MEDWIN PUBLISHERS
Committed to create value for Researchers
Open Access Journal of Waste Management & Xenobiotics
ISSN: 2640-2718

Geoelectrical Assessment of Aquifer Potentials and its Vulnerability to Contaminant at El-Amin Proposed University Site, Minna, Niger State, Nigeria

Ahmed A[1], Alhassan DU[1], Shehu J[1*], Alkali A[1], Alabi OO[2] and Mohammed A[3]

[1]Department of Geophysics, Federal University of Technology Minna, Nigeria

[2]Department of Physics, Osun State University, Osogbo, Nigeria

[3]Department of Physics, Niger State College of Education, Nigeria

Research Article

Volume 2 Issue 2

Received Date: April 24, 2019

Published Date: May 22, 2019

DOI: 10.23880/oajwx-16000121

***Corresponding author:** Shehu J, Department of Geophysics, Federal University of Technology Minna, Nigeria, Email: jameeelshehu@futminna.edu.ng

Abstract

Vertical Electrical Sounding (VES) survey was carried out at EL-Amin proposed University site, Located along Eastern bye pass Minna, Niger State, Nigeria. It lies in the basement complex region of Northern Nigeria. The survey was carried out with the aim of determine the ground water potentials of the area and evaluate its aquifer protective capacity. The technique employed was the Vertical Electrical Sounding (VES) using Schlumberger array. A total of 48 VES points were sounded on grid profiles separated by 100 m apart with VES spacing of 100 m. Three to four layers were observed. The Stratigraphy of subsurface shows: topsoil with resistivity range from 0.4 to 277.89 Ωm, Weathered/Fracture basement layer having resistivity vary between 31.0 and 982.89 Ωm and Fresh basement with resistivity range from 19.1 to 79935.239 Ωm. The Weathered/Fractured layer was considered as aquiferous horizon. The Longitudinal Conductance and resistivity Contour maps were produced. Thirteen VES points were delineated as groundwater potential with resistivity ranging from 45.5 Ωm to 611.77 Ωm, thickness ranging between 3.5 m and 13.07 m and depth ranging from 8.8 m to 24.43 m which represent about 18.75 percent of the area. The south, south-east and north-west portions of the area are underlain by materials of moderate to good protective capacity while the western and central part of the area with thin overburden coincided with weak to poor protective capacity which will expose the groundwater in the area to pollution.

Keywords: Geo-electric; Resistivity; Basement; Aquifer and Vertical Electrical Sounding (VES)

Introduction

The essential need for the development of any area is the availability of basic amenities like water, roads, electricity and industries among others. More than 300 million people in Africa today do not have access to clean water [1]. Many communities meet their daily water need from rivers, lakes, or reservoirs, sometimes using aqueducts or canals to bring water from distant surface water sources [2].

Groundwater is of significant importance to Northern Nigeria where the amount of rainfall is limited to very few months of the year with annual rainfall of 1000-1500mm [3]. Surface water sources are often inadequate or non-existent [4]. There is then need to carry out geophysical investigation in the proposed university site, particularly if satisfactory living conditions of the inhabitants are to be catered for. The University site is located in the capital where there is rapid growth in population. Consequently, there would be need to locate aquifer potential, the protective capacity of the aquifer to contaminant and delineate the areas.

Locations and Geology

The study area (Figure 1) is located in Minna, Niger State; Minna (Figure 2) is situated in the central part of Nigeria basement complex, surrounded by rugged terrain of granitic rocks. The area (Figure 1) is bounded by longitude $6^0$34'E to $6^0$43'E and latitude $9^0$36' to $9^0$59'N. It comprises of meta-sedimentary and meta-igneous rocks which have undergone poly phase deformation and Metamorphism. The area has a typical Guinea savannah climate with distinct wet and dry seasons: a dry season which usually last from December to March and accompanied rainy season which last from April to October. The study area is part of Minna Sheet 164 and falls within the Basement Complex Terrain of Nigeria. The Nigerian Basement Complex forms part of the ancient African shield, bordered to the west by West African Cratonic Plate and underlies about 61% of Nigeria's land mass [5].

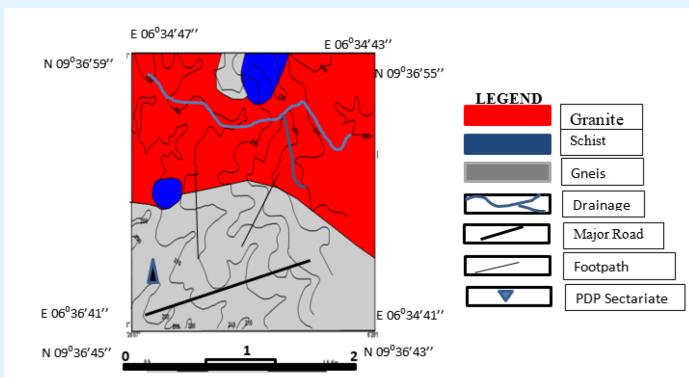

Figure 1: General Geology Map of Nigeria Showing the Location of the study Area.

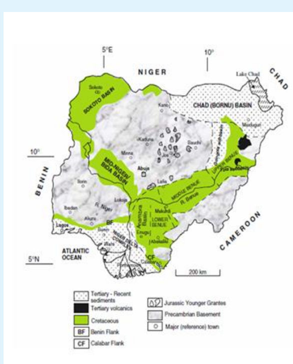

Figure 2: Geology Map of the Study Area.

Materials and Methodology

The instrument that was used for the d.c resistivity data collection is the Resistivity Meter with model number ABEM TERRAMETER SAS-4000. The instrument is house in a portable metal box and has the following components:

- **Power source:** The power is a d.c supply from a battery of 5,000 millivolts outputs.
- **Meters:** The Resistivity-Meter SAS-4000 Model has digital meters capable of displaying the value of resistivity for each measurement.

- Metal electrodes of about 0.5m long each
- Hammers with wooden handle
- Light insulated wires wound on portable reels
- Connecting cables
- Tape

General Principles of Electrical Resistivity Method

The electrical resistivity method measures both lateral and vertical variation in ground resistivity from different points on the earth surface. The resistivity of the ground is measured by sending current into the ground at the current electrodes and the corresponding potential difference is measured at the potential electrodes, which is then converted to apparent resistivity value by multiplying with an appropriate geometrical factor. Different factors affect the resistivity in the subsurface [6]. Pore spaces in rock particles may be in the form of intergranular voids, joint, or fracture openings and closed pores such as bubbles or vugs (in lavas). Only the interconnected pores effectively contribute to conductivity and the geometry of the interconnections. Also, the degree of saturation influences the resistivity of rocks. Moreover, as water forms a conductive electrolyte with the presence of chemical salts in solution, the resistivity varies inversely with to the salinity. Also, the effect of increase in temperature tends to decrease the resistivity of the electrolyte because the viscosity of the fluid decreases. The large variations in the electrical resistivity values of different rocks and minerals make the Electrical resistivity method very useful. The electrical resistivity method can be used in mineral exploration to map massive ores, in groundwater exploration to delineate aquifers, in geothermal exploration to locate geothermal fields, in engineering site investigation to determine depth to bedrock, and in environmental studies for environmental assessment.

Field Procedure

The field procedure began by pegging at equal distance of 100 m along each profile; the pegs were spotted for electrodes. The gridding strings ensure the profile were straight, the tape aided in measurement. After the pegging was done, an array of four non-polarizable electrodes consisting of two potentials electrodes flanked on the extremes by two current electrodes traversed each profile measuring 100 m long.

Data Collection

The Field data was collected using Schlumberger array, forty eight (48) VES points were sounded using a maximum electrode separation of 100 m and 15 m maximum for potential electrode (MN). The terameter ABEM SAS 4000 model instrument was used for data collection. Direct current was introduced into the ground and the resulting potential difference was measured across the two other electrodes. The ratio of the potential difference to current was displayed by the terameter as the earth resistance as the electrodes spacing is progressively increased and keeping the centre point of the electrodes array fixed. At a small electrode spacing, the apparent resistivity is nearly the resistivity of the subsurface material, but as the current electrodes spacing increases, the current penetrates deeper layers which ranges between one-third(1/3) to the one-fourth (1/4) of the current electrodes separation[7].

Aquifers Protective Capacities

The earth is made of soil particles of different types. The earth medium acts as a natural filter to percolating fluid, the ability of the earth to filter fluid is dependent on the aquifer depth, the covering materials and the protective capacity of the overlying overburden of the aquifer. Silts and clays are suitable aquitards. Which often constitute protective geologic barriers and when they are found above an aquifer they constitute a protective cover, they thus protect the aquifer from surface and near-surface contamination, because their low hydraulic conductivity leads to high residence time of percolating water [8]. Table 1 presents longitudinal conductance/protective capacity ratings. The table enables the classification of the study area into various grades. The areas that are classified weak and poor are most susceptible to contamination, while the good, very good and excellent classification indicates high protective geological formation. These first order geo-electric parameters (resistivity ρi and thickness hi) were utilised in deriving the total longitudinal unit conductance (S), which is a second order geoelectric parameter or the Dar Zarrouk Parameter [9] (Tables 2 & 3). The total longitudinal unit Conductance is

$$S = \sum_{i=1}^{n} \frac{hi}{\rho i} \quad (1)$$

hi is the layers thickness and ρi is the layers resisitivity, while the number of layer from the surface to the top of the aquifer, *(i)* varies from 1 to n.

Longitudinal Conductance (mhos)	Protective Capacity Rating
>10	Excellent
10-May	Very Good
0.7-4.9	Good
0.2-0.69	Moderate
0.1-0.19	Weak
<0.1	Poor

Table 1: Longitudinal Conductance/Protective Capacity Rating.

Rock Type	Resistivity (ohm-m)
Fadama loam	30-90
Sandy	100-200
Sand and gravel	100-180
Weathered and laterite	150-900
Fresh Laterite	900-3500
Weathered basement	20-200
Fractured basement	500-1000
Fresh basement	>1000

Table 2: Resistivity Values of Rock Types in Basement Area.

Rock Type	Resistivity Range (ohm-m)
Granite	$3x10^2$-10^6
Granite porphyry	$4.5x10^3$(wet)-$1.3x10^6$(dry)
Quartz porphyry	$3x10^2$-$9x10^5$
Quartz diorite	$2x10^4$-$2x10^5$(wet)-$1.8x10^5$(dry)
Schist's (calcaceous and calcareous Mica)	$20x10^4$
Graphites Schist	$10x10^2$
Slates (various)	$6x10^2$-$4x10^7$
Quartzites (various)	10-$2x10^8$

Table 3: Resistivity Values for Igneous and Metamorphic Rocks.

Results and Discussion

Data Analysis

The data collected were processed by reducing the resistance data obtained to apparent resistivity values by multiplying it with geometric factor. The apparent resistivity was used to obtain the equivalent n-layers model curves, for the sclumberger sounding using an iterative computer program called WinResist (Figure 3). The programs automatically perform interpretation of schlumberger sounding curves. The resistivity values for the various n-layers varying levels were interpreted for the forty eight VES points. The data obtained from these were then subjected to vague procedure using computer iterative window based software called surfer package (Surfer 8). This generates resistivity contour maps. This gives more information about the subsurface structure.

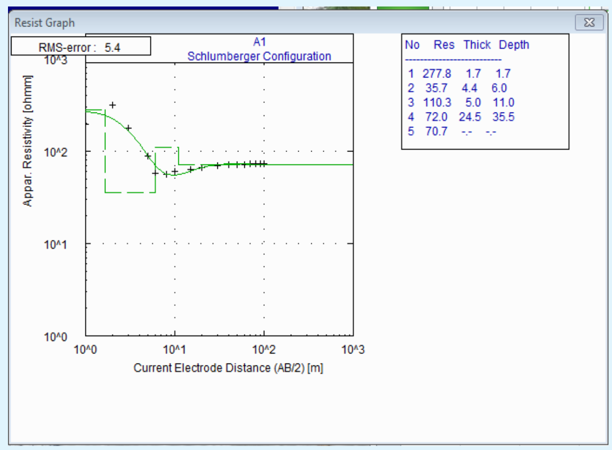

Figure 3: Resistivity-Depth Curve Plotted Using Win-Resist Software for VES.

Description of VES curves

The subsurface vertical sections through profile A - F are shown in Figures 4-9 respectively. These maps were contoured at an interval of 300 Ωm. From Figures 4-9 indicate that A1,A5,A8,B3,B5,B6,C8,D7, D8,E1,E7,F2 and F3 are depressions (valley) that may likely be good potential for underground water. The following are the lithology layers and their thicknesses as obtained in this work with respect to Table 2 above:

- First layer consists of dry fadama loam, sandy-clay, and gravel and has resistivity values below 300 Ωm with thickness between 0.4m to about 5.05 m
- The second layer consists of weathered and fractured basement with thickness between 1.4m to about 18.6 m, its resistivity values ranges from 31.0 Ωm and about 16266.89 Ωm. This constitutes the aquifer system of this area
- The third layer is the fresh crystalline basement, which constitutes the bedrock of the area and has infinite thickness.

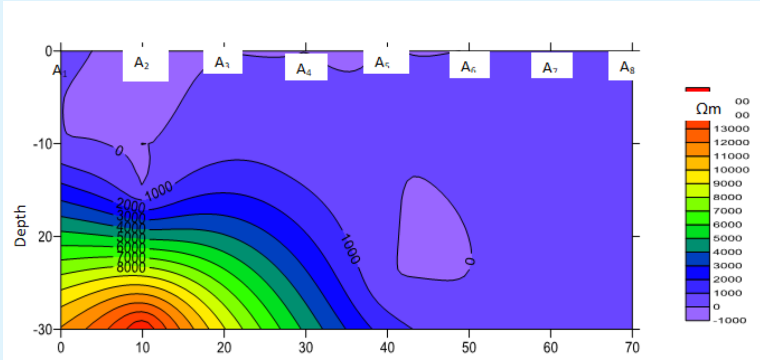

Figure 4: Vertical Section (Geo-electric) Contour Maps of Profile A Distance (m) x 10.

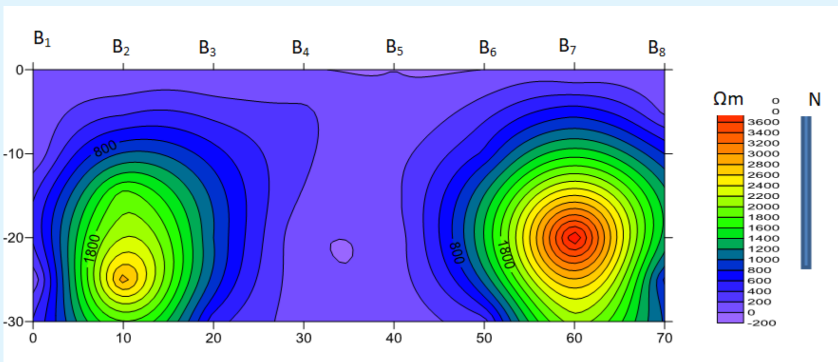

Figure 5: Vertical Section (Geo-electric) Contour Maps of Profile B (Contour Interval of 200 ohm-m)

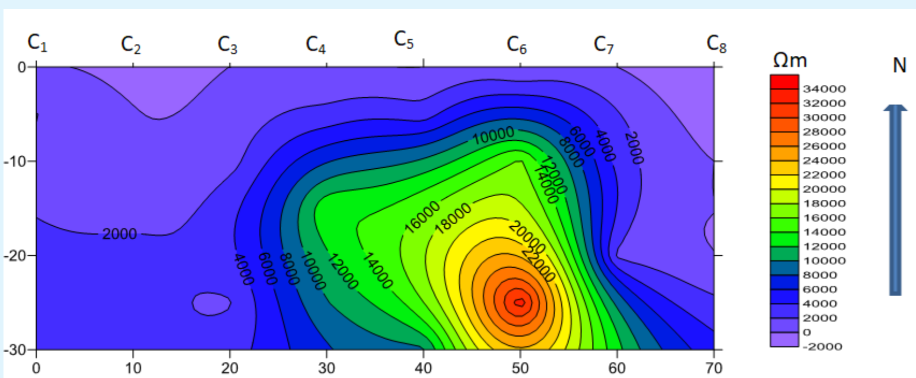

Figure 6: Vertical Section (Geo-electric) Contour Maps of Profile C (Contour Interval of 2000 ohm-m)

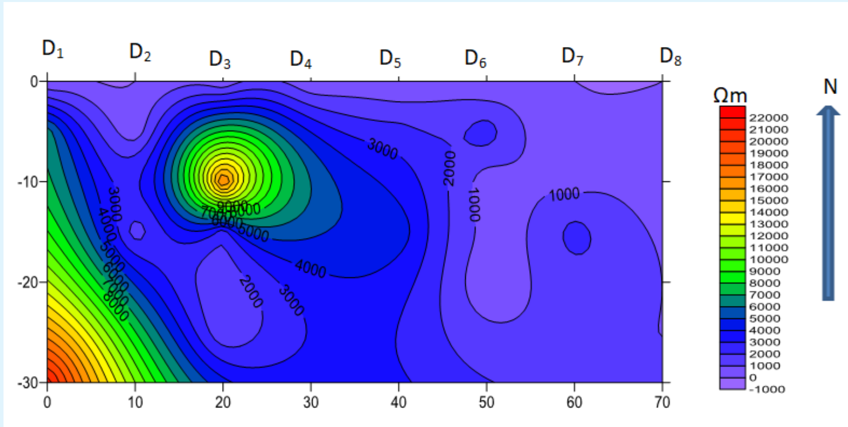

Figure 7: Vertical Section (Geo-electric) Contour Maps of Profile D (Contour Interval of 1000 ohm-m)

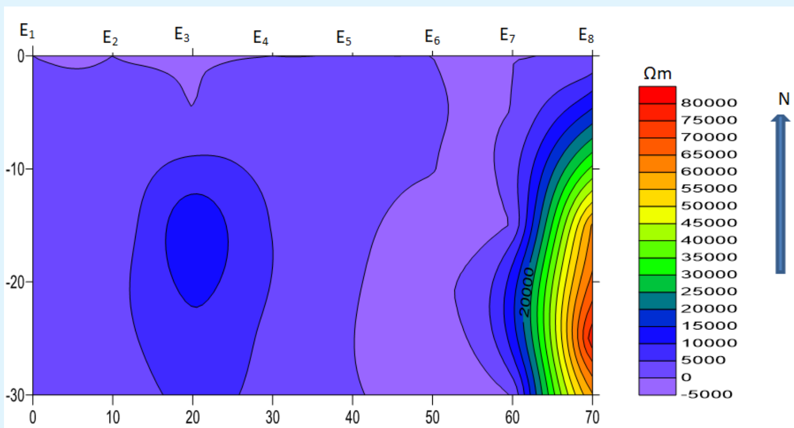

Figure 8: Vertical Section (Geo-electric) Contour Maps of Profile E (Contour Interval of 5000 ohm-m) (Contour interval 2000 ohm-m).

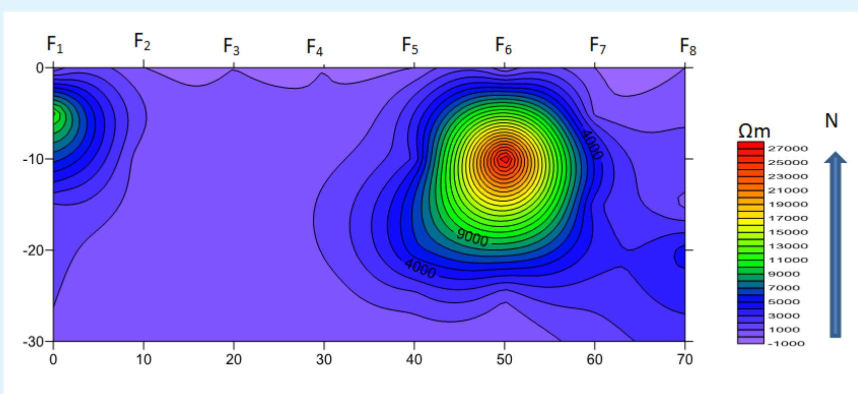

Figure 9: Vertical Section (Geo-electric) Contour Maps of Profile F (Contour Interval of 3000 ohm-m).

Interpretation of Iso-resistivity Contour Map at Various Depths

Iso-resistivity maps show the conductivity pattern with depth through slicing of the entire study area horizontally or through a cross-section. 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. For illustrations, few of these maps were presented here. The deductions made from them are as discussed below.

Figure 10 shows the iso-resistivity contour map for topsoil. The map was drawn at contour interval of 20 Ωm. The entire surface of the study area shows low resistivity values ranging between 0.4 Ωm to 277.8 Ωm, which covers most part of the area.

The Iso-resistivity contour map at 5 m depth was contoured at 500 Ωm interval as shown in Figure 11. The resistivity value of the range of 500 Ωm and 1000 Ωm could be observed at the northern, southern, southeast, and southwest zone which indicate fractured zones part, this zone may likely show saturated or nearly saturated (water) horizons. The high resistivity at the north-western part indicates fresh laterite deposited at that region. Very high resistivity value of 1000 Ωm and above was found prominent in central part. They are fresh basement rock. The iso- resistivity contour map at 10 m depth was contoured at 500 Ωm contour intervals, as show in Figure 12. The maps are similar to the map obtained at 5 m depth. The range of resistivity values at this depth is between 4.0 Ωm to 8000 Ωm

Similar to what was obtain at 5m depth, the central part was characterized with high resistivity value above 1000 Ωm which indicate fresh basement at that point, The south-eastern part of the area that are said to be weathered and fractured basement closed up and get consolidated to fresh basement. The north, south, and south-western part are the fractured basement.

The Iso resistivity maps at 15 m depth were contoured at a contoured interval of 200 Ωm as shown in Figure 13. This is different from what was obtained in 10m depth because the northern part and some part of the south-east that were said to be weathered and fractured basement get consolidate to fresh basement at this depth. It can be seen clearly that the southern, and toward the southwest part of the map are fractured basement. The iso resistivity contour maps at 20m depth were contoured at 1000 Ωm interval as shown in Figure 14. The resistivity range at this depth is 800 Ωm to 3800 Ωm. Areas delineated with less than 1000 Ωm are likely to be weathered and fractured basement rock.

The Iso- Resistivity a contour maps at 25 m depth was contour at 5000 Ωm contour interval as shown in Figure 15. The areas that were said to be weathered and fractured basement along the southern part of the map now get consolidated to fresh basement at this depth. The Iso- resistivity contour map at 30 m depth was contoured at 5000 Ωm intervals as shown in figure 15 summarized both the interpretations and deductions of the horizontals slicing that are Iso-resistivity contour maps at various depths of the study area. This region is characterized with resistivity greater than 1000 Ωm which indicate fresh basement at this region (Figure 16).

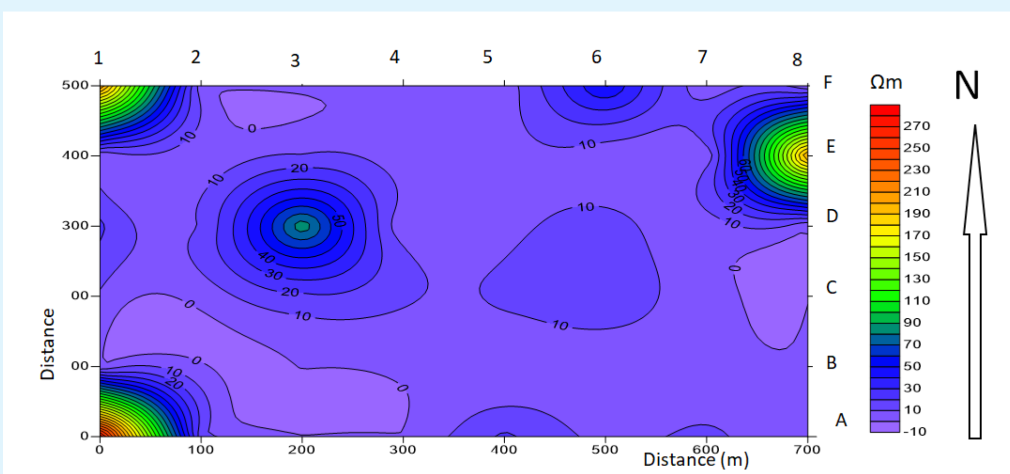

Figure 10: Iso-Resistivity Contour Maps at Surface

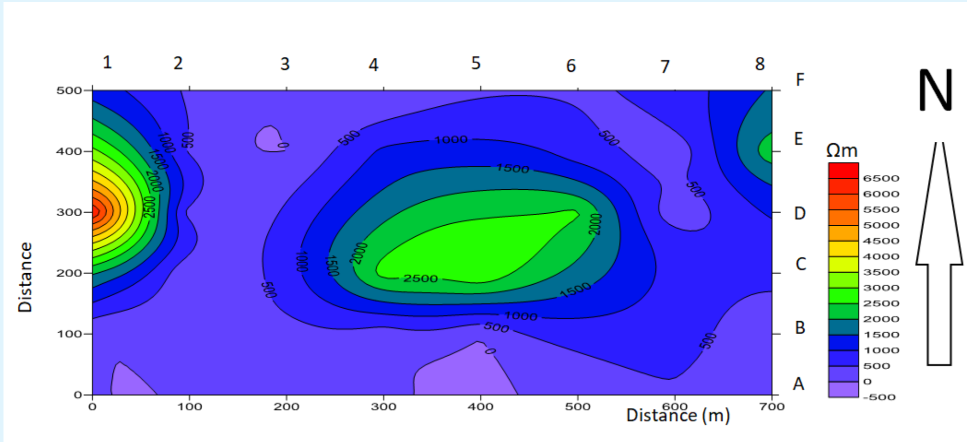

Figure 11: Iso-Resistivity Contour Maps at 5m depth.

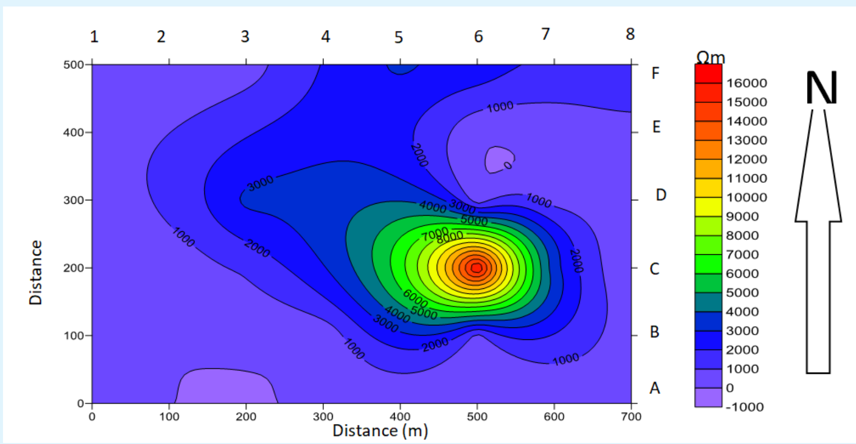

Figure 12: Iso-Resistivity Contour Maps at 10 m depth.

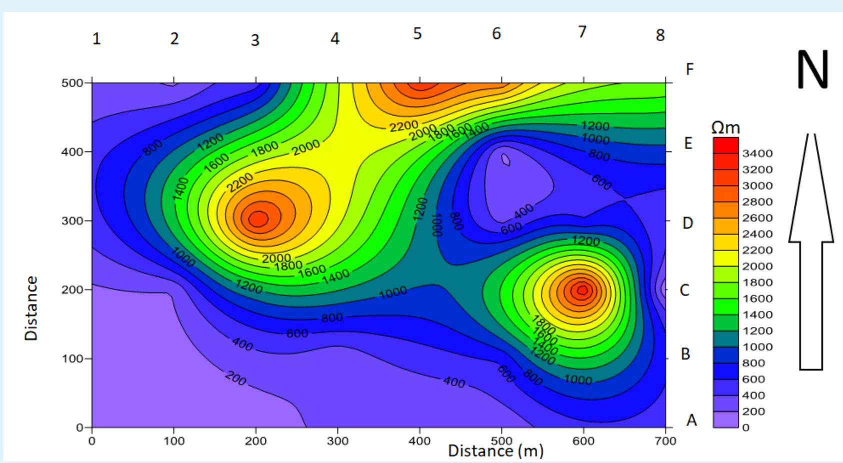

Figure 13: Isoresistivity Contour Map at 15 m depth.

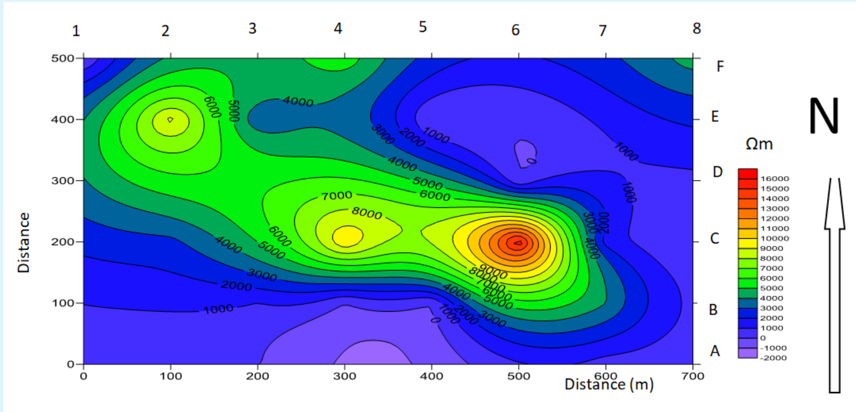

Figure 14: Iso-Resistivity Contour Maps at 20 m depth.

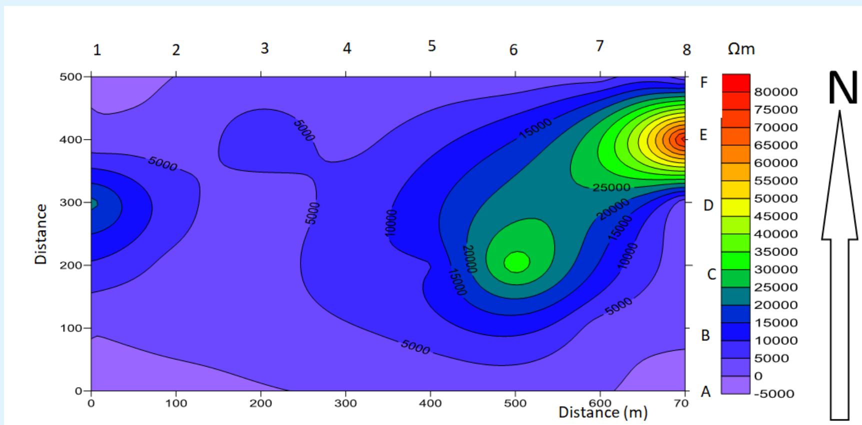

Figure 15: Iso-Resistivity Contour Map at 25 m depth.

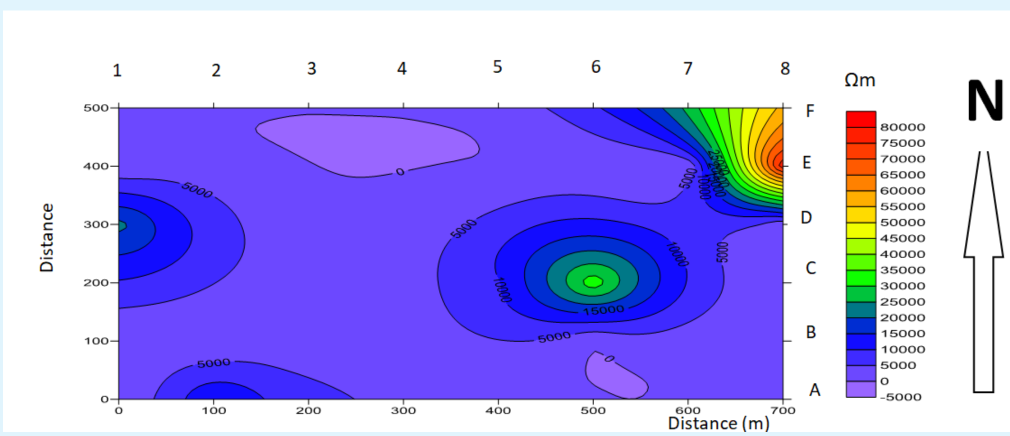

Figure 16: Iso-Resistivity Contour Map at 30 m depth.

Deduction from Depth to Basement Contour Map

The depth of basement contour map is shown in Figure 17. It is contoured at an interval of 2m and gives the depth of basement from the ground surface. The data used to produce this map were obtained from Win-Resist interpretations. The depth values corresponding to the last layer were picked until the entire (48) VES points were covered. The map shows that the basement varies from 2 m to 50 m. The shallow part of the region is the central part of the maps and north-west and south-eastern part of the map correspond to VES (A_4,A_7,B_1,B_2,B_7,B_8,C_4,C_5,D_1,D_2,D_5,D_6,E_3,E_4,E_6,E_8 F_1,F_4, and F_7).The north central, south-west and the Eastern part of the maps are the deepest part the area. This corresponds to the shaded area of the map.

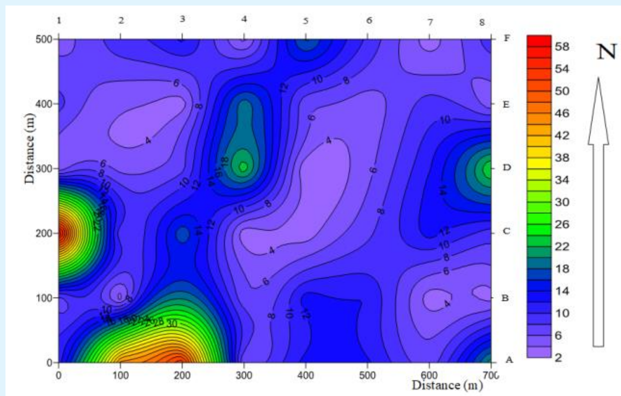

Figure 17: Depth to Basement Contour Map.

Aquifer Protective Capacities Evaluation

The nature of the materials that overlain the mapped aquifers were evaluated using the layer parameters (i.e. resistivity and thickness), the longitudinal unit conductance (S), helps in determine its capacity to prevent infiltration of unwanted fluids into the aquifer. It should be noted that the earth materials act as a natural filter to percolating fluids; therefore its ability to retard and filter percolating ground surface polluting fluids is a measure of its protective capacity [10-13]. That is to say that the geologic materials overlying an aquifer could act as seal in preventing the fluid from percolating into it.

The study has shown that the entire area (Table 4) is underlain by materials of good to poor protective capacity. The south, the south-east and the north-west portions of the area are underlain by materials of moderate to good protective capacity. The areas (Figure 18) with Good to moderate protective capacity coincide with zones of appreciable overburden thickness with clayey columns thick enough to protect the aquifer in the area from the surface polluting fluid. The western and central part of the area with thin overburden also coincided with weak protective capacity thereby exposing the groundwater in the area to pollution. If for example, there is leakage of buried underground storage tanks; this may constitute a serious environmental hazard.

Ves Stations	Longitudinal Conductance (mhos)	Ves Stations	Longitudinal Conductance (mhos)
A_1	0.00611951	D_1	0.01801802
A_2	0.03053435	D_2	0.19444444
A_3	1.00000000	D_3	0.00454545
A_4	1.00000000	D_4	0.30769231
A_5	0.01108648	D_5	0.06849231
A_6	0.11111111	D_6	0.02614379
A_7	0.06153845	D_7	0.11363636
A_8	1.00000000	D_8	0.71428571

B_1	0.50000000	E_1	0.71428571
B_2	0.30769231	E_2	0.15625000
B_3	0.66666667	E_3	0.09302326
B_4	0.22222222	E_4	0.09302325
B_5	1.41666667	E_5	0.05633809
B_6	0.25000000	E_6	0.05633803
B_7	0.16666667	E_7	0.26315799
B_8	0.66666667	E_8	0.00245464
C_1	0.04819277	F_1	0.00237642
C_2	0.09388972	F_2	0.14285714
C_3	0.07865169	F_3	0.26666667
C_4	0.03389831	F_4	0.66666667
C_5	0.03305785	F_5	0.09756098
C_6	0.02020202	F_6	0.00967118
C_7	1.00000000	F_7	0.13793103
C_8	0.89380531	F_8	0.22222222

Table 4: Calculated Longitudinal Conductance of the Area.

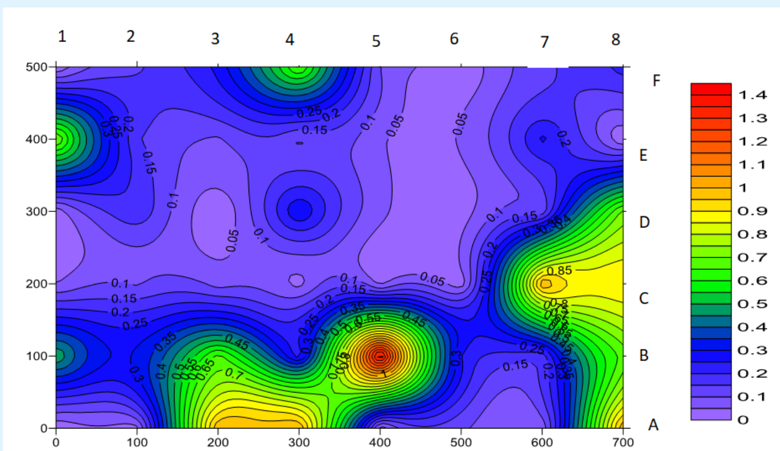

Figure 18: Contour map showing distribution of longitudinal conductance in the study area.

Conclusion

The study area is mostly three-layer formation. The topsoil (clay, silt, sand Fadama loam and laterite topsoil), the weathered or fractured basement and the fresh basement rock. The top layer resistivity ranges from 0.4 Ωm to 277.8 Ωm. The weathered basement has its resistivity ranges between 26.9 Ωm to 728.9 Ωm the fresh basement (solid bed rock) has a characteristics high resistivity value. The best areas found suitable for groundwater exploration are 18.75 per cent of the study area. The study area is generally characterized with the range of good to poor protective capacities, The south, the south-east and the north-west portions of the area are underlain by materials of moderate to good protective capacity while the western and central part of the area with thin overburden also coincided with weak protective capacity thereby exposing the groundwater in the area to pollution.

Recommendations

- Petrol filling stations should be positioned in the area where the protective capacity of the aquifer is moderate/good.
- Area delineated as aquifer potentials should be drilled.

References

1. Water for Africa (2010) http://www.waterforafrica.org.uk/
2. Plummer CC, McGeary D, Carlson DH (1999) Physical Geology, 8th (Edn.), London. McGrawHill Book Company 2(3): 9-15.
3. Eduvie MO (1998) Groundwater Assessment and Borehole characteristics, case study from part of Kaduna Metropolis (Kaduna State) a Paper Presented at a workshop organized by Kaduna State Water Board. National Teachers Institute 3(4): 13-16.
4. Baimba AA (1978) Resistivity and Refraction methods for Groundwater exploration at Zango, Kaduna State Unpublished M.Sc. Thesis ABU, Zaria 4(3): 112-123.
5. Akpan AE, George NJ, George AM (2008) Geophysica investigation of some prominent gully erosion sites in sites in calabar, Southern Nigeria and its implication to hazard prevention. Journal of Disaster Advances 2(3): 46-50.
6. Telford WM, Geldart LP, Sheriff PE (1990) Applied Geophysics, 2nd (Edn.), Cambridge University Press, Cambridge.
7. David LM, Ofrey (1989) An indirect method of estimating groundwater level in Basement complex Regolith water resources 1(2): 3-6.
8. Lenkey L, Hamori Z, Mihalffy P (2005) Investigating the hydrogeology of a water-supply area using direct-current vertical electrical soundings 70(4): 1-19.
9. Maillet R (1947) The fundamental equations of Electrical Prospecting. Geophysics 12(4): 527-556.
10. Olorunfemi MO, Ojo JS, Akintunde OM (1990) Hydro geophysical evaluation of the ground water Potential of Akure metropolis, southwestern Nigeria. Journal of Mineral Geology 35(2): 207-228.
11. Ajayi CO, Hassan M (1990) The delineation of the aquifer overlying the basement complex in the western part of the Kubanni basin of Zaria, Nigeria. Unpublished report 61(3): 1-19.
12. Ogungbemi OS, Badmus GO, Ayeni OG, Ologe O (2013) Geo- electric Investigation of Aquifer Vulnerability within AfeBabalola University, Ado–Ekiti, Southwestern Nigeria. Journal of Applied Geology and Geophysics 1(5): 28-34.
13. Telford WM, Geldart LP, Sherif PE, Keys DA (1980) Applied Geophysics.