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**Research Article**

# Groundwater Deductions from Geoelectric Survey in Burutu Island, Delta State, Nigeria

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**Abstract:** A resistivity survey was carried out in order to study the groundwater conditions in Burutu Island, the thickness, depth, location of aquifer and type of aquifer were determined utilizing the surface Schlumberger electrode array with maximum current electrode spacing of 300 m. A total of 4 VES stations were sounded and seven geoelectric layers were delineated in the survey area. The first layer was top soil with resistivity values ranging from (54-893 Ωm) and thickness between (0.5-1.4 m). The second layer had a resistivity ranging from (24.82-2768.0 Ωm) and thickness of (2.03-3.71 m) consisting of fine to medium sand. The third to fifth geoelectric layers consist of sandy clay sand with thickness varying from (3.12-17.23 m) and resistivity values of (1.21-163.91Ωm) which indicates saline intruded water zone. The results of the VES interpretation shows that a good source of aquifer was encountered at a depth of 49 m with a thickness of 19m which extends into the seventh layer. The results of the resistivity survey revealed that the parameters obtained through the interpretation of the VES curve using Win Resist software corresponds to the litholog of the borehole close to VES 4.

**Keywords:** Aquifer, geoelectric, resistivity, saline water, schlumberger electrode array

## INTRODUCTION

Increase in population and urbanization on a daily basis in the coastline of Niger delta areas of Nigeria have led to a corresponding reduction in quality of groundwater in these areas. Groundwater reservoir quality can be affected by a number of factors such as intrusion by saltwater or other anthropogenic interference (Abdul *et al*., 2000; Batayneh, 2006; Amadi *et al*., 2012). Most wells drilled to the subsurface to yield freshwater in coastal sedimentary basins in the world have been abandoned due to inundation of the wells by seawater and Nigeria is no exception (Oyedele and Momoh, 2009).

The phenomenon of saltwater intrusion in the coastal areas is a natural process and Burutu Island (Fig. 1) is not excluded. It is located within the coastal alluvium of Niger delta. All the groundwater extraction boreholes in Burutu have been done without preliminary geological and geophysical investigations resulting in temporarily functional boreholes which have been abandoned due to saltwater intrusion. The area is characterized by a highly permeable, porous soil and shallow water table making it prone to contamination (Amadi and Olasehinde, 2009). If the groundwater withdrawal in coastal environments is not sufficiently controlled, it can lead to seawater intrusion, degradation of aquifer quality as a result of infiltration rate and up-coning of the saline water layer at the saltwater-freshwater interface (Oteri, 1988).

Therefore, the application of geophysics to the successful exploration of groundwater in sedimentary terrain requires a proper understanding of its hydro-geological characteristics. Evidence has shown that geophysical methods are the most reliable and the most accurate means of all surveying methods of subsurface structural investigations and rock variation (Emenike, 2001). In view of its effective, economic and quick means of obtaining details of the electrical characteristics of the subsurface at a location, the vertical electric sounding technique has had a high rate of success for investigating groundwater quality in diverse lithological settings.

In view of the above, the Vertical Electric Sounding (VES) technique was used in the present study to investigate groundwater potential in Burutu Island, Burutu local government area of Delta State, Southern Nigeria such as freshwater and saltwater as well as depth to freshwater-saltwater interface.

**Geology and hydrogeology of the area:** Burutu Island is situated in South-Western part of Delta State some few kilometers away from the Atlantic Ocean in the

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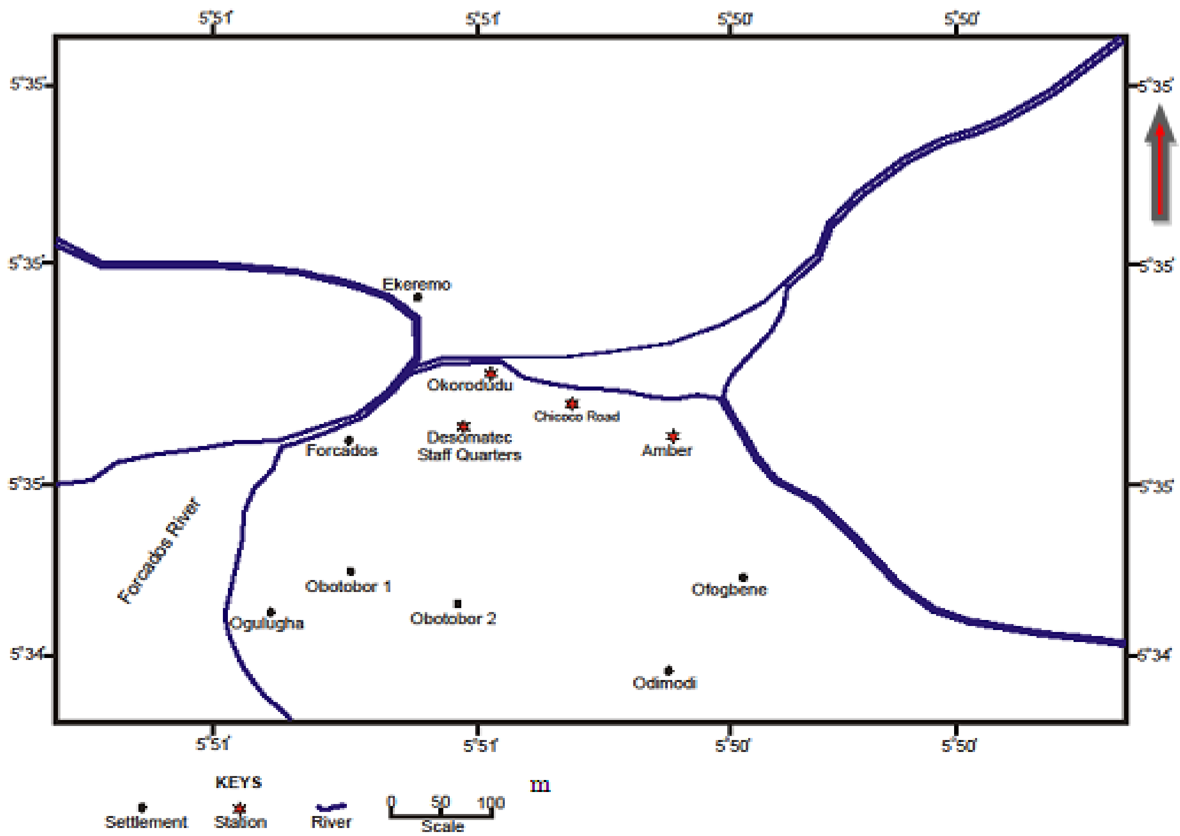



Fig. 1: Map of the study area

geomorphic sub-environment of the Niger Delta area. It lies within Latitude $5^{o}\ 34^{/}\ 80.8^{//}$N to $5^{o}\ 35^{/}49.8^{//}$N and Longitude $5^{\circ}\ 50^{/}\ 29.6^{//}$E to $5^{\circ}\ 51^{/}24.3^{//}$E and stands at an average elevation of 22 m above sea level (Fig. 1). Physically, it is about 2.5 km long and 0.5 km wide. It is located on the Burutu River which flows directly into the Atlantic Ocean. Geologically, it comprises of Miocene to recent sediments deposited by fluvial and shallow continental shelf hydrodynamic process. The lithological sediments consist of unconsolidated fine grained sands, medium to coarse grained sands which are poorly cemented and consist of alternating sequences of sand, silt and clay (Amadi, 2010). The area is basically underlain by the Benin formation is highly influenced by oxidation of near surface aquifers resulting in iron stained sandy surfaces (Amadi *et al.*, 2012). The area has a variable water table which is season dependent. It is shallow and ranges from 0.2-3 m depending on the season of the year. Going downwards, confined and unconfined aquifers are encountered.

## MATERIALS AND METHODS

In this study, a total of four VES points were occupied. The Schlumberger electrode array was used for acquisition of data which was done with a Pz-02 Earth Resistivity meter. The maximum current electrode spacing array spread in all the VES points were 300m due to availability of space.

The method involves applying current into the ground through two current electrodes (A and B) and two potential electrodes (M and N) were inserted into the ground between the outer current electrodes A and B, where the potential difference was measured across the potential electrodes. Increasingly deeper currents are achieved by using bigger separation between the current electrodes while keeping the potential electrodes fixed. As signals on the earth resistivity metre become weaker, the potential electrodes distance was increased and two values of AB/2 was measured, therefore having on for short and one for long MN spacing.

The apparent resistivity values were determined taking the product of the resistance measured on the Earth Resistivity metre and the geometric factor, a factor which is dependent on the type of array used. Shown below is the equation for determining the apparent resistivity:

$$\rho_a = K\frac{V}{I} \quad (1)$$

And the geometric factor k, for Schlumberger electrode configuration is shown below as:

$$K = \frac{\pi\left[\left(\frac{AB}{2}\right)^2 - \left(\frac{MN}{2}\right)^2\right]}{MN} \quad (2)$$

The interpretation of field data was got from qualitative process of plotting (and inspection) of the resistivity field curves to ensure data reliability. The observed field data was fed into the computer, while theoretical resistivity models are generated by means of layer parameters, using a 9-point digital linear filter (Koefoed, 1979). Automatic iterative interpretation using the Win Resist computer software was employed in the final selection of layer parameters. The number of geo electric layers and their corresponding specific resistivity's were first taken to be equal to the number of measurement points and the difference of adjacent current electrode spacing respectively. Layer parameters are consequently modified in iterative manner until subsequent iteration yields no improvement on the Root Mean Square (RMS) error. The resulting layer parameters were deduced for their geologic interpretation.

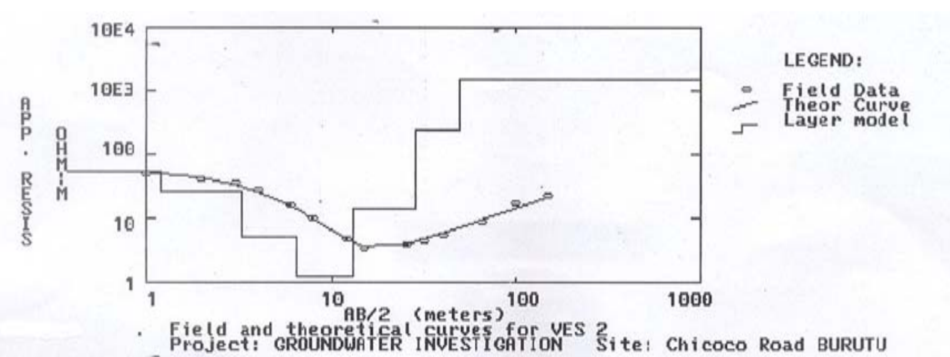
## RESULTS AND DISCUSSION

The analysis of the resistivity data showed the presence of seven geoelectric layers in all the VES points. Typical curve types exemplary of saline water intruded zones were observed in all the VES points such as QQ and KQ. All the curves descended gently indicating that there was conductivity decrease which shows saline water intrusion into subsurface formations (Fig. 2 and 3). These descending segments of the VES curves are characteristic of low resistivity zones (Fig. 2 and 3).

The resistivity of the first layer in VES 1-4 ranges from 54-413 Ωm while its thickness varies from 0.5-1.34 m. This layer constitutes the topsoil. The high resistance with recorded in VES 4 may be as a result of granites stones embedded with topsoil at the ground surface as the VES point was done beside a road under construction. Also, the resistivity value of layer one in VES 3 also had an exceptionally high value of 893.68 Ωm due to the effect of massive rubbles that were scattered on the surface.

Geo electric layer two in VES 1, 2 and 4 ranges from 24.82 to 171 Ωm with a thickness within the range of 2.03-3.71 m. Layer two in VES 3 had a very high resistivity value of 2768.0 Ωm which could have resulted from the effects of underground cement pipes, concrete slabs under the surface and granite stones mixed with sand below the surface. Generally, the second layer constitutes medium sand from the litho logy of the area.

Layer three and four in VES 1, 2 and 4 had very low resistivity values indicative of saline water intruded zones. Layer four in VES 1, 2 and 4 had the



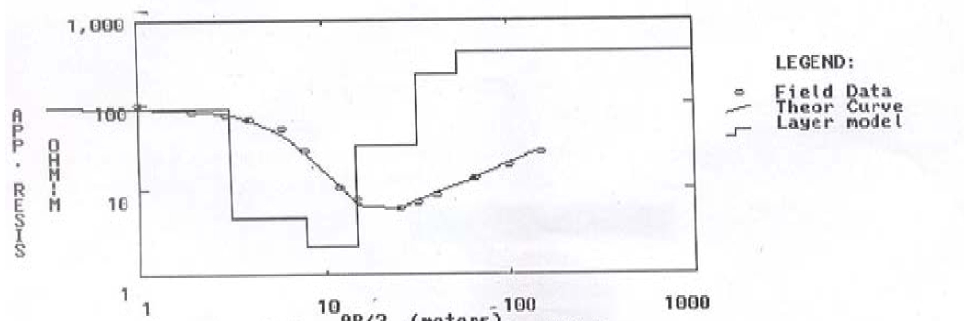

PROJECT: GROUNDWATER INVESTIGATION
SITE: Chicoco Road, BURUTU. VES NUMBER: 2

| AB/2 | OBSERVED RES | COMPUTED RES | LOG DIFFERENCE |
|---|---|---|---|
| 1.00 | 49.36 | 52.31 | -0.03 |
| 2.00 | 40.21 | 43.63 | -0.04 |
| 3.00 | 34.89 | 34.12 | 0.01 |
| 4.00 | 26.64 | 26.39 | 0.00 |
| 6.00 | 15.61 | 15.85 | -0.01 |
| 8.00 | 10.06 | 9.82 | 0.01 |
| 12.00 | 4.82 | 4.70 | 0.01 |
| 15.00 | 3.42 | 3.55 | -0.02 |
| 25.00 | 3.95 | 3.84 | 0.01 |
| 32.00 | 4.39 | 4.77 | -0.04 |
| 40.00 | 5.43 | 5.89 | -0.04 |
| 65.00 | 8.64 | 9.40 | -0.04 |
| 100.00 | 16.70 | 14.33 | 0.07 |
| 150.00 | 22.48 | 21.29 | 0.02 |

RMS error = 2.87 %

LAYER PARAMETERS OF MODEL

| LAYER | RESISTIVITY | THICKNESS | CUM THICK |
|---|---|---|---|
| 1.00 | 54.66 | 1.21 | 1.21 |
| 2.00 | 24.82 | 2.03 | 3.24 |
| 3.00 | 5.01 | 3.12 | 6.36 |
| 4.00 | 1.21 | 6.68 | 13.04 |
| 5.00 | 14.30 | 14.88 | 27.92 |
| 6.00 | 239.16 | 21.26 | 49.18 |
| 7.00 | 1530.00 | infinity | infinity |




Field and theoretical curves for VES 1
Project: GROUNDWATER INVESTIGATION Site: Okorodudu BURUTU

PROJECT: GROUNDWATER INVESTIGATION
SITE: Okorodudu, BURUTU. VES NUMBER: 1

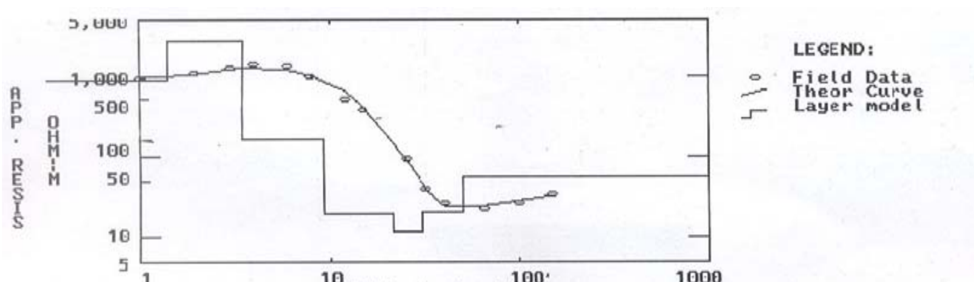
| AB/2 | OBSERVED RES | COMPUTED RES | LOG DIFFERENCE |
|---|---|---|---|
| 1.00 | 102.30 | 93.56 | 0.04 |
| 2.00 | 82.18 | 88.01 | -0.03 |
| 3.00 | 74.65 | 79.86 | -0.03 |
| 4.00 | 66.28 | 68.74 | -0.02 |
| 6.00 | 51.46 | 45.18 | 0.06 |
| 8.00 | 28.93 | 27.58 | 0.02 |
| 12.00 | 10.45 | 10.73 | -0.01 |
| 15.00 | 7.63 | 6.62 | 0.06 |
| 25.00 | 5.75 | 5.75 | 0.00 |
| 32.00 | 6.92 | 7.07 | -0.01 |
| 40.00 | 8.26 | 8.61 | -0.02 |
| 65.00 | 13.40 | 13.38 | 0.00 |
| 100.00 | 18.90 | 20.01 | -0.02 |
| 150.00 | 27.39 | 29.14 | -0.03 |

RMS error = 3.02 %

LAYER PARAMETERS OF MODEL

| LAYER | RESISTIVITY | THICKNESS | CUM THICK |
|---|---|---|---|
| 1.00 | 96.11 | 0.50 | 0.50 |
| 2.00 | 90.93 | 2.63 | 3.13 |
| 3.00 | 4.65 | 4.78 | 7.91 |
| 4.00 | 2.10 | 6.99 | 14.90 |
| 5.00 | 32.95 | 17.23 | 32.13 |
| 6.00 | 227.43 | 20.20 | 52.33 |
| 7.00 | 428.00 | infinity | infinity |

Fig. 2: Iterated curves for VES 1 and 2




Field and theoretical curves for VES 3
Project: GROUNDWATER INVESTIGATION Site: Quarters BURUTU

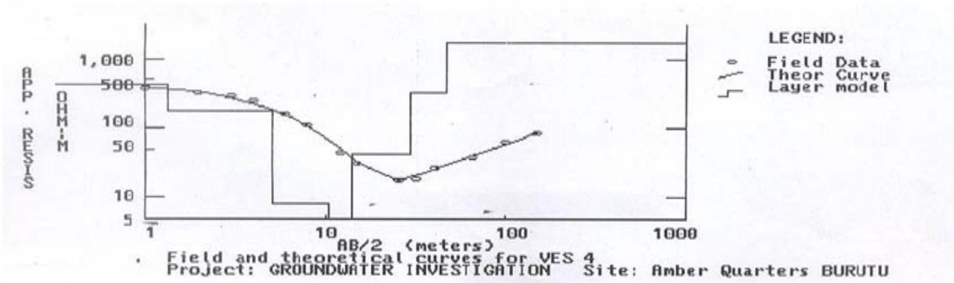
PROJECT: GROUNDWATER INVESTIGATION
SITE: Quarters, BURUTU. VES NUMBER: 3

| AB/2 | OBSERVED RES | COMPUTED RES | LOG DIFFERENCE |
|---|---|---|---|
| 1.00 | 946.39 | 921.64 | 0.01 |
| 2.00 | 1120.51 | 1048.90 | 0.03 |
| 3.00 | 1287.08 | 1186.03 | 0.04 |
| 4.00 | 1418.48 | 1264.98 | 0.05 |
| 6.00 | 1341.31 | 1231.20 | 0.04 |
| 8.00 | 1011.33 | 1051.76 | -0.02 |
| 12.00 | 511.20 | 640.96 | -0.10 |
| 15.00 | 369.41 | 413.32 | -0.05 |
| 25.00 | 95.23 | 91.86 | 0.02 |
| 32.00 | 40.21 | 39.69 | 0.01 |
| 40.00 | 26.12 | 24.61 | 0.03 |
| 65.00 | 22.70 | 24.22 | -0.03 |
| 100.00 | 26.50 | 27.74 | -0.02 |
| 150.00 | 34.36 | 33.39 | 0.01 |

RMS error = 3.84 %

LAYER PARAMETERS OF MODEL

| LAYER | RESISTIVITY | THICKNESS | CUM THICK |
|---|---|---|---|
| 1.00 | 893.68 | 1.42 | 1.42 |
| 2.00 | 2768.00 | 2.12 | 3.54 |
| 3.00 | 163.91 | 5.81 | 9.35 |
| 4.00 | 19.89 | 11.99 | 21.34 |
| 5.00 | 11.73 | 9.59 | 30.93 |
| 6.00 | 20.57 | 19.19 | 50.12 |
| 7.00 | 56.26 | infinity | infinity |




PROJECT: GROUNDWATER INVESTIGATION
SITE: Amber Quarters, BURUTU. VES NUMBER: 4

| AB/2 | OBSERVED RES | COMPUTED RES | LOG DIFFERENCE |
|---|---|---|---|
| 1.00 | 381.26 | 398.72 | -0.02 |
| 2.00 | 326.44 | 342.09 | -0.02 |
| 3.00 | 289.54 | 276.53 | 0.02 |
| 4.00 | 247.30 | 225.11 | 0.04 |
| 6.00 | 161.49 | 155.05 | 0.02 |
| 8.00 | 112.39 | 107.86 | 0.02 |
| 12.00 | 43.43 | 52.25 | -0.08 |
| 15.00 | 31.00 | 32.32 | -0.02 |
| 25.00 | 17.80 | 17.69 | 0.00 |
| 32.00 | 18.20 | 20.30 | -0.05 |
| 40.00 | 26.72 | 24.84 | 0.03 |
| 65.00 | 37.80 | 39.01 | -0.01 |
| 100.00 | 63.00 | 58.33 | 0.03 |
| 150.00 | 84.00 | 85.35 | -0.01 |

RMS error = 3.26 %

LAYER PARAMETERS OF MODEL

| LAYER | RESISTIVITY | THICKNESS | CUM THICK |
|---|---|---|---|
| 1.00 | 413.29 | 1.34 | 1.34 |
| 2.00 | 171.00 | 3.71 | 5.05 |
| 3.00 | 8.39 | 5.41 | 10.46 |
| 4.00 | 5.03 | 3.36 | 13.82 |
| 5.00 | 42.63 | 15.10 | 28.92 |
| 6.00 | 324.32 | 17.67 | 46.59 |
| 7.00 | 1766.28 | infinity | infinity |

Fig. 3: Iterated curve for VES 3 and 4

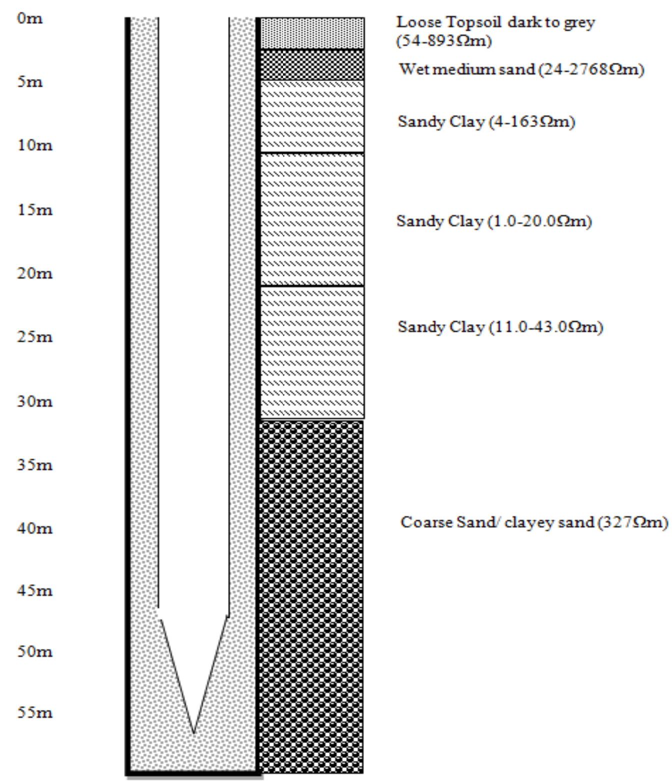



Fig. 4: The lithology (Geoelectric section) and the borehole drilled in the area

lowest resistivity values which ranged from 1.21 Ωm in VES 2 to 5.03 Ωm in VES 4. Also, the thickness of layer four in the above three VES points had the least thickness of 3.36 m in VES 4 and the highest thickness of 6.99 m in VES 1. In VES 1, 2 and 3, the average depth to the least resistivity value which is in layer four was 13.92 m. Layer four and five in VES 3 had the least resistivity value in layer five with a resistivity value of

Table 1: Summary of interpretation

| VES NO | Geoelectric layers | Resistivity (Ωm) | Thickness (m) | Depth (m) | Curve type | Probable lithology | Inferred interpretation |
|---|---|---|---|---|---|---|---|
| 1 | 1 | 96.110 | 0.500 | 0.50 | QQ | Fine to medium sand | Topsoil |
| | 2 | 90.930 | 2.630 | 3.130 | | Medium sand | Intermediate water quality |
| | 3 | 4.6500 | 4.780 | 7.910 | | Sandy clay | Saline water |
| | 4 | 2.1000 | 6.990 | 14.91 | | Sandy Clay | Saline water |
| | 5 | 32.950 | 17.23 | 32.13 | | Sandy Clay | Saline water |
| | 6 | 227.43 | 20.20 | 52.33 | | Coarse sand/clayey sand | Very good quality water |
| | 7 | 428.00 | ∞ | ∞ | | Coarse sand /clayey sand | Very good water quality |
| 2 | 1 | 54.660 | 1.210 | 1.210 | QQ | Fine to medium sand | Topsoil |
| | 2 | 24.820 | 2.030 | 3.240 | | Medium sand | Intermediate water quality |
| | 3 | 5.0100 | 3.120 | 6.360 | | Sandy clay | Saline water |
| | 4 | 1.2100 | 6.680 | 13.04 | | Sandy clay | Sea water/very saline water |
| | 5 | 14.300 | 14.88 | 27.92 | | Sandy clay | Saline |
| | 6 | 239.16 | 21.26 | 49.18 | | Coarse sand/ clayey sand | Very good water quality |
| | 7 | 1530.0 | ∞ | ∞ | | Coarse sand/ clayey sand | |
| 3 | 1 | 893.68 | 1.420 | 1.420 | KQ | Coarse sand | Topsoil |
| | 2 | 2768.0 | 2.120 | 3.540 | | Coarse sand/ sandstone | |
| | 3 | 163.91 | 5.810 | 9.350 | | Coarse sand/ clayey sand | Intermediate water quality |
| | 4 | 19.89 | 11.99 | 21.34 | | Sandy clay | Saline water |
| | 5 | 11.73 | 9.590 | 30.93 | | Sandy clay | Saline water |
| | 6 | 20.57 | 19.19 | 50.12 | | Sandy clay | Saline water |
| | 7 | 56.26 | ∞ | ∞ | | Sandy clay | |
| 4 | 1 | 413.29 | 1.340 | 1.340 | | Coarse sand | Topsoil |
| | 2 | 171.00 | 3.710 | 5.050 | QQ | Coarse sand | Intermediate water quality |
| | 3 | 8.3900 | 5.410 | 10.46 | | Sandy clay | Saline water |
| | 4 | 5.0300 | 3.360 | 13.82 | | Sandy clay | Saline water |
| | 5 | 42.630 | 15.10 | 28.92 | | Sandy clay | Saline water |
| | 6 | 324.32 | 17.67 | 46.59 | | Coarse sand/ clayey sand | Very good water quality |
| | 7 | 1766.28 | ∞ | ∞ | | Coarse sand/ clayey sand | |

11.73 Ωm and thickness of 9.59 m at a depth of 30.93 m. Layer three, four and five in virtually all the VES points comprises of sandy clay zones from the lithology of the area (Fig. 4). There was a drastic increase in resistivity values from layer five to six in all the VES points. The resistivity values are 227.43, 239.16, 20.57 and 324.32 Ωm in VES 1, 2, 3 and 4, respectively. The thickness of this layer varies from 17.67 m in VES 4 to 21.26 m in VES 2. An exceptionally low value of 20.57 Ωm was recorded at layer six at VES 3. This is the likely auriferous horizon in the survey area. The average depth to the auriferous formation is 49.55 m. This is in agreement with the borehole lithology of an abandoned borehole close to VES 4 where a good source of aquifer was gotten at a depth of 51 m. The lithology of this layer constitutes a coarse sand/clayey zone.

Underlying this layer is the fresh bedrock of infinite thickness (Table 1).

## CONCLUSION

The results of electrical resistivity survey where four electric sounding were carried out in Burutu Island, headquarters of Burutu Local Government Area, Delta State, Nigeria have been reported. From one dimensional interpretation of the acquired data, seven geo electric layers were identified down to the depth of investigation in the survey area. The area suffers from saline water up to an average depth of 29m below the subsurface. Though the water table in the area shallow, between 0.2-3 m, the groundwater in the survey area up to a depth of 3.75 m is unappreciable, unconfined and prone to saline water intrusion from nearby layers and also to surface pollutants which percolates the surface layers.

From the VES interpretation, we can see that the sixth layer with an average resistivity of 263.63 Ωm and average thickness of 19.71 m is an appreciable freshwater bearing formation at a depth of 49.99 m. Comparing with a borehole lithology which was which close to VES 4 where a good source of aquifer is gotten at a depth of 51 m, we can say that layer six will be a good source of aquifer in the survey area. Result from VES 3 was quite inconsistent with the other three VES points and no appreciable source of aquifer is achievable. However, what led to the abandonment of the drilled borehole in the area is as a result of saltwater intrusion from the overlying aquifer.

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