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RESEARCH ARTICLE

GEOELECTRICAL DETERMINATION OF GROUNDWATER POTENTIALS OF UGHELLI , DELTA STATE, NIGERIA

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ABSTRACT

Sixteen vertical electrical soundings (VES) were carried out at Ughelli, Nigeria in order to ascertain the groundwater potentials of the area. The instrument used was the ABEM Terrameter SAS 300B, employing the Schlumberger electrode configuration. Interpretation of the VES data by computer aided modelling showed that the subsurface structure can best be described in terms of three or four geoelectric layers. The first layer showed resistivity range of 14.0 - 763.2Ωm and thickness range of 0.5 - 5.4m. The resistivity of the second layer ranged from 102.7 - 4806.7Ωm while the thickness is in the range of 1.3 - 20.0m.The third layer showed resistivity range of 421.7 - 2237.4Ωm and thickness range of 9.1 - 48.0m. The resistivity of the fourth layer varied from 291.7 - 1728.5Ωm. The aquifer thickness was variable, ranging from 14.3m up to a maximum of 48.0m, around Afiesere area in the eastern part of the study area. The longitudinal conductance of the aquiferous layers varied from 0.005mho up to a maximum of 0.110mho, also at the eastern part of the study area. This portion of the study area promises high potentials for productive borehole development programme in Ughelli.

Key words: Aquifer, Groundwater, Resistivity, Thickness, Longitudinal Conductance.

INTRODUCTION

Insufficient supply of portable water has remained a serious problem in Ughelli due to the rapidly increasing demand for water as a result of urbanization. Being an operational base of many oil producing companies in Nigeria, the population of this town has been fast increasing, forcing some dwellers to resort to the use of surface water. The contamination of surface water in the Niger Delta has been discussed by several researchers (Etu-Effeotor, 1981; Edet, 1993; Esu and Amah, 1999).The need for portable water supply, such as groundwater, to meet up with the demands of such increasing population, both for domestic and industrial uses, cannot be overemphasized. Groundwater is better in quality than surface water, provided it is not degraded by human activities (Singh, 2000; Adepelumi *et al.*, 2001; Popoola and Fukunle, 2011).

Exploitation of groundwater in an area requires that boreholes be drilled at sites that will produce optimal and sustainable yield. This therefore calls for proper planning for a sustainable development of the groundwater resources of the area in order to avert the risk of spending large sums of money in sinking abortive or poor yield boreholes. Hence the need for appropriate geophysical study of the ground water potentials of the area. Vertical electrical sounding (VES) has been chosen for this study. The method has been proven to be an effective means of solving groundwater problems in most places in Nigeria (Onuoha and Mbazi, 1988; Mbonu *et al.*, 1991; Mbipom *et al.*, 1996; Ekine and Osobonye, 1996; Oseji *et al.*, 2006; Oseji, 2010; Ezeh and Ugwu, 2010; Ugwu and Ezeh, 2012). In the present study, an attempt has been made to establish the aquifer characteristics of the study area and hence delineate the best portion of the area for drilling productive boreholes. This information will be important to developers and prospective developers as a baseline data. Such a database will help to improve the success rates of drilling boreholes in the area.

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Geology and Hydrogeology of the Study Area

The study area lies between longitude 5^0 51^IE and 5^0 58^IE and latitude 5^0 25^IN and 5^0 38^IN (Figure 1).

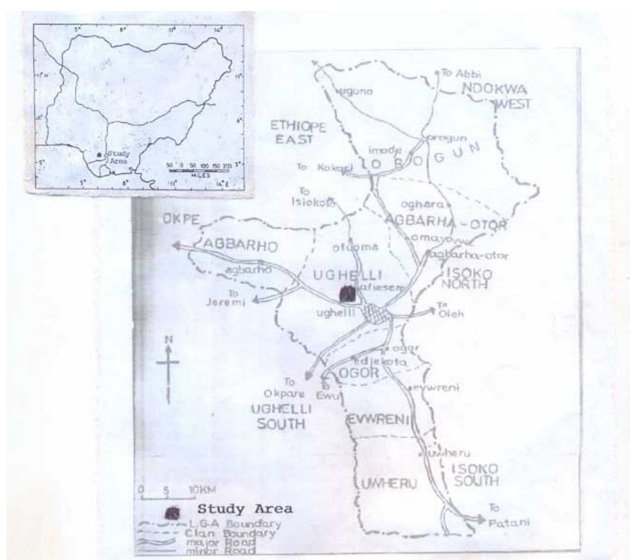

Figure 1. Location map of the study area

This area is within the Niger Delta sedimentary basin of Nigeria. The geology of the Niger Delta of Nigeria is now fairly well documented and includes the works of Reyment (1965), Short and Stauble (1967), Merki (1972), Murat (1972), Reijers (1996). The stratigraphic sequence consists of the Akata Formation which is overlain by the Agbada Formation and then followed by the Benin Formation (Figure 2). The Akata Formation consists of dark grey sand and silty shale with plant remains at the top. Thin sandstone lenses occur near the top, particularly near the contact with the overlying Agbada Formation.

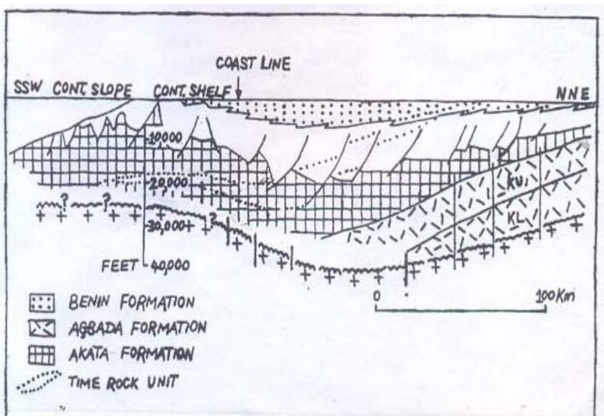

Figure 2. Niger Delta schematic dip section (Merki, 1972)

The overlying Agbada Formation is a sequence of sand and shale. A fluviatile origin is indicated by the coarseness of the grains and their poor sorting. The age ranges from Eocene to Pliocene/Pleistocene, with the major hydrocarbon accumulations occurring within the interval. The Agbada Formation is overlain by the Benin Formation. The unconsolidated and highly porous continental sand and sandstones of the Benin Formation have been identified as fresh water bearing sands (Short and Stauble (1967). The sands and sandstones are coarse grained, pebbly to fine grained, and are poorly sorted. They are sub-angular to well rounded, and are predominantly white in colour. The average thickness is about 2100m (Short and Stauble (1967) and ranges in age from Miocene to Eocene. The vegetation of the study area is typical of the rainforest region except along the streams which are swampy, typical of the mangrove region of the Niger Delta. Aquifers in the area are of considerable thickness and have high recharge potentials due to high precipitation, thus making the groundwater to be high.

METHODOLOGY

Sixteen vertical electrical soundings (VES) were carried out at various locations within the study area. The instrument used was the ABEM Terrameter SAS 300B, employing the Schlumberger electrode array (Figure 3). The instrument measures the resistance R of the earth subsurface sampled by the survey. This measured resistance was used to calculate the apparent resistivity ρ_a of the model earth subsurface structure using the relation:

$$\rho_a = \pi\left(\frac{L^2}{l} - \frac{l}{4}\right)R \;=\; KR$$

Where $K = \pi\left(\frac{L^2}{l} - \frac{l}{4}\right)$ is the geometric factor for the Schlumberger array.

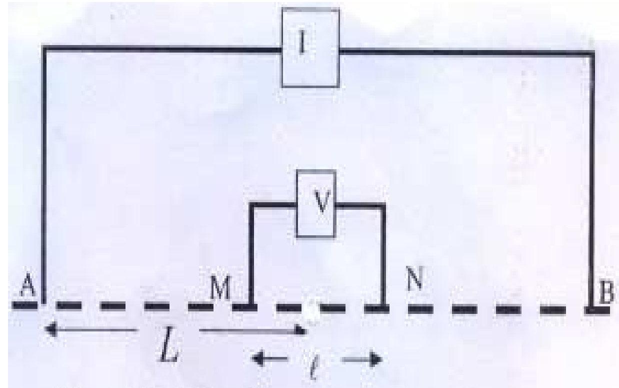

Figure 3. Schlumberger electrode array.

L=AB/2 = Half current electrode spacing,
l=MN = Potential electrode spacing.

The maximum current electrode separation (AB) achieved in the field varied from 600m to 800m, depending on the accessibility along the transverses. Values of apparent resistivity obtained from the field measurements at each sounding station were plotted as ordinate against half-current electrode separation (AB/2) as abscissa on log-log graphs. The field curves were first interpreted by partial curve matching technique in order to estimate the resistivity and thickness of the layers using the two-layer curves of Orellana and Mooney (1966). These initial estimates were then used as the starting parameters for computer modelling using the RESIST Version 1 software (Vander, 1988) to obtain better estimates of the resistivity and thickness of the geoelectric layers after several computer iterations. The VES interpretation results were then used to compute the longitudinal conductance S of the aquifer layer for each sounding station using the equation of Maillet (1947):

$$S = {h_i}/{\rho_i}$$

Where h_i and ρ_i are respectively the thickness and resistivity of the aquiferous layer for each VES station.

RESULTS AND DISCUSSION

The apparent resistivity curves generally showed three or four geoelectric layers. Eight representative curves (out of the Sixteen) are shown in Figure 4–11. A correlation between the lithologic log of one of the boreholes drilled in the area by the Federal Ministry of Water Resources and the interpretation results of VES 1–5 is shown in Figure 12. This correlation in conjunction with the geology of the study area was used to infer the lithology of the layers. The first layer has resistivity range of 14.0–763.2Ωm while the thickness of this topsoil ranges from 0.5–5.4m. The resistivity of the second layer varies from 102.7 – 4806.7Ωm. This layer was inferred to be fine sand – lateritic sand. The thickness of this layer varies from 1.3m to 20.0m. The third layer resistivity varies from 421.7- 2237.4Ωm and was inferred to be fine-medium-coarse grained sand and mostly constitutes the aquifer in the area. The resistivity of the fourth layer ranges from 291.7 – 1728.5Ωm and was inferred to be sand-fine sand. This fourth layer in some VES results was lumped into the third layer. This follows because geoelectric layers do not always coincide with geologic layers (Keller and Frischknecht, 1966).

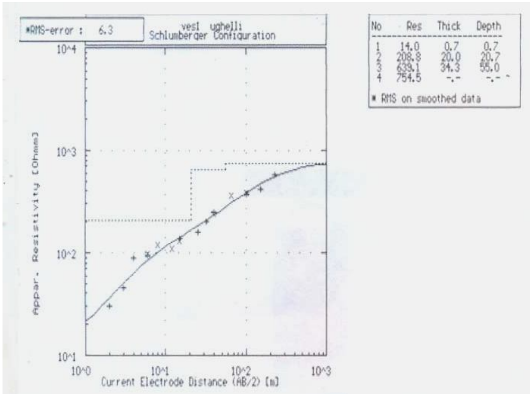

Figure 4. Interpretation result of VES 1 data

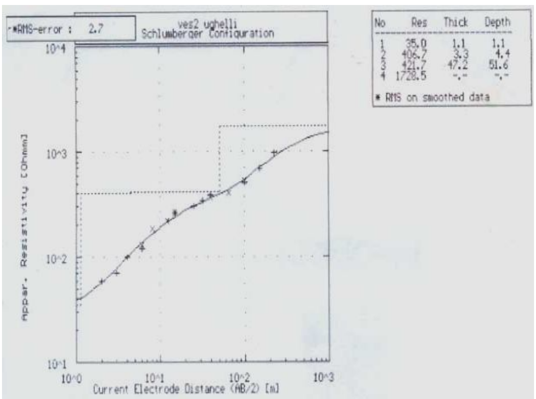

Figure 5. Interpretation result of VES 2 data

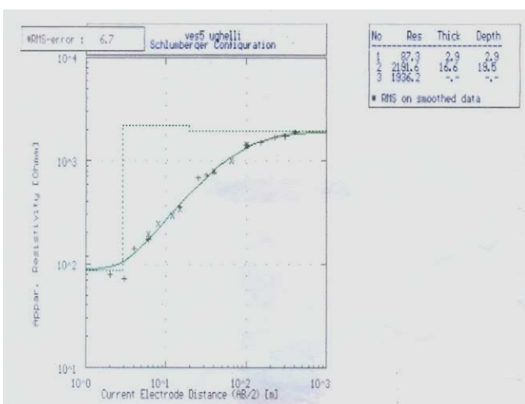

Figure 6. Interpretation result of VES 5 data

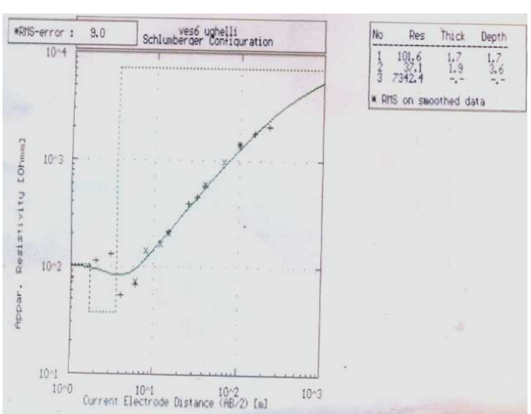

Figure 7. Interpretation result of VES 6 data

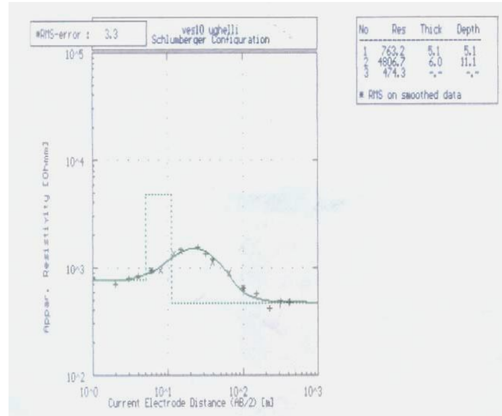

Figure 8. Interpretation result of VES 10 data

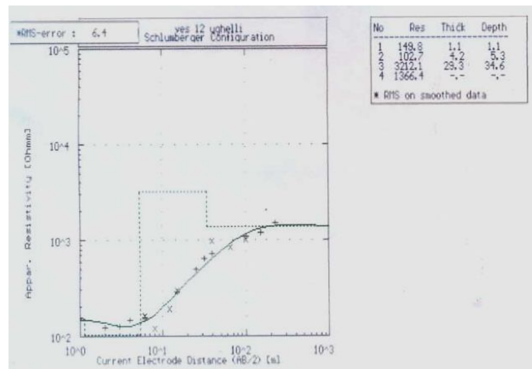

Figure 9. Interpretation result of VES 12 data

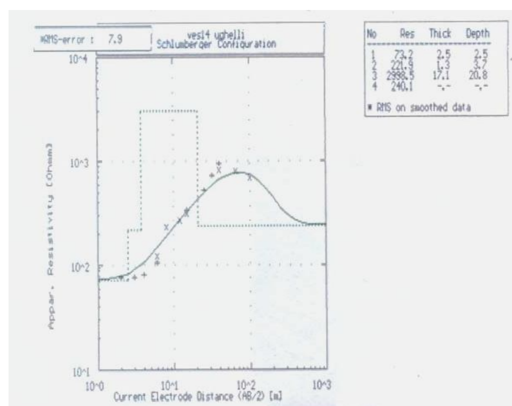

Figure 10. Interpretation result of VES 14 data

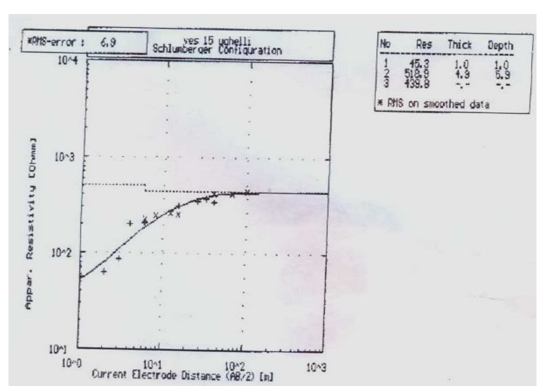

Figure 11. Interpretation result of VES 15 data

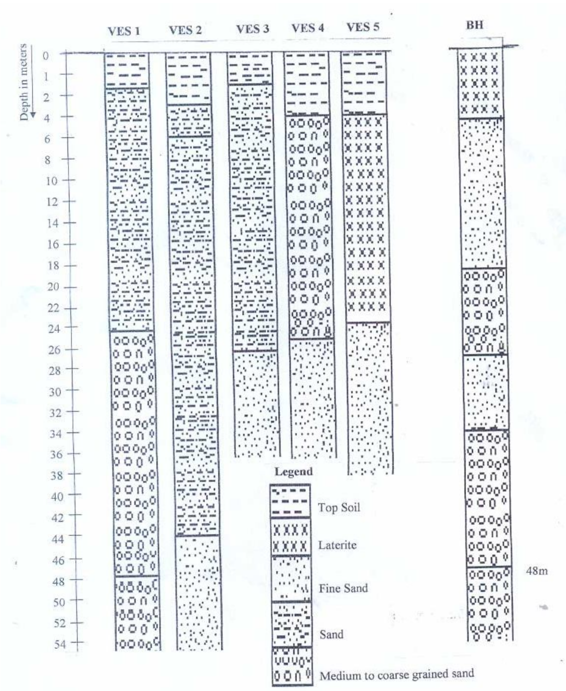

Figure 12. Correlation between VES 1-5 with borehole lithologic log

The overall subsurface distribution of resistivity in the study area is shown in Figure 13 by the isoresistivity map produced using SURFER 8 (Golden Software Inc, 2002). The eastern part of the map shows a resistivity range of 300–800Ωm, suggesting an aquiferous zone of medium-coarse grained sand.

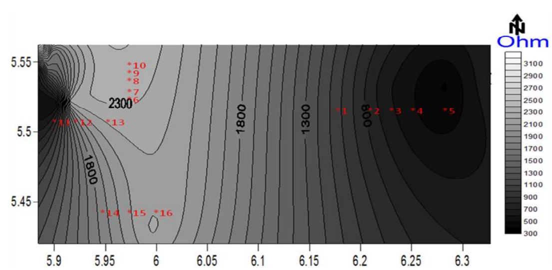

Figure 13. Isoresistivity map of the study area

The isopach map of the aquiferous layers in the study area is also shown in Figure 14. This shows variation in aquifer thickness from 14.3m around the western part of the study area up to a maximum of 48.0m around Afiesere area in the eastern part of the study area.

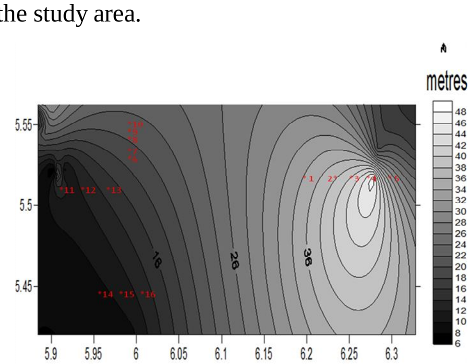

Figure 14. Isopach map of the aquifer layer at various VES stations

Considerable aquifer thickness is a favourable condition for productive and sustainable borehole yield. This result is further illustrated by the longitudinal conductance map (Figure 15) which shows a similar trend, also reaching its maximum around the eastern part of the study area.

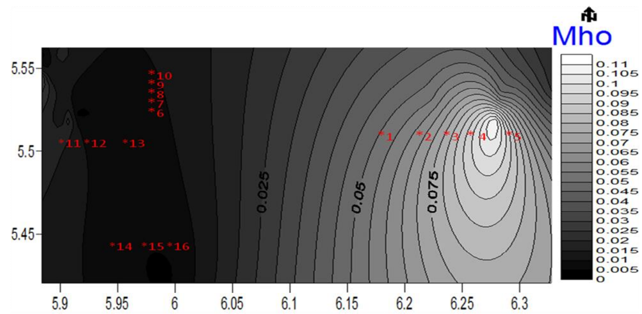

Figure 15. Longitudinal conductance map of the aquifer layer at various VES stations

Conclusion

Application of VES technique has been used to ascertain the groundwater potentials of Ughelli, Delta State, Nigeria. The aquifer in the area comprise fine-medium-coarse grained sands whose thickness varies from 14.3m to a maximum of 48.0m. The longitudinal conductance also varied from 0.005mho to a maximum of 0.11mho. The eastern part of the study area, around Afiesere community, has been identified as the best area for productive and sustainable borehole yield. The result of this study has produced additional baseline data on the aquifer characteristics of Ughelli. This information will no doubt be useful to developers and prospective developers on borehole progrmames in Ughelli.

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