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Geoelectrical assessment of groundwater potential in Oroogun Area, Ogbomoso, Southwestern Nigeria

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Abstract

Thirty Schlumberger vertical electrical soundings (VES) were carried out in Oroogun, Ogbomoso, southwestern Nigeria with a view to evaluating the groundwater potential of the area. The VES data were acquired with a resistivity meter using current electrode spacing varied from 1 to 100 m, and interpreted by partial curve matching and 1-D computer-aided forward modelling technique. Geoelectric sections, isopach maps of the aquifer units and groundwater potential maps were generated using the VES data. Results of the interpretation revealed three to four geoelectric layers defined as topsoil, lateritic layer, weathered layer and fractured/fresh bedrock with resistivity ranging from 63 to 820 Ωm, 164 to 864 Ωm, 20 to 429 Ωm and 100 to 7793 Ωm respectively. Overburden thickness varies from 7.4 to 48.9 m. The overburden is generally thin while only 27% of the study area has overburden thickness greater than 20 m. The overburden and weathered/fractured bedrock constitute the aquifer units.The groundwater potential is medium in about half of the study area. About 20% of the study area, located toward the western part, lies within high groundwater potential zone while 30% has low groundwater potential. The groundwater potential map is expected to serve as guide for groundwater development in the area.

Keywords: vertical electrical sounding, geoelectric sections, isopach map, overburden, fractured bedrock .

Introduction

With the increase in the population of the study area, the demand for water for domestic, industrial and irrigation purposes has increased. The community is not connected to the existing municipal water supply scheme, and hence depends on water vendors who bring water in tankers for sale to the residents. Many previous attempts at groundwater development in the area have failed as the water wells/boreholes either end up dry or have low yield.

Successful exploration for groundwater development in the basement complex terrain requires a thorough understanding of the characteristics of its hydrogeologic units and hence the groundwater potential. This is achievable by conducting hydrogeophysical investigation prior to drilling to furnish information about the subsurface sequence and delineate the aquifer units. Groundwater accumulates in aquifers located in the joint and fractured system within the basement rock and the overburden derived from *in-situ* weathering of the basement (Oladapo *et al*., 2008; Otutu and Oviri, 2010). For maximum groundwater yield, water wells and boreholes are often sited at points beneath which thick overburden overlies fractured bedrock (Olorunfemi and Oni., 2019).

The electrical resistivity method has been extensively employed in the search for groundwater with tremendous success (Anomohanran, 2011; Majumdar and Das, 2011; Sirhan *et al*., 2011; Amadi et al., 2012; Atakpo and Ofomola, 2012; Adeniji et al., 2013; Ademilua *et al*., 2014; Akintorinwa, 2015; Obianwu *et al*., 2015; Ojekunle *et al*., 2015, Oladunjoye and Jekayinfa, 2015; Olusegun *et al*., 2016; Nwachukwu *et al*., 2019). It is the most favoured due to its rapidity, non-invasiveness and cost-effectiveness. The significant resistivity contrast between the fresh and water-saturated weathered/fractured basement provides a strong basis for its application in groundwater exploration. It is used to estimate the depth to the bedrock and thickness of the regolith (Nwankwo, 2011).The aquifer unit in a basement complex terrain is characterized by relatively low resistivity resulting from the presence of groundwater within the overburden and the weathered/fractured bedrock.

This study was therefore carried out to investigate the groundwater potential of the Oroogun area, Ogbomoso, Southwestern Nigeria. The objectives are to delineate the subsurface geoelectric sequence, determine the thickness of the overburden and generate the groundwater potential map of the area.

The study area is situated within latitudes 08° 06′ 50″N - 08° 07′ 03″N and longitudes 04° 16′ 23″ E- 04° 16′ 58″E (Fig. 1). It experiences the tropical rain forest climate with two major seasons namely rainy season and dry season spanning April-October and November-March respectively. The underlying geology is that of the Precambrian Basement Complex (Rahaman, 1989). The dominant rock type is porphyroblastic gneiss. Basement Complex rocks are inherently characterized by low porosity and very low permeability but are often enhanced by development of secondary porosity due to weathering and fracturing of the basement rock.

Methodology

Thirty Schlumberger vertical electrical soundings (VES) were carried out with half current electrode spacing (AB/2) varied from 1 to 100m. The resistivity measurements were made with the ABEM Signal Averaging System (SAS) resistivity meter. The VES data were interpreted by initial partial curve matching and computer-aided 1-D inversion algorithm based on smoothness-constrained optimization technique (Vander-Velpen, 2004). The geoelectric parameters (layers resistivities and thicknesses) were used to generate geoelectric sections connecting VES stations as shown in Fig. 1. The thicknesses of the overburden measured beneath all the VES points were contoured with their geographic coordinates, with the aid of the ARCGIS software, to generate the isopach map of the overburden. The groundwater potential map for the study area was generated by identifying zones underlain by thick overburden and partially weathered/fractured basement.

Results and discussion

The results of the VES data interpretation revealed three to four geoelectric layers defined as topsoil, lateritic layer, weathered layer, fractured/fresh bedrock. The depth sounding curves are mainly H-type (50%). The other curve types are KH (26.7%), QH (10%), and K, A, HK, and HA (3.3% each). Typical sounding curves obtained in the study area is presented in Fig. 2. The resistivity of the topsoil ranges from 63 to 850 Ωm while the thickness varies from 0.6 to 2.2 m. The topsoil is composed of sand-clay mixtures in varying degrees. The low resistivity values, less than 100 Ωm indicate clay and occur only in few places. The weathered layer has resistivity of 20-429 Ωm and is 2.7-42.8 m thick. It is overlain by lateritic material with resistivity ranging from 164 to 864 Ωm and thickness varying from 1.5 to 12.4 m. Resistivity of the bedrock ranges from 100 to 7793 Ωm while depth to the bedrock varies from 6.2 to 48.9 m. Figs. 3-6 shows geoelectric sections connecting the VES stations along profiles established in different directions across the study area.

The isopach map presented in Fig. 7 shows the variation of overburden thickness across the study area. Its values vary from 6.2 m, beneath VES 14, to 48.9 m, beneath VES 24.

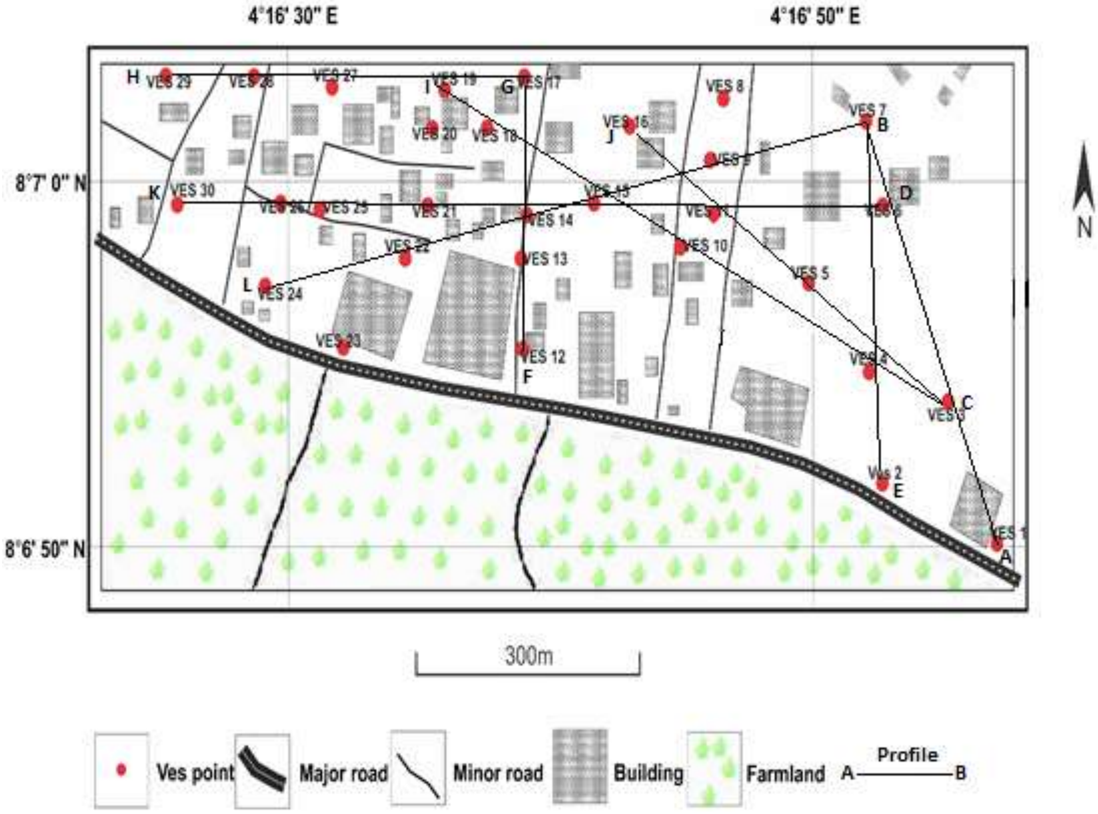
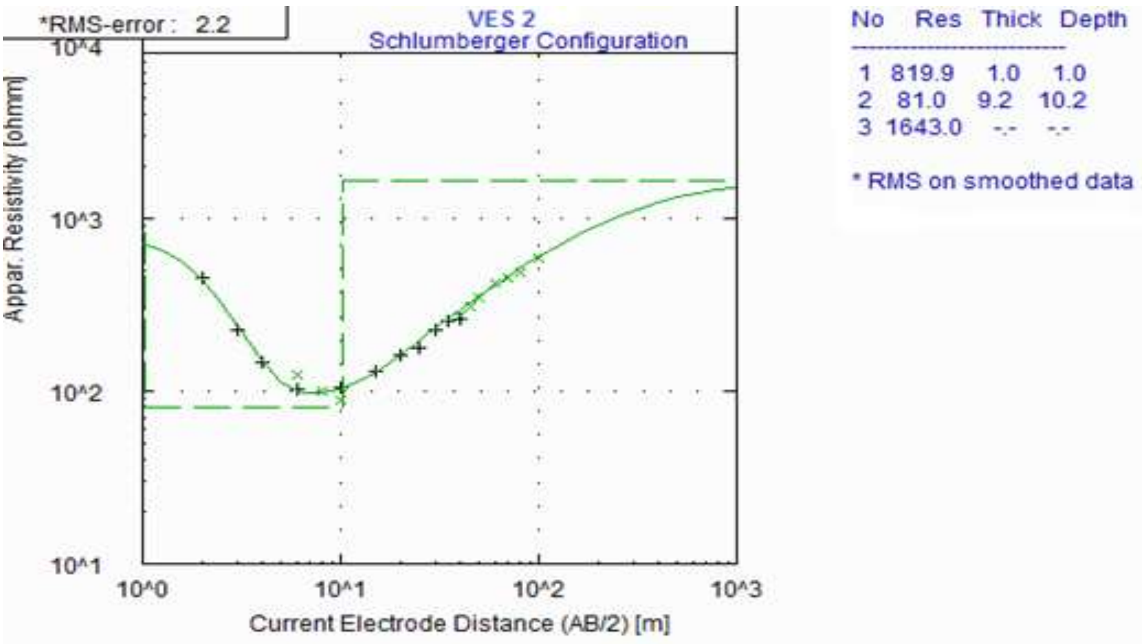
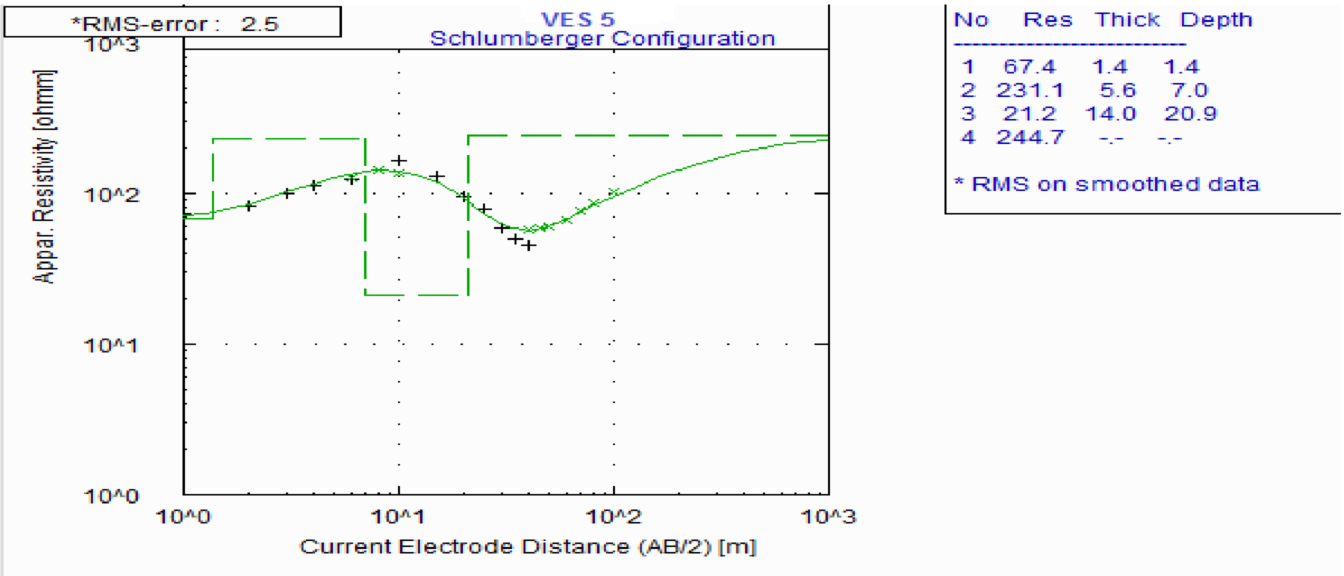


Fig. 1: Base map of the study area showing the VES stations

(a) H type



(b) KH type



(c) QH type

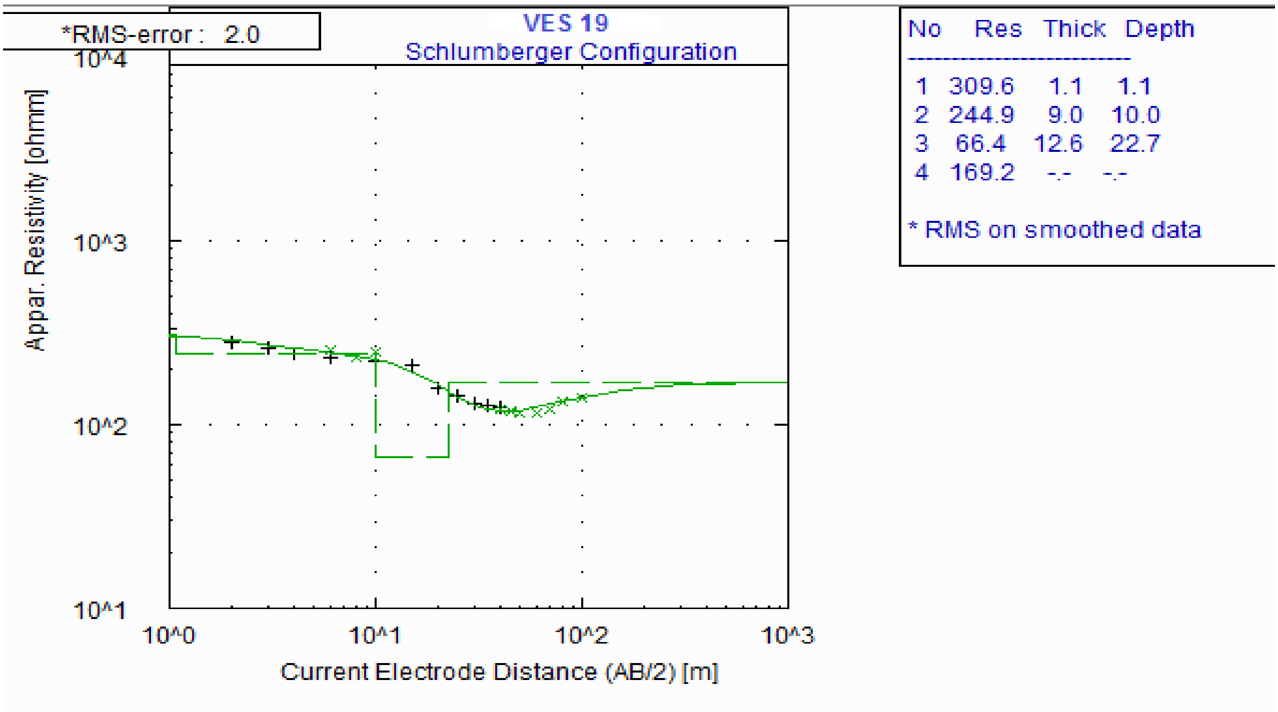


Fig. 2: Typical sounding curve obtained from the study area

These values fall within the range observed for basement complex terrains (e.g. Omosuyi, 2003; Akintorinwa, 2015; Fajana, 2020). Overburden is regarded as thick, fairly thick, relatively thin and thin where the thickness is greater than 30 m, 20-30 m, 10-20 m and less than 10 m respectively. Olayinka *et al*., 1997 ranked aquifer potential, based on this classification of overburden thickness as excellent, good, moderate and poor respectively. Areas with thick overburden are known to be high groundwater potential zones and are usually the targets for groundwater development (Omosuyi *et al*., 2003).

The overburden underlying the study area is generally thin, a condition which may not favour groundwater accumulation and development. Groundwater is encountered only if a well/borehole penetrates water-bearing bedrock fractures beneath thin overburden (Olorunfemi and Oni, 2019). About 27% of the study area has overburden thickness greater than 20 m. Zones around VES 8 and VES 11 within the east-northeast region, VES 18 and VES 19 to the northwest, VES 22, VES 24, VES 25 and VES 27 on the western side of the study area may thus have good-to excellent prospect for groundwater development.

The resistivity of the bedrock beneath most parts (about 60%) of the study area is less than 750 Ωm. This is suggestive of weathering/fracturing expected to favour groundwater accumulation and development resulting from high fracture permeability (Olayinka *et al*., 1997; Akanbi, 2018). Bedrock with resistivity greater than 3000 Ωm indicating fresh bedrock occurs beneath only VES 1, 9, 21, 23 and 30. Resistivities in the ranges of 750-1500 Ωm and 1500-3000 Ωm characterize the bedrock beneath VES 3, 4, 8, 10, 14 and VES 2, 11, 16, suggesting reduced and fairly low effect of weathering respectively. Aquifers in bedrock often complement those in the overburden where both exists (Omosuyi *et al*., 2003; Fajana, 2020).

The study area is zoned into high-, medium- and low groundwater potential zones based on the presence of thick overburden and weathered/fractured bedrock. Areas underlain by overburden with minimum thickness of 20 m and fractured bedrock are considered as high groundwater potential zones while those in the range of 10-20 m and less than 10 m are designated as medium groundwater potential and low groundwater potential zones respectively (Olayinka *et al.*, 1997; Omosuyi *et al.*, 2003; Akanbi, 2018). The summary of the groundwater potential rating for the study area is presented in Table 1 while the groundwater potential map is shown in Fig. 8. About 50% of the area lies within the medium groundwater potential zone while 30% has low prospect for groundwater development. Areas around VES 12, 18, 19 22, 24 and 25, covering about 20% of the study area, are underlain by thick overburden and partially weathered/fractured bedrock, and are classified as high groundwater potential zones since their subsurface conditions may favour groundwater accumulation and development. Efforts at groundwater extraction in the study area may thus be focused within this zone. The groundwater potential map is expected to serve as helpful guide for future groundwater development in the area.

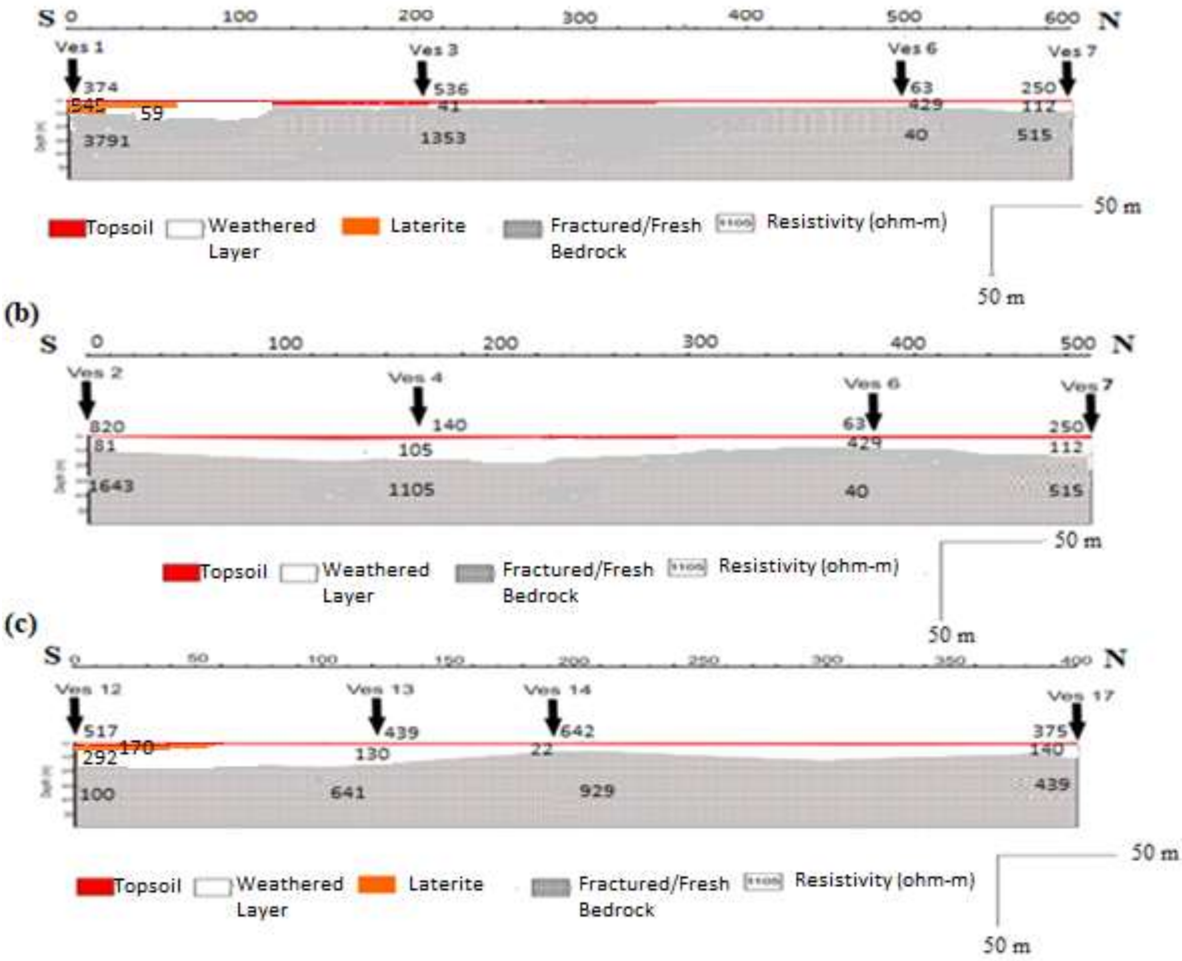


Fig. 3(a-c): Geoelectric sections along N-S profiles across the study area

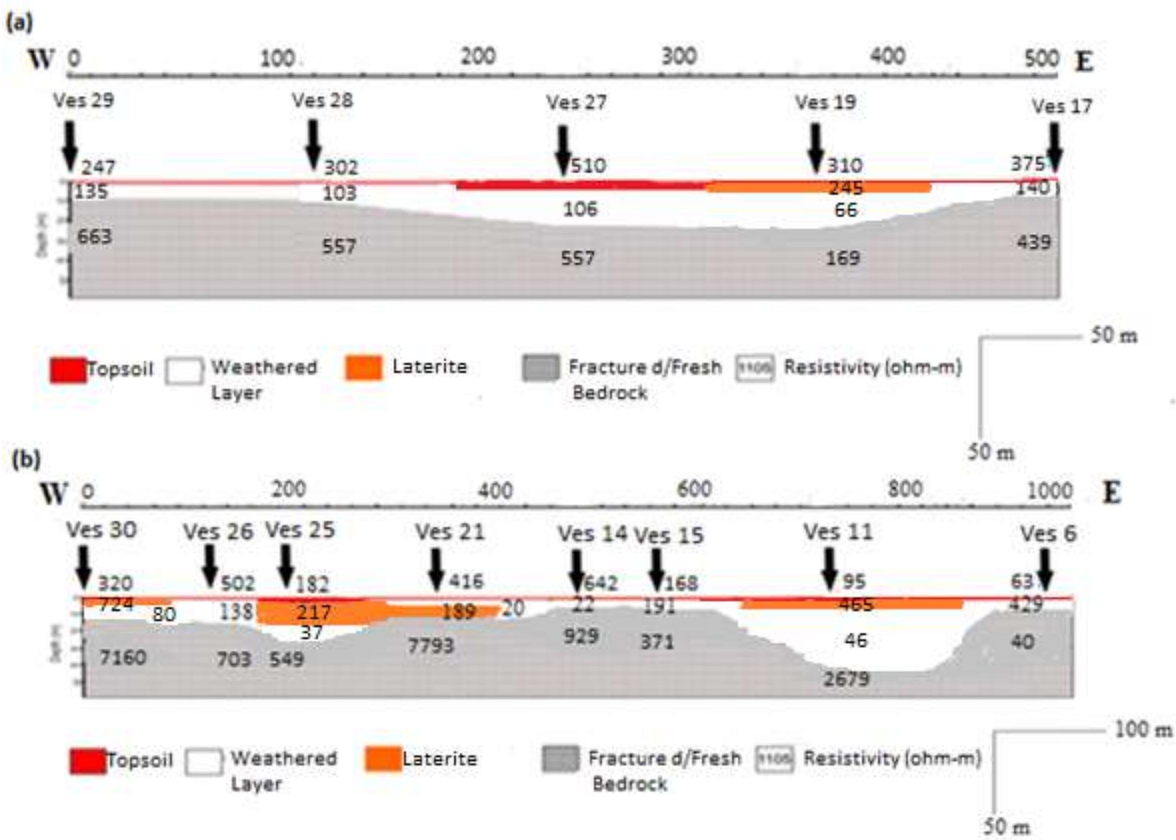


Fig. 4(a-b): Geoelectric sections along E-W profiles across the study area

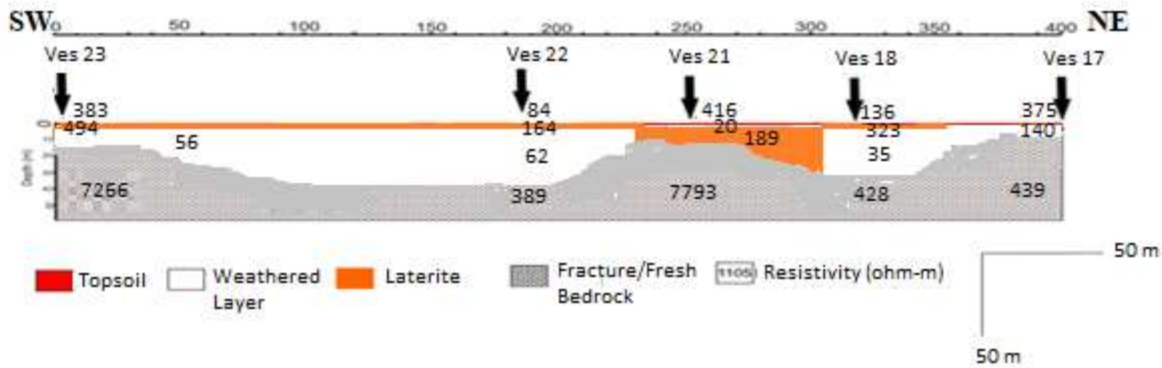


Fig. 5: Geoelectric section along SW-NE profile across the study area

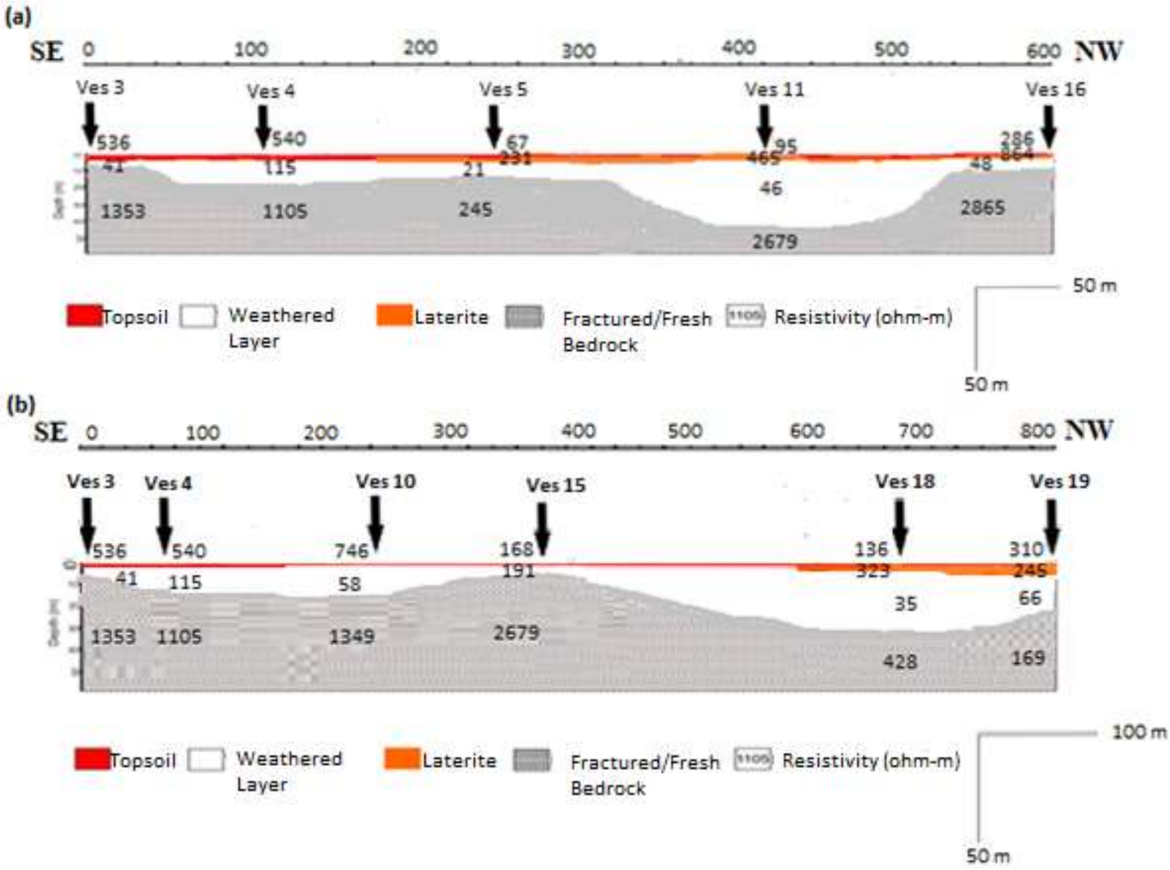


Fig. 6(a-b): Geoelectric sections along SE-NW profiles across the study area

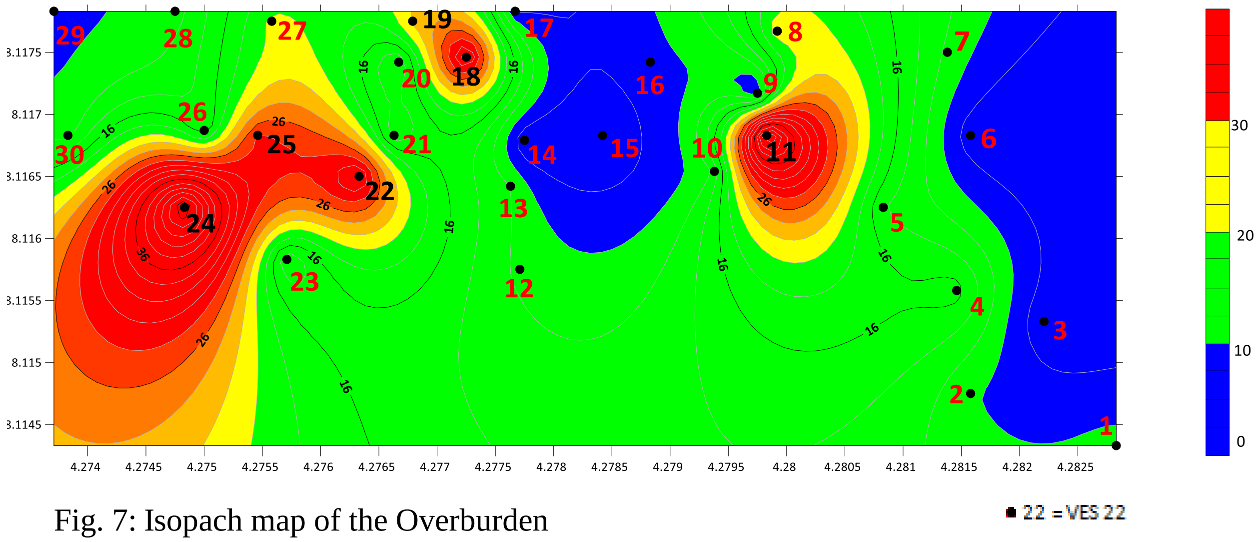


Fig. 7: Isopach map of the Overburden

Table 1 Groundwater Potential rating based on values of overburden thickness and bedrock resistivity in the study area

VES	Overburden thickness (m)	Bedrock resistivity (Ωm)	Groundwater Potential
1	10.8	3791	Low
2	10.2	1643	Medium
3	6.4	1353	Low
4	16.9	1105	Medium
5	14.0	245	Medium
6	6.8	40	Low
7	11.6	515	Medium
8	21.4	1514	Medium
9	7.4	7360	Low
10	12.1	1349	Medium
11	45.9	2679	Medium
12	11.5	100	High
13	12.1	641	Medium
14	6.2	929	Low
15	6.9	371	Medium
16	9.5	2865	Low
17	7.8	439	Medium
18	33.6	428	High
19	22.7	169	High
20	11.7	483	Medium
21	12.4	7793	Low
22	33.1	389	High
23	11.9	7266	Low
24	48.9	341	High
25	28.3	549	High
26	14.0	703	Medium
27	20.5	557	Medium
28	11.2	557	Medium
29	9.8	663	Medium
30	11.2	7160	Low

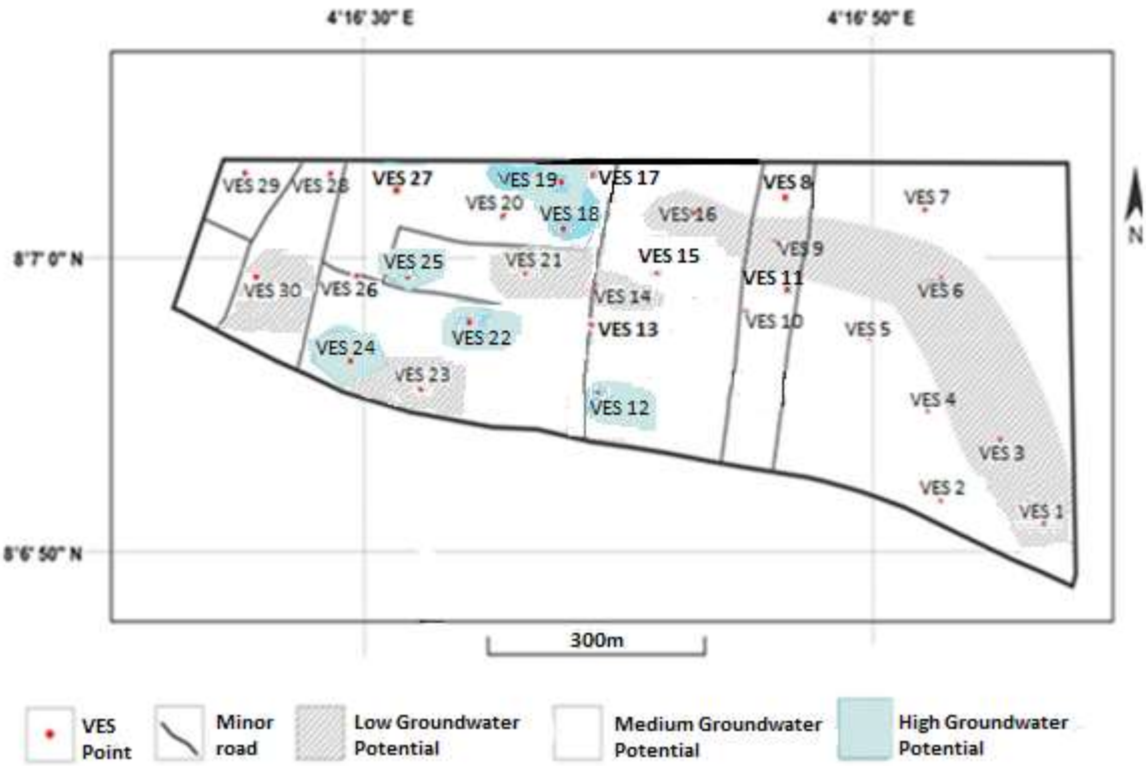


Fig. 8: Groundwater potential map of the study area

Conclusions

The study reveals that the area is underlain by three to four geoelectrc layers comprising topsoil, lateritic layer, weathered layer and fractured/fresh bedrock. The overburden thickness ranges from 6.2 to 48.9 m. The isopach map of the overburden shows that the overburden in the area is generally thin. The identified thick overburden and partially weathered/fractured basement constitute the aquifer units in the study area.

Areas with thick overburden underlain by weathered/fractured bedrock are ranked as high groundwater potential zones. The groundwater potential of the study area is generally medium (about 50%). About 20% of the study area (westward) has high groundwater potential while 30% lies within low groundwater potential zone.

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