The International Journal Of Engineering And Science (IJES)
|| Volume || 4 || Issue || 11 || Pages || PP -29-39|| 2015 ||
ISSN (e): 2319 – 1813 ISSN (p): 2319 – 1805

Geophysical Investigation for Groundwater Potential in Rufus Giwa Polytechnic Owo, Southwestern Nigeria

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ABSTRACT

Geophysical investigation was conducted at Rufus Giwa Polytechnic, Owo, Southwestern, Nigeria with the aim of evaluating the groundwater potential in the area. The geophysical survey involved Very Low Frequency Electromagnetic (VLF-EM) and Vertical Electrical Sounding (VES). A total of twenty seven (27) traverses were established along West – East and Southwest – Northeast direction in the studied area; covering a total distance of 8.45 km. The lengths of the traverses vary between 110 m and 920 m. Measurements were taken at 10 m spacing along the traverses for the VLF-EM. The result of the VLF-EM was used to determine the data point for the VES. The VLF-EM result reveals the presence of conductive zones. The geoelectric section revealed 3 to 5 major layers comprising the topsoil, clay, laterite, weathered layer, partly weathered layer/fractured basement, and fresh basement rock. The topsoil has resistivity that varies between 46 Ω-m and 1644 Ω-m, and depth that ranges from 0.3 m to 19.8 m. It is composed of clay/sandy clay, clayey sand, lateritic clay and laterite. The clay substratum has resistivity that ranges from 20 to 95 Ω-m and depth that varies from 1.5 m and 9.3 m. Laterite is characterized by resistivity that varies between 106 Ω-m and 1223 Ω-m with thickness that varies from 0.8 m to 11.4 m. The weathered layer which constitutes the first aquiferous zone and is characterized by resistivity that ranges between 28 Ω-m and 823 Ω-m, while its thickness varies from 0.4 m to 144.2 m. The composition of the weathered layer is predominantly clayey sand indicating an aquitard i.e. a subsurface geological formation that stores but fairly transmit water. The partly weathered layer/Fractured aquifer is the second aquiferous zone; it has resistivity that is between 16 Ω-m and 914 Ω-m with thickness in the range of 0.3 m to 148.6 m. The fresh basement has resistivity values that vary from 327 Ω-m to 17578 Ω-m. The low resistivity values (< 500 Ω-m) are due to screening effect by the overlying conductive material. The weathered layer and fractured basement aquifers correlate the suspected water filled geologic formation observed by the VLF-EM. Therefore the area shows a very good prospect for groundwater development.

Keywords *– aquiferous zone, conductive material, geological formation, geophysical investigation, groundwater*

Date of Submission: 14 November 2015 — Date of Accepted: 30 November 2015

I. INTRODUCTION

Access to clean water is a human right and a basic requirement for economic development. The safest kind of water supply is the use of groundwater. Groundwater accounts for about 98 % of the world's fresh water and is fairly evenly distributed throughout the world. It provides a reasonable constant supply which is not completely susceptible to drying up under natural condition unlike fresh water. Water from beneath the ground has been for domestic use, irrigation and livestock. Lakes, swamps, reservoirs and rivers account for 3.5 % and soil moisture accounts for only 1.5 % ([4]).

The works of ([1], [3]) revealed that it is necessary to monitor water quality on regular basis. Since groundwater normally has a natural protection against pollution by the covering layers, only minor water treatment is required. Detailed knowledge on the extent, hydraulic properties, and vulnerability of groundwater reservoirs is necessary to enable a sustainable use of the resources. The total replenishable water resource in Nigeria is estimated at 319 billion cubic metres, while the groundwater component is estimated at 52 billion cubic metres. Nigeria has adequate surface and groundwater resources to meet its current water demands. However, in spite of the tremendous efforts put by the various Governments to improve access to potable water supply to all Nigerians, estimates shows that only 58% of the inhabitants of the urban and semi-urban areas and 39% of rural areas have access to portable water supply.

Water shortages are acute in some major centres and in numerous rural communities due to a variety of factors including variations in climatic conditions, drought increasing demands, distribution system losses, and breakdown of works and facilities. Other challenges facing the sector include funding constraints for improving and rehabilitating broken down schemes, competition between water users, pollution from point and non-point sources and lack of competent and skilled human resources.

1.1 Description of the Project Environment

Rufus Giwa Polytechnic, Owo, Ondo State, is located in Owo "Fig. 1" which is within the south western part of Nigeria. The institution "Fig. 2" is situated in Owo local Government of Ondo State "Fig. 3". It lies within longitudes 6˚00ˡ E and 5˚30ˡ E and latitudes 7˚30ˡ N and 7˚00ˡ N. The study area is easily accessible by roads like Ikare – Owo highway, Benin – Ifon highway and Akure – Owo highway.

1.2 Geomorphology, Climate and Vegetation

Owo is relatively flat, as the terrain ranges from 940 ft to 1100 ft "Fig. 4". The terrain slopes from Rugipo down to Isuada town "Fig. 5". Elevation is much higher at Ikare Junction and lower around Emure and Isuada towns. In RUGIPO, the topography ranges from 311 m to 342 m above the sea level. The study area has a gently undulating topography. The area lies geographically within the tropical rain forest belt of hot and wet equatorial climatic region characterized by alternating wet and dry climate seasons ([6]), which is strongly controlled by seasonal fluctuation in the rate of evaporation.

The available rain data shows that mean annual rainfall ranges from 1000 mm - 1500 mm and mean temperature of 24˚C to 27˚C. There is rapid rainfall during the month of March and cessation during the month of November. June and September are the critical month when rainfall is usually on the high side. The vegetation is of tropical rainforest and is characterized by thick forest of broad-leaved trees that is ever green. The vegetation of the area (especially in undeveloped areas) is dense and made up of palm trees, kolanut trees and cocoa trees. Part of this area is also made the school farm.

1.3 Geology of the Studied Area

The area of study falls within the Southwestern basement rock "Fig. 6" which is part of Nigerian Basement complex. The area is underlain mainly by rocks of the Migmatite - Gneiss Complex "Fig. 7". RUGIPO is predominantly underlain by quartzite, granite and granite gneiss "Fig. 8".

Quartzite is the most dominant rock; which mineralogically contains quartz dominating mineral, other minerals such as muscovite, tremolite, microcline and biotite are common as well. Quartzites which are prominent as ridge vary in texture from massive to schistocity due to the presence of flaky minerals like mica.

II. METHODS OF STUDY

Twenty seven traverses were established in W-E and SW-NE direction with length that varies between 110 m and 920 m "Fig. 9". The total length of the traverses established is 8450 m (8.45 km).

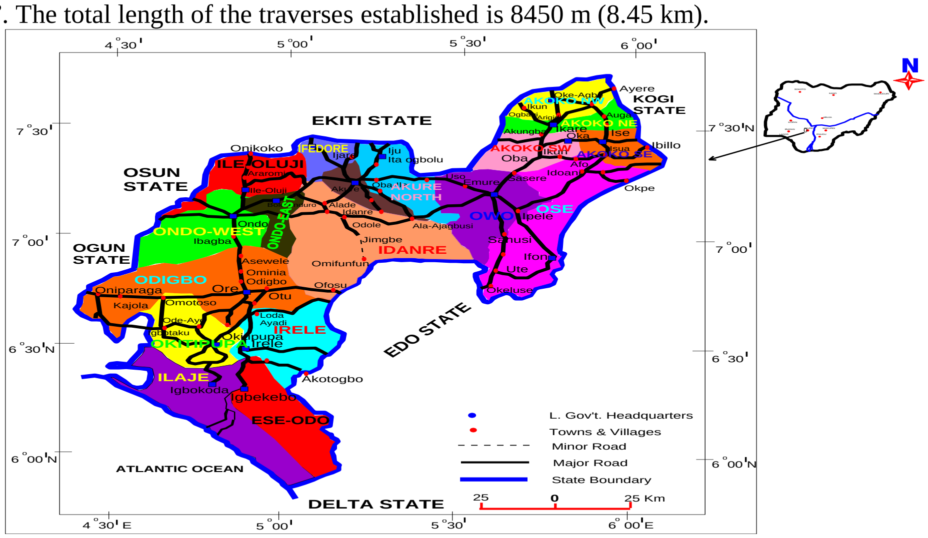

Figure 1: Road/Administrative Map of Ondo State

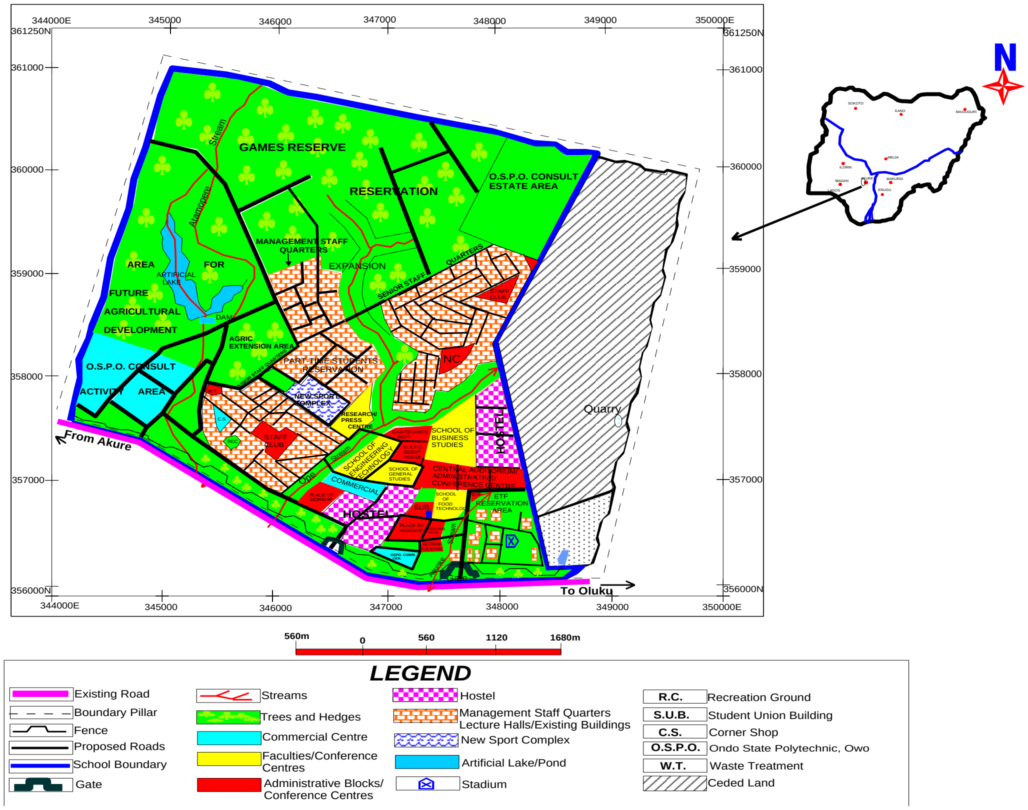

Figure 2: Land-Use Master Plan of RUGIPO

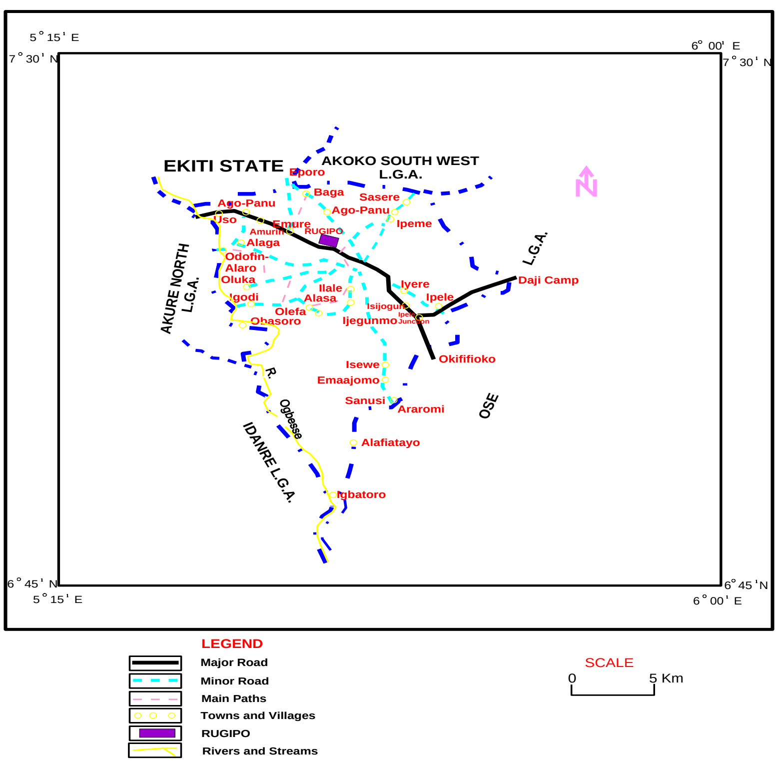

Figure 3: Map of Owo Local Government Area of Ondo State

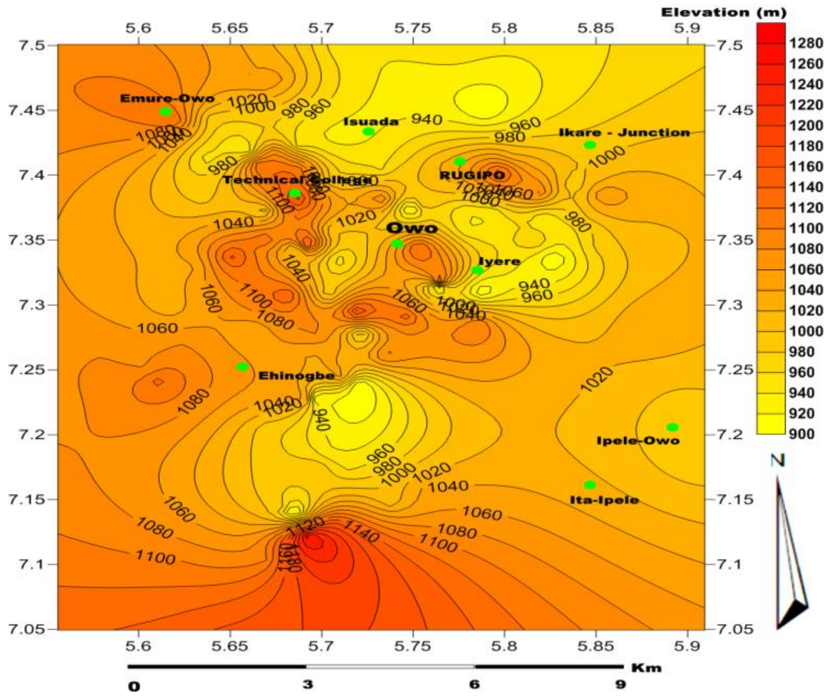

Figure 4: Topographical map of Owo and Environs

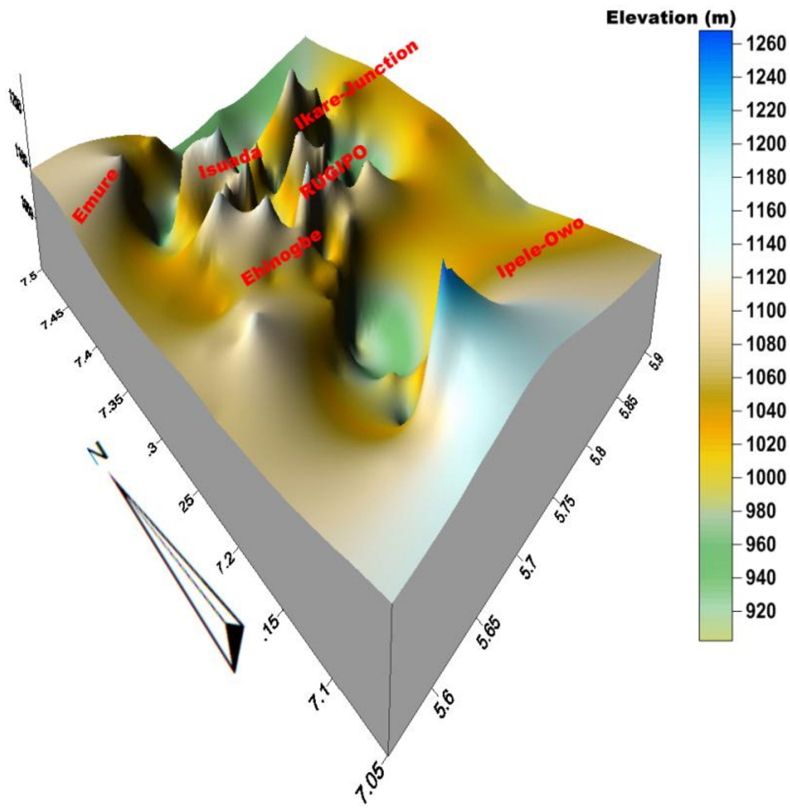

Figure 5: 3-D Surface Elevation Map around the studied Area

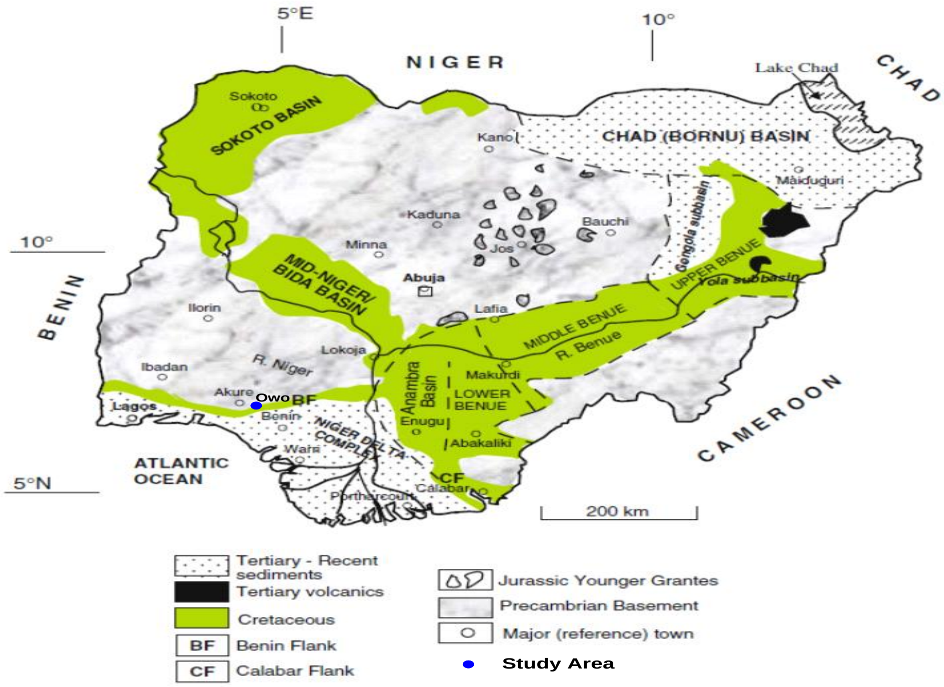

Figure 6: Geological sketch map of Nigeria showing the major geological component; Basement, Younger Granites, and Sedimentary Basins ([5]).

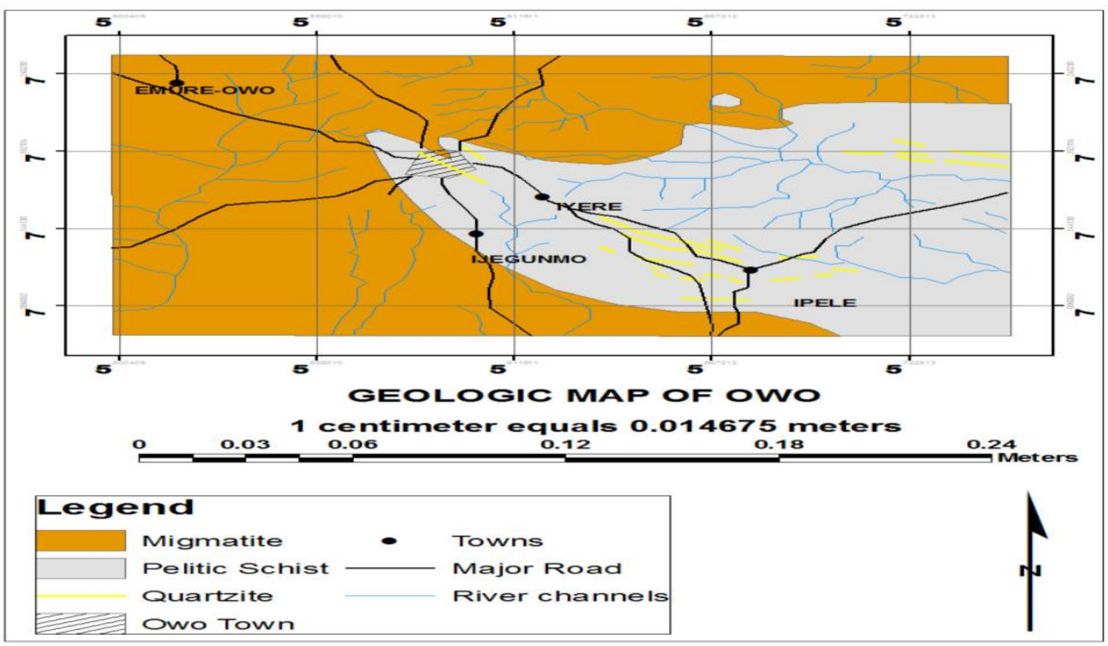

Figure 7: Geological Map of Owo and Environs, showing the Study Area ([5]).

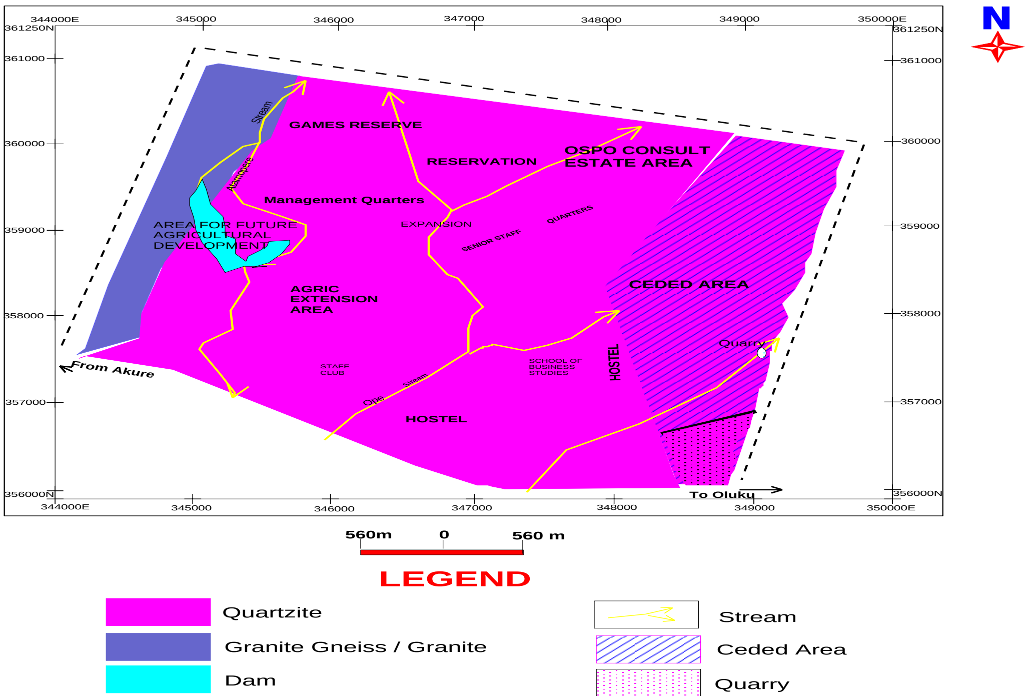

Figure 8: Geological Map of RUGIPO

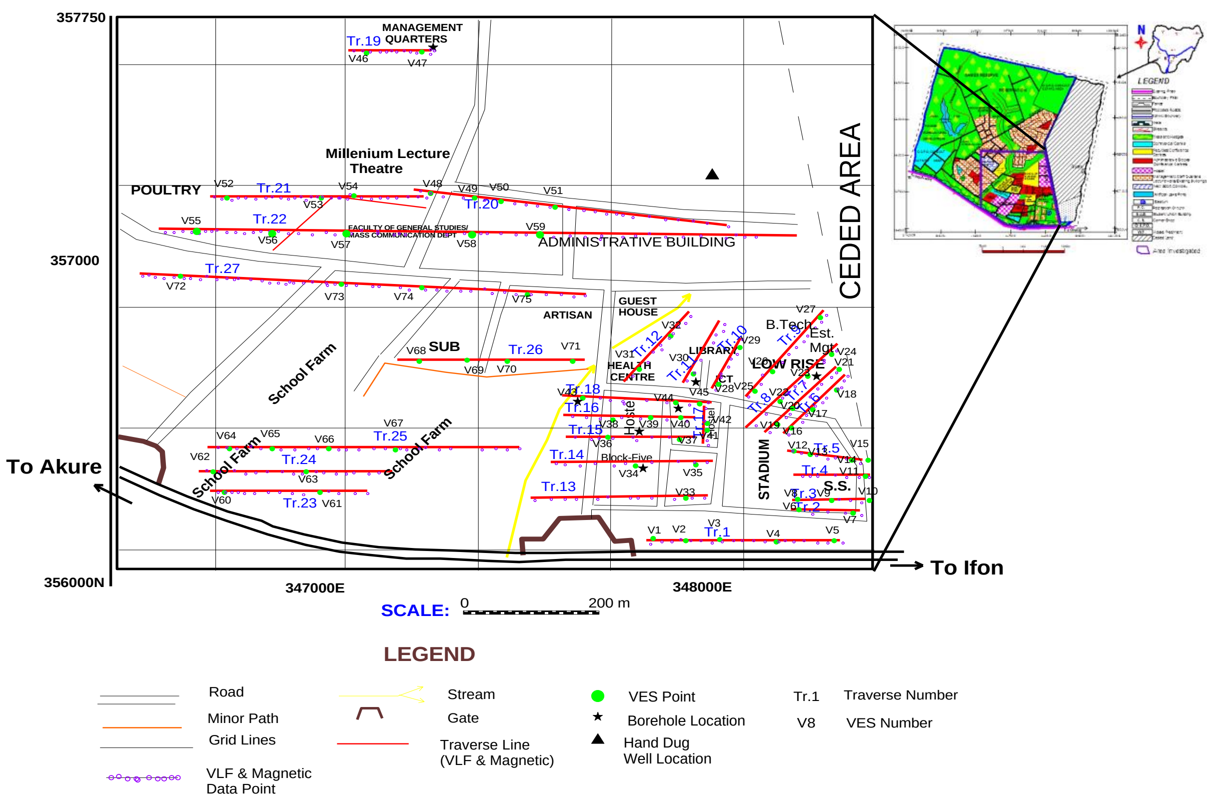

Figure 9: Data Acquisition Map of the Study Area

2.1 VLF-EM Survey

The VLF - EM method utilized the inline profiling technique. The measurements were taken at 10 m intervals along each traverse. The ABEM – WADI EM-VLF was used for the measurements. Although both real and quadrature components of the VLF-EM field were measured, the real component data, which are usually more diagnostic of linear features, were processed. The real and filtered real components were plotted against stations position using 'KHFFILT' software version 1.0 ([7]). The 2-D modeling of the filtered real component was carried out using the same software. The profiles were interpreted qualitatively by visual inspection of anomalies (conductor) that are diagnostic of possible geological structures in the bedrock while the 2-D modeling output was used for quantitative interpretation.

2.2 Electrical Resistivity Survey

The electrical resistivity method utilized Vertical Electrical Sounding (VES) using the Schlumberger array. The same traverses were used in each locality as in VLF method. Sounding stations were determined from conductive zones delineated by the VLF – EM. The location of each sounding stations in both geographic and Universal Traverse Mercator (UTM) coordinates was recorded with the aid of the GARMIN 12 channel personal navigator - Geographic Positioning System (GPS) - unit. The instrument used for the resistivity data collection was the Omega. The current electrode spacing (AB/2) was varied from 1 m to 225 m. The apparent resistivity(ρ_a) resistivity measurements at each station were plotted against electrode spacing (AB/2) on bilogarithmic graph sheets.
The resulting curves were then inspected visually to determine the nature of the subsurface layering. In each way, each curve was characterized depending upon the number and nature of the subsurface layers.

Partial curve matching ([9]) was carried out for the quantitative interpretation of the curves. The results of the curve matching (layer resistivities and thicknesses) were fed into the computer as starting model parameter in an iterative forward modeling technique using RESIST version 1.0 ([10]). From the interpretation results, geoelectric sections along the traverses were produced. The interpreted result was considered satisfactory since a good fit of RMS between the field curves and computer generated curves.

III. RESULTS AND CONCLUSION

3.1 Field Curves

The number of layers varies between 3-layers and 6-layers. Nine curve types have been identified in the study area: KH, HKH, H, KHKH, QH, HK, KQ, AK, and KAH. The most occurring curve types identified are KH and HKH curve types "Fig. 10". The root mean square (RMS) error of the generated curves ranges between 1.8 and 10.7; this shows models of well smoothened, iterated curves ([2]).

3.2. 2-D VLF – EM Modeling and Geoelectric Section

The 2-D structure of the real component of the VLF – EM along Traverse 2 is shown in "Fig. 11a". The 2-D structure reveals one strongly conductive zone located around 45 and 87 m. This structure has a depth greater than 20 m. This conductive is suspected to be a thick weathered zone or fractured zone. The geoelectric section along this Traverse shows that VES 1, 2 and 3 have thick weathered layer indicating good aquiferous unit for groundwater prospect. The most occurring resistivity range of 400 Ω-m – 700 Ω-m suggests a clayey sand/sand formation which is an aquitard i.e. a subsurface geological formation that can store water but poorly transmits.

"Fig. 12" displays the 2-D modeling of the VLF-EM and the geoelectric section along Traverse 8. The 2-D model identifies a highly resistive body suspected to be an outcropping basement at 25 m; and water filled geological formation with a highly weathered/fractured zone between distances 48 and 75 m and 10 and 40 m respectively. The depth of this strongly conductive target ranges between 0 and 35 m. The zone will be good for groundwater development.

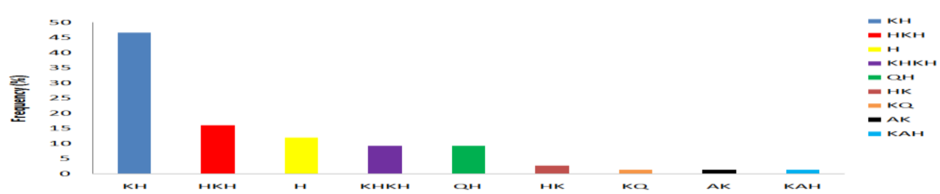

Figure 10: Bar-Chat of Curve Types obtained from the Study Area

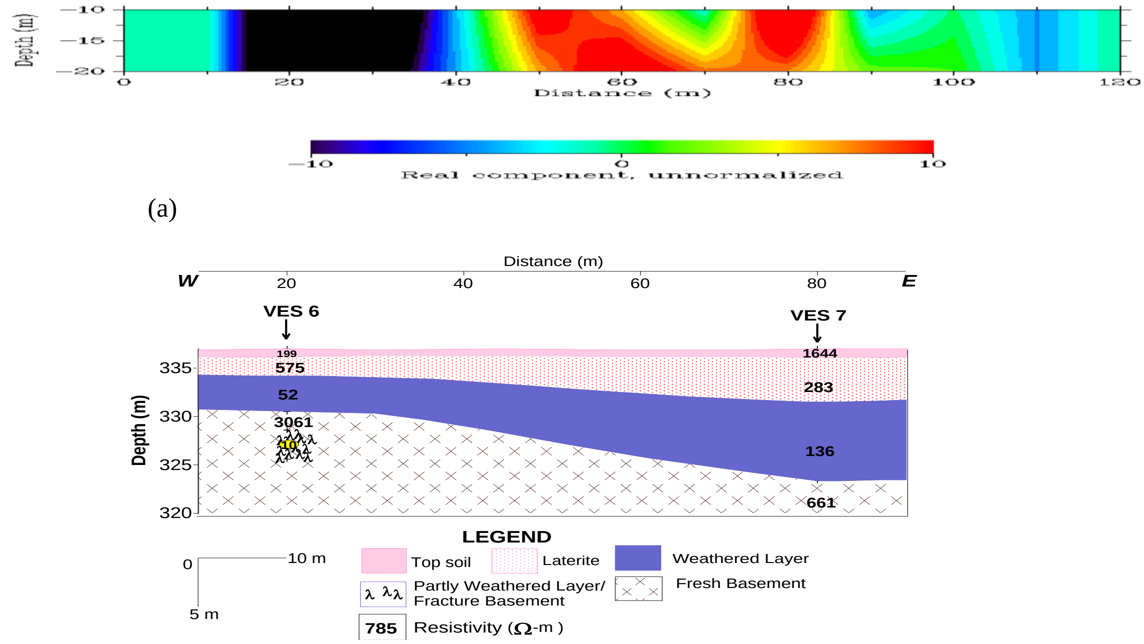

Figure 11: (a) 2-D modeling; (b) Geoelectric section along Traverse 2

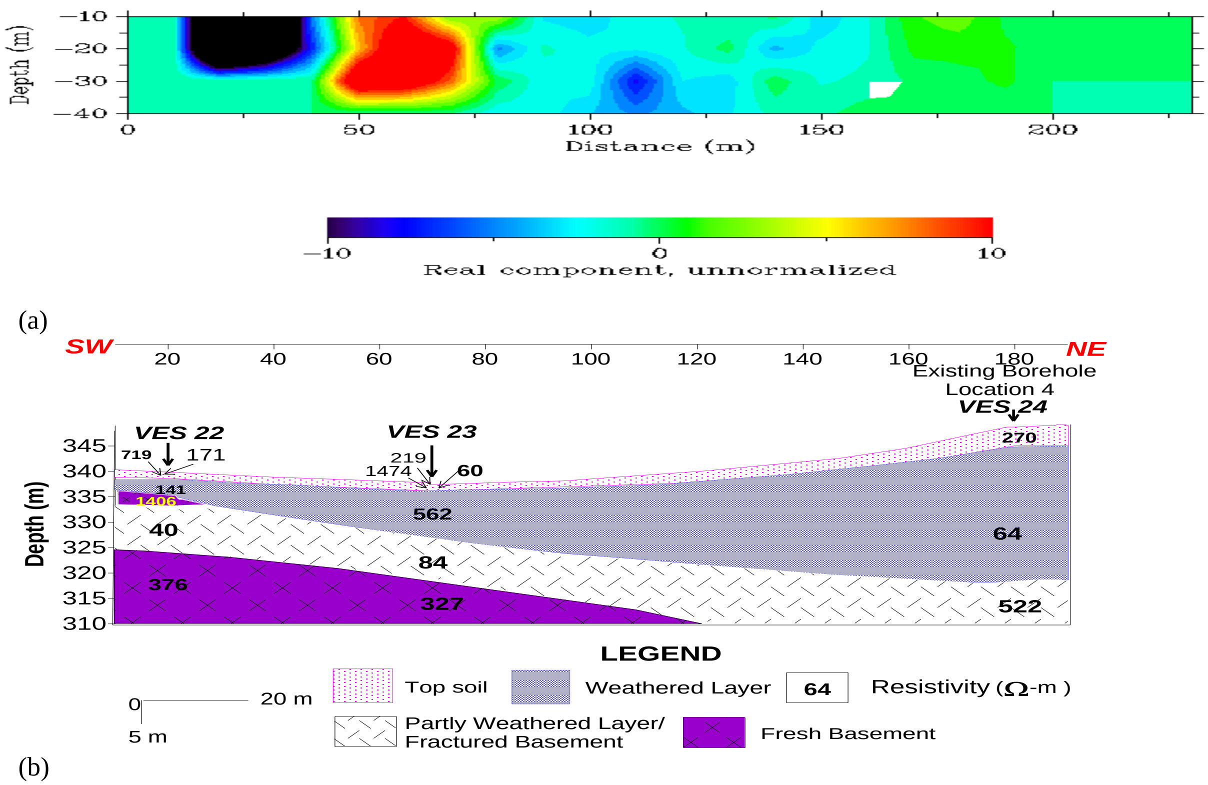

Figure 12: (a) 2-D modeling; (b) Geoelectric section along Traverse 8

The geoelectric section "Fig. 12b" along this Traverse revealed that weathered layer and the fractured basement (unconfined) constitute the major aquifers as evidenced by the existing boreholes under VES 24 with resistivity that ranges between 64 Ω-m and 562 Ω-m; and 40 Ω-m and 522 Ω-m respectively. The composition of the weathered layer is predominantly clayey sand. The thickness of the weathered layer varies from 5 m to 50 m.

The 2-D structure of the real component of the VLF – EM along Traverse 10 is shown in "Fig.13a". The 2-D structure reveals a strongly conductive zone suspected to be water filled geological formation with a highly weathered /fracture zone at distances between 70 and 115 m. The 2-D also identified a very poor conductive zone typical of lateritic hard pan between distances 10 and 60 m. Both have a depth extent greater than 20 m. The 2-D model corroborates the thickly weathered layer (with thickness greater than 20 m) under VES 29 but thin under VES 28. The resistivity of this weathered layer which constitutes the major aquifer unit along this Traverse varies from 28 Ω-m to 229 Ω-m

"Fig. 14" displays the 2-D structure of the real component of the VLF-EM and the geoelectric section along Traverse 12. The top of the main conductive target (at distance 80 m) as indicated by the 2-D model correlates with the geoelectric section "Fig. 14b" which identifies this target as a low resistivity (< 50 Ω-m) suspected to be a clayey material.

The 2-D structure of the real component of the VLF – EM along Traverse 21 is shown in "Fig. 15a". It identifies a strongly conductive feature suspected to be water filled geological formation/weathered zone or fractured zone at distances between 15 m and 45 m. This conductive target has a depth extent of 25 m. The geoelectric section delineates this feature as a low resistivity geomaterial composed of clay weathered layer and clayey sand as the topsoil. Therefore, the aquifer unit along this Traverse is clay with resistivity that is generally less than 100 Ω-m.

"Fig. 16" displays the 2-D structure of the real component of the VLF-EM and the geoelectric section along Traverse 25. The 2-D "Fig. 16a" model identifies a strongly conductive cross cutting linear feature at distance 400 m. This conductive target has a depth extent greater than 60 m. The presence of this cross cutting linear structure is indicative of weak/incompetent geologic formation. However, on the geoelectric section beneath VES 66 where this cross cutting feature occurred, it's revealed as fractured basement at a shallow depth (less than 10 m).

IV. CONCLUSIONS

Geophysical investigation of Rufus Giwa of Rufus Giwa Polytechnic has been carried out, with the aim of evaluating the groundwater potential of the institution. The 2-D modeling real component of the VLF-EM revealed the presence of conductive zones which were used as data points for the vertical electrical soundings. The geoelectric section revealed 3 to 5 major layers comprising the topsoil, clay, laterite, weathered layer, partly weathered layer/fractured basement, and fresh basement rock. The weathered layer and fractured basement aquifers correlate with the suspected water filled geologic formation as lineated by the VLF-EM. Therefore the area has a good prospect for groundwater development.

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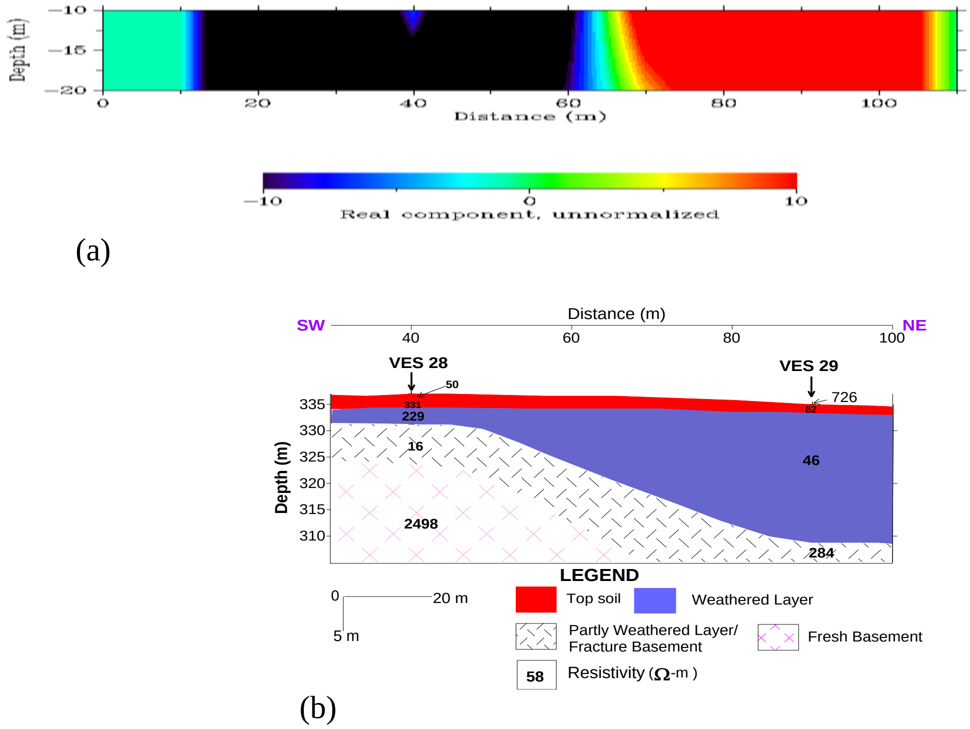


Figure 13: (a) 2-D modeling; (b) Geoelectric section along Traverse 10

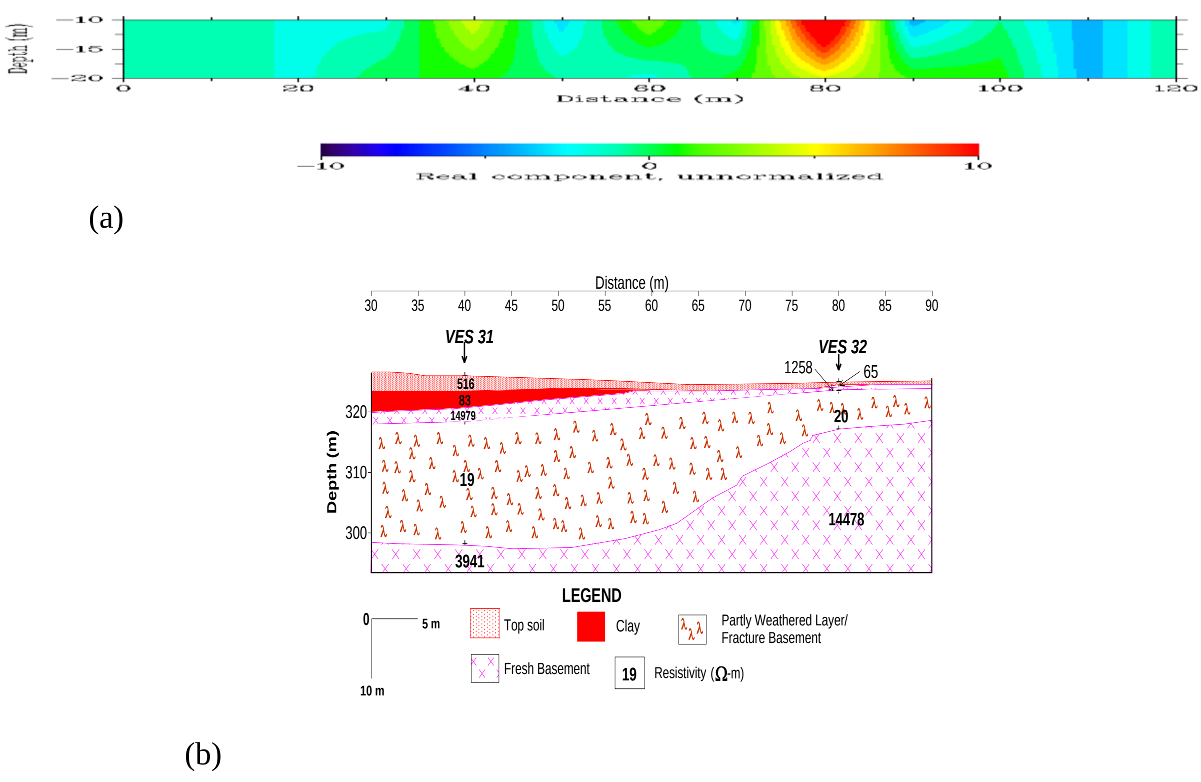
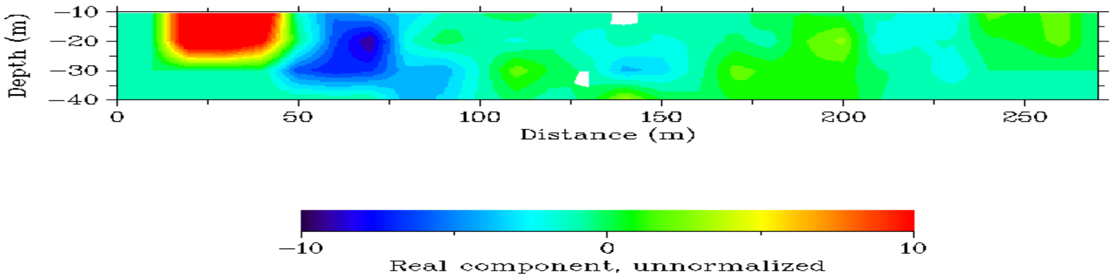
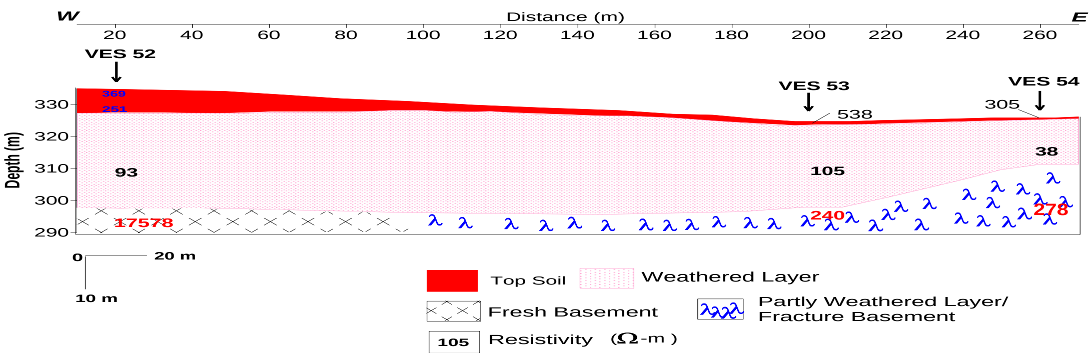


Figure 14: (a) 2-D modeling; (b) Geoelectric section along Traverse 12

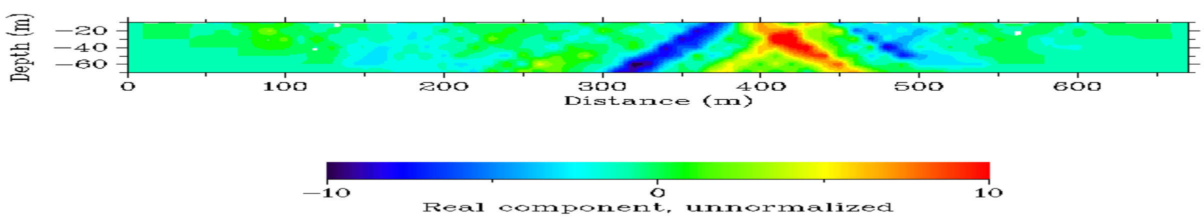


(a)

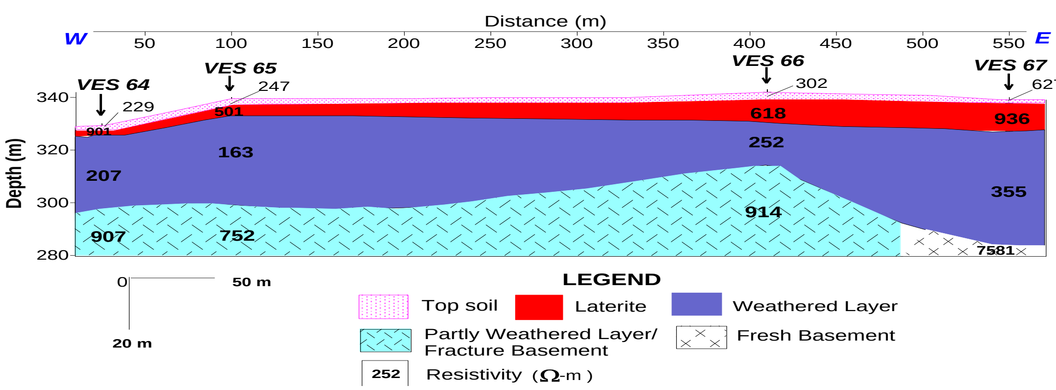


(b)

Figure 15: (a) 2-D modeling; (b) Geoelectric section along Traverse 21



(a)



(b)

Figure 16: (a) 2-D modeling; (b) Geoelectric section along Traverse 25