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Vertical Electrical Sounding Investigation for Groundwater at The South-Western Part (Site A) of Nigerian Mobile Police Barracks (Mopol 12), David Mark Road, Maitumbi, Minna.

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Abstract

A Geophysical Investigation of the South-Western part of the MOPOL 12 Barracks, David Mark Road, Maitumbi, Minna, Niger State, was carried out using Vertical Electrical Sounding (VES) method. A total number of thirty-six (36) VES Stations were mapped out and covered using the Schlumberger method of electrical sounding (VES). The Data obtained from the VES was subjected for analysis using Zohdy (computer software). Thereafter, the results from Zohdy curve were subjected for further processing using Surfer 8 (window based computer software). From the digitized Zohdy curve data obtained, Iso-resistivity maps at different depths, Geoelectric Vertical Sectioning of each profile, and the depth to basement maps were obtained. The Vertical Sectioning of each profile suggests the existence of three Geoelectric layers. The first layer has resistivity values between 20Ωm to 200Ωm which corresponds to lateritic topsoil, fadama loam, sandy-clay and gravel. The second layer has resistivity values ranging from 200Ωm to about 900Ωm typifies weathered and fractured basement. While the fresh basement forms the third layer and characterized with resistivity value above 1000Ωm. The results of VES, corroborates with the results from Electrical Profiling method earlier conducted for. The promising regions to exploit underground water (aquifer) within the survey area are VES points (needs review: A2, A3, A4, A5, B3, B4, B5, D2, D3, D4, D5, D6, E4, E5 and E6). The civil engineering work could be better located at Northeastern and southern parts of the study area where the basement is uplifted.

Keyword: Geoelectric, Resistivity, Basement, Vertical Electrical Sounding (VES) and Aquifer

Introduction

The search for clean, portable and long-lasting water is a struggle that will never end, as it aids in the growth of any community. This growth is a function of the availability of basic infrastructural needs such as water, good roads, and electricity. Niger State being one of the states in northern Nigeria used to experience an annual rainfall that varies from about 1,600mm in the south to 1,200mm in the north. The duration of the rainy season ranges from 150-210 days or more from the north to the south. The amount of rainfall is limited to very few months in a year so acquisition of water from surface sources cannot meet the demand or in most cases are non-existent (Baimba, 1978, Perez and Barber, 1965).

As a source of uncontaminated water, groundwater is becoming more important for many needs, especially for agriculture and drinking purposes. Therefore, methods used for locating suitable groundwater aquifers and their hydro geological conditions should be more efficient. Recently, geophysical methods - particularly the electrical resistivity methods - are playing a satisfactory role in groundwater investigations. Although the resistivity tool will never replace the test drilling for the groundwater investigations, it does sometimes reduce the amount of test drilling through the good selection of test hole sites. This will minimize the information/cost ratio and avoid the excessive drilling use for measuring the

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hydraulic parameters of any aquifer (Helaly A.M, 2002).

Groundwater is water found below the surface of the land, such water exists in pores between sedimentary particles and in the fissures of more solid rocks. Very deep-lying groundwater can remain undisturbed for thousands or millions of years. Groundwater is of major importance to civilization, because it is the largest reserve of drinkable water in regions where humans can live. Groundwater may appear at the surface in the form of springs, or it may be tapped by wells. During dry periods it can also sustain the flow of surface water, and even where the latter is readily available; groundwater is often preferable because it tends to be less contaminated by wastes and organisms. Obtaining groundwater depends on the type of subsurface rock materials found in the area. Saturated permeable layers capable of providing a usable supply of water are known as aquifers. Aquifer is a body of rock or soil that is sufficiently porous and permeable to store and transfer significant amounts of groundwater. The flow of water into aquifers is called recharge and the flow of water out of aquifers is called discharge. (www.mqtinfo.org)

The location of wells or boreholes must be done in areas that have high recharge rate of aquifers, for long lasting supply even during dry seasons. Practical methods of achieving this include application of scientific knowledge, drilling experience, and common sense. (Raymond S., www.mqtinfo.org)

Location of the Study Area

The site of survey was the Mobile Police Barracks 12, located on the outskirts of Maitumbi on David Mark Road. It shares a boundary with El-Amin Secondary Schools in Bosso L.G.A in Niger State. The study area is on the North-East part of Minna and lies between latitude 9:6139°N and longitude 6:5569°E. (Figure 1 shows the study area).

Minna is located in Niger State and like other states on the same latitude, is covered by two major rock formations, that is the sedimentary and basement complex rocks. The sedimentary rocks to the south are characterized of sandstones and alluvial deposits. (www.onlinenigeria.com, 2008). The site spans an area of 250m × 250m or 62.5square kilometers.

Geology of the study area

The rock types found in the study area are believed to be part of the older granitic suite and are mostly exposed along the river channel where they appear in most cases weathered [Udensi, Ojo and Ajakaiye, 1986]. The major rock types are porphyritic, medium to fine grained granite [Adesoye, 1986 and Adeniyi, Udensi, and Okosun, 1988]. The results of the borehole log from the area show that the area has a good potential for ground water development [Jimoh, 1998].

The surface geoelectric (resistivity) method, particularly the VES method has been chosen for this work because it has proved to be an economic, quick and effective means of solving most ground water problems in different parts of the world [Brusse, 1963, Zohdy and. Jackson, 1969 and Frohlich, 1974]. The method is also used to estimate the thickness of the overburden as it is presented in this work [Parasnis, 1987].

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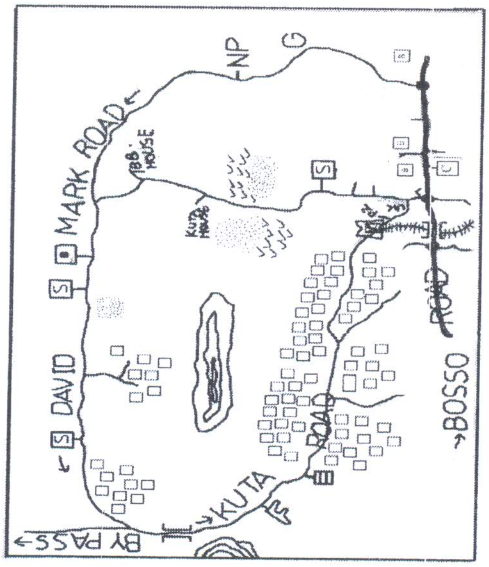

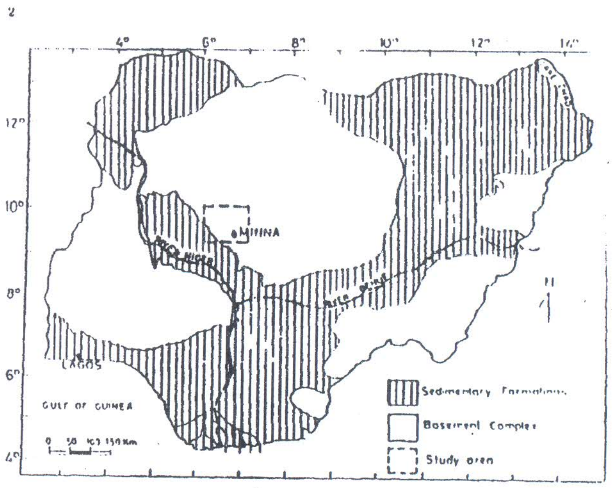

KEYS

	MAJOR ROAD		ROUND-ABOUT		POLICE STATION
	MINOR ROAD		CULTIVATION		BRIDGE
	SITE UNDER STUDY		HILL	G	GRAVEYARD
S	SCHOOL	F	FUEL STATION	NP	NIG. PRISON
B	BANK		SAW MILL	M	MARKET
	RESIDENTIAL BUILDING		RAILWAY	C	CENTRAL BANK OF NIG

Figure 1: Map of the Study Area, Showing the Location and Accessibility of the Study Area and The Geologic Map of Nigeria (Adesoye, 1986 and Udensi *et al,* 1986).

Data Collection

The study area was gridded as shown in Figure 2. Thirty-six (36) VES points were covered. The Terrameter SAS 4000 was the instrument used and it is capable of operating in different modes, namely: Resistivity, Self-potential and Induced Polarization. The Schlumberger array method was used for the VES survey.

Data Analysis

The resistance values obtained on the field was processed and converted into apparent resistivity using the general apparent resistivity equation illustrated in the preceding chapter. This apparent resistivity values obtained was then interpreted using an iterative computer program called Zohdy Graphical Method *(Zohdy et al, 1989).* The Zohdy Graphical Software performs an automatic interpretation and produces the Schlumberger sounding curves. The curves give the equivalent n-layered model of the earth subsurface from the apparent resistivity of each sounding point. Surfer8, a graphic computer package was then used to produce the contour maps of data deduced from the Zohdy interpretation.

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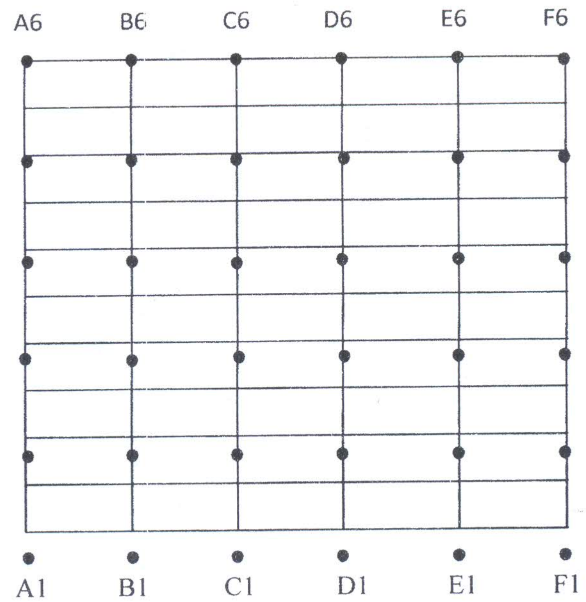

Figure 2: The survey outlay. The letters and numbers indicate profiles and sounding points respectively.

Data Interpretation

The interpreted Zohdy model was used to construct the following maps, which enhanced a very detailed interpretation of the field data obtained:

(i) Contour Map of Geo-electric Vertical Section through Profile

(ii) The Iso-resistivity maps at different depth and

(iii) Depth to Basement or Overburden Contour Map

Interpretation Of Vertical Sections Through Profile

For easy and accurate interpretation of the results of the VES, electrical vertical section of each profile was derived from the Zohdy curves and contoured. The geologic section of each of the profiles was derived from the geoelectric vertical-sections using the available resistivity values of rock types in basement area (Table 1).

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Table 1 shows the resistivity values of different rock types in the Basement complex of Nigeria (Olorunfemi and Fasuyi, 1993).

Table 1: Resistivity Values of Rock Types

ROCK TYPE	RESISTIVITY (Ωm)
Fadama loam	30 – 90
Sandy clay and sandy silt	100 – 200
Sand and general laterite	150 – 1000
Weathered laterite	150 – 900
Fresh laterite	900 – 3500
Weathered basement	20– 200
Fractured basement	500 – 1000
Fresh basement	>1000

(i) First layer consists of dry Lateritic topsoil, fadama loam, sandy-clay, and gravel and has resistivity values below 300Ωm with thickness between 0.39m to about 20.0m. This layer has average thickness of about 13m.

(ii) The second layer consists of weathered and fractured basement with average thickness of about 25m. Its resistivity values ranges from 300Ωm and about 900Ωm. This constitutes the aquifer system of this area.

(iii) The third layer is the fresh crystalline basement, which constitutes the bedrock of the area and has infinite thickness.

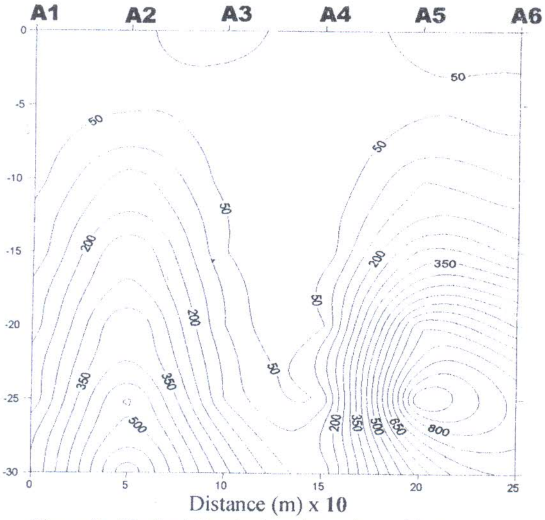

Figure 3: Vertical Sectioning through profile A
Contour interval 50ohm-m

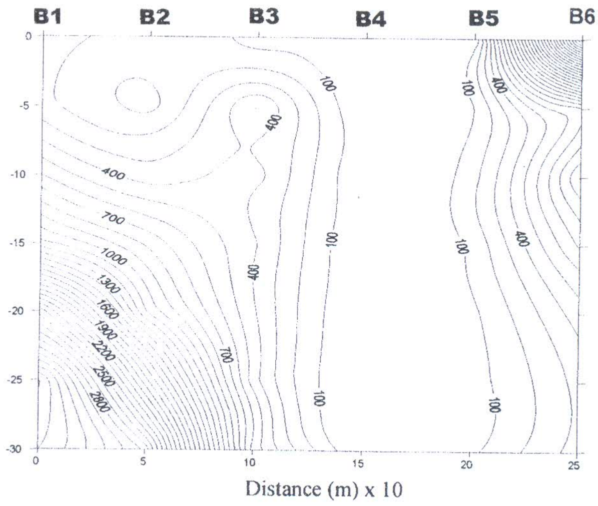

Figure 4: Vertical Sectioning through profile B
contour interval 100ohm-m

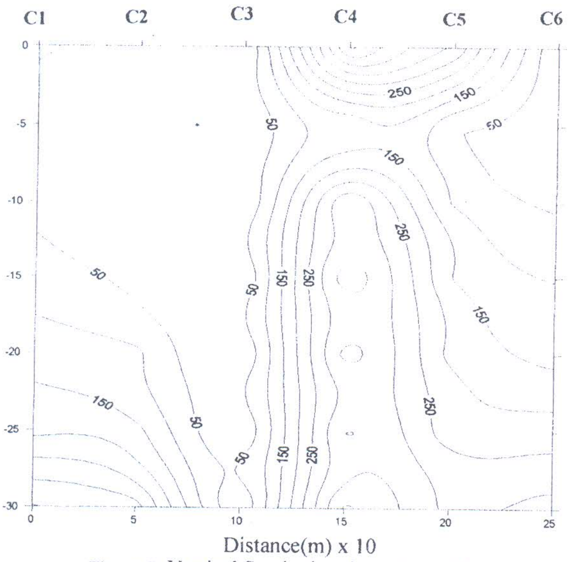

Figure 5: Vertical Sectioning through profile C
Contour interval 50 ohm-m

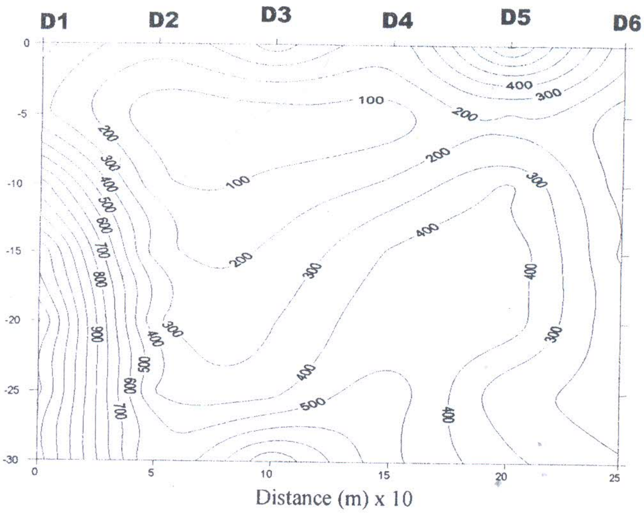

Figure 6: Vertical Sectioning through profile D
Contour interval 100ohm-m

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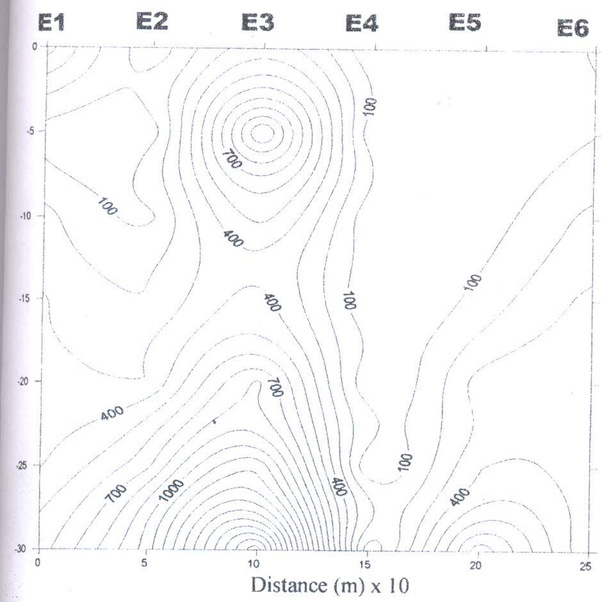

Figure 7: Vertical Sectioning through profile E
Contour interval 100ohm-m

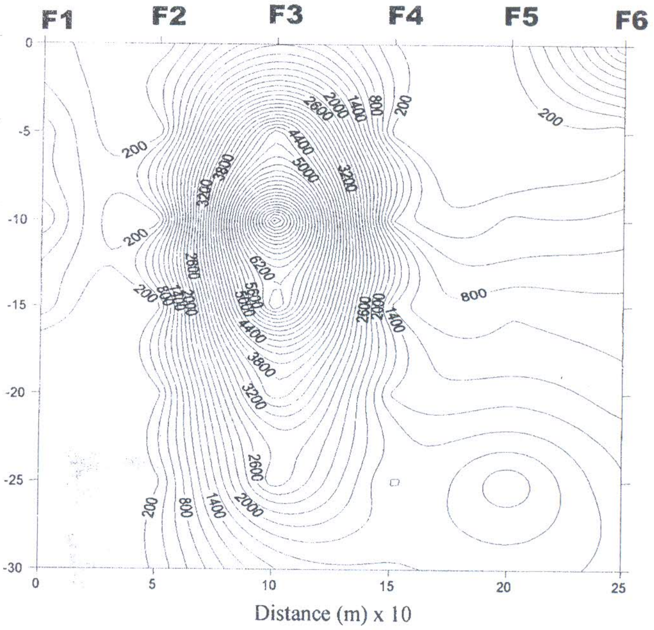

Figure 8: Vertical Sectioning through profile F
Contour interval 200ohm-m

Interpretation of Iso-Resistivity Contour Map at Various Depths and Deductions

Iso-resistivity maps show the conductivity pattern with depth through slicing of the entire study area horizontally or through a cross-section. These maps give a detailed and qualitative interpretation of hydro-geophysical aspect of the study area. The cross-sectional maps were used to corroborate the results of the vertical sections. These maps include the resistivity map of the topmost layer and iso-resistivity maps at depth of 5m, 10m, 15m, 20m, 25m and at 30m. The deductions made from them are discussed below.

Iso-Resistivity At The Topmost Soil (Surface):

The Iso-resistivity contour map at the surface was produced at 50Ωm contour interval in figure 9a. This map shows areas of low resistivity value between 50Ωm to 500Ωm at A1 to A5, B2 to B5, C1 to C6, D2 to D4 and D6, E1 to E5 and E6, F1 and F5. These areas of low resistivity values as observed on the field were covered with fadama loam, sandstones and clay. With respect to the result obtained from the vertical section map, the high resistivity value found apparent at B6, F3 and F6 of figure 4 and 8 respectively corresponds with the high resistivity values of 1000Ωm and above, of figure 9a. This was as a result of outcrop of rock found around the VES point

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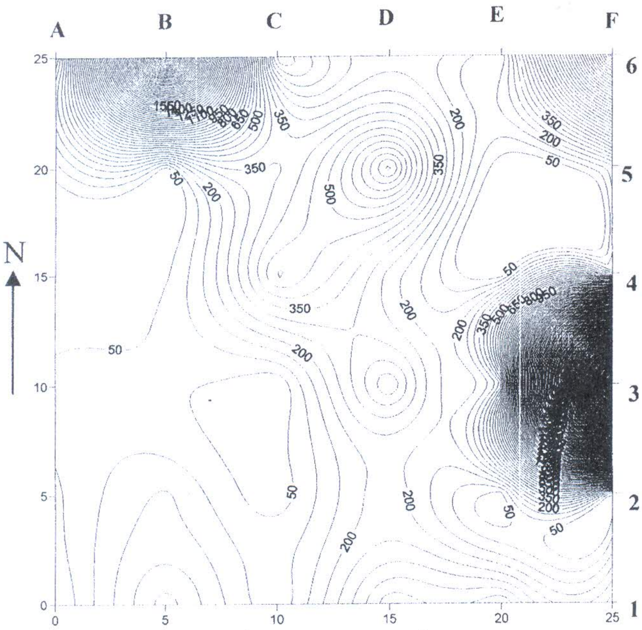


Distance (m) x 10 on both axes
Figure 9a: Iso-resistivity contour map at Surface
Contour Interval 50 ohm-m

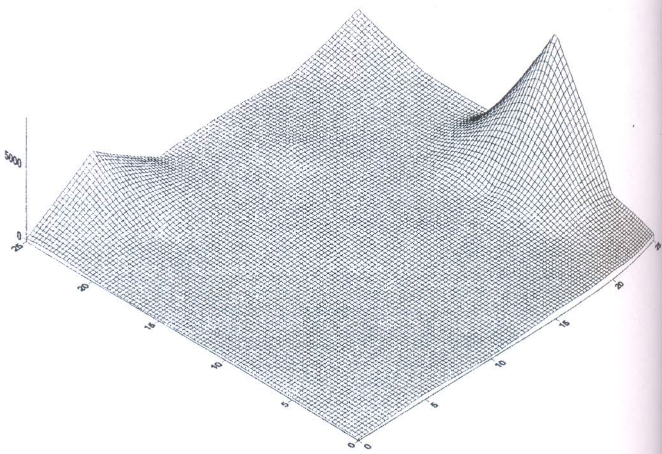


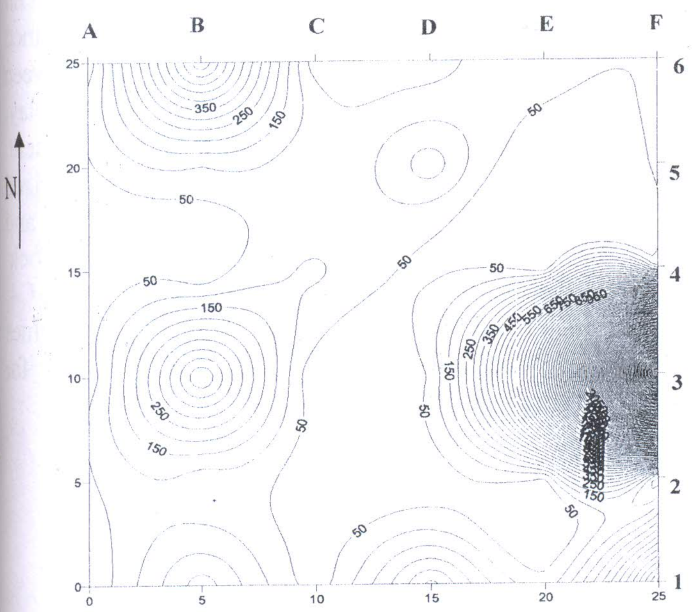
Figure 9b: three dimensional contour map of resistivity at depth

Figure 9b shows a three dimensional form (wire-frame) of the entire features at surface. This map shows the reflection of what was obtained or deduced from vertical section of the profiles. For example, the high resistivity area (Eastern Northeastern and Northwestern region) of figure 9a corresponds with the high resistivity area, B6, F3 and F6 of figure 3 and figure 7

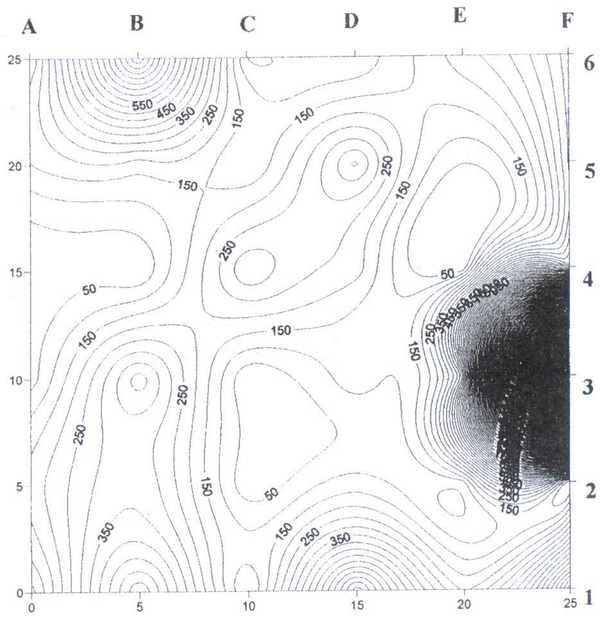
The Iso-Resistivity Contour Map at Various Depth and Basement Contour Map

Figure 10 shows the iso-resistivity contour map at 5m depth. The map is contoured at an interval of 50Ωm. It is characterized with a considerable low resistivity values between 50Ωm to 500Ωm which covers the entire area. This low resistivity values might be due to the presence of fluid (water content). The high resistivity value which was observed in iso-resistivity at topsoil is still feasible with relatively high resistivity value of 1000Ωm and above at B6 and F3. The material (rock sample) suggests here are fractured and fresh basement.

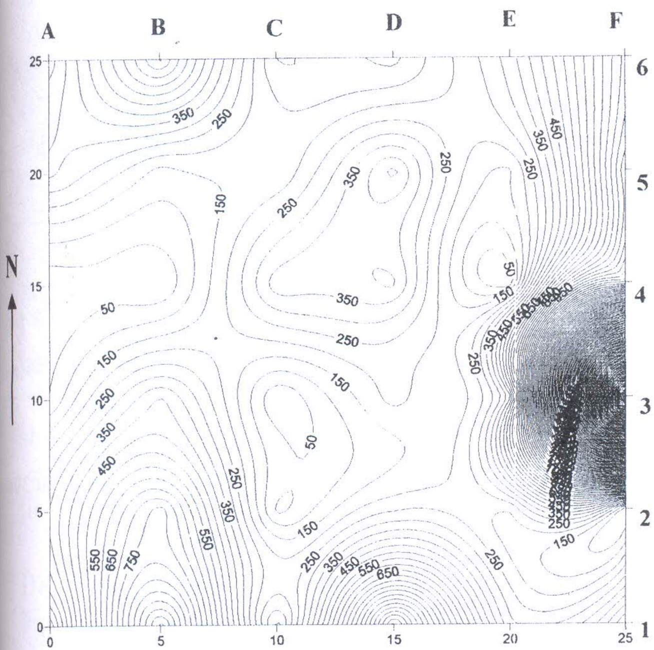
The Iso-resistivity contour map at 10m depth is shown in figure 11. The map is contoured at interval of 50Ωm, which is characterized with low resistivity values between 50Ωm to 500Ωm which spreads throughout the entire area except B6 and F3 which characterized with an outcropping material with resistivity value of 1000Ωm and above. From this feature, the material (rock sample) suggests here are fresh basement and clay rock type. Thus, this high resistivity value was noticed also at D1.



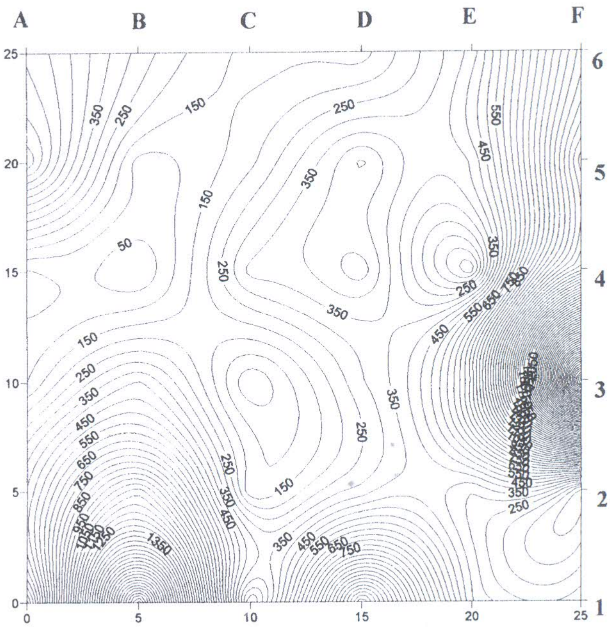
Distance (m) x 10 on both axes
Figure 10: Iso-resistivity contour map at 5m
Contour Interval 50 ohm-m



Distance (m) x 10 on both axes
Figure 11: Iso-resistivity contour map at 10m
Contour Interval 50 ohm-m



Distance (m) x 10 on both axes
Figure 12: Iso-resistivity contour map at 15m
Contour Interval 50 ohm-m



Distance (m) x 10 on both axes
Figure 13: Iso-resistivity contour map at 20m
Contour Interval 50 ohm-m

The Iso-resistivity contour map at 15m depth figure 12 is contoured at 50Ωm interval. This is very similar to map obtained at 10m depth, but the outcropping material is apparent at A1 and D1 apart from F3, hence,

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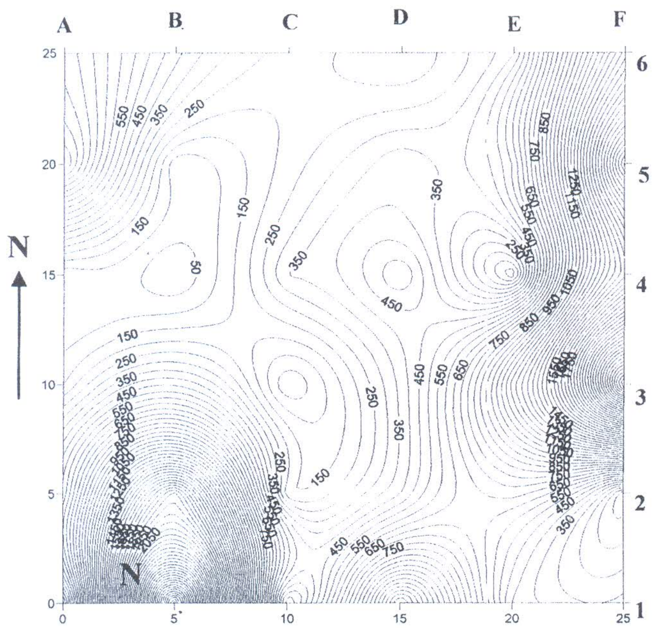
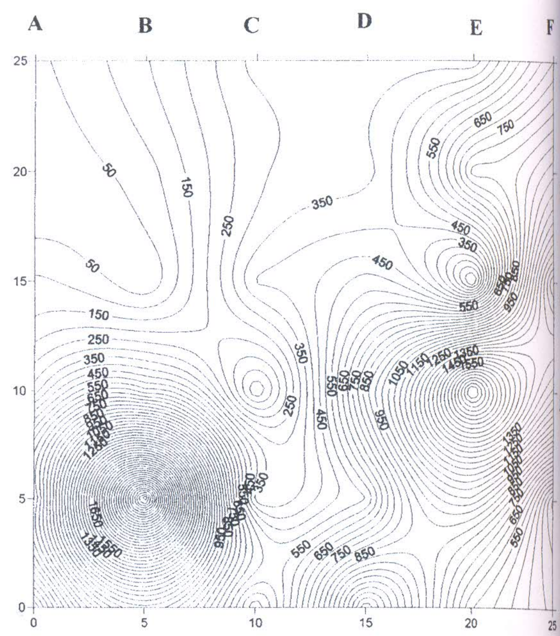
from this high resistivity values, it suggests fresh basement and clay rock types.

The Iso-resistivity contour map at 20m depth figure 13 is contoured at 50Ωm interval, which characterized with a resistivity value between 50Ωm to 500Ωm, except for A1, B1, B2 and F3 which have resistivity value ranges from 1000Ωm and above, meaning that the entire region is characterized with rock type of sandy clay, gravel, weathered basement and fractured basement. The Region with resistivity value greater than 1000Ωm A1, B1, B2 and F3 is likely to be fresh basement rock.

The Iso-resistivity contour map at 25m depth figure 14 is contoured at 50Ωm interval. This is very similar to map obtained at 20m depth with resistivity value between 50Ωm to 500Ωm, suggesting sandy clay, gravel, weathered and fractured basement. A1, B1, B2, F3, F4 and F5 are characterized with high resistivity values of 1000Ωm and above, thus suggesting fresh basement rock. Relating with VES profile, area A4, B4, C4, D2, D3, D5 and E5 with resistivity values below 500Ωm are likely good points for water development.



Distance (m) x 10 on both axes
Figure 14: Iso-resistivity contour map at 25m
Contour Interval 50 ohm-m



Distance (m) x 10 on both axes
Figure 15: Iso-resistivity contour map at 30m
Contour Interval 50 ohm-m

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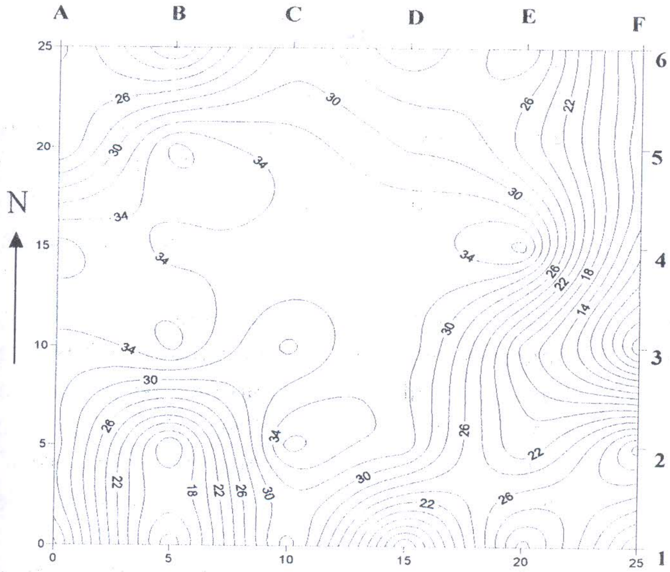

Distance (m) x 10 on both axes
Figure 16a: Depth to Basement contour map
Contour Interval 2m

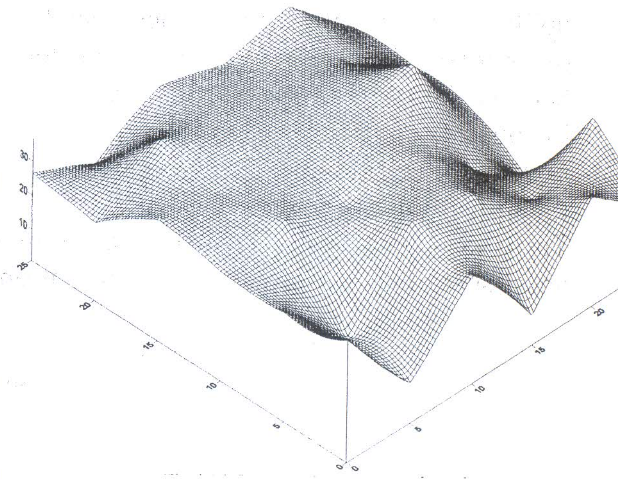

Figure 16b: Three Dimentional Depth to Basement

Figure 15 shows the iso-resistivity contour map at 30m depth contoured at 50Ωm interval. The area characterized with resistivity value between 50Ωm to 500Ωm suggests sandy clay and weathered basement as possible rock types. Those areas correspond to VES points E1, E4, F1 and F2 could be slightly weathered or fractured basement. And those areas above 1000Ωm are fresh basement.

In summary, the Central and North-Western part of the survey area are characterized with relatively low resistivity values, which shows the level of water saturation at the depth of 30m. This deduction agrees with those inferences drawn from figures 3 to 8.

Depth to Basement Map

Figure 16a is contoured at 2m interval; it shows that basement varies from 14m to 36m. From the map, it can be seen that the whole of the Central and North-Western region are characterized with deep basements. The depth of about 22m to 36m could be found in those regions. However, Northeastern and Southern region of the survey area are characterized with shallower basement. *A three dimensional form (wire-frame) of the basement depth structure is as shown in figure 16*b. The aquifer performances in the weathered basement are determined by its thickness at the drilled point. Similarly, areas of deep depressions of shallow basement may probably serve as recharge points for underground water.

Figure 16b however shows that, those areas with depressional features (valley) are those areas identified as having good potential for underground water resources, this agrees with both the vertical section and the iso-resistivity at various depths. Similarly, areas with elevated basement could be used for civil engineering works.

Discussion

There are three geologic sections found beneath the VES stations which revealed various lithological compositions. The first layer of this geologic section suggests the existence of lateritic topsoil, fadama loam, sand-clay and gravel. The second layer suggests the presence of highly weathered

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and fractured basement. The third layer consists of fresh basement of the area.

The map of depth to basement shows that, areas with outcrop of rocks are areas with uplifted basement and hence shallow overburden. The areas with basement depth between 15m to 28m are areas characterized by low land and fadama; this could be found prominent at Central and North-Western of the survey area.

There are three major factors that determines areas suitable for groundwater exploitation, these are:

1. The thickness of aquifer
2. The presence of suitable aquifer (weathered and fractured basement
3. The conductivity of the subsurface: the presence of groundwater will result to low resistivity value and hence high conductivity.

From the above factors, deductions made from this indicate that zones or areas that will be considered to be suitable for groundwater exploitations are the weathered basement, and fractured basement which is the major component for aquifer system.. Thus, where the fractured zone is saturated, relatively high groundwater yield can be obtained from borehole penetrating such a sequence. Weathered and fractured basement (the second layer of the survey area) satisfies these three conditions.

Conclusion

The results obtained from the interpretation of the data for this survey have shown the efficiency and suitability in the use of electric resistivity method in probing subsurface structures and underground water in the basement complex area.

The results of the investigations show that the study area is made up of three geologic layers. The first layer has lateritic topsoil, fadama loam, sandy-clay and gravel as its major constituents. The second layer is characterized by weathered and fractured basement, while the third layer is the fresh basement rock.

The areas identified as suitable for groundwater exploitation are VES points A2, A3, A4, A5, B3, B4, B5, C3, C4, C5, D2, D3, D4, D5, D6, E4, E5 and E6 of the study area, these points corresponds to Central and North-Western part of the survey area. This is so because they are made of weathered and fractured basement which constitutes the aquifer system found on the study area. Similarly, the North-eastern region and Southern region of the study area are identified as most suitable for civil engineering works.

We thereby noted that this work correlates almost in totality with our findings from the preliminary survey earlier carried out on this site (A).

Recommendation

It can be said convincingly that the use of electrical resistivity method is very reliable in subsurface water survey, though other geophysical survey methods could be employed for to compliment the deductions made from this method and perhaps to draw more detailed deductions and affirmations.

However, the promising regions to exploit underground water (aquifer) within the survey area are VES points A2, A3, A4, A5, B3, B4, B5, C3, C4, C5, D2, D3, D4, D5, D6, E4, E5 and E6 with an aquifer thickness of about 22m. Those areas are identified as good aquifer should be drilled and the water should be collected for analysis so as to ascertain its portability.

The civil engineering work will be located at Eastern, North-eastern and North-Eastern region of the study area.

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