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Groundwater Potential Evaluation in Parts of Southwestern Nigeria Using Dar-Zarouk Parameters

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Abstract

Dar-Zarouk parameters namely longitudinal conductance, transverse unit resistance, longitudinal resistivity, traverse resistivity, and coefficient of anisotropy, derived from electrical resistivity soundings,were employed in the western and south western portions of Sheet 223 Ilorin NW, Southwestern Nigeria to evaluate the subsurface water prospect. This is aimed at determining the potentiality and vulnerability of groundwater in the area.The longitudinal conductance values obtained range from 0.027 S at VES 3 in the north, indicating the poorest protective capacity, to 26440.95 S at VES 157 in the south, indicating the highest protectivity. Thus, the protective capacity rating of the study area shows very poorly, weak, moderate, good, and excellent ratings at VES stations 10, 12, 9, 2, and 178 respectively.The total transverse resistance range is 8.6 - 32733.87 Ωm^2, with the lowest at VES 206 in the southeastern part, indicating high prospects, and the highest at VES 47 in the northern part of the area, indicating poor prospect.The lowest longitudinal resistivity (0.1951 Ωm), indicating high potential as well, occurs at the southern part and while the highest value of 8095.63 Ωm is obtained at the northern part.Furthermore, the coefficient of anisotropy in the area ranges between 0.029 and 5349.78. The south-western boreholes have values that fall between the standard range of 1.39-1.66, indicating that those areas have boreholes with high productivity.In conclusion, most parts of the study area have excellent protective capacities and high potentiality.

Keywords: Dar-Zarouk parameters, Resistivity, Groundwater potential, Protective capacity, Vulnerability

Introduction

Most of the human body is water, with an average of roughly 60% (Claire, S., 2020). About 97.2% of the water on earth is salty and only 2.8% is present as freshwater from which about 20% constitutes groundwater (Goel, 2000). Groundwater potential of an area indicates how prospective or probable the groundwater in that area is.

In Nigeria today, the use of groundwater has become an agent of development because the government is unable to meet the ever-increasing water demand, therefore, inhabitants have to look for alternative sources, which groundwater resources such as shallow wells and boreholes are part (LAWMA, 2000). Most of the rural areas in Nigeria have their water supply from rivers, streams, and hand-dug wells while the urban settlements depend on treated pipe-borne water and boreholes for their water supply.Studies show that Nigeria has sufficient water resources that could meet the needs of its people. However, the actual potable water supply is very poor in most parts of the country. In exploring underground water, different methods have been employed by various researchers in which geophysical methods have been widely used because of their ability to produce accurate results. Among the geophysical methods, the electrical resistivity method has been the most commonly used for groundwater investigation because of its advantage which includes simplicity in field technique and data handling procedure (Anomohanran, 2013). Researchers such as Olasehinde *et al.,* (1998), Oseji *et al.*, (2009), Nejad, (2009), Egbai, (2011), Ibrahim *et al.* (2012), Utom *et al.*, (2012) and Anomohanran, (2014) have all used the electrical resistivity method to explore for groundwater in different locations. The electrical resistivity methodis effectively employed for groundwater exploration in areas where good electrical resistivity contrast exists between the water-bearing formation and the surrounding rock types (Nejad, 2009).

The study area is a sub-urban settlement within part of the Basement Complex of southwestern Nigeria. The area is bounded by latitudes 8^0 15', 8^0 25' and longitudes 4^0 30', $4^0$37.5'covering an area of approximately 72 km^2 (Figure 1). Locally, the geology of the area consists of migmatite gneiss, porphyroclastic gneiss, banded gneiss, augen gneiss, granite gneiss, quartz mica schist, and fine-grained granite. The area is of a dissected topography, lies within the humid tropical climate with a total annual rainfall of about 1200 mm, and has a dendritic drainage pattern (Figure. 1).

Most groundwater exploration methods might not delineate and define groundwater potential zones accurately as Dar-Zarouk in line with citation. Hence, this study looks at the evaluation of groundwater potential zones using Dar-Zaoruk parameters of the electrical resistivity method

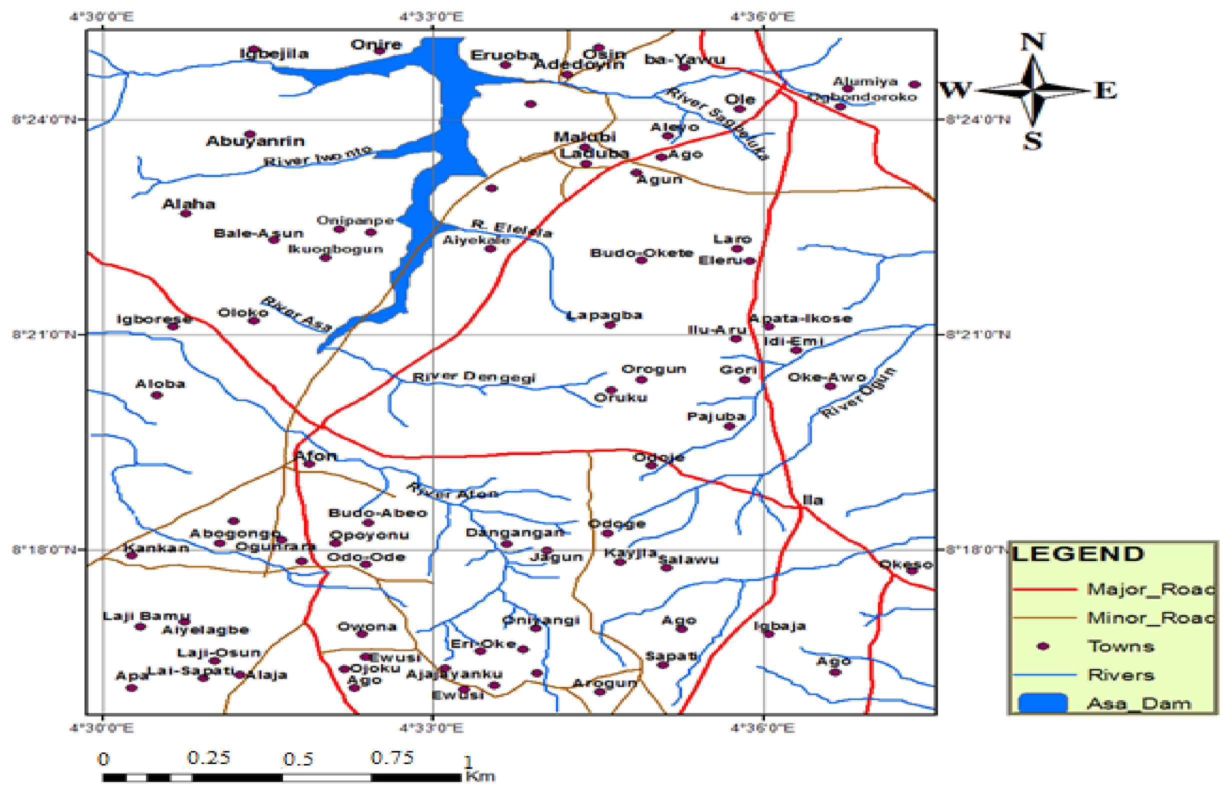

Figure 1: Topographical map of the study area showing its drainage pattern

Materials and Methods

The materials used in the evaluation of groundwater potential of the area are Dar-Zarouk parameters which include longitudinal conductance, transverse resistance, longitudinal resistivity,transverse resistivity, and coefficient of anisotropy. These parameters are used to delineate groundwater zones. Golam *et al.* (2014), Oborie and Udom, (2014) stated tha the longitudinal conductance is computed using a combination of resistivity and thickness of layers of the aquifer. The calculated longitudinal conductance of the overburden at each station was obtained from a mathematical model of Henriet, (1975) as:

$$S = \frac{h_1}{\rho_1} + \frac{h_2}{\rho_2} + \frac{h_3}{\rho_3} + \cdots + \frac{h_{n-1}}{\rho_{n-1}} \quad 1$$

Whereh_1, h_2, etc. are the thicknesses and ρ_1, ρ_2, ρ_n etc. are the resistivity of successive layers.

The transverse unit resistance is the product of a layer's true resistivity and its thickness. It is used in direct relations with transmissivity and the highest T values reflect most likely the highest transmissivity values of the aquifers or aquiferous zones and vice-versa (Kumar et al., 2001). It is calculated using:

$$T = \sum_{i=1}^{n} h_i\rho_i = h_1\rho_1 + h_2\rho_2 + h_3\rho_3 + \cdots h_n\rho_{n,} \quad 2$$

Where T is the total transverse resistance. The longitudinal resistivity was calculated using

$$\rho_L = \frac{H}{S} = \frac{\sum_{i=1}^{n} h_i}{\frac{\sum_{i=1}^{n} h_i}{\rho_i}}, \quad 3$$

The transverse resistivity was obtained using

$$\rho_t = \frac{T}{H} = \frac{\sum_{i=1}^{n} h_i\rho_i}{\sum_{i=1}^{n} h_1} \quad 4$$

Where h = thickness of layers, ρ = resistivity of layer,T= transverse resistance and H= summation of thicknesses of layers, and the coefficient of anisotropy of the area was calculated by using

$$\lambda = \sqrt{\frac{\rho_t}{\rho_L}} = \sqrt{\frac{ST}{H}} \quad 5$$

Where ρ_t= transverse resistivity, ρ_L= longitudinal resistivity, S= longitudinal conductance. T= transverse resistance and H= summation of thicknesses of layers.

Results and Discussion

Longitudinal conductance reveals the protective capacity of aquifers. From the analysis, the result shows that 10 VES stations show very poor protective capacity, 12 VES stations show weak protective capacity, 9 VES stations show moderate protective capacity, 2 VES stations show good protective capacity, and the remaining 178 VES stations were of excellent protective capacity.The highest total transverse unit resistance (T) value was obtained at VES station 47 (32,733.87 Ωm^2) and the lowest was at VES station 206 (8.6 Ωm^2). The analysis of the longitudinal resistivity (S) in the area shows values ranging from 0.1951Ωm (VES 20) to 8095.63 Ωm (VES 120).The transverse resistivity (ρ_t) value ranges between 0.00634 at VES 3 and 63697.66 at VES 67. The coefficient of anisotropy (λ) values in the area range between 0.029 and 5349.78**(λ).** 30 VES stations fall within the range of 1.39-1.66 proposed by Olorunfemi andOlorunnnwo, 1985, to consider boreholes in the stations productive.

The ten VES locations showing very poor protective capacity rating include Amayo, Ogbondoroko, Laduba/Malubi, AfonRoad, Kankan, and Ajibaa in the northern, North-eastern, southern, and southwestern parts, twelve VES stations with weak protective capacity include Egbejila, Sakamo, Gbogbin, AlapakoEtile, Odo-ode and Fepoyonu in the southwestern part of the area, the nine VES stations with moderate protective capacity include Reke, Ogbondoroko, Ago-Oja, Alaha, Onipampo, Oloko and Aloba in the northern and western parts of the area, the two VES stations with good protective capacity are Amayo and OrisunbareEgbejila in the North-eastern part and the VES stations with excellent protective capacity are found in the southern part of the area (Fig. 2). This protective capacity rating reveals a decrease in the vulnerability of aquifers to contaminants respectively.

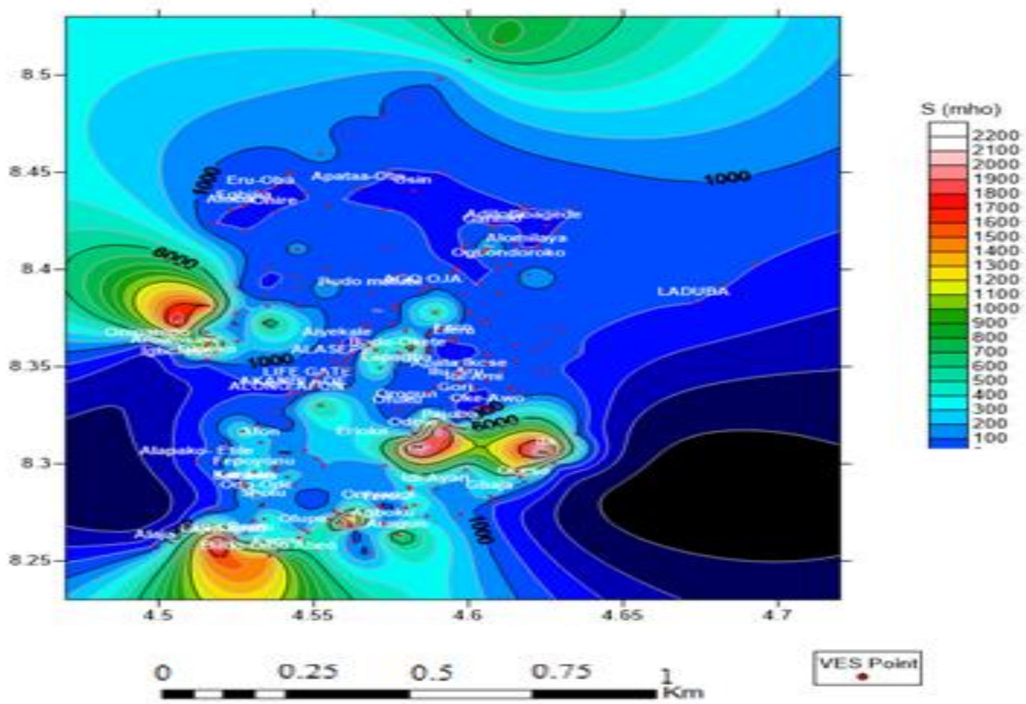

Figure 2: Longitudinal conductance Distribution map

Calculation of Transverse unit resistance shows that areas in the Northern part of the study area such as Apata-Otu and Osin are marked with the higher total transverse resistance while places like Ila, Okeso, and Gbaija are areas of lower total transverse resistance indicating higher and lower transmissivity respectively (Fig. 3).

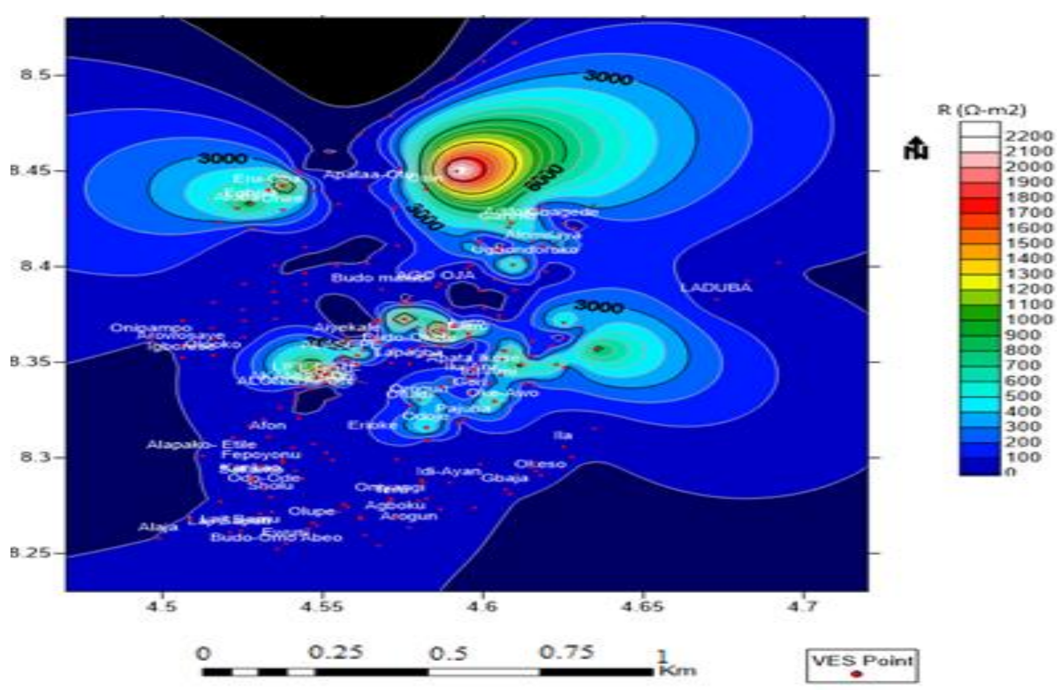

Figure 3: Transverse Resistance map

An isolated very high longitudinal resistivity is shown at the southern part of the area such as the Pajuba, Odoje, and Ila areas (Fig. 4). The highest transverse resistivity value (63697.66) was obtained at VES 67 in the eastern part indicating low groundwater potential while the lowest transverse resistivity was at VES 3 in the southern part indicating high groundwater potential (Fig.5).

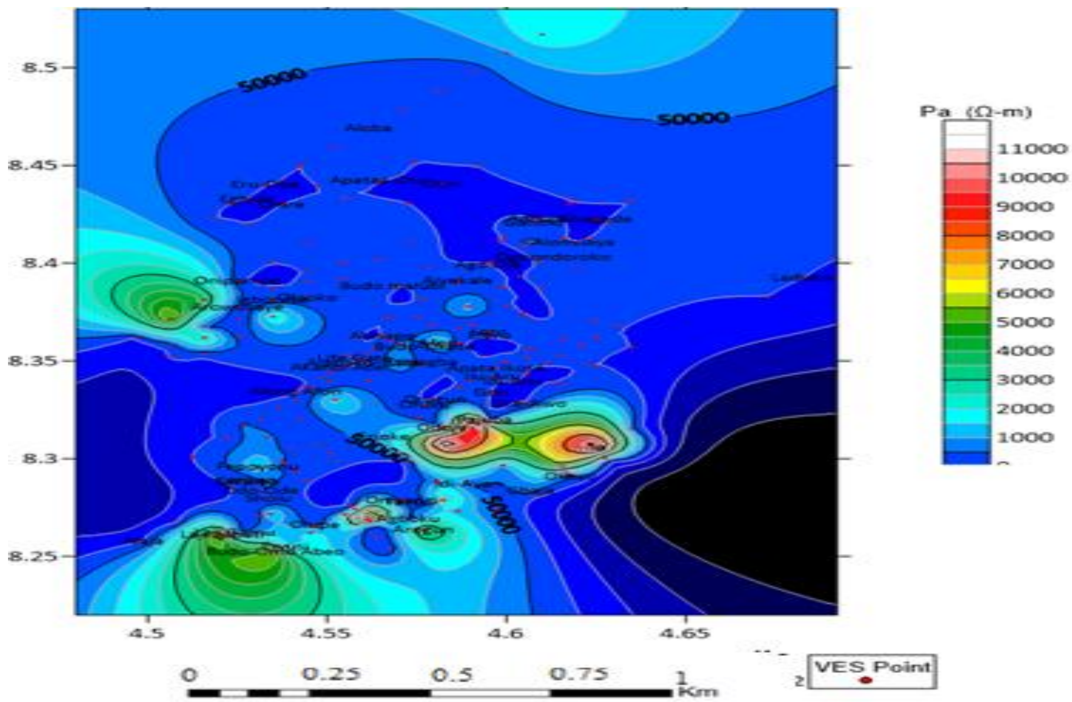

Figure 4: Longitudinal Resistivity Distribution map

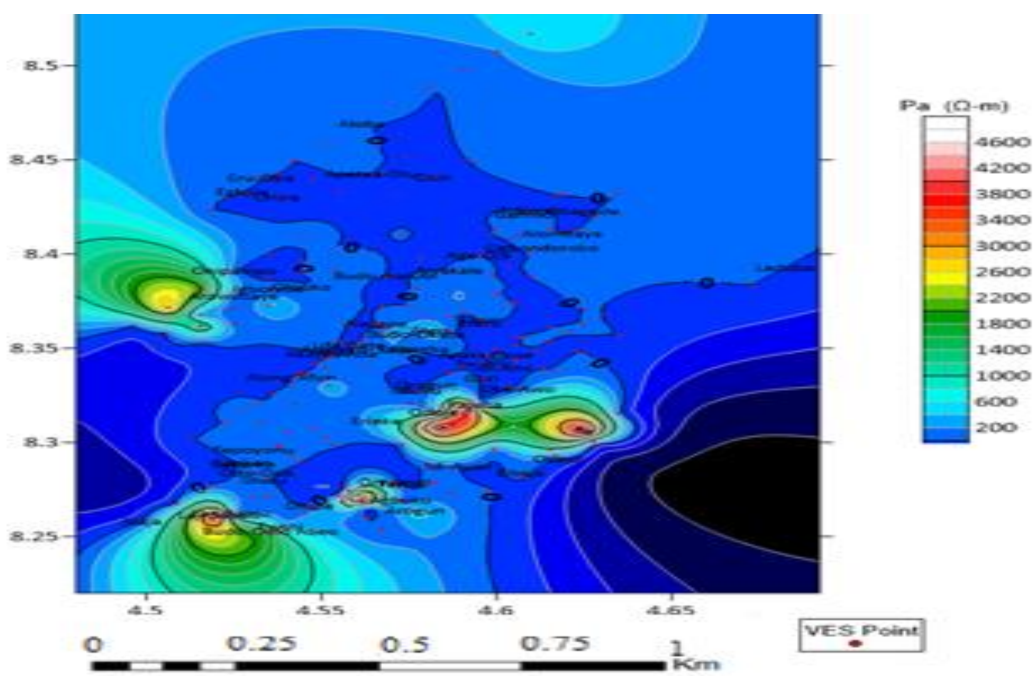

Figure 5: transverse resistivity distribution map

The coefficient of the anisotropy distribution map in the area is shown in Figure 6. According to Olorunfemi and Olorunnnwo, 1985, a range of 1.39-1.66 anisotropy coefficient has been judged necessary for boreholes to be considered productive in some parts of south-western Nigeria's Basement complex. Based onOlorunfemi and Olorunnwo's observation, 30 VES stations in the study area fall within the range to enhance their potentiality.

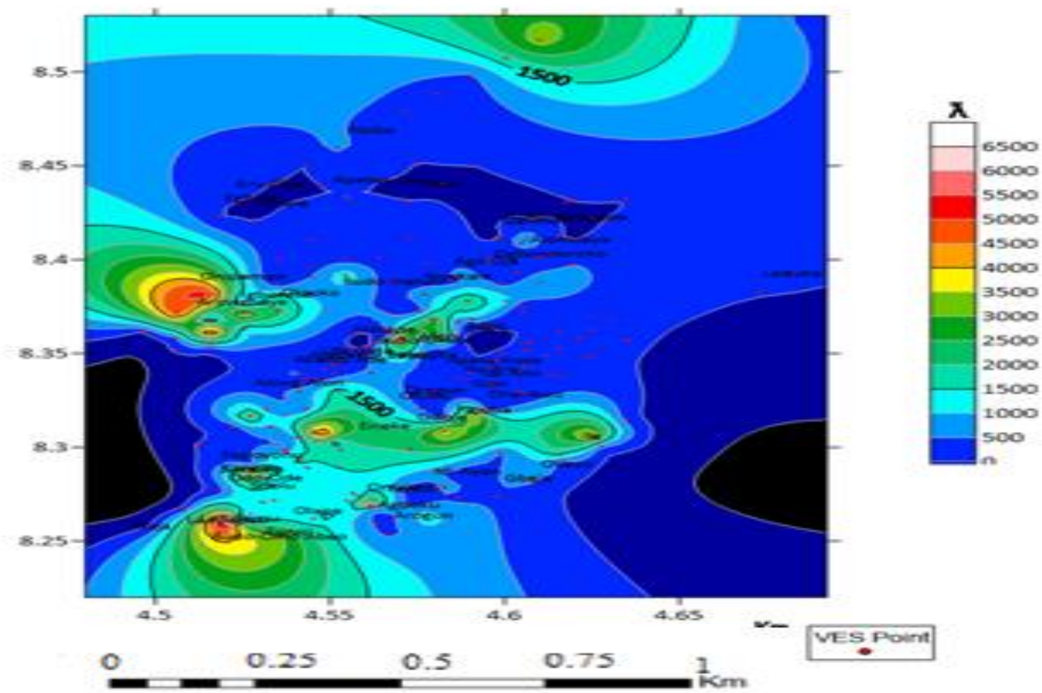

Figure 6: Coefficient of the anisotropy Distribution map

Conclusion

Over 80% of the VES stations in the area are of excellent protective capacity. The highest and lowest transverse unit resistance depicts that the aquifers or aquiferous zones delineated at the VES stations might have the highest and lowest transmissivity values respectively, indicating high and low groundwater potential respectively. An isolated high longitudinal resistivity is shown at Pajuba in the southern part of the study area, indicating low groundwater potential compared to the entire southern part with low resistivity, indicating high groundwater potential. Productivity of some boreholes is suggested in the area based on the calculated values of the coefficient of anisotropy (Olorunfemi and Olorunwo, 1985). Finally, the southern part with relatively low vulnerability coincided with a high potentiality makes the area recommendable for groundwater exploitation.

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