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Application of Resistivity Survey Method in Landslide Investigations along Mettupalayam to Coonoor Highway, Nilgiris District, Tamilnadu, India

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Abstract: A geophysical survey has been conducted in the study area in particular locations where the landslide is reported during the year 2007. A landslide occurred after heavy rainfall in a rock consisting of a succession of rock layer which was fractured. Electrical resistivity survey is carried out to obtain the characterization and quantification of the weathered zone in the region along Mettupalayam to Coonoor highway. The geophysical survey data analysis clearly shows, the thickness of top soil and depthness of weathering which are most vulnerable for landsliding. Fractured zones are encountered in the south-eastern part of the study region at depth of 10 to 30m with the resistivity 120-250 Ω-m.
Keywords: geophysical survey, landslide, Electrical resistivity

INTRODUCTION

Electrical resistivity technique of geophysical prospecting is entrenched and the most vital technique for groundwater investigation. The electrical resistivity method is one that has been broadly utilized in light of the hypothetical, operational and interpretational ease. The upsides of electrical methods additionally incorporate control over depth of investigation, portability of the equipment, accessibility of the wide range of simple and neat interpretation techniques, and the related software etc.

Direct current (D.C.) resistivity (electrical resistivity) methods measure earth resistivity by driving a D.C. motion into the ground and measuring the subsequent potentials (voltages) created in the earth. From the information acquired, the electrical properties of the earth (the geoelectric section) can be inferred. Thusly, from those electrical properties, we can derive the geological feature of the earth.

In geophysical and geotechnical narrative, the expressions "electrical resistivity" and "D.C. resistivity" are utilized synonymously. A few geographical parameters which influence earth resistivity (and its reciprocal, conductivity) incorporate clay substance, soil or formation porosity and scale of water saturation.

REVIEW OF LITERATURE

Geophysical methods are used for Reconnaissance survey in landslide investigations by McCann and Forster [1]. The methods of self-potential, resistivity, and temperature measurement are analyzed for characterization of the seepage flow through the landslide body [2]. The Electrical Resistivity Tomography (ERT) is an active geophysical method that can provide 2D as well as images of the distribution of the soil's electrical resistivity. In the cases of landslide investigation the electrical resistivity is used frequently because the factors that mainly affect the resistivity are the type of the soil, the porosity and the water content [3-7]. The resistivity methods are one of the standard methods of the geophysical prospecting for solution of shallow geological problems. It is also useful to determine some characteristics of landslides and it has been used in landslide investigations since late 1970s [2,8-10].

Study area

The study area is the Nilgiris district, which is located in Tamilnadu state. The Mettupalaym to Aravankadu ghat section of length 273.30 km2 has taken as the study area to identify the landslide prone areas. It lies in the toposheet Nos. 58 A/15 of the survey of India and located in between 76° 48' 8.34'' and 76°54' 2.48'' E longitudes and 11° 17' 41.25'' and 11° 17' 47.48'' N latitudes with an area of (273.30 km2). The study area is blessed with a deltaic system with different active and inactive distributaries, the study area is illustrated in the figure: 1. The proposed study area is covered by the villages like Mettupalayam, Odanthurai, Adatturai, Burliyar, Hulical Drug, Kallar, Killpilur, Marrapalam, wellington, Aravankadu, Lamb's rock and Tiger hill.

METHODOLOGY

Interpretation procedures

Vertical electrical sounding (VES)

There is four basic categories of sounding curve depending on the resistivity allocation with depth. If ρ^1, ρ^2 andρ^3 is the resistivity of the subsurface layers with $\boldsymbol{\rho^1}$at the top followed by $\boldsymbol{\rho^2}$ and $\boldsymbol{\rho^3}$.

i. $\boldsymbol{\rho1<\rho2<\rho3}$ is defined as A-type
ii. $\boldsymbol{\rho1<\rho2>\rho3}$ is defined as K-type
iii. $\boldsymbol{\rho1>\rho2<\rho3}$ is defined as H-type
iv. $\boldsymbol{\rho1>\rho2>\rho3}$ is defined as Q-type

The VES information was analyzed at first with the curve coordinating utilizing different master curve manuals [11-14] for acquiring the underlying models. Iterative inversion algorithms created by Gupta Sarma [15], Zohdy [16] are accessible utilizing diverse inversion codes. The sounding curves were interpreted utilizing the software IP2WIN [17] a program based on the steepest upright method. Table 4.1 gives the interpreted layer parameters (layer thickness and electrical resistivity) of 20 VES. Run of the mill sounding curves acquired in the study area are shown in Figure 4.3. The curves indicate a maximum of three layers. The maximum depth of data of 42.44 m is gotten at VES 7. The Dominant part of the sounding curves is found as "A" type. In view of the VES location VES Profile is prepared to cover the VES locations from north east to the southwest in the study area.

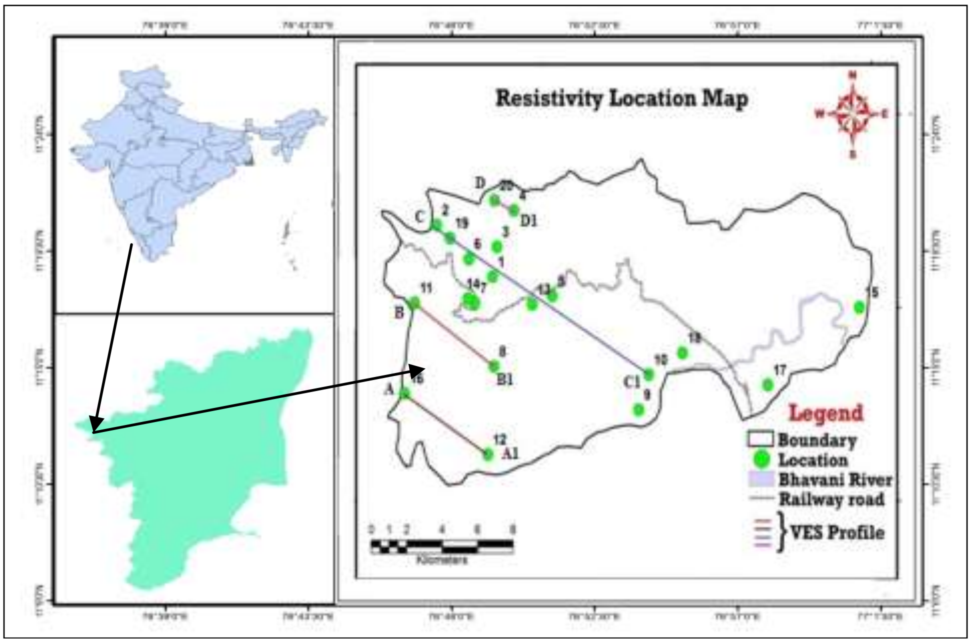


Fig-1: Location map of the Study Area.

Electrical Resistivity Method

In resistivity technique for electrical prospecting, an electric field is unnaturally made in the ground by methods for either galvanic batteries (DC) or low-frequency AC generators. Electrical resistivity is characterized as the resistance offered by a unit cube of material for the flow of current through its normal surface. On the off chance that "L" is the length of the conductor and "A" is its cross-sectional zone, then the resistance (R) is characterized as

$$\mathbf{R=\rho L/A}$$

In MKS system the unit of resistivity is Ohm-meter (W-m). The reciprocal of resistivity is called conductivity and denoted by $\boldsymbol{\sigma}$, the unit of conductivity is mho/meter.

Apparent resistivity

The homogeneous and isotropic directing medium ρ is independent of the position of electrodes on the surface and electrodes organization while measuring the potential distinction between any two points in a four-electrode array containing a couple of presents and potential electrodes. The apparent resistivity of geologic formation is equivalent to the true resistivity of made up homogeneous and isotropic medium in which, for a given electrode configuration and current strength, I, the calculated potential differentiation ΔV is equivalent to that for the given heterogeneous and anisotropic medium. The apparent resistivity depends upon the geometry and resistivity of the element constituting the given geologic medium.

$$\rho \mathbf{a = K\ (\Delta V/I)}$$

Where K, is the geometrical variable having the measurement of length (m). The resistivity of rock formations varies over a wide range, depending upon mineral constituents of rock, density, porosity, pore size and shape, water content, quality of water and temperature. There is no fixed limit for resistivity of different rocks, igneous and metamorphic rocks yield value in the scope of 102 to 108 Ohm m, sedimentary and unconsolidated rocks are different between 1 to 104 Ohm m.

Resistivity measurements

The most part, to measure the resistivities of the subsurface formation, four electrodes specifically two current electrodes A and B and two potential electrodes M and N are essential. There are different electrodes arrangements for measuring the potential differentiation, which is individually utilized for various purposes in exploration techniques [18]. The most well-known among them are Wenner [19] and Schlumberger [20].

Schlumberger array

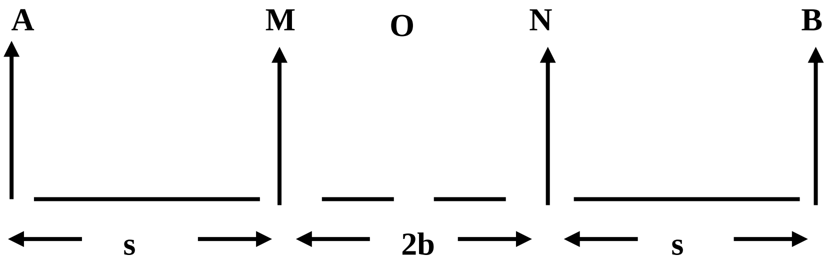
The Schlumberger array, comprising of four co-linear point electrodes to measure the potential inclination at the midpoint. In this array, the current electrodes and potential electrodes are spaced in the ratio of 1:5 and the geometrical variable K for this exhibit is given by

$$\mathbf{K = \pi \{(AB/2)^2 - (MN/2)^2\}/MN}$$

$$\mathbf{(i.e.)\ K = \pi (s^2 - b^2)/2b}$$

Apparent resistivity $\rho_a = K (\Delta V/I)$

Where s = half spacing of current electrodes and b = half spacing of potential electrodes.



Where $s \geq 5b$

The above sketch is the schematic representation of Schlumberger electrode configuration, when AM = MN = NB = s, results from the Wenner configuration.

Field investigations

In general, electrical investigations particularly vertical electrical soundings are conducted to determine the depth to bedrock, groundwater potential zones and sources of groundwater pollution. Some of the significant applications are lateral differentiation of permeable formations from impermeable or less permeable formations and vertical distribution of various layers. 20 vertical electrical soundings (VES) were carried out at selected locations within the study area in order to interpret the subsurface conditions. The VES was carried out using DDR3 Resistivity meter where in the current and potential readings are displayed for calculating the resistance. The entire VESs were carried out with a maximum current electrode separation (AB/2) as 120m covering an area of 273.30 km^2

RESULTS AND DISCUSSIONS

The profiles $A-A^{1,}$ $B-B^1$, $C-C^1$ and $D-D^1$ covered the North-west to South-eastern part of the study area VES locations, which are present in Charnockites rock formation and Anorthosite rock formation respectively (Figure-2). Based on the VES data interpretation it is found that the top soil zone presents up to 1.69 m depth with the resistivity value 6-34 (< 60) Ω-m. The thickness of weathering is more than 7 m. Weathered zone thickness is found to be increased in the middle and west of the study area with the resistivity value 60-120 Ω-m, which is bearing fresh groundwater with Total Dissolved Solids (TDS) value from 100-1000 mg/l. Moreover, it is acting as a potential zone for the wells. The fractured zone was encountered in south-eastern of the study area at depth of 10 to 30m with the resistivity 120-250 Ω-m (Figure 4.5). The hard rock was found in the area at depth of above 30m.

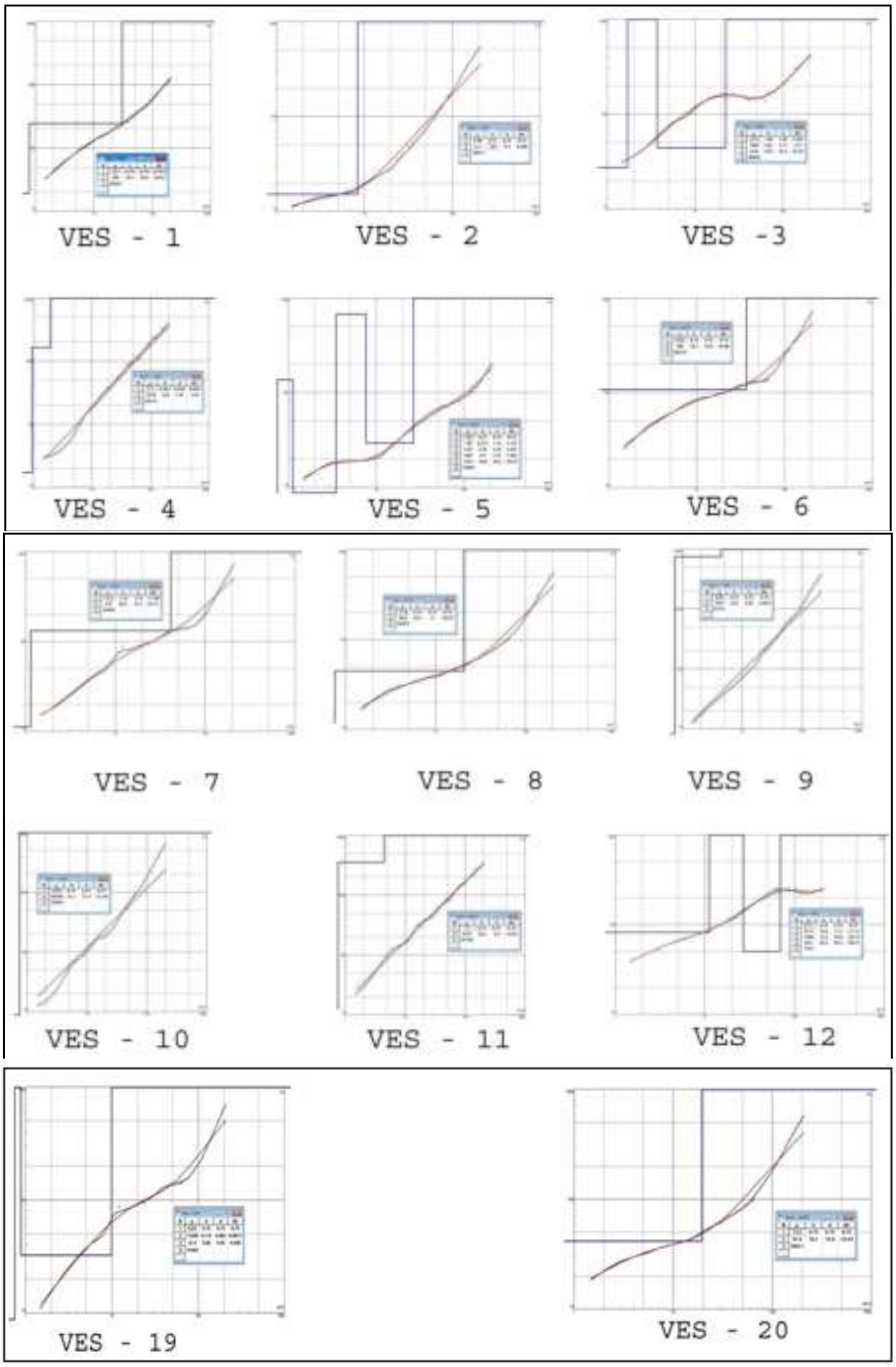


Fig-2: VES locations

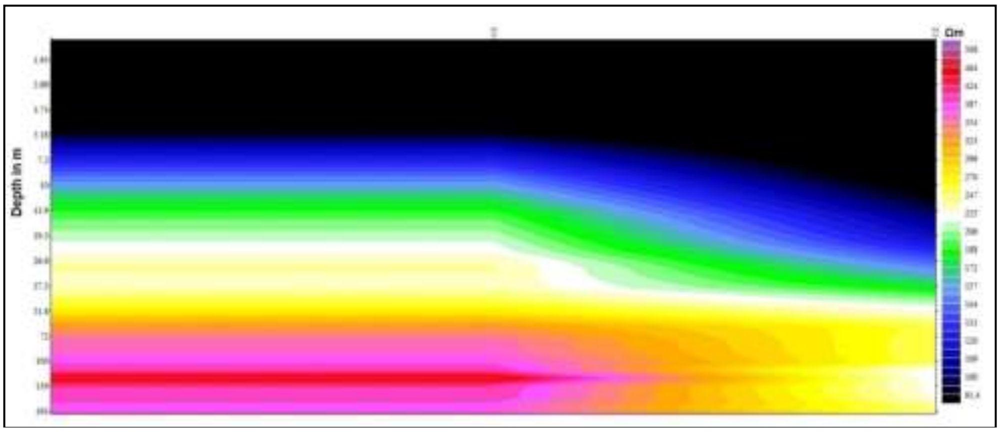


Fig-3: pseudo section of VES-1

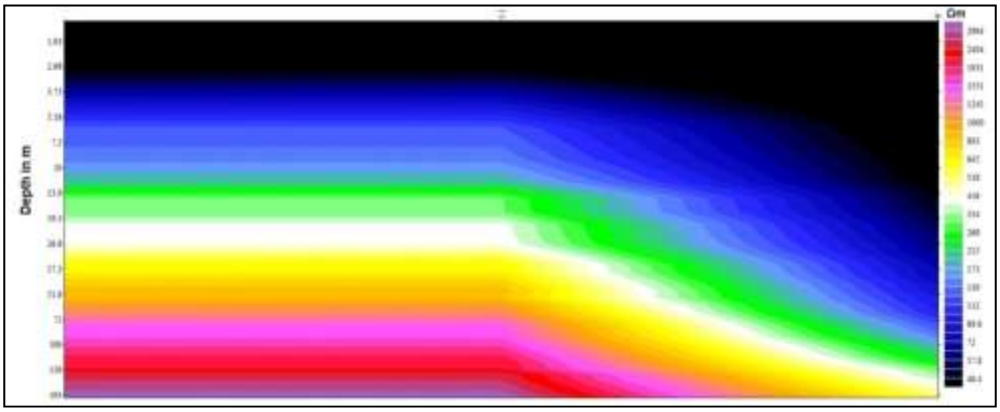


Fig-4: pseudo section of VES-2

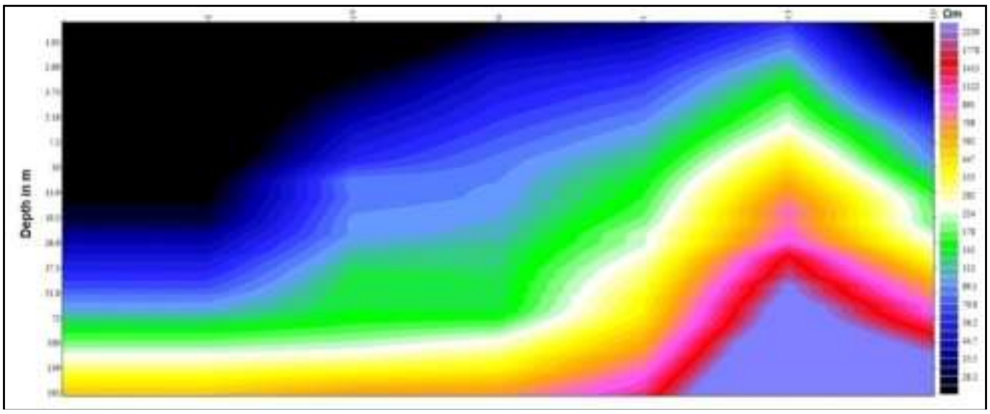


Fig-5: pseudo section of VES-3

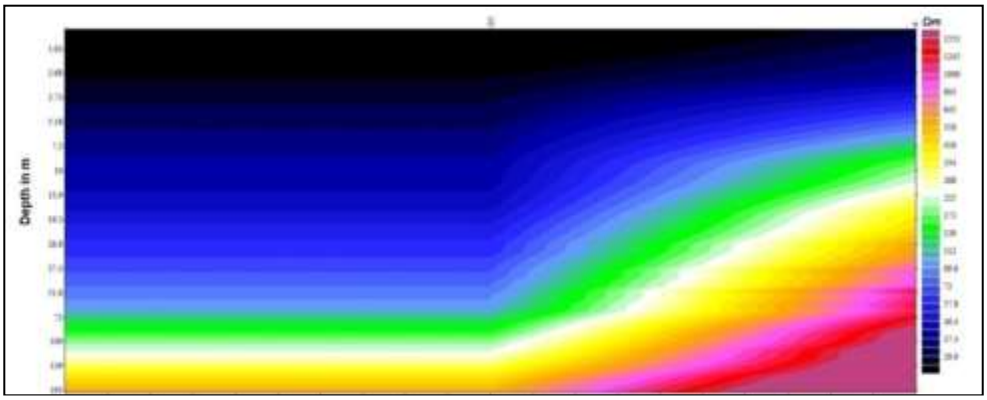


Fig-6: pseudo section of VES-4

From the pseudo section, the VES 1 & 2 covered the locations 12, 16 & 8, 11 and the weathered zone found from 0-14m thickness. VES 3 & 4 covered the locations 1, 2, 6, 10, 13, 19 & 4, 20 and the weathered zone found 0-120m. (Figure: 3 to 6).

Table-1: Interpreted layer parameters from geoelectric resistivity soundings of the study area. ρ, h and H are electrical resistivity (Ohm-m), layer thickness (m), and total thickness (m) respectively. Suffixes indicate the layer number.

VES	ρ_1 (ohm-m)	ρ_2 (ohm-m)	ρ_3 (ohm-m)	ρ_4 (ohm-m)	h_1 (m)	h_2 (m)	h_3 (m)	H (m)	CURVE TYPE
1	19.1	244	69397	-	0.792	30.5	-	31.29	A
2	9.99	15.1	18513	-	0.75	8.4	-	9.15	A
3	27.4	1464	43.8	99030	1.69	3.71	22.3	27.70	KH
4	17.1	1634	1	-	0.943	1.97		2.91	A
5	7.83	136	5.92	669	0.75	1.12	3.47	5.34	KHKH
6	16.8	108	50374	-	0.75	36.9	-	37.65	A
7	11.3	132	35494	-	1.14	41.3	-	42.44	**A**
8	11.9	44.6	25925	-	0.75	21	-	21.75	A
9	6.95	7512	67277	-	0.75	4.42	-	5.17	A
10	8.94	94188	92964	-	0.75	21.9	-	22.65	K
11	13	3547	94744	-	0.75	4.44	-	5.19	A
12	27.7	81.9	1058	50.1	0.75	11.2	26.8	38.75	AKH
13	33.7	48014	2.4	-	0.75	11.3	-	12.05	A
14	13.6	828	-	-	0.75	-	-	0.75	A
15	22.1	53331	142	771	0.75	0.826	5.52	7.10	KHA
16	13.8	76251	57.8	2935	0.75	0.8073	8.1	9.66	KHK
17	8.21	405	58623	-	0.788	24.8	-	25.59	A
18	25.3	424	2600	-	0.75	4.21	-	4.96	A
19	6.03	13508	32.4	31669	0.75	0.882	9.95	11.58	KH
20	13.5	41.6	26011	-	0.75	19.4	-	20.15	A

CONCLUSION

The VES curves show maximum of three layers and majority of the sounding curves are found as "A" type. Thirteen locations of the study region first layer thickness show around 1m and it's concluded that there is a maximum chance for landslides. Based on the VES data interpretation it is found that the top soil zones present up to 1.69 m depth with the resistivity value 6-34 (< 60) Ω-m. Weathered zone thickness is found to be increased in the middle and western part of the study area with the resistivity value 60-120 Ω-m and the thickness of weathering is more than 7m where the density of the drainage is higher in the study region. The fractured zone was encountered in the south-eastern part of the study region at depth of 10 to 30m with the resistivity 120-250 Ω-m. The hard rock was found in the region above 30m depth.

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