

Assessment of ground water in a coastal village of West Bengal using geo-electrical method

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Abstract: The ground water quality and potential at different depths can be assessed through resistivity soundings and geochemical data. Therefore, Vertical Electrical Sounding (VES) assuming Schlumberger configuration were carried out in 12 locations in a sea water inundated village (Kanthalberia) of Coastal West Bengal. Ground water samples were also collected from nearby tube wells. Five geo-electrical layers were found out in the area within a depth of 80 m below ground level. The VES data from one point were compared with bore hole data to assign resistivity values to different layers.

The inter relationship between longitudinal unit conductance (S) and EC of ground water samples showed that EC values increased linearly with S values. Chemical analysis of ground water samples showed that the quality of water was good with low salinity and low alkali hazard and could be grouped as C₃S₁ under USDA irrigation water quality classification. The approximate quantity of ground water in the study area was computed to be 2.5 ha-m using resistivity fence diagram.

Keywords: Ground water, Vertical Electrical Sounding.

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Introduction

Water is becoming a scarce commodity due to increase in population and expanding economy of the country. A well-planned long-term strategy is required for sustainable water resources assessment and management (Kumar *et al.* 2005). In coastal areas of West Bengal and Bangladesh, groundwater is saline at shallow-to-intermediate depths (typically 0–150 m) across much of the area, making the deeper, fresh coastal groundwater an invaluable source of water to meet growing demand in this region (Michael & Voss 2008). The excessive withdrawal of ground water for irrigation leads to the development of salinity (Mas-Pla *et al.* 2014). The productivity of Coastal West Bengal is low. This is mainly due to high ground water salinity particularly in *rabi* season. In many areas ground water may occur in perched aquifer at greater depths (>40 m and up to 300 m) which is non saline and available for cultivation of crops. Geological information and bore hole statistics of an area help in assessing potential ground water of the area. Exploration of ground water sources by geo-electrical methods is one of the inexpensive and *in-situ* methods and has been used for long (Chandrasekharan 1988; Chandrasekharan and Singh 1995). The electrical resistivity method in combination with hydrogeological data and tube well bore hole lithologs have been proved to be very successful for the assessment of ground water, its potential and quality at different depths. Field-based studies have been conducted by various researchers (Ayolabi *et al.* 2013; Barlow 2003; Goswami 1968; Dhar *et al.*, 2009; Dhar *et al.* 2010). Hence, in this study, assessment of ground water potential and

quality at various depths in the Kathalberia village of coastal West Bengal was done with the help of resistivity soundings and geochemical parameters.

Materials and methods

The study area is a coastal village namely, Kathalberia of West Bengal (approx. 8.0 ha). It is mostly under *kharif* rice. It is a plain area and is drained in the east-west direction through a small channel. The elevation is 2-3 m above mean sea level. It is an extensive alluvial tract and the general slope is towards east and south-east.

Hydrogeology

The study area comprises of quaternary & tertiary alluvium which are major water bearing formations in the study area. Quaternary deltaic sediments composed of clay, silt and sand of various grades, gravels, pebbles etc., remain underlain by upper tertiary formations. Ground water is restricted to weathered residuum with medium yield (5-6 lps). The fine sand and clay 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 0.5-6 m below the ground level. The pH of ground water is 4.5-7.0 and the chlorine content is high.

Geo-electrical investigations

Field investigations were carried out in different locations in Kathalberia village of coastal West Bengal. Twelve vertical

electrical sounding (VES) were carried out throughout the village to understand the overall geo-hydrological situations. Out of these, VES 1, 2, 3 come in the western side and VES 4, 5, 6, 7, 8, 9, 10, 11, and 12 come in the eastern side of the study area. A road passing north-south direction divides the VES points. The field data were interpreted for true resistivity and corresponding thickness of different sub-surface horizons. To locate the potential

aquifer, the Dar Zarrouk parameters (S ant T) were used. Ground water samples were collected from tube wells situated near different VES locations and analyzed for EC, pH, Na, K, Ca, Mg, CO₃, HCO₃, Cl etc. The interpreted (true) resistivity values along with the thickness of different formations for VES points indicate five geoelectric layers (Table 1).

Table 1. Resistivity data of Kathalberia village of coastal West Bengal

VES No.	Layer No.					T (40 m) Ohm-m ²	S (40 m) dS
	I	II	III	IV	V		
1 h ρ	1.58 170	4.15 400	13.9 200	28.5 330	? 400	14113.6	0.17
2 h ρ	2.0 160	19.8 460	49.8 503	67.9 240	? 250	34477.4	0.07
3 h ρ	1.2 120	6.4 49.5	25 111	50 236	? 158	15035.8	0.39
4 h ρ	2.81 200	5.76 150	10.66 100	17.81 300	? 250	10882.5	0.22
5 h ρ	2.69 150	9.09 200	14.55 105	20.78 350	? 200	11022.2	0.31
6 h ρ	2.8 150	4.57 100	9.3 130	24.7 314	? 255	11193.3	0.20
7 h ρ	3.33 150	6.55 200	10.33 300	16.33 450	? 245	15605.65	0.18
8 h ρ	1.51 200	6.88 530	11.40 150	17.62 480	? 210	16715.4	0.18
9 h ρ	1.89 250	7.02 480	12.5 200	19 500	? 250	15559.4	0.16
10 h ρ	1.82 140	8.70 250	15.91 307	30.6 170	? 201	12516.1	0.27
11 h ρ	4.4 150	10.9 220	20 300	25 120	? 400	14058	0.35
12 h ρ	3.7 300	4.92 110	10.54 90	25.0 350	? 260	12649.7	0.25

h: Layer thickness, ρ: resistivity in ohm-m; T: Transverse unit resistance, S: Longitudinal unit conductance

The iso-resistivity contour map for different depth zones were drawn separately in Surfer 26 (Fig. 1).

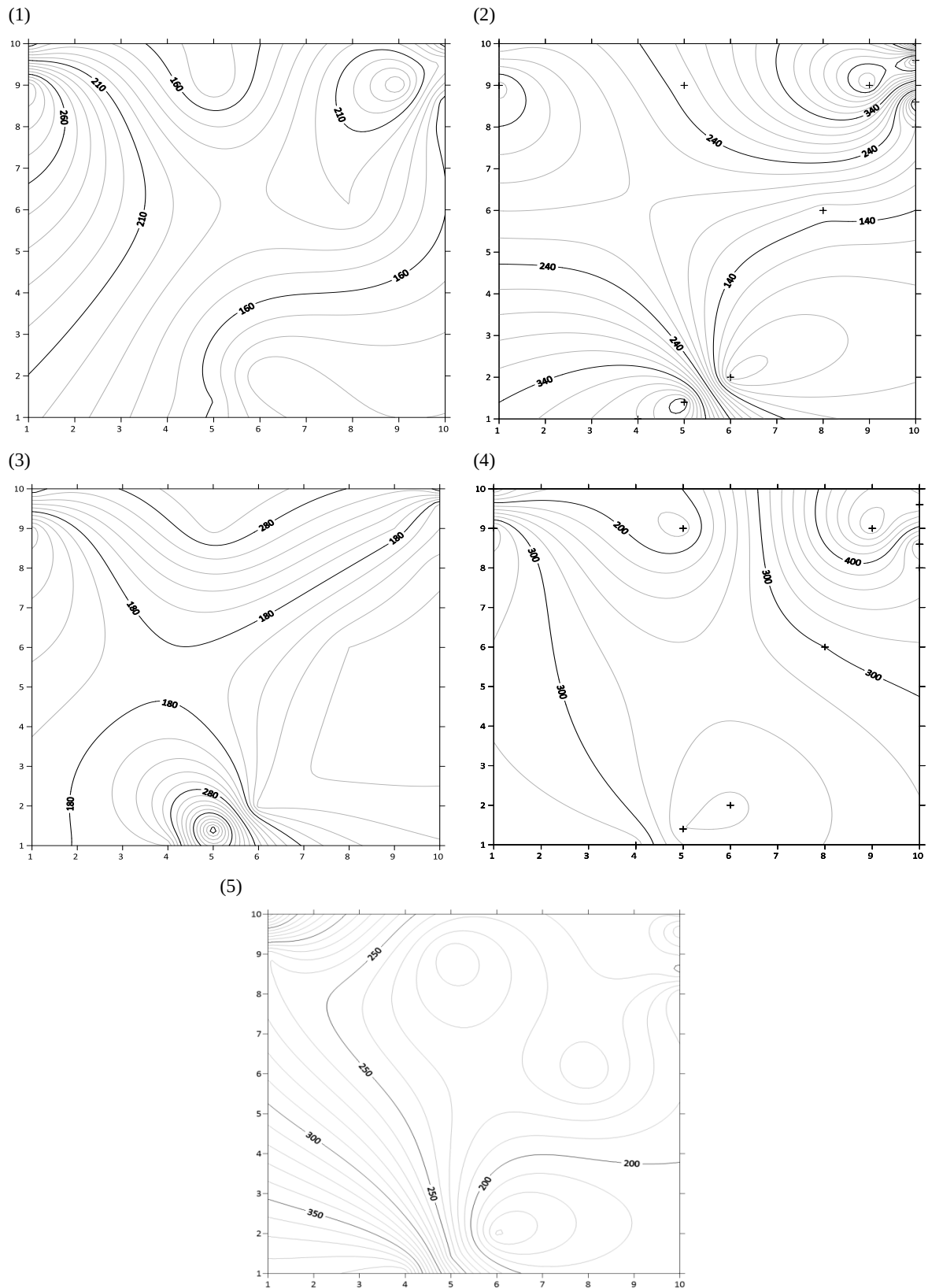


Fig. 1. Iso-resistivity contours of geoelectric layers for depth range (m) below ground level (1) 1.2-3.7, (2) 4.2-19.8, (3) 9.3-49.8, (4) 16.3-67.9 and (5) up to 80 (+): VES points

Resistivity data of VES 1 was compared with the borehole lithology of adjoining tube wells. The comparison of VES 1 with borehole lithology is given below. The true resistivity data of VES 1 show the presence of a layer of 400 ohm-m up to 5.7 m and another layer of 200 ohm-m at 13.9 m (Fig.2).

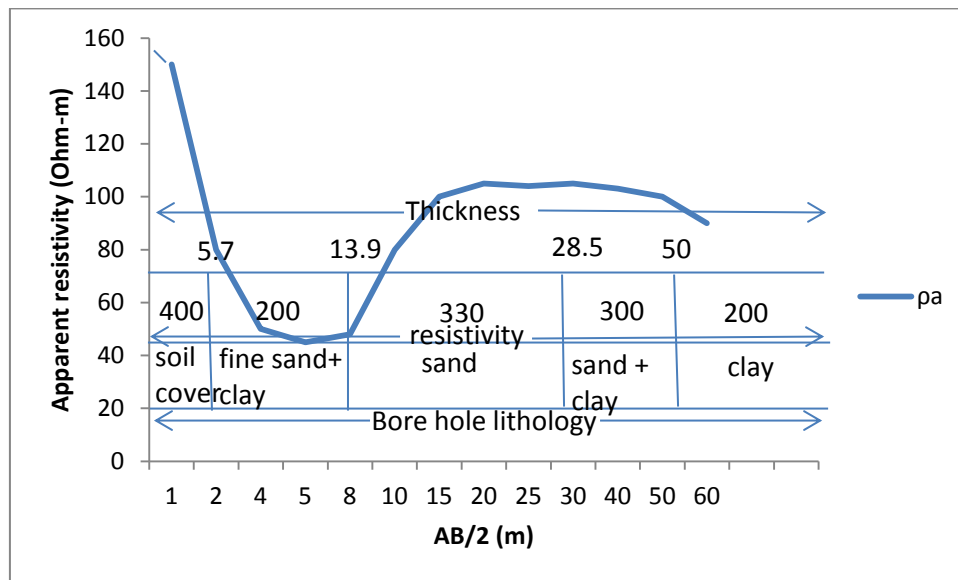


Fig. 2. Comparison of VES 1 data with bore hole lithology

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 values of 120-300 ohm-m up to 1.2-5.7 m indicate presence of soil cover (clay) and mangrove roots. The 200 ohm-m resistivity up to 13.9 m represents fine sand plus clay. The 3rd layer with a resistivity of 300 ohm-m corresponds to sand. In the interpreted data, the interface between 3rd and 4th layers is at 28.5 below ground level (bgl) which agrees well with the borehole data. The resistivities of 3rd and 4th layer indicated water bearing zones. The resistivity of 150 ohm-m in the 5th layer indicates presence of clay and small amount of kankar. 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	1.2-3.7	120-300	Upper ploughed layer and unsaturated soil. Predominantly clayey, high resistivity of 300 ohm-m at VES12 is due to the presence of hard plant root. Existence of a hard layer below the puddle rice soil, contains sand and clay with relatively higher resistivity values.
2	4.2-19.8	100-530	It is lower ploughed layer and saturated soil.
3	9.3-49.8	90-503	Semi weathered zone of gneisses, contains clay and fine sand at lower depth up to 20-25 m and clay and hard sand (kankar) with relatively high resistivity (>307 ohm-m) at higher depth up to 50 m. Occurrence of good quality of ground water throughout.
4	16.3-67.9	120-500	Water potential zones. Relatively high resistivity at VES 4,5,6,7 & 12 indicates materials with less saline to good quality ground water.
5	up to 80	158-400	Relatively low resistivities indicated presence of clay in most of the VES points. High resistivity at VES 1 indicated unsaturated zone and at VES11 indicated presence of kankar.

Resistivity fence diagram

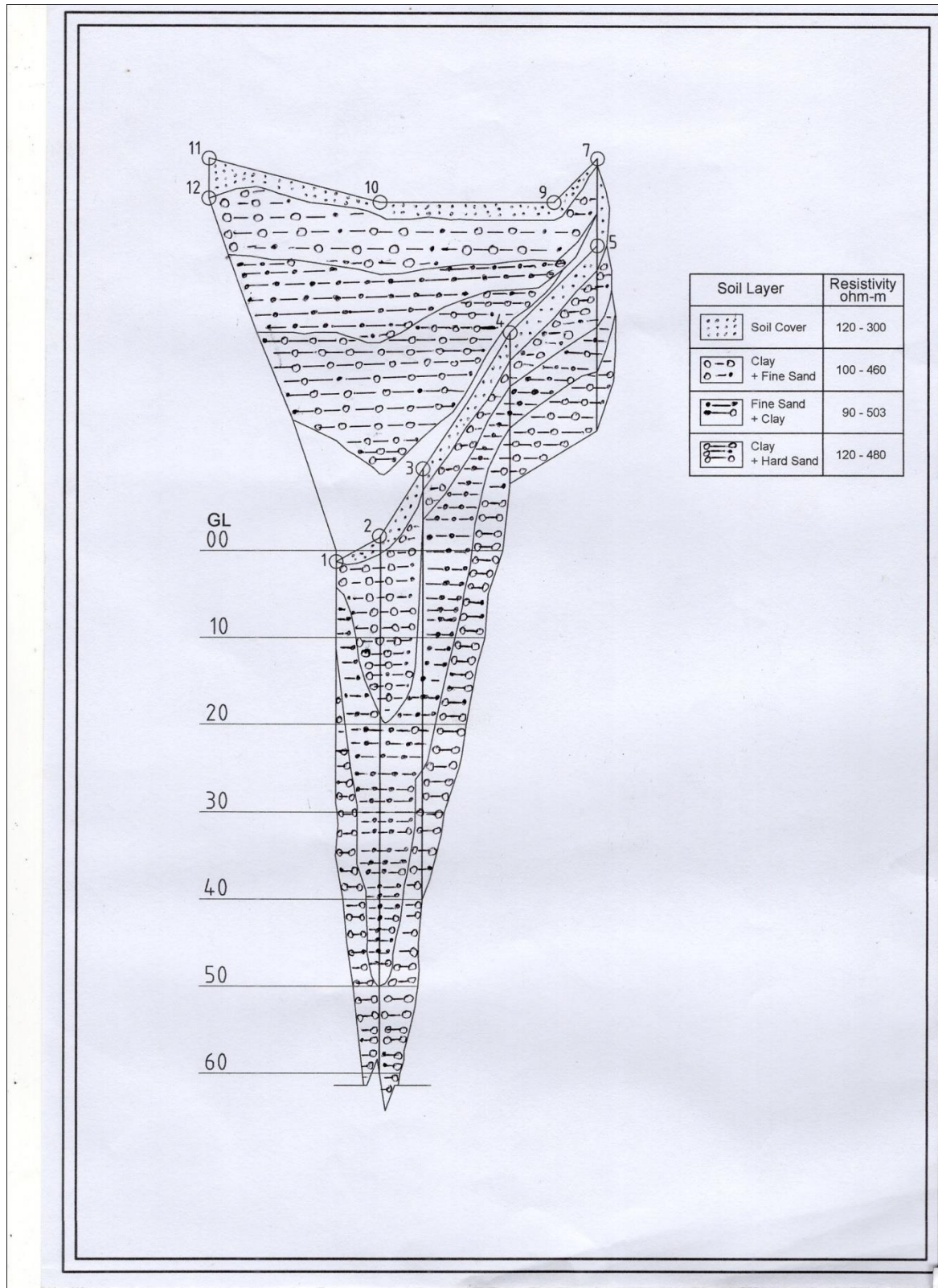


Fig. 3 Resistivity fence diagram of the study area (1: VES point)

The vertical and probable lateral extension of the several lithological units are delineated by the resistivity fence diagram. It reveals that clay and fine sand 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 50 m bgl. This soil along with sand, clay and hard root of mangrove plants in the upper layer form a potential aquifer at shallow depth in almost all the VES points. The clay and hard sand with high resistivity (>400 ohm-m) occupy about 15-20% of the total strata down to a depth of 50 m. On the basis of resistivity data and information on borehole lithology, the resistivity range for a given subsurface materials were assigned and shown in Fig. 3. The approximate quantity of available ground water from the phreatic aquifer (area of

water bearing zone = 2.2 ha) of the investigated area (approx. 8.0 ha), using the geometry of the aquifer zone (thickness 7.5 m) and specific yield (0.15, CGWB, 2009) of the formation, were worked out as 2.5 ha-m. The low to moderate resistivity of the formation particularly at a greater depth suggests a slightly saline ground water (Raut *et al.* 2011).

Geochemical investigations of ground water

The electrical conductivity (EC) of ground water ranged from 1.03 to 1.6 dS m⁻¹, representing medium (C₃) salinity group of USDA classification of irrigation water. The relatively high salinity (C₃) of irrigation water near some of the VES points was possibly due the presence of saline aquifer zone (Table 3).

Table 3: Geochemical data of ground water, Kathalberia village

Tube well location	EC (dS/m)	pH	Cations and anions (me/l)							RSC (me/l)	SAR
			Na ⁺	K ⁺	Ca ⁺²	Mg ⁺²	CO ₃ ⁻²	HCO ₃ ⁻¹	Cl ⁻¹		
1	1.03	7.7	6.5	0.14	6	6	Tr	13	9	1	2.6
2	1.16	8.3	5.4	0.15	6	6	2	11	18	1	2.2
3	1.83	8.0	9.0	0.21	8	3	2	11.5	18	2.5	3.8
4	1.12	7.7	2.8	0.13	4	7	Tr	13	18	2	1.2
5	1.15	7.8	6.5	0.14	5	7	2	11	4.5	1	2.6
6	1.21	7.7	6.5	0.14	6	4	Tr	12.5	9	2.5	2.9
7	1.13	7.7	6.7	0.15	5	3	2	8	9	2	3.4
8	1.60	7.6	10.6	0.15	4	6	2	9	18	1	4.7

Tube well location: 1. Near VES 1, 2. Near VES 3, 3. Near VES 4, 4. Near VES 5, 5. Near VES 6, 6. Near VES 7, 7. Near VES 9, 8. Near VES 10

The pH of the water samples varies from 7.6-8.3 with majority of the samples having pH>7.0, which indicates that the ground water was neutral to alkiline. Carbonates in the ground water samples were in trace amount in most of the tube wells (0-2 me l⁻¹). Bi-carbonate ions ranged from 8.0-13.0 me l⁻¹. The bi-carbonate content of the tube well water 7 and 8 were less than the other tube wells. High bicarbonate caused slight alkalinity in the ground water. The residual sodium carbonate (RSC) of the samples varied from 1.0 to 2.5 me l⁻¹. According to RSC irrigation water classification, samples 1, 2, 5 and 8 could be safe, although RSC of other samples were slightly higher (samples 3, 4, 6 and 7), the harmful effects were not prominent because of low carbonate content. In clay loam to loam soil under Indian conditions, the samples 3 and 6 are also considered to be safe, although these are not suitable for use as per USDA classification. The sodium absorption ratio (SAR) of ground water samples varied from 1.2-4.7 me l⁻¹. On the basis of USDA classification, the samples may be classified under S₁ (low alkali hazards). The high chloride and sodium ion concentration in sample 8 (> 5 me l⁻¹) in the ground water samples were responsible for relatively high SAR values. On the whole, the ground water of the study area could be grouped under C₃S₁. The interrelationship between the longitudinal unit conductance (S) and the EC of ground water samples collected from the tube wells adjoining to VES points showed that EC values of ground water increase linearly with the S values (Fig. 4).

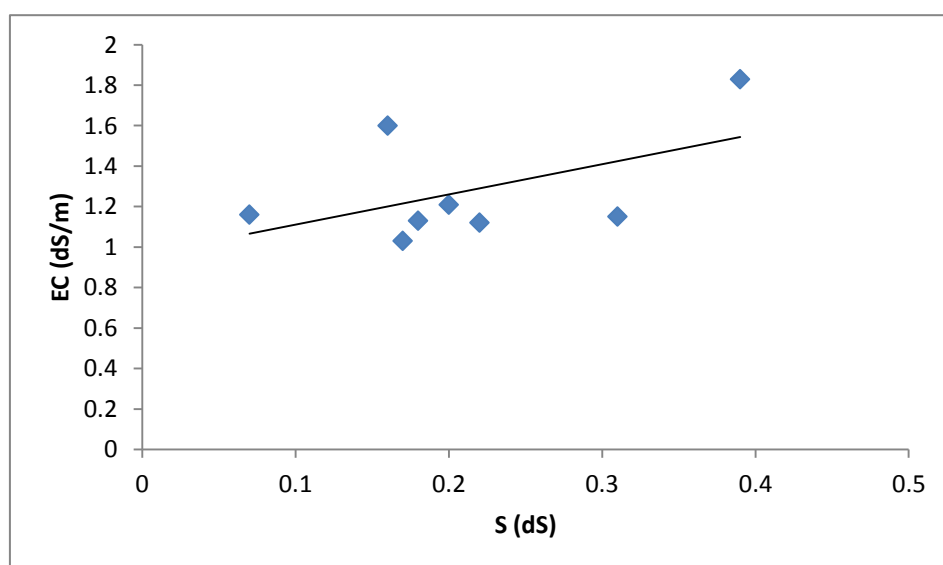


Fig 4. Relation between longitudinal unit conductance (S) and EC of ground water samples

Similar results were obtained elsewhere (Ezeh, 2011). 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.

Conclusions

The interpreted (true) resistivity values along with the thickness of different formations for VES points indicate presence of five geoelectric layers in the study area. The quality of ground water is more or less uniform. The approximate available water from the phreatic aquifer (area = 2.2 ha) of the investigated area (approx. 8.0 ha) were worked out as 2.5 ha-m. The ground water was low to medium saline ($<2.0 \text{ dS m}^{-1}$) for agricultural use with respect to salinity and less sodic as observed with SAR values (<5.0).

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