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Groundwater exploitation in the Abakaliki metropolis (southeastern Nigeria): Issues and challenges

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This paper assesses and evaluates geologically related problems and issues associated with five 'abortive' boreholes drilled within the Abakaliki metropolis, southeastern Nigeria. Results of the vertical electrical geophysical soundings (VES), carried out in these borehole locations, show that the underlying Abakaliki Shale Formation in those areas has six layered model. While the uppermost layer has an apparent resistivity value of range 240 to 1120 ohm-m and a thickness of range 1.0 to 1.2 m, and is interpreted as lateritic overburden. The 2nd to 5th layers have apparent resistivity values that range from of 25 to 1025 ohm-m, with depth that range from 0.8 to 25 m. The 6th layer has mean apparent resistivity value of 443.25 ohm-m and undetermined thickness. The range of the apparent resistivity values and a correlation with local geological data reveal that the formation, although layered, is predominantly shaley, which become fresh, unweathered and 'unfractured' at greater depth. Although the studied boreholes all exceeded the depth to watertable of some functional boreholes in the area (28-50 m below the surface), they are all sparsely productive to abortive, suggesting that the concept of a ground water table with regional flow is very likely to be unrealistic in the area. Hence, an integrated geophysical survey method is required to identify productive spots.

Key words: Abakaliki Shale, abortive boreholes, aquiclude, vertical electrical sounding.

INTRODUCTION

In the Abakaliki metropolis (Figure 1), the Ebonyi State Water Company Limited, which is mandated to provide potable water for the inhabitants of city and urban areas, is currently unable to supply adequate quantities due to the ever-increasing population accentuated by inability to expand the infrastructure to cater for the requirement of potable water. Most places do not have pipelines and those who have do not have water flowing through their taps constantly. This has led to the people resorting to alternative means of getting water, such as hand-dug wells, surface water bodies and drilled boreholes, for their daily water needs. The surface water sources are usually associated with diseases and sicknesses. It has been estimated that lack of clean drinking water and sanitation services leads to water-related diseases globally and between five to ten million deaths occur annually, primarily of small children (Snyder and Merson, 1982). This leaves the groundwater the best means of constant and safe water for most inhabitants.

Electrical resistivity method, precisely the vertical electrical sounding (VES), has been extensively employed in groundwater investigation across the world, both in basement and sedimentary terrains (Zorhy et al., 1974; El - Hussaini et al., 1995; Ayers, 1989; Vchery and Hobbs, 2003; Akaolisa, 2006; Tizro et al., 2010; Arabi et al., 2010). In characterizing the anisotropic properties of the fractures of the Abakaliki shales, Odoh and Onwuemesi (2009) indicated that there is significant anisotropy between 0 - 50 m depths, with fractures at depths of 28.3, 40 and 50 m striking NE - SW, NW - SE

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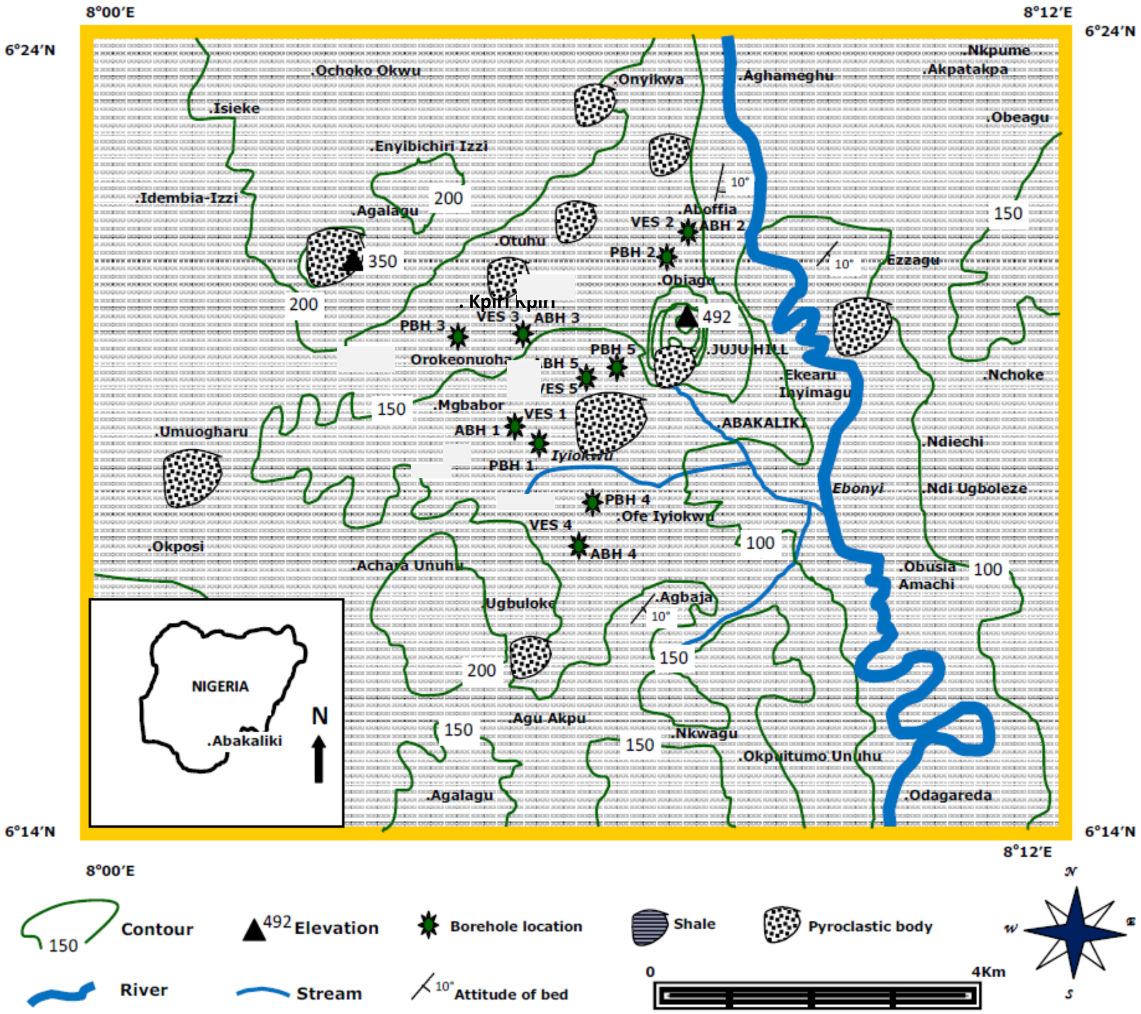

Figure 1. Geological map of the Abakaliki metropolis showing the surveyed locations.

and N-S, respectively, and a better permeability and porosity at the depth of 40 and 50 m. Since the groundwater in Abakaliki area occurs in fractures, faults and/or weathered zones, Odoh et al. (2012) suggested an integrated geophysical approach in investigating groundwater in the area in other to ensure greater percentage of success in interpretation of field results.

The availability and exploitation of the groundwater, on the other hand, is also becoming problematic. While some of the borehole drilled within the Abakaliki metropolis yield water at economic quantity all round the year (productive boreholes), some are only productive only in the peak of the rainy season, and the rest are completely unproductive, and are locally referred to 'abortive' boreholes. The three characters described above could be attributed to the presence of major fracture, presence of minor fracture and entire absence of weathered zone within the environment under investigation.

This work, therefore, attempts to evaluate, by means of geophysical investigation, the possible existence of regional flow within the Abakaliki shales and why five bore-holes despite being drilled in the proximity of (few metres away from) productive ones, failed to yield water at economic quantities. Highlights on the causes of the failure of the boreholes are strictly made on the basis of the results of the geophysical surveys conducted; other probable causes are not much emphasized in this work but can be found elsewhere.

MATERIALS AND METHODS

Description of the study area

Climate

Abakaliki is the capital territory of Ebonyi State, southeastern Nigeria. Two main seasons exist in the Abakaliki area, the dry season which spans from November to March and the rainy season which begins in April and ends in October with a short period of reduced rains in August commonly referred to as "August break". Most hand dug wells and boreholes in this area are renewed during the peak of the rainy season. Temperature in the dry season ranges from 20 to 38°C, and results in high evapotranspiration, while during the rainy season temperature ranges from 16 to 28°C, with generally lower evapotranspiration. A number of hand dug wells are completely dried up in the peak of this season. The average monthly rainfall ranges from 31 mm in January to 270 mm in July, with the dry season experiencing much reduced volume of rainfall unlike the rainy season, which has high volume of rainfall. Average annual rainfall varies from 1,500 to 1,650 mm. These climatic conditions are responsible for the development of thick lateritic soils in the Abakaliki area and its environs (Ezeh and Anike, 2009).

Geology and hydrogeology

The Abakaliki metropolis is, geologically, underlain by the Abakaliki Shale Formation of the Asu River Group (Reyment, 1965). The Asu River Group sediments are predominantly shales, and localized occurrences of sandstone, siltstone and limestone intercalations (Ofoegbu and Amajor, 1987). It was generally believed to have started depositing in the mid-Albian period and was deposited within the lower (or southern) Benue Trough, southeastern Nigeria. The geology of the Abakaliki metropolis is shown in Figure 1. Emplaced in these Asu River Group sediments are intermediates to basic intrusive, extrusives and pyroclastics (Murat, 1972; Nwachukwu, 1972; Ofoegbu and Amajor, 1987; Tijani et al., 1996). The group has average thickness of about 2000 m and rests unconformably on the Precambrian Basement (Benkhelil et al., 1989).

The Abakaliki Shale Formation, which has an average thickness of about 500 m, is dominantly shale, dark grey in colour, blocky and non-micaceous in most locations. It is deeply folded, faulted and fractured by the series of tectonic activities which has acted on the rocks (Ezeh and Anike, 2009). This has given the shales the ability to house groundwater at economic quantity in some areas, while its nature as aquiclude still exist other parts and fracturing is not pronounced. It is calcareous (calcite-cemented) and deeply weathered to brownish clay in the greater part of the formation.

The major part of the Abakaliki metropolis is underlain by aquiclude; except in locations or zones where secondary aquiferous conditions were made possible by syn- and post depositional circumstances. The syn-depositional circumstance is the occurrence of lenses of sandstone or siltstone beds, while the post depositional circumstances include weathering, fracturing or shearing, and volcanic intrusions. The zones are recharged mostly in the peak of rainy season and by surface waters in the area. The major river that drains the area is the Ebonyi River and its tributaries: Udene and Iyiokwu Rivers. Both tributaries are perennial and usually overflow their banks at the peak of the rains.

Methodology

Geophysical survey

The vertical electrical sounding (VES) using the Schlumberger electrode configuration was carried out within the locations of the studied 'abortive boreholes'. The VES stations are shown in Figure 1. The VES survey following guidelines are specified in Telford et al. (1990). The procedure involves driving current into the ground using a pair of electrodes and the resulting distribution of the potential in the ground measured using another pair of electrodes connected to a sensitive voltmeter (a recording instrument).

The difference in the potential in ohms is converted to apparent resistivity by using a factor that depends on the electrode configuration. The recording instrument used was OMEGA 5 (Signal Averaging System, SAS1000). The instrument automatically calculated the average of five cycles of the ratio of the potential difference across the layer and the current passing through the layer layer (recorded in ohms-metre, Ωm).

Some precautions were taken during the field surveys in order to generate an accurate or near accurate data. For example, the electrodes were hammered firmly into the ground to at least a depth of 35 cm in order to avoid error reading and achieve good electrical contacts with the ground. Water was poured at the point of electrode contact with the ground to possibly enhance ionic flow of current; survey was carried in the dry season. Also, positions of the electrodes were kept far away from power-lines to avoid altering the value of the potential difference.

Data analysis and interpretation

The processing of the data generated during the survey involved automatic plotting of apparent resistivity values of the formation surveyed against half the electrode spread with the aid of a computer software, known as OFFIX. This software ensured breaking of the subsurface into distinct layers of differing resistivity in relation to thickness and depth. The shape of the resulting curve depends on the resistivity contrast between the layers. The computer system also used a family of curves, given by Telford et al. (1990), to automatically match the curves and determine the layer resistivity.

RESULTS AND DISCUSSION

A set of resistivity curves obtained by software interpretation of data generated by means of VES surveys in this study is presented in Figures 2 to 6. It can be deduced from the curves that the surveyed portions of the geological formation coincidentally have five to six distinguishable layers. Each of the layers however differs significantly with each other with respect to their resis-tivity to electric current. Despite the variation, however, all the layers recorded relatively high apparent resistivity values (ranging between 50 and 1120 ohm.m).

The VES curves are all 'H - type' curves (Lowrie, 2007). The first (left arm) slope of the curves all occurred before the electrode spacing of 10 m, which is a depth of hand dug wells in Abakaliki and far above the depth of groundwater occurrence which is between 28 and 50 m (Odoh and Onwuemesi, 2009). This situation, geophysically, suggests that these VES points do not have water at economic quantity within the depth of investigation (12 to 25 m) (Figures 2 to 6).

The maximum apparent resistivity value of 1120 ohm m is quite within the ideal values for shale lithologies (Kearey et al., 2002). Schematic sections from the surveyed areas, developed from borehole data (Figures 7 to 11), also point to the fact that the lithology is shale. The smoothness of the H - type curves without any kink along the line suggests a complete absence of the sand-stone lenses usually associated with the Abakaliki shales, as well as the absence of a major fracture/weathered zone which may have water at economic quantity.

The very low yield observed in boreholes drilled at VES 1 and 5, respectively (partly productive in Table 1) suggests presence of minor fractures at the zones less than 10 m deep, of which the fractures are so small and few that the volume of water in them could not give a kink

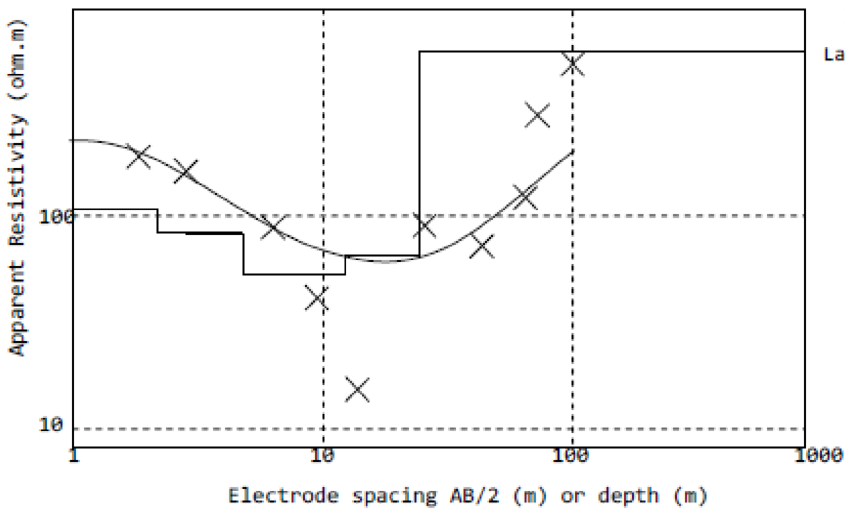

Figure 2. Interpretated model curve for VES 1.

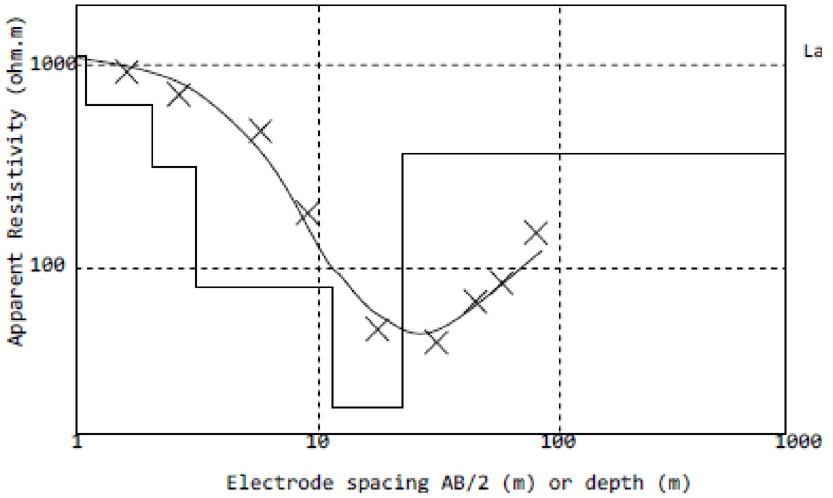

Figure 3. Interpretation model curve for VES 2.

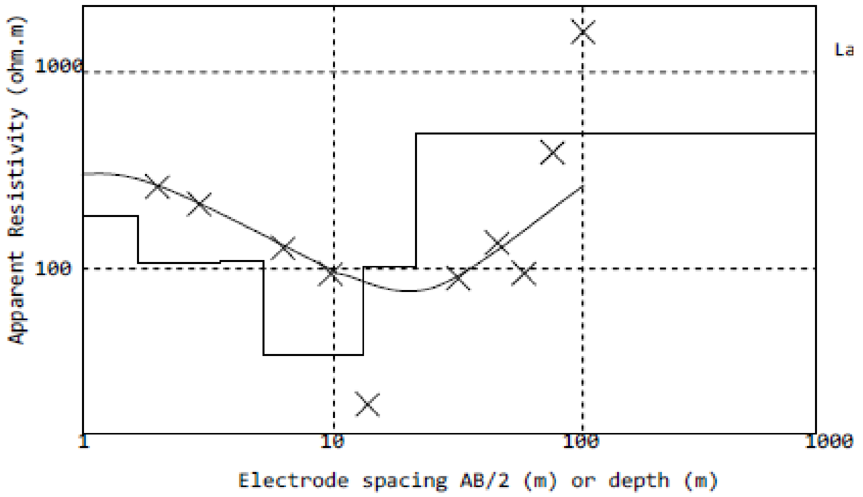

Figure 4. Interpretation model curve for VES 3.

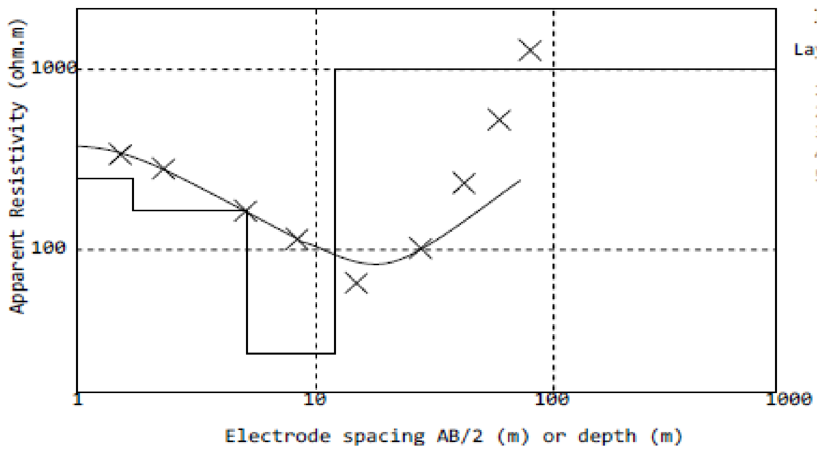

Figure 5. Interpretation model curve for VES 4.

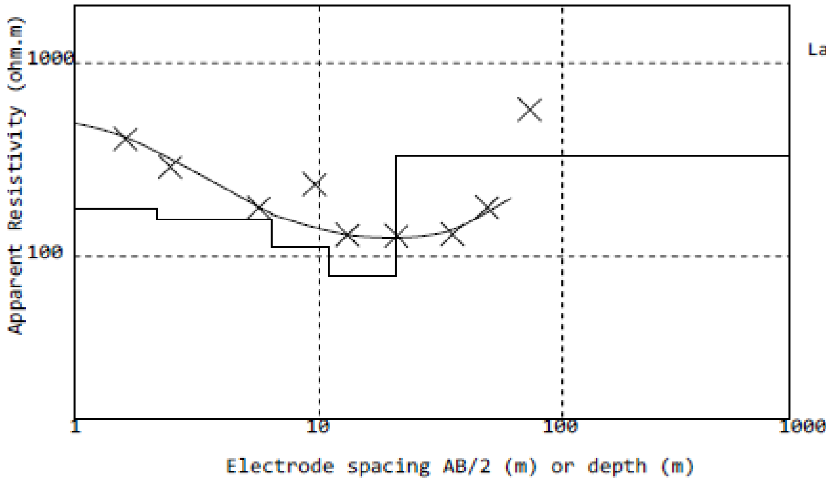

Figure 6. Interpretation model curve for VES 5.

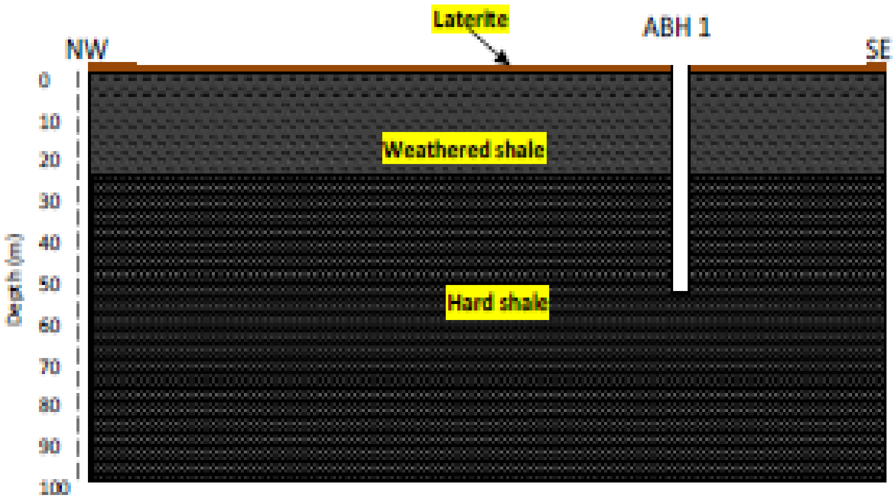

Figure 7. Schematic sections from the surveyed area (VES 1).

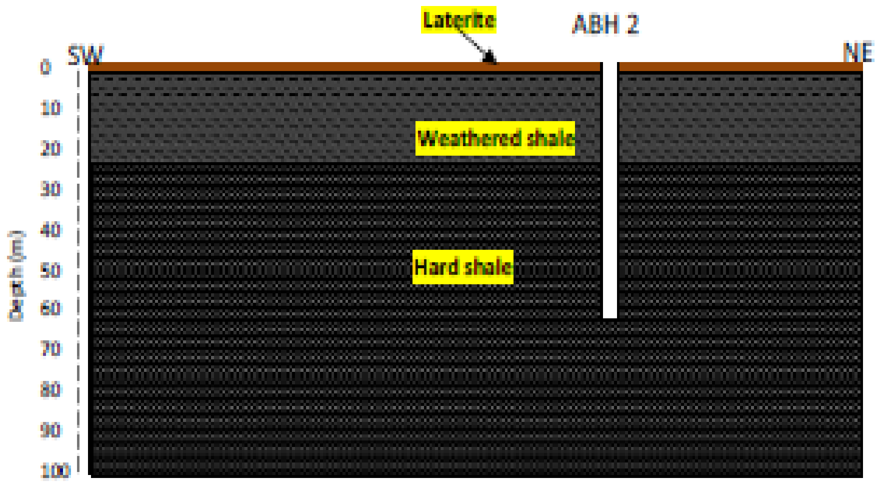

Figure 8. Schematic sections from the surveyed area (VES 2).

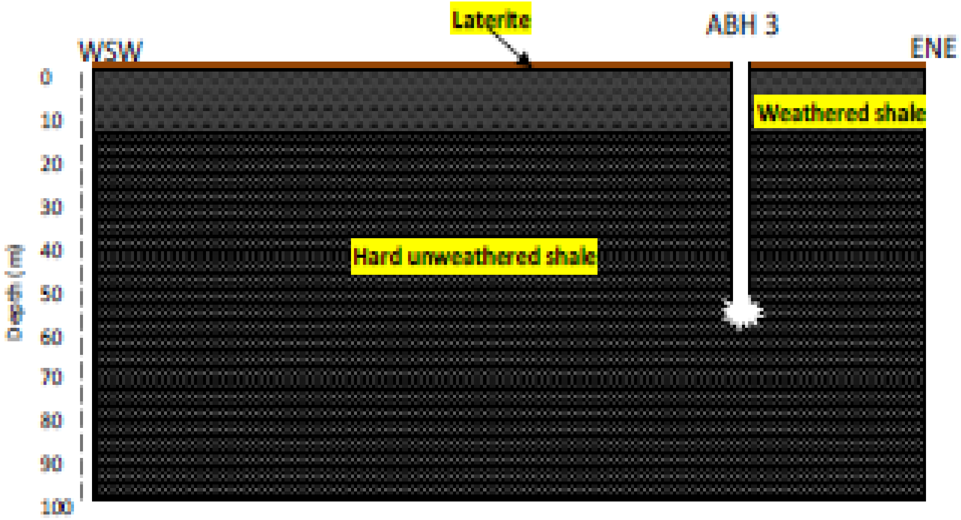

Figure 9. Schematic sections from the surveyed area (VES 3).

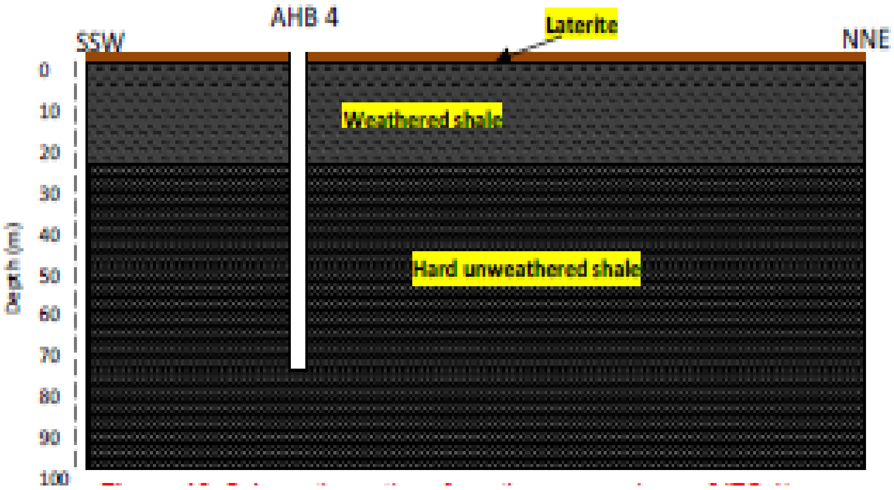

Figure 10. Schematic sections from the surveyed area (VES 4).

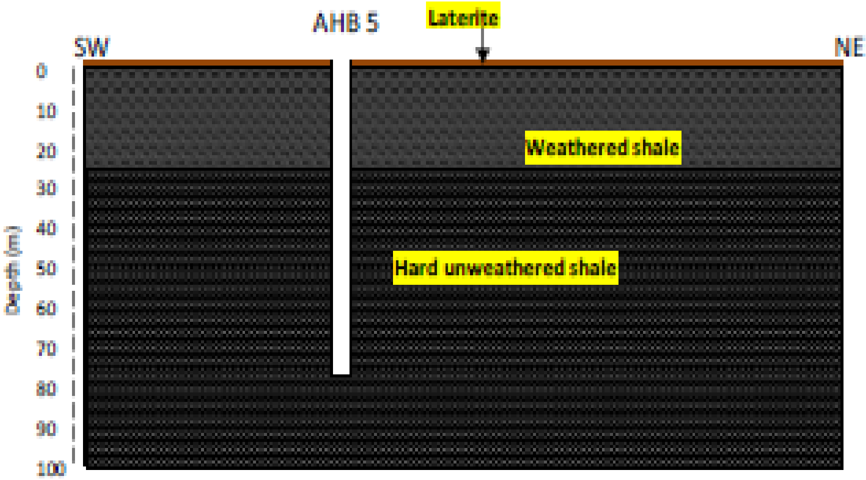

Figure 11. Schematic sections from the surveyed area (VES 5).

Table 1. Summary of the records of some investigated boreholes in the Abakaliki metropolis.

Borehole location	Designation	VES* Station No.	Elevation (m**)	Depth (m)	Drill date	Current status
Presco Campus, EBSU	ABH I	VES 1	54	46	1994	Sparsely productive
Village square, Aboffia	ABH 2	VES 2	65	65	2000	Abortive
Orokeonuoha	ABH 3	VES 3	62	Na	Na	Abortive
Nkaliki, near EBHA[#]	ABH 4	VES 4	54	78	1998	Abortive
Akam Street	ABH 5	VES 5	45	80	2008	Sparsely productive

ABH, Abortive borehole; PBH, productive borehole; **metres-above-sea level; [#]Ebonyi State House of Assembly; - VES not carried out. na: not available.

Table 2. Interpretation model for VES 1.

Layer	Resistivity (ohm.m)	Thickness (m)	Depth (m)
1	240	1.0	1.0
2	105	0.8	1.8
3	85	2.7	4.5
4	50	7.5	12.0
5	68	12.0	24.0
6	520	∞	∞

in the apparent resistivity signature. The water in them can favourably serve a hand dug well but could not satisfy the demand from a borehole, hence, the term low yield or sparsely productive.

A correlation of these resistivity values of the geology of the Abakaliki area give indications that the layers are shales, most probably, with slightly differed water bearing capacities due to heterogeneity in their physical properties. Grain size distribution, sorting, cementation, porosity, permeability and mineralogy (Pettijohn et al., 1973; Prothero and Schwab, 1996), amongst other syn- and post depositional factors, could result in the observed resistivity contrasts in the model layers.

The depths of the studied 'abortive' boreholes ranged from 45 to 80 m (Table 1). It is therefore most likely that they tap the hard shale layer (bottom), with an indeterminate depth and apparent resistivity values that ranged from 320 to 1025 ohm-m, as shown in Tables 2 to 6. Shale, as a geological material, is notoriously known for its low permeability, very low specific yield and high water

Table 3. Interpretation model for VES 2.

Layer	Resistivity (ohm.m)	Thickness (m)	Depth (m)
1	298	1.0	1.0
2	185	0.8	1.8
3	105	2.7	4.5
4	45	8.5	13.0
5	98	2.0	23.0
6	548	∞	∞

Table 4. Interpretation model for VES 3.

Layer	Resistivity (ohm.m)	Thickness (m)	Depth (m)
1	298	0.8	0.8
2	205	1.0	1.8
3	155	4.2	6.0
4	28	6.0	12.0
5	1025	∞	∞

Table 5. Interpretation model for VES 4.

Layer	Resistivity (ohm.m)	Thickness (m)	Depth (m)
1	240	1.0	1.0
2	105	0.8	1.8
3	85	2.7	4.5
4	50	7.5	12.0
5	68	12.0	24.0
6	520	∞	∞

Table 6. Interpretation model for VES 5.

Layer	Resistivity (ohm.m)	Thickness (m)	Depth (m)
1	520	1.0	1.0
2	205	0.8	1.8
3	180	3.7	5.5
4	105	6.5	12.0
5	80	10.0	25.0
6	320	∞	∞

retention capacity. This notoriety become more pronounced if it is fresh and unweathered, thus, been a major reason, among others, why the boreholes failed.

Most hand dug wells, and even some boreholes, in the Abakaliki area dry up in the middle of dry season leaving the town with acute shortage of portable water. This suggests that the ground water source is seriously geologically and climatically influenced. According to Ismael (1990), the fractured and weathered zone shale-aquifer systems have specific yields values as follows: range 1.26×10^{-3} to 1.60×10^{-3} litre per second (l/s) and 1.22×10^{-3} to 1.81×10^{-3} l/s, with average values of 1.48×10^{-3} l/s and 1.59×10^{-3} l/s, respectively. Fresh and unweathered types, however, have specific yield values much lower than these given (Ismael, 1990). Figure 12 reveals that the fracture zones in the study area are sparse and unevenly distributed. Therefore, an idea of a regional groundwater flow in the area is very doubtful.

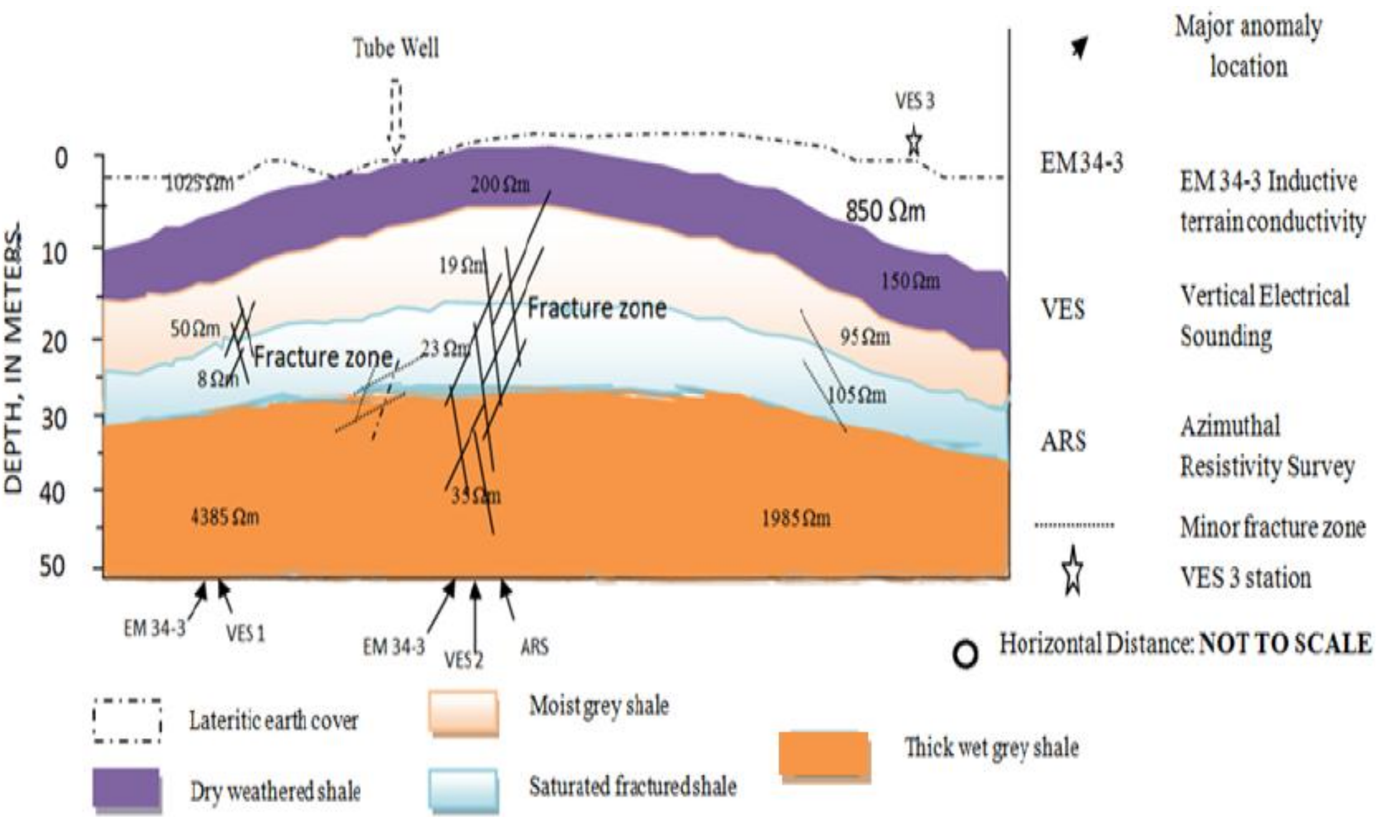

Figure 12. The distribution of fracture zones in the Kpiri Kpiri area of Abakaliki, southeastern Nigeria (Odoh et al., 2012).

Conclusions

This study has provided insights which indicated that the existence of secondary aquifer systems: via weathering, fracturing and lenses of siltstone or sandstone beds, is likely not a continuous (both laterally and vertically) phe0nomenon in the Abakaliki Shale Formation, especially within the Abakaliki metropolis. Consequently, the concept of a ground water table with regional flow is very likely to be unrealistic.

The implementation of a water resources management strategy by the state water corporation is imperative to ensure the availability and sustainable provision of potable water to the inhabitants of the Abakaliki metropolis. This becomes very necessary to reduce the health risk the inhabitant would be exposed to in an attempt to source water from alternative means especially when they are faced with the 'abortive borehole' phenomenon.

The economic wastage, material lost and frustrations associated with 'abortive' boreholes necessitate the need for a thorough geophysical investigation (preferably, an integrated approach) prior to citing of boreholes within some localities in the Abakaliki area. This is despite whether the site is in the proximity or distances away from a productive borehole or hand-dug wells.

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REFERENCES

Akaolisa C (2006). Aquifer transmissivity and basement structure determination using resistivity sounding at Jos, Plateau state, Nigeria. Environ. Monit. Assess. 114:27-34.

Arabi SA., Dewu BBM, Muhammad AM, Ibrahim MB, Abafoni JD (2008). Determination of weathered and fractured zones in part of the basement complex of North-Eastern Nigeria. J. Eng. Technol. Res. 2(11):213-218.

Ayers JF (1989). Conjunctive use of geophysical and geological methods in the study of alluvial aquifer. Ground Water 27:625-632.

Benkhelil J, Guiraud M, Ponsard JF, Saugy L (1989). The Bornu - Benue Trough, the Niger Delta and its offshore: Tectono-sedimentary reconstruction during the Cretaceous and Tertiary from geophysical data and geology. In: Kogbe CA (ed), Geology of Nigeria. 2nd ed. Rock view, Jos.

El-Hussaini AH, Ibrahim HA, Bakhelt AA (1995). Interpretation of geoelectrical data from an area of the entrance of Wadi Qena, eastern Desert, Egypt. J. King Saudi Univ. 7:257-276.

Ezeh HN, Anike OL (2009). The preliminary assessment of the pollution status of streams and artificial lakes created by mining in the mining district of enyigba, southeastern Nigeria, and their consequences. Glob. J. Environ. Sci. 8(1):41-48.

Ismael AMO (1990). Water resources of Abakaliki, Ishielu and Ohaozara areas of SE Nigeria. M.Sc Thesis, Nnamdi Azikiwe University, Awka, Nigeria.

Kearey P, Brooks M, Hill I (2002). An Introduction to Geophysical Exploration. Blackwell Science Ltd. London. p. 281.

Lowrie W (2007). Fundamentals of Geophysics. Cambridge University Press, New York. p. 393.

Murat RC (1972). Stratigraphy and paleogeography of the Cretaceous and lower Tertiary in Southern Nigeria. In: Dessauvagie TFJ, Whiteman AJ (eds). Proceedings of the Conference on African Geology held at Ibadan, Nigeria.

Nwachukwu SO (1972). The tectonic evolution of the southern portion of the Benue Trough, Nigeria. Geol. Mag. 109:411-419.

Odoh BI, Onwuemesi AG (2009). Estimation of anisotropic properties of fractures in Presco campus of Ebonyi State University Abakaliki, Nigeria using Azimuthal resistivity survey method. J. Geol. Min. Res. 1(8):172-179.

Odoh BI, Utom AU, Nwaze SO (2012). Groundwater Prospecting in Fractured Shale Aquifer Using an Integrated Suite of Geophysical Methods: a Case History from Presbyterian Church, Kpiri-Kpiri, Ebonyi State, SE Nigeria. Geosciences 2(4):60-65.

Ofoegbu CO, Amajor LC (1987). A geochemical comparison of the pyroclastic rocks from Abakaliki and Ezillo, southeastern Benue Trough. J. Min. Geol. 23 (1&2):45-51.

Pettijohn FJ, Potter PE, Siever R (1973). Sand and sandstone. Springer-Verlag, Berlin.

Prothero DR, Schwab FR (1996). Sedimentary Geology. W. H. Freeman, San Francisco.

Reyment RA (1965). Aspects of Geology of Nigeria. Ibadan University Press, Ibadan. pp. 145.

Snyder JD, Merson MH (1982). The Magnitude of the Global Problem of Acute Diarrhoeal Disease: A Review of Acute Surveillance Data. Bull. World Meteorol. Organ. 60:605-613.

Telford WM, Geldart LP, Sheriff RE (1990). Applied Geophysics; Cambridge University Press. pp. 334.

Tijani MN, Loehnert EP, Uma KO (1996). Origin of saline groundwaters in Ogoja area, lower Benue Trough, Nigeria. J. Afr. Earth Sci. 23(2): 237-252.

Tizro AT, Voudouris KS, Salchzade M, Mashayekhi H (2010). Hydrogeological framework and estimation of aquifer hydraulic parameter using geoelectrical data: a case study from West Iran. Hydrogeol. J. 18:917-929.

Vchery A, Hobbs B (2003). Resistivity imaging to determine clay cover and permeable units at an ex-industrial site. Near Surface Geophysics 1:21-30.

Zohdy AAR, Eaton GP, Mabey DR (1974). Application of surface geophysics to ground-water investigation. Techniques of Water Resources Investigation, U.S. Geological Survey. p. 116.