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Research Article

Geophysical Investigation for Groundwater Development at Oyo State Housing Estate Ogbomosho, Southwestern Nigeria

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Abstract: Water is life because it is one of the inevitable ingredients for life survival. The urge for ground water development is very high in Oyo state Housing Estate, Ogbomosho, Southwestern Nigeria. Because the site is experiencing structural developments and there is no other source of water nearby. Surface water is becoming inadequate, thus this study aimed at investigating the hydro geological prospects of the area with a view to delineating for groundwater and its development. Geophysical investigation was carried out in the study area using Very Low Frequency (VLF) method. VLF profiling of 20 m inter stations and 50 m of inter profiling distances were established. This study revealed a number of conductive zones for ground water development for both domestic and commercial purposes.

Keywords: Electromagnetic intensity, groundwater, high conductivity, profile, very low frequency

INTRODUCTION

International studies indicate that there will be a severe global shortage of surface water by 2023, particularly in developing nations. This shortage reflects increasing consumption, exhaustion of existing supplies and contamination of sources. (www.gemsys.ca) The study area needs the development of groundwater because it is residential government reserved area where hand dug well which is prone to contamination may not be necessary if geophysical work is done to ‘see’ beneath the ground for zones that are viable for groundwater detection and development.

Indeed measurements of the conductivity and dielectric constant of the earth using “wave-tilt” techniques were first performed in the 1930's (Ayantunji, 2005). These early measurements were, however, made at relatively high frequencies which resulted in a shallow depth of penetration. It was not until 1963 that Pal observed that radio waves at VLF frequencies (technically the 3-30 kHz band, but in fact limited to 15-25 kHz by the available high powered transmitters) could be used to prospect for electrically conductive ore bodies (Ayantunji, 2005).

For water detection, VLF- an electromagnetic geophysical technique that is effective for detecting lateral changes in subsurface electrical properties. It can be used on its own or combined with resistivity and/or seismic methods for water wells and for delineating contaminant pathways in bedrocks. In this present study, Very Low Frequency-Electromagnetic method has been used in order to know the areas that are good for groundwater exploration and the areas that are not suitable for groundwater exploration within the study area as the site is experiencing structural developments and no other source of water is available nearby.

MATERIALS AND METHODS

The study was conducted on 21st and 22nd October, 2011 at Oyo State Housing Estate Ogbomosho, Southwestern Nigeria. The equipment used for data acquisition was ABEM WADI. The VLF method uses powerful remote radio transmitters set up in different parts of the world for military communications. In radio communications terminology, VLF means very low frequency, about 15 to 25 kHz. The method is based on the physical phenomenon that conductive structures on the surface or subsurface or underground, even when covered with thick overburden, change the direction

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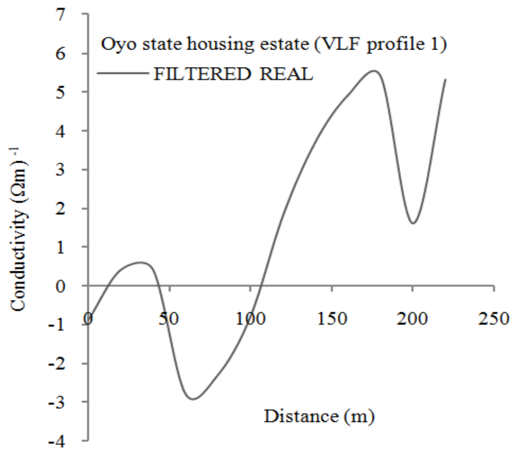


Fig. 1: VLF-EM plot of profile 1 at Oyo state housing estate Ogbomosho

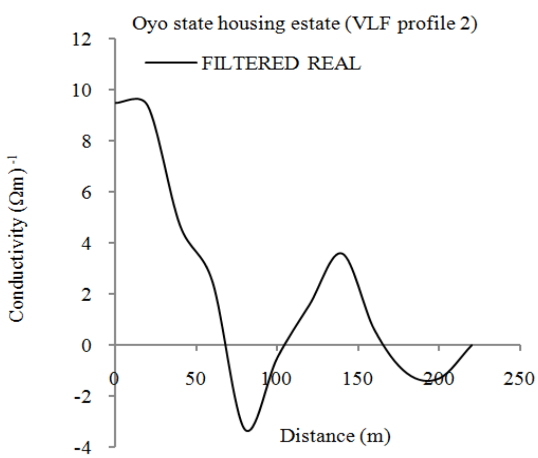


Fig. 2: VLF-EM plot of profile 2 at Oyo state housing estate Ogbomosho

and strength of the field generated by remote communication transmitter located around the world. The VLF-EM is a well known method for quick mapping of near surface geologic structures most especially in respect of mineral exploration and related geological structures (Saydam, 1981; Ligas and Palmoba, 2006; Babu *et al*., 2007).

The depth of penetration of an electromagnetic field (Spies, 1989) depends upon its frequency and the electrical conductivity of the medium through which it is propagating. Electromagnetic fields are attenuated during their passage through the ground, their amplitude decreasing exponentially with depth. The depth of penetration d can be defined as the depth at which the amplitude of the field A_d is decreased by a factor e^{-1} compared with its surface amplitude:

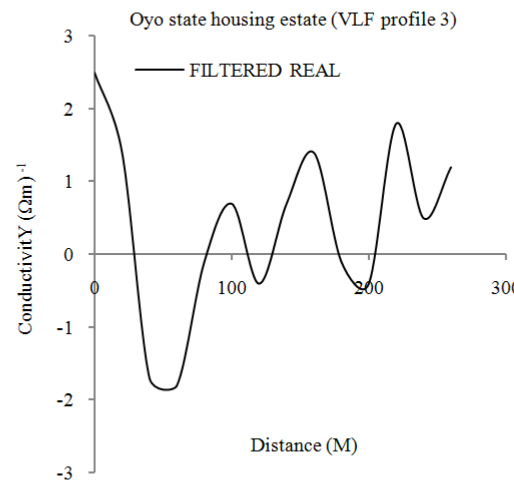


Fig. 3: VLF-EM plot of profile 3 at Oyo state housing estate Ogbomosho

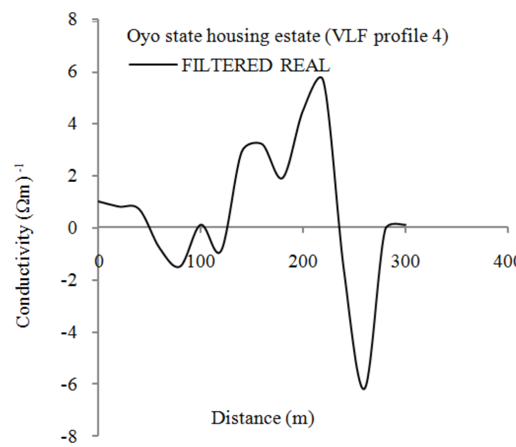


Fig. 4: VLF-EM plot of profile 4 at Oyo state housing estate Ogbomosho

$$A_o\ A_d = A_o e^{-1} \qquad (1)$$

In this case:

$$d = 503.8\ (\sigma f)\ ½ \qquad (2)$$

where,

d : Meters, the conductivity of the ground
σ : In S/m
f : The frequency of the field is in Hz

The depth of penetration thus increases as both the frequency of the electromagnetic field and the conductivity of the ground decrease. Consequently, the frequency used in an EM survey can be tuned to a desired depth range in any particular medium. For example, in relatively dry glacial clays with a

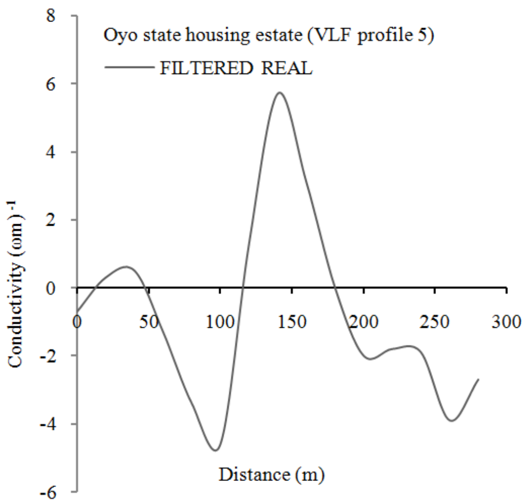


Fig. 5: VLF-EM plot of profile 5 at Oyo state housing estate Ogbomosho

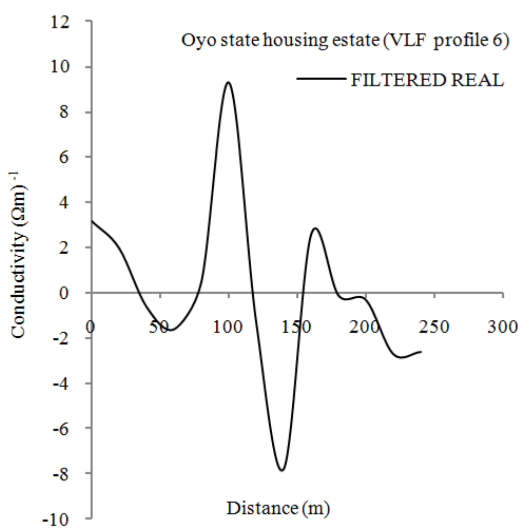


Fig. 6: VLF-EM plot of profile 6 at Oyo state housing estate Ogbomosho

conductivity of 5×10^4 S/m, d is about 225 m at a frequency of 10 kHz.

Equation represents a theoretical relationship. Practically, an effective depth of penetration z_e can be defined which represents the maximum depth at which a conductor may lie and still produce a recognizable electromagnetic anomaly:

$$z_e = 100\ (\sigma\ f)^{-1/2} \quad (3)$$

The relationship is approximate as the penetration depends upon such factors as the nature and magnitude of the effects of near-surface variations in conductivity, the geometry of the subsurface conductor and instrumental noise. The frequency dependence of depth of penetration places constraints on the EM method. Normally, very low frequencies are difficult to generate and measure. The maximum penetration is of the order of 500 m. The instrument works on the principle of electromagnetic induction. When the primary field emitted by a transmitter strikes a body having low electrical resistivity; secondary field is generated in the body. The difference between the transmitted and received electromagnetic field reveals the presence of an anomaly. The real and imaginary parts of the data were recorded at every 20 m on each of the profile taken at the survey area. Six profiling of at least 250 m long were run along North-South direction of the study area.

The VLF data are presented as VLF profiles by plotting EM intensity against distance along each station distance. The profiles are shown in Fig. 1 to 6 showing the filtered real components using Microsoft Excel.

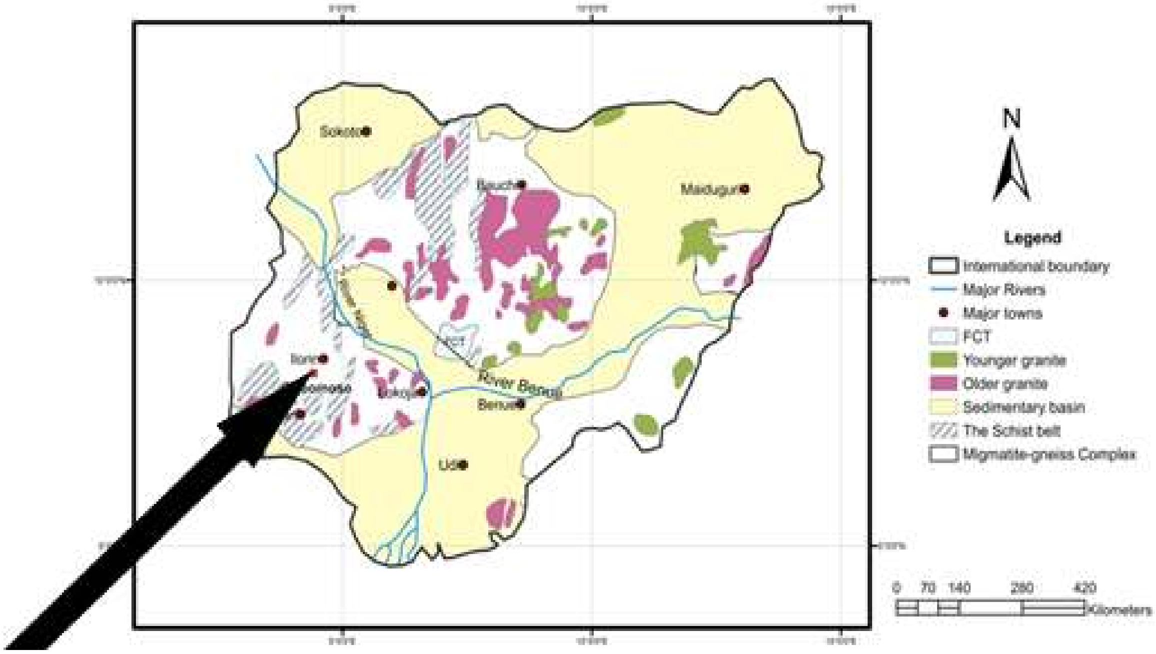
THE STUDY AREA

The study area is located at Northwest of Ogbomosho, between latitude N08^0 09$'$ 48.5$''$ and N08° 09′ 48.5$''$ and longitude E004° 14$'$ 41.1$''$ and E004° 14$'$ 32.9$''$ Southwestern Nigeria.

Regionally the area under investigation is concealed with the Southwestern Nigeria basement complex composing migmatite-gness complex, Meta igneous rock such as pehtic schist, quartzite, amphibolites, charnokitic rocks, older granite and UN metamorphosed dolerite dykes. The rock sequence consists of basically weathered quartzite of older granite (Fig. 7).

The basement complex rocks of Nigeria are made up of heterogeneous assemblages and have been variedly classified by Jones and Hockey (1964) and Rahaman (1976) among others. It is classified into three major rock units of ancient gneiss-migmatite series; the meta-sedimentary and the older granite with gneiss-migmatite suite as the most widely spread. However, all the aforementioned rock units are well represented in Ogbomosho area.

The basement complex rock in their unaltered forms is generally characterized by low porosity values usually less than one percent and permeability values that are almost negligible (Rahaman, 1976). The groundwater potential of such area is therefore dependent on the following factors; the presence of large fractures, joints or brecciate zones within the rock. The extent of weathered overburden and degree or



Study area

Fig. 7: Regional geological map of Nigeria (modified after Ajibade *et al*., 1988)

amount of precipitation recharging the aquifer, by far most significant factor in the groundwater capacities of an area underlain by crystalline rock is the depth of weathering. The absolute depth of weathering has implications on the zone of saturation because groundwater is known to fill the regolith from Phreastic surface down to the bedrock.

Generally, Ogbomosho is located in southwest Precambrian basement complex of Nigeria, predominantly composed of:

- **Older granite:** Comprising of rocks varying in composition from granites and pottassic syenite-older granites were first distinguished from the younger tin-bearing alkalic granite by Falconer (1911). Older granites include rocks like synites pegmatite's quartz monzoneites and adamelites. Graniticoradiontic are most common, in older granite and found in Iseyin area. Rahaman (1976) recognized the late kinematics and post kinematics and equated them to the main and late phase of granites, Jones and Hockey (1964), respectively. This can be found in Okeho, Iseyin, Ajawa, Ikoyi and Ogbomosho area.
- **Migmatite gneiss complex:** Which comprises biotite horn blende, gneiss, quartzite and quartzschist and small lenses of calcsilate rocks? In general the outcrops are poorly grown but few good out crops occur around Ibadan and Iseyin (Rahaman, 1976). Similar occurrence has been found at Ife , Kuta and Iyanu.
- **UN metamorphosed dolerite dykes:** They occur as tabular; UN metamorphosed bodies crosscutting the foliation in the host rocks and are regarded as youngest member of the basement complex. In some cases the dykes are stepped and there is exact correspondence of opposite walls. The general trend of all Dykes observed by Jones and Hockey (1964) and Rahaman (1976) is NE-SW and ENE-WSW. The rock is generally black and fine grained; in some cases a pale green color of olivine may be observed in the hand specimen. The rock is composed largely of augite and plagioclase of andesine.
- **Charnockitic rocks:** Charnockitic rocks occur in West of Ibadan as dyke-like bodies scattered over a wide area. Jones and Hockey (1964) described two main areas of diorite or charnockitic rocks have three major mode of occurrence commonly in core of aureole of granite bodies especially prophyritic, biotitic, hornblende granites. Example of this occurred in North of Akure, west of Egusi and South of Otta. They occur as discrete individual bodies in gneiss complex such as the occurrence at Lagun, Iwo, Osuntedo and some part of Ola.

Slightly magnetized to unmagnified para-schists and met igneous rocks: comprising schist's, quartzite amphibolites, talcose rocks and met conglomerates, marble and cale-silicate rocks.

RESULTS AND DISCUSSION

The results of the analysis of the VLF data from the study area were interpreted and discussed quantitatively.

The quantitative interpretation of the data involve the estimation of depths to the anomalous bodies and are as shown in Fig. 1 to 6, they indicate various profile with depth to each conductive zone.

In the profile 1, the major anomalous areas are at distances 160 m which is the most conductive zone. This depicts the point for hydro geological exploration.

Profile 2, shows areas of high conductivities; at distances 15 and 130 m along the profile but the most promising area is the distance 130 m for hydro geological prospect.

In the Profile 3, the anomalous zones of high conductivities are at distances 0, 100, 175 and 225 m, respectively which areas for groundwater delineations with distances 0 and 225 m been most prosperous. The profile 4 reveals homogenous trend in the first 100 m of the profile while distance 240 m reveals the point for groundwater development.

The profile 5 reveals anomalous zone of high conductivity at distance 150 m which is the only area for groundwater development in the profile.

Profile 6 reveals high conductivities at distances 100 and 165 m while the formal is the most prominent zone for groundwater development of high resistance (competent zone) is at distance 125 m, respectively.

CONCLUSION

Geophysical investigation for groundwater development at Oyo State Housing Estate Ogbomosho was done by establishing six VLF-profiles which runs in the North-South direction. Certain distance showed to be promising area for groundwater development across the profiles. The distances include 160 m at profile 1, 15 and 130 m at profile 2, 0, 100, 125 and 225 m at profile 3, 240 m at profile 4, 150 m at profile 5, 100 and 165 m at profile 6, respectively. Because Oyo State housing estate, Ogbomosho is experiencing development by individuals, with respect to the results of this study, the study area is averagely good for groundwater exploration or borehole development. It is hereby recommended that zones that have been delineated for high groundwater yields should not been designated for any other purpose for the good of individuals and the community at large.

Other relevant geophysical techniques should be used to confirm the predictions from this research.

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