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Application of electrical resistivity method in groundwater potential assessment of Dass town and environs, Bauchi, Nigeria

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ABSTRACT

Twenty-six electrical resistivity soundings were conducted around Dass town and its immediate environs for groundwater potential assessment within the basement complex of Bauchi. A computer-aided interpretation of the vertical electrical sounding (VES) data enabled the identification of geoelectric layers/geologic units like topsoil, weathered basement, and bedrock which have hydrogeologic significance in groundwater development. Resistivity value range from 50 to 263 ohm/m, 32 to 137 ohm/m, and 75 to 311 ohm/m in the topsoil, weathered layer, and bedrock, respectively. Layer thickness also varied from 0.1 to 4.28 m in the topsoil, 7 to 29 m in the weathered layer, and ≥33 m to infinity in the bedrock layer. The depth to bedrock (basement) ranged from 0.2 to 33 m across the study area. Based on the VES interpretation, geoelectric/lithological sections and isopach maps were modeled; these models assisted with the classification of groundwater zones into low, medium, and high potential areas. It is established from this study that zones with thickness overburden thickness within depressions have good groundwater potential. Expectantly, the result of this study is meant to serve as a baseline to guide groundwater resources development in the study area.

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1. Introduction

Dass town of Bauchi state is strategically important because of its agricultural and economic activities. The population of Dass stood at 294,931 as of the 2006 population census and was projected to be 329,763 in 2010 (Bauchi State Planning Commission, 2005).

The public water supply to the town is from a borehole water scheme constructed about four decades ago with a combined yield of 8,332 l/hour (Offodile, 2002). Access to good and adequate water supply over the last decade has become very difficult due to the rapid increase in population. The scheme supplies only the central old town settlement, which constitutes only a quarter of the town's population. Therefore, to cope with the ever-increasing demand for potable water in the LGA, the need for an expanded groundwater supply scheme (centralized or decentralized) has become cogent and urgent (Isiaka 2003).

This study presents the results of geophysical (geoelectric) investigations for determination of groundwater potential of Dass and its immediate environs.

1.1. Geography, geology, and hydrogeology

The study area is situated between longitude 9.3922E and 9.6503E and latitude 9.4036N and 9.6977N. The climate is controlled by the seasonal migration of intertropical convergence zone (Ajaegbu et al., 1992). The wet season begins around May and ends in September

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and the dry spell (Harmattan) begins from October and ends around April. The amount and distribution of rainfall, temperature, relative humidity, and wind runs follows these two seasons.

The vegetation cover is typically in Guinea Savannah and characterized by secondary vegetation of scattered trees, shrubs, and grass savannah. Generally, the vegetation has been tempered by human activities.

The main drainage networks around the study area rise from the northern high grounds and flow eastward (Fig. 1). The rivers are ephemeral in character.

Dass and its environs lie within the crystalline basement complex environs and consist mainly of quartz hypersthene diorite, porphyritic biotite granite, migmatites, and biotite granite (Macleod et al., 1971).

Hydrogeologically, the study area falls within the crystalline basement complex and is classified into poor groundwater regions (du Preeze and Berber, 1965). However, despite the relatively poor hydrogeological characteristics of these basement rocks, they have remained a very important source of water supply for more than half of the population of rural area in Nigeria (Offodile, 2002).

The weathered regolith usually consists mainly of clay, sand, sandy clay, and where aquifers are generally thickness (Offodile, 1983). Highly tetanized basement rocks with incipient fractures, joints, and folds are potential groundwater storage and flow zones and significant in basement surveys for groundwater development (Omosuyi et al., 2003).

The wells and boreholes drilled around the area and within the immediate outskirts, either by private or public agencies like the Millennium Development Goals, UNICEF, United Nations Development Programme, and State Rural Water Supply and Sanitation Agency, and are within the average depth of 50–70 m with a yield ranging from 0.3 to 1.5 l/second.

2. Method of Study

This study involves the geoelectrical resistivity measurement across Dass town and some towns where accessibility is available (Fig. 1). The survey was conducted using the Schlumberger array (vertical electrical sounding) technique. The current electrode (AB/2) separation and potential electrode separation varied from 1.5 to 215 m and from 0.5 to 14 m, respectively. The field readings were carried out using an allied omega earth resistivity meter. A total of 26 vertical electrical sounding (VES) were conducted around the area. The field data were interpreted using a computer-simulated program, Win Resist version 1.0 (Vander Velpen, 1998, 2004).

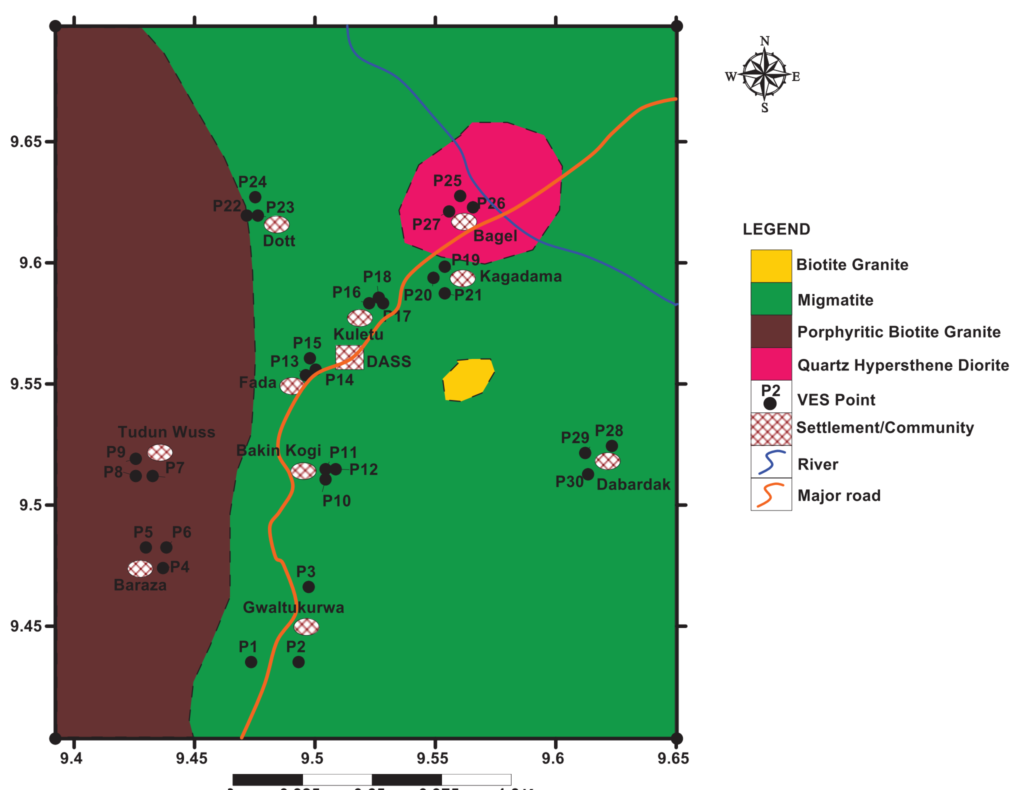


Figure 1. Location and geological map of the study area.

The VES locations' coordinates were determined in the field by the use of the Garmin eTrex 12 channel, a global positioning system. The maps were produced using Surfer 9 geographic information system program.

The correlation of the model curves' interpretation with a borehole log in the study area is shown in Figure 3.

3. Results and Discussion

3.1. Geoelectric resistivity soundings

Figure 2 and Table 1 show the typical VES curves and model interpretation from the study area:

3.2. Geoelectric sequence

The VES data interpretation delineates three lithologic/geologic units: the topsoil, the weathered layer, and the bedrock. The geoelectric sections were taken from three directions: SE-NW, SW-NE, and NW-SE (Fig. 4) in an attempt to correlate the geoelectric sequence across the study area. The resistivity in the topsoil ranges from 50 to 263 ohm-m. The layer thickness is variable from 0.1 to 4.28 m (Table 1 and Fig. 4).

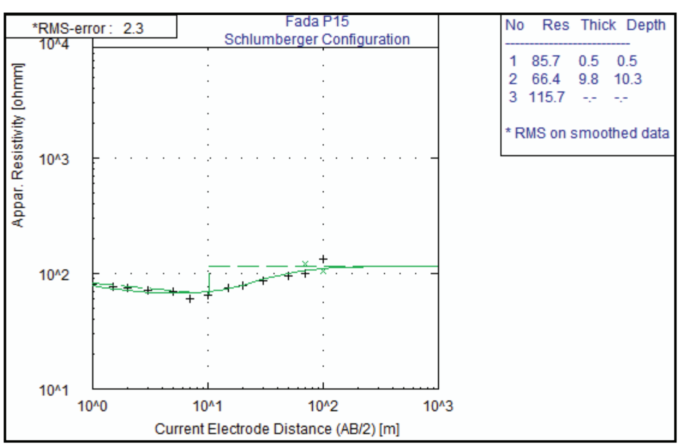
The second layer (weathered) has a resistivity value range of 32–137 ohm-m. The zones suggest they are most likely in the clay/sandy clay suite. The thickness of these geoelectric units varies from 7 to 29 m (Table 1 and Fig. 4). The low resistivity characteristics are most likely controlled by its water saturation (Omosuyi et al., 2003; Longpia et al., 2013).

The third layer is the bedrock which is characterized by high resistivity values from 75 to 311 ohm-m with a varying depth of ≥33 m.

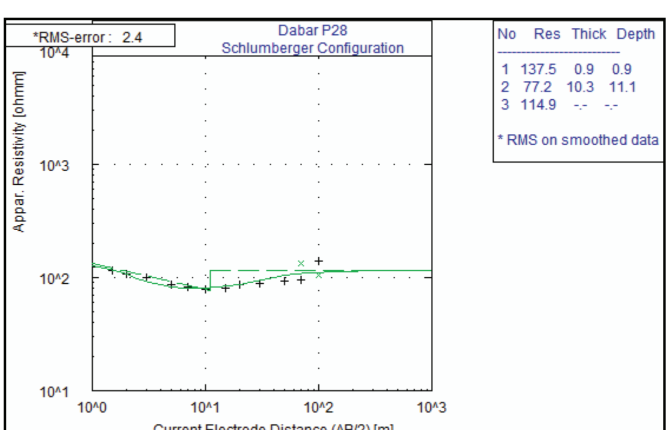
3.3. Isopach map of the overburden

Figure 5 shows a contour of the overburden layer thickness over the VES stations conducted in the study area. The overburden thickness is variable from 2 to 32 m. The areas with overburden thickness of 20–32 m are generally limited in extent, isolated, and are spotted around Dott, Tudun Wuss, and Fada settlements, all in the western part of the study area.

Related geophysical studies in basement terrain revealed that areas with relatively thickness



(a)



(b)

Figure 2. (a) and (b) Typical VES curves in the study area.

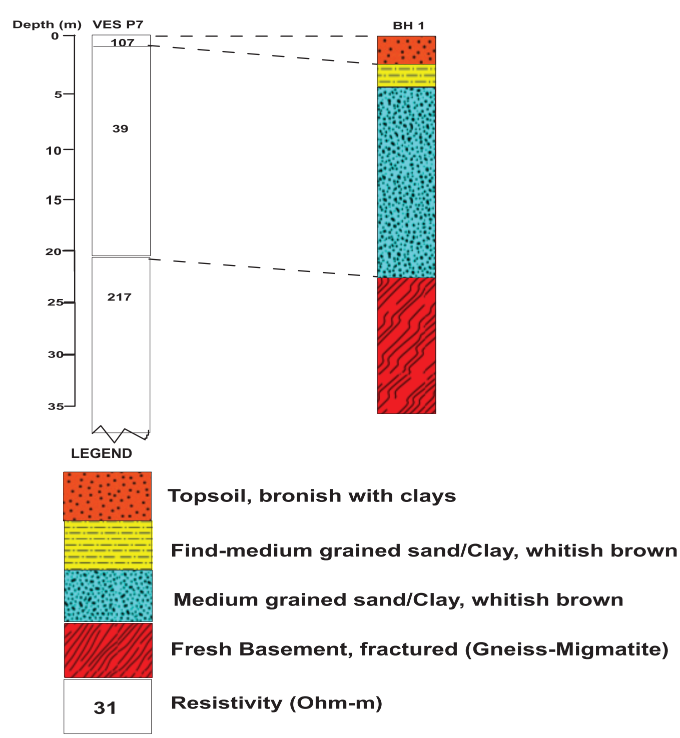


Figure 3. Correlation of model curve with borehole log in the study area.

Table 1. Summary of VES interpretation.

VES No.	Depth (m) d_1/d_2-----d_n	Resistivity (ohm-m) $\ell_1/\ell_2 \dots \ell_n$	Curve type
P1	0.18/7/∞	157/38/204	HA
P2	0.19/11/∞	153/47/235	HA
P3	0.28/9/∞	153/46/148	H
P4	0.43/16/∞	227/108/227	H
P5	0.31/11/∞	143/42/168	H
P6	0.30/8/∞	107/39/217	HA
P7	0.99/21/∞	50/41/75	HA
P8	1.48/29/∞	56/39/95	H
P9	1.36/19/∞	77/47/107	H
P10	0.3/10/∞	208/133/249	H
P11	0.6/12/∞	98/53/157	H
P12	0.5/8/∞	94/58/168	H
P13	4.28/29/∞	119/32/204	KH
P14	1.33/33/∞	41/28/113	HA
P15	0.5/10/∞	86/66/116	HA
P16	0.18/7/∞	157/38/204	HA
P17	0.19/11/∞	153/47/235	HA
P18	0.28/9/∞	153/46/148	H
P19	0.8/10/∞	82/52/118	H
P20	0.26/12/∞	263/70/27	H
P21	0.25/12/∞	263/70/267	H
P22	1.79/25/∞	181/137/301	HA
P23	1.28/25/∞	159/122/311	HA
P24	0.70/6/∞	115/62/123	H
P25	1.57/12/∞	141/79/234	HA
P26	0.9/11/∞	138/77/115	H

overburden have good groundwater potential (Bala et al., 2001; Dan-Hassan and Olorunfemi, 1991; Olayinka et al., 1992; Olurufemi et al., 1992). Therefore, these identified and isolated areas are the high potential and priority areas for groundwater development. Areas in the eastern and southern part of the study area have an overburden thickness of 2–10 m.

3.4. Groundwater potential evaluation and significance of the weathered overburden and bedrock relief

In crystalline basement's hydrogeology, weathered overburden thickness with constituent material type, bedrock relief, and structural settings are main factors in groundwater resources evaluation (Omosuyi et al., 2003). The regolith and weathered basement layers are characterized by low to moderate resistivity, which may suggest saturation by water, constituting the main aquifer (Balogun et al., 2000). The bedrock relief/structures of the bedrock are very significant and hence the cardinal objective in basement groundwater surveys. Depressions filled with overburden materials and fractured bedrock constitute reliable and sustainable aquifer unit (Balogun et al., 2000; Omosuyi et al., 2003).

In the groundwater potential assessment, isopach maps and geoelectric sections prepared from the geoelectric parameters of the geoelectric sounding interpretations were used. The maps and sections revealed thickness overburden which generally overlies the areas with depression. The groundwater potential characterization map (Fig. 6) of the study area is produced based on aquifer's geoelectric parameters established in terms of lateral and vertical extents.

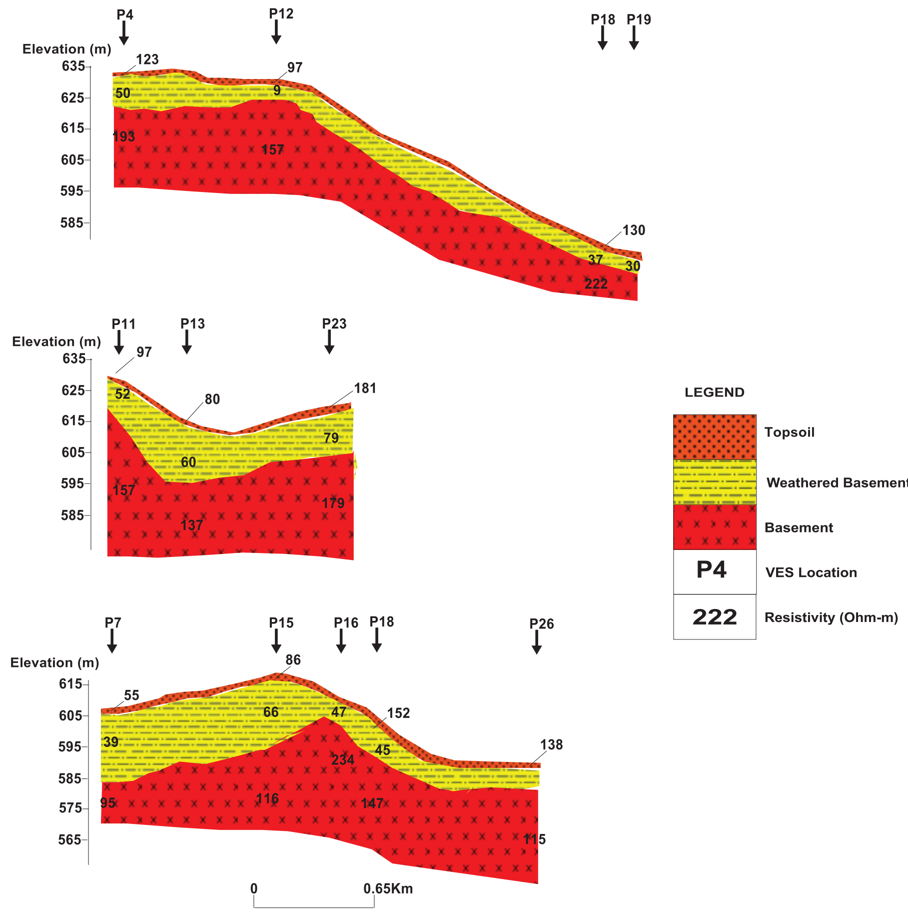


Figure 4. Geoelectric sections: SE-NW, SW-NE, and NW-SE directions.

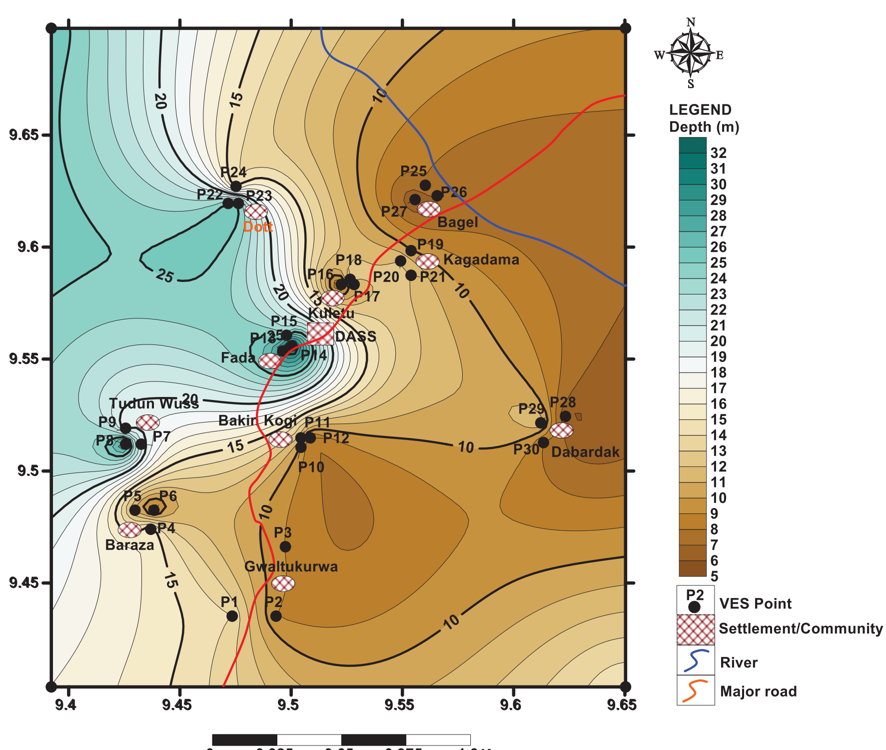


Figure5. Isopach map of the study area.

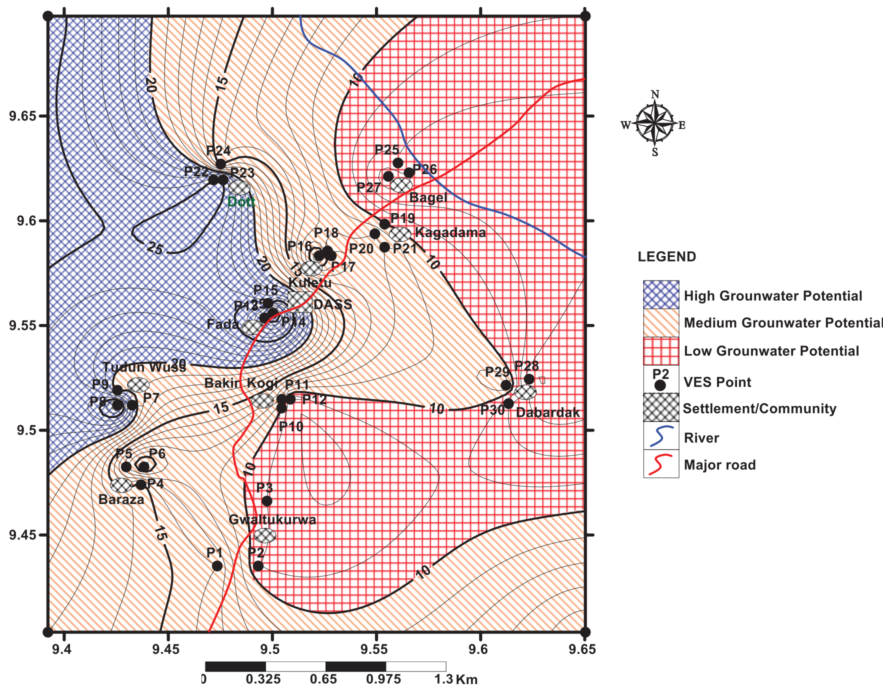


Figure6. Groundwater potential map of the study area.

For this purpose, potential classification areas with overburden thickness of 20–30 m, 10–20 m, and <10 m are classified as high, medium, and low, respectively.

4. Conclusion

The VES interpretations as obtained from the overall survey were used to produce relevant maps and sections with geologic/hydrogeologic significance. The findings of the study include the following:

i) Thickness overburden areas fall within the bedrock depressions and are zones apparently with high groundwater potential.

ii) Zones with thick overburden and bedrock fractures connected are the reliable and sustainable aquifers.

iii) This result is meant to be used as a general guide for groundwater resources development within the study area. However, the high groundwater resources potential zones are recommended for development as decentralized mini schemes for the areas where they occur.

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