IOSR Journal of Applied Geology and Geophysics (IOSR-JAGG)
e-ISSN: 2321–0990, p-ISSN: 2321–0982.Volume 4, Issue 1 Ver. I (Jan. - Feb. 2016), PP 43-48
www.iosrjournals.org

Evaluation Of Groundwater Potential Using Geoelectric Method In Mutito Fault Zone, Kitui County, Kenya

Mwangi L. W[1*], Munyithya J. M.[1], Githiri J. G.[1] and K'orowe M. O.[1]
[1] *Jomo Kenyatta University of Agriculture and Technology, Nairobi, Kenya*
** leahjoe25@gmail.com*

Abstract: *Vertical electrical resistivity soundings was conducted in order to delineate groundwater potential zones in the Mutito fault zone. A total of ten vertical electrical soundings were conducted using schlumberger configuration with current electrode spacing (AB/2) ranging from 1 to 160m. The field data were smoothened and interpreted using electrical imaging computer software IPI2WIN. From this interpretation three different curve types were obtained from the acquired data; HA-type, QH-type and KH-type indicating presence of a four layered subsurface. The aquifer layer was identified as the third layer having depths varying between 44.4 to 130m, while thickness ranges from 43.2 to 124m. The layer parameters thus obtained from the analysis were used to estimate the Dar-Zarrouk parameters. For aquifer characterization, the transmissivity of the aquiferous zones was obtained which revealed areas of high groundwater potential with values ranging between 140.2 to 2287 m^2/day.*
Keywords: *groundwater potential, hard rock terrain, vertical electrical sounding (VES), transmissivity.*

I. Introduction

The area of study, Mathima location, is largely underlain by hard complex basement rocks and is faced by acute shortage of potable water and thus need to establish groundwater resources. Groundwater being an important source of uncontaminated water, there is need for suitable and efficient methods for characterization of the potential aquifers in semi-arid areas. Siting zones of groundwater potential in hard rock terrains is a challenge since crystalline basement rocks are generally impermeable and have no appreciable water storage capacity, however, groundwater wells have been successfully developed in basement areas in different parts of the world [1]. The availability of groundwater in these aforementioned rocks is largely due to the development of secondary porosity and permeability resulting from weathering and fracturing.

The most commonly used methods in identifying areas of groundwater potential, involve conducting pumping test on existing or newly drilled wells followed by analysis and interpretation of the pumping test data. This can be a very expensive and time-consuming method. Thus an alternative approach for estimating aquifer characteristics is the use of surface geo-electrical methods [2]. The surface geo-electrical method especially the Vertical Electrical Sounding (VES) method has been successfully and extensively used for groundwater exploration especially in the complex basement terrains as it is capable of defining the significant contrast in the geo-electric parameters of the topsoil and in-situ weathered material, fractured zone and the fresh basement rock.

This study is focused on aquifer characterization using geo-electric and geo-electrically derived hydraulic parameters to delineate groundwater potential zones.

1.1 Area of study

The area of study is Mathima in South Kitui County and lies between latitudes 1^0 30' and 2^0 00' S and Longitudes 38^0 00'E and 38^0 30'E (Fig. 1). The climate is largely semi-arid characterized by erratic and unreliable rainfall [3]. This area falls under the concealed Mutito fault zone, which is about 130km long and 2km wide with a series of fractures covered by recent sandy alluvium deposits and is underlain by hard Precambrian rocks [4] As the study area is underlain by the hard crystalline rock, groundwater is likely to occur in the weathered zone and fractured rocks, provided the zones are connected with recharging sources. Fractures play an important and crucial role in fluid flow, especially for the movement and accumulation of groundwater in hard rock areas.

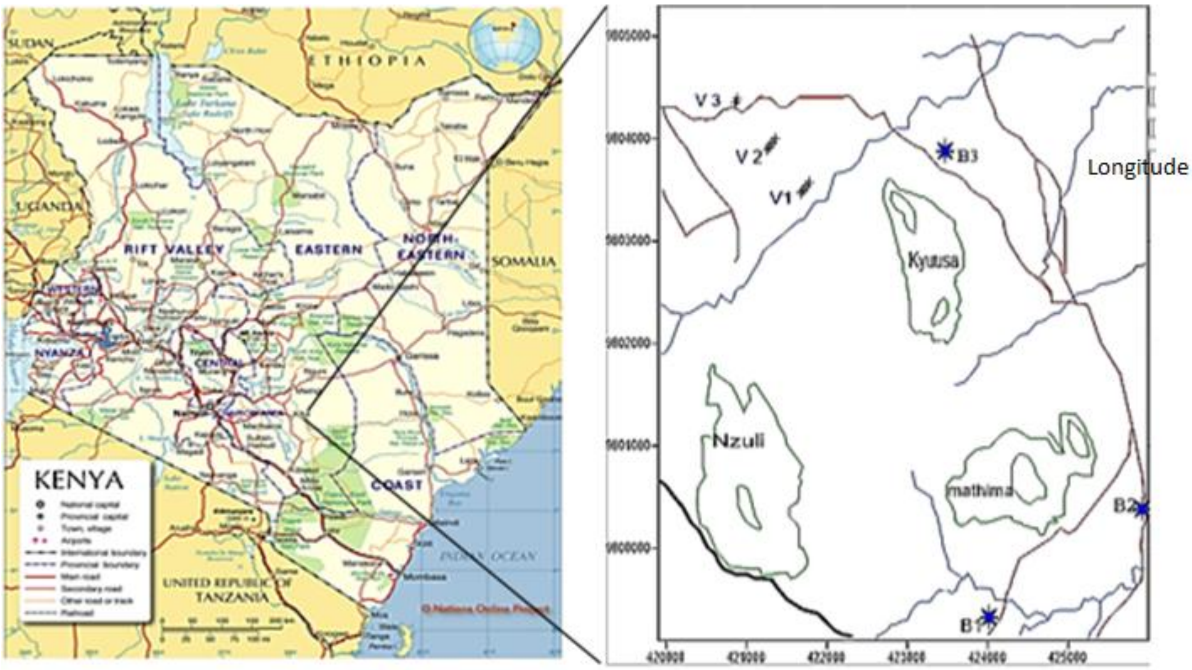

Figure 1. A map of the area of study showing the drainage, VES stations and boreholes within area of study. (Note B1, B2 and B3 are boreholes in the area of study, V1, V2 and V3 represent the VES stations)

1.2 Geology of area of study

The area of study is part of the extensive Mozambique belt segment, in the Central sub-area II of the Eastern Mozambique Belt Segment (EMBS) which occurs east of the Rift System. The geology of the area is composed of mainly mica (biotite, muscovite), hornblende schists and gneisses that occasionally show the presence of staurolite, almandine garnet, kyanite and sillimanite. Present also are amphibolites migmatites, granitoid gneisses and granites, intrusive and meta-intrusive mafic and ultramafic rocks that include diorites, gabbros, anorthosites, peridotites and picrites [5]

There are major antiformal and synformal which are oriented approximately north-south but with curved axial traces because of refolding. Examples of these formations are the Kitui anticline and the Nziwani Syncline. The extension of the covered Mutito fault, indicated by the dashed line (figure 2) is inferred to pass longitudinally intersecting the Nzwani fault and syncline [5]. This syncline which exists where the stipulated Mutito fault is inferred to be, provides a perfect set up for groundwater potential.

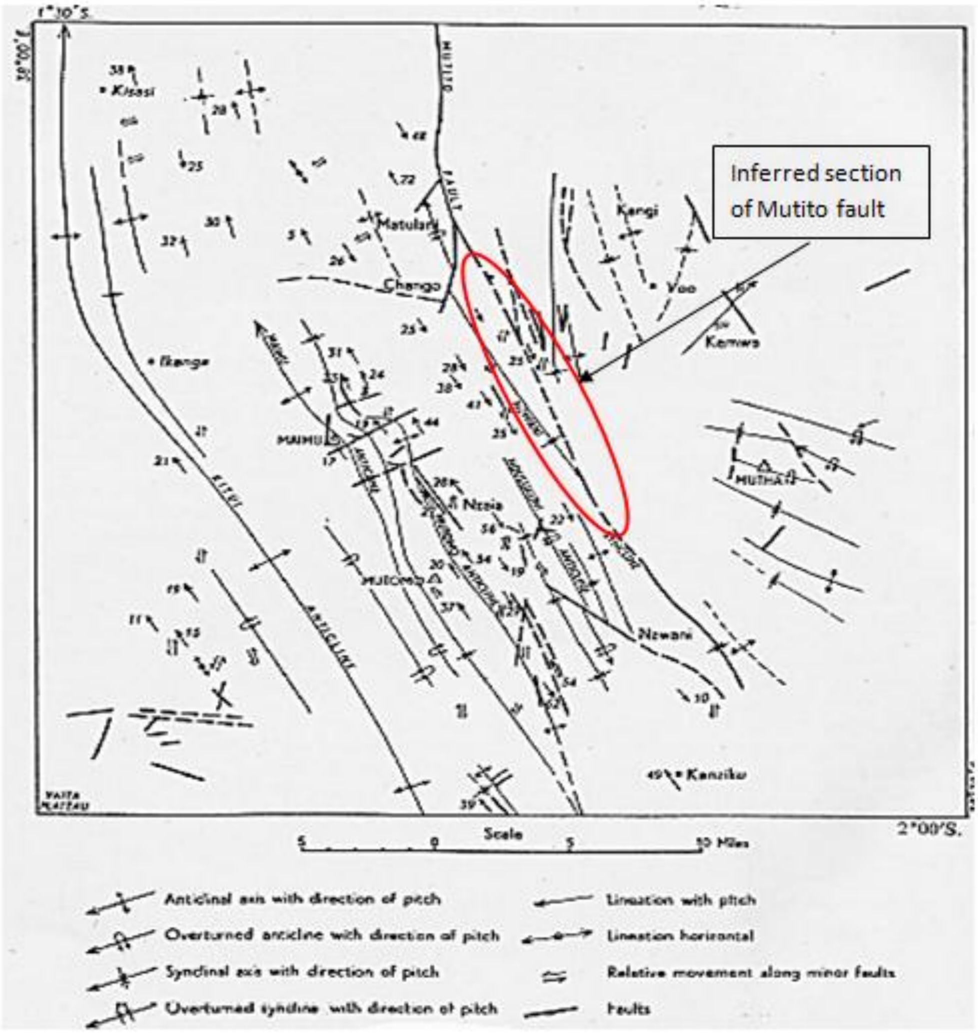

Figure 2: Structural Map of South Kitui Area (Saggerson, 1957).

II. Data Acquisition And Interpretation

2.1 Data Acquisition

2.1.1 Geo-electrical resistivity data

Schlumberger vertical electrical soundings (VES) survey was carried out at 10 locations (Fig. 1) using ABEM SAS 1000 terrameter. This method was carried out by applying direct current to the ground through two electrodes (A and B) and then measuring the resultant potential difference (ΔV) between the potential electrodes (M and N). The center point of the electrode array remains fixed but the spacing of the electrodes was increased so as to obtain information about the stratification of the ground. This was done with the maximum electrode spacing of 320 m. The current electrode (AB/2) spacing varied from 1 to 160 m and the potential electrode (MN/2) spacing varied from 0.5 to 15m.

Apparent resistivity values were determined from the measurement of potential difference (ΔV) and injected current (I) as:

$$\rho = K \frac{\Delta V}{I} \tag{1}$$

K is the geometric coefficient, a parameter which is dependent on the potential and current electrode spacing.

The VES curves were obtained by plotting the apparent resistivity against the current electrode spacing (AB/2) and interpreted by curve matching techniques. The IPI2WIN computer Software was used to reduce the geo-electrical sounding curves into values number of layers (N), thickness (h) and resistivity ρ of individual layers. The degree of uncertainty of the computed model parameters and the goodness of fit in the curve fitting algorithm are expressed in terms of curve fitting error (<10%).

2.1.2 Groundwater resistivities.

Groundwater resistivities in the area were determined from measurements of specific conductance of groundwater at wells and boreholes distributed in the area (Fig. 1). A conductivity-meter was dipped into the water sample instrument and a reading of specific conductance in units of µMho/cm recorded. The resistivity value of the saturating water was obtained by taking the reciprocal of groundwater specific conductance. For the estimation of groundwater resistivities at specific VES stations, kriging was performed using Surfer 10 computer software.

2.2 Results and Discussion.

The data interpretation revealed three curve types HA, QH and KH types. They are considered to have four geo-electric layers (Table 1), with the first one as the thin surface soil, the second as weathered zone, the third as the fractured zone and the fourth as the massive fresh basement. Each layer's geo-electric characteristic is shown in Table 2.

Table 1. Established resistivity and thickness ranges of the different layers.

Subsurface Layer	Resistivity ohm-m	Thickness (m)
Surface soil	81.12 to 14243	0.237 to 3.92
Weathered rock	26 to 329	0.733 to 10.3
Fractured rock	22.5 to 152	4.23 to 139
Fresh basement rock	5097 to 26971	Infinite

Table 2. Geo-electric characteristics of the area.

VES no.	ρ_1	ρ_2	ρ_3	ρ_4	h_1(m)	h_2(m)	h_3(m)	Depth to basement (m)	Curve type
1	453	66.4	152	8036	1.71	4.06	124	130	HA
2	81.12	26	139.4	302.4	0.96	1.27	63.05	65.28	HA
3	298	56.9	34.5	310	0.463	9.94	4.23	14.6	QH
4	178	30.2	142	26971	0.634	4.31	66.6	71.5	HA
5	144	329	125	241	3.92	1.47	85.4	90.8	KH
6	275	26.2	94.2	340	0.606	0.733	43.1	44.4	HA
7	1213	120	22.5	233	1.27	2.58	4.66	8.51	QH
8	14243	112	48.8	9513	0.237	1.78	45.2	47.2	QH
9	800	40.6	90.5	5097	1.81	5.48	83.2	90.5	HA
10	716	98	68.4	15191	0.524	10.3	59.8	70.6	QH

2.2.1 HA-type curve

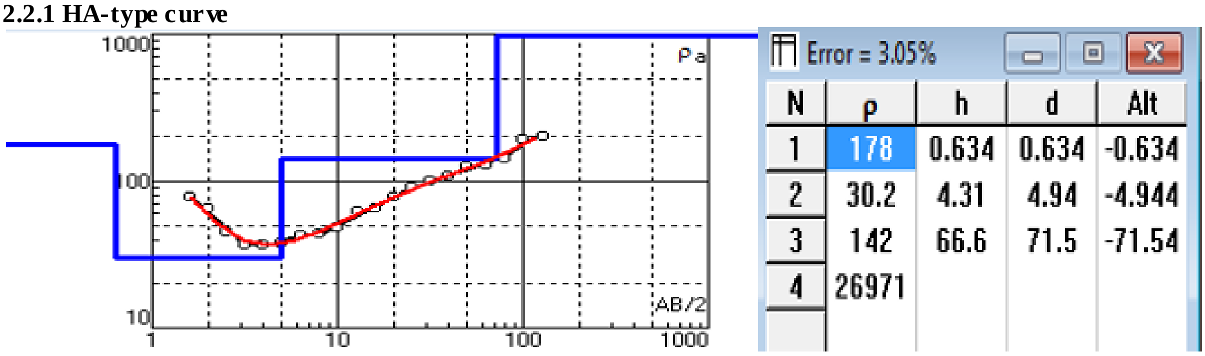

Figure 3. Typical interpretation results of HA curve type.

The HA-type curves are the most predominant curve accounting for 50% of the total curves. These includes VES stations 1, 2, 4, 6 and 9 and the geo-electric sequence is such that $\rho 1 > \rho 2 < \rho 3 < \rho 4$ (Fig. 3). The top layer consists of dry sandy soils with thickness (0.606 to 1.81m) and high resistivity values of up to 800 ohm-m. The second layer has very low resistivity value of up to 26 ohm-m which extends to a depth of (1.34 to 7.29m). At this depth this could be an indication of unsaturated weathered rock. The third layer beneath is characterized by very low resistivity values (90.5 to 152 ohm-m) at maximum depths of (44.4 to 130 m) which is an indication of either a fractured zone or weathered formation saturated with water. The fourth layer mapped is the basement rock characterized by very high resistivity values of up to 26971ohm-m and occur at maximum depths greater than 45m.

2.2.2 QH-Type curve

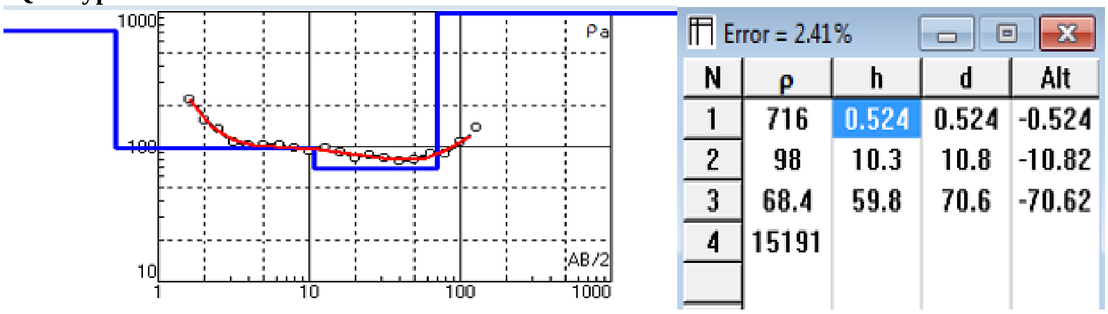

Figure 4: Typical interpretation results of QH curve type.

This type accounts 40 % of the total curves which includes VES stations 3, 7, 8 and 10 and the geo-electric sequence is such that ρ1 < ρ2 < ρ3 < ρ4 (Fig. 4). Top dry sandy soil (first layer) is characterized by very high resistivity values of up to 14243 ohm-m and thickness (0.27 to1.27 m). The second layer resistivity reduces up to 112ohm-m and thickness increases (1.21 to 10.3m) with a maximum depth of 10.8m. The low resistivity values in this layer could not be as a result water saturation at these small depths. Resistivity of the third layer further reduces (22.5 to 48.8 ohm-m) with an increased thickness of (45.2-60m) with a maximum depth of up to 70.6m. This layer indicates the weathered or fractured formation saturated with water. The basement rock resistivity values rapidly increases up to 15191ohm-m at a maximum depths beyond 70.6m. For VES 3 and 7 the third layer was considered to be weathered with some water content at shallow depths of 14.6 and 8.5m respectively which could be an indication of shallow aquifer.

2.2.3 Dar Zarrouk parameters and transmissivity

The total transverse resistance (Tr) and total longitudinal conductance (S) can be used to define target areas for groundwater potential.The total transverse resistance have a direct relation with transmissivity and highest T values reflect most likely the highest transmissivity values of the aquifers or aquiferous zones and vice versa. T for each VES stations was computed (Table 3) from the relation:

$$Tr = hi * \rho i \qquad (2)$$

Where hi and ρi is the i^{th} layer thickness and resistivity respectively and i=1, 2, 3……..

High total longitudinal conductance (S) usually indicate relatively thick succession and should be accorded the highest priority in terms of groundwater potential and vice-versa. S for VES station was computed (Table 3) from the relation:

$$S = \frac{hi}{\rho i} \qquad (3)$$

An estimate of transmissivity (T) for all VES stations was made using a theoretically derived relation (Table 3), derived from a hard-rock environment in Jangaon sub-watershed, India covered with granites of the Archean group of rocks [6]:

$$T = -2.5F_a + 9.9 \qquad (4)$$

The formation factor (Fa) was computed (Table 3) using the bulk aquifer resistivity (ρ) obtained from the VES curves and groundwater resistivities (ρ_w) at VES stations obtained from the krigged estimates of groundwater resistivity of boreholes in the area of study.

$$Fa = \frac{\rho}{\rho_w} \qquad (5)$$

Table 3. Summary of parameters at VES stations.

Vesstation	ρ (ohm-m)	Depth(m)	ρ_w	Fa= ρ/ρ_w	T (m²/day)	Tr(ohm-m)	S(mho)
1	152	130	20.92932	7.262539	140.2149097	19117.58	0.876934
2	139.4	65.3	20.8806	6.676053	173.0676398	8822.19	0.501142
3	34.5	14.6	20.84664	1.654943	5656.630355	145.935	0.122609
4	142	71.5	20.7974	6.827777	163.6127415	9587.362	0.469014
5	125	90.8	20.63708	6.057058	220.7297938	10675	0.6832
6	94.2	44.4	20.59504	4.573917	445.4456409	4079.225	0.485514
7	22.5	8.51	20.56751	1.093958	15922.57739	103.05	0.203556
8	48.8	47.2	20.52784	2.377259	2287.304324	2205.76	0.92623
9	90.5	90.5	20.41779	4.432409	481.8543174	7756.248	1.053805
10	68.4	70.6	20.3891	3.354734	966.8748336	4090.32	0.874269

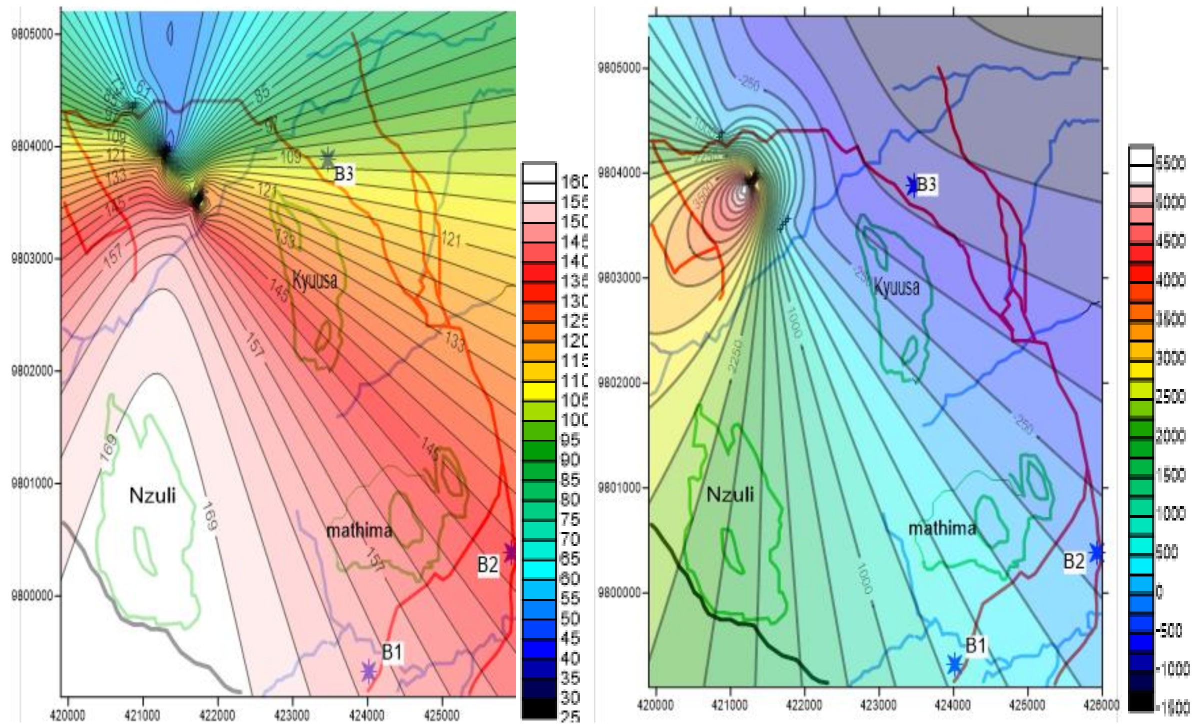

Figure 5: (a) Iso-resistivity map across area of study **(b)** A map of transmissivity across area of study

III. Conclusion

In this paper, we have presented the results from geo-electric sounding for the evaluation of groundwater potential in the hard complex basement terrain in the Mutito fault zone, Kitui County. The results show that the subsurface has four geo-electric layers, namely the top surface soil (81.12 to 14243ohm-m) with thickness (0.237 to 3.92), weathered rock (26 to 120 ohm-m) with thickness (0.733 to 10.3), fractured rock (22.5 to 139.4ohm-m) with thickness (4.23 to 139) and the fresh basement rock (233 to 26971 ohm-m). The aquifer layer or aquiferous zone is considered to be the layer overlying the fresh basement rock. The depth and thickness values of aquifer reveal that best aquifer thickness varies from 43.1 to 124m and the bedrock depth lies between 45 and 130 m. This study has also helped to provide data for aquifer characterization on Transmissivity (T) and Dar Zarrouk parameters: longitudinal conductance (S) and the transverse resistance (Tr) of the aquiriferous zones. The estimated aquifer parameters revealed that the transmissivity (T) values ranges 140m^2/day to 2287.3m^2/day. Tr values ranging 2206 to 19118ohm-m^2 and S values ranging from 0.45 to 1.05 mho (table 2) were obtained at VES stations 1, 2, 4, 5, 6, 8, 9 and10 which were considered to be the best sites for groundwater potential. The results revealed presence of potential aquifers within the area of study

References

[1]. Anudu G., Onuba L. and Ufondu L. Geo-electric sounding for groundwater exploration in the crystalline basement terrain around Onipe and Adjoining areas, southwestern Nigeria, *Journal of applied technology in environmental sanitation, 1 (4),* (2011), 343-354.

[2]. Okiongbo K. and Odubo E. Geoelectric Sounding for the Determination of Aquifer Transmissivity in Parts of Bayelsa State, South South Nigeria, *Journal of Water Resource and Protection,4,* (2012), 346-353.

[3]. Kuria D., Gachari M., Macharia M. and Mungai M. Mapping groundwater potential in Kitui District, Kenya using geospatial technologies, *Water Resources and Environmental Engineering, 4(1)*, (2012), 15-16

[4]. Saggerson E. Geology of South Kitui area, *Geological Survey of. Kenya, 1,* (1957), 37.

[5]. Nyamai C., Mathu E., Opiyo N. and Wallbrecher E. A Reappraisal of the Geology, geochemistry, structures and tectonics of the Mozambique belt in Kenya, East of the Rift system, *African Journal of Science and Technology Science and Engineering Series, 4 (2)* , (2003),51-71.

[6]. K'Orowe M., Nyadawa M., Singh V. and Ratnakar D. Hydro geophysical parameter estimation for aquifer characterization in hard rock environments: A case study from Jangaon sub-watershed, India, *Oceanography and Marine Science, 1(1),* (2010)., 6-12.