Available online at http://www.ajol.info/index.php/njbas/index
Nigerian Journal of Basic and Applied Science (December, 2017), 25(2): 28-40
DOI: http://dx.doi.org/10.4314/njbas.v25i2.5

ISSN 0794-5698

Full Length Research Article

Delineation of Saline Water Intrusion Lateral Extent Using Hydro-chemically and Geo-electrically Derived CRS - Model Parameters - A Case Study of Eastern Dahomey Basin, Nigeria

I.A. Adeyemo and G.O. Omosuyi
Department of Applied Geophysics, Federal University of Technology, Akure, Nigeria
[*Corresponding Author: E-mail: iaadeyemo@futa.edu.ng; ☎: +234-8060042770]

ABSTRACT
This study was another attempt to map the subsurface lateral extent of saline water intrusions into aquifers at the eastern part of Dahomey basin, Nigeria. The study comprised geo-electric sounding method consisting of 108 vertical electrical soundings (VES) data acquired using Schlumberger array technique and hydro-chemical analysis of 61 water samples. The geoelectric survey results were presented as average longitudinal Conductance and average longitudinal Resistivity maps. The longitudinal conductance values vary from moderate to high (20 - 180 mhos) in the coastal areas, while lower values (lesser than 10 mhos) were recorded in the mainlands. Conversely the average longitudinal resistivity values were low to moderate (0.26 - 41.7 ohm-m) in the coastal areas and in few places such as Agbabu, Legbogbo and Sabomi in the mainland, while higher values (more than 60 ohm-m) were obtained from the mainlands. The hydro-chemical analysis results was presented as equivalent **S**alinity map; its values range from 25.8 mg/l (Ode-Irele) to 2808 mg/l (Asisa), high values were obtained from Ugbo, Ugbonla, Odonla, Idogun and Ayetoro area in the southeastern part of the study area and likewise at Agbabu in the north central part of the study area. The results were synthesized using CRS-model. The final CRS-model map showed that the saline water intrusion extended to 35 % of the total area which covers; most part of the coastal area and Agbabu in the mainland.
Keywords: Saline water intrusion, saline-freshwater boundary, vertical electrical sounding (VES), hydrochemical analysis, synthesis and CRS-model.

INTRODUCTION
A major environmental problem regularly confronting continental areas adjoined by oceans is saline water intrusion into the coastal/continental aquifer. This has been reported by severally authors across the world [Choudhury et al., 2001; Chachadi et al., 2005; Batayneh, 2006; Khalil et al., 2006; Martinez-Retama et al., 2007; Adepelumi, 2008; Samsudin et al., 2008; Oyedele and Momoh, 2009; Adeoti et al., 2010; Jansen, 2011; Satriani et al., 2011; Ayolabi et al., 2013; Rahaman and Bhattacharya, 2014; Adeyemo et al., 2015 and Adeyemo et al., 2017]. Very few works have been done on saline water Intrusions in the study area [Omosuyi et al., 2008; Omoyoloye et al., 2008; Adeyemo et al., 2015 and Adeyemo et al., 2017]. In all these previous works no model was generated for the determination of the saline water intrusion extent, while only two attempted to determine the saline water extent of the area [Adeyemo et al., 2015 and Adeyemo et al., 2017]. This study will be the first attempt to generate the saline water intrusion extent map in the study area using an appropriate scientific model which was generated by synthesizing the average longitudinal Conductance, average longitudinal Resistivity and equivalent Salinity values across the study area.

The Study area
The study area cut across six Local Government areas in the southern part of Ondo and Ogun States, South Western Nigeria. The area is located within the following coordinates; longitudes 4° 22' 22.5" E and 5°10' 2.0" E and latitudes 5° 50'44.1" N and 6° 39' 39.5" N and it cover a total area of about 4,200 km^2 (Figures 1 and 2). The area is generally characterized by flat and gently undulating topography. The elevations vary between 13 to 83 m above sea level in the mainland and 2 to 10 m in the coastal area (Figure 3). The study area is

underlain by the sedimentary sequence of the Dahomey basin. The Dahomey Basin stretches from south-eastern Ghana to south-western Nigeria [Burke et al., 1971; and Klemme, 1975].

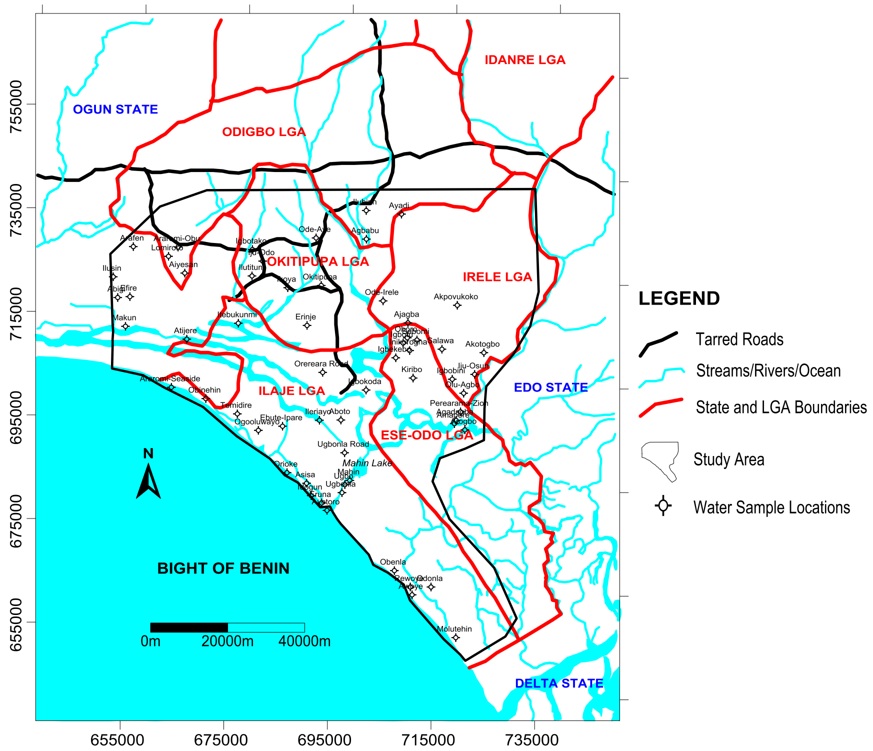

Figure 1: Location map of the study area showing water sampling locations.

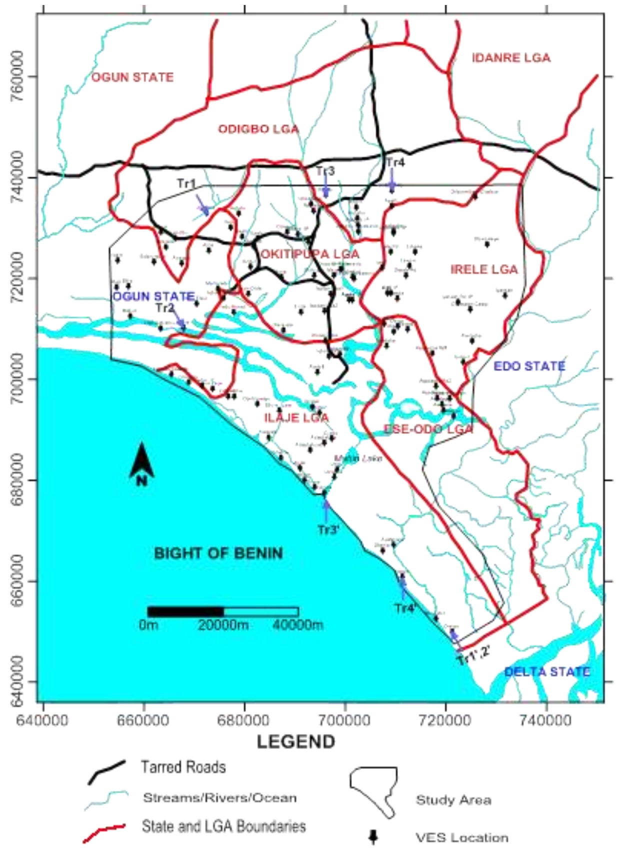

Figure 2: Location map of the study area showing VES locations

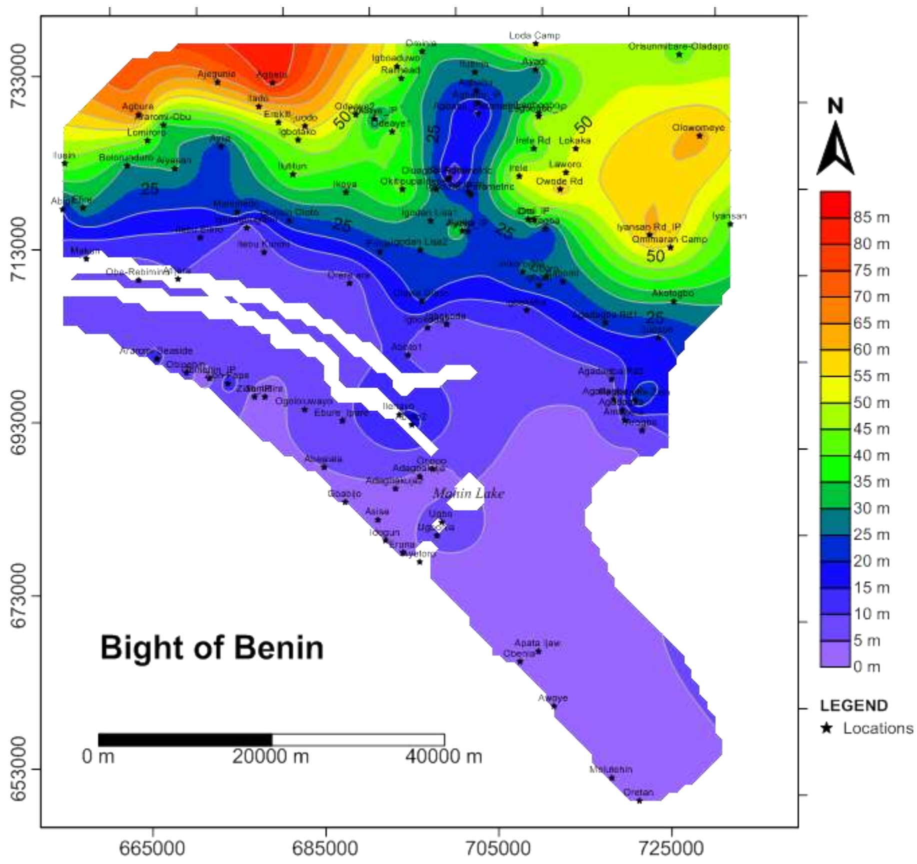

Figure 3: Topographic map of the study area

It is demarcated from the Niger Delta by Okitipupa Ridge (a subsurface structural ridge) around Okitipupa in Ondo State, Nigeria [Burke et al., 1971; Klemme, 1975; Omosuyi, 2001; Omosuyi et al., 2008]. Six lithostratigraphic units have been identified by various workers (Figure 4). The formations from the oldest to the youngest comprises; Abeokuta Group (Cretaceous), Ewekoro Formation (Palaeocene), Akinbo Formation (Paleocene-Eocene), Oshosun Formation (Eocene), Ilaro Formation (Eocene) and Benin Formation (Oligocene-recent). The known aquifers in the study area are mostly within the Benin Formation [Burke et al., 1971; Okosun, 1998; Omosuyi et al., 2008] which consists of unconsolidated, poorly sorted sands with lenses of clayey shale [Okosun, 1998].

METHODOLOGY

The study integrated hydrochemical data and geoelectric parameters. A total of 61 (Figure 1) water samples were analyzed for 17 relevant parameters such as conductivity, pH value, total hardness, calcium hardness, magnesium hardness, total dissolved solids, total suspended solid, alkalinity concentration, and concentration of the following anions and cations; chloride, calcium, sulphate, bicarbonate, calcium, magnesium, sodium, manganese and nitrate. Equivalent salinity was also derived from the hydrochemical analysis results (Table 1). 108 vertical electrical soundings (VES) and data were acquired using Schlumberger array technique (Figure 2). The maximum current electrode separation (AB/2) was varied from 225 to 750 m. The field data were interpreted using the conventional partial curve matching technique supported with computer iteration. The VES results were presented in table 2 and different maps.

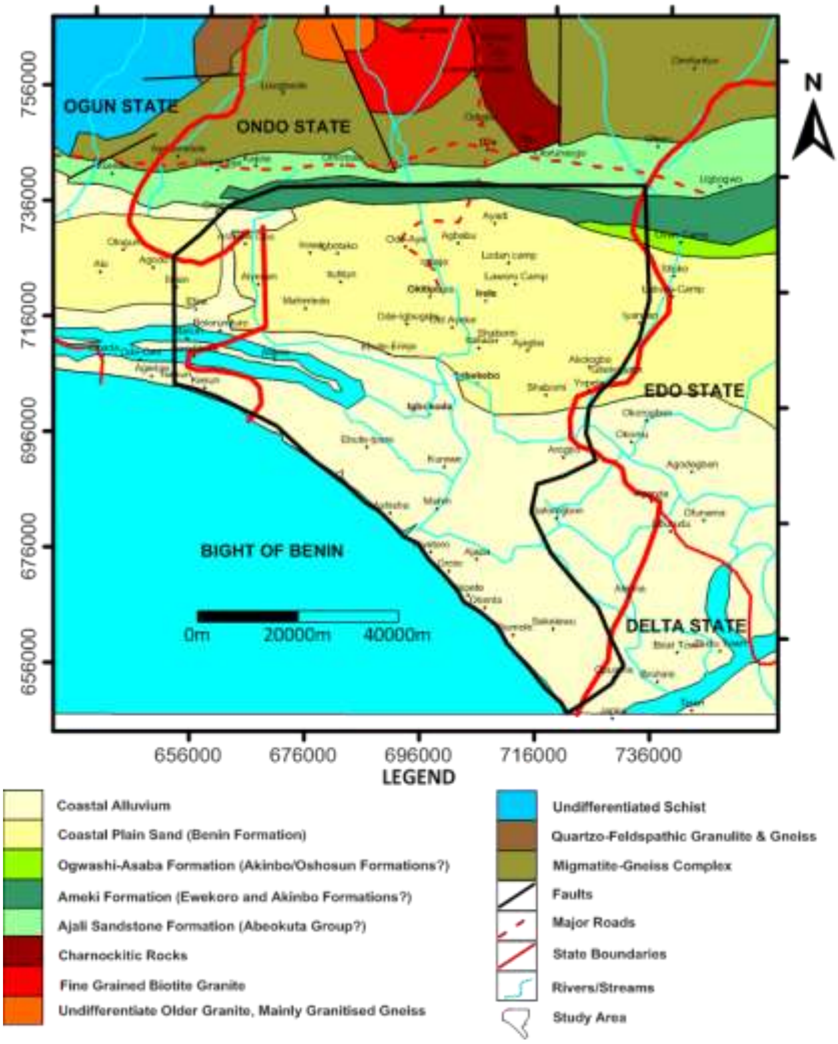

Figure 4: Geological map of the study area [Source: Nigeria Geological Survey Agency, 2004]

RESULTS AND DISCUSSION

The geo-chemical analysis results (Table 1) shows possible saline water intrusion in the coastal area and Agbabu in the north central area as evident from high concentration values of equivalent salinity (135 - 2808 mg/l). The VES results delineated three to seven layers. The layer resistivity values vary from 0.2 - 21806, 0.2 - 36762, 0.2 - 7958, 0.4 - 14243, 2 - 10798, 9 - 5285 and 10 - 18527 ohm-m in the topsoil, second, third, fourth, fifth, sixth and seventh geoelectric layers respectively. The eighth geoelectric layer was delineated only at Ode Aye 1 with resistivity value of 523 ohm-m. Layer thicknesses across the study area vary respectively from 0.4 - 10.6, 0.1 - 58.6, 0.5 - 206, 1.7 - 423.5, 7.6 - 263 and 81.2 - 133.5 m in the topsoil, second, third, fourth, fifth and sixth geoelectric layers respectively. At Ode Aye 1, the thickness value of the seventh layer is 15.2 m. Thirty-five (35) different curve types were delineated across the study area (Figure 5) varying from simple to complex types.

Saline Water Lateral Extent

The saline water lateral extent was determined by synthesizing the average longitudinal Conductance, average longitudinal Resistivity and equivalent Salinity values across the study area, the product is referred to as CRS-model. The synthesis was done using a previously used approach [Chachadi, 2005 and Adeyemo et al., 2017]. Each of these indicators was assigned weight based on their degree importance to occurrence of saline water. Each of these indicators was subdivided into different ratings; saline, brackish and fresh water and the

results of the weighting and rating factors were integrated using the following relationship;
CRS-model value = $\{[Wt_{long\_cond} * Rt_{long\_cond}] + [Wt_{resistivity} * Rt_{resistivity}] + [Wt_{salinity} * Rt_{salinity}]\}$ (1)
Where,
Wt = Weight
Rt = Rating

Table 1: Hydrochemical Analysis Results

S/N	Location	Equivalent Salinity
1	Ayadi	42.152
2	Ode-Irele	25.795
3	Igbobini	35.488
4	Olu-Agbo	31.312
5	Ugbonla Road	26.4441
6	Sabomi	49.272
7	Ajagba	29.895
8	Akpovukoko	25.363
9	Akotogbo	29.83
10	Iju-Osun	36.895
11	Agadagba	30.892
12	Amapere	44.906
13	Igbekebo	39.235
14	Ode-Aye	154.569
15	Ikoya	26.155
16	Ilutitun	26.603
17	Iju-Odo	32.19
18	Igbotako	34.895
19	Okitipupa	45.776
20	Igbokoda	172.743
21	Mahin	78.136
22	Ugbo	315.229
23	Ugbonla	720.72
24	Aboto	42.451
25	Aiyesan	38.7321
-	-	-
50	Molutehin	174.336
51	Awoye	147.368
52	Odonla	243.96
53	Rewoye	154.3401
54	Obenla	134.816
55	Ayetoro	168.305
56	Orioke	2806.11
57	Asisa	2808.54
58	Idogun	1763.297
59	Eruna	913.705
60	Orereara Road	55.2922
61	Arogbo	121

Indicators Description

Average longitudinal conductance

Average longitudinal conductance map (Figure 6) provided a good tool in delineating brackish/saline water lateral extent across the study area. The longitudinal unit conductance values was calculated across the study area from the layer thickness and resistivity values based on the relationship below. The longitudinal unit conductance (S_i);

$$S_i = {hi}/{\rho i} \quad (2)$$

Where,
h_i = layer thickness
ρ_i = layer resistivity
While, for n layers the total longitudinal conductance is;

$$S = \sum_{i=1}^{n} \frac{hi}{\rho i} = \frac{h1}{\rho 1} + \frac{h2}{\rho 2} + \frac{h3}{\rho 3} + \cdots + \frac{hn}{\rho n} \quad \text{(Zhody et al., 1974)} \quad (3)$$

The average longitudinal conductance map (Figure 6) reveals that the costal locations such as Obe-Rebiminu, Abealala, Gbabijo, Asisa, Idogun, Ayetoro, Eruna, Apata Ijaw, Obenla, Awoye, Molutehin and Oretan recorded moderate to high longitudinal conductance values (20 - 180 mhos), while locations farther from the coastline recorded low longitudinal conductance values (lesser than 10 mhos). The map has a good correlation with the hydro-chemical analysis results (Adeyemo et. al., 2015) and the experience of the inhabitants of the area. Moderate to high longitudinal conductance values are expected at brackish/saline water intruded zones, since higher concentration of dissolved salt occurring in brackish/saline water intruded zones are associated with high conductivity. This map best describe the brackish/saline water intruded zone and hence the parameter was assigned the highest weight which is 6 (Tables 3 and 4).

Table 2: Vertical Electrical Sounding Results

VES No	Location	Resistivity (Ω-m) $\rho_1/\rho_2/\rho_3 \ldots\ldots\rho_N$	Thickness (m) $D_1/D_2/D_3/\ldots\ldots D_n$	Curve Type
1	Omi	1274/ 646/ 6170/ 369/7	0.7/ 8.9/ 28.1/ 165.3	HKQ
2	Sabomi	192/ 444/ 696/ 65/ 3763	0.9/ 9.0/ 40.8/ 420.0	AKH
3	Igbotu	796/ 2012/ 860/ 757/ 69	0.8/ 5.4/ 81.6/ 9.2	KQQ
4	Agadagba	4681/ 1800/ 153/ 31	1.5/ 2.0/ 247	QH
5	Ijuosun	76/ 118/ 290/ 1352/ 203	0.9/ 1.9/ 17.9/ 65.2	AAK
6	Akotogbo	1349/ 2104/ 4745/ 1175/ 50	0.6/ 5.9/ 38/ 80.8	AKQ
7	Ajagba	1232/ 2062/ 396/ 59	1.4/ 23.3/ 73.7	KQ
8	Igbekebo	1333/ 631/ 1245/ 350/ 176	0.6/ 4.2/ 19.0/ 80.6	HKQ
9	Asisa	0.6/ 0.8/ 1.9	2.7/ 143.9	A
10	Obenla	1.6/ 0.2/ 24/ 124	4.4/ 20.2/ 31.7	HA
11	Igbobini	1372/ 662/ 3328/ 411/ 195	0.8/ 3.0/ 16.5/ 169.8	HKQ
12	Oluagbo	3024/ 145/ 631/ 428/ 206/ 5285	0.7/ 0.1/ 12.4/ 2.8/ 64.4	HKQ
13	Irele	709/ 142/ 876/ 8818/ 428/ 3243	0.9/ 0.8/ 1.2/ 20.3/ 187.5	HAKH
14	Laworo Camp	157/ 762/ 386/ 4237/ 8522/ 119	0.4/ 0.2/ 13.2/ 7.6/ 34.5	KHAK
15	Lokaka Camp	876/ 492/ 5844/ 878/ 1494	1.0/ 1.0/ 1.4/ 116.5	HKH
16	Owode Road	843/ 824/ 6165/ 790/ 21	1.2/ 5.0/ 22.2/ 276.8	KKQ
17	Okitipupa	1543/ 898/ 5416/ 113	0.9/ 8.3/ 45.1	HK
18	Ikoya	401/ 1276/ 41/ 568/ 4731	0.5/ 1.7/ 0.5/ 25.9	KHA
19	Ilutitun	230/ 106/ 678/ 852/ 262	0.8/ 7.8/ 10.6/ 43.6	HK
20	Igbinsin Oloto	4254/ 1128/ 3247/ 563	1.0/ 7.4/ 77.5	HK
21	Igboegbugurin	10608/ 821/ 1314/ 356/ 10798	0.8/ 5.3/ 18.6/ 25.4	HKH
22	Itebu Kunmi	21806/ 36762/ 2647/ 7925/ 1320	0.7/ 1.0/ 15.6/ 134.2	QHK
23	Mahintedo	1298/ 190/ 7958/ 757/175	0.8/ 0.7/10.8/89.9	HKQ
24	Itebu Elero	1457/ 476/ 1000/ 213/ 9675	0.4/ 3.1/ 32.2/ 287.7	HKH
25	Loda Camp	197/ 3480/ 597/ 3739/ 623	0.5/ 0.8/ 11.8/ 112.3	KHK
26	Ayila	350/ 1377/ 1121/ 291/ 56	0.8/ 0.4/ 30.0/ 111.2	KQQ
27	Aiyesan	432/ 1154/ 392/ 2011/ 179	0.8/ 1.5/ 2.7/ 62.0	KHK
28	Lomiroro	456/ 837/ 1258/ 2273/ 165	0.8/ 5.2/ 11.3/ 49.3	AAK
29	Efire	56/ 1199/ 218/ 1551/ 434/ 82	0.7/ 0.2/ 8.8/ 12.9/ 81.6	KHKQ
30	Atijere	3582/ 11265/ 4762/ 176/ 139	0.8/ 0.6/ 8.1/ 93.5	KQQ
31	Makun	2023/ 4007/ 2978/ 119/ 84/ 139	0.7/ 2.8/ 7.0/ 13.1/ 97.4	KQQH
32	Araromi-Obu	2236/ 2592/ 6412/ 466/ 335	0.9/ 13.5/ 51.0/ 24.9	AKQ
33	Agbure	1395/ 1296/ 2410/ 620/ 274/ 72	1.3/ 3.5/ 24.7/ 14.7/ 123.7	HKQQ
34	Ilusin	1055/ 236/ 9179/ 717/ 71	1.8/ 2.6/ 23.4/ 26.0	HKQ
35	Abigi	568/ 450/ 2084/ 297/ 56	0.8/ 3.9/ 68.1/ 121.0	HKQ
-	-	-	-	-
105	Adagbakuja2	0.9/ 0.6/ 0.9/ 7.4	1.0/ 7.2/ 43.0	HA
106	Oluagbo	Noisy data		
107	Agbabu2	Noisy data		
108	Igbobini2	Noisy data		

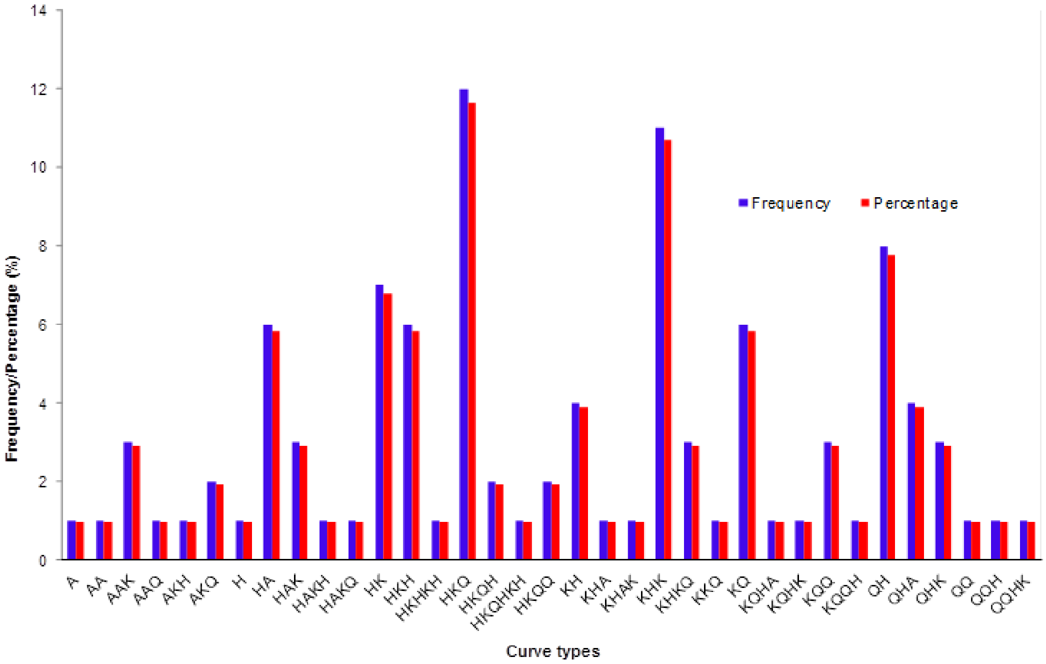

Figure 5: Curve types obtained from the study area and their rate of occurrence

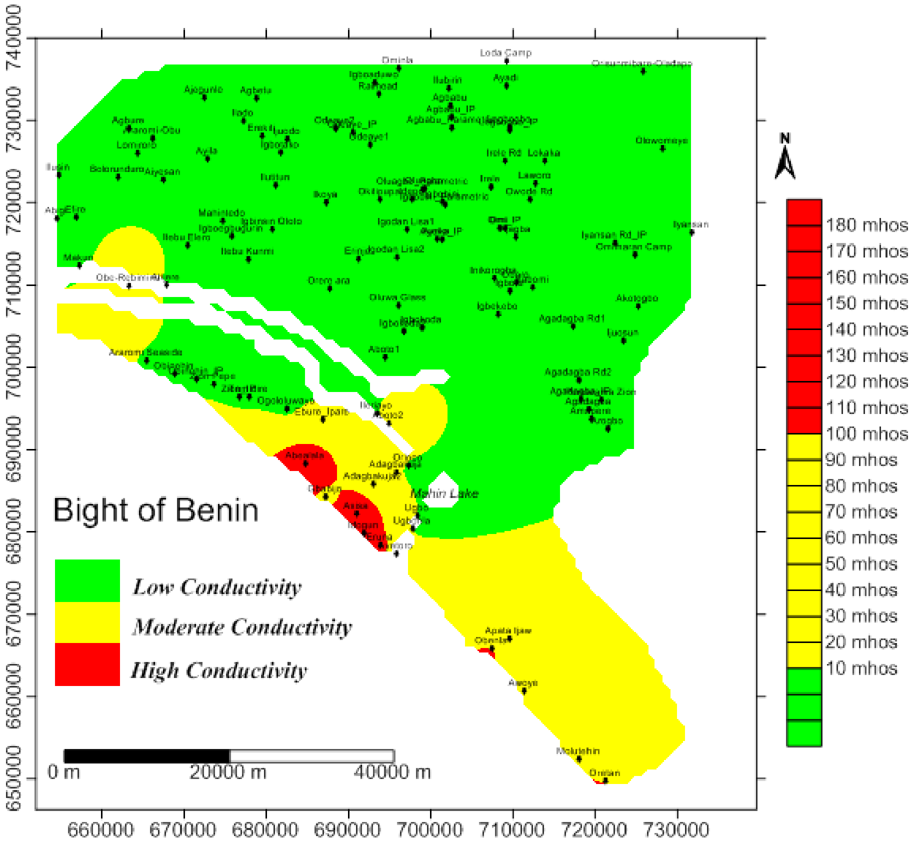

Figure 6: Map of average longitudinal conductance of the study area

Table 3: CRS Indicator Weights

S/N	Factors	Weights
1	Average longitudinal **C**onductance	6
2	Average longitudinal **R**esistivity	3
3	Equivalent **S**alinity	1

Table 4: Rating Adopted for CRS Parameter C

Indicator	Factors	Variables	Ratings
	Saline water	Above 100 mhos	1
Average longitudinal **C**onductance	Brackish water zone	10 – 100 mhos	1
	Fresh water zone	Below 10 mhos	0

Average longitudinal resistivity

Average longitudinal resistivity map (Figure 7) is also useful in the delineation of brackish/saline water lateral extent across the study area. Resistivity value of any geologic material depends on the concentration of salt in its water content. Low longitudinal resistivity values (below 60 ohm-m) were considered to be indicative of brackish/saline water zones in the area based on its good correlation with the hydro-chemical analysis results (Adeyemo et. al., 2015) and the experience of the inhabitants of the area. The average longitudinal unit resistivity was calculated from the first order geoelectric parameters based on the relationship below.

The average longitudinal unit resistivity (ρ_L);

$\rho_L = {}^{H}/_{S}$ (Zhody *et al.*, 1974) (4)

Where,

H = sum of the total thickness of the layer beneath each VES point

S = longitudinal conductance value for each VES point

While, for n layers the total average longitudinal conductance is;

$\rho_L = \sum_1^n h_i \Big/ \sum_1^n \frac{h_i}{\rho i}$ (Zhody *et. al.*, 1974) (5)

The average longitudinal resistivity map (Figure 4.23) reveals that the costal locations such as Obe-Rebiminu, Abealala, Gbabijo, Araromi Seaside, Obinehin, Zion Pepe, Asisa, Idogun, Ayetoro, Eruna, Apata Ijaw, Obenla, Awoye, Molutehin and Oretan recorded low to moderate longitudinal resistivity values (0.26 - 41.7 ohm-m), Likewise Agbabu, Legbogbo and Sabomi in the northern part of the study area. Genearally locations farther from the coastline recorded high longitudinal resistivity values (more than 60 ohm-m). To a good extent the map described the brackish/saline water intruded zone, hence it was assigned a relatively high weight 3 (Tables 3 and 5).

Table 5: Rating Adopted for CRS Parameter R

Indicator	Factors	Variables	Rating
Average longitudinal **R**esistivity	Saline water	0 - 30 ohm-m	1
	Brackish water zone	30 - 60 ohm-m	1
	Fresh water zone	Above 60 ohm-m	0

Equivalent salinity

Equivalent salinity was derived from calcium, sodium, chloride and sulphate concentrations based on the following relationship;

$0.81Ca + 0.45SO_4 + (Na+Cl)$ (Agat Laboratory, 2008) (6)

The equivalent salinity value is a direct reflection of subsurface water salinity. However the water samples were mostly collected at shallow depth from hand dug wells and surface water. This implies that where salinity occurs at relatively much depth, equivalent salinity will not reflect the salinity status of such locations. Thus equivalent salinity (Figure 8) was assigned the least weight, 1 (Tables 3 and 6). The equivalent salinity values range from minimum of 25.8 mg/l (Ode-Irele) to maximum of 2808 mg/l (Asisa). The equivalent salinity map (Figure 8) shows that high values were obtained from Ugbo, Ugbonla, Odonla, Idogun and Ayetoro area in the southeastern part of the study area and likewise at Agbabu in the north central part of the study area.

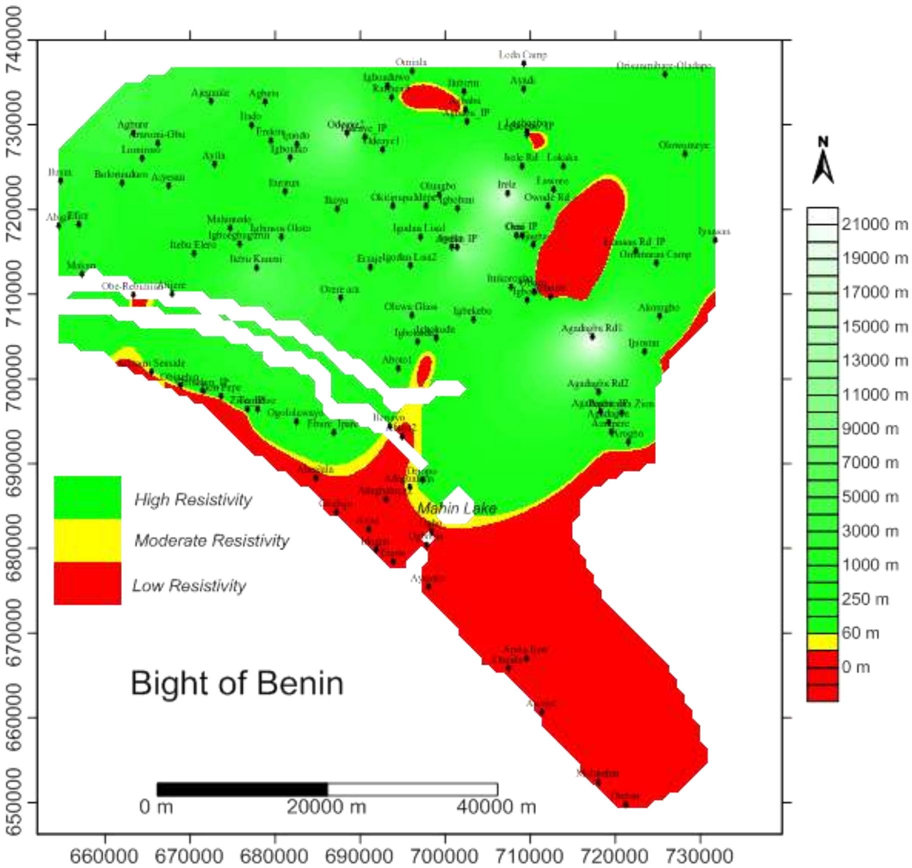

Figure 7: Map of average longitudinal resistivity of the study area

Table 6: Rating adopted for CRS parameter S

Indicator	Factors	Variables	Ratings
Equivalent **S**alinity	Saline water	Above 300 mg/l	1
	Brackish water zone	200 – 300 mg/l	1
	Fresh water zone	Below 200 mg/l	0

Saline Water Extent Map

Saline water extent map (Figure 9) was generated based on CRS-model. A model generated by synthesizing the average longitudinal **C**onductance, average longitudinal **R**esistivity and equivalent **S**alinity values across the study area (Table 7). The map project with high degree of accuracy the possible extents of saline water incursion across the study area and this represents about 35% of the study area. The map shows that the southeastern part are the largely affected by saline water intrusion, this perhaps due to the fact that there are more tributaries in this area through which sea water can move land ward.

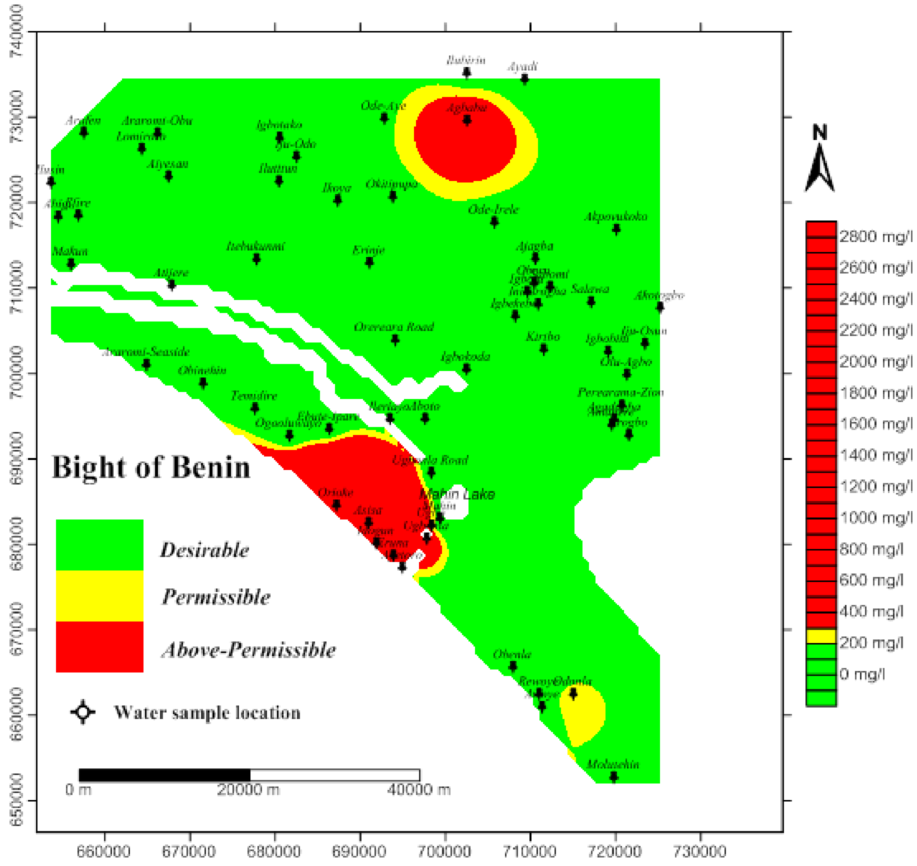

Figure 8: Equivalent salinity map of the study area.

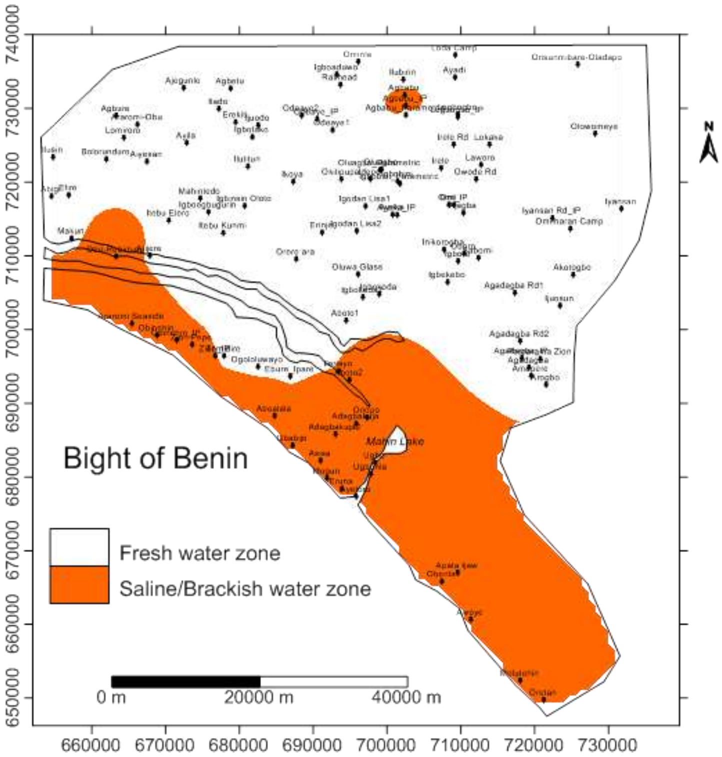

Figure 9: Map of saline water lateral extent of the study area

Table 7: CRS Model Calculation

VES NO	Towns	Long. Cond.	Long. Rest	Equiv Salinity	Weight Long. Rest	Rating Long. Rest	Weight Long. Cond.	Rating Long. Cond.	Weight Salinity	Rating Resistivity	CRS Index
1	Omi	0.4668483	434.83074	0	0.3	0	0.6	0	0.1	0	0
2	Sabomi	6.5451169	71.91621	0	0.3	0	0.6	0	0.1	0	0
3	Igbotu	0.1107259	876.0373	0	0.3	0	0.6	0	0.1	0	0
4	Agadagba	1.6158106	155.03054	0	0.3	0	0.6	0	0.1	0	0
5	Ijuosun	0.1378928	622.94773	0	0.3	0	0.6	0	0.1	0	0
6	Akotogbo	0.0800233	1565.7931	0	0.3	0	0.6	0	0.1	0	0
7	Ajagba	0.1985472	495.60008	0	0.3	0	0.6	0	0.1	0	0
8	Igbekebo	0.0321571	1019.994	0	0.3	0	0.6	0	0.1	0	0
9	Asisa	184.375	0.7951186	0	0.3	1	0.6	1	0.1	1	1
10	Obenla	105.05453	0.5359122	0	0.3	1	0.6	1	0.1	1	1
11	Igbobini	0.4232114	449.18446	0	0.3	0	0.6	0	0.1	0	0
12	Oluagbo	0.0271145	2965.1988	0	0.3	0	0.6	0	0.1	0	0
13	Irele	0.0105752	19924.032	0	0.3	0	0.6	0	0.1	0	0
14	Laworo	0.0388009	1440.69	0	0.3	0	0.6	0	0.1	0	0
15	Lokaka	0.1361016	880.95977	0	0.3	0	0.6	0	0.1	0	0
16	Owode Rd	0.3614722	844.32503	0	0.3	0	0.6	0	0.1	0	0
17	Okitipupa	0.0164545	2740.8834	0	0.3	0	0.6	0	0.1	0	0
18	Ikoya	0.0603729	473.7226	0	0.3	0	0.6	0	0.1	0	0
19	Ilutitun	0.1467203	425.98054	0	0.3	0	0.6	0	0.1	0	0
20	Igbinsin Oloto	0.0306635	2801.3723	0	0.3	0	0.6	0	0.1	0	0
21	Igboegbugurin	0.0920345	544.36095	0	0.3	0	0.6	0	0.1	0	0
22	Itebu Kunmi	0.0228865	6619.6167	0	0.3	0	0.6	0	0.1	0	0
23	Mahintedo	0.1244159	821.43826	0	0.3	0	0.6	0	0.1	0	0
24	Itebu Elero	1.3896914	232.71354	0	0.3	0	0.6	0	0.1	0	0
25	Loda Camp	0.0525682	2385.4717	0	0.3	0	0.6	0	0.1	0	0
26	Ayila	0.4114686	346.07744	0	0.3	0	0.6	0	0.1	0	0
-	-	-	-	-	-	-	-	-	-	-	-
105	Adagbakuja2	60.888889	0.8408759	0	0.3	1	0.6	0.5	0.1	1	0.7

CONCLUSION

This study integrated 108 vertical electrical soundings (VES) data acquired using Schlumberger array technique and hydro-chemical analysis of 61 water samples in delineating subsurface lateral extent of saline water intrusions into aquifers at the eastern part of Dahomey basin, Nigeria. The geoelectric survey results were presented as average longitudinal **C**onductance and average longitudinal **R**esistivity maps. The longitudinal conductance values vary from moderate to high (20 - 180 mhos) in the costal areas, while lower values (lesser than 10 mhos) were recorded in the mainlands. The average longitudinal resistivity values at the coastal areas and Agbabu, Legbogbo and Sabomi areas in the mainland were low to moderate (0.26 - 41.7

ohm-m), while higher values (more than 60 ohm-m) were gotten from the mainlands. The hydro-chemical analysis values presented as equivalent **S**alinity map vary from 25.8 mg/l (Ode-Irele) to 2808 mg/l (Asisa), while higher values were obtained from Ugbo, Ugbonla, Odonla, Idogun and Ayetoro area in the southeastern part of the study area and at Agbabu in the north central. The three results were synthesized using CRS-model. The final CRS-model map showed that the saline water intrusion extended to 35 % of the total area which covers; most part of the coastal area and Agbabu in the mainland. The presence of saline water at Agbabu in the central mainland is probably suggesting connate water, since there is no established path linking the sea to Agbabu area.

ACKNOWLEDGEMENT

The authors wish to acknowledgement many students of the Department of Applied Geophysics FUTA, who assisted during the field work stage of this work.

REFERENCES

Adepelumi, A.A. (2008). Delineation of Saltwater intrusion into the freshwater aquifer of Lekki Peninsula, Lagos, Nigeria. The 3rd Inter. Conference on Water Resources and Arid Environments and the 1st Arab Water Forum, 15pp.

Adeoti, L., Alile, O. U. and Uchegbulam, O. (2010). Geophysical Investigation of Saline Intrusion into Freshwater aquifers: A Case Study of Oniru, Lagos State. *Scientific Research and Essays,* **5**(3): 248 - 259.

Adeyemo, I.A., Omosuyi, G.O. and Adelusi, A.O. (2015). Hydrochemical investigation of saline water intrusion into aquifers in part of eastern Dahomey basin, Southwestern Nigeria. Journal of Environment and Earth Sciences *(JEES), of International Institute for Science, Technology and Education (IISTE)*, **5**(14): 176 - 189.

Adeyemo, I.A., Omosuyi, G.O. and Adelusi, A.O. (2017). Geoelectric soundings for delineation of saline water intrusion into aquifers in part of eastern Dahomey basin, Nigeria. *Journal of Geoscience and Environment Protection (GEP), Scientific Research Publishing,* **5**(3): 213 - 232.

Agat Laboratory (2008). Agat Laboratory Water Analysis Report Manual, www.agatlabs.com, 19p.

Ayolabi, E.A., Folorunso, A.F., Odukoya, A.M. and Adeniran, A.E. (2013). Mapping Saline Water Intrusion into the Coastal Aquifer with Geophysical and Geochemical Technique: The University of Lagos Campus case (Nigeria). *Springerplus*, **2(433)**: 1 - 14.

Batayneh, A.T. (2006). Use of electrical resistivity methods for detecting subsurface Fresh and saline water and delineating their Interfacial configuration: a case study of the Eastern Dead Sea coastal aquifers, *Jordan Hydrogeology Journal*, **14**: 1277 - 1283.

Burke, K.C., Dessauvagie, J.F.T., Whiteman, A.J. (1971). The Opening of the Gulf of Guinea and the Geological History of the Benue Depression and Niger Delta Nature. *Physical Science*, **233**(38): 51 - 55.

Chachadi, A.G. (2005). Seawater Intrusion Mapping Using Modified Galdit Indicator Model- Case Study in Goa. Jalvigyan Sameeksha, **20**: 29 - 45.

Choudhury, K., Saha, D.K. and Chakraborty, P. (2001). Geophysical Study of Saline Water Intrusion in A Coastal Alluvial Terrain. *Elsevier Journal of Applied Geophysics*, **46**: 189 - 200.

Jansen, J.R. (2011). Geophysical Methods to Map Brackish and Saline Water in Aquifers. Proceedings of the 2011 Georgia Water Resources Conference, April 11-13, 2011, University of Georgia. 4pp.

Jones, H.A. and Hockey, R.D. (1964). The Geology of Part of Southwestern Nigeria, Geological Survey Nigeria Bulletin, 31: 87.

Khalil, M.H. (2006). Geoelectric Resistivity Sounding for Delineating Saltwater Intrusion in the Abu Zenim area, West Sinai, Egypt. *Journal of Geophysics and Engineering*, **3**: 24 - 251.

Klemme, H.D. (1975). Geothermal Gradient Heat flow and hydrocarbon Recovery In: A.G. Fischer and Judson, S. (Eds). Petroleum and Global Tectonics. Princeton University Press, 25 - 304.

Martinez-Retama, S., Flores, C. and Castillo-Gurrola, J. (2007). Saline Intrusion in Guaymas Valley, Mexico from Time-Domain Electromagnetic Soundings. *Geofisica International*, **46**(3): 175 - 98.

Samsudin, A. R., Haryono, A, Hamzah, U. and Rafek, A.G. (2008). Salinity Mapping of Coastal Groundwater Aquifers using Hydrogeochemical and Geophysical Methods: A case Study from North Kelantan, Malaysia. *Environmental Geology,* **55**: 1737 - 1743.

Satriani, A., Loperte, A. and Proto, M. (2011). Electrical Resistivity Tomography for Coastal Salt water Intrusion Characterization along the Ionian Coast of Basilicata Region, Southern Italy. IWTC-15, 15th International Water Technology Conference, Alexandria, Egypt, 12pp.

Okosun, E.A. (1998). Review of the Early Tertiary Stratigraphy of Southwestern Nigeria. *Journal of Mining and Geology*, **34**: 27 - 35.

Omosuyi, G.O. (2001). Geophysical and Hydrogeological Investigations of Groundwater Prospects in the Southern Part of Ondo State, Nigeria. PhD Thesis, Department of Applied Geophysics, Federal University of Technology, Akure, Nigeria, 195pp.

Omosuyi, G.O., Ojo, J.S. and Olorunfemi, M.O. (2008). Geoelectric Sounding to Delineate Shallow Aquifers in the Coastal Plain sands of Okitipupa Area, Southwestern Nigeria. *The Pacific Journal of Science and Technology*, **9**(2): 562 - 577.

Omoyoloye, N.A., Oladapo, M.I. and Adeoye, O.O. (2008). Engineering Geophysical Study of Adagbakuja Newtown Development SW, Nigeria. *Medwell Online Journal of Earth Sciences*, **2**(2): 55 - 63.

Oyedele, K.F. and Momoh, E.I. (2009). Evaluation of Seawater Intrusion in Freshwater Aquifers in a Lagoon Coast: A Case Study of the University of Lagos Lagoon, Akoka, Nigeria. *New York Science Journal*, **2**(3): 32 - 42.

Nigeria Geological Survey Agency (2004). Geological Map of Southern Part of Ondo State

Rahaman, M.M. and Bhattacharya, A.K. (2014). Saline water Intrusion in Coastal Aquifer: A case study from Bangladesh. *Journal of Engineering,* **4**(1): 7 - 13.

Zohdy, A.A.R., Eaton, G.P. and Mabey, D.R. 1974. Application of Surface Geophysics to Ground-WaterInvestigations, In Techniques of Water-Resources Investigations of the United States Geological Survey. Book 2, Chapter D1. 63p.