THOMSON REUTERS ENDNOTE
[Fasludeen, 5(1): January, 2016] ISSN: 2277-9655
(I2OR), Publication Impact Factor: 3.785

IJESRT
INTERNATIONAL JOURNAL OF ENGINEERING SCIENCES & RESEARCH TECHNOLOGY

A HYDRO-GEOPHYSICAL INVESTIGATION OF GROUNDWATER BY ELECTRICAL PROFILING

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ABSTRACT

Hydro geophysical investigation of groundwater was performed using electrical resistivity method. Wenner configuration of electrode arrangement with vertical electrical sounding (VES) was done with IGIS signal stacking resistivity meter model SSR-MP-ATS. Resistivity survey was conducted to obtain the pattern of aquifer distribution in the area and to delineate possible sites for locating aquifers. An estimate of the resistivity and thickness of various subsurface layers at a location could be obtained by successively increasing electrode spacing. The inverse of the resistance measured 1/R was plotted against Wenner electrode separation on a linear graph to detect thin layers at deeper layers in the eight locations under consideration. Analysis of 2 -D cross-section of strip resistivity was done to identify site favourable for recharge structure.

KEYWORDS: Groundwater, Aquifer, Electrical Profiling, Wenner electrode configuration, Vertical electrical sounding (VES), Inverse slope curve.

INTRODUCTION

Groundwater is located beneath the earth's surface in soil pore spaces and in the fractures of rock formations. An aquifer is a layer of porous substrate that contains and transmits groundwater. Surface investigations help us in finding the information about the type, porosity, water content and compactness of aquifers. Electrical resistivity method is one of the geophysical techniques to investigate the nature of subsurface formations, by studying the variations in the electrical properties of the formations (Mohammad 1975). Resistivity is a physical property of a substance defined as the resistance by a unit length of a substance of a unit area to the flow of electric current, when the voltage is applied at the opposite faces. If the resistivity in the ground is uniform, then the measured resistivity will be constant and independent of electrode spacing and surface location. If the resistivity in the ground is not homogeneous, then the measured resistivity will vary with relative and absolute location of the electrodes. The measured resistivity is an apparent resistivity (ρa), which depends on the shape and size of anomalous regions, layering and relative values of resistivity in these regions (Kurien *et al.* 2013). Both porous and non porous rocks behave as insulators until they are in dry condition. Resistance decreases with increase in pore water. Unconsolidated material has more resistance than compacted material of same composition. Sedimentary rock has better conductance i.e. lesser resistance than igneous rocks. Clay has higher conductivity than sand because of presence of iron cluster on surface of the clay. Based on this knowledge from resistivity survey it is possible to distinguish between major rock group and the water bearing zones (Aweto 2012). The study was conducted at a selected plot in the Kerala Agricultural University campus at Thrissur. The area falls within 10^0 32' N 76^0 latitude and 16' E longitude at 22.5m above MSL. The study area spreads over 15136 m^2 with high yielding coconut plants. The present study was undertaken with the objective of determining the ground water potential and identification of suitable sites for locating sites tube well by conducting hydro geophysical survey.

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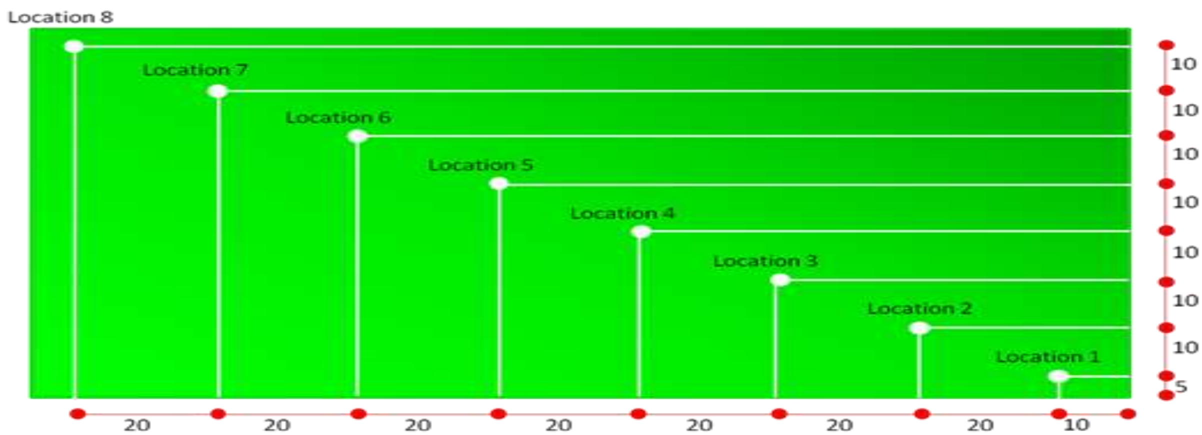
MATERIALS AND METHODS

The IGIS Signal Stacking Resistivity Meter Model SSR-MP-ATS is a high quality data acquisition system incorporating several innovative features. It is a microprocessor based signal stacking resistivity meter in which running averages of measurements up to the chosen stacks are displayed and the final average is stored automatically in memory utilizing the principle of stacking to achieve the benefit of high signal to noise ratio. It can be used for resistivity investigations up to about 600 m depth or more under favourable geological conditions. There are four winches. Each winch has a wire winded on it which has a different colour end. The open end of wires has a pin connected to it which in turn is to be attached to the respective probes. The other end of the wires is concluded on the banana socket located at the reverse side of handle of the winch. At this end the corresponding wires from instrument terminals are connected. Four stainless steel probes which are of the appropriate sizes and they are supplied along with the instrument. Each probe has a pointed end. This facilitates to hammer the probe in ground. The probes are hammered in the ground in such a way that the firm electrical contact is established. To these electrodes the corresponding wire ends are connected. Battery box is a compartment with 2x12 7 AH batteries. This battery supplies charge to the main instrument while taking the measurements.



(All dimensions are in metres) ***Fig 1. Site map***

The location 1 was selected near to one of the corners of the field and was at five meters and 10 meters away from both the adjacent boundaries. Remaining locations were selected diagonally towards the opposite corner of the garden so that the location 2 remains at 15 m and 30 m away from the respective boundaries.

Wenner configuration

In this configuration, all the four electrodes are kept along a line at equal distances called electrode separation 'a'. For each measurement, all the electrodes are moved simultaneously keeping the inter-electrode spacing the same. The current is sent normally through outer current electrodes and potential difference is measured across the inner potential electrodes, (Paramasivam *et al.* 2011)

The resistance is multiplied by the configuration factor 2 πa, to get the value of apparent resistivity (ρ_{aw})

$\rho_a = 2\,\pi a$ R, where $R = \Delta V / I$

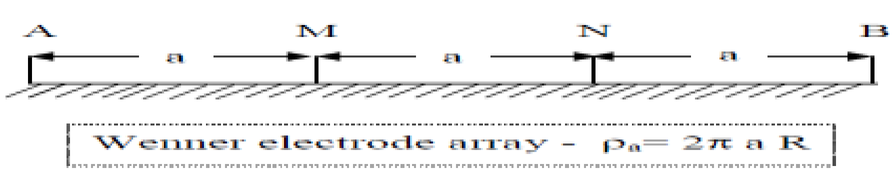


Fig. 2.Wenner electrode arrangement.

Vertical electrical sounding (VES):
The vertical electrical sounding is used to estimate the resistivities and thickness of various subsurface layers at a given location and is mainly employed in groundwater exploration to determine the disposition of the aquifers. In this approach, the center of the configuration is kept fixed and the measurements are made by successively increasing electrode spacing. The apparent resistivity values obtained with increasing values of electrode separations are used to estimate the thicknesses and resistivities of the subsurface format. (Ahilan and Kumar 2011)

Electrical profiling
In profiling surveys the value of apparent resistivity is plotted generally at the centre of the electrode array. This technique is used to examine a slice of the subsurface parallel to the surface of the ground, the thickness of the slice being a function of the electrode separation. Maximum apparent resistivity anomalies are obtained by orienting the profiles perpendicular to the geologic structure. (Hussong 1967)

The measurements were taken in a straight line of about 100 meter. At a centre point "O" the device was placed and the points at which the electrodes are to be placed were marked on the basis of electrode spacing which ranges from two meters for the first reading and gradually increased by two meters for further readings. The potential electrode spacing is considered as "AB" and the current electrode spacing is "MN".

The resistivity meter was switched on the details of location was entered. When the resistivity meter asked for AB/2, MN/2, number of stacks for the measurement and confirmation of all the values respective values were entered. After completing all the stacks, instrument finally shows R for resistance, RHOa for resistivity, d for depth of sounding and STRIP for strip resistivity.

The linear plot was prepared between (AB/2) on X-axis and $\{(AB/2)/\rho a\}$ on Y-axis. Interpretation of VES was done with inverse slope software (AT 3.0) to obtain various types of lithologic formations can be identified on the basis of readings.

Resistivity Scanning Technique
Normal resistivity techniques have certain limitations in detecting small fractures, which yield most of the water in hard rock. The problem will be compounded if fractures are located at deeper depths. The resistivity soundings are investigations at discrete points and hence cannot identify any fracture zones at a few meters away. Even if a sounding is conducted exactly over the fracture, its identification is practically impossible due to poor delectability of the conventional interpretational techniques through curve matching and inversion because of the logarithmic data collection and plotting schemes (Oseji *et al.* 2009). Close spaced measurements at larger electrode spacing to identify thin and deep fracture zones will not reflect any changes in sounding curves, when plotted on double logarithmic scale.

RESULTS AND DISCUSSION
The geophysical observations were taken from eight locations spread over the plot. As the campus is mostly of lateritic terrain, chances for the occurrence of a phreatic water surface are minimum. However, certain points may be located where there is a chance for occurrence of ground water and feasibility for digging bore wells. Vertical electrical sounding using SSR-MP-ATS meter was conducted. Inverse slope curves were plotted using the VES Interpretation Software. Different types of formations were distinguished from the curve

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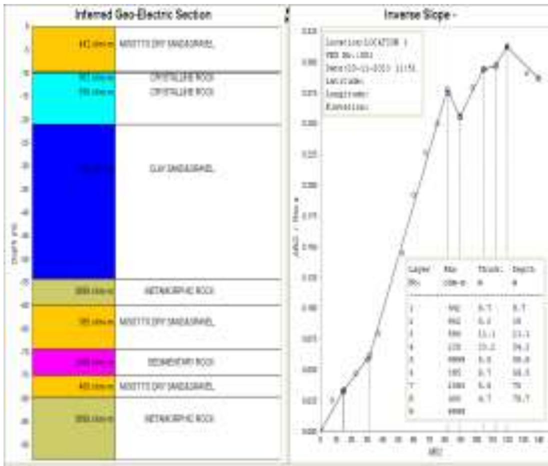


Fig.3 Inverse slope curve (Location 1).

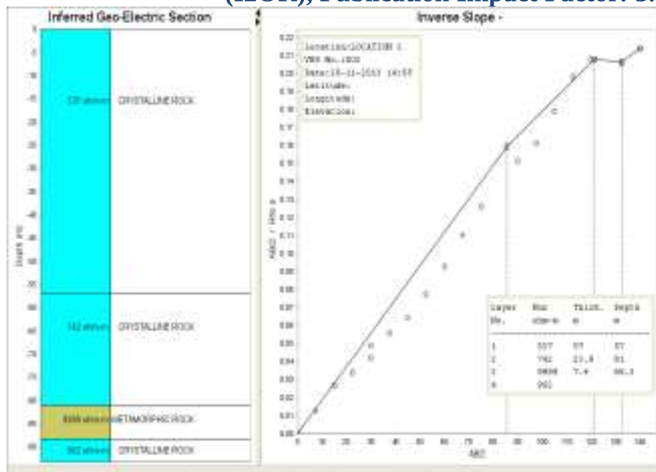


Fig.4 Inverse slope curve (Location 2).

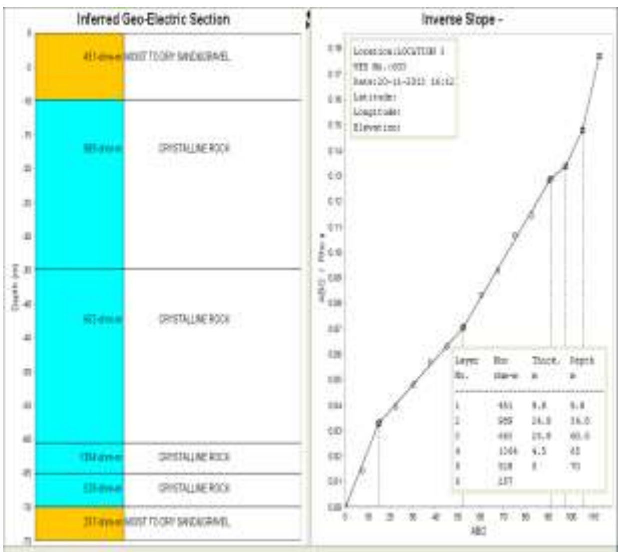


Fig.5 Inverse slope curve (Location 3).

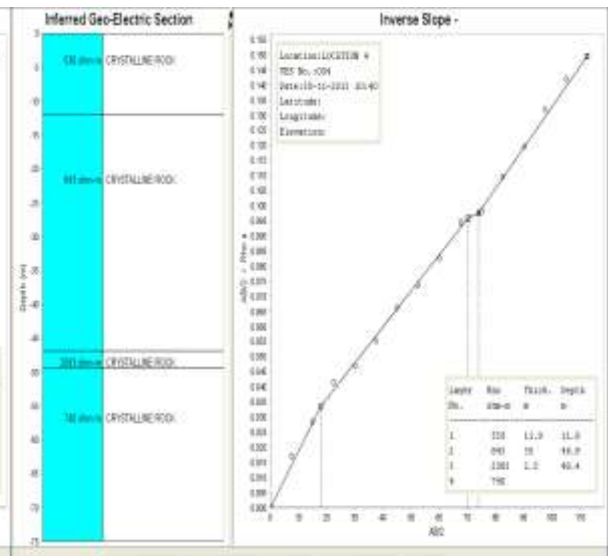


Fig.6 Inverse slope curve (Location 4).

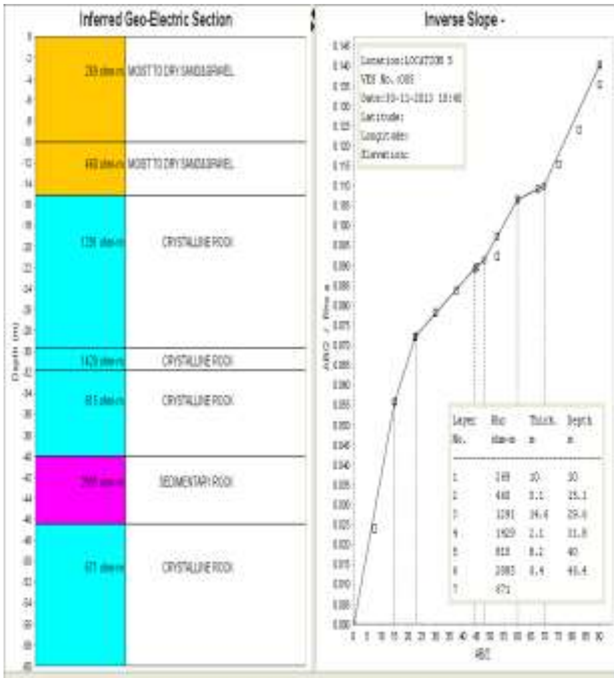


Fig.7 Inverse slope curve (Location 5).

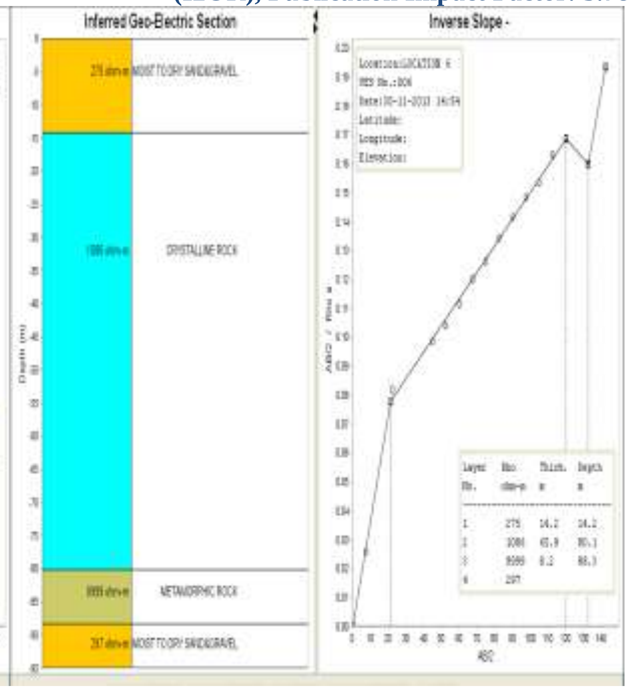
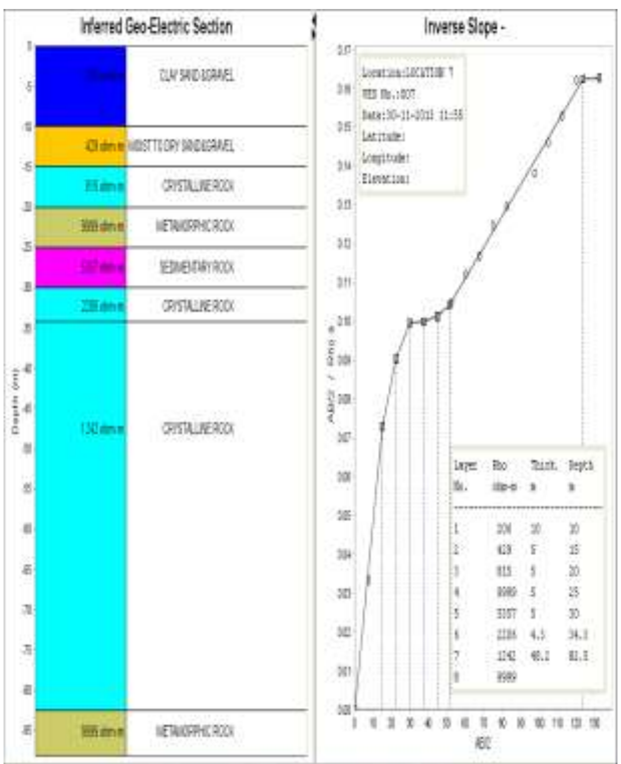


Fig.8 Inverse slope curve (Location 6).



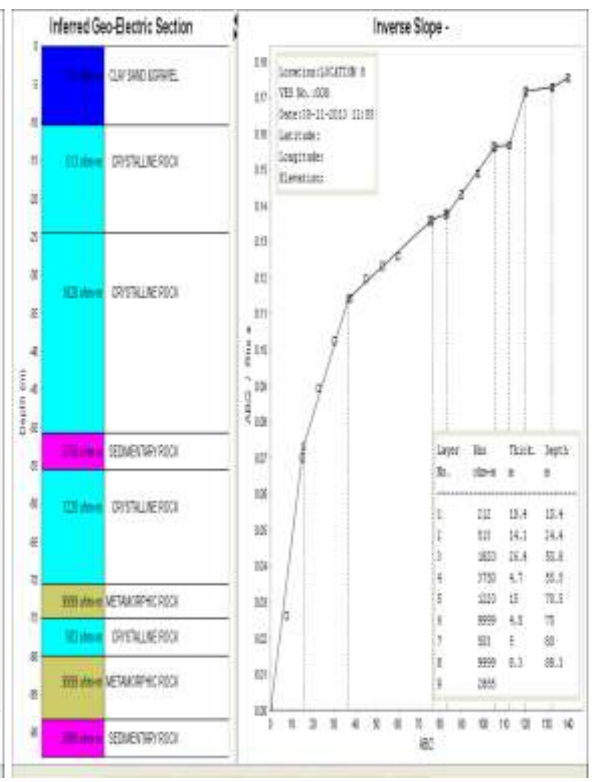


Fig. 9. Inverse slope curve (Location 7).

Fig.10. Inverse slope curve (Location 8).

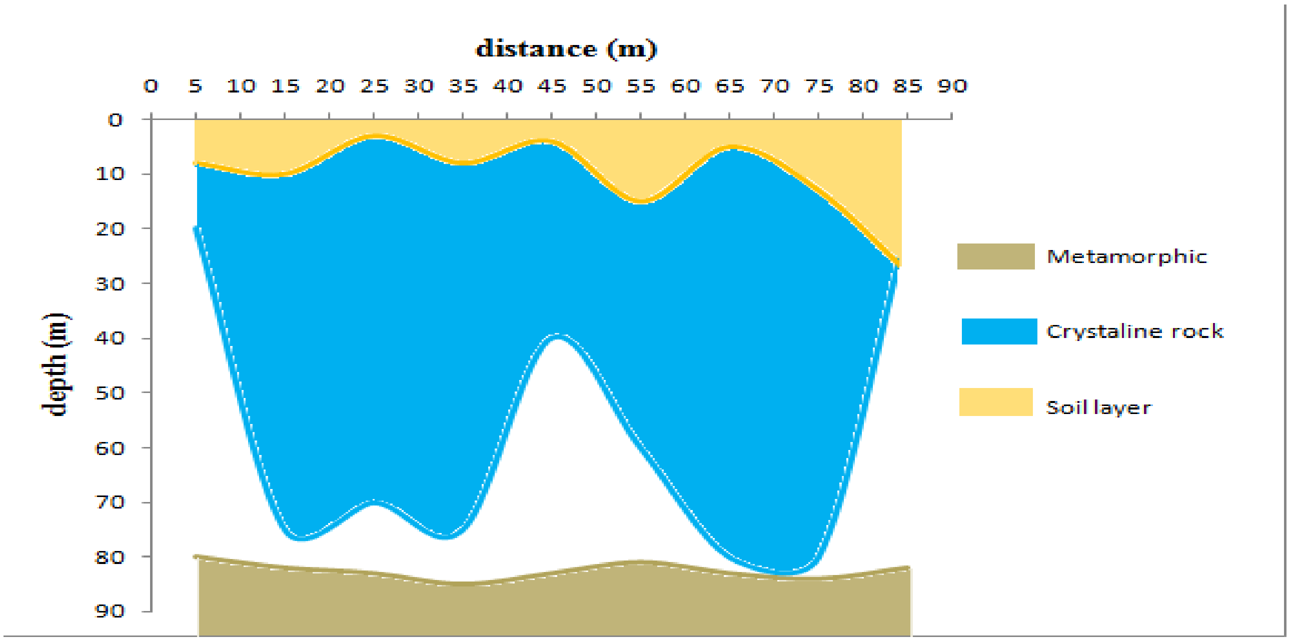


Fig.11. Cross-section of strip resistivity for recharge structure (2D).

At the location 1 and the inferred geo-electric sections and the layer details of the point are presented in the inverse slope curve shown in fig.3. The electric soundings to a depth of 90 meters were done and an eight layered formation was found to be present.

The inverse slope curve for the location 2 is given in the fig.4.The electric soundings were conducted up to a depth of 96 meters and a four layered formation was obtained. The graph showed rock formations of varying resistivity values. The resistivity value of the formation up to the initial 57 m depth was 537 ohm-m. The fractures present may not be the aquifer suitable for ground water extraction.

The third VES was carried out and the inverse slope curve was obtained from location 3. The electric soundings were done up to a depth of 75 meters (Fig.5). From the graph a six layered formation was found to exist. The geological formations were found to have less variation in their resistivity values.

The formations at the location 4 were found to be basically rocky, extending up to a depth of 75 meters with total four layers (Fig.6). The formations were found to be crystalline having resistivity values of 530 ohm-m, 843 ohm-m, 2083 ohm-m, 740 ohm-m respectively. These hard rock formations without effective fractures cannot yield reasonable amounts of discharge.

On location 5, the electrical sounding could identify a seven layered profile with hard rock formations extending up to 60 meters depth (Fig.7). The chances for getting appreciable discharges were low.

Fig.8 shows the inverse slope curve for location 6. A four layered formation was found to be present in the profiled depth of 95 meters. The graph showed rock formations of varying resistivity values.

The soundings were done at the location 7 and are shown in Fig.9. The electrical soundings up to a depth of 88 meters resulted in an eight layered formation. The upper layers were identified as clay sand and gravel, moist to dry sand and gravel, crystalline rock, metamorphic rock, sedimentary rock, crystalline rock formations respectively whereas the bottom layer was identified as metamorphic form. The formation was not much fractured and the chance of availability of water is less.

On location 8, the electrical sounding (Fig.10) could identify a nine layered profile with hard rock formation extending to 93 meters depth. The upper layer was clay sand and gravel and the next two layers were identified as crystalline rock. Below that crystalline rock was found to exist. Bottom layer was identified as sedimentary rock. These formations also could not yield ground water at appreciable quantities.

The Inverse slope curves plotted using the VES Interpretation Software were compared with existing data relationship between resistivity values and formation of rocks appeared on par with findings of experiments and from this data base a conclusion to the project can be obtained

CONCLUSION

To obtain aquifer distribution within the study area in order to delineate possible sites for drilling tube wells for irrigation water supply a special technique called 'Resistivity Scanning' is found to successfully delineate the fractured geometry of formation.From the eight locations under consideration, none of the locations could serve as potential groundwater sources. By the analysis of 2 -D cross-section of strip resistivity ,to identify site favourable for recharge structure, we can arrive at the conclusion that a continuous soil layer of average depth 10 m was observed at the top.Major portion of area was occupied by a continuous layer of crystalline rock formation which extended up to 80 m depth. Beyond crystalline rock, there was a layer of continuous metamorphic formation which could not provide sufficient water. By this study, all possible sites in the study area were explored for the presence of ground water. The study could come to a conclusion that, potential areas for sustainable water supply were not available in the study area.

ACKNOWLEDGEMENTS

Our sincere thanks to Dr. M. Sivaswami, Dean, KCAET, Faculty of Agricultural Engineering and Technology for the unfailing guidance and support that he offered while carrying out the project work.We wish to engrave our deep sense of gratitude to Dr. V.M. Abdul Hakkim, Associate Professor and Head, Department of Land and Water Resources and Conservation Engineering, KCAET, Tavanur, for his support that he offered while carrying out this work.We express our sincere gratitude to faculty and staff of the Department of Land & Water Resources and Conservation Engineering for their sincere support during the course of the project work.

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