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GROUNDWATER INVESTIGATION USING ELECTRICAL RESISTIVITY METHOD IN YUNUSARI AREA, YOBE STATE, NIGERIA

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Abstract

Geoelectrical investigation of Yunusari area, Yobe State, Chad Formation, Nigeria. The study area is underlain by sand and gritty clay of recent sediment under Chad Formation. A total of twenty (20) were carried out with current electrode ranging from 1 to 140 m and potential electrode ranging from 0.5 to 20m the interpretation was carried out using the Win Resist and surfer 12 computer software. The study area is mostly characterized by five

Keywords: Groundwater, aquifer, vertical electrical sounding, electrical resistivity, Schlumberger array.

INTRODUCTION

Ground water is the water present beneath the earth's surface, in the soil pore spaces and in the fractures of rock formations. Water that occurs below the ground surface, where it occupies all part of the void spaces or geological strata it is also called groundwater.

Groundwater is very important to human life, it is the major source of drinking water to about 95% of the world population (Agada et al., 2020). The importance of groundwater to the socio-economic development of a country is tremendous the provision of quality drinking water is very important to the wellbeing of any given population. Water is highly needed for human existence and for the advancement of human civilization, water place a great role in both agricultural and geoelectric layers comprising of Top soil composed with resistivity values varying from 24-16000 Ωm and thickness of 0.3 - 4.2m, Lateritic ranges from 72.9 - 8287.1Ωm with thickness of 0.3m to 25.3, Sandy has resistivity of 9.9-2095.6Ωm with thickness from 4.9m-55.9m, sand (aquiferous) ranging from 3.4 - 248.9Ωm with thickness of 15.1m to 79.4m and gritty clay and clay (aquiferous) and fresh basement whose resistivity vary from 9.8-804Ωm. generally Yunusari and environ has with good prospect for groundwater development between 70 – 130m depth, Also, the investigation was carried out to deduce the nature of subsurface for proper description of relationship between yield and other parameters to improve our knowledge of the variable of interest.

industrial expansion. Therefore, request for quality groundwater cannot be over emphasis. Ground water constitutes significant amount of the total volume of fresh water on earth. Groundwater exploration has increased recent time due to rise in population and industrialization. Groundwater is used for domestic, industrial and agricultural purposes. Detailed investigation of ground water is important, because it provides information on the depth to groundwater, subsurface layer's thickness and aquifer characteristics. (Agada *et al*., 2020).
Different geophysical techniques have been used in groundwater exploration to find good locations for productive boreholes. The electrical resistivity method, which incorporates VES and Horizontal Profiling (HP), is one such approach that is frequently employed (Omosuyi, et al. for 2008). Because of its simplicity and dependability, VES method is a depth sounding galvanic method has shown to be very helpful in groundwater studies. It is possible that the number and thickness of the geoelectric units identified by VES measurements at a particular location may differ from those of the geological units (Emmanuel et al. in 2011). The ultimate goal of VES in a particular location is to obtain, without drilling the well, a true resistivity log that resembles the induction log of the well (Hamill and Bell, 1986).

GEOLOGY AND HYDROGEOLOGY OF THE STUDY AREA

Yunusari area lies within the Chad Formations (Figure (a)). The study area is underlain by gritty clay and sand of recent sediment predominate the study area. Furthermore, the formations consist of top soil/laterite, gritty clay, sand, (aquiferous) sand gritty clay and sand (aquiferous). The formation is usually less compact, more permeable and better prospect for aquifer. The usefulness of the Formations as a potential groundwater reservoir depends on its secondary permeability derived from weathering and fracturing.

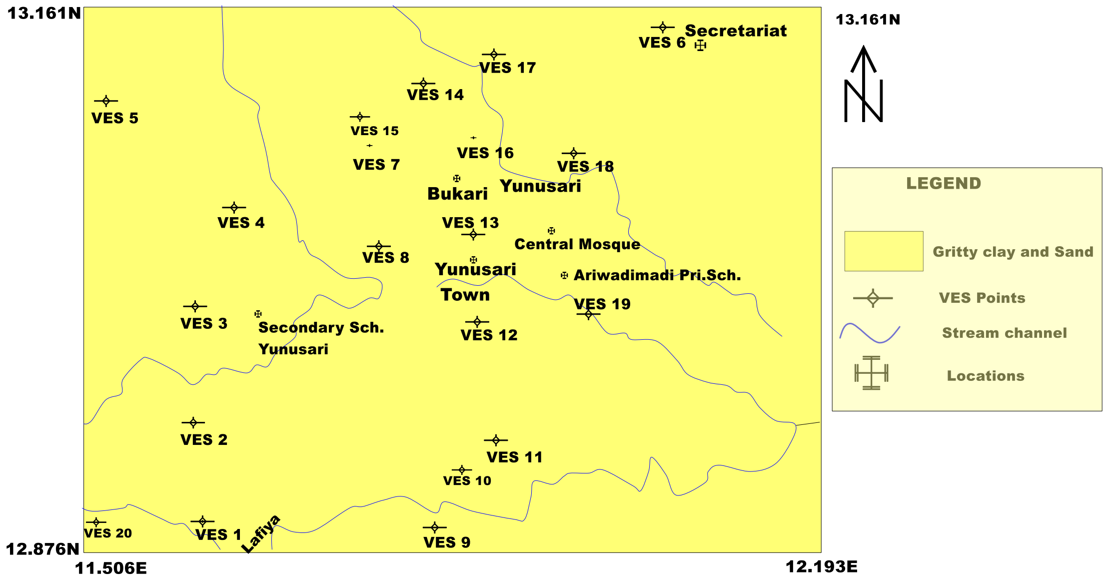

Figure (a): Geology map of the area showing he VES points.

MATERIAL AND METHOD

Electrical resistivity surveys are usually designed to measure the electrical resistivity of the subsurface materials by making measurements at the earth surface (Abdel-Azim, et al., 1996). The common electrode arrays suitable for VES work are the Wenner and the Schlumberger arrays (Sharma, 1997). In the Schlumberger array the spacing between the potential electrodes was recommended not to exceed 40% of half the distance of the spacing (AB) of the current electrodes (Adewumi, *et al.,* 2005). Schlumberger electrode configuration with maximum current electrode separation (AB/2) of 140 m was employed. Its apparent resistivity ρ_a computed from the following equation (Sharma, 1997).

$$\rho a = \pi \left[\frac{\left[\frac{AB}{2}\right]^2 - \left[\frac{MN}{2}\right]^2}{MN} \right] R$$

But $V = IR$ according to Ohm's law

Therefore, $R = \frac{V}{I}$ then above equation becomes

$$\rho a = \pi \left[\frac{\left[\frac{AB}{2}\right]^2 - \left[\frac{MN}{2}\right]^2}{MN} \right] \frac{V}{I}$$

The geometric factor K is expressed as: $K = \pi \left[\frac{\left[\frac{AB}{2}\right]^2 - \left[\frac{MN}{2}\right]^2}{MN} \right]$

Therefore, $\rho a = KR$

Where: ρa= Apparent resistivity, K = geometric factor, R = measured resistance, AB = current electrode spacing in meter, MN = potential electrode spacing in meter, V = potential difference in volts and I = electric current in Amperes

ABEM Terrameter Signal Averaging System, (SAS 300) was used along with four metal electrodes, hammer for driving in the ground, and four reels of connecting cables, measuring tape, cutlass for cutting traverses and clips. Global positional system (GPS) was use to establish the coordinates of the points. Calibrated rope and data sheet were used for recording the field data during geophysical data acquisition. A total of twenty (20) vertical electrical sounding were acquired within the study area. The Schlumberger electrode configuration was used with maximum current electrode spacing 140m. The resistance readings at every probe point were automatically displayed on the digital readout screen and then written down on the field data. The field data was interpreted using a computer simulated program, Win Resist version 1.0 (Vander Velpen, 2004). The VES point was determined in the field using GARMIN channel personal navigation Global Position System (GPS) receiver to locate the points and the maps were produced using Golden Surfer 12 program.

RESULTS AND DISCUSSION

The apparent resistivity ρ_a, values were plotted against the electrode spacing (AB/2) on a log-log scale to obtain the VES sounding curves using an appropriate computer software Wine Resist in the present study. The modeling of the VES measurements carried out at twenty (20) stations has been used to derive the geoelectric sections for the various profiles. The model curve type ranges from Three (3) to Four (4) layers, HA, HAH, QH, QQ, HK and HA curve types. The field results obtained from the twenty (20) sounding is show in table 1. From table 1, the layers of the 20 sounding reveal various thickness and aquifer resistivity of aquifers in the area, which revealed four to five geologic layers, composed of Top soil composed with resistivity values varying from 24-16000 Ωm and thickness of 0.3-4.2m, clay ranges from 72.9-8287.1Ωm with thickness of 0.3m to 25.3, Sandy has resistivity of 9.9-2095.6Ωm with thickness from 4.9m-55.9m, sand (aquiferous) ranging from 3.4- 248.9Ωm with thickness of 15.1m to 79.4m and gritty clay and clay (aquiferous) and fresh basement whose resistivity vary from 9.8-804Ωm with an infinite depth. The aquifer resistivity in Yunusari and her environ ranging from 50 - 200Ωm, with thickness of 5 to 75m having an average value of 35m.

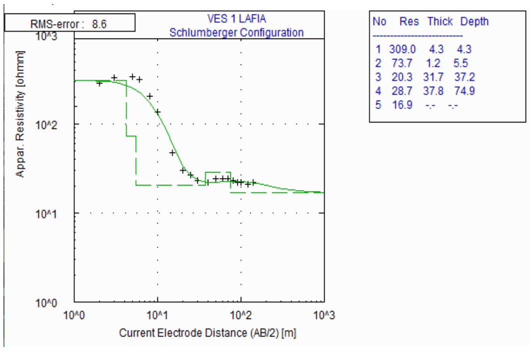

Figure 1: HA-curve type

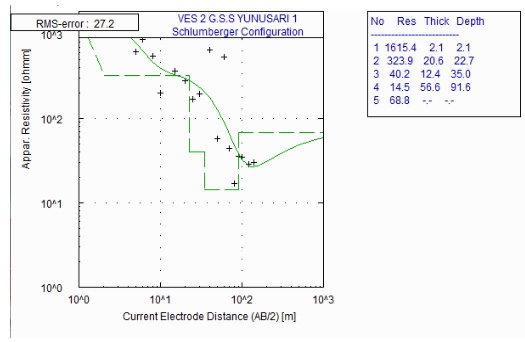

Figure 2: QH-curve type

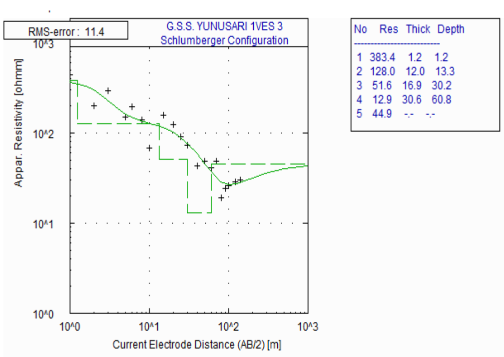

Figure 3: QH-curve type

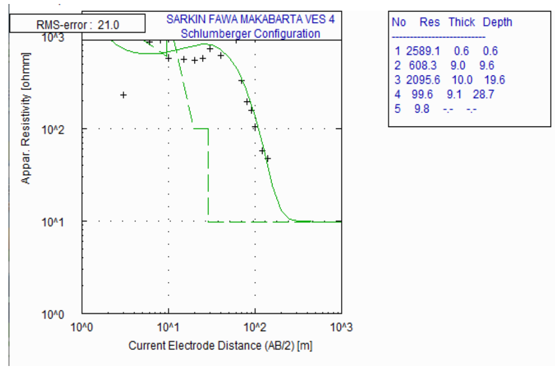

Figure 4: QQ-curve type

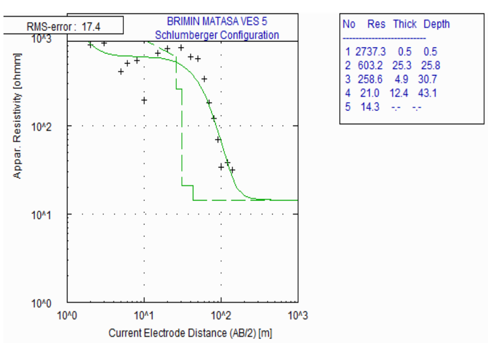

Figure 5: QQ-curve type

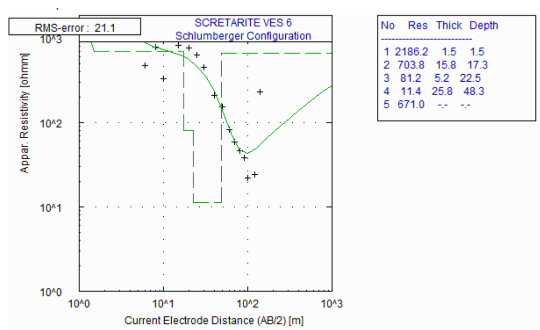

Figure 6: QH-curve type

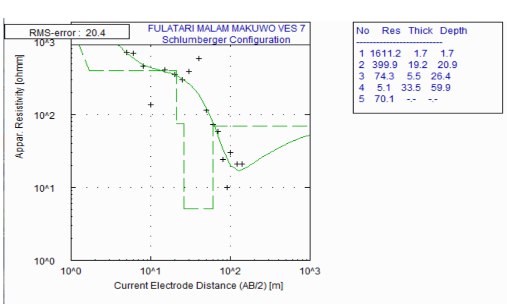

Figure 7: QH-curve type

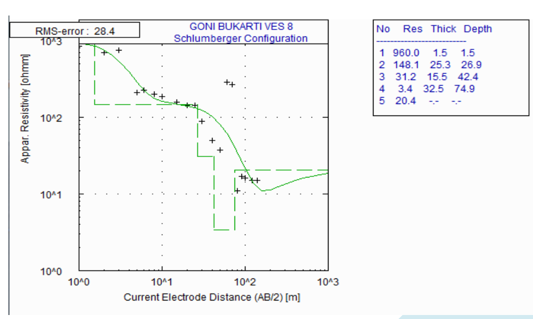

Figure 8: QH-curve type

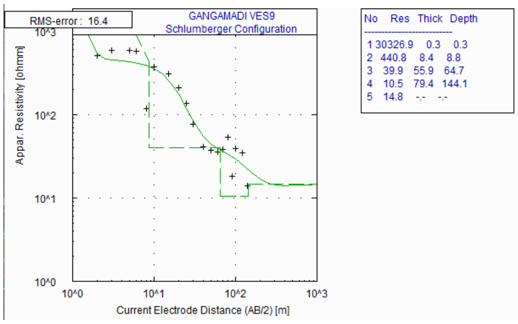

Figure 9: QQ-curve type

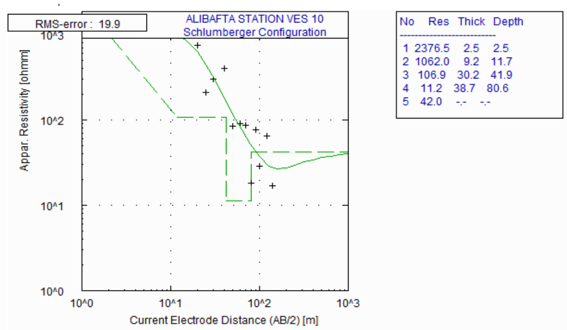

Figure 10: QH-curve type

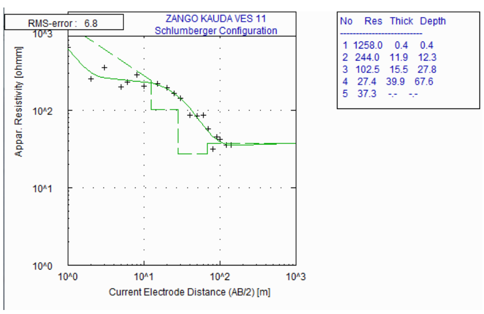

Figure 11: QQ-curve type

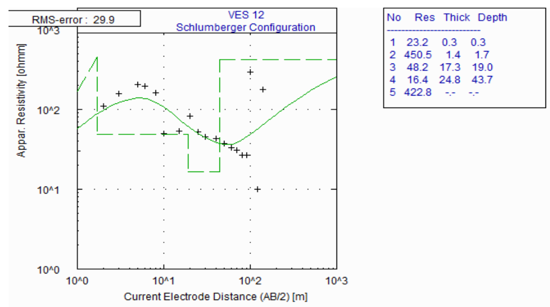

Figure 12: QH-curve type

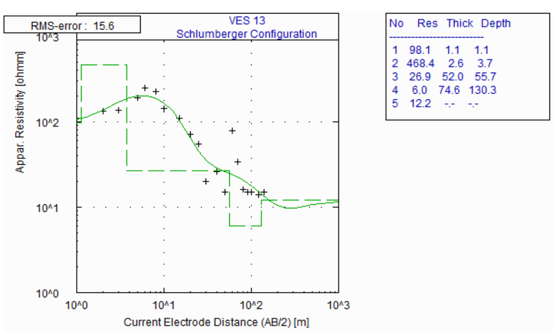

Figure 13: HK-curve type

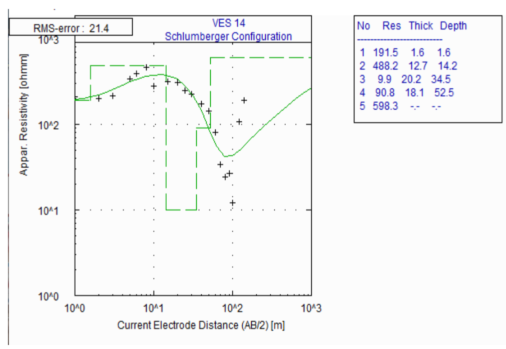

Figure 14: QH-curve type

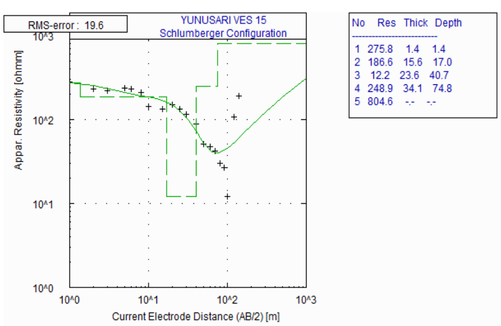

Figure 15: H-curve type

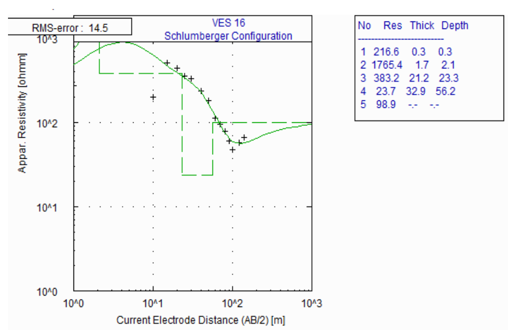

Figure 16: HA-curve type

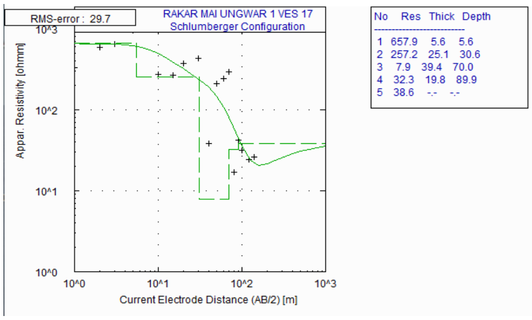

Figure 17: QH-curve type

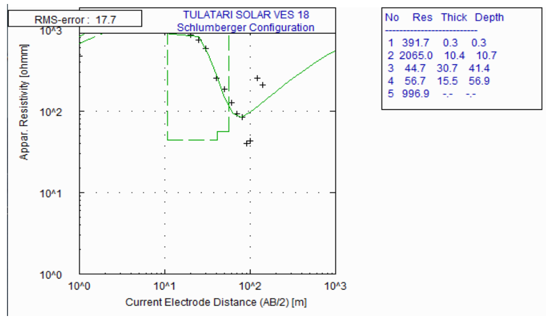

Figure 18: HK-curve type

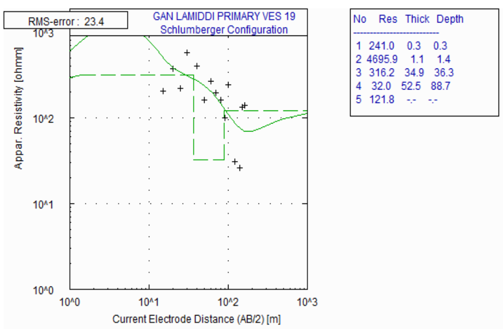

Figure 19: HK-curve type

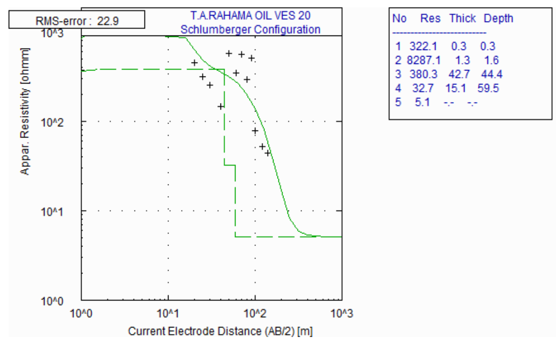

Figure 20: QQ-curve type

Table 1: Quantitative Interpretation of Data for Vertical Electrical Sounding (VES) Results.

S/N	*Sample ID*	*Thickness of Layers (m)*					*Resistivity of Layers (Ωm)*					*No of Layers*
		h1	h2	h3	h4	h5	ρ1	ρ2	ρ3	ρ4	ρ5	
1	V1	4.2	1.2	31	55	-	3098	72.9	20.8	27.2	16.7	5
2	V2	2.1	21	12	57	-	16154	323.9	40.2	14.5	68.8	5
3	V3	1.2	12	16.9	30.6	-	383.4	128	51.6	12.9	44.9	5
4	V4	0.6	9	10	9.1	-	2589.1	608.3	2095.6	99.6	9.8	5
5	V5	0.5	25.3	4.9	12.4	-	2737.3	603.3	258.6	21	14.3	5
6	V6	1.5	15.8	5.2	25.8	-	2186.2	703.8	81.2	11.4	671	5
7	V7	1.7	19.2	5.5	33.5	-	1611.2	399.9	74.3	5.1	70.1	5
8	V8	1.5	25.3	15.5	32.5	-	960	148	31.2	3.4	20.4	5
9	V9	0.3	8.4	55.9	79.4	-	130326	440.8	39.9	10.5	14.8	5
10	V10	2.5	9.2	30.2	38.7	-	2376.5	1062	106.9	11.2	42	5
11	V11	0.4	11.9	15.5	39.9	-	1258	244	102.5	27.4	37.3	5
12	V12	0.3	1.4	17.3	24.8	-	23.2	405.2	48.2	16.4	422.8	5
13	V13	1.1	2.6	52	74.6	-	98.1	468.4	26.9	6	12.2	5
14	V14	1.6	12.7	20.2	18.1	-	191.5	488.2	9.9	90.8	598.3	5
15	V15	1.4	15.6	23.6	34.1	-	275.8	186.6	12.2	248.9	804.6	5

16	V16	0.3	1.7	21.2	32.9	-	216.5	1765.4	383.2	32.7	98.9	5
17	V17	5.6	25.1	39.4	19.8	-	657.9	257.2	7.9	32.3	38.6	5
18	V18	0.3	10.4	30.7	15.5	-	391.7	2065	44.7	56.7	996.9	5
19	V19	0.3	1.1	34.9	52.5	-	241	4695.9	316.2	32	212.8	5
20	V20	0.3	1.3	42.7	15.1	-	322.1	8287.1	380.3	32.7	5.1	5

NOTE: For 5 Layers; the 1st Layer is Topsoil, 2nd Layer is Laterite, 3rd Layer is weathered basement, 4th Layer is fractured basement and the 5th Layer is Fresh basement.

Table 2: Qualitative Interpretation of Data for Vertical Electrical Sounding (VES) Results

S/N	*VES No*	*Latitude*	*Longitude*	*Elevation (m)*	*Topsoil Resistivity*	*True Aquifer Resistivity*	*Aquifer thickness*	*Piezometric value*
1	VES 1	13.1369	11.52722	322	3098	27.2	55	230.9
2	VES 2	13.14138	11.52666	314	16154	14.5	57	222.4
3	VES 3	13.14666	11.5268	327	383.4	12.9	30.6	266.3
4	VES 4	13.1511	11.5286	326	2589.1	99.6	9.1	297.3
5	VES 5	13.15583	11.52250	335	2737.3	21	12.4	291.9
6	VES 6	13.15908	11.5325	333	2186.2	11.4	25.8	284.7
7	VES 7	13.15366	11.5351	334	1611.2	5.1	33.5	274.1
8	VES 8	13.1491	11.5355	335	960	3.4	32.5	260.2
9	VES 9	13.14500	11.53822	334	130326	10.5	79.4	190
10	VES 10	13.3066	11.539	336	2376.5	11.2	38.7	255.4
11	VES 11	13.14055	11.5413	324	1258	27.4	39.9	256.3
12	VES 12	13.1463	11.5402	327	23.2	16.4	24.8	283.2
13	VES 13	13.15111	11.53936	319	98.1	6	74.6	188.7
14	VES 14	13.15650	11.5378	340	191.5	90.8	18.1	287.4
15	VES 15	12.8759	11.5550	355	275.8	248.9	34.1	280.3
16	VES 16	13.1538	11.5402	327	216.5	32.7	32.9	270.9
17	VES 17	13.15778	11.54111	315	657.9	32.3	19.8	225.1
18	VES 18	13.15277	11.5449	341	391.7	56.7	15.5	284.1
19	VES 19	13.147944	11.5455	342	241	32	52.5	253.2
20	VES 20	13.3077	11.5127	335	322.1	32.7	15.1	275.6

Top Soil resistivity map

The topsoil resistivity map of the study area was generated (Table 1 and Table 2). The entailed the resistivity of each VES points which gives the information on the topsoil composition in the study area. Bukari, Yunusari, Yunusari Town, Central Mosque, Secondary school Yunusari, Ariwadimadi Primary, VES 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 16, 18,19 and 20 and south of VES 1 with resistivity ranges from 0 – 16000 Ωm represented with gray for low resistivity value (Gritty fine clay), green and yellow-red depicts high resistivity colour. The present of the low resistivity values means clay properties content and recent sediment, the high gritty reddish clay and dry clayed content depict high resistivity values which might be from the transportation and deposition of recent sediment underlain the area respectively (Figure 21).

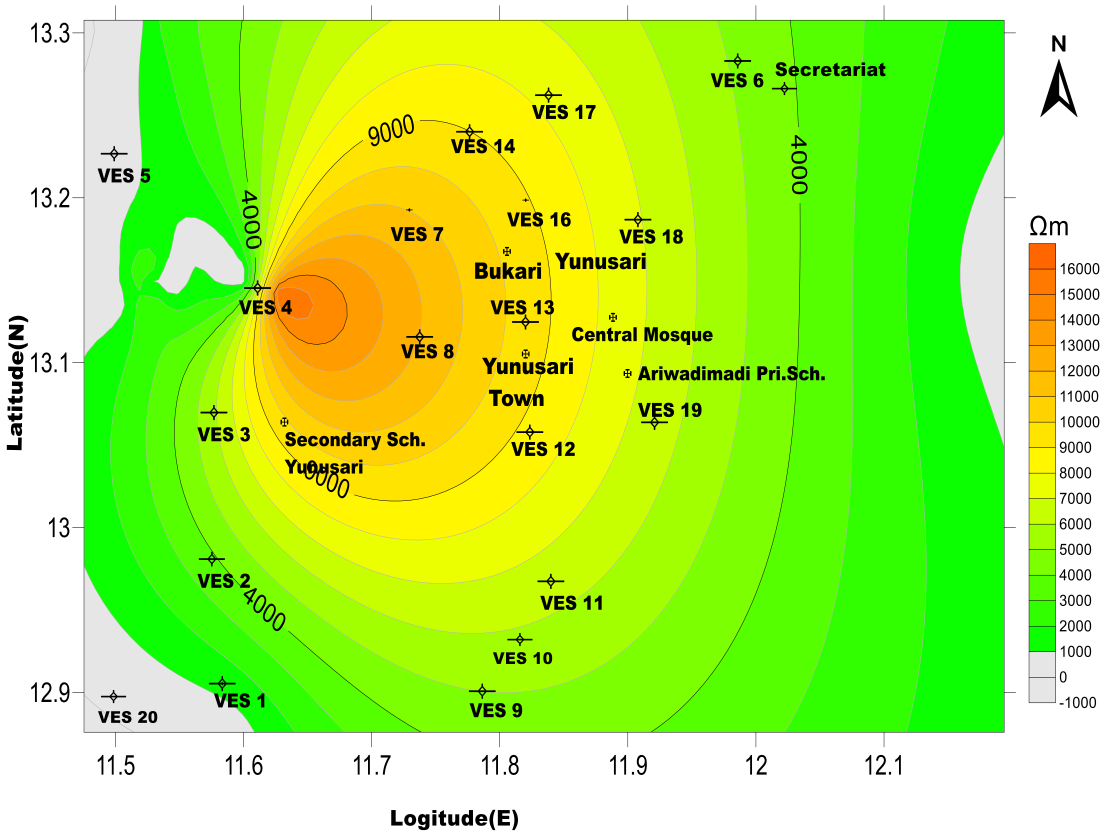

Figure 21: Top Soil resistivity map

Aquifer Resistivity Map

The aquifer resistivity in the study area ranges from 6-250 Ωm (Table 1 and Table 2). The map reveals the observed resistivity values of the aquifer obtain from the sounding points; it plays an important role in determining the zones of groundwater potential in the study area. The resistivity of the aquiferous layer ranges from 6-250 Ωm in the study area. From the aquifer resistivity map (Figure 2), VES 3, 4, 5, 7, 14 and 17 represented with yellow colour depict low to resistivity value ranges from 0-50 Ωm which might be gritty clay and fine sand. Moderate-High resistivity values of 60-250 Ωm are observed in Bukari, Yunusari, Yunusari Town, Central Mosque, Secondary school Yunusari, and Ariwadimadi Primary. VES 1, 2, 6, 8, 9, 10, 11, 12, 13, 16, 18, 19 and 20 and south of VES 1 showed with green to red colour. The moderate to high resistivity might be underlain by sand with some content of iron. Generally, the study area has good potential for groundwater because of the geology (sand and gritty clay) recent sediment (Figure 22).

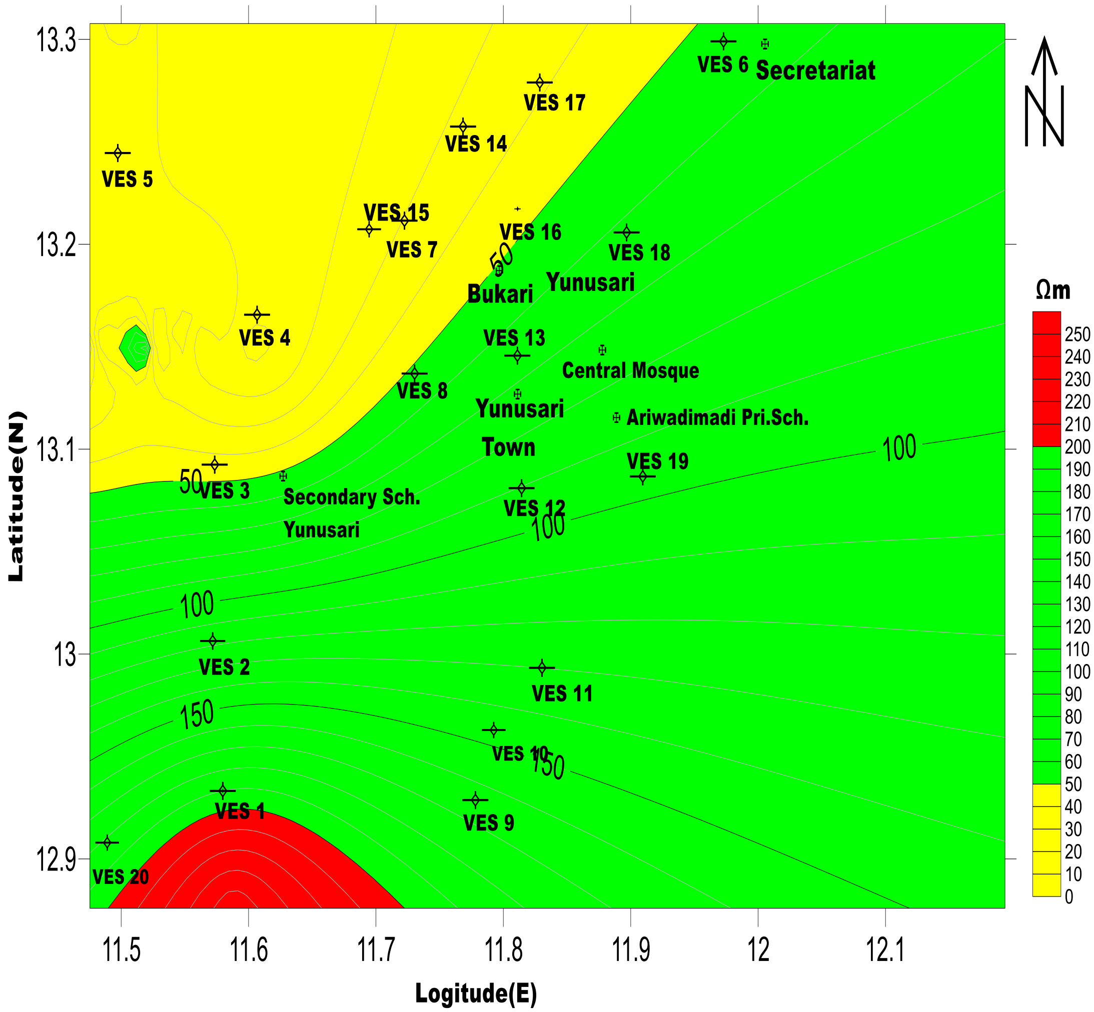

Figure 22: Aquifer Resistivity Map of the study area.

Aquifer Thicknes map

The aquifer thickness in the study area is the distance between the water table and the base of the groundwater reservoir or impermeable boundary. The aquifer thickness Map reveals the variation in thickness of the weathered or partially weathered/fractured layer (Fine, medium and coarse sand). It ranges from 6-75m (Table1, Table 2 and Figure 23), Bukari, Yunusari, Yunusari Town, Central Mosque, Secondary school Yunusari, Ariwadimadi Primary. VES 1, 2, 3, 5, 6, 8, 9, 10, 11, 12, 13, 16, 18, 19 and 20 represented with green colour whose aquifer units are relatively low-moderate varying 5 to 60 m such zones are considered having moderate groundwater potential and yield while ves 4 have thicker aquifer thickness range from 20m to 42m have high groundwater potential represented with yellow colour (Figure 23). Therefore, the groundwater potential of this research can be zoned into low-moderate and high potentials.

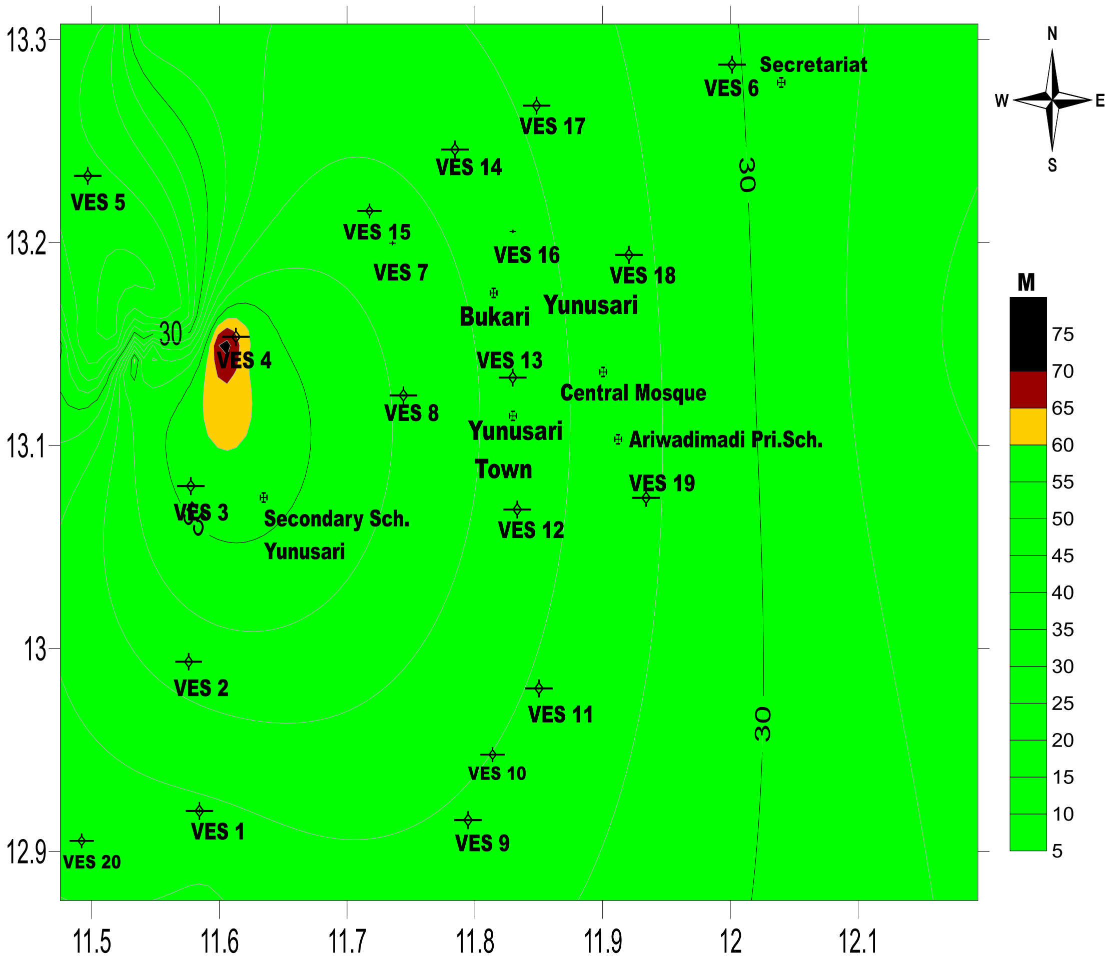

Figure 23: Aquifer Thicknes map.

Piezometric Map

The Piezometric map is determined by subtracting the total depth from the elevation of sounding point in the area and it ranging from 190-295m (Table1, Table 2 and Figure 24). The Piezometric map helps to delineate the direction flow of groundwater of the area. Ariwadimadi, VES 1, 5, 6, 11, 19 and eastern ward of the study area represented with dark yellow-red colour with value ranging from 260-295m have the high values, which deduce or characterized with ridges and divergence zones for surface and groundwater flow while low – moderate(190-240m) is observed in VES 3, 4, 7, 8, 9, 10, 14, 16, 17, Secondary school, Yunusari, Central Mosque, Bukari and Yunusari depicts convergence zones for surface and groundwater flow. High value is shows which vary from 170-190m (Figure 24). This quantitative geophysical interpretation correlates with the geology of the study area.

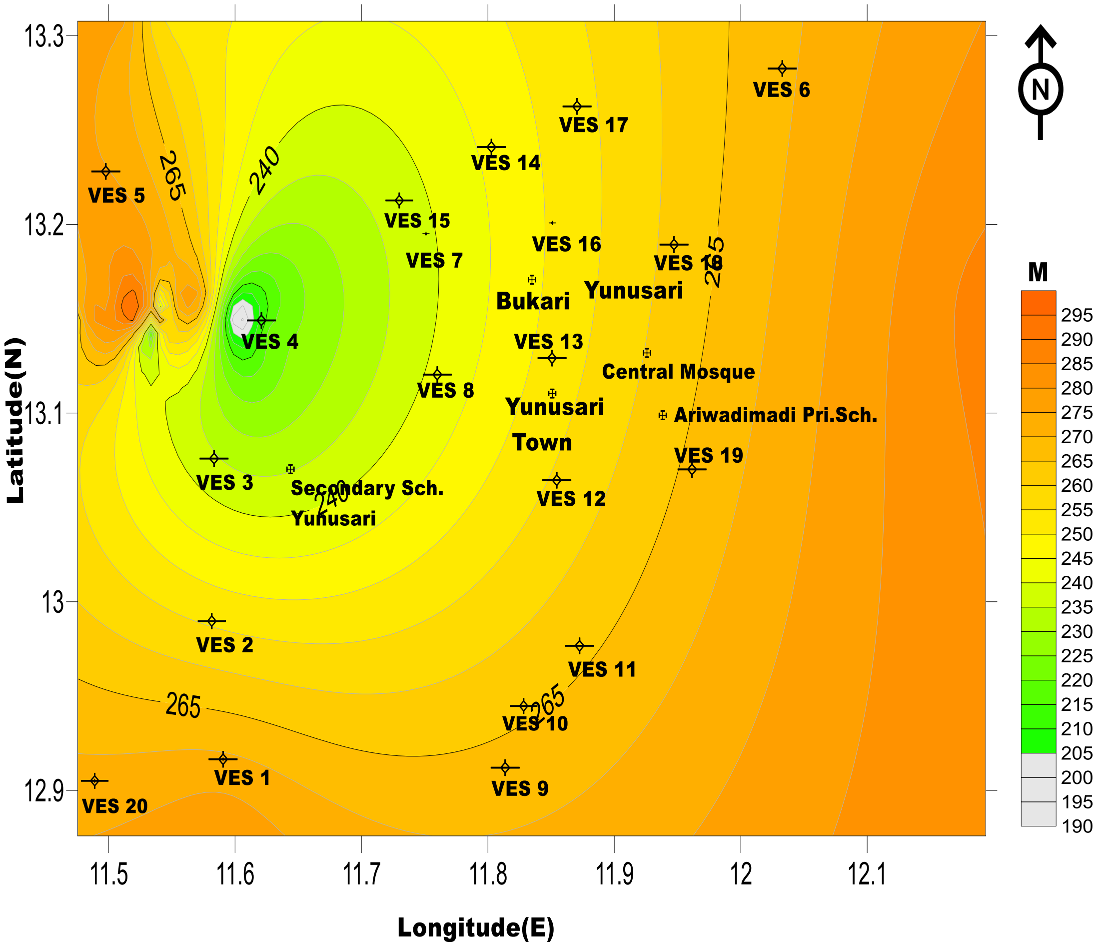

Figure 24: Piezometric Map.

Bedrock Relief Map

The 3-D bedrock relief map of the study area ranges in relief or elevation from 316-354m (Table 2). It reveals the uneven nature of the bedrock comprising of ridges (areas of high relief) and depressions (areas of low relief). Low to medium relief areas are represented by lemon green-yellow purple-blue colour with altitude 316 to 338 m in VES 3, 4, 7, 8, 9, 10, 14, 16, 17, Secondary school, Yunusari, Central Mosque, Bukari and Yunusari, and high relief are represented by sky blue colour with elevation ranging from 340 m to 354 m in Ariwadimadi, VES 1, 5, 6, 9, 11, 12, 19 and eastern ward of the study area.
The reliefs of the area is trending NW, central portion and North region of the area, acts as convergence zones for good groundwater flow/accumulation; while areas of high reliefs in part of the northeast and southeast of the study area acts as divergence zones for groundwater flow/accumulation due to the presence of the ridges and also serves as structural control to the streams in the study area (Figure 25).

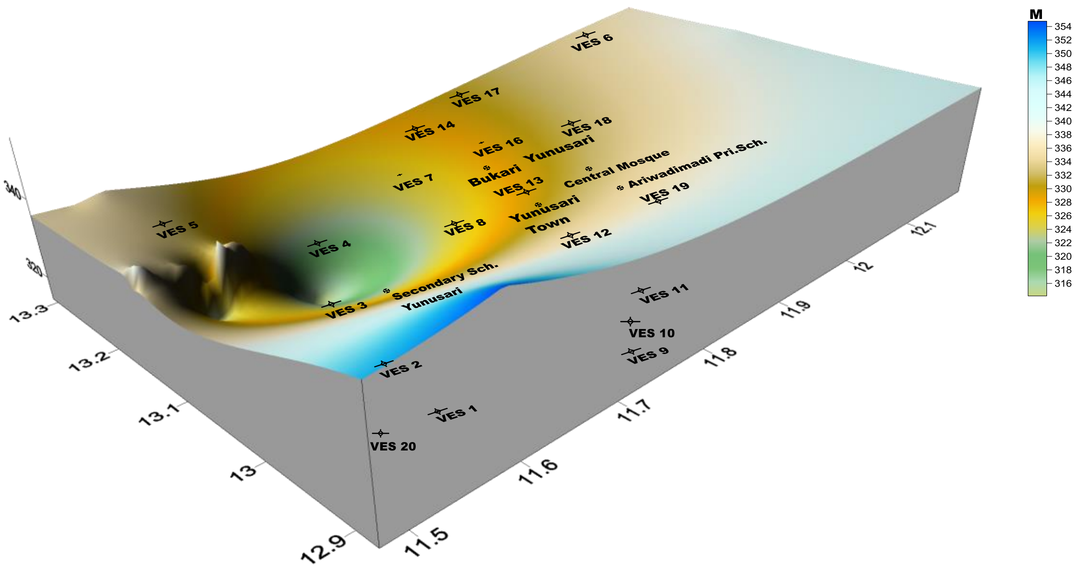

Figure 25: Bedrock Relief Map

CONCLUSION

Yunusari and environ is underlain by sand and gritty clay of recent sediment under Chad Formation. Vertical electrical sounding was employed to established twenty (20) VES points, aimed in determined the groundwater potential of the area in part of Yobe state, Nigeria. The study area is mostly characterized by five geoelectric layers comprising of Top soil composed with resistivity values varying from 24-16000 Ωm and thickness of 0.3-4.2m, Lateritic ranges from 72.9-8287.1Ωm with thickness of 0.3m to 25.3, Sandy has resistivity of 9.9-2095.6Ωm with thickness from 4.9m-55.9m, sand (aquiferous) ranging from 3.4- 248.9Ωm with thickness of 15.1m to 79.4m and gritty clay and clay (aquiferous) and fresh basement whose resistivity vary from 9.8-804Ωm. generally Yunusari and environ has with good prospect for groundwater development between 70 – 130m depth, Also, the investigation was carried out to deduce the nature of subsurface for proper description of relationship between yield and other parameters to improve our knowledge of the variable of interest.

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