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Aquifer Mapping using VES Augmented by Dar Zarrouk Method in Thirukkazhukundram Block, Tamil Nadu, India

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***Abstract*— The knowledge base of aquifer disposition and characteristics form input to evolve an effective and sustainable plan to manage groundwater resources. This research paper explains how the Hydro-geological and hydro-geophysical aspect of the Thirukkazhukundram block has helped in successfully demarcating the shallow and deep Aquifers. 30 Vertical Electrical Soundings(VES) were conducted using Schlumberger array. The data was analyzed by curve matching method and pseudo-resistivity maps were prepared using 'IPI2Win' Software. 12 curve types are an additional proof. This VES technique with Dar Zarrouk and Aquifer anisotropy parameters estimation is best in identifying shallow and deep aquifer which is of mammoth use to water-related supervisors, planners and other academicians in the field of groundwater resources management.**

***Keywords* — Aquifer, VES, Schlumberger array, IPI2WIN, Dar Zarrouk parameters.**

I. INTRODUCTION

On account of the growing population, the groundwater exploitation shows a constant increase in proportion with the demanding domestic, agricultural and industrial activities.VES survey by Schlumberger method which is the quickest, simplest and highly economical means with relatively better resolving-powers, simplified interpretational procedures efficiently yielding good results was carried out in Thirukkazhukundram Block to delineate the Aquifers(Zhody et al 1974, Ako and Olorunfemi 1989,Ekine and Osobonye 1996).

II. STUDY AREA

Thirukkazhukundram coastal block in Kanchipuram district, Tamil Nadu, South India(fig.1) with an areal extent of 352.82 km^2 is categorized as semi-critical area(CGWB, 2010) and engulfed by Bay of Bengal in the East, Maduranthagam in the West, Kattankolathur, Thiruporur in the North and Lattur in the South. It lies between Latitudes 12˚00"N and 12˚10"N and Longitudes 80˚00"E and 80˚100"E. From the Survey of India, the toposheet nos. of Thirukkazhukundram block are 66 D/2,66 D/3 and 66 D/6.

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III. GEOLOGY, GEOMORPHOLOGY AND HYDROGEOLOGY

The geology of the entire study area includes the recent alluvium followed by Pleistoceand crystalline rocks(charnockite or gneiss).The Lithography of alluvium and beach sands is sand-gravel-silt-clay and that of Pleistocene are laterites-sandy-clay-silt followed by the Archaean age lithology which is the mixed gneisses-charnockites.

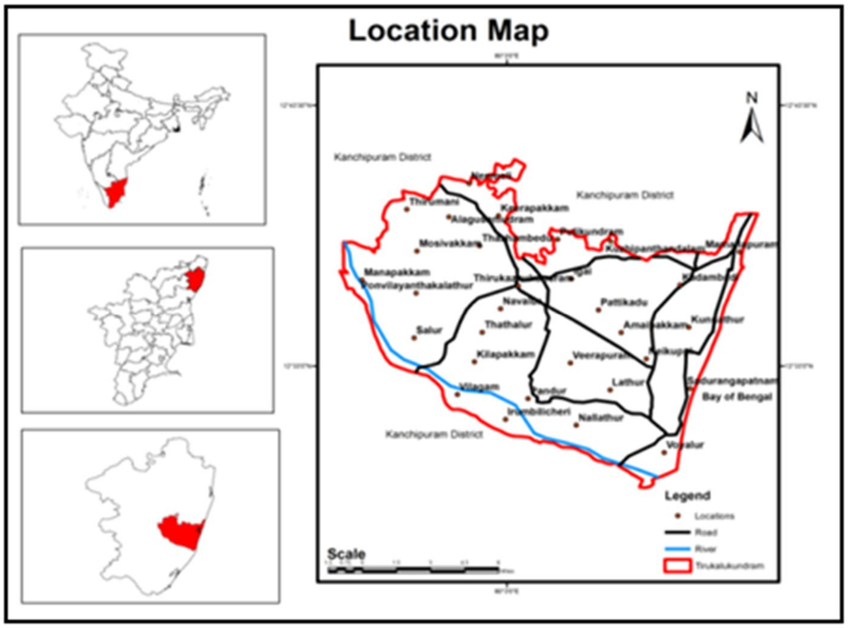

Figure.1:LocationmapofThirukkazhukudramBlock

IV. METHODOLOGY

Base map was prepared with VES at locations based on SOI Toposheet in 1:50,000 scale by using ArcGIS.VES was carried out at 30 locations with CRM 500 Aquameter using Schlumberger configuration.VES locations are named as S1,S2,etc.Maximum electrode spacing was taken as 100 m. The current electrode spacing varied from 1 to 100 m.The field data was collected, analyzed and interpreted by curve matching method with 5% error limitation (Fig.3).Inversion technique in IPI2win Software was used to determine the true resistivity from the apparent resistivity and thickness parameters. Hence delineation of the thematic maps for different geo-electric layers and geo-electrical Images has been prepared.

V. RESULTS AND DISCUSSIONS

Based on the interpretation of VES data from 30 locations, it is inferred that the subsurface is made up of 4 to 5 layers and characterized by 12 different curve types(Table2)(Rijkwaterstata1966,Orellana, andMooney 1966).Representative resistivity values are shown in(Table1).Qualitative analysis of the curve types shows that the H type curve is the most seen in the study area which indicates high resistivity values followed by weathered formation of low resistivity with successive hard crystalline basement. QH curve type at Thirumani(S2), KH curve type at Kunnathur(S20)and HK curve type at Pandur(S25) reveal the presence of shallow Aquifers.HA curve type at Alagusamudram(S3)and Kadambadi(S15) infers the deep aquifer occurrence.Shallow as well as deep aquifers at various depths seen at Nenmeli(S1), Manapakkam(S7), Ponvilayanthakalathur(S25),Neikuppi(S23) are confirmed by KQH curve type.In Keerapakkam(S4),Thazhambedu(S6),Thirukkazhukundram(S12),Amaipakkam(S19),Lattur(S27),Irumbilicheri(S28) KHA Curve type occurs which infer saturated lithology. The presence of deeper saturation zone at Mosivakkam(S5),Pulikundram(S9),Thathalur(S18),Veerapuram(S21),Kilapakkam(S22), Vilagam(S24), Sadurangapatnam(S26)is con firmed by QHA curve type. Kuzhipanthanda lam(S8), Navalur(S14), Pattikadu(S7), Nallathur(S29)has HAA curve type which indicates saturation zone at slightly deeper horizons. The appearance of the shallow water table at Mamallapuram(S10) is revealed by AKQ type curve.

Igai(S13) and Salur(S16) show QQH and KHK curve type respectively which reveal aquifers presence. AKH curve type at Voyalur(S30) indicates deep aquifer presence.

Table I: Representative Resistivity Values of Regional Soil Resistivities(After Mooney, 1980)

Soil	
Wet areas	500-200 ohm-meters
Dry areas	100-500 ohm-meters
Arid regions	200-1000 ohm-meters (sometimes as low as it the soil is saline)
Waters	
Soil water	1 to 100 ohm-meters
Rain water	30 to 1000 ohm-meters
Sea water	Order of 0.2 ohm-meters
Ice	10^5 to 10^8 Ohm-meters
Representative Resistivity values for Earth materials	
Low resistivity material	Less than 100 ohm-meters
Medium resistivity material	100 to1000 ohm-meters
High resistivity material	Greater than 1000 ohm-meters
Rock types below the water table	
Igneous and Metamorphic	100 to 10,000 ohm-meters
Consolidated sediments	10 to 1000 ohm-meters
Unconsolidated sediments	1 to 100 ohm-meters
Ores	
Massive sulphides	10^{-4} to 1 ohm-meters
Non-metallics (Gypsum, Quartz, dry rock salt)	Order of 10^{10} ohm-meters

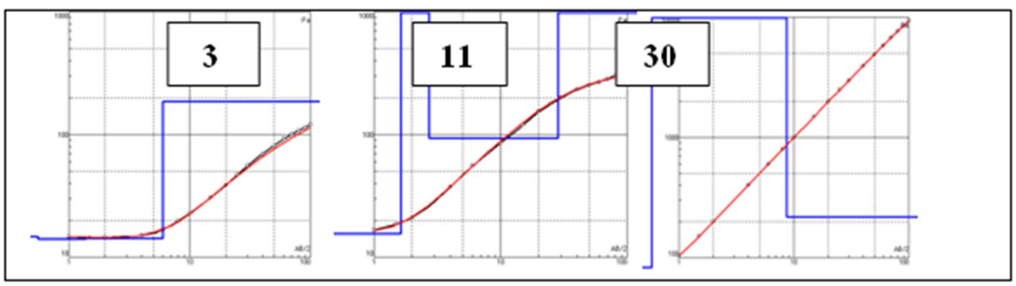

Figure. 3: Different type of Curves generated from IPI2Win

Iso-resistivity Layers

The first layer Iso-resistivity contour map shows that major area is covered by highly weathered formations with resistivity ranging from 1.96 to 152.9 Ω m (Fig.3a). The presence of unconsolidated hard crystalline formation with resistivity above 100 Ω m occur at two locations. The second layer resistivity varies from 1.79 to 15378 Ω m with its thickness ranging from 0.95 to 4.26m(Fig.3b). Unconsolidated sediments are seen in Pandur(S25) which has a resistivity less than 100 Ω m. Most of the study area is underlain by highly weathered rock having resistivity values from 100 to 10,000 Ω m. The third layer resistivity distribution clearly indicates the presence of weathered rock signifying the aquifer presence (Fig.3c). The resistivity ranges from 3.64 to 20,245 Ω m with thickness varying from 1.03 to 1.25 m. The resistivity distribution of the fourth layer reveals the presence of unconsolidated sediments in the northwestern part of the study area(Fig.3d). The rest of the block is underlain with weathered charnockite or gneissic rock. The resistivity varies from 7.31 to 2700 Ω m and thickness from 3.73 to 5.84 m. The fifth layer resistivity distribution revokes the presence of charnockite and gneissic rocks with resistivity range from 42.04 to 12889 Ω m. The 4 profile lines A-A’, B-B’, C-C’, and D-D’ for the study area are drawn to prepare pseudo sections with the VES data(Fig.3f).

TABLE II:SUMMARY OF VES NOS. WITH RESISTIVITY, DEPTH, DAR ZARROUK AND AQUIFER ANISOTROPY PARAMETERS’ DATA INTERPRETATION

VES No.	ρ_1	ρ_2	ρ_3	ρ_4	ρ_5	h1	h2	h3	h4	T ($\Omega\ m^2$)	S (Ω^{-1})	Λ	Cure Type
S1	152.9	213.7	17.95	12.81	442.6	0.06	0.07	1.98	5.75	133.3	0.56	1.1	KQH
S2	4.7	18.04	11.43	461.5		0.28	1	1.62		43.47	0.21	1.04	QH
S3	14.8	14.10	14.2	186		0.55	0.83	4.61		85.30	0.42	1	HA
S4	20.08	20.29	12.92	49.13	291.4	1.39	2.05	3.02	7.88	495.7	0.56	1.2	KHA
S5	21.8	21.7	20.3	82.24	1680	0.86	1.28	6.32	14.3	1347.6	0.58	1.2	QHA
S6	4.22	4.95	3.64	7.31	1548	0.16	0.95	1.03	3.73	36.393	1.02	1.04	KHA
S7	20.33	32.37	14.47	10.41	42.04	0.09	0.19	0.99	18.5	214.99	1.86	1.01	KQH
S8	31.3	21.88	212.3	417.1	458.8	2.91	4.37	7.76	6.09	4374.3	0.34	1.8	HAA
S9	87.25	16.18	16.17	52.57	467.3	0.09	0.37	3	4.58	303.12	0.3	1.2	QHA
S10	37.52	233.5	1896	1213	251.9	32.5	12.4	10.9	83.7	126380	0.99	2.5	AKQ
S11	15.5	14374	1337	94	5258	1.63	0.73	0.35	25.8	13411	0.38	2.5	KQH
S12	4.44	68.62	8.49	10.48	235.7	0.01	0.12	0.3	0.66	17.743	0.1	1.2	KHA
S13	140.8	133.5	94.39	63.32	313.8	0.1	0.17	0.44	10.1	716.57	0.17	1.01	QQH
S14	63.1	20.60	24	288	670	0.28	1.24	4.42	31.4	9192.5	0.36	1.5	HAA
S15	67.35	47.30	56.45	445.2		0.61	5.45	19.8		1413.8	0.47	1	HA
S16	49.87	3496	121.2	31594	322.1	8.1	8.04	7.13	10.1	349107	0.22	8.4	KHK
S17	35.17	12.69	15	36.46	735.1	0.24	0.09	1.43	7.84	316.88	0.32	1.1	HAA
S18	20.35	20.02	14.89	69.69	468.5	0.22	0.25	1.28	15.6	1114.3	0.33	1.1	QHA
S19	8.67	14.67	8.15	18.93	12899	0.7	0.06	2.02	12.6	261.93	1	1.1	KHA
S20	17.42	26.36	12.43	131.3		0.09	0.2	6.14		83.16	0.51	1.01	KH
S21	86.5	30.40	18.9	58.7	291	0.43	1.89	1.86	11.5	804.86	0.36	1.1	QHA
S22	27.62	12.73	8.33	19.87	96.59	0.31	0.64	2.19	12.5	283.33	0.95	1.1	QHA
S23	8.27	67.70	37.2	12.8	128	0.05	0.12	0.01	4.61	67.918	0.37	1.04	KQH
S24	53.71	15.70	6.33	57.37	84.07	0.12	0.27	6.6	15	913.01	1.32	1.6	QHA
S25	1.96	1.79	2100	385.9		1.02	4.26	6.79		14269	2.9	17	HK
S26	14.1	12.70	11.34	21.96	517.7	0.45	0.88	8.19	64.8	1534.3	3.78	1.02	QHA
S27	16	91.40	29.7	220	3513	3.46	2.73	6.12	43.2	9990.6	0.65	1.5	KHA
S28	5.4	6.91	5.32	9.55	7114	0.4	0.25	1.19	3.13	40.11	0.66	1.04	KHA
S29	8	7.17	16.92	19.88	52.51	0.36	1.93	2.65	10.8	276.26	1.01	1.1	HAA
S30	58.75	15378	20245	2.70	217	0.58	0.95	1.25	5.84	127549	0.01	4.2	AKH

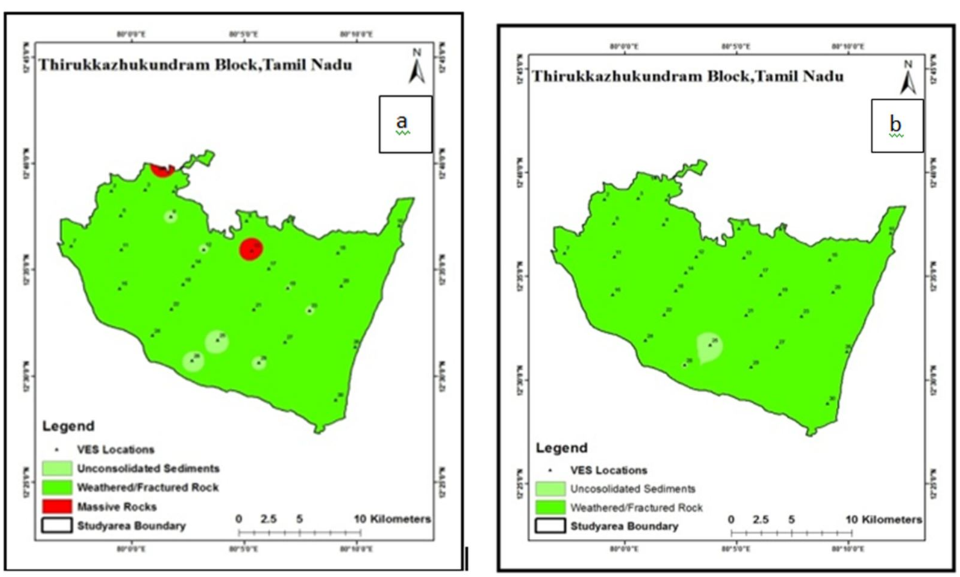

Figure.3.(a,b):Distributionofthe1st,2ndlayerresistivities

Geoelectric Survey along Profile lineA-A'

The profile line AA' is drawn from west to East between Mosivakkam(S5) and Mamallapuram(S10)(Fig.5a). Resistivity below 13.11 Ω m reveals the presence of topsoil only at Thazhambedu(S6) and extends up to 10 m (bgl). Resistivity from 13.11 to 25.81 Ω m is an indication of weathered formations, sandy clay and clay formations. Fractures and cracks are observed at Thazhambedu(S6), Pulikundram(S9) and Kuzhipanthandalam (S8) and are confirmed by resistivity range between 25.81 and 100 Ω m. Hard compact gneissic rocks (Resistivity >100 Ω m) are seen below 20m in the entire profile section.

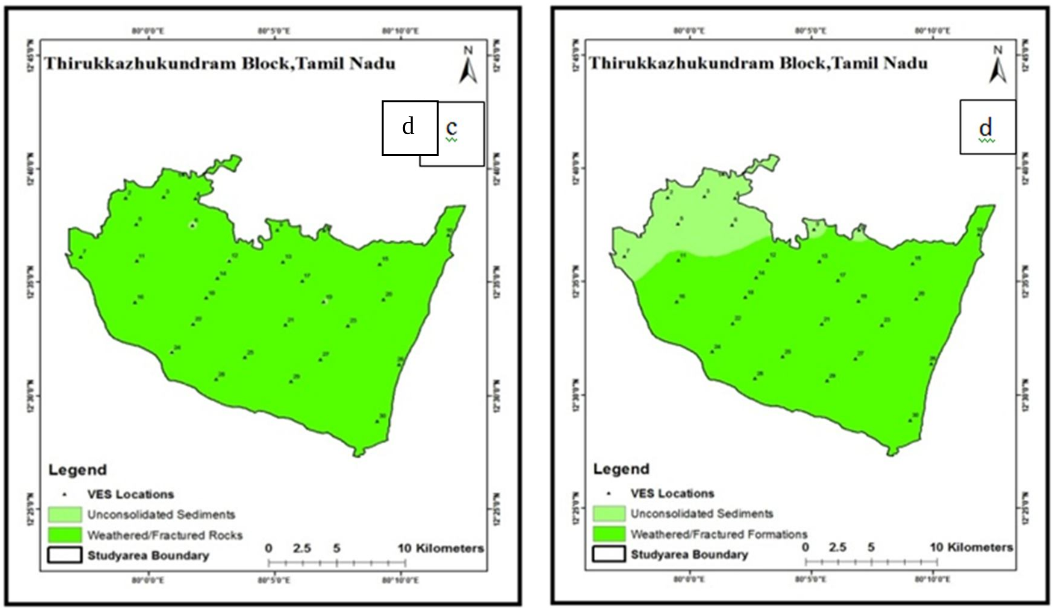

Figure.3.(c,d):Distributionofthe3^{rd},4^{th}layerresistivities

Geoelectric Survey along Profile line B-B'

The profile line B-B' is drawn in a west to east direction from Manapakkam (S7), to Kadambadi(S15)throughPonvilayanthakalathur(S11),Thirukkazhukundram(S12),Igai (S3)(Fig.4b).This line,reveals that resistivity below 18 Ω m which is an indication of saturated topsoil is noticed at S7, 11, 12 namelyManapakkam,Ponvilayanthakalathur, Thirukkazhukundram.The subsurface zones made up of weathered, jointed and fractured charnockite at Igai(S13) and Kadambadi (S15) are confirmed by the resistivity range between 10 and 100 Ω m at 2 to 3 m bgl. The depth to basement is shallow at the eastern part and deeper towards the western region. The gneissic basement rock is seen at the depth of 52 m, bgl at Manapakkam(S7).

GeoelectricSurvey along Profile line C-C'

The profile line C–C' connects Salur (S16) in the west and Kunnathur(S20) in the east and passes through Thathalur(SNo.18) and Amaipakkam(S19)(Fig.4c).C-C' reveals that the top soil is exposed to the surface only at Amaipakkan(S19) and remaining locations are directly exposed by weathered formations. Sandy clay and sand formation(resistivity range between 10 and 50 Ω m) are seen at the depth up to 10 m, bgl at Kunnathur(S20), Amaipakkam(S19) and Thathalur (S18).Depth to the basement is shallow at the western part near Salur(S16) and deeper at Amaipakkam (S19) and Kunnathur(S20).

Geoelectric Survey along Profile lineD-D'

The profile line D-D' is drawn between Vilagam(S24) and Sadurangapattinam(S 26)(Fig.5d).D-D' concludes that the saturated topsoil with resistivity less than 3 Ω m is seen at Pandur(S25) and extends up to 10 m, bgl. The basement rock is found at the depth of 30 m, bgl at Lattur(S27) and not encountered at other locations up to depth more than 100 m, bgl.

In order to confirm the groundwater potential zones, to determine the Anisotropy coefficient, λ and also to get refined resolution of the thin layer resistive and conductive properties of the geologic formations, T and S,(Singh 2003) (Fig.5.a,b)are calculated using the formula,

$$T = \sum_{i=1}^{n} (h_i \times \rho_i)\ \Omega\, m^2 ; \quad S = \sum_{i=1}^{n} (h_i / \rho_i)\ \Omega^{-1}$$

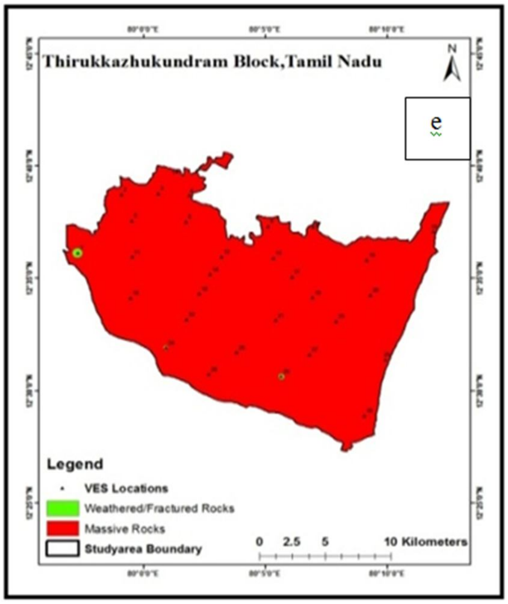

Figure.3e:Distribution of the 5thlayer resistivity.

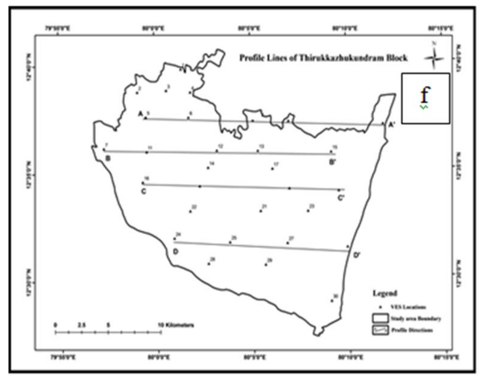

Fig.3f:Profile lines of Thirukkazhukundram Block.

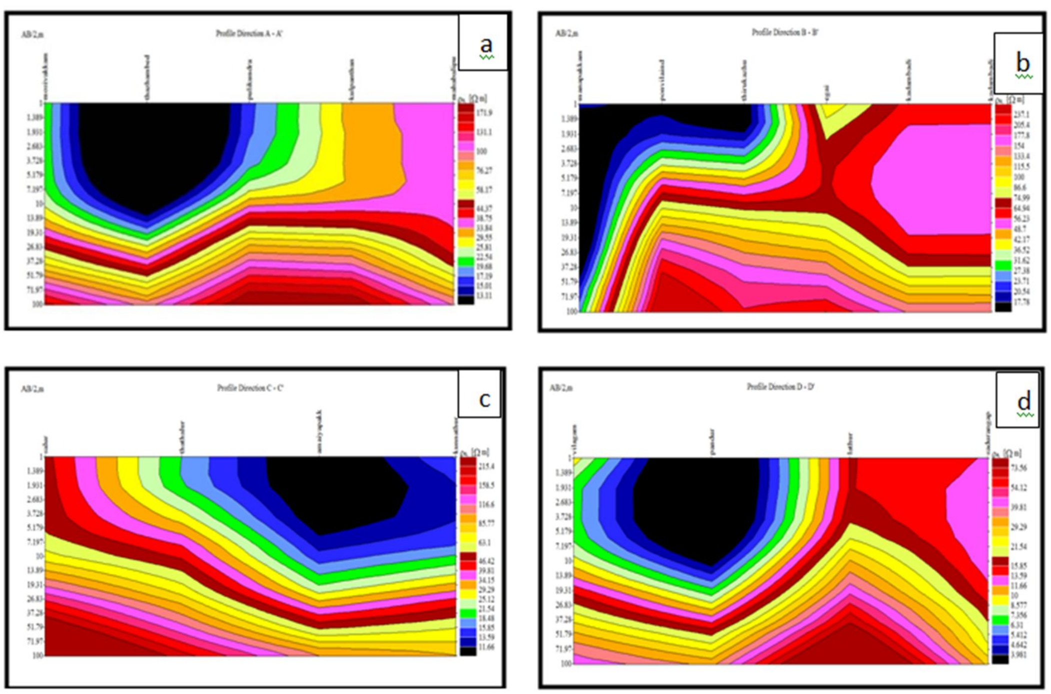

Figure.4(a,b,c,d)Pseudo section maps of Profile lines A-A',B-B',C-C',D-D' respectively.

Where, h_i = ith layer thickness and ρ_i = ith layer resistivity. T values increase often implies that there is a variation in thickness of the resistive formation in any particular area(Zohdy, 1974). Difference in S between two VES locations account for the variation in the total thickness of the low resistive formations.T value ranges from 17.7 to 349107 Ω m^2 and S value ranges from 0.01 to 3.8 Ω^{-1}. Averages of T and S are 22159.3 Ω m^2 and 0.8 Ω^{-1} respectively.

Groundwater potential zones are spotted by the values of Transverse resistance,T, above that of their average values and S, Longitudinal Conductance values below that of their average values.

(Zohdy, 1969; Henriet, 1975; Worthington, 1977 and Galin, 1979).High T and low S values at VES locations S(10,16,30) and S(1to5,11to18,20,21,23,27,28,30) in the study area respectively confirms the presence of a good potential zone and deeper basement. Below

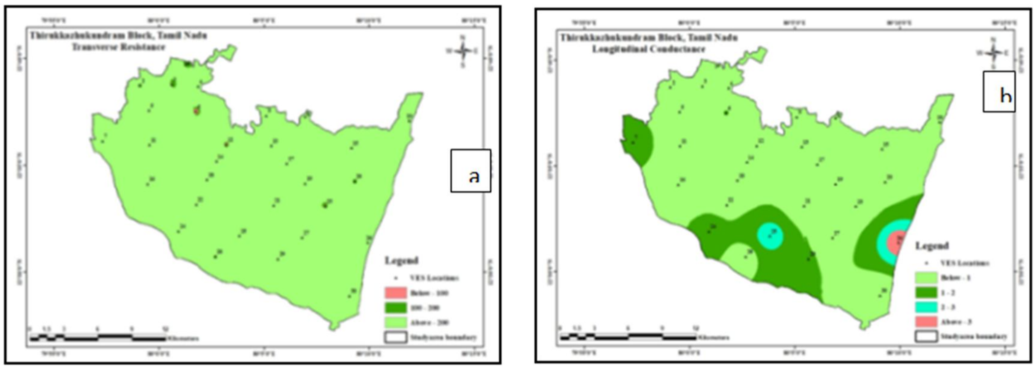

Figure.5.(a,b)-Transverse Resistance and Longitudinal Conductance maps of Thirukkazhukundram Block.

average values of T and above average values of S confirms shallow basement at VES locations S(1 to 9,11 to 15,17 to 29) and S(6,7,10,22,24,25,26,29) of the study area respectively.Low T and S values reveal shallow basement with poor potential. Values of T and S confirm wide spread shallow, deep potential zones throughout the study area. Coefficient of anisotropy, λ, a measure of the degree of inhomogeneity in a basement terrain arises from near surface effects, variable degree of weathering, and structural features such as faults, fractures, joints and foliations and beddings. λ is usually greater than 1 but less than 2(Zohdy et. al., Op. cit). The area with Aquifer anisotropy values 1 and < 1.5 are considered good groundwater potential zones with high porosity and permeability, Rao et al. (2003).In Thirukkazhukundram block, λ ranges from 1 to 17. Except for VES locations, S(8,10,11,16,24,25) all other locations have λ values between 1 and 1.5 which confirm widespread aquifers.

VI. CONCLUSION

The concluding part predicts four to five layered lithologic strategy with 12 curve types. The Pseudo sections prepared in east-west direction reveal the presence of unconsolidated formation at shallow to moderate depth along the river course. Potential zones are present at all other locations of the study area except for VES locations, S(8,10,11,16,24,25) as per λ value interpretation. Thus, VES with D-Z parameters and λ value augmentation in the study area has succeeded to be very authentic in mapping shallow as well as deep aquifers with all terrain utility to bring out the subsurface image without drilling and other penetrating techniques which is more economic.

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