International Journal of Physical Sciences Vol. 8(1), pp. 37-50, 9 January, 2013
Available online at http://www.academicjournals.org/IJPS
DOI: 10.5897/IJPS09.299
ISSN 1992 - 1950 ©2013 Academic Journals

Full Length Research Paper

Evaluation of groundwater potential and aquifer protective capacity assessment at Tutugbua-Olugboyega area, off Ondo road, Akure Southwestern Nigeria

M. A. Ayuk, A. O. Adelusi* and K. A. N. Adiat

Department of Applied Geophysics, Federal University of Technology, Akure, Nigeria.

Accepted 15 December, 2012

A total of thirty-two (32) vertical electrical sounding (VES) data were acquired using R 50 d.c. Resistivity meter within the Precambrian basement geology of part of Akure metropolis southwestern Nigeria. The VES data were interpreted; eight type curves were identified, from the geoelectric section the subsurface was characterized into four lithologies namely topsoil, weathered layer (clay /lateritic clay), weathered / fractured basement and bedrock. Thus, two major aquifers were mapped these are weathered/partially weathered layer and weathered basement/fractured basement aquifers. These aquifers are characterized by thick overburden, found within basement depressions and exhibit moderate to relatively high values of coefficient of anisotropy, λ, (0.97-1.11) with depth. Also, ancient river channel trending approximately NE-SW was mapped. The assessment of the materials above the aquifers showed that longitudinal conductance (S), values ranged from 0.0035 to 0.17 mhos; thus the S values are generally low suggesting that the materials above the aquifers are loose and porous thus having less capacity to protect aquifers in the study area. Thus the aquifers are poorly protected, and by implication vulnerable to infiltration.

Key words: Basement aquifer, Dar-Zarrouk parameters, Protective capacity Aquifer Risk.

INTRODUCTION

Hydrogeophysics has emerged over the years as one of the dominant sub-disciplines in near surface geophysics (Miller, 2006). This worldwide geosciences discipline is ripe with research opportunities and abundance of potential applications. Maintaining and protecting current water supplies and developing new sources of clean water are essential as modern society expands and civilization continues to develop. Water is essential for life. It had been and will continue to be a hot topic in both the political and scientific arenas for years to come (Miller, 2006). Development of new supplies of potable water will be essential for the prosperity of many communities as demand steadily increases and known supplies of water dwindle. Expansion of population densities requires greater volume of fresh water and at the same time emphasizes the need to protect and sustain known supplies and sources. With advances in technology over the last decade has come an exponential increase in the potential number and diversity of viable geophysical applications in the water science. Both surface and borehole geophysical methods have been utilized with great success.

This article focuses on the use of surface geophysical method involving electrical resistivity for hydrogeological studies. Electrical methods can give information at locations where neither gravity nor magnetic anomalies can exist for horizontal bedding. Further, the electrical resistivity methods can be used where structure is not complicated; apparent resistivity can be estimated with minimum error. Although, the apparent resistivity is diagnostic to some extent, of the actual resistivity of a zone in the vicinity of the electrode array, the apparent

*Corresponding author. E-mail: debo_adelusi@gmail.com.

resistivity reflects the true resistivity only in a homogeneous ground. These resistivities are controlled among others by the bulk resistivity of the subsurface rocks (ρ_b) and the pore water resistivity (ρ_w) as obtained from Archie (1942) where Formation factor, F, is determined as:

$$F = \rho_b / \rho_w \tag{1}$$

In hard rock environment, it is not sufficient to consider only the weathered layer. Deep saturated fractures in bedrock are also potential targets of groundwater exploration. The electrical methods like vertical electrical sounding (VES) and profiling are widely used for this purpose. Also, vertical or sub vertical localized fractures can be located at larger depths using the conventional electrical methods (Sundararajan et al., 2007).

The direct current (DC) resistivity method for conducting a VES is effectively used for groundwater study due to the simplicity of the technique, easy interpretation and the rugged nature of the associated instrumentation. The technique is widely used in soft and hard rock areas and previous study using this technique includes (Ebraheem et al., 1997; Frohlich et al., 1994; Olorunfemi et al., 1999; Adelusi and Balogun, 2001; Omosuyi et al., 2003; Oladapo et al., 2004) The present study is to determine the geoelectric and Dar-Zarrouk parameters in evaluating the groundwater potential and aquifers risk to surface infiltrations.

Study location and geology

The area investigated lies within the Akure metropolis along Ondo road southwest Nigeria (Figure 1a), located on latitudes 7°14'27. 97''N to 7°14'50.64''N and longitudes 5°10'5.03"E and 5°10'27.95"E. that is, (800900 to 801600 northings and 739400 to 740100 eastings) using the Universal Traverse Marcartor (UTM). The area of investigation falls in hard rock terrain and it is underlain by the Precambrian crystalline rocks typical of the Nigeria basement complex. The crystalline rocks are porphyritic granite, migmatite gneiss, biotite granite, charnokites, granite gneiss, pelitic schist, and quartzites (Figure 1b), which has been reviewed by workers like (Rahaman, 1988; Folami, 1998). The dominant rock type is migmatite gneiss (Figure 1b).

MATERIALS AND METHODS

The R_{50} d. c. resistivity meter equipment was used for the VES survey. The vertical electrical resistivity sounding utilized both schlumbeger and wenner configurations. In Schlumbeger array (Figure 2a), the separation between the current electrodes (AB) is successively expanded while the two potential electrodes (MN) have a short separation and remain partially stationary at the depth sounding position while in Wenner configuration all the electrodes utilize a constant separation so that AM = MN = BN = AB/3 = "a" (Figure 2b) and gradually expands the electrode distance (a) while all the four electrodes are moved. The geoelectric survey is such that the minimum electrode spacing "AB/2" and "AB/3 = 1 m and gradually increase to a maximum spread length "AB/2" and "AB/3 of 100 m (Ako and Osondu, 1986; Olorunfemi and Fashuyi, 1993). A total of 32 VES points were occupied to cover the study area (Figure 2b).

The Schlumbeger and Wenner depth sounding are used to investigate the change of resistivity with depth (Kunetz, 1966, Barker et al., 1996). The measured unit is the apparent resistivity, ρ_a, which is the product of a geometrical factor, K, and the quotient of the measured potential, ΔU, and the source current, I. The apparent resistivity is plotted versus AB/2 or AB/3 in meters on bilogarithmic paper resulting in a VES curve. The VES curve showed the change of resistivity with depth, since the effective penetration increases with increasing electrode spacing. The interpretation of the VES curve is both qualitative and quantitative. The qualitative interpretation involved visual inspection of the sounding curves while the quantitative interpretation utilized partial curve matching technique using 2-layer master curve which was later refined by a computer iteration technique Resist version (Vander, 2004) that is based upon an algorithm of Ghosh (1971).

The quantitatively interpreted sounding curves gave interpreted results as geoelectric parameters (that is, layer resistivity and layer thickness) see Figures 3a to i. The Dar-Zarrouk parameters are obtained from the first order parameters (geoelectric parameters) which are Total longitudinal unit conductance (S), Total transverse unit resistance (T), and coefficient of anisotropy (λ).

$$\text{Si} = \sum_{i=1}^{n-1} hi / p_i \tag{2}$$

$$\text{Ti} = \sum_{i=1}^{n-1} hip_i \tag{3}$$

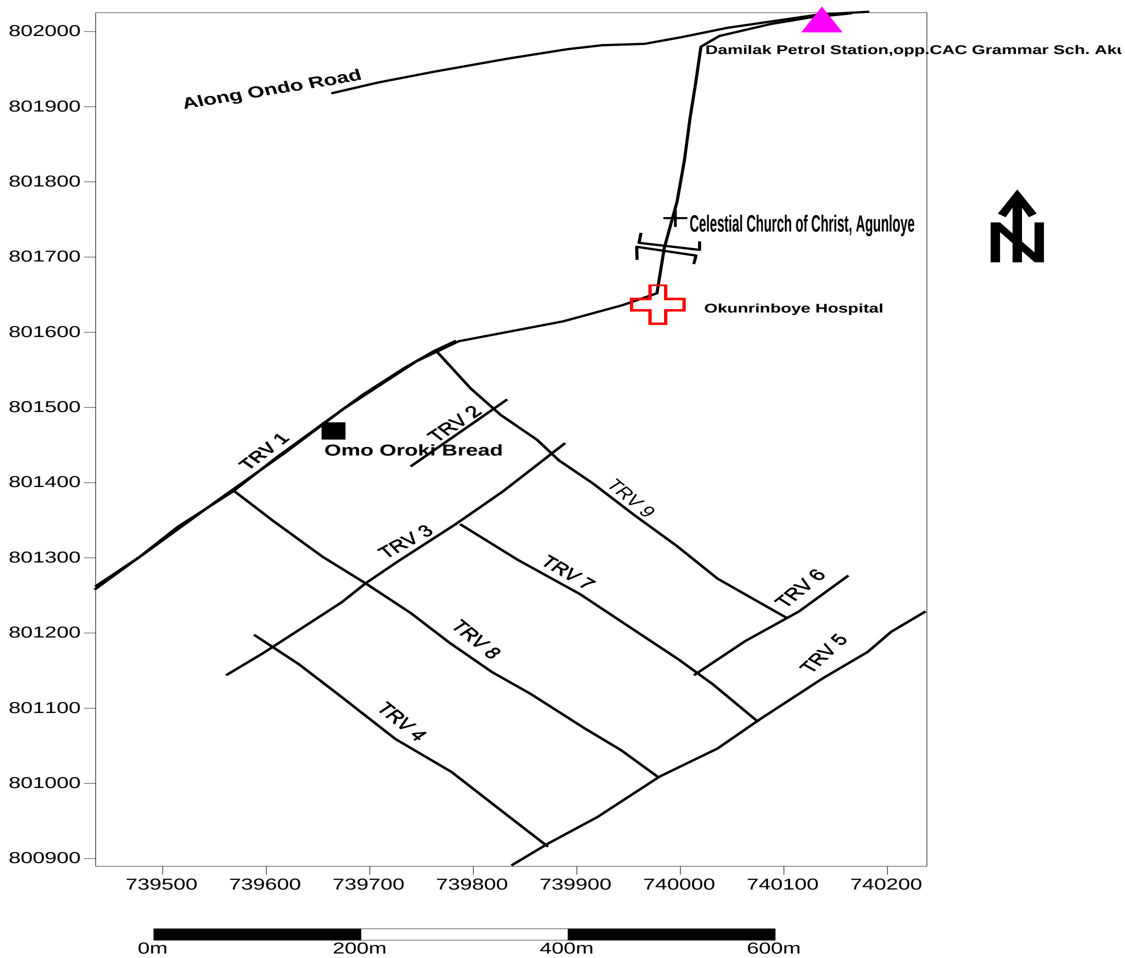
$$\rho_t = \frac{\text{Ti}}{\text{hi}} \tag{4}$$

$$\rho_L = \frac{\text{hi}}{\text{si}} \tag{5}$$

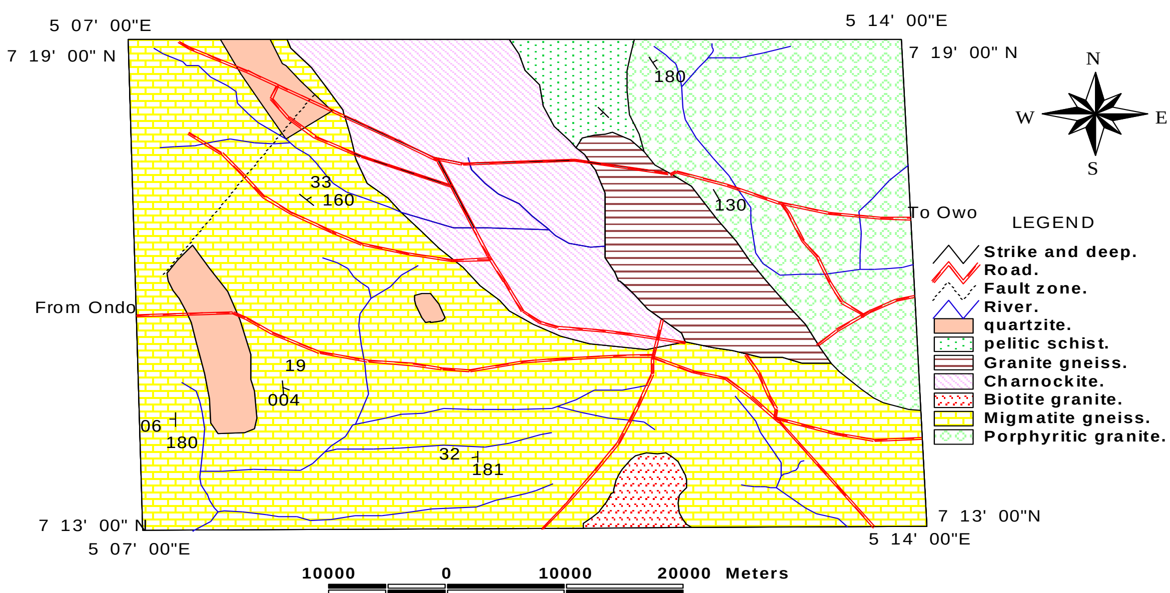
$$\lambda = \left(\frac{\rho_t}{\rho_L}\right)^{1/2} \tag{6}$$

Si = Total longitudinal unit conductance,
Ti = Total transverse unit resistance,
Hi = Layer thickness,
ρ_i = Layer resistivity,
ρ_t = Transverse resistivity,
ρ_L = Longitudinal resistivity,
n = number of layers,
λ = coefficient of Anisotropy.

Electrical anisotropy is a measure of the degree of in homogeneity (Billings, 1972; Maliek et al., 1973) in a basement terrain; which arises from near surface effects, variable degree of weathering and structural features such as faults, fractures, joints, foliations, and beddings. These in turn are responsible for creating secondary porosity (Φ_s) and hence effective porosity (Φ_e). Since the basement rocks are significantly anisotropic and the degree of electrical

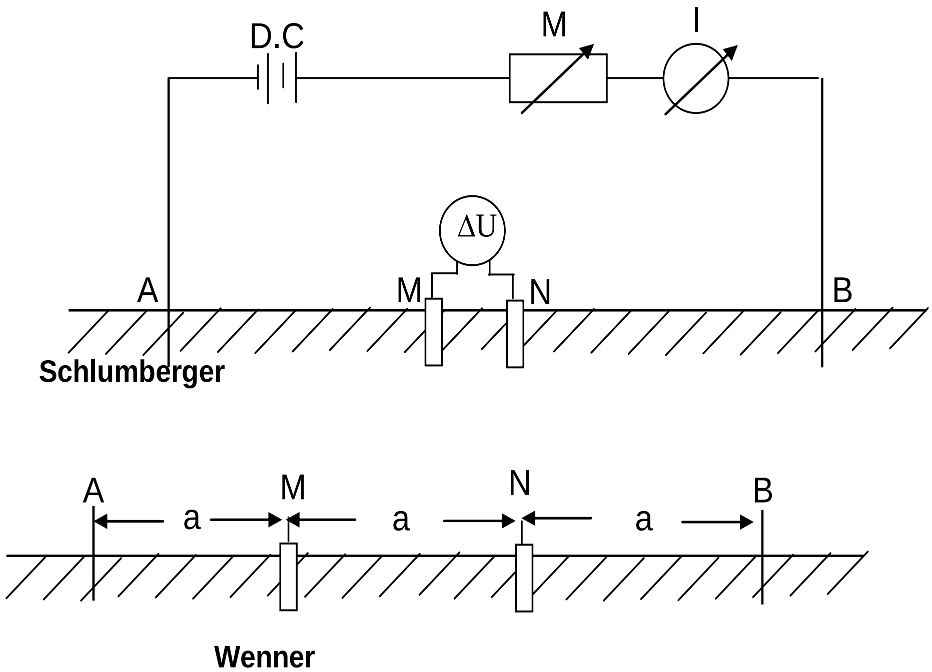


a

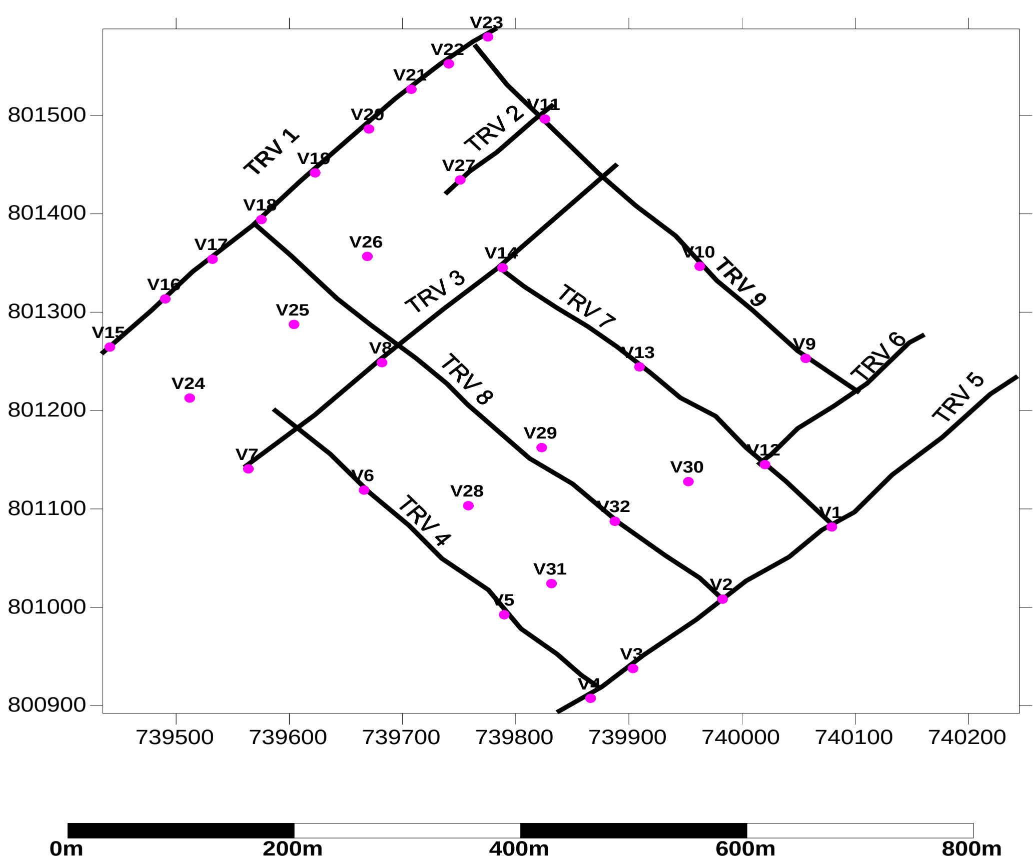


b

Figure 1. (a) Location map of the study area, (b) Geological map of Akure area Southwestern Nigeria.



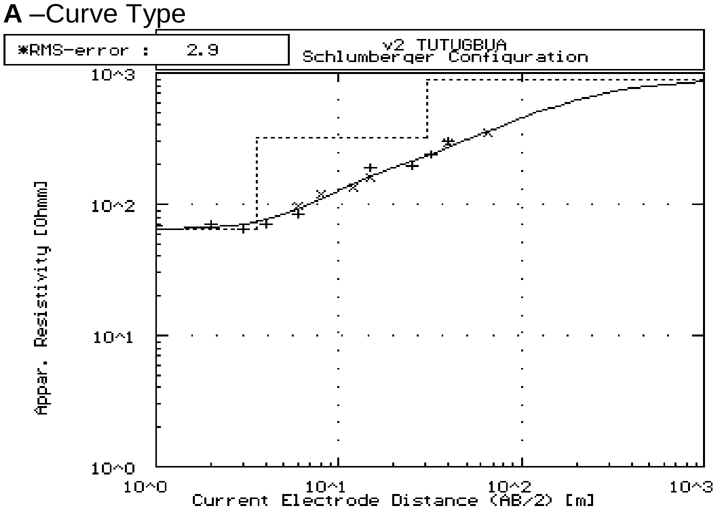
a



b

Figure 2. (a) Geoelectrical method with electrode configurations, (b) Base map of the study area showing VES positions.

A –Curve Type



No	Res	Thick	Depth
1	64.9	3.6	3.6
2	316.6	27.1	30.6
3	892.4	-.-	-.-

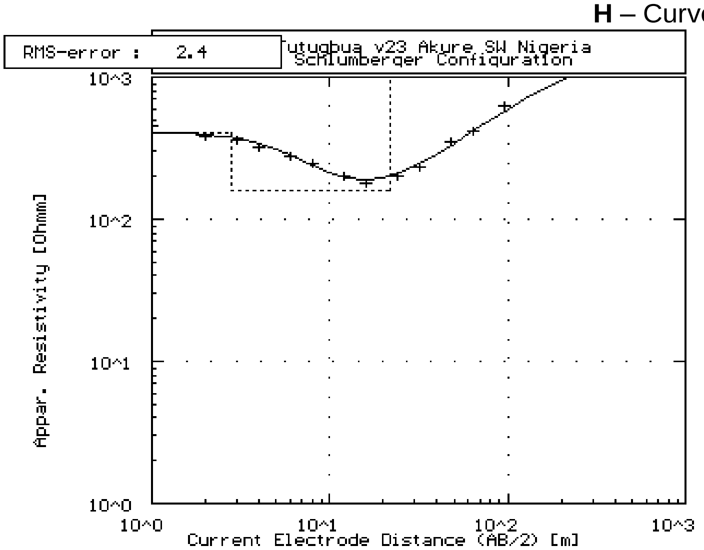
* RMS on smoothed data

+++xxxx observed data

------------ calculated curve

(a)

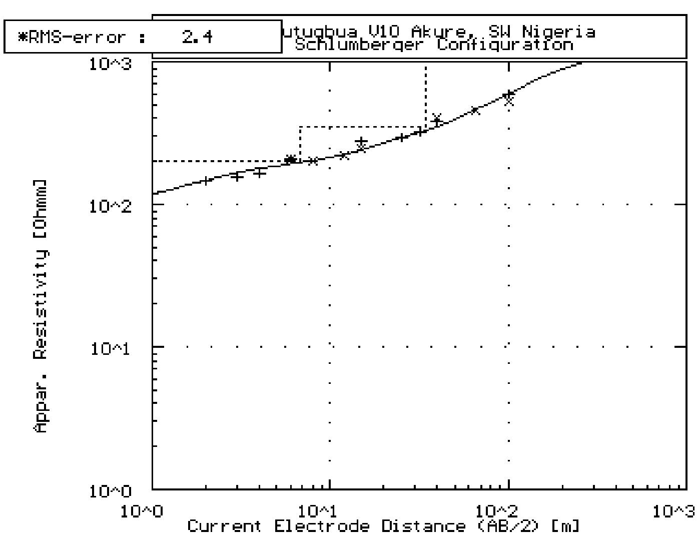
H – Curve Type



No	Res	Thick	Depth
1	408.2	2.8	2.8
2	158.6	18.8	21.6
3	2005.1	-.-	-.-

(b)

AA- Curve Type

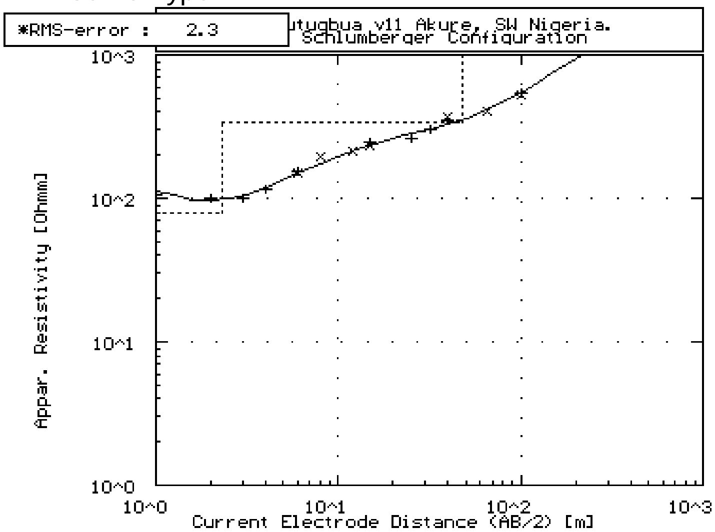


No	Res	Thick	Depth
1	99.3	0.6	0.6
2	198.5	6.1	6.7
3	348.5	27.8	34.6
4	1499.0	-.-	-.-

* RMS on smoothed data

(c)

HA –Curve Type

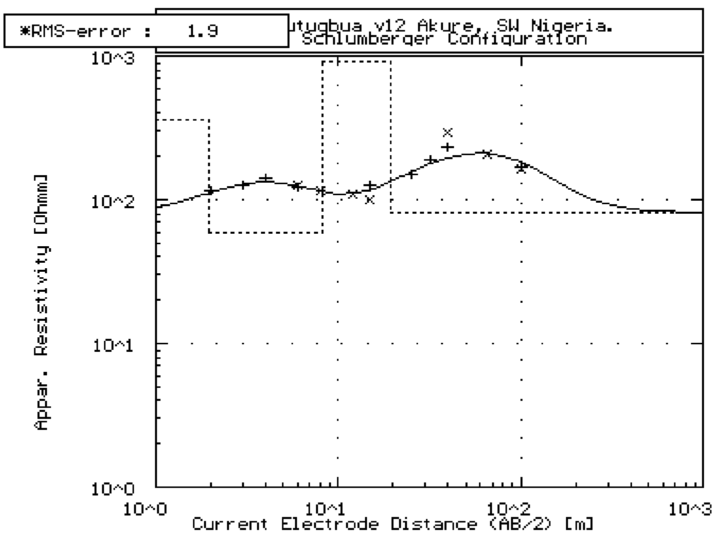


No	Res	Thick	Depth
1	162.0	0.4	0.4
2	80.2	1.9	2.3
3	335.9	45.5	47.8
4	3237.9	-.-	-.-

* RMS on smoothed data

(d)

KHK – Curve Type

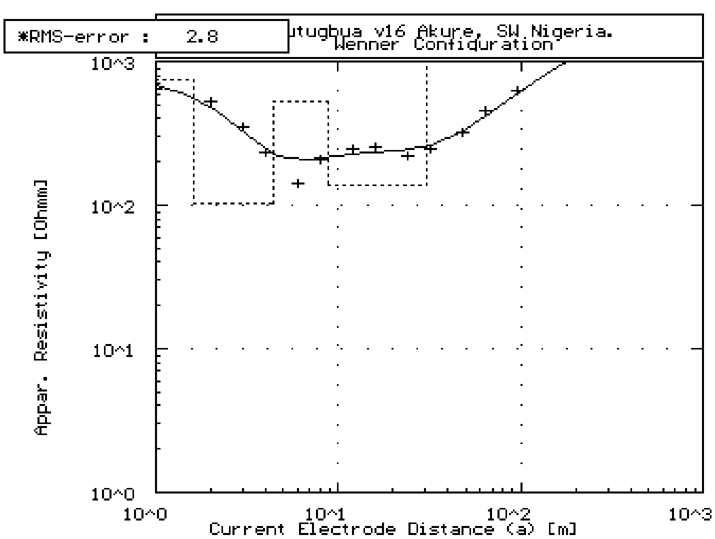


No	Res	Thick	Depth
1	79.1	1.0	1.0
2	359.3	1.0	2.0
3	59.3	6.3	8.2
4	908.1	11.3	19.5
5	81.5	-.-	-.-

* RMS on smoothed data

(e)

HKH – Curve Type

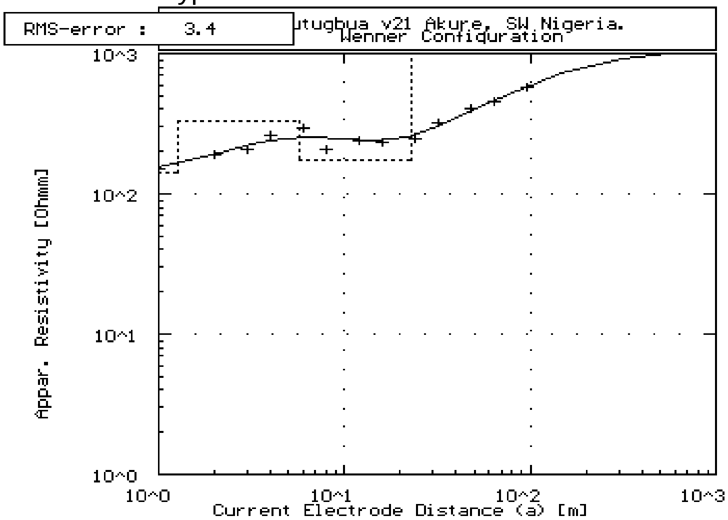


No	Res	Thick	Depth
1	754.0	1.6	1.6
2	102.2	2.8	4.4
3	522.2	4.4	8.8
4	139.3	21.9	30.7
5	4821.9	-.-	-.-

* RMS on smoothed data

(f)

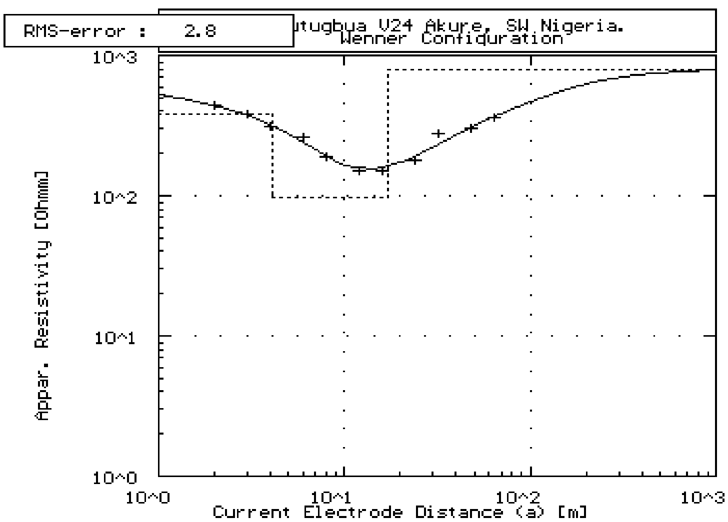
KH – Curve Type



No	Res	Thick	Depth
1	143.0	1.3	1.3
2	327.0	4.4	5.7
3	173.8	17.3	23.0
4	1073.9	-.-	-.-

(g)

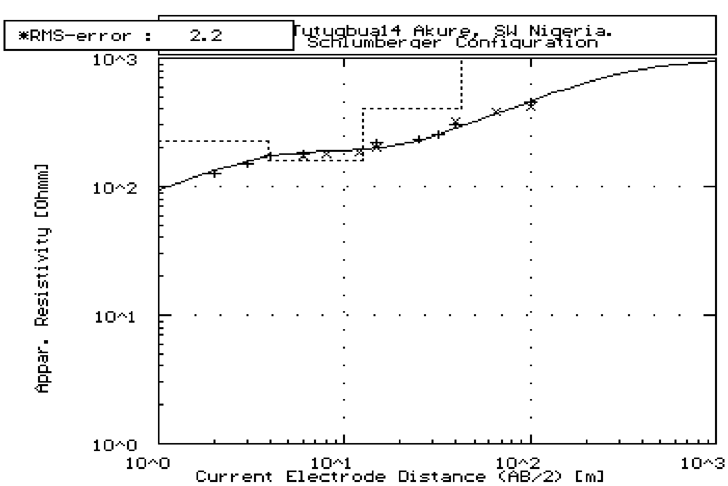
QH – Curve Type



No	Res	Thick	Depth
1	565.4	1.0	1.0
2	380.2	3.1	4.1
3	97.5	12.9	17.0
4	798.3	-.-	-.-

(h)

KHA – Curve Type



No	Res	Thick	Depth
1	65.0	0.5	0.5
2	223.4	3.4	3.9
3	161.2	8.6	12.5
4	405.6	30.0	42.5
5	987.6	-.-	-.-

* RMS on smoothed data

(i)

Figure 3. Typical sounding curves of the study area**;** a, A –curve type; b, H –curve type; c, AA- curve type; d, HA –curve type; e, KHK –curve type; f, HKH –curve type; g, KH –curve type; h. QH –curve type; i KHA –curve type.

Table 1. Curve type distribution of the study area.

Curve type	Frequency (f)	Percentage (%)
H	7	21.9
A	8	25
AA	1	3.1
QH	4	12.5
HA	4	12.5
KH	4	12.5
KHA	2	6.3
KHK	1	3.1
HKH	1	3.1

Table 2. Curve types relevant to groundwater study as obtained from their layer parameters.

Curve type	Frequency (f)	Percentage (%)
H	2	6.3
A	1	3.1
AA	1	3.1
QH	2	6.3
HA	3	9.4
KH	4	12.5
KHA	2	6.3
HKH	1	3.1

anisotropy can be measured in terms of the anisotropy coefficient (λ); it can therefore be inferred that:

Where,

$$\lambda = f(\Phi_e) \tag{7}$$

also the groundwater yield, Y, is a function of the volume of the accumulated groundwater and the permeability of an aquifer. This is influenced, controlled, and dependent on the effective porosity (Φ_e). The relationship is shown as:

$$Y = f(\Phi_e) \tag{8}$$

The degree of inhomogeneity, expressed as electrical coefficient of anisotropy (λ), correlates linearly with groundwater yield;

Hence, $Y = f(\lambda)$ (9)

RESULTS AND DISCUSSION

Sounding curves and aquifer types

In the study area, 9 curve types were identified, these are H, A, AA, QH, HA, KH, KHA, KHK, and HKH (Figure 3). The occurrences of these type curves are shown in Table 1, where type curve A has the highest percentage (25%) of occurrence. The least percentage of (3.1%) corresponds to the AA, KHK, and HKH each.

The curve types were grouped on the basis of the aquifer types. The curve types were grouped into two viz:

i) Group A: H, A, AA, QH,
ii) Group B: HA, KH, QH, KHA, HKH.

Group A: Aquifers in this group correspond to layer 2 in A, H, and layer 3 in AA, QH curve types. The aquifer type is that of weathered/partially weathered layer.

Group B: Basement aquifer in this group consist of layer 3 of HA, KH, QH, and layer 4 of KHA and HKH which correspond to the weathered/fractured basement.
Thus, from the study area, two major aquifer types were mapped which were the weathered layer and the weathered/fractured aquifer. However, area underlain by the weathered/fractured basement aquifer is more promising in terms of groundwater development than the weathered layer aquifer.

Curve types and evaluation of relevant layer parameters for groundwater study

From the analysis of the geoelectric parameters obtained from the quantitative interpretation of the sounding curves, the percentage occurrence of the curve types showing prospect to groundwater development would reduced as shown in Table 2. Thus, about 50% of the total number of sounding points in the study area could be developed for groundwater development as deduced from the geoelectric parameters. The geoelectric parameters of the layer that correspond to the aquiferrous zone of the different type curves were shown in Table 3.

In basement terrain of this type, the major aquifers are the weathered/partially weathered layer and weathered/ fractured basement. The weathered layer/partially weathered layer aquifer had resistivity of 130 to 295 Ωm while the weathered/fractured basement aquifer had resistivity ranging from 130 to 425 Ωm with layer thickness of 10 to 35 m mostly in the study area. Where the layer thickness is generally > 10 m and of moderate resistivity, is relevant in the groundwater development of the area.

Geoelectric sections

The 2-d geoelectric sections (Figures 4a to b) were drawn in W-E and NE-SW directions. The strike length is about 1.2 km, (Figure 4a) with varying topsoil resistivity of 108 to 770 ohm-m and thickness of 0.9 to 3.5 m. The second lithologic layer corresponds to clay with layer resistivity of 32 to 125 ohm-m and thickness of 2.8 to 6.4 m. The third layer is the basement having resistivity of

Table 3. Geoelectric parameters of the sounding curves relevant to groundwater development.

Curve type	Range of basement aquifer resistivity (Ωm)	Range of layer thickness (m)
H	132-295	19.5-25.5
A	295	33.6
AA	341	27.7
HA	260-375	19.8-31.1
QH	140-215	13.4-23.3
KH	132-190	12.2-22.0
KHA	155-425	10.1-29.0
HKH	150	23.8

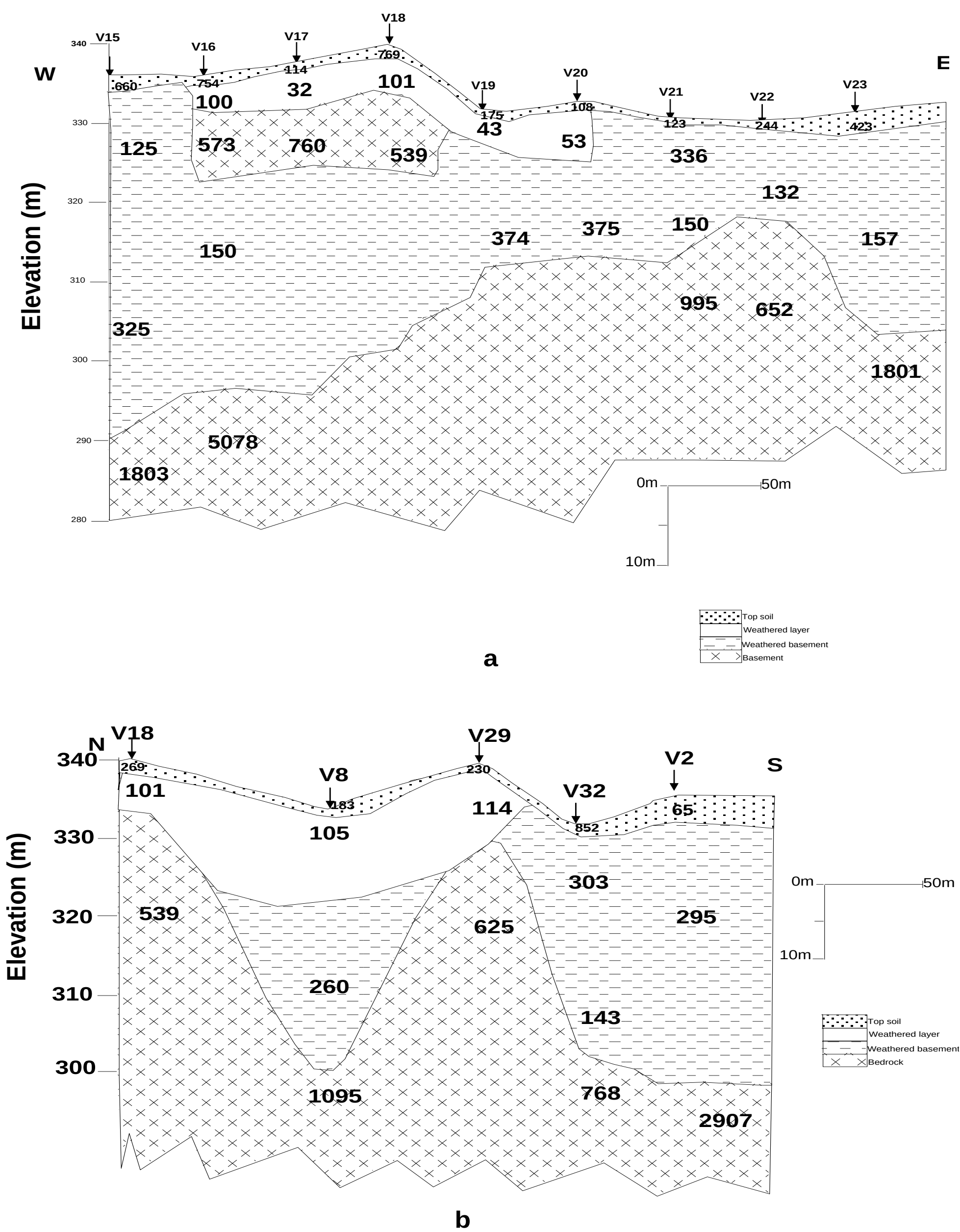


Figure 4. (a) Geoelectric section along Traverse 1 (W-E) Tutugbua, Akure SW Nigeria, (b) Geoelectric section along Traverse 8 Tutugbua area, Akure SW Nigeria.

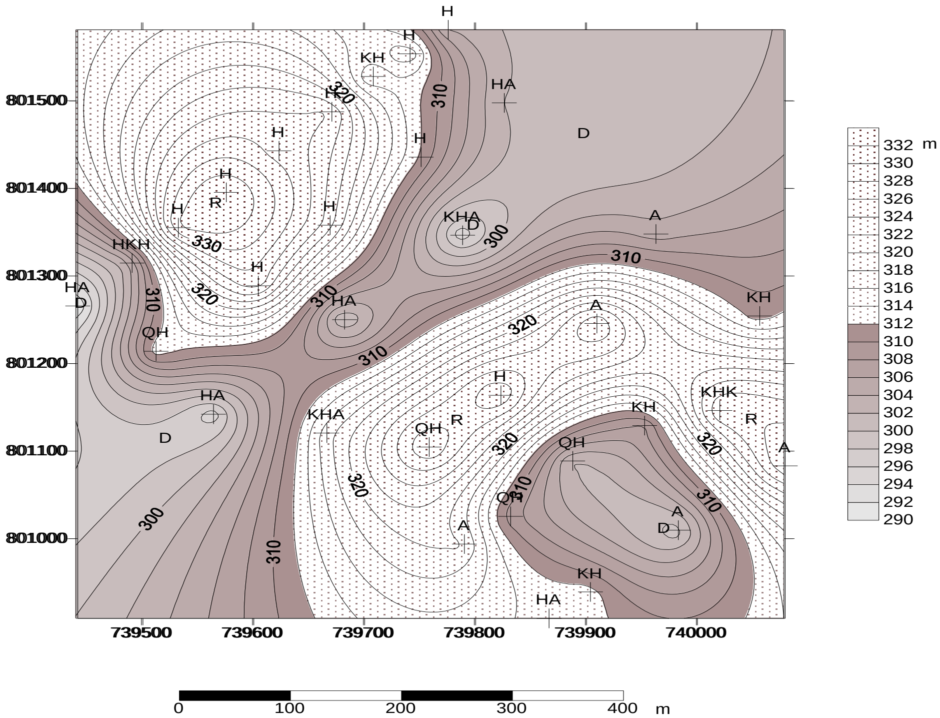


Figure 5. Bedrock relief map of Tutugbua Layout Akure, SW Nigeria.

340 to 760 ohm-m and thickness of 3.5 to 4.5 m. There is presence of weathered basement on v_{21}, v_{22}, and v_{23}. Its resistivity varies from 130 to 160 ohm-m and thickness 10 to 25 m. Also, there is presence of fractured basement with resistivity of about 150 ohm-m and thickness of 24 m found at v_{16}. The partially weathered basement with resistivity of 325 ohm-m is found at v_{15}. The bedrock has resistivity of 540 to 5078 ohm-m and an infinite thickness. The bedrock resistivity of less than 1000 ohm-m could be fractured bedrock.

The structural variation showed thickening of the overburden towards the western part of the area, the depth to bedrock is deep towards the western side, basement dipping towards the western side. The down dip side had the highest depth to bedrock, which is controlled by structural features relevant for groundwater development. In Figure 4b the topsoil resistivity range from 65 to 852 Ωm with thickness of about 0.7 to 3.5 m. The second layer had resistivity of 101 to 114 Ωm and thickness of 3.7 to 8.8 m, which correspond to clay materials. In v_{18}.and v_{29} the clay materials overlay the bedrock with resistivity of 540 to 625 Ωm. However, in v_2, v_8 and v_{32} there is presence of thick weathered basement (23.3 to 33.6 m) with resistivity of 143 to 295 Ωm, harboring the groundwater in the area.

Structurally, the basement is close to the surface around v_{18} and v_{29} while it is very deep around v_2, $v_{8,}$ and v_{32}. Thus, the basement highs and lows coincide with low depth to bedrock and high depth to bedrock. The structural changes from highs to lows are marked by plane of weakness which may be due to the presence of joints/fractures/faults that are promising geologic features that harbor groundwater. The aquifers in the study area are the weathered basement/fractured basement and the fractured bedrock were mapped in the area. The layer thickness and its lithology were compared with sections of shallow hand-dug wells in the area.

Bedrock relief distribution map of the study area

The bedrock relief map (Figure 5) of the study area shows series of basement ridges (R) and depressions (D) that were mapped. These depressions formed an elongated/linear structures that trend NE-SW and approximately N-S thus, the presence of a buried river channel cannot be ruled out. Also, at the southern portion of the study area another depression was mapped trending approximately NW-SE. These series of depressions serve as groundwater collecting centers. The depressions coincide mostly with curve types such as KH, QH, KHA, and HKH while the basement ridges coincide with H and A curve types thus, suggesting that the basement is close to the surface and not relevant in groundwater development.

Point map of coefficient of anisotropy and basement relief map

The coefficient of anisotropy (λ) range from 0.97 to 1.35

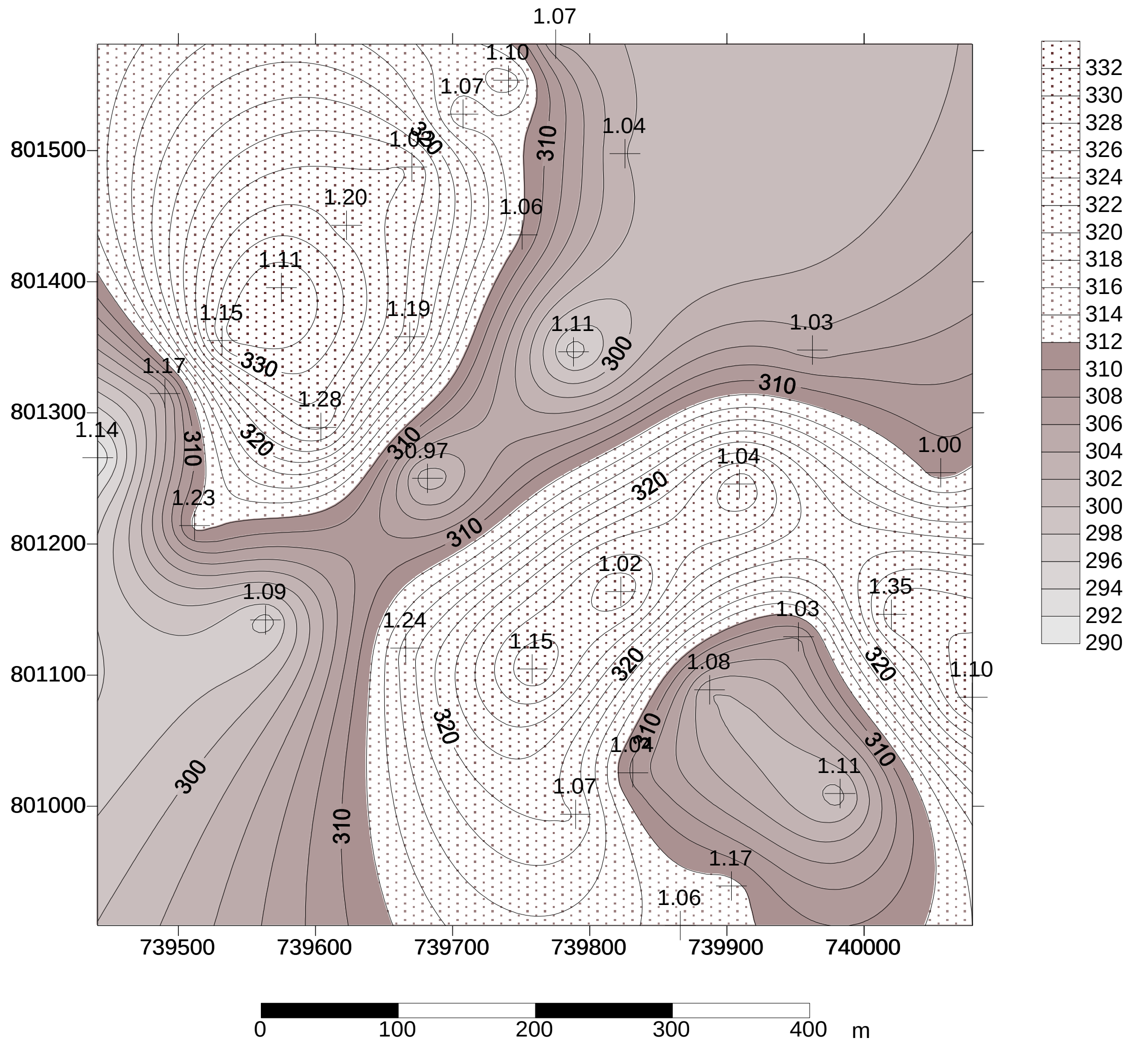


Figure 6. Coefficient of Anisotropy values and basement relief map in Tutugbua, Akure SW Nigeria.

(Figure 6), from the northwestern side there is presence of a basement ridge with characteristics λ value of 1.03 to 1.28. This relative high λ value coincides with shallow basement ridge thus, suggesting that it arises from near surface inhomogeneity materials such as the topsoil and weathered/partially weathered layer that could not support groundwater development. However, within the basement depression the λ values range from 0.97 to 1.11 which is of moderate λ values. These λ values are found within the basement depression of significant depth.

Thus, the λ arises from structural features such as fractures, joints, and faults, and are relevant in the groundwater development of the study area. The basement ridge at the southern portion is characterized by large λ values of 1.02 to 1.35 similar to the northwestern portion, also of shallow depth, which could not support groundwater resource development in the area.

Isopach map of the overburden

The study area is characterized by thin and thick overburden (Figure 7). The thin overburden (2 to 22 m) is found at the northwestern and south central portions of the area. Also, the thick overburden (24 to 44 m) is found at the northeastern, southwestern, and southeastern parts of the area. The presence of thick overburden favours the groundwater resources in the area particularly when underlain by weathered/fractured basement and fractured bedrock.

Variation of anisotropy with depth

The plot of coefficient of anisotropy values with depth (Figure 8) showed a form of scatter diagram. This variation (scatter diagram) is mostly geologically controlled; the factors include weathering, near surface

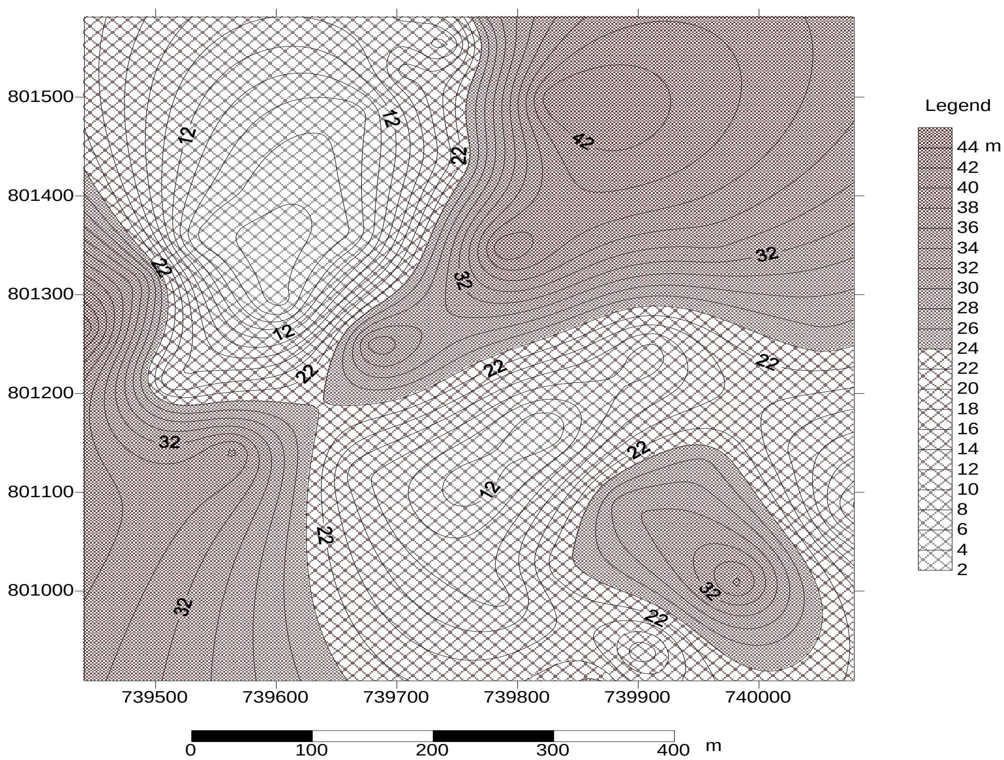


Figure 7. Isopach map of the overburden in the study area.

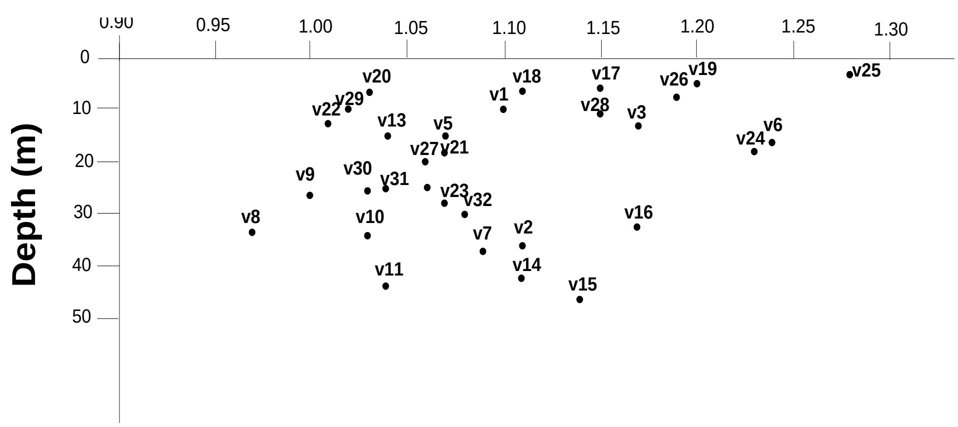


Figure 8. Variation of coefficient of anisotropy with depth in Tutugbua, Akure SW Nigeria.

inhomogeneities and structural features among others (Henriet, 1976; (Olorunfemi et al., 1991).

The λ values that are characterized by shallow depth showed non-presence of significant structural features that are diagnostic of good groundwater development. However, large λ values (1.05 to 1.35) of appreciable depth (> 25 m) suggest the presence of structural features such as fractures, joints, and faults with good subsurface impression that are relevant in groundwater resource development.

Evaluation of overburden materials as protective medium

The materials overlaing the mapped aquifers were evaluated using the layer parameters and S to determine its capacity to prevent infiltration into the aquifer. This is because the earth medium acts as a natural filter to percolating fluid. Its ability to retard and disallow the percolating fluid is a measure of its protective capacity (Adelusi, 2008). Thus, the geologic materials could act as

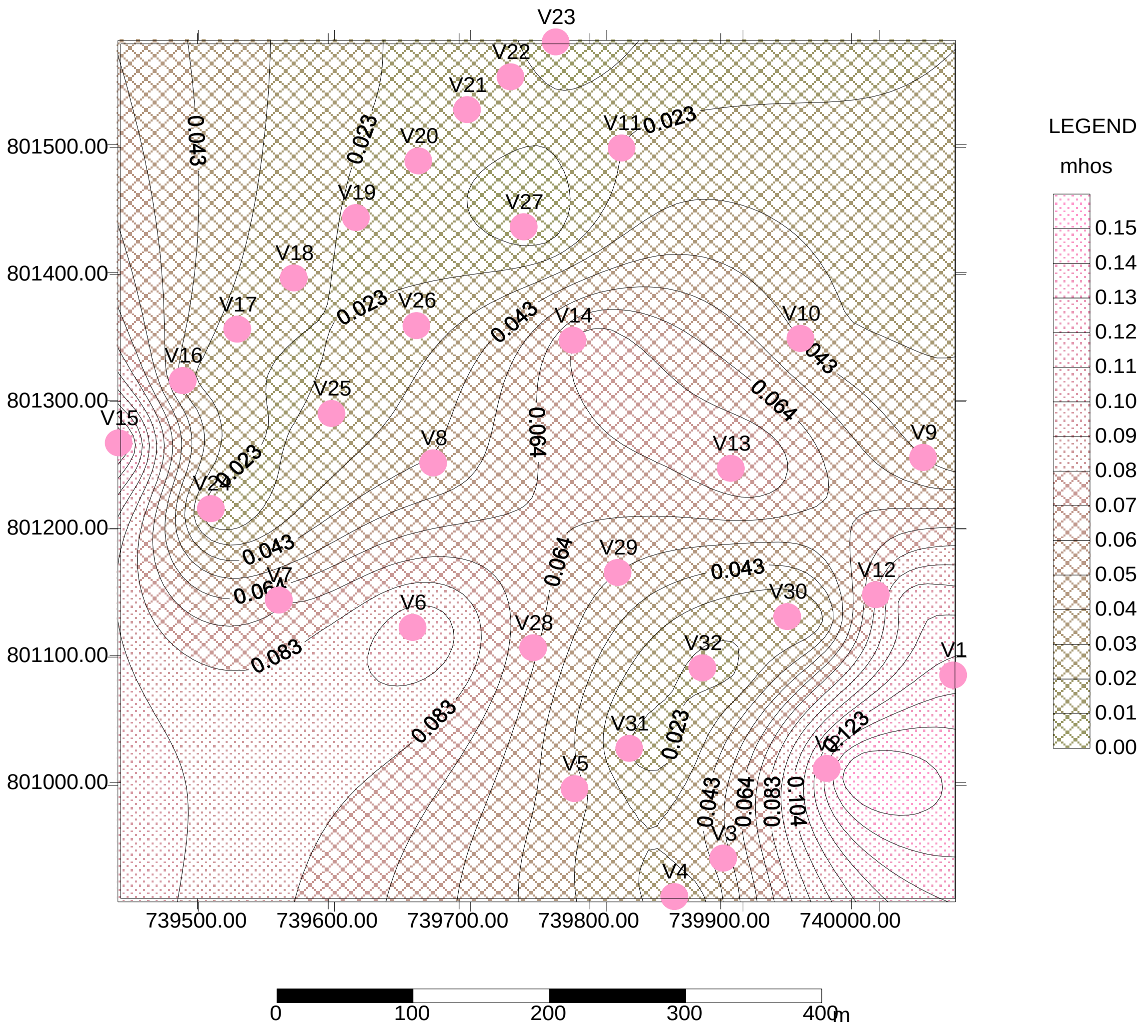


Figure 9. Overburden longitudinal conductance map of Tutugbua Akure, SW Nigeria.

seal in preventing the fluid from penetrating the aquifer thus protecting it. In the study area, the materials above the aquifers are relatively low to moderate layer resistivity and of thin thickness (< 15 m) thus making the aquifer vulnerable. The S value ranges from 0.0035 to 0.17 mhos (Figure 9). According to the classification of (Oladapo and Akintorinwa, 2007) in Table 4, the S values from the study area are very low and the corresponding rating is poor to weak. Therefore the basement aquifer is vulnerable to infiltration.

Conclusion

The use of geoelectric technique in evaluating the aquifer system and its risk has been established in the study area. The aquifer types delineated are the weathered/partially weathered layer, the weathered basement/fractured basement/fractured bedrock. These aquifer types are mostly marked by series of depressions, relative thick overburden and high λ values.

ACKNOWLEDGEMENTS

We are grateful to Messrs Ogunmola Idowu and Musa Bawallah who assisted in data gathering. Also the assistance of other colleagues both academic and technical are acknowledged with thanks

REFERENCES

Adelusi AO (2008). Aquifer Mapping and Assessment of its Risk using Electrical Resistivity Sounding Technique in Akure Metropolis Southwestern Nigeria. Niger. J. Pure Appl. Phys. (In press).

Adelusi AO, Balogun O (2001). A geoeletric investigation for groundwater development of Orita-Obele area, near Akure SW Nigeria. Global J. Pure Appl. Sci. 7(4):707-717.

Ako BD, Osondu UC (1986). Electrical resistivity survey of Keri-Keri

Formation Darazo, Niger. J. Afr. Earth Sci. 5(5):527-534.
Archie GE (1942). The Electrical Resistivity Log as an aid in determining some reservoir characteristics. Trans. A.I.M.E. 146:54-62.
Barker R, Blunk I, Smith I (1996). Geophysical consideration in the design of U.K. National Resistivity Sounding database. First Break 14(2):45-53.
Billings MP (1972). Structural Geology (3rd Edition) 33-34 Prentice-Hall Englewood Cliffr. NJ.
Ebraheem AM, Sensosy MM, and Dahab KA (1997). Geoelectrical and Hydrochemical studies for delineating groundwater contamination due to salt water intrusion in the northern part of the Nile delta, Egypt. Groundwater 35:216-222.
Miller R (2006). Hydrogeophysics: Introduction to this special section. The Leading Edge. P. 713.
Folami SL (1998). Geological and geophysical mapping of Precambrian rocks in Odo-Igbo area of Osun State, Southwestern Nigeria. AMSE J. 57(1):1-24.
Frohlich RK, Urish DW, Fuller J, O'Relly M (1994). Use of geoelectrical methods in groundwater pollution surveys in a coastal environment. J. Appl. Geophys. 32:139-154.
Ghosh DP (1971). The application of linear filter theory to the direct interpretation of geoelectrical resistivity sounding measurements. Geophys. Prospecting 19:192-217.
Henriet JP (1976). Direct application of Dar-Zarrouk parameters in groundwater surveys. Groundwater Prospecting 24:344-353.
Kunetz G (1966). Principles of Direct current prospecting. Geophys. Monogr. 1(1):103.
Maliek SB, Bhattacharya DC, Nag SK (1973). Behavior of fractures in hard rocks – a study by surface geology and radial VES methods. Geoexploration 21:529-556.
Oladapo MI, Akintorinwa OJ (2007). Hydrogeophysical study of Ogbese southwestern Nigeria Global J. Pure Appl. Sci. 13(1):55-61.
Oladapo MI, Mohammed MZ, Adeoye OO, Adetola BA (2004). Geoelectrical investigations of the Ondo state Housing Corporation Estate Ijapo Akure, Southwestern Nigeria. J. Min. Geol. 40(1):41-48.
Olorunfemi MO, Ojo JS, Akintunde OM (1999). Hydrogeophysical evaluation of the groundwater potential of Akure metropolis, southwestern Nigeria. J. Min. Geol. 35(2):207-228.
Olorunfemi MO, Fasuyi SA (1993). Aquifer types and the geoelctric/hydrogeologic characteristics of part of central basement terrain of Nigeria (Niger State). J. Afr. Earth Sci. 16(3):309-317.
Olorunfemi MO, Olarewaju VO, Alade O (1991). On the Electrical Anisotropy and Groundwater Yield in a Basement complex Area of S.W. Nigeria. J. Afr. Earth Sci. 12(3):462-472.
Omosuyi GO, Ojo JS, Enikanselu PA (2003). Geophysical Investigation for groundwater around Obanla-Obakekere in Akure area within the basement complex of southwestern Nigeria. J. Min. Geol. 39(2):109-116.
Rahaman MA (1988). Recent advances in the study of the basement complex of Nigeria. In Precambrian geology of Nigeria, Geological survey of Nigeria, Kaduna South. pp. 11-43.
Sundararajan N, Nandakumar G, Chary NK Ramam K, Srinivas Y (2007). The Leading Edge. pp. 708-715.
Vander Velpen BPA (2004). RESIST Version 1.0. M.Sc. Research Project, ITC, Delft Netherland.