Groundwater Investigation using 2-D Electrical Resistivity Imaging (ERI) at Ilubirin, Southwestern Nigeria

A. I. Olayinka, M. O. Oladunjoye, A. O. Korodele

Abstract-- There have been reported cases that the presence of tar sands deposits that are startigraphically and structurally controlled within the study has penetrated (seep) into the hand-dug wells causing blockage to the flow of groundwater; subsequently leading to contamination making groundwater unpalatable to the people within the area. In this research, non-destructive geophysical investigation techniques comprising eight 2-D Electrical Resistivity Imaging (ERI) were taken with Wenner Configuration at Ilubirin, Southwestern, Nigeria. The Electrical Resistivity Imaging has a maximum electrode spacing (AB) of 150m. Two Electrical Resistivity Imaging profiles were taken very close to the contaminated hand dug well along the area where tar sands seepages were sighted. The current and potential electrodes were kept constant at equal interval to one another with the potential electrodes in the middle. The result obtained showed that areas with depression having true resistivity ranging from 192Ωm to 426Ωm with a geological formation described as clayey sand can serve as very good groundwater potential zones which are probably not vulnerable to contamination if proper groundwater management is done.

Index Terms: Contamination, Groundwater, Hand-dug well, Resistivity, Seepages, Tar sand, Vulnerable.

1 Introduction

Water has been described as the elixir of life. This is because it is an essential commodity to humanity. It is found everywhere in the earth's ecosystem however, the only naturally occurring in organic liquid and is the only chemical compounds that occurs in normal condition as a solid, liquid, and gas. However the water, which exists in such abundance on the terra (earth), is unevenly distributed in both time and space and in circulation [10].

The exploration and exploitation for groundwater resources has been on the increase and every government is making invigorating effort to meet the demands of her citizenry with respect to the supply of potable water for their consumption. Most Nigerians rely on groundwater abstraction because it is easier and cheaper to develop. As a result, it is imperative to understand groundwater potability and its vulnerability to contamination or pollution. Groundwater quality has been comprised as a result of anthropengic activities rendering groundwater resources unwholesome for consumption and other uses [1].

Series of research work has been carried out at the Dahomey basin. It dates back from 1954 to 1961 where oil companies were interested in exploring for the presence of hydrocarbons (petroleum and oil sands) leading to the drilling of oil wells such as Bodashe-1 well, Illepaw-1 well, Afowo well, and Ojo - 19 well [4]. [2] conducted geoelectric sounding, hydrogeochemical and hydrogeophysical investigations of the eastern Dahomey basin, and the adjoining basement complex in the southern part of Ondo State. Their result showed that saline intrusion occurred at the silt/fine sand substratum. However, in this research, 2-D Electrical Resistiving Imaging was carried out to delineate the proper aquifer for groundwater development, planning, and construction within the studied area.

2 Geology and Stratigraphy of The Studied Area

The studied area lies within the eastern portion of the Dahomey basin, Southwestern Nigeria is in the Gulf of Guinea, West Africa. It is bordered to the north by the crystalline rocks of the southwestern Nigeria Basement Complex and to the South by the Atlantic Ocean christened the Bight of Benin. The Dahomey basin comprises inland basin that stretches from south-eastern Ghana through Togo and the Republic of Benin to southwestern Nigeria. It is separated from the Niger Delta by a subsurface Basement high known as the Okitipupa Ridge. Its offshore extent is poorly defined [6]. The Dahomey Basin covers much of the continental margin of the Gulf of Guinea, extending from Volta-Delta in Ghana in the west to the Okitipupa Ridge in the east. The basin is a marginal pull-apart basin [17] which developed in the Mesozoic due to the separation of African from Southern American plate in the Mesozoic era [12], [16]. The eastern Dahomey Basin (the part within Nigeria sector) contains extensive wedge of Cretaceous to Recent Sediments, up to 3000m which thickens towards the offshore. The sediment deposition in the basin follows the east-west trend. The summary of the general sequence of the Nigeria section of the eastern Dahomey basin is shown in the table 1 below:

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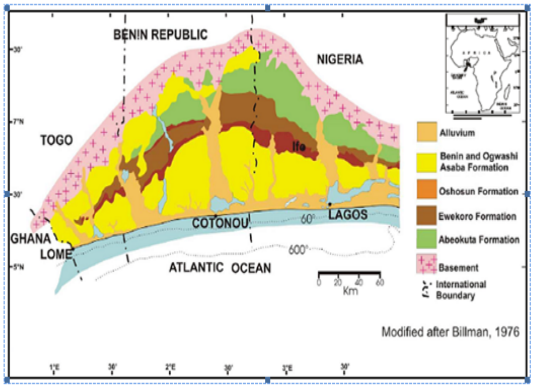

Fig 1: Geological Map of Dahomey Basin (After Billman, 1976)

TABLE 1
RECOGNIZED STRATIGRAPHIC SEQUENCE WITHIN THE EASTERN DAHOMEY BASIN

JONES AND HOCKEY (1964)		REYMENT (1965)		ADEGOKE (1969)		FAYOSE (1970)		BILLMAN (1976)		OMATSOLA (1981)		AGAGU (1985)	
AGE	FORMATION	AGE	FORMATION	AGE	FORMATION	AGE	FORMATION	AGE	FORMATION	AGE	FORMATION	AGE	FORMATION
RECENT	ALLUVIUM	RECENT	ALLUVIUM	RECENT TO POST-EOCENE	BENIN	EARLY MIOCENE	BENIN	LATE MIOCENE	BENIN IJEBU	PLEISTOCENE TO OLIGOCENE	COASTAL PLAIN SANDS	RECENT	ALLUVIUM
PLEISTOCENE TO OLIGOCENE	COASTAL PLAIN SANDS	PLEISTOCENE PLIOCENE NEOCENE	BENIN IJEBU		OGWASHI ASABA	EARLY MIOCENE & LATE OLIGOCENE	OGWASHI ASABA	MIDDLE & EARLY MIOCENE	AFOWO BEDS			PLEISTOCENE TO OLIGOCENE	COASTAL PLAIN SANDS
LATE MIDDLE AND EARLY EOCENE	ILARO	MIDDLE EOCENE EARLY EOCENE	AMEKI OSHOSUN	EOCENE	AMEKI OSHOSUN	EARLY OLIGOCENE TO MIDDLE EOCENE	AMEKI	MIDDLE EOCENE	OSHOSUN	EOCENE	ILARO OSHOSUN	EOCENE	ILARO OSHOSUN
PALEOCENE	EWEKORO	PALEOCENE	IMO EWEKORO SHALE	PALEOCENE	IMO SHALE EWEKORO	EARLY EOCENE & PALEOCENE	IMO	EARLY EOCENE & PALEOCENE	IMO SHALE	PALEOCENE	EWEKORO	PALEOCENE	EWEKORO
LATE SANTONIAN	ABEOKUTA	DANIAN LATE CRETACEOUS	NKPORO SHALE ABEOKUTA WHERE SANDY	NOT DISCUSSED	ABEOKUTA	LATE CRETACEOUS UPPER MAAST-RICHTIAN	ABEOKUTA	EARLY PALEOCENE DANIAN MAASTRIC-HTIAN SENONIAN TURONIAN ALBIAN	NKPORO SHALE AWGU ABEOKUTA RESTRICTED UNNAMED ALBIAN SANDS	MAAST-RICHTIAN TO NECOMIAN	ARAROMI FORMATION AFOWO FORMATION ISE FORMATION	MAAST-RICHTIAN TO NECOMIAN	ARAROMI MEMBER AFOWO MEMBER ISE MEMBER
PRE-CAMBRIAN	CRYSTALLINE BASEMENT	PRE-CAMBRIAN	CRYSTALLINE BASEMENT				CRYSTALLINE BASEMENT	PRE-ALBIAN	UNNAMED OLDER FOLDED SEDIMENTS				

3 DESCRIPTION OF 2-D ELECTRICAL RESISTIVITY IMAGING (ERI) METHOD

The greatest limitation of the resistivity sounding method is that it does not take into account horizontal changes in the subsurface resistivity. A more accurate model of the subsurface is a two-dimensional (2-D) model where the resistivity changes in the vertical directions, as well as in the horizontal direction along the survey line. In this case, it is assumed that resistivity does not change in the direction that is particular to the survey line. To obtain a good 2-D picture of the subsurface, the coverage of the measurements must be 2-D as well. In a typical survey, the electrodes are placed along a straight line with a constant spacing between the electrodes. The figure below shows possible sequence of measurements for the Wenner electrode configuration for a system. In this example, the spacing between adjacent electrodes is ‘’a’’.
Ohmega Resistivity Meter was used to obtain 2-D Electrical Resistivity measurements at eight (8) traverses in the following directions: traverse 1(NE-SW), traverse 2 (NE-SW), traverse 3 (W-E), traverse 4 (N-E), traverse 5 (N-E), traverse 6 (N-S), traverse 7 (W-E), and traverse 8 (W-E).

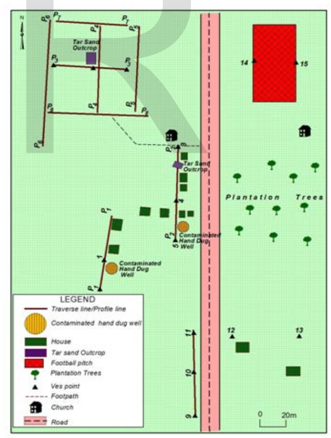

Fig.2: Location Map of Studied area showing traverses and VES points.

Fig. 3: Existing contaminated hand-dug well at the studied area.

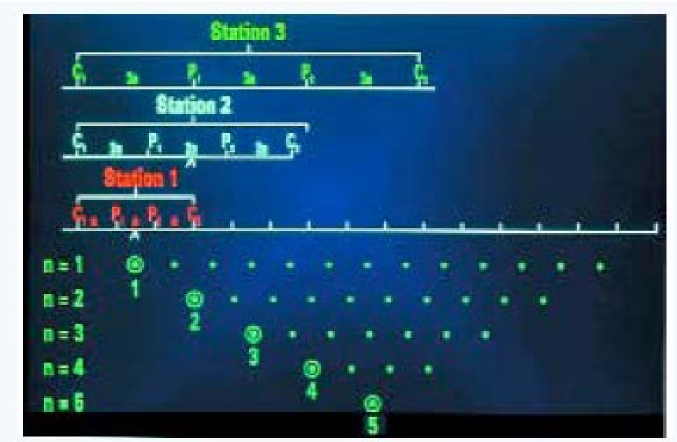

Fig. 4: The arrangement of electrodes for 2-D Electrical Resistivity Imaging and the sequence of measurements used to build up pseudosections to define apparent resistivities at greater depths (adapted by Dahlin, 1993).

4 DISCUSSIONS OF RESULTS

The 2-D resistivity data obtained from the studied area was interpreted using Dipro^{tm} software. Dipro provides a rapid fully automated inversion. It adopts its unique regularization algorithm based on the model parameters resolution analysis [7] to provide higher resolution and more stable performance. It also provides high resolution colour or contour images of both the field data pseudosection and the two-dimensional resistivity distribution resulted from the inversion. To obtain the maximum information about the resistivity distribution within the earth when lateral changes are present, a combination of dc-resistivity sounding and profiling are used. The apparent resistivity data from such measurements can be presented as basic form of electrical image referred to as pseudosection which is a vertical cross-section of the apparent resistivity of the earth along the line of traverse, a concept introduced by [8] for use with dipole-dipole surveys.

4.1 Traverse 2

A 100m 2-D Electrical Resistivity survey was carried out parallel to traverse 1. The result shows the distribution of the high electrical resistivity values ranging from 553Ωm to 1700Ωm [15] with a depth of 1m to 6m in the top left of the northeast of the survey area and is geologically interpreted as lateritic cover. The subsurface layer underneath the lateritic cover with resistivity value between 219Ωm and 480Ωm can be described as clayey sand which occurs between 10m and 15m. The tar sands formation occur at a depth between 2m and 25m in the southwestern part extending towards the central part of the subsurface image with a true resistivity varying from 46Ωm to 98Ωm [13] while at the northeast portion of the model it occurs from the depth of 15m. A conductive layer described as clay/shale found underlying the tar sand formation with resistivity value from 0Ωm to 34Ωm [13] at a depth of 10m to 25m. A thin layer with a true resistivity ranging from 101Ωm to 170Ωm [14] occurring at the northeast and at the top of central position is probably described geologically as the sandy clay. It is seen along 47m to 60m of the traverse.

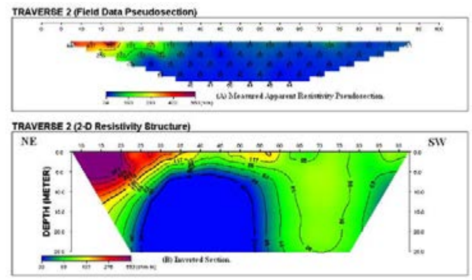

Fig. 5: 2-D Electrical Resistivity Distribution of Traverse 2.

4.2 Traverse 5

The subsurface model reveals a high resistivity value varying from 597Ωm to 1001Ωm [15] for the superficial layer stretching from the north to the south. This geological formation was described as the lateritic cover occurring at a depth from 1m to 4m. Clayey sand occur as thin layer underlying the lateritic cover having true resistivity between 212Ωm and 490Ωm at depth 4m to 6m in the northern portion of the model while its depth extends to 50m at the southern portion. This is a good aquiferous zone for groundwater management for the people within the area. Tar sands deposits with a true resistivity between 45Ωm and 75Ωm [13] are found at the flank of the north portion extending to the central portion before a discontinuity which was as a result of deposition and then appearing at the flank of the south end of the subsurface model. Its depth of occurrence is about 25m. Impregnation of clay/shale is seen in the model to occur with the tar sands having a true resistivity between 27Ωm and 35Ωm. It extends from a depth of 10m to 18m at the northern portion while at the central it occurs between the depths of 10m to 15m. Overlying the tar sands deposit is a thin layer of sandy clay with a true resistivity between 127Ωm and 170Ωm.This occur at the depth of 3m.

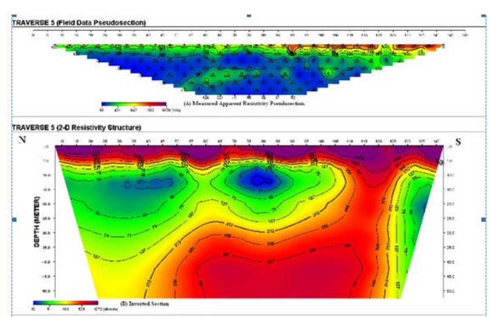

Fig. 6: 2-D Electrical Resistivity of Traverse 5.

4.3 Traverse 6

This traverse reveals topsoil with high resistivity regions 510Ωm to 810Ωm starting from the beginning of the profile in the north direction extending towards the south end portion. The true resistivity is seen to be pertinent for the topsoil and is described as laterite. The depth of occurrence is 6m. A thin layer of clayey sand with true resistivity ranging from 202Ωm to 500Ωm at both the northern and southern portion of the model while the central portion has depression with true resistivity of 202Ωm is apportion the same geological lithology with thickness of 40m. This area can be regarded as good aquiferous zone for groundwater planning and management. A thin layer of sandy clay formation was found underlying the clayey sand with true resistivity ranging from 127Ωm to 200Ωm. Tar sands horizon was encountered at 10m to 50m with true resistivity of 32Ωm to 80Ωm at both the north and southern portion of the subsurface model but discontinued at the central part. The result of the discontinuity was a result of sediment deposition (regressive erosion). A low true resistivity value ranging from 0Ωm to 32Ωm was seen at the bottom flank in the northern portion and at traverse distance from 70m to 115m towards the southern portion is described as clay/shale formation [11].

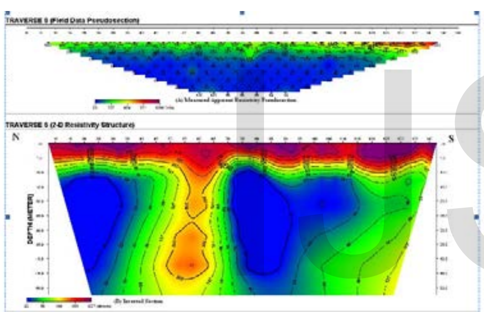

Fig. 7: 2-D Resistivity Distribution of Traverse 6.

4.4 Traverse 7

A 150m electrical resistivity survey was carried out. The topsoil reveals high resistivity region 1026Ωm from the west to east occurring to a depth of 3m.This resistivity value corresponds to a geological formation known as laterite. A thin layer of clayey sand with resistivity of 431Ωm occurs underneath the superficial topsoil formation. The depth of the occurrence is at 4m. This extends from the west to the east of the surveyed area. A layer with a resistivity of 161Ωm is geologically described as sandy clay with thickness of 2m.Underlying the sandy clay is a formation with true resistivity ranging from 40Ωm to 75Ωm is described as tar sand. The thickness of this biodegraded geological formation is 6m. The horizon of the tar sands bearing is continuous indicating that it is stratigraphically controlled. The geological formation having the resistivity ranging from 0Ωm-32Ωm is referred to clay/shale. It occurs at the bottom of the model.

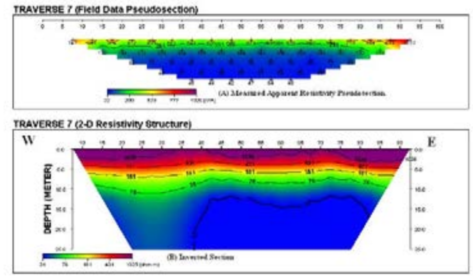

Fig. 8: 2-D Electrical Resistivity Distribution on Traverse 7.

5 CONCLUSION

From the pseudosections of the resistivity distribution, traverses 1, 4, 5 and 6 are good groundwater potential zones because of the presence of thick clayey sand formation that can be described as the main aquiferous zones in the area. If proper groundwater management is carried out it will not be vulnerable to contamination as a result of tar sands while traverses 2, 3, 7, and 8 are vulnerable to groundwater contamination and pollution.

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