JOURNAL OF
ENVIRONMENTAL HYDROLOGY
The Electronic Journal of the International Association for Environmental Hydrology
On the World Wide Web at http://www.hydroweb.com
VOLUME 19 2011

DELINEATION OF FRESH-BRACKISH WATER AND BRACKISH-SALINE WATER INTERFACES USING VES SOUNDINGS IN SHANI, BORNO STATE, NIGERIA

O.T. Nkereuwem
S.N. Yusuf
M.U. Mijinyawa

Department of Geology,
University of Maiduguri
Borno State, Nigeria

Eighteen VES stations established and sounded in 1991 along a SE-NW profile in Shani area were revisited and sounded afresh in 2010. It was observed that VES stations (1 - 9) which revealed four-layered curves in 1991, now revealed six-layered curves in 2010, with significant reductions in layer resistivity values. Analyses of water samples obtained from a hand-dug well and a borehole close to VES stations 3 and 7 respectively, revealed the water from the shallow hand-dug well to be fresh with a TDS value of 0.4 ppt and the water from the deeper borehole to be brackish with a TDS value of over 17 ppt. Two parallel faults reported along the basin of River Hawal by Carter et al. (1963) are suspected to act as migratory routes of salt water to the Bima sandstone aquifer in Shani area. This study has permitted the delineation of the fresh water - brackish water and brackish - saline water interfaces in Shani. The study has revealed that due to considerable mixing of the freshwater with the saltwater, a zone of brackish water has evolved between the freshwater above and the saline water below. The depth to the fresh - brackish water interface in Shani has been established by this study as ranging from 50 to 53 m below ground surface, thus enabling water developers in the area to produce salt-free water for human and industrial uses.

INTRODUCTION

Salt water intrusion of coastal aquifers is a widely reported phenomenon. Etu-Effeotor and Michalski (1989) worked on salt water intrusion in the coastal areas of parts of the eastern Niger Delta. On the other hand, saltwater intrusion of distant aquifers from the coast is rare. The situation in Shani (Figure 1) which is over 400 km from the coast of the Gongola River is somehow puzzling. In the area, previously fresh water boreholes and hand-dug wells have become saline with time and chlorine contents now range well over 600 ppm. It is obvious that a sound knowledge of this problem and its causative factors is vital to the success of future groundwater development projects in Shani area.

In order to find solutions to this problem, the present study was conducted to establish the correct fresh water – brackish water interface, the brackish water – salt water interface and probably to detect the source of the intruding salt water. It is hoped that the findings of this work will guide future borehole drilling programs in Shani and that the loss of fresh water boreholes to salt water will be minimized.

STRUCTURAL GEOLOGY

Structurally, the project area lies within the Gongola arm of the Benue valley and as such movements that led to the deformation of the sediments/basement within the Benue valley would have probably extended to the northwestern and southwestern parts of Shani area or even further. This is illustrated in Figure 2. There is an evidence of faulting in the Hawal Basin during the pre-Cretaceous faulting (Carter et al, 1963) which is situated on the eastern flank of Bogna Hills. The fault bounds the Hawal Valley on the west and is approximately parallel to the middle Benue Valley; suggesting that this line must have been controlled by the pre-Upper Cretaceous faulting.

The major linear features of this area as observed from aerial photos as well as from existing compilation of topographic and Geologic maps of the study area are as follows:

(1) Hawal Valley

(2) Foliation trends

(3) Cracks and fractures

(4) Faults.

The Hawal Valley which has an evidence of faulting line parallel to Middle Benue Valley depicts a probable pre-Upper Cretaceous movement which led to the fracturing of rocks, trending approximately in a SW-NE direction across the region.

HYDROGEOLOGY AND HYDROLOGY

The hydrogeology of Shani area will be considered under two aspects; viz: surface water and groundwater.

The Hawal River which drains the entire area and flows into River Gongola, forms the main source of surface water in Shani area. Other sources such as small intermittent tributaries joining the main river are significant. The volume of water in River Hawal depends on the response to wet and dry seasons. During the rainy season, there is a great increase in flow volume in the main river, while there is hardly water in it during the dry season.

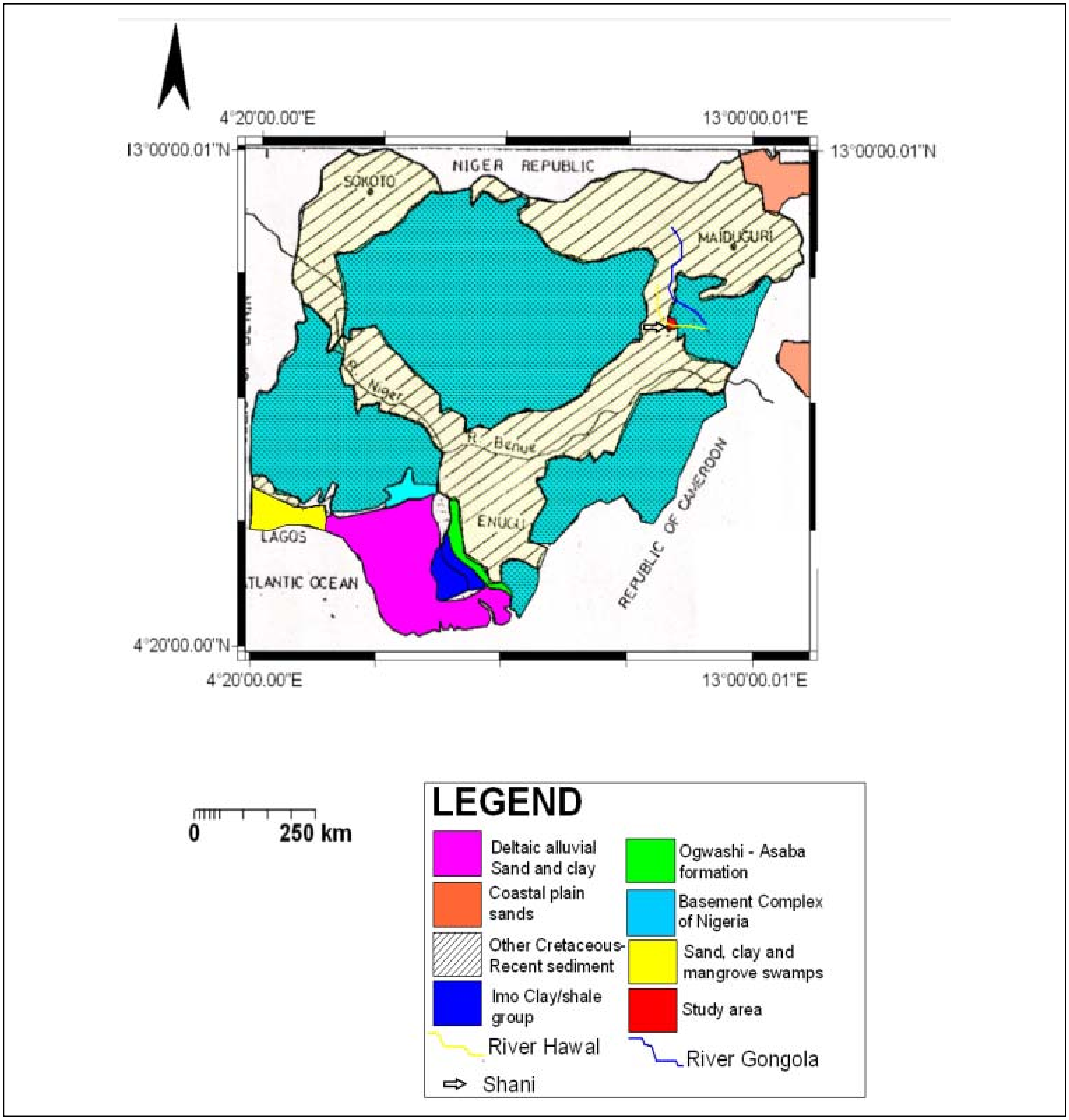

Figure 1. Map of Nigeria showing location of study area.

Rainfall is the major source of recharge in Shani area. During the rainy season, the Shani catchment area enjoys a fairly high amount of rainfall. Rainfall data gathered in the last 30 years show that rainfall is highest in August and lowest in November (Consulint, 1976). The average annual rainfall is about 780 mm (Consulint, 1976). The higher the precipitation over an area, the greater the recharge. Consulint (1976) observed that the water table falls progressively throughout the dry season in the study area and that the amount of fall is determined by the distance between the well and River Hawal. Generally, the closer a well is to the river channel, the smaller the fall. Since the groundwater in the area is unconfined, there is seasonal fluctuation in the water table (Consulint, 1976). The aquifer system in the area consists of two major components. These are the weathered layer of the basement and the fractured part of the fresh basement (Consulint, 1976).

FIELD PROCEDURE

Using the ABEM terrameter SAS 300C and adopting the Schlumberger array with a maximum current electrodes separation of 400 m, Nkereuwem (1991) sounded 229 VES stations in Shani area, along selected profiles. Notable among the profiles sounded in 1991, was a NE-NW profile, EE' (Figure 2) along which were sounded eighteen VES stations. The said profile was revisited and sounded using the same equipment, same array and same current electrodes separation in 2010, nineteen years later, with a view to sounding the eighteen stations afresh, to observe possible changes in the shapes of the VES curves with time. The first nine VES stations (1 – 9) was sounded on the profile EE' in 2010 revealed six-layered curves as against the four-layered curves which they all revealed in 1991. Stations (10 – 16) revealed the same four-layered curves which they revealed in 1991. Thus, only sixteen VES stations (1 – 16) were sounded in 2010 (Figure 2). Results obtained from the 1991 investigation were used to draw the hydrogeological section in (Figure 4), which correlated well with the borehole log of No.2 in Shani area (Figure 5); while the 2010 results were used to draw the hydrogeological section in Figure 8.

The techniques of VES sounding are well discussed in standard textbooks (Dobrin, 1976; Telford et al., 1976; Kearey & Brooks 1984) and so no further comments will be made on this aspect

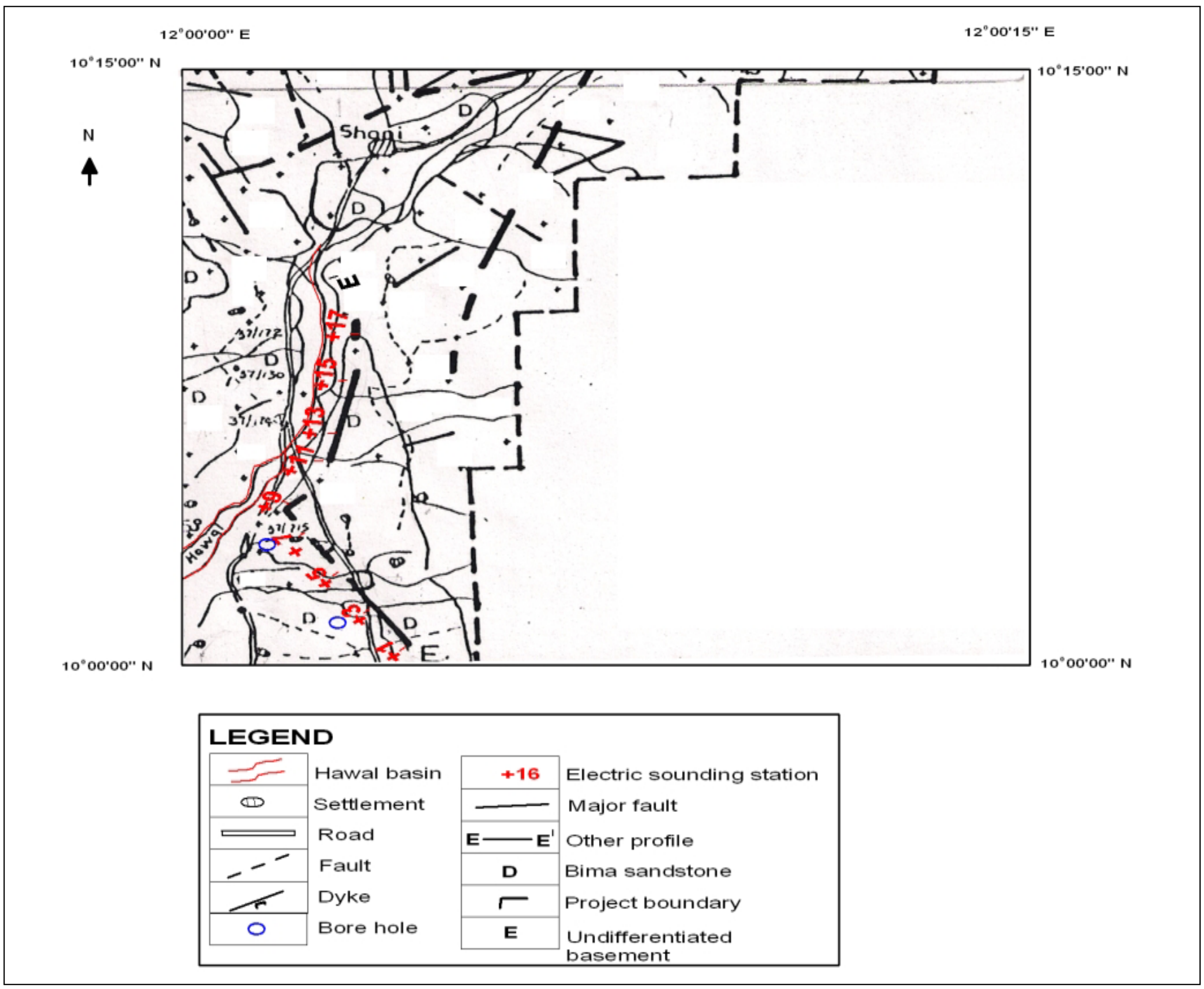

Figure 2. Site map showing fractures and sounding points (after Nkereuwem, 1991).

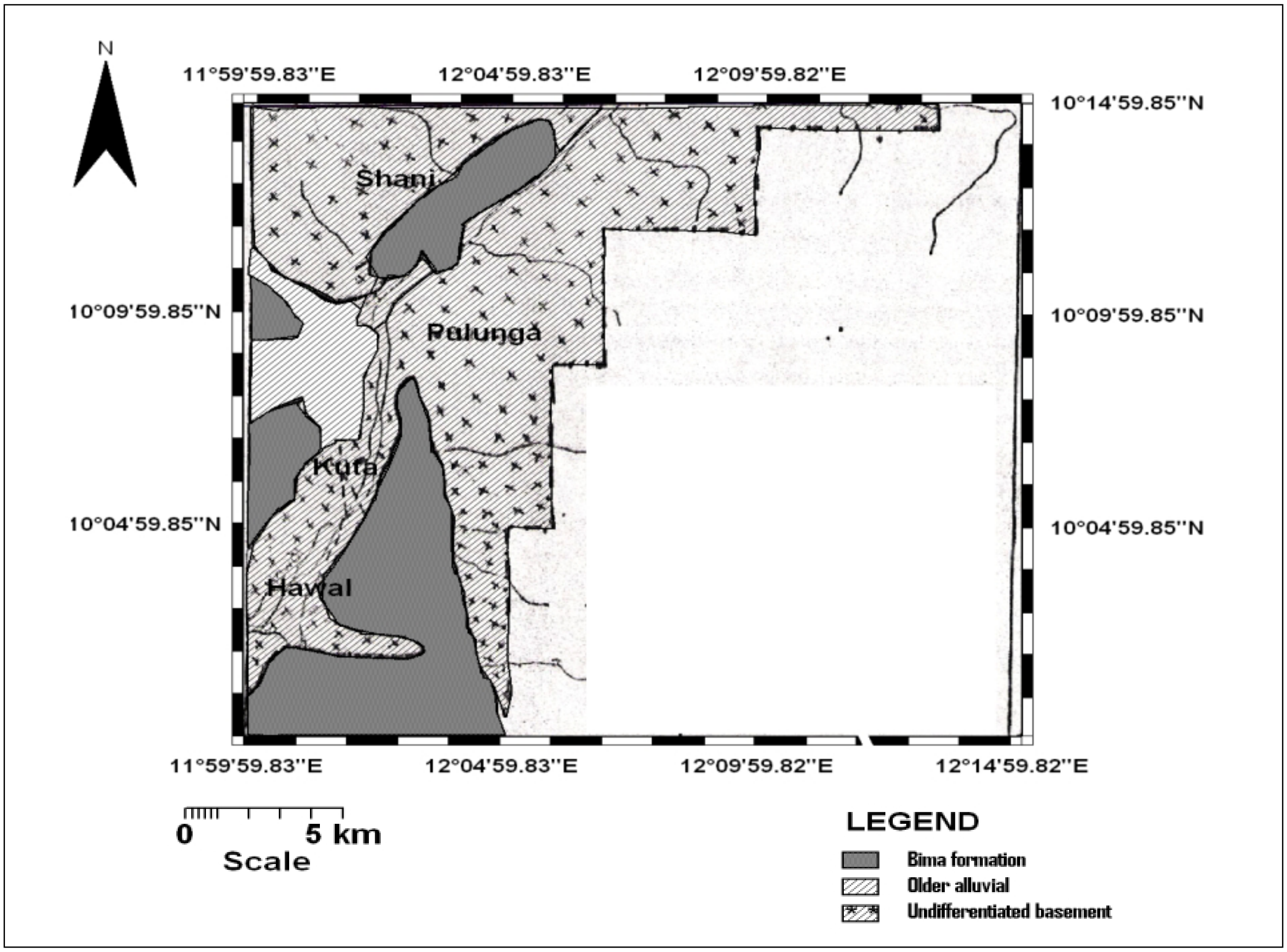

Figure 3. Geological map of Shani area (after Consulint.1976).

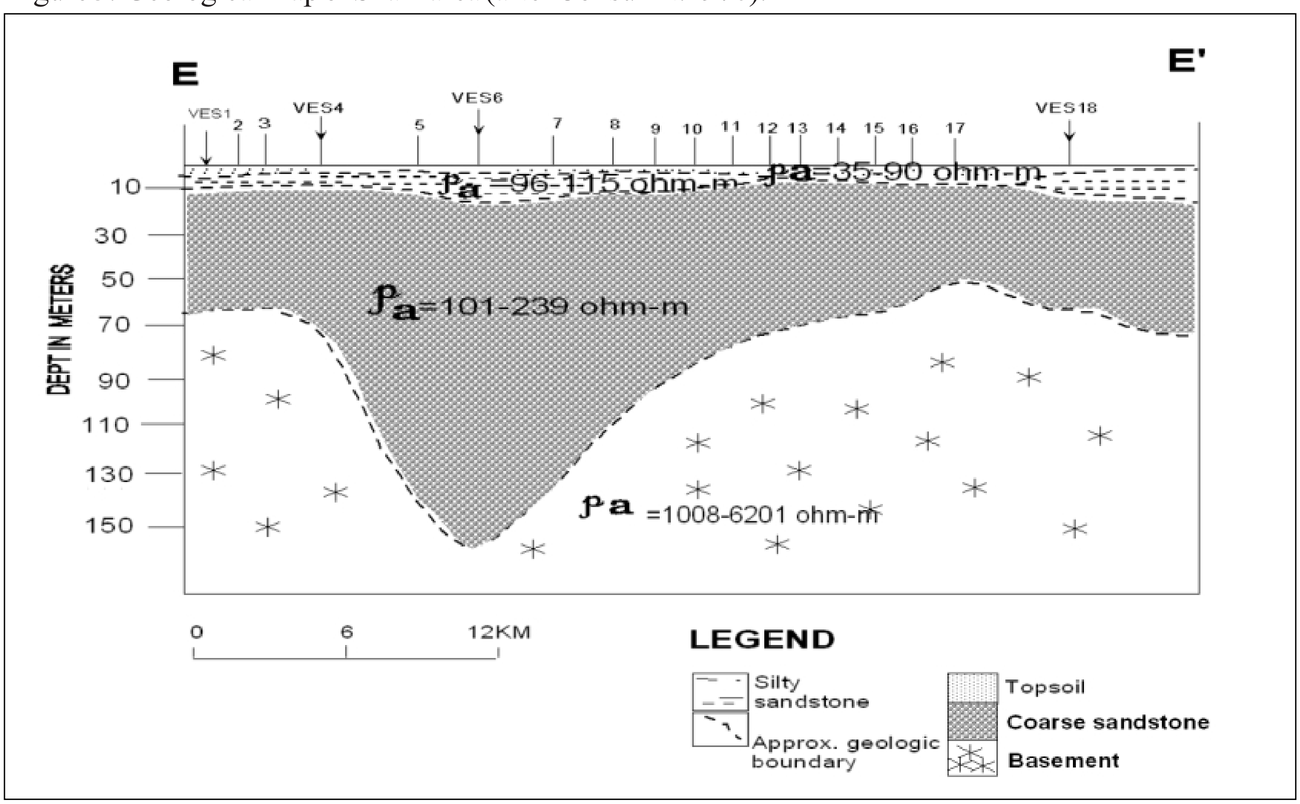

Figure 4. Hydrogeologic section across E-E' (after Nkereurem, 1991)

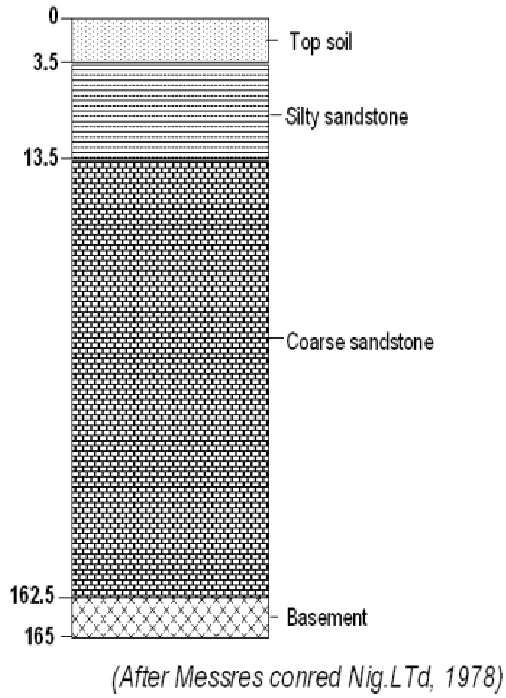

Figure 5. Borehole log of well No. 2 (in meters).

INTERPRETATION OF GEOPHYSICAL DATA

The VES curves obtained at the sixteen stations sounded in this work were interpreted using the IPI2win Resistivity software and the results used for the construction of the hydrogeological section in Figure 8. Some of the results are also presented in Figure 6.

Unlike the four-layered structure obtained at all stations sounded along the profile EE' in 1991, the situation was quite different in 2010 as VES stations (1 – 9) yielded six-layered structure, while VES stations (10 – 16) retained their four-layered structure (see Figures 4 and 8). The work has established that the rock layer saturated with fresh water ranges in resistivity from 91 to 188.2 Ohm-m; the layer saturated with brackish water ranges in resistivity from 61 to 85.6 Ohm-m,while the layer saturated with saline water ranges in resistivity from 42 to 51.1 Ohm-m. The increase in the number of layers at VES stations (1 – 9) from four in 1991 to six in 2010 is interpreted in this work as occasioned by the saltwater intrusion of the aquifer beneath those VES points (Figure 8).

Results obtained at VES station 5 in 1991 as well as in 2010 are presented in Figures 6 and 7 respectively. A comprehensive interpretation of the two sets of results obtained along the profile EE' (Figure 2) has permitted the delineation of the fresh – brackish water and the brackish – salt water interfaces in Shani.

DISCUSSION

Shani is drained by the Hawal Basin which is a major tributary of River Gongola, which is an arm of the Benue Valley (Figure 1). River Benue is a major tributary of River Niger which is salty. Previous works in Shani by Carter et al. (1963) and Bassey et al.(2000) all reported evidences of faulting even beyond the area. Nkereuwem (1991) confirmed that the Hawal Basin is bounded by two parallel faults (Figure 2). The most plausible explanation is that major Southwest-Northeast

S/N	Resistivity (ohm-m)	Thickness (m)	Rock type
1	35.4	1.5	Topsoil
2	112.3	8.2	Silty sandstone
3	239.8	69.8	Coarse sandstone
4	6201.1	_	Fresh Basement

(After Nkereuwem,1991)

Figure 6. Interpretation of VES data at Station 5 in 1991.

S/N	Resistivity (ohm-m)	Thickness (m)	Rock type
1	32.7	1.5	Topsoil
2	106.5	8.2	silty sandstone
3	188.2	412	Coarse sandstone (satureted with fresh water)
4	85.6	17.8	Coarse sandstone (saturated with brakish water)
5	51.1	9.8	Coarse sandstone (saturated with saline water)
6	1003.4	–	Fresh Basement

Figure 7. Interpretation of VES data at Station 5 in 2010.

trending faults from Rivers Niger and Benue are interconnected with these reported faults to intrude the Bima Sandstone aquifer in Shani area.

The two visible faults on both sides of the Hawal Basin (Figure 2) might be serving as migratory routes for salt water from River Niger through River Benue to the Bima Sandstone aquifer in Shani area. This assumption is strengthened by the results of a parallel study by Nkereuwem et al, (2010),

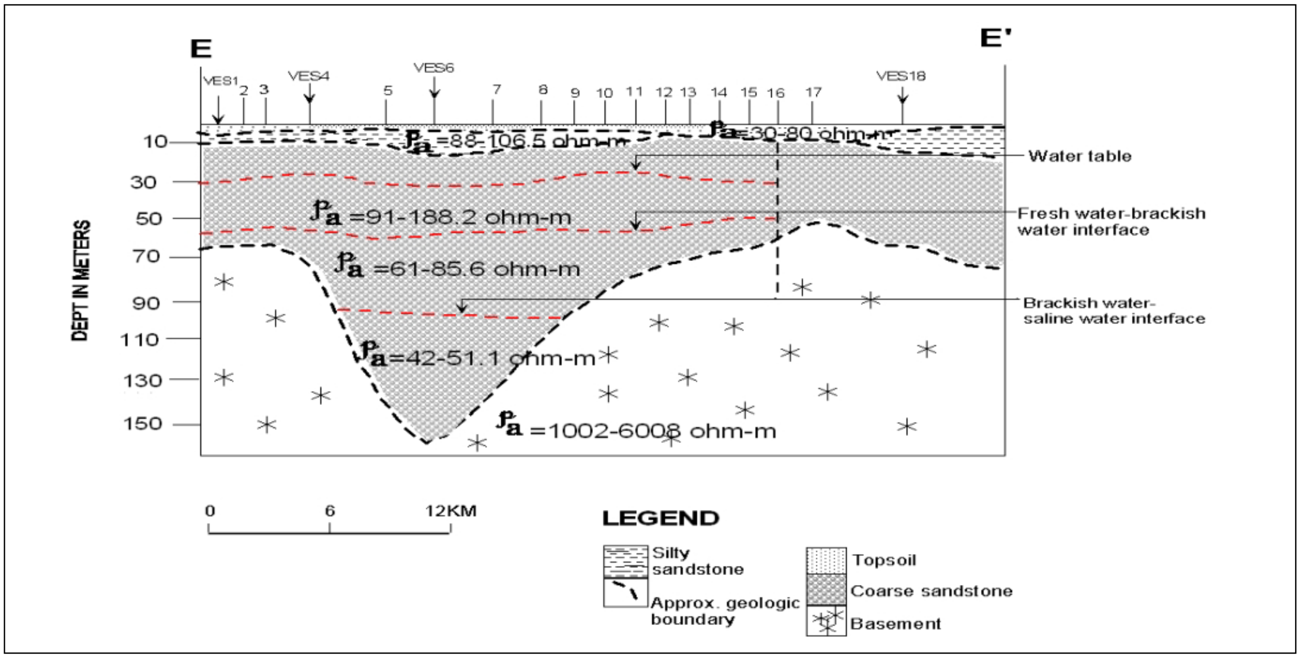

Figure 8. Hydrogeologic section across E-E' in 2010 showing probable fresh-brackish water and brackish-saline water interfaces.

in which faults and other lineaments were established as migratory routes of water from Lake Chad in Northeastern Nigeria to the Benue Trough in the central parts of the country.

CONCLUSION

The depth to the fresh – brackish water interface in Shani area ranges from 50 to 53 m below ground surface. There is a progressive intrusion of the fresh water aquifer in Shani by saltwater which seems to be using extensive faults as migratory routes.

RECOMMENDATION

It is recommended that further drilling programmes in Shani area should be guided by the results of this and similar studies to avoid future encounters with brackish or saline water in boreholes.

ACKNOWLEDGMENTS

We acknowledge the effort of Prof. E.A. Fayose Department of Geology and Mineral Sciences, Crawford University Igbesa Ogun State and Dr. I.B. Goni of Department of Geology, University of Maiduguri, Maiduguri Borno State for reviewing our paper.

REFERENCES

Bassey, N.E., A. Nur, and G.I. Obifuna. 2000. Analysis of Aerial photographic data over Guyuk area, North-eastern Nigeria. Journal of mining and Geology, Vol. 36(2), pp. 145-152.

Carter, J.D., W. Barber, and E.A. Tait. 1963. The geology of parts of Adamawa, Bauchi and Bornu provinces in north eastern Nigeria. Bulletin No. 30, Geol. Survey of Nigeria.

Consulint (Nigeria) Ltd. 1976. Water survey of the North-eastern state. General report, Vol. 4, Borno State Water Board, Maiduguri.

Dobrin, M.B. 1976. Introduction to geophysical prospecting. McGraw-Hill Inc; New York.

Etu – Effeotor, J.O., and A. Michalski. 1989. Geophysical investigation for groundwater in parts of the eastern Niger Delta. Journal of mining and geology, Vol. 25, 1 and 2.

Kearey, P., and M. Brooks. 1984. An introduction to geophysical exploration. Blackwell scientific publications, Osney Mead; Oxford.

Nkereuwem, O.T. 1991. Electrical and hydrogeological investigations for underground water in Shani area (Borno state), Nigeria. Unpublished Ph.D thesis, Department of Geology, University of Ibadan. Nigeria.

Nkereuwem, O.T., M.U. Mijinyawa, and S.N.Yusuf. 2010. Faults and prominent lineaments: migratory routes of water from Lake Chad to the Benue Trough. Continental Journal of Earth Sciences, Vol. 5, pp. 1 – 7.

Telford, W.M., L.P. Geldart, R.E. Sheriff, and D.A. Keys. 1976. Applied geophysics. Cambridge University press; Cambridge.

ADDRESS FOR CORRESPONDENCE
S.N. Yusuf
Department of Geology
University of Maiduguri
Borno State, Nigeria

Email: solomonnyusuf@yahoo.com