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Evaluation of Groundwater Prospect in a Clay Dominated Environment of Central Kwara State, Southwestern Nigeria

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Abstract— *In this research, groundwater prospect of Central Kwara have been investigated using electrical resistivity method for both domestic and industrial application in the face of scarce water resources, occasioned by incessant borehole failure/low yield, has prompted researches for viable source of water. The central Kwara state falls within the basement complex region of Nigeria known as the hard rock terrain, where availability of groundwater is dependent mainly on structural features. The general curve types obtained from the study area were H, HA, KH and HKH types with the H curve type more prominent in the study area. Three geoelectric sections generated with resistivity parameters ranging between 350 to 1900 ohm-meters, 7.7 to 99.1 ohm-meter and above 3000 ohm-meter; making up the topsoil, weathered layer and bedrock respectively. The topsoil is interpreted as laterite/hard pan within thickness range of 0.4 and 2.2 m while the weathered layer zone ranged between 0.9 to 36.1 m thickness respectively; making the overburden of the area with thickness range of 1.4 to 42.7 m. The bedrock resistivity ranges from 400 ohm-meter to 8192 ohm-meter, indicative of weathered/fractured and fresh basement respectively. The results of the vertical electrical sounding were used to generate clay horizon resistivity map, clay horizon thickness map, aquifer resistivity map and overburden thickness map. This study reveals that the study area is dominated by clay which lead to borehole failure and dry up of hand pump well because most of the hand pump well were terminated within the clayey formation.*

Keywords— clay horizon resistivity, clay horizon thickness, aquifer resistivity, overburden thickness.

I. INTRODUCTION

The importance of water to the existence of life deserves attention, because health and growth are closely associated with it. Water plays a very crucial role in the survival of both plant and animal hence the common saying "water is life". Generally groundwater sources are generally accepted as the best quality sources of water for both domestic and industrial purposes around the world (Hoque *et al.,* 2009). The rapid pace of urban development and rise in the demand for private, public and industrial water supply demand for private, public and industrial water supply occasioned by growth in population (Adul *et al.,* 2001). Demand for groundwater as source of water for drinking, irrigation and industrial uses ahs caused tremendous rise in various domain of groundwater related studies. Different factors have been used as indices of groundwater resources occurrence in different study areas. Some of which includes, subsurface layers, and structural features on fractures that cause 'stratigraphical disturbances' (Tizro *et al.,* 2010) among other factors also includes geoelectric and geological parameters (such as aquifer resistivity, aquifer thickness, overburden resistivity and overburden thickness) derived from derived from 2D resistivity imaging. Recharge rate is another important factor that can determine the occurrence of groundwater resource in an area. An aquifer can be recharge by the infiltration of river and lateral subsurface inflow that usually occur through subsurface water zones. Such as fracture, joints, cracks, rock contacts, etc. In a typical Basement Complex Area such as Central Kwara, and its environs, the occurrence of groundwater in recoverable quantity is controlled by geological factors (Olorunfemi and Fasuyi, 1993; Amadi and Olasehinde, 2010; Ilugbo *et al.,* 2018). The delineation of these geological factors or fissures i.e. faults, joints, fractures, and weathered materials is very essential for better understanding of the geology in terms of their groundwater potential. Therefore to target potential bedrock aquifers that can give copious supply of groundwater, the mentioned geologic fissures must be identified through Geophysical Investigations and intercepted by boreholes (Ilugbo and Adebiyi, 2017). Considering the many cases of failed/abortive borehole that are common occurrence in this study Area, making majority of the inhabitants to depend on surface water from river, stream, and hand dug well for their daily survival. These sources of water are highly vulnerable to pollution, thereby making the people susceptible to water borne diseases. It therefore becomes a challenge to find a lasting solution to this predicament facing the Government and people of the Area. The delineation of these geologic fissures in low permeability rocks, as is the case of Central Kwara Basement Complex, requires the use of Integrated Geophysical approach, as was the case with (Adelusi *et al.,* 2013; Omosuyi *et al.,* 2003; Olorunfemi *et al.,* 1991; Okereke *et al.,* 2012; Ilugbo *et al.,* 2018) all of whom deployed Integrated Geophysical approach in different parts of the Nigerian Basement Complex, in groundwater potentials evaluation and study. More so, that Geophysical Methods are of low cost, non-invasive and can furnish broad composite images of the subsurface over large areas at relatively low cost and higher speed (Telford *et al.,* 1976).

Therefore, in this research work, Electrical resistivity methods were used in Central Kwara comprising four Local Government i.e. part of ASA, MORO Kwara East, Kwara West Local Government of the state, which are underlain by rocks of the Precambrian Basement Complex of Nigeria with the aim of evaluating the groundwater in a clay dominated environment.

Site Description and Geology of the Study Area

The area is geographically enclosed within latitude 8^0 31' 0"N to 8^0 43' 0"N and longitude $4^0$28'00"N to 4^0 34' 0"E, It is sandwich between four local government areas, within the Central of Kwara State in present Nigeria. Moro Local Government to the North and North Eastern part of the study area, Asa Local Government to the West, and Kwara West and Kwara East Local Government to the South of the study area. The area is made up of about forty (40) Towns and Villages accessibility is through major and minor road networks. The topography is generally undulating (Figure 1) with some areas characterized by hilly ridges and gentle steeps. The area enjoys a tropical climate with two distinct seasons, comprising of rainy season (April to October) and dry season (November to March) with the temperature ranging between 23^0C to 32^0C and dry season. The study area is located within north Central Basement Complex region of Nigeria. It belongs to the Precambrian Basement Complex (Figure 2). It is made up of mainly older granite towards the North Western part of the study area, while the rest is of the undifferentiated basement complex rock. The hydrogeology of the study area consists of streams, rivers, drainage and geological structures (like faults, fractures, crack, joints and weathered materials).

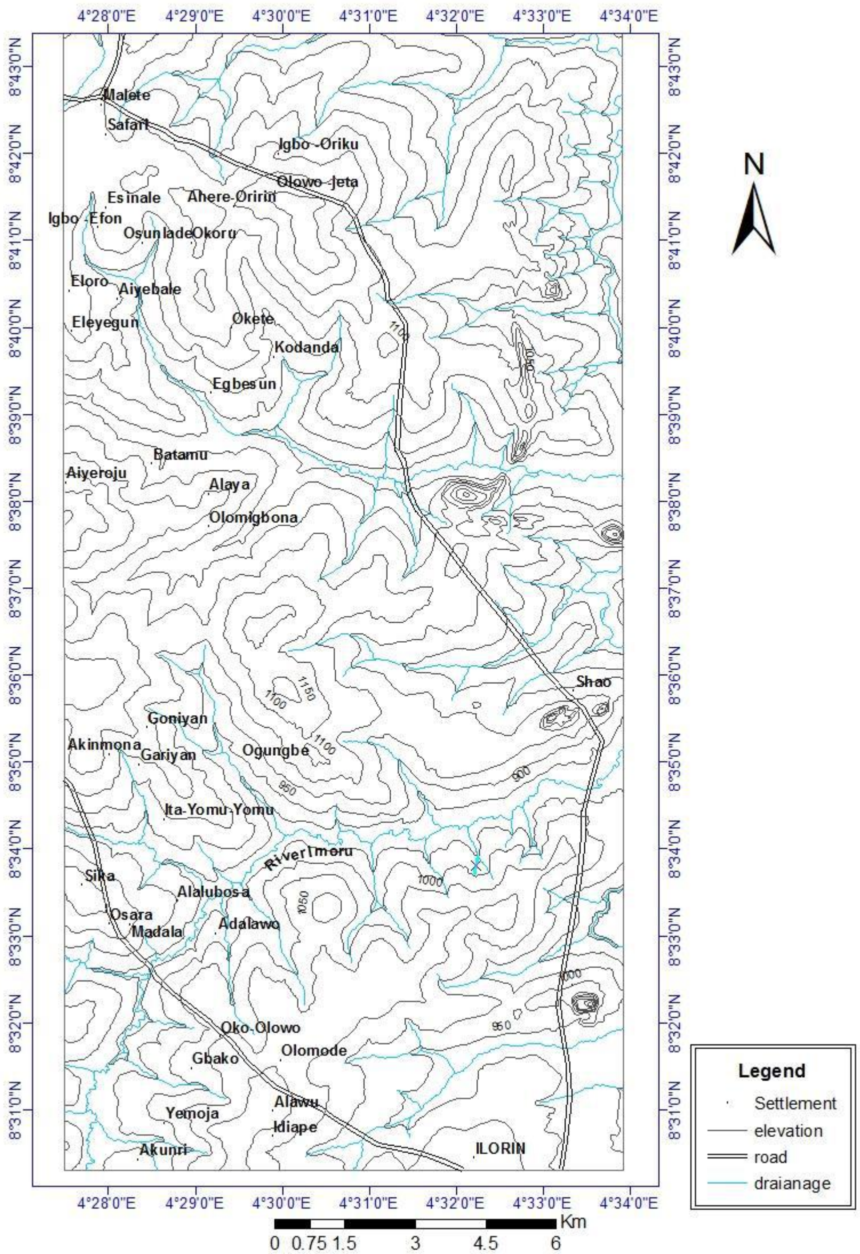

Fig.1: Location Map of the Study Area

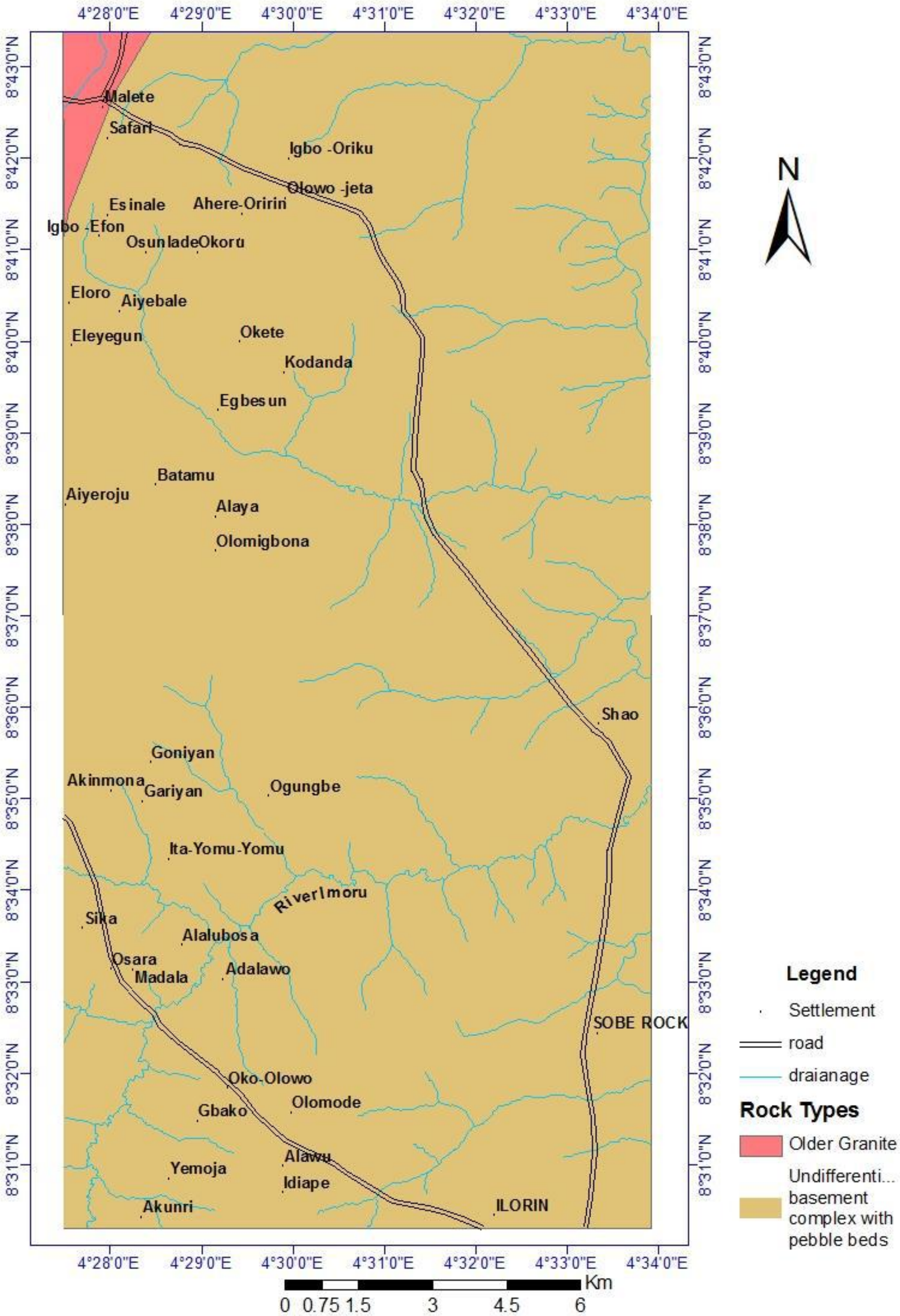

Fig.2: Geological Map of the Study Area

II. RESEARCH METHODOLOGY

The Schlumbeger depth sounding was used to investigate the change of resistivity with depth (Hoque *et al.*, 2009; Barker *et al.*, 1996). The measured unit is the apparent resistivity, ρa, 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 in meters on bilogarithmic paper resulting in a vertical electrical sounding (VES) curve. The vertical electrical sounding (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 that is based upon an algorithm of Vander Velpen 2004. The quantitatively interpreted sounding curves gave interpreted results as geoelectric parameters (that is, layer resistivity and layer thickness).

III. RESULT AND DISCUSSION

Data acquired from vertical electrical sounding (VES) using Schlumbeger array were interpreted, first using manual partial curve matching techniques, and later subjected to computer iterative modeling. Figure 3 (a to d) shows typical iterated VES data curves and the estimated geoelectric parameters. In the study area, four (4) curve types were identified, these are H, HA, KH and KHK. The H curve type is the most dominant curve type in the study area.

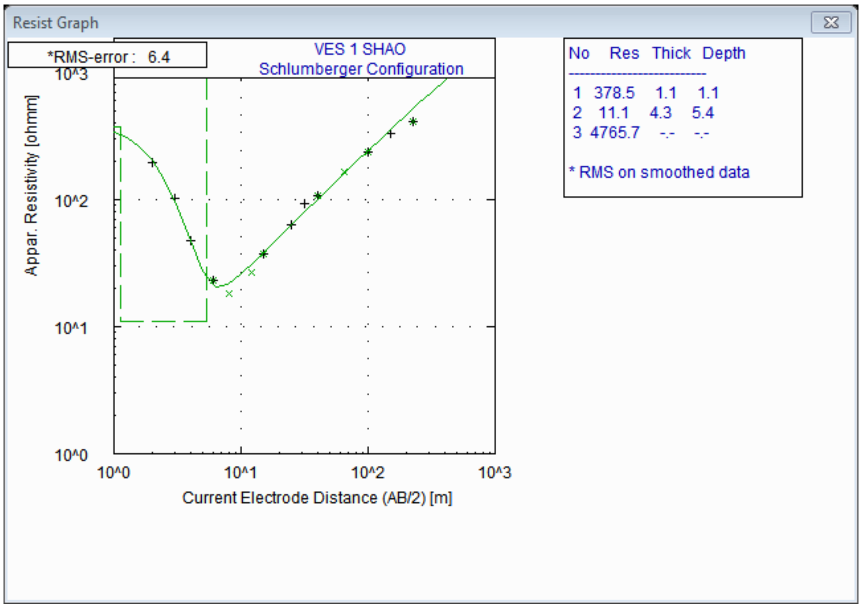

Fig.3a: Showing Typical Curve Types H Curve

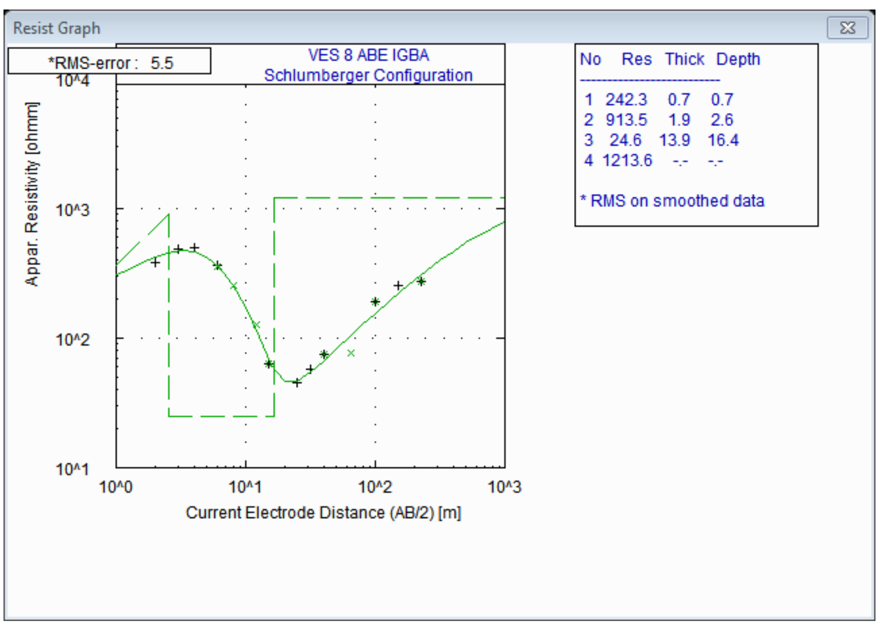

Fig.3b: Showing Typical Curve Types KH Curve

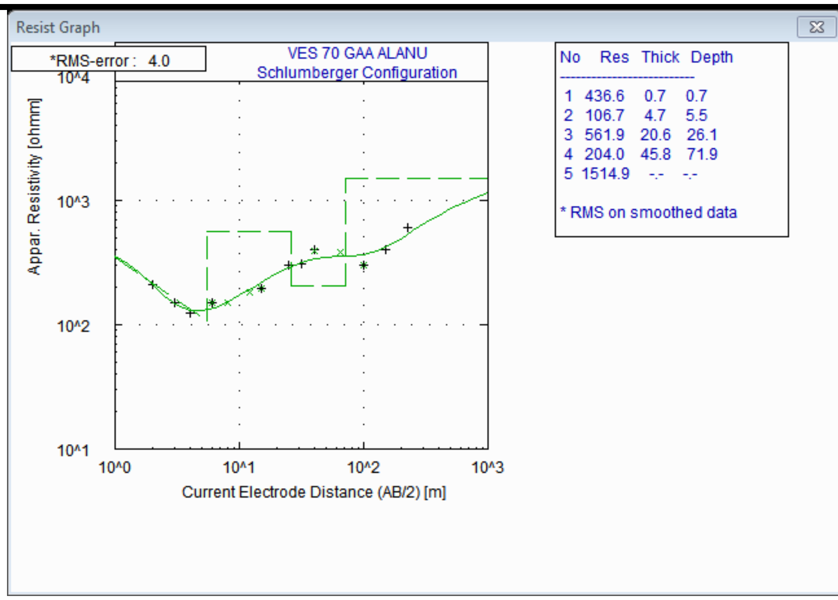

Fig.3c: Showing Typical Curve Types HKH Curve

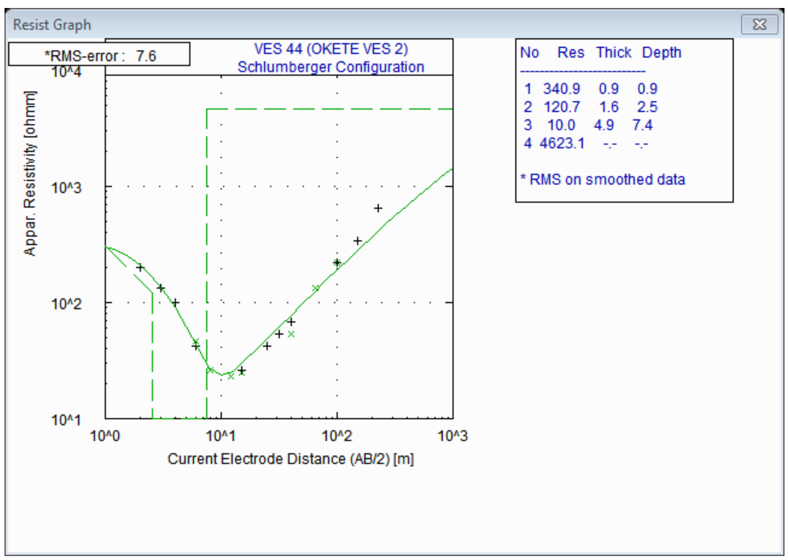

Fig.3d: Showing Typical Curve Types HA Curve

Geoelectric Section

Geoelectric section along W-E (Figure 5a): the section cuts across VES 3, VES 53, VES 57 and VES 58. This section is characterized by a thin layer topsoil of resistivity variation from 93 to 232 Ωm and layer thickness of 0.8 to 1.3 m, a thin weathered layer with layer resistivity variation of 16 Ωm, 206 Ωm, 33Ωm and 19Ωm respectively. The fresh basement has a resistivity variation from 968 to 3200 Ωm. the bedrock is generally shallow throughout this section, though a basement depression is observed but rather exaggerated due to the distance apart from one VES to another which is about a minimum of 2 kilometer apart being a regional study.

Geoelectric section along SW-NE (Figure 5b): this section was taken across VES 10, VES 11, VES15, VES46 and VES 57 as it was in the earlier section bedrock is generally shallow, with layer resistivity variation of 406 to 3200 Ωm. the topsoil layer resistivity and layer thickness varies between 189 to 572 Ωm and 0.8 to 1.6 m. While the weathered layer resistivity and layer thickness ranges between 19 to 211 Ωm and 1.3 to 22.4m. The topography is generally undulating with abasement depression between VES 10 and VES 11, between VES 15 and VES 46, but is however exaggerated due to the distance apart between a VES and another which is most cases is not less than 2 kilometer being a report study.

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Geoelectric section along NW-SE (Figure 5c): when compared with the two previous sections, a thicker overburden is observed throughout this section and a gently undulating topography is also observed. The topsoil layer resistivity distribution and layer thickness varies from 40 to 1578 Ωm and 0.8 to 3.2 m respectively. The topography is undulating gently, when compared with the two previous sections, but is however exaggerated due to the distance apart between a VES and another which is most cases is not less than 2 kilometer being a report study. This section is expected to have better prospect for groundwater, when compared with the two previous sections.

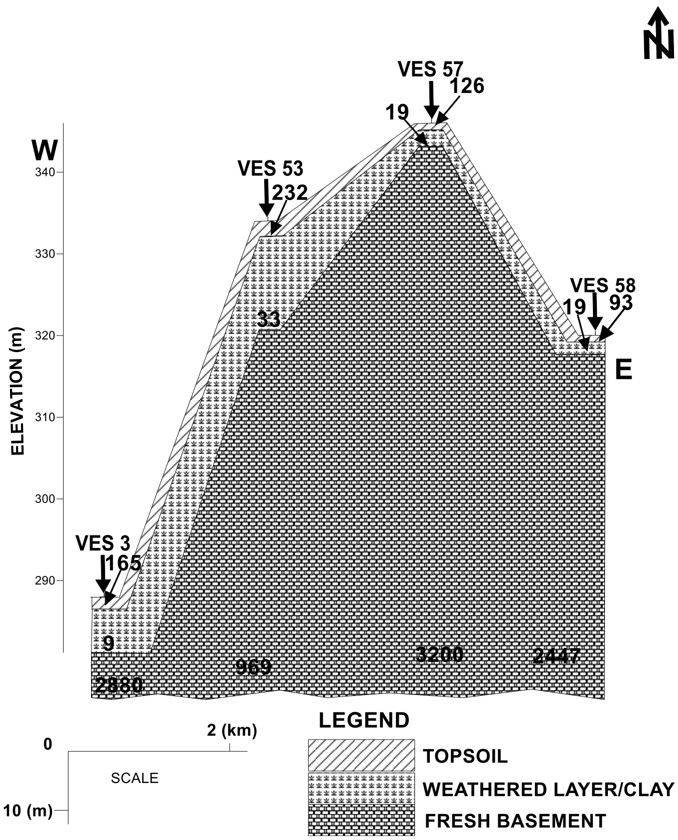

Fig.4.6a: Geoelectric Section Along W-E Direction

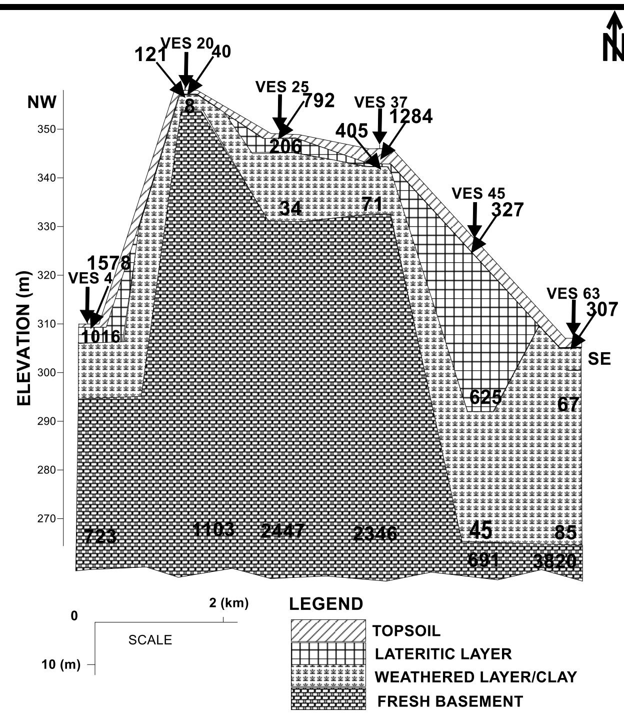

Fig.5b: Geoelectric Section along NW-SE

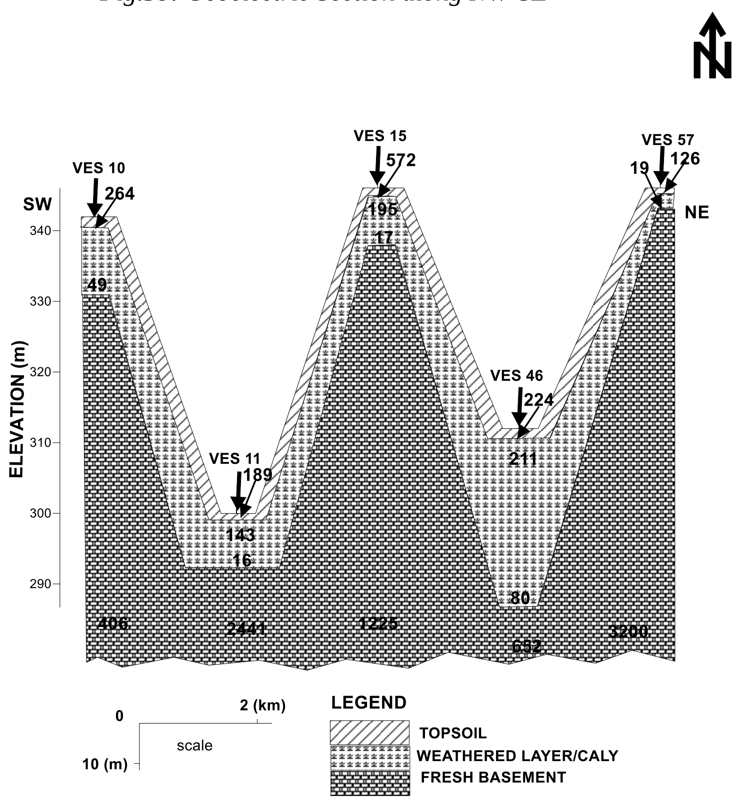

Fig.5c: Geoelectric Section Along SW-NE

Geoelectric Map

Clay Horizon Resistivity Map

Figure 6 displays clay horizon resistivity map of the study area and is based on the variation in layer resistivity within the upper horizon below the topsoil. The value varies between 7.7 to 99.1 Ωm. This map classified into three to four region i.e. region of extremely low resistivity between 7.7 to 20 Ωm, this occurred as pockets, and were found at the northern end, part of the south and part of the south eastern end region of low resistivity between 20 to 40 Ωm, which was the case in the northern eastern end, down to the centre and towards the southern end of the study area. Implication to the study implies good aquifer protection. This was followed by the region of moderately low resistivity between 40 to 90.1 Ωm, as obtained at the north western end, part of the centre and the south western end of the study area. Implication to the study implies moderate aquifer protection and cause low groundwater prospect around the study area.

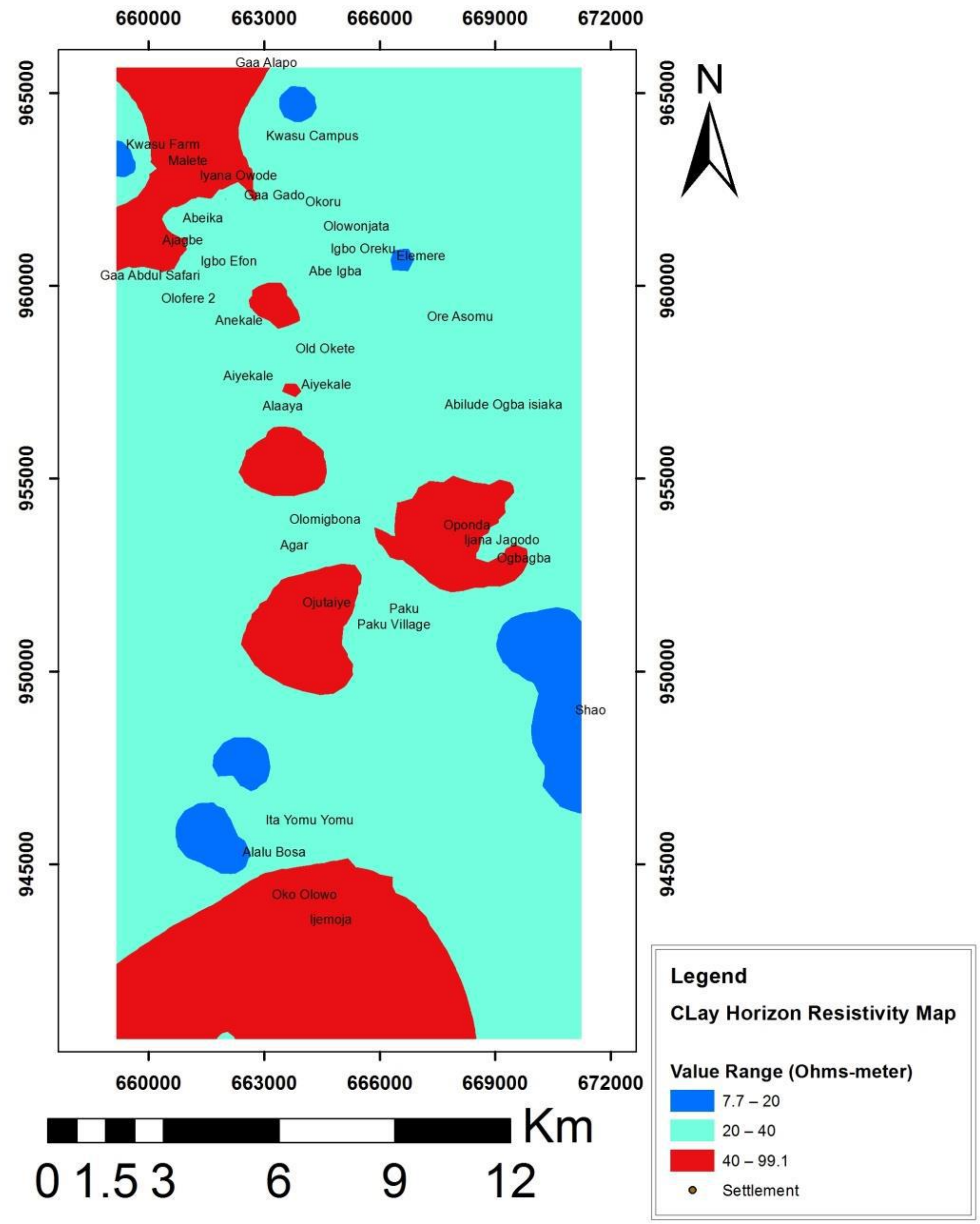

Fig.6: Clay Horizon Resistivity Map of the Study Area

Clay Horizon Thickness Map

Figure 7 illustrates the clay horizon thickness map and was generated from the variation in thickness of the clay horizon from the study area, as the thickness of clay varies from one part of the study area to the other. The clay horizon varies between 0.9 to 20.1 m. The highest thickness between ranges from 10 to 20.1 m can be found around the centre and part of the southwestern part of the study area, while the rest of the area is characterized by moderately thick layer of clay horizon, while a few pockets around the central south western and at the edge of south western part of the study area has a thin layer thickness between 0.9 to 5.0 m. in terms of groundwater prospect, the centre and part of the south western part of the study area has a better aquifer protective capacity low groundwater prospect.

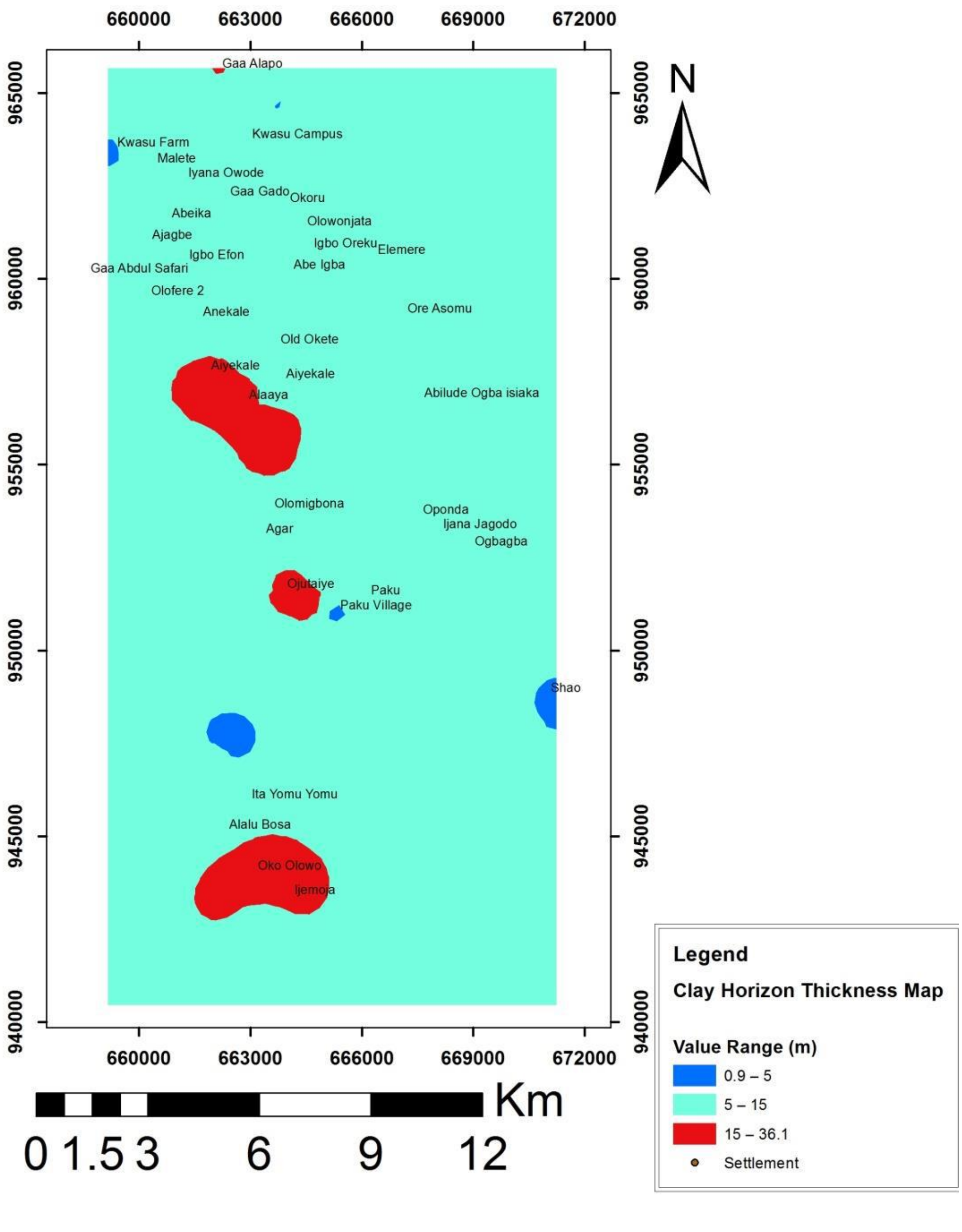

Fig.7: Clay Horizon Thickness Map of the Study Area

Aquifer Layer Resistivity Map

Figure 8 illustrate the aquifer resistivity map of the study area. The eastern part, down to the south eastern, and up to the north eastern, part of the south western end and pocket of the northwestern end of the study area has low aquifer resistivity. While the rest of the study area is characterized by moderate aquifer resistivity and a little pocket of the northwestern end has a high aquifer resistivity. It has geologic implication to groundwater occurrence in the study area. The aquifer of the entire area is good expected for the region of low aquifer resistivity due to the existence of thick clay within the study area.

Overburden Thickness Map

Figure 9 displays the overburden thickness map which shows the variation in overburden of the study area, from the topsoil down to the fresh bedrock. The overburden thickness varies from 1.4 to 42.7 m. the overburden thickness is very thin between 1.4 to 12 m at the north western extreme end, the central towards the eastern and part of the south western end, while it is moderately thick between 12 to 20 m in the rest of the area, expect for the part of the central and part of the south western end where the highest overburden thickness ranges between 20 to 42.7 m were recorded.

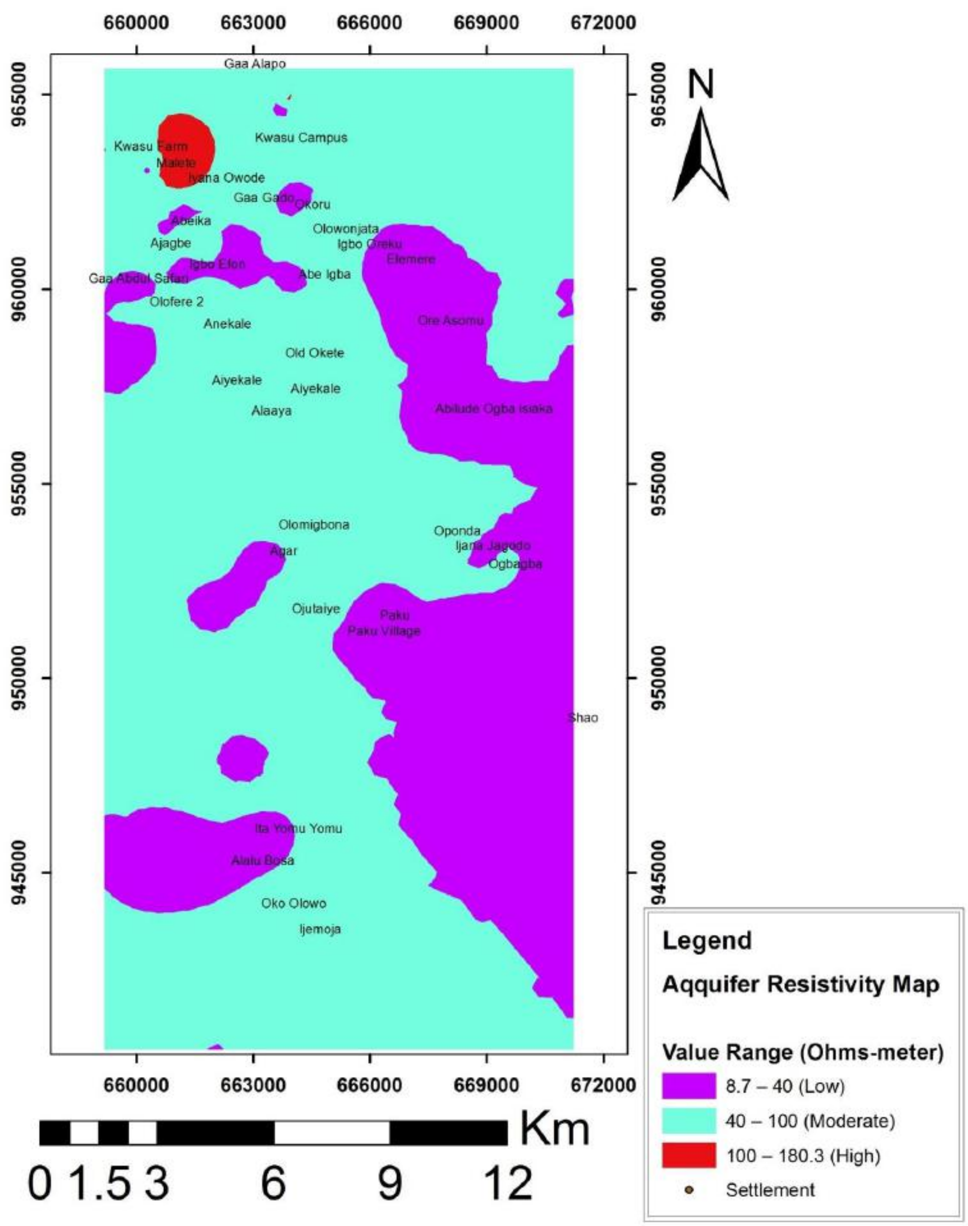

Fig.8: Aquifer Resistivity Map of the Study Area

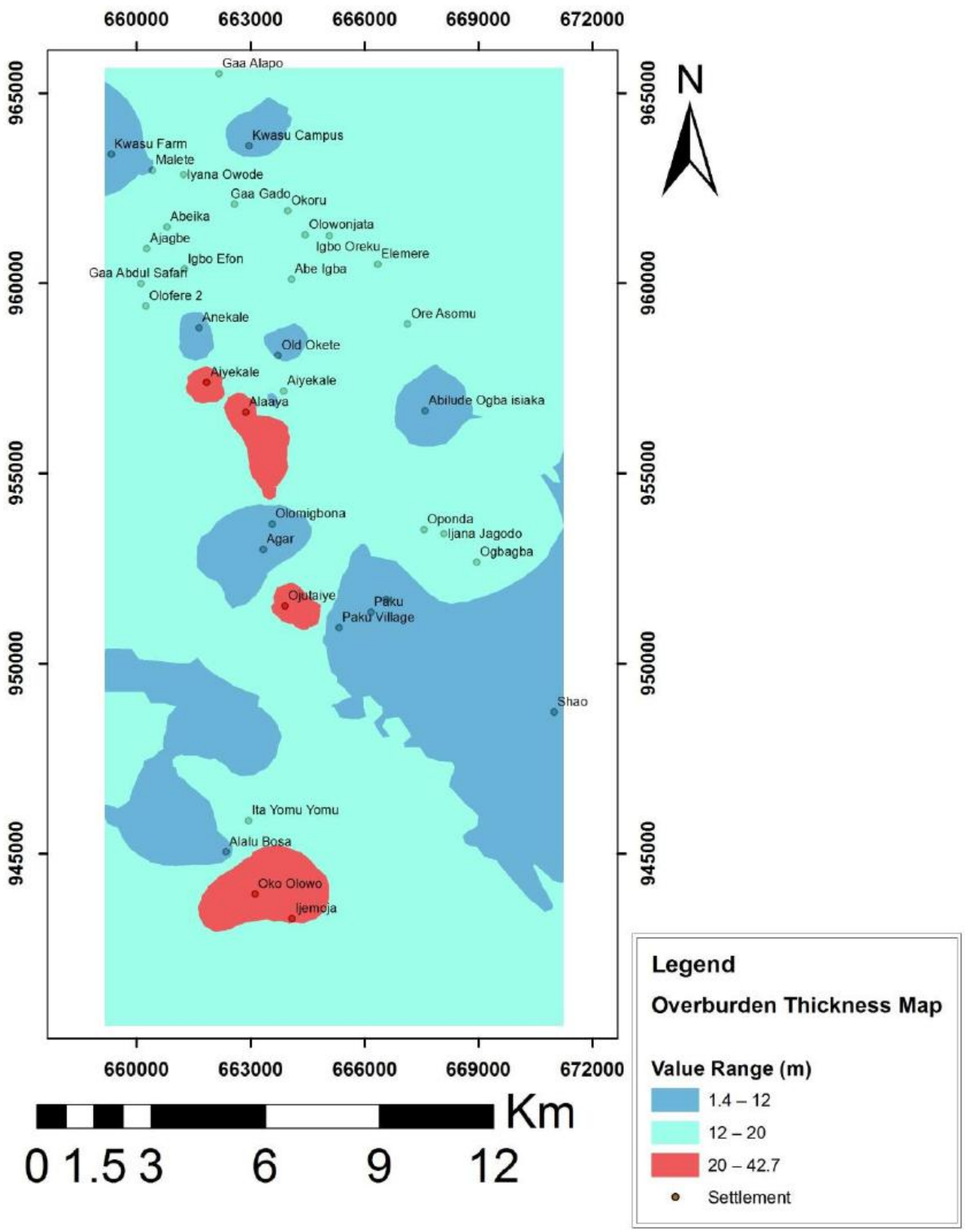

Fig.9: Overburden Thickness Map of the Study Area

IV. CONCLUSION

In this research, groundwater prospect of Central Kwara have been investigated using electrical resistivity method for both domestic and industrial application in the face of scarce water resources, occasioned by incessant borehole failure/low yield, has prompted researches for viable source of water. The central Kwara state falls within the basement complex region of Nigeria known as the hard rock terrain, where availability of groundwater is dependent mainly on structural features (such as fracture, weathered basement, etc) and their dispositions to yield groundwater. The general curve types obtained from the study area were H, HA, KH and HKH types with the H curve type more prominent in the study area, while the curve types obtained from the study area allowed for the aquifer characterization. Three geoelectric sections generated with resistivity parameters ranging between 350 to 1900 ohm-meters, 7.7 to 99.1 ohm-meter and above 3000 ohm-meter; making up the topsoil, weathered layer and bedrock respectively. The topsoil is interpreted as laterite/hard pan within thickness range of 0.4 and 2.2 m while the weathered layer zone ranged between 0.9 to 36.1 m thickness respectively; making the overburden of the area with thickness range of 1.4 to 42.7 m. The bedrock resistivity ranges from 400 ohm-meter to 8192 ohm-meter, indicative of weathered/fractured and fresh basement respectively. The result of the vertical electrical sounding were used to generate aquifer characterization vis-à-vis, the clay horizon resistivity map, clay horizon thickness map, aquifer resistivity map and overburden thickness map, . This study reveals that the study area is dominated by clay which lead to borehole failure and dry up of hand pump well because most of the hand pump well were terminated within the clayey formation.

REFERENCES

[1] Abdul, R.S, Umar H. and Zuraidah, R. (2001). Geophysical investigation of the Olak Lempit Quaternary Basin, Selangor, Malaysia. In: Proceedings of 10th GEOSEA regional congress on geology, mineral and energy resources, Jogjakarta, Indonesia, pp 280–282.

[2] Adelusi A. O., Akinlalu A.A and Nwachuc.u A.I. (2013): Integrated geophysical investigation for post-construction studies of building around School of science area, Federal University of Technology, Akure, Southwestern, Nigeria. Int. J. Phy. Sci.

[3] Amadi A.N. and Olasehinde P.I. (2010). Application of Remote Sensing Techniques in Hydrogeological Mapping of Parts of Bosso Area, Minna, North-Central Nigeria. *Int. J.Physical Sciences*. 5:1465-1474,

[4] Barker R., Blunk I. and Smith I. (1996). "Geophysical consideration in the design of U.K. National Resistivity Sounding database. First Break" 14(2):45-53.

[5] Hoque, M. A., Khan, A. A., Shamsudduha, M., Hossain, M.S., Islam, T., And Chowdhury, S.H. (2009). Near surface lithology and spatial variation of arsenic in the shallow groundwater: southeastern Bangladesh. Environ Geol 56:1687–1695. doi: 10.1007/s00254-008-1267-3.

[6] Ghosh D.P. (1971). "The application of linear filter theory to the direct interpretation of geoelectrical resistivity sounding measurements" *Geophys. Prospecting* 19:192-217.

[7] Okereke, C.N., Onu, N.N., Ibe, K.K., Selemo, A.O.I., Opara, A.I., Ikoro, D.O., Ibeneme, S.I. and Oha, I.A. (2012). Analysis of Landsat and Aeromagnetic Data for Mapping of Linear Structures:A Case Study of Yola Area, Upper Benue Trough, Nigeria. *International Journal of Engineering Research and Applications* (IJERA), **2**, 1968-1977.

[8] Olorunfemi, M.O., Ojo, J.S., and Akintunde O.M. (1999). Hydrogeophysical evaluation of the groundwater potential of Akure metropolis, southwestern Nigeria. J. Min. Geol. 35(2):207-228,

[9] Olorunfemi, M.O. and Fasuyi, S.A. (1993). Aquifer Types and the Geoelectric/Hydrogeologic Characteristics of Part of the Central Basement Terrain of Nigeria (Niger State). Journal of African Earth Sciences, **16**, 309-317.

[10] Omosuyi, G.O., Ojo, J.S. and Enikanselu, P.A. (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,

[11] Telford, W.M., Geldart, L.P., Sheriff, R.E. and Keys, D.A. (1976). Applied geophysics, 2nd Edn., Cambridge University Press, USA, pp: 113 – 114.

[12] Tizro, T. A., Voudouris, K.S., And Mashayekhi, M.S. (2010). Hydrogeological framework and estimation of aquifer hydraulic parameters using geoelectrical data: a case study from West Iran. *Hydrogeology Journal*, 18:917–929. doi:10.1007/ s10040-010-0580-6,

[13] Vander Velpen B.P.A (2004).. "RESIST Version 1.0. M.Sc. Research Project, ITC, Delft Netherland",

[14] Ilugbo S.O, Adebo B.A, Olomo K.O., Adebiyi A.D. (2018). Application of Gis and Multi Criteria Decision Analysis to Geoelectric Parameters for Modeling of Groundwater Potential around Ilesha, Southwestern Nigeria. *European Journal of Academic Essays* 5(5), pp. 105-123, (2018).

[15] Ilugbo S.O. and Adebiyi A.D. (2017). Intersection of Lineaments for groundwater prospect analysis using satellite remotely sensed and aeromagnetic dataset around Ibodi, Southwestern Nigeria. *Int. J. of Phys Sci.* Vol. 12(23), pp. 329-353. (2017).