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Investigation of Groundwater Potential Zone Using Geophysical and Geospatial Technology in Akuku-Toru Local Government Area, Rivers State, Nigeria

Erefama Ekine Esonanjor [a*], Bright Ukachukwu Amechi [a] and Arobo Raymond Chinoye Amakiri [b]

[a] Department of Geology, Faculty of Science, Rivers State University, Nigeria.
[b] Department of Physics, Faculty of Science, Rivers State University, Nigeria.

Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Background of the Study: The study area is located within four communities in Akuku-Toru Local Government Area, which is a coastal region within the Niger Delta. The study area is heavily reliant on groundwater for domestic, industrial, and agricultural purposes. The hydrogeological dynamics of the area are complex, with diverse geological formations and intricate subsurface structures. As a result, an innovative and integrated approach is necessary for effective groundwater management. The study investigated the potential of groundwater resources in the study area and identification of fresh water zones using electrical resistivity, remote sensing, and GIS which employs geophysical surveys, remote sensing techniques, and geospatial analysis to explore the

**Corresponding author: E-mail: erefama.esonanjor@ust.edu.ng;*

interplay between aquifer characteristics, geological formations, and topographical attributes. The fresh water zones are regions with low saline content.
Aim: This study aims to assess groundwater potential in some parts of Akuku-Toru Local Government Area by integrating the geophysical data from Vertical Electrical Sounding (VES) surveys with geospatial analysis from GIS and Remote Sensing Technology. The research seeks to provide a comprehensive understanding of groundwater availability and its correlation with geophysical and geospatial parameters.
Study Design: A thorough methodology was employed to investigate the possibility of freshwater resources in the study area. The approach involved gathering Vertical Electrical Sounding (VES) data from 8 locations, as well as incorporating geospatial data such as elevation, drainage density, geology, apparent resistivity, and slope maps. The collected data underwent rigorous processing, correlation analysis, and reclassification to explore the potential of freshwater resources in the study area.
Place and Duration of the Study: The research was conducted in four communities (Abonnema, Ekulama, Jacobkiri and Belema) within the Akuku-Toru Local Government Area over a span of 18months. The area's hydrogeological context and topographical features are investigated to determine groundwater potential zones.
Methods: The research utilized the Vertical Electrical Sounding (VES) method to obtain aquifer resistivity data, reflecting subsurface Lithological variations. Geospatial analysis involved accessing elevation and drainage density patterns. Correlation analysis was also performed to link the geophysical and geospatial data with qualitative interpretations, facilitating the assignment of numerical values representing groundwater potential zones.
Results: The Correlation analysis revealed insightful patterns. Aquifer resistivity, elevation and slope were identified as influential parameter affecting groundwater potential. The geology of the study area, categorized into dominant formations, exhibited varying degrees of potential for freshwater resources. The Correlation of geophysical and geospatial data provided a comprehensive understanding of groundwater availability across the study region.
Conclusion: The integration of geophysical and geospatial analysis offers a robust approach to groundwater potential assessment. The research findings contributed to valuable insights into the spatial distribution of potential freshwater resources in the study area. The correlation between aquifer resistivity, elevation, slope, and geology enhanced our understanding of hydrological conditions and provides a foundation for future groundwater studies and management strategies.

Keywords: Groundwater potential assessment; vertical electrical sounding; geospatial analysis; aquifer resistivity; geological formations; freshwater resources.

1. INTRODUCTION

Water, a fundamental natural resource, is indispensable for sustaining life and fostering societal progress. Its availability and equitable distribution are pivotal for ensuring the well-being of communities and ecosystems. In the context of water resources, both surface water and groundwater play indispensable roles. While surface water is more conspicuous, groundwater constitutes an essential yet often overlooked reservoir of freshwater. Groundwater resources, accounting for less than 30% of the world's freshwater reserves, contribute significantly to supporting diverse human and environmental needs [1,2]. Over 1.5 billion people globally rely on groundwater for their drinking water requirements, underlining its vital importance [3].

Groundwater's significance is particularly pronounced in regions grappling with sporadic surface water availability. Its inherent resilience to pollution risks, ease of extraction, and potential for long-term storage make it an invaluable asset. However, despite its crucial role, many areas encounter challenges related to groundwater overexploitation and resource management, stemming from inadequate knowledge of subsurface dynamics [4]. Addressing these challenges demands a deeper understanding of hydrogeology, which serves as the foundation for informed groundwater management strategies [5].

In this endeavor, the integration of geophysical techniques, remote sensing, and Geographic Information Systems (GIS) has emerged as a transformative approach. Vertical Electrical Sounding (VES) surveys facilitate the characterization of subsurface lithological variations and potential aquifer zones, contributing to a more comprehensive understanding of groundwater distribution [6,7]. Remote sensing harnesses electromagnetic radiation to analyze surface spectral characteristics, enabling the identification of potential groundwater-rich areas [8,9]. GIS complements these techniques by enabling the creation of accurate groundwater resource maps and modeling of hydrological processes [10].

Within the Akuku Toru Local Government Area of Rivers State, Nigeria, the availability of reliable freshwater resources is a paramount concern for sustainable development. Communities such as Abonnema, Ekulama, Jacobkiri, and Belema heavily depend on groundwater for domestic, industrial, and agricultural needs. However, a dearth of hydrogeological insights hampers effective water resource management and planning [3,11]. Traditional mapping methods fall short in delineating groundwater potential zones with precision [1,12]. To bridge this gap, a multidisciplinary approach integrating electrical resistivity, remote sensing, and GIS techniques is imperative to map and define freshwater potential zones accurately [6] in the study area.

This research aims to employ a multidisciplinary approach combining VES, remote sensing, and GIS to comprehensively assess groundwater potential in the Akuku Toru Local Government Area. By integrating geophysical and spatial data, the study endeavors to contribute valuable insights into the distribution and characteristics of groundwater resources. Through these efforts, the research seeks to enhance groundwater management practices and promote sustainable water resource utilization within the study region.

In the following parts of this document, we explore the methodology, outcomes, and consequences of our research discoveries. Our study aims to establish a basis for efficient water resource management and guide future research efforts by addressing gaps in hydrogeological knowledge.

2. MATERIALS AND METHODS

In this study, primary and secondary data were used to comprehensively assess groundwater potential in Akuku-Toru Local Government Area. The materials employed encompassed geophysical data obtained thorough Vertical Electrical Sounding (VES) surveys, geospatial information acquired through remote sensing techniques, geospatial analyses conducted using Geographic Information Systems (GIS), The integration of these multidisciplinary approaches allowed for a comprehensive exploration of groundwater resources, their distribution and potential zones within the study area [6,13].

2.1 Study Location

The Akuku-Toru Local Government Area is located in the Niger Delta region of Nigeria and has a complex geological and hydrogeological environment that affects its freshwater resources [14]. The area is part of a large sedimentary basin that covers about 75,000 square kilometers and is influenced by the interaction of geological, hydrological, and environmental factors [15]. The geology of Akuku-Toru is mainly made up of sandstones, shale, and clay deposits, which were formed by sedimentation from the Niger River and its tributaries during the Cretaceous and Tertiary periods. As part of the Niger Delta Basin, the area has rich layers of sediment formed by rivers such as the Niger and Benue [16].

The Niger Delta region is an interesting example of how the hydrology and geology of an area are interconnected [7]. The flow of the Niger River and its tributaries creates a unique hydrogeological environment, with sedimentary rocks that date back to the Eocene period [15]. The communities of Abonnema, Belema, Jacobkiri, and Ekulama, located in the Akuku-Toru Local Government Area, share the same geological and hydrological characteristics as the rest of the Niger Delta region [14,16]. These communities rely on shallow aquifers made up of sand and gravel deposits for their water supply. These aquifers are unconfined and are found along the banks of the Niger River and near the coast of the Atlantic Ocean [14].

By studying the geology and hydrogeology of the region, the research endeavors to discover sustainable sources of freshwater that may be hidden beneath the surface.

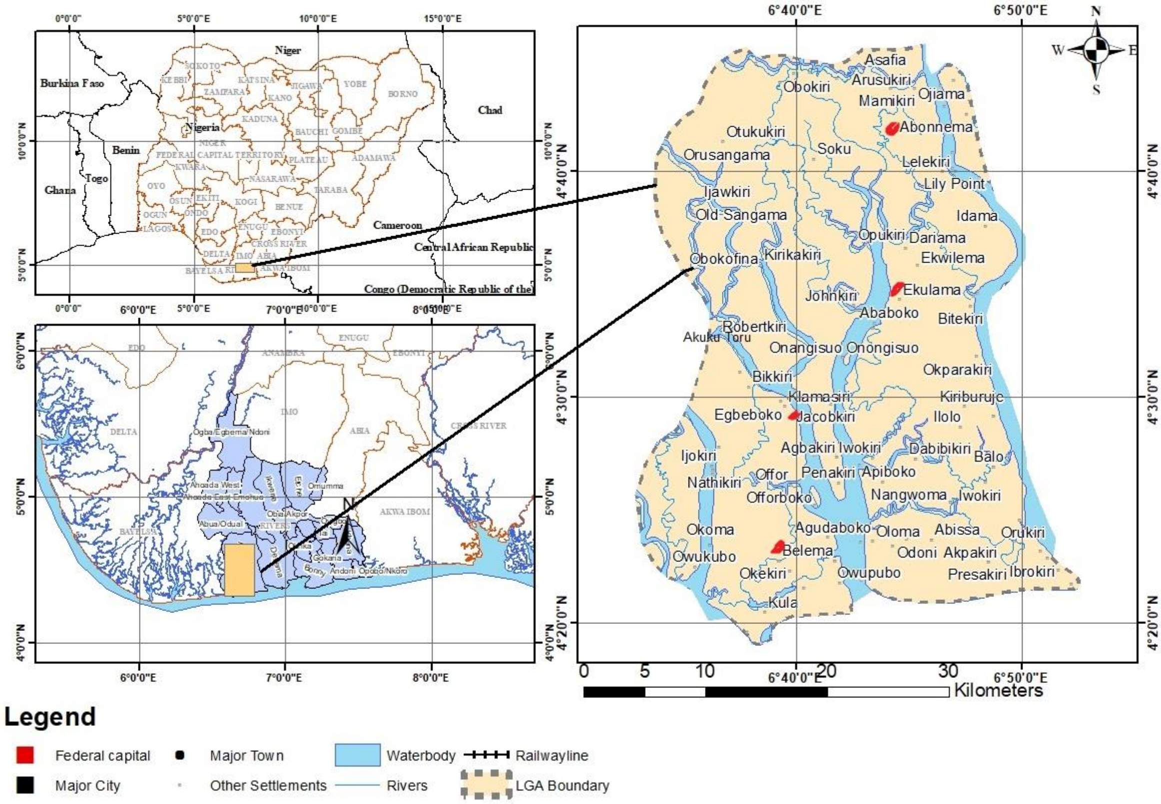


Fig. 1. Location map of study area

2.2 Vertical Electrical Sounding (VES)

For the electrical resistivity analysis, eight VES data were collected from four coastal communities in Akuku-Toru (Abonnema, Belema, Jacobkiri and Ekulama). Two VES data were acquired from each community using the Abem Terrameter SAS 300B. Four pairs of electrodes were used in the VES measurements. These electrodes help in injecting electrical current into the ground and measuring the resulting voltage to determine the subsurface resistivity. IP2WIN software was also used to interpret the resistivity data. Stream delineation was done using the GPS to monitor the flow of stream in the study area [2].

To provide a visual representation of the sampling locations, the study area's vertical electrical sounding (VES) sampling points as depicted in Fig. 2 is presented. This figure highlights the coverage of the data collection. Additionally, Table 1 showcases the borehole and VES coordinates in the study area, establishing the spatial relationship between the VES points and Borehole data emphasizing their relevance to the study.

Table 1. Borehole and VES coordinates

S/N	Location	Coordinates		Elevation
		Longitude	Latitude	
1	Abonnema 1	6º46'25'.23'E	4º43'46'.96'N	38 ft
	Abonnema 2	6º46'25'.99'E	4º43'34'.35'E	40ft
2	Ekulama 1	6º41'07'.82'E	4º32'14'.10'N	17ft
	Ekulama 2	6º40'13'.45'E	4º32'40'.28'E	9ft
3	Jacobkiri 1	6º40'46'.07'E	4º28'37'.98'N	4ft
	Jacobkiri 2	6º41'47'.33'E	4º28'40'.57'E	3ft
4	Belema 1	6º38'48'.89'E	4º22'55'.09'N	38 ft
	Belema 2	6º38'53'.74'E	4º22'50'.14'N	40ft

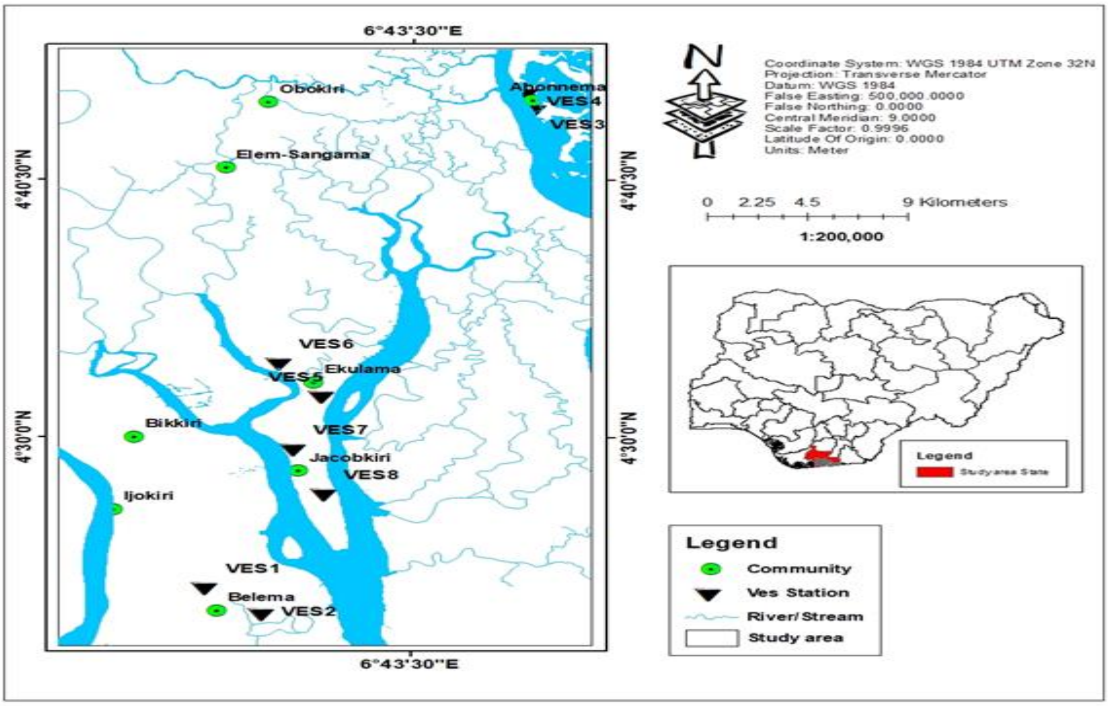


Fig. 2. VES Sampling Location Map

2.3 Remote Sensing Data Acquisition

The remote sensing analysis involved the use of satellite imagery to gather information about the study area's topography and land cover types. ASTER GDEM (Advanced Spaceborne Thermal Emission and Reflection Radiometer Global Digital Elevation Model) data were utilized to obtain topographic information, providing valuable insights into the terrain and elevation variations in the study area. High resolution multispectral satellite images, Landsat 8 OLI data offers multispectral bands with varying resolutions, enabling the analysis of spectral signatures and land cover characteristics [9,10]. These images were used to generate elevation maps, drainage patterns and spectral information. The multispectral data were subjected to preprocessing steps, including atmospheric correction to enhance data quality and suitability for subsequent analysis.

2.4 Geospatial Analysis using Geographic Information Systems (GIS)

Geographic Information Systems (GIS) software was utilized to integrate the VES and remote sensing data with other spatial datasets. The GIS platform enabled the creation of thematic maps depicting groundwater potential zones based on the correlation of geophysical and geospatial parameters. Data layers, including aquifer resistivity, elevation, slope, and drainage density, were overlaid and processed to delineate areas with varying degrees of groundwater potential [6,10,11].

These integrated methodologies allowed for a comprehensive investigation into the hydrogeological characteristics of the study area, offering insights into the spatial distribution of potential groundwater resources in the study area. The workflow presented in Fig. 3 serves as a guide for executing the methodology, ensuring a systematic and organized approach to the delineation of freshwater potential zones in the study area.

3. RESULTS

The presented results encapsulate the intricate interplay between geophysical, geospatial and hydrogeological factors, shedding light on the hydrological dynamics that govern the availability of groundwater resources in the study area.

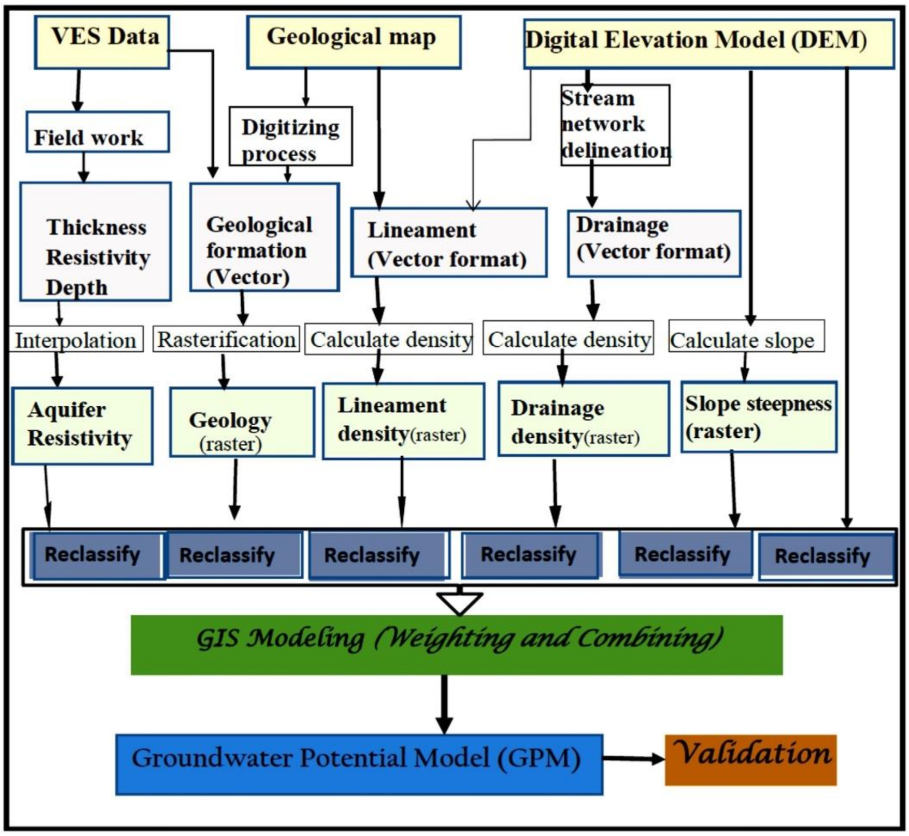
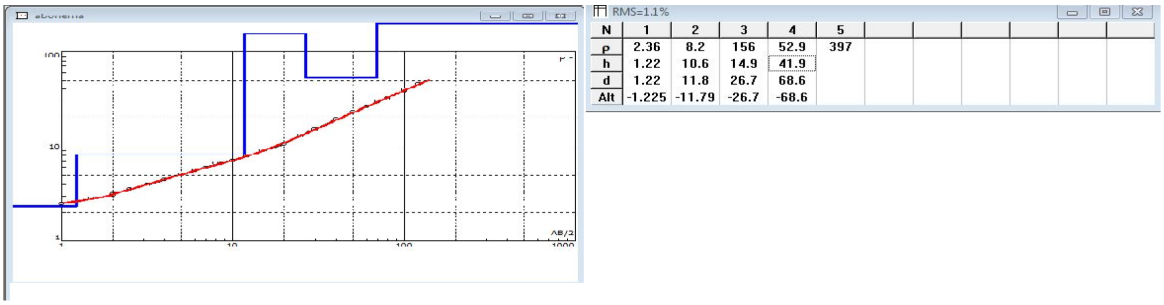


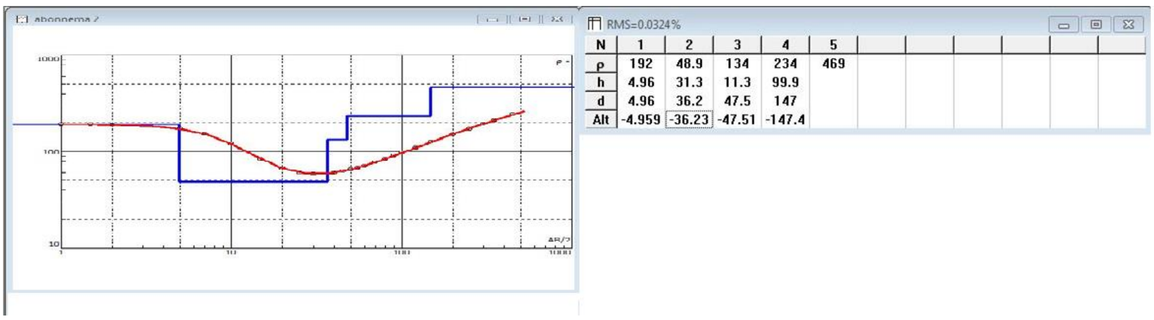
Fig. 3. Workflow of Groundwater Potential Model of Study Area [6]



RMS=1.1%

N	1	2	3	4	5
ρ	2.36	8.2	156	52.9	397
h	1.22	10.6	14.9	41.9	
d	1.22	11.8	26.7	68.6	
Alt	-1.225	-11.79	-26.7	-68.6	

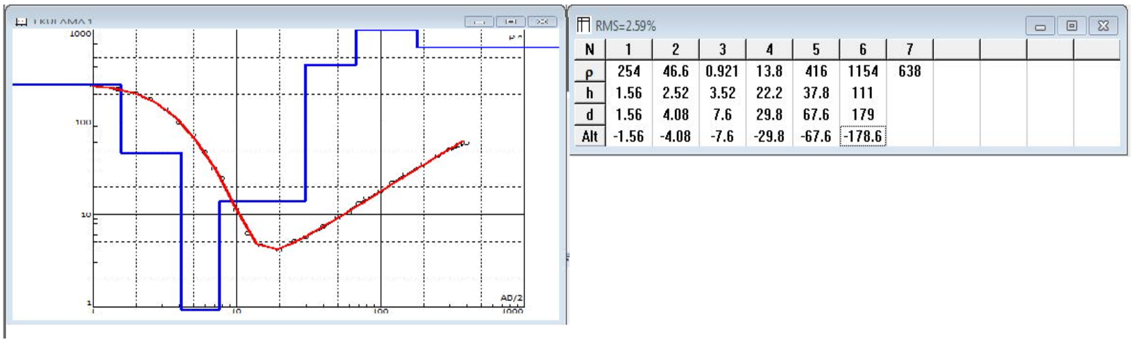
Fig. 4. VES a. Curve type of Abonnema 1 b. Model of Abonnema 1



RMS=0.0324%

N	1	2	3	4	5
ρ	192	48.9	134	234	469
h	4.96	31.3	11.3	99.9	
d	4.96	36.2	47.5	147	
Alt	-4.959	-36.23	-47.51	-147.4	

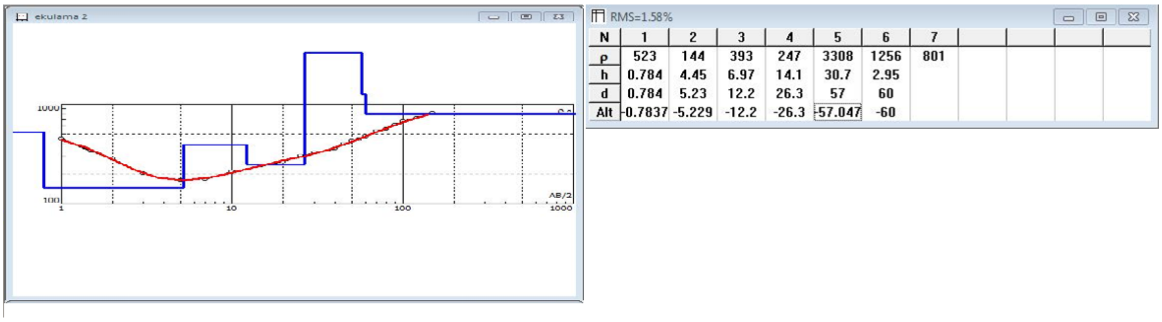
Fig. 5. VES a. Curve type of Abonnema 2 b. Model of Abonnema 2



RMS=2.59%

N	1	2	3	4	5	6	7
ρ	254	46.6	0.921	13.8	416	1154	638
h	1.56	2.52	3.52	22.2	37.8	111	
d	1.56	4.08	7.6	29.8	67.6	179	
Alt	-1.56	-4.08	-7.6	-29.8	-67.6	-178.6	

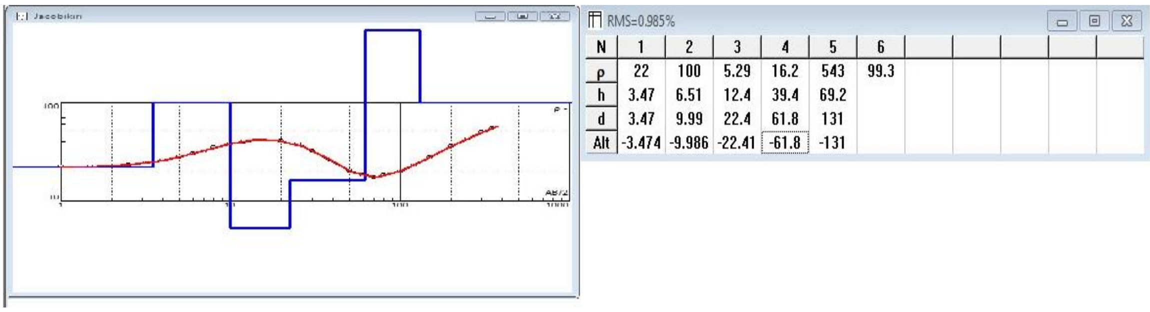
Fig. 6. VES a. Curve type of Ekulama 1 b. Model of Ekulama 1



RMS=1.58%

N	1	2	3	4	5	6	7
ρ	523	144	393	247	3308	1256	801
h	0.784	4.45	6.97	14.1	30.7	2.95	
d	0.784	5.23	12.2	26.3	57	60	
Alt	-0.7837	-5.229	-12.2	-26.3	-57.047	-60	

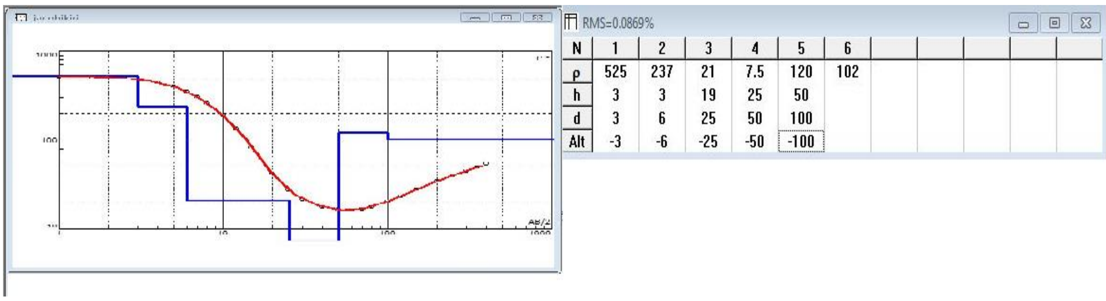
Fig. 7. VES a. Curve type of Ekulama 2 b. Model of Ekulama 2



RMS=0.985%

N	1	2	3	4	5	6
ρ	22	100	5.29	16.2	543	99.3
h	3.47	6.51	12.4	39.4	69.2	
d	3.47	9.99	22.4	61.8	131	
Alt	-3.474	-9.986	-22.41	-61.8	-131	

Fig. 8. VES a. Curve type of Jacobkiri 1 b. Model of Jacobkiri 1



RMS=0.0869%

N	1	2	3	4	5	6
ρ	525	237	21	7.5	120	102
h	3	3	19	25	50	
d	3	6	25	50	100	
Alt	-3	-6	-25	-50	-100	

Fig. 9. VES a. Curve type of Jacobkiri 2 b. Model of Jacobkiri 2

Table 2. Summary of VES results for sounding locations

VES Location	Coordinate		Layer Resistivities						Layer thickness						Error %	Curve Types
	Northings	Easting	ρ1	ρ2	ρ3	ρ4	ρ5	ρ6	h1	h2	h3	h4	h5	h6		
Abonnema 1	6º46'25'.23'E	4º43'46'.96'N	2.36	8.2	156	52.9	397		1.22	10.6	14.9	41.9			1.1	A
Abonnema 2	6º46'25'.99'E	4º43'34'.35'E	192	48.9	134	234	469		4.96	31.3	11.3	99.9			0.0324	HA
Ekulama 1	6º41'07'.82'E	4º32'14'.10'N	254	46.6	0.921	13.8	416	1154	1.56	2.52	3.52	22.2	37.8	111	2.59	QA
Ekulama 2	6º40'13'.45'E	4º32'40'.28'E	523	1441	393	247	3308	1256	0.784	5.23	12.2	26.3	57	60	1.58	HHQ
Jacobkiri 1	6º40'46'.07'E	4º28'37'.98'N	22	100	5.29	16.2	543	99.3	3.47	9.99	22.4	61.8	131		0.985	KA
Jacobkiri 2	6º41'47'.33'E	4º28'40'.57'E	525	237	21	7.5	120	102	3	3	19	25	50		0.869	HA
Belema 1	6º38'48'.89'E	4º22'55'.09'N	78.4	23.9	5.85	25.8	220	1616	1.63	3.91	15	6.01	22.4		1.73	HA
Belema 2	6º38'53'.74'E	4º22'50'.14'N	1961	29.8	58.1	569	317		0.755	22.6	44.8	62.5			1.26	HA

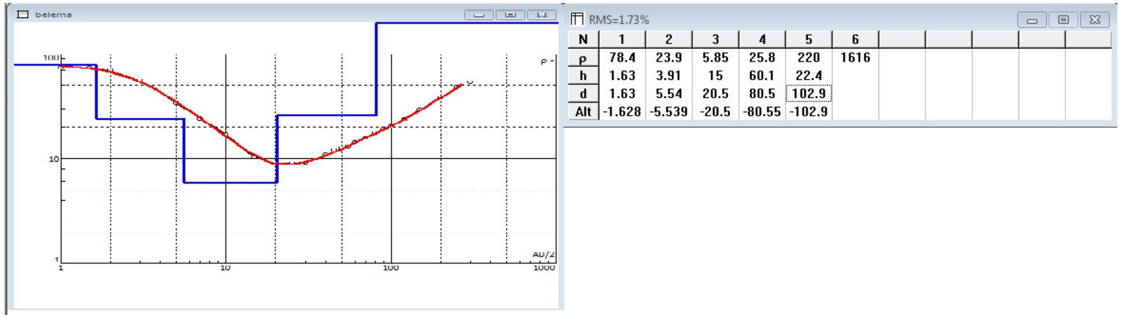


Fig. 10. VES a. Curve type of Belema 1 b. Model of Belema 1

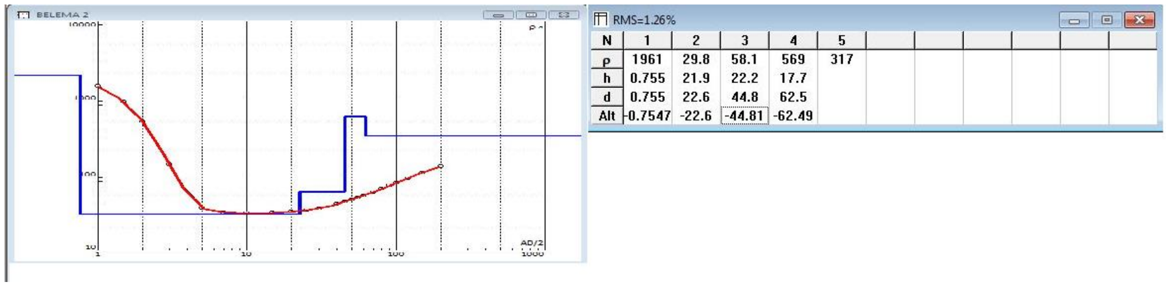


Fig. 11. VES a. Curve type of Belema 2 b. Model of Belema 2

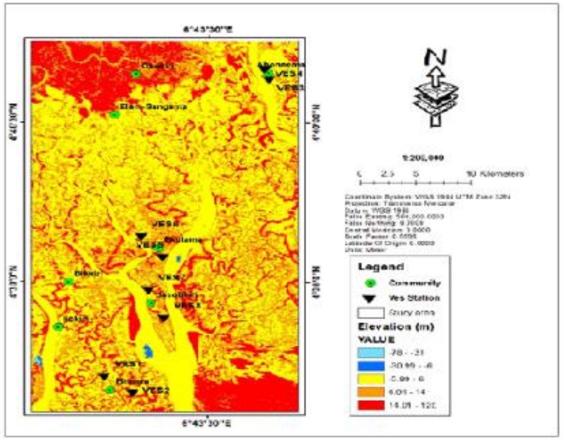


Fig. 12. Elevation map of study area

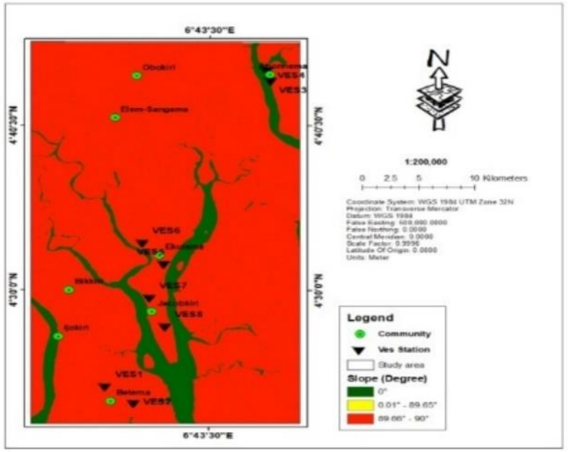


Fig. 13. Slope map of study area

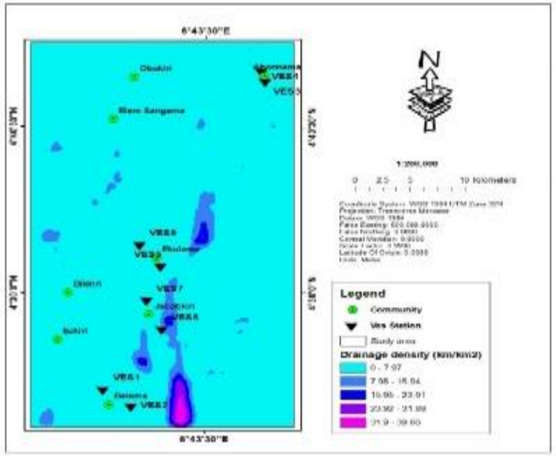


Fig. 14. Drainage density map of study area

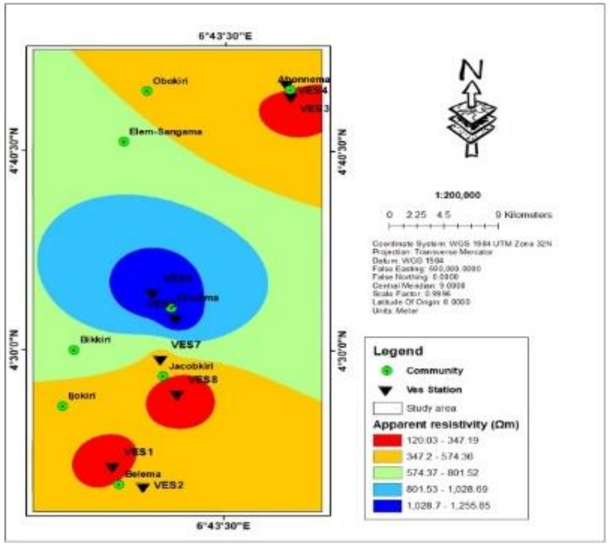


Fig. 15. Apparent Resistivity map of study area

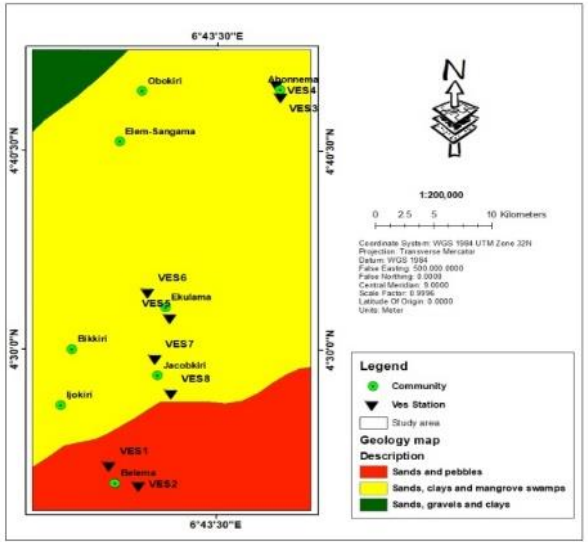


Fig. 16. Geology map of study area

3.1 Geospatial Results

Table 3. Summary of reclassification results

Community	Apparent Resistivity	Elevation	Slope	Geology	Drainage Density	Remarks
Abonnema	Very High, High, moderate, low	Very low, Low, Moderate High, Very High	Flat, gentle, moderate, Steep, very steep	Clay, Sand Gravel	Very Low, Low, Moderate,	Highest Groundwater Prospect
Ekulama	Very high, High, Moderate, low	Very low, low, moderate, high, very high	Flat, gentle, moderate, steep, very steep	Clay, Sand Gravel	Very low, low, moderate, high, very high	Lower groundwater prospect compared to Abonnema, Belema, and Jacobkiri
Jacobkiri	Very high, high, moderate, low	Very low, low, moderate, high, very high	Flat, gentle, moderate, steep, very steep	Clay, Sand Gravel	Very low, low, moderate, high, very high	Moderate groundwater prospect

Community	Apparent Resistivity	Elevation	Slope	Geology	Drainage Density	Remarks
Belema	Very high, high, moderate, low	Very low, low, moderate, high, very high	Flat, gentle, moderate, steep, very steep	Clay, Sand Gravel	Very low, low, moderate, high, very high	Higher groundwater prospect compared to Ekulama, lower than Abonnema

Table 4. Descriptive statistics of study area

Community	Variable	Min	Max	Mean	Standard Deviation
Abonnema	Aquifer Resistivity	2.36	397	141.08	171.42
	Elevation	0	40	19	16.43
	Slope	0	15	7.5	6.46
	Geology (Saturated Sand)	1.22	41.9	18.24	17.71
	Geology (Clay)	10.6	41.9	26.2	11.6
	Geology (Fine Sands)	14.9	68.6	36.76	23.54
	Drainage Density	1	1	1	0
Ekulama	Aquifer Resistivity	0.921	144	528.86	623.28
	Elevation	2.52	37.8	15.39	131.16
	Slope	0	37.8	10.98	13.54
	Geology (Coastal flood plain)	2.59	111	39.43	44.69
	Geology (Shallow marine deposit)	3.52	111	39.43	44.69
	Geology (Clay)	22.2	111	44.8	43.65
	Geology (Sand)	37.8	111	57.9	32.37
	Drainage Density	1	1	1	0
Jacobkiri	Aquifer Resistivity	5.29	543	156.14	236.14
	Elevation	3	131	39.28	51.17
	Slope	0	25	9.65	11.75
	Geology (Coastal plain Sands)	0.869	3	1.75	1.29
	Geology (Clay)	3	19	12.33	7.95
	Geology (sand)	19	25	22	2.83
	Drainage Density	1	1	1	0
Belema	Aquifer Resistivity	23.9	1961	448.96	688.67
	Elevation	1,63	1616	326.38	548.61
	Slope	0	22	6.58	9.71

Community	Variable	Min	Max	Mean	Standard Deviation
	Geology (Coastal plain Sands)	1.26	1961	695.3	748.91
	Geology (Shallow marine Deposits)	29.8	317	163.9	124.64
	Drainage Density	1	1	1	0

Table 5. Results of groundwater potential zone prediction

S/N	Rating	Class	Area (km^2)	Percentage area (%)
1	2	Low	4.56	0.4
2	3	Moderate	233.97	21.7
4	4	High	797.31	74.1
5	5	Very high	40.5	3.8

Table 6. Correlation between apparent resistivity and inferred lithology/remarks

Community	Apparent Resistivity	Lithology	Remarks
Abonnema 1 (VES 3)	High	Topsoil Clay Fine Sand Sand Fine Sand	Non-potential Non-Potential High Potential Medium Potential Highly Potential
Abonnema 2 (VES 4)	High	Topsoil Silty Clay Fine Sand Coarse Sand	Highly Potential Medium Potential Potential Zone Medium Potential
Ekulama 1 (VES 5)	Relatively Uniform	Topsoil Clay Peat Medium Sand Gravel Coarse Sand	Non-Potential Non-Potential Non-Potential Potential Potential Potential
Ekulama 2 (VES 6)	Low to Moderate	Topsoil Fine Sand Medium Sand Gravel Coarse Sand	Non Potential Non Potential Non-Potential Potential Potential
Jacobkiri 1 (VES 7)	Low to Moderate	Clay Fine Peat Clay Coarse Sand Silty Sand	Non-Potential Non-Potential Non-Potential Non-Potential Potential Potential
Jacobkiri 2 (VES 8)	Low-Moderate	Topsoil Fine-Medium Sand Clay Peaty Sand Fine Sand Fine Sand	Non-Potential Non-Potential Non-Potential Non-Potential Potential Potential
Belema 1 (VES 1)	Moderate	Silty-Sand Clay Peat Clay Fine Sand	Moderate Non-Potential Non-Potential Non-Potential Potential
Belema 2 (VES 2)	Varied	Topsoil Clay Silty-Clay Coarse Sand Medium-Sand	Non-Potential Non-Potential Non-Potential Potential Potential

Table 7. Correlation between Slope/Lithology and Inferred Lithology/Remarks

Community	Slope	Elevation	Lithology	Remarks
Abonnema 1 (VES 3)	Gentle	Low	Topsoil Clay Sand Sand Sand	Non-potential Non-Potential High Potential Medium Potential Highly Potential
Abonnema 2 (VES 4)	Gentle	Low	Topsoil Silty Clay Fine Sand Coarse Sand	Highly Potential Medium Potential Potential Zone Medium Potential
Ekulama 1 (VES 5)	Moderate to Steep	Low to Moderate	Topsoil Clay Peat Medium Sand Gravel Coarse Sand	Non-Potential Non-Potential Non-Potential Potential Potential Potential
Ekulama 2 (VES 6)	Gentle to Moderate	Low to Moderate	Topsoil Fine Sand Medium Sand Gravel Coarse Sand	Non Potential Non Potential Non-Potential Potential Potential
Jacobkiri 1 (VES 7)	Gentle to Moderate	Low to Moderate	Clay Fine Peat Clay Coarse Sand Silty Sand	Non-Potential Non-Potential Non-Potential Non-Potential Potential Potential
Jacobkiri 2 (VES 8)	Gentle to Moderate	Low to Moderate	Topsoil Fine-Medium Sand Clay Peaty Sand Fine Sand Fine Sand	Non-Potential Non-Potential Non-Potential Non-Potential Potential Potential
Belema 1 (VES 1)	Gentle Moderate	Low	Silty-Sand Clay Peat Clay Fine Sand	Moderate Non-Potential Non-Potential Non-Potential Potential
Belema 2 (VES 2)	Moderate	Low	Topsoil Clay Silty-Clay Coarse Sand Medium-Sand	Non-Potential Non-Potential Non-Potential Potential Potential

4. DISCUSSION

The study seeks to gain insight into the complex hydrogeological processes in the Akuku Toru Local Government Area by utilizing geophysical data, remote sensing observations, and geospatial analyses. This research adds to the larger conversation on evaluating and managing groundwater potential in tropical areas.

4.1 Integration of Multidisciplinary Techniques for Groundwater Assessment

The study has demonstrated that combining Vertical Electrical Sounding (VES) surveys, remote sensing, and Geographic Information Systems (GIS) is a powerful and successful method for evaluating groundwater potential. By merging these different datasets, the study takes advantage of their combined strengths and overcomes the limitations of each individual method. This combination not only improves the identification of potential zones but also provides a thorough understanding of the factors that affect groundwater occurrences. This integrated approach enables comprehensive groundwater management and promotes sustainable resource allocation strategies.

4.2 Groundwater Potential Zonation

The groundwater potential map (Fig. 17) classified the study area into four categories: low,

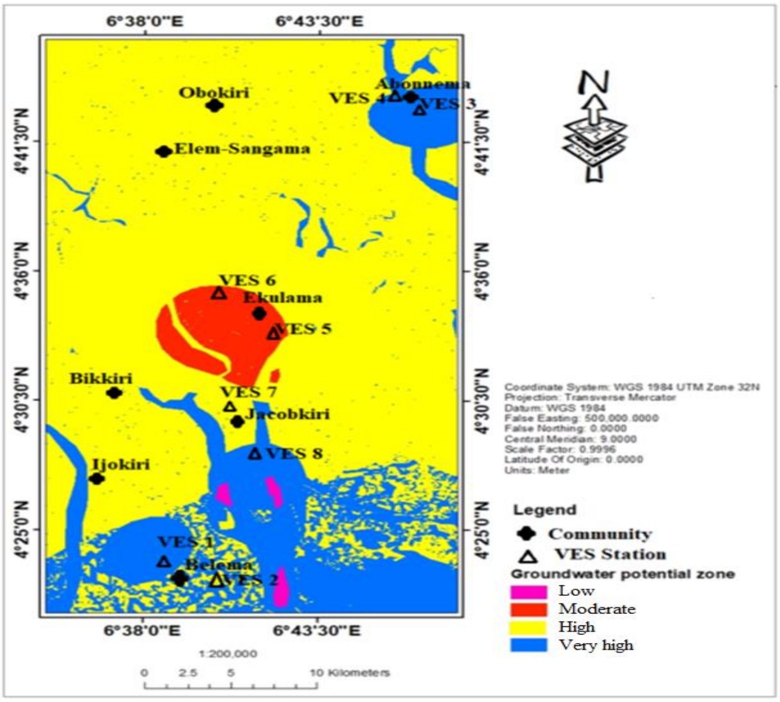


Fig. 17. Groundwater Potential map of study area

moderate, high, and very high potential zones. The majority of the study area (approximately 78.2%) falls within the high and very high potential categories, indicating favorable conditions for groundwater resources.

4.3 Influential Parameters

Aquifer resistivity, elevation, slope, geology, and drainage density were identified as influential parameters in determining groundwater potential. These parameters were assigned weights based on the Analytical Hierarchy Process (AHP) to assess their relative importance in the overall groundwater potential analysis [17,18].

4.4 Correlation Analysis

Correlations between apparent resistivity, slope, elevation, lithology, and inferred groundwater potential were established. Certain lithological formations, such as fine sands and saturated sands, were associated with higher groundwater potential, while clay or silty clay formations indicated lower potential.

4.5 Geospatial Factors

Geospatial factors such as elevation, slope, and drainage density were found to be important indicators of groundwater potential. Areas with higher elevations, gentle slopes, and higher drainage density exhibited higher potential for groundwater resources.

4.6 Implications of Geophysical Parameters on Groundwater Potential

The connection between the resistivity of an aquifer, its elevation, slope, and potential groundwater zones highlights their combined impact on the availability of water below the surface. The resistivity of an aquifer is a crucial sign of changes in rock types and the paths that groundwater takes, allowing for precise identification of potential aquifer areas. The patterns of elevation and slope offer information on how groundwater is recharged and how it flows, further improving the identification of appropriate locations for extracting groundwater. The complex interplay between these factors reveals the hydrogeological complexities of the area being studied, guiding the development of targeted strategies for managing resources [6-8].

4.7 Hydrogeological Significance of Geology and Remote Sensing

By combining geology and remote sensing data, the study reveals the geological formations that contain potential groundwater reservoirs. The study's categorization of the main formations in relation to potential groundwater zones provides a useful structure for evaluating resources. Remote sensing, using spectral analysis, enhances the identification of potential zones by detecting surface characteristics that suggest the presence of water below the surface. Combining this information with geophysical data improves our overall understanding of hydrogeological structures and provides direction for managing water resources in an informed manner [5,13,7].

5. CONCLUSION

The study's integrated approach, which involved geophysical, remote sensing, and geospatial analyses, has provided a comprehensive understanding of groundwater potential assessment. The findings have illuminated the complex hydrogeological dynamics within the Akuku Toru Local Government Area and established a valuable foundation for sustainable groundwater management. The synthesis of diverse datasets has enhanced our comprehension of groundwater occurrences, facilitated informed decision-making, and serves as an essential tool for policymakers, water resource managers, and researchers in tropical regions and beyond.

The thorough examination of groundwater occurrences in the Akuku Toru Local Government Area is not the end but rather a starting point for further exploration. Our study serves as both a foundation and a springboard for future research. As we look to the future, we are encouraged to dig deeper, improve our understanding, and go beyond the limits of what we currently know. We urge future researchers to take up this challenge and use our findings as a guide towards developing predictive models, flexible management strategies, and real-time monitoring.

6. LIMITATIONS AND FUTURE DIRECTIONS

This study improves our knowledge of evaluating groundwater potential in the Akuku Toru Local Government Area, but there are some limitations that need to be taken into account. Using secondary data for some factors may result in some uncertainty in the results. Furthermore, the complicated hydrogeological characteristics of the Niger Delta region necessitate additional investigation to improve the precision of identifying potential zones. Future research could include real-time monitoring, the use of climate data, and predictive modeling to improve the ability to predict groundwater assessments.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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