Rjeas GEOELECTRIC SOUNDING FOR GROUNDWATER POTENTIAL APPRAISAL AROUND THE NORTHEASTERN -SOUTHWESTERN PARTS OF THE FEDERAL POLYTECHNIC ADO – EKITI CAMPUS, SOUTH....

Article · January 2013

3 authors, including:

Romanus Obasi
Ekiti State University, Ado Ekiti

Akinola Eluwole
Federal University Oye-Ekiti

www.emergingresource.org

GEOELECTRIC SOUNDING FOR GROUNDWATER POTENTIAL APPRAISAL AROUND THE NORTHEASTERN - SOUTHWESTERN PARTS OF THE FEDERAL POLYTECHNIC ADO – EKITI CAMPUS, SOUTHWESTERN NIGERIA

Romanus A. Obasi, Oladimeji L. Ademilua and Akinola B. Eluwole
Department of Geology,
Ekiti State University, Ado-Ekiti, Nigeria.
Corresponding Author: *Oladimeji L. Ademilua*

ABSTRACT

The electrical resistivity method of geophysical prospecting was used to determine the factors responsible for the non-availability of adequate productive boreholes and the reason for the failure of a particular existing borehole around the Northeastern – Southwestern part of the Federal Polytechnic Ado- Ekiti. The vertical electrical sounding (VES) technique involving the Schlumberger electrode array was adopted and a total of twenty-five (25) VES stations were occupied. The data collected were interpreted quantitatively by partial curve matching and computer iteration. The interpretation results revealed the presence of four lithologic units which include the lateritic topsoil/laterite, the highly weathered/clayey layer, the partly weathered/fractured basement and the non-fissured/fresh bedrock. Contour maps were prepared from the highly weathered layer, partly weathered/fractured basement and overburden thicknesses for appraisal. These maps were carefully examined and synthesized to characterize the study area into good and poor groundwater prospective segments. The highly weathered layer and partly weathered/fractured basement constitutes the main aquifer units, but that of the highly weathered layer is dominant. The two existing productive boreholes were observed to be located within the zones identified as good groundwater potential zones, while the failed borehole exists on a poor groundwater potential zone. The study area has generally limited groundwater potential, and this may be responsible for the non-availability of adequate productive boreholes. This study therefore is significant in that it will assist the institution's authorities in deciding which part of the study area is to be focused for the purpose of siting groundwater boreholes or any ancilliary water facilities in that regards in the future times so as to forestall recurrence of failures as has been witnessed in the past, while the reading public will find it as a useful reference in proferring solutions in the areas of general basement complex groundwater location, and more particularly where the geology is similar to that of the study area.

KEYWORDS: Northeastern – Southwestern Part, Non-Availability, Aquifer Units, Prospective Segments

INTRODUCTION

Geoelectric sounding has been successfully used in the Basement Complex region of Nigeria and has drastically reduced the failure rate of borehole drilling projects (Ako and Olorunfemi 1989; Olayinka, 1990 and Ajayi *et al.*, 2006). Electrical resistivity method is one of the most useful techniques in underground water geophysical exploration because the resistivity of rock is very sensitive to its water content. Naturally, groundwater exploration occurs widely in soft rocks (sedimentary rocks) that are permeable enough to transmit sufficient water, whereas it is erratic in hard rocks (Basement Complex) that lacks primary porosity which can serve as aquifer. However, with some degree of chemical weathering, fracturing, faults and thick overburden which serve as secondary porosity, a good yield may be obtained in a basement terrain. Water is an absolute inexhaustible necessity for the survival of life, for which there is no alternative. Students' population growth has imposed a great deal of stress on the existing boreholes at the Federal Polytechnic Ado-Ekiti, thus making them inadequate, while the increase in the exploitation and pollution of the surface water resources at Ago Igbira, Aduloju and other adjoining communities hosting the Federal Polytechnic also propelled the need for additional sources.

Geologically, about half of the total area of Nigeria is covered by igneous and metamorphic rocks, referred to as basement rocks and the remaining half are made of sedimentary rocks accumulated in various sedimentary basins within the country (Oyawoye, 1964). Technological advancement has made the investigation of groundwater easier, faster and more reliable. The Federal Polytechnic community relies essentially on water from boreholes, since the water from the public water corporation is at best erratic. There are a number of existing boreholes within the campus, but three of the boreholes are situated within the Northeastern – Southwestern part investigated by this study. Two of the boreholes can be said to be fully functional but are grossly inadequate. Hence, the need for geophysical investigations involving the electrical resistivity method. This method was adopted around the Northeastern – Southwestern part of the campus with the aim of establishing the factor behind the failure of the third borehole and also to characterize the area into good and poor groundwater potential zones which will guide future borehole drilling and development for sustainable groundwater supply for use on the campus.

Geological and Hydrogeological Setting

The study area, Federal Polytechnic Ado-Ekiti is situated along Ado- Ikare road, opposite the Afe Babalola University campus in Ado-Ekiti Local Government area of Ekiti State. It is located approximately within Latitudes 840150N and 841710N, and Longitudes 752302E and 756480E.

The area lies within the Precambrian Basement Complex terrain of Southwestern Nigeria (Rahaman, 1988), made up of undifferentiated granitic and charnockitic rocks, medium to coarse granite and migmatite-gneiss rocks (Figure 1). The geologic structures include faults, folds and joints (Rahaman, 1976 and Olarewaju, 1988) . These structures together with others control the flow of groundwater and determine the volume of recharge and discharge. The area is located in the tropics characterised by high annual rainfall of about 1500mm. The major surface water are the rivers Ureje and Ogbese and their tributaries plus other adjoining streams.

Materials and Methods

Groundwater exploration entails an integrated approach that is not restricted to one technique and some of these include; remote sensing methods, topographical method, geological method and geophysical method. The electrical resistivity method of geophysical prospecting was employed in this study to reveal information about resistivity variations with depth (Hazel *et al.*, 1992). Two basic electrode configurations adopted for conducting these probes are horizontal profiling and vertical electrical sounding (VES) which are respective methods of probing lateral and vertical resistivity variation. In probing the resistivity variation laterally, a fixed separation is maintained between the various electrode spacing and the array is moved as a whole along the traverse while in the case of vertical probing, the spacing between the various electrodes are gradually increased.

Vertical electrical soundings were carried out at twenty-five (25) locations (Figure 2) with the aid of the ABEM SAS 300B Terrameter, using the Schlumberger electrode configuration. The data obtained from the field surveys were processed to obtain the apparent resistivity. The data were interpreted quantitatively by partial curve matching with a set of two layer master curves (Orellana and Mooney, 1972). The results gathered from the curve matching process were input to the WinResist 1.0 software (Vander, 2004) which uses the Gaussian iterative method to reduce percentage manual estimation error to a minimum. The geoelectric parameters (layer resistivities and thicknesses) were used to generate geoelectric and subsurface lithologic sequences characteristic of the VES curve types obtained in the study area. The weathered layer, fractured layer, as well as overburden thicknesses were posted and plotted on the VES positions on the location map and thereafter contoured to produce the maps of the highly weathered and partly weethered/fractured layers, and overburden thicknesses. The maps were synthesized and integrated (Ademilua and Olorunfemi, 2002) to obtain a geoelectric groundwater potential map through which the area was characterized into good and poor groundwater prospective zones

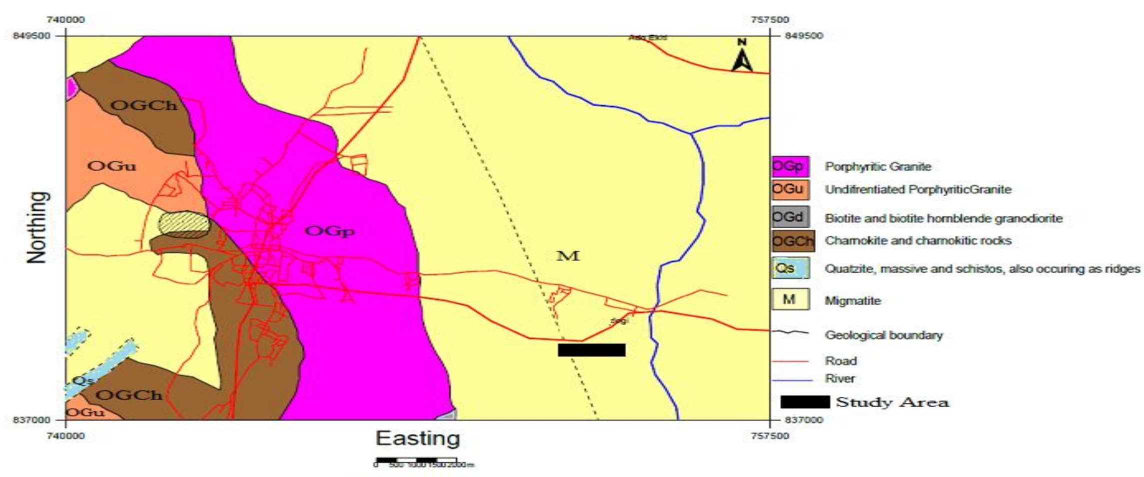


Figure 1: Geologic Map of Ado-Ekiti Showing the Study Area (Modified after Oyedele and Olayinka, 2012)

Rjeas Research Journal in Engineering and Applied Sciences 2(3) 211-219 Rjeas
© Emerging Academy Resources (2013) (ISSN: 2276-8467)
www.emergingresource.org

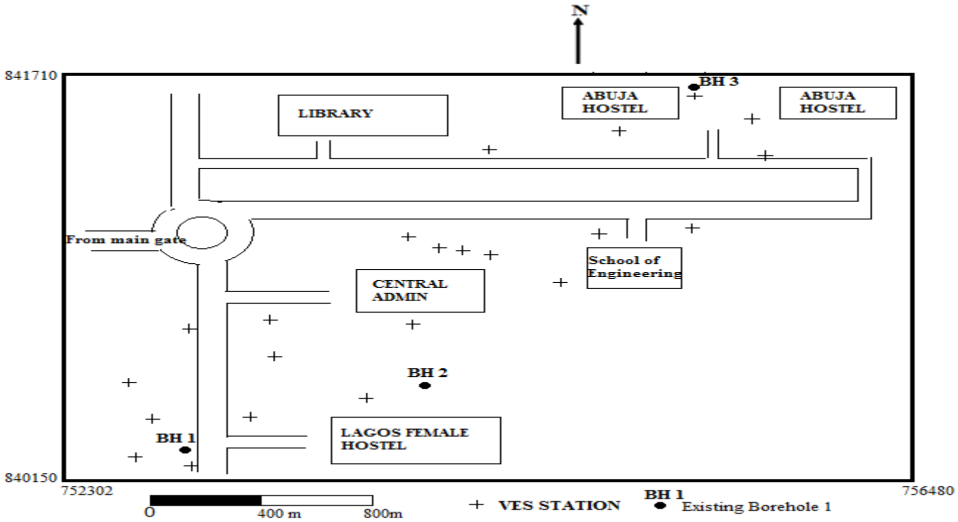


Figure 2: Location Sketch Map of the Study Area Showing VES Points and Existing Borehole Locations (shapes are not to scale)

RESULTS AND DISCUSSION

The VES Curves

The VES curves obtained in the study area are the H, HA, KH, QH, QHA, and the KHA types (Figures 3a-f). The H-type curve is characterised by three geoelectric layers and three lithologic units (Figure 4a) which comprises the lateritic topsoil, the highly weathered/clayey layer and a basal infinitely thick fresh basement bedrock. The HA-type curve is characterised by four geoelectric layers with corresponding three lithologic units (Figure 4b) which include the lateritic topsoil, the highly weathered/clayey layer and a relatively thick partly weathered/fractured basement. The KH and QH curves (Figures 4c and d) also delineated four geoelectric layers with characteristic three lithologic units which comprises the lateritic topsoil/laterite, the highly weathered/clayey layer and the infinitely thick fresh basement bedrock. On the other hand, five geoelectric layers and four lithologic units (lateritic topsoil/laterite, highly weathered/clayey layer, partly weathered/fractured basement and the fresh basement) were observed on the QHA and KHA-type curves (Figures 4e and f). Of all the lithologic units identified on the curves, only the highly weathered/clayey layer and the partly weathered/fractured basement posses hydrogeologic significance in a typical Basement Complex environment. Previous works (Wright, 1992 and Olorunfemi, 2009) have shown that weathered layers with resistivity range between 20-100 ohm-m and thickness greater than 25 m may be regarded as good groundwater potential zones. Although, the resistivities (10 – 80 ohm-m) of the weathered layers identified in this study suggests high clay to sand ratio, which engenders low aquifer permeability, it is expected that areas with thick (>25 m) weathered layers could be considered satisfactory for groundwater development. However, the partly weathered/fractured basement usually possesses good groundwater potential due to enhanced porosity especially when its thickness is greater than 10 m.

Details of the curve types and their subsurface implications are presented in Table 1 and figures 4a-f respectively.

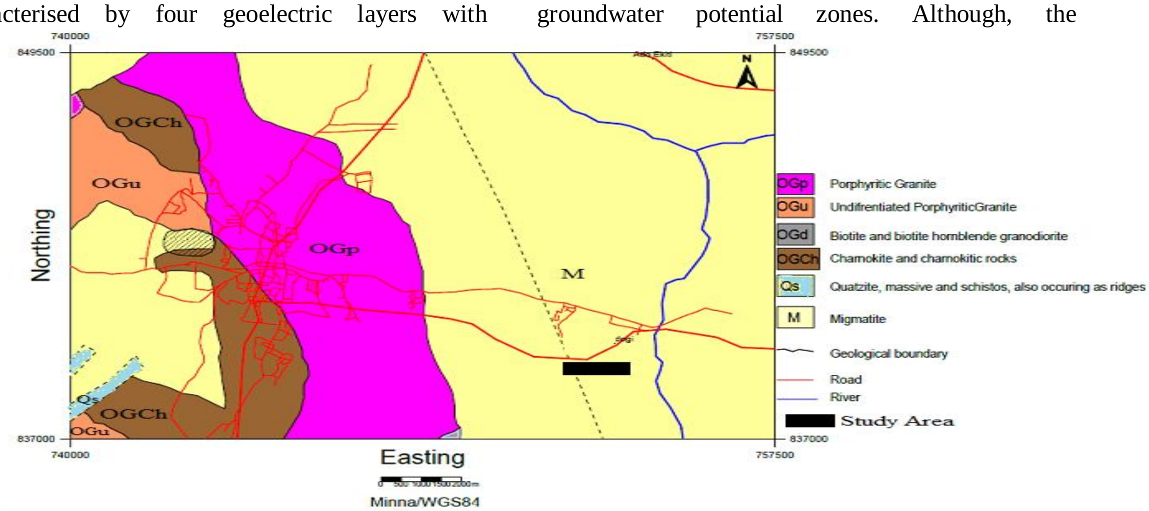


Figure 1: Geologic Map of Ado-Ekiti Showing the Study Area (Modified after Oyedele and Olayinka, 2012)

The Highly Weathered Layer Thickness Map

The weathered layer thickness map (Figure 5) shows that the range of weathered layer thickness in the study area is 4 – 44 m. The essence of this map is to identify zones within the study area characterised by relatively thick (> 25 m) weathered layers as earlier discussed and denote the zones as satisfactory for groundwater development. Such zones are denoted as WL1, WL2 and WL5 on the map

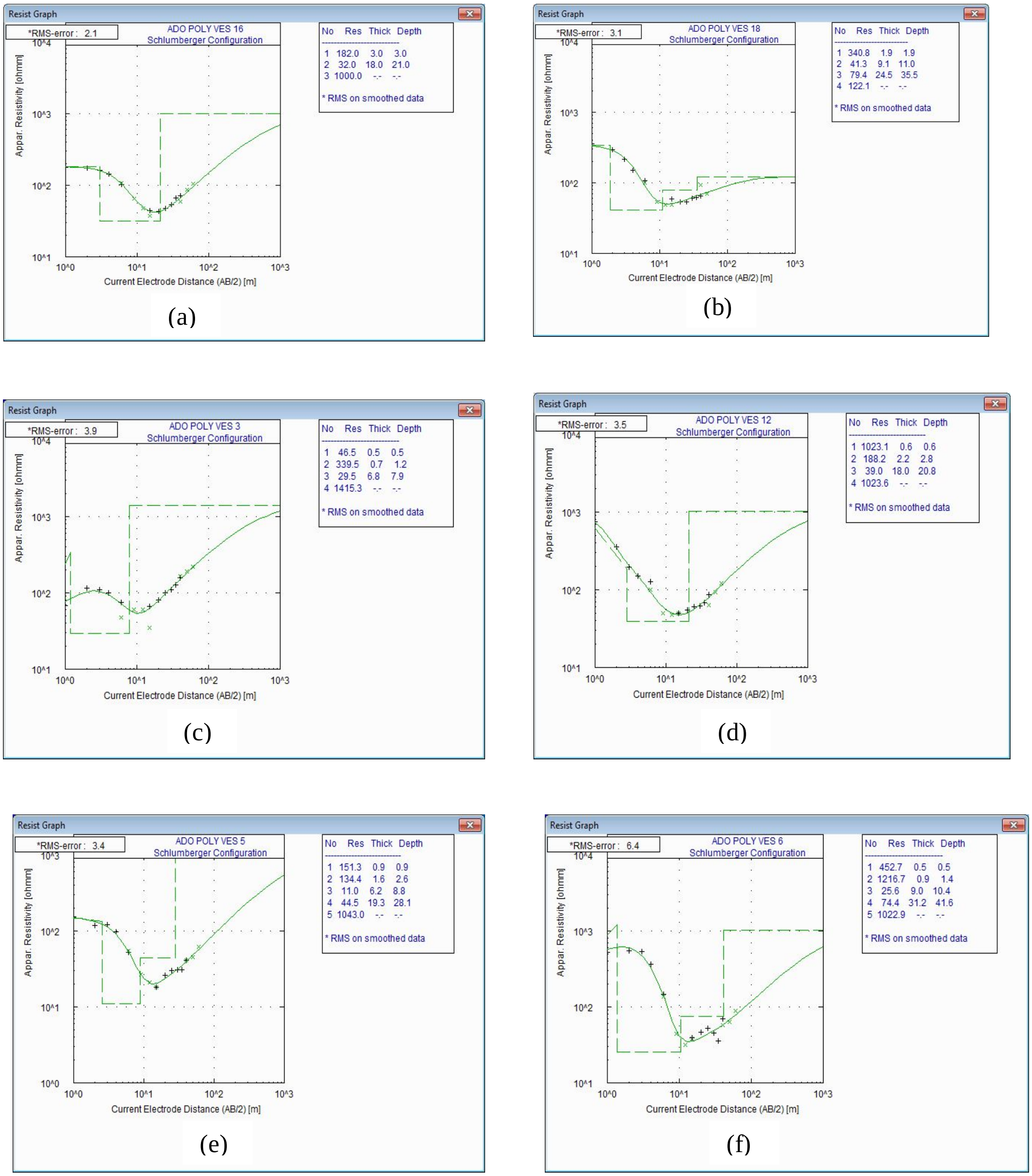


Figure 3: VES Curve types obtained in the Study Area (a) H, (b) HA, (c) KH, (d) QH, (e) QHA, (f) KHA

very thin weathered layers and are not good for groundwater development. WL1 and WL2 coincides with the positions of the two productive boreholes BH2 and BH3 respectively. Meanwhile, failed borehole BH1 is located in the zone WL4 whose very thin weathered layer may have occasioned its failure

Table 1: Summary of the Geoelectric Parameters Obtained from the Study Area.

CURVE TYPE	VES NUMBER	LAYER	RESISTIVITY RANGE (Ohm-m)	THICKNESS RANGE (m)	LITHOLOGY
3-Layer H	14, 15, 16, 17, 19, 20, 21, 23, 24, 25	1	70 – 380	0.5 – 3	Lateritic topsoil
		2	10 – 80	3.8 – 38	Highly weathered/ clayey layer
		3	133 – 10000	Not determined	Fresh basement
4-Layer HA	18, 22	1	114 – 341	0.8 – 1.9	Lateritic topsoil
		2	26 – 41	2.1 – 9.1	Highly weathered/ clayey layer
		3	80 – 111	19.1 – 25	Partly weathered/fractured basement
		4	122 – 132	Not determined	Partly weathered/fractured basement
4-Layer KH	2, 3, 4, 7, 9	1	79 – 143	0.4 – 0.8	Lateritic topsoil
		2	146 – 798	1.0 – 2.1	Laterite
		3	11 – 32	8.7 – 36	Highly weathered/ clayey layer
		4	248 – 1340	Not determined	Fresh basement
4-Layer QH	10, 11, 12, 13	1	79 – 1023	0.6 – 0.8	Lateritic topsoil
		2	100 – 188	1.4 – 2.5	Laterite
		3	10 – 67	10 – 31	Highly weathered/ clayey layer
		4	1023 – 1120	Not determined	Fresh basement
5-Layer QHA	5	1	151	0.9	Lateritic topsoil
		2	134	1.6	Laterite
		3	11	6.2	Highly Weathered/clayey layer
		4	45	19.3	Partly weathered/fractured basement
		5	1043	Not determined	Fresh basement
5-Layer KHA	1, 6, 8	1	75 – 453	0.5	Lateritic topsoil
		2	299 – 1217	0.7 – 0.9	Laterite
		3	22 – 26	4.2 – 9	Weathered basement
		4	74 – 93	31 – 40	Partly weathered basement
		5	970 – 1023	Not determined	Fresh basement

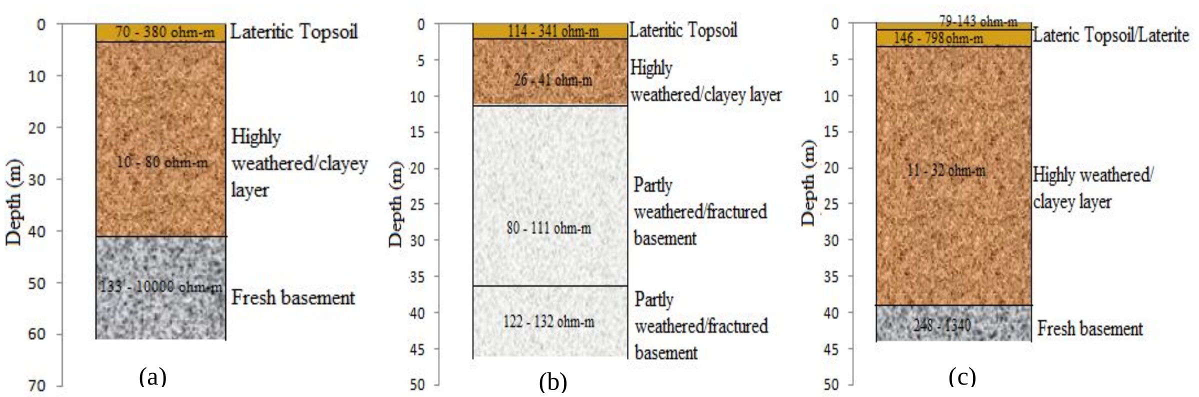


Figure 4: Subsurface models of the geoelectric/lithologic sequence inferred from the VES curves. (a) H model, (b) HA model, (c) KH model

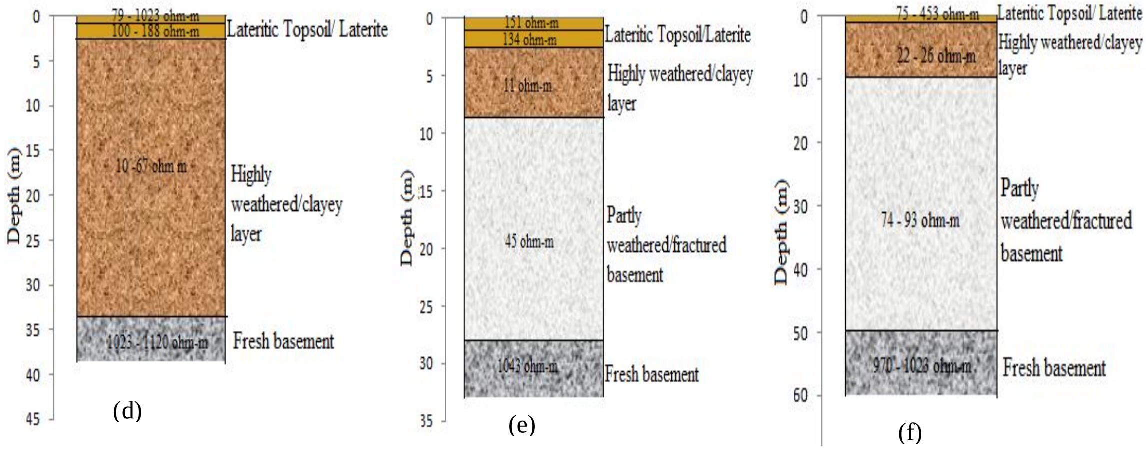


Figure 4: Cont'd (d) QH model, (e) QHA model, (f) KHA model.

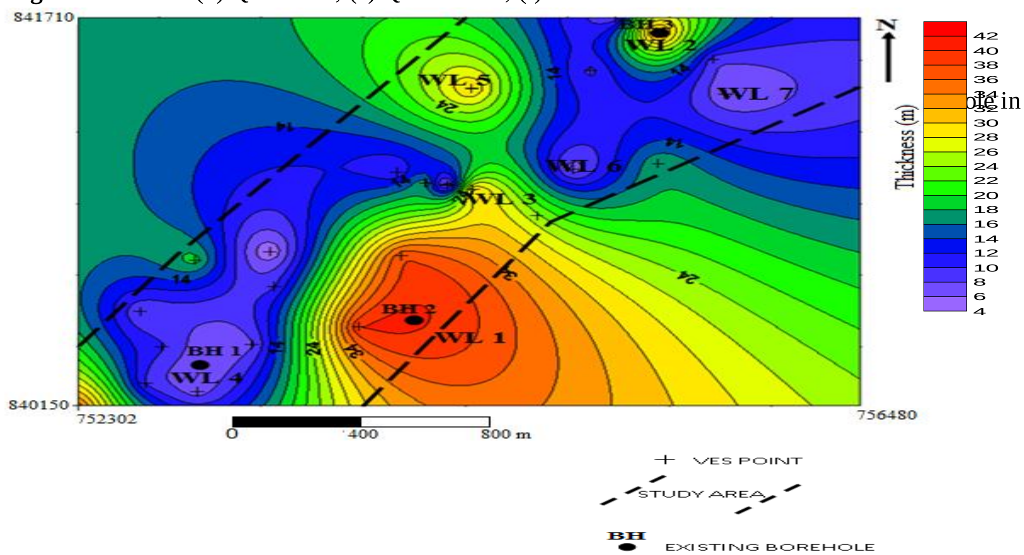


Figure 5: The Highly Weathered Layer Thickness Map

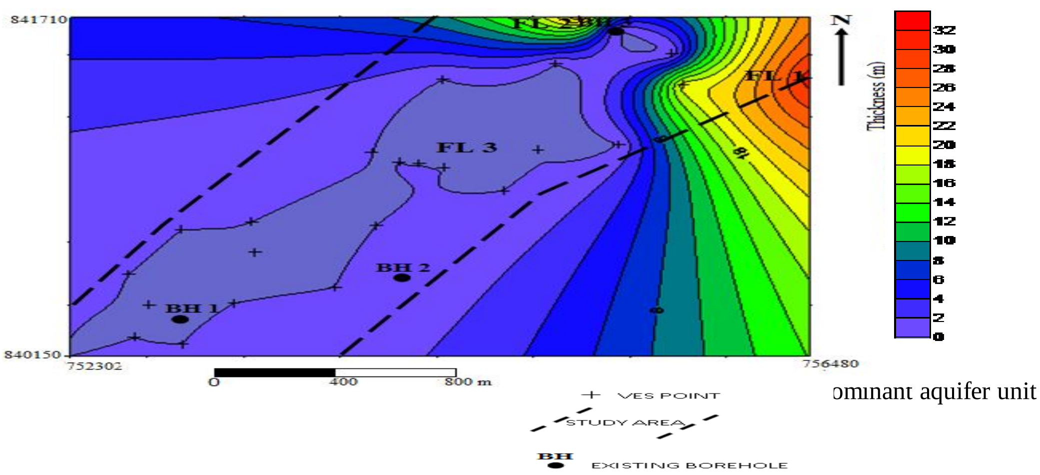
The Partly Weathered/Fractured Basement Thickness Map

The range (0 -34 m) of the partly weathered/fractured layer thickness observed in the area is presented in figure 6. The area is generally poor in terms of fracturing, because about eighty-five percent (85 %) possess little or no degree (0 – 6 m) of fracturing. The two significant relatively thick (> 20 m) fractured basements designated FL1 and FL2 respectively are present. The map shows that the aquifer tapped by the productive borehole (BH2) is not fracture-dependent, due to the absence of fracture in the vicinity of the borehole. The failure of borehole (BH1) may also be attributed to its existence on a non-fractured zone FL3. Although the productive borehole (BH3) is not directly located on the fractured zone FL2, its productivity may be influenced by its nearness to the fractured zone.

The Overburden Thickness Map

In a typical Basement Complex environment, the overburden thickness, which connotes the depth to groundwater exploration. The range (4 – 44 m) of overburden thickness observed in the study area as shown in figure 7 supports the claims of Oyedele and Olayinka (2012) and Ademilua and Eluwole (2013) that the overburden thickness range obtainable in Ado-Ekiti is between 1 and 79.9 m.

Ademilua and Eluwole (2013) prescribed an overburden thickness greater than 25 m as good enough for groundwater development at the Afe Babalola University, Ado-Ekiti. Therefore zones identified as OT2, OT3, and OT7 with overburden thicknesses greater than 25 m on figure 7 are also considered good for groundwater development in the study area. The presence of productive boreholes BH2 and BH3 in the vicinity of zones OT2 and OT3 is a proof of the reliability of the good potential at zone OT7. Whereas, zones OT1, OT4, OT5 and OT6 identified as zones with relatively thin (4 – 12 m) overburden possess poor groundwater potential. This is evident from the presence of borehole BH1 in the zone OT1



ominant aquifer unit

Figure 6: The Partly Weathered/Fractured BasementThickness Map

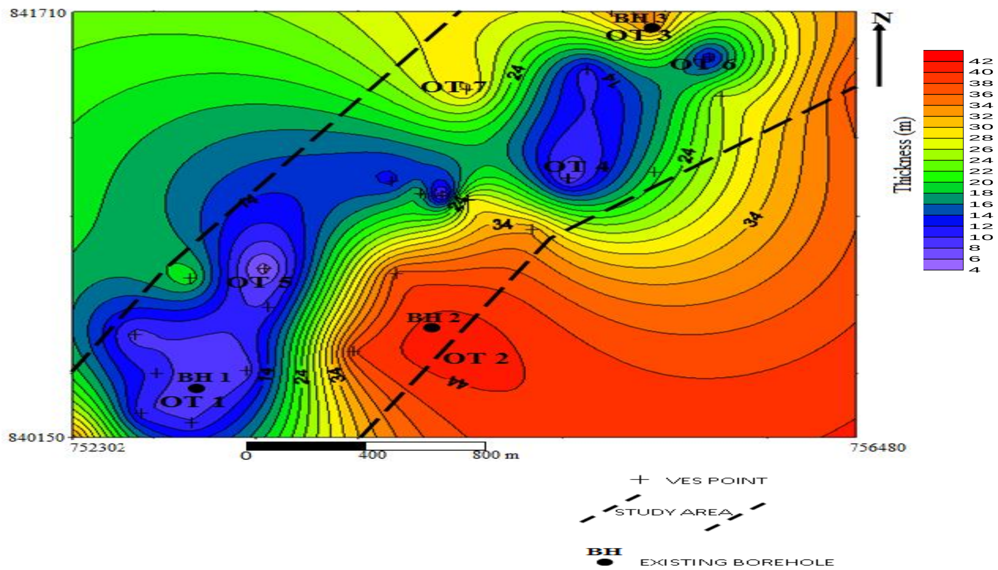


Figure 7: Overburden Thickness Map

The Geoelectric Groundwater Potential Map

The groundwater potential map (figure 8) is a multifactorial presentation of mosaicked highly weathered layer thickness map, partly weathered/fractured basement thickness map and the overburden thickness map. The map presents a holistic classification of the study area into good and poor groundwater potential zones based on the contribution of the factors (weathered layer, fractured layer and overburden thickness) necessary for groundwater development in a typical Basement Complex environment. Three good groundwater potential zones (GP1, GP2, and GP3), two of which accommodates the productive boreholes BH2 and BH3 are present in the area. Other zones (PP1, PP2 and PP3) are zones with poor groundwater potential, a claim corroborated by the presence of failed borehole BH1 on zone PP1. The good semblance between the weathered layer thickness map and the groundwater potential map suggests that the highly

CONCLUSIONS

Detailed analyses of electrical resistivity data have been used to evaluate the groundwater potential of the Northeastern-Southwestern part of the Federal Polytechnic, Ado- Ekiti in the Basement Complex area of Ekiti State. The analyses provided information on the subsurface geoelectric layers and lithologic units coupled with their hydrogeologic implication in the area.

Four major subsurface lithologic units were identified. These include the lateritic topsoil/laterite, with resistivity ranging from 70 to 1023 ohm-m and thickness between 0.4 and 3 m; the highly weathered/clayey layer with resistivity range of 10 – 80 ohm-m and thickness ranging from 2.1 to 38 m; the partly weathered/fractured basement characterised by a resistivity range of 45 – 132 ohm-m and thickness range of 19.1 – 40 m; and the fresh basement bedrock with characteristic resistivity generally greater than 130 ohm-m and infinite thickness. The highly weathered layer and the partly weathered/fractured constitute the two major aquiferous units in the area, but the weathered layer has been observed to have more influence on the groundwater potential. The aquifers occur in combination in some cases

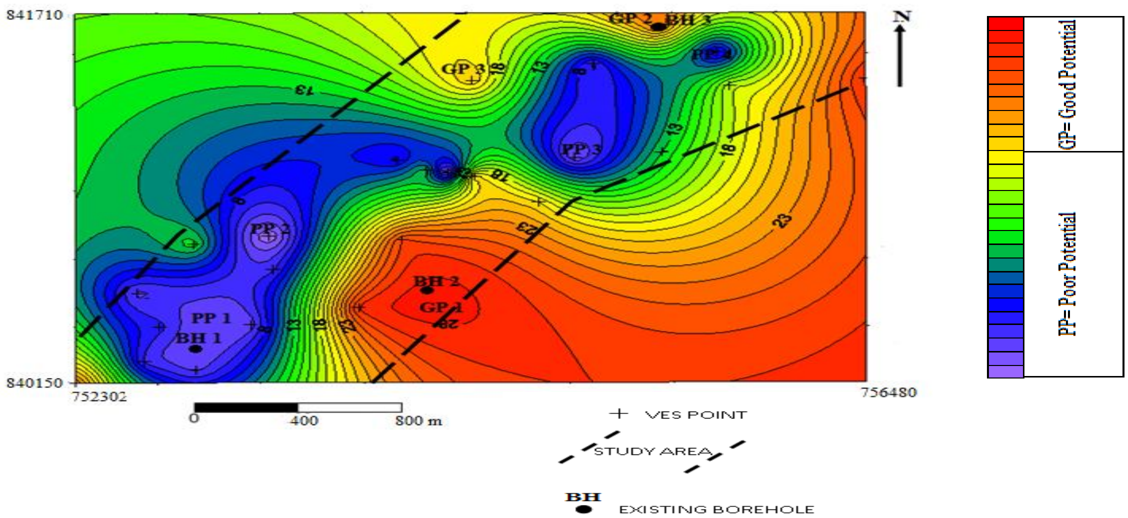


Figure 8: Geoelectric Groundwater Potential Map of the Study Area

The weathered layer and the overburden thickness maps as well as the partly weathered/fractured layer thickness maps were synthesized, integrated and correlated to reveal zones with good and poor groundwater potential.

The good potential zones are labelled GP1, GP2 and GP3, while the low potential zones are labelled PP1, PP2, PP3 and PP4. The groundwater potential map presents a regional picture of the groundwater potential of the study area and it depicts a generally limited groundwater potential, a factor that may be responsible for the non-availability of adequate boreholes in the study area. The productivities of borehole BH2 and BH3 are attributed to their presence in the good potential zones GP1 and GP2, while the presence of borehole BH1 on poor potential zone PP1 is a proof of its failure.

RECOMMENDATIONS

For the purpose of this study, a total of twenty five VES stations only were occupied, and this cannot be said to be sufficiently representative of the study area for a detailed result. This can be said to be a limitation as more than this number will give an enhanced and more reliable results. Arising from this limitation it becomes imperative to recommend that, for a more detailed and accurate groundwater potential evaluation, it is recommended that: (1) Additional VES data are obtained at closer intervals within the study area and extended to other parts of the campus as a means of enhancing the quality of the maps. (2) borehole data should also be obtained from the existing ones on campus and more from the adjoining localities as a means of improving the information on the general groundwater situation in the environment. (3) further geophysical investigations involving very low frequency electromagnetic (VLF-EM), magnetics and seismic refraction be carried out to corroborate the results of this study.

REFERENCES

Ademilua L.O and Olorunfemi M.O., 2002. A geoelectric and geologic estimation of the area of the groundwater potentials of Ekiti and Ondo States, southwest Nigeria. Journal of Technoscience Vol. 4, University of Ado Ekiti center for research and Devt., Ado – Ekiti Nigeria, pp. 4 – 18.

Ademilua, O.L. and Eluwole, A.B., 2013. Hydrogeophysical Evaluation of the Groundwater Potential of Afe Babalola University Ado-Ekiti, Southwestern Nigeria. Journal of Emerging Trends in Engineering and Applied Sciences. vol 4. No. 1, pp. 77-83.

Ajayi, O., Olorunfemi, M.O., Ojo, J.S., Adegoke-Anthony, C.W., Chikwendu, K.K., Oladapo, M.I., Idornigie, A.I. and Akinluyi, F., 2005. Integrated geophysical and geotechnical investigation of a damsite on River Mayo Ini, Adamawa State, Northern Nigeria. Africa Geoscience Review, vol. 12, No. 3, pp. 179-188.

Ako, B.D. and Olorunfemi M.O., 1989. A geo-electric survey for groundwater in the Newer Basalts of Vom, Plateau State, Nigeria. Journal of Mining and Geology, vol. 25 (Nos. 1 & 2), pp. 247 – 250.

Hazell, J.R.T, Cratchley C.R. and Jones C.R.C., 1992. The hydrogeology of Crystalline aquifers in northern Nigeria and geophysical techniques used in their Exploration. *In* Wright, E.P. and Bongess W.G. (Eds.) Hydrogeology of Crystalline basement aquifers in africa. Geological Society special Publication vol 66. pp.155 182.

Orellana, E. and Mooney H.M., 1972. Two and Three- layer master curve and auxiliary point diagram for VES. Madrid, Interciencia.

Oyawoye, M.O., 1964. The Geology of Nigerian Basement Complex. J. Mining Geosci.vol., No. 2 pp. 87 – 108.

Olarewaju, V. O.,1988. Petrology and geochemistry of the charnokitic and associated granitic rocks of Ado-Ekiti-Akure area, Southwest Nigeria. In: Precambrian Geology of Nigeria, Oluyide, P. O.; Mbonu, W. C.; Ogezi, A. E.; Egbunwe, I. G.; Ajibade, A.C; and Umeji, A. C., (eds), Geological Survey of Nigeria, pp 129-143.

Olayinka, A. I., 1990. Electromagnetic profiling and resistivity soundings in groundwater investigation near Egbeda-Kabba, Kwara State. Journal of Min. and Geol., vol. 26, pp 243-250.

Olorunfemi, M.O., 2009. Groundwater Exploration, Borehole Site Selection and Optimum Drill Depth in Basement Complex Terrain. Water Resources, Special Publications Series 1, ISSN 0795-6495. 20p.

Oyedele, E. A. A and Olayinka, A. I, 2012. Statistical evaluation of groundwater potential of Ado-Ekiti, Southwest, Nigeria. Transnational Journal of Science and Technology, 2(6), pp 110-127

Rahaman, M. A. (1976). Review of the basement geology of southwestern Nigeria. In:Geology of Nigeria (Kogbe C. A. Ed.) Elizabethan Publ. Co., Nigeria pp 41-58.

Rahaman, M.A., 1988. Recent advances in the study of the Basement Complex of Nigeria. (Edited by Nigeria Geological Survey), pp. 11-43.

Vander, V.B.P.A., 2004. WinRESIST version 1.0. ITC, IT-RSG/GSP.

Wright, C. P., 1992. The hydrogeology of crystalline basement aquifers in Africa. In: C. P. Wright and W. C. Burgess (eds). Hydrogeology of Crystalline Basement aquifer in Africa. Geological Society of London Special Publication No. 66 Pp. 1 – 27.