LAUTECH Journal of Civil and Environmental Studies e-ISSN: 2714-3988
Volume 4, Issue 1; March 20020

Groundwater Prospecting Using Combined Vertical Electrical Sounding and Borehole Performance

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DOI: 10.36108/laujoces/0202/40(0140)

Abstract

This study aimed to determine the prospect of groundwater in Afe Babalola University, Ado-Ekiti (ABUAD); result of which will inform of the possibility of getting sufficient water underground. Geophysical survey was carried out in the study area and complemented with performance of an existing borehole. The survey involved 1-D Vertical Electrical Sounding (VES) utilizing the Schlumberger electrode array with half-current electrode separation (AB/2) that ranged from 1m to 50m. The VES data interpretation involved partial curve matching and computer assisted 1-D forward modeling using IPI 2 WIN software. The results showed the subsurface to have 3-layer earth strata comprising of sandy-clay top soil up to 3.26m deep, weathered/fractured basement in the next 9.06m depth and then, the fresh basement with the weathered layer constituting the main aquifer unit. The resistivity values of the weathered and fractured basement are 174 and 192 ohm-m indicating relatively low potential for groundwater resource. Pumping test on a nearby borehole gave specific capacity of 7.95m^2/day which depicts a low to intermediate transmissivity conforming to the VES.

Keywords: ABUAD, transmissivity, groundwater, resistivity, basement, VES.

Introduction

Groundwater is a major source of water for drinking, industry and agriculture in a large part of the driest continent (Chandra, 2016). It occurs almost everywhere beneath the land surface, flowing generally in low magnitudes of order less than velocities of stream flow and moving along flow paths from areas of recharge at springs, or along streams, lakes and wetlands (Alley *et al.*, 1999). It is believed to have significant protection from surface pollutants with its different subsurface layers acting as a natural filter to any infiltrating water. It is found underground, filling the pore spaces in soils and pervious cracks in rocks; where it cannot flow through, it collects there and is stored. Such geological formation is known as aquifer. Borehole is normally drilled to bring the groundwater to the surface. However, an examination of the possibility of getting adequate groundwater quantity in an area or location is first investigated before carrying out drilling. Such examination is referred to as a geophysical survey. Study carried out by Oyebode *et al.* (2019) showed that the major and most relied upon source of drinking water in Afe Babalola University, Ado-Ekiti, Ekiti State, Nigeria, which is the study area and for the people of her neighbouring communities is the groundwater.

Geophysical survey gives adequate knowledge of local geology and hydrogeological conditions of a given geophysical system; its approach depends on the objective of the survey. Geophysical surveys can deliver information on thickness of weathered zones, saturated weathered zone thickness and extent, bed rock topography, anomalous fractured zone locations, their orientation and lateral continuity, dykes and quartz reefs, vadose zone, suitability of a site for artificial recharge, quality of groundwater and contamination in terms of electrical conductivity variations, suitability of an area for waste dumping and landfills, dynamics of groundwater movement, dried-up aquifers, aquifer boundaries and approximate hydraulic characteristics (Chandra, 2016). The methods vary from the self-potential method, electrical resistivity method and the magnetic method among others.

Borehole pumping test on the other hand, is a physical characteristic of a large volume of rock or geological formation around a given well. The yield of a water-bearing formation during pumping test is an indication of the rechargeability of the fractures or porosity. The pumping test affects the drawdown around a well. The hydraulic properties (i.e. transmissivity, permeability, storability, specific capacity, drawdown, entrance velocity, discharge rate) of the lithology of a place tell a lot about the performance of the borehole system.

Geophysical survey works have been done to examine the prospect of groundwater and have guided well in successful siting of boreholes. Ogungbemi *et al.* (2013) and Oyegoke *et al.* (2015) respectively carried out detailed work on the evaluation of aquifer protective capacity of ground water resources, and exploitation of groundwater in fractured basement within the study area; Ojekunle *et al.* (2015) used the Vertical Electrical Sounding (VES) method to determine the groundwater resources in Elekuro and environs, Abeokuta. This study aims to combine performance of an existing borehole and geophysical survey (Vertical Electrical Sounding) to determine the prospect of groundwater and within the study area.

Materials and Methods

Afe Babalola University, Ado Ekiti (ABUAD) is located at the outskirts of Ado-Ekiti, along Ijan road, opposite Federal Polytechnic, Ado Ekiti. It lies within 7°35'59.16" and 7°36'31.32"N and Longitude 5°18'6.61" and 5°18'37.56"E. ABUAD is located within 130 hectares of land (Oyegoke *et al.*, 2015) with terrain gently undulating having topographic elevation ranging from 350m to 370m above sea level (Oladimeji *et al.*, 2013).

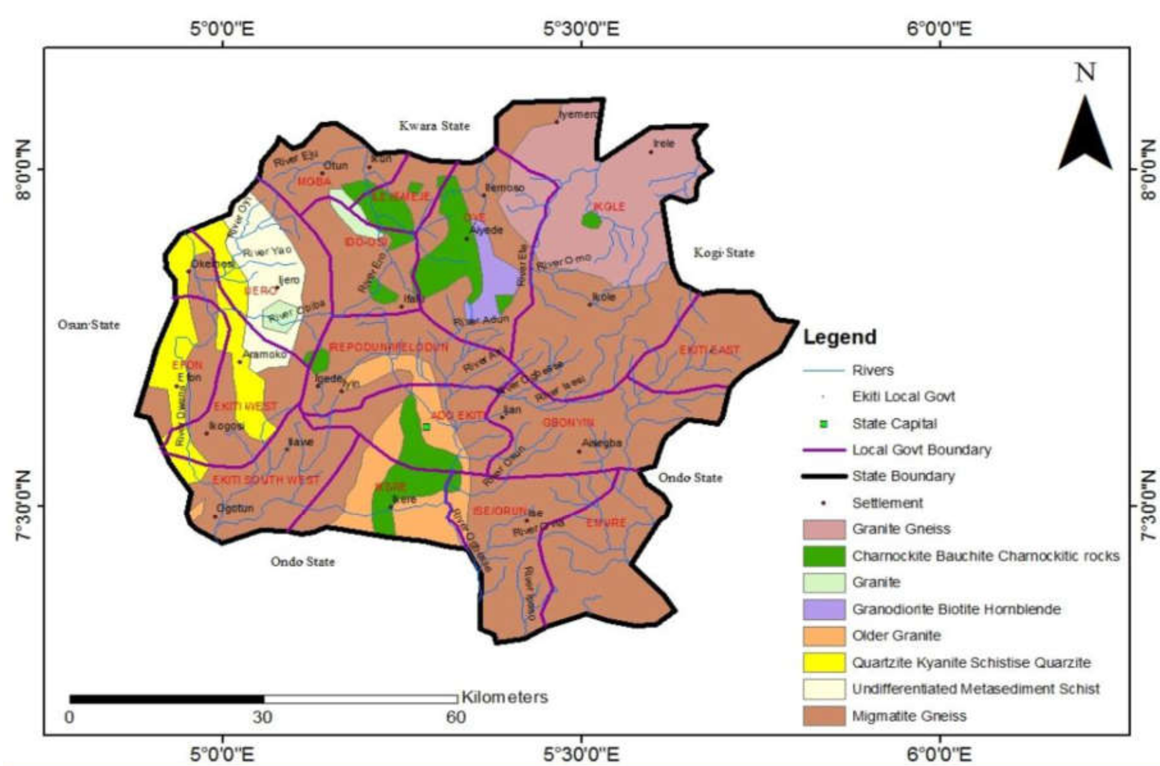


Figure 1: Geological map of Ekiti State. Source: Oyegoke *et al.*, 2015

Afe Babalola University has the same geological properties as Ado-Ekiti. It is underlain by crystalline rocks made of older granite, migmatite and charnockites with little or no fracture in most locations and shallow overburden (Ogundana and Talabi, 2014). Its geology is within the Precambrian Basement Complex of South-Western Nigeria which forms a part of the Basement Complex of Nigeria (Rahaman, 1989). Geological map of Ekiti State as presented by Oyegoke *et al*. (2015) is shown in Figure 1. The groundwater of the study area is contained in the weathered or fractured basement rocks. Basement aquifers, according to (Satpathy and Kanugo, 1976) are normally limited in extent both in lateral and vertical direction making it worthy of investigating the subsurface geology before drilling. The discontinuous nature of the Basement aquifer system makes detailed knowledge of the subsurface geology, its weathering depth and structural disposition through geologic and geophysical investigations inevitable (Adiat *et al.*, 2009).

Geophysical prospecting is of great importance in delineating the ground water potential of a basement complex because of the anisotropic nature of the complex and it is very effective when the survey is taken along a longer distance and accurate interpretation of the result from the software.

Groundwater exploration within the basement complex rocks of Africa is usually carried out with the use of Vertical Electrical Sounding (VES), which is a technique in Electrical Resistivity (Palacky, 1989). The VES technique has been used extensively in groundwater investigation in the basement complex terrains (Olayinka and Olorunfemi, 1992). Hence, VES technique finds its application in the drilling programs for groundwater development in areas of Precambrian Basement terrain. The purpose of this study therefore, is to determine the prospect of groundwater in ABUAD.

The geophysical survey method used is the Electrical Resistivity method which involved 1-D Vertical Electrical Sounding (VES). The VES utilized the Schlumberger electrode array with half-current electrode separation (AB/2) ranging from 1m to 50m. The Schlumberger array consists of four (4) collinear electrodes. The outer two electrodes are the current source electrodes and the inner two electrodes are the potential electrodes. The potential electrodes were installed at the center of electrode array with a small separation, less than one fifth of the spacing between the current electrodes. The current electrodes were increased to greater separation during the survey while the potential electrodes remained in the same position until the observed voltage became too small to measure. The instrument used for this survey is the ARES (Automatic Resistivity) device which automatically displays the resistance readings on the digital read out screen.

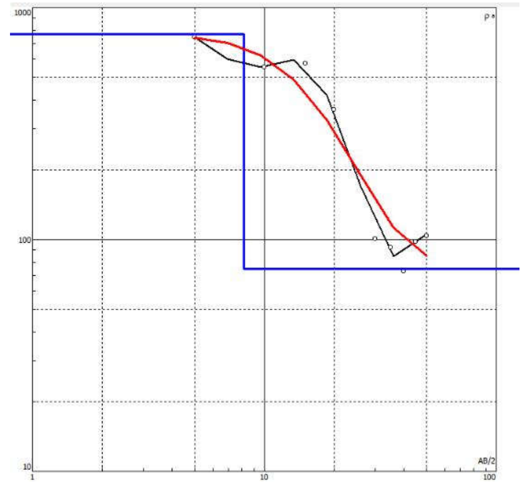
The resistivity sounding curve obtained from the study area was a 3-layer Q type curve and was interpreted quantitatively by partial curve matching and computer assisted 1-D forward modelling using IPI 2 WIN. By the use of IPI2win software, the results of apparent resistivity and electrode spacing were plotted in a log-log scale to obtain VES sounding curve.

The groundwater prospecting of the region was also determined by analyzing the hydraulic properties of previously drilled borehole in the region using a constant rate-pumping test. The intent of the test was to assess the borehole performance, and obtain values of the aquifer transmissivity and Specific Capacity (*q*); it was performed on one borehole located near the geophysical prospecting site. The pumping test data was analysis based only on information obtained from the pumped borehole itself since there was no observation borehole. The groundwater flow was modelled using Darcy's law. Constant rate pumping test and well hydraulics are very important in analyzing the performance of borehole systems so as to delineate the groundwater prospecting.

Results and Discussion

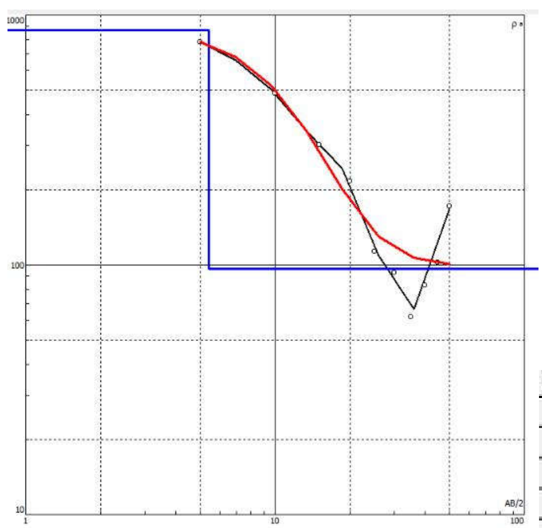
The final VES interpretation results (Figures 2 & 3) were used to analyse the groundwater potential of Afe Babalola University, Ado-Ekiti.

The groundwater potential analyzed from the combination of the weathered layer resistivity and overburden thickness showed that the study area has a low groundwater potential.



N	ρ	h	d	Alt
1	771	3.26	3.26	-3.26
2	174	9.06	12.3	-12.32
3	437			

Figure 2: VES 1 Showing the Curve and the Table of Values Based on the Interpretation



N	ρ	h	d	Alt
1	871	2.17	2.17	-2.17
2	192	7.15	9.32	-9.32
3	389			

Figure 3: VES 2 Showing the Curve Type and Table of Values Based on the Interpretation

<u>Keys for Tables in Figures 2 and 3</u>
N= Number of layers
P= Ressisitivity
h= Thickness of the layer
d= Overburden thickness
Alt= Altitude

The discharge rate of flow observed during pumping test is $0.00046\ m^3/s$. From Darcy's law, the hydraulic conductivity was obtained from analyzing the power of the pump which gives rise to pressure, a function of the cross-sectional area of the installed pump and force. The pressure head was used in calculating transmissivity and specific capacity:

The transmissivity is given by:

$$T = kb \tag{1}$$

Where:

k is hydraulic conductivity (m^3/m^2/day) and

b, aquifer (unconfined) thickness (m),

$Therefore,\ T = 5.5\ \times 12.2 = 67.1\, m^2/day$

Specific capacity (q): With an obtained drawdown of 5m (from Driscoll classification of transmissivity, (1986))

$$q = Q/s; = 0.00046/5$$

$$q = 9.2 \times 10^{-4}\, m^2/s$$

$$q = 9.2 \times 10^{-4}\, m^2/s \times 86400 = 7.95\, m^2/day$$

Based on Driscoll (1986) classification of transmissivity (Table 1), the value of transmissivity obtained is $67.1 m^2/day$ and it falls within class 4 out of class six with a designation of private consumption, so apparently the capacity of the borehole system is low. Based on the specific capacity using a drawdown of $5m$, the value gotten from calculation is $7.95 m^2/day$ which is also within the same class four having a range of 0.864 to 8.64 4 $\mathrm{m}^2/\mathrm{day}$.

Table 1: Classification of transmissivity

S/N	Magnitude	Class	Designation	Specific Capacity (m^2/day)	Groundwater Supply Potential	Expected Q if S=5m
1.	> 1000	I	Very high	> 864	Regional importance	> 4320
2	100-1000	II	High	86.4 – 864	Lesser regional Importance	432 – 4320
3	10-100	III	Intermediate	8.64 – 86.4	Local water Supply	43.2 – 432
4.	1-10	IV	Low	0.864 – 8.64	Private` Consumption	4.32 – 43.2
5.	0.1-1	V	Very low	0.0864 – 0.864	Limited Consumption	0.423 – 4.32
6.	<0.1	VI	Imperceptible	< 0.0864	Very difficult to utilize for local water supply	< 0.432

Source: Driscoll (1986**)**

Conclusion

The Vertical Electrical Sounding technique carried out at two different locations in Afe Babalola University, Ado-Ekiti, Ekiti state revealed that the type of aquifer is the weathered basement aquifer. It also gave an indication that the study area has a poor groundwater potential.

When the well hydraulic parameters were calculated, the performance of borehole systems as indicated from the transmissivity value and specific capacity was low according to Driscoll, 1986 conforming with the Vertical Electrical Sounding (VES).

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