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RESISTIVITY INVESTIGATION FOR WELL-SITE DEFINITION AROUND BARIKA VILLAGE, SOUTHEAST SULAIMANY CITY IRAQI KURDISTAN REGION

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Abstract

An electrical resistivity survey involving Vertical Electrical Soundings (VES) was carried out in the Barika collective village, southeast of Sulaimany City in the Iraqi Kurdistan Region, to study groundwater characteristics such as depth, thickness and aquifer boundaries. Vertical electrical soundings by Schlumberger array were conducted in this area. The resistivity Schlumberger soundings which have a maximum current electrode spacing (AB) of 800m were carried out at fourteen sites along lines in the NE-SW and NW-SE directions. Interpretation of these soundings showed the presence of three geo-electrical horizons. The upper one is representing the alluvial deposits with 3Ωm to 60Ωm range of resistivity values reflecting the heterogeneity of the slope deposits. The middle one is taken to be the unconfined jointed aquifer represented by the Tanjero Formation with a resistivity range of 10Ωm to 42Ωm and a thickness range of 24m to 106m. The third horizon is representing the lower part of the Tanjero Formation with a relatively high resistivity range of 51Ωm to 556Ωm. Based on these results and upon our recommendations, a successful water well was drilled yielding quite enough amount of fresh water.

Keywords: *Arbat, Iraq, resistivity, water.*

1. Introduction

The area of investigation is located about 20 km to the southeast of Sulaimany City at the cross of latitude 35°22’25”N longitude 45°36’25”E covering an area of about 19 km^2 (Figure 1). Barika village lacks sufficient surface and subsurface sources for water and devoid of springs and permanent streams. The villagers used to depend upon some shallow hand dug wells which may dry in summer during some years. Type of groundwater in the whole surrounding area is fresh. Among many wells drilled around the village during the last few years, one was yielding considerable amount of water. The present study aims to locate the best site/s to drill more wells in view of the population growth of the village. It aims to give the recommended depth and type of water.

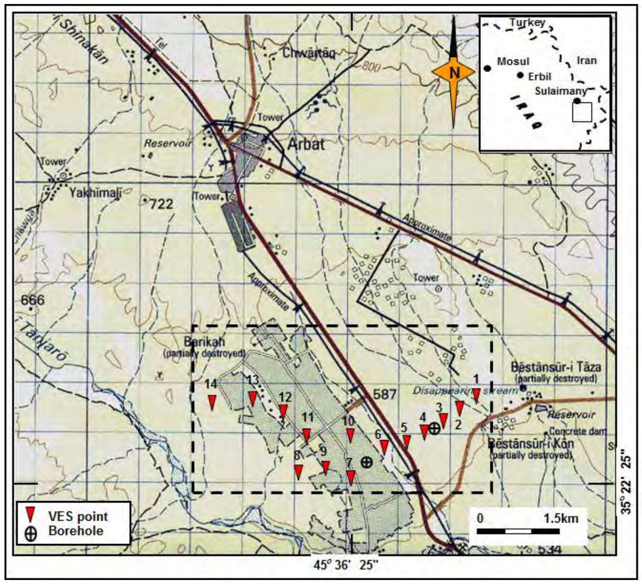

Figure 1 - Topographic map showing Barika collective village.

2. The Resistivity Method

The resistivity method involves measuring the electrical resistivity of earth materials, by introducing an electrical current into the ground and monitoring the potential field developed by the current. In most earth materials, electricity is conducted electrolytically by the interstitial fluid. The resistivity is controlled mostly by porosity, water content and water quality than by the resistivities of the matrix (Ayer, 1989). The main target is identification of the horizontal and vertical variations in lithology, which might lead to more structural information about the subsurface. The electrical resistivity is the resistance offered by the opposite faces of a unit cube of material to direct current. In geophysical literature the unit of resistivity is taken as the Ω.meter. The resistance (R) of the material having a resistivity (ρ) over a length (L) and surface area of current flow (A) is given by [$R = \rho\ (L/A)$]. This is governed by ohm's law. The inverse of resistance is called conductance. The resistivity of the geological formation is generally very high under dry conditions and decreases in clayey rock. The presence of water containing salt even in minor amounts makes them relatively conductive and as the moisture increases the resistivity falls considerably. As the salinity of water increases the resistivity of the rock formation decreases.

The vertical electrical sounding (VES) has been chosen for this study. The method has been proven to be an effective mean of solving groundwater problems (Mbonu *et. al.*, 1991, and Ghaib, F. 2009).

3. Geomorphology and Hydrology of the Study Area

The study area is located hydrologically within the Arbat sub-basin which is one of four sub-basins of the main Sharazor basin (Ali, 2008). The Barika village is located within a hilly terrain. All the surface runoff and the groundwater discharge of this sub-basin are drained exclusively to the Darbandikhan reservoir by the Tanjero stream some 10 kms to the south of Arbat town. Almost all the studied area consists of gently sloping plain which now makes up the main cultivation land in the sub-basin.

The basin boundary at the north, northeast, south and southwest are bounded by the summits of Goizha, Barda Kar, Baranan and Bakir Agha mountains (or anticline) respectively. Some hills are also present. They are formed due to the differential erosion of the surface rock types of sand and clay.

The climate of the studied area as is the case in the northern Iraq is characterized by clear seasonal differences, caused mainly by the change in the type of atmospheric circulation during the year, and by the intensity of the insulation It is generally classified as moist type, and from the metrological data, the area shows seasonal variation between cold, rainy, humid, low evaporation and low vapor pressure in winter months (January, February and March) and hot, low humidity, high vapor pressure and high evaporation rate in summer months (June, July and August), (Ali, Op. Cit.)

4. General Geology of the Area

The study area is covered by agricultural recent sediments with no signs about the underlying formations (Figure 2). However, a general reconnaissance revealed that the expected underlying rock unit is Tanjero Formation. This formation is composed of khaki to olive green sandstone, claystone, shale and occasionally conglomerate. These inter-bedded lithologies have no regular pattern in their distributions which makes direct interpretation of their subsurface positions unpredictable. In view of the general geology of the area, Tanjero Formation should be underlain by the Shiranish Formation which is composed of alternating marl and marly limestone. Shiranish Formation is expectedly underlain by the Komitan Formation which makes up the anticline situated to the northeast of Barika village area. Scattered exposures of compacted sandstone are present to the southwest of the village. They are believed to be remnants of the Tanjero Formation (Buday and Jassim, 1987).

5. Fieldwork

Vertical Electrical Sounding (VES) technique is the best resistivity way in investigations for water well sites. Here, a series of measurements of resistivity are made by increasing the electrode spacing in successive steps about a fixed point. This method of vertical exploration is known as the expanding electrode method, resistivity sounding or depth probing or vertical electrical sounding (VES). The apparent resistivity values obtained with increasing values of electrode separation are used to estimate the thickness and resistivities of the subsurface formations. VES is mainly employed in groundwater exploration to determine the disposition of the aquifers (Ahilan and Senthil Kumar, 2011)

Among many electrode spreading configurations, the Schlumberger method is more suitable. In this method the four electrodes are kept in a line with the outer electrode spacing kept large compared to inner electrode spacing usually by more than five times. For each measurement only the current electrodes are moved keeping the potential electrodes at the same locations. The potential electrodes are moved only when the signal become too weak to be measured.

This method was used in this study to collect the data in fourteen sites along lines in the NE-SW and NW-SE directions (Figure 1). The used maximum electrode spread in the NW-SE direction is 400 m on each side of the center-point. SAS300 Tetrameter present in Qandil Organization (Erbil) was used to collect the resistivity data which were of good quality while the coordinates of the investigation sites were measured by Global Positioning System (GPS-Garmen).

6. Sounding Curve and Interpretation

The basic interpretation of field curve for apparent resistivity is a correlation with a master curve and auxiliary curves, and through that the real resistivity and thickness of subsurface layers are calculated.

There are several methods for interpreting the field curve such as a complete curve matching and auxiliary point, in addition to some computer programs used for this purpose such as the commercial program IPI2WIN as shown in Figure (3). The VES curves were obtained by plotting the apparent resistivity against electrode spacing. The resistivity for each of the vertical electrical sounding was drawn on transparent double log graph paper.

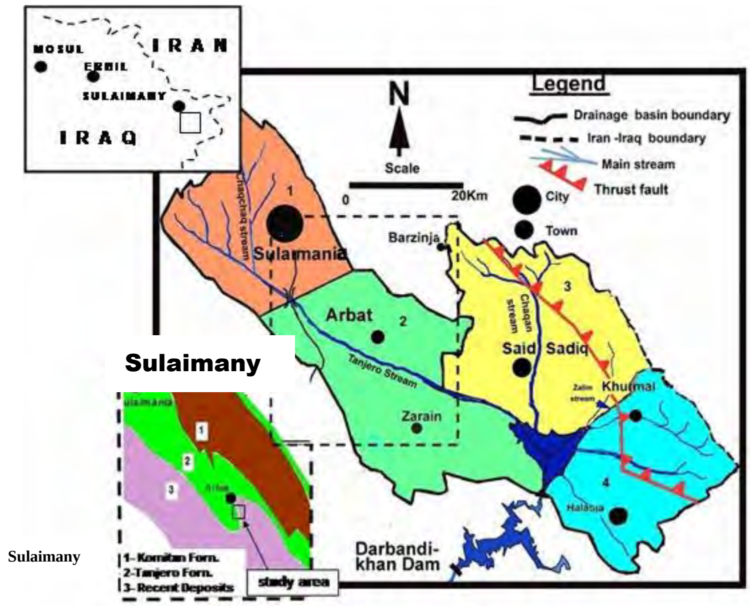

Figure 2 - A simplified geologic map of the study area relative to the hydrological basins.

7. Geo-electric Sections

The VES curves which are the plot of apparent resistivities collected in the field against AB/2 have been prepared by IPI2 Win software Program in order to estimate the true resistivities of different horizons and their thickness. Some examples are shown in Figure 3.

Geo-electrical sections show the vertical distribution of resistivities within a particular volume of the earth. The section consists of a sequence of uniform horizontal or slightly inclined layers (electrical horizons). The layers true resistivity is noted on each one for each VES sounding. After that several sections for VES points on a certain traverse can be linked together to show a cross sectional view of the traverse. Each layer (horizon) in a geo-electrical section may completely be characterized by its thickness and true resistivity. For the purpose of constructing geo-electrical sections, the VES points were grouped to three traverses (Figures 4, 5 and 6).

7.1. Traverse 1

This traverse extends in the NE-SW direction and involves six VES points (VES-1 to VES-6). All points are located on recent sediments (Fig. 4). The geo-electrical section shows three main horizons, they are:

(Z1) It is exhibited in all VES points along the traverse and is characterized by resistivity values ranging from 5.48 Ω.m at VES-5 and 52 Ω.m at VES-6. It has a maximum thickness of about 32 m below the VES-4, under which a relatively high resistivity lens is being revealed. The thickness is decreasing to reach 4 m below the VES-3. Within this horizon, several horizontal and vertical lithological variations are present. This horizon is believed to consist of clayey soil having generally low resistivity values in some locations and a high resistivity values when gravel and sands are present such as under VES-6 and 3.

(Z2) It has a thickness of about 84.6 m underneath the VES-6, decreasing to about 37.6 m beneath the VES-1. The average thickness is about 63.93 m. Its resistivity varies from 16.5 Ω.m below VES-3 to 41.7 Ω.m below VES-1. This horizon is expected to be rich in gravel, sand and clay. It belongs to the upper part of Tanjero Formation.

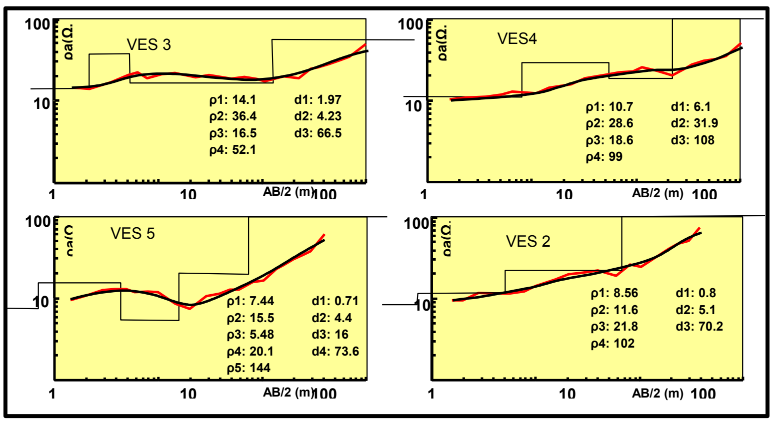

Figure 3 - Examples of Some Sounding Curves and interpretations.

(Z3) It most probably represents the Tanjero Formation which is expected to be composed of marl and marly limestone. The depth of this horizon is ranging from 57 m to 99 m below VES-1and 6, respectively. Resistivity has a minimum value of 52 Ω.m beneath VES-3 and a maximum value of 556 Ω.m beneath VES-1. In this horizon the ratio of the resistivity value has increased relatively to the second horizon. The lower boundary of this horizon is not defined in this survey.

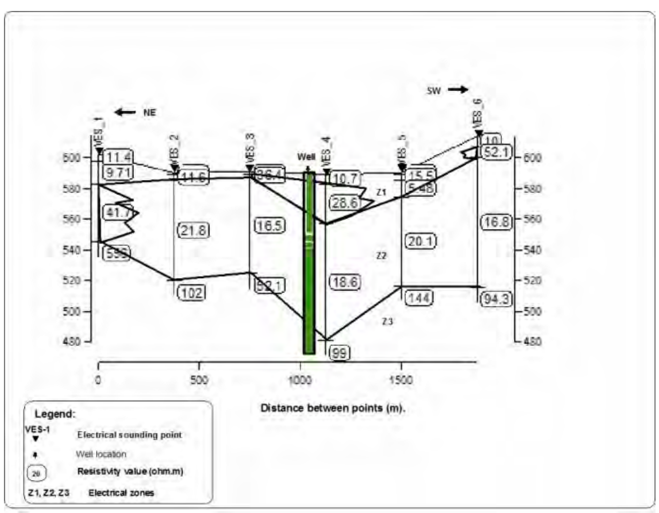

Figure 4 - Geo-electrical section along traverse 1.

7.2- Traverse 2

It involved six VES points (VES-7 through VES-14) which extends in the NW-SE bending to E-W along VES-13 and 14. The geo-electrical section shows three main horizons (Fig. 5), they are:

(Z1) It has a thickness of about 10.7 m that decreases to 0.75 m below VES-13 with an average thickness of 6.08 m. The resistivity values of this horizon range from 3.19 Ω.m to 46.9 Ω.m. Within this horizon, a vertical lithological variation is present beneath VES-11 which possibly represents the top soil, sand and gravel sediments that belong to Quaternary deposits.

Z2: It is characterized by resistivity values ranging from 13 Ω.m below VES-13 to 28 Ω.m below VES-7, averaging 22 Ω.m. The resistivity value is generally decreasing in the SE direction which is referred to the increase of sand, silt and clay materials. The maximum thickness of this horizon is about 106 m which is observed beneath VES-9, while the minimum thickness is about 24 m which is observed beneath VES-11. It is believed to represent the Tanjero Formation again.

Z3: The resistivity value of this horizon is ranging from 51 Ω.m below VES-14 to 114 Ω.m below VES-7, with an average value of 22 Ω.m.

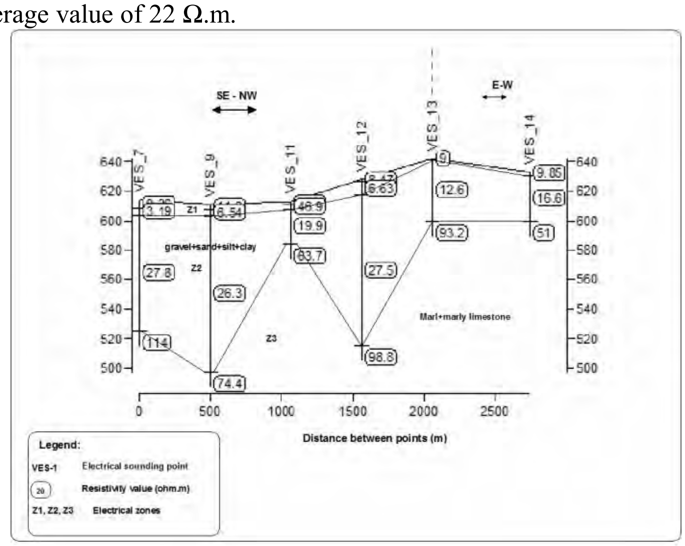

Figure 5 - Geo-electrical section along traverse 2.

7.3- Traverse 3

This section involves three points (VES-8, VES-9 and VES-10). The geo-electrical section shows three horizons:

(Z1) the resistivity values of this horizon vary from 6.5 Ω.m to 60 Ω.m, with an average of 20 Ω.m The average thickness is about 8 m; the maximum thickness is more than 9 m below VES-10, while the minimum thickness is more than 6 m below the VES-8. The horizon comprises alluvial deposits represented by clay, silt and gravel.

(Z2) It represents the upper part of the Tanjero Formation in the study area. It has a thickness of about 60 m below VES-8 increasing to 106 m below VES-9 with an average of about 83. The maximum resistivity values is 32 Ω.m. which is observed beneath VES-8 and a minimum resistivity values of 10 Ω.m. which is observed below VES-10, giving an average of about 24 Ω.m It is composed of gravel, sand, silt and clay materials.

(Z3) It mostly represents the marl and marly limestone of the the Tanjero Formation. The depth of this horizon is ranging from 67 m to 114 m and has a resistivity value of about 74 Ω.m beneath VES-9 increasing to 357 Ω.m below VES-10.

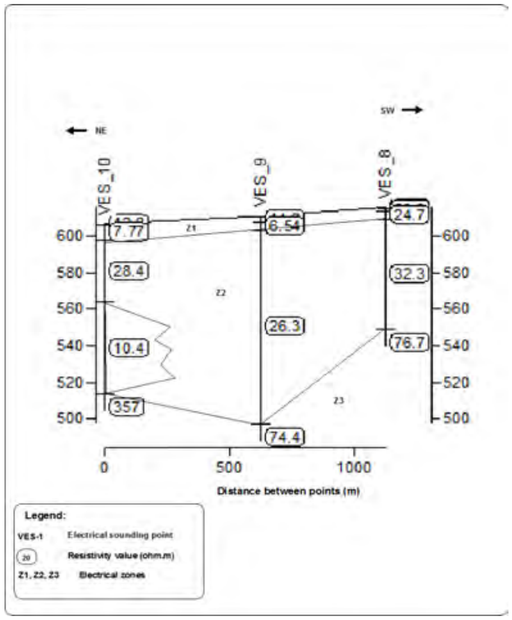

Figure 6 - Geo-electrical section along traverse 3.

8. Apparent Resistivity Maps

These maps are constructed by plotting the apparent resistivity value at each VES point for individually half distance current electrode (AB/2) and drawing the contour lines for similar values. Four apparent resistivity maps for (AB/2= 80m, 100m, 140m, 200m) were constructed (Figures 6 and 7).

These maps show the following:

1- Two prominent anomalies, one positive and the other negative that appear in all maps. The negative one appears at almost the same spacial location at maps AB/2 = 80 m and 100 m (Fig. 6), while is shifted towards southeast and east in the other two maps (i.e. AB/2 = 140 and 200m (Figure 7).

2- The negative anomaly on the other hand is shifted towards southeast in maps AB/2 = 100 m, 140 m and 200 m with respect to the map AB/2 = 80 m.

3- Both anomalies are shifted towards east and southeast.

4- The resistivity values generally increase with the increase in the value of AB/2.

5- The resistivity values are increased toward SE direction.

9. Results

The description of the present aquifer in the area comes only from the resistivity sounding interpretation results given in the form of geo-electrical sections (Figures 3, 4 and 5). All sections show the presence of three horizons. The upper one is representing the alluvial deposits with a broad

range of resistivity values reflecting the heterogeneity of the slope deposits. The middle one is taken to be the unconfined jointed aquifer. It is the Tanjero Formation which is composed of jointed sandstone, claystone, marl and some conglomerates. This was approved later on by the drilling of the recommended water well. The drilling site on the ground was recommended by the present authors after drawing the geo-electrical sections.
The potentiality of yielding water for a certain well depends upon the topography of the bedrock (i.e. underneath the aquifer) in addition to the lithological characteristics of the aquifer itself. In our case the lower boundary of the Tanjero Formation is taken as bedrock.

As a principle, depressions within the bedrock are the best sites for accumulating water hence are best sites for drilling. Davis and DeWieste (1976) stated such a situation (Fig. 8).

Few months after carrying out the fieldwork and submitting our recommendation, a water well sponsored by the same Swedish Organization was drilled. The recommended site was between the VES-3 and VES-4 (Fig. 4). It yielded more than 90 Gallon/minute when tested. This amount is quite enough for the present population of the village for domestic uses.

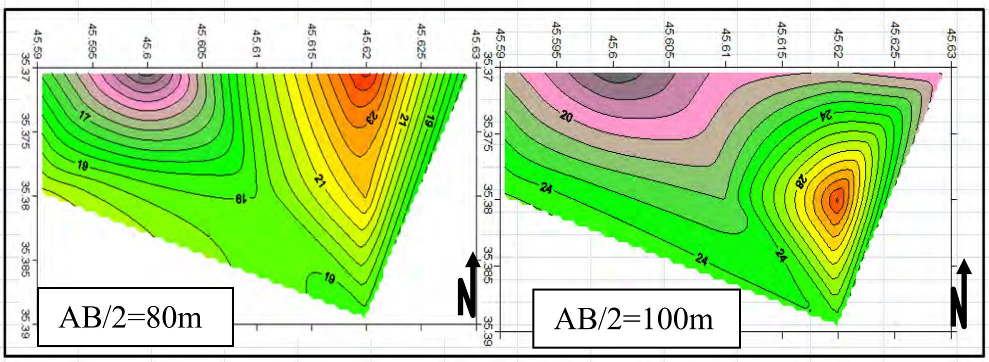

Figure 6 - Apparent resistivity map for AB/2 equal to 80 and 100m.

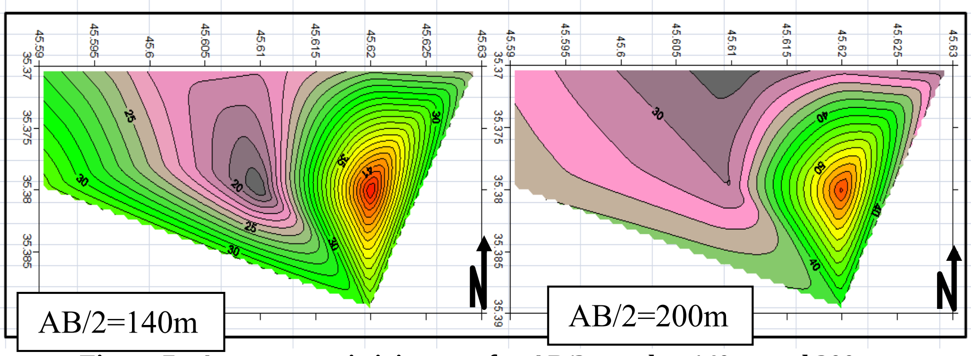

Figure 7 - Apparent resistivity map for AB/2 equal to 140 m and 200 m.

10. Conclusions

1- The subsurface is divided into three electrical horizons having different resistivity values and thicknesses.

2- The thickness of the uppermost recent deposit horizon that covers the Tanjero Formation was found to be between 0.75m and 32 m through the studied area. This horizon has resistivities ranging from 3 Ω.m to 60 Ω.m.

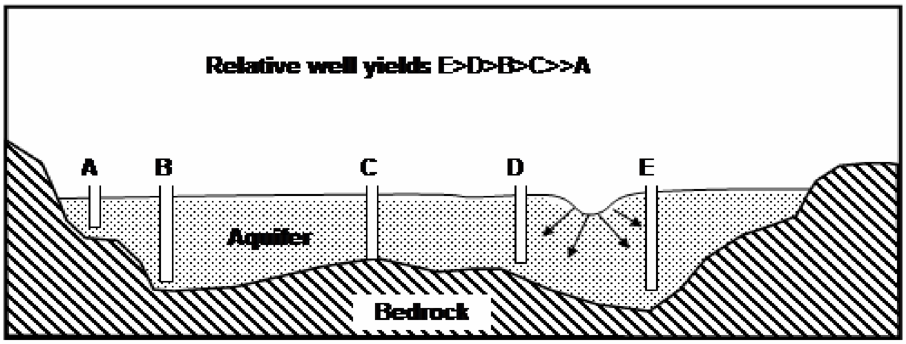

Figure 8 - Hypothetical cross section of a valley showing the effects of aquifer thickness and hydrogeologic boundaries on well yield (Davis and DeWiest, 1976).

3- The thickness of the second lower horizon ranges from 24 m to 106 m. with resistivity values ranging from 10 Ω.m to 42 Ω.m with an average value of 24 Ω.m which is a consistent value of holding water according to personal experience.

4- The third horizon is believed to represent the lower marly and marly limestone part of the Tanjero Formation with a relatively high value of resistivity ranging from 51 Ω.m to 55 6Ω.m with an average value of 201 Ω.m.

5- According to the authors recommendation a successful water well was drilled to yield quiet enough amount of water within the distance between the VES's 3 and 4.

11. Acknowledgements

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