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Geophysical Image Investigation of Salt/Brackish Water Intrusion into Freshwater Aquifer in Lagooncoastal Region: A Case Study of University of Lagos, Nigeria.

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Abstract

Groundwater is very essential to humans from all ages. Many factors affect the quality of groundwater aquifer, these include contamination by salt-water intrusion or by toxic industrial/chemical wastes. An assessment of the University of Lagos campus ground water was done using geo-electrical resistivity survey. A total of six electrical imaging lines were traversed with Wennerarray coupled with ten vertical electrical soundings (VES) within the area. The Schlumberger electrode array with current electrode half spacing from 1 to 100m was used to acquire 1D data. For the 2D field surveys, Wenner 64 electrode spread was used, while the spacing between adjacent electrodes ranged from 1.5 to 3.0m. Interpretations include quantitative and qualitative deductions from 1D and 2D geoelectric models. Two software packages were utilized for the analyses in this study: WinResist for 1D plotting andRES2DINV for 2D inversion. The depth of the saline/freshwater interface varied from 6.9 to 64.0m and the thickness of the saline water was greater in the proximity of the coastline.The resistivity inverse model of various positions (1.04-20.0m depth) exposed the zone of brackish/saline water.Two major freshwater aquifers were delineated and they occurred unprotected.

Keywords: Salinity, vertical electrical sounding (VES), 2D profiles, coastal region

1.0 Introduction

Saltwater intrusion occurs in coastal freshwater aquifer when the different densities of both the saltwater and freshwater allow the ocean water to intrude into the freshwater aquifer. According to the findings of National water summary by Geological Survey (U.S.)[1]. These areas are usually supporting large populations where the demand for groundwater withdrawals for domestic, industrial and agricultural purposes from these aquifers is exceeding the recharge rate. Spatafora [2], in 2008 found that a combination of large groundwater withdrawals and a new drainage canal system has resulted in a decline in the freshwater level, promoting the landward movement of the saltwater into the fresh aquifer and canal systems [3,4].

The encroaching seawater typically encounters an area known as the zone of dispersion, where the freshwater and saltwater mix and form an interface. This interface moves back and forth naturally because of fluctuations in the recharge rate of freshwater back into these coastal aquifers [5]. Aquifers are naturally replenished by precipitation and surface waters that saturate into the ground and work their way through the soil and geologic material to the water table. So, as the demand for freshwater increases due to the population increase in these coastal regions, freshwater supplies are constantly being depleted [6]. This gives rise to issues such as saltwater intrusion, resulting in an increased importance of groundwater monitoring, management and conservation [7].

Literature review

Some simulations of saltwater intrusion into freshwater aquifers have been carried out using geophysical techniques, especially the electrical resistivity and electromagnetic methods. NurIslami[8] used the geophysical resistivity method survey to detect, map, and image the occurrence of salt/brackish water in the subsurface. He proved that the geo-electrical method is a useful tool for delineating the boundary between freshwater and saltwater because of its inherent capability to detect the changes in pore-water electrical conductivity. He also inferred that fresh-saline water boundary is almost two-dimensional and is good target for 2D electrical imaging surveys.

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Longe and Enekwechi[9] carried out a physio-chemical analysis of water samples and reported the presenceof anions and cations characteristics of leachate contamination. This work coupled with the research work of Olorode and Alao [10] also attributed the attenuation of the leachate contaminants to stratigraphic variations, which go further to influence the pattern of distribution and subsequent break through into aquifer. They further suggested that there is a tendency for an increase in groundwater contamination around the landfill location, considering the levels of chloride, nitrate and organics in groundwater.

Adeoti et al. [11] investigated the saline water intrusion into the freshwater aquifer at Oniru, in Lagos state, using the 2D Wenner geo-electrical model and the 1D vertical electrical sounding (VES) survey, varying the Schlumberger electrode spacing between 1 and 500m. They sought to obtain valuable information on the hydrogeologic system of the aquifers and the subsurface lithology, and to delineate the groundwater salinity. They inferred that the 1D and 2D results correlate to a high degree, indicating saline water intrusion between a depth interval of 13 and 64m in the study area.

Choudhury et al. [12] reported that saline water intrusion into coastal aquifers have resulted in acute environmental problems in the past. They further confirmed that the extent of saline water intrusion is influenced by the nature of geological formations present, the hydraulic gradient, and the rate of withdrawal of groundwater and its recharge.

Oyedele andMomoh[13] carried out an extensive geophysical survey, using an Induced Polarization (IP) data (within the proximity of the University of Lagos lagoon front) to evaluate the extent at which seawater has intruded towards the freshwater aquifer. They discovered from one dimensional interpretation of the data acquired that saline water intrusion, which is characteristic of seawater, penetrated the subsurface in contact with the lagoon. They also inferred that the depth of the intrusion increased as the distance from the coastline increased. They attributed the causes of intrusion of saline water into freshwater aquifers to saline water founding its way into the aquifers due to an upwelling of saline water, whose origin is connate.The 2D geo-electrical method was not used in their study. Thereforethis study seeks to obtain better resolution on the horizontal and vertical resistivity variations, using the 2D geo-electrical method.

2.0 Geology and Hydrogeology of the Study Area.

The study area (Fig.1.0) is in the Benin basin of Lagos state. It lies on the longitude E003° 24’ 02.0”and latitude N006° 30’ 54.5”, with alternate wet and dry seasons.The geology has no basement outcrop. The surface geology of the study area is made up of the Benin formation (Miocene to Pleistocene), cross-bedded and peddly sands, clay lenses with lignite, marine fossils from boreholes, including foraminifera, ostracods and Molluscs. The formation also represents the delta-top sands and gravels, poorly sorted and often cross-bedded with clay lenses. It is up to about 2000m thick.The coastal landscape in the study area contains multi-layer aquifers that are harnessed through hand-dug wells with very shallow depth extent. Longe et al. [14] delineated three major aquifer zones in the region, and they suggested that the aquifers belong to the recent littoral and alluvium deposit, and the Benin formation. The first aquifer is a water table aquifer that is prone to pollution because of its nearness to the ground source. It is encountered at the depth of 8m and average thickness of 8m. The second and third aquifers are confined aquifers, made up of alternating sequences of sand and clay of varying depth. They are harnessed through boreholes and are the basis of mini-water works in Lagos state. These aquifers belong to continental Ilaro formation. The third aquifer is the most productive and most exploited horizon.Lagoons are common features on the Guinea coast of West Africa. The Lagos lagoon with a surface area of 2453.59943 square miles is open, tidal and brackish, and is the largest of the eight lagoons in southwest Nigeria. The Lagos lagoon, a water body in the heart of the metropolis, cuts across the southern parts, linking the Atlantic Ocean (on the West and South) and the Lekki, Lagoon.

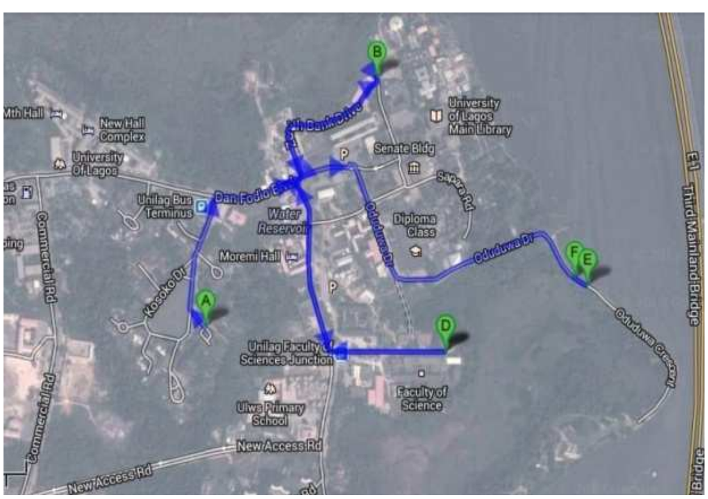

Fig 1.0: Sitemap of the study area.

3.0 Experimental Work

Two resistivity methods were employed— 2D Wenner 64 electrodes and 1D vertical electrical sounding (VES). The results from the 2D Wenner electrode spread (the primary method used) were correlated with those from the 1D vertical electrical sounding. The 2D electrical resistivity imaging survey utilizedan ABEM SAS 4000 Terrameter resistivity meter and a multi-core cable. Electrodes were connected to the multi-core cable at take outs andmoldedat predetermined equal intervals. A total of six 2D imaging profile data were obtained at different stations within the study area. Profiles 1 and 4 were acquired at the lagoonfront at the back of the Faculty of Science building; profiles 2 and 3 were acquired at the Man 'O' War Base; profile 5 was acquired at the back of UNILAG guest house; profile 6 was acquired at a field within Kosoko Drive along CITS. Profiles 1, 2, 4, 5, and 6 were laid parallel to the shoreline of the lagoon while profile 3 was taken perpendicular to the shoreline of the lagoon front.Furthermore, a total of ten VES were acquired on the same site of coverage, at the same spot where the traverses were conducted. The idea was to have two vertical electrical soundings on each traverse. This was achieved on all the traverses, except traverse 4, where we could not continue with the data recorded, because of the unusually high resistivity of the area. The vertical electrical sounding utilized Schlumberger electrode array.

4.0 Results and Discussion

The results are presented as profiles, and inverted sections. Interpretations of these results involve both qualitative and quantitative deductions from 1D and2Dgeo-electric models. The qualitative analysis involves inspection of profiles and sections for geo-electric signatures that are indicative of saline water intrusion, while the quantitative interpretations involve extraction of geo-electric parameters that are indicative of saline water intrusion.

The analysis of resistivity data revealed the presence of three to four geo-electric layers along profiles AA', BB', DD' and EE', while five geo-electric layers characterized profile CC'. Typical curve types characteristic of saline water intruded zones were observed, such as KQ, AKQ and HAKQ. The curves were found to descend gently, indicating a resistivity increase which can be explained in terms of the seawater intrusion into subsurface formations. The geo-electric section along AA' comprises VES 1 and 2, having 4 geoelectric layers, which varies from topsoil, clayey sand, clay/peat, clay and sand.

The topsoil is characterized by resistivity values ranging from 44.7 to 21.7 $\Omega.m$ and thicknessof 0.5 and 0.7m. The second layer represents clayey sand with resistivity value 95.4Ω.m and thickness 3.6m in VES 1, while the second layer for VES 2 represents sand with resistivity value124.8Ω.m and thickness 6.4m.The third geologic unit along VES 1 and VES 2 is interpreted as clay in VES 1 and clay/peat in VES 2, with resistivity contrast of 2.9 and 3.3Ω.m and layer thickness 7.2 and 34.3m, repectively.The fourth geoelectric layer in VES 1 and VES 2 is sand, having resistivity values of 112.1 and 104.6 Ω.m. The thickness could not be determined because the current terminated within the horizon.

Geoelectric section along BB'

This geoelectric section comprises VES 3 and VES 4, having 3 to 4 geologic units— topsoil, clay/peat, sandy clay and sand. The topsoil is characterised by resistivity values of 16.9Ωm and 74.5Ωm for VES 3 and VES 4, respectively; and a layer thickness of 0.5 to 0.7 m. The layer beneath the topsoil for VES 3 connotes clay/peat, and for VES 4, sandy clay, having resistivity of 1.5 and 51.5Ωm and thicknesses of 1.1 and 3.7m for VES 3 and VES 4, respectively. The third layer for VES 3 is sand, with a resistivity value of 188.3Ωm, while that of VES 4 is clay, with a resistivity of 15.8Ωm, and a thickness of 13.2m. The thickness of VES 3 could not be determined because the current terminated at the horizon. The fourth layer via VES 4 is sand with resistivity value of 256.3Ωm. The thickness could not be determined as the current terminated atthe horizon.

Geoelectric Section Along CC'

This comprises VES 5 and 6 having 4 to 5 geologic units— topsoil,clay/peat, sand/saline and sandy clay. The topsoil has a resistivity of 11.2 and 64.0Ωm and a layer thickness 0.6 and 0.7m for VES 5 and VES 6, respectively. The layer beneath this connotes clay/peat in VES 5 and 6 with resistivity values of 4.9 and 6.1Ωm, and a thickness of 1.7 m for both VES. The geologic unit along VES 5 and 6 is interpreted as sand/saline with resitivity contrasts of 74.5 and 75.7Ωm, and thicknesses of 13.1 and 5.2m, respectively. The fourth geoelectric layer of VES 5 has a resistivity contrast of 13.4 Ωm, while the fourth geoelectric layer of VES 6 has a resistivity contrast of 20.0Ωm. The thickness of VES 5 could not be determined because the current terminated with the horizon, while VES 6 has a thickness of 56.9m. The fifth geoelectric layer in VES 6 is sand having resistivity value 98.0Ωm. The thickness could not be determined because the current terminated in the horizon.

Geoelectric section along DD'

This comprises VES 7 and 8 having 4 geologic units—topsoil, clay, clayey sand and sand. The topsoil is characterised by resistivity values of 43.5 and 36.4Ωm, and layer thickness of 0.5 and 0.7m, for VES 7 and 8, respectively. The second layer connotes clayey sand for VES 7 and clay for VES 8,having resistivity values of 47.5 and 32.1Ωm and thicknesses of 4.5 and 3.0m in VES 7 and 8, respectively. The third stratum is interpreted as sand for VES 7 and clayey sand for VES 8. It has resistivity values of 260.4 and 63.9Ωm, and thicknesses of 5.6 and 10.3m in VES 7 and 8, respectively. The fourth layer in VES 7 and 8 is clay having resistivity values of 27.8 and 37.8Ωm, respectively. Thickness here could not be determined because the current terminated at the horizon.

Geoelectric section along EE'

This geo-electric section comprises VES 9 and 10 having 3 goelogic units—topsoil, sandy clay and clay. The topsoil is characterised by resistivity values of 1061.8 and 1071.4Ωm, with layer thicknesses of 1.0 and 3.0m in VES 9 and VES 10, respectively. The layer beneath this comprises sandy clay in both VES 9 and VES 10, with resistivity values of 509.4 and 474.4Ωm, and thicknesses of 14.2 and 14.0m in VES 9 and VES 10, respectively. The third stratum in VES 9 and VES 10 is clay, having resistivities of 32.2 and 29.6Ωm, respectively. The thickness could not be determined because the current terminated at the horizon.

Discussion on 2-D Wenner Survey

Station1: Geo-electrical resistivity survey traverses 1 and 4. In the Wenner inverse model for the traverse 1, three distinct resistivity zones can be depicted, as shown in Fig. 2.1. The high resistivity value of about 188Ωm was found at the surface 58-91m mark, which corresponds to clayey sand mixed with peat especially at the right hand side of the traverse, due to decreased resistivity value. It could be seen that at the position 0-58 and 70-108m marks of the Wenner inversion model, the resistivity value is low (<8.98Ωm). The vertical extension differs; the 0-58m mark has depths from 0-10m,while the 70-108 m mark has a horizontal extension from 6.87-15.1 m. It corresponds to clay/peat; and could also be interpreted as saline/brackish water content because of the decreased resistivity values. At position 35m, having horizontal extensions with a corresponding depth of 7m, it could be noticed that first aquifer (top aquifer) has been contaminated due to its proximity to the surface. The cause could be related to surface seawater infiltration as the right side is only 2m away to the lagoon. The second zone is observed as a layer of high resistivity (<527Ωm). It has approximately 10m vertical extension, which corresponds to sandy clay based on the lithology cross section of the area. The third zone is underlined by a higher resistivity (1216-2076Ωm) from 35-78m mark, depth from18.7-23.8m.It corresponds to sandy formations that are compacted together. This value could indicate that the clay content in this zone has decreased, and a good aquifer could be seen beyond the formation.

Traverse 4:

The Wenner inversion model of traverse 4 (shown in Fig. 2.2) displays three resistivity regions. The top layer is a layer of high resistivity 29.4 – 76.7Ωm, with vertical extension of 0-2.72m, but it has been infiltrated possibly by surface seawater at the 50-96m mark, causing a resistivity decrease. There could also be peat sediments within the spot. The top layer is underlined by a low resistivity region (<1.82Ωm) from the right side of the traverse or 8-40 m mark with a vertical extension from 2.72-15.5m. It corresponds to clay/peat with saline water. The first aquifer resistivity is 89.8Ωm, with a depth of 7.8m, while the higher resistivity values of the traverse (238-638 Ωm) with a depth of 11.9-17.4 m corresponds to a clayey region.

Station 2 (comprising traverse 2 and 3):

For traverse 2, the survey was from the lagoon front facing the Man 'O' War Base. A space along 198m was used to survey the data with 3.0m electrode spacing for both traverse 2 and 3. In the survey, the geo-electrical line of traverse 2 was placed 4m onshore while the geo-electrical line of traverse 3 was along the Julius Berger road extending from the lagoon front up to the Julius Berger auditorium.

In the Wenner inverse model of traverse 2, three distinct regions were identified; the first region is the region of low resistivity ranges from (5.38-12.8Ωm) with depth 0-16m from 98-196m mark, though the thickness decreased from 0-6.11m, with horizontal extension of 0-68m. This corresponds to clay/peat, and could also be interpreted as saline/brackish water. The second zone is a high resistivity region (243-638Ωm) with a vertical extension of 16-28m, and it corresponds to sandy clay. Underlying the second region is a zone of higher resistivity (1637-4257 Ωm), a horizontal extension of 58-108m, and a vertical extension of 28.7-38.3m. This third region corresponds to sandy aquifer or to sand. The first aquifer with a resistivity of 98.7Ωm is at 10.6m depth. The boundary between brackish/freshwater is clearly seen at a 22.7m depth.

In the Wenner inverse model for traverse 3, there is a display of similar feature as traverse 2, with different resistivity values and vertical extensions. The low resistivity values (4.30-11.7Ωm) at the right side of the line from the 100-198m mark with depth 5-19m corresponds to clay/peat, it could also be interpreted as brackish/saline water. Underlying the low resistivity zone or region, is the clayey sandy layer with depth 16.6-27.4m from 78-120 m mark, while the sandy aquifer is detected at 31-34m depth of a higher resistivity values (268-3574Ωm) from 88-100 m mark. There is a high possibility that the surface seawater infiltrated the right side of the traverse which affected the top aquifer.

Traverse 5 was conducted behind university of Lagos guest house. The geo-electrical line was laid 20m offshore. There was enough space to cover electrode spacing of 3m with total horizontal coverage of 198m. In the Wenner inversion model, traverse 5 displayed a similar result with traverse 4. The topsoil has a high resistivity of 58-144Ωm of depth 0.769-5.45m; it corresponds to sandy clay, except from the 149-198m mark of the traverse where the resistivity is low (9.65Ωm),corresponding to peat/clay/brackish water. It could be as a result of seawater infiltration due to its proximity to the lagoon. Brackish water can be delineated at the 49.8-98m mark of the traverse, as the resistivity of the point is 3.92Ωm of depth 5.45-27.6m.

Underlying the low resistivity is a high resistivity region (384-872Ωm) at the 90-130m mark of depth12-31.8m, which corresponds to sandy clay, while the sandy aquifer is detected at the 31.9-34.8m depth, with a resistivity value of 2146Ωm.
Traverse 6 served as "the control", and was conducted at a small field within the Kosoko drive along CITS. The space to lay the long cable was restricted due to poor road network within the drive. A space along 126m was used with 2.0m electrode spacing. In the survey, the geo-electrical line was about 1000m onshore to evaluate the hydrology characteristics of the area. In the Wenner inversion model, the characteristics of the traverse 6 were different from those of the other traverses. Traverse 6 consists mainly of strata with high resistivity, except the right side of the traverse from the 0-58m mark of depth 0.512-17.6m, which recorded a low resistivity of 0.312-2.76 Ωm. It corresponds to saline water or clay. The first aquifer of this traverse is at point 92m and at a depth 10.7m. It is in the sand formation of the traverse, considering the resistivity (364-1235Ωm), and it will likely produce good quality water. Underlying the aquifer is the region of higher resistivity (4187Ωm) at the 60-88m mark with a depth of 15-23.5 m, corresponding to sand or sand stone formation.

Correlation of 2D and 1D results

Traverse 1: the inverted 2D resistivity section images a low resistivity zone (<8.90Ωm) below the 80-120m mark, between a 4.07-10.7m vertical extension. The interpreted 1D VES 1 and VES 2 results show a low resistivity of 2.9 and 3.3Ωm at 4-11.6m and 6.9-41.1m depth. These indicate a zone of saline water intrusion (polluted subsurface aquifer) in the specified location below the traverse.
Traverse 2: The inverted 2-D Wenner resistivity section images a low resistivity zone (<5.34Ωm) at the two sides of the traverse 0-78 and 108-196m mark, at 16.6m depth. Furthermore, the 1D VES 5 and VES 6 results show low resistivity of 4.9, 6.1 and 13.4Ωm at 2.4-15.5m vertical extension. These indicate a zone of saline water intrusion, probably from surface sea water infiltration.
Traverse 3: The 2D Wenner inversion section images a low resistivity zone (4.3-11.2Ωm) between the depth 0-15m and 5-19.8m at different points of 0-60m, 110-160m mark. This correlates with the 1D VES 3 and VES 4 results, which show low resistivity values of 1.5 and 15.8Ωm at depths of 1.6 and 17.7m, respectively. These indicate a zone of saline water intrusion (polluted by subsurface aquifer) in the specified location.
Traverse 5: The VES 7 and 8 depict a low resistivity region of (27.8 and 37.8Ωm) at depths 10.8 and 13.9m, respectively. This agrees with the 2D inverted resistivity, which images a low resistivity (<9.65Ωm) from a 7-27.4m vertical extension. These correspond to a zone of saline water intrusion, which is infiltrated from the lower right side corner of the section into the subsurface aquifer at 10.0m depth.
Traverse 6: The inverted 2D resistivity section images a high resistivity contrast of 1285Ωm for the topsoil, which agrees with the 1D VES 9 and VES 10 results that show a high resistivity of 1071 Ωm at the topsoil. Furthermore, the right side of the traverse depicts a low resistivity of 0.812-9.35 Ωm. It extends from 0-17.5m vertical extension, which means that seawater or saltwater has intruded from the right side of the traverse from 17.5m depth to the surface. It agrees with the VES results as it shows a drastic drop in resistivity from the 15.5m vertical extension. This is the zone of seawater from the lagoon.
Table 1 reflects the summary of the interpreted VES results.

Table 1: Data and Summary of the interpreted VES results.

VES No	Geoelectric Layer	Resistivity(Ωm)	Thickness (m)	Depth (m)	Curve Type	Probable Lithology	Inferred interpretation
1	1	21.7	0.7	0.7		Fine to Medium sand	Top soil
	2	95.4	3.6	4.4		Clayey sand	Good quality water
	3	2.9	7.2	11.6		Clay	Saline water
	4	112.1	--	--		Sand	Very good quality water
2	1	44.7	0.5	0.5		Medium sand	Top soil
	2	124.8	6.4	6.9		Sand	Very good quality water
	3	3.3	34.3	41.1		Clay/peat	Saline water
	4	104.6	--	--		Sand	Good quality water
3	1	16.9	0.5	0.5		Fine to medium sand	Top soil
	2	1.5	1.1	1.6		Clay/peat	Saline water
	3	188.3	--	---		Sand	Very good quality water
4	1	74.5	0.7	0.7		Medium sand	Top soil
	2	51.5	3.7	4.4		Sandy clay	Intermediate quality water
	3	15.8	13.2	17.5		Clay	Saline water
	4	256.3	----	--		Sand	Very good quality water
5	1	11.2	0.6	0.6		Fine to medium sand	Top soil
	2	4.9	1.7	2.4		Clay/peat	Saline water
	3	74.5	13.1	15.5		Sand	Intermediate quality water
	4	13.4	---	-		Clay	Saline
6	1	64.0	0.7	0.7		Medium sand	Top soil
	2	6.1	1.7	2.4		Clay	Saline water
	3	75.7	5.2	7.6		Sand/ saline	Intermediate quality water
	4	20.0	56.9	64.5		Sandy clay	Saline water
	5	98.0	-	--		Sand	Intermediate quality water
7	1	36.4	0.5	0.5		Fine to medium sand	Top soil
	2	47.5	4.6	5.1		Clayey sand	Saline water
	3	260.4	5.6	10.8		Sand	Very good quality water
	4	27.8	--	--		Clay	Saline water
8	1	43.5	0.7	0.7		Medium sand	Top soil
	2	32.1	3.0	3.6		Clay	Saline water
	3	63.9	10.3	13.9		Clayey sand	Intermediate quality water
	4	37.8	-	--		Clay	Saline water
9	1	1061.8	1.0	1.0		Coarse Sand	Top soil
	2	509.4	14.2	15.2		Sandy clay	Very good quality water
	3	32.2	-	-		Clay	Saline water
10	1	1071.4	1.3	1.3		Coarse Sand	Top soil
	2	474.4	14.0	15.3		Sandy clay	Very good quality water
	3	29.6	-	-		Clay	Saline water

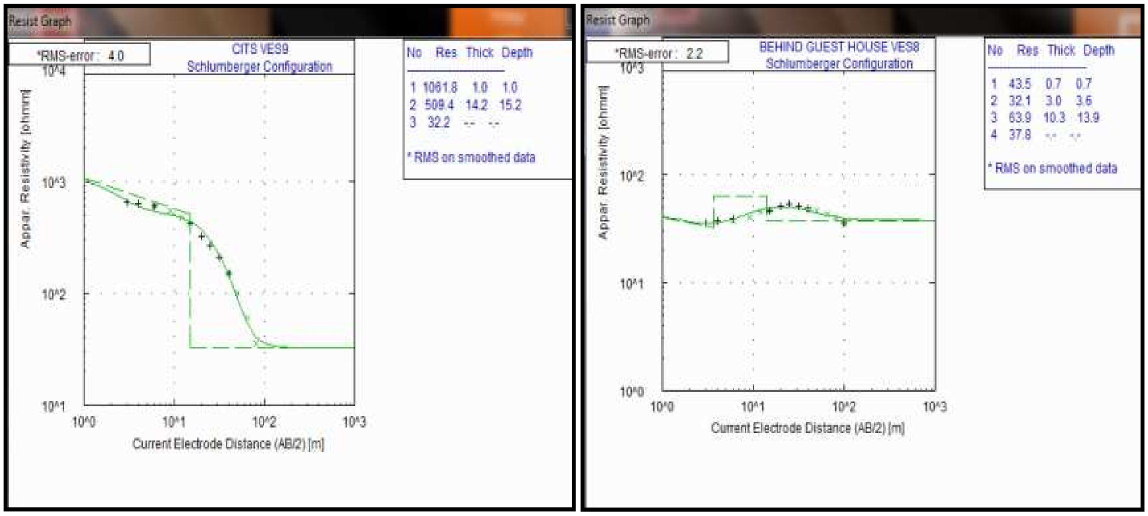

Fig 2.1: 2D Wenner survey results

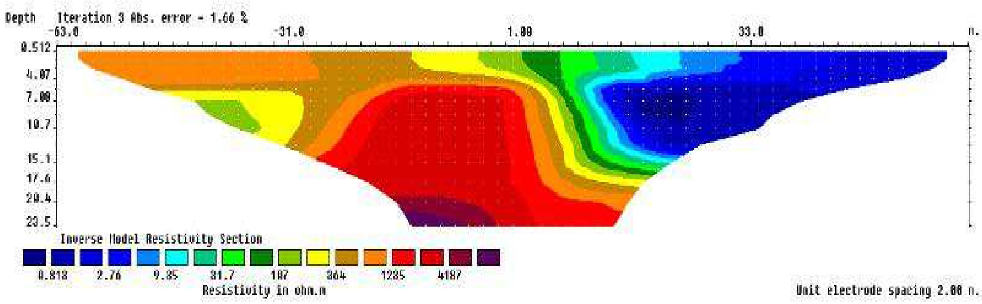

Fig. 2.2: Traverse 6 CITS

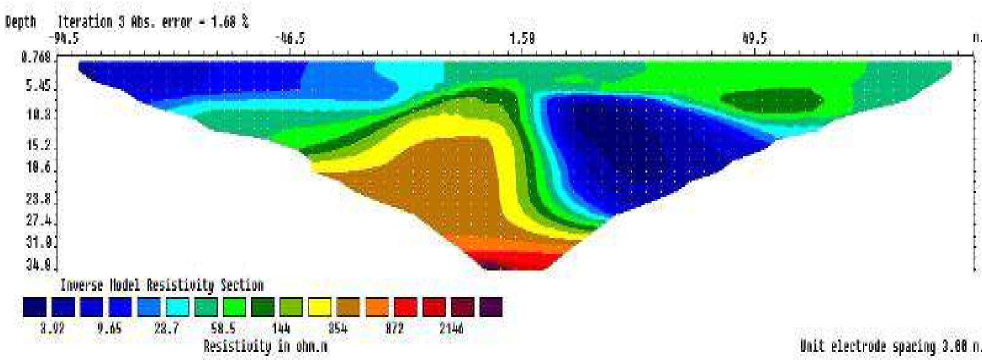

Fig. 2.3: Traverse 5 BEHIND UNIVERSITY OF LAGOS GUEST HOUSE

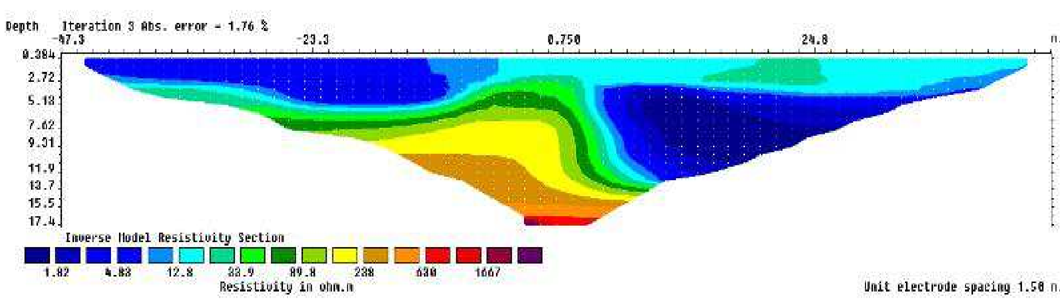

Fig.2.4: Traverse 4 SCIENCE INSIDE LAGOON

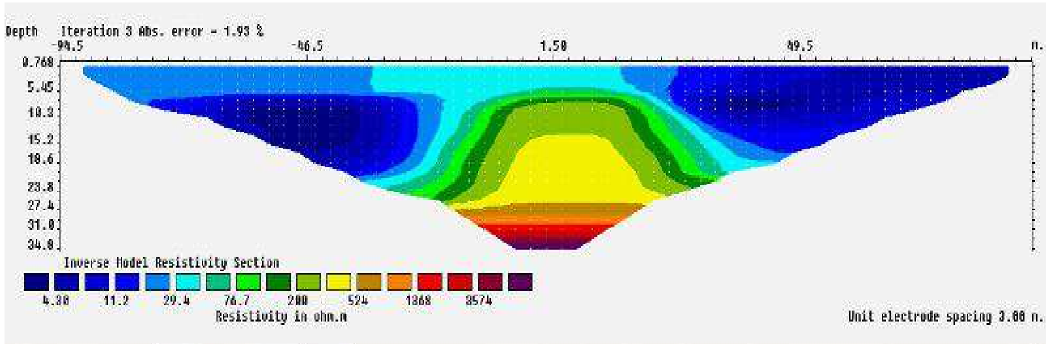

Fig.2.5: Traverse 3 JULIUS BERGER ROAD

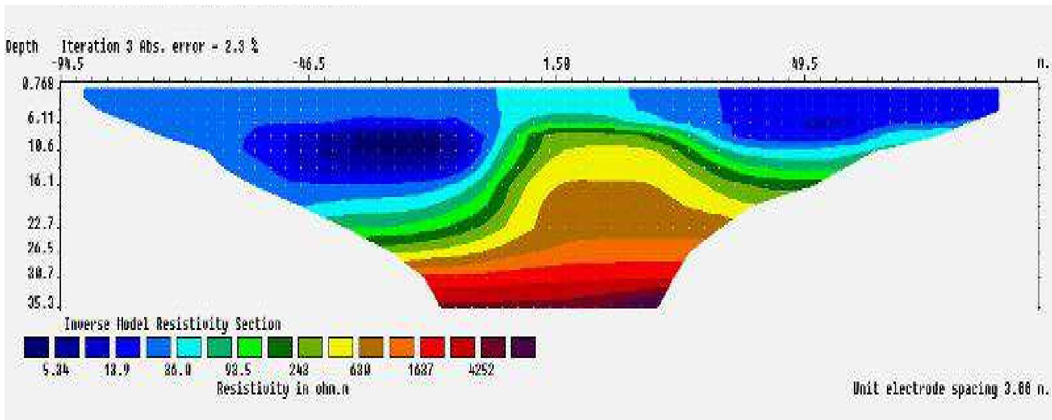

Fig.2.6: Traverse 2 LAGOON FRONT

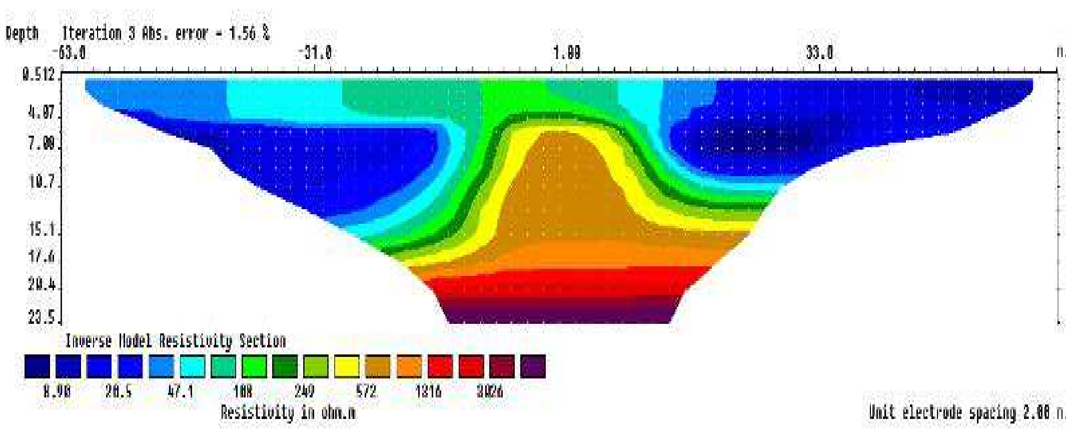

Fig.2.7: Traverse 1 behind Science complex

7.0 Conclusion

Geophysical survey, involving electrical resistivity methods, was used to investigate the problem of saline water intrusion into the coastal aquifer in the lagoon environment of the University of Lagos, at selected stations. Ten Schlumberger resistivity depth soundings and six 2D electrical resistivity Wenner-64 electrode spreads were used to acquire data in the study area. The subsurface structure was composed mainly of sandy clay, clay and sand. The interpreted results show that saline water intrusion, which is characteristic of seawater, penetrated the subsurface in contact with the lagoon. The 1D and 2D results correlate to a high degree, indicating saline water intrusion between a depth interval of 5m and 17.7m in the study area. The first freshwater aquifer (shallow <10m) was delineated and occurred unprotected.The results of the present survey show the importance of the role of 1D and 2D resistivity imaging in environmental and groundwater investigations in coastal areas.

It is a successful tool for mapping the freshwater/saltwater boundary which alternate at various depths in the study area. From the resistivity results and geological information obtained, inland depression (e.g. CITS on Kosoko Drive) contain saline water aquifer with the greatest thickness and these aquifers occur at greater depths.

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