Groundwater potential evaluation using surface geophysics at Oru-Imope, South-Western Nigeria

Kayode Festus Oyedele
University of Lagos

Difference Ogagarue
Federal University of Petroleum Resources

European Journal of Scientific Research
ISSN 1450-216X Vol.63 No.4 (2011), pp. 515-522

http://www.europeanjournalofscientificresearch.com

Groundwater Potential Evaluation using Surface Geophysics at Oru-Imope, South-Western Nigeria

Oyedele, K. F.
Department of Geosciences
University of Lagos, Lagos, Nigeria

Ogagarue D. O.
Department of Earth Sciences
Federal University of Petroleum Resources
Effurum, Delta, Nigeria
E-mail: kayodeunilag@yahoo.com

Esse, O.
Department of Geosciences
University of Lagos, Lagos, Nigeria

Abstract

The application of Electrical resistivity technique in the evaluation of groundwater potential and aquifer protective capacity at Oru-Imope, Ogun state, Nigeria, using Schlumberger electrode array has revealed the occurrence of substantial amount of water in the weathered rock (consisting of sand). The resistivity of the weathered layers range from 88.6 to 251.1Ωm.The clay content of the overburden is low and this informed the high groundwater potential rating of the area. It was observed that over 85% of the study area show high groundwater potential rating while the remaining 15% show medium groundwater potential rating. On the other hand, the total longitudinal conductance in the study area varies between 0.07 and 0.18mhos indicating poor to weak protective capacity owing to the high content of sand in the overburden layer. The depths to potential aquifer range from 5 to over 20m.

Keywords: Geo-electric section, weathered basement, longitudinal conductance, aquifer

Introduction

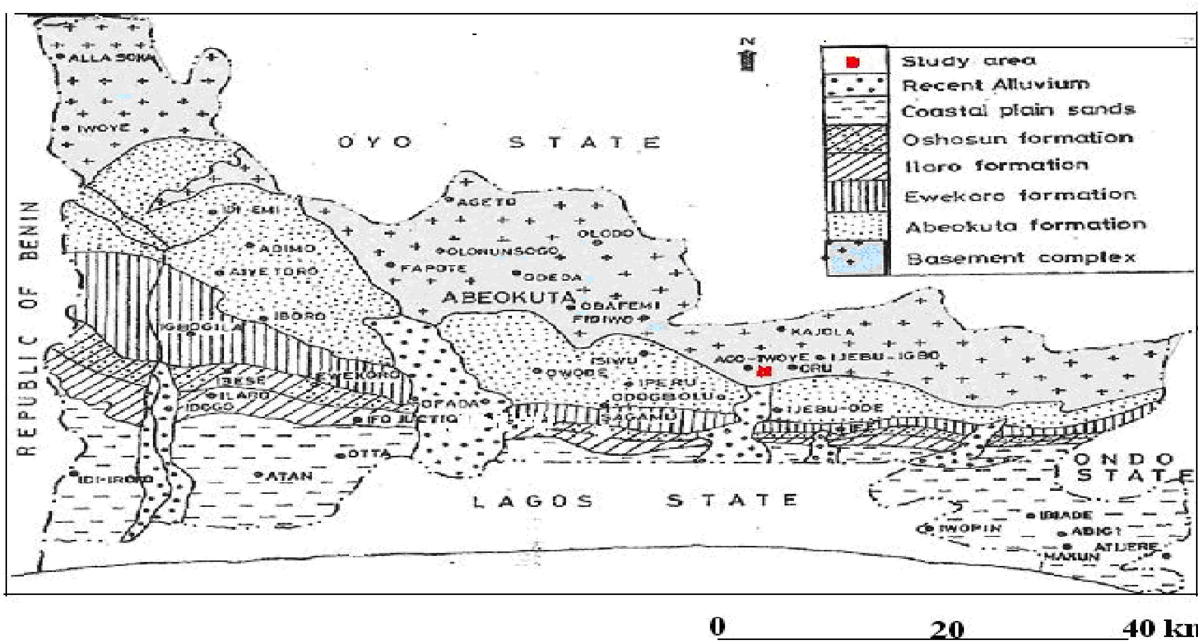
Many people in the urban and rural communities of Nigeria are battling with the problem of inadequate availability of potable water for their daily activities. Often time, this impact is greatly felt mostly by those people in the rural communities. In Oru-Imope, the situation is worrisome as many citizens mainly depend on water supply from nearby stream and hand-dug wells constructed by private individuals and in most cases some of the wells were seasonal in nature. Borehole development is difficult and capital intensive particularly in a crystalline basement environment where the rocks are devoid of primary porosity and permeability and also where run off is high and infiltration rate is very low. In most cases the occurrence of groundwater in this environment is confined to weathered and fractured basement (Ariyo,2005 and Appa, Rao,1997). Several of such boreholes drilled in the past were abortive and this might not be unconnected to the lack of understanding of the complex nature of the subsurface geology of the area prior to drilling exercise.

The study area is underlain by Precambrian basement complex rocks. These rocks are inherently characterized by low porosity and near negligible permeability. The highest groundwater yield in basement terrains is found in areas where thick overburden overlies fractured zones. These zones are often characterized by relatively low resistivity values. (Olorunfemi and Fasuyi, 1993). The success of abstraction well in any basement environment requires an adequate understanding of the geo-hydrological properties of the aquifer units in relation to its environmental conditions. This is particularly important in view of the discontinuous (localized) nature of the basement aquifers (Satpatty and Kanugo, 1976). Therefore, detailed pre-drilling geophysical investigations become inevitable. This study is aimed at unravel the subsurface geology and its associated features that are favourable for groundwater development at Imope, Ogun State for the purpose of serving as a working guide for future groundwater development in the area. Vertical electrical sounding has been found suitable for groundwater exploration in the basement complex areas of Africa (Oyedele et al, 2008, Ariyo, 2005, Olorunfemi et al, 1999, Barongo and Palacky 1991, Benson and Jones, 1988). The method amongst other things is capable of delineating the depth to potential aquifer, depth to bedrock and cost effective.

Geological Setting

Imope falls within latitudes 7º 622´ N and 7º 348´N and longitudes 5º 675E and 5º 644´E (figure 1). Notable outcrops on the surface include biotite-hornblende gneiss, granite gneiss and related rocks. However, general geology of south-western Nigeria reveal the occurrence of older granite (consisting of pepmatite, granite-gneiss, granoiorite, migmatite and quartz diorite), charnockitic intrusives (consisting of pyroxene-diorite and metagabbro) and gneiss complex (consisting of quartizite, biotite- and biotite hornblende-gneiss mica-schist, amphibolite schist and granulitic gneiss), (Jones and Hockey, 1964).

Figure 1: Geologic map of Ogun state showing the study area.



Data Acquisition

The data were acquired using Vertical Electrical Sounding (VES) involving the Schlumberger electrode configuration. A total of nine (9) VES were performed along three (3) traverses in the study area (figure 2). ABEM Terrameter model SAS 1000 was used to measure the apparent resistivity and induced polarization effect. A portable battery was used as the power source, while four metal steel rods were utilized as electrodes. Other equipments used include: hammers, four reels of copper wire, Global Positioning System (GPS) and measuring tapes. The electrodes were arranged using the Schlumberger electrode array and were planted firmly in the ground to ensure good contact. The cables were connected to the electrodes using a cello-tape and to the ABEM SAS 1000 Terrameter. For the first reading, the potential electrodes and current electrodes were at 0.25m and 1m respectively from the mid-point. The current electrodes were expanded subsequently symmetrically about the mid point. The potential electrodes were only moved at specified distances so that the Terrameter could measure the voltage arising from the current injected into the subsurface.

Data Processing and Interpretation

The data acquired were processed to remove noise arising from instrumentation and environmental influence. Interpretation software for 1D inversion of apparent resistivity data called WinGlink was used for processing the VES data. The program basically determines a resistivity model that approximates the measured data within the limits of data errors and which is in agreement with all a prior information. The difference between the measured and calculated apparent resistivity values is given by the root-mean-square (RMS) error. The data were processed to the lowest allowable root-mean-square error of about 2.5%. The first step in the processing of the data was to enter the field data into the program, after which processing commences to obtain the layer parameters. Also the total longitudinal conductance for each layer unit were obtained by dividing the thickness value of each layer unit with its resistivity value (Table 1).

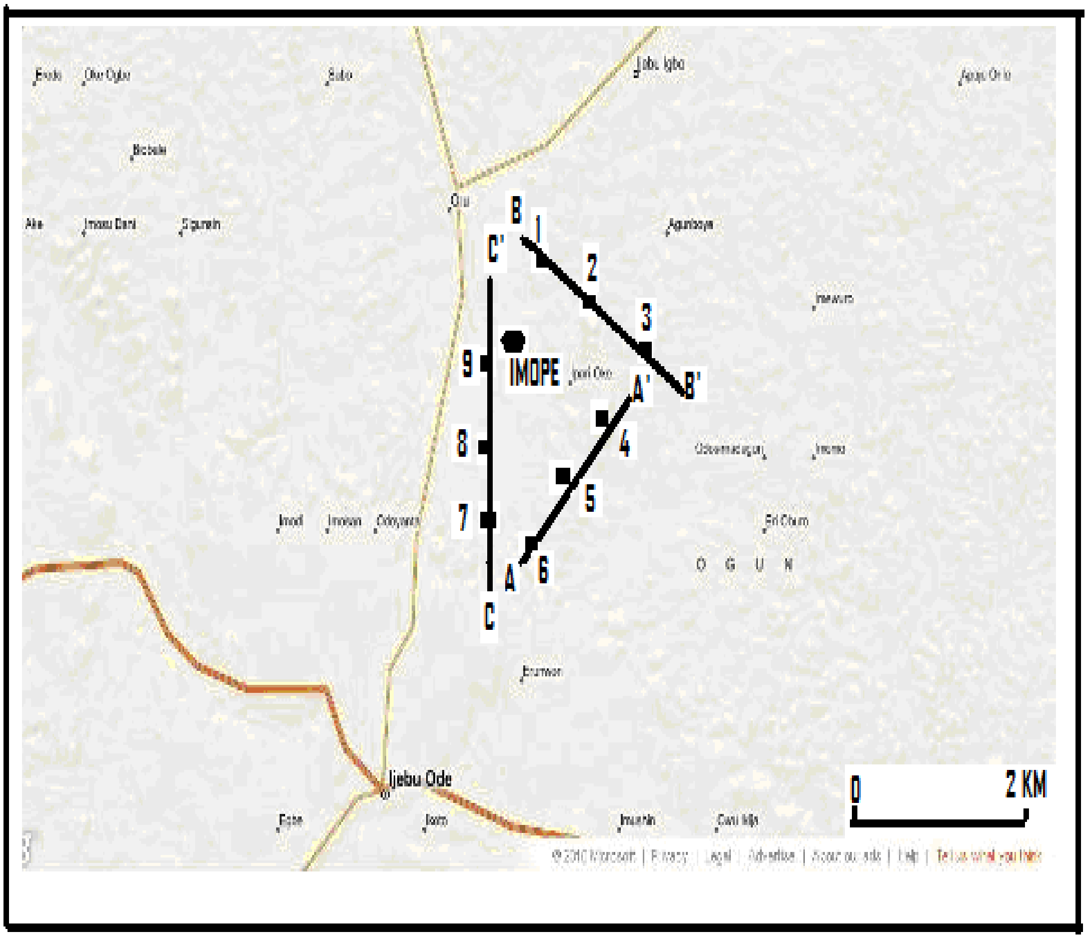
Presentation of Results

The 9 Vertical electrical Soundings were grouped into three profiles (figure 2) which were analyzed. The resistivity value of each layer was highlighted, its thickness and inference was made based on its resistivity signature and the geology of the area. The inferred layers are represented in a pictorial structure known as geo electric section (figure 3). The geo-electric section illustrates a line image (1-D) that changes vertically. Various geo-electric sections on the same profile can be related to form an assumed tomography model. The Isopach, Isoresistivity and depth slice contour lines indicates the distribution of a given subsurface property over the area (figures 4 to 7). Map of total longitudinal conductance of the study area were prepared for groundwater protective capacity rating (Table 1).

Table 1: Longitudinal conductance values of the subsurface layers.

VES	Layer	Resistivity (Ωm)	Thickness (m)	Lithology	Longitudinal Conductance (Ω^{-1}m)
1	4	202.54	13.26	Weathered Basement	0.066
2	3	102.73	13.95	Weathered Basement	0.136
3	3	99.96	12.54	Weathered Basement	0.126
4	3	210.23	15.30	Weathered Basement	0.0728
5	4	142.76	13.99	Weathered Basement	0.098
6	3	103.57	14.75	Weathered Basement	0.14
7	4	91.71	16.54	Weathered Basement	0.18
8	3	88.59	19.88	Weathered Basement	0.224
9	3	251.45	4.14	Weathered Basement	0.0165

Figure 2: Part of map of Ijebu-North showing the study area and sounding locations

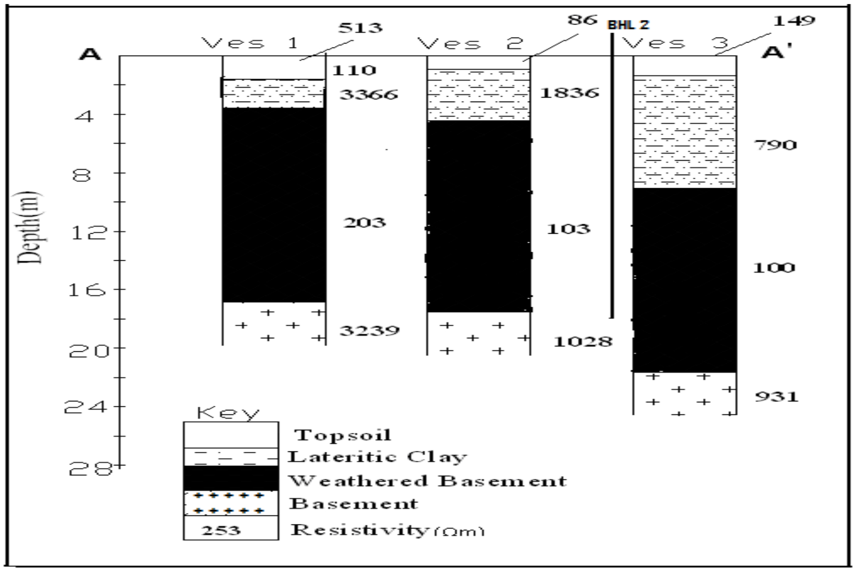


Discussion of Results

Geo-Electric Sections

Three geo-electric sections were constructed along the three traverses showing the variations of the resistivity and thickness values penetrated beneath all the VES stations in the study area. Averagely, the study area revealed about four layers. This consists of the topsoil, lateritic clay, weathered layer and the fresh basement rock (figure 3). The top soil has thickness value that ranges between o.6 and 1.4m, while its resistivity value varies from 85.8 to 558.6Ωm. suggesting that the topsoil is predominantly sand and sandy clay. The second layer (lateritic clay) has thickness value that ranges between 2.0 and 16.7m and resistivity value that varies from 789.6 to 4942.9Ωm. The third layer (weathered basement rock) has thickness value that ranges between 4.1 and 19.9m with resistivity values that varies from 88.6 to 251.5, which suggest high degree of fracturing and water saturation. Here this layer is of infinite thickness because it is the last observable layer which is underlain by basement rock. This layer is mostly of sand and gravel, constituting the potential groundwater source zone. The fresh basement rock represents the last layer with resistivity value varies between 1027.9 and 2659.8Ωm and infinite thickness because of current termination.

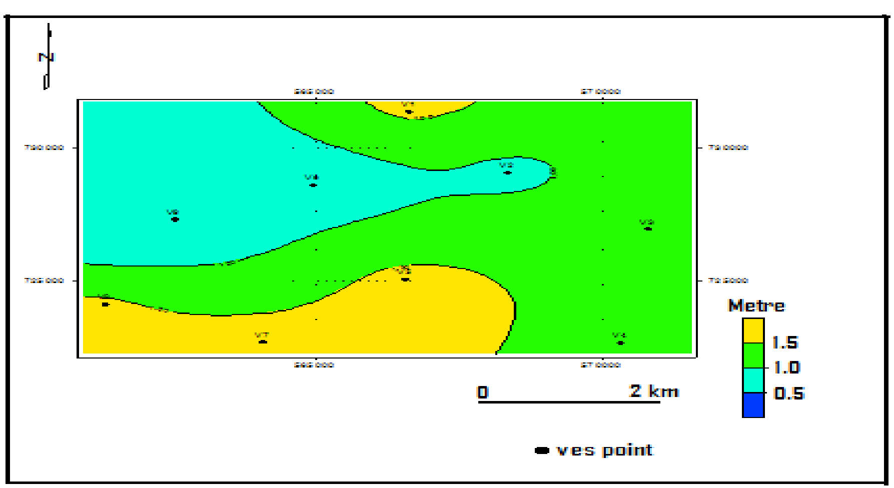
Figure 3: Sample of geo-electric section beneath traverse AA'



Isopach Maps

Figures 4 to 7 represent the isopach maps of depths to weathered basement rock, thicknesss of weathered basement rock, depth to lateritic clay and depth to the basement rock. These maps show the variations of thickness of each litho-logical unit across the study area in relationship to their depth equivalent. Figure 4 shows the depth to lateritic clay layer with increasing values in the east-west portion. The highest value is in the southern portion. Figure 5 show the depth to weathered basement rock that varies from 1 to over 10.0m. The highest value is found on the north central portion while the lowest value can be found on the western half. On the other hand, figure 6 shows the thickness of the weathered basement rock which varies from 2 to over 20m. This layer composed of sand saturated with water which was observable in borehole log. This aquifer was observed beneath VES 1 2, 3, 4, 5, 7 and 8. Two productive boreholes were drilled within the study area, one between VES 2 and 3 and the other between VES 4 and 5 (figure 4). The resistivity of the topsoil and that of the weathered layer show that the clay content of the overburden is low which informed the high groundwater potential rating of the area. It was observed that over 85% of the study area show high groundwater potential rating while the remaining 15% show medium groundwater potential rating.

Figure 4: Contoured map of depth to lateritic clay (m)



In addition to this, map of longitudinal conductance of the study area was produced for aquifer protective capacity rating (figure 7). This is because the earth medium acts as a natural filter to percolating fluid. Its ability to retard and filter percolating ground surface polluting fluid is a measure of its protective capacity (Olorunfemi et al., 1999). The highly impervious clayey overburden, which is characterized by relatively high longitudinal conductance, offers protection to the underlying aquifer.The longitudinal conductance of each layer unit obtained in the study area (table 2) was used to infer the aquifer protective capacity rating. The total longitudinal conductance in the study area varies between 0.07 and 0.18mhos. The area where the longitudinal conductance value is above 0.7 mhos is considered as good protective capacity. The portion where the conductance value ranges between 0.2 and 0.69 mhos is classified as zones of moderately protective capacity. The areas which have conductance value ranging from 0.1 and 0.19 mhos was classified as zones of weak protective capacity and where it is less than 0.1 mhos was considered as poor aquifer protective capacity (Oladapo and Akintorinwa, 2007). Based on the above classification, the aquifer protective capacity within the study area falls between poor to weak owing to the high content of sand in the overburden layer. Figure 8 shows the isopach map of depth to the basement which ranges from 18 to over 26m. The north central and the eastern portions indicate the highest values wile the western and the southern portions have the lowest values.

Figure 5: Contoured map of depth to weathered layer (m)

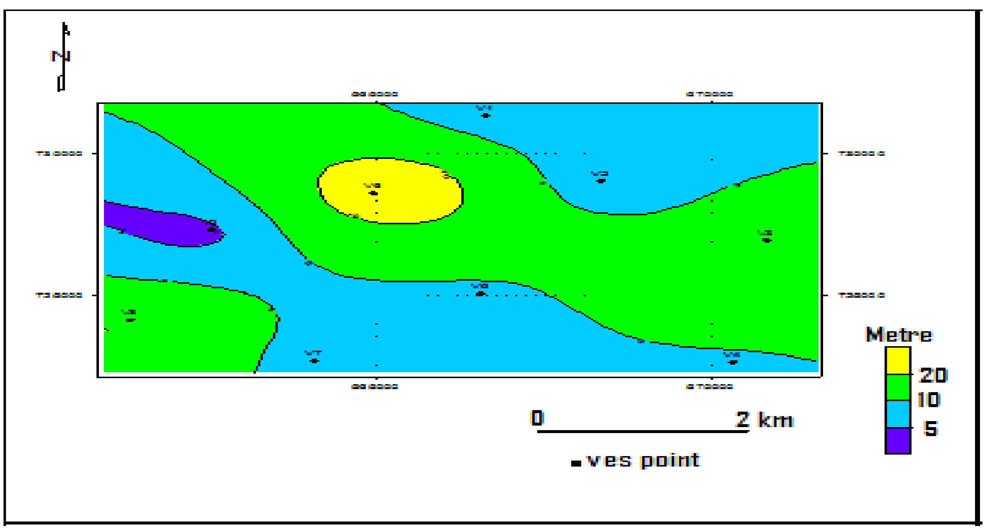


Figure 6: Contoured map of thickness of weathered basement (m)

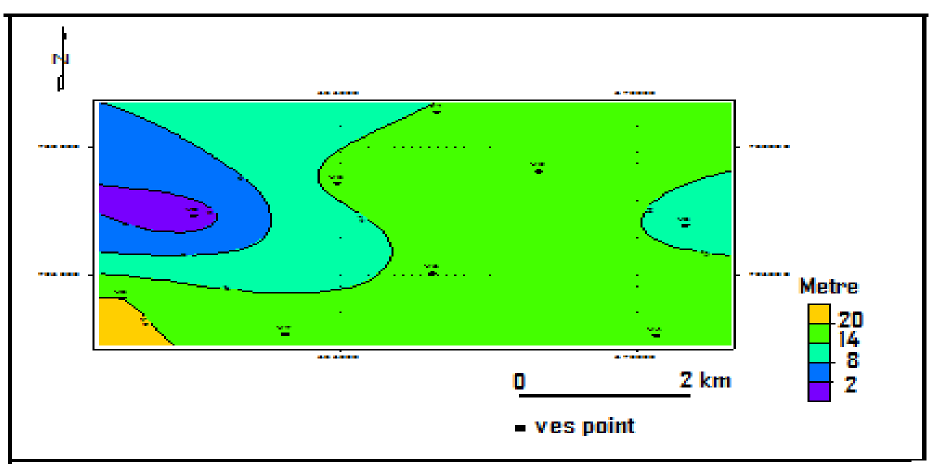


Figure 7: Contoured map of longitudinal conductance values (mhos)

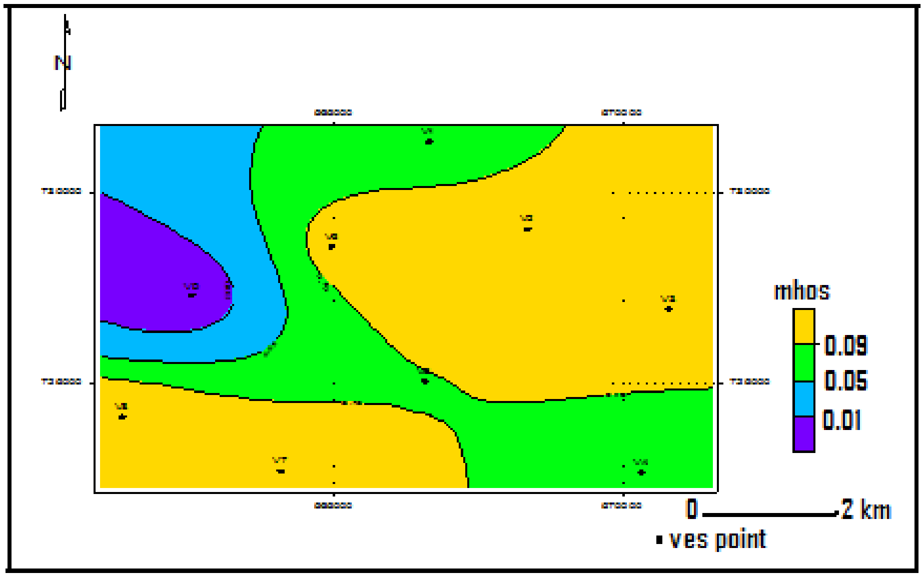
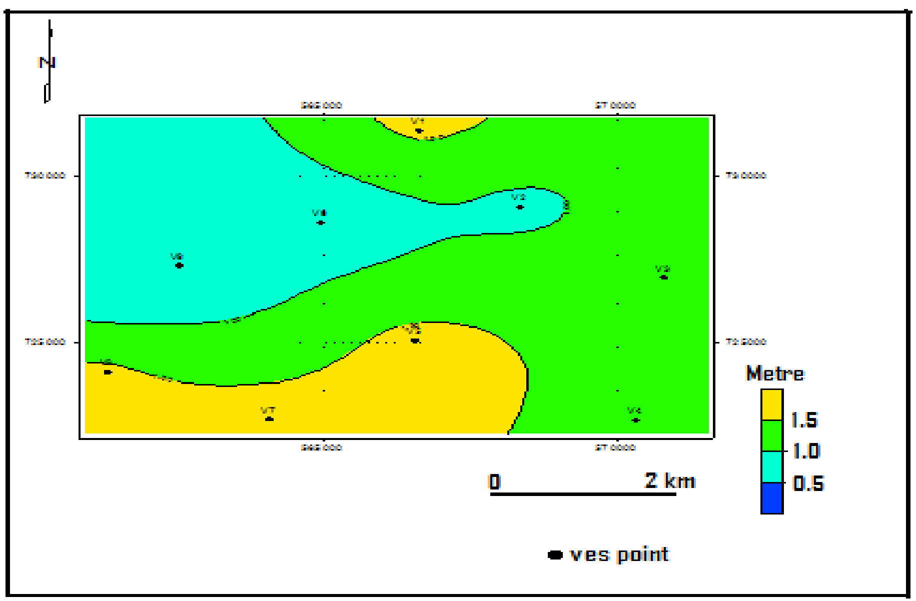


Figure 8: Contoured map of depth to basement (m)



Conclusion

The geophysical investigation conducted at Imope, Ogun state revealed the underlying lithology to be made up of topsoil (consisting of sand and sandy clay), lateritic clay ,sand, weathered basement and fresh basement. It was observed that over 85% of the study area show high groundwater potential rating while the remaining 15% show medium groundwater potential rating, due to the low content of clay material in the overburden and weathered layers.The aquifer protective capacity within the study area falls between poor to weak owing to the high content of sand in the overburden layer thus making the underground water to be vulnerable to surface contamination. The depth to probable potential aquifer ranges from 5 to over 20m.

References

[1] Appa, Rao. A (1997). Development in Geoelectrical Methods.AA Balkema, Rotterdam, The Netherlands, pp 293.
[2] Ariyo, S.O. (2005). Geoelectrical Characterisation of Aquifers and Geochemical Study of groundwaters in the Basement Complex/Sedimentary Transition Zone Around Ishara, south-western, Nigeria". M.Phil. Thesis. University of Ibadan: Ibadan, Nigeria.
[3] Barongo J.O, Palacky G.J (1991). Investigations of electrical properties of weathered layers in the Yala area, Western Kenya, using resistivity soundings. Geophys. 56(O.I): 133-138.
[4] Benson S, Jones CR (1988). The combined EMT/VES Geophysical method for siting bore-holes pp. 54-63.
[5] Jones, A.A and Hockey, R.A. (1964). The geology of part of southern Nigeria. Geol.Bull. 31, 101p
[6] Oladapo MI, Akintorinwa O.J (2007). Hydrogeophysical Study of Ogbese Southwestern, Nigeria. Global J. Pure and Applied Sci. 13(1): 55-61.
[7] Olorunfemi, M.O, Fasuyi S.A (1993). Aqufier types and geoelectric/hydrogeologic Sci., 16(3): characteristics of part of central basement terrain of Nigeria (Niger State). J. Africa Earth 309-317.
[8] Olorunfemi, M.O, Ojo, J.S., and Akintunde, O.M. (1999). "Hydrogeophysical Evaluation of the Groundwater Potentials of the Akure Metropolis, Southwestern Nigeria". *Journal of* Mining and Geology. 35 (2):201-228.
[9] Oyedele, K.F, Ayolabi, E.A, Adeoti, L, and Adegbola, R B. (2008). Geophysical and hydrogeological Evaluation of rising groundwater levels in the coastal area of Lagos, Lagos, Nigeria. Bull. of Eng. and the Envt. 68: p137-143. Springer, Germany
[10] Satpatty BN, Kanugo BN (1976). Groundwater Exploration in Hard rock terrain, a Case study, Geophysical Prospecting, 24 (4): 725 – 736.