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Hydrogeologic and Geoelectric Determination of Groundwater Flow Pattern in Alaba-Apatapiti Layouts, Akure, Nigeria

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ABSTRACT

Alaba and Apatapiti are fast growing residential areas of Akure metropolis in Nigeria, with increasing demand for potable water for domestic and industrial use. In order to guide in the proper planning of groundwater development in the areas, this research work is aimed at delineating groundwater flow pattern across the study area, using hydrogeologic measurements and Geoelectric soundings. Hydrogeologic measurements of 72 wells and 42 Geoelectric soundings were carried out in the study area to determine the groundwater flow pattern. The results were presented as maps, charts, and geoelectric sections. Maps of groundwater head and groundwater vector show that groundwater flows from the center and the north central parts into other areas, majorly towards the south-western part. Likewise, aquifer layer resistivity and elevation maps reveal that groundwater flow directions are from center and north central parts to the flanks of the study area. This shows that there is a good correlation between Hydrogeologic measurements and Geoelectric sounding results. In conclusion, this research work shows that in areas where there is little or no well from where hydrogeologic measurement could be made, geoelectric sounding can be used to correctly determine groundwater flow direction.

KEYWORDS: *Hydrogeologic measurement, geoelectric sounding, groundwater head, aquifer layer resistivity, aquifer layer elevation, recharge, discharge and groundwater flow direction.*

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I. INTRODUCTION

Groundwater often migrates through saturated soils and rocks supplying wells and springs beneath the earth surface. The water in the saturated zone can be delineated via the use of Electrical Resistivity method because of its relatively lower resistivity than the area of unsaturated zone (Olayanju et al., 2011; Mogaji et al., 2011).Groundwater moves from areas of higher elevation or higher pressure/hydraulic head (recharge areas) to areas of lower elevation or lower pressure/hydraulic head (Delleur, 1999). Groundwater usually flows towards and eventually drains into streams, rivers, lake and seas. The study of groundwater flow pattern is very important in locating dam site for agricultural and hydroelectric power generation purposes, locating perfect site for refuse dumps and determination of groundwater potential of an area. The groundwater flows direction generally follows the bedrock topography, which may or may not mirror the flow of water on the surface (Adeyemo and Omosuyi, 2012). Geophysical methods provide opportunity for quick and cost effective determination of groundwater flow, especially when combined with hydro-geological measurements. Electrical Resistivity method could be adapted to delineate groundwater flow direction, because it can easily define the subsurface geologic structures and it is less expensive. It has been used extensively in groundwater exploration in basement complex of Nigeria by various authors (Omosuyi et al., 2003; Omosuyi et al. 2007; Olayanju et al., 2011; Olorunfemi et al., 1999; and Mogaji et al., 2011). This study focused on the review of groundwater system and groundwater flow pattern in the study area. Hydrogeologic measurements of static water level were made from which static water elevations could be inferred, while geoelectric soundings carried out across the study area were intend to delineate possible geoelectric stratigraphic sequence of the underlying subsurface layers beneath the sounding locations.

II. DESCRIPTION OF THE STUDY AREA

The study area, which comprise of Alaba and Apatapiti layouts (Figure 1) is situated in the north-eastern part of Akure, south-western Nigeria. The area falls within geographic grids extending between 737000 to 738000 m (Eastings) and 805200 to 806600 m (Northings) defined by Minna-Nigeria 31N datum of the UTM (Universal Traverse Mercatum) system. The area is moderately to highly undulating with surface elevation ranging from 344 to 388 m above sea level (Figure 2). The main rock types underlain the study area are Charnockites and Migmatite-gneiss, with a series of low-lying quartzite rubbles in some parts of the area.

The increasing growing rate of houses and the resultant indiscriminate dumping of waste in most part of the study area could pose threat of pollution to the groundwater resources in the study area, especially since the groundwater flow direction of the underlying aquifers was not taken into consideration before sitting these waste dump sites. This trend if not checked can results into major pollution and contamination of the much needed groundwater sources in the area. A good knowledge of the groundwater flowing pattern of the study area will also assist in determining the appropriate foundation design at different parts of the area.

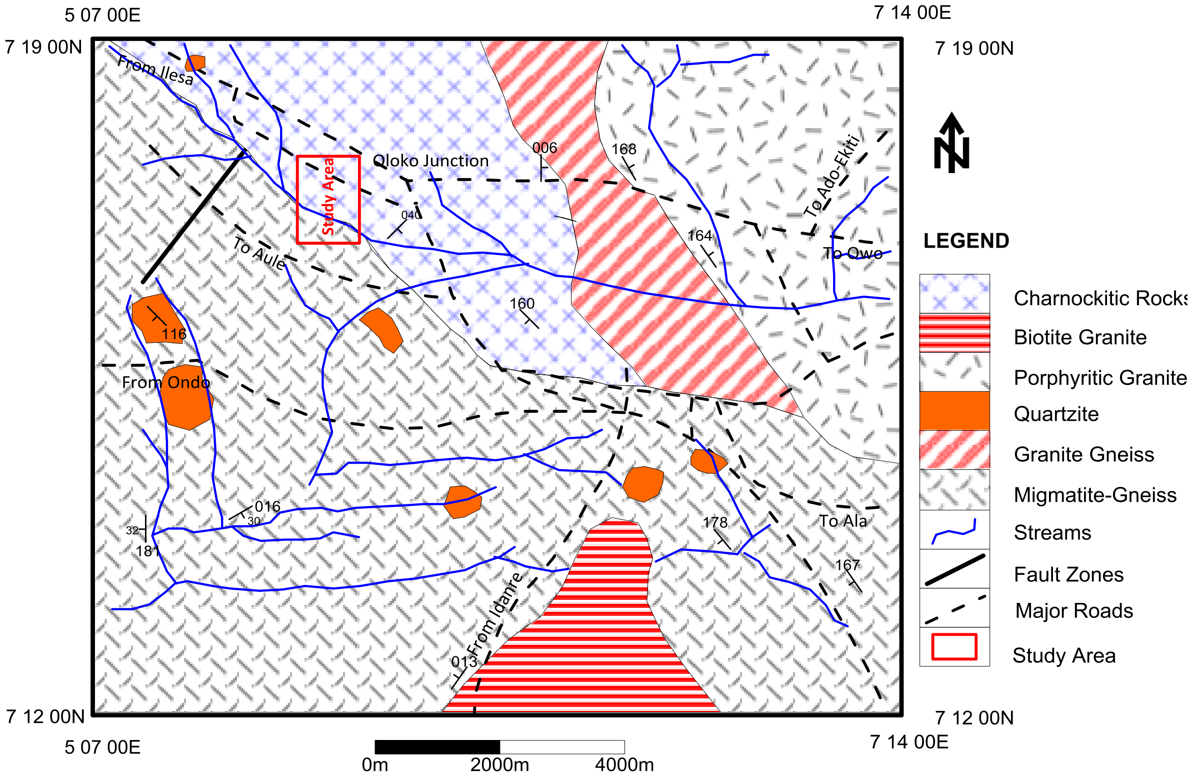


Figure 1: Simplified geological map of Akure, showing the study area (Modified after Owoyemi, 1996)

III. MATERIALS AND METHODS

The hydrogeologic measurements involving Static water levels measurement of 72 accessible hand-dug wells across the study area. The hand-dug wells were positions were geo-referenced using a hand held eTrex Legend™ Global Positioning System (GPS) device. A total of 42 geoelectric soundings were carried out across the study area, using PASI 16GL Earth Resistivity Meter and its accessories. The Schlumberger electrode array was adopted for this work, with current electrode spread (AB/2) varying from minimum of 1 m to maximum of 65 to 100 m depending on depth to bedrock and availability of space. The sounding positions were also geo-referenced using the eTrex Legend™ GPS.The hydrogeologic data were analyzed and presented as maps of static water level and static water elevation, from which the water shed and recharge zones delineated. The static water level elevations were obtained by subtracting the static water level value from the ground level elevations at each well location. Geoelectric sounding data were interpreted manually using the conventional partial curve matching technique involving the use of theoretical and auxiliary curves (Keller and Frishchnecht, 1966; Koefoed, 1979). The derived geoelectric parameters were further refined using a forward modelling computer algorithm, WinRESIST Version 1.0 (Vander Velpen, 2004). The geoelectric results were presented as curves distribution charts, curve types, and maps of aquifer layer elevation and aquifer layer resistivity.

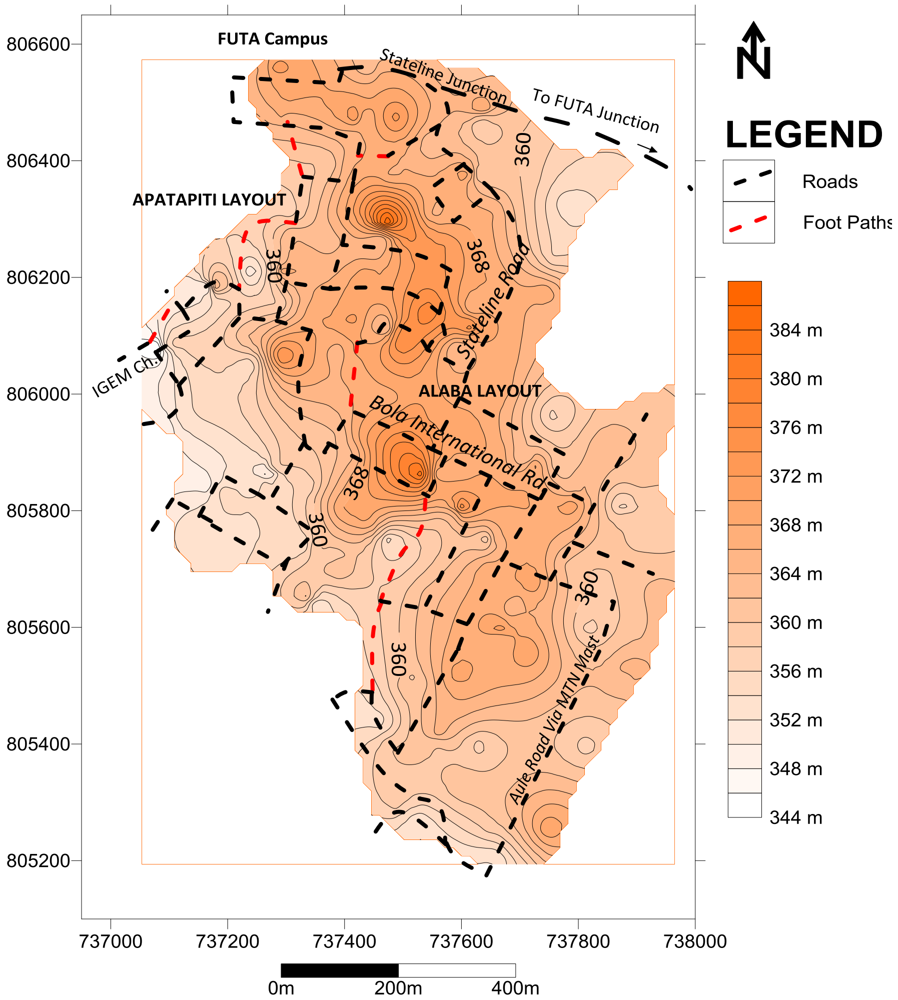


Figure 2: Topographic and layout map of the study area

IV. RESULTS AND DISCUSSION

Figures 3 (Groundwater head map of the study area) and 4 (Groundwater vector map of the study area) were derived from the hydrogeologic measurement across the study area. They both revealed the areas of recharge and discharge across the study area. The two maps shows that the water recharges areas are located along central and northeastern parts of the study area, while the discharge areas are visibly situated between the recharge areas and at the southern parts of the of the study area. From the analyses of hydrogeologic data, the static water elevation across the study area varies from 344 to 374 m. The groundwater head map (Figure 3) shows that groundwater occurs at greater depth within the central part and a bit towards the northern part of the study area, but occurs at shallow depth at the western, eastern and parts of north-eastern area. This may be due to relative lower ground surface elevation and near-surface outcropping of the bedrock along the 'Ala' stream at the south-western part of the study area.Groundwater flow direction is shown as vector grids, with arrows showing the flow pattern from higher elevation to lower elevation areas (Figure 4). The discharge areas serving as groundwater collection centre are good groundwater potential zones. In addition, the discharge areas are possible areas of spill points into the springs, streams, water channels or drainage systems, which can be harness for agricultural and groundwater reservoir developments.

Figure 5 shows the geoelectric curve type distribution. Figure 6 shows typical curve types identified in the study area. The dominant sounding curve type in the study area is the KH-type (40.78 %), followed by A-type (21.43 %), H-type (16.67 %), K-and HKH-types (7.14 %), and HA-, HK and KHK (2.38 %) in that order. Both the isopach and resistivity maps of the delineated aquifer layer in the study are shown in Figures 7 and 8 respectively. In addition, Figures 9 and 10 shows the correlation between the groundwater head and geoelectric layer resistivity maps of the aquiferous layer in the study area.

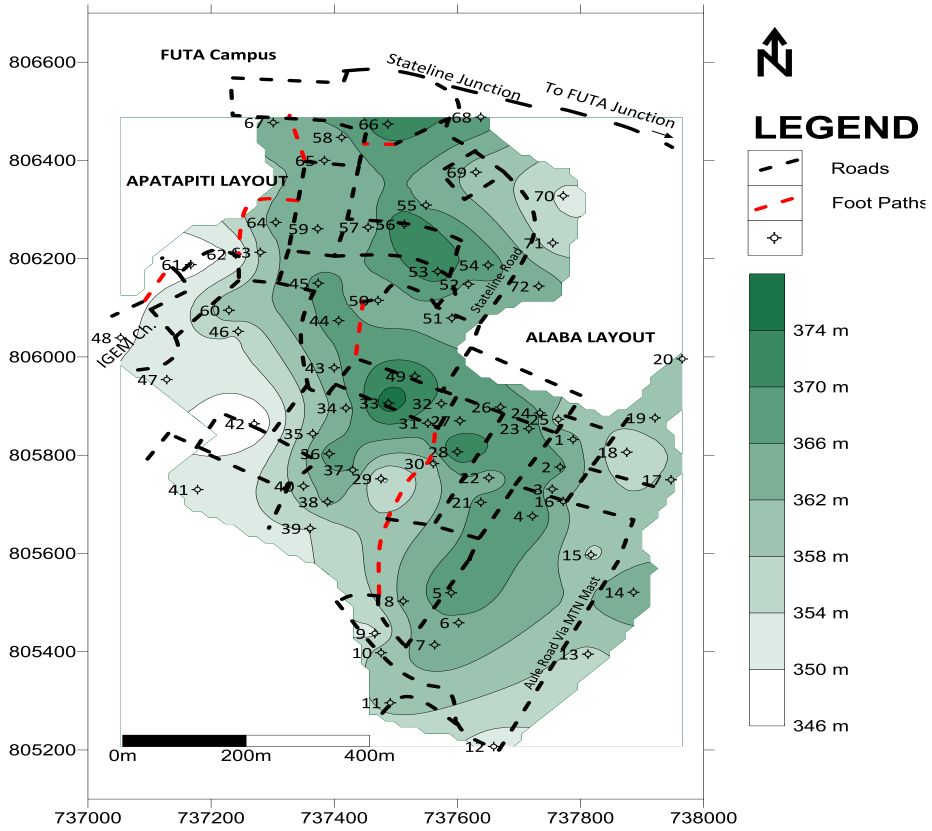


Figure 3: Groundwater head map of the study area

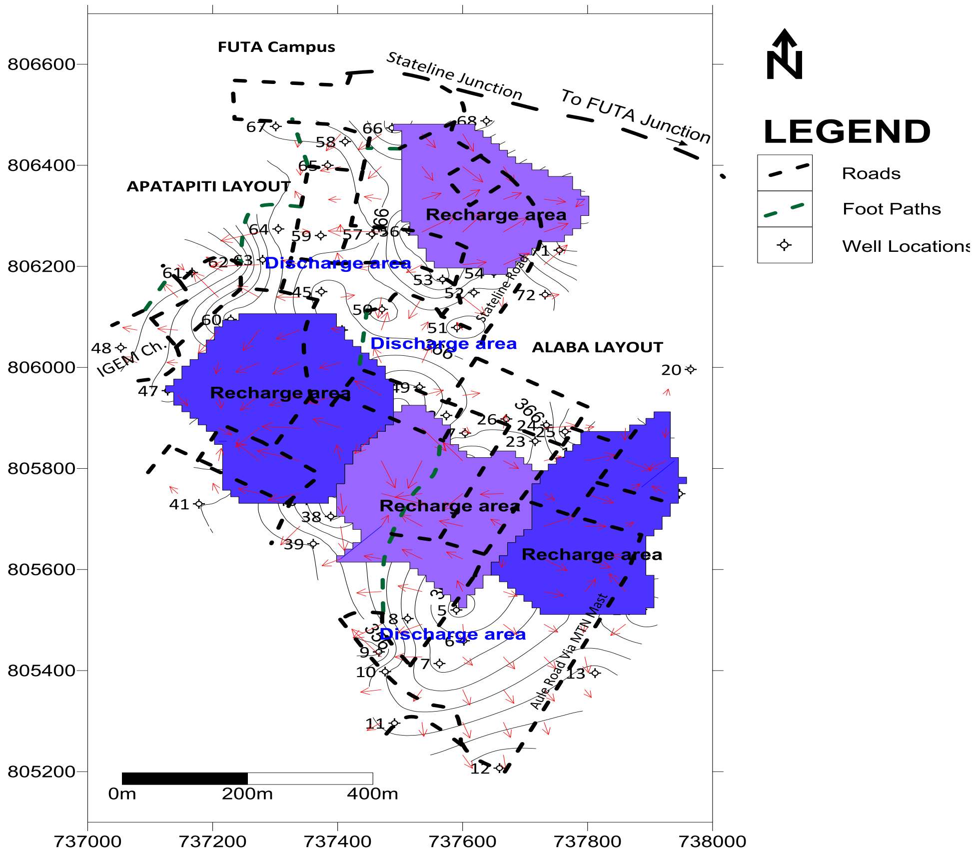


Figure 4: Groundwater vector map of the study area

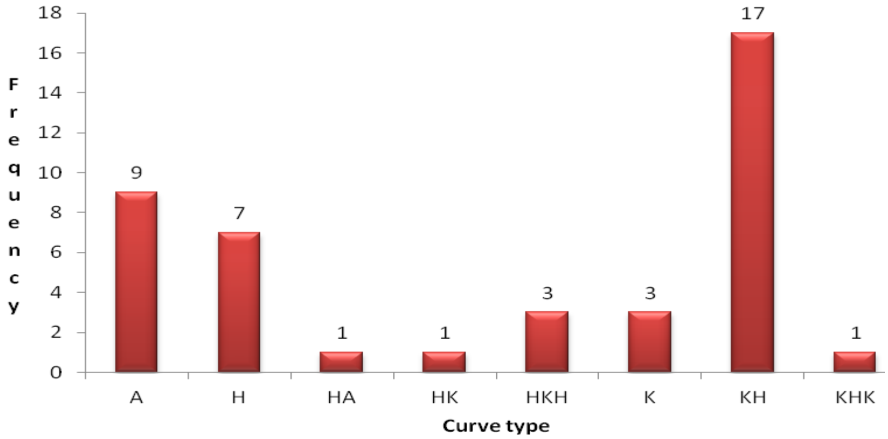
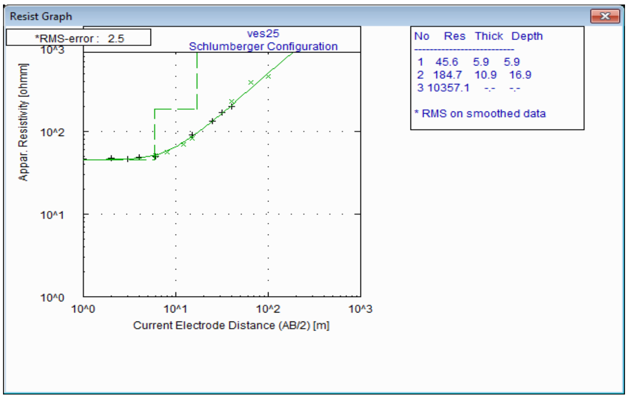
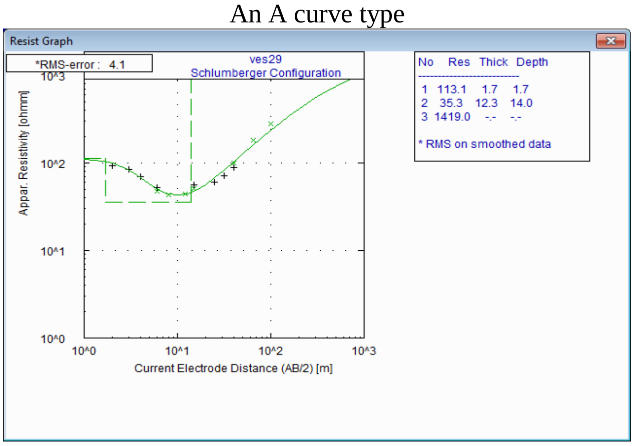


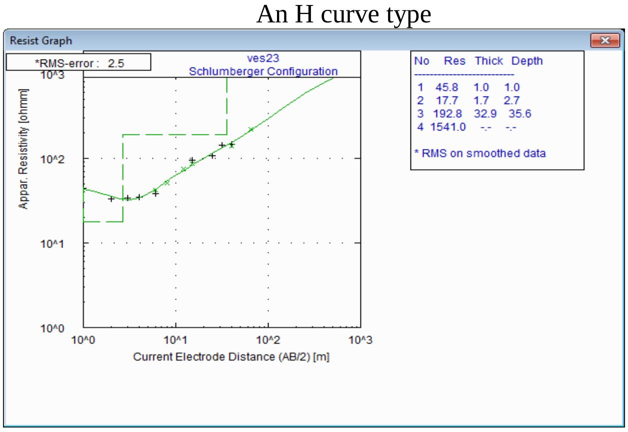
Figure 5: Curve types frequency distribution in the study area.



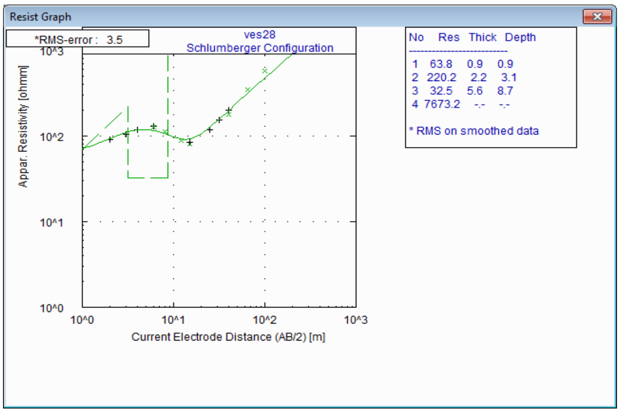
An A curve type



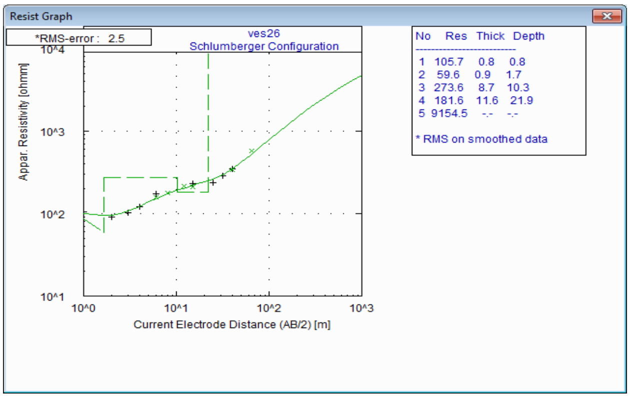
An H curve type



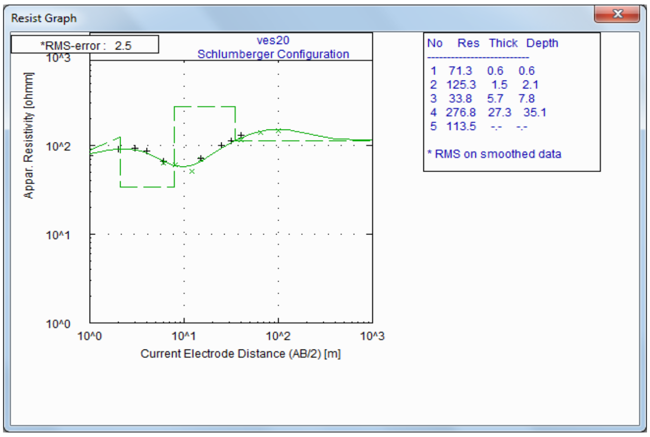
An HA curve type



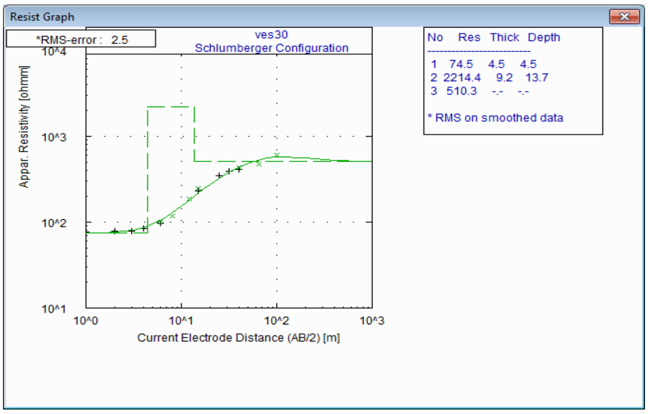
A KH curve type



An HKH curve type



A KHK curve type



A K curve type

Figure 6: Typical curve types obtained from the study area.

The geoelectric sounding results delineated three to five geoelectric units across the study area, which corresponds to the top soil, weathered layer (clay/sandy clay/clayey sand or lateritic layer), partially weathered layer, and fractured/fresh bedrock. Five geoelectric layers were delineated beneath VES points 7, 12, 20 and 26, while the remaining VES points have three (3) layers or four (4) layers. The layer resistivity values vary respectively across the study area from 11 to 370 ohm-m in the top soil, 33 to 531 ohm-m in the weathered layer (clay/sandy clay/clayey sand or laterite) and 64 to 7775 ohm-m in the weathered and/ or fractured/ fresh bedrock.

Aquifer elevations were determined by subtracting depths to aquifer layer from the ground surface elevation and values obtained were subsequently plotted and contoured to generate aquifer elevation map (Figure 7). The Aquifer elevation map shows that the aquifer elevations at the centre and north central parts of the study area are higher (above 360 m), while aquifer layers occurs at relatively shallow elevation (below 360 m) at the flanks, i.e. western, eastern and parts of north-eastern portion of the study area. Since groundwater flows from higher elevation to lower elevation, it can be deduced from the map that groundwater will flow from the centre of the study area to the flanks.

Aquifer layer resistivity map (Figure 8) shows that resistivity value varying from 30 to 1100 ohm-m across the study area. Since groundwater follows the path of least resistance (Kosinski and Kelly, 1981), the current flow through the pore space is conducted electrolytically through the interstitial fluid; hence electricity is controlled more by porosity and water than by the resistivity of the rock matrix. Thus, electrical path is similar to hydraulic path at the pore level and resistivity values should reflect this (Kosinski and Kelly, 1981). Hence, aquifer resistivity values could be used to determine groundwater flow direction. In cases where there are multi aquifer layers, the auxiliary point method could be used to reduce the aquifer layer resistivity values to a single representative resistivity value. Bhattaraya and Patra (1968) derived an equation for reducing multi layers aquifer resistivities to a single representative resistivity value (ρ_a). The relationship between the representative aquifer resistivity and aquifer thicknesses and aquifer longitudinal conductance were derived using the following equation,

$\rho_a = H_a/S_a$ (aquifer longitudinal resistivity) ----------------------------1

Where,

$H_a = h_1 + h_2 + h_3 --- h_{n-1} + h_{n;}$ summation of h_n (Aquifer thicknesses)

$S_a = h_1/\rho_1 + h_2/\rho_2 + h_3/\rho_3 --- + h_{n-1}/\rho_{n-1} + h_n/\rho_{n;}$ summation of h_n/ρ_n (Aquifer longitudinal conductance)

The aquifer resistivity is high at the centre (above 300 ohm-m) and moderate to low at the flanks (below 300 ohm-m) with the exception of the south-eastern part of the study area, where the aquifer layer exhibit high resistivity values. Since groundwater water flow within aquifer is from higher resistivity to lower resistivity zones (Kosinski and Kelly, 1981), it could be inferred that groundwater will flow from the centre of the study area to other parts, especially the flanks. Comparing both hydrogeological and geoelectric sounding results, both maps of static water elevation and aquifer layer resistivity (Figure 9) show that groundwater will flow from the centre, east and a small portion of the northern parts of the study area to the flanks; southeast, northeast, northwest and southwest.

V. CONCLUSION

In this paper, the report of the geophysical and hydro-geologic investigations carried out in this work has been presented in terms of the results of quantitative and qualitative interpretation of 42 geoelectric sounding data and hydrogeological measurements from 72 accessible wells at Alaba and Apatapiti layouts in Akure, Southwestern Nigeria. Spatial distribution of aquifer layer resistivity and aquifer layer elevation revealed that groundwater flow pattern shows outward flow from the centre and North central part to the flanks of the study area. In addition, groundwater head map alongside the aquifer resistivity map show that groundwater flow is directed from the central part of the study area to the flanks demonstrating the significance of the geoelectric sounding in delineating groundwater flow pattern, especially in areas where there are little or no well information.

VI. ACKNOWLEDGEMENTS

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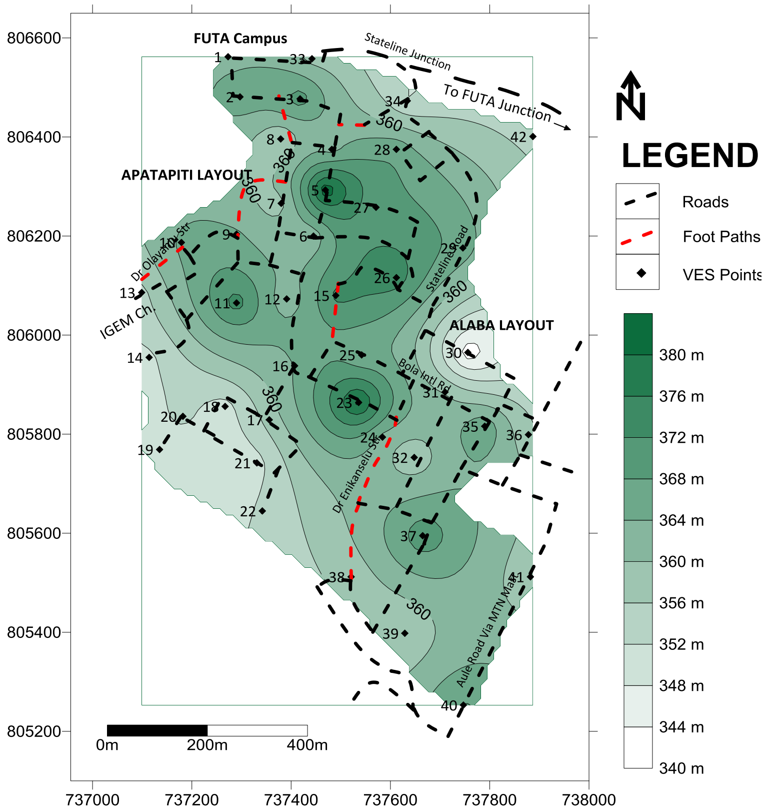

Figure 7: Aquifer layer elevation map of the study area

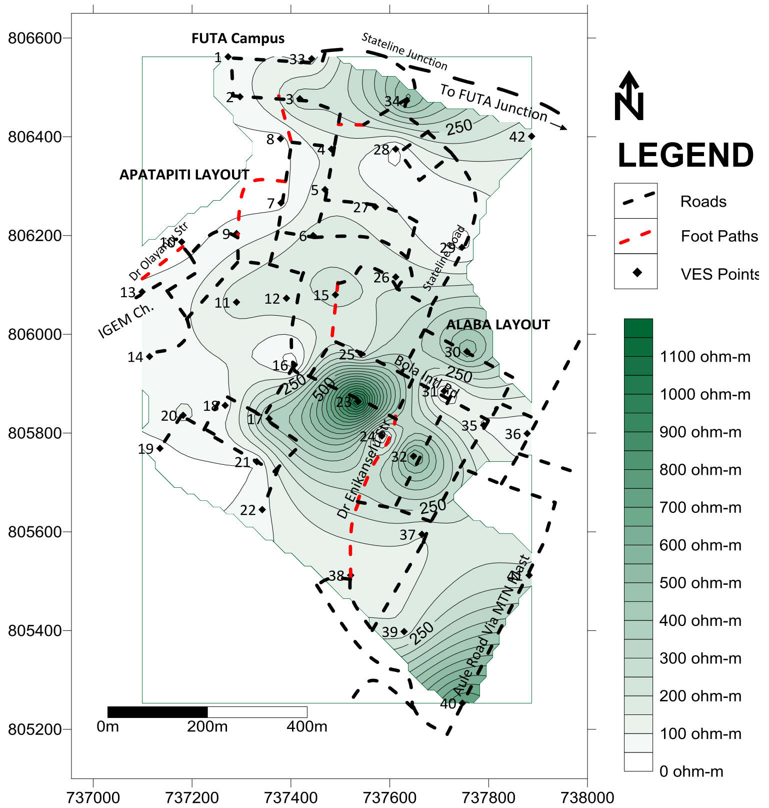

Figure 8: Aquifer layer resistivity map of the study area

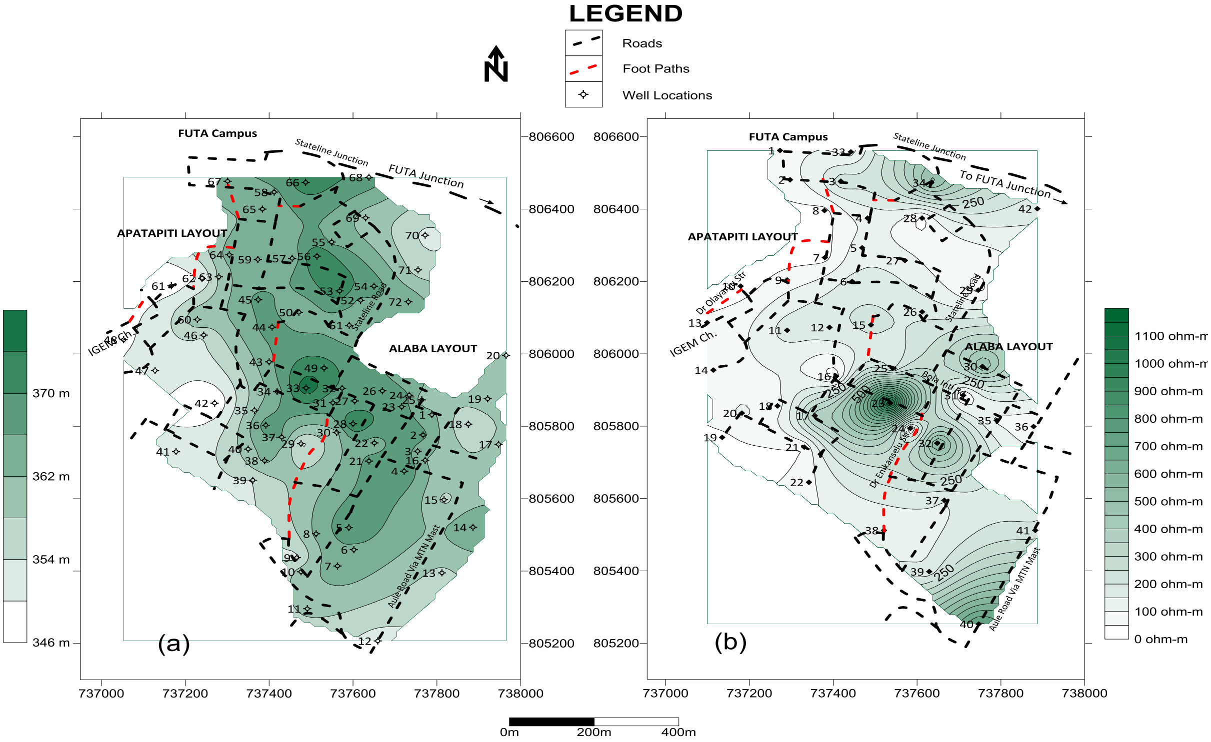

Figure 9: Comparison of groundwater elevation (a) and aquifer resistivity (b) maps

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