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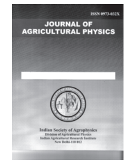

Research Article

Geoelectrical Investigations for Shallow Ground Water at Few Villages Located in a Canal Command Area of Odisha

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ABSTRACT

Vertical Electrical Soundings (VES) assuming Schlumberger configuration and profiling assuming Wenner configuration respectively were carried out in sixteen positions along two traverses in three different villages covering approximately an area of 410 ha in Balipatna canal command of Odisha. Five geoelectric layers were found in the area within a depth of 40 m below ground level. VES data from two points were compared with bore hole data to assign resistivity values to different strata. Using resistivity fence diagram the quantity of ground water under shallow aquifer was computed to be around 12.2 ha-m. Chemical analysis of ground water samples showed that the quality of ground water was good with low salinity and low alkali hazard and could be grouped as C_1S_1 under USDA irrigation water quality classification.

Key words: Electrical Soundings, Ground water quality, Geochemical analysis

Introduction

Water is one of the most essential natural resources for sustaining life and it is likely to become critically scarce in the coming decades, due to increasing demand, increase in population and expanding economy of the country (Singh, 2009). A well planned long term strategy is needed for assessment of sustainable water resources use and management (Kumar *et al*., 2005). Appraisal of water resources encompasses the twin approaches, to explore and assess the available water in the light of its present and anticipated withdrawal and to ensure crop planning based on water availability. It is therefore necessary to get the information on quantity and quality of ground water before such planning particularly in areas where surface water is limited. Exploration of ground water sources by geo-electrical methods is one of the inexpensive and in-situ methods and has been used for long (Keller and Frischnecht, 1966; Koefoed, 1979; Balakrishna *et al*., 1978; Chandrasekharan, 1988; Chandrasekharan and Singh, 1995). The present study was carried out in three different villages namely Balipatna, Fakirpara and Pompalo falling under Balipatna canal command area of Odisha where canal water seldom reach the farmers' fields, particularly to grow *rabi* crops. This study includes assessment of ground water at shallow depths through vertical electrical soundings (VES) and geochemical parameters in an attempt to help the farmers to plan two crops i.e., *rabi* rice / vegetables depending on the availability of ground water resources instead of single *kharif* crop generally cultivated in the area.

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Materials and Methods

Study area

The study area comprises of three villages namely, Balipatna, Fakirpara and Pompalo coming under Khurda district of Odisha State (approx. 410 ha). The area is mostly cultivated for rice (*kharif*). It falls under Balipatna canal command area but the canal water does not reach the villages to cultivate *rabi* crops. Information on quality of ground water (pH, chlorine, fluorine etc.) is available for this area but no information on quantity of available ground water and its geo-referenced locations were available.

Physiography and Drainage

The area is a plain area and drained by the Mahanadi and Kathjhori (Daya) rivers and its altitude range from 40-45 m above mean sea level. It is an extensive alluvial tract and the general slope is towards east and south-east. It enjoys a subtropical monsoon climate. The areas coming under Fakirpara and Pompalo villages are 1-2 m lower than those of Balipatna village (Figure 1).The canals called Gaeridipanchanan minor, Fakirpara minor and Danapara distributary pass through Balipatna, Fakirpara and Pompalo villages but in winter all these canals remain dry.

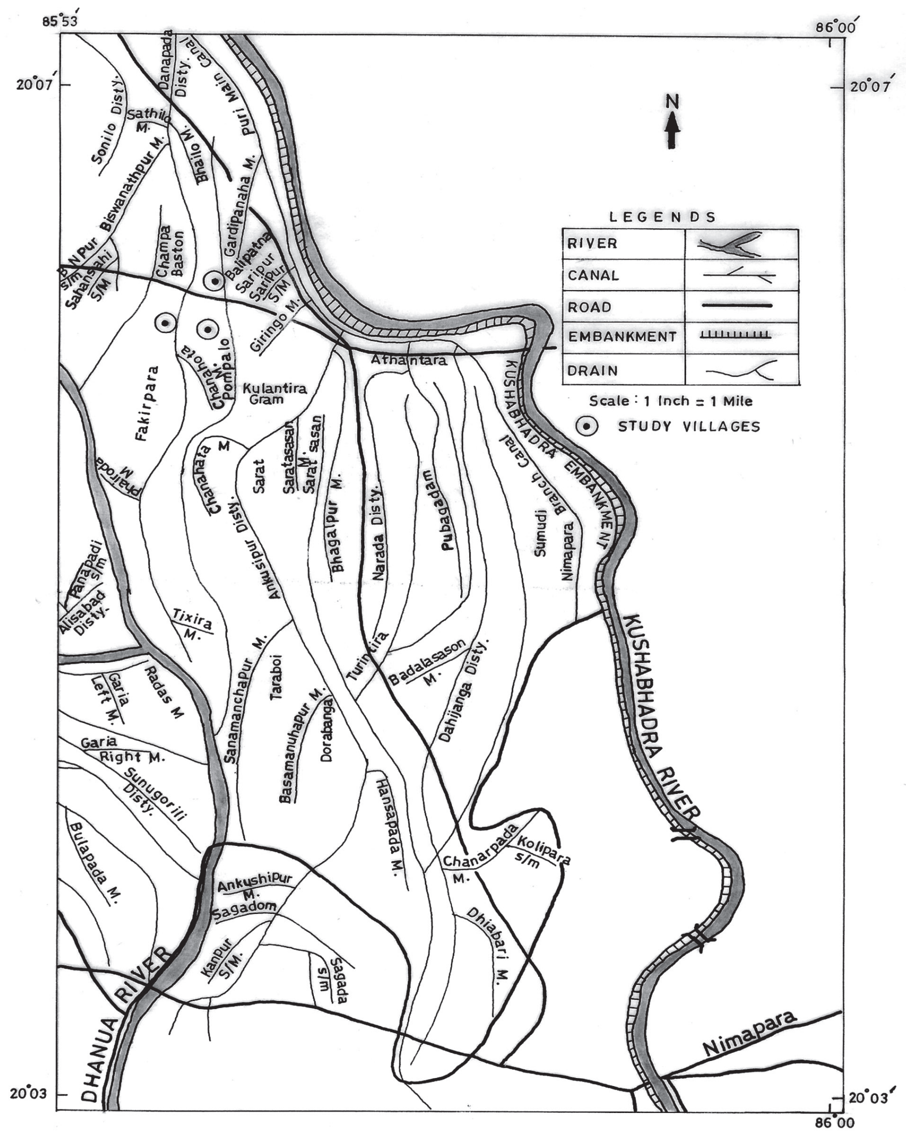

Fig. 1. Balipatna canal command area (Source: Nimapara Irrigation Division, Nimapara)

Table 1. Resistivity data of the study villages, Khurda district, Odisha

VES		Layer Number					T (25 m)	S (25 m)
No.		I	II	III	IV	V	Ohm-m^2	dS
1	h	0.5	0.5	13.9	2.6	- -	562.37	1.635567
	p	31.3	60	10.5	25.2	40.7		
2	h	0.2	1.4	2.6	0.71	- -	9790.638	1.06603
	p	2.5	19	3.1	21.8	487		
3	h	0.5	0.5	0.3	15.2	- -	333.39	2.175936
	p	6.2	60	24.4	9.6	17.3		
4	h	0.2	1.3	3.5	11.5	- -	25	1.86
	p	5	15	4	20	30		
5	h	1.0	0.8	4.0	9.0	- -	457.7	1.527597
	p	8.0	14.0	10.0	16.5	25		
6	h	0.6	0.9	3.0	8.0	- -	507.13	1.561338
	p	8.0	14.2	9.1	12.0	29.3		
7	h	0.5	0.5	1	6.5	- -	334.3	2.05612
	p	3.2	25	7.7	10	15		
8	h	0.5	0.9	2.5	12	- -	282.15	2.494246
	p	9	21	7.5	8	16		
9	h	0.6	0.5	1.8	11.5	- -	290.93	2.489338
	p	10.1	19.5	5.9	9.0	14		
10	h	0.2	0.9	0.6	3.8	- -	403.41	1.936845
	p	8.7	75.3	2.5	10.5	15		
11	h	0.3	0.7	0.9	5.9	- -	348.976	1.886181
	p	3.5	26.9	7.9	11.3	15		
12	h	0.2	0.9	0.7	14.7	- -	336.02	2.355618
	p	10	63.8	3	10	15		
13	h	0.2	03	0.5	12.0	- -	741.82	1.969527
	p	2.8	31.7	9.1	6.0	54.6		
14	h	0.5	0.6	3.7	11.0	- -	330.95	2.304107
	p	7.3	12.0	9.0	12.0	17.2		
15	h	0.4	0.1	0.3	15.7	- -	479.61	1.549458
	p	2.9	21.5	10	14.5	28.9		
16	h	0.5	0.7	4.5	8.0	- -	388.8	1.742885
	p	8.0	14	10	13.0	20		

h in m; p in ohm-m; T in Ohm-m^2; S in dS.

Hydrogeology

The study area falls into semi-consolidated formations derived from granite gneisses. Ground water is restricted to weathered residuum and fracture zones with low to medium yield (3-1 lps). The sand and gravel layers form the potential aquifers which are regionally extensive and often interconnected. Adequate thickness of aquifers (12-60 m) is available for tapping in shallow and deep tube wells. Water table lies 2-5 m below ground level. The pH value of ground water is 6.5 and chlorine content is almost nil (Anonymous, 2010).

Geo-electrical Investigations

Field investigations were carried out in a close grid pattern in the study area. In total 16 VES and two profiling were carried out throughout the villages (Figure 1 and 3) to understand the overall geohydrological situation. Out of 16 VES points, VES 1-4 comes under Balipatna village, VES 7, 10, 11, 12 in Fakirpara and VES5, 6, 8, 9, 13, 14, 15 and 16 in Pompalo village. Two profiling namely, AB and CD were carried out through Balipatna (VES 1 and 3 direction) and Fakirpara-Pompalo villages (VES10 and 14 direction; Figure 5).The field data

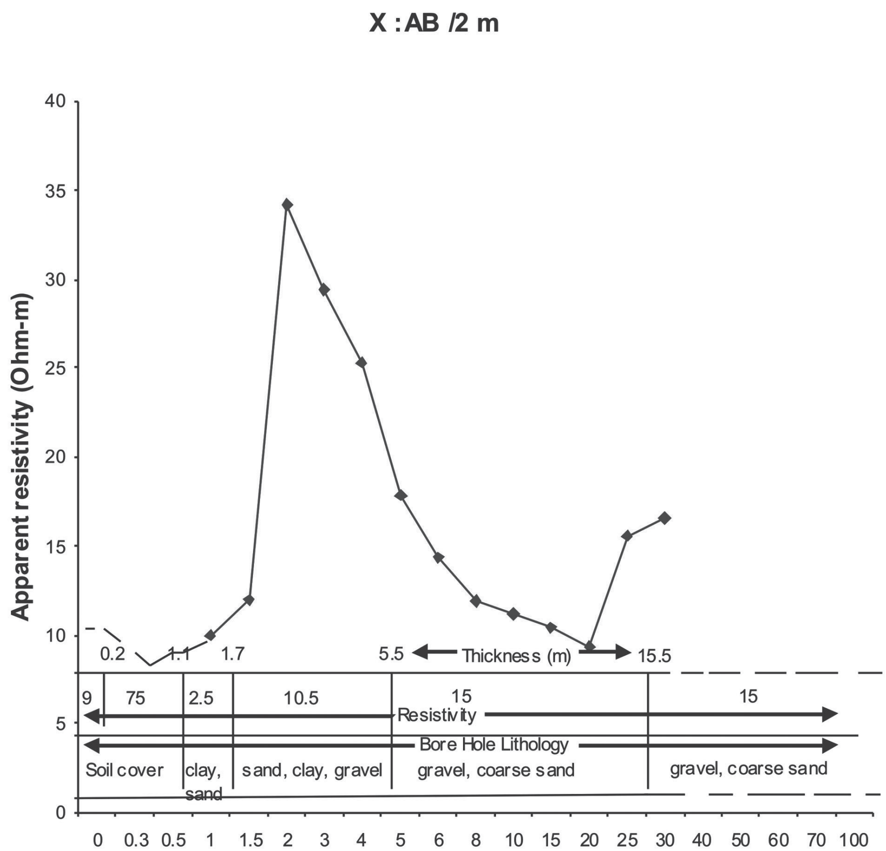

Fig. 2. Comparison of VES 10 data with bore hole lithology

were interpreted for true resistivity and corresponding thickness of different subsurface horizons. To locate the potential aquifer, the Dar Zarrouk parameters were used. Ground water samples were collected from tube wells situated near different VES locations (Table 3) and analysed for EC, pH, Na, K, Ca, Mg, Cb, CO_3, HCO_3, Cl, etc.

RESULTS AND DISCUSSION

The interpreted (true) resistivity values along with the thickness of different formations for VES points indicate five geoelectric layers in the study villages (Table 1). The iso-resistivity contour map for different depth zones were drawn separately in Surfer 9 (Figure 3). Resistivity data of VES 10 and 1 were compared with the borehole lithology of adjoining tube wells.

The true resistivity data of VES 10 shows the presence of a layer of 9-75 Ohm-m up to 1.1 m and another layer of 2.5-10.0 Ohm-m at 5.5 m (Figure 2). As the apparent resistivity curve, drawn on the basis of field data started with 1 m half electrode spacings, the curve was extrapolated backwards to show the resistivity data for depths below 1 m to represent the soil cover. The resistivity value of 2.5 Ohm-m up to 1.7 m indicates the presence of clay and sand. The 10.5 Ohm-m resistivity up to 5.5 m represents sand, clay and small amount of concretions. The fifth layer with a resistivity of > 15 Ohm-m corresponds to concretions and coarse sand. In the interpreted data, the interface between fourth and fifth layer is at 5.5-16.5 m below ground level which agrees well with the borehole data. The presence of sand, clay and concretions and coarse sand , concretions in the fourth and fifth layer started from a depth of 1.5 m below ground level and extends up to >15 m indicates the water potential zones. The inferences drawn from the five geoelectric layers are presented in Table 2.

Table 2. Sub-surface configuration based on iso-resistivity contours

Geo-electric layer	Depth below ground level (m)	Resistivity range (Ohm-m)	Inference
1	0.2-1.0	3.0-31.0	Upper ploughed layer and unsaturated soil. Predominantly clayey, high resistivity of 31.3 Ohm-m at VES1 is due to the presence of kankar
2	0.1-1.4	12.0-75.0	Lower ploughed layer and unsaturated soil. Hard layer below the puddled rice soil, contains sand and clay with relatively higher resistivity values
3&4	3.3-16.5	3.0-22.0	Semi weathered zone of gneisses, contains clay and sand at lower depth upto 5 m and sand, clay and kankar with relatively high resistivity (10-22 Ohm-m) at higher depth upto 17 m .Occurrence of good quality of ground water throughout
5	>16.5	14-487	Water potential zones. Relatively high resistivity at VES2 indicates presence of hard rock at greater depth. Contains mainly coarse sand and kankar with good quality ground water

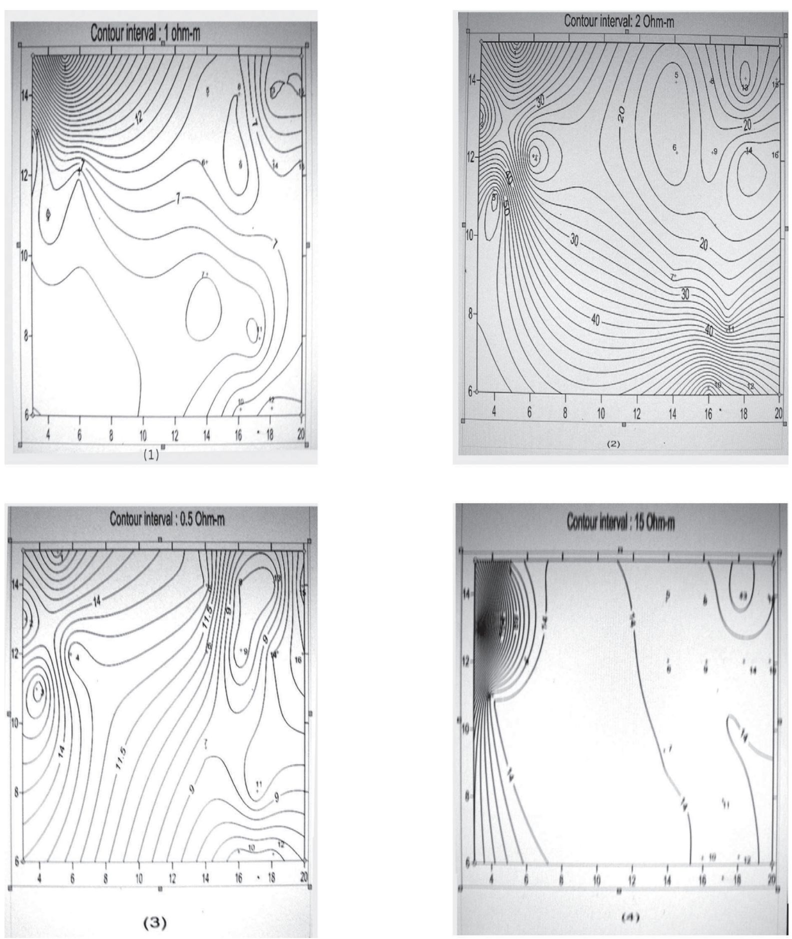

Fig. 3. Iso resistivity contours of geoelectric layers for depth range (m) below ground level (1) 0.2-1.0 (2) 0.1-1.4 (3) 3.3-16.5 and (4) >16.5 (+ VES point)

Table 3. Geochemical data of ground water in the study villages, Khurda district, Odisha

Tubewell location	EC (dS/m)	pH	Some cations and anions (me/l)							RSC (me/l)	SAR (me/l)	Adj. SAR
			Na^+	K^+	Ca^{2+}	Mg^{2+}	CO_3	HCO_3	Cl^-			
1	0.5	7.6	4.5	0.13	2.0	2.0	Tr	4.4	Tr	0.4	3.2	8.9
2	0.4	7.8	3.6	0.06	2.0	1.0	Tr	4.8	Tr	1.8	2.9	7.7
3	0.7	7.4	3.3	0.06	2.0	1.0	Tr	4.0	Tr	1.0	2.7	7.6
4	0.6	8.1	3.5	0.07	2.0	1.0	Tr	4.8	Tr	1.8	2.9	8.0
5	0.5	7.5	3.8	0.09	1.0	3.0	Tr	5.6	Tr	1.6	2.7	8.1
6	1.3	7.5	4.1	0.07	2.0	2.2	Tr	5.6	Tr	1.4	2.8	9.1
7	0.6	6.3	5.1	0.12	1.0	3.0	Tr	4.4	Tr	0.4	3.6	11.5
8	0.4	7.1	3.8	0.33	2.4	1.2	Tr	4.9	Tr	1.4	2.8	9.1
9	0.5	7.2	4.1	0.10	1.0	2.6	Tr	4.8	Tr	1.2	3.1	9.8

Tube well location: 1. Near VES6, 2. Near VES9, 3. Near VES13, 4. Near VES9, 5. Near VES2, 6. Near VES1, 7. Near VES7, 8. Near VES12, 9. Near VES11; Tr: Trace

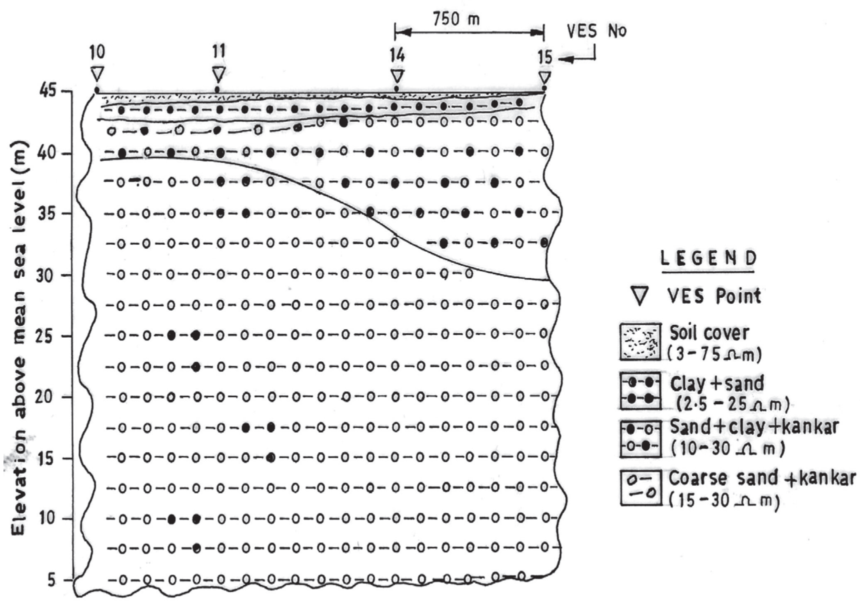

Fig. 4. Geoelectric section along 10-11-14-15 VES point of study area

Resistivity Fence Diagram

The resistivity fence diagram reveals the vertical and probable lateral extension of the several lithological units. Coarse sand and concretions dominate most of the geoelectric layers, as is supported by borehole data and occupies about 60-70% of the total formation encountered down to a depth of 40 m below ground level. This soil, along with sand, clay and concretions in the upper layer form a potential aquifer at shallow depth in almost all the VES points. The sand, clay and concretions materials occupy about 15-20% of the total strata down to a depth of 40 m. On the basis of resistivity data and information on bore hole lithology, the resistivity range for the given subsurface materials were assigned and shown in figure 5. The approximate quantity of available ground water from the shallow (phreatic) aquifer (area of water bearing zone = 15.25 ha) of the investigated area (approx. 410 ha), using the geometry of the aquifer zone (thickness 4.0 m) and specific yield (0.2 assumed) (Raut *et al.*, 1996) of the formation, were worked out as 12.2 ha-m. The moderate resistivity of the formation suggests a good quality of ground water.

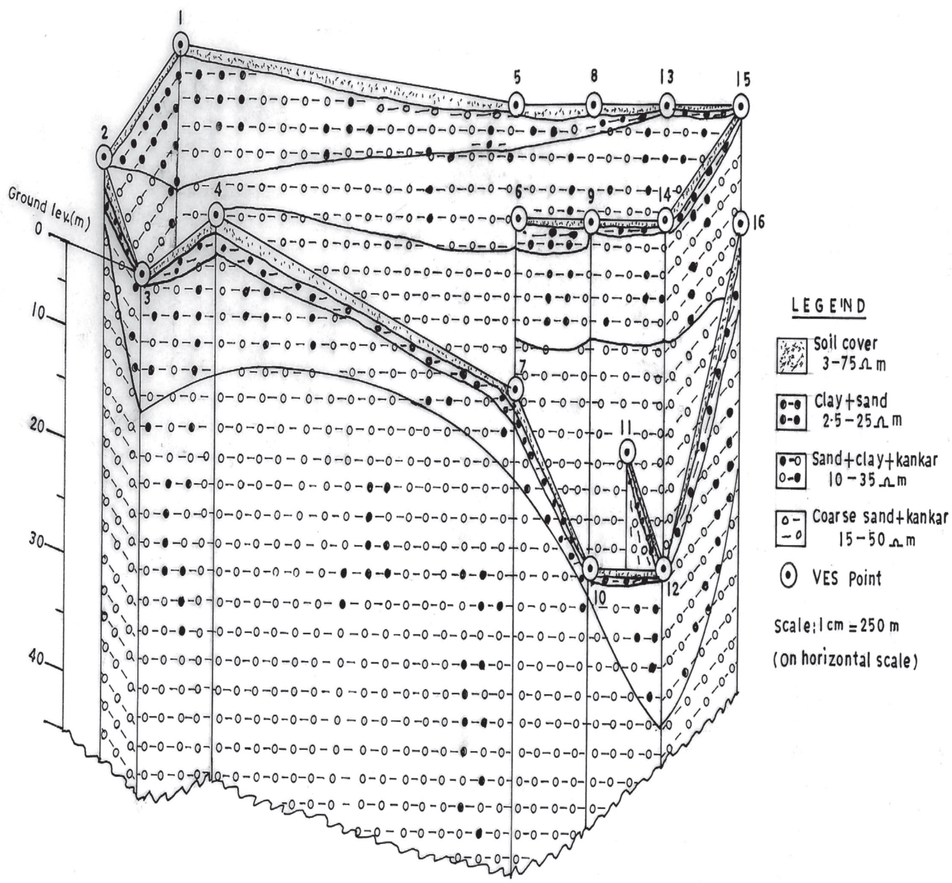

Fig. 5. Resistivity fence diagram of the study area

Geo-electric Section along Traverse 10-11-14-15 VES Points

Qualitative and quantitative interpretations of VES data along this traverse indicate a thin layer of formation (0-1m) representing the soil cover with a resistivity of 3-75 Ohm-m (Figure 4). The high value of 75 Ohm-m at VES10 may be possibly due to hard clay layer below the rice soil. Below this layer, there is a thin layer of clay and sand with low resistivity (<25 Ohm-m). A distinct sand, clay and gravel layer of variable thickness (5-15m) exists below this zone. A layer of coarse sand and concretions exists at a depth of 5-40 m below the ground level with a resistivity of 15-35 Ohm-m throughout the traverse which along with the previous layer forms the potential aquifer for ground water in the study area.

Of the two Wenner profiles with 25 m electrode spacing (AB and CD; figure 7) the apparent resistivity of the profile AB varies from 25 Ohm-m at observation point 5 to 40-45 Ohm-m at observation points 3 and 4. These data indicate a continuity of water potential zones in the Balipatna area. In profile CD, the constant resistivity values of around 10-15 Ohm-m indicates that the aquifer along the traverse is associated with finer material than the traverse AB with good quality ground water.

Geochemical Investigations of Groundwater

Geochemical data of ground water samples gave the following information. The electrical conductivity (EC) of ground water ranged from 0.4 to 0.6 dS /m, representing medium (C_2) salinity group of USDA classification of irrigation water. The high salinity (C_3) of irrigation water near VES1 was possibly due to the presence of a saline pocket zone (Table 3).

The pH of the water samples varied from 6.3 to 8.1 with majority of the samples having pH above 7.0 indicating that the ground water was slightly alkaline. Carbonates present in the ground water samples were in trace amounts. Bi-carbonate ions ranged from 4.0-5.6 me/l. The highest value (5.6 me /l) was observed for the tube wells situated near VES 1 and 2 and lowest (4.0 me/l) for those situated near VES13. High bicarbonate caused alkalinity in ground water. The residual sodium carbonate (RSC) of the samples varied from 0.4 to 1.8 me/l. According to RSC irrigation water classification, samples 1, 3, 7, 9 are safe, although RSC of other samples were slightly high (samples 2 and 4), the harmful effects were not prominent because of low carbonate content (Kanwar and Kanwar, 1969; Paliwal *et al*., 1975). In clay loam to loam soil under Indian conditions, the samples 2 and 4 are also considered to be safe, although these are not suitable for use as per USDA classification (Paliwal, 1972).

The sodium absorption ratio (SAR) of ground water samples varied from 2.7-3.6 me/l. On the basis of USDA irrigation water classification, the samples may be classified under S_1, i.e. low alkali hazard which was more precisely predicted with Adjusted SAR values. The adjusted SAR values for all samples were low (<16) which indicated that water was safe for application to crops in case of Alfisols/Inceptisols present in the study area (Ayers and Wescot, 1976; Yadav and Khera, 1998). The low chloride and sodium ion concentration (< 5 me/l) in the ground water samples were responsible for low EC values. On the whole, the ground water of the study area could be grouped under C_2S_1.

The interrelationship between the Longitudinal Unit Conductance (S) and the EC of ground water samples collected from the tube wells adjoining to different VES points showed that EC values of ground water increased linearly with the S values (figure 6). Similar results were obtained elsewhere (Kelly, 1977). The slope of the possible regression line between EC and S is low which might be due to the high clay content for which there is large increase in S compared to EC values.

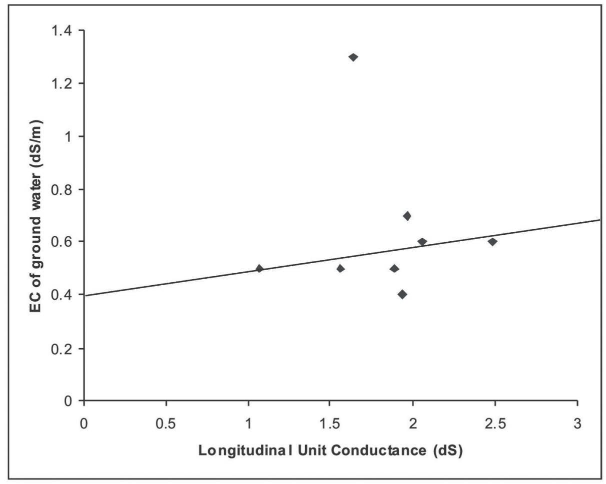

Fig. 6. Variation of EC of ground water with Longitudinal Unit Conductance (S) (dS)

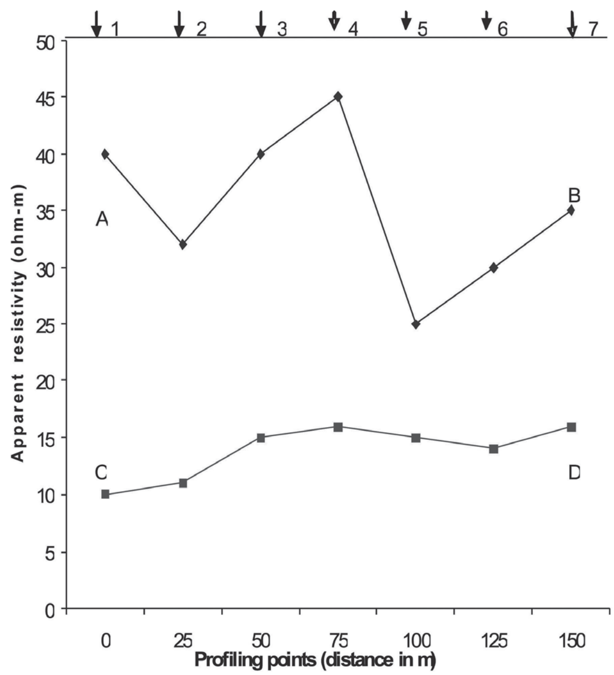

Fig. 7. Resistivity profilings along traverse AB and CD

Conclusions

The interpreted (true) resistivity values along with the thickness of different formations for VES points indicate five geoelectric layers in the study villages. The first layer extends up to a depth of 1 m below ground level with a resistivity of 3-31 Ohm-m indicating soil cover. The second layer is also lower plough layer with relatively high resistivity (75 Ohm-m) and is a hard layer with higher clay content. The third and fourth layers with moderately high resistivity up to a depth of 16.5 m indicate good quality ground water potential zones. The fifth layer contains sand and gravel (15-30 Ohm-m) which extends up to depth > 40 m below ground level.

Dar Zarrouk parameters (S and T values at 25 m depth) showed that there was a combination of low S and high T values at points VES 2, 5, 6 and 15, representing water potential zones because a combination of low value of S and high value of T represent potential aquifer of a region where quality of ground water is more or less uniform (Chandra and Athavale, 1979). On the basis of linearity between transmissivity and T, the VES 3, 4, 7, 8, 9, 11, 12 and 14 are expected to have lower transmissivity than other VES points.

The approximate available ground water from the shallow (phreatic) aquifer (area = 15.25 ha) of the investigated area (approx. 410 ha) worked out as 12.2 ha-m. The ground water is safe for agricultural use with respect to salinity and sodicity as observed with adjusted SAR values (<16).

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