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Original paper

Featural analysis, protective capacity and potential of shallow hydro-geological layers of densely populated residential area, Akwa Ibom State, Southern Nigeria

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Abstract: Relevance. Geoelectrical resistivity technology (GRT), together with geological data, was employed to delineate the hydrokinetic characteristics, protective capacity, and groundwater potential of a sought-after housing development in Southern Nigeria. **Aim.** The GRT utilized Schlumberger's 1-D vertical electrical resistivity sounding (VES) and 2-D electrical resistivity tomography (ERT) techniques. **Methods.** The primary and secondary geoelectric indices were combined with existing geological data to calculate hydrodynamic parameter maps of the shallowest aquifer unit. These maps are crucial for effectively managing the unconfined aquifer system beneath, which is extensively utilized in the area. The study area's saturation dynamics were determined by analyzing total porosity (ranging from 0.282 to 0.691), specific yield (ranging from 0.040 to 0.107), field capacity/specific retention (ranging from 0.242 to 0.623), and storage-dependent drainability efficiency (ranging from 7.6% to 40.5%). **The results** indicated that the area experiences the most effective release of pore water when the drainability efficiency, which is reliant on storage, exceeds 21%. The range of potential index parameters, including transmissivity (57.4–4339.2 m^2/day), transverse resistance/aquifer potential scale (453.6–152,756.5 Ωm^2), permeability (91.7–7269.7 mD), and hydraulic conductivity (57.4–4339.2 m/day), exhibited favorable potential but limited to moderate protection, as indicated by the longitudinal conductance index (0.004–0.6218 Siemens). Given the strong preference of many people to live in this rapidly growing and competitive housing estate, it is important to establish effective waste disposal systems to prevent the leakage and infiltration of harmful substances, such as leachates and other organic/inorganic waste, into the vulnerable underground water sources that provide water for various purposes.

Keywords: GRT, VES, hydrokinetic properties, parametric characterization, leachates.

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ГЕОФИЗИКА

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Оригинальная статья

Анализ характеристик, защитная способность и потенциал неглубоких гидрогеологических слоев густонаселенного жилого района, штат Аква-Ибом, Южная Нигерия

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Резюме: Актуальность работы. Технология геоэлектрического сопротивления (GRT) вместе с геологическими данными была использована для определения гидрокинетических характеристик, защитной способности и потенциала грунтовых вод востребованной жилой застройки в Южной Нигерии. **Цель.** Технология GRT использовалась в виде способов одномерного вертикального электрического зондирования (ВЭЗ) и двухмерной электрической томографии с помощью установки Schlumberger (ERT). **Методы.** Первичные и вторичные геоэлектрические индексы сопоставлялись с имеющимися геологическими данными для расчета карт гидродинамических параметров наиболее мелкого водоносного горизонта. Указанные карты имеют решающее значение для эффективного управления системой незамкнутого водоносного горизонта под ним, которая широко используется в этом районе. Динамика насыщения исследуемой области определялась путем анализа общей пористости (в диапазоне от 0,282 до 0,691), удельной водоотдачи (в диапазоне от 0,040 до 0,107), полевой влагоемкости/удельного удержания (в диапазоне от 0,242 до 0,623) и эффективности дренируемости, зависящей от хранения (в диапазоне от 7,6% до 40,5%). **Результаты.** Установлено, что наиболее эффективное высвобождение поровой воды происходит, когда дренируемость превышает 21%. Диапазон потенциальных индексных параметров, включая проницаемость (57,4–4339,2 м^2/день), поперечное сопротивление/шкала потенциала водоносного горизонта (453,6–152 756,5 Ом·м^2), проницаемость (91,7–7269,7 мД) и гидравлическая проводимость (57,4–4339,2 м/день), показывают положительный потенциал, но ограниченный умеренной защитой, на что указывает индекс продольной проводимости (0,004–0,6218 Сименс). Учитывая стремление большинства населения проживать в этом быстрорастущем и конкурентоспособном жилом комплексе, важно создание эффективных систем утилизации отходов для предотвращения утечки и инфильтрации вредных веществ, таких как фильтраты и другие органические/неорганические отходы, в уязвимые подземные источники воды, которые население использует для различных целей.

Ключевые слова: GRT, ВЭЗ, гидрокинетические свойства, параметрическая характеристика, фильтраты.

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Introduction

Shallow sedimentary hydrogeological units play a crucial role in storing groundwater at both regional and local levels. However, obtaining reliable hydrogeological data to effectively understand their distribution and hydraulic properties can be challenging, costly, and time-consuming. Accurate knowledge of hydraulic parameters, including porosity, hydraulic conductivity, permeability tortuosity, specific yield, and specific retention, is essential for assessing the resources of a groundwater system. These parameters help evaluate the potential, protectivity, and vulnerability of the system to contamination, which are all crucial factors in targeted integrated water management [Bhatt, 1993; Tizro et al., 2012; Frind, Molson, 2018]. Porosity is a hydrokinetic feature of a hydrogeological unit that represents the ratio of the void space in a particular volume of soil or rock sample to its total volume. It is typically stated as a percentage [Hilberts et al., 2005; George et al., 2011]. Voids, pore spaces, and cracks play a crucial role in hydrodynamic investigations and parametric characterization in the fields of hydrogeology and hydrogeophysics. According to Fetter (1988), soil moisture and groundwater are found in the empty spaces within the solid earth. This dictates how pollutant plumes are spread in interconnected pore networks. The hydrodynamic properties of rocks and soils on Earth, such as total porosity (¢), depend on factors such as the geometry, extent of voids, arrangement of grain sizes, and interconnectedness of the pores. These properties determine how water accumulates and passes through the material [Karanath, 1994; George et al., 2011]. According to Mazac et al. (1985), the size of grains does not affect the overall porosity in sediments of the same size. The effective porosity encompasses both specific yield and specific retention. Specific retention refers to the amount of water that is retained within a hydrogeological unit due to capillary forces and adhesion when it is emptied. The specific yield refers to the substantial quantity of water that is readily accessible for groundwater extraction when the water table is lowered, resulting in the drainage of porous materials [Ikpe et al., 2022]. The soil water retention curve is a tool that quantifies the relationship between the water content of the soil and the capillary pressure it exerts. This relationship is influenced by both climatic conditions and the velocity of water flow at the pore scale, which is determined by the specific yield and specific retention capacity [Nielsen, Perrochet, 2000]. These factors are valuable for calculating the capacity of water pumps for various aquifer units using the storage-dependent drainability efficiency tool, which is the ratio of specific yield to specific retention. The methods commonly employed to investigate specific yield, as outlined by Todd [1980], include pumping, field saturation, recharge analysis, particle density measurement, and sampling following water table decline. Nevertheless, as stated by George et al. [2011], these methods require a significant investment of resources, including equipment, borehole data, and a substantial workforce, due to the complex and labor-intensive nature of each methodology. From an economic standpoint, the geo-sounding technique has been demonstrated to be an effective method for assessing the structure, vulnerability, and potential of underground hydrogeological units in both large and medium-sized study areas [Zohdy et al., 1974; Zohdy, 1989; George, 2021]. Geo-sounding technologies operate under the assumption that the rock/soil matrix is primarily an insulating material. This means that it can conduct electric current when there is water or moisture present in its pores [Ibuot et al., 2013, 2019]. The skillful application of geo-sounding techniques by numerous researchers has enabled the production of reliable evidence that revealed both qualitative and quantitative estimates of transmitting variables of hydrogeological units [Obianwu et al., 2011; Obiora et al., 2015; Ibuot et al., 2019] The effectiveness of studying the parametric characteristics, protective nature, and potential of hydrogeological units can be enhanced by analyzing the spatial distribution of aquifer system indices on maps. This approach has been explored in many studies conducted by Aweto (2011) and Shamsudduha et al. (2012). This paper aims to investigate the estimates of primary and secondary geo-electrical attributes obtained through geo-electrical resistivity technology, along with other hydro-geological variables such as specific yield and retentive retention. The goal is to characterize a medium-sized housing estate and assess the protectivity, vulnerability, and potential of shallow groundwater resources that are heavily abstracted by the residents of the estate.

Description of the Study Area

Site Location

Shelter Afrique, a moderately-sized housing development, is situated in the mid-western region of Akwa Ibom State, located in Southern Nigeria. The majority of its land area is in Ibesikpo County, with a smaller section in Uyo County (fig. 2). The occupied territory spans from latitudes 4.958° to 4.9917°N and longitudes 7.9417° to 7.9750° E, with an approximate area of 30.8 square kilometers. The region is characterized by a flat terrain, with altitudes ranging from a low point of 54 meters to a high point of 68 meters above sea level. The average elevation is 59 meters, as shown in figure 1. The study area is a recently constructed and quickly growing residential area in the Uyo Senatorial District. It is home to past and current governors, deputy governors, members of the political class, and other influential individuals from Akwa Ibom State, as well as other states in Nigeria and those living abroad. The area is characterized by a high population density of individuals and physical infrastructure due to its medium size. The region experiences a semi-temperate climate characterized by distinct dry and wet seasons. The dry season lasts from April to September, while the wet season occurs from October to March. The entire catchment area is affected by the tributaries of the Enyiong River, which is the primary source of perennial surface water in Itu County. The temperature range spans from 26 to 32 °C, while the annual rainfall varies from 200 to 250 cm [George, 2021].

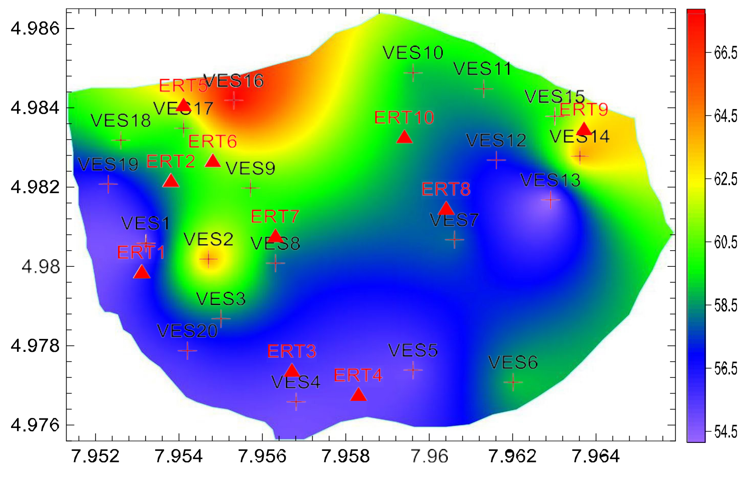

Fig. 1. Elevation map of the study area showing the topography of the study area

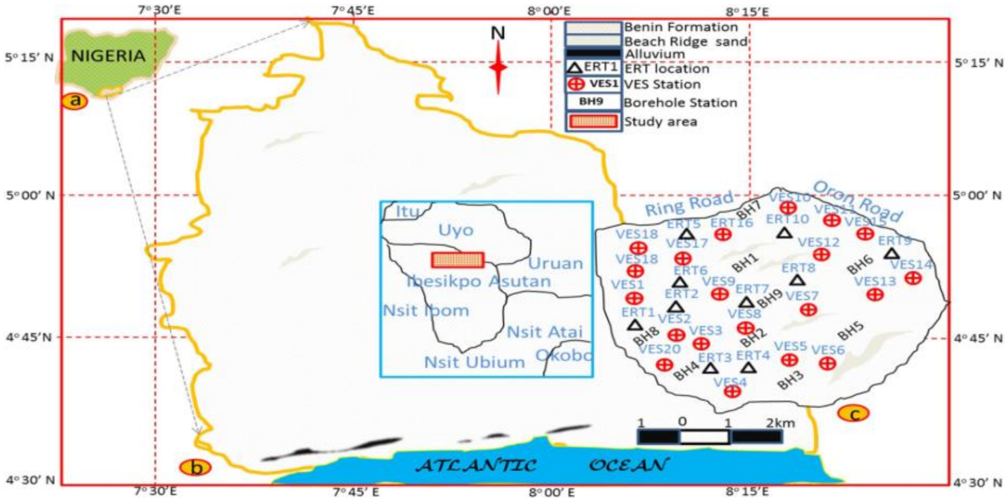

Fig. 2. Schematic map of Nigeria.
(a) geographic location of Akwa Ibom State in Southern Nigeria;
(b) map of Akwa Ibom State showing Atlantic Ocean and the geographical settings of the study area;
(c) geographic and model domain map showing geology, VES points and Boreholes

Geology of the Study Area

The groundwater extraction in the studied region occurs within the Youngest Continental Plain sand/Benin Formation of the Niger Delta in Southern Nigeria. The Benin Formation, which consists of alternating layers of sandstones and small amounts of claystones, is located above the Agbada Formation and Akata Formation in a specific order of burial depth [Petters, 1982, 1989]. The research region is located in Southern Nigeria, as indicated by the Geological Survey Map series of Nigeria on sheets 79 for Umuahia and 82 for Calabar, with a scale of 1:250,000.

Benin Formation, often referred to as Coastal Plain Sand [GSN, 1962]. Specifically, the area is predominantly located within the Benin Formation and partially within the Beach Ridge Complex and Alluvium of the Quaternary Period, as seen in figure 2. The composition of alluvial sands ranges from fine to coarse grained sands (fig. 3), whereas the light grey argillites are relatively little in quantity and scattered irregularly. Following rainfall, it is occasionally observed that sedimentation, erosion, and morphological differences occur in the surface layers. The alluvial sediments consistently occur at lower elevations and are attracted by gravity. The alluvial grains, characterized by a greyish hue, exhibit a characteristic texture that varies from fine to coarse, with alternating intercalations, as described by Short and Stauble in 1967. The presence of groundwater in the area is influenced by various geological factors, including the structure, disturbances in the stratigraphy, and the arrangement of hydrogeological units [Tizro, 2002; Akpan et al., 2013]. The hydraulic interconnections between the seasonal reduction in water levels and the groundwater level or the topography of groundwater conduits determine the depth and shape of wells and water bodies.

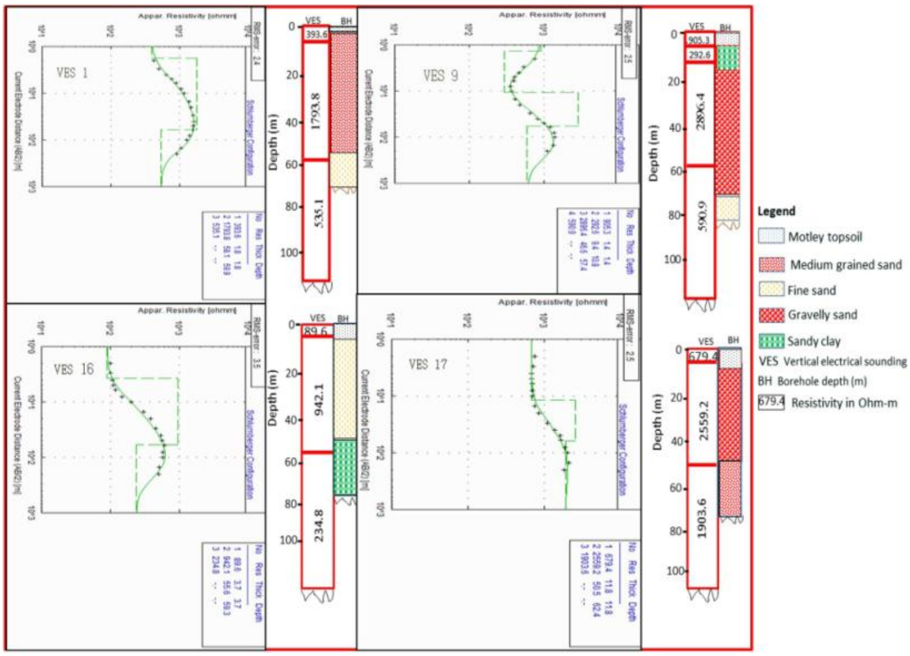

Fig. 3. Sampled correlations of VES 1, 9, 16 and 17 curves with their adjoining lithological log in the study area

Materials and Method

The research region employed the geo-sounding resistivity technology, which consisted of a 1-D vertical electrical sounding (VES) and 2-D electrical tomography (ERT). The IGIS signal enhancement resistivity meter SSP-MP-ATS and its accessories were used in close proximity to water wells for the execution of this technology. Twenty VES stations and ten ERT stations were selected based on the existing infrastructure in the area (fig. 2). The VES process utilized the Schlumberger array, with a maximum spread (AB) of 400 m for the current electrodes. On the other hand, the 2-D technique employed the Wenner electrode configuration, with a spread length of 105 m, taken at 5 m intervals or separations [Thomas et al., 2020]. Earth apparent resistance, Ras and Raw, were measured in each VES and ERT technique, following the recommended precautions outlined by Zohdy et al. [1974] and Akpan et al. [2013]. The apparent resistivities ρ_{as} and ρ_{aw} for VES and ERT methods were determined using the equations provided in Eqs. 1 and 2, respectively.

$$\rho_{as} = n.\frac{\left(AB/2\right)^2 - \left(MN/2\right)^2}{MN}.R_{as} \quad (1)$$

$$P_{aw} = 2JraR_{aw}, \quad (2)$$

where AB, MN and are, respectively, current electrode separation, potential electrode separation and Wenner electrode separations. The entire term multiplied by R_{as} and R_{aw} in Schlumberger and Wenner electrode configurations, respectively, in order to obtain the apparent resistivities P_{as}.

The apparent resistivities were graphed manually on a logarithmic scale, using half of the current electrode separations. This was done to eliminate any noisy data points (outliers) that deviate from the overall trend of the curve. Subsequently, the curves were analyzed using a computer program called WINRESIST, which utilizes 1-D least square computer-assisted forward modeling. This software, developed by Vander Velpen and Sporry in 1993, quantitatively interprets the data electronically. The analysis takes into account the restrictions provided by adjacent logged borehole information. The software program provided data on the interpreted curve by determining the main geo-electric parameters such as layer resistivity, layer thickness, and layer depth. It also calculated the root-mean square (usually less than 10%), which measures the accuracy of the fit between the theoretical curve and the actual field data (refer to figure 2). The ERT images were modeled by inverting the apparent resistivities obtained from Eq. 2. This was done by preparing the separation and apparent resistivity values together with the RES2DINV VER 3.59 Geotomo software code, which was developed by Loke and Barker [1996], Loke and Dalhin [2002], and Loke et al. [2003]. The program constructs a resistivity model of the shallow subsurface using an iterative smoothness-constrained least squares method, as seen in the resulting electrical resistivity tomography (fig. 4). Table 1 presents the geographic information, as well as the measured and predicted hydrokinetic parameters, of the shallowest aquifer that lies above the other deeper aquifers in the unconfined aquifer system.

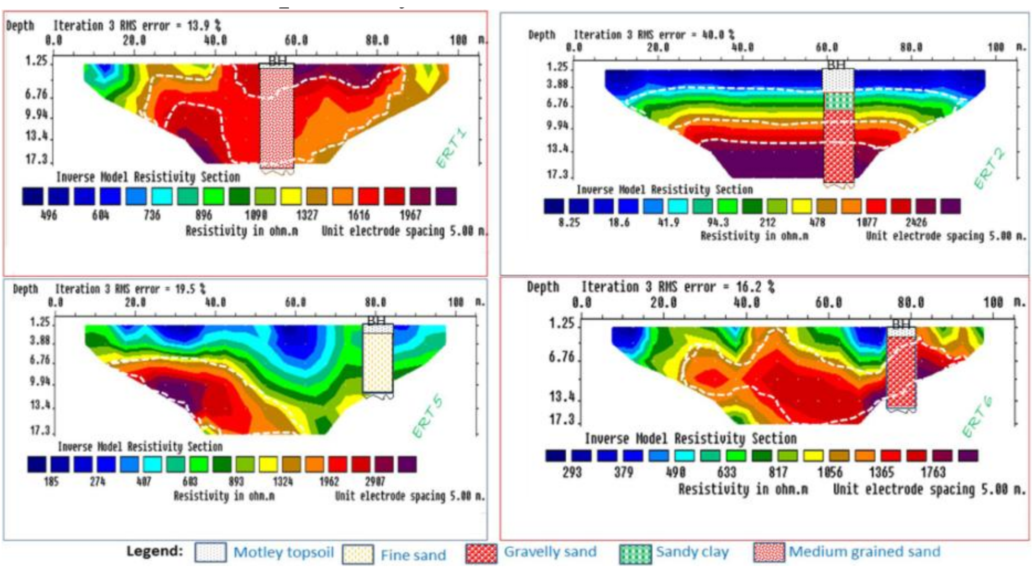

Fig. 4. Representatives of ERTs 1, 2, 5 and 6 with their adjoining lithological log in the study area

a_W:water electrical conductivity (S/m), p_W: water resistivity (Ω m), F: formation factor, k_p: permeability mD), k_h: hydraulic conductivity (m/day), p_b: bulk resistivity of the topmost aquifer (Ω m), p_{sat} : resistivity of saturated part of aquifer (Ω m), p_{unsat}: resistivity of unsaturated part of aquifer (Ω m), Sy: Specific yield, $\cent f$: specific retention and h: thickness (m) of shallowest aquifer considered.

Table 1

Measured and estimated hydrokinetic properties associated with the aquifer system

VES / ERT No	Location	Long. (deg.)	Lat. (deg.)	a_W(S/m)	p_w	p_b	p_{sat}	F	p_{unsat}	¢	s_y	¢f	k_h	k_p	h
1/1	Imoh ita	7.9492	4.9791	0.000711	1406.9	1793.8	386.9	1.27	393.6	0.641	0.063	58.1	58.1	58.1	58.1
2	murray Avenue	7.9522	4.9790	0.000587	1702.9	2051.9	349.0	1.20	351.8	0.660	0.046	52.6	52.6	52.6	52.6
3/2	Ambasador ubok udom	7.9506	4.9778	0.00496	201.6	779.9	578.3	3.87	1234.4	0.368	0.062	7.8	7.8	7.8	7.8
4/3	kufre ekanem Crescent	7.9517	4.9750	0.00061	1639.6	2591.8	952.2	1.58	996.3	0.576	0.052	23.4	23.4	23.4	23.4
5/4	godswill akpabio Crescent 4	7.9594	4.9745	0.009434	106.0	411.9	305.9	3.89	1464.2	0.367	0.106	19.3	19.3	19.3	19.3
6	Udo udoma street	7.9606	4.9786	0.00052	1923.0	2109.9	186.9	1.10	187.6	0.691	0.058	72.4	72.4	72.4	72.4
7	Alison attah	7.9619	4.9815	0.010989	91.0	301.1	210.1	3.31	560.5	0.398	0.107	16.6	16.6	16.6	16.6
8/7	godswill akpabio Crescent 1	7.9531	4.9800	0.009174	109.0	427.1	318.1	3.92	1121.1	0.366	0.090	15.0	15.0	15.0	15.0
9	godswill akpabio Crescent 2	7.9556	4.9862	0.013699	73.0	292.6	219.6	4.01	905.3	0.362	0.093	9.4	9.4	9.4	9.4
10	Godswill akpabio Crescent 3	7.9597	4.9878	0.059524	16.8	71.2	54.4	4.24	361.1	0.352	0.100	29.5	29.5	29.5	29.5
11/10	shelter afrique Entrance	7.9614	4.9855	0.001617	618.3	1131.4	513.1	1.83	562.2	0.535	0.060	69.9	69.9	69.9	69.9
12/8	chris Ekpenyong	7.9639	4.9830	0.000558	1793.4	2085.8	292.4	1.16	294.2	0.672	0.050	50.2	50.2	50.2	50.2
13	sunday Mbang street	7.9644	4.9820	0.052356	19.1	81.0	61.9	4.24	348.3	0.352	0.094	5.6	5.6	5.6	5.6
14	aniekan Umana street	7.9658	4.9835	0.071429	14.0	53.0	39.0	3.79	110.5	0.372	0.084	18.3	18.3	18.3	18.3
15/9	godswill akpabio crescent 5	7.9675	4.9838	0.1	10.0	43.7	33.7	4.37	208.3	0.346	0.092	77.7	77.7	77.7	77.7
16	Akpan hogan ekpo avenue	7.9550	4.9878	0.001172	852.9	942.1	89.2	1.10	89.6	0.689	0.073	55.6	55.6	55.6	55.6
17	Justice edet robert	7.9539	4.9877	0.000526	1900.0	2559.2	659.2	1.35	679.4	0.624	0.077	50.5	50.5	50.5	50.5
18/5	Engr atauyo Ekwerre	7.9525	4.9867	0.000956	1045.9	1255.5	209.6	1.20	211.8	0.661	0.062	73.0	73.0	73.0	73.0
19/6	Dan udofia avenue	7.9522	4.9853	0.000662	1510.0	1938.8	428.8	1.28	436.5	0.639	0.062	56.1	56.1	56.1	56.1
20	uduak udoudoh avenue	7.9494	4.9755	0.021322	46.9	308.3	261.4	6.57	1409.0	0.282	0.040	5.0	5.0	5.0	5.0
Mean	0.144	754.0	81,918.1	307.5	2.38	596.3	0.470	0.075	0.395	21.4	2445.2	38.3			
Range	0.004–0.6218	10.0–1923.0	43.7–2591.8												
	33.7–952.2	1.1–6.57	89.6–1464.2	0.282–0.691	0.040–0.107	0.242–0.623	57.4–4339.2	91.7–7269.7	5.0–77.7						

Protectivity and potentiality of shallow unconfined hydrogeological units assessed

The assessment of the protective capacity and potential of the unconfined/open aquifers in the medium-sized housing estate in Shelter Afrique was conducted using the Dar Zarrouk parameters. The longitudinal conductance (S) was estimated as h/ρ in Siemens, while the transverse resistance (TR) was expressed as (h • ρ) in Ωm^2. Additionally, the transmissivity (T) was estimated as (k. h) in m^2s^{-1}. The protection of an aquifer system relies on the characteristics of the lithological unit that covers and surrounds it. The level of protection and susceptibility to surface contamination is directly related to its longitudinal conductance S. Longitudinal conductance values below 1.0 Siemens suggest that the overburden medium has a negligible amount of impermeable argillites above the aquifer system, indicating a high rate of infiltration for surface contaminants.

Result and Discussion

The geoelectrical resistivity technology was corroborated by mechanical boreholes situated adjacent to the profiles, aiding in the interpretation of VES and ERT data. The primary objective of electrical studies is to accurately determine the subsurface resistivity distribution by conducting measurements on either the surface or a borehole [Braga et al., 2006]. An electrical current is applied to the ground using a set of current electrodes, and the resulting voltage is measured using another set of electrodes. The variability in resistivity was determined by performing inversion, which involves finding the resistivity model that best fits the whole sequence of quadrupole observations. The apparent resistivities were calculated using Equations 1 and 2 [Sri, Muhammed, 2012]. The nonlinear problem of inversion was numerically solved using iterative techniques, as described by Tripp et al. in 1984. In order to avoid any confusion, the actual resistivities were taken into account when discussing the matter.

The interpretation of the geoelectrical resistivity technology data from VES and ERT was corroborated by adjacent mechanical boreholes as shown in Fig. 5, which is a pictorial view of 2-D image map of distribution of (a) topmost aquifer transmissivity (m^2/day) (b) topmost aquifer transverse resistance ($\Omega\ m^2$) (c) topmost aquifer longitudinal conductance (Siemens), and (d) storage-dependent drainability efficiency (%).

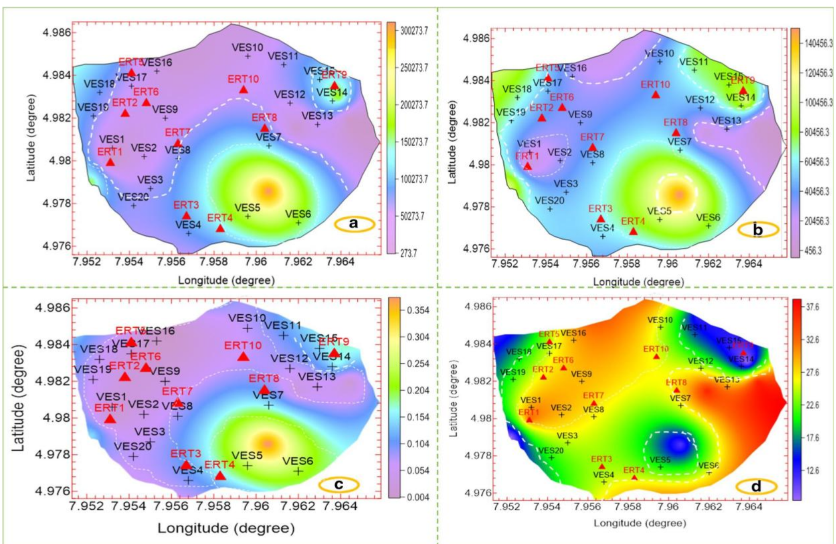

Fig. 5. 2-D image map of distribution of (a) topmost aquifer transmissivity (m^2/day) (b) topmost aquifer transverse resistance ($\Omega\ m^2$) (c) topmost aquifer longitudinal conductance (Siemens), and (d) storage-dependent drainability efficiency (%)

The primary objective of electrical investigations is to accurately determine the subsurface resistivity distribution in a cost-effective manner, using measurements taken either on the surface or in a borehole [Braga et al., 2006]. An electrical current is applied to the ground using a set of current electrodes, and the resulting voltage is measured using another set of electrodes. The variability of resistivity was assessed by performing inversion, which involves determining the resistivity model that best matches the whole sequence of quadrupole observations. The apparent resistivities were calculated using Equations 1 and 2 [Sri, Muhammed, 2012]). Numerical methods were employed to solve the nonlinear problem of inversion, utilizing iterative techniques [Tripp et al., 1984]. In order to avoid any confusion, the actual resistivities were taken into account when discussing the unknown situation.

Table 2

Summary of

VES number	ERT number	Location	Transverse resistance R (Ωm^2)	Longitudinal conductance S (mhos)	ASPC rating	Transmissivity (m^2/ day)	Comparative aquifer potentials
1	1	Imoh ita	104,219.78	0.148	Weak	149,033.1	Very high
2		Murray avenue	107,929.94	0.150	weak	163,159.5	Very high
3	2	Ambasador ubok	6083.22	0.006	Poor	1219.7	High
		udom					
4	3	Kufre ekanem	60,648.12	0.023	Poor	31,108.0	Very high
		crescent					
5	4	Godswill akpabio	7949.67	0.013	Poor	2990.0	High
		crescent 4					
6		Udo udoma street	152,756.76	0.386	Moderate	314,158.9	Very high
7		Alison attah	4998.26	0.030	Poor	3616.0	High
8	7	Godswill akpabio	6406.5	0.013	Weak	2284.0	High
		crescent 1					
9	Godswill akpabio		2750.44	0.010	Poor	1365.6	High
		crescent 2					
10		Godswill akpabio	2100.4	0.082	Poor	3821.7	High
		crescent 3					
11	10	Shelter afrique	79,084.86	0.124	Weak	62,123.7	Very high
		entrance					
12	8	Chris ekpenyong	104,707.16	0.171	Weak	176,187.6	Very high
13		Sunday mbang street	453.6	0.016	Poor	724.5	Moderate
14		Aniekan umana	969.9	0.166	Weak	2993.9	High
		street					
15	9	Godswill akpabio	3395.49	0.373	Moderate	9456.9	High
		crescent 5					
16	Akpan hogan ekpo		52,380.76	0.621	Moderate	235,294.9	Very high
		avenue					
17		Justice edet robert	129,239.6	0.074	Poor	108,529.9	Very high
18	5	Engr atauyo ekwerre	91,651.5	0.345	Moderate	229,394.0	Very high
19	6	Dan udofia avenue	108,766.68	0.129	Weak	140,625.4	Very high
20		Uduak udoudoh	1541.5	0.004	Poor	273.7	Low
		avenue					
Mean				0.144		81,918.1	
51,401.7							
Range				0.004–0.6218		273.7–314,158.9	
453.6–152,756.5							

Conclusion

The geoelectrical resistivity technology and geological information have been used to map the shallowest hydrogeological unit of the unconfined aquifer system in a medium-sized housing estate of Shelter Afrique. The findings unveiled the dispersion of several characteristics, as well as the ability to safeguard and the potential of the aquifer system in the highly sought-after residential area in Akwa Ibom State, Southern Nigeria. The findings indicated that the hydrogeological units, consisting of fine- to medium- and medium-to coarse-grained sands, have a high capacity for extracting groundwater. However, they offer only moderate to poor protection, as indicated by the Transmissivity/aquifer potential Scale [Gheorghe, 1978] and the range of values for longitudinal conductance that determine the protective scale [Oladapo et al., 2004]. The hydrokinetic parameters inferred from geological information align with those obtained from similar geological conditions both within and outside the study area. The innovative aspect of this study lies in the determination of the specific yield and field capacity, as well as the SDE, which provide a hydrodynamic explanation for the dynamics of pores and the factors that affect the optimal and effective extraction of pore water through well pumping. An analysis has been conducted to determine the hydrokinetic characteristics, parametric maps, and the potential and protectivity maps of the aquifer system. This analysis is aimed at facilitating the efficient extraction, monitoring, and management of groundwater resources. Given the high demand for living in this newly constructed housing estate, it is crucial to establish effective waste disposal systems to prevent the leakage and contamination of harmful substances such as leachates and other organic/inorganic waste into the underlying hydrogeological units. These units store groundwater that is extracted for various purposes and are naturally susceptible to damage.

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