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Article

Groundwater-Bearing Potential of The Permanent Site of Ajayi Crowther University, Offa- Meta, Oyo, Southwestern Nigeria

[1]***Olanrewaju Akinfemiwa Akanbi**, [1]**Olukayode Adeyinka Falana, and** [2]**Isreal Olatoye Akande**

[1] Department of Earth Sciences, Ajayi Crowther University, Oyo, Oyo State, Nigeria.
oa.akanbi@acu.edu.ng (O.A.A.); falanaolukayode@yahoo.co.uk (O.A.F.)
[2]Department of works/Water and Sanitation unit, Oluyole LGA, Oyo State, Nigeria
akandeisrael646@gmail.com (I.O.A.)

* Correspondence: oa.akanbi@acu.edu.ng; Tel: +234-805-560-6353

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Abstract

The need to provide reliable water supply within the permanent site of Ajayi Crowther University in Oyo Town is now inevitable. This is due to the fact that there is no nearby source of potable water neither is there any existing piped town water supply scheme in this area. The present study employed resistivity geophysical methods including seven horizontal profiling (HP) to delineate probable zones with groundwater potential and sixteen vertical electrical sounding (VES) for further deeper subsurface proving of the probable zones. The field data were curved matched and iterated using WinResist software to compute the geoelectric section parameters and these were used to describe the extent of weathering and bedrock fracturing of the subsurface horizon. From the HP results, sixteen probable zones with resistivities spread between 31.4 and 342.9 Ωm were delineated for further vertical probes. VES results showed that the dominant geo- electric sequence is the 3- layer H type curve with the sub-surface units categorized into top soil, saprolite units and weathered/fractured/fresh bedrocks. The thickness of the top soil was 1.0 - 4.9 m, and that of the saprolite was between 10.1 m and 38.1 m while the resistivity of the saprolite ranged from 32.1 to 424.5 Ωm. The total regolith thickness was between 11.3 and 42.9 m with an average of 26.2 m – this is an indication of good weathering development and good potential for groundwater occurrence. The bedrock resistivities lie between 242 and 3636.5 Ωm. The resistivities of most of the underlying bedrocks at the western part and to a lower extent at the middle section of the study area were found to be less than 600 Ωm and were interpreted as fractured bedrocks. Locations underlain by fractured bedrock in conjunction with areas with thick overlying weathered units constitute the aquifer zones that represented locations with good groundwater potentials in the area. Hence, the western and the middle sections of the study area were classified to have good groundwater potential while the potential is moderate at the eastern end.

Keywords: Groundwater, Resistivity, Weathered-layer, Bedrocks, Aquifer-potential.

1. Introduction

The need for groundwater development is very high in Ajayi Crowther University permanent (new) site located at Offa-meta at the fringe of Oyo town in southwestern region of Nigeria. This is as a result of increase in school population and structural development. The fact remains that over 70% of earth surface is covered by water but about 99% of this is marine water, which is not fit for domestic and most other usage due to high salinity. Likewise, inland surface waters are not widely distributed in most places and are prone to pollution while other fresh water bodies occur in solid state in form of glaciers and snow. However, groundwater, which occurs below the water table in the crust is more available and more desirable than other fresh water bodies because it is less exposed to pathogens and surface dirt; hence, comparatively it is less vulnerable to contamination. Accordingly, approximately 50% of world citizens rely on groundwater for domestic, industrial and agricultural utilisation [1]. This is more so in Nigeria where piped treated water is no longer within the reach of people [2].

However; in Nigeria, from geological point of view, groundwater occurrence is limited due to the fact that about half of the country is underlain by impermeable rocks of igneous or metamorphic origin, which can neither store nor transmit water [3,4], except when there is development of weathered units and/or fractured bedrock. Hence, successful groundwater yield will entail an appropriate understanding of the hydrological attributes of the weathered layer and the underlying bedrock. In the light of this, application of suitable geophysical methods such as electrical resistivity methods including horizontal profiling (HP) and vertical electrical sounding (VES) techniques are useful for investigating groundwater potential of the weathered-fractured components of basement areas [5-11]. Consequently, constructions of boreholes with good water yield are now feasible in basement areas [3]. These methods were employed for ground water investigation in the permanent site of Ajayi Crowther University at Offa-meta along Oyo-Ogbomoso Road with the aim of investigating the groundwater potential of the site.

1.1 Study area

The study area lies within the crystalline basement Complex of Nigeria [12,4]. The area spread within latitude N 7^0 51′ 25″ and N 7° 52′ 10″ and longitude E 3° 58′ 10″ to E 3° 59′ 15″ (Fig.1). The study area is geographically located on the outskirt of Oyo Town along old Ogbomosho Road. The study area is a low to medium lying with a gentle undulating landform. It is situated within the derived savannah region with moderate climatic condition characterized by seasonal annual wet and dry periods. The wet season runs between the months of March and October while the rest of the year falls into dry period, part of which is harmattan period.

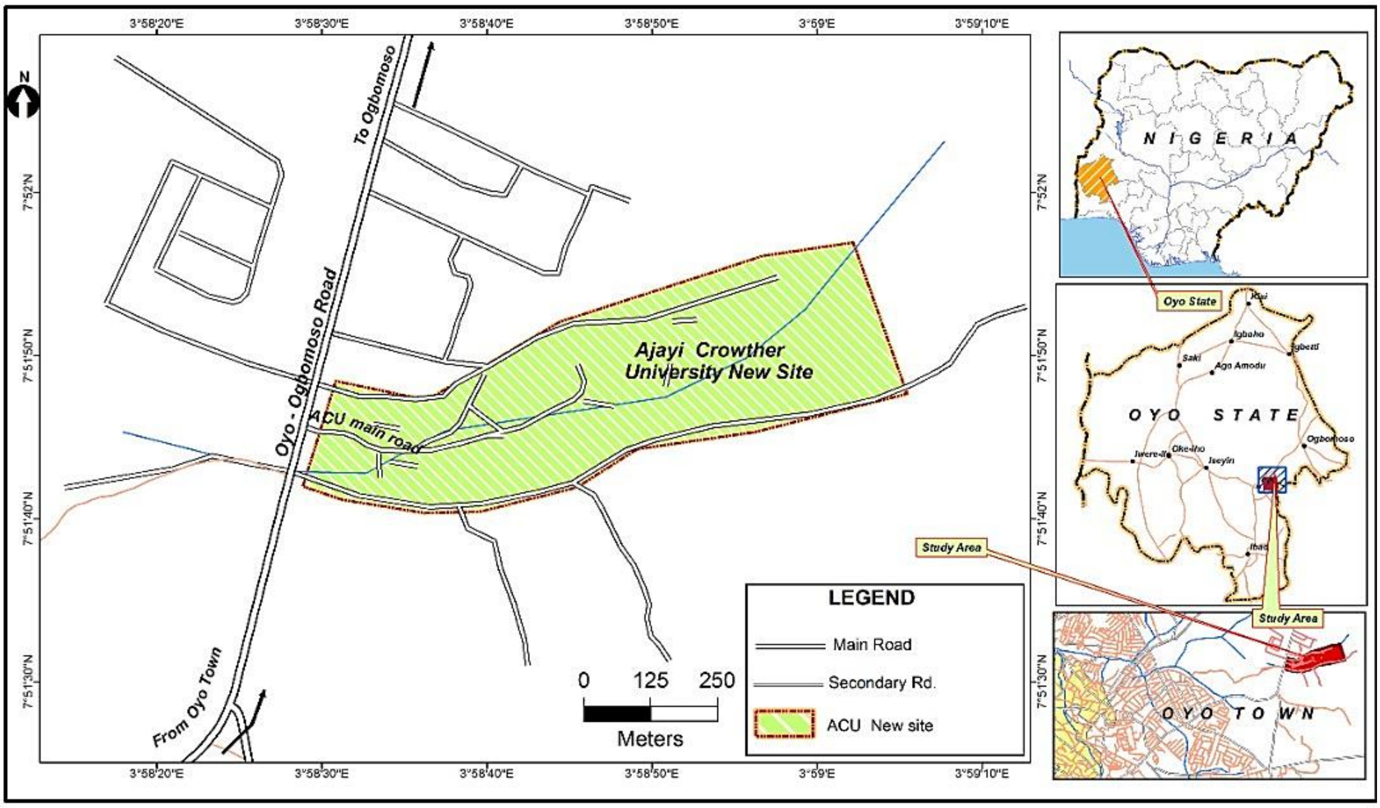

Figure 1: Location and accessibility map of the study area.

The study area is underlain by impervious crystalline intrusive rocks; namely quartzite and migmatite (Fig. 2). Though, there is absence of major rock exposures in the study area. The rock units are concealed by overlying regolith units.

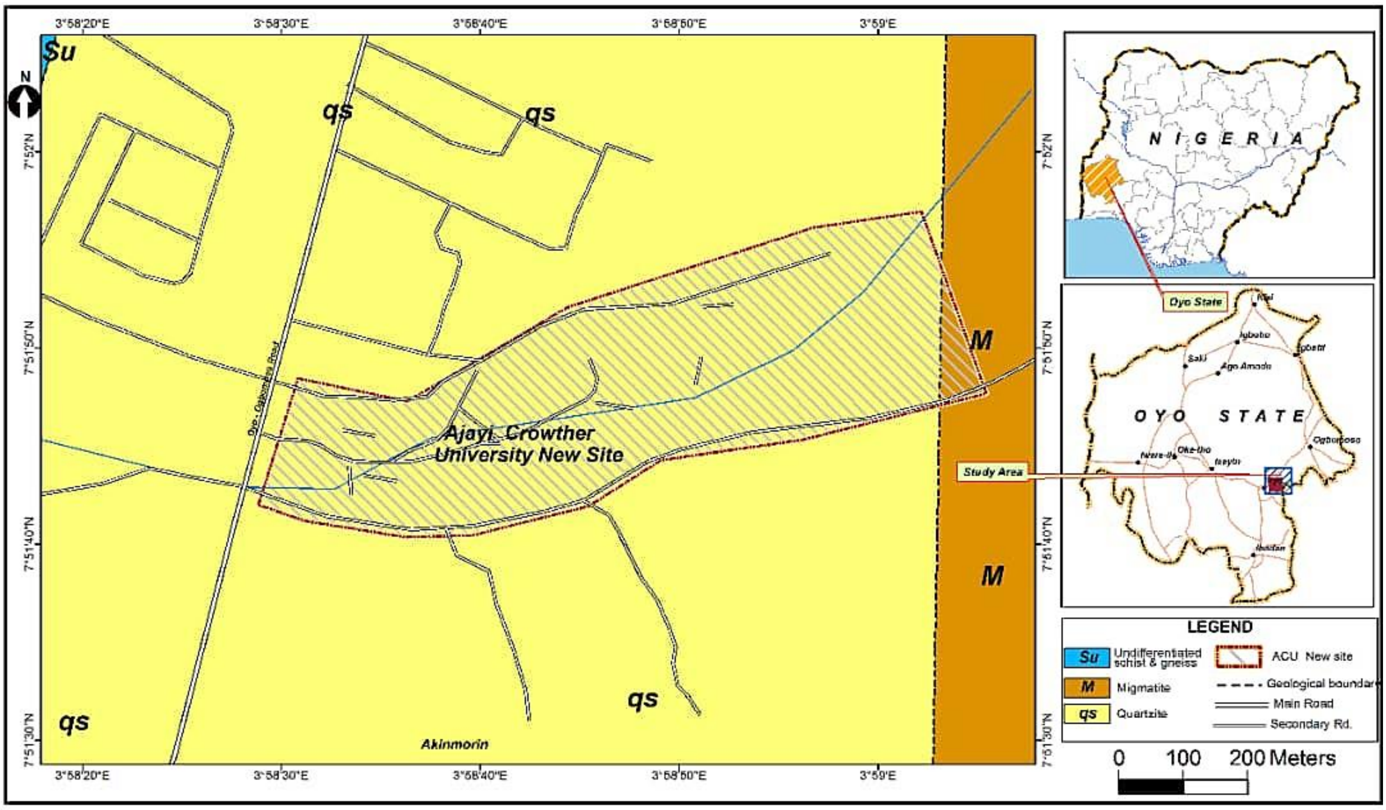

Figure 2: Geological map of the study area (NGSA, 2006)

2. Methods

For the present study, electrical resistivity geophysical method was employed. Horizontal electrical profiling (HP) and vertical electrical sounding (VES) were used for groundwater bearing investigation in the study area. These methods are useful in ground water investigation in basement terrain for studying the lateral and vertical variations in conductivity in ground layers. The field procedure involves passing current into the ground through the current electrodes and measuring the potential difference between other electrodes as apparent resistivity across a specified depth of investigation. If the spacing between electrodes is increased, a deeper penetration of the electrical field occurs and a different apparent resistivity is obtained. Actual sub-surface resistivity varies with depth therefore; apparent resistivity will change as electrode spacing is increased.

The field apparent field resistivity data were acquired with DDR2 resistivity meter. A total of 7 HPs were carried out to demarcate probable groundwater potential zones for further vertical -depth investigation. Points of lowest resistivity values from the HPs that were carried out were demarcated and further investigated for vertical heterogeneity using VES method. A total of sixteen VES were systematically conducted on the demarcated zones across the study area as shown in Figure 3. For VES investigation, Schlumberger array method was used. The apparent resistivity data were manually curved matched with master's curves [13] and computer iterated using WinResit software to obtain the true geo-electric parameters including the layers' resistivities and thicknesses. From the resistivity values, the grain-size or the lithology as well as the groundwater potential of the weathered layers and that of the bedrock were interpreted [14] and presented in Table 1.

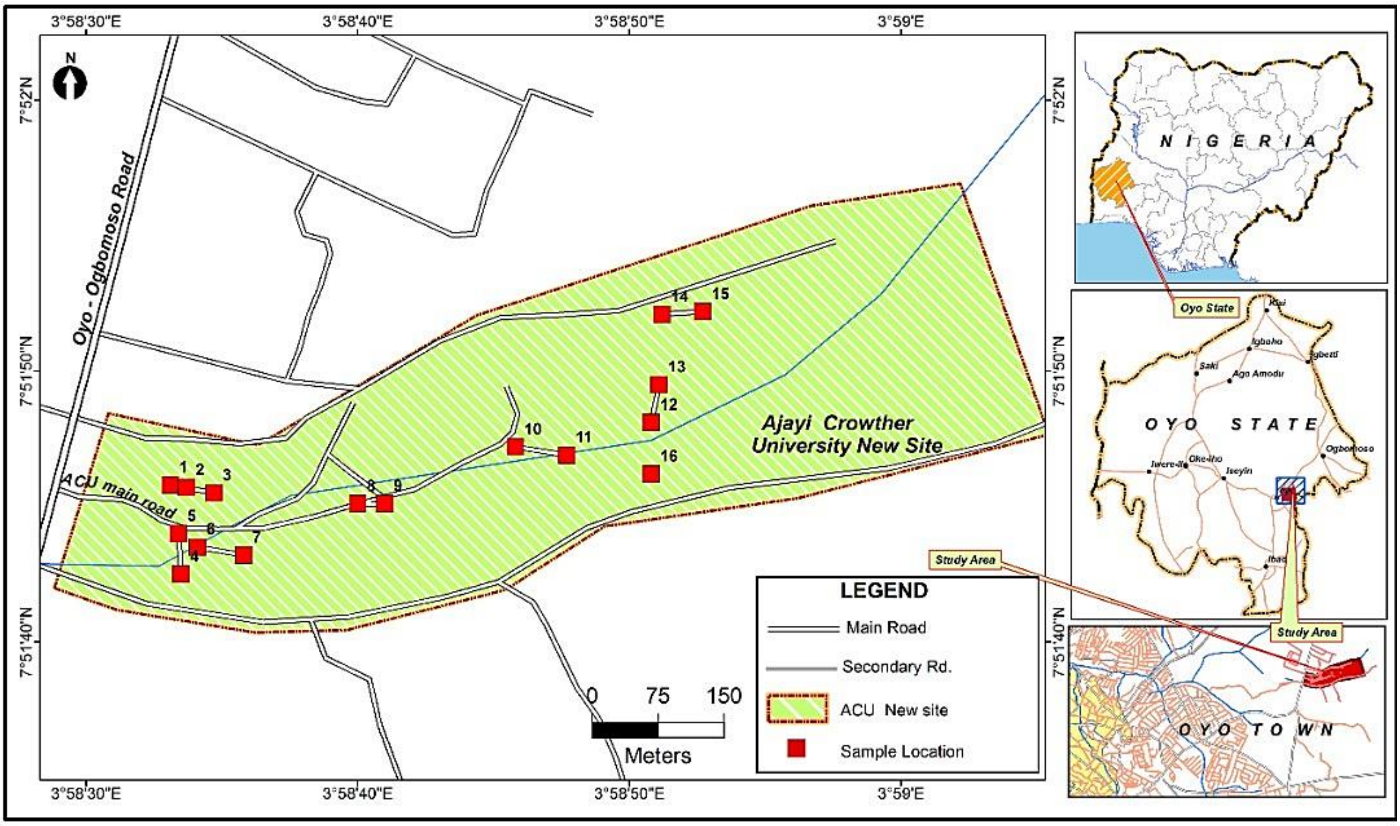

Figure 3: Location map of the study area showing the VES points

Table 1. Lithologic description of the saprolite and bedrock (after Akanbi, 2018)

S/N	Resistivity Range (Ωm)	Lithologic Description of saprolite	Groundwater Prospect of saprolite	Bedrock resistivity (Ωm)	Description of the bedrocks	Groundwater prospect of the bed rock
1	0-50 >400	Predominantly clayey Compacted clay /hardpan	Poor	>1800	Fresh	Negligible/ poor
2	51 - 150	Sand and clay	Moderate	600 - 1800	Weak/slightly weathered	Moderate
3	151 - 400	Predominantly sands and gravel	Good	< 600	Fractured	Good

3. Results and Discussion

The resistivities of the low resistive locations that were further investigated in the study area from the seven-horizontal profiling were between 31.4 and 342.9 Ωm. This included three points with resistivities of 208.5 Ωm, 342.89 Ωm and 119.32 Ωm in HP1; two in HP2 with 62.8 Ωm and 35.17 Ωm; three in HP3 with 141.3 Ωm, 113.04 Ωm and 125.6 Ωm. For HP4, the low resistive points were two with resistivities of 116.8 Ωm and 91.69 Ωm; HP5 two points as well with 31.4 Ωm and 84.15 Ωm. Likewise two zones were demarcated for each of HP6 and HP7 with resistivities of 84.15 and 129.37 Ωm for the HP6 and for HP7 the values were 47.73 Ωm and 163.28 Ωm

The computer-generated VES curves from the iterated apparent resistivities obtained in the field were mainly 3-layer H type except for VES04 and VES07, which are 3- layer A type and 4-layer KH type respectively. The H-type curve is characterized by a lower resistive middle layer that terminates on more resistive infinity layer. Samples of VES curves are given in in Figure 4. Figure 4a is an example of geo-electric sequence that terminates on fractured bedrock with the last layer resistivity being 252.9 Ωm whereas that of VES09 in Figure 4b terminates on slightly weathered bedrock and the infinity layer on VES15 terminates on fresh bedrock with resistivity of 3636 Ωm.

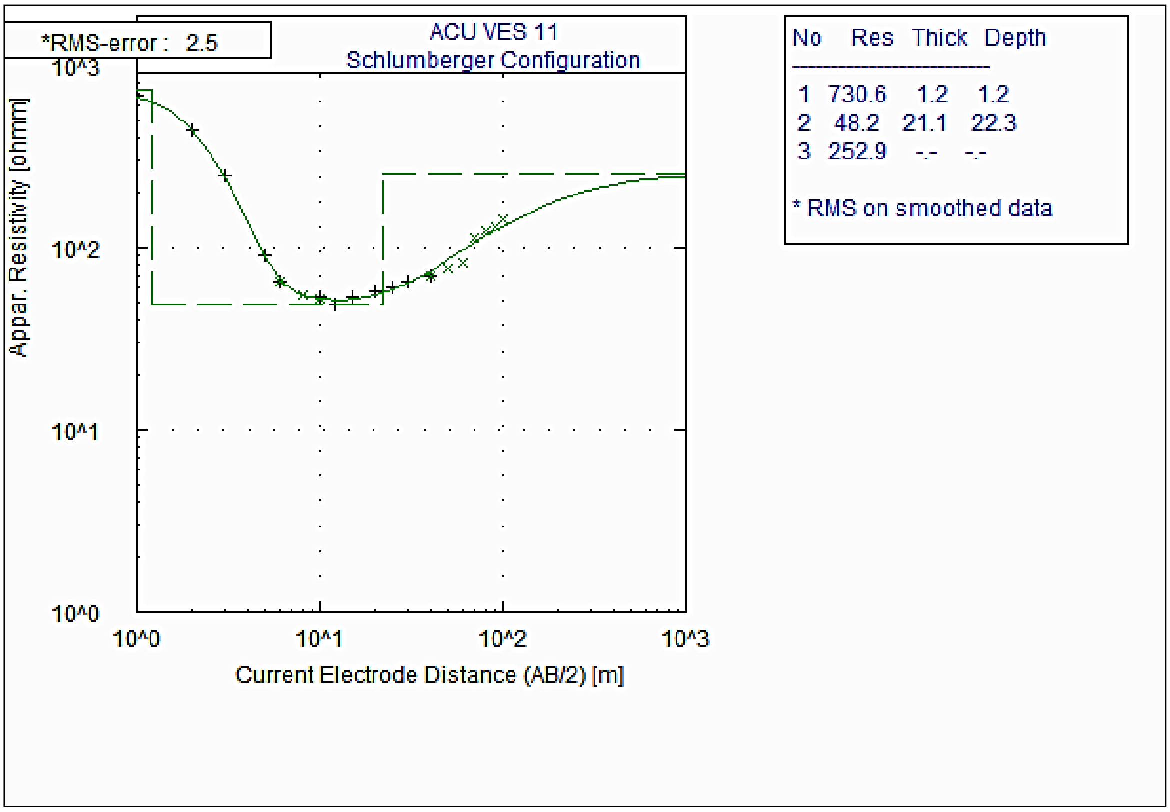

Figure 4(a): H type (VES 11)- Terminates on fractured bedrock

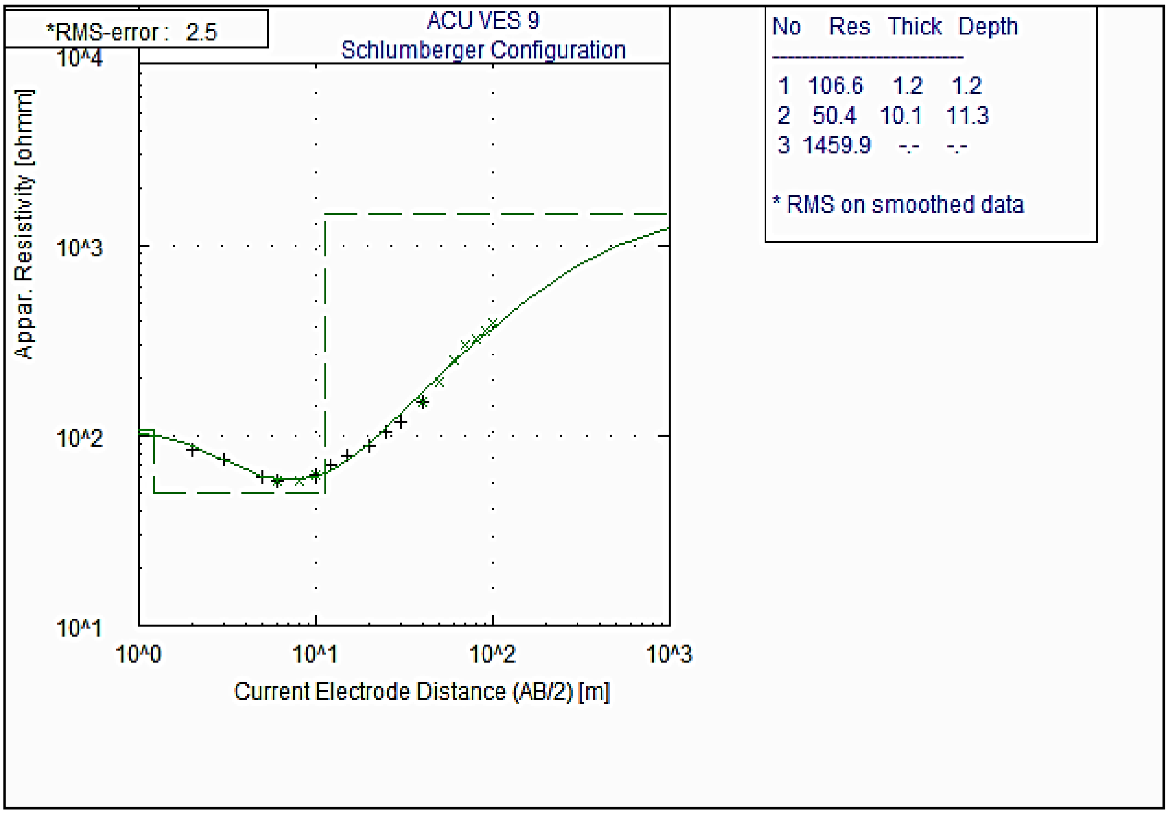

Figure 4(b): H type (VES 09)- Terminates on slightly weathered bedrock.

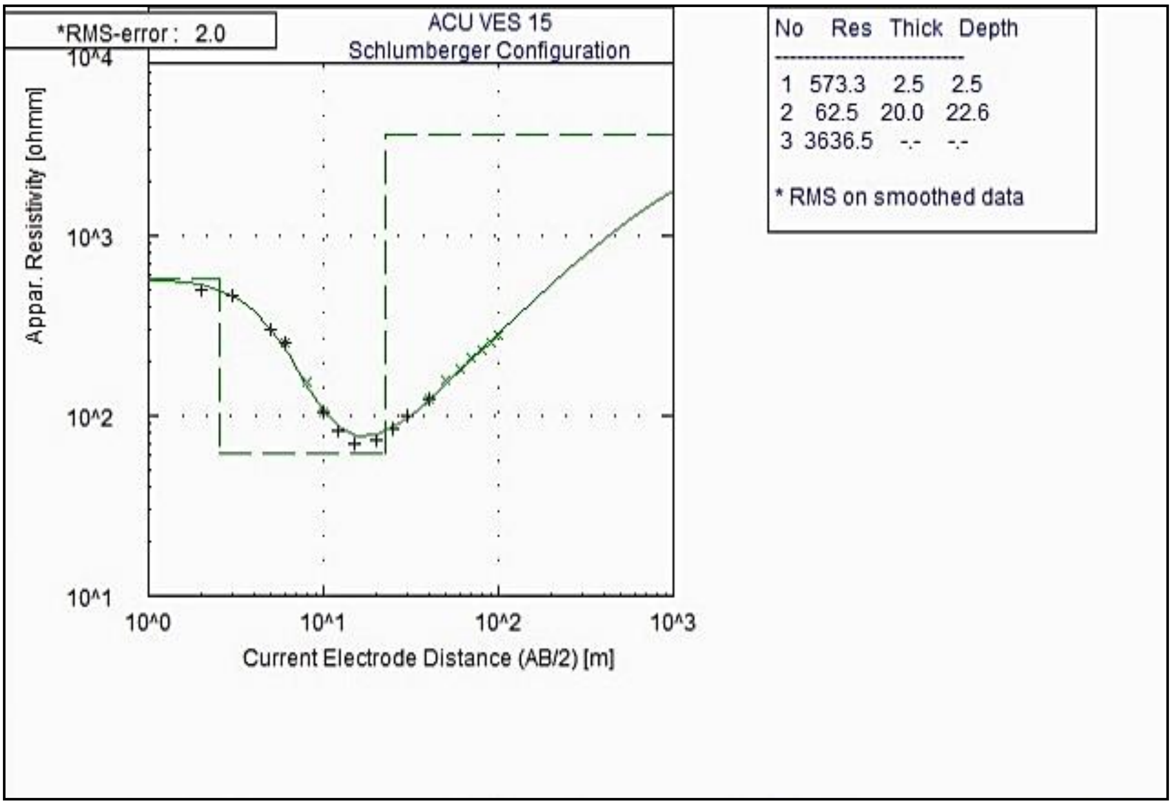

Figure 4(c): H type (VES 15)- Terminates on fresh bedrock

3.1 Quantitative and Lithologic Interpretations of Geo-electric Parameters

The H type geoelectric sequence is interpreted as top soil, weathered layer and bedrock. The top soil and the weathered layer make up the regolith that is called the overburden unit. The top soil is relatively thinner compared to the underneath middle layer that is known as the saprolite. From the quantitative interpretations of the VES curves, the thickness of the top soil ranges from 1.0 to 4.9 m with average of 2.5 m. The saprolite thickness was between 10.1 m in VES09 and 38.1 m on VES02. The total regolith thickness was between 11.3 and 42.9 m with an average thickness of 26.2 m. This showed that there is good weathering development in the area, which is crucial for sustaining good groundwater yield in areas underlain by hard crystalline rocks. The resistivity value of the saprolite ranges from 32.1 - 424.5 Ωm. but the resistivity of two saprolite units at two locations namely VES01 and VES07 were exceptionally high with values- 424.5 and 563.3 Ωm and were interpreted as compacted lateritic soils. The bedrock resistivities were between 242 on VES 10 and 3636.5 Ωm on VES15. The lithology and groundwater potential of the VES points are presented in Table 2.

Table 2: Summary of the geo-electric parameters and lithologic interpretation

VES Point	Curve Type	Layer Number	Thickness (m)	True Resistivity (Ωm)	Lithology	Regolith Thickness (m)	Groundwater potential
VES 01	H	1	4.9	2046.0	Top soil		
		2	33.8	424.5	Compacted clay		
		3		662.8	Slightly weathered bedrock	38.7	Moderate
VES 02	H	1	4.8	1786.3	Top soil		
		2	38.1	229.6	Sandy		
		3		562.9	Fractured bedrock	42.9	Good
VES03	H	1	2.8	1063.6	Top soil		
		2	37.3	155.5	Sandy		
		3		417.0	Fractured bedrock	40.1	Good

VES04	A	1	1.6	26.4	Top soil		
		2	16.5	32.1	Clayey		
		3		343.4	Fractured bedrock	18.1	Good
VES 05	H	1	2.6	935.6	Top soil		
		2	30.6	88.3	Sandy clayey		
		3		245.5	Fractured bedrock	33.2	Good
VES 06	H	1	2.7	1126.6	Top soil		
		2	24.1	144.9	Clayey sandy		
		3		1222.6	Slightly weathered bedrock	26.8	Moderate
VES 07	KH	1	2.3	1363.4	Top soil		
		2	2.0	563.3	Compacted Clay		
		3	17.5	81.3	Sandy clayey		
		4		247.4	Fractured bedrock	21.3	Good
VES 08	H	1	3.6	484.6	Top soil		
		2	22.7	123.7	Clayey sandy		
		3		1468.7	Slightly weathered bedrock	26.3	Moderate
VES 09	H	1	1.2	106.6	Top soil		
		2	10.1	50.4	Clayey		
		3		1459.9	Slightly weathered bedrock	11.3	Low
VES 10	H	1	1.4	954.6	Top soil		
		2	21.9	51.7	Sandy-clayey		
		3		242.0	Fractured bedrock	23.3	Good
VES 11	H	1	1.2	730.6	Top soil		
		2	28.1	48.2	Clayey		
		3		252.9	Fractured bedrock	26.6	Good
VES 12	H	1	1.9	268.1	Top soil		
		2	24.7	131.2	Clayey-sandy		
		3		1212.4	Slightly weathered bedrock	20.4	Moderate
VES 13	H	1	2.8	278.9	Top soil		
		2	16.5	49.8	Clayey		
		3		983.7	Slightly weathered bedrock	19.3	Moderate
VES 14	H	1	3.0	234.6	Top soil		
		2	25.4	149.5	Clayey		
		3		352.7	Fractured bedrock	28.3	Good
VES 15	H	1	2.5	573.3	Top soil		
		2	20.0	63.5	Sandy-clayey		
		3		3636.5	Fresh bedrock	22.5	Moderate
VES 16	H	1	1.0	626.0	Top soil		
		2	19.0	56.2	Sandy-clayey		
		3		658.7	Slightly weathered bedrock	20.1	Moderate

3.2 Groundwater potential of the study area

On general point of view, the weathered layer in the permanent site is thick enough to guarantee prolific groundwater yield provided that there is a recurring yearly recharge and the yield (discharge) is regulated accordingly. Though, the thickness of the weathered layer is favourable, the lithology across most points of investigation will not guarantee prolific wells due to the fact that the grains were interpreted as fine to medium size in most locations (Table 2). From the graphical illustration of the lithology classification of the saprolite in Figure 5; twenty-nine (29) percent of the saprolite unit is predominantly clayey, 29% is sandy clay, 18% clayey sand and 12% for each of compacted lateritic clay and those that were interpreted as being predominantly sandy. This showed that fine grained weathered units are the more predominant in the area than sandy regolith, and this will not aid good water recharge within the regolith unit and water yield will be poor in locations underlie by fresh bedrocks. However, fine grained regolith (weathered layers) will guarantee good quality water by hindering direct recharge, thereby preventing groundwater pollution and this is an advantage if the bedrock is fractured. Therefore, due to the predominant clayey saprolite units, the only alternative for good water yield in the study area is the underlying bedrocks fractures. Fortunately, bedrock resistivities are fairly favourable in many points of investigation in the site. This is likely to guarantee good quality prolific water bearing zones in the area.

The incidence of the underlying bedrock status is illustrated in Figure 6. The underlying bedrocks of half of the probed points are fractured, six locations on VES 01, 08, 12, 13, 15 and 16 were interpreted as being slightly weathered and just only one bedrock is interpreted as being fresh (Fig. 6). The high frequency of bedrock fractures in the study area is a good alternative for the largely fine grained saprolite/weathered layer.

With these results, there is a 50% chance of striking a prolific water bearing zones with good quality water (Fig. 7) in locations where the bedrocks are fractured. There is also the possibility of striking artesian aquifers where clayey weathered units overlie fractured bedrocks in VES points locations 04, 05, 07, 10, 11 and 14. The overlying fine-grained regolith will act as confining units to the expected prolific fractured bedrocks beneath. The distribution of the groundwater potential across the study area is presented in Figure 8 based on bedrock status.

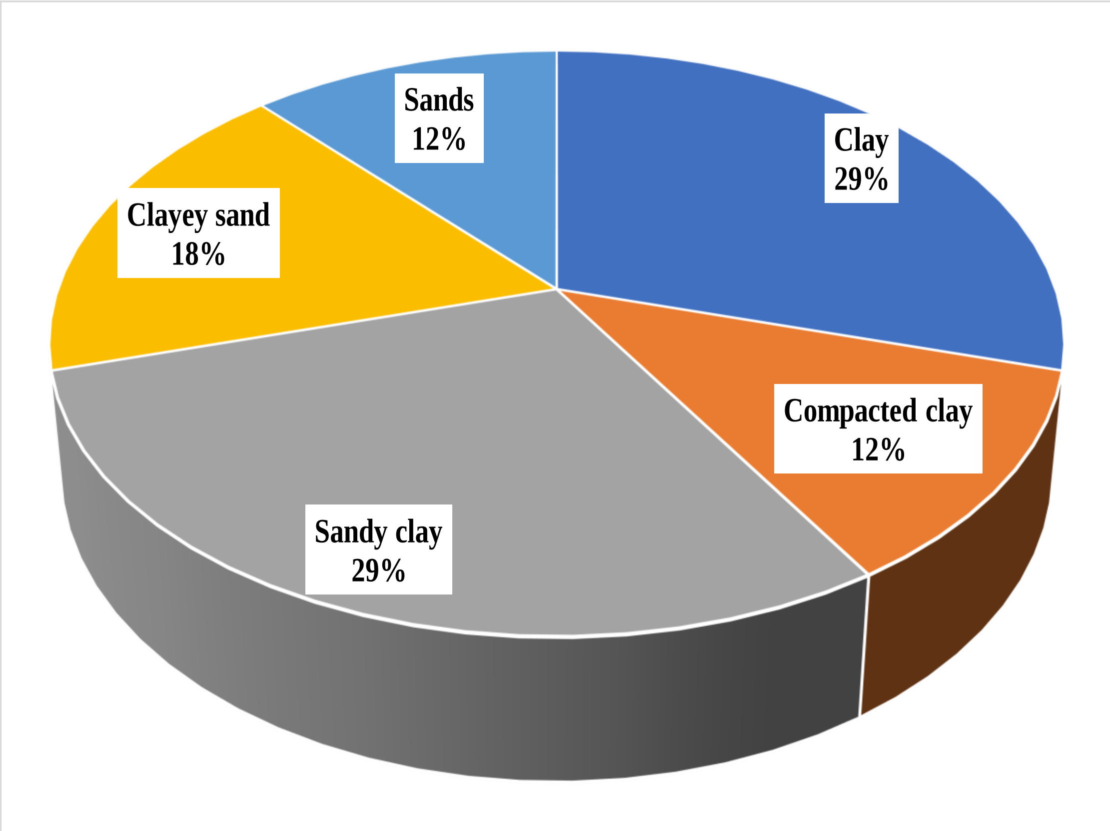

Figure 5: Lithological classification of the weathered/ saprolite layer

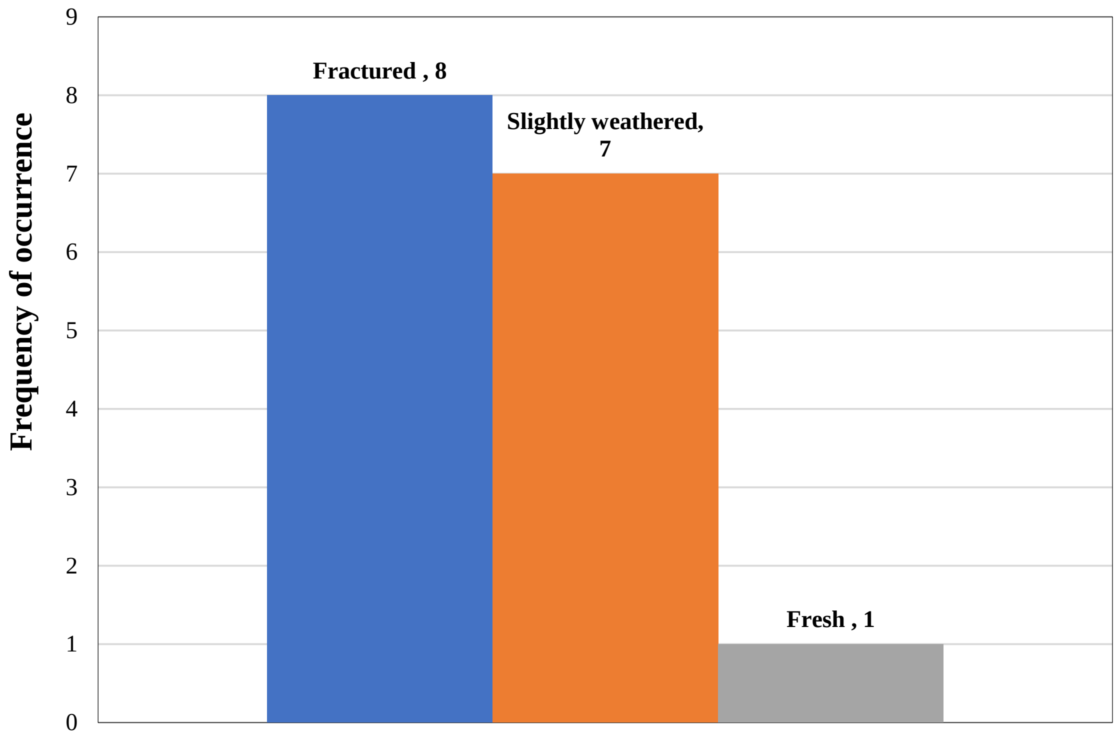

Figure 6: Frequency of underlying bedrock status

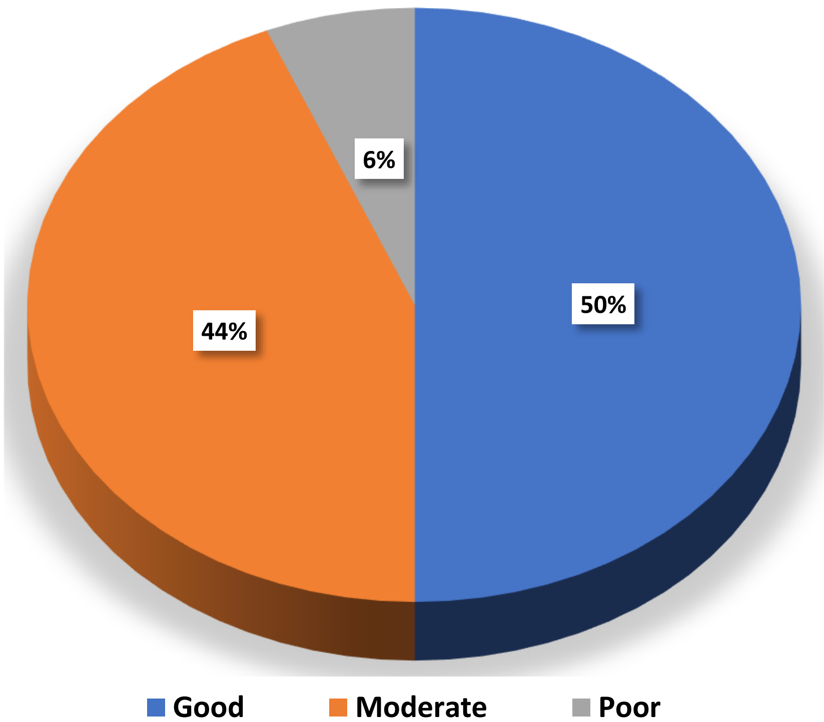

Figure 7: Groundwater potential based on the frequency of bedrock

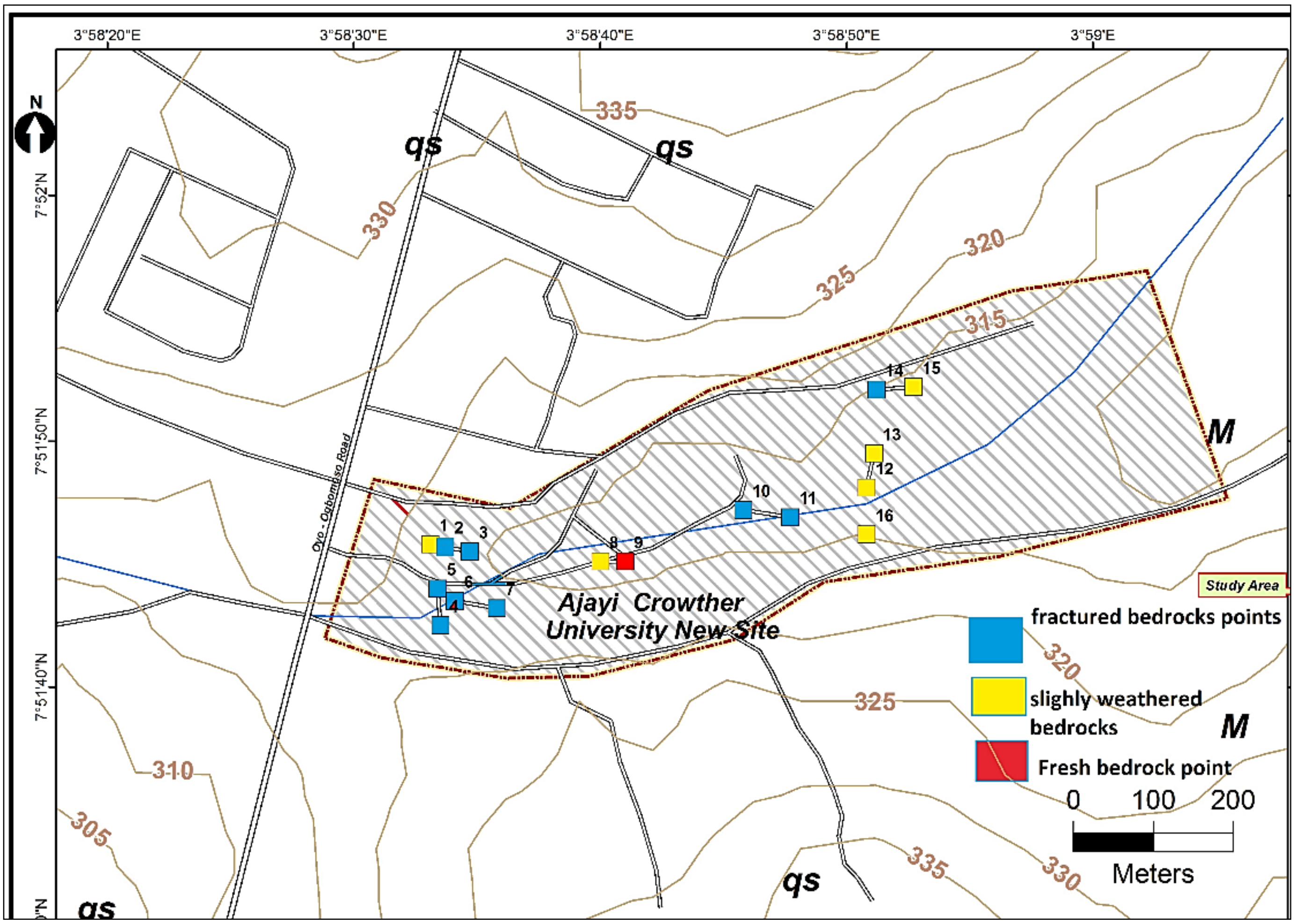

Figure 8: Ground water bearing zone of ACU-Permanent site.

4. Conclusions

Groundwater potential of the permanent site of Ajayi Crowther University located at Offa-Meta, Oyo Town in southwestern region of Nigeria has been carried out using electrical resistivity methods to characterize the degree of weathering and bedrock fracturing of the sub-surface environment. The area has a thick development of weathered layer that ranges from 11.3 m to 42.9 m at the western part. Bedrock resistivities spread between 242 and 3636.5 Ωm but half of the underlying bedrocks are fractured with resistivities of less than 600 Ωm. Most VES points including 02, 03, 04, 05 and 07 that are characterized by fractured bedrocks are situated at the western part and in conjunction with thick weathered layer, this part of the study area is regarded to be most viable zone for sourcing for groundwater. This is evidenced from the occurrence of spring at the middle section of the area that represents a natural discharge point for the underneath groundwater.

The spring occurrence is owed to the fact the underlying groundwater-bearing zones are overlain by leaky largely fine-grained regolith as interpreted for VES 08, 09, 10 and 11 at the middle part of the study area. The spring is a treasure for agricultural practice in the site. For the eastern end of the study area, most VES points namely 12, 13, 15 and 16 terminate on slightly weathered bedrock and the groundwater potential is moderate.

The hydrogeology of the Ajayi Crowther University permanent site at Offa-Meta should be critically considered prior to further physical development in the site, bearing in mind that groundwater is the only dependable fresh water in the area. Recharge and discharge zones should be protected to ensure sustainable water management scheme all year around. Good waste water drains are to be put in place to forestall the pollution of the underground water.

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