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Groundwater potential zone detection using geophysical surface resistivity survey in agricultural lands instant benefit to the farmers in Balurghat area, West Bengal, India

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Abstract

Government of West Bengal initiated the West Bengal Accelerated Development of Minor Irrigation (WB-ADMI) Project across the State of West Bengal for the development of groundwater resources through sinking of shallow and medium depth tube wells, and also enhancing the agricultural productivity of small and marginal farmers. Thus, geophysical surface resistivity survey (mainly VES) was carried out at 45 pre-defined sites with a maximum of 1400m current electrode spread to derive subsurface hydrogeological conditions comparatively deeper depths. The computer IX1-D Interpex software was used to ascertain geoelectrical layer parameters and then standardized with the existing litho logs and well cuttings. The results show that within the thick column of sedimentary sequence upto the explored depth (~285 m) the aquifers are present. In general, the layer of fine to coarse sand is admixed with gravel and pebbles of varying thickness evident at most of the sites form the multi-aquifer system. Its thickness and depth of occurrence are varied significantly. The shallow aquifer is identified to be consisting of coarse sand admixed with gravels and pebbles. It extended from around on average 10 to 75 m depth below ground level (bgl) at most of the sites. Deeper aquifer is also inferred to be present beyond approximately 220 m depth, bgl at some places. Overall, both the shallow aquifer (average depth: upto 10m, bgl) and deeper aquifer (average depth: upto 60m) are clearly delineated in Balurghat area. But the granularity of shallow aquifer is better than the deeper aquifer. The general depth of drilling has been recommended to be minimum 50 m and can go up to 140 m.

Keywords: Groundwater exploration, VES data, Balurghat district, West Bengal.

1. Introduction

The officials of the WB-ADMI prepared a list of cluster villages from different blocks of 12 districts (i.e., Paschim Medinipur, Hooghly, N 24 Paraganas, Nadia, Bardhaman, Birbhum, Malda, Murshidabad, Dakshin Dinajpur, Uttar Dinajpur, Coochbehar, Jalpaiguri) of West Bengal for detecting groundwater potential zones through the conducting VES. Out of them, the survey was covered in 8 districts during the period of January to March 2016 including Balurghat block in Dakshin Dinajpur district. Based on the groundwater potential zones, the drilling of bore well depths are recommended. The main objectives of conducting VES for delineation of aquifers at the cluster sites provided by WB-ADMIP, and Selection and recommendation of suitable cluster site for borehole drilling.

2. Methodology

Geophysical Surface Resistivity Survey was initiated by CSIR-NGRI, Hyderabad in the collaboration of WAPCOS, New Delhi with VES measurements at a few existing boreholes for standardization and validation of the VES derived layer parameters. The VES data was interpreted with aid of IX1-D Interpex software. On the basis of the results of 45 VES conducted, village cluster-wise recommendations were given for drilling depths of boreholes.

3. Study area in brief

Dakshin Dinajpur district is constituted by 8 numbers of blocks. The block surveyed (Balurghat) is located in the eastern part of the district (**Fig.1**). Topography varies from 13 to

34 m with an average of 24 m amsl. The general land surface of the district is flat and sloping towards south. The area forms a part of the Garo-Rajmahal gap filled up with older and younger alluvium as a result of shallow subsidence and concomitant deposition in for deep area. The thickness of the sediments is shallower as is evidenced by the occurrence of coarse-grained biotite granite basement rock at a depth of approx.310 m. Groundwater occurs under unconfined aquifer, and semi confined to confined condition under a clay horizon in recent alluvial plain available as a patchy occurrence in the eastern part of Balurghat. In general, coarse to fine sand, gravel deposits in the recent alluvium are the main repository of groundwater having large yield potentiality.

4. Geophysical survey,data and location

Surface geophysical survey comprising Vertical Electrical Sounding (VES) was conducted at pre-defined clusters yielding depth wise geo-electrical layers, i.e., 1-diamension information of aquifers. In total, 45 VES data were collected using indigenous instrument Syscal Jr. and R1^{+} Instruments of IRIS make, France. Their locations are shown in **Fig. 1.**

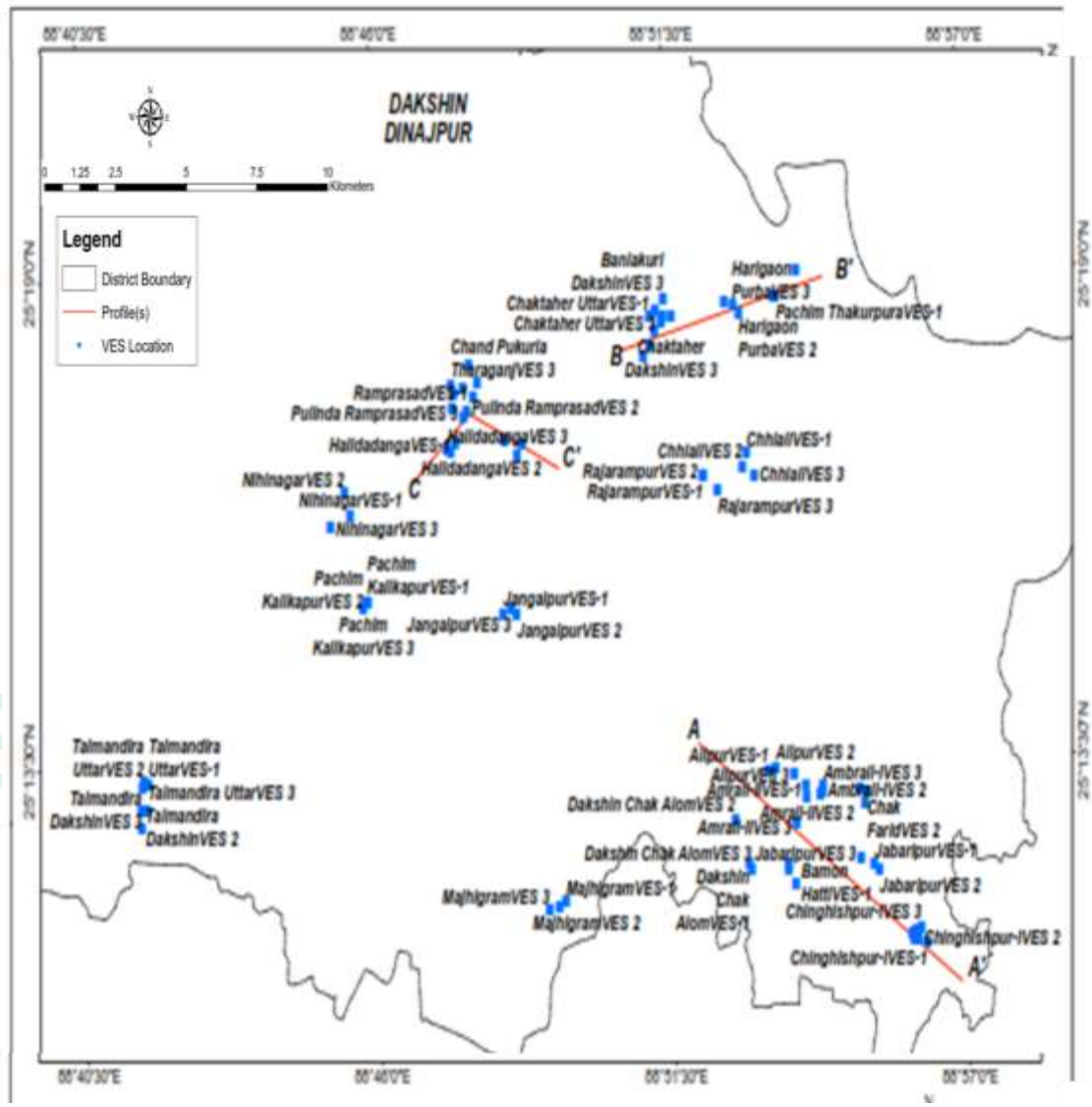


Fig.1:Location of VES sites at Balurghat block in Dakshin Dinajpur District,West Bengal.

Table 1: Schlumberger Vertical Electrical Sounding data at Majhigram Village

Name of Cluster	**MAJHIGRAM**	**Village**	**MAJHIGRAM**	**Mauza**	**MAJHIGRAM**	**Block**	**BALURGHAT**
District	**DHAKSHIN DINAJPUR**	**Toposheet No**		**Instrument Used**	**AQUA METER**	**Date of Survey**	
Ground water levels	**30 FT**	**Ground water Quality**	**FRESH**	**Geological Formation**			
VES No.: 3	**3**	**Land Survey No**	**467**	**VES Orientation**	**NE - SW**	**Name of landowner**	**BALARAM BARMAN**
Longitude	**E88° 48.919¹**	**Latitude**	**N 25° 11.832¹**	**Elv**	**22M**		
S. N	**AB/2 (m)**	**MN/2 (m)**	**K**	**V (mv)**	**I (mA)**	**R (ohm)**	**Rho (ohm-m)**
1	1.5	0.5	6.28		100	5.480	34.41
2	2	0.5	11.78		100	2.220	26.15
3	3	0.5	27.48		100	0.860	23.63
4	4	0.5	49.46		100	0.488	24.13
5	5	0.5	77.72		100	0.330	25.64
6	6	0.5	112.26		100	0.241	27.05
7	8	0.5	200.18		100	0.158	31.62
8	10	0.5	313.22		100	0.117	36.64
9	10	2	75.36		100	0.476	35.87
10	12	2	109.90		100	0.370	40.66
11	12	0.5	451.38		100	0.092	41.52
12	15	2	173.49		100	0.265	45.97
13	20	2	310.86		100	0.180	55.95
14	25	2	487.49		100	0.132	64.34
15	30	2	703.36		100	0.102	71.79

16	30	5	274.75		100	0.262	71.98
17	35	5	376.80		100	0.207	77.99
18	35	2	958.49		100	0.081	77.63
19	40	5	494.55		100	0.164	81.1
20	45	5	628.00		100	0.136	85.4
21	50	5	777.15		100	0.111	86.26
22	55	5	942.00		100	0.094	88.54
23	60	5	1122.55		100	0.081	90.92
24	65	5	1318.80		100	0.070	92.31
25	70	5	1530.75		100	0.061	93.37
26	80	5	2001.75		100	0.048	96.08
27	90	5	2535.55		100	0.037	93.81
28	90	10	1256.00		`100	0.074	92.94
29	100	10	1554.30		100	0.058	90.14
30	100	5	3132.15		100	0.030	93.96
31	120	10	2245.10		100	0.038	85.31
32	140	10	3061.50		100	0.027	82.66
33	160	10	4003.50		100	0.019	76.06
34	180	10	5071.10		100	0.014	70.99
35	180	20	2512.00		100	0.028	70.33
36	200	10	6264.30		100	0.010	62.64
37	200	20	3108.60		100	0.020	62.17
38	250	20	4874.85		100	0.011	53.62
39	300	20	7033.60		100	0.006	44.24
40	300	50	2747.50		100	0.016	43.96
41	350	50	3768.00		200	0.011	41.44

42	400	50	4945.50		250	0.008	38.03
43	450	50	6280.00		250	0.006	35.85
44	500	50	7771.50		200	0.005	35.59

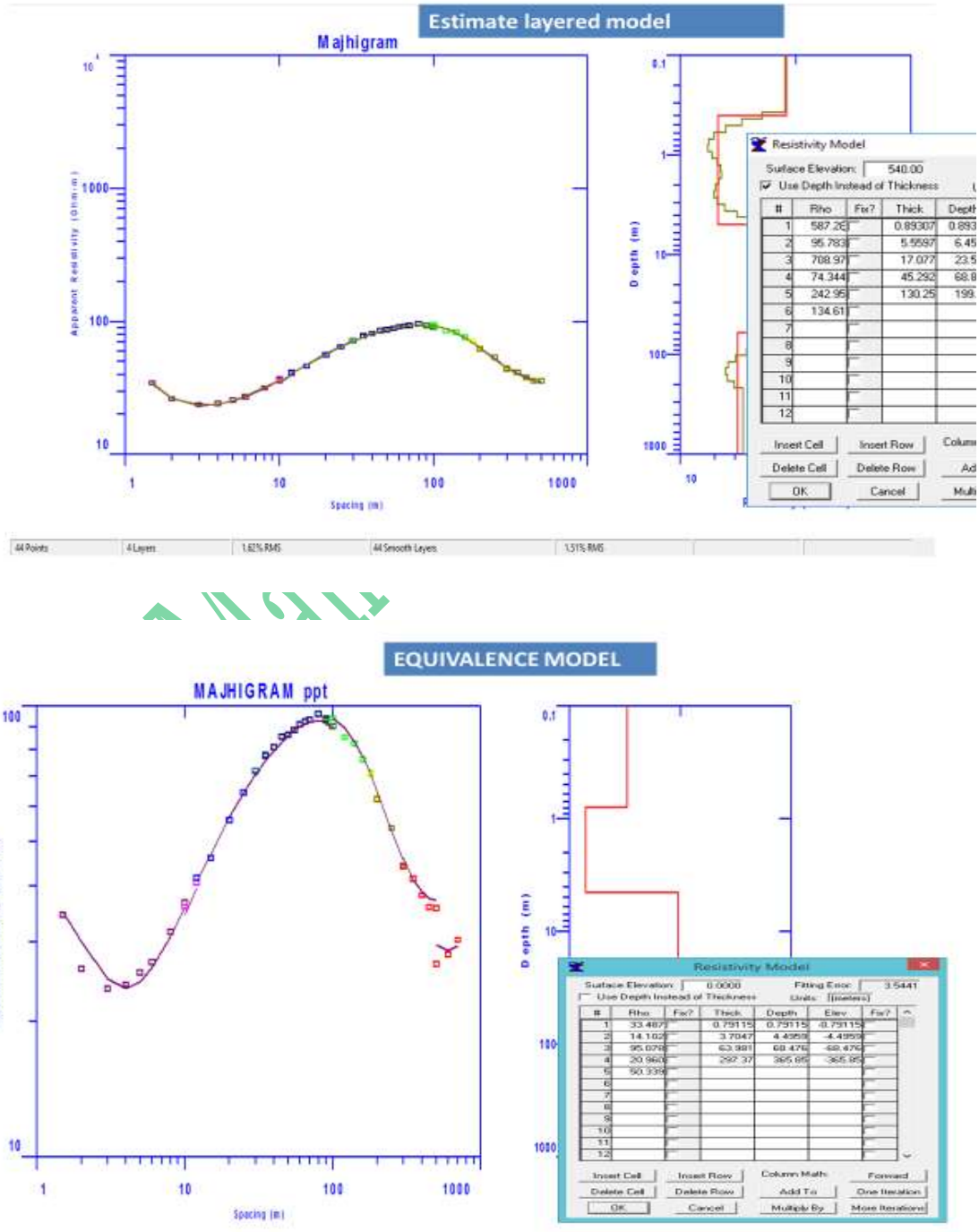


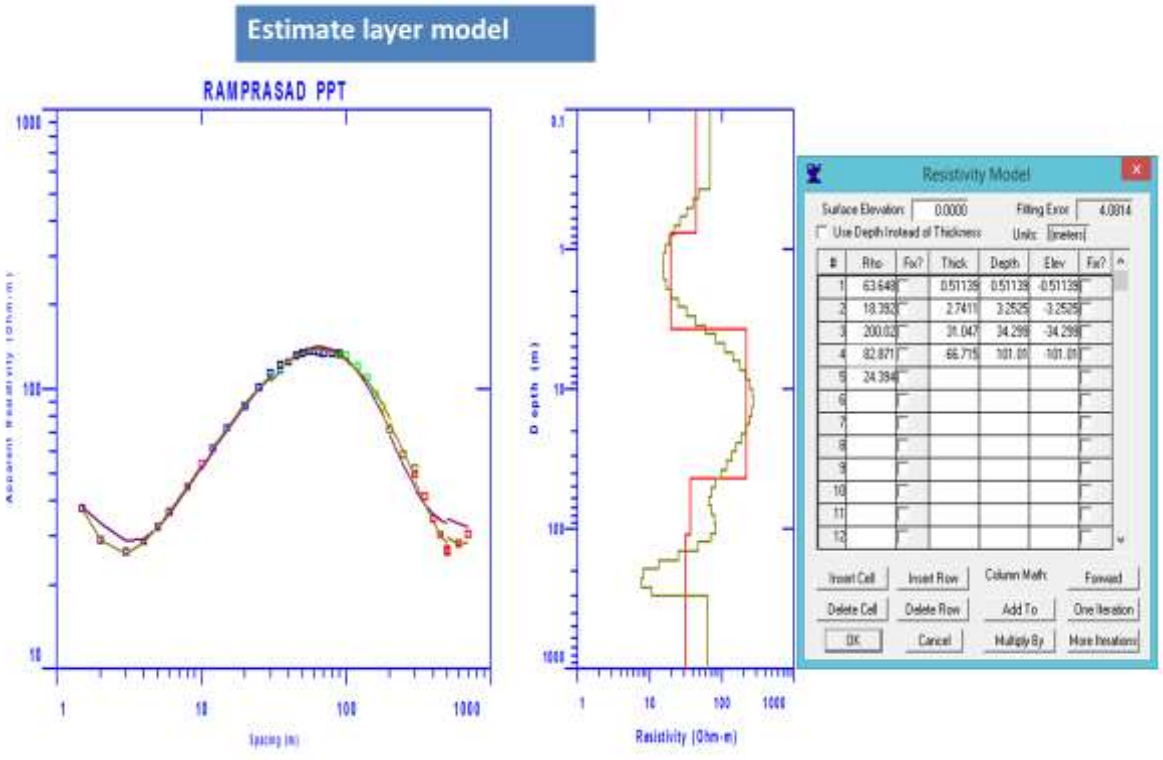
Fig.2: Estimate layer model and equivalence model curves at Majhigram village

Table 2: Schlumberger Vertical Electrical Sounding data at Ramprasad Village

Name of Cluster	**RAMPRASAD**	**Village**	**RAMPRASAD**	**Mauza**	**RAMPRASAD**	**Block**	**BALURGHAT**
District	**DHAKSHIN DINAJPUR**	**Toposheet No**		**Instrument Used**	**AQUA METER**	**Date of Survey**	
Ground water levels	**30 - 40 FT**	**Ground water Quality**	**FRESH**	**Geological Formation**			
VES No.: 3		**Land Survey No**	**209**	**VES Orientation**	**N - S**	**Name of land owner**	**SATTARMANDAL**
Longitude	**E88° 47.531¹**	**Latitude**	**N 25° 17.984¹**	**Elv**	**31m**		
S.N.	**AB/2 (m)**	**MN/2 (m)**	**K**	**V (mv)**	**I (mA)**	**R (ohm)**	**Rho (ohm-m)**
1	1.5	0.5	6.28		100	5.960	37.42
2	2	0.5	11.78		100	2.450	28.86
3	3	0.5	27.48		100	0.957	26.29
4	4	0.5	49.46		100	0.576	28.48
5	5	0.5	77.72		100	0.413	32.09
6	6	0.5	112.26		100	0.324	36.37
7	8	0.5	200.18		100	0.224	44.84
8	10	0.5	313.22		100	0.173	54.18
9	10	2	75.36		100	0.721	54.33
10	12	2	109.90		100	0.560	61.54
11	12	0.5	451.38		100	0.137	61.83
12	15	2	173.49		100	0.420	72.86
13	20	2	310.86		70	0.280	87.04
14	25	2	487.49		100	0.209	101.88
15	30	2	703.36		100	0.162	113.94

16	30	5	274.75		100	0.402	110.44
17	35	5	376.80		100	0.310	116.8
18	35	2	958.49		100	0.127	121.72
19	40	5	494.55		100	0.253	125.12
20	45	5	628.00		100	0.210	131.88
21	50	5	777.15		100	0.173	134.44
22	55	5	942.00		100	0.145	136.59
23	60	5	1122.55		100	0.122	136.95
24	65	5	1318.80		100	0.103	135.85
25	70	5	1530.75		100	0.088	134.7
26	80	5	2001.75		100	0.067	134.11
27	90	5	2535.55		100	0.053	134.38
28	90	10	1256.00		100	0.106	133.13
29	100	10	1554.30		100	0.086	132.11
30	100	5	3132.15		100	0.042	131.55
31	120	10	2245.10		100	0.054	121.22
32	140	10	3061.50		200	0.036	110.21
33	160	10	4003.50		200	0.024	96.08
34	180	10	5071.10		200	0.017	86.2
35	180	20	2512.00		200	0.034	85.4
36	200	10	6264.30		200	0.012	75.17
37	200	20	3108.60		200	0.023	71.49
38	250	20	4874.85		100	0.012	58.64
39	300	20	7033.60		100	0.007	52.04
40	300	50	2747.50		100	0.018	49.44
41	350	50	3768.00		100	0.011	41.44

42	400	50	4945.50		100	0.007	34.42
43	450	50	6280.00		100	0.005	30.2
44	500	50	7771.50		100	0.004	26.18
45	500	100	3768.00		100	0.007	26.82
46	600	100	5495.00		100	0.005	28.13
47	700	100	7536.00		100	0.004	30.29



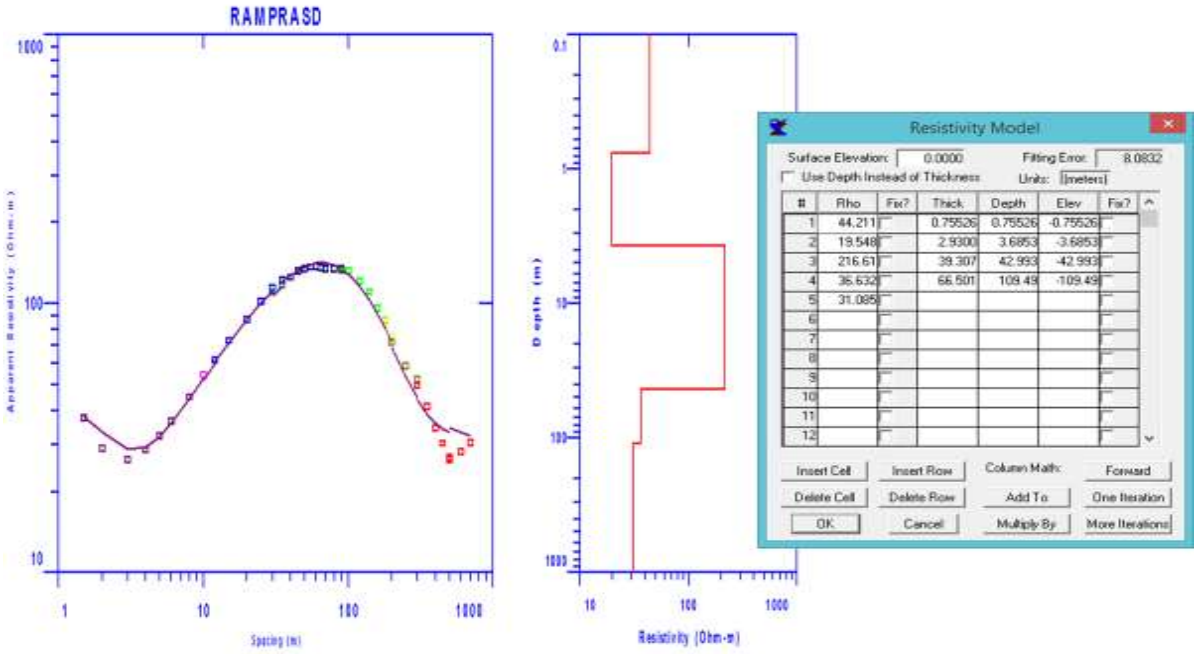
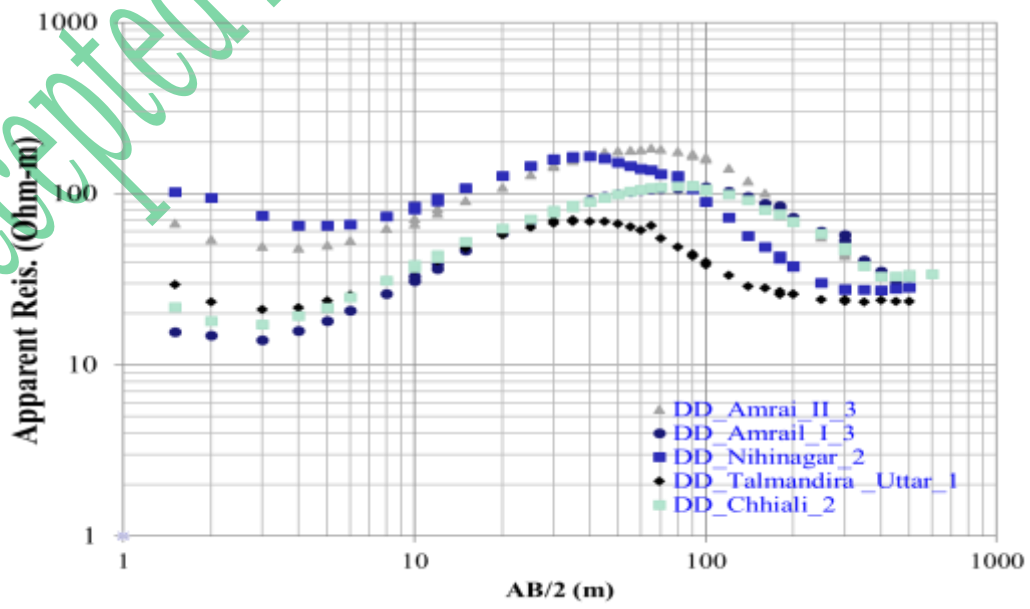


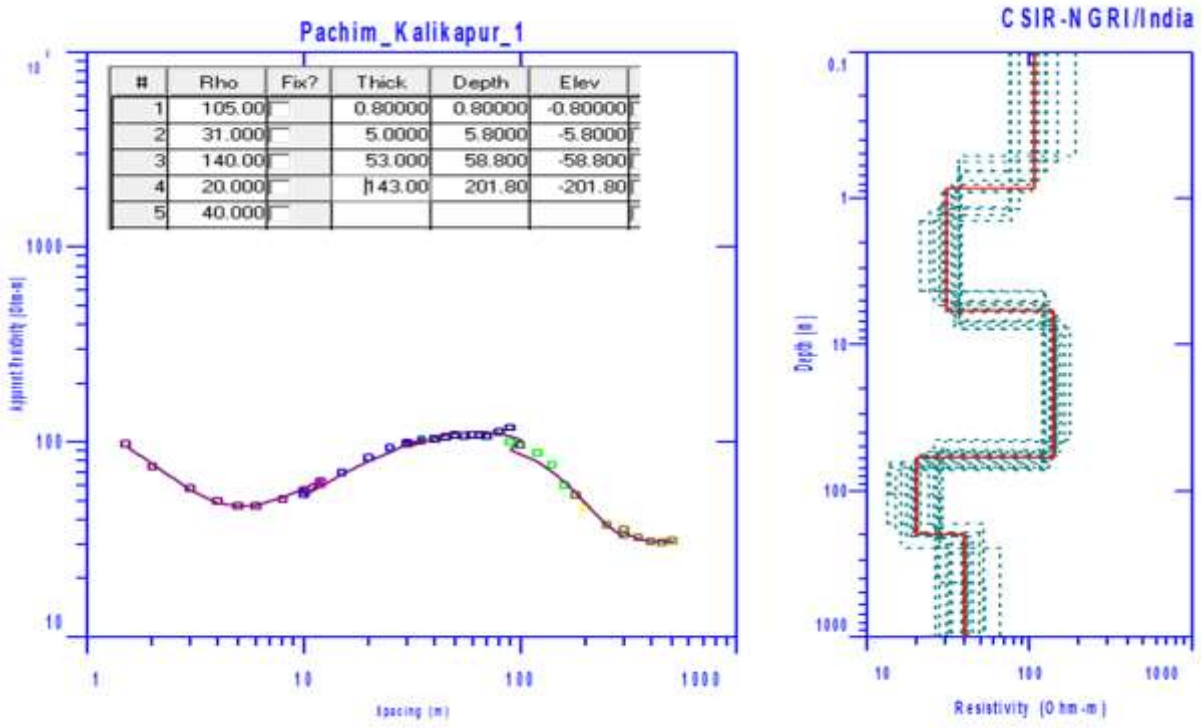
Fig.3: Estimate layer model and equivalence model curves at Ramprasad village

5. Types of VES curves

Spectrum of the selective apparent field resistivity curves is shown in **Fig. 4a**. The variations in near surface layer granularity bring in a wide range in apparent resistivity for smaller current electrode spacings. The VES curves are more spread out in the short spacing while they converge together as the electrode spacing increases. This attributes to a small change of granularity in deeper aquifers. Typical interpreted geo electrical parameters are shown in **Fig. 4b**.



(a)



(b)

Fig.4:(a) VES curves from Dakshin Dinajpur district showing grneral trend in variations of apparent resistivity with current electrode spacing (AB/2),(b) a typical model curve.

6. Interpretation of VES Data

Based on the standardization, resistivity ranges for various litho units have been established (**Table 3)**. It is indicative of a depth sequence of top soil, sandy clay, coarse sand mixed with gravels and pebbles, sandy clay and fine to medium sand. The higher values of resistivity indicate better granularity and the lower values indicate clay predominance in the fine to medium sand zones.

Table 3: Resistivity ranges for different lithological predominance & interstitial water quality

Layered Resistivity (ohm-m)	**Inferred Lithological predominance**	**Inferred groundwater quality**
Less than 10-20	Clay	Fresh
20-30	Fine sand mixed with clay	Fresh
30-50	Fine to medium sand	Fresh
50-80	Medium to coarse sand	Fresh
70-90	Coarse sand	Fresh
>90	Coarse sand with gravels and pebbles	Fresh

7. A cross-sections for subsurface geophysical parameters along with hydrogeological inferences

Two dimensional (2-D) perceptions on geo-electrical layer dispositions through a cross-section depicts a good continuity of all the layers delineated between the selective five sites (along A- profile). In general, it shows the coarse sand mixed with gravels acting as the principal aquifer with variable thicknesses. The aquifer shows a decline in granularity on moving towards south-east from Amrail-II. The shallow aquifer has a minimum thickness of 26 m extending upto 32 m depth, bgl at Amrail-II and it has the maximum thickness of 68 m extending upto 73m depth, bgl at Chak Farid. The principal aquifer is underlain by a layer of fine sand at all sites upto 182-221m depth, bgl. The entire sequence rests upon a sandy clay layer of resistivity around 16-22 ohm.m. A several sections were made in Balurghat area in order to understand the aquifer conditions over the proposed area. This attempt enabled in distinguishing lithological setting/discontinuity and formed an important aspect on understanding the hydrogeological condition of aquifer disposition.

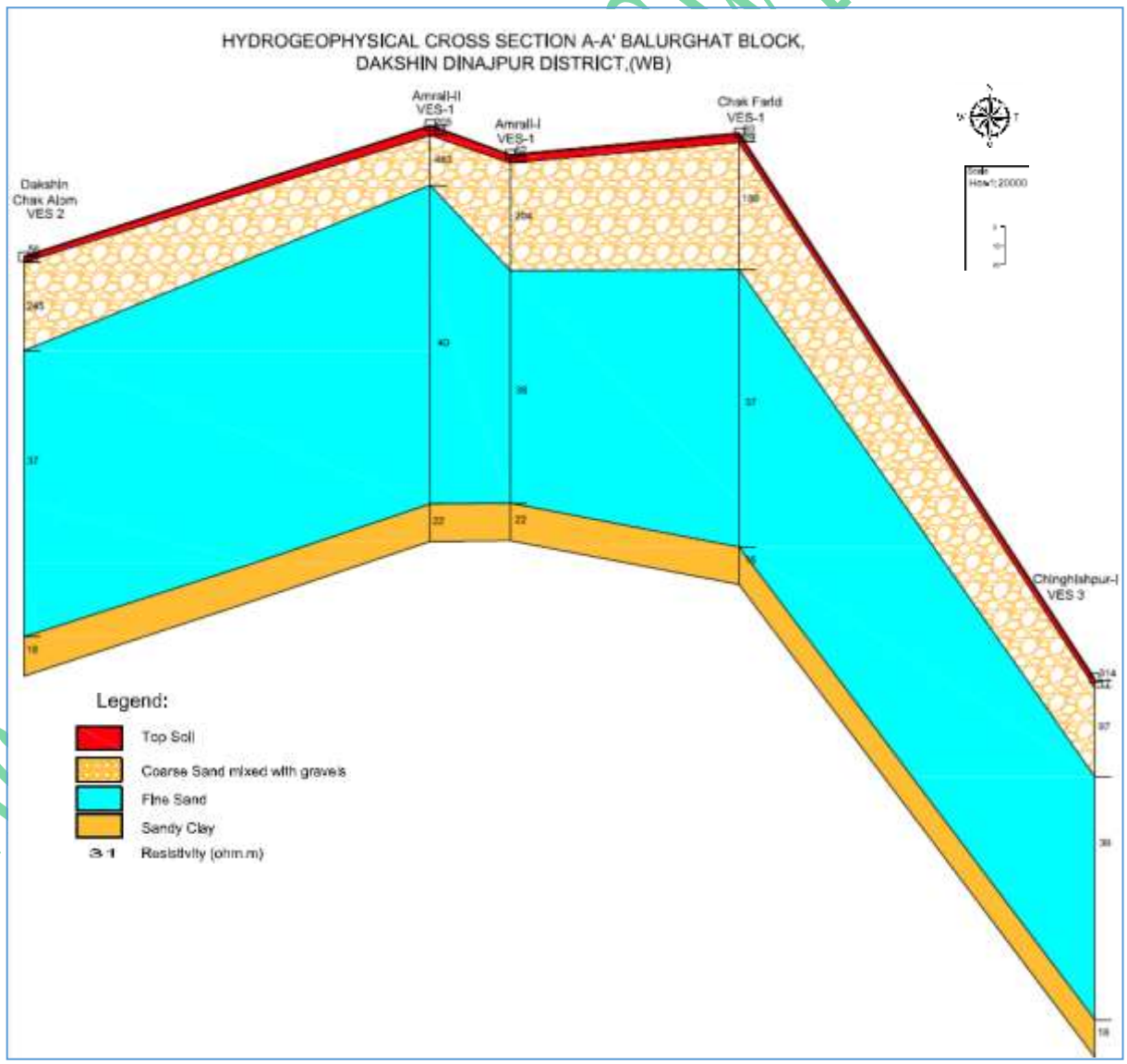


Fig. 5: Geoelectrical layer parameters and corresponding aquifer deposition along the profile 1(A-A')

8. Conclusions

Resistivity ranges for various litho units has been observed that resistivity of fine sand to coarse is in the range of 30-90 Ω-m, whereas the range of coarse sand with gravels and pebbles is more than 90 Ω-m. Aquifers are present within the thick column of sedimentary sequence upto the explored depth (~285 m). In general, the layer of fine to coarse sand is admixed with gravel and pebbles of varying thickness evident at most of the sites form the multi-aquifer system. Its thickness and depth of occurrence are varied significantly. Shallow aquifer is identified to be consisting of coarse sand admixed with gravels and pebbles. It extended from around on average 10 to 75 m depth below ground level (bgl) at most of the sites. Deeper aquifer is also inferred to be present beyond approximately 220 m depth, bgl at some places. Overall, both the shallow aquifer (average depth: upto 10m, bgl) and deeper aquifer (average depth: upto 60m) are clearly delineated in Balurghat area. But granularity of shallow aquifer is better than deeper aquifer. Drilling depth has been recommended to be minimum 50 m and can go up to 140 m. The information obtained provides to the local famers in agricultural lands for the instant benefits.

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