Hydro-Geophysical Investigation of the Federal Housing Estate Akure, Southwestern Nigeria

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Abstract
Hydro-geophysical investigation for deep fractured columns involving the Very Low Frequency Electromagnetic (VLF-EM) and the electrical resistivity methods has been carried out within the Federal Housing Estate Akure, Southwestern Nigeria. This was with a view to assessing the groundwater potential of the Estate. Four (4) VLF-EM and Horizontal Profiling (HP) traverses were established. Eighteen (18) Vertical Electrical Soundings (VES) were conducted at the investigated site. The VLF-EM data were presented as profiles and 2-D images. Horizontal Profiling (HP) data were also presented as profiles while the VES data were presented as geoelectric sections. The VLF-EM profiles and 2-D images identified conductive zones (suspected to be basement structures) which were confirmed by the subsurface geoelectric sections developed from the interpretation results of the Vertical Electrical Sounding (VES). The geoelectric sections delineated five subsurface geologic layers. These include the top soil, weathered layer, fresh basement, fractured basement and the fresh basement bedrock. The fractured basement constitutes the main aquifer unit within the study area. The weathered layer is generally thin and clayey. The confined fractured basement columns (Olorunfemi and Fasuyi, 1993) are characterized by relatively low resistivity values (82 – 602 ohm-m) and moderate to significant thickness (20.4 – 65.6 m). The relatively low fractured basement resistivity could indicate enhanced permeability due to significantly fractured density and tendency for moderate groundwater potential and yield. This study demonstrates the effectiveness of integrated geophysical investigation in groundwater potential assessment in a typical basement complex environment.

Keywords: hydro-geophysical, deep fracture, aquifers, delineation, basement rocks.

INTRODUCTION
The Federal Housing Estate is located within Akure Metropolis. Due to inadequate public water supply, the inhabitants of the estate largely depend on groundwater from hand dug wells to meet their daily water need. Previous geophysical investigation for groundwater within the estate, which was targeted at locating thick overburden, has not been successful. Also boreholes drilled by both Government and private individuals within the estate are presently abortive. Olorunfemi et al., (1999), in a regional study, classified the referenced area as falling within the low groundwater potential zone of the Akure Metropolis. However, attempts have not been made to identify geological structures such as faults and fracture zones that can aid groundwater accumulation and enhance groundwater storage in this typical basement complex terrain with very thin overburden. The aforementioned geologic structures are amenable to geophysical delineation.

The application of geophysics in groundwater investigation include identification of aquifer units, delineation of depths to and thicknesses of aquifer, identification of aquitard or confining units, location of preferential fluid migration paths (fractures, faults and joints) and mapping of groundwater contamination. Previous authors who have engaged geophysical methods for groundwater investigation in crystalline basement complex terrain involving VLF-EM, electrical resistivity and borehole geophysical methods include Porsari et al., 2004, Kellett and Komex 2004, Olorunfemi et al., 2004, Sharma and Baranwal 2005, and Omosuyi et al., 2007. This study intends to use the VLF-EM and electrical resistivity methods to identify aquifer units within the crystalline rocks of the Federal Housing Estate, Akure. The objectives of the present study include the delineation of the surface sequence, identification of the aquifer type(s), mapping of groundwater accumulating geological structures such as faults and fracture zones as a means of assessing the groundwater potential of the study area.

DESCRIPTION OF THE STUDY AREA
The Federal Housing Estate is located in the Northeastern part of Akure Metropolis, Southwestern Nigeria. It lies between geographic co-ordinates of Northings 805067 and 806200 mN and Eastings 741550 and 743100 mE in the Universal Traverse Mercator (UTM), Minna Zone 31 (Fig. 1). The topographic elevation in the area ranges from 345.0 to 375.0 m above mean sea level. The study covers an areal extent of about 2100 km². The study area is
located within the tropical rain forest of Southwestern, Nigeria with dry and wet seasons. The wet season starts from around mid March and ends in October with an average annual rainfall of between 1500 mm and 2100 mm while the dry season starts around November and ends in March. The average maximum temperature is about 33 °C (Iloeje, 1980).

which is considered to be insignificant in terms of groundwater storage and yielding capacity. Based on this, subsurface structural discontinuities (faults, shear zones, fractures and joints) are targeted for productive boreholes within the study area.

GEOLOGY AND HYDROGEOLOGY
The study area is underlain by the Precambrian Basement Complex of Southwestern Nigeria (Rahaman, 1976). The lithological units in the study area include porphyritic granite and granite gneiss (Fig. 2). The Basement Complex rocks have been subjected to tropical weathering resulting in regolith of between 3.4 and 13.3 m thick. The concealed basement rock is suspected to contain secondary structures (faults, shear zones, fractures and joints) imposed on it by previous tectonic activity. Outcrops of the basement rock are present within the study area. The thickness of regolith is dependent on the rock type, location of faults and fractures, topography and rainfall (Richard and Paul, 2004). The earlier geoelectric survey conducted in the Estate at the first phase of this work delineated thin regolith cover

Fig. 2: Geological Map of Akure Showing the Study Area (Owoyemi, 1996)

MATERIALS AND METHOD OF STUDY
Four (4) traverses, which ranged in lengths from 200 m to 1020 m, were established in an approximately E – W direction across the study area (Fig. 1). Traverse 1 is 1020 m long while Traverse 2 is 400 m long and Traverses 3 and 4 are each 200 m long. Very Low Frequency Electromagnetic (VLF-EM) and the electrical resistivity methods were employed in the survey. The electrical resistivity survey involved (a multi-electrode spacing a = 10 m and 25 m) Horizontal Profiling (HP) with Wenner array and Vertical Electrical Sounding (VES) with Schlumberger array. The horizontal profiling adopted a station interval of 10 m. The resistivity measurements were made with the Omega resistivity meter. The VLF-EM measurements were taken at 20 m interval along Traverse 1 while 10 m station separation was adopted along Traverses 2, 3 and 4. The VLF-EM measurements were made using the ABEM WADI equipment. The VLF-EM method was used for locating geologic features (e.g. fractures, faults, joints and shear zones) which were subsequently investigated using the VES technique. The VLF-EM real component data were inverted into 2-D subsurface images using the KHFILT software.
The multi-electrode spacing profiling was adopted so that the subsurface can be imaged at two different depth levels. The field data were presented as profiles and used to delineate low resistivity suspected fault/fractured zones some of which were subsequently depth sounded. Eighteen (18) VES were acquired in the study area along the four traverses (Fig. 1). Maximum electrode spacing (AB/2) m of 225 m was used. The VES data interpretation involved the partial curve matching and 1-D computer assisted forward modelling with the Win RESIST 1.0 (Vender Velper, 2004) software. The interpreted layer geoelectric parameters (resistivities and thicknesses) were used to generate geoelectric sections.

RESULTS AND DISCUSSION

The type curves obtained in the study area are the H, K, HK, KH, AKH and HKH type (Fig. 3). The HKH type predominates with a percentage frequency of occurrence of 50%. The HK and KH types account for 22.2% and 11.11% respectively while the H, K and AKH curve types have percentage frequency of 5.6% each. The predominance of the HKH type curve followed by the HK and KH types, which are indicative of basement rock with unconfined and confined fracture (Olorunfemi and Fasuyi, 1993), may be indicative of a geologic environment that have been subjected to extensive tectonic activity with enhanced secondary porosity.

The VLF-EM measurements along Traverses 1, 2, 3 and 4 are presented as profiles and 2-D subsurface images (Figs. 4a and b – 6a and b). The filtered real amplitudes generally vary from a minimum -45 to a maximum value of 50 along Traverses 1 – 4. The VLF-EM peak positive filtered real (with amplitudes > 20) located on yellowish – reddish colour bands in the 2-D image are typical of suspected basement fractures (Afolayan et al., (2004). The locations of the peaks were depth sounded (see Figs 4a – 7a). The profiles (Figs. 4c – 7c) with the exception of the profile along Traverse 4 (swamp) display very low resistivity < 1000 ohm-m) values typical of near-surface (shallow) basement bedrock.

The VES interpretation results were used to develop geoelectric sections. The summary of the geoelectric parameters obtained in the study area are presented in Table 1. The geoelectric sections delineate five subsurface geologic layers (Table 1). These are the topsoil, weathered layer, fresh basement, fractured basement and fresh basement bedrock (Figs. 4d – 7d).
Fig. 4 (a – d): Correlation between the HP profile, 2-D Inverse Model Resistivity Section and Geo-electric Sections along Traverse 1.

Fig. 5 (a – d): Correlation between the HP profile, 2-D Inverse Model Resistivity Section and Geo-electric Sections along Traverse 2.
Fig. 6 (a – d): Correlation between the HP profile, 2-D Inverse Model Resistivity Section and Geo-electric Sections along Traverse 3

Groundwater Potential Evaluation
The Electromagnetic (VLF-EM) method delineates suspected conductive zones typical of fractures and fault zones that are characterized by yellowish – reddish colour bands on the 2-D

Fig. 7 (a – d): Correlation between the HP profile, 2-D Inverse Model Resistivity Section and Geo-electric Sections along Traverse 4
images. These conductive zones are presumed to contain groundwater. This study identifies two aquifer units – the weathered layer and the fractured basement. The weathered layer generally has low to moderate resistivity values of 41 – 205 ohm-m while the thickness ranges from 1.7 – 10.6 m. The fractured basement is characterized by resistivity values of 82 – 602 ohm-m and thicknesses that vary from 20.4 – 65.6 m. The fractured basement constitutes the main aquifer unit in the study area. The weathered layer is generally thin and clayey. The moderately to significantly thick fractured basement is confined beneath a variably thick fresh basement rock with tendency for moderate groundwater yield.

### CONCLUSION

Hydro-geophysical investigation involving the Very Low Frequency Electromagnetic (VLF-EM) and the electrical resistivity methods was carried out to investigate deep basement fractures within the Federal Housing Estate Akure, Southwestern Nigeria. The VLF-EM filtered real profiles and 2-D images identify suspected conductive targets that are indicative of basement fractures/fault zones along the profiles the horizontal resistivity profiles along Traverses 1, 2, 3 and 4 depict near surface basement. The geoelectric sections delineate five subsurface layers. These include the topsoil, weathered layer, fresh basement, fractured basement and the fresh basement bedrock. The fractured basement rock constitutes the main aquifer unit within the investigated area. The weathered layer thickness is generally thin with tendency for low groundwater potential. The geoelectric sections show that the fractured basement is characterized by relatively low resistivity values of 82 – 602 ohm-m while the thickness varies from 20.4 – 65.6 m. This relatively low resistivity values may be indicative of high density of fracturing, enhanced secondary porosity and permeability with tendency for moderate groundwater yield.

### ACKNOWLEDGEMENTS

The authors are grateful to Mr. P. Edugbe, A. A. Badmus, H. U. Abubakar, C. A. Ajayi, Mr. F. Aiwekohe, Mr. T. Adewumi, and Mr. A. Adewale who assisted with the field work.

### REFERENCES


