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Determination of Aquifer Parameters from Resistivity Data: A Case of University of Ilorin Campus, Northcentral Nigeria

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Abstract

A total of twenty-one (21) vertical electrical sounding (VES) data were acquired using *Pz-02* resistivity meter within the Precambrian basement area of part of Ilorin Metropolis north central Nigeria to evaluate the hydraulic characteristics of aquifers. The Schlumberger configuration with half-current electrode separation (AB/2) varying from 1 m to 60 m was used. The aquifer hydraulic characteristics such as hydraulic conductivity K and transmissivity T (Ωm^2) were calculated from the interpreted VES data using the concept of Dar-Zarrouk parameters. The data, processed with computer software *IPI2WIN*, indicated three to four geo-electric layers, namely; topsoil, clayey (wet to dry), weathered or fractured basement and fresh basement with resistivity values ranging from 130 to 1469 Ωm, 52.6 to 8552 Ωm, 46.2 to 249 Ωm and 454 to 5022 Ωm, respectively. The depth to aquifer ranges between 6.17 m and 24.9 m and the overburden thickness ranges between 4.1 m and 22.7 m. The assessment of the materials above the aquifers showed that longitudinal conductance lies between 0.02 and 0.468 Ω^{-1}, transmissivity values vary from 246 to 2419.8 Ωm^2. The results obtained have offered worthwhile hydrologic information that will aid both exploration and exploitation of the groundwater system of the study area.

Keywords: Dar-Zarrouk parameters; aquifer; groundwater; VES; geoelectric layer.

Introduction

Understanding the aquifer parameters such as depth, thickness, hydraulic conductivity and transmissivity is important for the determination of groundwater flow through an aquifer as water is a key ingredient supporting food production, sanitation and human livelihoods as well as ensuring continuity and functioning of ecosystem. It dictates the pace of settlements, agricultural and industrial development of any society and even in recent times, establishment of any human settlement was usually centered on available sources of water supply and in modern times, issues of water have taken prominences in global matters (Humaira and Jose 2009). Although these parameters could be deduced from pumping test analysis, attempts have been made in this work to employ resistivity data of vertical electrical sounding (VES) in order to reduce the amounts of hydrogeological observations and the resulting costs. There is no gainsaying in the analysis of the correlation between the geoelectric parameters and aquifer in both saturated and unsaturated zones which was reported by Mazac et al. (1985). Therefore, surface geophysical methods like VES technique play vital roles as alternatives to reduce the number of necessary pumping tests, which are not only expensive but also time consuming in determining aquifer parameters. The VES survey was conducted beside all the twenty one (21) existing boreholes in the main campus of the University of Ilorin with the aim of investigating the hydrogeological characteristics of aquifer in the study area in predicting the sustainability of the existing boreholes and also the viability of any proposed boreholes. The results of the resistivity data obtained beside all the twenty-one (21) expecting boreholes (Figure 1) in the main campus were used to estimate the aquifer hydraulic characteristics such as hydraulic conductivity, K and transmissivity, T (Ωm^2) via the concept of Dar-Zarrouk parameters. The concept of Dar-Zarrouk parameters was first proposed by Maillet (1947). This postulation holds from the fact that, when the thickness and resistivity of a lithologic subsurface layer is known, its transverse resistance (R) and longitudinal conductance (*S*) can be calculated easily. Use of layer thickness, as derived from the interpretation of resistivity soundings data and hydraulic conductivity calculated on the basis of both hydrogeological and geophysical data led to the calculation of aquifer transmissivity. This technique was used for the determination of aquifer parameters in the study area.

Locations and Accessibility

The study locations comprise some selected existing bore hole sites in the main campus of University of Ilorin, covering an area between latitudes 8° 27’ 36” to 8° 29’ 46” and longitudes 4° 38’ 25” to 4° 40’ 48” (Figure 1). The study area can be rated moderately accessible due to the road network systems which include the major road which leads into the campus from the school main gate, minor roads which connect the various establishments and footpaths linking the other parts of the area. Relatively good network of tarred and track roads made the field data acquisition possible. Ilorin, by virtue of its location, enjoys a warm tropical climate with relatively high temperatures throughout the year, with well-defined rainy (wet) and dry seasons. The rainy season occurs from March to October, while the dry season occurs between November and February. The rainfall is concentrated between May and October but characterized by two peaks in July and September. The dry season is usually characterized by bright sunshine, bringing with it, hot and dry winds known as the harmattan. This makes the humidity extremely low, the grasses dried, and most of the rivers and streams in the area dried up. Variations in the climatic conditions have adverse effects on vegetation in the study area. The natural vegetation zones resulted from the interactions of the climate, humidity, rainfall and soils (Iloeje 2001). These factors have been modified by human activities and man’s patterns of land use. Generally, vegetation of major part of southwestern Nigeria represents that of the rain forest characterized by thick to light vegetation. Natural vegetation is characterized by tall trees and thick forest. Very light vegetation is found only where there have been human activities such as cultivation, mining, charcoal production and man’s patterns of land use. The topography of the study area is generally undulating, as it is lithologically controlled, consisting of rugged terrains with series of highlands, lowlands with steep and gentle slopes. Thus, the landforms can simply be classified into highlands, hills, plains and river valley systems. The drainage is perfectly dendritic and the drainage system is such that most of the streams generally empty into the bigger River Oyun which flows southwards. This major river has however been dammed at the south, thereby acting as a major source of water for the university community. Most of the streams and rivers especially the small ones are seasonal as they often dry up in the dry season.

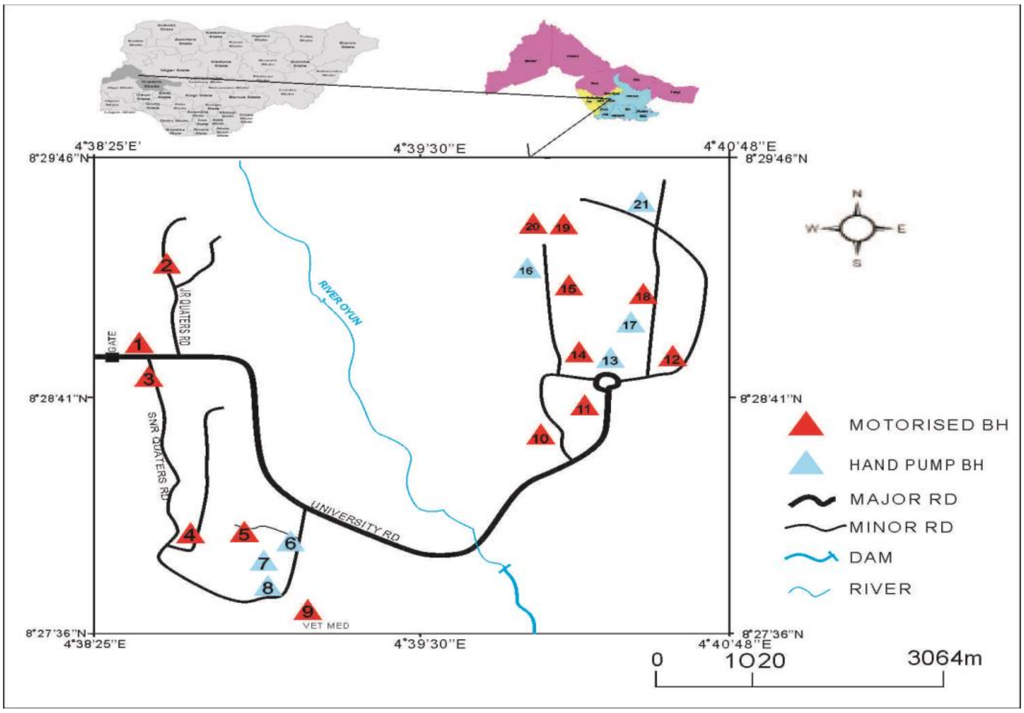

Figure 1: Location map of some existing boreholes on University of Ilorin.

Geological Settings

The study area, within Ilorin Metropolis, is mainly underlain by banded gneiss, but bordered at the southeastern corner by granite gneiss. These rocks are intruded intermittently by pegmatitic veins. While the banded gneiss rocks are strongly foliated, those of the granite gneiss are weakly foliated. Foliation planes of these rocks generally strike north-south, with gentle to moderate dips. These rocks which belong to the Southwestern Nigerian Basement Complex are poorly exposed in the area, and where seen, they occur as low-lying outcrops. The Nigerian Basement Complex, of which the Southwestern Nigeria Basement Complex is a part, forms a part of the African crystalline shield occurring within the Pan African mobile belt that lies between the West African and Congo Cratons and south of the Tuareg Shield (Black 1980). Different ages have been ascribed to the Nigerian Basement Complex using different radiometric dating methods such as Rb/Sr, K/Ar and Th/Pb. Grant (1970) observed that the majority of the radiometric ages obtained; fall in the range of 600 Ma, which corresponds to the Pan-African thermo-tectonic event. The Nigerian Basement Complex terrain occupies about half the landmass of the country, with its pronounced deformation and mobilization during the Pan-African age (600 Ma) (Figure 2). The Pre-Cambrian rocks consist predominantly of folded gneisses, schist and quartzite into which have been emplaced granitic and to a lesser extent, more basic materials.

Three principal subdivisions are recognizable within the basement complex. Elueze (2000) gave these subdivisions as: (i) The ancient Migmatite Gneiss Complex, (ii) The Schist Belts, and (iii) The Pan African plutonic series.

The Migmatite-Gneiss Complex has a heterogeneous assemblage comprising migmatites, orthogneises, paragneisses and a series of basic and ultrabasic metamorphosed rocks. Gneisses vary in mineralogical composition and character, with two types recognizable in the Basement Complex; the biotite gneiss and the hornblende biotite gneiss (Okunlola and Udoudo 2005). The imprint of the Pan-African event did not only structurally overprint and re-set many geochronological clocks in the older rocks, but also gave rise to granite gneisses, migmatites and other similar lithological units. The Migmatite–Gneiss Complex has ages ranging from Pan-African to Liberian.

The Schist Belts which comprise low grade, metasediments-dominated belts, trending north-south are best developed in the western half of Nigeria, west of 8°E longitude. The lithological variations of the schist belts include quartzites, amphibolites, pelitic and mica-schists, calc-silicate rocks, marbles, phyllites, meta-conglomerate iron formations and subordinate meta-igneous rocks (Elueze 1992).

The Pan African plutonic series referred to as the Older Granites occur intricately associated with the Migmatite-Gneiss Complex and the Schist Belts into which they generally intruded and are believed to have been emplaced during the Pan-African orogeny (Harper et al. 1973). The Pan-African intrusive suite comprises mainly granites and granodiorite, with subordinate pegmatite and aplites.

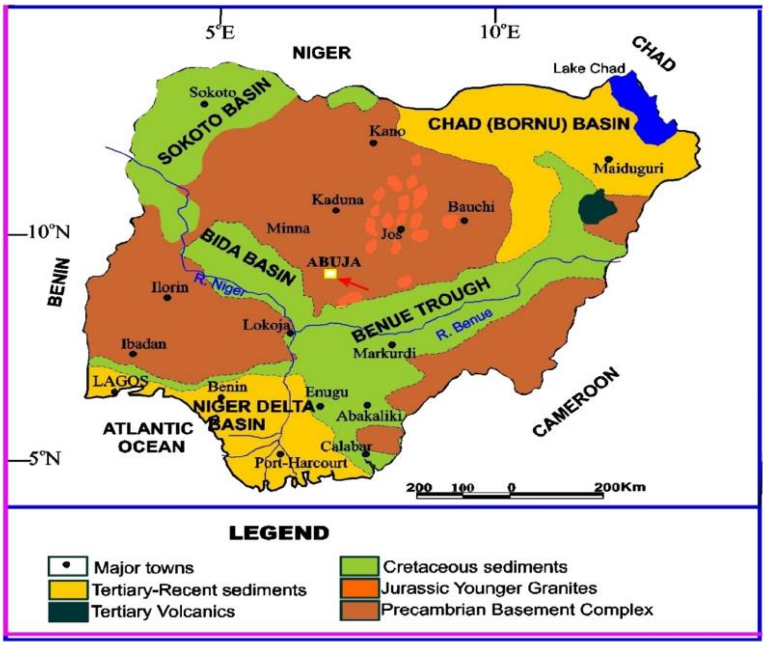

Figure 2: Generalized geological map of Nigeria showing the three lithological units (After: Obaje 2009a, b).

Materials and Methods

The geophysical data were acquired with a Pz-02 resistivity meter which contains both the transmitter unit, through which current enters the ground and the receiver unit, through which the resultant potential difference is recorded. Other materials included: two metallic current and two potential electrodes, two brown coloured connecting cables for current and two blue coloured cables as potential electrodes, two tapes, hammer for driving the electrodes into the ground, compass for finding the orientation of the traverses, cutlass for cutting traverses and data sheet for recording the field data.

Vertical Electrical Sounding (VES) of resistivity method has been applied for the data acquisition. VES survey was carried out in 21 locations on some existing water boreholes using Schlumberger electrode configuration (Figure 3).

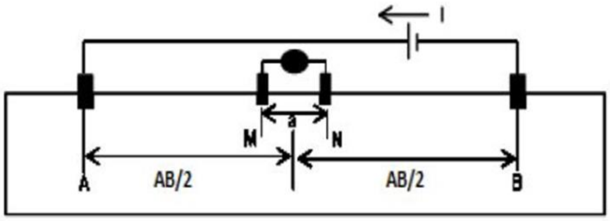

Figure 3: A Schematic representation of the Schlumberger Array.

The Schlumberger method was adopted for this study because its fieldwork is faster, easier and more economical and softwares are readily available for its interpretation (Todd 1980). The Schlumberger sounding techniques were carried out with current electrode spacing (AB) ranging from 2 to 120 m (AB/2 = 1 m to 60 m). The distances used for potential electrode spacing (MN) ranged from 0.5 m to 12 m (MN/2 = 0.25 m to 6 m). At each VES station, electrodes were placed in a straight line and the inter-electrode spreads were gradually increased about a fixed centre. The potential electrodes were increased only when it became too small for reliable readings to be obtained and the separation did not exceed 6 m in any VES station. The data collection points of the study area are shown in Figure 1. The current was sent into the ground and the potential difference (V) due to this current was measured and recorded against the electrode spacing. With these values of currents (I) and potential (V) of the electrode configuration, apparent resistivity was deduced. The apparent resistivity values were plotted against AB/2. The manner in which apparent resistivity values increase or decrease with electrode separation forms the basis for choosing the shape of the field curve that can perform quantitative interpretation of the sub surface resistivity distribution. The plot was curve matched with the aid of computer-aided iteration curve matching techniques using *IPI2WIN* software. The VES curves generated yielded the thickness and the apparent resistivities of the different geoelectric layers.

Dar - Zarrouk Parameter

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).

$$S = \frac{h}{\rho} = h\sigma \qquad (1)$$

To obtain a layer parameter, a unit square cross sectional area is cut out of the aquifer layers of infinite lateral extent. The transverse resistance, R is given by:

$$R = h\rho \qquad (2)$$

where; σ is the electrical conductivity, which is analogous to the hydraulic conductivity K of the layer, S is the longitudinal conductance which is analogous to layer transmissivity T, and h is the thickness of the layer. R and S are called Dar-Zarrouk parameters, which have been shown to be powerful interpretational aids in groundwater surveys (Zohdy et al. 1974). Maps such as longitudinal conductance (S) and transmissivity (T) are generated in order to characterize and delineate depth to the aquifer, its thickness and to evaluate its protective capacity in the area as well as assessing its recharge capability.

Results and Discussion

VES data and field curve analysis

The sounding data were analyzed with the IPI2WIN software to delineate the subsurface layers as well as their depths, thickness and the resistivity values (Table 1). Sample field curves at sounding locations across the study area are shown in Figures 4 to 7. In each of these diagrams, both the variations in apparent resistivity values with electrode spacing as well as the modelled layer resistivity versus depth are plotted. These curves suggest that the area is underlain by 3-4 geoelectric layers of various lithologies. The topsoil with resistivity values ranging from 130 to 1469 Ωm, clayey (wet to dry) with resistivity values varying from 52.6 to 8552 Ωm, weathered or fractured basement with resistivity values of 46.2 to 249 Ωm and fresh basement with resistivity values of between 454 and 5022 Ωm (Table 1).

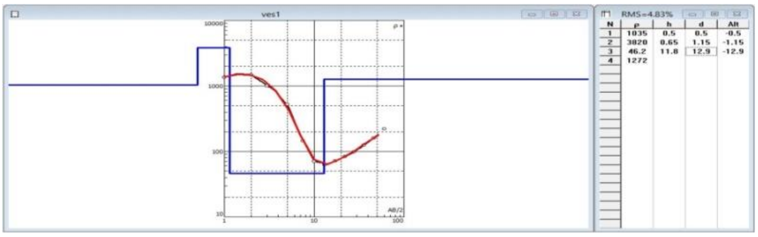

Figure 4: Resistivity curve for VES 1 (004°38'21.4"N, 008°28'53.3"E).

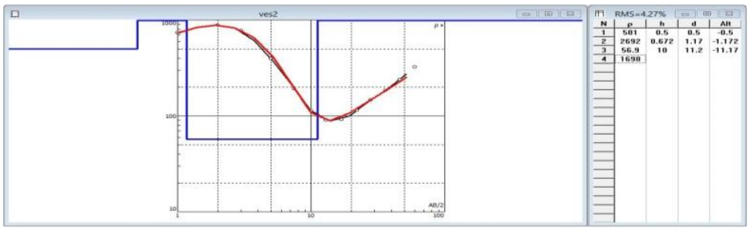

Figure 5: Resistivity curve for VES 2(004°38'28.9"N, 008°29'11.2"E).

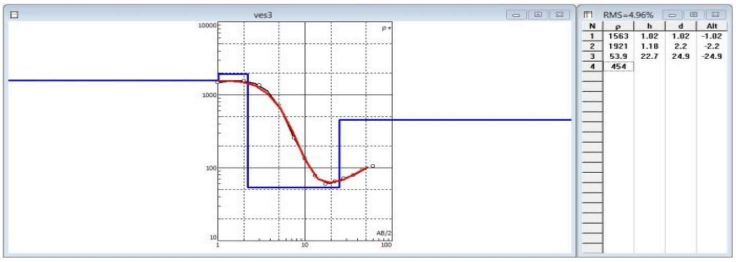

Figure 6: Resistivity curve for VES 3(004°38'27.3"N, 008°28'43.7"E).

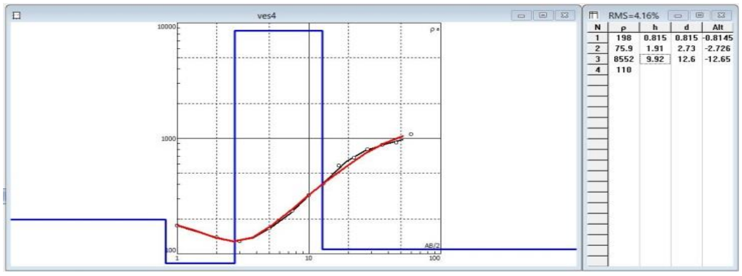

Figure 7: Resistivity curve for VES 4(004°38'43.6"N, 008°28'01.2"E).

Table 1: Summary of the geoelectric parameters obtained for the study area

VES point	No of layers	Resistivity layer (Ωm)	Layer thickness (m)	Lithological description
1	4	1035, 3820, 46.2, 1272	0.5, 0.65, 11.8	Lateritic top soil, dry clayey sand, weathered or fractured basement, fresh basement
2	4	501, 2692, 56.9, 1698	0.5, 0.672, 10	Top soil, dry clayey sand, weathered or fractured basement, fresh basement
3	4	1563, 1921, 53.9, 454	1.02, 1.18, 22.7	Lateritic top soil, dry clayey sand, weathered or fractured basement, fresh basement
4	4	198, 75.9, 8552, 110	0.815, 1.91, 9.92	Top soil, clayey sand, dry clayey sand, weathered or fractured basement
5	3	1172, 127, 1461	1.08, 6.91	Lateritic top soil, weathered or fractured basement, fresh basement
6	4	398, 1387, 91.5, 542	0.5, 0.882, 7.27	Top soil, dry clayey sand, weathered or fractured basement, fresh basement
7	4	666, 414, 93.3, 842	0.5, 2.64, 13.3	Lateritic top soil, clay sand, weathered or fractured basement, fresh basement
8	4	880, 1992, 101, 528	0.699, 0.551, 7.8	Lateritic top soil, dry clayey sand, weathered or fractured basement, fresh basement
9	3	872, 52.6, 197	1.11, 7.22	Lateritic top soil, clayey sand, weathered or fractured basement
10	4	604, 78.2, 1053, 629	1.46, 1.89, 17.8	Lateritic top soil, weathered or fractured basement, dry clayey sand, weathered or fractured basement
11	4	362, 1109, 38.5, 1216	0.5, 1.05, 6.39	Top soil, lateritic soil, weathered or fractured basement, fresh basement
12	4	372, 881, 79, 768	0.5, 1.57, 4.1	Top soil, lateritic soil, weathered or fractured basement, fresh basement
13	4	325, 71, 25.3, 249	0.646, 4.21, 4.96	Top soil, clayey sand, weathered basement, fractured basement
14	4	564, 1735, 98.7, 1893	1.22, 1.19, 18.7	Lateritic top soil, soil, dry clayey sand, weathered or fractured basement, fresh basement
15	4	290, 1047, 111, 832	0.923, 3.82, 21.8	Top soil, lateritic soil, weathered or fractured basement, fresh basement
16	4	1469, 5974, 82.7, 2418	0.5, 0.822, 8.9	Lateritic Top soil, dry clayey sand, weathered or fractured basement, fresh basement
17	3	213, 36.5, 5022	1.55, 17.1	Top soil, weathered or fractured basement, fresh basement
18	4	235, 533, 46.2, 716	0.627, 1.45, 11.1	Top soil, lateritic soil, weathered or fractured basement, fresh basement
19	3	447, 41.4, 1144	1.46, 6.72	Top soil, weathered or fractured basement, fresh basement
20	3	447, 24.9, 2276	1.87, 5.7	Top soil, weathered or fractured basement, fresh basement
21	4	130, 731, 46.8, 884	0.489, 0.734, 6.95	Top soil, lateritic soil, weathered or fractured basement, fresh basement

Aquifers depth and thickness estimation

The aquifer thickness (Table 2) in the study area ranged between 4.1 and 22.7 m. They are categorized as thickest, thick and fairly thick as shown in (Figure 8) with VES 3, having the highest thickness of about 22.7 m thick and VES 12 with the lowest aquifer thickness of 4.1 m. The aquifer unit in the area is the second or third geoelectric layer. The depth to the aquifer ranged between 6.17 and 24.9 m across the entire study area. The depth to the aquifer was shallow around VES 12, 13, 20, and 11 with an average depth of about 12.88 m. The deepest aquifers at about 24.9 m depth lie coincidentally around the location of the thickest aquifer. The thickest aquifer in the area is suitable for the groundwater exploitation due to its greater depth and is presumably free from sewage and surface contaminations. However, chemical analysis of the groundwater is still required to determine its suitability for consumption.

Table 2: Aquifer thickness and depth to aquifer inferred from resistivity data curve interpretation and reflection coefficient

VES No	Longitude	Latitude	Elevation	Depth to aquifer (m)	Aquifer thickness (m)
1	004°38'21.4"	008°28'53.3"	326	12.9	11.8
2	004°38'28.9"	008°29'11.2"	329	11.2	10
3	004°38'27.3"	008°28'43.7"	336	24.9	22.7
4	004°38'43.6"	008°28'01.2"	365	12.6	9.92
5	004°38'58.2"	008°28'00.5"	331	7.99	6.91
6	004°39'03.4"	008°28'00.8"	318	8.65	7.27
7	004°39'00.4"	008°27'57.4"	333	16.4	13.3
8	004°39'00.5"	008°27'53.7"	325	9.05	7.8
9	004°39'04.5"	008°27'43.5"	351	8.33	7.22
10	004°40'06.9"	008°28'27.8"	349	21.1	1.89
11	004°40'19.0"	008°28'38.6"	363	7.94	6.39
12	004°40'38.3"	008°28'45.1"	351	6.17	4.1
13	004°40'25.0"	008°28'48.2"	362	9.81	5.64
14	004°40'18.3"	008°28'49"	353	21.1	18.7
15	004°40'14.3"	008°28'54.6"	349	26.5	21.8
16	004°40'07.5"	008°28'56.4"	344	10.2	8.9
17	004°40'26.5"	008°29'01.1"	383	18.6	17.1
18	004°40'28.8"	008°29'04.8"	371	13.2	11.1
19	004°40'10.3"	008°29'06.4"	336	8.18	6.72
20	004°40'10.5"	008°29'05.7"	336	7.57	5.7
21	004°40'30.7"	008°29'28"	382	8.17	6.95

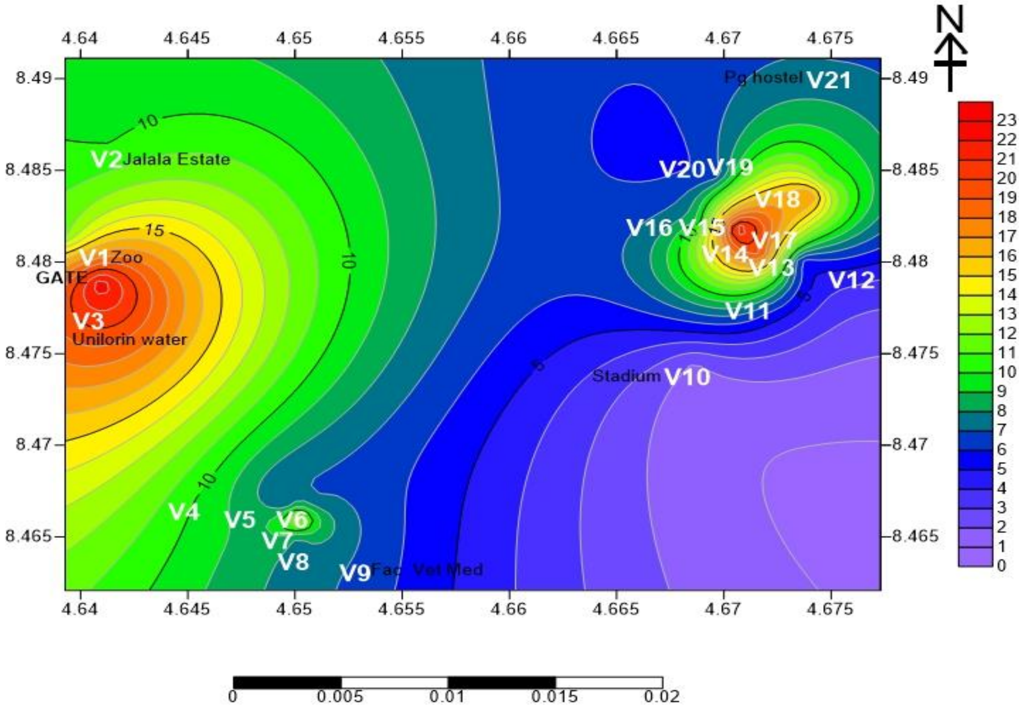

Figure 8: Aquifer thickness map of the study area.

Characteristics of the aquifer systems

The hydraulic characteristics of the several aquifer types within the study area were established using the concept of Dar-Zarrouk parameters (Niwas and Singhal 1981), the results are shown in Table 3. The longitudinal conductance (S) values varied from 0.02 to 0.468 Ω^{-1} in the study area with contour intervals of 0.02 Ω^{-1} (Figure 9). The south eastern part was dominated with low S values (0.02 to 0.1 Ω^{-1}), whereas the VES stations 17 and 3 had very highest values of 0.468 and 0.412, respectively. High S values (> 0.2 Ω^{-1}) were observed at VES stations 1, 18 and 21. Elsewhere, the S value with moderate clayey overburden, which is characterized by relatively high longitudinal conductance values, offers protection to the underlying aquifer. According to the classification of Oladapo and Akintorinwa (2007), and Atakpo (2013), the longitudinal conductance values facilitate to classify the area into poor, weak, moderate, good and very good protective capacity zones. Where the conductance is greater than 0.4 Ω^{-1}, they are considered as zones of very good protective capacity. The part having conductance values ranging from 0.2 to 0.4 Ω^{-1} was classified as zone of good protective capacity, areas with S values ranging from 0.1 to 0.2 Ω^{-1} were classified as moderate protective capacity and the section having a conductance values in the range of 0.01 to 0.1 Ω^{-1} exhibits weak protective capacity, while the zones where the conductance values were less than 0.01 Ω^{-1} were considered to have poor protective capacity.

Table 3: Summary of the aquifer parameters

VES No	Aquifer thickness h (m)	Apparent resistivity of aquifer ρa (Ωm)	Transverse resistance R = hρ (Ωm^2)	Longitudinal conductance S = h/ρ (Ω^{-1})	Hydraulic conductivity K (Ωm)	ransmissivity T = R (Ωm^2)
1	11.8	46.2	545.16	0.255	46.2	545.16
2	10	56.9	569	0.178	56.9	569
3	22.7	53.9	1223.53	0.421	53.9	1223.53
4	9.92	110	1091.2	0.09	110	1091.2
5	6.91	127	877.57	0.054	127	877.57
6	7.27	91.5	665.2	0.079	91.5	665.2
7	13.3	93.3	1240.9	0.143	93.3	1240.9
8	7.8	101	787.8	0.077	101	787.8
9	7.22	197	1422.3	0.037	197	1422.3
10	1.89	78.2	147.8	0.023	78.2	147.8
11	6.39	38.5	246	0.166	38.5	246
12	4.1	79	323.9	0.052	79	323.9
13	5.64	289	1629.9	0.02	289	1629.9
14	18.7	98.7	1845.7	0.189	98.7	1845.7
15	21.8	111	2419.8	0.196	111	2419.8
16	8.9	82.7	736	0.108	82.7	736
17	17.1	36.5	624.2	0.468	36.5	624.2
18	11.1	46.2	512.8	0.24	46.2	512.8
19	6.72	41.4	278.2	0.162	41.4	278.2
20	5.7	24.9	141.93	0.229	24.9	141.93
21	6.95	46.8	325.3	0.149	46.8	325.3

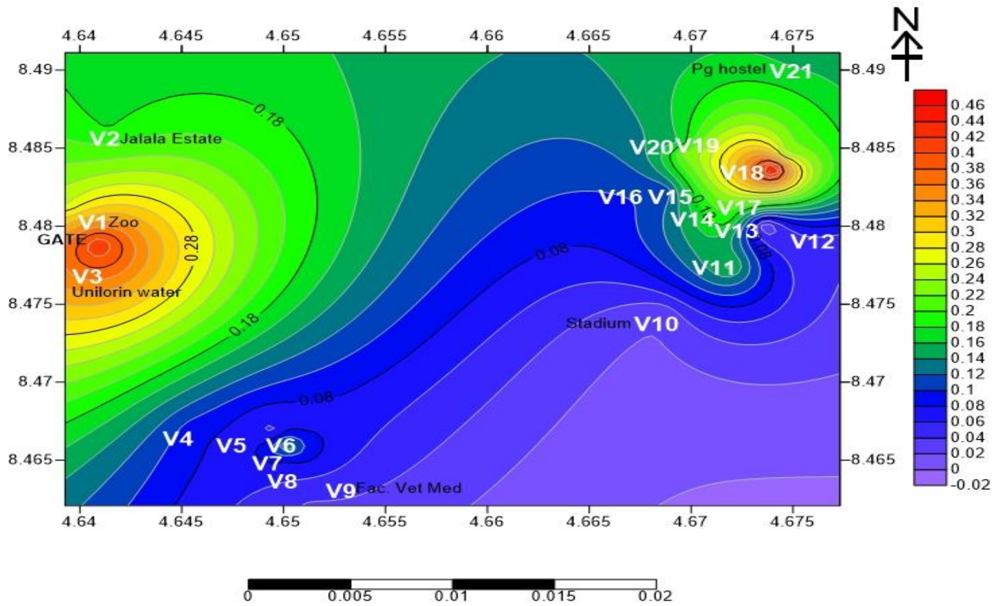

Figure 9: Longitudinal conductance map of the study area.

The S-map revealed that about 10% of the area falls within the very good protective capacity, while about 52% constitutes the good/moderate protective capacity rating and the remaining 38% exhibits weak protective capacity. This suggests that the entire study area, which is characterized by relatively moderate to high longitudinal conductance, envisages good aquifer protective capacity rating. Clayey/silty overburden in this part, which is characterized by relatively high longitudinal conductance, offers protection to the underlying aquifers. This means that aquifers within the unconsolidated overburden at the study area are mostly capped by impervious/semi-pervious materials, geologically protecting the underlying aquifers from near-surface contaminants. Oteri (1981) reported that a marked increase in S values may correspond to an average increase in the clay content, and therefore, a decrease in the transmissivity of the aquifer. The longitudinal conductance value at VES 17 has very good protective capacity rating. In Figure 9, the north-western and north-eastern parts of the study area reflects very good to good protective capacity rating as indicated from the high longitudinal conductance values. The low value of the protective capacity is a consequence of the absence of significant amount of clay as an overburden impermeable material in the south-eastern part thereby enhancing the percolation of contaminants into the aquifer. The aquifers here may be prone to contaminations such as industrial and agricultural wastes, septic tanks and landfills, if located close to the sounding points. The transmissivity (T) contour map with a contour interval of 100 Ωm^2 is shown in Figure 10. The T values varied from a minimum of 246 Ωm^2 at VES 11 to a maximum of 2419.8 Ωm^2 at VES 15. It is evident from Figure 10 that high T values (> 700 Ωm^2) were encompassing VES stations 3, 4, 5, 7, 8, 9, 13, 14, 15 and 16 in the study area, indicating fresh water zone. Increasing T values indicate high recharge of aquifers. The south-eastern and southern parts of the study area was characterized by low T values < 700 Ωm^2. The Dar-Zarrouk (D-Z) parameters are highly useful to comprehend the spatial distribution of groundwater in addition to the geometry of the sub-surface units and provide an indication to aquifer prospective zones in the study area. The advantage of using D-Z parameters to estimate protective capacity is that the non-uniqueness of interpreting resistivity data is minimized. These parameters provide positive solutions as they reflect very clear, conspicuous and widely varying ranges of sub-surface resistivities. They also do not possess an overlapping character and in turn facilitate easy resolution. These results also give a useful first approximation of the D-Z parameter variations and could be used to site exploratory boreholes. The aquiferous zones are clearly reflected in the longitudinal conductance (S) and transmissivity (T) maps.

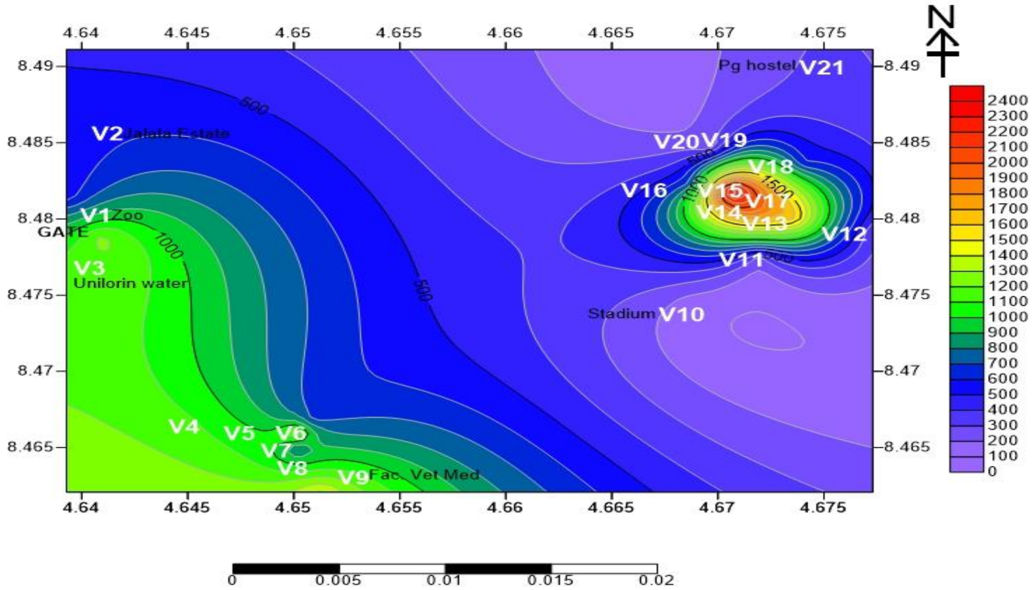

Figure 10: Transmissivity distribution in the study area.

As mentioned earlier, the entire area exhibited moderate to high S values (0.1 to 0.49 Ω^{-1}), thus indicating that clayey overburden was dominant in this region. Due to an increase in clay content, a decrease in transmissivity of aquifer is expected. However, the protective capacity rating of the aquifer is good at most of the sites. The low values of protective capacities at some stations in the south-eastern part of the study area indicate that the overburden material has no clayey overlying strata, which is a risk to groundwater contamination. Clay often constitutes protective geologic barriers. When found above an aquifer they constitute its cover. Transmissivity measures the amount of water that can be transmitted horizontally by a full saturated thickness of aquifer. Values (above 700 Ωm^2) are evident at VES stations 3, 4, 5, 7, 8, 9, 13, 14, 15 and 16 of the study area indicating high recharge water regimes. High T values are related with zones of high transverse resistance R and thus are highly porous to water movements. Such zones suggest that the groundwater aquifers have a high tendency of being contaminated, this indicates a weak protective capacity, which also results from absence of suitable aquitards (silts and clays) as results of the high transmisivity values in that zone, envisaged from VES 15.

Conclusion

The resistivity method used in this study has greatly assisted in delineating subsurface geoelectric parameters for determining aquifer potential within the University of Ilorin campus. Electrical resistivity probing data over the area were inverted and interpreted in terms of the distribution of the geoelectrical parameters in the area. The interpreted results of the twenty one (21) VES points revealed that the aquifers were made of weathered and fractured rocks showing three to four subsurface layers which include topsoil, clayey, weathered or fractured basement and fresh basement. Combination of electrical sounding results and Dar-Zarrouk parameters signify potential aquifer zones in the study area. The overburden protective capacity in the area was evaluated using the longitudinal conductance and transmissivity values from the transverse resistance. The transmissivity values indicated that majority of the aquifers in the study area have high yields. The longitudinal conductance map suggested good aquifer protective capacity rating in most parts of the study area. Groundwater development can be undertaken within areas that have the highest transmissivity, indicating that the aquifer can transmit water at higher rates and sustain the needs of the area. It can be concluded that the DC electrical methods are efficient tools for determining subsurface disposition of aquifer parameters units in a typical crystalline terrain.

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