ELECTRICAL RESISTIVITY DATA INTERPRETATION FOR GROUNDWATER DETECTION IN TITTAGUDI TALUK OF CUDDALORE DISTRICT, TAMIL NADU, INDIA

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Abstract

The present study aims to detect the groundwater potential in Tittagudi Taluk of Cuddalore District, Tamil Nadu, India using electrical measurement. Electric resistivity data interpretation was carried out using Schlumberger configuration with electrode spacing (AB/2) of 100 m distance. The VES was calculated by multiplying the resistance by constant obtained from the Schlumberger formula. The resistivity curves were analysed with curve matching techniques along with the help of computer programme. The sub-surface lithology was evaluated and correlated with the available borehole data. The results of quantitative interpretation of geoelectrical data indicated that the layer system having minimum of two layers to a maximum of eight layers in the area. The low and high resistivities obtained are ranging from 0.5 to 27755 ohm/m respectively. Majority of resistivity curves are falling in 'A' type. The contact zone of sedimentary and crystalline rock formations are clearly delineated on Northeast to Southwest directions along Sirumangalam, Agaram and Sirumalai habitations. The prominent low resistivity anomaly observed in and around Adari area (VES. 03), this have been encountered in all the iso-resistivity contour maps, indicating that, a trend of structural elements like a weaker zone or lineament or fracture occurred in NE direction of the study area which may be a favorable zone for targeting groundwater.

Key words: *Electrical Measurements, Tittagudi Taluk, Schulmberger Configuration And Iso-Resistivity Maps.*

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1. INTRODUCTION

The atmosphere and earth's physics is known as geophysics. The investigation of the physical properties of the earth is termed as geophysical exploration and it is used as one of the tool in understanding the groundwater occurrence in the womb of mother earth. Geophysics is highly helpful in assessing the groundwater potentiality of geological formations, estimated weathered zone thickness and bedrock topography, fractures in hard rock terrain, delineate resistive granular zones in sedimentaries and paleochannels and asses quality of groundwater. Geophysical study in groundwater investigation involves two stages; i) deep exploration and ii) shallow exploration. In deeper exploration, the exploring depths beyond the weathered zone of 100 or 200 m thickness in hard rocks where as in shallow exploration, the exploring depth is 20 to 30 m thickness. Different authors used different geophysical tools such as resistivity and magnetism for groundwater exploration [1]. One of the geophysical methods employed in the groundwater exploration is the electrical resistivity method. This method is used in groundwater prospecting for its efficiency in detecting the water bearing parameters, and its aerial extension, electrical conduction attributable to pressure of the interstitial water in pores and its chemical quality. This method can differentiate between unsaturated and saturated formation, brackish and saline nature of water. This electrical resistivity method has its ability to determine depth, thickness of the layers and lithology as geo-electrical layers. The resistivity methods are based on the measurement of resistivity of ground after passing an electric current into the Earth. For a metallic conductor, such as a copper rod, the resistance varies directly to the length and inversely to the cross-section and its specific resistance is given by the formulae: $R=\rho^{L}/_{A}$ (A = area of cross section and L = length of the rod). The resistivity determined in this case will be true resistivity of copper, if the rod is pure copper metal. In the case of the earth, the conduction is mostly electrolytic. The resistivity determined will be true resistivity, if the ground is homogeneous and isotropic. Usually, the ground is constituted of various materials and there may be some variation in vertical and lateral dimension and the resistivity determined is called as *apparent resistivity*. In the resistivity method, a known amount of electrical current is sent into the ground by a pair of electrodes and the potentials developed due to current between these electrodes are measured by placing another pair of electrodes present between them. Multiplication of the ratio of the developed potential difference to current input with, geometric factor of electrode configuration gives apparent resistivity of the homogeneous ground.

2. LOCATION OF THE STUDY AREA

The present study area Tittagudi Taluk falls in Cuddalore District, Tamil Nadu, S.India (Location map shown in

Figure 1). The study area lies between the latitudes North 11°22'03" to 11°36'29" and the longitudes East 78°52'42" to 79°18'59" in the Survey of India toposheet No. 58M/2, 58M/3, 58I/14 and 58I/15. The study area occupies an areal extent of about 615 sq.km and the relief ranges from 62 to 121 m above MSL. The study area receives an average rainfall of 1100 mm with more than 80% of the rainfall received during the NE monsoon. The minimum and maximum temperature ranges between 20°C and 34°C in the month of January and May respectively. River Vellar flows in the Southern part of the study area. Geomorphologically the area consists of old flood plains, pediments, duricrust and pediments covered by forest land [2].

3. GEOLOGY AND HYDROGEOLOGY

The study area comprises both crystalline and sedimentary formations. The crystalline rock formations comprise 2/3rd portion of the study area. The intermediate contact zone is stretching in between these two terrains. The study area rocks belong to early to mid Precambrian period represented by charnockite, charnockitic gneiss, granitoidal gneiss and migmatites indicating the oldest and subjected to granulite facies of metamorphism. The charnockites are intermediate to acid in composition, coarse to medium grained and form the high land topography. The charnockitic rocks are massive to foliate and the foliations usually trending ENE–WSW with an average dip of 45° towards South. The charnockite shows different depth of weathered zone. Eastern part of the study area is occupied by Quaternary formations represented by semi-consolidated sand, sandstone and clays. Inliers of limestone with calcareous clays of cretaceous age are noticed in few locations. In the study area groundwater occurs under water table conditions in the joints, fractures and weathered rocks. Generally, the charnockite of the study area is highly massive and compact and devoid of joints and fractures making it impervious, which in turn result in poor potential. The open wells give better yield than bore wells. Geology map of the study area is shown in Figure 2.

4. MATERIALS AND METHODOLOGY

The vertical electrical sounding (VES) measurements were carried out in thirty locations of the study area (Figure 3) by using an Indian electronic compensator, Microprocessor based signal stacking digital resistivity meter Model – SSR-MP-AT-S. The well known Schlumberger configuration of electrode separation spacing AB/2 of 100m as maximum was used for measuring VES.

The resistivity curves of thirty VES locations were analysed and interpreted with the help of curve matching techniques using the Master curves by [3]. The apparent resistivity curves were drawn on the log-log paper and superposed over the particular set of master curves fixed on the hard board. The fitting curve is found by shifting the curve horizontally and vertically parallel to the axis. The values of the resistivity (ρ) and the thickness (h) of the first layer from the graph, and the resistivity of the second bed were calculated.
Then combining the resistivities and estimated thickness of the first two layers, a hypothetical single layer, an auxiliary curve is drawn and the lower part of the field curve relating to the larger electrode separation may be matched with the relevant family of theoretical curves. By this means, the resistivity and depth to the third layer may be determined. According to [4] the thickness and resistivities of the second, third and fourth layers determined from the ρ_2 / ρ_1, ρ_3 / ρ_1, ρ_4 / ρ_1 and h_2 / h_1, h_3 / h_1 and h_4 / h_1 ratios were given on the type curves.
In the present study, the analytical method was carried out using a computer program *RESIST 87* developed by [5]. First, the surveyed resistivity data were analyzed manually, and the obtained results of the manual interpretation were used as initial models for the analytical methods required for the computer software. This software program has been used to match the model curve with observed field data. The sub-surface lithology was evaluated and correlated with the available borehole data.

5. RESULT AND DISCUSSION

There are two types of interpretation methods to analyse the resistivity data. One such method is qualitative method, which include resistivity profiling, iso-resistivity contour and different resistivity curve patterns. Another method is quantitative method based on curve matching method and computerised interpretation methods.
The geoelectrical data is representing the layer system having minimum of two layers to a maximum of eight layers in the area. The minimum and maximum resistivities obtained are ranging from 0.5 to 27755 ohm/m (Table 1).

Table -1: Geoelectrical data of Tittagudi Taluk

VES No	VES Location	Resistivity (ohm.m)					Apparent Resistivity (ohm.m)				
		ρ1	ρ2	ρ3	ρ4	ρ5	-10m	-20m	-40m	-60m	-80m
1	Ja.Endal	24	90.4	517.7	517.4		68.05	136.5	243	349.5	406.94
2	Rettakuruchi	22.6	125.1	1711.3	326.1		50.45	72.28	91.54	113.46	142.5
3	Adari	7.8	385.8	2775.5	93.3		1.5	2.25	3.64	3.86	4.78
4	S.Naraiyur	13.3	188.5	456	813.9		51.06	87.82	176.17	261.06	294.9
5	Sirupakkam	10.4	178.8	309.5	319.5		37.33	79.64	124.31	159.2	244.2
6	Kaluthur	18.2	387	1012.4	117.5		145.33	175.62	236.95	250.37	286.08

7	Paniyandur	75.2	154.2	38.6	371.5		55.4	100	135.5	158.2	168.5
8	Mangalur	75.9	471.9	714.6	1908.2		20	39.62	74.59	88.48	110.1
9	Pullur	99.3	347.9	214			28	38.45	68.31	108.85	142.66
10	Sirumangalam	0.8	28.3	6.2	18.3	30.7	15.6	38.3	79.2	83.4	186.54
11	Lakshmanapuram	45.5	76.5	97.8	281	408.1	140	142.76	158.25	175.1	192.24
12	Orangur	14	232.8	41.1			81.17	76.04	113.9	157.79	199.25
13	Avatti	8.9	264.5	226.8	339.9	355.2	119.27	175	205.75	250	236
14	Agaram	12	98.2	202.5	468.3	1084.9	17.05	33.28	65.1	99.26	129.86
15	Narasigamangalam	0.8	25.3	194.6	4.5	73.1	7.8	16.4	34.8	73.25	76.8
16	Tivalur	1.2	3.9	8.4			1.5	1.7	2.5	2.9	3.35
17	Meladananur	4.7	112.2	183.3	594.5	183.3	114.63	169.24	265.49	274.04	265.16
18	Melur	1.4	28.1	2591.7			2	3	5.74	7.8	12
19	Vadakarampundi	118.9	38.3	146.5	378.3	2591	53.5	64.9	93.5	123.2	162.2
20	Thachchur	2.4	82.3	929.3	101.8	675.8	56.8	75.7	112.9	99.24	93.7
21	Adamangalam	12.9	3.9	228	7.1		8.26	8.85	16.94	25	30.05
22	Kilnemili	4.9	36.1	10.3	67.7	13.9	5.63	5.82	6.18	6.9	7.9
23	Mosatti	7.6	72.9	0.5	23.4	1	10.2	17.2	19	12.7	8
24	T.Endal	12	251				18.43	33.56	68.88	95	124.5
25	Sirumalai	8.4	18.5	2370.8	68.3	198.6	5.5	12.22	19.35	27.74	32.7
26	Tholudur	17.2	62.8	114.6	489.2	45.4	98.52	72.6	95	125.02	140.71
27	Pennadam	11.1	151.5	10.6			20.96	33.97	55.68	55.3	56.05
28	Tiitagudi	17.9	99.4	2712.8	44.2		12.31	19.63	33.27	42.9	55.79
29	Neyvasal	17.9	89.4	712.8	44.2		30.01	49.05	80	134.2	157.2
30	Semberi	19.3	4.7	4.1	80.8	17.3	20.99	12.99	9	11.15	12.73

5.1 Qualitative Method

5.1.1 Schlumberger Apparent Resistivity Type Curves

The resistivity curve pattern depends upon the electrical conductivity of sub-surface formations. The whole set of three-layer-sounding curves can be divided into four groups, depending on the relative values of ρ_1, ρ_2, ρ_3.

1) Minimum type: when $\rho_1 > \rho_2 < \rho_3$ High – low – high, referred to as *H - type.*

2) Double ascending type: when $\rho_1 < \rho_2 < \rho_3$ Low – low – high, known as *A - type.*

3) Maximum type: $\rho_1 < \rho_2 < \rho_3$ Low – high – low, known as *K - type.*

4) Double descending type: when $\rho_1 > \rho_2 > \rho_3$ High – low – low, known as *Q - type*. The VES resistivity curve types observed in the study area is shown in Table.2.

Table -2: Study area VES curve types

VES No	VES Location	Curve types	VES No	VES Location	Curve types
1	Ja.Endal	AQ	16	Tivalur	A
2	Rettakuruchi	A	17	Mel Adananur	A
3	Adari	A	18	Melur	A
4	S.Naraiyur	AQ	19	Vadakaranpundi	A
5	Sirupakkam	A	20	Thachchur	AQ
6	Kaluthur	A	21	Adamangalam	A
7	Paniyandur	AQ	22	Kilnemili	A
8	Mangalur	A	23	Mosatti	AQ

9	Pullur	AQ	24	T.Endal	A
10	Sirumangalam	A	25	Sirumalai	A
11	Lakshmanapuram	K	26	Tholudur	QA
12	Orangur	A	27	Pennadam	K
13	Avatti	A	28	Tiitagudi	A
14	Agaram	A	29	Neyvasal	AQ
15	Narasingamangalam	A	30	Semberi	H

5.2 Iso-Resistivity Maps

The iso-resistivity values are drawn for the depth of 10m, 20m, 40m, 60m and 80m selected along X, Y coordinates of the locations. The iso-resistivity maps are prepared by using surfer software incorporating all the thirty VES data in the study area. These resistivity contours were helpful in delineating the lateral variation in the sub-surface geology of the area. Low resistivity denotes good conductors and high resistivity values are poor conductors.

5.2.1 Iso-Resistivity At 10 Meter Depth

The Figure 4 shows the iso-resistivity values at the depth of 10m. This map mainly represented the top soil zone and to a certain extent of shallow weathered zone. The resistivity value ranges from 1.5 to 145.3 ohm/m. The low resistivity of 50 Ωm is mainly encountered in the Eastern side of the study area and it generally increases to 100 Ωm in the Western side. There is a patch of high resistivity zone noticed in and around the Kaludur, Avatti, and Meladanur area. The transition from sedimentary rocks in the Eastern side to hard rock in the West. Northern and Southern parts are represented by variation in resistivity. The good conductive low resistivity are indicative of sedimentary rocks underlined by clay, fine, medium and coarse sands. The poor conductive high resistivities are well marked in the Western and Southwestern parts. The low resistivity zones present on the Eastern and Southern sides are indicative of weathering to certain extent and it is thinning down in central portion of the study area.

5.2.2 Iso-Resistivity At 20 Meter Depth

The Figure 5 represents the iso-resistivity values at the depth of 20m. The resistivity ranges from 1.7 to175.6 Ωm. The sharp boundary between the sedimentary and hard rock is well illustrated and the low resistivity zone of 0-25 Ωm is conspicuously absent in the hard rock zone. The charnockitic rocks have shown two distinct types of resistivity zones upto 10m depth by the presence of weathered zone and show only uniform range of resistivity upto 20m depth with same type of composition in spatial distribution. The high resistivity of more than 100 Ωm is registered in and around Kaluthur, Avatti, and Meladanur areas. In the Northeastern part of the study area, high resistivity migmatite gneiss is present and within this, a very low resistivity enclave of 10 to 25 Ωm zone is noted in and around Adari.

5.2.3 Iso-Resistivity At 40 Meter Depth

The Figure 6 illustrates the iso-resistivity values at the depth of 40m, the resistivity ranges from 2.5 to 265.5 Ωm. The high resistivity zone of 100 - 200 Ωm found in and around Kaluthur, Avatti, and Meladanur and changed over to the lesser resistivity 10 to 25 Ωm in the 40m depth range. When we go deeper from 20m to 40m depth vertically, the area around these habitations contains a good conductive zone favourable for targeting aquifers in the charnockite belt of the study area. The very low resistivity zone of Adari is well registered in this particular depth. The high resistivity of 100 to 200 Ωm range, are prominent in the Northwestern part of the study area. A well-marked moderate resistivity zone of 50-100 Ωm is represented around VES no. 8 and 2. The slope in the study area is from NNW to SSE, and the elevation is declining towards Tittagudi, Agaram, and Sirumangalam regions. Similar the resistivity is higher on the NNW part of the study area (i.e. Lakshmanapuram, Paniyandur and S. Naraiyur habitations), and gradually decreases towards SSW part (i.e. Avatti, T.Endal, Meladanur and Pullur) habitations.

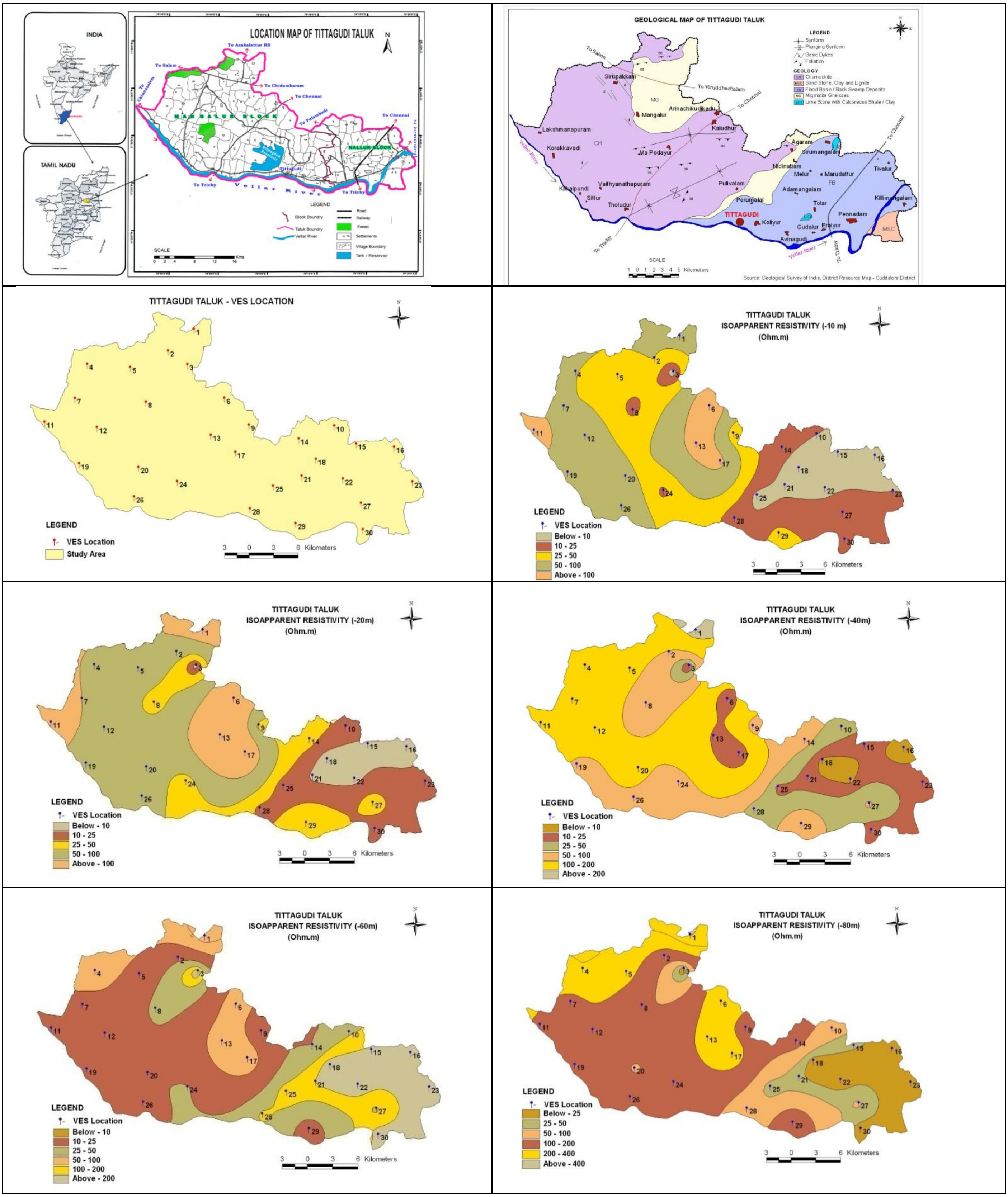
5.2.4 Iso-Resistivity At 60 Meter Depth

The Figure 7 accounts for the iso-resistivity values at the depth of 60m. The resistivity ranges from 2.9 to 349.5 Ωm. The very high resistivity of 200 to 300 Ωm is well marked once again, in the places in and around Kaluthur, Avatti and Meladanur. The very high resistivity value of 300 Ωm is registered near Ja.Endal, on the Northern part of the study area. This high resistivity is uniform and same at the depth of 20 and 40m. The very high resistivity clearly indicates that the rock types present beneath i.e., migmatite gneiss and the boundary between migmatite gneiss and charnockite portion with lesser resistivity is clearly illustrated by the iso-resistivity contours of 20, 40, and 60m depth. It noticeably indicates that a weaker zone of structural importance (?) of minor extent is possibly present in that area.

It is evident from the iso resistivity map of 60 m depth, that the Eastern most part of the study area, where the sedimentary rocks are prevalent and the lithology of the borehole data also indicates the maximum thickness of sediments (clay, fine, medium and coarse sand) which is also clearly indicated with the low resistivity of 25 Ωm. The sediments of moderate thickness are virtually portrayed in the Narasingamangalam, Tivalur, Mosatti, Kilnemeli, Adamangalam, and Semberi areas. The resistivity values below 25 Ωm in the extreme East-Southeast region, clearly indicates the back swamp deposits of sedimentary origin.

5.2.5 Iso-Resistivity At 80 Meter Depth

The Figure 8 exhibits iso-resistivity values at the depth of 80m. The resistivity ranges from 3.4 to 407 Ωm. The sedimentary portion of the iso-resistivity curves at 80m shows the similarity of contours at the 60m depth. The same is the case with the hard rock area except the Southern most part, where the resistivity range is 50-100 Ωm. The low resistivity zone encountered at shallow depth of Adari is present once again in this depth without any deviation. The hard massive charnockite with resistivity range of 200- 400 Ωm is prevalent in and around Kaluthur, Avatti and Meladanur, habitations. The very same formation also continues around Ja.Endal, Sirupakkam, and S.Naraiyur.



5. CONCLUSION

Based on the detailed geophysical investigations in the study area the following deliberations were made:

1. The East, Northeast and Southeast areas are represented by low resistivity contours in the range of 10 to 100 Ωm, indicating porous sedimentary formations.
2. The West, Northwest and Southwest areas are represented by high resistivity contours in the range of 100 to 400 Ωm indicating crystalline formations.
3. The contact zone of sedimentary and crystalline rock formations are clearly delineated on Northeast to Southwest directions along Sirumangalam, Agaram and Sirumalai habitations.
4. Majority of resistivity curves are falling in 'A' type.
5. The prominent low resistivity anomalies observed in and around Adari area (VES. 03), have been represented in all the iso-resistivity contour maps, indicating a weaker zone or lineament. (Northeasterly oriented fracture may be a favorable zone for targeting groundwater).
6. Another low resistivity anomaly represented in the regions of Kaluthur (VES .06), Avatti (VES.13) and Meladanur (VES. 17) may be a good fractured zone at a depth of 40m bgl sandwitched between two high resistivity layers, indicating a feasible zone for groundwater prospecting.

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