Available online at www.worldnewsnaturalsciences.com

World News of Natural Sciences

An International Scientific Journal

WNOFNS 23 (2019) 154-165 EISSN 2543-5426

Geophysical Survey of Basement Complex Terrain Using Electrical Resistivity Method for Groundwater Potential

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ABSTRACT

A geophysical survey of basement complex using electrical resistivity method was carried out so as to provide geological and geophysical information on the different subsurface features. The sought-for parameters include thickness, depth, basement for groundwater potential and aquifer protective capacity. The acquired data were process using Win-Resist software and surfer 8, and the result was then analyzed and interpreted. Accordingly, 3-4 geoelectrical layers within the subsurface delineate the area: top soil, lateritic layer, weathered/fractured layer and fresh rock. Resistivity values of the top soil range between 55.5 mΩ to 749.7 mΩ, with average thickness of 0.4 m to 3.6 m, while the lateritic layer ranges between 153.3 mΩ to 862.0 mΩ, with average thickness of 4.5 m to 20.7 m, the weathered/fractured layer in turn ranges between 15.6 mΩ to 698.9 mΩ, with average thickness of 7.7 m to 55.2 m, and the fresh rock ranges between 13.4 mΩ to 5102 mΩ, with infinite homogeneous half space. Over all, the longitudinal conductance of the overburden units range from 0.147 mhos to 0.957 mhos and the overburden is thick enough for groundwater exploration activities. The results provide reasonably information that the aquifer units are weathered/fractured layers with a significant groundwater potential that is free of contamination.

***Keywords*:** Basement, Electrical resistivity, Groundwater, Schlumberger, Geological materials

1. INTRODUCTION

Nigeria consists of two broad geological terrains, namely: the basement complex and sedimentary terrain as show in (Figure 1). The basement complex region of Nigeria consists of

(Received 23 January 2019; Accepted 07 February 2019; Date of Publication 08 February 2019)

crystalline igneous and metamorphic rocks, these rocks occur either directly exposed or covered by shallow mantle of superficial deposit [1-3]. The basement lies between the West Africa and Congo cartons. The crystalline basement rocks have broadly classified into five major lithological groups. [4-6]; these includes; Magmatic-gneiss complex, Meta sedimentary and metavolcanic rocks, Charnonkite rocks, Older granite, Unmetamorphosed dolerite dykes. The Sedimentary rocks are found in seven basins located in the northeast, (Chad basin), northwest (Sokoto basin), Benue Trough, Niger, Anambra, southwest (Dahomey basin) and the Niger Delta [7-10]. There is association between the charnonkites and non-charnonkites granite rocks due to their relations [11-14].

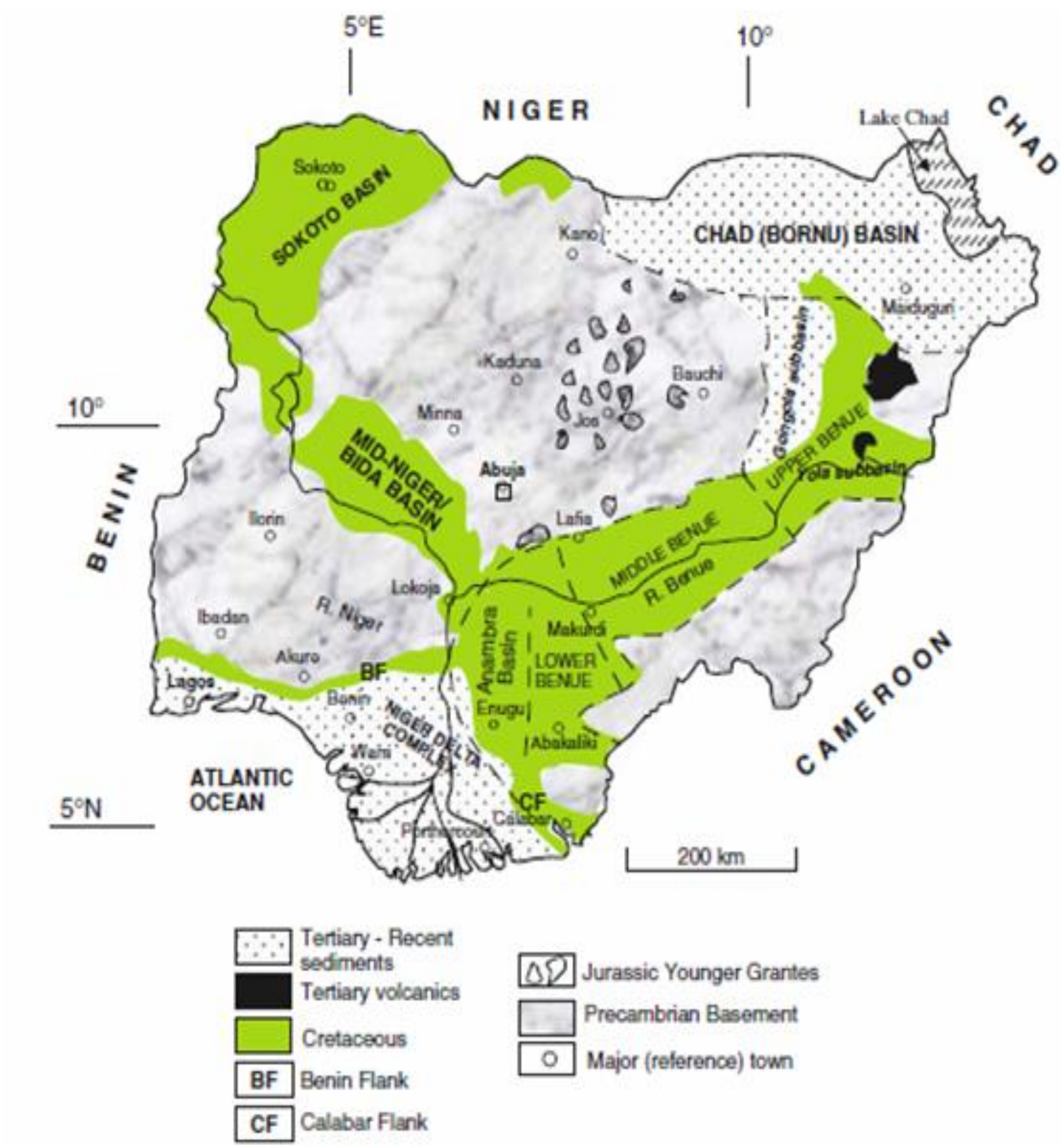

Figure 1. Geological map of Nigeria showing the basement complex and the sedimentary terrain. [15].

The geophysical surveys of the subsurface involve the measurement/establishment of Geoelectric parameters such as resistivity layer (p_a), thickness and depth for each lithologic unit, these Geoelectric parameters then used to describe the hydrological condition of the subsurface, aquifer protective capacity rating and longitudinal conductance as applied in this paper. The study area is Iseyin towm in Iseyin area council of Oyo State, the area is underlain Precambrian Basement Complex Rocks (PBCR) of the southwestern Nigeria and the aim of this study is to investigate groundwater potential using electrical resistivity method, due to lack of adequate quality supply of water in the area and increase in population.

2. SITE DESCRIPTION

The study area is located at Iseyin Saki road in Iseyin Local Government area of Oyo state. It is located on latitude 7º58'0" North and longitude 3º36'0" East as shown in (Figure 2). Iseyin city is also known as Ebedi city which is centrally located with road networks accessible from Ibadan, Oyo, Abeokuta, and Ogbomoso. It is approximately 100 kilometers north of Ibadan. Iseyin is estimated to have a population of 236,000 per a United Nations 2005 estimated; by 2006 Nigeria Census it was 255,619.

The study area was underlain specifically by charkonite. The charkonite consist of quartz, alkalis feldspar, plagioclase, orth pyroxene, chinopyroxene, horriblende biotite and altanite. The charkonite rocks are mainly of magnetic origin and not the result of the high-grade metamorphism in the granitic faces.

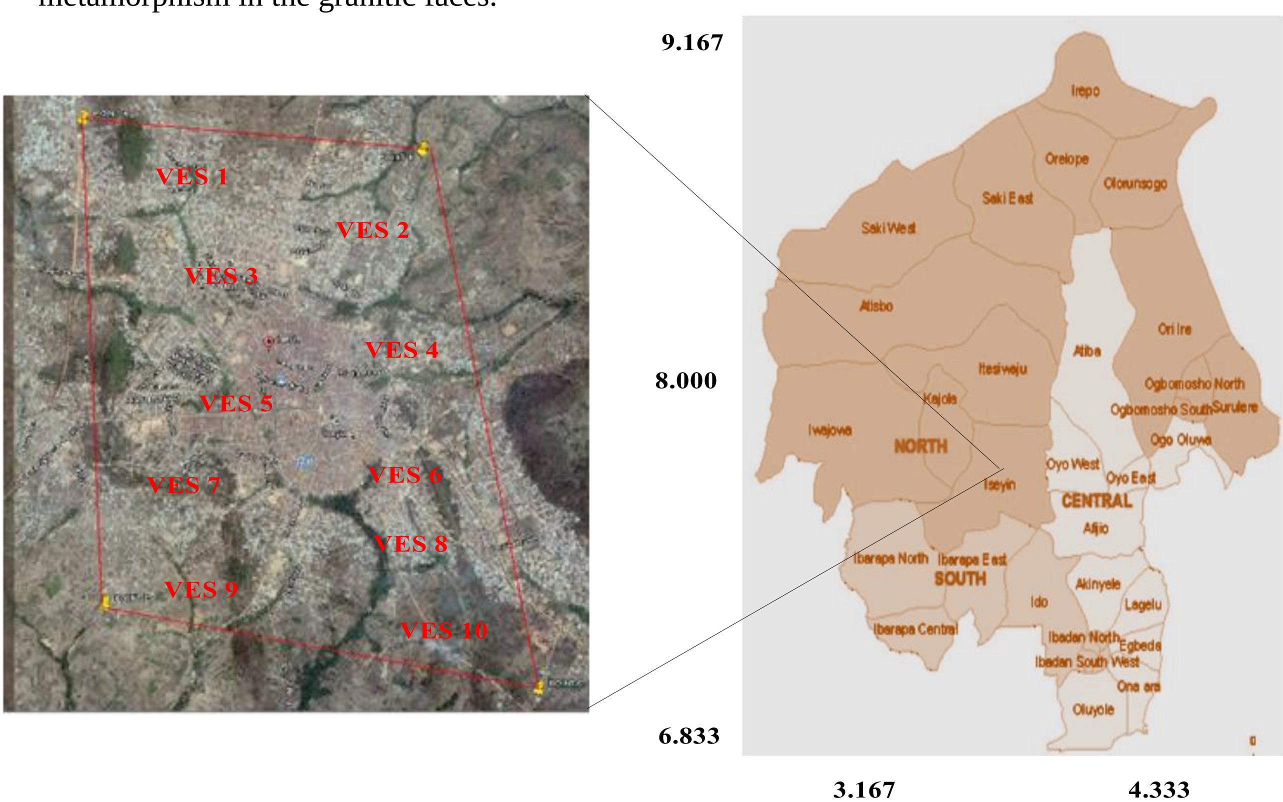

Figure 2. Map of Oyo State and the study area

3. EXPERIMENTS DESIGN

By proper interpretation of the resistivity data from the field curves so obtained and matching them with standard curves available, it is possible to identify the water bearing formations and accordingly limit the depth of well drilling. The Vertical Electrical Sounding (VES) technique was adopted for the survey, the total number of ten VES, were occupied in the study area using the resistivity meter (RD 50) for measuring electrical resistivity. These sounding were distributed across the study area and the schlumberger array was adopted with electrode spacing (AB/2) ranging from 1-80 m, 1-100 meter respectively. In the current study 10 vertical electrical sounding along with Schlumberger configuration has been used. The technique is good for determine lithology degree saturation and identification of aquifer.

Table 1. Longitudinal conductance and aquifer protective capacity rating [16].

Longitudinal conductance (mhos)	**Aquifer protective capacity rating**
>10	Excellent
5-10	Very good
0.7-4.49	Good
0.2-3.69	Moderate
0.1-0.19	Weak
<0.1	Poor

4. RESULTS AND DISCUSSION

The raw data of vertical electrical sounding (VES) were process by partial curve matching technique using standard curve and refined through computer iteration to delineate different geoelectric layers in terms of their thickness, depths and resistivity in order to have better understanding of subsurface lithological characterization (Table 2).

Table 2. Interpreted VES Results of Iseyin Area

S/N	**Layers**	**Resistivity**	**Thinkness**	**Depth**	**Curve Type**	**Lithological Infered**
VES 1	i.	749.7	3.6	3.6	K	Sandy top soil
	ii.	862.0	7.9	11.5		Weathered
	iii.	698.9	∞	∞		Fractured basement

VES 2	i.	43.6	1.5	1.5	AK	Top soil
	ii.	153.3	10.8	12.3		Lateritic
	iii.	276.2	13.1	25.4		Weathered
	iv.	13.4	∞	∞		Fractured basement
VES 3	i.	172.3	0.4	0.4	KH	Top soil
	ii.	274.3	4.5	4.9		Lateritic
	iii.	144.9	33.7	38.6		Weathered
	iv.	176.4	∞	∞		Fractured basement
VES 4	i.	55.5	0.8	0.8	AK	Top soil
	ii.	229.0	20.7	21.5		Lateritic
	iii.	339.5	55.2	76.6		Weathered
	iv.	117.6	∞	∞		Fractured basement
VES 5	i.	97.1	1.0	1.O	K	Top soil
	ii.	268.0	13.4	14.5		Weathered
	iii.	199.4	∞	∞		Fractured Basement
VES 6	i.	127.7	1.4	1.4	K	Top soil
	ii.	249.2	14.3	15.7		Weathered
	iii.	100.8	∞	∞		Fractured basement
VES 7	i.	183.0	0.5	0.5	K	Top soil
	ii.	599.1	11.5	12.0		Weathered
	iii.	119.5	∞	∞		Fractured basement
VES 8	i.	72.7	3.1	3.1	K	Top soil
	ii.	702.1	8.0	11.1		Basement
	iii.	15.6	∞	∞		Fracture basement
VES 9	i	597.8	0.9	0.9	QH	Top soil
	ii	384.9	12.2	13.1		Lateritic
	iii	174.5	7.7	20.8		Weathered

	iv.	5102.0	∞	∞		Fresh basement
VES 10	i	67.3	1.5	1.5	KQ	Top soil
	ii	181.1	6.2	7.7		Lateritic
	iii	161.9	4.6	12.3		Weathered
	iv	59.6	∞	∞		Fractured basement

Table 3. Longitudinal conductance of the study area

VES	1	2	3	4	5	6	7	8	9	10
Longitudinal conductance (mhos)	0.561	0.837	0.098	0.487	0.147	0.602	0.667	0.957	0.859	0.491

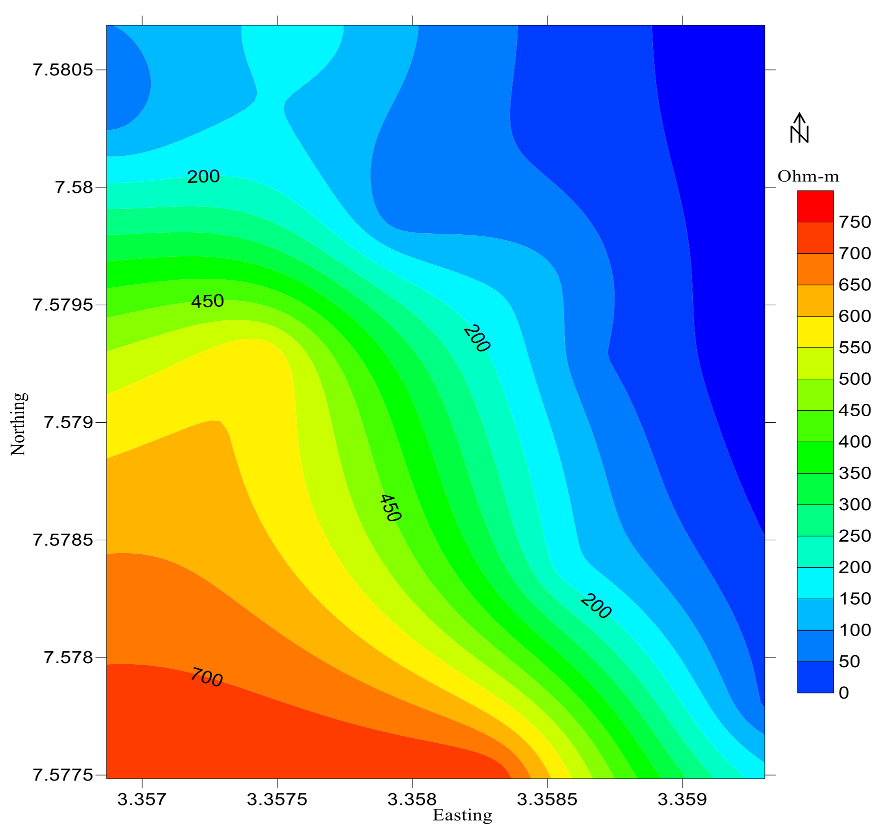

Figure 3. Isoresistivity of the top layer

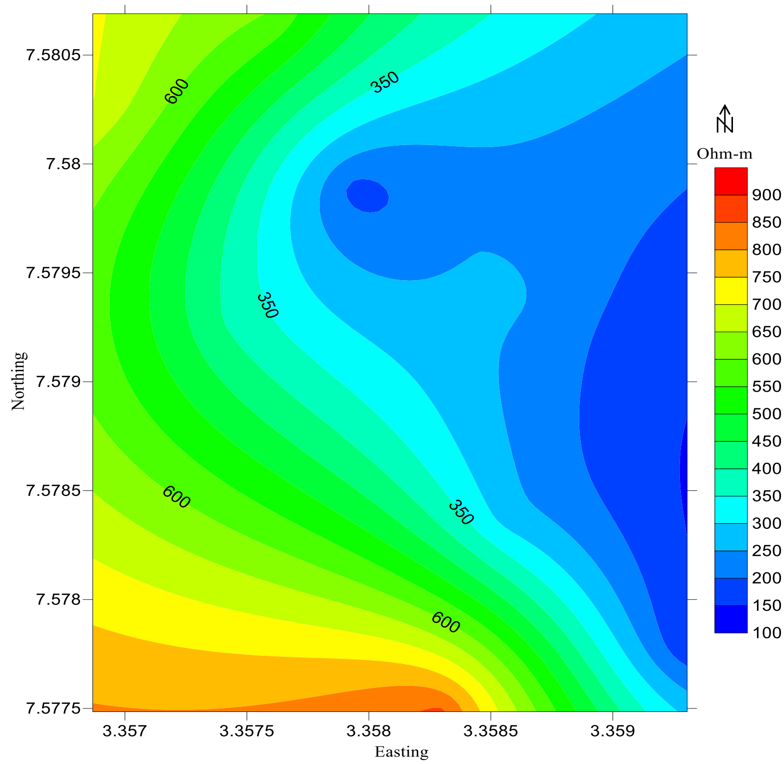

Figure 4. Isoresistivity of lateritic layer

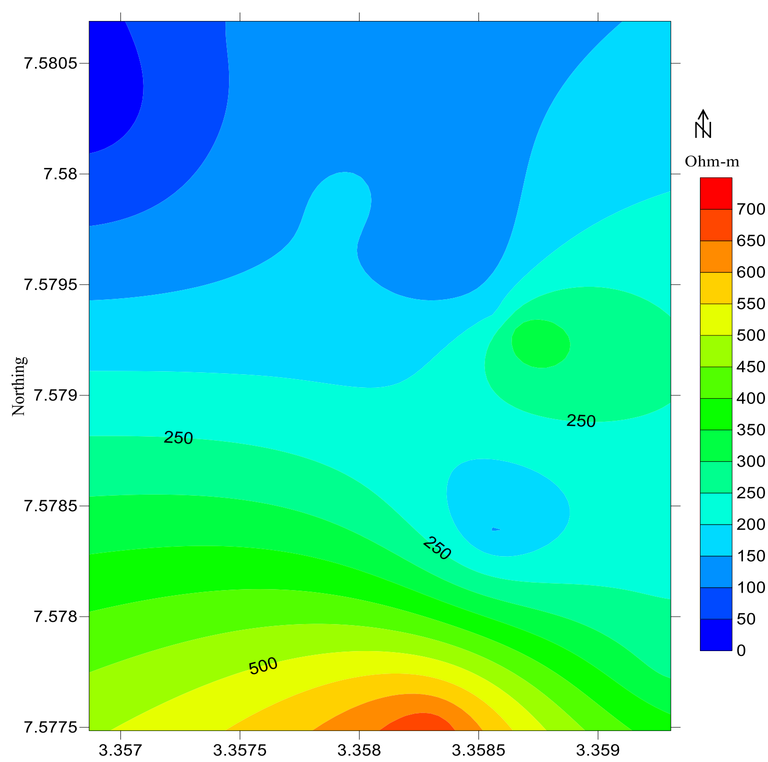

Figure 5. Isoresistivity of weathered/fractured

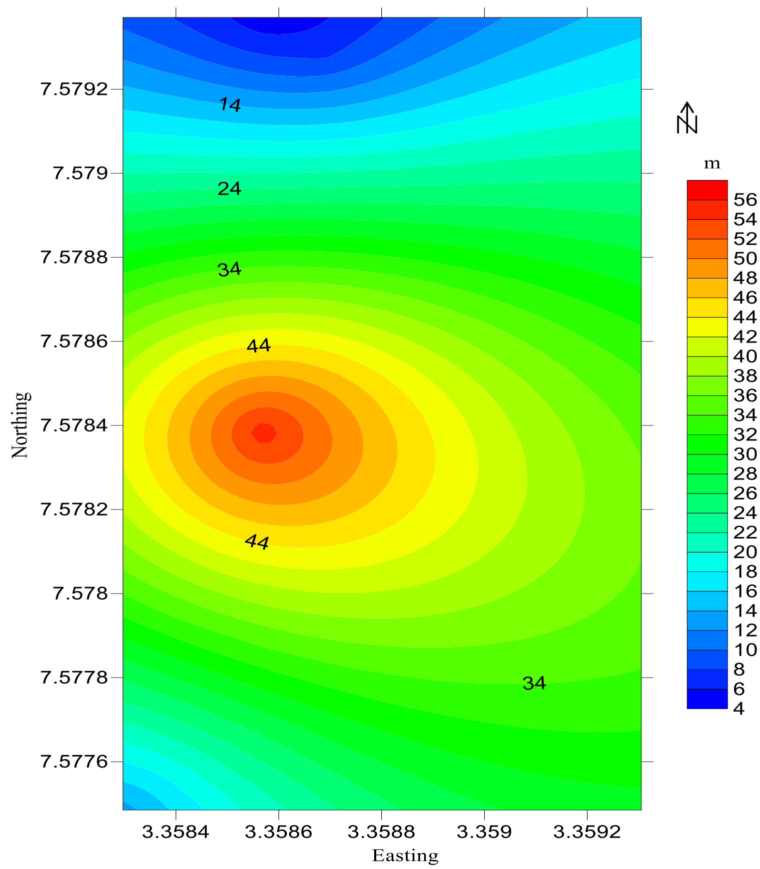

Figure 6. Isopach of the weather/fractured layer

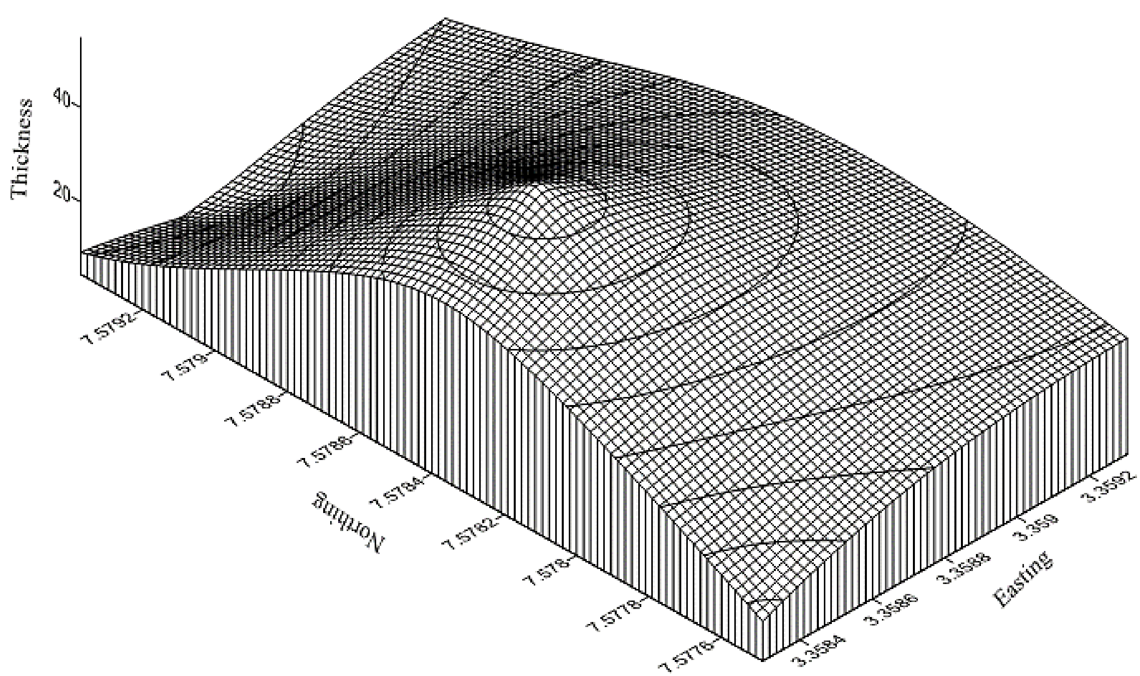

Figure 7. 3-D Wireframe map of the weather thickness

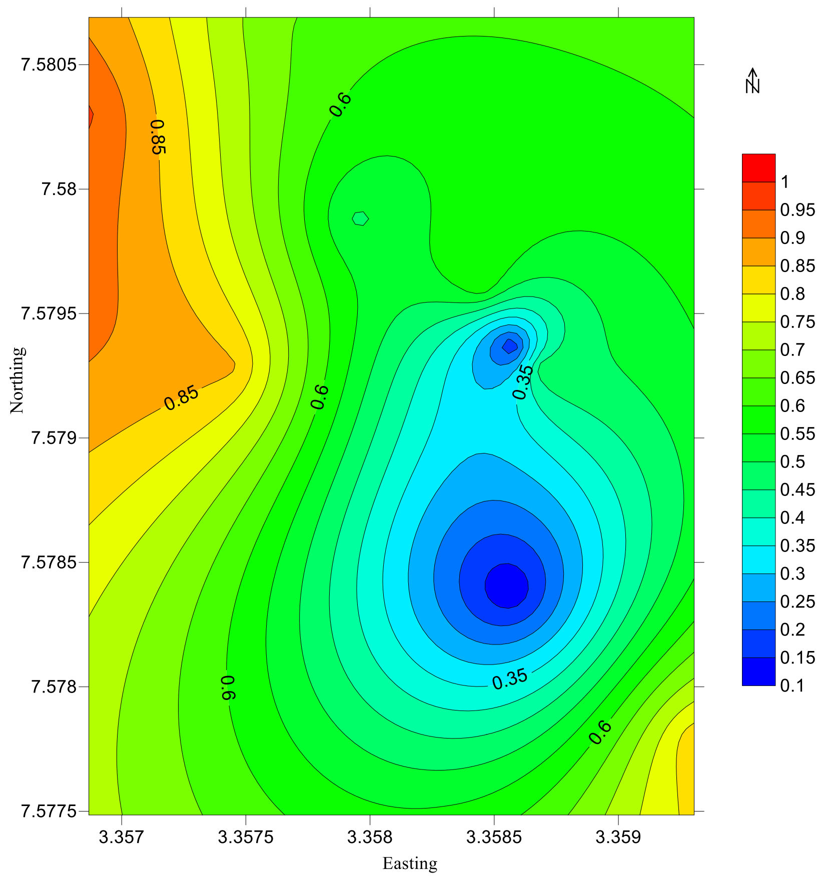

Figure 8. Longitudinal conductance variation in the study area

The software used in process the raw data works in a way that it merges close layers of slightly different resistivity to minimized detecting layers. The curves show 3-4 layers earth models as reveal in table 2. The three layers curve characterized by K type curve which is the predominant curve type in the study area with 50% which can be found VES 1, VES 5, VES 6, VES 7 and VES 8. The four layers shows AK, QH, KQ and KH curve types, the AK curve type was found in VES 2 and VES 4 with 20% of the survey, QH curve type was located VES 9 with 10% of the survey, KQ curve type was reveal in VES 10 with 10% and KH curve type was indicated in VES 3 with 10% of the study area. The observed geoelectric sections include the top soil, lateritic layer, weathered/fractured layer and fresh basement. The first geoelectric layer, topsoil which is thin, low resistive layer, with resistivity between 55.5 mΩ to 749.7 mΩ, difference in values of resistivity was due to the variation in the amount of organic content; thickness of topsoil ranges from 0.4 m to 3.6 m with a depth of 0.4 m to 3.6 m. Lateritic layer with resistivity ranges from 153.3 mΩ to 862.0 mΩ, the thickness of this layer varies between 4.5m to 20.7 m with a depth ranges from 4.9 m to 21.5 m. The weathered/fractured layer is a resistive wet layer with resistivity values ranges between 15.6 mΩ to 698.9 mΩ with a thickness of 4.6m to 55.2 m at depth ranges from 12.3 m to 76.6 m. Fresh basement rock is characterized by high resistivity values which exceed 1000 mΩ with an infinite homogeneous half space. It is deduced that the thickness of aquifer varies from place to place; the thickness of aquifer materials is more than 22 m.

The potential aquifer is confined to weathered/fractured Precambrian Basement Complex Rocks (PBCR) of the southwestern Nigeria has revealed in this study. The fresh basement depth within the study area is 6m to 54 m as Figure 7. The depth of fresh bedrock is greater than 22 m which is mostly observed within the study area. Several studies agree that weathered and fractured layer constitute the aquifer of basement area such as [17-20]. The aquifer protective capacity rating model after [16] as show in table 1 was used to classify the aquifer protective capacity of the study area as in Table 3; Table 3 shows the aquifer protective capacity of the study area and there are four distinct zones which are poor, weak, moderate and good according to the number of each point. VES 3 has poor aquifer protective capacity rating with10%, VES 5 has weak aquifer protective capacity rating with 10%, VES 1, 4, 6, 7, 10 has moderate aquifer capacity rating with 50% and VES 2, 8, 9 has good aquifer protective capacity rating with 30% of the study area. Figure 8 reveal that 80% of the areas are cover by moderate and good aquifer protective capacity zone which are safe of contamination and 20% of the area are cover by poor and weak aquifer protective capacity zone which are exposed to surface contamination.

4. 1. Isoresistivity Map of Topsoil

Isoresistivity map Figure 3 shows the values of resistivity between 1 mΩ to 750 mΩ, the southwest part shows a resistivity values between 500 mΩ to 750 mΩ and the part of north, eastern part show resistivity values ranges from 1 mΩ to 100 mΩ.

4. 2. Isoresistivity Map of Lateritic Layer

The isoresistivity map figure 4 shows that the southwest parts has a resistivity values between 650 mΩ to 900 mΩ and the eastern part have resistivity values between 100 mΩ to 250 mΩ.

4. 3. Isopach and Isoresistivity of Basement/Fractured Layer

The isopach map of the weathered/fractured layer, it is corresponding to layer-3 i.e. third layer and it ranges from 4 m to 56 m; the thickness is good for groundwater accumulation especially in an area where the thickness is above 20 m as in Figure 6. It shows that the overburden covering the fresh rock is thick enough to accommodate much water for groundwater exploration. The isoresistivity map Figure 5 shows that the southern part has resistivity values between 250 mΩ to 700 mΩ and the remaining parts has resistivity values between 1 mΩ to 250 mΩ.

5. CONCLUSIONS

Resistivity data are analyzed with both expect qualitatively and quantitatively, the result showing the importance of electrical resistivity technique in determine depth, thickness, groundwater potential zone and aquifer protective capacity; interpretation of the vertical electrical sounding data resulted in the delineation of 3-4 layers within the subsurface of the study area and this includes the top soil, lateritic layer, weathered/fractured layer, and fresh rock. The overburden thickness and aquifer resistivity value obtained from electrical resistivity VES point shows that the area have moderate groundwater potential, and any drilled location here will yield high groundwater potential. The aquifer protective capacity reveals four distinct zones poor, weak, moderate and good; 20% of the study area was unsafe of surface contamination and 80% of the study area was safe of contamination. Furthermore, other geophysical method such as seismic refraction and magnetic etc. can be integrated with electrical resistivity method in future research work in the study area in order to get better view and effectively delineate the subsurface lithological characterization.

Acknowledgment

The authors acknowledge University of Abuja, Physics Department and the survey section of Iseyin Local Government Area, Oyo State for their support during the data collection.

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