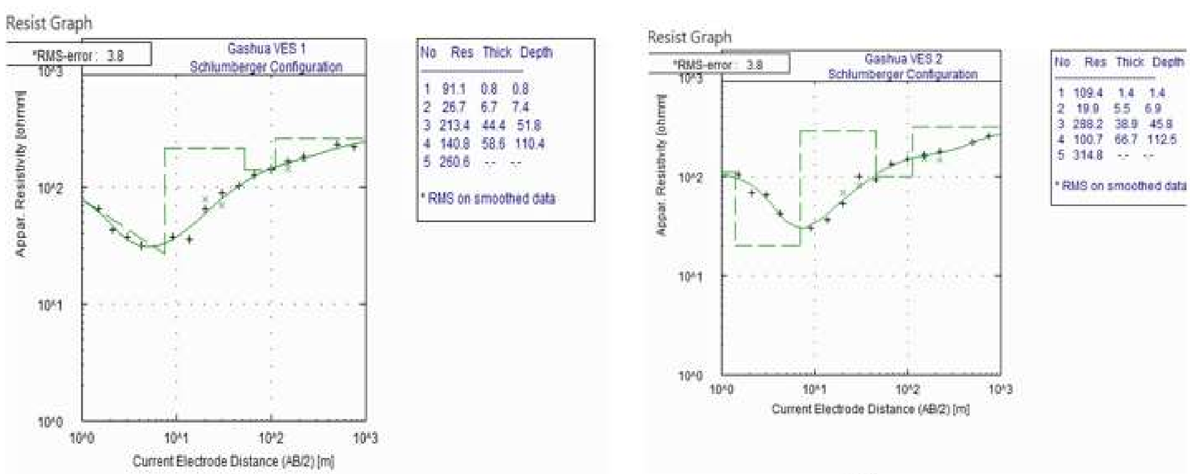
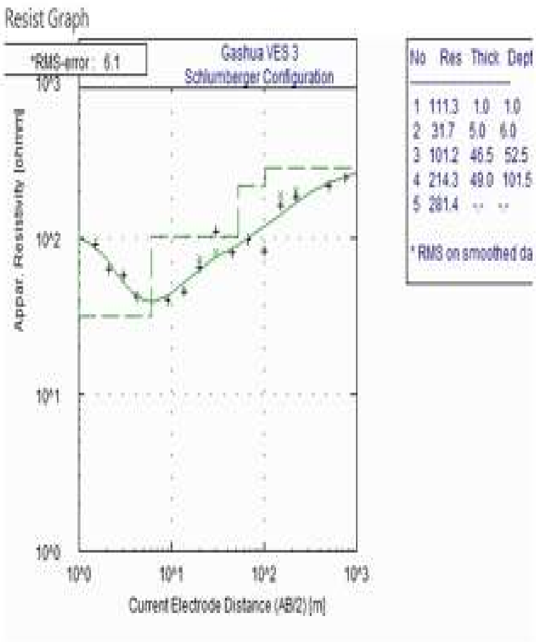


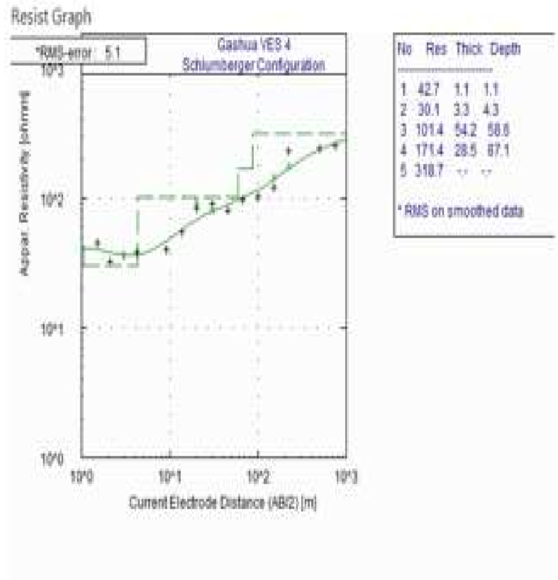
Fig. 5: Correlation of the geoelectric sections of VES 6-10 with an existing Borehole from Katuzo area of the study area



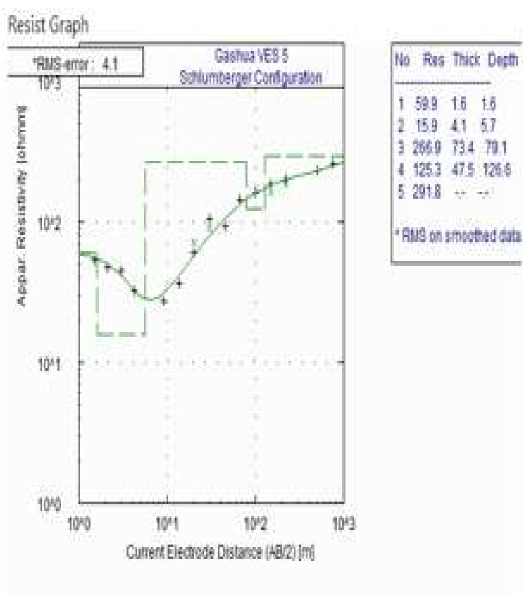
(a) (b)


Resist Graph
*RMS-error : 6.1
Gashua VES 3
Schlumberger Configuration
Appar. Resistivity [ohmm]
Current Electrode Distance (AB/2) [m]
No Res Thick Dept
1 111.3 1.0 1.0
2 31.7 5.0 6.0
3 101.2 46.5 52.5
4 214.3 49.0 101.5
5 281.4 -.- -.-
* RMS on smoothed da

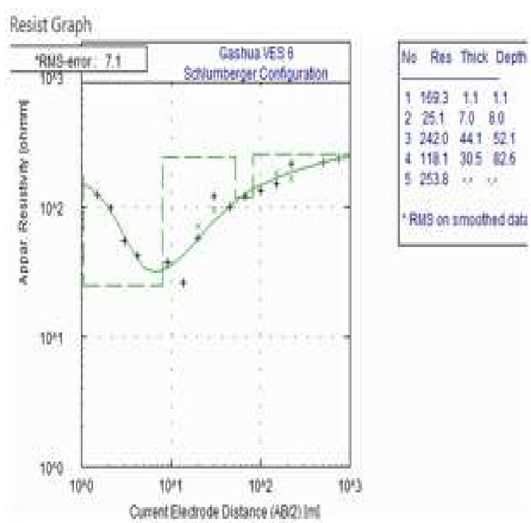
(c)


Resist Graph
*RMS-error : 5.1
Gashua VES 4
Schlumberger Configuration
Appar. Resistivity [ohmm]
Current Electrode Distance (AB/2) [m]
No Res Thick Depth
1 42.7 1.1 1.1
2 30.1 3.3 4.3
3 101.4 54.2 58.6
4 171.4 28.5 87.1
5 318.7 -.- -.-
* RMS on smoothed data

(d)


Resist Graph
*RMS-error : 4.1
Gashua VES 5
Schlumberger Configuration
Appar. Resistivity [ohmm]
Current Electrode Distance (AB/2) [m]
No Res Thick Depth
1 59.9 1.6 1.6
2 15.9 4.1 5.7
3 266.9 73.4 79.1
4 125.3 47.5 126.6
5 291.8 -.- -.-
* RMS on smoothed data

(e)


Resist Graph
*RMS-error : 7.1
Gashua VES 6
Schlumberger Configuration
Appar. Resistivity [ohmm]
Current Electrode Distance (AB/2) [m]
No Res Thick Depth
1 169.3 1.1 1.1
2 26.1 7.0 8.0
3 242.0 44.1 52.1
4 118.1 30.5 82.6
5 253.8 -.- -.-
* RMS on smoothed data

(f)

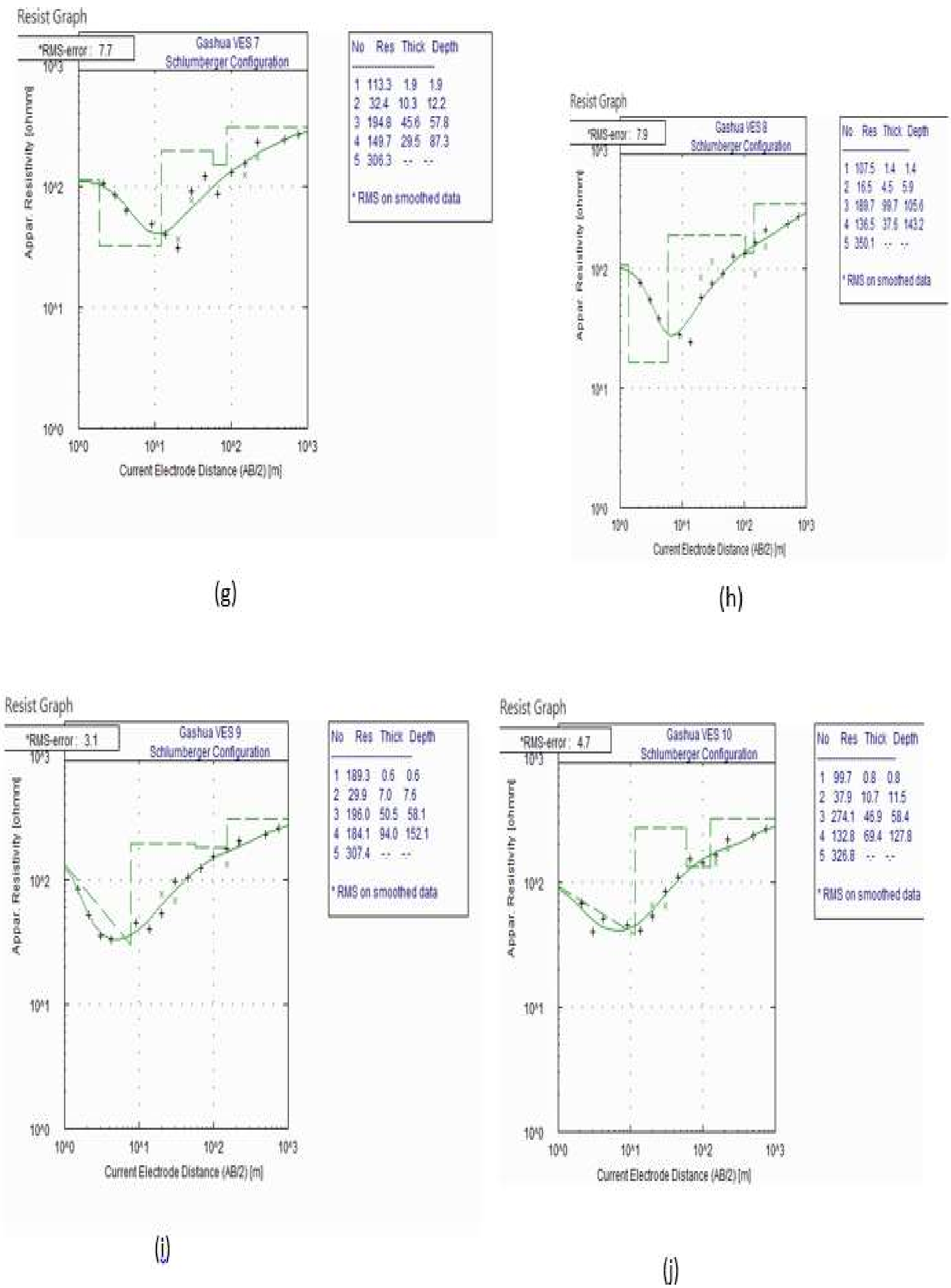


Fig. 4 (a-j): Geoelectric Curves and their Parameters

4.0 Conclusion

From the results and findings of the study, the area under study is composed of two potential aquifers that are capable of producing groundwater. The first aquifer is unconfined and unsuitable for siting of boreholes. The second aquifer is confined and is therefore recommended for groundwater abstraction for domestic consumption. Base on the findings of this study, it is advisable to drill boreholes for domestic water consumption to a depth beyond 120m in the study area in order to ensure sustainability and quality groundwater supply in the area.

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