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Assessment of Coastal Aquifer Properties and Depth-wise Water Quality with use of *State- of- art* Multi-electrode Imaging Techniques

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ABSTRACT

Even as the inland aquifers are suffering from the maladies of over exploitation of ground water by way of unscrupulous pumping, the coastal aquifers encounter the danger of sea water intrusion and saline water upcoming. Fresh water skimming is the only alternative in coastal zones to stabilize crop production. The aquifer properties and depth-wise water quality need to be assessed to harvest the shallow depth fresh water in coastal sands. Using the multi-electrode imaging survey, layer-wise 2D- resistivity images were obtained upto a depth of 12m for 24 locations of Bapatla coastal area. Based on the image data, for all the locations, depth-wise groundwater quality assessed using the laboratory relationship ($Y = 25.624\ X^{-0.9448}$, where X is the salinity of groundwater in dS/m and Y is the resistivity of water sample in sands in ohms-m) developed. For agricultural productivity, one can tap the existing shallow depth fresh water or marginal waters only without the upconing of saline waters for which, suitable extraction structures such as improved skimming techniques or pumping strategy are to be planned.

Key words : Multi-electrode imaging, Resistivity, Salinity

Even as the inland aquifers are suffering from the maladies of over exploitation of ground water by way of unscrupulous pumping, the coastal aquifers encounter the danger of sea water intrusion and saline water upcoming. Fresh water skimming is the only alternative in coastal zones to stabilize crop production. Hence a study has been taken-up with *state-of-art* geophysical techniques in different locations of the Bapatla coastal area of Andhra Pradesh to access the thickness of top sandy aquifers, subsurface litho-logical characteristics and the quality of groundwater exist.

Multi-electrode resistivity imaging survey, a combination of both profiling and sounding directly gives resistivity image of the profile or the area in 2D or 3D respectively (Griffiths and Barker, 1993). Advantage of resistivity imaging is not only mapping the sub-surface information of the area in terms of geo-electrical layers, but also generation of reliable data information of large dimension.

MATERIAL AND METHODS

Multi-electrode image survey carried in 24 locations of Bapatla coast and obtained layer-wise resistivity images for different locations upto a depth of 11.5 m. In the study area to identify the freshwater lens and contact depth of fresh-saline waters, resistivity imaging was carried out with 2 m electrode spacing following Wenner configuration for profile length of 80 m using ABEM terrameter- the multi-electrode imaging system (SAS4000 Model) of Ground Water Replenishment Division, National Geophysical Research Institute, Hyderabad. The image data collected was downloaded using lap-top computer and processed using the software (RES2DINV) to create 2D resistivity images (Loke, 1999).

Further to access the map layers for different gradients of groundwater salinity, a laboratory test was carried out using the permeameter cum resistivity apparatus developed by National Geophysical Research Institute(NGRI), Hyderabad., for estimation of soil permeability as well as resistivity of flowing media (water) in that soil. With the permeameter cum resistivity apparatus, the resistivity was measured, when flowing media with different salinity levels passed through the saturated sand column (Table 1) and by plotting, relationship between groundwater salinity and resistivity for sandy soil established as shown in Fig.1 and resistivity ranges for different quality classes of groundwater derived and used in depth-wise classification of ground waters.

RESULTS AND DISCUSSION

Multi-electrode resistivity imaging survey was carried out in 24 locations and obtained layer-wise 2D resistivity images for different locations upto a

Table 1.Observed and predicted values of resistivity for different graded saline water passing through medium sandy soils

Salinity of water (dS/m)	Resistivity (Ohms-m)	
	Observed	Predicted
0.1	210.48	225.66
0.4	71.28	60.90
0.6	39.79	41.52
1.0	27.23	25.62
2.0	12.36	13.31
2.7	9.27	9.85
3.5	7.51	7.85
5.5	5.59	5.12
7.0	4.01	4.08
10.0	2.77	2.91
13.0	2.43	2.27
16.0	1.84	1.87

depth of 11.5 m. The images were further interpreted using the resistivity and salinity relationship developed for the sandy soils.

Salinity of groundwater and resistivity in sandy soils

To access the map layers, for different gradients of groundwater salinity, relationship was developed between groundwater salinity vs resistivity using permeability test results (Table 1). Using the best-fit relation(Fig.1), Resistivity (Y) = 25.624 Salinity(X) $^{-0.9448}$, resistivity for different water quality classes were derived. From the predicted values of the resistivity, it was observed that at 226 ohms-m resistivity, the ground water salinity is 0.1 dS/m, while at 1.87 ohms-m resistivity, the ground water salinity is 16 dS/m.

Interpretation of images

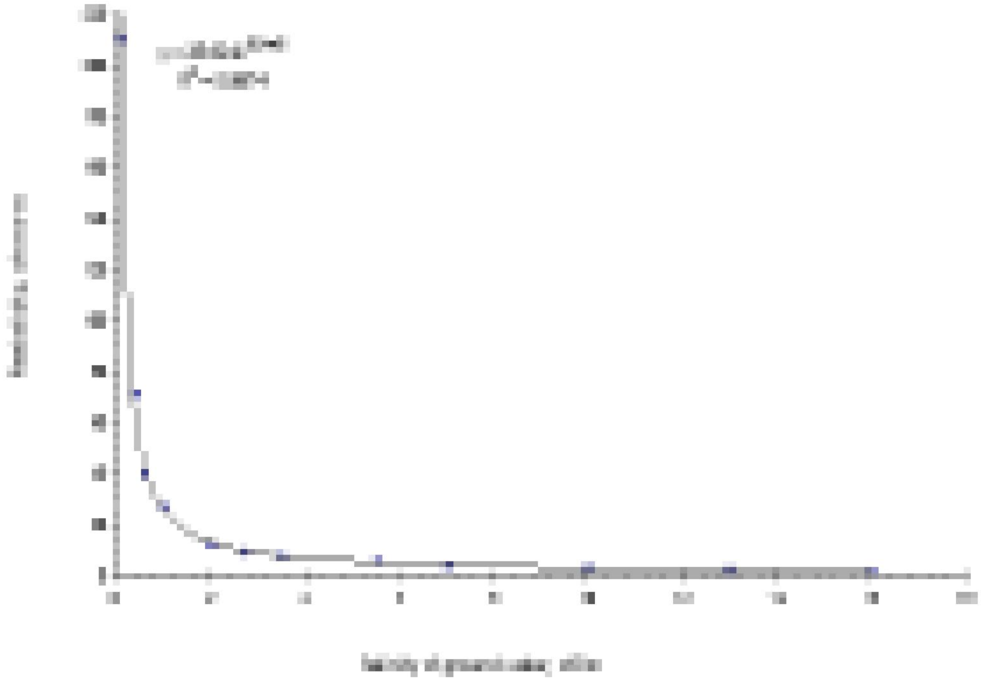
The resistivity images of all 24 locations were interpreted by considering the relationship derived between groundwater salinity vs resistivity, ground truth as well as local conditions and the experiences of the tool operating scientists of National Geophysical Research Institute(Table 2). The aquifers at different locations were classified into four depth groups, i.e. dry sand (top layer), fresh water having 0- 2 dS/m salinity, marginal water having 2- 4 dS/m and saline water having more than 4 dS/m. The interpretation of aquifers at different locations situated from sea coast to 14.3 km away from sea coast were derived with feasible usage of ground waters, while the depth-wise water quality chart for different locations was prepared as shown in Fig.2.

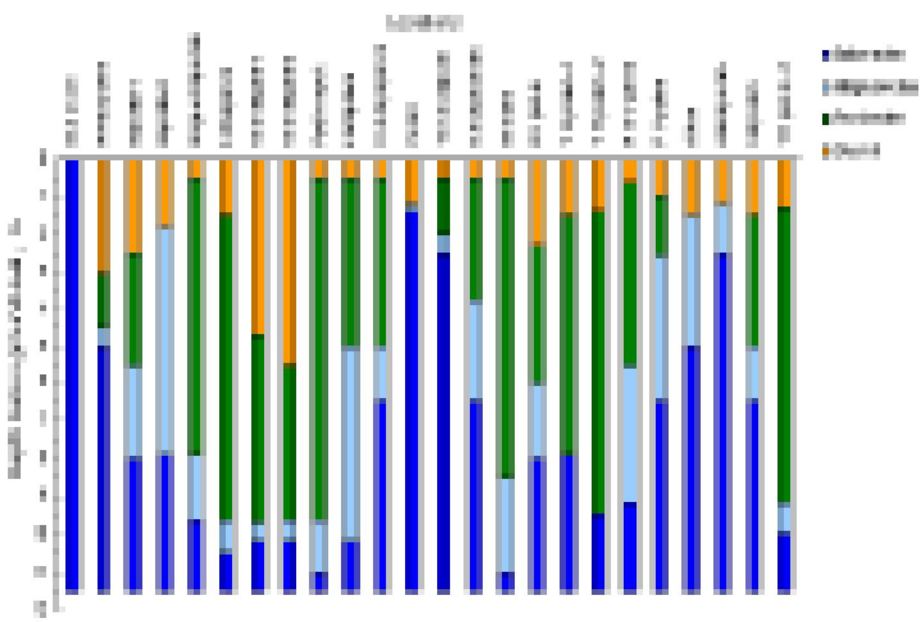
Conclusion

From the results (Fig.2), it is clearly indicated that fresh water aquifers exist at a depth of 0.5 to 3 m below ground level in all the locations except near sea coast and Vedullapalli areas and the thickness of fresh water aquifer was about 1.5 to 8.1 m in all the study locations except Sea shore, Bapatla 2, Parali, Alluru and Alakapuram. The marginal fresh water aquifer exist to a depth of 0.5 to 6.1 m in all the locations except near seashore, Parali and T R Palem 1 and 2. Saline waters exist in different locations from 1.4 to 11 m below ground level except seashore. In the seashore, entire length of aquifer is of saline waters due to the sea influence. For agricultural productivity, one can tap the shallow depth fresh water or marginal waters only without the upconing of saline waters for which, suitable extraction structures such as improved skimming techniques or other pumping strategies need to be planned. Further, from the study it may be concluded that the *state of art* Multi-electrode imaging can be used as a good tool to asses the depth-wise ground water quality and in planning water harvesting techniques in coastal sands.

Table 2 Depth-wise classification of ground waters using multi-electrode resistivity imaging data for coastal sandy soils of Guntur district

S. No.	Location	Resisitivity Image No.	WT depth (m)	GW salinity (dS/m)	Dis-tance from coast (km)	Depth of layers from ground surface (m) with resistivity: Dry top soil	Saturated sand with fresh water (0-2 dS/m)	Saturated sand with marginal saline water (2-4 dS/m)	Clay/sand with saline water (>4 dS/m)	Suitable application
1	Sea shore, Suryalanka	18	0.30	35.45	0	-	-	-	0 (<1.2)	Shore with tides
2	Skimming well, Muthaipalem	19	3.03	4.70	3.00	0-3.0 (100-500)	3.0-4.5 (14-100)	4.5-5.0 (7-14)	>5 (<7)	Skimming marginal saline waters
3	Skimming well I, Bapatla	14	2.46	1.05	9.15	0-2.5 (650-1950)	2.5-5.5 (14-650)	5.5-8.0 (7-14)	>8 (<7)	Suitable for skimming,
4	Skimming well II, Bapatla	12	1.83	2.36	9.45	0-1.8 (5.72-14.3)	-	1.8-7.9 (10-55)	>7.9 (<10)	Skimming marginal saline waters /Non-uniform soil
5	Skimming well, Nagendrapuram	39	0.77	1.23	7.25	0-0.5	0.5-7.9 (14-112)	7.9-9.6 (6.46-14)	>9.6 (<6.46)	Suitable for skimming
6	Skimming well, Kothapalem	40	1.48	0.68	8.20	0-1.5 (230-1021)	1.5- 9.6 (14-230)	9.6-10.5 (7-14)	>10.5 (<7)	Suitable for skimming
7	Skimming well I, Vedullapalli	20	3.95	1.09	7.75	0-4.7 (190-380)	4.7-9.7 (14-190)	9.7-10.2 (7-14)	>10.2 (<7)	Suitable for skimming
8	Skimming well II, Vedullapalli	23	4.00	1.10	7.80	0-5.5 (150-800)	5.5-9.6 (14-150)	9.6-10.2 (7-14)	>10.2 (<7)	Suitable for skimming
9	Skimming well, Padisonpet	42	0.45	0.80	8.20	0-0.5	0.5-9.6 (14-49.7)	9.6-11 (7-14)	>11 (<7)	Suitable for skimming
10	*Doruvu* well, Karlapalem	27	0.40	1.25	9.30	0-0.5	0.5-5.0 (21-50)	5.0-10.2 (7-21)	>10.2 (<7)	Feasible for skimming
11	Open well, Chintayapalem	38	0.40	1.06	6.55	0-0.5	0.5-5.0 (14-30)	5.0-6.5 (7-14)	>6.5 (<7)	Feasible for skimming
12	Open well, Parali	34	1.20	7.25	2.60	0-1.2 (4-20)	-	-	>1.4 (<4)	Suitable for aquaculture
13	Open well, Ganapavaram	37	0.60	1.96	6.00	0-0.5	-	2-2.5 (7-14)	>2.5 (<7)	Suitable for skimming
14	*Doruvu* well, Tummalapalli	35	0.90	1.23	2.30	0-0.5	0.5-3.75 (14-72.8)	3.75-6.50 (7-14)	>6.5 (<7)	Feasible for limited skimming
15	Open well, Buddam	50	1.00	1.92	9.40	0-0.5	2.6- 8.0 (14-24)	1.5-2.6, 8.0-10.5 (7-14)	0.5-1.5, >10.5 (<7)	Complex natured image -Clay with salinity dominant
16	Skimming well, DV Palem	43	2.10	1.42	11.05	0-2.3 (342-800)	2.3-6.0 (14-342)	6.0-8.0 (7-14)	>8.0 (<7)	Suitable for skimming
17	Skimming well I, T R Palem	28	1.45	0.87	12.55	0-1.5 (200-302)	1.5-7.9 (14-200)	-	>7.9 (<7)	Feasible for skimming
18	Skimming Well II, T R Palem	32	1.37	0.92	12.25	0-1.4 (100-500)	1.4-9.5 (20-100)	-	>9.5 (<20)	Feasible for skimming
19	Skimming well, R B V Palem	30	0.60	1.31	14.30	0-0.6	0.6-5.5 (14-22)	5.5-9.2 (7-14)	>9.2 (<7)	Feasible for skimming
20	Skimming well, PV Palem	46	1.00	2.21	11.30	0-1.0 (22-50)	1.0-2.6 (14-22)	2.6-6.5 (7-14)	>6.5 (<7)	Skimming marginal saline waters
21	Open well, Alluru	45	1.50	3.30	6.80	0-1.5 (17-40)	-	1.5-5.0 (7-17)	>5.0 (<7)	Skimming not advisable
22	Doruvu well, Alakapuram	44	1.00	2.79	8.45	0-1.2 (18-13)	-	1.2-2.5 (7-13)	>2.5 (<7)	Suitable for aquaculture
23	Skimming well, Kajipalem	47	0.78	3.21	10.90	0-1.5 (22-600)	1.5-5.0 (12.7-22)	5.0-6.5 (12.7-7)	>6.5 (<7)	Skimming marginal saline waters
24	Skimming well III,TR Palem	33	1.30	0.79	11.60	0-1.3 (280-2098)	1.3-9.2 (14-280)	9.2-10.0 (7-14)	>10.0 (<7)	Feasible for skimming





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