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Delineation of Groundwater Potential Zones through Electrical Resistivity Parameters in hard rock terrain , Osmania University Campus, Hyderabad, Telangana State, India.

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Abstract: *This study motivated to determine electrical resistivity parameters of Osmania University campus area which is underlain by granitic terrain. A total 103 Vertical Electrical Soundings were conducted with maximum electrode spacing of 150m, the results reveals four subsurface geoelectrical layers, the top soil layer of variable resisitivity value between 11.2 Ωm to 599 Ωm whose maximum thickness is 0.75 m to 8.46 m. The highly weathered second layer resistivity value varing from 1.72 Ωm to 1800 Ωm, thickness is 0.12 m to 36.6m. The third fractured layer indicated by resistivity value of 16.3 to 460 Ωm and thickness is 4.9 m to 87.4 m. The groundwater potentials of the area are evalueted based on the Longitudinal Conductance (S), Transverse Resistance (T), Coefficient of Electrical Anisotropy (λ), Resistivity for the Formation (ρ_m), Reflection Coefficient (R_c) and Resistivity Contrast (F_c), Locations where weathered layer thickness > 25 m and of a low clay content as indicated by the resistivity range < 60 Ωm value is categorized to be the area of highs groundwater potentials.*

Key words : *Coefficient of Electrical Anisotropy (λ), Longitudinal Conductance (S), Resistivity formation (ρ_m), Reflection Coefficient (R_c) and Transverse Resistance (T).*

I. Introduction

The Osmania University campus (O.U) located in Hyderabad city. After about ninty seven years of existence, the University has connected to a municipal water source but it is very meager. Recent grouth in students, new departments and staff populations has imposed significant on the existing inadequate water sources, based on groundwater abstraction from boreholes in the Osmania University campus. The foucs was to delineate the area in to groundwater potential zones in order to increase the number of bore holes in the area.

Groundwater occurance in the hard rock terrain can be vary irregular due to abrupt discontinuity in lithology, thickness and electrical properties of the over burden and weathered bed rock (Udaya Laxmi and Ramadass 2009[1]). Consequently groundwater exploraion wtihin such a geological setting needs broad geophysical data sets effectively charaterise the good acquifer zones and to enhance successful identification.

Though several geophysical methods are applicable for weathered zone studies under various geological conditions, the electrical methods are especially suited; they can quickly and cheaply demarcate the weathered zones and determine the extent of layers strata. The basic methodology of the electrical method rests on the fact that the resistivity of saturated soil is variable, depending upon on the layers resistivity and the properties of the geological formationsfor geological studies (Patangay et al., 2002[2]; Ebrahim et al.,1990[3]; De Lima et al., 1995[4]). There has been growing need and interest in the application of electrical resistivity survey any observed change in apparent resistivity is interpreted as in indication of fracture aniostrophy, which in most cases might also be produced by the presence of dipping bed or inhomogeneties or lateral changes in apparent resistivity (Hansen et al.,1996[5]; Skyernaa and Jorgensen,1993[6] and Bayewu et al., 2014[7]) have worked on the use of different array types in azimuthal resistivity surveys to characterize the electrical anisotrophy of different rock types in terms of the anisotropic parameters,viz; the direction and coefficient of electrical anisotropy (λ).

Therefore , the aim of this work is to carry out electrical investigations (VES) in chosen area to study the electrical resistivity parameters of Longitudinal Conductance (S), Transverse Resistance (T), Coefficient of Electrical Anisotropy (λ), Resistivity Formation (ρ_m), Reflection Coefficient (R_c) and Resistivity Contrast (F_c) of the surbsurface rocks in the area in order to delineate the subsurface fractures for of groundwater potential zones in the study area.

II. Study Area And Topography

The study area selected for surface geophysical surveys in the O.U campus (78^0 31′ 00″E Longitude to 78^0 32′ 30″ E Longitude and 17^0 23′ 48″N Latitude to 17^0 25′42″ N Latitude) area has on approximate 6.58

sq.kms (1627.32 acers) and lies in Hyderabad metro politon city (SOI toposheet No. 56 K/11/N-W :1:25000). The topography of the O.U campus area can be treated as undulating with a gradual relief towards N-E. The maximum elevation observed is 535m and (Fig.1) minimum elevation is 503 m with respect to mean seal level. Most of the construction of the University are on its ridges. The area in general gently slopes approximately from north to south.

III. Geology and Drainage of the Study Area

The Osmania University campus is situated in granitic terrain mainly consists of three types of granites exist–pink, grey and the leucogranites (Fig.2) (Balakrishana and Rao, 1961[8]; Sitaramayya, 1968[9], 1971[10]) and some pegmatite patches traversed by narrow white apatite veins, which intersect each other randomly. The granitic host rocks are intruded at places with dolerite dykes. The general geological section consists of a surficial soil layer underlain by weathered rock, which is in turn followed by the fractured rock at a few places. The basement, occurring at an average depth of 15 m consists of hard impervious granite.

In hard rock areas like the present granitic terrain, geomorphology, structure and weathering are the most important factors that control groundwater. Discharge areas which are normally low lying areas are believed to contain much more groundwater than recharge areas which normally coincide with ridges. This may be due to less subsurface runoff, influent seepage from upland areas, weak structural planes and thick weather mantle. The analysis of drainage network in the area also suggests suitable locations for exploration of groundwater.

Weathered disintegrated material and the fractured/jointed granitic rocks of the region are the source for groundwater accumulation. Greater the thickness of the weathered rock, greater the potentials for tapping groundwater. Similarly, greater the density of fractures⁄joints and greater the potential of subsurface water.

As is well known weathering process in a granitic area which penetrates deep causes joints, faults and other fractures because of the weight of the overlying material, and openings at great depths are large enough to supply water to wells. The narrow fractures which are more or less parallel to the surface in sheet structure which is the common feature to a granitic terrain are important sources of water.

The drainage is mostly dendritic which is characteristic of the granitic country and becomes radial at some places. The general trend of the drainage is towards the south joining the musi river. There is nallah running parallel to the road leading to Elegugutta hill, which takes many turns and finally attains north-south trend. There are three tanks in the area–Mohini Cheruvu, Landscape Garden tank and Ramanthapur Cheruvu (Fig.2). The last one falls outside the University area, which was once part of it.

IV. Geophysical Database

The study area is located in the northeastern part of Hyderabad & GHMC; Telangana covers Osmania University Campus area. This area falls in the NW quadrant of toposheet no. 56 K/11 (56K/11/NW; 1:25000 scales).

A total of 103 vertical electrical soundings (VES), Schlumberger configuration with maximum AB/2 spacing of 150m were carried out with N-S and E-W azimuth at selected locations covering the entire area in the field seasons during the period 2011 - 2014 (Fig.3).

The resistivity sounding curves obtained from the study area vary of a 3-layers A and H types which are characterizing of the basement complex terrain. The H type is the most dominant curve type in the study area with particularly curve of 46% similarly, A type 26%, 4 -layers HA, HK and KH type with percentage curve of 22%, 1% and 5% respectively. It is observed that the dominant type of curves is the A type followed by the H type. Occasionally, wherever fracture and multilayer zones present four layers. Quantitative interpretation of VES data are performed using curve matching method and inversion IPI2WIN software analysis aims at obtaining the electrical configuration of the subsurface and consisted of generation and examination of geoelectric section, resistivity contour maps, depth contour maps and contour maps of longitudinal conductance, transverse resistance, anisotropy and formation resistivity. The various components of the quantitative analysis of electrical data from the study areas are discussed in the following sections.

V. Electrical Resistivity Parameters

Six representative parameters - Longitudinal Conductance (S), Transverse Resistance (T), Coefficient of Electrical Anisotropy (λ), Resistivity for the Formation (ρ_m), Reflection Coefficient (R_c) and Resistivity Contrast (F_c) reflecting the characteristics of layered earth (Murali & Patangay, 1998[11]; Udaya Laxmi and Ramadass, 2009[1]). When the current flows parallel to the geoelectrical boundaries, the parameter that influences current flow is the longitudinal conductance (S) and when the current flows normal to the bed boundaries, the transverse resistance (T) is significant. The 'S' and 'T' values are also known as Dar Zarrouk parameters and for a layer of thickness 'h' and resistivity 'ρ', are defined as:

$$S = \sum_{i=1} \frac{h_i}{\rho_i} \quad \dots \quad (1)$$

And

$$T = \sum_{i=1} h_i \rho_i \quad \dots \quad (2)$$

When a number of layers with thicknesses of h_1, h_2, h_3, ….., transverse resistances of T_1, T_2, T_3, ….., and conductance of S_1, S_2, S_3,…. respectively, are involved in a geoelectrical section, their total longitudinal conductance (S) or total transverse resistance (T) may have to be considered (Murali and Patangay, 1998[11]) and are given by:

$$S = S_1 + S_2 + S_3 + \dots \text{ Where } S_1 = \frac{h_1}{\rho 1} \quad \dots \quad (3)$$

and

$$T = T_1 + T_2 + T_3 + \dots \text{Where } T_1 = h_1 \rho_1 \quad \dots \quad (4)$$

If the total thickness of the layers in the geoelectrical section considered is **H**, then the average longitudinal resistivity ρ_l is given by

$$\rho_l = \sum_{i=1} \frac{h_i}{S_i} \quad \dots \quad (5)$$

And the average transverse resistance ρ_t is given by

$$\rho_t = \sum_{i=1} \frac{T_i}{h_i} \quad \dots \quad (6)$$

ρ_t is always greater than ρ_l. Therefore, the entire section will thus be always anisotropic (Niwas S, Singhal DS (1981) [12]) with regard to electrical resistivity. The coefficient of electrical anisotropy is defined as

$$\lambda = \sqrt{\frac{\rho_t}{\rho_l}} \quad \dots \quad (7)$$

Where λ is always greater than 1.

A mean value of resistivity for the formation (ρ_m) can be defined as

$$\rho_m = \sqrt{\rho_t \rho_l} \quad \dots \quad (8)$$

It is well known that the resistivity of formations depends besides moisture, on the lithological content and more on the grain size for erinaceous formations. Rocks with clay content generally possess lower resistivity. For sandy rocks, the resistivity depends on the grain size increasing with the grain size. The highest resistivity values can be observed for gravels and pebbles, and lowest resistivities are observed for clay formations. Parameters λ and ρ_m have great significance in groundwater prospecting, particularly in hard rock areas where the water is present in fracture zones.

In regions of uniform geoelectric conditions, **S** is proportional to **H** (Murali and Patangay, 1998[11]). While high values of **S** are indicative of a relatively deep basement, low values of **S** are indicative of shallow basement. The basement topography is thus a mirror image of the S values.

The reflection coefficient (R_c) and resistivity contrast (F_c) of the fresh basement rock of the study area was calculated using the method of Olayinka (1996) [13], Bhattacharya and Patra (1968) [14] and Loke (1999) [15].

$$R_c = \frac{\rho_n - \rho_{n-1}}{\rho_n + \rho_{n-1}} \quad \dots \quad (9)$$

And

$$F_c = \frac{\rho_n}{\rho_{n-1}} \quad \dots \quad (10)$$

Where ρ_n is the layer resistivity of the n^{th} layer

VI. Contour Maps of Electrical Resistivity Parameters.

Variation in longitudinal unit conductance from one VES point to the other VES points indicate changes in the total thickness of low resistivity materials (Worthington, 1977[16]; Glain, 1979[17]). From Fig.4, it is seen that though the total range of longitudinal conductance in the area is 0.1 – 0.8mhos, over the major part it varies only from 0.1 - 0.2mhos. The S values are higher west of the study area of Engineering College, Ladies Hostel Complex, PGRRCDE, and north of Central Workshop and nearby Manjeera Hostel. This suggests a relatively deeper basement in these areas.

The total longitudinal conductance (**S**) is one of the geoelectrical parameter used to determine target areas of groundwater potential. S_i Values indicating relating thick succession and should be accorded the high priority in terms of groundwater potential and vice versa.

The transverse resistance values were contoured with an interval of 10 Ωm^2 (Fig.5). T values range from 5.8 – 16585Ωm^2 in the study area. While low **T** values are associated with low resistivity formations (such as clayey soil) and a relatively shallow basement large, higher **T** values are characteristic of high resistivity formations and relatively deeper occurrence of the basement. Very high transverse resistance values correspond to very highly resistive formations in the subsurface, viz., granitic dykes/intrusions with considerable strike length. In the study area low values (<550Ωm^2) are evident at Genetics Department, Behind the Ladies Hostel Complex, Ladies Hostel, New Building, CEG, adjacent to swimming pool and old Banana Garden, while higher values are apparent around Arts College, Tagore Auditorium, Swimming pool and Spot valuation building.

From transverse resistance values, it is also possible to determine the direction of flow of groundwater in the aquifer. Fig.5 shows that the flow direction of the artesian water is NW-SE. The total transverse resistance (**T**) is one of the geoelectrical parameter used to define the largest area of groundwater potential. It has a direct relation with transmisvity and the highest **T** values reflect most likely the highest transmisvity values of the aquifers or aquifer zones and vice – versa. The total transverse resistance (Eq: 2).

The coefficient of electrical anisotropy (**λ**) varies from 0.9 – 1.7 in the study area (Fig. 6). Seven low anisotropy (< 1.0) zones & six high anisotropy (> 1.0) zones characterized by elliptical patterns are discerned. These occur at O.U Police Station, Central Workshop, Professors Quarters, Old Banana Garden and Behind the Kinnera hostel are low anisotropy zones and Swimming pool, nearby Arts College, Tagore Auditorium and Behind the CEG are high anisotropy zones.

It is evident from high anisotropy, the disposition of the contour, it is inferred that in the study area, the weathered zone extends down to depth a 17m, while the joints and fractures continue up to the basement. Electrical anisotropy (**λ**) can provide some insight into the aquifer nature of the basement rock, low **λ** values less than 0.9 and resistivity contrast (F_c) (Fig.7) values less than 19 may be indicating high-density water-filled fractures. The formation resistivity values were contoured with an interval 15Ωm (Fig.8). Formation resistivity values range from 18 – 280Ωm in the study area.

The reflection coefficient ($\boldsymbol{R_c}$) map of the area is plotted and presented in Fig.9 observed that and area of lower reflection coefficient value exhibits a weathered or fractured of its basement rocks, thus, has a high water potential. It, therefore, measures the degree of fractures of an area.

VII. Evaluation of Groundwater Potential

The Groundwater potential of the area are evaluated based on the following indices: weathered layer thickness and resistivity overburden thickness, Transverse Resistance (**T**), Coefficient of Electrical anisotropy (**λ**), Reflection Coefficient ($\boldsymbol{R_c}$), Formation Resistivity ($\boldsymbol{\rho_m}$), Resistivity contrast ($\boldsymbol{F_c}$). The weathered or fracture layer constitute the water saturated zone are aquifer units. Locations where weathered layer thickness > 25m and of a low clay content as indicated by the resistivity range (< 60Ωm) value is categorized to be the area of high groundwater potentials.

The spatial distribution of the weathered layer is presented in Fig.3. From the figure it is evident that 9 VES stations (dv-14, dv-30, dv-61, dv-71, dv-77, dv-82, dv-88, dv-99 and dv-102) (in the range of 40, 60m) have high weathered layer thickness while are around 22 VES stations (dv-6, dv-7, dv-9, dv-11, dv-14, dv-15, dv-16, dv-20, dv-22, dv-33, dv-36, dv-41, dv-42, dv-43, dv-50, dv-52, dv-55, dv-59, dv-62, dv-72, dv-75 and dv-87) have very low zone (with range of 15 - 40m), that have thick over burden and low percentage of clay in which inter granular flow is nominal are known to have high groundwater potential particularly in crystalline basement complex terrain in this study area with overburden thickness > 30m such as around VES stations (dv-14, dv-15, dv-30, dv-36, dv-60, dv-61, dv-71, dv-77, dv-87, dv-88, dv-99 and dv-102) are classified as high potential zones.

Generally the electrical anisotropy is 1 and does except 2 most of the geological conditions (Zohdy et al., 1974[18]). Compact rock at shallow depth increases the electrical anisotropy. Hence, these areas can be associated with low porosity and permeability. These areas with 1.0 and < 1.5 electrical anisotropy (Figure: 3.21) values (high porosity and permeability) area considered as high groundwater potential zones. The $\boldsymbol{R_C}$ (Fig.9) and $\boldsymbol{F_C}$ (Fig.7) and also fresh basement rock interpolation can provide some insight into the aquifers nature of the basement rock. We observed that area of lower $\boldsymbol{R_C}$ values exhibits a fracture of the basement rock and hence, as higher water potentials. In the present investigations, $\boldsymbol{R_C}$ values < 0.9 – 1 of respectively may be indicative of high-density field fracture.

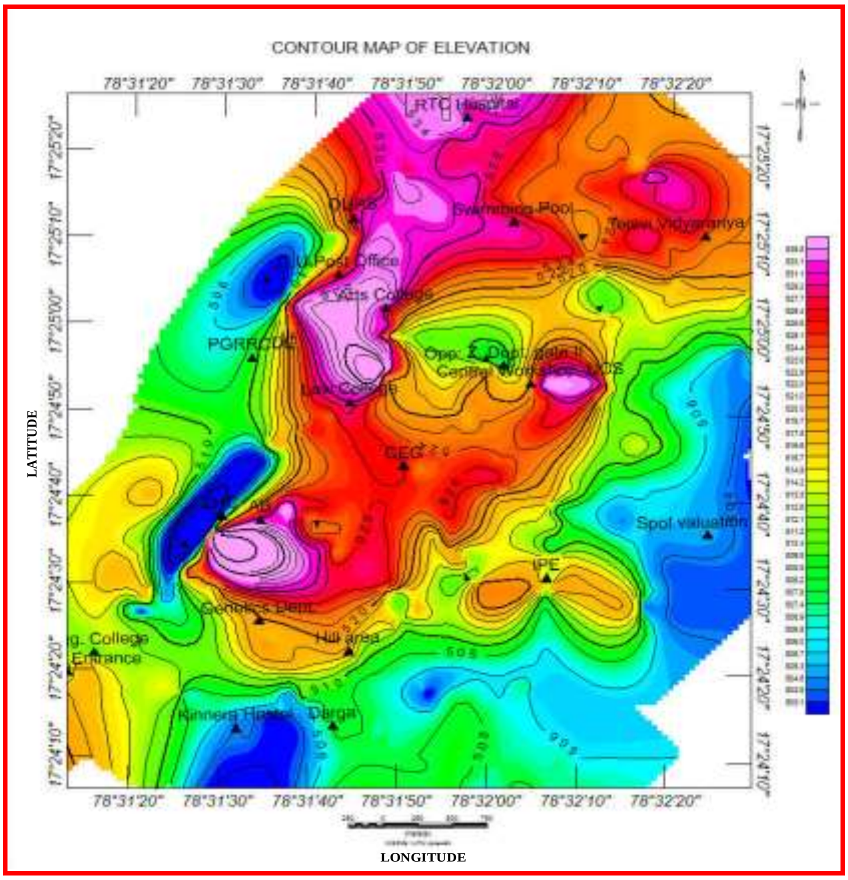

FIGURE: 1 contour map of elevation of study area Osmania University (contour interval 1.5 m)

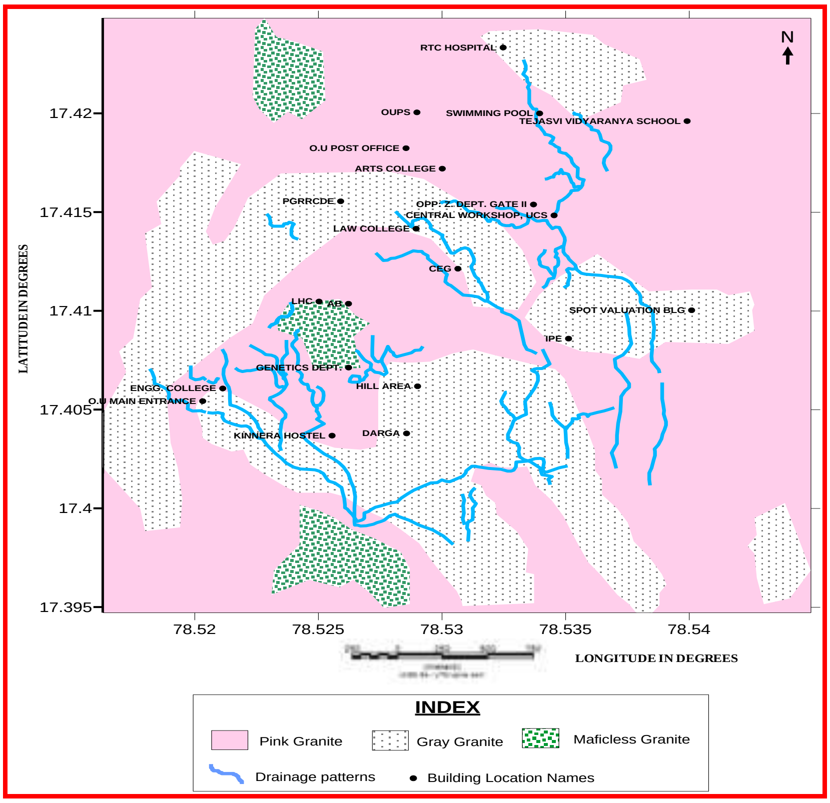

FIGURE: 2 drainage pattern and geology of the study area

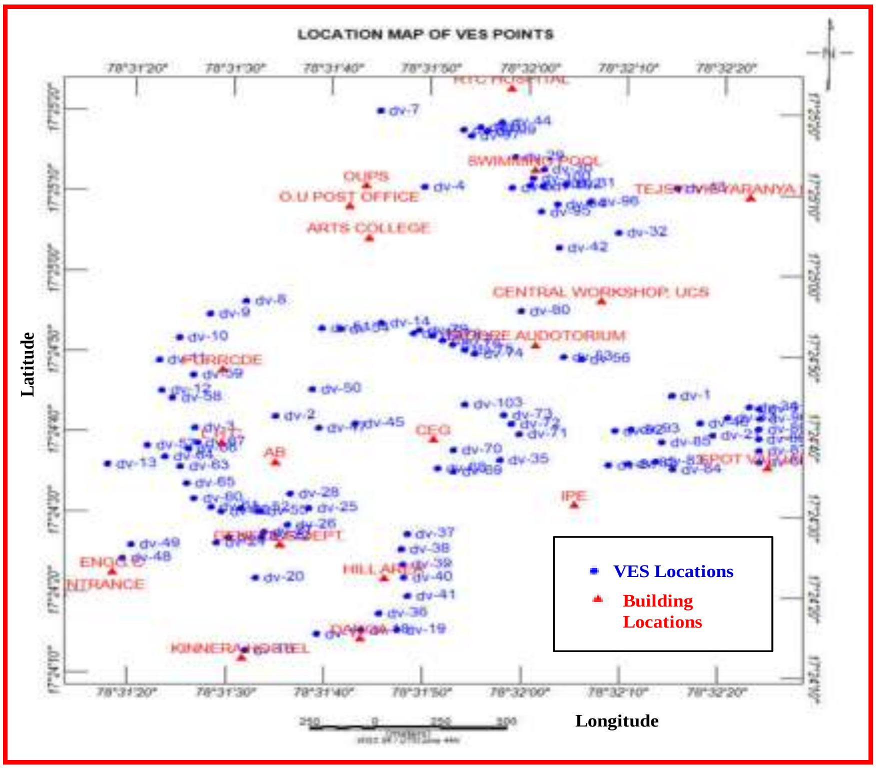

FIGURE: 3 map of locations of vertical electrical sounding (VES) points carried

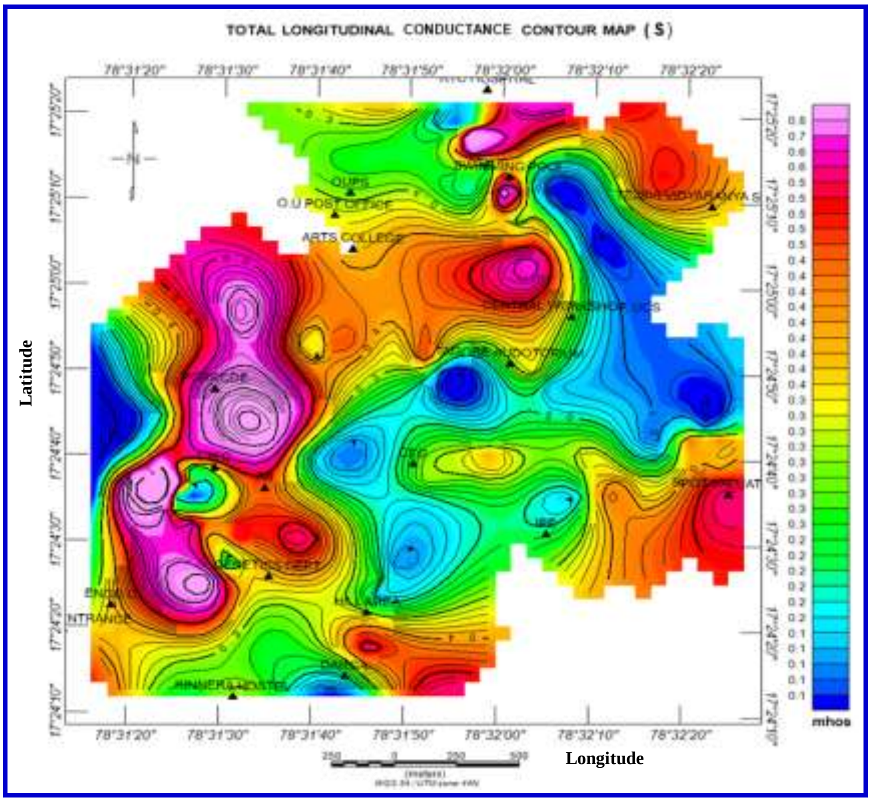

FIGURE: 4 contour map of longitudinal conductance (S) (contour interval 0.1mhos).

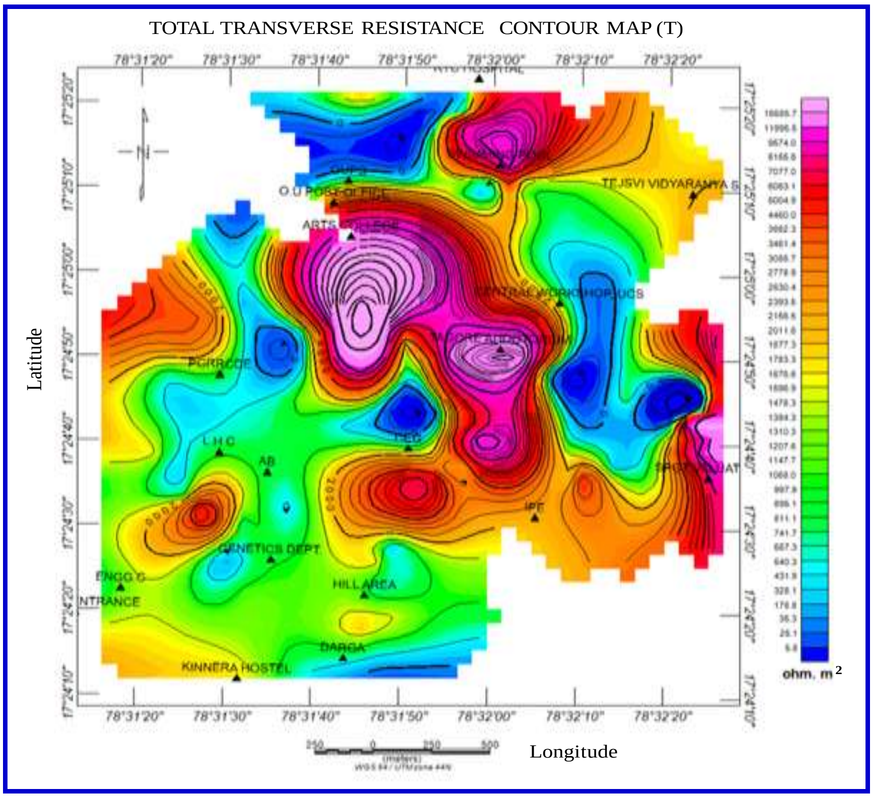

FIGURE: 5 contour map of total transverse resistance (T) (contour interval 10 Ωm^2).

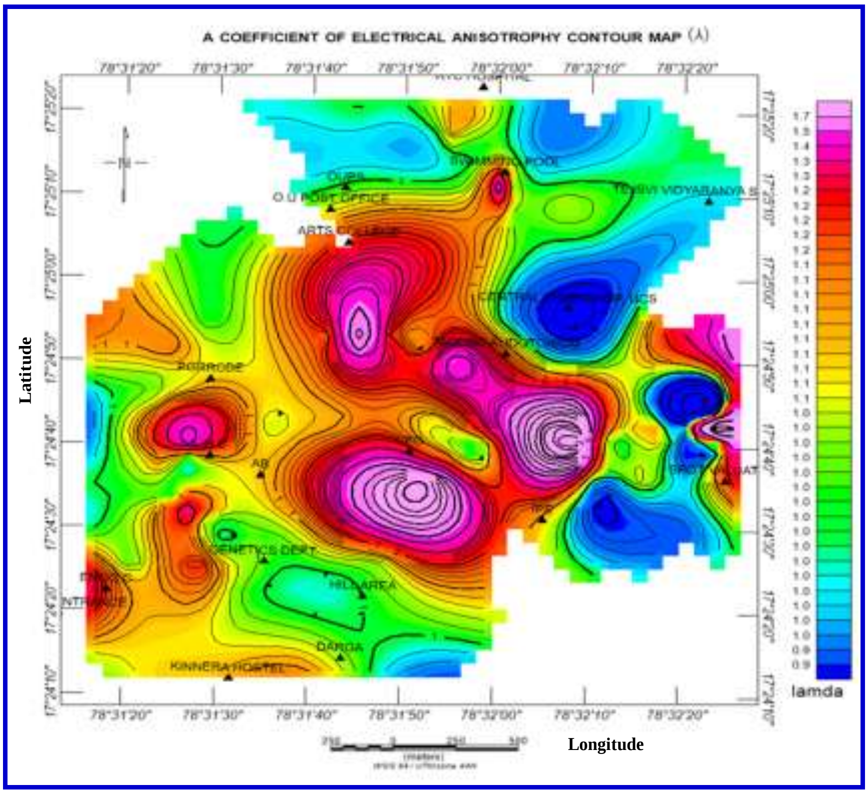

FIGURE: 6 contour map of a coefficient of electrical anisotropy (λ) (contour interval 0.1).

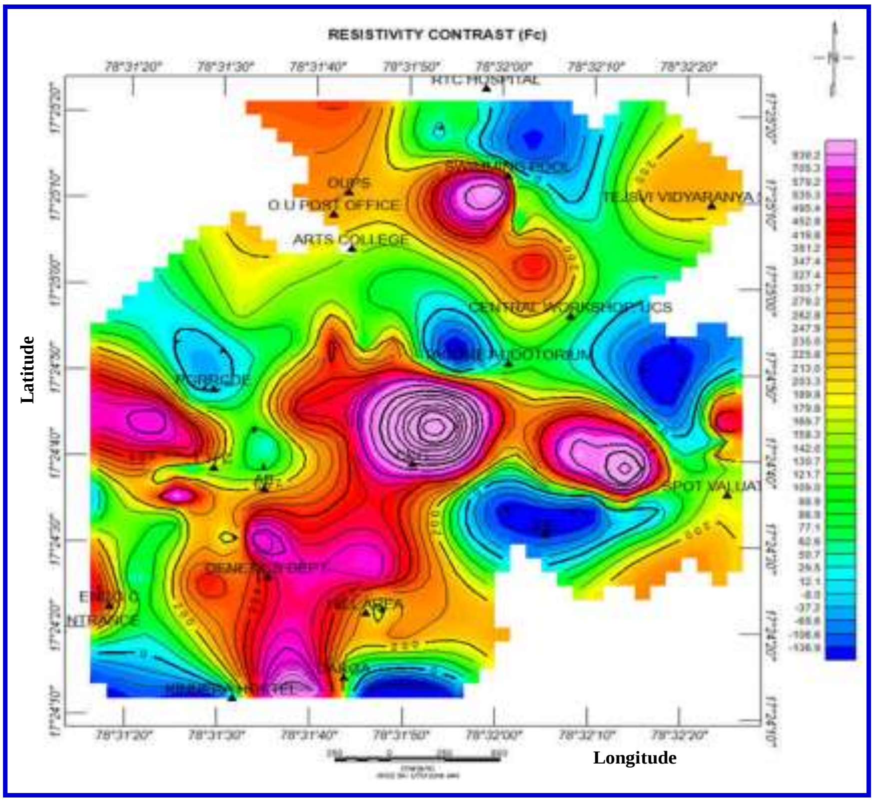

FIGURE: 7 contour map of resistivity contrast (F_C) (contour interval 10Ωm).

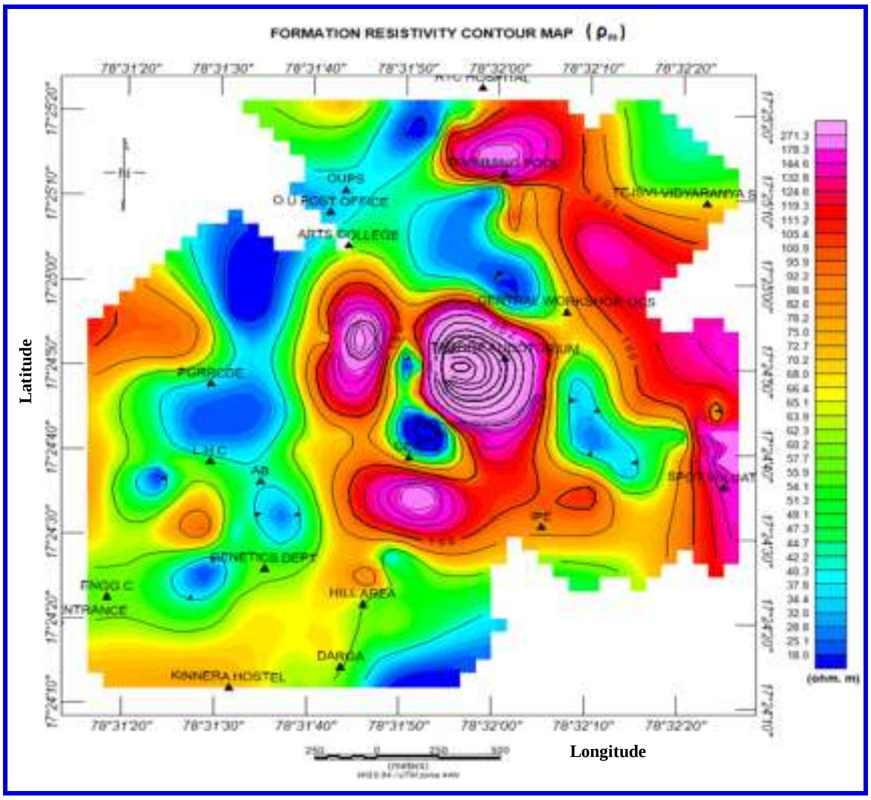

FIGURE: 8 contour map of formation resistivity (ρ_m) (contour interval 5Ωm).

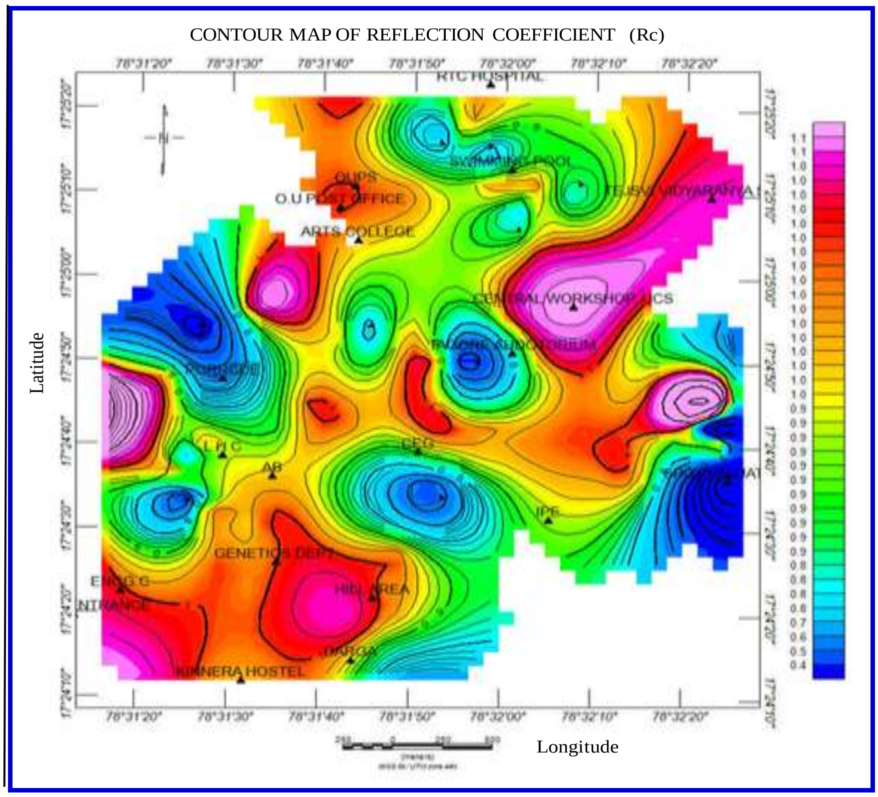

FIGURE: 9 contour map of reflection coefficient (R_C) (contour interval 0.1Ωm).

VIII. Conclusion

The total 103 VES data were used to estimate the apparent resistivity and thickness of the layers constituting the subsurface. By and large, the VES data suggested 3-layers (A and H-types) and 4-layers (HA, HK, KH) geoelectric configurations in study area O.U campus. These layers are: a first layer of topsoil (clay or clay with sand), a second layer of weathered rock, a third layer of fractured/hard rock, and the layer below the non-porous and impermeable basement that shows resistivities ranging to infinity. Typical resistivity ranges for the different lithological formations are : 11.2 - 599 Ωm for topsoil, 1.72 – 1800 - 250 Ωm for weathered rock, < 15 Ωm in the conductive zone (within the weathered layer), 16.3 - 46074 Ωm for fractured rock and > 150 Ωm for hard granites

The basement that is associated with hard rock and very high resistivities ranging to infinity. The water bearing capacity (porosity and permeability) below the basement is insignificant, the weathered and fractured rock layers constitute the main water-bearing formations and lie below the ground surface at an average depth of 10 - 25m. In study area of O.U campus, longitudinal conductance (S) varies from 0.04 to 0.3 mhos at ‘A’ ground, professor quarters, CEG, IPE, quarters behind the PGRRCDE. Over other areas, it ranges from 0.5 - 0.89 mhos. High S values at PGRRCDE and nearby Engineering College.

The transverse resistivity (T) ranges from 40 -16585 Ωm^2 in study area. Low values (< 600 Ωm^2) at EFLU, CEG, Maneru Hostel, Kinnera Hostel and high values over other areas of Arts College and Tagore Auditorium are a reflection of the depth to basement with higher values indicating relatively deeper basement and lower values, a shallow basement. The elliptical contours in the map of the coefficient of anisotropy indicate the fracture directions/weathered zones in the study area.

It is well known that the resistivity of formations depends besides moisture, on the lithological content and more on the grain size for erinaceous formations. Rocks with clay content generally possess lower resistivity (0 - 1.0 Ωm). For sandy rocks, the resistivity (1.0 - 1. Ωm) depends on the grain size increasing with the grain size. The highest resistivity values (1.2 - 1.7 Ωm) can be observed for gravels and pebbles, and lowest resistivities are observed for clay formations. Parameters λ and ρ_m have great significance in groundwater prospecting, particularly in hard rock areas where the water is present in fracture zones.

The R_C and F_C also fresh basement rock interpretation can provide some insight into the aquifers nature of the basement rock. We observed that area of lower R_C values exhibits a fracture of the basement rock and hence, as higher water potentials. In the present investigations $R_C$values (< 0.9 – 1 Ωm) of respectively may be indicative of high-density field fracture.

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