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Assessment of the Subsurface for Identification of Borehole Sites for Irrigation at Challawa-Gorge Dam, North West Basement Complex, Nigeria

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Authors' contributions

This work was carried out in collaboration with all authors. Author AMI performed the project work and data analysis. Author JG designed the first draft of the manuscript and geophysical survey while. Author GA supervised the entire work, field data collection and technical assistance. All authors read and approved the final manuscript.

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ABSTRACT

A geo-electric survey using 1-D carried out to identify suitable sites and construction of boreholes that will give water supply for large irrigation work at Challawa-Gorge Dam, North West Basement complex, Nigeria. The data was acquired using Schlumberger technique at points chosen across the study area. The data analyzed with IPI2WIN software, information from a borehole where use as control for delineation of virtual geologic model of the study area. Th eresults suggest 4-5 geo-electric layers exist in the study area. The topsoil layer having resistivity range between 158 ohm m to 417 ohm m and thickness range between 0 m to 3 m. Sand layer having resistivity range between 58 ohm m to 107 ohm m and thickness range between 7 m to 14 m. Weathered rock layer having resistivity range between 122 ohm m to 192 ohm and thickness range between 7 m to 9 m. Moderately fractured layer having resistivity range between 166 ohm m to 317 ohm m and

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thickness range between 28 m to 31 m. Fresh bedrock layer having resistivity greater than 1000 0hm m and infinite thickness. Lithological units suggest weathered and underlain by partially weathered, fractured basement as the aquifer zone where it is extensively thick and suitable points for borehole selected based on the depth and thickness range of the aquifer layers.

Keywords: Geo-electric; aquifer; borehole; irrigation.

1. INTRODUCTION

Groundwater is one of the best alternatives to surface water in everyday usage. It is no doubt that it is auseable, replenishable resource, its presence and distribution greatly depend on local and regional geology, hydrogeological setting and the scope of nature of human activities within the land. However, groundwater resources face growing demand for irrigated agriculture, and to some extent, for domestic use. In this paper, an effort made to identify borehole sites for irrigation in one of the dams in Northern Nigeria using geophysical techniques. Groundwater presence in Basement terrain is found within zones of weathering and fracturing which sometimes are not continuous in vertical and lateral extent [1]. There is a constant rise in the demand for groundwater in most areas underlain by basement rocks. The Kano area is underlain by rocks of the Nigerian Basement Complex comprising of Migmatite-gneiss complex, Younger Metasediments, Older and Younger Granites [2]. The aquifers of hard rock's areas in Kano are the regolith and the fractures in the fresh bedrock which are interconnected at depth [2,3].

The process used previously to provide aquifer properties that are important sources of groundwater for irrigation activities. The main agricultural activities of the community Challawa village is farming and fishing. This is because of the difficulty of water supply, farming activities are only practiced at rainy season, leaving the famers doing nothing for almost eight month in a year [4,5]. In a way to provide better living standards of the community, provision of sustainable water is an ultimate goal, which must be achieved to reduce the level of poverty in the community. In a bid to ensure adequate water supply for irrigational farming in the community, Vertical Electrical Soundings survey were done at the request of the Hadejia Jama'are River Basin Development Authority, Kano State, to identify suitable points for construction of Tube Wells, which will serve as sources for sustainable water supply for the proposed Challawa-Gorge irrigation scheme.

2. MATERIALS AND METHODS

2.1 Study Area

The study area is geographically located between latitudes 11.773434° and 11.611168° N and longitudes 7.911570° – 8.090897° E, at Karaye Local Government Area, about 90 km southwest of Kano city, Kano State, Nigeria. The study area is characterized by Tropical Savanna climate with temperature averages 26.1°C/79.0°F. Precipitation in the area is about 752 mm/29.6 inch per year. The study area (Challawa-Gorge Dam) is a major reservoir on the Challawa River, built in 1990-1992 using rock fill construction with a full storage capacity of 904,000,000 m^3 and a direct catchment area of 3857 km^2 [6]. The dam is 42 m High and 7.8 km in length.

2.2 Methodology

Many geophysical techniques used in estimating the distribution of aquifer layers in the subsurface. The method used here required measurement of ground resistance by simultaneously passing current into the ground through two current electrodes and measuring voltage across the current flow in the area of the electrodes using two potential electrodes. The earth resistance which is usually lowered by the presence of conductive materials and specific meters that have high impedance are used in resistivity survey application [7]. Such a voltmeter draws virtually no current and the voltage drop via the electrodes is small. The resistances at the current electrodes limit the current flow but do not affect resistivity assessment [8]. A competitive factor is required to convert the measurement obtained with these four-electrode arrays to resistivity. The results of any single measurement with any array could be interpreted as due to uncanny ground with a constant resistivity. The competitive factors used to calculate this apparent resistivity, can be derived from the formula [9,10].

$$V = \frac{\rho I}{2\Omega a} \quad (1)$$

For the electric potential v at a lengtha from a point electrode at the surface of an unvarying half-space (homogeneous ground) of resistivity ρ (referenced to a zero potential at infinity). The current I may be positive (if into the ground) or negative. For arrays, the potential at any voltage electrode is equal to the sum of the endowment from the individual current electrodes. In a four-electrode survey over homogeneous ground the expression for K is as given in equation (2).

$$K = \frac{2\Omega}{\frac{1}{AM} - \frac{1}{BM} - \frac{1}{AN} - \frac{1}{BN}} \quad (2)$$

2.3 Data Collection and Processing

The demandfor geophysical methods for groundwater investigation is based on the fact that certain physical properties of rocks change substantially with water content in them [1]. These changes (in physical properties) compose to physical boundary which indicate by contrast in density, conductivity and elastic properties[11,12]. These contrasts make electrical resistivity, gravimetric and seismic methods of geophysical survey a useful tool in groundwater investigation. Each of these technique has varying degree of success in furnishing helpful details concerning groundwater investigation [13,14]. Of all these techniques, resistivity has prime aspect of responding to non-identical materials than seismic and other methods, precisely to water content and salinity of subsurface segment [15,16]. In line with this, the D.C resistivity technique used [2].

Generally, four electrode arrays are used at the surface, one pair for introducing current into the earth and the potential difference entrenched in the earth by the current is measured in the place of current flow with the second pair [16,17]. There are two basic types of field method normally used in resistivity surveys. These are the VES (electrical drilling or expanding probe) and the resistivity profiling. In this work, Omega Ω Resistivity meter used to obtain Vertical Electrical Sounding (VES) data at points spread across the suggested irrigation site (Fig. 2). The Schlumberger electrode array with maximum electrode array of 200 m used.

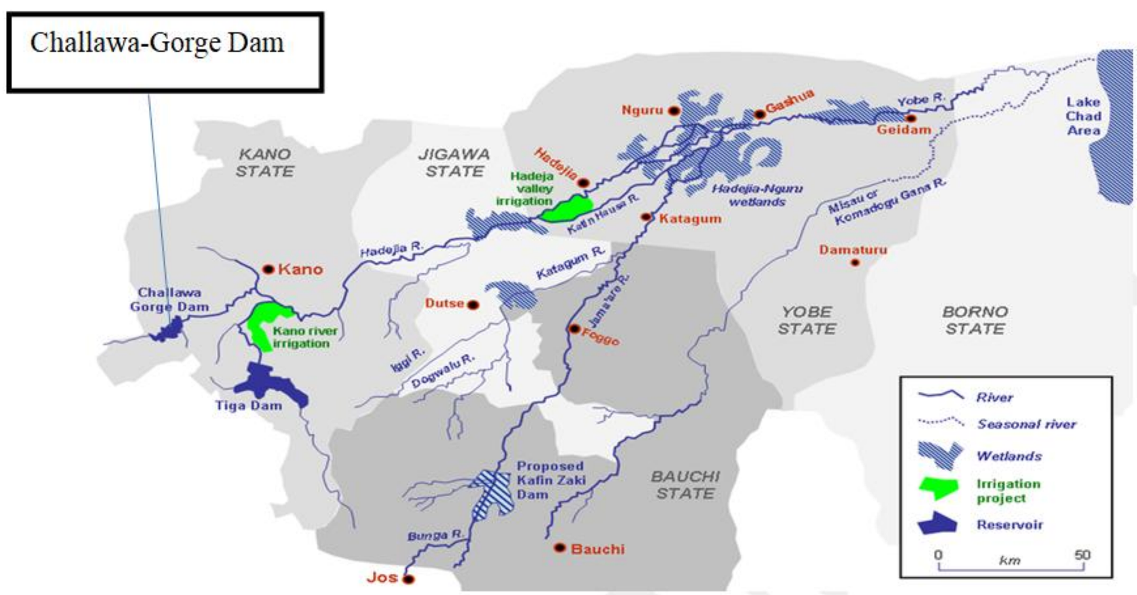


Fig. 1. Location of Challawa-Gorge Dam

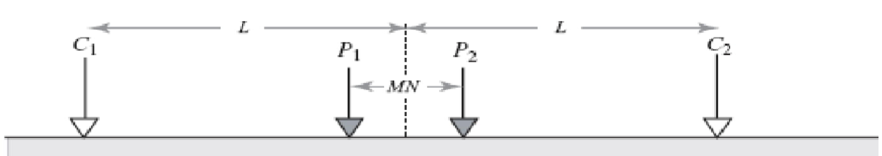


Fig. 2. Schlumbeger array

3. RESULTS AND DISCUSSION

The data obtained were processed and interpreted with IPI2WIN iterative software that interprets 1D electrical resistivity sounding data and give layered resistivity model that divulge subsurface geology. Figs. 3-8 are the iterated curves with layered resistivity models of the data obtain at the VES selected points. Because, in some cases, geo-electric and geologic segment do not often correspond [17], [18], realistic geologic equivalent of the apparent resistivity models of the data obtain at VES selected stations were obtained with details from borehole log, nature of surface deposit [19] and published resistivity data [20] used as direction.

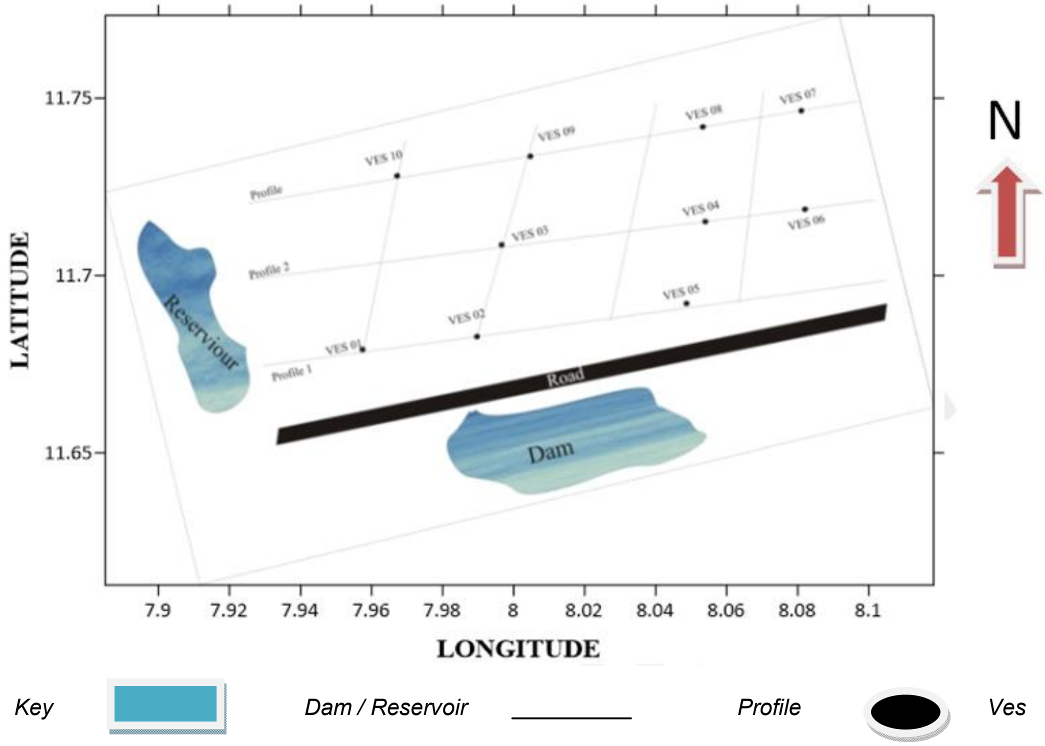
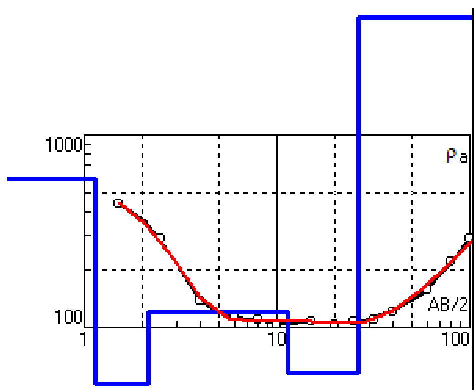
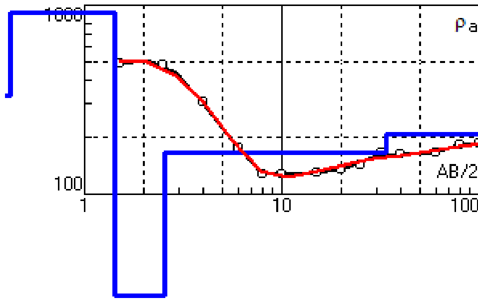


Fig. 3. Field layout at Challawa-Gorge irrigation Scheme, Karaye LGA, Kano State



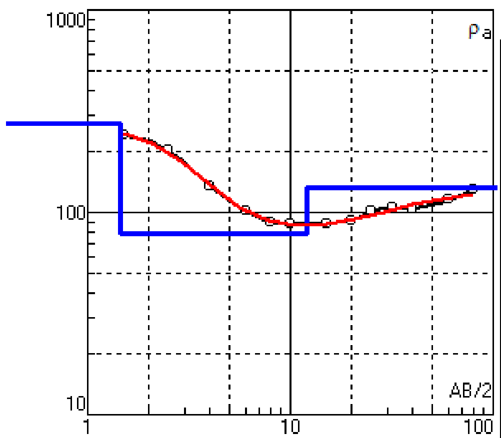
N	ρ	h	d	Alt
1	587	1.15	1.15	-1.15
2	50.8	1.01	2.16	-2.16
3	122	9.31	11.5	-11.4
4	57.9	15.2	26.6	-26.6
5	20270			

Fig. 4. Iterated field curve and log table of VES 1



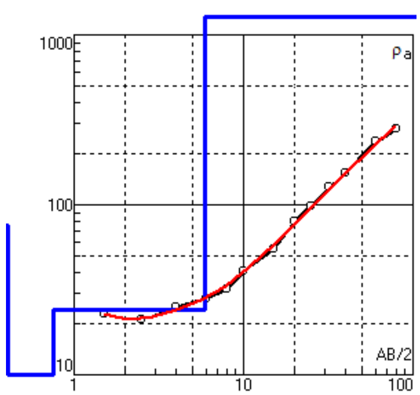
N	ρ	h	d	Alt
1	330	0.421	0.421	-0.421
2	919	0.995	1.42	-1.417
3	29.2	1.12	2.54	-2.535
4	166	31.2	33.7	-33.7
5	208			

Fig. 5. Iterated field curve and log table of VES 2



N	ρ	h	d	Alt
1	273	1.44	1.44	-1.445
2	77.9	10.5	12	-11.99
3	132			

Fig. 6. Iterated field curve and log table of VES 3



N	ρ	h	d	Alt
1	75.8	0.391	0.391	-0.391
2	10.1	0.36	0.751	-0.751
3	24.3	5.2	5.95	-5.953
4	5113			

Fig. 7. Iterated field curve and log table of VES 4

Firstly, the sounding curves of the studyreflected four to five geo-electric layers. Their curve types are H, KH and HK. The equivalent lithological units are as depicted in Table 1.

The first two parts make up the overburden while the last part makes up the weathered with possible fractures and the fresh basement. The overburden is estimate to be at a range of between 10 – 31 mat the different VES selected points. Nature of the apparent resistivity curves reflects degrees of weathering at all the VES selected points [21]. The highly weathered and the underlain partially weathered and fractured basement are the aquifer zones of the study area because they are identified by apparent resistivity values that indicates good conductivity, thus suggesting favorable groundwater availability. Possibility of the water bearing areas also indicated by the sharp resistivity contrast between the zones and the high apparent resistivity value of the crystalline and fresh Basement, which are not aquiferous.

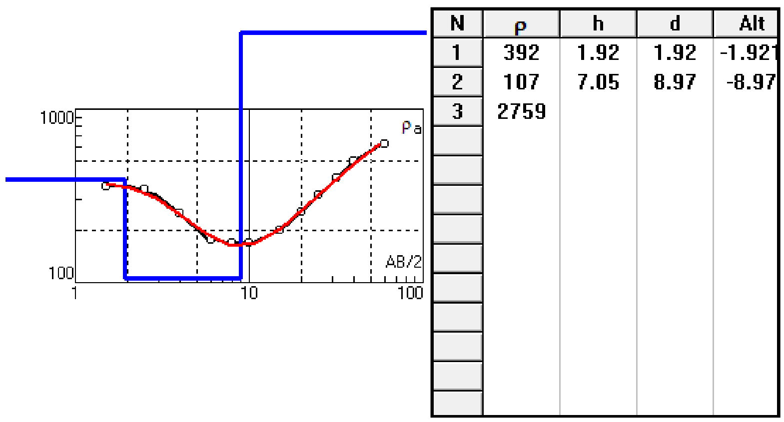


Fig. 8. Iterated field curve and log table of VES 5

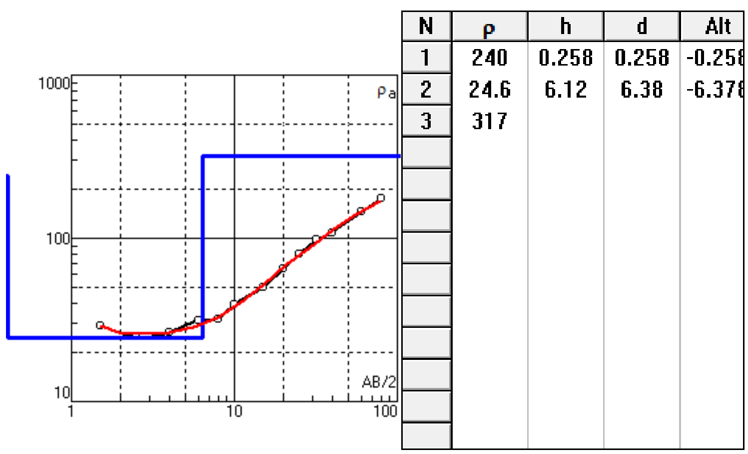


Fig. 9. Iterated field curve and log table of VES 6

Table 1. VES result and interpretation

layer number	Resistivity (ohm-m)	Thickness (m)	Lithology
1.	158 – 417	0 – 3	Top soil
2.	58 – 107	7 – 14	Sand
3.	122 – 192	7 - 9	Weathered rock
4	166 – 317	28 – 31	Moderately fractured rock
5	>1000	∞	Fresh basement rock

4. CONCLUSION AND RECOMMENDATIONS

In all the geologic layers, the highly weathered basement and the partially weathered and fractured basement considered as evaluate as the main aquifer portions because of their importance as water bearing units in basement Complex [2]. From the result, VES selected stations that are most approving for construction of the suggested pump-fitted. Tube Wells, based on high thickness range (20 m – 25 m) of the aquifer components. VES 01, 02, 03, 07, 08, 09, 10 along profile 1, 2 and 3 recommended for drilling of the wells. The borehole drilling can be terminated between 60 – 70 m or as considered right by the site Geologist (depending on the yield/site condition).

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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