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Research Paper

Geophysical Imaging of Subsurface Layers for Hydrogeological Study at Federal Polytechnic Ado-Ekiti, Southwest, Nigeria.

Oso O.O.[1], Oke O.O.[2] and Rotibi A.[2]
Department of Mineral and Petroleum Resources Engineering Technology,
Federal Polytechnic Ado-Ekiti.

ABSTRACT
In order to ascertain the hydrogeological potential of an area within the Federal Polytechnic Ado-Ekiti, Southwest Nigeria, nine (9) Vertical Electrical Sounding points were established using schlumberger configuration andsix (6) traverses were alsocreated within the study area, along which dipole-dipole configuration of resistivity measurements were carried out. The data acquired were analyzed using partial curve matching technique, 1-D computer iteration using WIN RESIST softwareand 2-D imaging using DIPROFWIN software. The results were presented as VES curves, geo-electric sections and pseudo-sections. Six (6) geo-electric sections (each section on each traverse) across the study area revealed that the study area is underlain mostly by three subsurface layers and four layers in a very limited area within the general study area.The analyses of the sections along the traverses clearly depicted these layers as topsoil which contains clayey sand/sandy clay, weathered layer which contains clayey materials and the fractured/fresh basement with the fractured part acting as the aquifer in the area.The correlation of the results of the 2D resistivity imaging and geo-electric section show that the study area is characterized by moderate groundwater potential zones.The overburden thickness varies from 6.2m to > 35.9m.The weathered layer and the fractured basement are considered to be the major aquifer units especially in the area of a relatively thick overburden. Based on the fact stated above and from the interpretation of the field data, borehole drilling for prolific groundwater potentials will be achieved in all the VES points except VES 4 and VES 8.
KEYWORDS: *Pseudo-section, aquifer, overburden, geo-electric, schlumberger*

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I. INTRODUCTION

The basement complex rocks are naturally insufficient aquifer which is characterized by crystalline igneous and metamorphic rocks with low porosity and negligible permeability. However, fracturing and weathering activities of basement complex rock may lead to appreciable secondary porosity and permeability of the rocks thereby making them good aquifers (Davis and De weist,1996).The Federal Polytechnic Ado-Ekiti, which is the study location, occurs within the Precambrian basement complex of the Southwest Nigeria and therefore should be expected to have groundwater problem unless fracturing and weathering activities had occurred on the rocks constituting the area. Also, the degree or extent of these activities would determine the quality of aquifers. Highly productive water wells are obtained by drilling in the rock that is broken along the factures and the joints.

Groundwater is fresh water (from rain or melting ice and snow) that infiltrates into the soil and is stored in the tiny spaces (pores) between rocks and particles of soil. It can stay underground for hundreds of thousands of years, or it can come to the surface and help to fill rivers, streams, lakes, ponds, and wetlands. Groundwater can also come to the surface as a spring. According to Plummer (2001), the source of groundwater is rainfall and snowmelt. In prospecting for groundwater or looking for good site to drill water wells, a certain favourable geologic material called aquifer is sought for. Groundwater and other mineral resources such as hydrocarbons and solid minerals are of great abundance in Nigeria but the true riches of any country depend on her ability to provide for its dwellers. Potable water is one of the major resources that a citizen of any nation can benefit from according to Alile, (2008).

II. METHODOLOGY

Electrical geophysical prospecting method has been employed for this research, and this method of geophysics detects the surface effects produced by electric current flow in the ground. Using electrical methods, one may measure potentials, currents, and electromagnetic fields that occur naturally or are introduced artificially in the ground. In addition, the measurements can be made in a variety of ways to determine a variety of results. There is a much greater variety of electrical and electromagnetic techniques available than in the other prospecting methods, where only a single field of force or anomalous property is used. Basically, however, it is the enormous variation in electrical resistivity found in different rocks and minerals that makes these techniques possible (Telford, et al., 1976). This method involves the use of artificially generated electric current (direct or alternating) introduced into the ground to investigate the variations in the electrical property of the subsurface materials (rocks). The expected variations result in the build-up of varying potentials distributed according to the presence or absence of conducting materials in the earth. The potential distributions generated are those measured from the ground surface which provides information on the form of, and electrical properties of such subsurface in homogeneities. Two different electrode configurations of Electrical resistivity method were used for this research, and these are Schlumberger Vertical Electrical Sounding and Dipole-dipole for 2-D electrical imaging.

Schlumberger Configuration

In Schlumberger electrode configuration (figure 1), four electrodes are needed, a pair of potential electrodes and another pair of current electrodes. These electrodes will be arranged linearly. The potential electrodes remain fixed while the current electrode spacing is expanded symmetrically about the center of the spread. For large values of AB/2, it may be necessary to increase MN/2.

Geometrical factor K for this array is given by;

$$\boldsymbol{k} = \frac{\boldsymbol{\pi}\left[\frac{AB}{2}\right]^2 - \left[\frac{MN}{2}\right]^2}{\boldsymbol{MN}}$$

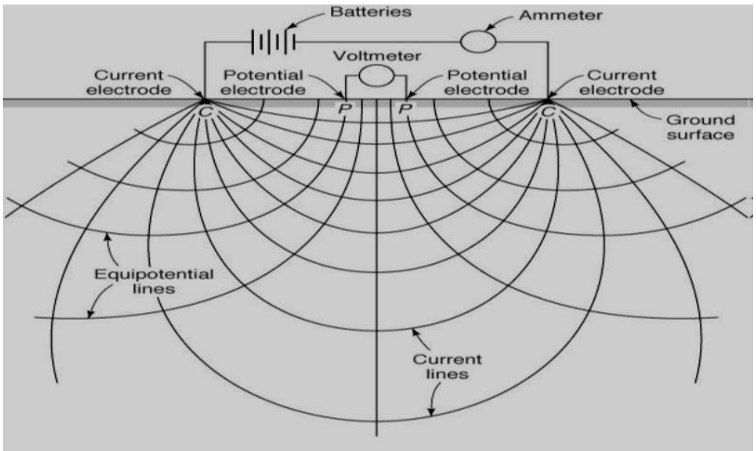


Figure 1: Schlumberger configuration and the current line

Dipole-dipole Configuration

The Dipole-dipole configuration imagines the subsurface in a 2-dimensional manner. It apparently measures both lateral and vertical variations in resistivity of the subsurface. This array consists of two sets of electrodes, the current (source) and potential (receiver) electrodes.The dipole-dipole method places the A and B electrodes on one side with a spacing between them denoted as "a". The M and N electrode pair with equal “a” spacing are placed collinearly a distance "na" away from A and B. A distance equal to an integer multiple of “a” is denoted "na". As measurements are taken at various n's, that is, the pairs of electrodes are moved apart, a sounding is obtained. If the electrodes are moved across the surface, a profile of comparative values is generated. Thus the dipole-dipole method produces a combination sounding-profiling set of data if measurements are taken at various values of n along a profile. Figure 2 depicts dipole-dipole configuration. The figure 3 below shows the data acquisition map for both VES and Dipole-dipole surveys.

$$\rho_A = \frac{V}{I}\pi\, a\, n(n+1)(n+2)$$

Figure 2: Dipole-dipole configuration

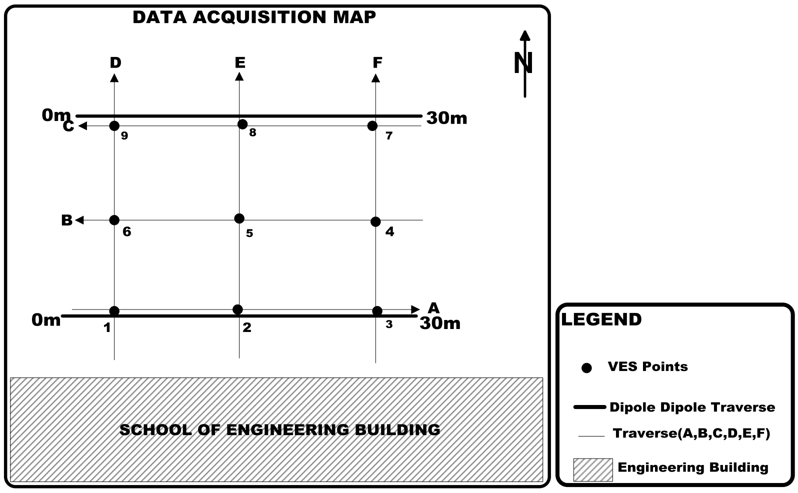
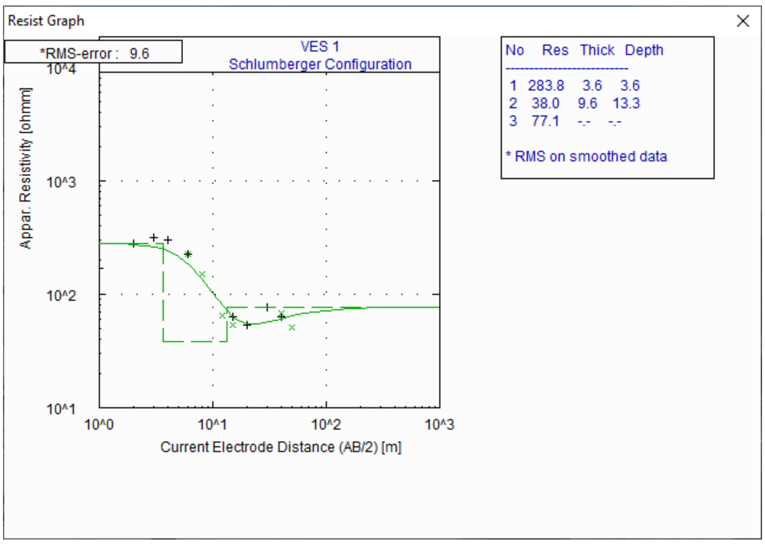


Figure 3: Data Acquisition Map

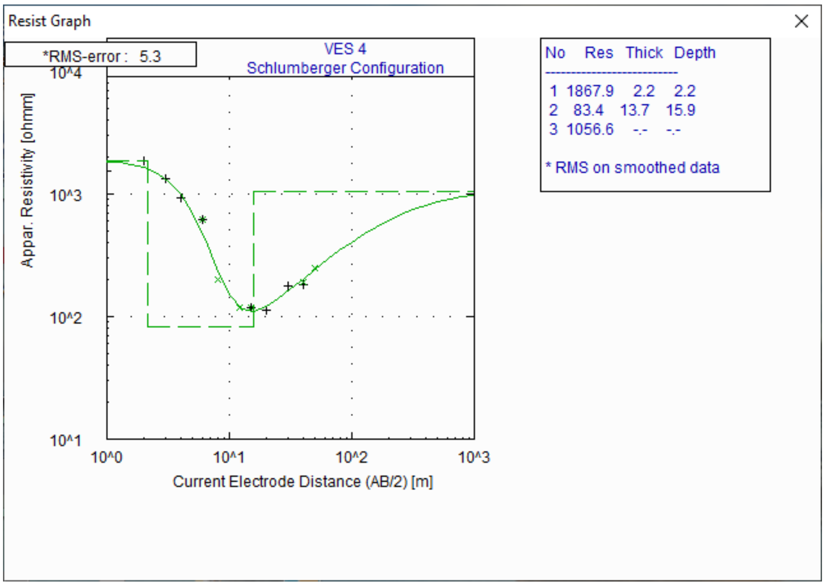
III. RESULTS AND DISCUSSIONS

The geophysical data obtained were subjected to qualitative and quantitative analyses. Field data for VES using Schlumberger configuration were presented as sounding curves by plotting apparent resistivity $\rho_a$against AB/2 (i.e half the electrode spread length) on a bi-log graph paper. Resistivity curves were generated by partial curve matching and computer iteration, using WinResist software. Figures 4a-c show the representative of the resistivity curves. Also, the table 1 below shows the geo-electric parameters for the VES curves. These parameters were subsequently used to generate geo-electric sections along the Vertical Electrical Sounding (VES) traverses, and these sections reveal the vertical and lateral variations in resistivity along the traverses.

(a)



(b)



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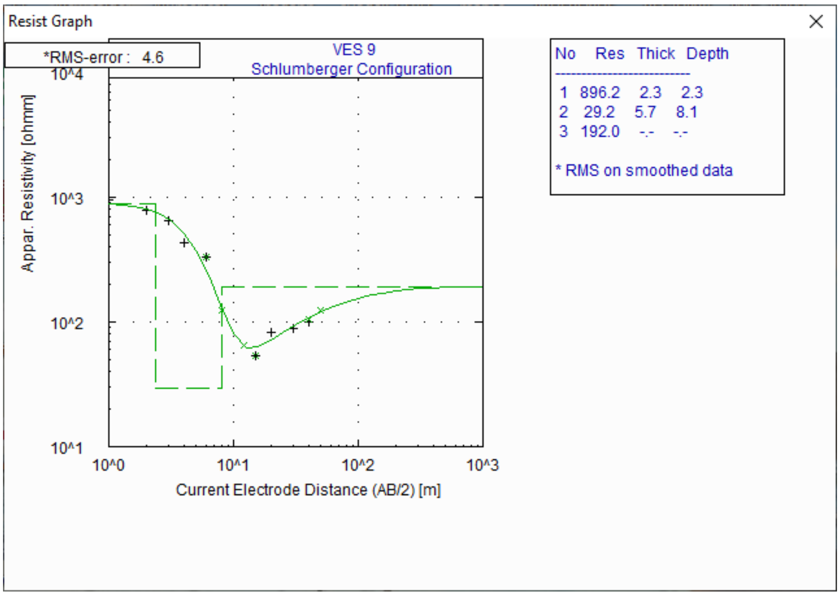


Figures 4a-c: Representative VES curves

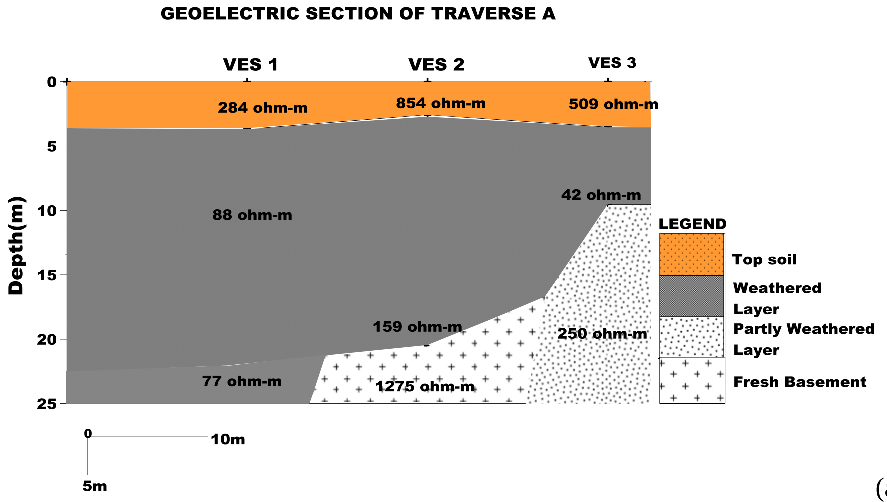
Table 1: Geo-electric Parameters for VES Curves

VES No	Layers	Resistivity (Ωm)	Depth (m)	Lithology	Curve Type
1	1 2 3	284 38 77	3.6 13.3 -	Top Soil Weathered Layer Weathered Layer	H
2	1 2 3	854 159 1275	2.6 20.5 -	Top soil Weathered layer Fresh Basement	H
3	1 2 3	509 42 250	3.5 9.5 -	Top soil Weathered Layer Partly Weathered Layer	H
4	1 2 3	1868 83 1057	2.2 15.9 -	Top Soil Weathered Layer Fresh Basement	H
5	1 2 3	2577 34 1949	1.6 6.2 -	Top Soil/Lateritic Layer Weathered Layer Fresh Basement	H

6	1 2 3	1158 87 22	1.7 35.9 -	Top soil/Lateritic Layer Weathered Layer Highly Weathered Layer	Q
7	1 2 3	2070 21 1292	1.8 6.5 -	Top soil/Lateritic Layer Weathered Layer Fresh Basement	H
8	1 2 3	878 13 2251	1.7 6.6 -	Top soil/Lateritic Layer Weathered Layer Fresh Basement	H
9	1 2 3	896 29 192	2.3 8.1 -	Top soil/ Lateritic Layer Weathered Layer Partly Weathered Layer	H

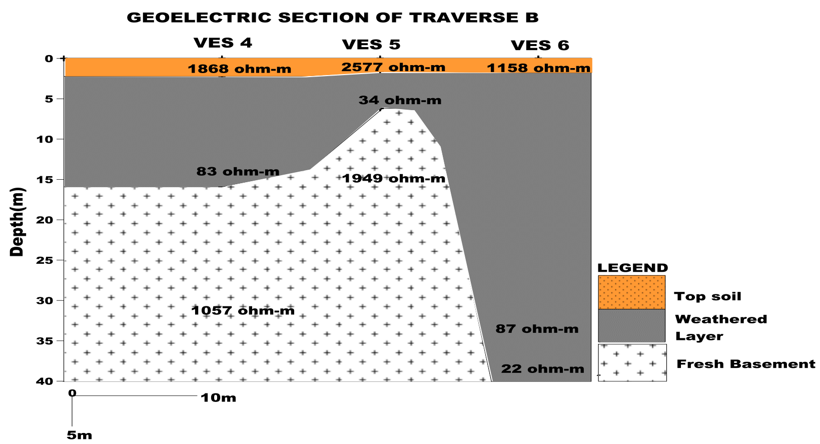
Geo-electric Section

The VES interpretation results were used to prepare 2-D geo-electric sections along two directions; W-E and S-N directions.The geoelectric sections across the study are presented in Figures 5a-d (as the representative).Four subsurface geoelectric units were delineated. These are the topsoil, weathered layer, partly weathered layer and the fresh basement.The topsoil constitutes the first layer with resistivity values ranging from 284 to 2577ohm-m, indicating that the topsoil is mainly lateritic and clayey sand, with thickness range of 1.6 to 3.6m.The weathered layer is the second layer with resistivity values ranging from 13 to 159 ohm-m, indicating that the material composition is largely clayey to sandy clay and thickness of 4.6 to 34.2 m. The highest thickness was obtained around VES 6. In respect of the hydrogeology, the second layer has groundwater significance, where it is thick enough and the amount of water saturating it is high. The third layer is the partly weathered layer. The partly weathered layer was delineated beneath VES 3 and VES 9. The layer constitutes the main aquifer unit in the study area. The resistivity values fall between 192 and 250 ohm-m. It occurs as the last observable layer in VES 3 and 9.The fresh basement is the last layer with resistivity values ranging from 1057-2251 ohm-m which is of infinite depth at most of the VES stations except VES 3 and VES 9; it is infinitely resistive because of its crystalline nature.



(a)

(b)



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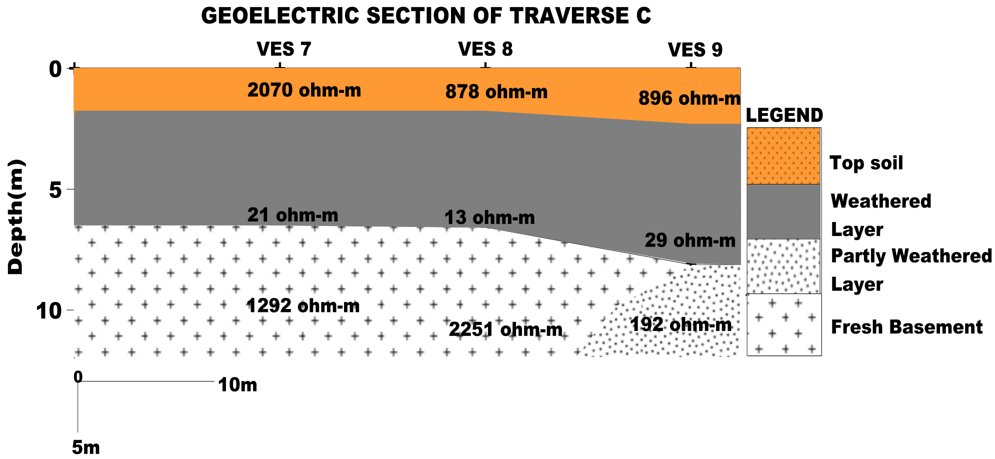
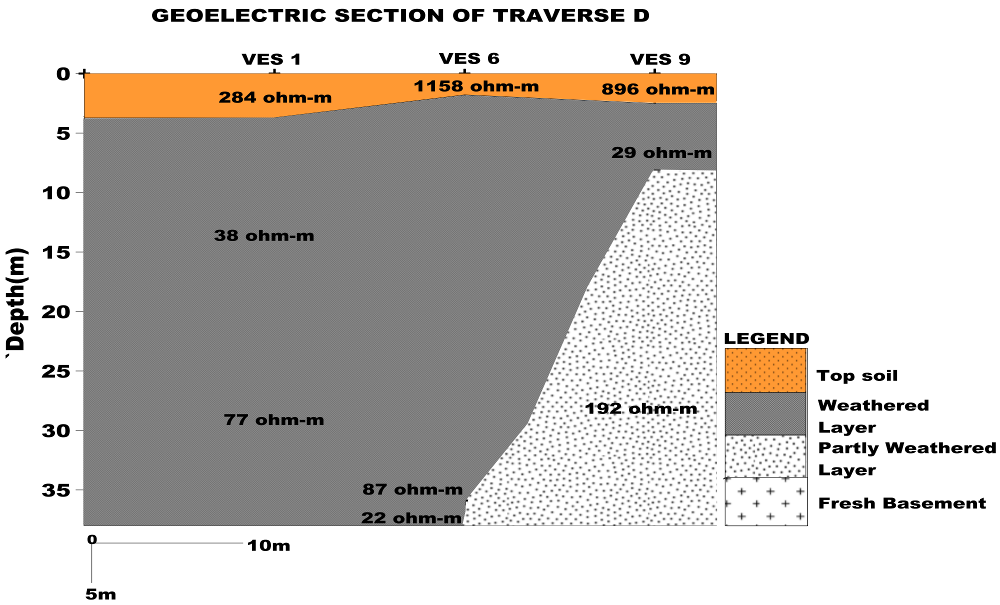


(d)



Figures 5a-d: Representative Geo-electric Sections

2-Dimensional Imaging of the Subsurface

The 2D imaging results of the resistivity values obtained along Traverses 1-2 in the study area from dipole-dipole array are presented in form of Psuedo-section. These results are presented as original and corresponding parallel profiles where traverses were made in order to intersect the underlying geological structures as shown infigures 6 and 7.

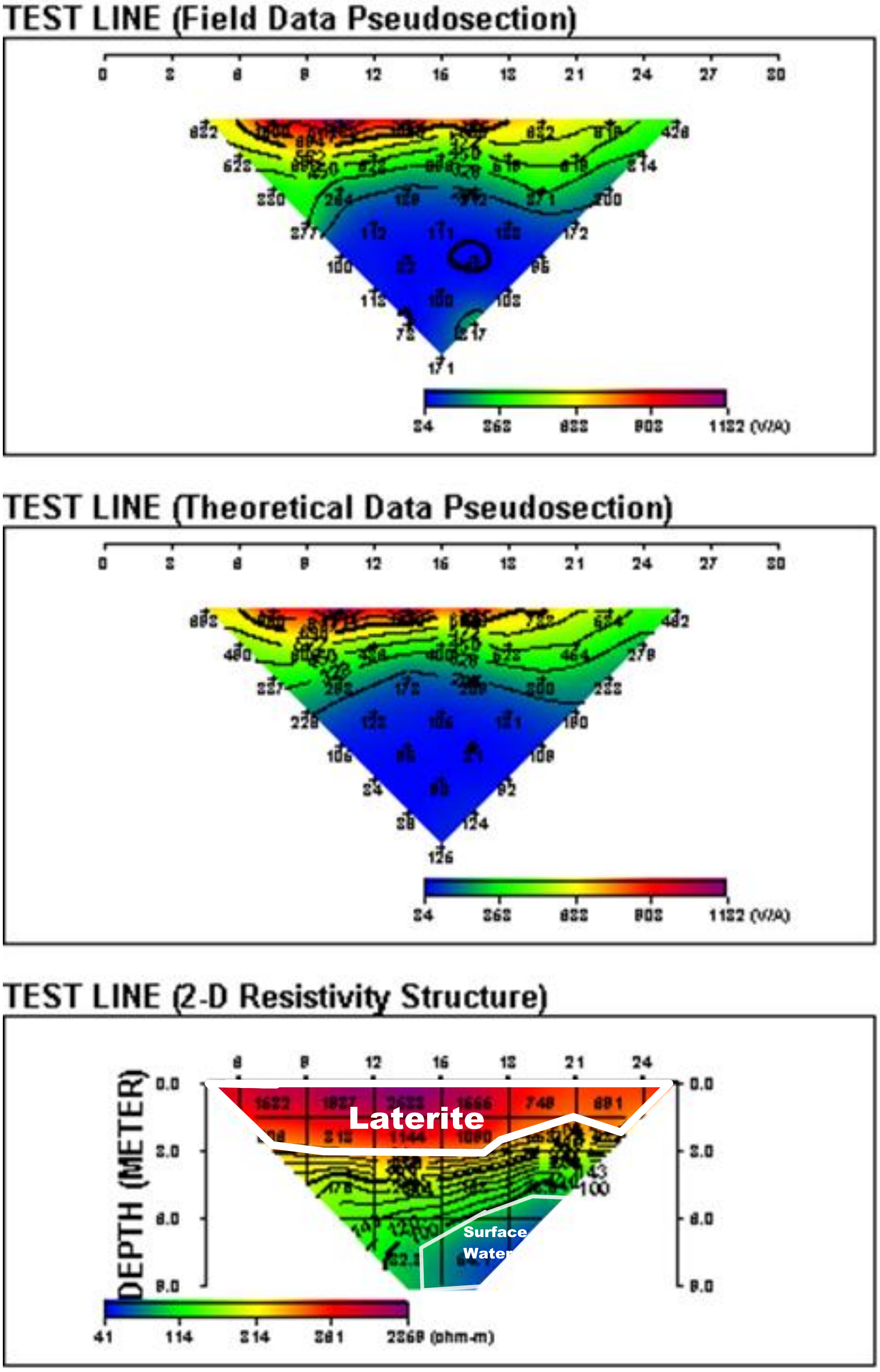


Figure 6: 2D Electrical Resistivity Image for Traverse 1 along W-E Direction.

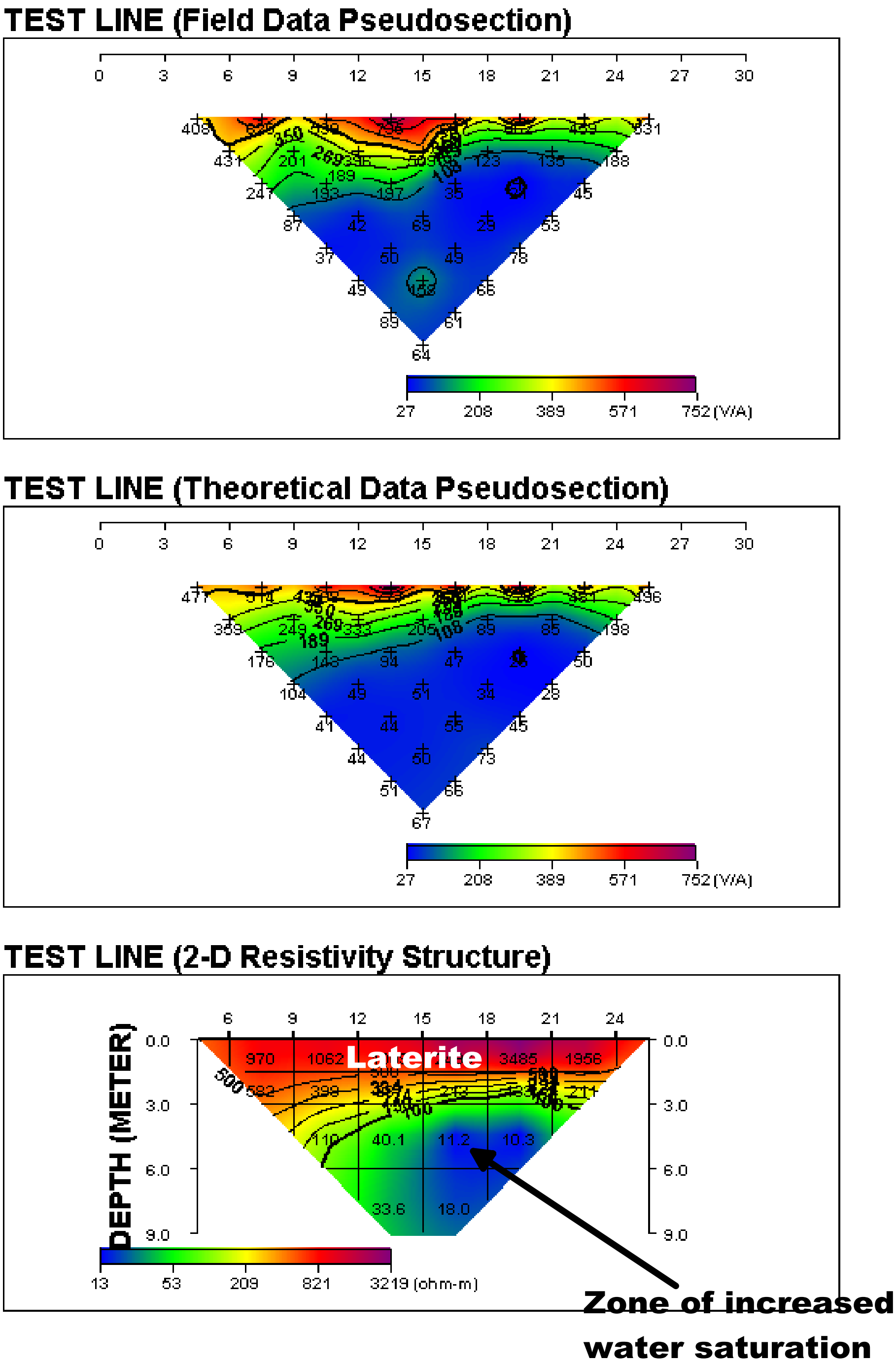


Figure 7: 2D Electrical Resistivity Image for Traverse 2along S-N Direction.

Traverse 1 located at the southern part of the study area trends W-E direction with a length of 30m. The upper part of the layer revealed resistive materials as the top layer, which has resistivity value of between 261-Ohm-m and 2268-Ohm-m and is about 2 m thick. The top layer was interpreted as lateritic clay/sandy clay. This layer is underlain by a conductive layer, which is about 5 m thick with resistivity value between 41-Ohm-m to 114-Ohm–m, which is interpreted as clay/clayey sand/sandy clay. This layer was absent between lateral distance of 6 m to 14 m where the resistivity of the material is 214-2268-Ohm-m. It coincides with a basement rise. The low resistivity zone between stations 14-20 (5-9m) could be diagnostic of weathered zone. This low resistivity zone is confined to a small region and is the effect of constant recharge from the surface.

Traverse 2 showed the section of 2-Dimensional imaging of the western section of the study area trending S-N direction. The maximum length of the profile is 30 m. The profile showed top layer of about 3m thick with resistivity values ranging from 821-Ohm-m to 3219-ohm-m at the southern part of the profile due to the presence of lateritic layer. The variation in the resistivity reveals the in-homogeneity along the top layer. This layer is underlain by more conductive layer, which has resistivity value of between 13- Ohm-m to 53-Ohm-m and thinned out towards the northern and southern ends of the profile with considerable thickness. The low resistivity zone between stations 15-21 (4-9m) could be diagnostic of weathered zone. This low resistivity zone is confined to a small region and is the effect of constant recharge from the surface. The uneven nature of the lateritic zone was also revealed by the 2-D resistivity structure between 15m and 21m. The layer is interpreted as clay/clayey sand. The uneven thickness across the profile line indicates that there was no uniform weathering across the traverse line.

IV. CONCLUSION

The study has employed dipole-dipole array (combine HP and VES) and Schlumberger array using VES techniques to map the hydrogeological significance of the subsurface structure in the vicinity of Federal Polytechnic, Ado Ekiti, Ekiti State. The geological and hydrogeological setting of the area is relatively favourable for groundwater accumulation at shallow and deeper strata and augmentation with respect to 1D (one dimension) and present 2D resistivity investigations and their results.The analyses of the sections along the profiles clearly show three divisions viz., top layer, which is clayey sand/sandy clay/lateritic clay; weathered layer which contains clayey materials and the fractured/fresh basement with the fractured part acting as the aquifer in the area. The overburden thickness varies from 6.2 m to above 35.9 m. The water-bearing unit in the area of study is the regolith (weathered basement) derived mostly from in-situ weathered crystalline rocks. The bedrock depressions and the fractured zones being groundwater collecting centres are priority areas for groundwater development. Based on the results, groundwater exploration and development in the area should be targeted towards the weathered layer and fractured basement in areas with relatively thick overburden.The advantage of using dipole–dipole array in conjunction with the schlumberger array proved their capability which gives clear insight of the aquifer variability and their dimension from shallow to deeper levels from hydrogeological perspective in the present geological setting. The correlation of the results of the 2D resistivity imaging and Geo electric section shows the study area is characterized by moderate groundwater potential zones.

V. RECOMMENDATION

Since the weathered layer and fractured basement are considered to be the major aquifer units in the study area, and based on the interpretation of the field data, I recommend that all VES points will be suitable for borehole development as a result of their low resistivity values except VES points 4 and 8.

REFERENCES

[1]. Alabi, Aderemi Bello, R. Ogungbe, A.s Oyerinde, H.O. 2010/01/016875 Determination of groundwater potential in Lagos State University, Ojo using geoelectric methods (vertical electrical sounding and horizontal profiling) vl. 2.
[2]. Alile, M.O., S.I. Jegede and O.M. Ehigiator, 2008.Underground water exploration using electrical resistivity method in Edo State, Nigeria. Asian J. Earth Sci., 1: 38-42.
[3]. Davis, S.N. and De Weist, R.J.M. (1966) Hydrogeology. John Wiley and Sons, New York, page 463.
[4]. Jones HA, Hockey RD (1964).The geology of parts of Southwestern Nigeria. Geol. Survey Nig. Bull. 31: 22 – 24. Kogbe CA (1976). The Cretaceous and Paleogene sediments of southern Nigeria.In C. A. Kogbe (Ed.) Geology of Nigeria.pp. 325- 334.
[5]. Kelly, W.E. and M. Stanislav, 1993. Applied Geophysics in Hydrogeological and Engineering Practice. Elsevier, Amesterdam, pp: 292. 11.
[6]. Rahaman, M. A., (1976). Review of the basement geology of the southwestern Nigeria. In Kogbe, C. A. (et), Geology of Nigeria. Lagos: Elizabeth Publishing Co., 41-58pp.
[7]. Oyedele, K.F, Ayolabi, F.A, Adeoti, L. and Adegbola, R.B. (2009); Geophysical and hydrogeological Evolution of Rising Groundwater level in the coastal areas of Lagos, Nigeria Bull Eng. Geol. Eviron vol.; 68;pp. 137-143.
[8]. Telford et al (1976): Recapitulate that the electrical resistivity method of G|eopyhsical prospecting, Cambridge university press publication 1976 pg 637-705.