



EVALUATION OF THE SUBSURFACE STRUCTURES IN PART OF FEDERAL UNIVERSITY OF GUSAU CAMPUS , ZAMFARA STATE, NIGERIA

*Shaibu, I., Ovwasa, M. O., and Misbahu, A.

Department of Geological Sciences, Federal University Gusau, Nigeria

*Corresponding authors' email: isahshaibu1982@gmail.com

ABSTRACT

Geo-electric evaluations of the subsurface structures of federal University Gusau Campus, Zamfara State, Nigeria were carried out using vertical electrical soundings technique (VES). The area lies within the Pre-Cambrian Basement Complex of Northern Nigeria. Thirty-six (36) vertical electrical soundings (VES) along six profiles (A-F) were carried out during the survey. The surveys were carried out on grid 500m by 500m. The data obtained were interpreted using computer based program named Zohdy. The result of the interpreted curves reveals three distinct geo-electric curves types were delineated: K, H and HK-curves with H-type having the most prolific aquifer. The result also shows 3 geo-electric layers which were confirm by some borehole lithology. The aquifers in the study area are likely to be found in the fractured basement layers of western and southeastern parts of the study area. The civil engineering work can be sited mostly in the northern and southwestern parts of the study area which are the region of shallow basement within the study areas. Further boreholes in the area should reached an effective depth of 75m to 90m and the borehole be supervised by a certified hydrogeologist for optimum groundwater yields. Pumping test should be carried out in order to ascertain the size and type of submersible pump to install.

Keywords: Gusau, Zamfara, Vertical Electric Sounding, Aquifer, Precambian Basement Complex

INTRODUCTION

The increase in groundwater demand for various human activities has placed great importance on water science and management of practice world-wide (Amadi *et al.* 2015). The Federal University Gusau, Zamfara State, Nigeria was designed Originally for about four Faculty, but currently has a populations of over 500, 000 people and basic amenities are over stretched. This populations and yearly increase of admissions have resulted in acute water shortage in the campus. Groundwater accounts for greater percentage of the world's fresh water and it is fairly distributed throughout the world. It is the world's greatest essential factor for sustainable development. The need to explore the groundwater quantitatively as a far better alternative and to supplement the shortage in the daily water supply in the University campus, especially during the dry season cannot be overemphasized. This present study evaluates the subsurface structures in part of federal university gusau, zamfara state, using electrical resistivity methods. This is necessary in order to ascertain the availability of the groundwater and structural formations in the areas for domestic, irrigations, building of structures and industrial purposes. Furthermore, pre-drilling geophysical survey using electrical resistivity method was employed in this study to determine the groundwater potentials in the area because it is more efficient and cost-effective. In electrical resistivity method, artificially generated electric current are introduced into the ground and the resulting potential difference are measured at the surface. It is based on the

measurement of the electrical resistivity of the ground which is dependent primarily on the porosity, fracturing, degree of saturations and the salinity of the pore water.

There is need for scientific identification of parameters governing ground water resources, evaluations, assessment and management, particularly, if satisfactory living conditions of the inhabitants are to be catered for within the university campus and its environs. This is paramount, due to the presence of four(4) Faculties of the Federal University Gusau, Zamfara State; there is an increasing demand for portable water supply to complement the current one on the campus and the need to conduct hydro-geophysical survey of the area in order to provide useful information on the possible sites for ground water exploration in the future.

Since the aim of Vertical Electrical Sounding (VES) is to determine the variation of electric conductivity with depth, vertical electrical sounding (VES) has been the most important geophysical method of water prospecting in area of deep in situ weathering of fresh bedrock. The geo-electric resistivity method, particularly the (VES) method has been chosen for this particular work basically, because it has proven to be an economic, quick and effective means of solving most ground water problems in different parts of the world (Zohdy and Jackson, 1969; Frohlich, 1974; Chinwuko *et al.* 2015 and 2016). The VES method is also used to estimate the thickness of the overburden as it is presented in this work (Parasnis, 1987).

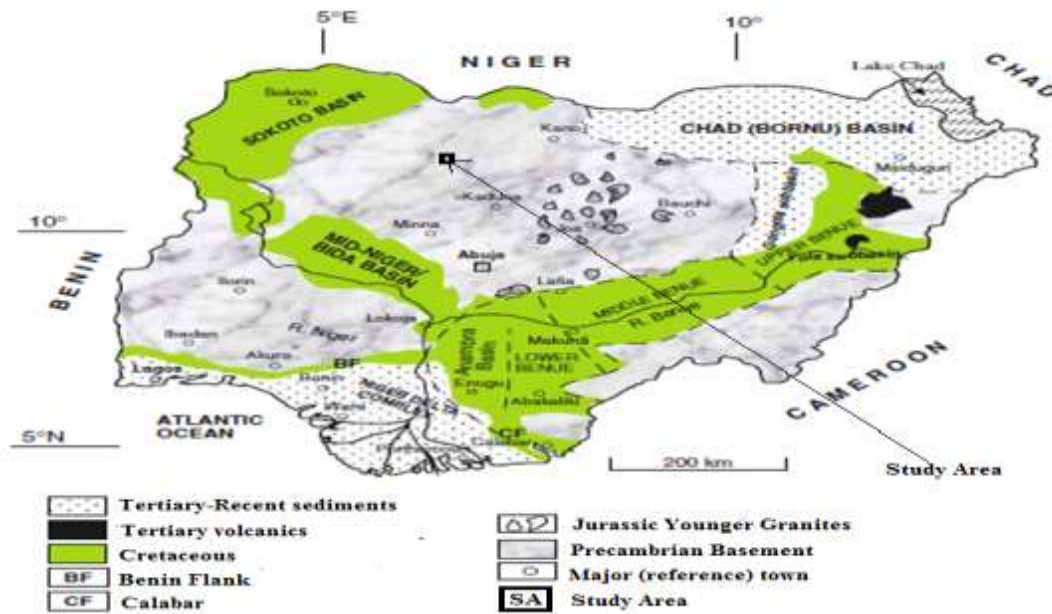


Figure 1: Geological map of Nigeria showing the study area (After Obaje, 2009)

Justifications of the present Study.

1. To determine the lithology and evaluations of aquifer bearing zone
2. To also determine the strength of layers for structural and engineering purposes
3. To determine the layers and overburden thickness

Geology of the Study Area

The study area lies within the basement complex of Nigeria. Basement complex of Nigeria lies within Pan Africa belt of West Africa Craton, which was affected by a major organic event about 600 million years (Pan –Africa Orogeny). MC Curry (1976) described the major rock in Basement complex and named them as older granites, schist and migmatite gneiss complex. Actually, the northern/ southern part of the Campus, Federal University Gusau, Zamfara State, lies within the Northern Nigerian massif subdivision of the basement complex of Nigeria. But there are other subdivisions, which are West African Massif, Adamawa Sadauna Massif and Uban Massif. The Northern part of the Campus, FUGUS. Gusau, is also on the South Western portion of Northern Nigerian Massif. Eight-N-S trending schist belts have been recognized in the western portion of the Northern Nigerian Massif. According to (Ajibade, *et al.*, 1976), the schist belts are separated by migmatite- gneiss complex and older granites.

The rock types found here are believed to be part of the older granite suite and are mostly exposed, where they appear in

most cases weathered. Based on relative grain size, the major rocks types are:

1. Porphyritic to coarse-grained granite:- this is mostly found outcropping along the river channels. They are believed to continuously underlay the region that is covered by thick overburden. They are mostly flat lying and ranges in sizes from few meters. North-South (N-S) trending quartz and aplitic veins ranging in length the outcrops are broken into boulders, which could be attributed to biological, mechanical and chemical weathering.
2. Medium to fine grained granite: - these are flat lying out crop along the river channels and relatively high rising elongated outcrops on the surface, these are fresher (less weathered) compared to the first type. The rocks are found in East-West (E-W) trending vein and joints, which are at times filled by aplites or quartz. The rocks are in some places broken into boulders, and show the effect of weathering in form of colour change, and loose rock fragment.

Figure 2: Geological Map of Federal University Gusau Zamfara State (Shaibu I, 2018). Showing the geology of the study area below.

While Figure3 shows Geological and Mineral Resources Map of Zamfara State (NGSA, 2010)

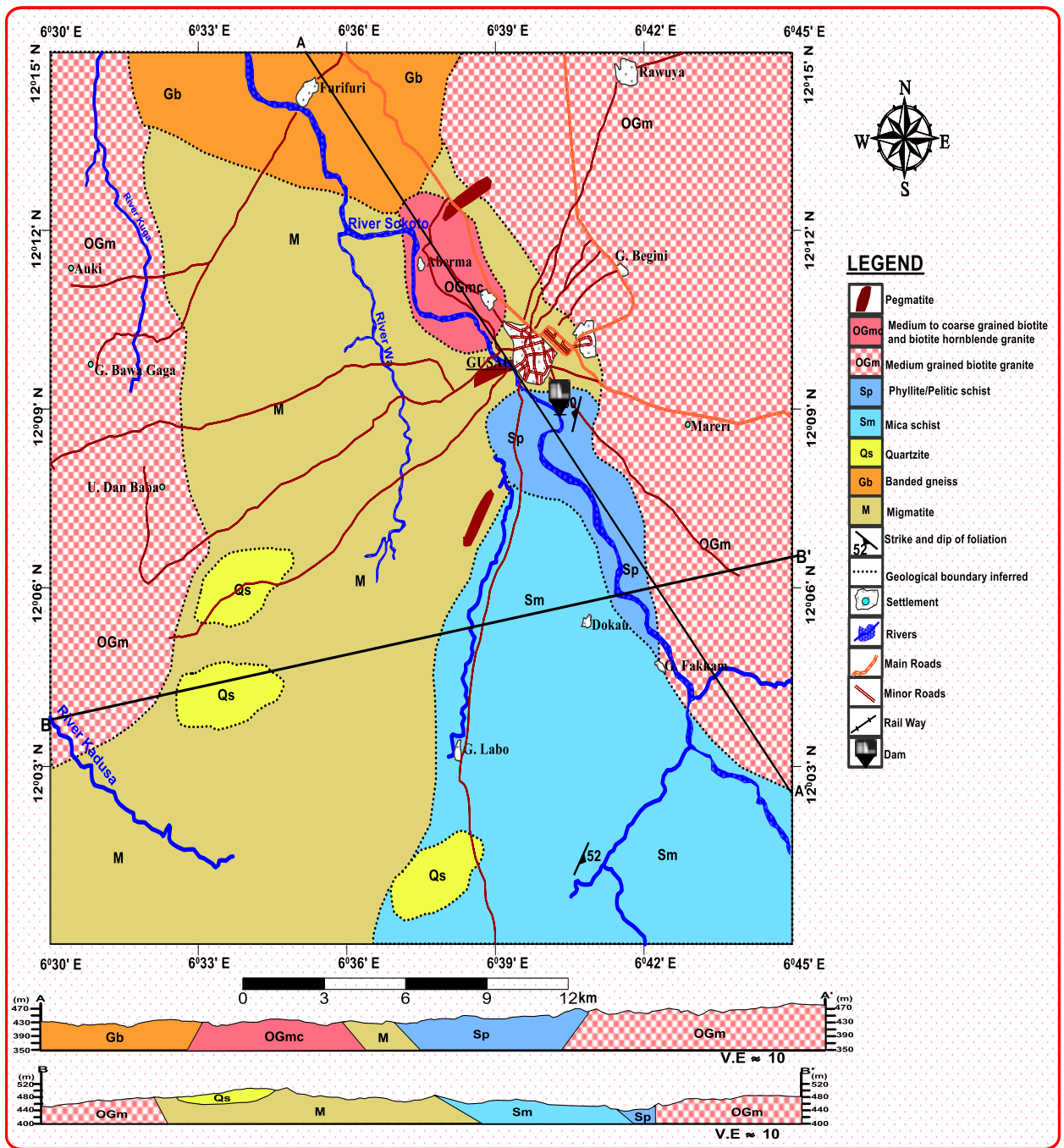


Figure 2: Geological Map of Federal University Gusau Zamfara State (Shaibu, 2018)

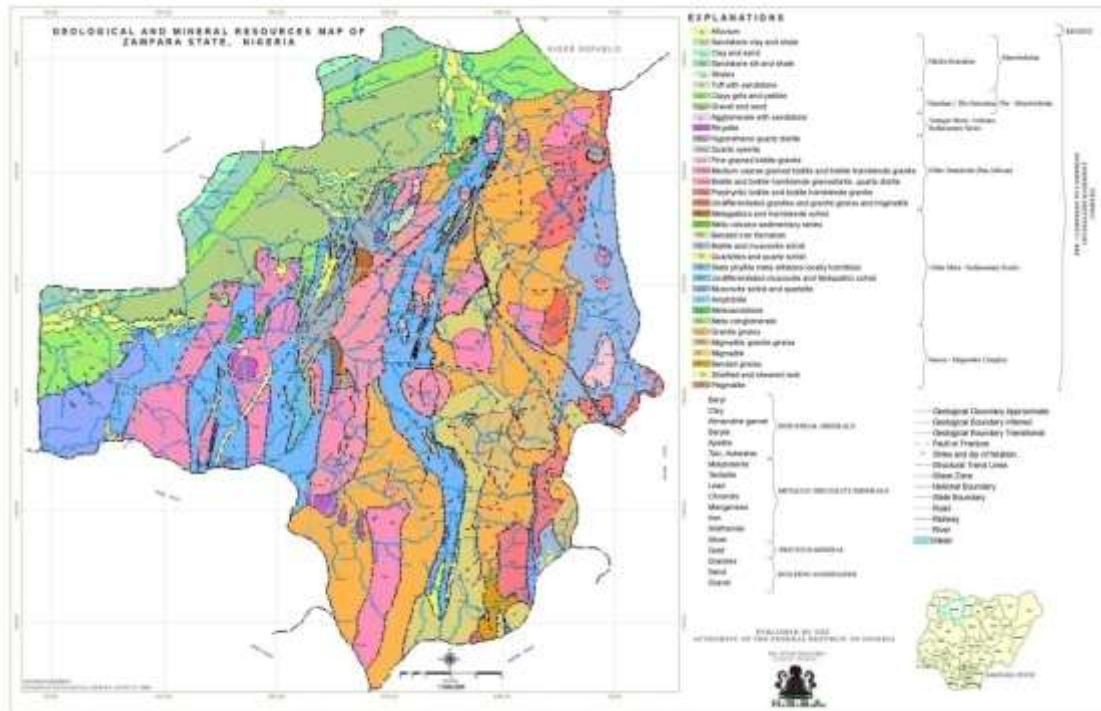


Figure 3: Geological and Mineral Resources Map of Zamfara State (NGSA, 2010)

The Federal University Gusau, Zamfara State, Nigeria. is located along Zaria Sokoto . The study area is located within Federal University Gusau Campus, Zamfara State. and is in between Faculty of Sciences, Administrative Block and Students Hostel. The site covers an area of about 250,000 square meters.

MATERIALS

Terrameter (ABEM SAS 1000)-

This is the major power source of the whole set-up. It measures the resistance of the subsurface layers and can also measure the voltage of the power source. The equipment has an in-built system of reducing the effect of noise. The instrument is portable and fixed with a rechargeable battery. it has a maximum power of 18 watts, manual selection of current in steps up to 100mA, a choice of sample time/ signal length averaged three frequency settings.

Electrodes-

These are steel rods of about 30cm with a base and a pointed end. The pointed end is use to penetrate the ground. The material makes it a good conductor. Four electrodes will be used; the first pair is the potential electrode while the second pair is the current electrode. Their basic function is to pass current into the ground and measure potential between two points. Two-third of the length of the electrodes will be driven below the earth surface.

Cables-

They are made of conducting material (copper). There will be four reels of cables used during the geophysical survey. The cables will be connected to the terrameter on one end and the other is connected to the electrodes.

Clips-

These are objects used for passing the currents from the cables to the electrodes by clipping the electrodes after wounding the cable on it. The mouth is made of conducting materials while

the base (handle) is made of insulating material to prevent electrocution. The clips ensure good electrical contact

Hammer and Cutlass-

These will be used to drive the electrodes into the ground. It consists of a relatively slim wooden cylindrical handle embedded into a metallic head. While the cutlass will be used to clear the path along which measurement are to be taken.

Tapes-

These are used for making measurements of length on the field as they have been calibrated in metric units. The tapes used will be of 100m in length. They will be used in measuring electrode spacing on the field.

Global Positioning System and Compass-Clinometer-

This equipment will be used for taking coordinates and bearing. GPS will be used for taking the longitudes, latitudes and elevation of various locations. It is portable and handy. The compass-clinometer will be used to take direction of the profiles.

Field Stationery-

These are writing materials that will be used to record all observation and field data. The stationery consists of pencils, pens, recording sheets, rulers and so on.

Geology of the Study Areas

Federal University Gusau, main Campus is actual located along Zaria-Sokoto Road, within Kotokoroshi Community, , Nigeria (Figure 1). The study area lies within Basement Complex of Northwestern Nigeria (Obaje, 2015). Indeed, many previous workers (such as, Black, 1980; Ajibade and Fitches, 2018; Obaje, 2015; Danbatta and Garba, 2017; Obaje, 2015; Nwachukwu et al., 2016; Folorunso et al., 2016; Opara et al., 2015; [Saleh and Maunde, 2017](#); Ekeleme et al., 2017; etc.) have written so much on the basement complex of Nigeria. The Nigerian Basement Complex is a part of the Pan-

African mobile belt which lies among the West African and Congo Cratons as well as south of the Tuareg Shield (Black, 1980).

However, Ajibade and Fitches (2018) reported that the basement comprises three major lithological groups: (i) the migmatite gneiss complex which is widespread throughout the country; (ii) metasedimentary and metavolcanic rocks which form schist belts and appear to be dominantly restricted to the western half of the country; (iii) the Older Granites which intrude both the migmatite gneiss complex and the schist belts and have consistently yielded Pan-African ages. Thus, the study area is underlain by Old-Granites. While (Figure 4) shows the general geology map of Federal University GusauZamfara State,

METHODOLOGY

In this study area the data collected were basically collected from main measuring mode of the Terrameter SAS 4000 (Resistivity). The profiling data were collected using Wenner electrical profiling method. 10m-electrode spacing was used and this corresponds to 15m probe depth. Care was taken to ensure that the electrode layout follow a straight line along the N-S profile layout. Similarly, Schlumberger method of electrical sounding was employed for electrical drilling (VES data). The maximum current electrode separation of 200m and potential electrode separation of 30m were reached and this corresponds to 100 m probed depth (i.e. AB/2). There was no need for data reduction or repeated measurement since the

receiver of SAS 4000 discriminates noise and measures voltages corrected with transmitted signal current. The system has the built-in function to average the best measurement of maximum of four staking with the standard deviation of unity or even less (ABEM instrument AB, 1999). The field layout is shown in Table. 1.

The apparent resistivity values acquired from the measurement were plotted against half the current electrode spacing on a bi-logarithmic graph in order to determine the apparent resistivities and thicknesses of various layers penetrated. Some many researchers have written on the need and uses of Schlumberger method in groundwater investigation (Udensi, and Salako, 2005; Mohammed, 2007; Anakwuba et al.,2014; Chinwuko et al., 2015;Osele et al., 2016;Chinwuko et al., 2016 and others). An iterative software computer program called the Zohdy graphical method was used to interpret the data (Zohdy and Bisdorf, 1989). This software performs automatic interpretation of the Schlumberger sounding curves which gives the equivalent n-layer model input from the apparent resistivity data of each sounding point. It converts the apparent resistivity as a function of electrode spacing to the true resistivity as a function of depth in two dimensions.The profile data were processed using computer iterative window-based application software called surface 8.0, from Golden software and Minitab 14, which gives a graphical presentation of the contour map. The software generates the resistivity contour map of both contour map and profiling data.

Table 1: Show the Profile Layout along which the Data were collected below

	A1	A2	A3	A4	A5	A6
Works Dept.	B1	B2	B3	B4	B5	B6
N ↑	C1	C2	C3	C4	C5	C6
	D1	D2	D3	D4	D5	D6
	E1	E2	E3	E4	E5	E6
Admin Blocks.	F1	F2	F3	F4	F5	F6

RESULTS AND DISCUSSION

Results of the VES Interpretation along the Profiles

From the digitized Zohdy curves showing in (Figure4) below, visual inspection of the curves based on their distinct geo-electric characteristics were used to classify the curves types in the following order:

Group A: (K-type); The group consists of curves with 3 layers $\rho_1 < \rho_2 > \rho_3$ and there are few types in the study area, covering about 10% of the VES points (A6, A5, B5,B6,E2,E3, E3, F5 and F6) most of which have marked characteristics of water bearing formation (aquifer) because of its thick weathered layers.

Group B: (H-type) the group is made up of curves having 3 layers with $\rho_1 > \rho_2 < \rho_3$ and typical of VES locations (A1, A5, A4, B3, B5, C3, C5 and D6) which are either weathered or partly weathered layer. This layer is also potential aquifer

Group C:(HK-type);the group consists of curves with 4 layers $\rho_1 > \rho_2 < \rho_3 > \rho_4$ and there are few types in the study area. It hasvery limited aquifer potential.

Table 2 contains the summary of the VES interpretation along some representative profiles. From the general interpretations (from Profile A-F), the following deduction could be made: the first layers have the resistivity value range from 19.25 Ωm to 2170.65 Ωm . It is highest at A5 (profile A VES point-5) and lowest at A1(profile A VES point-1); the second layers have resistivity value from 21.31 Ωm to 4103.91 Ωm .It is highest at F5 (profile F VES point-5) and lowest at B3 (profile B VES point-3); the third layers have resistivity value range from 98.86 Ωm to 6229.26 Ωm . It is highest at D6(profile D VES point-6)and lowest at C2 (profile C VES point-2). More so, the shallowest basement occur at F5 (2.32 m) and deepest at B3 (33.11m). Thinnest topsoil thickness of 0.34 m occurs at F5 while the thickest topsoil of 2.03 m thick which occurs at VES A6.

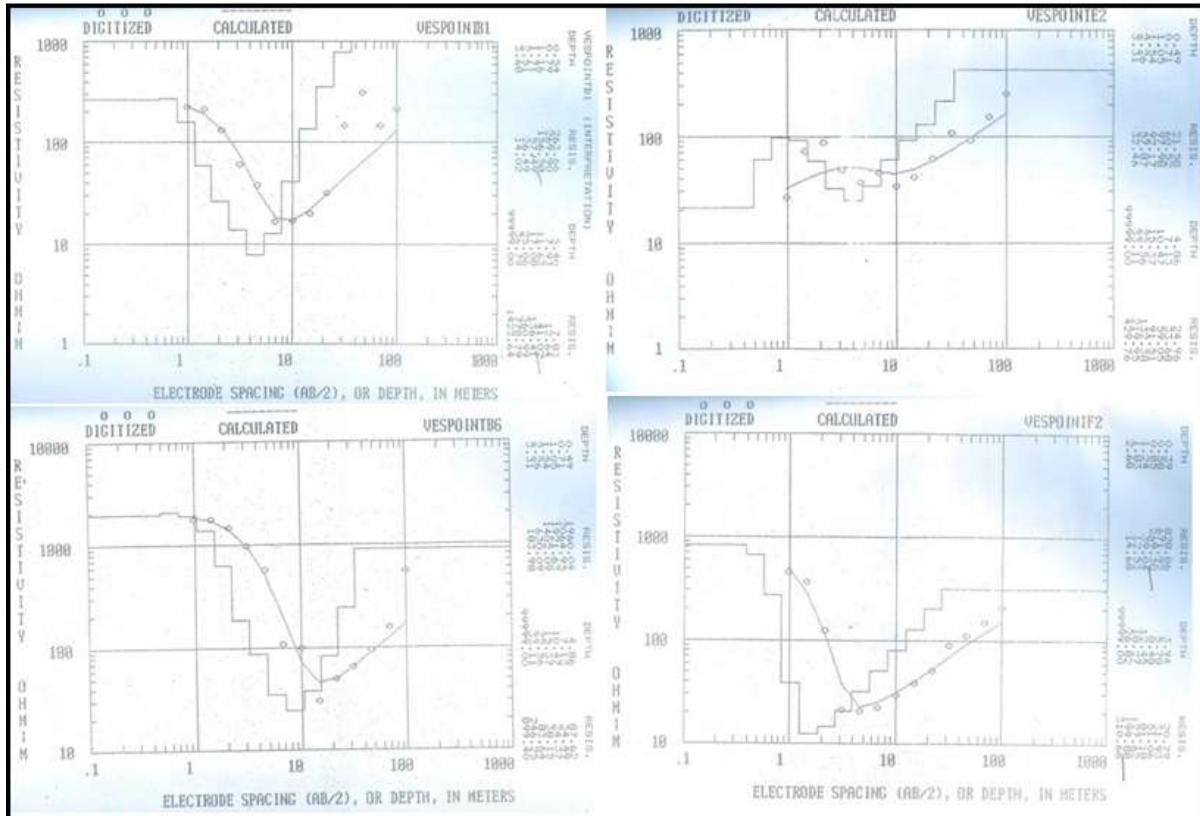


Figure 4: digitized Zohdy curves

Table 2: VES interpretation along profiles

VES Pt	No of Layers	Types of Layer Curve	Average (Ωm)	Resistivity	Layer Thickness(m)	Depth ()
Profile A						
	1		19.25		1.16	0
A1	2	H	49.32		15.92	1.16
	3		588.51		∞	17.08
	1		40.01		0.71	0
A2	2	HK	92.4		14.66	0.71
	3		321.81		∞	15.37
	1		28.74		0.85	0
A3	2	HK	38.75		17.42	0.85
	3		260.15		∞	18.27
	1		407.7		0.44	0
A4	2	H	26.13		13.39	0.44
	3		619.78		∞	13.83
	1		2170.65		1.54	0
A5	2	H	184.3		21.02	1.54
	3		388.97		∞	22.56
	1		1818.8		2.03	0
A6	2	HK	495.15		4.39	2.03
	3		284.53		∞	6.42

Profile B

	1		229.94	1.16	0
B1	2	H	26.58	10.47	1.16
	3		674.96	∞	11.63
	1		228.13	1.16	0
B2	2	H	27.61	10.47	1.16
	3		687.28	∞	11.63
	1		42.78	0.71	0
B3	2	H	26.41	32.4	0.71
	3		416.2	∞	33.11
	1		40.39	0.79	0
B4	2	H	21.31	24.27	0.79
	3		200.91	∞	25.06
	1		381.05	0.44	0
B5	2	H	42.15	13.39	0.44
	3		782.83	∞	13.83
	1		1837.18	1.54	0
B6	2	H	154.62	21.02	1.54
	3		572.83	∞	22.56

Geo-electric sections with geology

According to Shaibu I (2018), there are three Lithological units that are found with Federal University Gusau, Zamfara State. axis from the borehole logs he produced after boreholes were drilled within the area (Figure 5) and the following deductions were made from Shaibu I (2018):

1. The first layer consists of weathered lateritic with thickness between 0.0 m -10.0 m.

2. The second layer consists of weathered basement with thickness between 10.0 m to about 28.0 m. The areas of fracture have good aquifer potential.
3. The third layer is the fractured basement and fresh basement which constitutes the bedrock of the area and has infinite thickness.

The following Figure 5 shows Geo- electric Sections for 3 Layer Thickness, while Figure 6 shows Geo- electric Sections for 4 Layer Thickness below

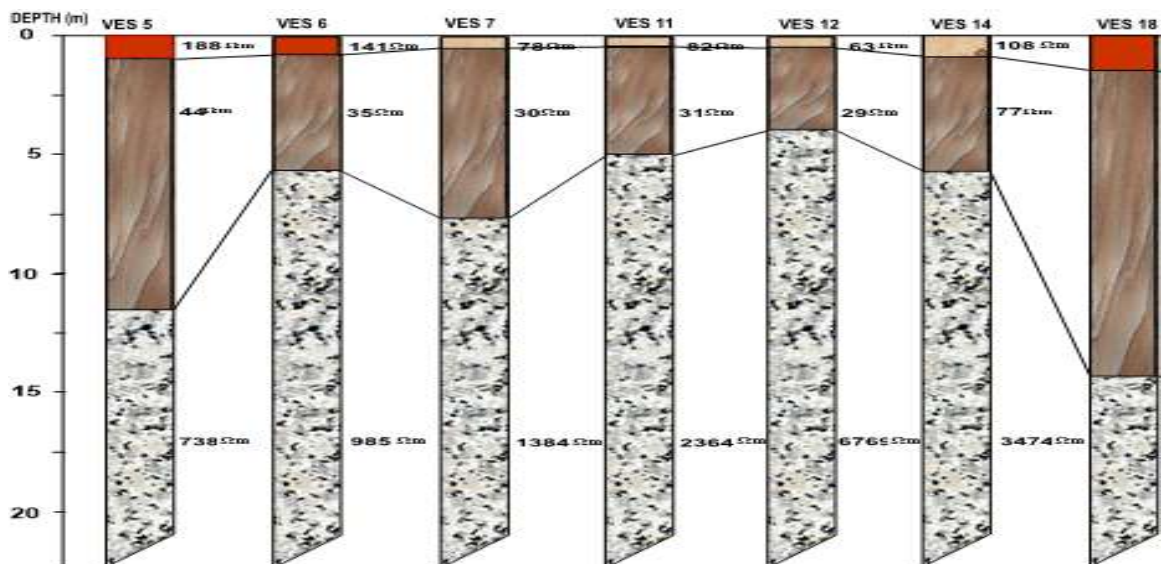


Figure 5: Geo- electric Sections for 3 Layer Thickness

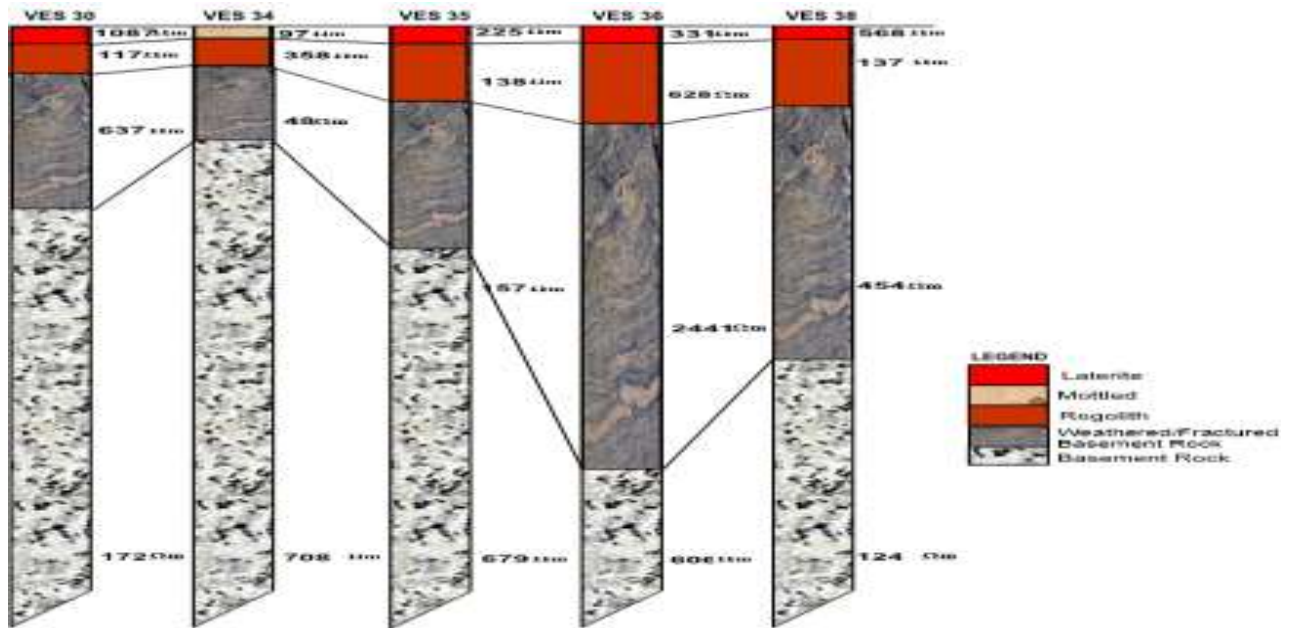


Figure 6: Geo- electric Sections for 4 Layer Thickness

Furthermore, Hockney (1986) wrote that it takes several thousand years before the geologic history of an area can change. Taking this into consideration, the geologic sections for profiles A to F can be deduced as follows:

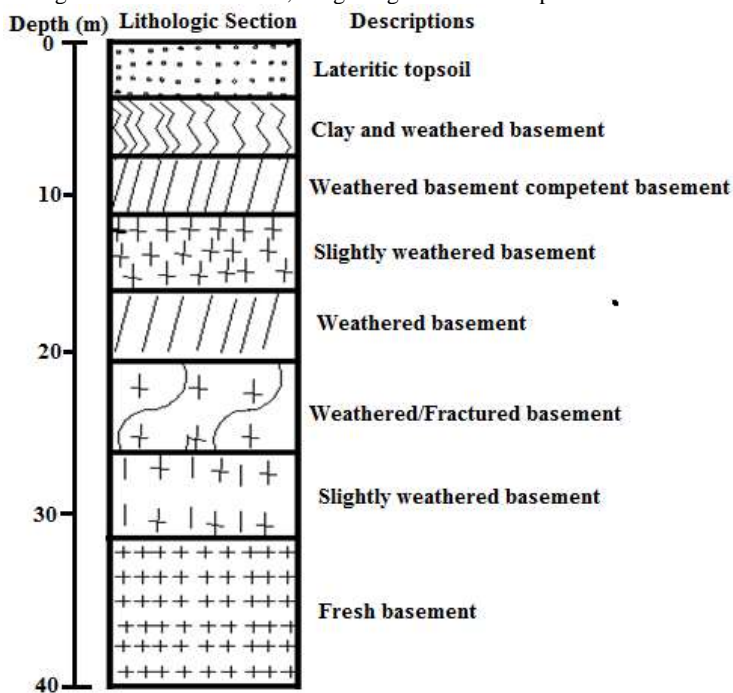


Figure7: Drilling log for the borehole around student’s hostel, Federal University Gusau.(Source: Shaibu I, 2018)

Figure 7 shows the composite for geo-electric sections with its equivalent geologic section of profile A within the study area. Figure 7 is the equivalent geologic map of Figure 8 suggests the existence of three geologic sections namely weathered lateritic, weathered basement and fractured basement. The first layer has average resistivity value of about 747.53 Ωm with thickness of ranging from 0.44 - 2.03 m. The highest thickness occurs at VES A5 and A6, while the least thickness occur at A4. The layer is suggested to be weathered lateritic.

The second layer consists of weathered basement which is hydro-geologically called saprolite or saprock (Rao, 1987).

The thickness ranges from 4.39m - 21.02 m with the deepest (thickest overburden) at A5 whereas the thinnest occurred at A4 (4.39 m). The third layer could constitute the fractured basement of good aquifer potential; it is deepest on A5 (22.56 m) and shallowest at A6 (6.42 m). The resistivity range varies between 260 Ωm to 619.7 Ωm. The central part of the profile is shallow unlike the flanks. The combination of weathered lateritic, sandy, thick saprolite and thick saprock on the eastern flank of the profile (A3 – A6) makes it first choice for locating groundwater borehole which confirms the borehole lithology on Tables 5.1 – 5.3.

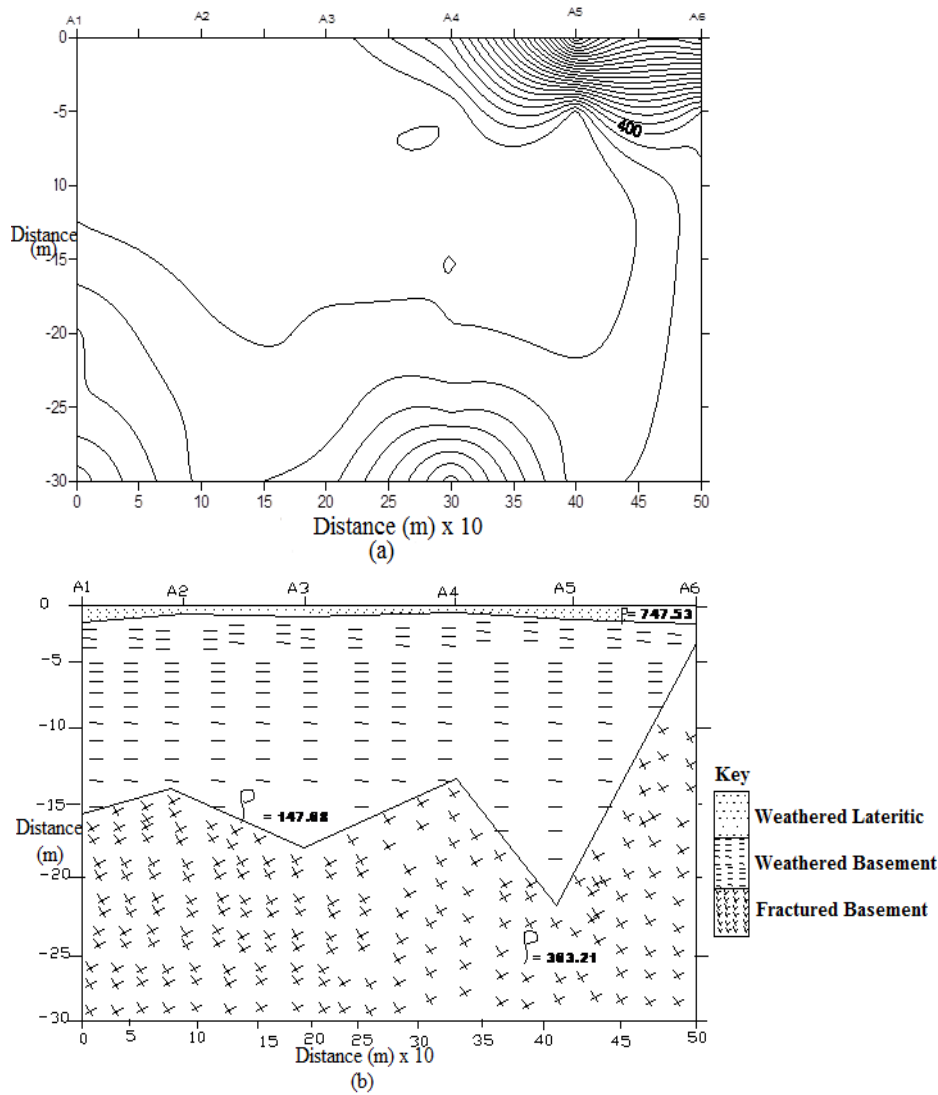


Figure 8: Correlation of geo-electric section with Geology of the area.

Iso-resistivity within the area

The iso-resistivity contour at 15 m and 30 m depth were generated as shown in Figure 6. At 15 m depth, fresh basement rocks with resistivity values of 1000 Ω m and above begins to appear at this depth (Figure 8). The southern part through the north-east part of the study area at the VES points (A2, C2, and E2, has resistivity below 500 Ω m and are points that may likely be good for ground water development. The southern east central end of this map exhibit very high resistivity, (D2, D5, E6, and F5). These points also agree with

the result obtained from the vertical section through profile and the VES interpretations. However, at 30 m depth, some parts of the study area are characterized moderate resistivity values of about 1000 Ω m, corresponding with VES points (A1, B1, B2, C1, E1, F1 and F4). The zone could be slightly weathered or fractured basement with reasonable aquifer potential. They have the ability of maintaining this resistivity value above 1000 Ω m, which are found around north central are, VES (D1, D2, D3, D5, E6, and F5) which corresponds to the points where depth is beyond 30 m in the vertical sections.

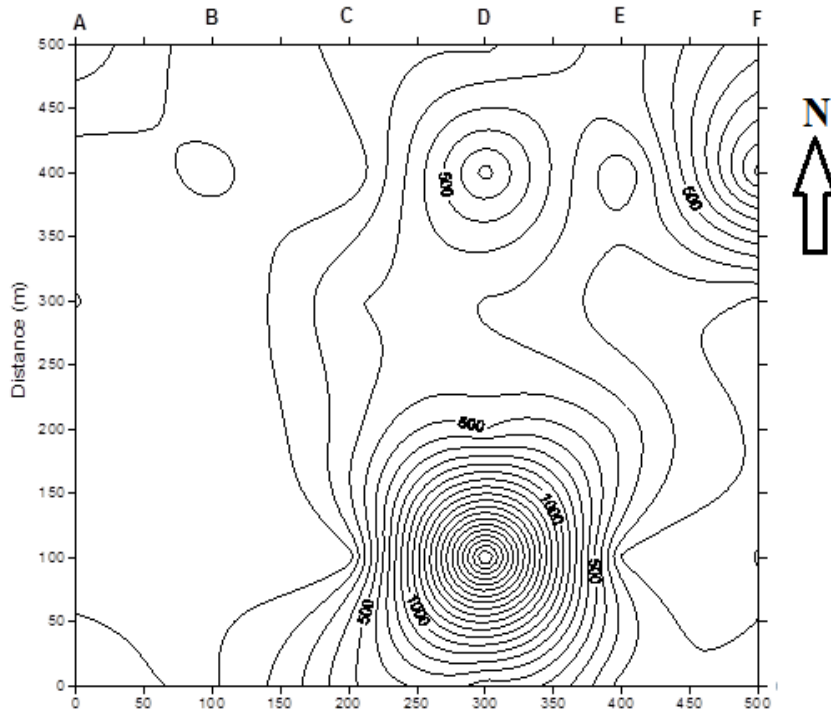


Figure9a: Iso-Resistivity Contour Map at 15 m(Contour interval ~ 100 Ωm)

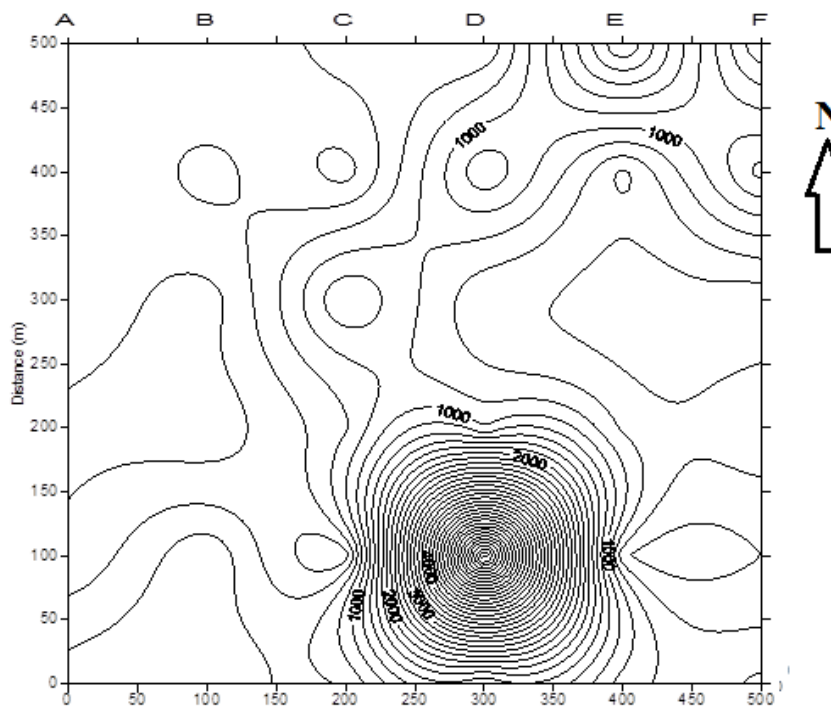


Figure 9b: Iso-Resistivity Contour Map at 30m (Contour interval ~ 200 Ωm)

Regolith Thickness Map

The regolith thickness represents the difference between the base of the weathered basement and the topsoil. According to Wright(1992) and Olayinka(1997), they infer thick regolith as weathered interval with optimum weathered and a high aquifer potential. At the southeastern and southwestern parts

of the map (Figure 10),there is a thin regolith section and non-conductive region for aquifer potential while at northwestern and eastern portions, there is thick overburden. The thick overburden region indeed suggests sites for further depth probing to ensure high aquifer reservoir.

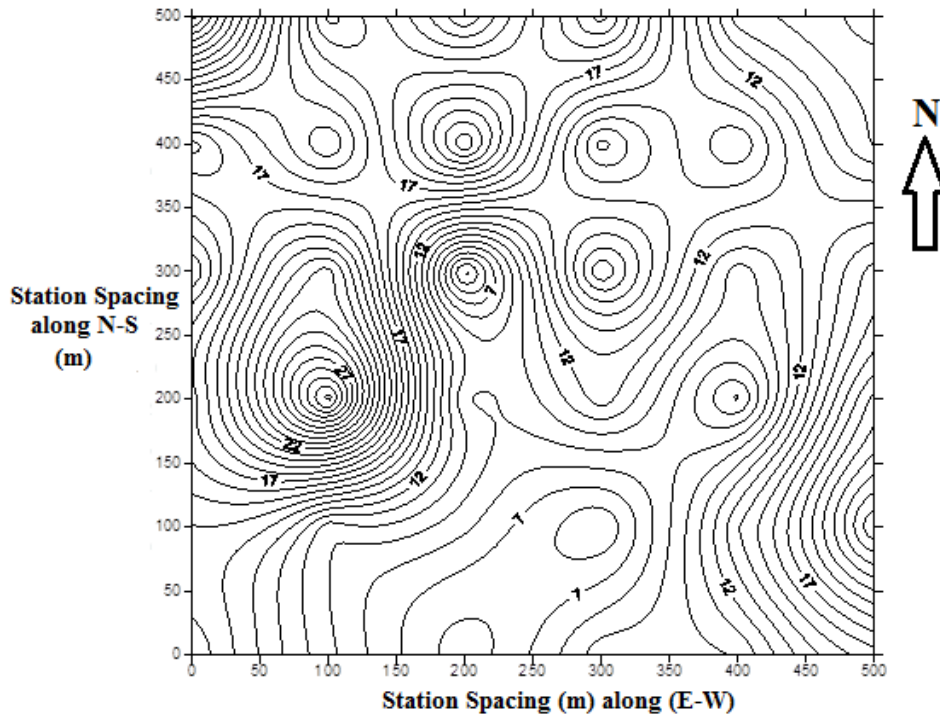


Figure 10: Regolith Thickness Contour Map (Contour interval ~ 1m)

Depth to Basement Map

Figure 11 shows the depth to basement from the surface. The depth values which correspond to the last layer were picked for the whole 36 VES points. The areas with the largest depth to basement are found at north region of the survey area (Figure 11). The area that has the thickest overburden is B3, which conforms to Olorunmiwo and Olorunfemi(1987); Aboh and Osazuwa (2000). They suggested that areas with highest ground water yield in basement terrain are found in area, where thick overburden overlies fractured Zones which are characterized by relatively low resistivity. Similarly areas of deep basement depressions of shallow basement by the sides

may probably serve as recharge point for groundwater. Hence, Figure 10 also shows that those areas with depression valley are areas delineated as having good potential for ground water potentials. This also corroborates both the vertical section and iso-resistivity at various depths. Similarly, those areas with elevation basement could be better used for civil engineering works at very low risk. In any basement complex terrain like the study area, ground water is confined within weathered layer (saprolite) or fractured basement (saprocks) columns (Afolayan et al, 2004 and Udensi and Salako,2005). Therefore, this study satisfies the three conditions with good aquifer potential.

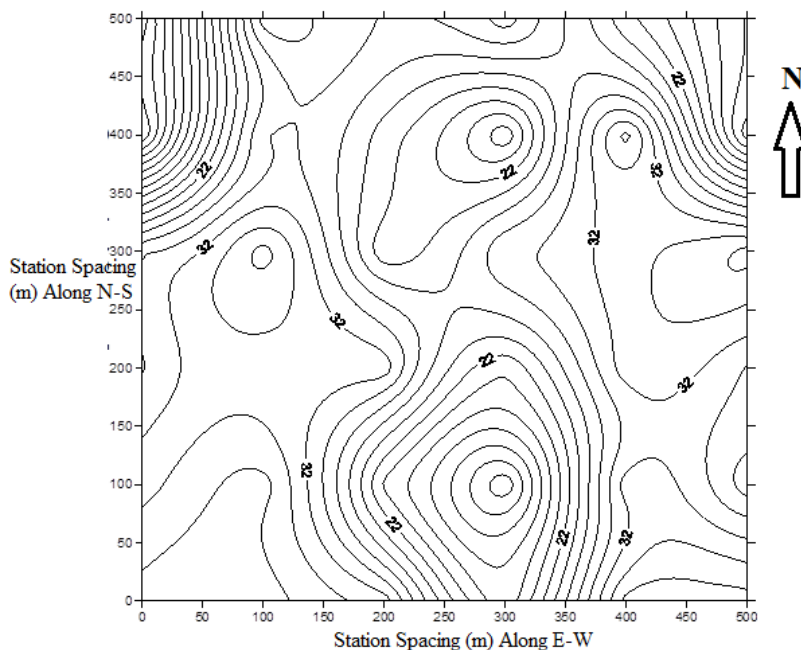


Figure 11: Depth to basement map (Contour interval ~ 2m)

CONCLUSION AND RECOMMENDATIONS

The present study evaluation of the subsurface structures in part of Federal University Gusau, Zamfara State, Nigeria, using Vertical Electrical Sounding of the Electrical Resistivity method. The study became necessary due to the increases of admissions and populations of the area and the incessant water scarcity experienced by the occupants of the campus and its environs. A total number of 36 VES points were conducted and the data obtained were analyzed using zbody softwares. The area comprises of 3-layers and 4- layers respectively. The 3- layers were predominantly H-types curve while 4- layers were mainly HA-curve types and are typical of basement terrain. The field data, geo-electric sections, and iso resistivity map of both 3 and 4 – layers model curves shows that the northern part of the study area correspond to recharge zone while the southern portions correspond to discharge zone.

RECOMMENDATIONS

A total drill depth of 75 m to 90 m were recommended for optimum groundwater yield in the entire area and the entire area are good for civil engineering purposes. It is also recommended that water analysis should be conducted to reduced intake of groundwater contaminations.

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CONFLICT OF INTEREST

There is no conflict of interest associated with this particular research work.

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