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Research Article

APPLICATION OF 2D IMAGING IN GROUNDWATER EXPLORATION: A CASE STUDY OF IGBO-ORA, SOUTH-WESTERN, NIGERIA.

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ABSTRACT
This study was carried out in parts of Igbo-Ora, south western Nigeria to delineate subsurface geology of the area by using 2D electrical resistivity methods. This was done by using Wenner electrode configuration using an Omega tetrameter. The electrodes were arranged in straight lines along seven profiles in order to get coverage that is continuous with a lateral distant of about 160m. The data was processed using Res2Dinv.software. Resistivity was plotted against depth to give color modulated sections. The findings showed that the layers associated with low resistivity are located at depth ranging from 5.5 to about 13.4mwith the low resistivity1.25 to about 10.5m, 3.88m to around 10m, 1.25 to about 10m,>1om,5.8m to about 13.4m and 1.25 to about 13m for Profile I,II,III,1V,V,VI and VII respectively. From the investigations carried out, the results show that water found in this area can be classified into the vadoze water zone which is suitable for shallow water wells except for profiles V and V1in which a borehole can be recommended.

Keywords: *2-D resistivity imaging* Subsurface* Groundwater* Vadoze zone* Groundwater exploration*

INTRODUCTION
There are many failed boreholes in the area. This information necessitated the changing the geophysical methods to 2D electrical tomography so as to give pictorial image of the subsurface and groundwater occurrence Ground water occurrence in crystalline rocks are both isolated and compartmentalized (Abudulawal, 2015). The basement rocks in their deformed state possess little or no primary intra granular porosity and permeability and thus occurrence of groundwater is due largely to the development of secondary porosity and permeability resulting from weathering and fracturing of the parent rock. Ground water is a unique natural resources because though it is renewable it is irreplaceable (Manzuma et al., 2015).Ground water is relatively pure and grossly protected from surface pollutants due to its depth of storage and natural filtration process. Omali, (2014); Zhou et al. (2004); Hsu et al (2010) and Roa et al (2013) were able to demonstrate that 2D electrical resistivity tomography can be employed in detecting bedrock and groundwater exploration. 2D ERT method has been a powerful tool to investigate shallow sub surface electrical structures in various environments (Yang et al., 2003; Cheny et al., 2008 and Croock et al., 2008). In addition, the basic sounding interpretation assumption of horizontally stratified earth model, which do not match the local geological model, and failure of the profiling method to map changes in resistivity with depth are the major limitations of these methods (Griffiths and Barker, 1993). Electrical resistivity tomography (ERT) provides a more realistic 2-D resistivity model of the subsurface, where resistivity changes in the vertical as well as in the horizontal direction along the survey line are mapped continuously even in the presence of geological and topographical complexities (Loke, 2000).Thickness of the weathered/ fractured layer overlying fresh basements rocks is the factors that determine groundwater potential of an area. Sharma and Baranwal (2005) observed that fractures are primary source to store and allow movement of groundwater in hard rocks. Long term high yields boreholes cannot be expected in an area which is not overlaid by thick regolith. Different geophysical methods have been applied in groundwater search. Many researchers have used electrical resistivity methods notably (Sharma and Baranwal, 2005;Olayinka et al., 1997; Abudulawal et al., 2015;Oladunjoye et al (2013) all these researchers used 1 –D model of the subsurface which employs profiling and sounding. This model is not adequate for a complete terrain. Grifitts and Barker (1993) noted that basic

sounding interpretation of horizontally stratified earth model do not match the local geology. Loke (2000) noted that 2D resistivity model of the subsurface where resistivity changes in the vertical as well as in the horizontal direction along the survey line can be used in areas of complex geology and topography.

LOCATION AND ACCESSIBILITY

The area of investigation is a semi urban area with coordinates of 7˚43"4'N and 5 ˚42"32'E with altitude of about 130m (450ft) in Ibarapa region. It is an agrarian community with undulating topography traversed by Agogo stream. The community draws their water from ponds, swamps, hand dry wells and few boreholes. The steams and ponds are seasonal.

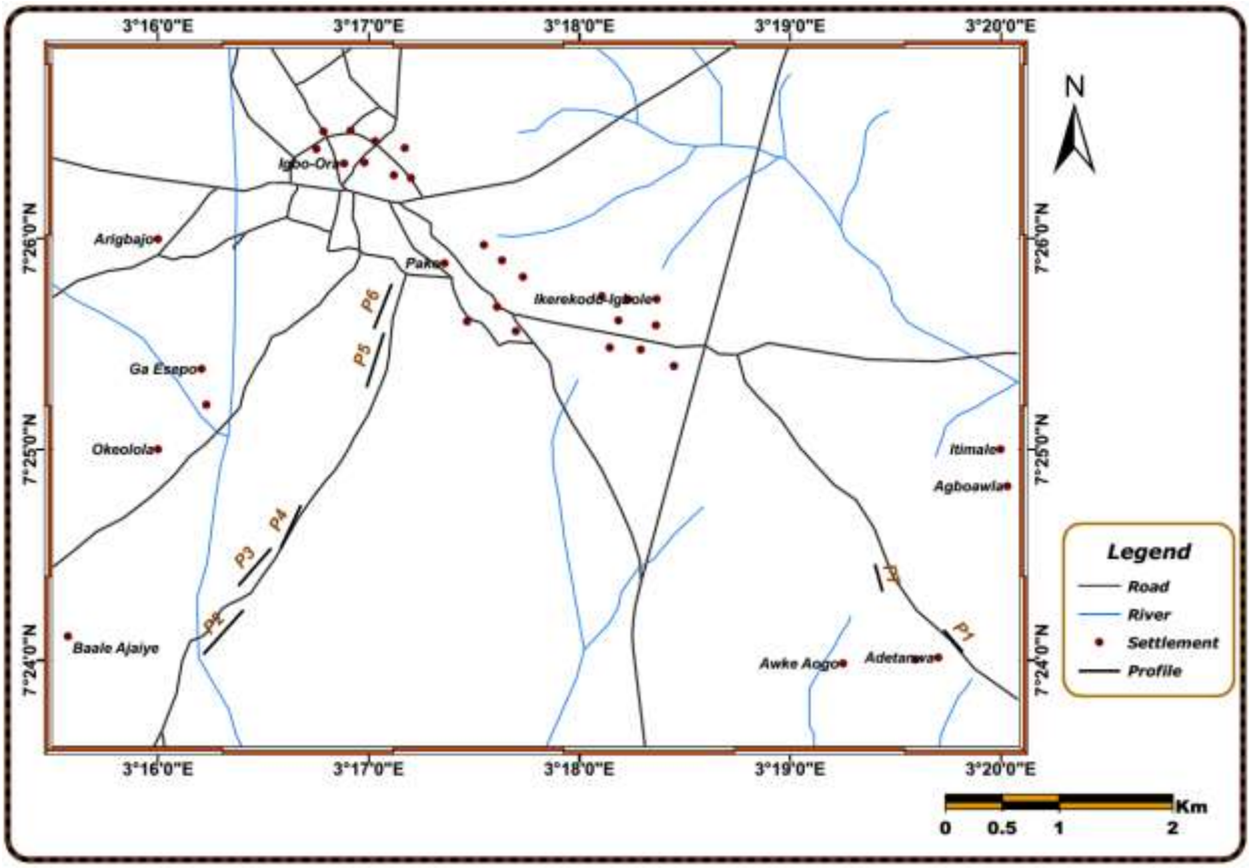

Figure 1: showing the accessibility, drainage pattern of the study area

In terms of geology the area is underlain by metamorphic rocks of granitic and quartzite suites. A lot of workers have written very extensively on this notably (Oyawoye, 1972, Rahman, 1976, Elueze, 1982 among others). The main rocks found in the area during field mapping are gneissic rocks, migmatites, porphyrfic granite, granodiorite, pegmatite and amphibolites. The pegmatite and andqurtzofelspathic veins occur as minor intrusion.

MATERIALS AND METHODS

Using Allied Omega resistivity meter, 45 electrodes were arranged in a straight line with constant spacing to investigate subsurface geology of the area and to appraise ground water conditions of the area. This is used to image the subsurface using electrical resistivity method.

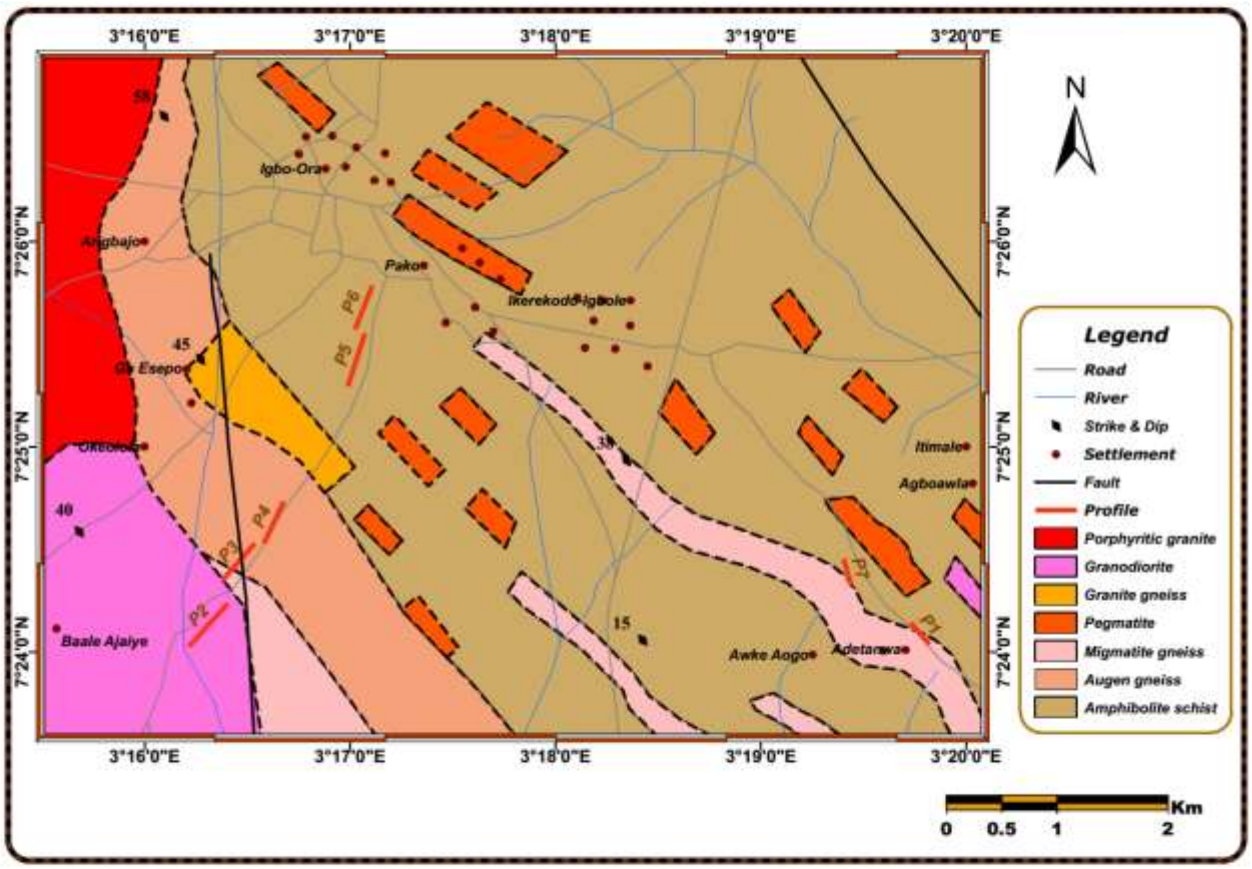

Figure 2: Showing the Geological map of the study area and the profile lines.

DATA ACQUISITION AND INTERPRETATION:

Acquisition of data on the field consumes time and requires intensive labor because four electrodes are moved from one point to another to measure every point. Maximum of five persons are required because four persons will move the electrodes and the fifth person will be taking the readings on the equipment and noticing if there are errors on the electrodes. The electrode spread (Wenner array configuration) for data acquisition along the four profiles surveyed, used different electrode spacing of 5m,10m, 15m,20m and 25m respectively. A total length of 160m was surveyed for profiles I, II, III , IV, V,V1 and VI respectively. One major precaution taken for using the Wenner array method was the provision of high signal-to-noise, good resolution of horizontal layers and good depth sensitivity of the method Jayeoba and Oladunjoye 2015).To obtain true two-dimensional resistivity distribution in the subsurface, the measured apparent resistivity data were inverted using the software RES2DINV (Loke, 2000; Loke and Barker, 1996). Manual editing was applied to remove data that are still characterized by repeated error less than 5% but which were clearly outlier values (possibly caused by poor electrode contact) from the measured apparent resistivity data (LaBrecque and Yang, 2001). These outlier values were identified easily as localized anomalous apparent-resistivity spots from the pseudo-section plots. The RES2DINV is a computer program that automatically determines a two-dimensional resistivity model of the subsurface from the input apparent resistivity data. The program uses an array of rectangular blocks to model the subsurface and by iterative forward modeling and correction scheme, calculates resistivity values that agree with the actual measurements. The inversion routine based on smoothness-constrained least-square optimization method was used for the data inversion (Loke and Barker, 1996; Amidu and Dunbar, 2008).

RESULTS AND DISCUSSION

Basement topography and Bedrock depth are important factors in terms of groundwater prospecting (Kumar, 2012). According to Olayinka et al., (1997), the typical geological sequence in a basement complex terrain consists of top layer, highly weathered layer, which is mostly clay/clayey sand. The interpretation of data result from the 2D ERT provide information on the lateral variations of formations, depth to basement rocks, resistivity of the weathered/fractured basement, presence or absence of fracture zones and aquifer potential.

PROFILE 1

The profile runs to about 160m with latitude N 7^0 24’23” and longitude E$3^0$19’ 2”. The first layer has a resistivity values ranging from 1100Ωm to about 2700Ωm with depth <1.6m with a lateral distance extending to about 43m which is then suspended by an underlain material. It then continues from about 52m to about 72m and suspended by same material. It also continues from 85m to 102m and to about 140m. The first layer is an outcrop that can be interpreted as a pegmatite. The second layer which occur around depth of about 1.6m-3.7m with a less resistivity material ranging from about 1100Ωm to about 850Ωm. It extends with a lateral distance to about 44m which then suspends and then continues to about 152m. It can be interpreted as a weathered material. The third layers occur at depth which ranges from 3.7m to about 11m. it extends down to about 150m in length. It has a resistivity value of about 420 to about 764Ωm. The third layer can also be interpreted as weathered material. It plays host to a water bearing unit with depth at about 6.6m to above 11m with lateral distance from 6m to about 37m. A water bearing unit can also be found at lateral distance 62m to 88m which can be called confined aquifer. It can also be found at about 3.5m to about 11m in depth with a lateral distance or about 102 to about 107m. It can be interpreted to be a perched aquifer. The medium has a resistivity ranging from 202 to about 393m.This is then underlain by a material which can be interpreted by a fresh bedrock with resistivity value ranging from about 1300Ωm to about 2100Ωm with depth >12m (Figure 3).

PROFILE1

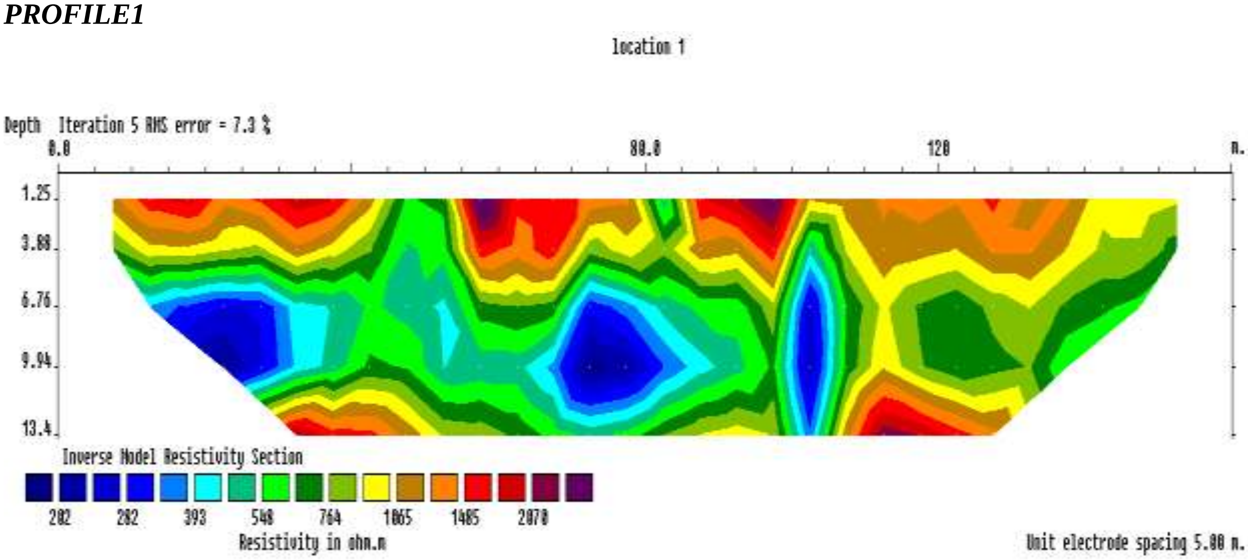

Figure 3: Showing the pseudo section for profile

PROFILE 11

The profile to about 150m with latitude 7° 24’ 02.3” N as longitude of 3 ⁰ 16’ 24.3” E with elevation of 146m.This profile depicts high level of weathering. This first layer extend to a lateral distance of about 40m and it is suspend at and continues to about 58, suspend at. Then from >5m in depth, it can be interpreted as a regolith with resistivity value ranging from about 7.09 to about 176Ωm.The second layer constitute weathered material with resistivity value of 176 to about 512 with depth >9.94m from lateral distance 25m to about 130m.The fresh bedrock /fresh basement can be seen at a lateral distance of about 80 to 122m at depth >9.9m (Figure 4).

PROFILE 11

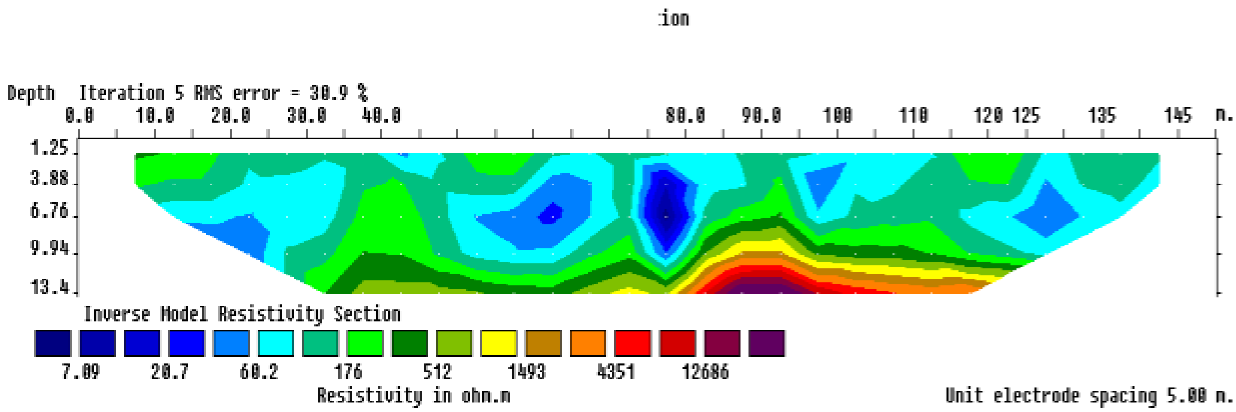

Figure 4: Showing the pseudo section for profile II

PROFILE 111

The profile run to about 150m with latitude N7° 24’ 31.8” and longitude E 3 ° 16’ 34.8” and elevation of about 142m**.**The first layer can be interpreted to be a weathered material with resistivity value ranging from 96.7 to about 231Ωm with depth > 10m. its extends down to about 143m in length. Enclosed in this weathered material are water bearing unit with resistivity value ranging from 7.15 to about 50Ωm at 143m.At the underlain layer can be interpreted to a (fresh) basement rock with resistivity ranging from 1100Ωm to about 3121 and with depth712m. It extends from about 20m to about 125m (Figure 5).

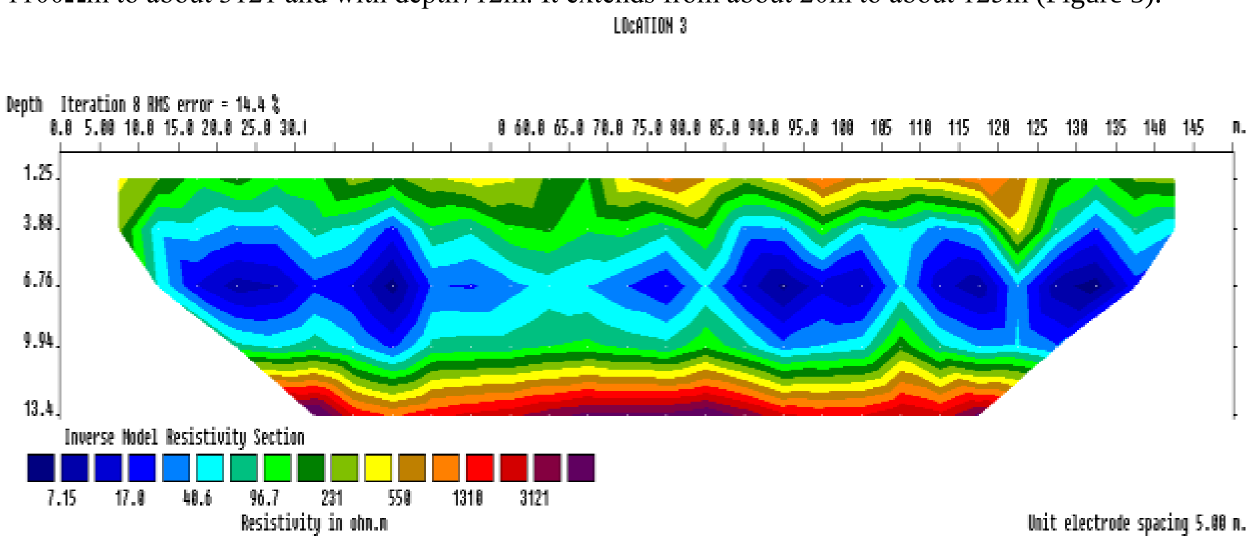

Figure 5: Showing the pseudo section for profile 5

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PROFILE 1V

The location runs to about 150m. It has latitude of N 7 ° 24 9" and longitude E 3 ° 6 32.2" .The first layers depict weathered material which is then suspended at interval 37 to 64m, 77 to 90m and then continues to about 145m. It is suspended by a less resistive material. The second layers show a medium that can be classified as a water bearing unit. It get recharge between lateral distance of about 27 to 64m, same with 79 to 90m.The second layer is underlain by a material tht can be interpreted as a basement rock at depth >11m with lateral distance of about 25m to about 93m. Resistivity value ranges from about 1783Ωm to 3991Ωm (Figure 6).

PROFILE 1V

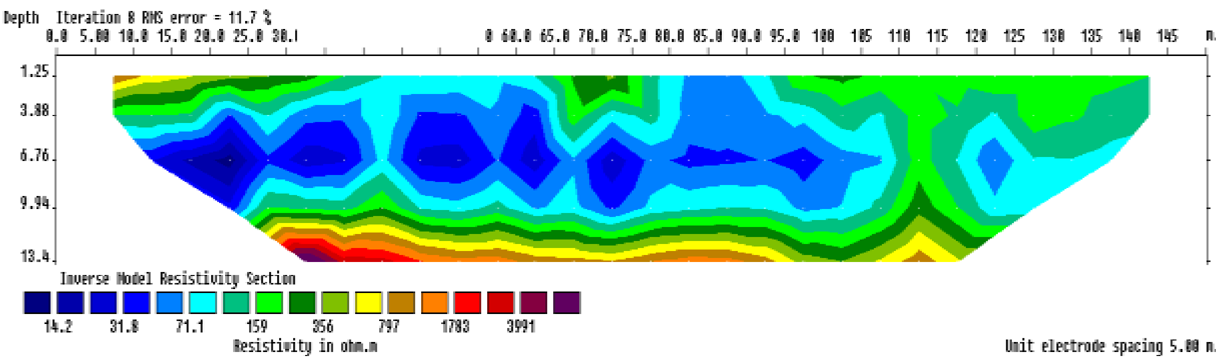

Figure 6: Showing the pseudo section for profile IV

PROFILE V

The profile runs to above 150m with latitude 7 ° 25' 33.2" and longitude E 3 17 '4.3". The profile depicts a high level weathering zone 1 Differential weathering. At depth <9.94.the different material depict regolith materials, which are loose material. At lateral distance which extends to about 25m show a material which can be interpreted as a regolith with depth < 13.4m and resistivity values which ranges between 36.0 to 50.4Ωm. At a lateral distance or about 25m to 60m show a material which can be interpreted as a weathered material with resistivity values ranging from 99 to bout 139Ωm which then suspended and continues at 80 to 95m in length (Figure 7)

PROFILE V

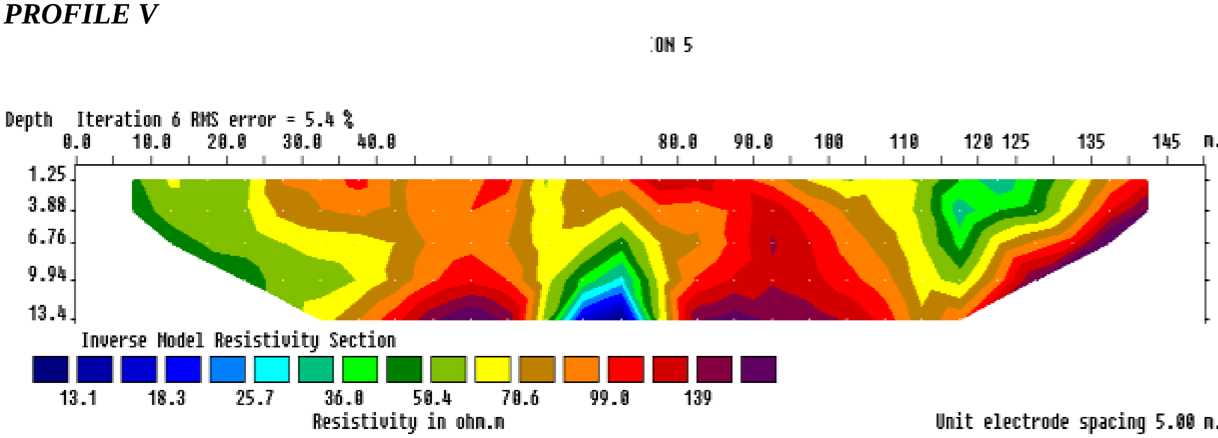

Figure 7: Showing the pseudo section for profile V

PROFILE V1

The profile runs to about 150m with latitude 7 ° 35' 34.3" and longitude E 3 ° 17' 14".The layer shows exhibit a high degree of weathering. The first layer shows /has a resistivity values ranging from about 82 to 124Ωm with lateral distance ranging from 35 to about 145m. it can be interpreted to be with depth of about < 3.75m.It is then underlain by a less resistive material which extend to about 145m at depth >3.75-3.88m with resistivity values 54.2 to about 56Ωm.This is then underlain by a weathered material of resistivity values about 23.7 to 35.9Ωm at depth of about 3.85 to about 150Ωm.The weathered material enclosed a water bearing unit of depth of about 6.5 to 11.4m and lateral distance of about 60 to 135m and resistivity values ranging from about 6.88 to 15.7Ωm(Figure 8)

PROFILE V1

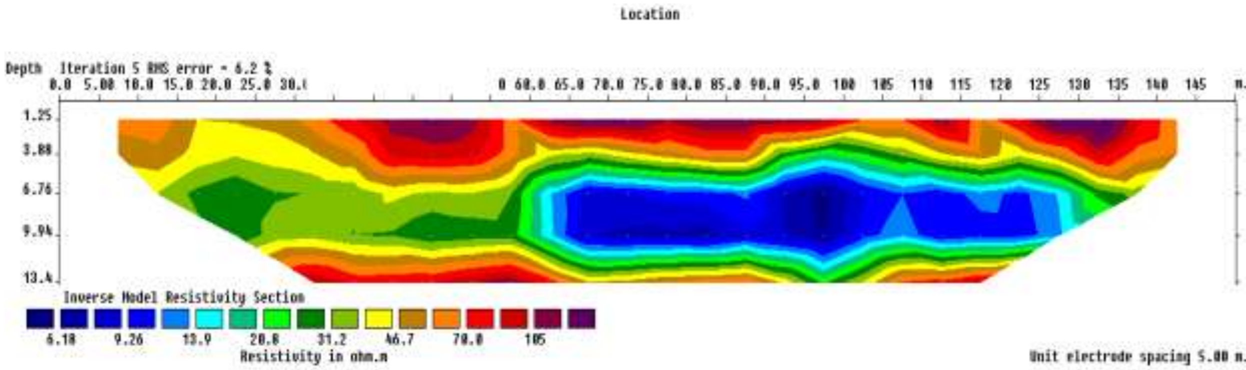

Figure 8: Showing the pseudo section for profile VI

PROFILE V11

The profile runs for about 150m with latitude N 7 ° 24' 19.5" and longitude of about E 3 ° 19 '26.3".The first layer runs from about 10m to around 35m (lateral distance)and was suspended and later emerge from about 80 m which runs to about 145m.it has a resistivity values which ranges from 27.8 Ωm to about 200 Ωm with depth from 1.25m to about 9.94 m. it can be interpreted as a thick regolith material.The layer which suspended this layer can be interpreted to be a weathered material with a lateral distance of about 20m to 60m and resistivity values of 25.8 Ωm to 600 Ωm. It was suspended by a fractured material with lateral distance 65m to 75m with depth from about 1.25m to about 13.4m and resistivity of about a 27.8 Ωm to about 58.4 Ωm. Between lateral distance 75m to about 90m shows an intrusion at about 6.5m to about 13.4min depth with resistivity values ranging from 258 Ωm to about 5022 Ωm. Fig. 9

PROFILE V11

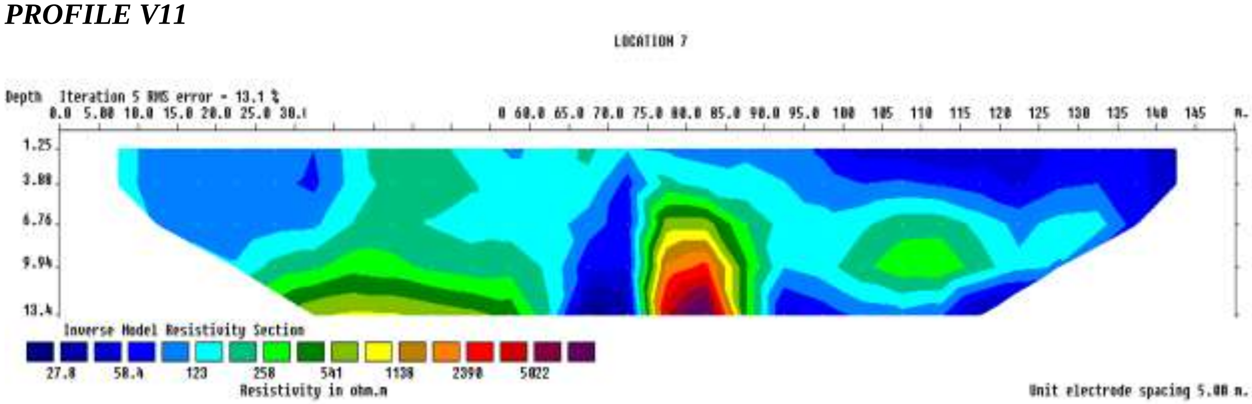

Figure 9: showing the pseudo section for profile VI1

CONCLUSION AND RECOMMENDATION

The pseudo section of location 1 depicts that water can be exploited from vadoze zone through shallow well because water occurred in vadoze zone at around 4.2m to about 15m in depth with lateral distance 5m to about 35m , 65m to 85m and a confined aquifer. In the location 2, the area is marshy, it has a thick regolith. The groundwater potential here can only surface to provide for shallow well due to its distance around > 1.25 to about 10.5m.Location 3, groundwater can be exploited in this area, but also at shallow depth at around 3.88m to above 10m in depth. As it can be found in the vadoze zone as shown by the pseudo-section of the area. In location 4, the location here has a high recharge rate, groundwater can be exploited in these area. The water that can be exploited here is referred to as vadoze water zone. This zone is underlain by a more resistive material. The water can be explored at depth 1.25m to above 10m.Location 5, highly weathered, thick regolith, water can be exploited at around 10m depth at lateral distance of about 65-80m.Location 6, water can be explored in these area, at about 60 to above 120m in relation to the lateral distance and with depth of about 5.8m to about 13.4m.Location 7, water can be exploited in these area at a lateral distance 60m to 75m at depth > 1.25m to about 13m. 2D electrical resistivity tomography has provided a clear view of lithological unit of weathering profiles and geological structure favorable for ground water exploration. The result shows the geo-electric layers with possible rock type. Here the possible aquifer / groundwater potential of each location can be determined.

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