2026 Volume: 02 Issue: 07 www.ijrpa.com ISSN 2456-9995 Research Article

International Journal Research Publication Analysis

Page: 01-14

INTEGRATION OF RESISTIVITY CROSS PLOTS AND AQUIFER CONTOUR CLOSURE FOR GEOLOGICAL INVESTIGATION IN PARTS OF RUMUJI, RIVERS STATE

Oghonyon, Rorome[1], *Juliet, Layefa Deribi[2]

[1]Department of Geology, University of Port Harcourt, Rivers State, Nigeria.

[2]Department of Geology, Federal University of Petroleum Resources Effurun, Delta State, Nigeria.

Article Received: 07 June 2026

Article Revised: 27 June 2026

Published on: 17 July 2026

***Corresponding Author: Juliet, Layefa Deribi**

Department of Geology, University of Port Harcourt, Rivers State, Nigeria.

DOI: https://doi-doi.org/101555/ijrpa.1140

ABSTRACT

This paper presents an integrated geophysical approach combining 2D electrical resistivity tomography (ERT) and 1D vertical electrical sounding (VES) to address the challenges of severe lateral facies variations and single-method geophysical artifacts during subsurface characterization in Rumuji, Rivers State. The primary objective was to map the spatial extent of underlying lithological units to evaluate foundation stability and groundwater potential. Data acquisition involved dual-line field measurements evaluated via depth-calibrated log-log cross-plots and 2D advanced digital magnetic tomography (ADMT) inversion mapping. The geoelectrical profiles reveals a heterogeneous form of stratified geo-electric framework highlighting a standard HA-type, and KH-type curve. Results demonstrate a thick, highly competent sand units, exhibiting elevated apparent resistivity values that provide excellent geotechnical stability, while the 2D tomograms delineate high resistive fluid-bearing zones. The subsurface architecture satisfies the technical requirements for civil engineering loads and deep industrial borehole development. This research significantly contributes to regional geological knowledge by validating a joint exploration workflow that eliminates single-method artifacts, establishing a high-resolution subsurface model for the Coastal Plain Sands.

KEYWORDS: Electrical Resistivity Tomogram (ERT); Vertical Electrical Sounding (VES); Benin Formation; Aquifer Characterization.

INTRODUCTION

The subsurface geology of the Niger Delta basin is highly complex, consisting of thick fluvial-to-continental deposits that belong to the Coastal Plain Sands of the Benin Formation (Reijers, 2011). In areas like Rumuji in Rivers State, these geological formations exhibit sharp lateral variations and unpredictable lithological changes over very short distances (Akpokodje, 1987). Review papers on regional deltaic systems emphasize that high-energy depositional regimes create irregular lens-shaped bodies where clean, permeable sand packages can abruptly terminate against dense, low-permeability mud or clay pockets (Oghonyon *et al*., 2025; Reijers, 2011). Traditional ground investigations that rely solely on standard wide-spaced drilling or one-dimensional electrical depth checks often fail to detect these localized subsurface features, such as clay pockets, ancient river channels, or variations in groundwater horizons (Loke, 2004; Oghonyon & Njoku, 2024). Consequently, relying on limited data can lead to geological misinterpretations, creating significant risks for structural engineering stability and water resource planning (Oghonyon et al., 2025).

To overcome these limitations, modern site investigations increasingly rely on integrated, non-invasive geophysical methods that combine vertical profiling with continuous spatial imaging (Dahlin, 2001; Loke et al., 2013; Ugwu *et al*., 2016). One-dimensional (1D) Vertical Electrical Sounding (VES) provides detailed information on vertical changes in layer thickness and electrical properties directly beneath a single point (Loke, 2004; Rorome *et al*., 2025). Comprehensive methodological reviews on electrical imaging note that while VES offers excellent vertical depth resolution, it suffers from an inability to detect lateral boundaries or map irregular geological structures (Dahlin, 2001). Conversely, when integrated with 2D tomographic inversion contour maps, which display continuous horizontal variations across a site, geologists can accurately trace the continuity of key structural zones and eliminate single-method data errors (Oghonyon & Ogaji, 2026). Recent reviews of environmental and engineering geophysics confirm that this joint approach is essential for identifying solid strata capable of supporting heavy structural loads and mapping reliable, productive zones for freshwater development (Oghonyon et al., 2025).

The objective of this study is to implement an integrated geophysical workflow combining ID VES and 2D electrical resistivity tomography (ERT) to accurately map the thickness, vertical depth, and lateral continuity of resistivity zones within the subsurface strata in parts of Rumuji. By calibrating depth-specific resistivity cross-plots alongside continuous spatial tomograms, this research aims to identify resistive sand layers for engineering foundations and high-yielding, protected freshwater aquifer horizons for sustainable borehole development.

METHODOLOGY

Description of the Study Area: Rumuji lies within the Coastal Plain Sands (Benin Formation). The stratigraphy is dominated by unconsolidated, medium-to-coarse-grained sands with gravelly components (Akpokodje, 1987). These sediments represent a transition from the continental deposits to the more brackish swamp environments found further south. The area features a high-yielding freshwater aquifer. However, the presence of localized clay lenses which appear as resistive lows on a tomogram is a critical factor for both groundwater flow and foundation stability. The target "resistive zone" at 35-40m depth is hypothesized to be a thick, competent sand unit that may serve as either a deep foundation base or a major water-bearing horizon.

Data Acquisition and Theory of Advanced Digital Magnetic Tomography (ADMT): ADMT series product is a new generation intelligent prospecting instruments designed by AIDU and Guilin Technology Hydrogeological Investigation Institute. Based on more than four decades R&D experiences, it involves the use of mobile phone or table PC to run the complicated data calculation to realize the quickly calculation inversion and rapid graph drawing, and quickly draw 2D/3D profile maps, contour maps and curve diagrams by an APP. This is a leap in technology because it makes the complicated geophysical data acquisition becomes easier and simpler. With the APP many intelligent functions such as field measurement control, instantly data process, data cloud backup, online expert analysis and Bluetooth data transaction are carried out. Main features include; instant mapping (directly drawing the 2D/3D map by the APP after data collection), simple operation (walking and stopping to complete the measurement, so easy), efficiency (unique wireless prospecting tech, one person can complete all work, saving time and manpower), precision (strong anti-interference ability, field source correction and patent tech to process data). The instrument is connected to the software through the built-in Bluetooth, so you can use the software to visualize all the operations of the instrument such as measurement signal input, data checking and processing. Using wireless sensor probe, you can complete all the measurements just by walking and stopping. No need for long cable, saving time and manpower. Many innovative designs make the instruments become more intelligent, efficient and accurate to obtain dozens of invention patents.

Fig. 1: A digital terrameter for subsurface exploration.

Data Acquisition and Theory of Vertical Electrical Sounding Method: The Vertical electrical sounding using the schlumberger array configuration was carried out by pegging current to the ground through two electrodes (C_1 and C_2 as shown in Figure 2 below) and then measuring the resultant potential difference (V) between the potential electrodes (P_1 and P_2 as shown in Figure 2 below). The center point of the electrode array remains fixed but the spacing of the electrodes was increased so as to obtain information about the stratification of the Earth's subsurface (see Figure 2 below).

Firstly, four electrodes were driven into the ground with the use of hammer. The two electrodes at the middle are potential electrodes (C_1 and C_2 as shown in Figure 2 above), the two other electrodes at both ends are called current electrodes P_1 and P_2 see Figure 2 above). Installed cables are connected to both the current and potential electrodes to the terminals (positive and negative) of the terrameter which is positioned adjacent to the center of the arrangement of the electrodes. When the circuit is properly set up and the electrode configuration is found to be alright, the terrameter is then switched on to obtain readings which is referred to as resistance value for each sounding station. The values obtained from the Terrameter are then seen and read from it. The Schlumberger array, which is often preferred for speed and convenience (Oghonyon *et al*., 2025), was adopted for this study. The mid-point of the array (potential electrodes) was kept fixed in each case while the current electrodes were progressively increased. This is because current lines penetrate increasingly at greater depths just as the current electrode separation is increased (Oghonyon et al., 2025). The Schlumberger array configuration was employed not only because it is faster and less likely to be influenced by lateral variations but also because it requires a lower number of operators (as only the current electrodes C_1 and C_2 are displaced). Other equipment employed as accessories to the terrameter during data acquisition include electrodes, hammer, cables, measuring tape, global positioning system (GPS) and water to moisturize the Earth's subsurface where it is hard and non-conducting (see Figure 3 below). The raw field data was processed by first of all calculating for the apparent resistivity using the equation (modified from Oghonyon *et al*., 2025):

$$\rho \boldsymbol{a} = \boldsymbol{k} \times \boldsymbol{R} \ldots \ldots \ldots (\mathbf{1})$$

Where $\rho \boldsymbol{a}$= Apparent Resistivity, $\boldsymbol{k}$=Geometric factor, $\boldsymbol{R}$=Resistance.

But geometric factor $\boldsymbol{k}$, is calculated using the equation (modified from Oghonyon *et al*., 2025):

$$k = \frac{\pi}{4}\left(\frac{L^2 - a^2}{a}\right) \ldots\ldots\ldots (2)$$

Where ‘L’ is the current electrode spacing from A-B (see figure 4) and is calculated using the equation (modified from Oghonyon *et al*., 2025):

$$L = AB \ldots\ldots\ldots (3)$$

But,

$$AB = 2n \ldots\ldots\ldots (4)$$

Where ‘n’ is the halve current electrode spacing (AB/2);

‘a’ is the product of the potential electrodes between A, M, N, and B (see Figure 4).

Mathematically; $a = MN \ldots\ldots\ldots (5)$

But, $MN = 2n \ldots\ldots\ldots (6)$

Where ‘n’ is the halve potential electrode spacing (MN/2) that is $n = MN/2$

Each resistivity value was plotted on the vertical axis against the halve current electrode spacing on the horizontal axis using log-log graph (Oghonyon & Ogaji, 2026) using resistivity software like IPI2WIN. These plots called cross plots allow initial assessment of curve type (e.g. H or K shape) and layer estimates. 1D VES data acquired at specific intervals along the ADMT profile are converted into depth-resistivity cross-plots. By overlaying these plots onto the 2D tomogram, the tomographic image was calibrated with precise depth values. This dual-validation ensures that the identified resistive zones are not geophysical artifacts but represent actual lithological units like gravelly sand or compact sand for geological interpretation.

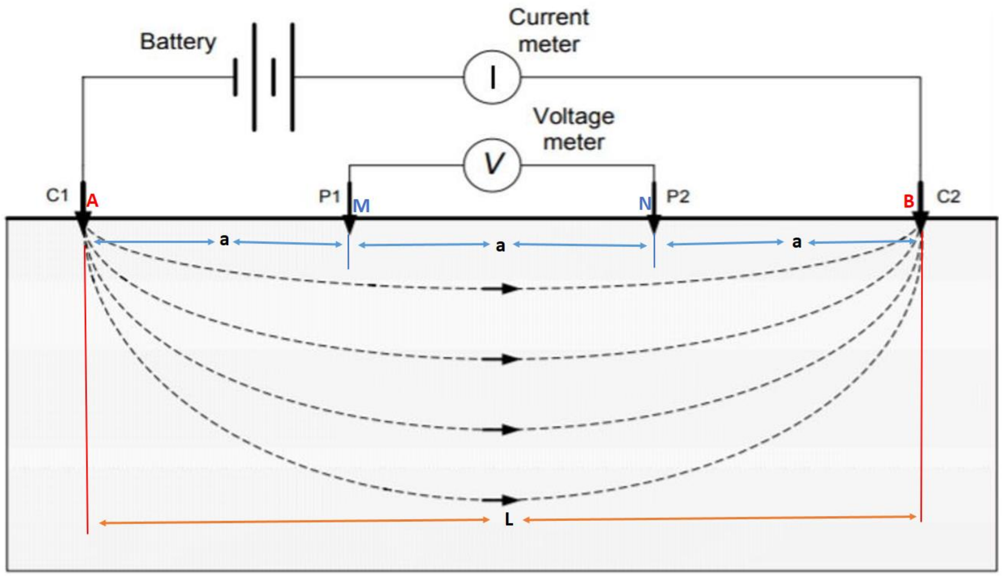

Fig. 2: A hypothetical diagram for schlumberger array configuration.

Fig. 3: Resistivity equipment for subsurface investigation.

RESULTS AND DISCUSIONS

The integrated geophysical investigation conducted in the Rumuji environment utilized 1D Vertical Electrical Sounding (VES) cross plots and 2D Advanced Digital Magnetic Tomography (ADMT) spatial cross-sections to investigate the subsurface architecture and characterize the lithological variations.

The geoelectrical cross plot of line-1 (see figure 4) reveals a distinct stratified architecture yielding a standard KH-Type curve with the resistivity trend $\rho 1<\rho 2> \rho 3<\rho_4$, where an initial highly resistive near-surface zone of 3,831.01Ωm indicates dry, loose continental alluvial sands that subsequently give way to a lower intermediate wet resistivity of 1,601.91Ωm before stabilizing into a deeper, massive, and highly competent underlying sand stratum; this specific structural arrangement warns project engineers that engineering foundations have the likelihood of encountering softer, fluid-saturated horizons prone to differential settlement, thereby implying that heavy infrastructural assets must utilize deep pile foundations driven past these depths, unstable clay-rich lenses to safely anchor directly into the high-bearing sand reservoir below.

Table 1: Processed geophysical survey data for line-1.

S/No.	AB/2 (m)	MN/2 (m)	Geometric Factor (K)	Resistance (Ω)	Apparent Resistivity (Ωm)
1	1	0.3	4.77	100.2491	478.188207
2	2	0.3	20.48	70.1834	1437.356032
3	3	0.3	46.66	49.5298	2311.060468
4	4	0.3	83.32	35.5867	2965.083844
5	4	0.5	49.49	59.2831	2933.920619
6	5	0.5	77.76	41.8542	3254.582592
7	6	0.5	112.33	30.4782	3423.616206
8	7	0.5	153.17	23.6983	3629.868611
9	8	0.5	200.3	19.0801	3821.74403
10	8	1	98.97	38.5231	3812.631207
11	10	1	155.53	24.6320	3831.01496
12	15	1	351.9	10.3048	3626.25912
13	15	1.5	233.29	15.5902	3637.037758
14	20	1.5	416.58	8.1322	3387.711876
15	25	1.5	652.23	3.6356	2371.247388
16	30	1.5	940.24	2.1843	2053.766232
17	30	2.5	561.63	3.5513	1994.516619
18	40	2.5	1001.51	1.5995	1601.915245
19	50	2.5	1567.07	1.0301	1614.238807
20	60	2.5	2258.31	1.1414	2577.635034
21	60	5	1123.27	1.2833	1441.492391
22	70	5	841.74	1.6994	1430.452956
23	80	5	2003.03	1.1007	2204.735121
24	80	7.5	1328.8	1.1851	1574.76088
25	100	7.5	2082.88	0.8805	1833.97584
26	100	10	1555.29	1.1470	1783.91763

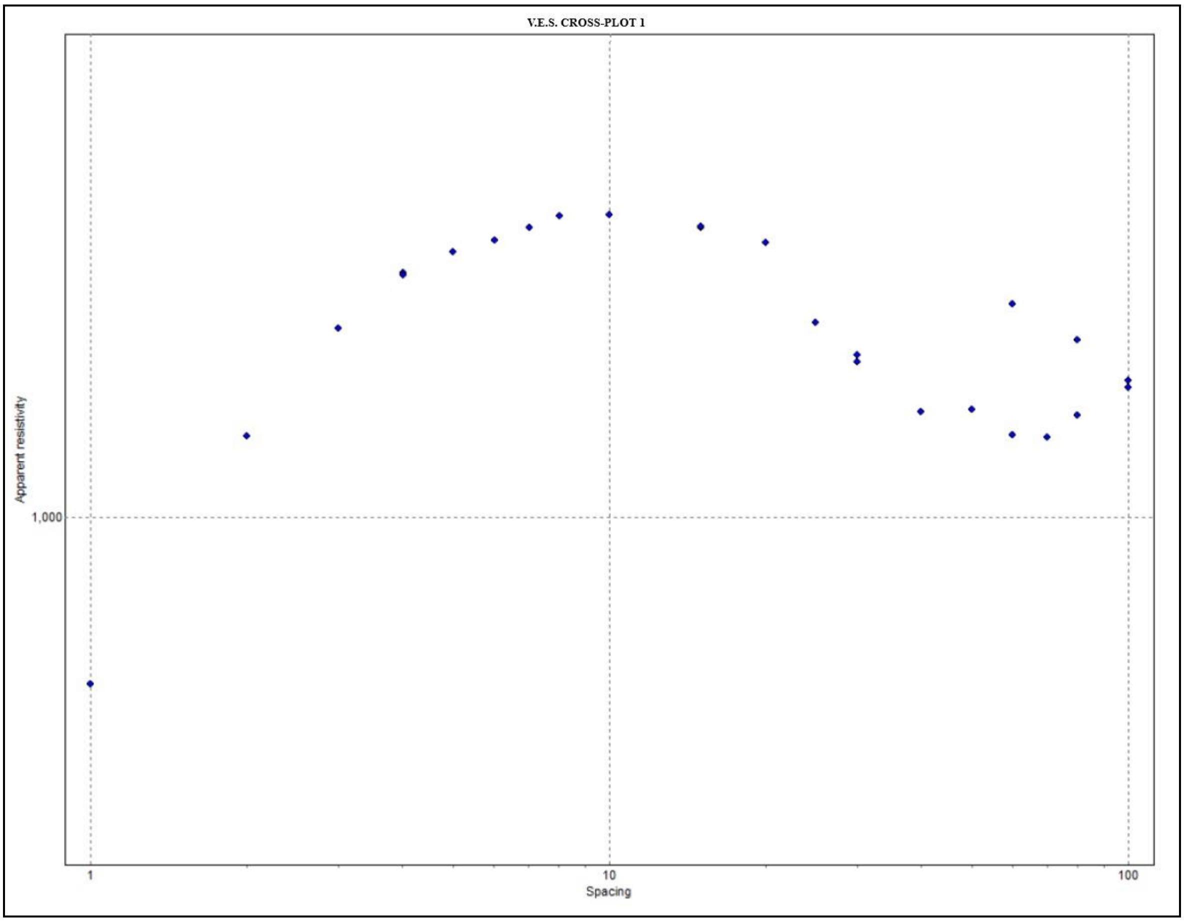

Fig.4: Resistivity cross-plot for line-1.

The line-2 geoelectric cross plot (see Table 2 and Figure 5) reveals a less complex stratified sequence characterized by an HA-Type curve with the resistivity trend ρ1>ρ2<ρ3>ρ4 variant, which initiates with a remarkably low near-surface apparent resistivity of 280.01Ωm due to damp, clay-rich swamp-muck topsoil before rising steadily to a dense, compact sand peak of 1,975.25Ωm at an intermediate depth variation where it merges into the regional aquifer complex; this geoelectric behavior implies that heavy static surface loads placed directly over the Line-2 sector will face incredibly weak shallow structural support, signaling a severe risk of soil plasticity or waterlogging that will crack standard shallow concrete pads.

Table 2: Processed geophysical survey data for line-2.

S/No.	AB/2 (m)	MN/2 (m)	Geometric Factor (K)	Resistance (Ω)	Apparent Resistivity (Ωm)
1	1	0.3	4.77	70.2183	334.941291
2	2	0.3	20.48	13.6724	280.010752
3	3	0.3	46.66	8.1536	380.446976
4	4	0.3	83.32	6.3881	532.256492
5	4	0.5	49.49	11.2723	557.866127
6	5	0.5	77.76	10.7505	835.95888
7	6	0.5	112.33	9.6463	1083.568879
8	7	0.5	153.17	7.5731	1159.971727
9	8	0.5	200.3	5.9626	1194.30878
10	8	1	98.97	12.2845	1215.796965
11	10	1	155.53	8.5952	1336.811456
12	15	1	351.9	4.3011	1513.55709
13	15	1.5	233.29	6.1901	1444.088429
14	20	1.5	416.58	4.2433	1767.673914
15	25	1.5	652.23	1.0011	652.947453
16	30	1.5	940.24	2.1008	1975.256192
17	30	2.5	561.63	2.4461	1373.803143
18	40	2.5	1001.51	1.3848	1386.891048
19	50	2.5	1567.07	0.8171	1280.452897
20	60	2.5	2258.31	0.4959	1119.895929
21	60	5	1123.27	0.9385	1054.188895
22	70	5	841.74	0.8775	738.62685
23	80	5	2003.03	0.6257	1253.295871
24	80	7.5	1328.8	0.7889	1048.29032
25	100	7.5	2082.88	0.6181	1287.428128
26	100	10	1555.29	0.5805	902.845845
27	150	10	3518.584	0.4247	1494.342625
28	150	15	2331.45	0.2358	549.75591

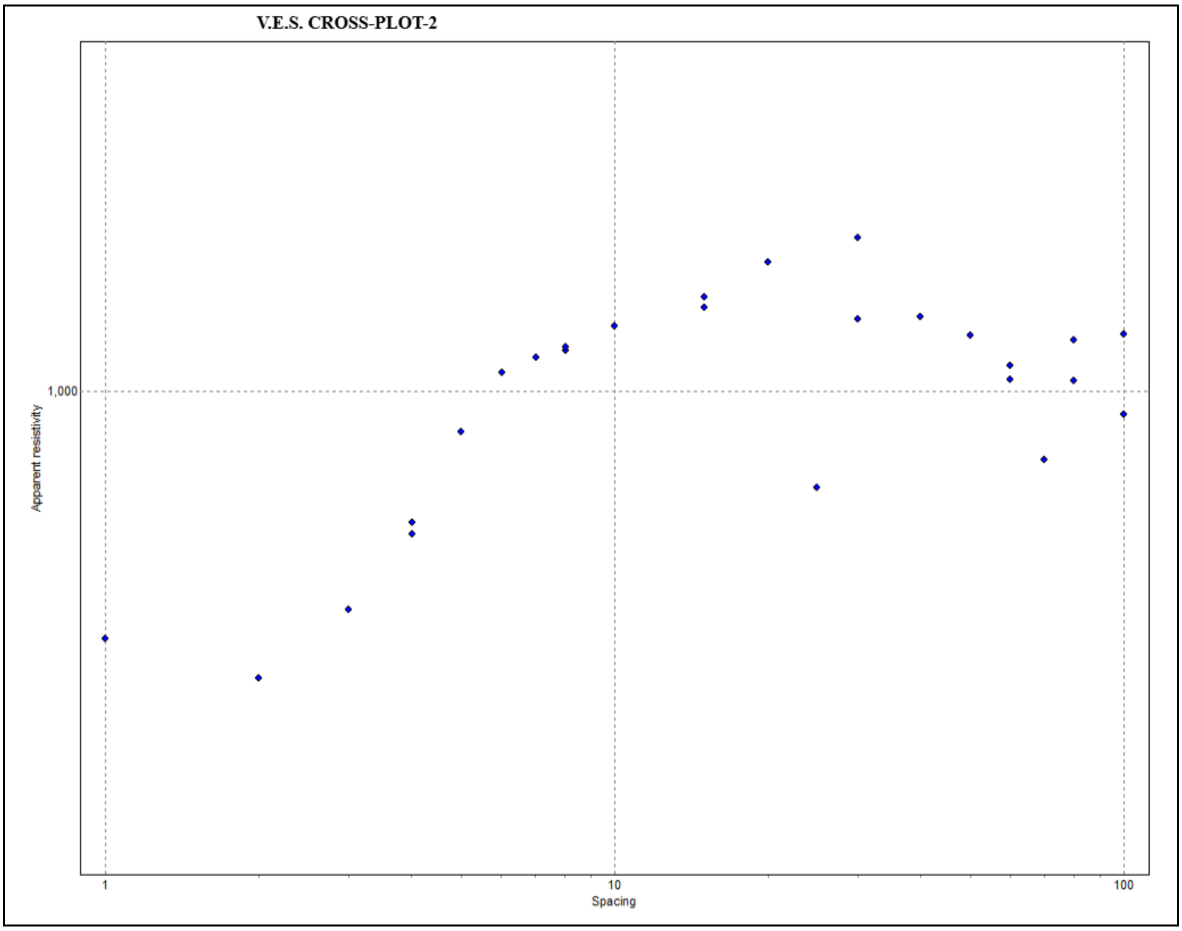

Fig. 5: Resistivity cross-plot for line-2.

The 2D ADMT spatial cross-section (see figure 6) reveals a continuous vertical and horizontal imaging of the subsurface facies, mapping distinct high-conductive fluid bearing reservoir zones; this continuous spatial imaging implies that while the shallowest zone highlights a localized, unpredictable perched water table or thin clay-rich boundary that could lead to moisture accumulation beneath near-surface engineering layouts, the extensive deep-seated anomalies at confirm highly productive, laterally continuous, and naturally insulated sand-bed aquifer horizons capable of sustaining long-term, high-capacity industrial water boreholes.

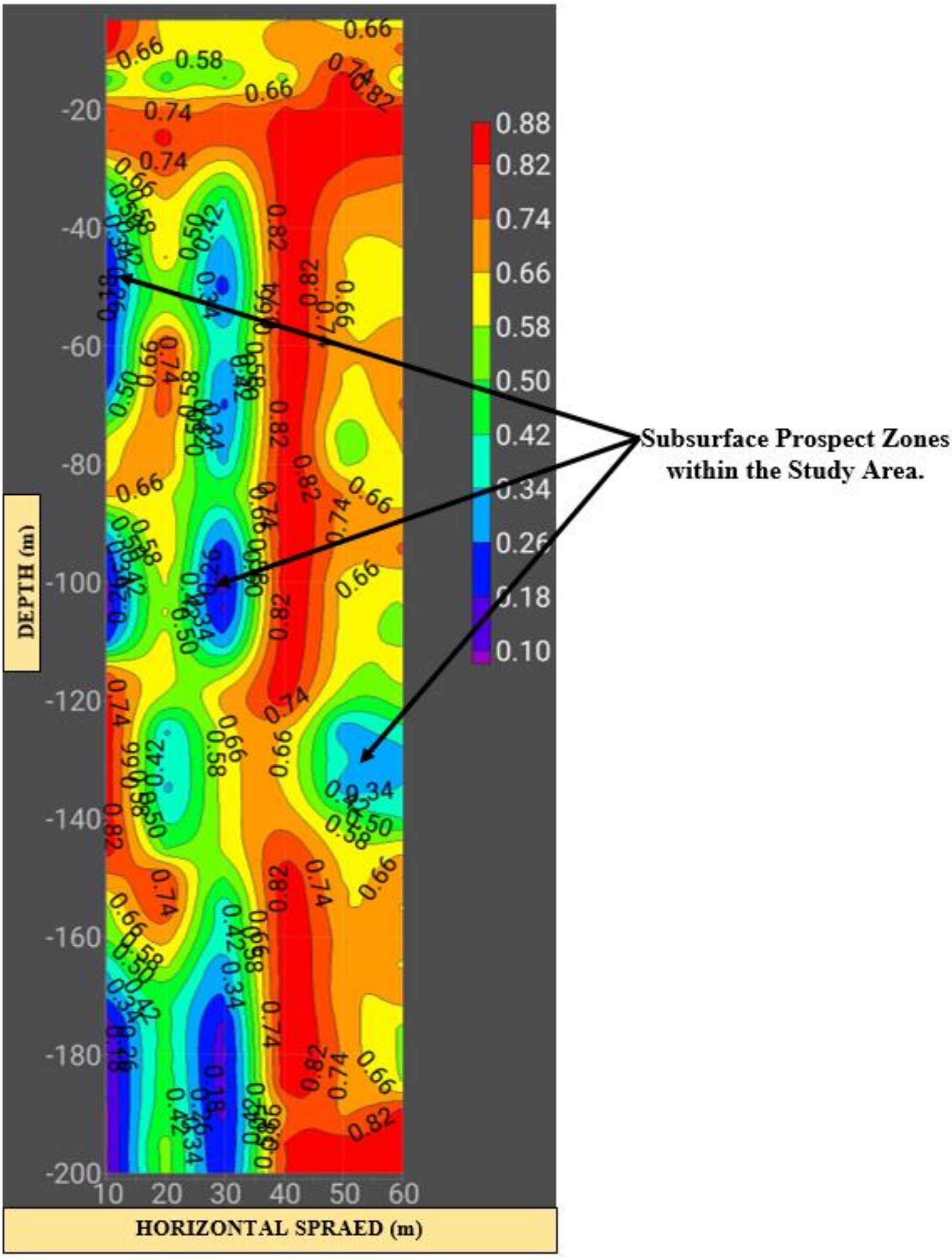

Fig. 6: ADMT resistivity contour map for line-1.

The 2D ADMT spatial cross-section for Line-2 (figure 7) prominent low-resistivity, porous, and permeable prospect zones that appear slightly offset due to regional lateral facies variations, pinpointing key subsurface targets, this spatial mapping implies that the major hydrogeological target zones remain open, robust, and laterally correlated across the site, which assures groundwater engineers that drilling into the saturated intervals will successfully bypass unpredictable near-surface structural movements and guarantee an optimal, sustainable freshwater yield in Rumuji environment.

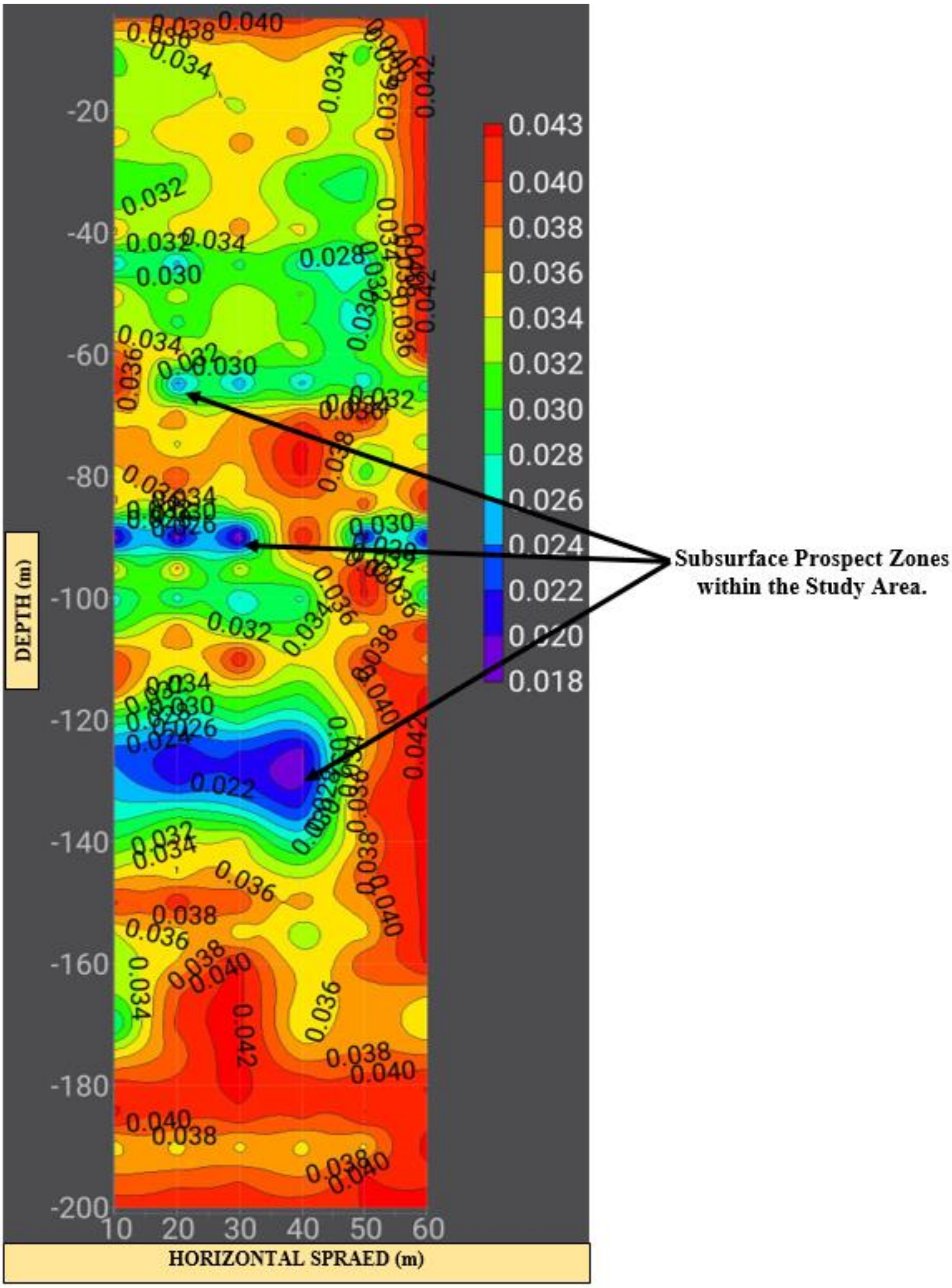

Fig. 7: ADMT resistivity contour map for line-2.

CONCLUSION

This research significantly contributes to regional geological knowledge by validating a dual-method exploration workflow that integrates 1D Vertical Electrical Sounding and 2D Advanced Digital Magnetic Tomography to overcome single-method artifacts in highly variable environments. By establishing a high-resolution, laterally continuous subsurface model of the Coastal Plain Sands, this paper provides an innovative framework for resolving subtle lateral facies changes and identifying structural boundaries. Ultimately, this work offers a reliable blueprint for future engineering and hydrogeological micro-zonation within the Niger Delta basin, ensuring precise alignment between infrastructure development and complex subsurface conditions.

Declarations

Ethical Approval: This study did not involve human participants or animal experimentation and therefore did not require formal ethical approval. All procedures involving data handling and analysis were conducted responsibly and in accordance with standard academic and institutional guidelines.

Disclaimer (Artificial Intelligence): Author(s) hereby declare that no generative Artificial Intelligence (AI) technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during writing or editing of this manuscript.

Declaration of Conflict of Interest: The authors declare that no known conflict of interest or personal relationships that could have influence the work reported in this paper.

Declaration of Data Availability Statement: Data are available upon request from the Second Author.

REFERENCES

1. Akpokodje, E.G. (1987). The Engineering Geological Characteristics of the Major Superficial Soils of the Niger Delta. *Engineering Geology*, 23,1993-211. DOI: http://dx.doi.org/10.1016/0013-7952(87)90090-1
2. Dahlin, T. (2001). The Development of DC Resistivity Imaging Techniques. *Computers and Geosciences*, 27(9): 1019-1029. DOI: http://doi.org/10.1016/s0098-3004(00)00160-6
3. Eniye, M; Amakiri, ARC; Tamunubereton-ari, I; Amonnieah, J (2025). Investigation of Groundwater Iron Using Electrical Resistivity Tomography in Yenagoa, Bayelsa state, Nigeria. *Int. J. Sci. Res. Arch*. 16(2): 1434-1442.

DOI: http://dx.doi.org//10.30574/ijsra.2025.16.2.2411

4. Loke, M. H.; Chambers, J. E; Rucker, DF; Kuras, O; Wilkinson, PB (2013). Recent developments in the Direct-current Geoelectrical imaging method. *J. Appl. Geophys*. 95: 135-156. DOI: http://dx.doi.org/j.jappgeo.2013.02017
5. Loke, M.H. (2004). Tutorial: 2-d and 3-D Electrical Imaging Surveys. *Geotomo Software, Res2dinv 3.5 Software.*
6. Loke, MH.; Barker, RD (1996). Rapid Least-Squares Inversion of Apparent Resistivity Data by a Quasi-Newton Method. *Geophys. Prospect*. 44(1): 1083-1092. DOI: http://dx.doi.org/10.1111/j.1365-2478.1996.tb00142.x
7. Nwankwoala, HO; Udom, GJ (2008). Groundwater Protection as Viable Option for Sustainable Water Supply in Nigeria. *Glob. J. Geol. Sci.* 6(2): 153-156. DOI: http://dx.doi.org/10.4314/gjgs.v6i2.18765
8. Oghonyon, R.; Kiamuke, I.; Okereke, V; Maxwell, DC (2025). Subsurface depth delineation for aquifer prospecting at redeemed church field, Choba, Rivers State. *Int. J. Adv. Eng. Manage.* 7(9): 476-485. DOI: http://dx.doi.org/ijaem/10.35629/5252-0709476485
9. Oghonyon, R.; Nnurum, EU; Okereke, V; Okorie, GC (2025). Investigation of Leachate Percolation to Groundwater Depth Around Choba Campus, University of Port Harcourt. *Int. J. Eng. Sci. (IJES)*. 14(7): 43-50. DOI: http://dx.doi.org/ijes/10.9790/1813-14074350
10. Oghonyon, R; Njoku, DK (2024). Lithological Characterization of the Subsurface Layers at NASS Field, Choba, Rivers State. *Sci. Afr*. 23(4): 133-140. DOI: http://dx.doi.org/10.4314/sa.v2314.12
11. Oghonyon, R; Ogaji, F. M. (2026). Subsurface Beddings, Characterization of Hydrogeological Potential, and Identification of Potential Hazards in Parts of Rumuosi, Obio-Akpo Local Government Area, Rivers State, Nigeria. Journal of Applied Science and Environmental Management. 30 (1) 154-158. DOI: http://dx.doi.org/10.4314/jasem.v30i1.18
12. Oghonyon, R; Ogaji, F. M; Matthew, I. (2025). Decline Analysis of Electrical Resistivity Curves for Subsurface Evaluation in Parts of Choba, Rivers State. Scientia Africana. 24 (6): 237-244. DOI: http://dx.doi.org/10.4314/sa.v24i6.22
13. Okiongbo, KS; Akpofure, E (2015). Hydro-geophysical Characterization of Shallow Unconsolidated Alluvial Aquifer in Yenagoa and Environs, Southern Nigeria. *Arab. J. Sci. Eng.* 41(6): 238-245. DOI: http://dx.doi.org/ajse/101007/s13369-015-1827-2

14. Reijers, T.J.A. (2011). Stratigraphy and sedimentology of the Niger Delta. *Geologos*, 17, 133-162. DOI: http://doi.org/10.2478/v10118-011-0008-3
15. Rorome, O; Victoria, O; Nnurum, E. U; George, P. (2025). Interpretation of Leachate Contaminant Along the Department of Student Affair, University of Port Harcourt. The International Journal of Engineering and Sciences. 14 (11): 48-57. DOI: http://dx.doi.org/10.9790/1813-14114857
16. Ugwu, SA; Nwankwoala, HO; Worlu, SN (2016). 2D Resistivity Imaging and Modelling of a Dumpsite in Eneka, Rivers State, Nigeria. *Iss. Sci. Res*. DOI: http://dx.doi.org/1015739/ISR.16004