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Electrical Resistivity Tomography and Vertical Sounding for Groundwater Potentials in Erhoike Community, Delta State, Nigeria

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ABSTRACT: This study investigated the Electrical Resistivity Tomography (ERT) A geophysical investigation involving Electrical Resistivity Tomography (ERT) and Vertical Electrical Sounding (VES) for groundwater potentials in Erhoike Community, Delta State, Nigeria, using standard geophysical methods. Six (6) lithologies including the topsoil, dry sand, saturated sand, clayey sand, sandy clay and clay were delineated within the area. The top soil with resistivity and thickness of 547.5 – 8348.6 ohm-m and 0.7 – 1 m respectively represent the first delineated geoelectric layer. This overlies the dry sand having geoelectric parameter of 3.9 – 19.7 m and 761.4 – 8248.6 ohm-m respectively. The dry sand layer underlain by the saturated sand having resistivity ranging from 114.3 – 1380.6 ohm-m. The resistivity of the clayey sand oscillates between 47.6 – 85.3 ohm-m. This layer represents the last layers at the locations where it was delineated, as such the thickness could not be estimated. The clay layer underlies sandy clay in places while in other cases, it succeeds the topsoil. The resistivity and thickness of the clay layer were 11.4 – 48.9 ohm-m and 25.8 – 56.1 m respectively. The sandy clay was found to have resistivity of 50.6 – 115.3 ohm-m and thickness of 2.9 – 8.8 m. The results of the study showed that the saturated sand layer represents the aquiferous layer within the area where groundwater can be tapped for the community. The thickness of this layer is found to be more than 58.2 m which is quite significant for groundwater development. The study concluded that there is abundance of groundwater accumulation beneath the area. It further reinforced the applicability of combined ERT and VES in groundwater potential mapping in an area underlain by similar geology.

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Water is an indispensable resource for life on Earth, including humans (Travassos and Menezes 2004). Although groundwater potential is generally high in sedimentary/unconsolidated environment (Clark 1985), sometimes there could be the problems of quality and low yield because of the nature of the water-bearing layer within the subsurface. Hence the need for predrilling geophysical investigations. Geophysical investigation in groundwater development-related problems usually involves delineation and assessment of aquifer potential, aquifer protective capacity, water quality and sometimes pollution assessment studies among others (Kinnear *et al*., 2013; Orakwe *et al*., 2018; Olorunfemi and Oni 2019). The integration of geophysical methods and techniques, especially the magnetic and the very low frequency (VLF) electromagnetic (EM) as reconnaissance geophysical methods (Hasan *et al*., 2018), and the 2D resistivity imaging and 1D vertical electrical sounding (VES) techniques for detailed follow-up studies have become standard procedure in groundwater investigation (Olorunfemi and Oni 2019; Manu *et al*., 2019). This is due to the close correlation between hydrogeological parameters and geoelectrical measurements (Goldman and Neubauer 2004) and the ability of the methodology to provide basis for the assessment of the groundwater potential (Akinwumiju *et al*., 2016).

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The 2D resistivity tomography is now frequently used as both reconnaissance and confirmatory studies (Gao *et al*., 2018; Olorunfemi and Oni 2019; Olorunfemi *et al*., 2020). 2D resistivity structures derivable from the inversion of 2D resistivity data are close approximations of images of horizontal layers (sedimentary environment) that are three-dimensional in nature (Shemang and Chaoka 2003; Owen *et al*., 2005; Olorunfemi and Oni 2019; Olorunfemi *et al*., 2020) and could account for the very strong lateral variation in weathered and fractured consolidated rock that creates ambiguities in VES interpretation (Acworth 2001; Sandberg *et al*., 2002; Kellet *et al*., 2004; Kumar *et al*., 2007; Olorunfemi *et al*., 2020). 2D imaging also has the ability to distinguish hydro-geologically significant lineament (Owen *et al*., 2005; Kumar 2012), while hydrogeological properties can be correlated with the inverted true resistivity value. In view of the forgoing, this paper evaluates the electrical resistivity tomography and vertical electrical sounding for groundwater potentials in Erhoike community, Delta State, Nigeria.

MATERIALS AND METHODS

The study began with a reconnaissance survey of the area and profile preparation. The traverse lines were oriented. All the profiles were 200 m and inter-electrode spacing of 10 m was used for deeper penetration. Wenner electrode configuration was adopted for the 2-D ERT and Res2Dinver software was used for inversion of the resistivity data to generate the 2D resistivity image of the subsurface. For the 1-D VES, the Schlumberger electrode array with maximum AB of 400 m was employed in all cases. The VES data was processed using partial curve matching technique and the derived parameters i.e. apparent resistivity and layer thicknesses were inverted using appropriate computer assisted iteration. The results (ERT and VES) were then interpreted qualitatively and semi-quantitatively to determine the prospect of the area for groundwater development.

RESULTS AND DISCUSSION

2-D Resistivity Tomography: The 2D resistivity image obtained from the inversion of traverse 1 is as displayed in figure 1. The image shows three (3) geoelectric zones beneath the profile. These include the topsoil (made up of clayey sand) with resistivity ranging from < 60 ohm-m to > 100 ohm-m. It extends from the top to a depth of about 13 m. The second subsurface geoelectric layer has resistivity ranging from about 133 ohm-m to about 298 ohm-m. This subsoil encloses the third geoelectric material whose resistivity ranges from 298 ohm-m to > 390 ohm-m. This third geoelectric material extends from a depth of about 12.8 m to beyond 31.9 m at a horizontal distance of between 80 – 140 m. This layer could serve as aquifer where groundwater could be tapped.

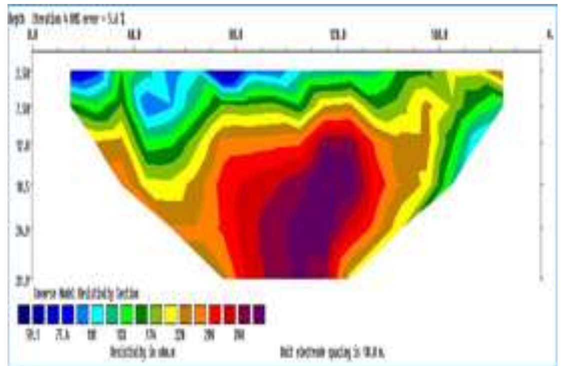

Fig. 1: 2D Resistivity Section along Traverse 1

The 2D resistivity structure along transect 2 displayed in figure 2 delineated mainly two geoelectric layers. The first geoelectric zone is composed of sandy clay and sand. The resistivity value for this zone ranges from about 32.3 ohm-m to more than 116 ohm-m and it extend to depth of about 18.5 m. The second subsurface geoelectric layer has resistivity values ranging from about 1.32 ohm-m to about 32.3 ohm-m. This subsoil is suspected to be clay/saline water saturated sand.

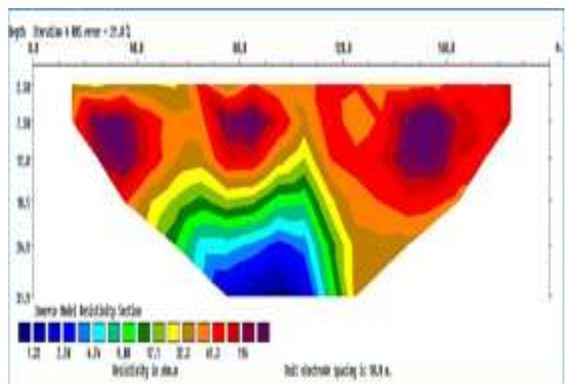

Fig. 2: 2D Resistivity Section along Traverse 2

The inverted 2D resistivity image along traverse 3 is shown in figure 3. The image shows the general resistivity distribution beneath the traverse with a prominent sand layer from lateral distance of 75 – 135 m. This sand layer extends from depth of 7.5 to more than 31.9 m. Its resistivity value ranges from about 82.5 ohm-m to more than 90.7 ohm-m. This layer is suspected to be the aquifer where groundwater could be tapped. The subsurface 2D resistivity image along traverse 4 is shown in figure 4. The image shows the general resistivity distribution beneath the traverse with a prominent sand layer from lateral distance of 75 – 130 m. This sand layer extends from depth of 7.5 to more than 31.9 m..

Table 1: Summary of VES interpretation

VES No	Layers	Resistivity (Ωm)	Thickness (m)	Depth (m)	Curve Type	Lithology
	1	8348.6	0.8	0.8	**QQH**	Topsoil
	2	3910.8	3.7	4.5	$\rho_1 > \rho_2 > \rho_3 > \rho_4 < \rho_5$	Sand (Dry)
1	3	1622.4	16.0	20.5		Sand (Dry)
	4	747.5	46.6	67.2		Sand (Saturated)
	5	1380.6	---	---		Sand (Saturated)
2	1	6219.8	0.8	0.8	**QQH**	Topsoil
	2	2353.2	3.9	4.7	$\rho_1 > \rho_2 > \rho_3 > \rho_4 < \rho_5$	Sand (Dry)
	3	553.9	15.2	19.9		Sand (Saturated)
	4	183.6	49.9	69.8		Sand (Saturated)
	5	415.4	---	---		Sand (Saturated)
3	1	8247.6	1.0	1.0	**QQH**	Topsoil
	2	1781.2	4.8	5.8	$\rho_1 > \rho_2 > \rho_3 > \rho_4 < \rho_5$	Sand (Dry)
	3	761.4	14.1	19.8		Sand (Dry)
	4	185.7	58.2	78.1		Sand (Saturated)
	5	386.3	---	---		Sand (Saturated)
4	1	547.5	0.8	0.8	**QQH**	Topsoil
	2	115.3	2.9	3.7	$\rho_1 > \rho_2 > \rho_3 > \rho_4 < \rho_5$	Sandy Clay
	3	33.0	9.1	12.7		Clay
	4	13.2	47.0	59.7		Clay
	5	114.3	---	---		Sand (Saturated)
5	1	669.7	0.9	0.9	**QHA**	Topsoil
	2	48.9	4.5	5.4	$\rho_1 > \rho_2 > \rho_3 < \rho_4 < \rho_5$	Clay
	3	11.4	21.3	26.6		Clay
	4	47.6	50.8	77.4		Clayey Sand
	5	158.0	---	---		Sand (Saturated)
6	1	1327.8	1.0	1.0	**QH**	Topsoil
	2	249.8	5.2	6.1	$\rho_1 > \rho_2 > \rho_3 < \rho_4$	Sand
	3	50.6	51.7	57.9		Sandy Clay
	4	368.6	---	---		Sand (Saturated)
7	1	1204.0	0.8	0.8	**QQH**	Topsoil
	2	326.5	3.8	4.6	$\rho_1 > \rho_2 > \rho_3 > \rho_4 < \rho_5$	Sand
	3	77.3	16.4	21.0		Sandy Clay
	4	23.6	54.9	75.9		Clay
	5	85.3	---	---		Clayey Sand
8	1	743.8	0.7	0.7	**QQH**	Topsoil
	2	280.5	2.8	3.5	$\rho_1 > \rho_2 > \rho_3 > \rho_4 < \rho_5$	Sand
	3	85.9	8.8	12.3		Sandy Clay
	4	30.8	55.4	67.7		Clay
	5	129.9	---	---		Sand (Saturated)

Its resistivity value ranges from about 82.5 ohm-m to more than 90.7 ohm-m. This layer is suspected to be the aquifer where groundwater could be tapped.

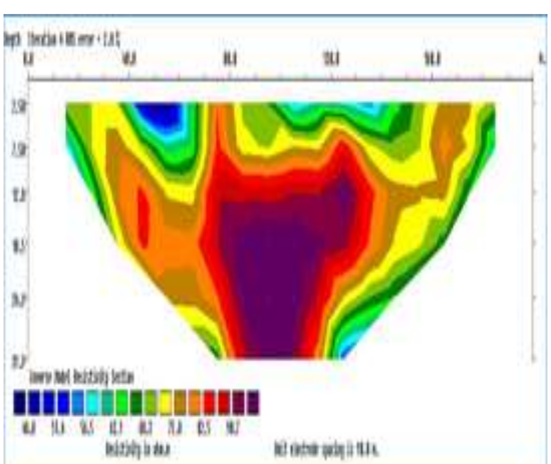

Fig. 3: 2D Resistivity Section along Traverse 3

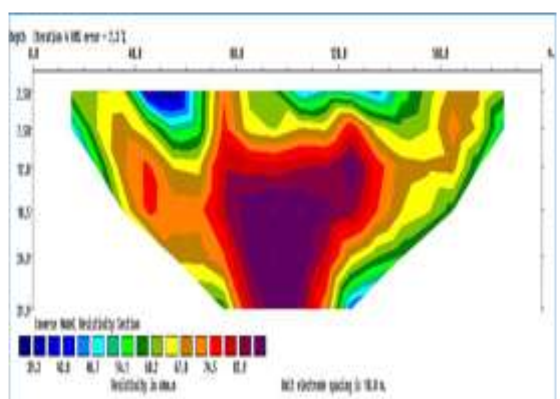

Fig. 4: 2D Resistivity Section along Traverse 4

1-D Resistivity Survey: Eight vertical electrical sounding (VES) acquired along the four 2-D profiles were interpreted appropriately. The summary of the results of the inverted 1-D VES data are presented in table 1. Six (6) subsurface layers including the topsoil, dry sand, saturated sand, clayey sand, sandy clay and clay were delineated within the area. The top soil has resistivity values ranging from 547.5 – 8348.6 ohm-m and thickness of 0.7 – 1 m. This overlies the dry sand with resistivity value of 761.4 – 8348.6 ohm-m and thickness 3.9 – 19.7 m. The dry sand layer was underlain by the saturated sand having resistivity ranging from 114.3 – 1380.6 ohm-m while the thickness could not be ascertained in places. The resistivity of the clayey sand oscillates between 47.6 – 85.3 ohm-m. This layer represent the last layers at the locations where it was delineated, as such the thickness could not be estimated. The clay layer underlies sandy clay in places while in other cases, it succeeds the topsoil. The resistivity and thickness of the clay layer were 11.4 – 48.9 ohm-m and 25.8 – 516.1 m respectively. The sandy clay was found to have resistivity of 50.6 – 115.3 ohm-m and thickness of 2.9 – 8.8 m. The results of the study showed that the saturated sand layer represents the aquiferous layer within the area where groundwater can be tapped for the community. The thickness of this layer is found to be more than 58.2 m which is quite significant for groundwater development.

Conclusion: The results of the study showed that six (6) lithologies. The results of the study showed that the saturated sand layer represents the aquiferous layer within the area where groundwater can be tapped for the community, with a reasonable thickness quite significant for groundwater development. This therefore shows that electrical resistivity method of geophysical investigation, especially combined ERT and VES techniques, is truly applicable in groundwater potential mapping of Erhoike and area underlain by similar geology.

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