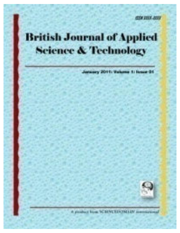

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Evaluation of Aquifer Potentials for Irrigation Practice in Parts of the Basement Complex of North-Central Nigeria

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Research Article

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ABSTRACT

A Geoelectric survey involving Vertical Electrical Sounding was carried out with the aim of using the results to delineate aquifer and assess its sustenance for adequate water supply for irrigation work in Fadama parts of some villages in Igabi Local Government Area, Kaduna state, Nigeria. The data were acquired with symmetric Schlumberger configuration at stations chosen across the study area. The acquired data were inverted with 1D Earth Imager iterative software. The interpreted results suggest four geoelectric layers. From their equivalent geologic/lithologic units, the weathered and the underlain fractured basement, which are characterized with relatively low resistivity values (14 to 217Ωm), were considered as the aquiferous layers of the study area. Suitable sites for construction of pump-fitted wells were suggested based on thickness of the aquiferous layers. On assessment of the groundwater from estimated aquifer parameters, the well yield will serve the intended irrigation purpose.

Keywords: Vertical Electrical Sounding (VES); transmissivity; irrigation;

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1. INTRODUCTION

Resistivity measurement is one of the commonest geophysical parameters that are often employed to surmise fundamental information about subsurface geology. The overall success of groundwater supply development often depends on borehole sitting, the greater the sitting successes, the fewer boreholes that have to be drilled to achieve the project objectives (Arabi et al., 2009).

These measurements have been used to solve groundwater and its related problems; notably in determining suitable site for drilling of boreholes and in studying groundwater contamination (Sundararajan *et al*., 2007; Adepelumi *et al*., 2001; Osazuwa and Abdullahi, 2008). Because of its rapid and cost effective advantage of locating water bearing units (aquiferous zones) over other geophysical methods, the method was used to determine favourable sites for construction of pump-fitted Tube Wells at localities (Damari and Kan Kurmi) proposed for irrigation scheme. The inhabitants of these localities (study area) are mainly farmers and despite the presence of riverine alluvium, locally termed 'Fadama', which are important source of groundwater for irrigation, the groundwater has not been exploited for dry season farming; leaving the famers idle for most part of the year. The scheme was further driven by the flexibility and timeless water supply which ground water offers as an alternative to non existing surface water supply by public service. The study area is located in Fadama parts of some villages in Igabi Local Government Area, Kaduna state, Nigeria (Figure 1).

Fig 1: Map of part of north-central Nigeria showing location of the irrigation sites (Damari and Kan Kurmi)

It falls within the north-central sector of the Nigerian basement complex. Details of the geology of the sector are also described by McCurry (1976); Fitches et al. (1985); Ajibade et al. (1987). In summary, the study area is underlain by gneisses, migmatites and granites of the Nigerian basement complex (Fig. 2) which bears the imprints of thermo-tectonic events of the Archean to early Paleozoic times (Oyawoye, 1972; Mccurry, 1976; Fitches et al., 1985; Ajibade et al., 1987).

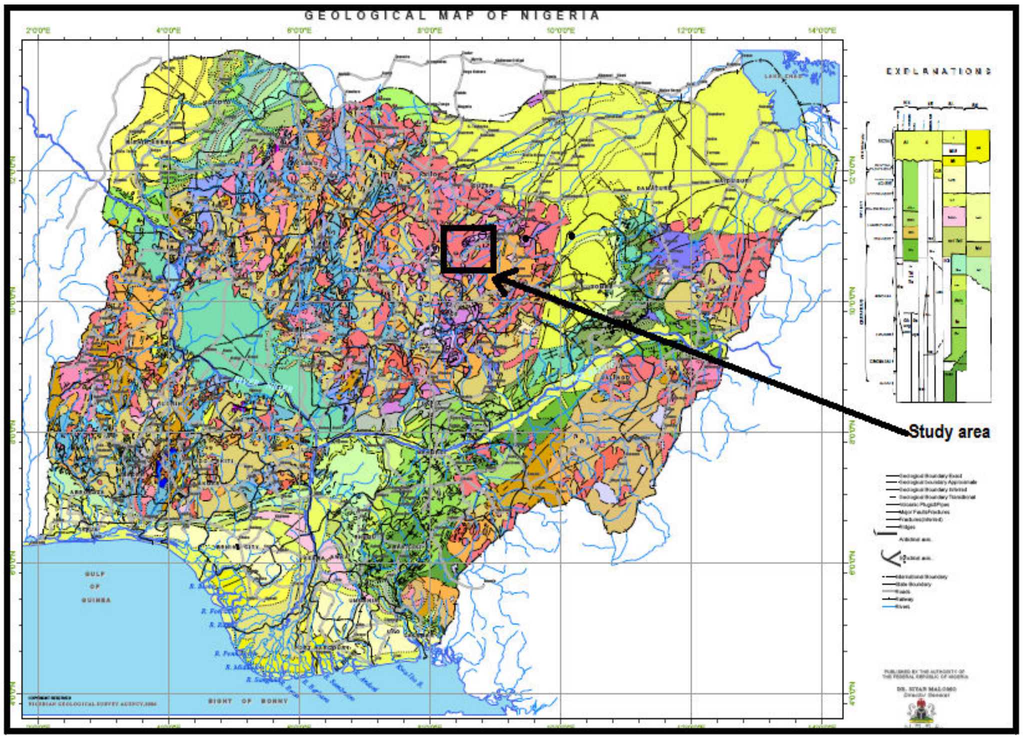

Fig. 2: Geological of Nigeria showing the study area (GSNA, 2006)

According to Eigbefo (1978), the superficial deposits (overburden) which overlay the basement rocks, act as recharge materials, especially where they are underlain by weathered basement. The main aquifer components of the basement complex of Nigeria are weathered and fractured basement (Olowu, 1967).

2. MATERIALS AND METHODS

The D.C resistivity method, involving Vertical Electrical Sounding was employed. Details of this method are contained in Keller and Frischknecht, 1966, Telford et al., 1990. A Sting Resistivity/IP meter was used to acquire the Vertical Electrical Sounding (VES) data at stations spread across the proposed irrigation sites (Figures 2a and 2b). The Schlumberger electrode configuration with maximum electrode configuration of 200m was adapted. The acquired data were processed and interpreted with 1D Earth Imager iterative software that interprets 1D electrical resistivity sounding data and produce layered resistivity model that reveals subsurface geology of the study area. Summary of the results from the interpretation of the data are provided in table 1 while Figures 3 and 4 are typical iterated curves with layered resistivity models of each site. Because, in some cases, geoelectric and geologic sections do not often correlate (Keller and Frischknecht, 1966), realistic geologic equivalent of the layered resistivity models of the acquired data were obtained with information from nature of superficial deposit (Tokarski; 1972; Wright and Mc Curry, 1970) and published resistivity data (Telford et al.; 1990; Shemang, 1990) used as controls.

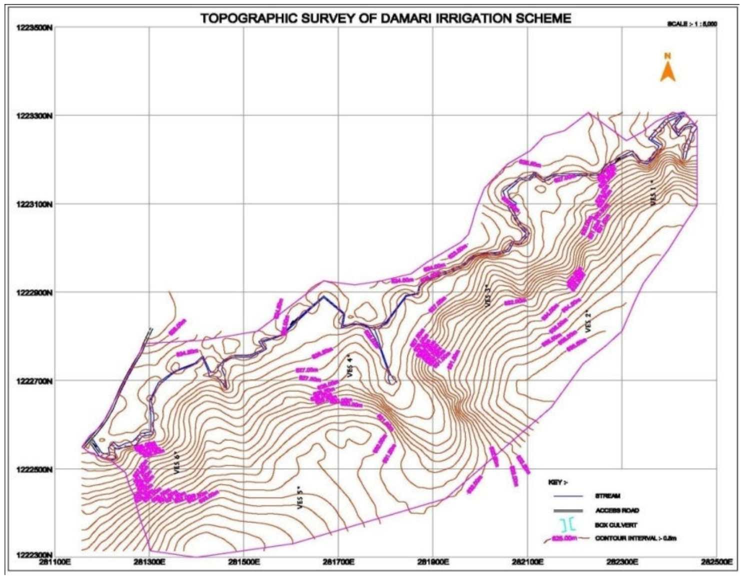

Figure 2a: Topographic map of Damari Irrigation Scheme site showing distribution of VES stations.

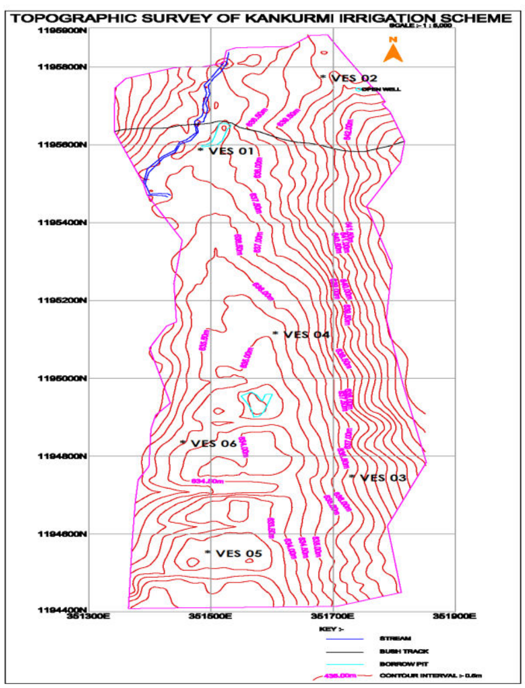

Figure 2b: Topographic map of Kankurmi Irrigation Scheme site showing distribution of VES stations

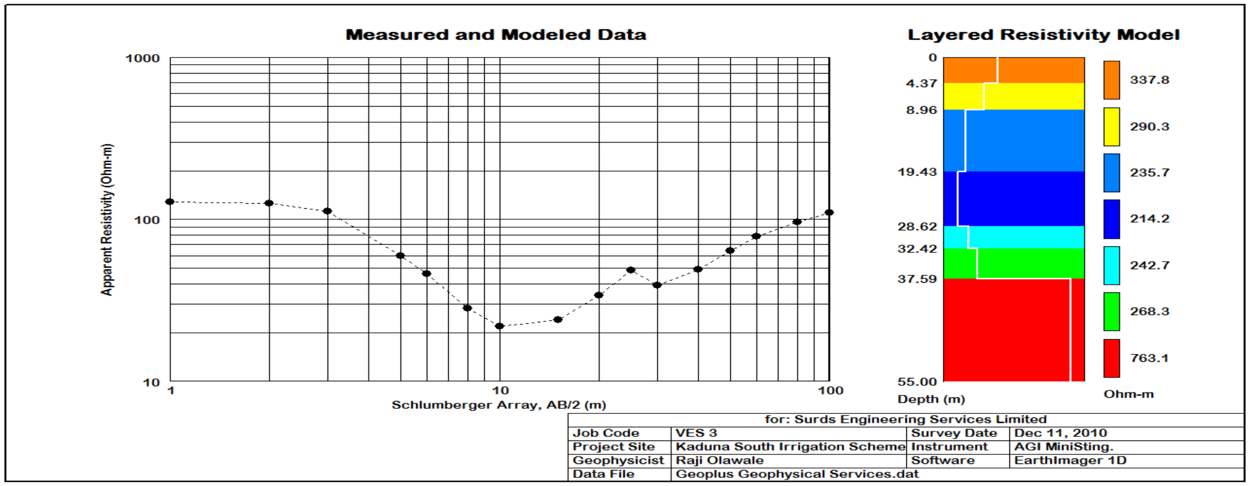

Figure 3: Field curve and the layered resistivity model of *VES 2* at Damari

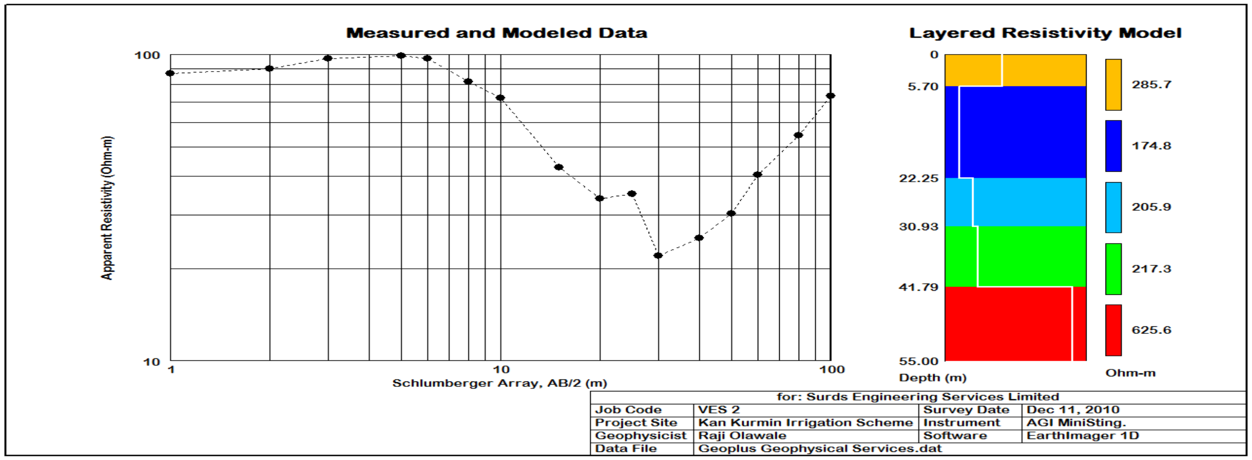

Figure 4: Field curve and the layered resistivity model of *VES 3* at Kankurmi

2.1 Estimation of Aquifer Parameters

The main aquifer components of the basement complex of Nigeria are the weathered and fractured basement (Olowu, 1967) and water yielding capacities of wells drilled to these components always vary. To avoid drilling abortive wells, geophysical investigation is imperative because it helps to delineate aquifer (or potential water bearing geological units) while on the other hand, assessment of Water yielding capacity of aquifer are traditionally determined from parameters obtained from well pump tests and well log data (Singh, 2005). These are time consuming and expensive. A rapid and cost effective means of determining these parameters; hydraulic conductivity and transmissivity, is with resistivity data (Kelly, 1977; Niwas and Singhal, 1981; Singh, 2005), particularly where bore wells are not sufficient (Dhakate and Singh, 2005) or not available like in the present study area. In an attempt to infer on the potential of the aquifer of the study area for the proposed irrigation scheme, the relations established by Singh (2005), Niwas and Singhal (1981) and the standard set by Krasny (1983) were adapted.

According to Niwas and Singhal (1981), the analytical relationship between aquifer transmissivity (T), hydraulic conductivity (K) and aquifer thickness (h) is given by:

$$T = K\,h \tag{1}$$

And in accordance with Singh (2005)

$$K = 8 \times 10^{-6}\, e^{-0.0013\rho} \tag{2}$$

Where ρ is resistivity of the aquifer The relation (Equation 2) was used to estimate hydraulic conductivity (K) because the water bearing unit of the study area is a hard rock aquifer and the unit is sandwiched by resistive layers (Singh, 2005). The hydraulic conductivities were multiplied with the aquifer thickness of interpreted VES stations to determine aquifer transmissivity of the study area using equation (1). These results are presented in Table 1 while conclusion on significance of aquifer for the proposed irrigation scheme was drawn from standard set by Krasny (1983).

3. RESULTS AND DISCUSSION

The sounding curves of the study area reflect four geoelectric layers. These curve types are A, QH, KH and HKH. The equivalent lithologic units are: the top sandy soil; silty/sandy clay (regolith), weathered transition zone (saprock), partially weathered basement rock with possible fractures and fresh basement rock. The highly weathered and the underlain partially weathered/ fractured basement are the water bearing units (aquiferous zone) of the study area because of the sharp resistivity contrast between the aquiferous zone and the high apparent resistivity value of the crystalline/ fresh basement, which is not aquiferous. This zone varies in depth and thickness across the study area. On aquifer properties, the results (Table 1) revealed an average hydraulic conductivity value of 0.54 m day^{-1} and a mean transmissivity of 13.45 m^2 day^{-1}. By the standard set by Krasny (1993) (Table 2), the aquifer has moderate transmissivity capacity that offers withdrawal that meets local water supply (small community, plants, etc).

Table 1: Summary of results of aquifer properties of VES stations

Area	Location	VES No.	Aquifer thickness (m)	Resistivity (Ωm)	Hydraulic conductivity x10^{-6}(m/s)	Hydraulic conductivity (m day^{-1})	Transmissivity (m^2 day^{-1})
Damari		1	16.8	503	4.16	0.36	6.1
	10^0 40’-10^0 43’N	2	20.6	348	5.08	0.43	9.0
	07^0 19’- 07^0 23’E	3	35	211	6.08	0.52	18.4
		4	20.0	309	5.35	0.46	9.25
		5	35.8	275	5.60	0.48	17.3
		6	12.2	30	7.69	0.66	8.1
Kankurmi		1	19.1	107	6.06	0.61	11.7
	10^0 46’ – 10^0	2	36.1	186	6.28	0.54	19.6
	49’N	3	17.4	96	7.06	0.61	10.6
		4	19.3	220	6.01	0.52	10.0
	07^0 39’ – 07^0 43’	5	33.1	78	7.23	0.62	20.7
	E	6	26.5	83	7.18	0.62	16.4

Table 2: Standards for transmissivity (Krasny, 1993)

Transmissivity (m day^{-2})	Designation	Groundwater supply potential
1000	Very high	Withdrawal of great regional importance
100– 1000	High	Withdrawal of lesser regional importance
10– 100	Intermediate	Withdrawal of local water supply (small community, plants, etc)
1– 10	Low	Smaller withdrawal for local water supply (private consumption)
0.1– 1	Very low	Withdrawal for local water supply (private consumption)
< 0.1	Impermeable	Sources for local for local water supply are difficult

4. CONCLUSION

In all the delineated geologic layers, the highly weathered basement and the partially weathered/ fractured basement were considered as the aquifer zone because of their importance as water bearing units in basement Complex (Olowu 1967). From the result of the interpretation of the data of this work, VES stations that are most favorable for construction of the proposed pump-fitted Tube Wells, based on high thickness of the aquiferous zone are 3 and 5 in Damari with respective thickness of 35.0m and 35.8m. In Kankurmi, the VES stations are 2 and 5 with respective thickness of 36.1 m and 33.1m. These VES stations are therefore recommended for drilling of the wells. The borehole drilling is recommended to be terminated between 40 – 45m for maximum yield. Also, result of the average transmissivity of the study area indicates that the well yield will serve the intended irrigation purpose because the aquifer will provide withdrawal that meets communal needs.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

Adepelumi, A.A., Ako, B.D., Ajayi, T.R. (2001). Groundwater contamination in the basement-complex area of Ile-Ife, southwestern Nigeria: A case study using the electrical-resistivity geophysical method. Hydrogeology Journal, 9, 611–622.

Ajibade, A. C., Woakes, M., Rahaman, M. A. (1987). Proterozoic crustal development in the Pan – African regime of Nigeria. American Geography J., 259 – 271.

Arabi, A. S., Nur, A., Dewu, B.B.M. (2009). Hydro Geo-Electrical Investigation in Gombe Town and Environs, Northeastern. J. Appl. Sci. Environ. Manage., 13(3), 65 – 68.

Dhakate, R., Singh, V.S. (2005). Estimation of hydraulic parameters from surface geophysical methods, kaliapani ultramafic Complex, Orissa, India. Journal of Environmental Hydrology, 13(12), 1-11.

Eigbefo, C. (1978). Hydrology of Kubani drainage basin, Zaria. Unpublished M.Sc. Thesis, Department of Geology, Ahmadu Bello University, Zaria.

Fitches, W. R., Ajibade, A. C., Egbuniwe, I. G., Holt, R. W., Wright, J. B. (1985). Late Proterozoic Schist belts and plutonism in NM Nigeria. Journal of Geological Society of London, 142, 319–337.

Keller G.V., Frischknecht, F.C. (1966). Electrical Methods in Geophysical Prospecting, Pergamon Press, Oxford.

Kelly, W.E. (1977). Geoelectric sounding for estimating hydraulic conductivity. Groundwater, 15, 420-425.

Krasny, J. (1993). Classification of transmissivity magnitude and variation. Groundwater, 31(2), 230-236.

McCurry, P. (1976). The Geology of the Precambrian to Lower Paleozoic Rocks of Northern Nigeria, a review in Kogbe, C.A. (2nd edition), Geology of Nigeria. Elizabethan Publ. Co., Lagos, 13-37.

Niwas, S., Singhal, D.C. (1981). Estimation of aquifer transmissivity from Dar-Zarrouk parameters in porous media. Journal of Hydrology, 50, 393-399.

Olowu, J. (1967). Preliminary Investigation of Groundwater Condition in Zaria Sheet 102 S.W GSN Report No.1462.

Osazuwa, I.B., Abdullahi, N.K. (2008). 2-D Electrical Resistivity and Induced Polarizations Investigation at an Open Solid Waste Dumpsite: Case Study from Kaduna, North Central Nigeria. Journal of Environmental Hydrology, 16(29), 1-11.

Oyawoye, M.O. (1964). The Basement Complex of Nig. African Geology. University of Ibadan Press.

Shemang, E.M. (1990). Electrical Depth Soundings at Selected well sites within the Kubani River Basin, Zaria, Nigeria. Unpublished M.Sc Thesis, Department of Physics, Ahmadu Bello University, Zaria.

Singh, K.P. (2005). Nonlinear estimation of aquifer parameters from surficial resistivity measurements: Hydrology and Earth System Sciences Discussions (HESSD), 2, 917-93.

Sundararajan, N., Nandakumar, R., Chary, N.M., Ramam, K., and Srinivas, Y. (2007). VES and VLF- an application to groundwater exploration, Khammam, India. The Leading Edge, June, 708-716.

Telford, W.M., Geldert, L.P., Sheriff, R.E., Keys, D.A. (1990). Applied Geophysics. Cambridge University Press, England.

Tokarski, A. (1972).Heterogeneous Terrace Arrangements, West of Ahmadu Bello University. Occasional paper No. 2, Department of Geology, Ahmadu Bello University, Zaria.

Wright, J.B., McCurry, P. (1970). The geology of Zaria sheet 102 S.W and its regions in M.J Mortimore (Ed). Department of Geography, occasional paper 4, Ahmadu Bello University Zaria.