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GEOELECTRICAL INVESTIGATION OF GROUNDWATER POTENTIAL OF ADMINISTRATIVE BLOCK AT PERMANENT SITE, FEDERAL UNIVERSITY DUTSIN-MA, KATSINA STATE, NIGERIA.

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Abstract
A geophysical survey for groundwater resources was carried out in the administrative block of Federal University Dutsin-Ma, permanent site. This was successfully done by employing the electrical resistivity method to investigate the water table variations, the depth to basement, thickness of weathered basement, thickness of aquifer and area suitable for boreholes establishment within the areas covered with the application of Schlumberger arrangement. ABEM TERRAMETER SAS 300 was the principal instrument used in this survey. A total of two transverses with five VES stations along each traverse, having separation of 20 m apart, were investigated. It has a maximum current electrode separation (AB/2) of 160 m. Three to four layers were observed namely; Top layer, weathered layer, fractured layer, and fresh basement layer. First layer has resistivity, depth and thickness range of 101-1573 Ωm, 13.2-36.6 m and 6.06-17.3m respectively. Second layer has a range of: resistivity, 2.36-3040 Ωm; depth, 0.406-20.m and thickness, 0.0409-20 m. Third layer has a range of: resistivity, 190-3194 Ωm; the depth, 0.19-111 m and thickness, 0.19-107 m. Fourth layer has a resistivity range of 26.3-896 Ωm; its depth, 0.366-2.23 m and thickness, 0.366-1.22 m. While the fifth layer has resistivity, depth and thickness range of: 95.7-1711 Ωm, 0.44-50.6 m and 0.44-49 m. The VES curves were interpreted using IPI2Win resistivity computer software and contour Maps were produced using SURFER 10 computer software. The results of the interpreted VES data showed that the saturated groundwater bearing layer (aquifer) lie within the weathered and fractured basement of the predominantly four-layered structure. VES 01, 02 and 03 have high potential for groundwater. However, the sitting of borehole can be done on VES 03 because it has the ability to retain and sustain portable water.

Keywords: *Groundwater, Borehole and Resistivity, vertical electrical sounding VES, depths to basement.*

Introduction

Groundwater has gained increased popularity over the past decade in many parts of the world today because of its ability to retain and sustain portable water. Water is said to be essentials for life and therefore its importance cannot be overemphasized. Groundwater and other mineral resources such as hydrocarbons and solid minerals are of great abundance in Nigeria. The true riches of any country depend on its ability to provide for its dwellers. Potable water is one of the major resources that a citizen of any nation can benefit (Alile *et al*., 2008). This is so because water is a free course of nature and access to clean potable drinking water is critical for the health around the world. The scarcity of water is more intense in the developing countries where statistics show that 67% of the rural populations have no access to safe water supply (Rosen and Vincent, 1999; Somiah, 2013). This is so because people in the rural areas tend to depend mostly on surface water from lakes, streams, ponds and rivers for sustenance which may easily be contaminated. Surface water bodies are associated with high evaporation rates usually in high temperate environments and often susceptible to pollution and waterborne diseases (Yusuf, 2007). In order to supply water from these sources particularly for domestic purposes, one requires treatment especially in small settlement communities. Groundwater which is found to exist below the surface in the soil pores, fractures within rocks, fissures, faults and other weak geological features or zones is comparatively protected from pollution and evaporation and can be useful for both domestic and industrial purposes (Ayoade, 2003). It also comes along with another added advantage over surface waters regarding the ease with which the resource can be tapped from close point of need. These benefits have made groundwater more reliable for domestic, agricultural and industrial purposes. Since groundwater cannot be easily located, a variety of scientific techniques are needed to provide information concerning its occurrence and location. The use of geophysical method in groundwater exploration involves the delineation of potential aquifers and geological situations favorable for its occurrence (Akpaneno, 2014).

Many of these geophysical techniques have been applied to groundwater with some showing more success than others. The methods include gravity, magnetic, seismic, electrical and electromagnetic methods (Reynolds, 1997 and Somiah, 2013). Potential field methods like gravity and magnetic have been successfully used to map regional aquifers and large scale basin features. Seismic methods on the other hand have been used to delineate bedrock aquifers and fractured rock systems (Kearey *et al.,* 2002). One of the methods that have proved effective to groundwater studies are the electrical and electromagnetic. This is because many of the geological formation properties that are critical to hydrogeology such as porosity and permeability of rocks can be correlated with electrical conductivity

signatures. Many of these geophysical techniques have subsequently been used for groundwater characterization but once again, the greatest success has been shown with the the length and breadth of Nigeria in the field of groundwater exploration. These methods are regularly used to solve a wide variety of groundwater problems. At

electrical method (Eke and Igboekwe, 2011). A lot of geophysical work has been done across present, the students' population of FUDMA stands at about 2,000 students out of which about 52% are male and this population increases virtually every year (FUDMA student's matriculation Handbook, 2013/2014). Since the permanent site is developing, there will be a great need for adequate water supply. The study was carried out with a view of determining the groundwater potential and the geologic characteristics of aquifers of the area by examining the depth to basement, investigate the depth to and thickness of aquifer, investigate the depth and thickness of weathered basement and to delineate areas suitable for borehole development.

Location and Extent of Survey

The study was carried out in Federal University Dutsin-Ma, Dutsin-Ma Local Government area of Katsina State, Nigeria (Figure 2). The survey area is located within the Federal University permanent site, Dutsin-Ma between latitude 12.2953°N and 12.2957°N and longitude 007.4603°E and 007.4615°E. It is bounded by Kurfi and Charanchi LGAs to the north, Kankia LGA to the east, Safana and Dan-Musa LGAs to the west, and Matazu LGA to the southeast. Dutsin-Ma LGA has a land size of about 552.323 km^2

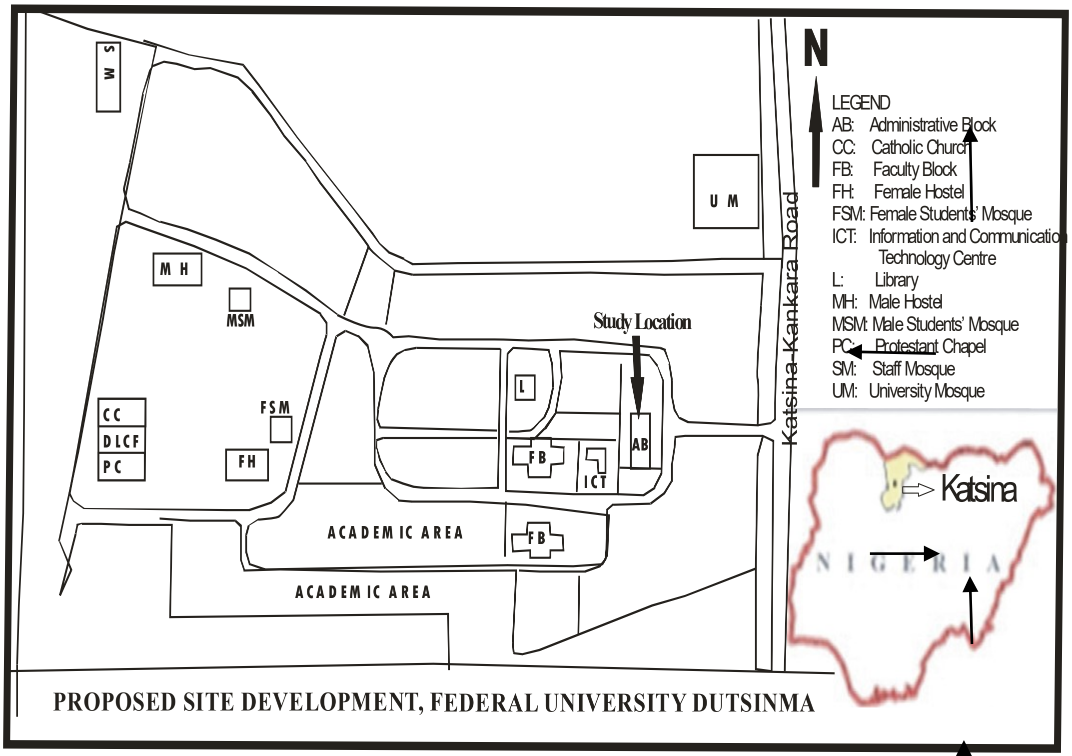


Figure 1. Map of the parts of Federal University Dutsin-Ma (Adapted from Works department and Planning, FUDMA; modified).

Climate, Vegetation and Topography

The state can be classified into two zones climatically; tropical continental and semi-arid continental. The south of the state (from Funtua to Dutsin-Ma) belongs to the tropical continental with total annual rainfall figures ranging from 1000 mm around Funtua to over 800 m around Dutsin-Ma. The north of Katsina State (from around Kankia to the extreme northeast) has total rainfall figures ranging from 600 mm - 700 mm annually. Generally, climate varies considerably according to months and seasons. There are cool dry (harmattan) season from December to February, a hot dry season from March to May, a warm wet season from June to September; a less marked season after rains during the months of October to November characterized by decreasing rainfall and a gradual lowering of temperature (www.links.onlinenigeria.com/linksread).

The southern half of the state belongs to the Northern Guinea Savannah Zone, while the north belongs to the Sudan Savannah Zone. The vegetation in the south thus consists of broadleaved species with tall tussocky grasses of guinea affinities, mixed up with fine leafy species of thorny trees with continuous short and feathery grass cover. The northern districts consist of trees that grow long tap roots and thick barks that make it possible for them to withstand the long dry season and bush fires. The grass cover here has durable roots which remain underground after stalks are burnt away or wilted in the dry season only to germinate with the first rains. The existing vegetation in Katsina State is a function of many years of human interference and degradation (Abaje *et al.,* 2014). The entire area of Federal University Dutsin-Ma, consist of low lying terrains and few gentle hill (Akpaneno *et al.,* 2017). Southern and central parts of the site are typified by relatively flat and monotonous landscape underlain by biotite-hornblend granite. The Northern part of the site is remarkable for profuse outcrops, which is perhaps responsible for the rugged landscape (Akpaneno *et al.,* 2017).

Geology of the Study Area

The geology of Dutsin-Ma and its environs is underline by two formations; they are the Illo-Gundumi formation of the Sokoto basin which covers 20% of the total geology of Katsina and the chad basin. The remaining 80% is underline by basement complex area (older-granite and migmatite-gneiss). Dutsin-Ma is surrounded by rocks (older- granite) that are more than 600 million years old (pre-protozoic). Federal University Dutsin-Ma is underline by Meta-Sediment which is subjected to transformation from one form to another; from shale, slate, pyrite, Gneiss, and migmatite. Figure 2 is the map showing the geology of Katsina state, the area marked green is the Illo-Gundumi formation which covers 20% of the geology of the state and the area marked pink is the basement complex area. It covers 80% of the geology of the state (Geo Invest (Nig) Ltd. Katsina, 2014).

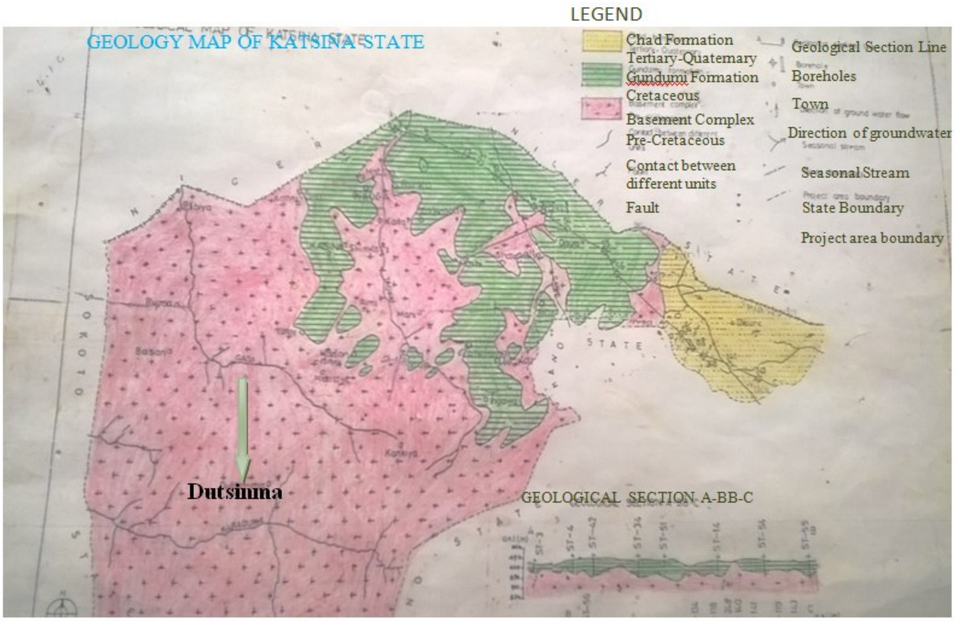


Figure 2 Geological Map of Katsina State showing the study area
(Adapted from GEO-INVEST and BOREWELL (NIG) Ltd Katsina State).

Theory

The basic theory of electrical resistivity methods was analyzed by Telford *et al*., (2009) and expanded by other researchers. In a homogeneous isotropic medium, the potential due to a single point current source such as the current electrode, satisfy Laplace's equation arising from the equipotential surface that is hemispherical, so that:

$E = -\nabla V$ and $J = \delta E$ …………………………………………………………….. (1)

But $J = \delta E$ from Ohm's law

$J = \delta \nabla V$……………………………………………………………………………. (2)

where ∇ represents del operator.

$\nabla = \hat{\imath}\,\frac{\delta}{\delta x} + j\,\frac{\delta}{\delta y} + \hat{k}\,\frac{\delta}{\delta z}$ ……………………………………………………………... (3)

V = electric potential, E = electric field intensity,

σ = conductivity, J = current density.

$\nabla . J = -\sigma \nabla \nabla V = 0$………………………………………………………………. (4)

$\nabla . J = -\sigma \nabla^2 V = 0$……………………………………………………………….. (5)

$\nabla^2 V = 0$……………………………………………………………………………… (6)

Where ∇^2 (del squared) is the usual Laplacian operator (6) can be expanded in spherical polar co-ordinate as:

$\frac{d^2V}{dr^2} + \frac{2}{r}\frac{dV}{dr} + \frac{1}{r^2 \sin\theta}\frac{d}{d\theta}\left(\sin\theta \frac{dV}{d\theta}\right) + \frac{1}{r^2 \sin^2\theta}\frac{d^2V}{d\phi^2} = 0$………………………………… (7)

Equation (7) shows that the potential distribution satisfies Laplace's equation. The solution to the equation may be developed from first principle for a particular earth's model by selecting a co-ordinate system to match the earth's model geometry and apply appropriate boundary conditions. This solution produce apparent resistivity (l_a) as a function array, namely $\frac{AB}{2}$, $\frac{MN}{2}$, electric current, I and potential difference, ΔV. The calculated apparent resistivity (l_a) according to Schlumberger array condition of $AB \geq 5MN$ is

$$l_a = \pi\left[\frac{\left(\frac{AB}{2}\right)^2-\left(\frac{MN}{2}\right)^2}{MN}\right]\frac{\Delta V}{I} \quad (8)$$

AB is current electrode spacing in meter

MB is potential electrode spacing in meter

ΔV is potential difference in volts.

I is electric current in Amperes

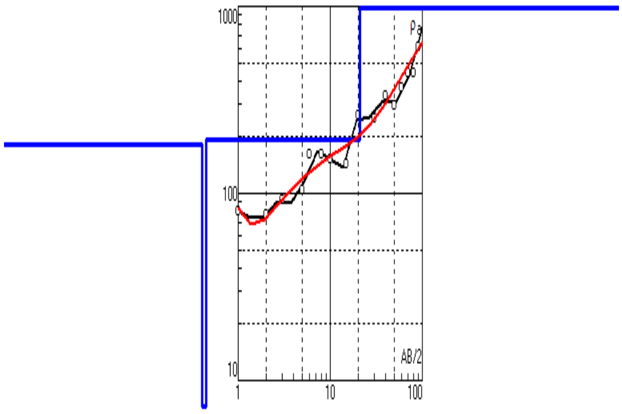
Materials and Methods

The vertical electrical resistivity sounding (VES) method involve injecting an artificially generated direct current on low frequency alternating current into the ground through two current electrodes, the resulting potential difference, is measured by another pair of potential electrodes in the vicinity of the current flow. Although resistivity generally increases as porosity decreases, the electrical properties are controlled more by water quality, than by the rock matrix (Telford *et al.,* 2009). Vertical Electrical Sounding (VES) Schlumberger array and Wenner array configuration respectively were used in this research work. The basic field equipment used for the study is ABEM TERRAMETER SAS 300 which displays apparent resistivity value digitally as computed from Ohm's law. On profile where Schlumberger configuration was used, the four electrodes are positioned symmetrically along a straight line, the current electrodes on the outside and the potential electrodes on the inside. To change the depth range of the measurements, the current electrodes are displaced outwards while the potential electrodes in general are left at the same position. When the ratio of the distance between the current electrodes to that between the potential electrodes becomes too large, the potential electrodes must also be displaced outwards otherwise the potential difference becomes too small to be measured with sufficient accuracy. Measurements of current and potential electrode positions are marked such that AB/2 ≥ MN/2. Where AB/2 = Current electrode spacing and MN/2 = Potential electrode spacing.

Results and Discussion

The interpretation of the VES field data was carried out using the Resistivity interpretation software IPI2Win which produces the resistivity model (resistivity, thickness and depth) fitting the aquifer field data with the least RMS-error between the observed and synthetic resistivity curve (Figure 3). The interpreted VES curves show that the survey area is dominated by mainly four layers, namely: Topsoil (comprising of sandy clay or clayey sand, silts/clays), Weathered basement, fractured basement and Fresh basement. The results of the interpreted VES data showed that the weathered and fractured basement of the predominantly four layered geoelectric structure constitutes the aquiferous zone in all the VES points within the study area. The thickness of the aquifer varied from 1.22-49.00 m with an average of 25.11 m. Summary of the variations in resistivity of the topsoil, aquiferous and depth to basement are also presented in Table 1 below.

Appar Resistivity (Ωm)



N	ρ	h	d	Alt
1	181	0.406	0.406	-0.40
2	2.36	0.0409	0.447	-0.446
3	192	20.4	20.9	-20.8
4	3040			

Figure 3: Typical digitized curve of VES point 02

Table 1: Shows the variation in resistivity of topsoil, aquifer thickness and depth to basement within the area.

S/N	VES POINTS	Resistivity of Topsoil (Ωm)	Aquifer Thickness (m)	Depth to Basement (m)
1	01	101	17.3	36.6
2	02	2.36	20.4	20.9
3	03	190	107	111
4	04	52.7	1.22	2.23
5	05	95.7	49	50.6

Contour maps of the resistivity of the top soil, aquifer thickness and depth to basement were also produced using SURFER 10 computer software at each VES point at an interval of 10 ***Ω***m, 1m and 1m respectively. On correlation, it was observed that in the region of high resistivity of the top soil, aquifer thickness and depth to basement are relatively low and vice versa. Similarly studies in basement complex terrain reveals that areas with thick overburden cover have high potential for groundwater. Consequently, areas with aquifer thickness of 15 m and above are good for groundwater development (Coker, 2012). On these bases it was observed that VES 01, VES 02, VES 03 and VES 05 have high potential for groundwater.

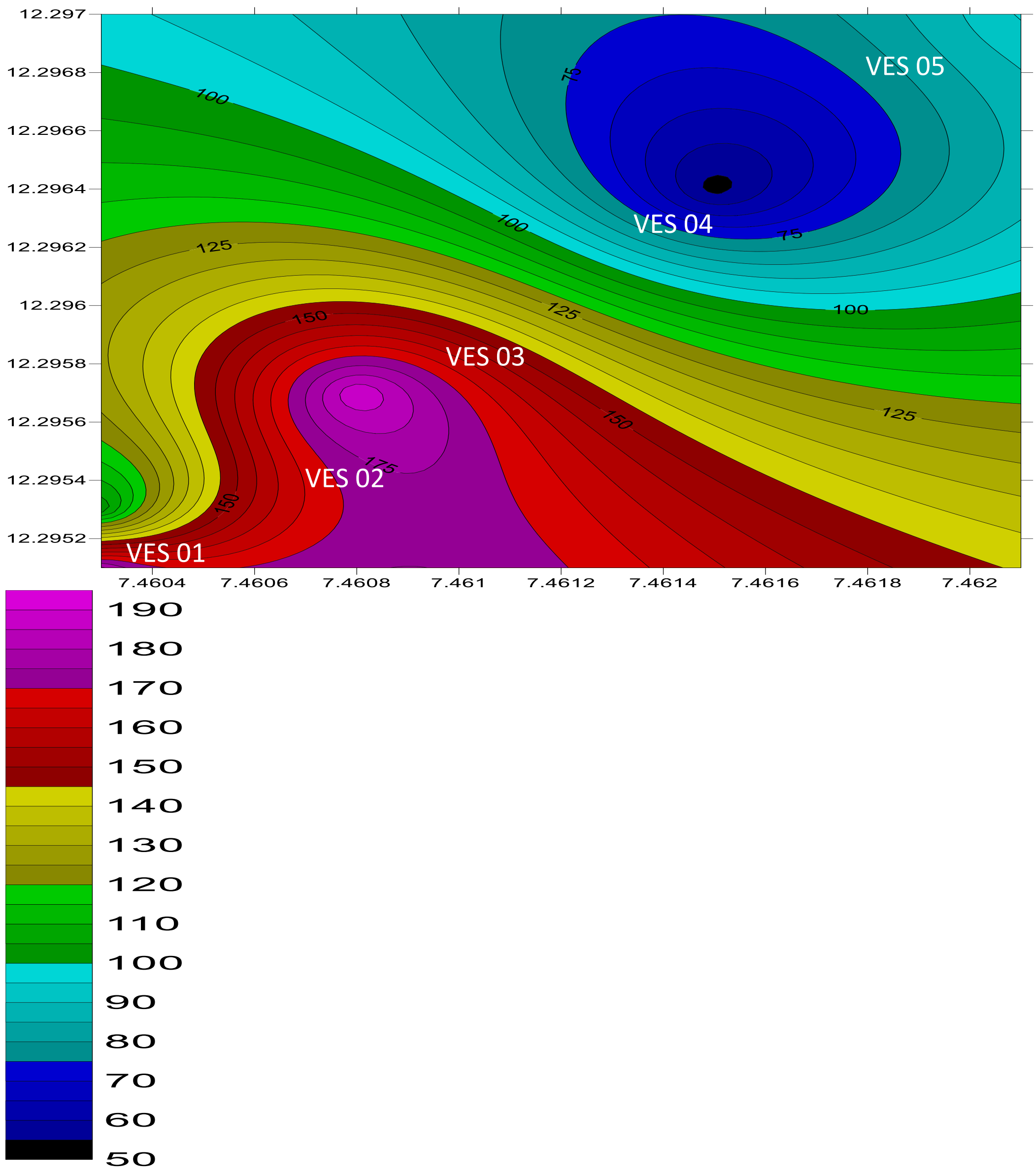


Figure 4: Contour map of resistivity of topsoil

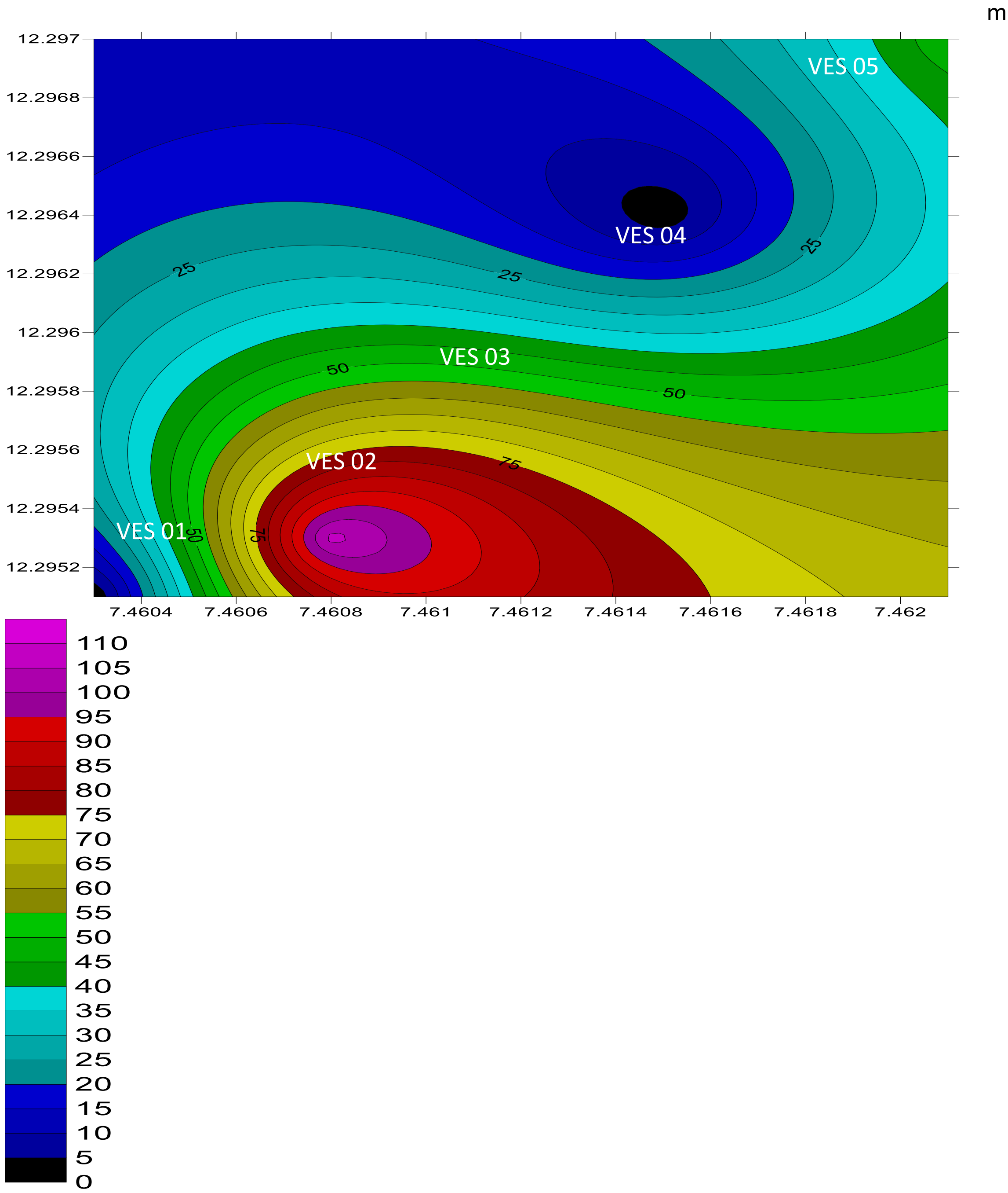


Figure 5: Contour map of thickness of aquifer

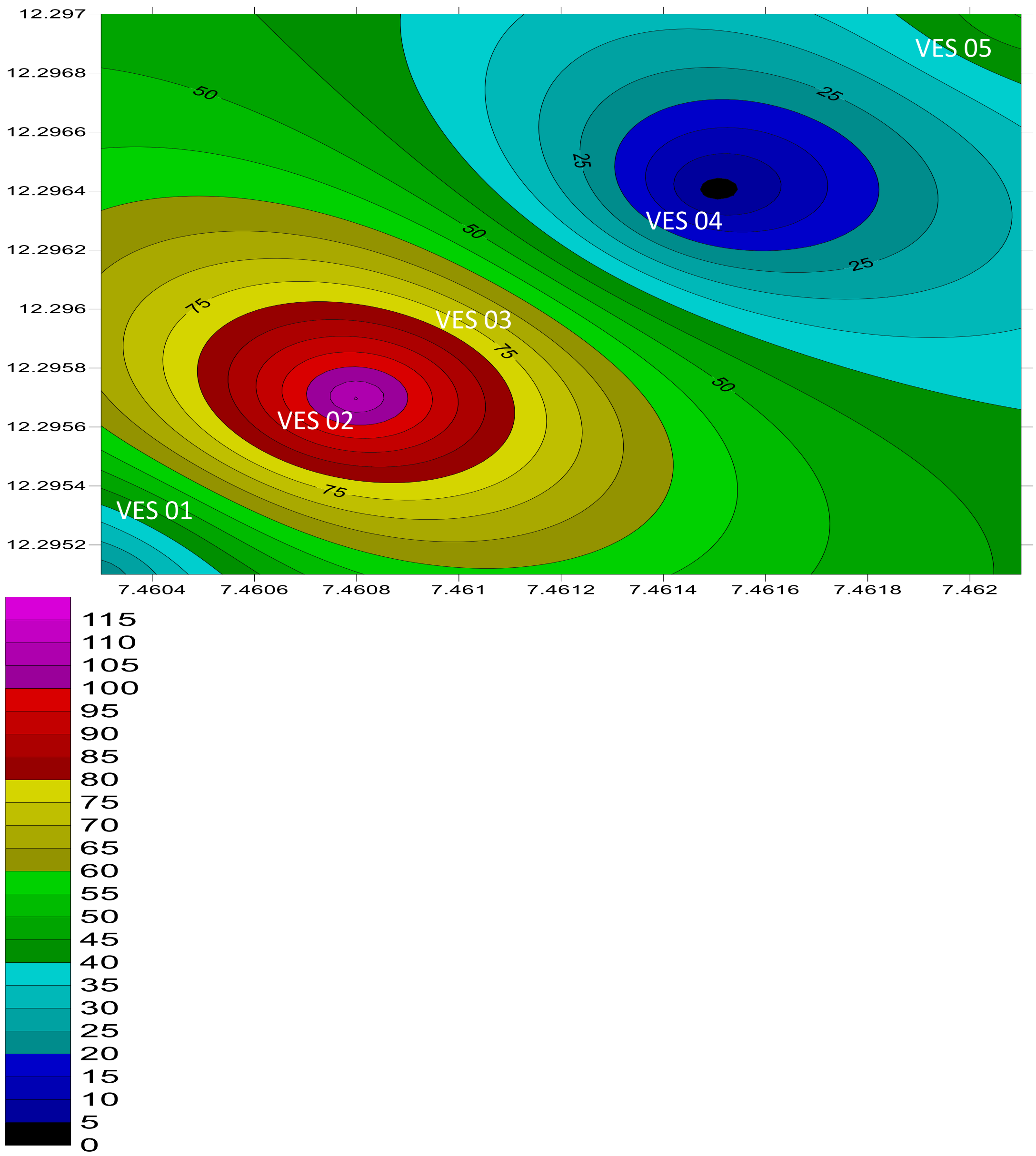


Figure 6: Contour map of depth to basement

Conclusion

In conclusion, the main objective of this study has provided information of the depth of the ground water (Aquifer) and also the thickness of the layers. This information is needful for effective improvement of water scheme, for the area and its environs. VES 01, 02 and 03 have high potential for groundwater development. However, the sitting of borehole can be done on VES 03 because it has the ability to retain and sustain portable water. It is recommended that, other methods be applied.

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