Geophysical Investigation For Groundwater In Edu And Pategi Local Government Areas (Kwara State), Middle Niger Basin, Nigeria

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ABSTRACT
The interpretation of twenty-five Schlumberger Vertical Electrical Sounding (VES) data was carried out in the old Edu (now Edu and Pategi) Local Government Area (LGA) of Kwara State. This is in an attempt to investigate the geologic and geolectric characteristics of the aquifer as an aid to determining the changes in the production capacity of the aquifer within the southern part of the Middle Niger Basin. The 25 VES data were interpreted using empirical methods and computer modelling techniques. The VES curves are dominated by the--QH four-layer type curves ($\rho_1>\rho_2>\rho_3<\rho_4$). The results of the interpreted VES data indicates that the saturated groundwater bearing (aquifer) layers lie within the second and third layers of the predominantly four-layered geoelectric structure. The resistivities of the aquifer ranged from 4.2 to 564.0 ohms while the thickness of the Nupe Sandstone Group aquifers and the weathered basement aquifers varied from 3.05m to 58.16m. The southern part of the Lafiagi district have been identified as the area with the prospect for sustainable groundwater development. [Academia Arena, 2009;1(3):47-50]. ISSN 1553-992X.

INTRODUCTION
One of the most important (basic) conditions sufficiently and necessarily required for sustainable development of any region is water. However, in most least-developed-countries, LDCs like Nigeria inadequate supply .of water in terms of quality and quantity has become endemic. In most cases, water for domestic and agricultural use are obtained from rivers, streams, ponds, cesspools and such other surface water systems which are usually located at great distances from the areas they serve. Ai times, the limited water resources are shared between human beings for every conceived need/use (drinking, washing, toileting) and animals and are therefore often highly contaminated. This depressing situation is caused by such compelling factors as climate, geomorphology, physiography, geology, hydrogeology as well as peculiar conditions like lack of economic and financial wherewithal, technology and proficient manpower required for effective development of water resources (RCA, 1990). In spite of these constraints, many boreholes have been constructed in many rural areas in Kwara State by the state, national and international agencies for groundwater. Within the past two decades, the United Nations International Children Education/Emergency Funds Rural Water Sanitation, UNICEF RUWATSAN project, the State Utility Board, the Lower Niger Basin, Messrs Biwater Shellabear (Nigeria) Limited, etc. have drilled boreholes to provide supplementary water supplies and help alleviate the scourge of such water-borne disease as guinea-worm. However, the productivity of these boreholes have been found to be highly varied and unreliable (MIS Biwater Shellabear (Nig.) Ltd, 1985; UNICEF RUWATSAN Project, 1988). Of recent, geophysical exploration techniques especially the Vertical Electrical Sounding, VES has continued to play a leading role in the exploitation of groundwater in Nigeria (Agwunobi and Onitsha; Van Overmeeren, 1989). In this study, VES data and borehole drilling logs collected by the UNICEF RUWATSAN project, Borin, are complied and interpreted in order to investigate the potentials of the aquifer in Edu now split in two LGAs namely: Edu and Pategi Local Government Areas LGA Kwara State, Nigeria. The work was aimed at:

- Identifying the aquifers
- Determining the characteristics of the aquifer.
- Identifying favourable geological structures like fractures basement rocks
- Assessing the groundwater potential of the study area so the Lower Niger Basin.

LOCATION, GEOMORPHOLOGY AND PHYSIOGRAPHY

The project area which is in the southern-end of the Middle Niger (Nupe) Basin (otherwise called the Lower Niger Basin) lies within the northern edge of Kwara State in the west-central part of Nigeria (Fig. 1). The areas studied consist of 20 communities located within old Edu (Fig.2). As can be seen in figure 1, the study area is situated between the River Niger to the north and the Western Nigeria Uplands to the south. It thus forms the southern limit of the Cretaceous Middle Niger Basin which according to Udo (1982) extends from Jebba to Lokoja and is approximately bounded by longitude 4°37'E and 4°43'12"E and latitude 8°43'52"N and 8°34'28"N. the Lower Niger Basin which is an elongated approximate NW-SE trending topographic depression is of low relief with an average elevation of less than 150m above mean sea level. The vegetation is mainly of the derived Guinea Savannah type (Udo, 1982) and the climate is of the humid tropical Guinea type which according to Kehinde and Leohnert (1989), the evapotranspiration rate in this region is as high as 90%. Light forest and parkland vegetation occur along stream and river channels especially along the flood plain of the River Niger. Drainage is dendritic and the courses of most of the rivers in this area whose

headwaters rise from the southwestern Nigeria Precambrian Basement Complex are controlled by the Niger and its tributaries. The moderate vegetation cover along with the subdued relief in the area would help in trapping rain-water and thus prevent severe runoff of the lateritic top soil cover (Udo, op.cit.)

GEOLOGY AND HYDROLOGY

Figure 3 shows that the study areas of Edu and Pategi LGAs is mostly underlain by the Recent to Tertiary superficial alluvial deposits and the Nupe Sandstone sediments which are of Campanian to Maestrichtian age. Both geologic fonnations, which are the most hydrogeologic ally extensive in the area studied, belong to the Upper Cretaceous Nupe Sandstone Group. According to the borehole logs collected from well drillings carried out for groundwater exploitation in this region; MIS Biwater Shellbear (Nig) Ltd. (1985) and the UNICEF RUWATSAN project (1988) reported that the Nupe Sandstone formation ferruginised ironstones and clays in highly varied proportions. Magnetic instrusives of the Palaeozoic basement complex rocks occur as inliers in most parts of the region (fig.3). Boreholes logs (UNICEF RUWATSAN project, 1988) indicate that fracturings occur within the basement rock units at Masha, Bishewa and Lema which are all located in the southern part of Lafiagi district.

In view of the geologic settings of the study areas there are four main types of aquifer units within the basin viz:
- The superficial alluvial sediments which consist of fine-grained to medium-grained to coarse-grained sands, Silts, Clays, laterites, gravels and pebbles;
- The' Nupe Sandstones which are made up of poorly-sorted and well-sorted fine medium-coarse-grained sandstones, siltstones and intermixes of clays within the lithologic units;
- The weathered basement rock, and
- The fractured basement complex rocks.

Alode (1981) has suggested that the alluvial deposits (river alluvium) which exists along most water courses range in size and lateral extent from the thin discontinuous sands occurring in the .smallest streams to the thick alluvium which is a highly porous material, usually serves as recharge zones to the underlying Nupe Sandstone and or basement rocks. According to the geological map shown in figure 3, most of the northern part of the region appears homogeneous with a consequent reliable and high groundwater yield capacity.

DATA ACQUISITION, PROCESSING AND INTERPRETATION

Data Used

25 VES and their corresponding borehole drilling data were compiled from the sedimentary region of Edu and Pategi LGA. They were collected by UNICEF under the RUTWATSAN project, Horin. The Schlumberger array with a maximum half the length of the current electrode spacing (AB/2) - value of between 150m and 250m, was used. According to Barker (1989), the depth of investigation in a Schlumberger configuration is 0.38 AB/2 (or 0.19AB). Also, Van Overmeeren (1989) has suggested that aquiferous zones usually lie between 10m and 30m below the ground surface; it is therefore hoped that the range of values of AB/2 considered in the compilation by the VES data used for this study would provide reliable subsurgence information.

Data Processing

The VES data were interpreted using the algorithm of a computer program published by Mooney (1980). To suit and used, each of the 25 complied VES data was first digitized to six data points per decade (0' Neill, 1975) and then plotted on a bi-logarithmic paper. O'Neill (1975) and Mooney (1980) have recommended a sampling interval of six points per logarithmic cycle (or decade) because, six points per decade is considered commensurate with the electrode spacing intervals used in the field.

Interpretation of Data

The interpretation of vertical Electrical Sounding (VES) field data is an inversion process of electrical theory. This therefore, involves determining the source of an anomaly from its electrical field measurements observed on the ground surface. In essence, the prime motive of interpreting VES data in the determination of the number of layers (n), thickness (h) and resistivity of each VES station within a given study area. The quantitative interpretation of VES data according Van Overmeeren (1989) is mostly affected by the influence of the principle of adequate and suppression. To safeguard against the ambiguities inherent in the degree of accuracy of the interpreted VES data results due to these effects, information obtained from the collected borehole logs served as control in estimating the geoelectric parameters (n, h, and ρ) for each VES station studied. To interpret the VES data, the program of Mooney (1980) was modified in this work for use on the CDC Cyber 72 mainframe computer system of the Ahmadu Bello University, ABU Zaria. Figure 4 shows a typical interpretation of the VES data used in this work. The figure is the interpreted result of the field

data for the VES station in Shonga, Edu LGA. The observed resistivity values, the computed values for the initial and final model, the "best" fit model curve, the geoelectric and the geologic sections for this station are all shown in figure 4. The parameters of the initial model determined by empirical method (Van Nostrand and Cook, 1966; Shiftan, 1970) which were fed to the computer were: h_1 = 1.5m, h_2=5.0m, h_3=25.0m; and ρ_1 =900Ωm, ρ_2 = 120Ωm, ρ_3 = 100Ωm, ρ_4 = 50Ωm. The root-mean-square, r.m.s. error, ε, which is a measure of the degree of fit between the computed curve and the observed curve, for this trial model was 28.056. The iteration was terminated after iteration 16 when the model parameters were: h_1 = 6.3m, h_2 = 22.4m, h_3 = 53.1m; and ρ_1 = 1249.4Ωm, ρ_2 = 520.3Ωm, ρ_3 = 60.0Ωrn, ρ_4 = 26Ωm. The r.m.s. error obtained for this iteration was 0.771. The remaining 24 VES data at the 23 stations were interpreted following the above procedure.

RESULTS AND DISCUSSIONS

The resistivity type curves associated with the study area were of the three-five -layer types. The sounding curves consist mainly of the QH four -layer type with a resistivity pattern of very high - high - moderately high -low ($\rho_1>\rho_2>\rho_3<\rho_4$). These type curves with final segment of positive gradient reflect presence of highly resistive rocks at the ground surface and at depth. The borehole data collected for the VES stations suggest that these characteristic type curves have aquiferous units with fairly good groundwater potentials whose estimated yield values range from 1.00 to 3.75 kJs. As earlier mentioned, the storage elements for the aquifer units in the Lower Niger Basin are:

- The medium to coarse sand by the alluvium which exists along the floodplains of the Niger and its tributaries.
- The medium to coarse sandstone of the Cretaceous Nupe Sandstone and
- The weathered and fractured basement for the Basement complex.

The depths of the alluvial aquifer units as indicated by borehole logs are usually shallow and range from less than 1m to about 30m (MIS Biwater Shellabear (Nig.) Ltd., 1985 and UNICEF RUWATSAN project, 1988). Even though evidence abound from the collected borehole logs that the alluvium is the most productive in terms of ease and amount of groundwater abstraction, but there were cases where boreholes constructed in certain villages within the alluvium were abandoned. Such cases were observed at Manuga and Chetta Maiyaki by UNICEF project (1988) and at Pategi and Rogun by MIS Biwater Shellabear (1985). In the case of the aquifer units of the Nupe Sandstone Group, the well yields range from as low as 0.5 ls^{-1} to about 3.75 ls^{-1} (UNICEF RUWATSAN project, 1988) while the groundwater yields obtained from the weathered/fractured bedrocks vary from 1.00 ls^{-1} to 3.75 ls^{-1}. Although, Idornighie and Olorunfemi (1992) have suggested in their work in this region, that the groundwater production capacity and or the aquifer potentials increases northernly, this study shows that the Nupe Sandstone aquifers have comparable yield capacity as the aquifers derived from the weathered basement. The estimated yield of the boreholes constructed in the sedimentary region consisting of the alluvias and sandstones (Nupe Sandstone Group) as well as in the areas of the southern edge of the Middle Niger Basin have also been observed to have comparable values of 0.2006 *Is/m* and 0.22051 *ls/m* respectively.

The geoelectric interpretations of the VES data show that the aquifer resistivity values range from 4.2Ωm to 106.7Ωm, while the thickness of the aquifer varies from 3.05 to 58.16m. as shown in fig 3 and based on the information obtained from the borehole data, fractured basement rocks occur in Gnagota, Macha Bishewa and Ndanaku, all of which are situated in the southern part of Lafagi district. The resistivity values of these fractured rocks were interpreted to be 546.8Ωm, 345.7Ωm 564.0Ωm and 427.3Ωm respectively for the VES stations situated at the above named villages. In an earlier work, Bello and Ajayi (in press) quantitatively examined the confidence limit to put on geologic section normally derived from geoelectric section. As can be seen in figure 4, the work showed that there exist very high degrees of agreement for some of the paired sections studied. The analyses of the geologic sections and the geoelectric sections of the 25 ls^{-1} VES stations investigated in this work suggest that the VES stations situated in the southern part of Lafiagi district consist of moderately thick aquiferous layers which comprise of geologic formations of low resistivity underlain by highly fractured basement rocks and or fresh basement with relatively low resistivity (figure 5). The estimated yield values of the two boreholes drilled by the UNICEF-RUWATSAN project (1988) were observed to be 3.75 ls^{-1} and 2.50 ls^{-1} respectively. Figure 5 has also shown that multistory aquifers and or aquicludes formed by thin clayey formations which separate the main saturated water-bearing layers possibly exist most especially around Mach and Lema. Also, the existence of fractured basement rocks at depth suggest that fresh water of high quality can be tapped at depth apart from the near-surface lying sandstone within this part of the study area.

CONCLUSIONS

The following are the conclusions reached from this study:

1. Based in the information from the geologic sections of the collected borehole by, the superficial deposits and medium to coarse sand/sandstone of the Nupe Sandstone Group, the weathered and fractured basement have been identified as the components of the aquifer in the study area.
2. The saturated groundwater-bearing layers lie within the second or third layers of the predominately 4-layered geolectric structure. In most cases, the aquiferous layers are found within the penultimate layers. The resistivities of

the aquifer varied from 4.2Ωm to 106.7Ωm. The low resistivity of some of the aquifers is due to the existence of intercalating mixes of clay within the lithologic units. There is, therefore, the possibility of existence of multistorey aquifers and perched aquicludes at some VES sites. The thickness of the aquifers ranges from 3.05m to 58.16m.

3. Fractured basement rocks exist in the southern part of Lafiagi district. The resistivity of these rocks is $345.7\Omega m \leq \rho \leq 564.0\Omega m$.
4. The aquifers derived from the crystalline rock units and the primary porosity of the sedimentary Nupe Sandstone Group have been found to have comparable specific yield capacity values. The respective values determined for the two units were: 0.2205 tls/m and 0.2006 tls/m.
5. The results of the analyses of the collected YES data and borehole logs show that the southern part of Lafaigi district (around Bishewa, Macha and Lema) has the best prospect for sustainable groundwater exploitation activity in this region.

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