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Groundwater Investigation of Gadam town, Gombe State, Northeastern Nigeria

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Abstract
A resistivity survey was carried out in Gadam Kwami LGA, sheet 152MW between Latitude 10˚ 27'30" - 10˚30'30" and Longitude 11˚04'00" - 11˚07'00". Gombe state Northeastern Nigeria to study the groundwater potential such a depths, thickness, resistivity and sediment at which water can be obtained. The Geo-electrical method used in the survey is Vertical Electrical Sounding, with the aim of determining Groundwater potential. Fifteen (15) Vertical Electrical Sounding were conducted using Schlumberger configuration with a maximum electrode separation of AB/2 = 200m to determine location favorable for sitting of borehole. The VES data were subjected to an iteration software (WINRESIST) which shows that the area is compose of top soil soft clay, compacted clay, Arkosic sand and clayey sand. The quantitative analysis comprises of Geo-electric section and Iso-rsistivity Maps. The Iso-resistivity map at AB/2 = 200m and an Iso-resistivity map of AB/2 = 150m shows the area of low resistivity with sky blue which include VES2, VES3, VES6, VES5, VES7 VES11, VES3, VES6, VES14, the area is good for groundwater potential. The rest of the VES points has high resistivity which indicated the absence of groundwater.

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I. Introduction

Water is one of the essential necessities in nature, indispensable to all organic life and a necessary resource for livelihood all life requires water. The hydrosphere (Earth's water) is an important agent to geologic change. Communities rely on suitable water sources for consumption, power generation, crop production and many other things. Access to water has always play an important role in human settlement and its daily activities the electrical resistivity method is one of the most widely used and it has proved particularly effective in groundwater exploration because many geological formation properties such as porosity and permeability that are critical to hydrogeology can be correlated with electrical conductivity signature (Mohammed A. G and Ibrahim A. 2013). And also Direct current resistivity method is common tool for surveying water in arid area. It is well known that this method can be successfully employed for groundwater investigation, `where a good electrical resistivity contrast exists between the saturated and unsaturated layers. Geophysical methods have been a very useful tool in determining the geological characteristics of underlying rocks by measurement of their physical properties. There are various techniques employed in groundwater exploration. However, electrical resistivity method is reliable in identifying zones of relatively low resistivity which might be indicative of saturated strata.

The Vertical Electrical Sounding with Schlumberger array as a low-cost technique and veritable tool in groundwater exploration and is more suitable in hydrogeological survey of sedimentary basin. This method is regularly used to solve a wide variety of groundwater problems. Accordingly, the Nigerian geological survey agency in 1923, carried out a hydrogeological investigation of Northern Nigeria, this has led to the drilling of the first borehole in Misau town (Misau1) in Bauchi State (Carter et al., 1963). Several prospecting for groundwater revealed the groundwater potential across the vast areas of northern Nigeria.

Vertical Electrical Sounding (VES) is an important geophysical tool for investigation of geological media. It is by far the most used method for geoelectrical surveying because it is cost effective and produces moderate results. Moreover, the field measurement technique is adjustable for different topographic conditions. The results of VES measurements can be interpreted qualitatively and quantitatively. However, it is a common technique in groundwater prospecting. The principle of this method is to insert an electric current of known intensity through the ground with the help of two electrodes (power electrodes – AB) and measuring the electric potential difference with another two electrodes (measuring electrodes – MN). The investigation depth is proportional to the distance between the power electrodes. The method is based on the estimation of the electrical conductivity or resistivity of the medium. The interpretation of the measurements can be performed based on the apparent resistivity values. To obtain the apparent resistivity as the function of depth, the measurements for each position are performed with several different distances between current electrodes. Despite several geoelectrical investigations reported for the northern Nigeria, substantial parts of the region remain unexplored. Therefore this research employed the use of electrical resistivity method using vertical electrical sounding (VES) techniques to explore the groundwater potential of the study area for human sustainability and development. The study will provide information on depth to which groundwater can be exploited and reveal the geoelectrical layers one may encounter in the subterranean, which may coincide with geological layers. The study area is located on the upper Benue trough with latitude N10˚27'30" - N10˚30'00" longitude E11˚04'00" – E11˚07'00" kwami local government of Gombe State on the topographic map of kwami sheet 152 NW. There is a major road that runs through it from Gombe to Dukku local government North-West. The people of Gadam community depended on farming and hunting as a source of livelihood.

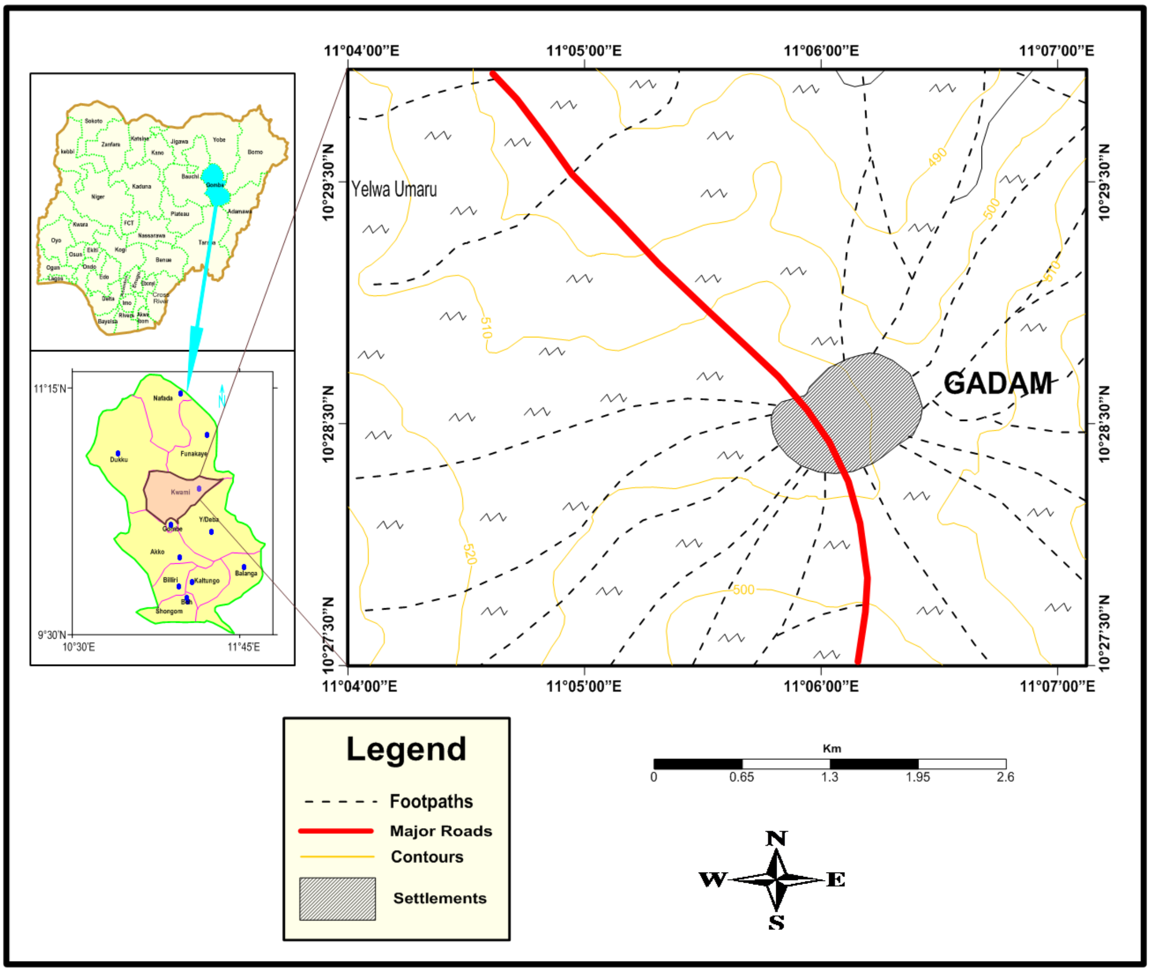

Figure 1: The topographic map of the study area

Olorunfemi and Fasuyi (1993) studied lithological logs from 40 wells drilled in 12 localities in parts of the Northern Nigeria and the interpretation results of the Vertical electrical Soundings (VES) were carried out to identify the geoelectric/hydrogeologic characteristics of the basement complex area. In this investigation, five aquifer types were identified. These include the weathered aquifer; the weathered/fractured (unconfined) aquifer; the weathered/fractured (confined) aquifer; the weathered/fractured (unconfined)/ fractured (confined) aquifer and the fractured (confined) aquifer. The mean groundwater yield for the aquifer types varies from 0.83 L/S for the weathered layer aquifer to 3.0 L/S for the weathered/fractured (unconfined) and fractured (confined) aquifers.

According to Konikow, and Kendy, (2005), since 1960, access to pumped wells has caused a rapid worldwide increase in groundwater development for municipal, industrial, and agricultural purposes. The global use of groundwater was estimated to be 750–800 km3/a (Wada Y., van beek 2010. In recent times, many organizations worldwide depend on groundwater for use due to several factors. Some of these include increase in population, inability of government to provide adequate water supply for use and high cost of providing this resource from surface water. According to the U.S. Census in 1990.

Arabi et al. (2009) considered results from 33 vertical electrical soundings (VES) around Gombe and environs, employing Schlumberger array with a maximum electrode separation of AB/2 = 200 m to determine locations favourable for sitting boreholes. From resistivity data interpretation, the result, it was shows that 21 of the VES points are three layers while twelve are four layers. The first layers have thicknesses ranging from 0.8 m to 16.1 m, the second and third layer have thicknesses ranging from 0.994m to 149m and 11.7 m to 108.2 m, respectively while the fourth layer had a thickness that extended beyond the probing depth. Fairly-high resistivity (40.9 – 74.4 Ωm) layers: These layers are interpreted to represents the slightly weathered and fractured zone, and the slightly porous and permeable rocks underlying the weathered material. The extent of weathering and fracturing is generally limited in crystalline rocks (Offodile, 1976). As a result, groundwater may occur only in small pocket or basins depending on the extent of weathering.

II. Method

Most resistivity techniques define a response function called apparent resistivity, (a) which can be calculated from the surface measurements. These apparent resistivities are usually functions of a variable that is related to the depth of current penetration. The apparent resistivity is equal to the true resistivity only when the subsurface is homogeneous. In practice, this condition is difficult to obtain. This is a convenient way of representing a response of the actual distribution of lateral resistivity in the subsurface measurements. If the electrodes are laid out along a profile and their separations are increased systematically, the change in the apparent resistivity will be a function of electrode spacing. Haven said that the subsurface resistivity is measured by applying an electric current through two current electrodes and measuring the resulting voltage difference between potential electrodes. For the general four electrode spread, the potential difference ΔU between the potential electrodes is given below:

$$U_1 - U_2 = \Delta U = \frac{I\rho}{2\pi}\left\{\left(\frac{1}{r_1} - \frac{1}{r_2}\right) - \left(\frac{1}{r_1} - \frac{1}{r_2}\right)\right\} \ldots\ldots\ldots\ldots\ldots\ldots \quad (1)$$

$$\Delta U = \frac{I\rho}{2\pi}\left(\frac{1}{r_1} - \frac{1}{r_2} - \frac{1}{r_1} + \frac{1}{r_2}\right) \ldots\ldots\ldots\ldots\ldots\ldots \quad (2)$$

$$\rho = \frac{\Delta U}{I}\frac{2\pi}{\left(\frac{1}{r_1} - \frac{1}{r_2} - \frac{1}{r_1} + \frac{1}{r_2}\right)} \ldots\ldots\ldots\ldots\ldots\ldots \quad (3)$$

Where ρ is the resistivity, I is the current and r_1, r_2, r_3 and r_4 are the inter-electrode distances as shown in Figure

$$\rho_a = K_f\left(\frac{\Delta U}{I}\right) \ldots\ldots\ldots\ldots\ldots\ldots \quad (4)$$

Where K_f is the geometric factor and it depends on electrode configuration used in the field measurement. Resistivity measuring instruments normally give a resistance value, $R = \frac{\Delta U}{I}$ so in practice the apparent resistivity value is calculated by

$$\rho_a = K_f R \ldots\ldots\ldots\ldots\ldots\ldots \quad (5)$$

The calculated resistivity value is not the true resistivity of the subsurface, but an “apparent” value that is the resistivity of a homogeneous ground that will give the same resistance value for the same electrode arrangement. The relationship between the “apparent” resistivity and the “true” resistivity is a complex relationship. Over uniform earth or homogeneous isotropic medium this calculated resistivity is constant for different electrode separation and any current. However, if the ground is inhomogeneous, the calculated resistivity varies as the electrode spacing is varied or the array is moved about. This calculated resistivity is called “apparent resistivity ρa”, which is diagnostic of the true resistivity of the subsurface in the vicinity of the electrode array. The apparent resistivity may be smaller or larger than the true resistivity or in rare cases identical with one of the true resistivity values. The apparent resistivity is the same as the true resistivity in a homogeneous subsurface, but normally a combination of contributing strata of an inhomogeneous subsurface. The value of the apparent resistivity obtained with small electrode spacing is called the surface resistivity. In any electrode layout, the potential and current electrodes can be interchanged and from the principle of reciprocity, the apparent resistivity should be the same (unchanged) in either case.

Igneous and metamorphic rocks typically have high resistivity values. The resistivity of these rocks is greatly dependent on the degree of fracturing, and the percentage of the fractures filled with groundwater. Thus a given rock type can have a large range of resistivity, from about 1000 to 10 million Ωm, depending on whether it is wet or dry. This characteristic is useful in the detection of fracture zones and other weathering features, such as in engineering and groundwater surveys. Sedimentary rocks, which are usually more porous and have higher water content, normally have lower resistivity values compared to igneous and metamorphic rocks. The resistivity values ranges from 10 to about 1000 Ωm, with most values below 1000 Ωm. The resistivity values are largely dependent on the porosity of the rocks, and the salinity of the contained water.

Unconsolidated sediments generally have even lower resistivity values than sedimentary rocks, with values ranging from about 10 to less than 100 Ωm. The resistivity value is dependent on the porosity (assuming all the pores are saturated) as well as the clay content. Clayey soil normally has a lower resistivity value than sandy soil. However, note the overlap in the resistivity values of the different classes of rocks and soils. This is because the resistivity of a particular rock or soil sample depends on a number of factors such as the porosity, the degree of water saturation and the concentration of dissolved salts. The resistivity of groundwater varies from 10 to 100 Ωm. depending on the concentration of dissolved salts. Note the low resistivity (about 0.2 Ωm) of seawater due to the relatively high salt content. This makes the resistivity method an ideal technique for mapping the saline and fresh water interface in coastal areas. One simple equation that gives the relationship between the resistivity of a porous rock and the fluid saturation factor is Archie’s Law. It is applicable for certain types of rocks and sediments, particularly those that have low clay content. The electrical conduction is assumed to be through the fluids filling the pores of the rock. Archie's Law is given by:

$$C_t = \frac{1}{a} C_w \ \phi^m \ S_w^n \ \dots\dots\dots \qquad (6)$$

Metallic sulfides (such as Pyrrhotite, Galena and Pyrite) have typically low resistivity values of less than 1Ωm. The resistivity value of a particular ore body can differ greatly from the resistivity of the individual crystals. Other factors, such as the nature of the ore body (massive or disseminated) have a significant effect. Graphitic slate has low resistivity value, similar to the metallic sulfides, which can give rise to problems in mineral surveys. Most oxides, such as hematite, do not have a significantly low resistivity value. Metals, such as iron, have extremely low resistivity values.

$$\rho_a = \frac{(AB/_2)^2 - (AB/_2)^2}{MN} - \frac{\Delta V}{I} \dots\dots\dots \qquad (7)$$

The Geophysical field mapping phase: the resistivity meter used in this research was Direct Resistivity Meter (DDR-3) water stone, In view of its high resolution and depth probe, the Schlumberger configuration was used for this survey. The resistivity meter is placed at the survey site which is suitable for lateral spreading of the cable wires in either direction. The non polarizing electrodes (inner electrodes) needed for measuring the potential differences are placed at predetermined distances on either side of chosen center near to the measuring equipment and current electrodes (outer electrodes) were also placed on either side. Covered cable is connected to the potential electrodes as also the current electrodes are connected to the proper terminals on the equipment. The power supply pack is also connected to the instrument. The current electrodes are driven into the ground at least 10 to 15 cm deep each on either side of the center with use of hammer. The working of the instrument begins and is operated as per the principles used in the instrument. Current is passed through the two extreme electrodes (current electrodes); the potential difference was received by potentiometer of DDR-3 meter between the two inner electrodes spaced at $\left(MN/_2\right)$ = 0.5 m, 2 m, 10m. While AB = 200m due to the fact that the overburden in the area is not as thick as to require a large current electrodes spacing for deeper penetration and current electrodes were moved equally on the either side (as the distance between electrodes increases, the depth of penetration also increases) of the station point according to designed acquisition parameters in the study, the design was 1.5, 2, 3, 4.5, 7, 10, 10, 14, 17, 20, 25, 30, 45, 45, 60, 70, 80, 100 and 200m.

A total of thirteen (15) VES point were marked out for the survey and the data of each VES point were recorded on data sheet, the locations (co-ordinates and elevation) of each VES point was also recorded with the aid of GPS (Global Positioning System) meter.

III. Results

The apparent resistivity (ρ_a) was then calculated for each VES point using ρ_a = RK_f. Where K_f the Geometric factor and R is is the Resistance. The resistivity data were processed using WINRESIST Computer software.

The acquired data was analyzed using WINRESIST computer software.

Table: 1 summary of the interpreted VES curves

No.of VES	LOCATION /ELEVATION	NO. OF LAYERS	RESISTIVITY	LAYER THICKNESS	DEPTH	INFERED LITHOLOGY	CURVE TYPE
VES 01	N 10˚29'36"	1	401.9	14.8	14.8	Top soil	KQ
	E 11˚4'10"	2	6095.4	32	46.8	sandstone	
	ELEV.523m	3	2256.5	11.2	58	sandstone	
		4	1369.2			sandstone	
VES 02	N 10˚29'22"	1	115.8	4.6	4.6	Top soil	AAK
	E 11˚4'6"	2	387.4	6.5	11.1	Clayely sand	
	ELEV.503m	3	497.6	28	39/1	sandstone	
		4	1177.6	38.2	77.3	arkosic sand	
		5	616				
VES03	N 10˚30'19"	1	490.7	0.8	0.8	Top soil	HKA
	E 11˚4'14"	2	153.7	12.8	13.6	Compacted clay	

	ELEV.508m	3	1926.5	32.1	45.7	sandstone	
		4	438.5	24.7	70.4	clayely sand	
		5	137.4				
VES 04	N 09˚29'49"	1	688.4	0.5	0.5	Top soil	HAK
	E 11˚4'44"	2	94.1	9.7	10.2	Clayely sand	
	ELEV.498M	3	518.3	4.2	14.4	Arkosic sand	
		4	1416.1	24.5	38.9	Sandstone	
		5	12703.8			Arkosic sand	
	3m						
VES 05	N 10˚29'48"	1	249.4	2.5	2.5	Top soil	HAA
	E 11˚4'51"	2	183.1	4.3	6.8	Compacted clay	
	ELEV.500m	3	223.5	2.9	9.7	Clayely sand	
		4	722.6	47.2	56.9	Arkosic sand.	
		5	2836.1				
VES 06	N 10˚29'19"	1	226.1	2.4	2.4	Top soil	AA
	E 11˚5'15"	2	425.2	19.7	22.1	Clayely sand	
	ELEV.499m	3	452.8	47.3	69.4	Clayely Sand	
		4	2602.9				
VES 07	N 10˚28'39"	1	1377.8	0.6	0.6	Top soil	HKH
	E 11˚5'48"	2	202.2	8.3	8.8	Compacted clay	
	ELEV.521m	3	2087.5	13.5	22.3	sandstone	
		4	326.9	41.7	64	clayely sand	
		5	1866.3				
VES 08	N 10˚28'30"	1	235.7	1.9	1.9	Top soil	KHK
	E 11˚5'40"	2	598.7	2	3.9	Arkosic sand	
	ELEV.527m	3	107.9	5.8	9.7	Compacted clay	
		4	7080.9	30.9	40.6	sandstone	
		5	5497.9			sandstone	
VES 09	N 10˚28'40"	1	5674.3	2.2	2.2	Topsoil	HKA
	E 11˚5'59"	2	380	3.8	6	Arkosic sand	
	ELEV.517m	3	7746.8	21.7	27.7	sandstome	
		4	2966.1	22.4	50.1	sandstone	
		5	213.2				
VES 10	N 10˚28'30"	1	2192.2	2.7	2.7	Top soil	HAA
	E 11˚5'40"	2	203.6	2.9	5.5	Compacted clay	
	ELEV.527m	3	318.9	1.6	7.1	Clayely sand	
		4	723.6	56.3	63.4	Arkosic sand	
		5	4780.4				
VES 11	N 10˚28'37"	1	139.7	0.5	0.5	Top soil	QHA
	E 11˚6'09"	2	1118.1	1.1	1.6	sandstone	
	ELEV.512m	3	13.2	4.1	5.7	soft clay	
		4	816.9	7.5	13.2	arkosic sand	
		5	8074				
VES 12	N 10˚28'12"	1	117.2	3.8	3.8	Top soil	KAK
	E 11˚6'6"	2	1151.4	8.3	12.1	sandstone clayely	
	ELEV.513m	3	290.4	17.9	30	sand	
		4	15694.6	187.1	217.1	sandstone	
		5	1693.4				
VES 13	N 10˚27'45"	1	1013.9	0.5	0.5	Top soil	HAK
	E 11˚6'7"	2	77.5	6.0	6.5	Compacted clay	
	ELEV.503m	3	203.9	3.3	9.7	sandstone	
		4	5627.5	33.6	43.3	sandstone	
		5	2203.1				
VES 14	N 10˚27'37"	1	1186.5	0.6	0.6	Top soil	HA
	E 11˚6'7"	2	15.2	1.6	2.3	Soft clay	
	ELEV.439m	3	547.4	56.6	58.8	Arkosic	
		4	5346.2			sandstone	
VES 15	N 10˚27'32"	1	632.4	1.2	1.2	Top soil	HKH
	E 11˚7'2"	2	113.5	2.5	3.7	Compacted clay	
	ELEV.442m	3	3933.4	13	16.7	Sandstone	
		4	781.2	12.2	29	Arkosic sand	
		5	772.5				

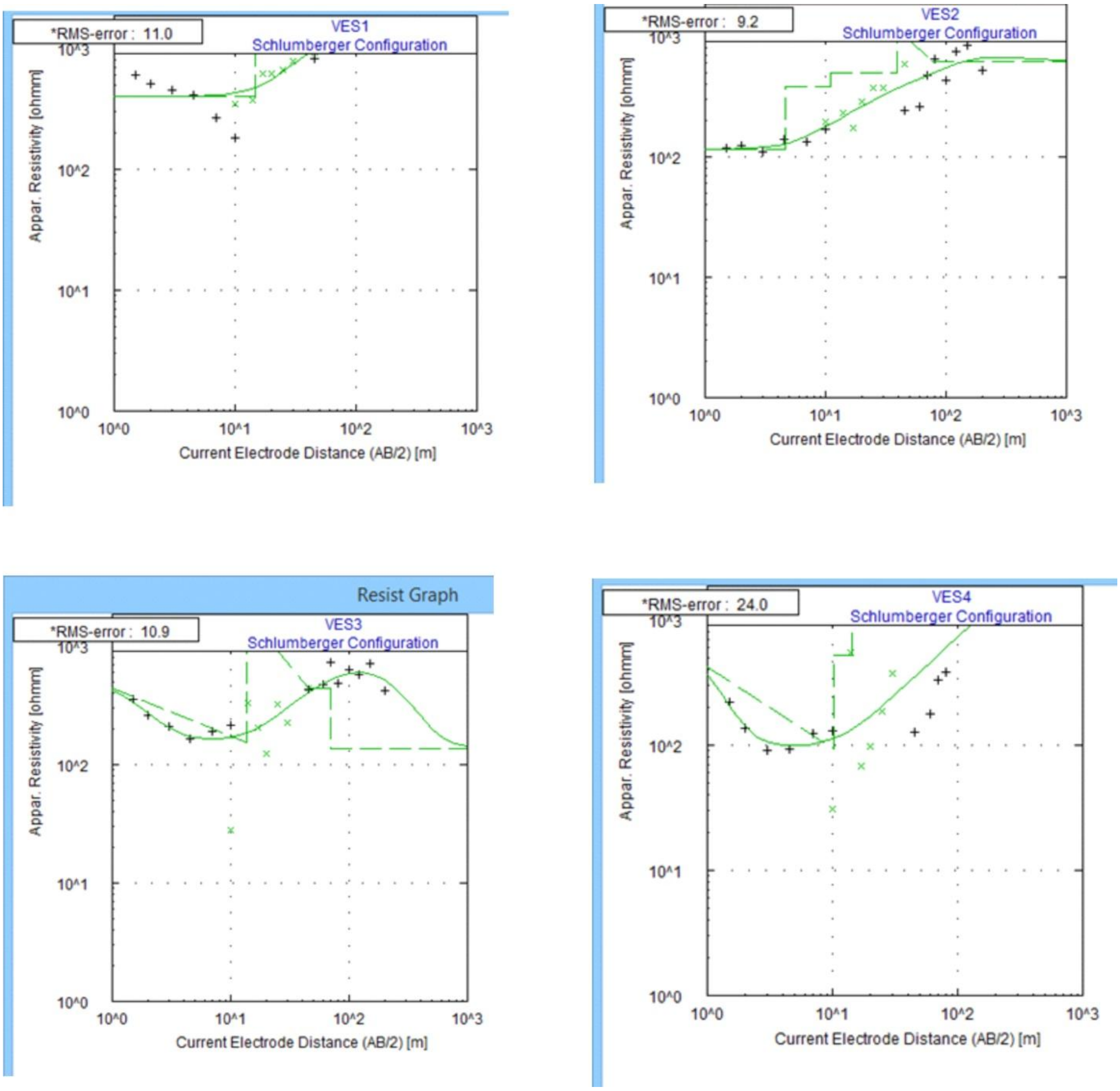

Figure 2: Interpreted Curves of VES 1, 2, 3 and 4

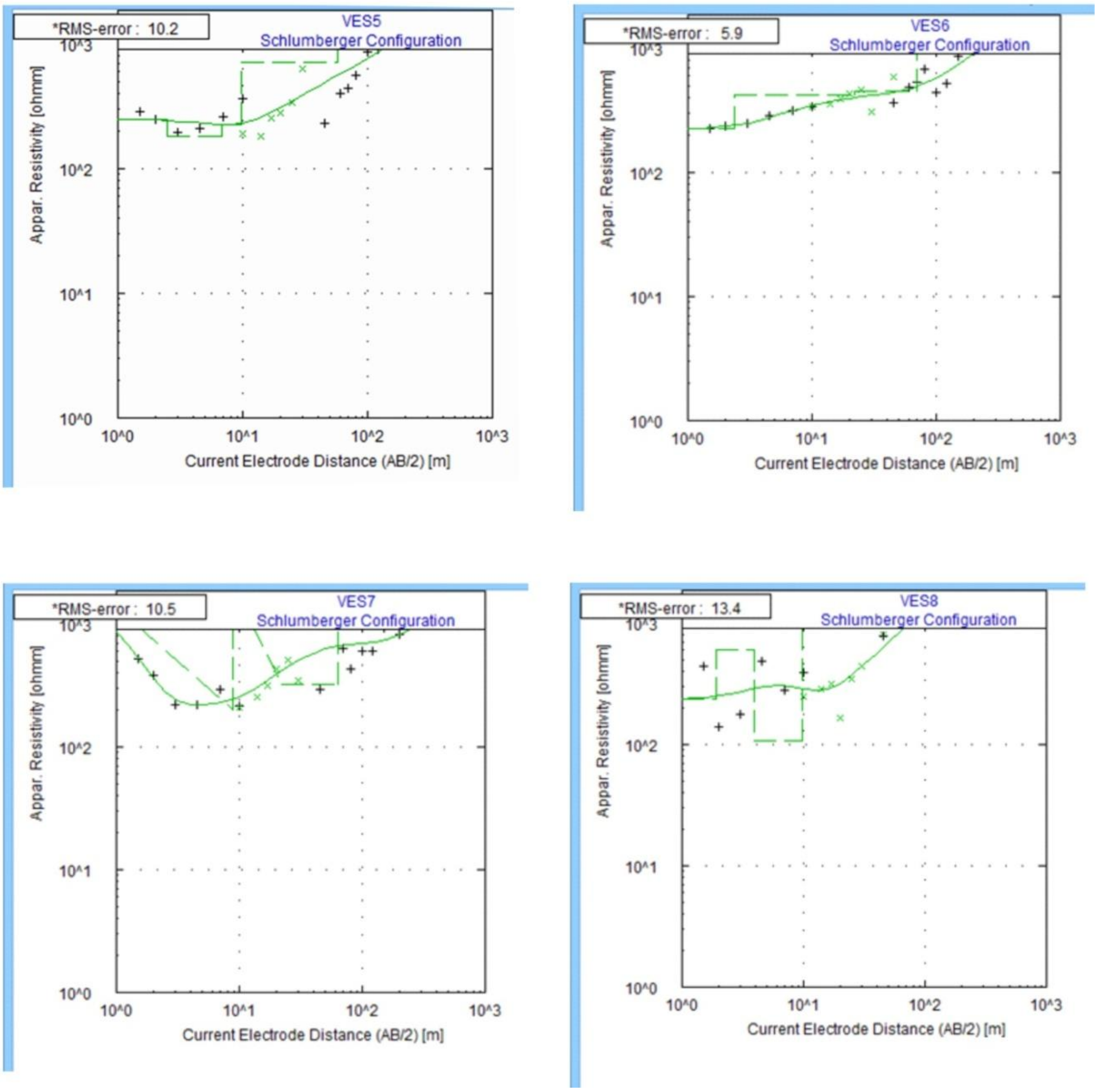

Figure 3: Interpreted Curves of VES 5, 6, 7 and 8

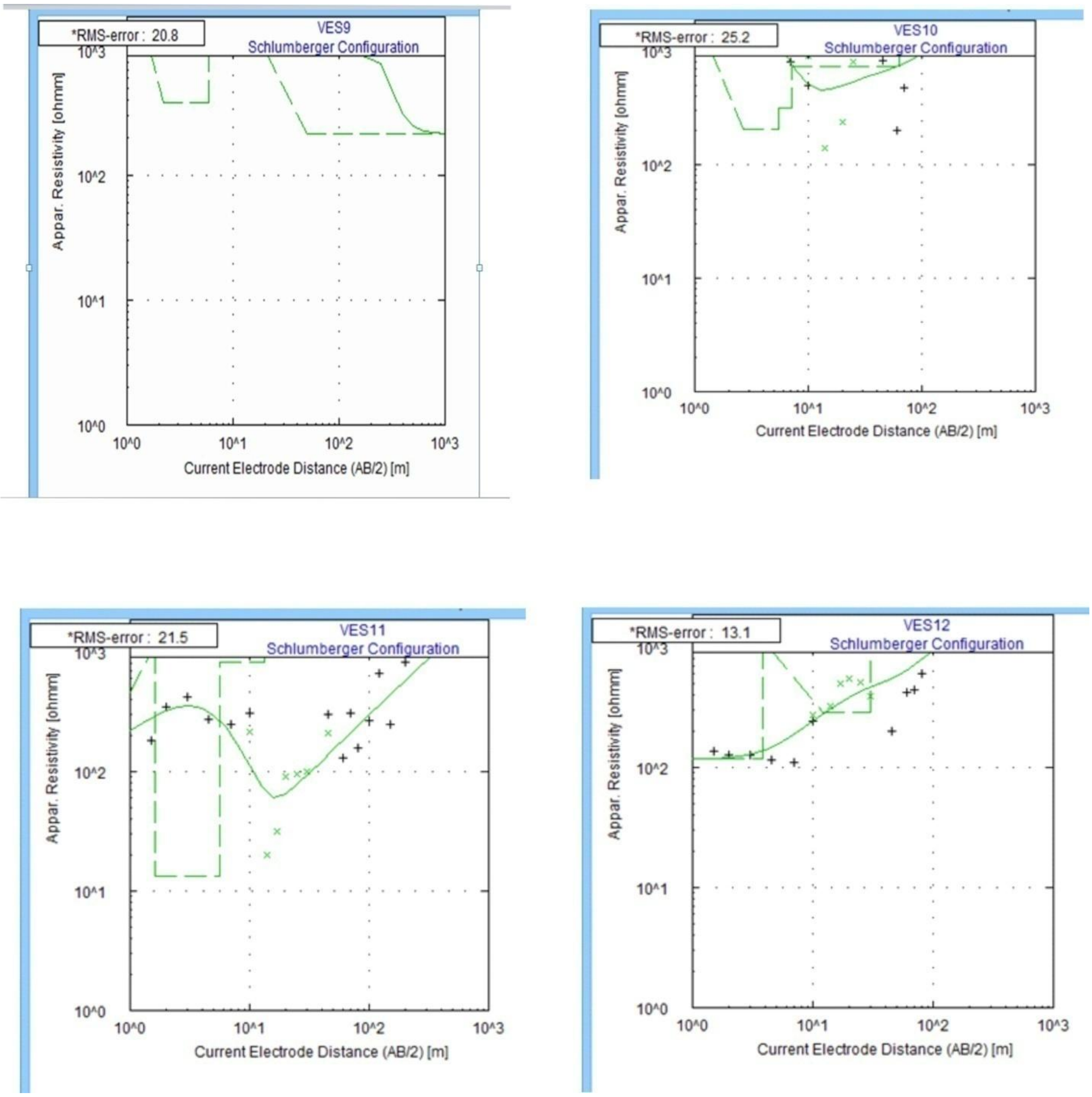

Figure 4: Interpreted Curves of VES 9, 10, 11 and 12

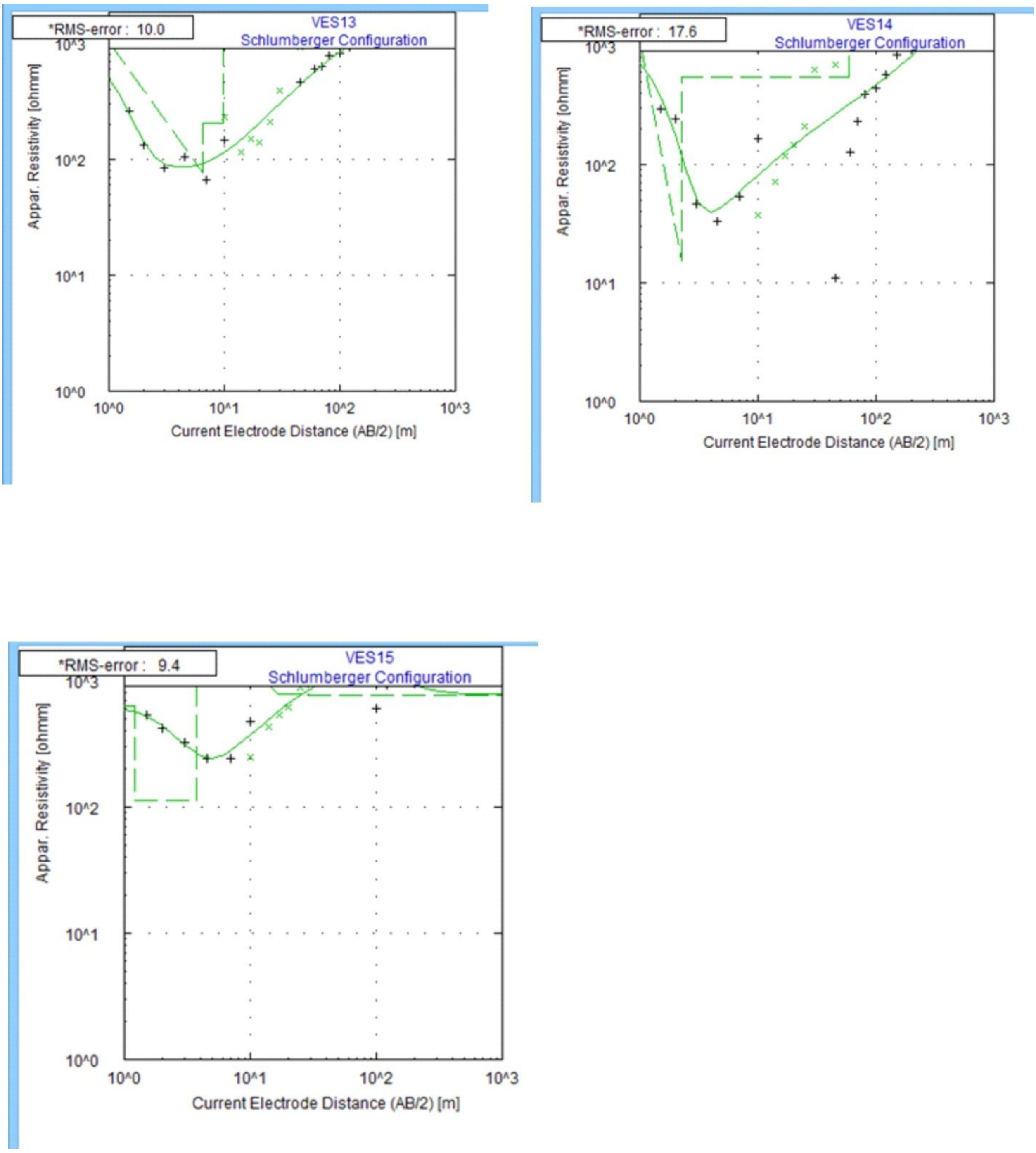

Figure 5: Interpreted Curves of VES 13, 14 and 15

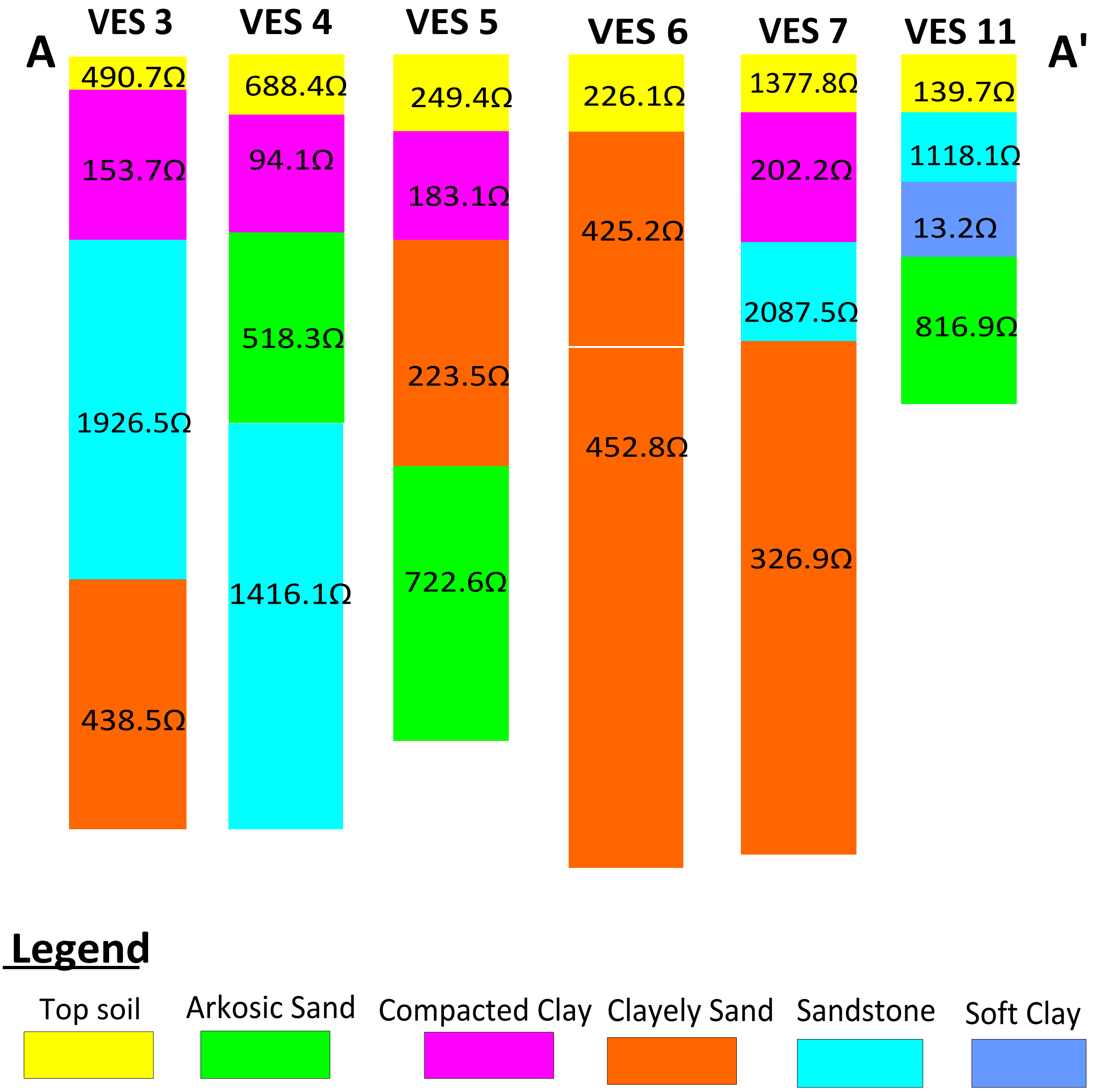

Figure 6: Geo-electric section of VES3, VES4, VES5, VES6, VES7 and VES11.

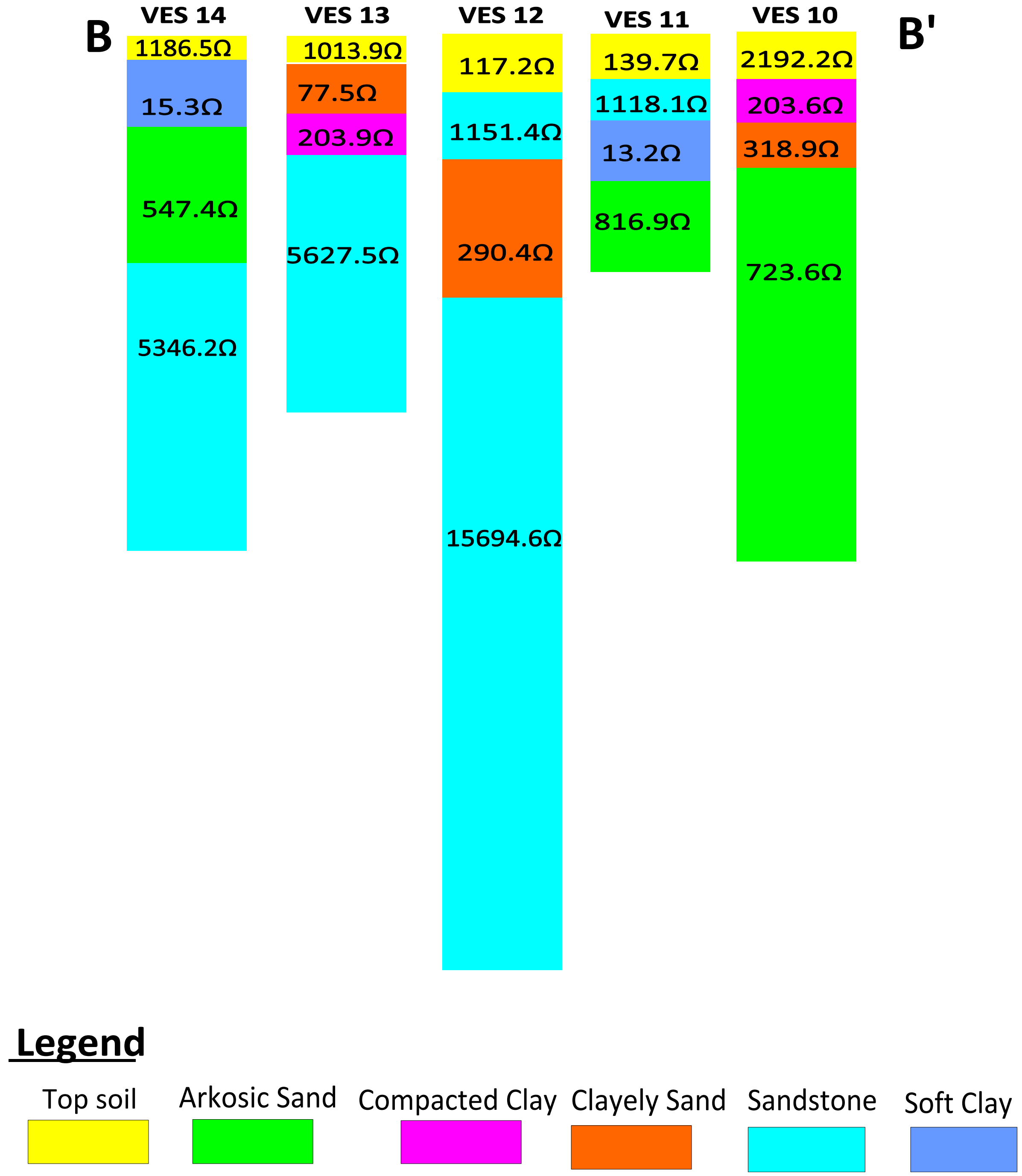

Figure: 7 Geo-electric section o VES10, VES11, VE12, 13, and VES 14

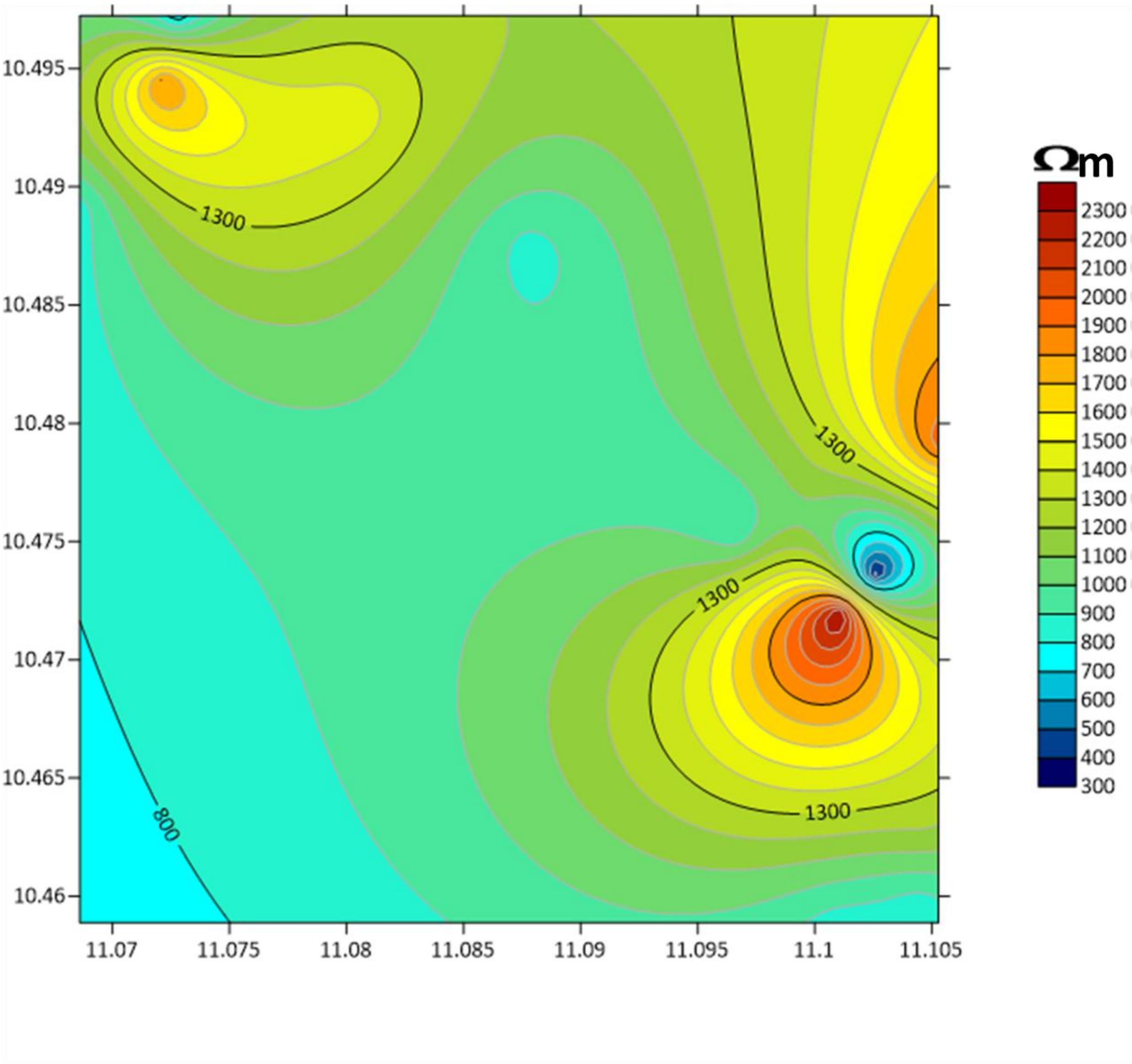

Figure 8: Iso-resistivity Map at AB/2 = 150m

The iso-resistivity map indicated that the area colored with sky blue has low resistivity which means is a good area for groundwater potential. The VES points with low resistivity are VES2, VES3, VES6, VES5, VES6, and VES7 the rest of the VES point has high resistivity which indicated that there is no groundwater.

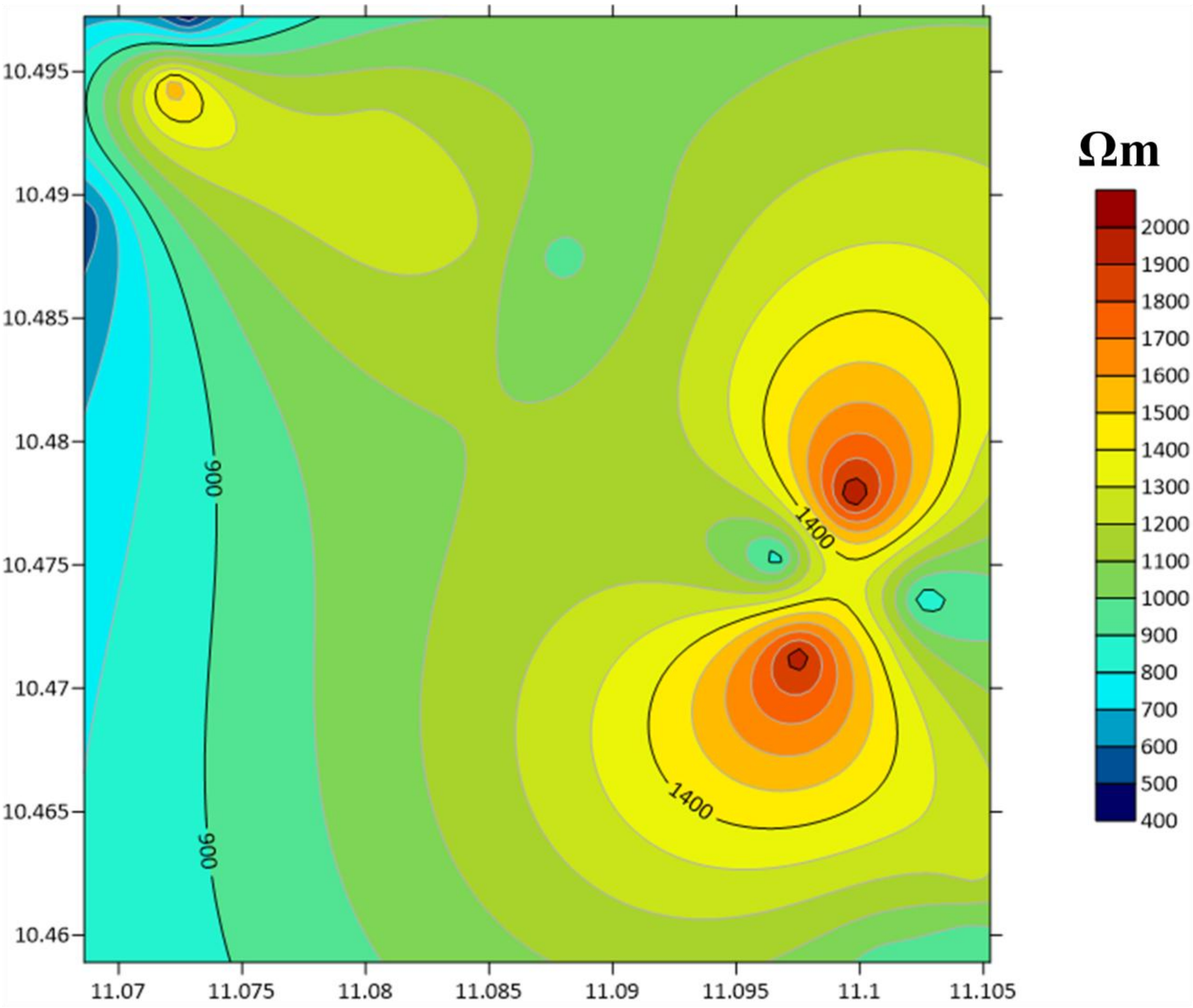

Figure 9: Iso-resistivity Map at AB/2=200m

The iso-resistivity map indicated that the area colored with sky blue has low resistivity which means is a good area for groundwater potential. The VES points with low resistivity are VES2, VES3, VES6, VES14, and VES11 the rest of the VES point has high resistivity which indicated that there is no groundwater.

IV. Summary And Conclusion

The geophysical method used in this study area has captured the geologic information and a good method to investigate the groundwater potential of Gadam and environs of Gombe state, Northeastern Nigeria. Fifteen Vertical electrical Sounding (VES) were carried out and the acquired data was analyzed using WINRESIST computer software. The apparent resistivity measured in the field provide a guideline for establishing Geo-electric layers, All the VES point posses layers in geo-eletric section and the geo-electric section provide information on the groundwater potential in the study area. Base on these analyses of the geophysical survey data, it revealed that the groundwater of the study area is scarce in providing adequate potable water for the community. Therefore detailed integrated survey methods were recommended.

References

[1]. Arabi, a., nur, a. & dewu, b. 2009. Hydro geo-electrical investigation in Gombe town and environs, northeastern Nigeria. Journal of Applied Sciences and Environmental Management, 13.

[2]. Carter, J. D., Barber, W. & Tait, E. A. 1963. The Geology of Parts of Adamawa, Bauchi and Bornu Provinces in North-eastern Nigeria: Explanation of 1: 250,000 Sheets No. 25, 36 and 47, the authority of the Federal Government of Nigeria.

[3]. Konikow, L.; Kendy, E. Groundwater depletion: A global problem. Hydrogeol. J. 2005, 13, 317-320.

[4]. Mohammed, A. G. and Ibrahim, A. ((2014). Geo-Electrical Data Analysis to Demarcate Groundwater Pocket Zones in Kaltungo and Environes, Northeastern Nigeria. Journal of Applied Geology and Geophysics (IOSR-JAGG) Vol 2, Issue 3. Pp 43-50.

[5]. Offodile, M. E. (1976) Review of the geology of the Cretacious Benue Valley.in Kogbe,C.A,Ed., Geology of Nigeria,Elizabethan Publishing Coy, Lagos 319-330.

[6]. Olorufemi,M.O and Fayusi, S.A.(1993) Aquifer Types and the Geoelectric/Hydrogeologic Characteristics of Part of Central Terrain of Nigeria (Niger State). Journal of African Earth Sciences, 16,309-317.