

Geoelectrical Investigations of Ground Water in the Coastal aquifers of Krushnaprasad Block, Puri District, Odisha, India.

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Abstract

Vertical Electrical Sounding was conducted in part of Krushnaprasad Block to isolate the coastal aquifers which are affected by saltwater contamination. A total of 9 soundings with Schlumberger Arrangement were conducted and the results were analysed using IPI2WIN software. The analytical results brought out an indication of underlying strata affected by saltwater. The basis of resistivity pattern and higher resistivity value (more than 30Ωm) indicate lithology without any presence of saline water. Whereas low

resistivity value ($1\Omega\text{m}$) indicates aquifers with presence of saline water. The resistivity cross-section separating depth of 9 to 25 metre consists of clay layer with lower resistivity value ($0.5\Omega\text{m}$) indicating saline aquifer. The lithology is thick clay layer admixed with sand.

Keywords: Electrical Soundings, Ground water quality, Geoelectrical analysis

INTRODUCTION

Over the decades in addition to surface water, groundwater has taken a lead role in sustaining the agricultural production of a country which there by helps in feeding the millions. In another way it can be said that a developing economy is very much dependent on use of groundwater for ultimate agricultural production (Singh, 2009). Since groundwater is a natural resource and its quantity is limited, its dimension over space and time is very much important which helps the planners to draw a road map of groundwater use (Kumar, et. al. 2005). The quantitative requirement of water is always determined by the statistics that contains individual water use by various sectors such as human consumption, industrial consumption, agricultural consumption etc. The agricultural consumption, in turn, depends on cropping pattern of a country in various seasons (Keller and Frischnecht, 1966; Koefoed, 1979; Balakrishna, et. al. 1978; Chandrasekharan, 1988; Chandrasekharan and Singh, 1995). The work carried out here includes several isolated places of Krushnaprasad Block, Odisha where piped water supply is near absent and the groundwater which very near to the coast is utilised both for human and agricultural consumption. To find out real qualitative picture of groundwater, geophysical investigation was carried out so as to help the local farmers to take sound decisions for the use of groundwater in various seasons.

STUDY AREA

The study area (Fig-1) is located between longitudes $85^{\circ} 10' 28.38''\text{E}$ and $85^{\circ} 37' 50.68''\text{E}$ and latitudes $19^{\circ} 28' 00.58''\text{N}$ and $19^{\circ} 53' 02.25''\text{N}$ falling in Survey of India toposheet no. E45B2, E45B6, and E45B10, in 1:50,000 scale and cover an area of about 151 km^2 in Krushnaprasad, in the coastal belt of Odisha. It is situated at a distance of 75 km to the eastern side of Puri town. The mean sea level position is 25 m and Bhubaneswar, the capital city of Odisha is located at distance of 175 km from this block. As the study area is situated well within the Chilika lagoon, it is considered as an environmental active zone. Moreover, it is also important that the whole coastal track is situated in the saline zone.

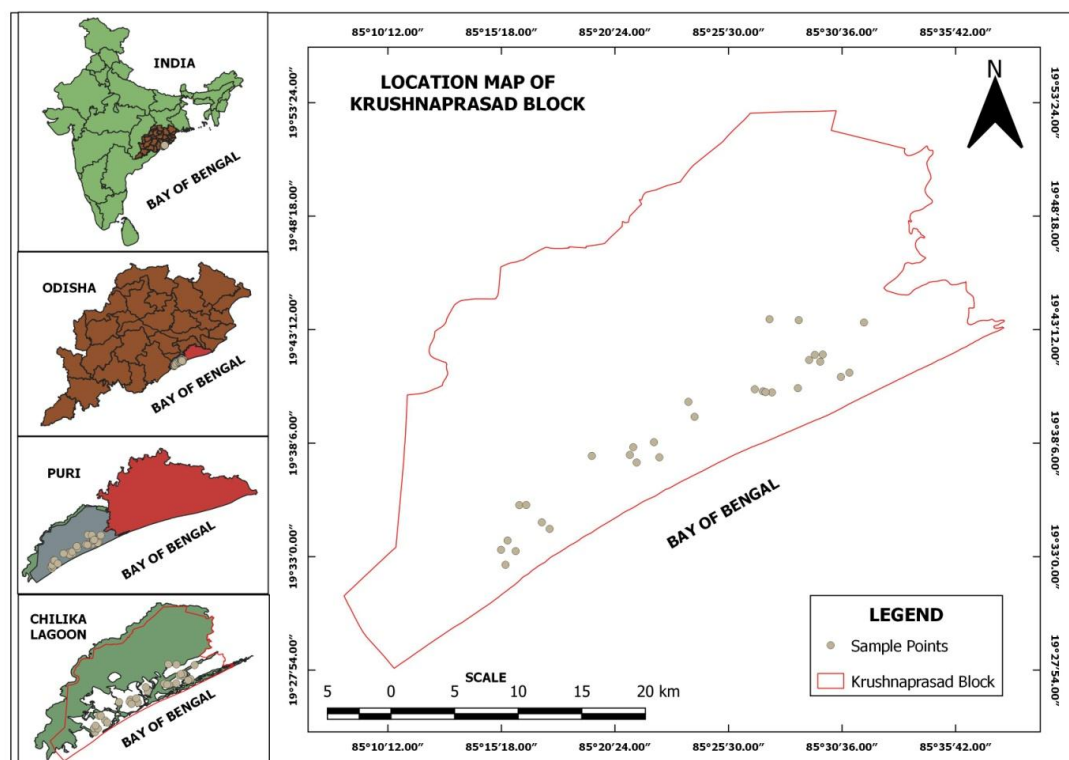


Figure 1: Location map of Krushnaprasad block

GEOLOGY AND GEOMORPHOLOGY OF THE STUDY AREA

The study area consisting mainly of small sandy islands come under two broad divisions (I) the littoral division and (II) the alluvium division. The littoral division is outcropped in the shape of a sandy ridge whose width varies from 6.5 km to 0.1 km and extends between the Bay of Bengal and the alluvium division. This division is consisted of sandy ridges of reconstituted sand and some other sands which are blown to this area from the hinterland. The dynamic character of this division is characterised by the width of the ridge which vary in space and time. The second division is known as alluvium division. This division is mainly consisting of alluvial deposits which are the product of transportation of southern branches of Mahanadi River. The sedimentary column from coast to the hinterland decreases. The soil is mostly consisted of laterites and deltaic sands.

The study area forms part of Mahanadi delta and it is underlain by unconsolidated alluvial sediments of sub-Recent to Recent periods. According to Mahalik, (2000), the sediments comprise mainly of sand, clay, gravel and silt of varying proportions. The sand and gravel layers generally form potential aquifers. The sediments deposited are in heterogeneous pattern due to several phases of marine transgression and regression and depositional environments.

The Quaternary period comprises alluvial sands and lateritic terrains. The lateritic terrains are seen in the NW and western side of the study area and their thickness

varies from a metre to thousands of metres. The alluvium domain is consisted of an older unit and a younger unit. The older unit consisting of kankar clay and sand is exposed in the NW part of the study area. To the eastern part of this region, there lies the younger horizon which accounts for around 85% of the study area. This horizon occurs as floodplain deposits by the side of major streams and rivers. In addition to some sands, some pebbles are also seen. This horizon has a varying thickness that increases towards the sea that truncated into the sand dunes at the coast.

A few ash beds of volcanic origin have been recorded in Mahanadi river valleys. It is believed that they are belonging to an age of 74,000 years. Besides the above, Quaternary sediments are met with in both coastal tracts and upland river valley.

The Puri district may be divided into three hydrogeological regions. They are hilly area, consolidated formations and unconsolidated formations. The hilly areas come under the consolidated areas. The unconsolidated strata consists of clay, silt and sands consisting 30% of the district. A part of the consolidated formation comprises soil regions having groundwater at a less potential whereas the unconsolidated formations consisting of alluvium outcrop is potentially groundwater regions.

METHODOLOGY

A total of nine soundings were undertaken in the study area covering the entire coastal part of most of island periphery of Chilika lagoon for collecting the resistivity value. Schlumberger arrangement was adopted in which two current electrodes and two potential electrodes are lined up. The current electrodes are put in the periphery, and they are continuously extended outer wards so that the distance between two extreme current electrodes increases. The potential electrodes are placed in between and hence the potential is measured for each change in current electrodes. The minimum and maximum electrode spacing varied between 5 to 200 metres. The apparent resistivity is calculated by adopting the following formula,

$$\rho_a = \pi \frac{(L/2)^2 - (b/2)^2}{b} * \frac{V}{I}$$

Where “L” and “b” are current and potential electrode spacing respectively. “V” and “I” are Potential difference and Current respectively. In theory $b \ll l$ and that works for most of the arrangements in electrodes. However, in ground conditions l should be equal to $5b$. After the results were obtained, apparent resistivity is projected in relation to $l/2$ and a curve is obtained. Once this curve is analysed, one can get the following results.

1. Interpretation in terms of various layers of actual resistivity and their depth.
2. Interpretation of the actual resistivity in terms of subsurface geologic groundwater condition. In this case four layers of resistivity conditions were obtained after the data were fed into the analysis software. Comparison of actual resistivity with depth was made with data from a nearby litholog to enable a correlation between two data sets.

RESULT AND DISCUSSION

Apparent resistivity data (ρ) were plotted against $L/2$ in IPI2WIN SOFTWARE to form field curves (Fig-2). This software has been so designed that manual curve matching is not necessary. This software can analyse information with regard to multi-layer disposition of strata. In this manner, the individual layer information such as apparent resistivity and thickness were determined for each point and are shown in Table-1.

Table 1: resistivity, thickness and curve type for isolated, maximum, minimum, average resistance value in Ω and thickness in meter.

Location No.	Location Name	ρ_1	ρ_2	ρ_3	ρ_4	h_1	h_2	h_3	h_4
1	Alanda	40.8	16.3	6.74	3.76	2.07	18.1	42.4	76.9
2	Badajhada	14.4	126.2	15.2	5.27	1.31	1.77	16.9	141
3	Bramhapur	73.9	7.56	2.7	16.3	1.38	13	44.2	296
4	Jenapur	9.46	4.3	196	22	0.71	6.09	1.98	137
5	Maluda	13.3	5.55	38	10.7	2.16	18.2	29.4	55.8
6	Nuapada	13.09	5.36	59.83	8.68	2.24	16.65	44.05	150.7
7	Siala	11.6	5.36	77.6	23.6	0.89	6.64	2.17	167
8	Siandi	19.3	5.84	48.4	18.7	0.43	8.89	58.9	232
9	Tubuka	14.6	2.97	13.1	61.2	3.08	2.84	14.3	383
Maximum		73.9	126.2	196	61.2	3.08	18.2	58.9	383
Minimum		9.46	2.97	2.7	3.76	0.43	2.84	1.98	55.8
Average		23.38	19.93	50.84	18.91	1.58	10.24	28.25	182.15

Let us have a look at the field curves (Fig. 2). In all these cases, the software provides us the data regarding five layers wherein the bottommost layer has a significant depth for which the analytical data is insufficient. However, for our study, a four-layer information is adequate. The value of ρ_1 at all these points may be considered. It is the topmost layer that is exposed on the ground. At all the points, the ρ_1 value registers a double-digit number except Jenapur where it is 9.46 Ω m. This means, the aquifer properties at all points are not amenable to saltwater intrusion. The thickness of the strata at all the points is not so high. The maximum thickness is 3.08 m. The litholog data has been collected and it is confirmed that the first or the topmost layer is highly clayey in nature.

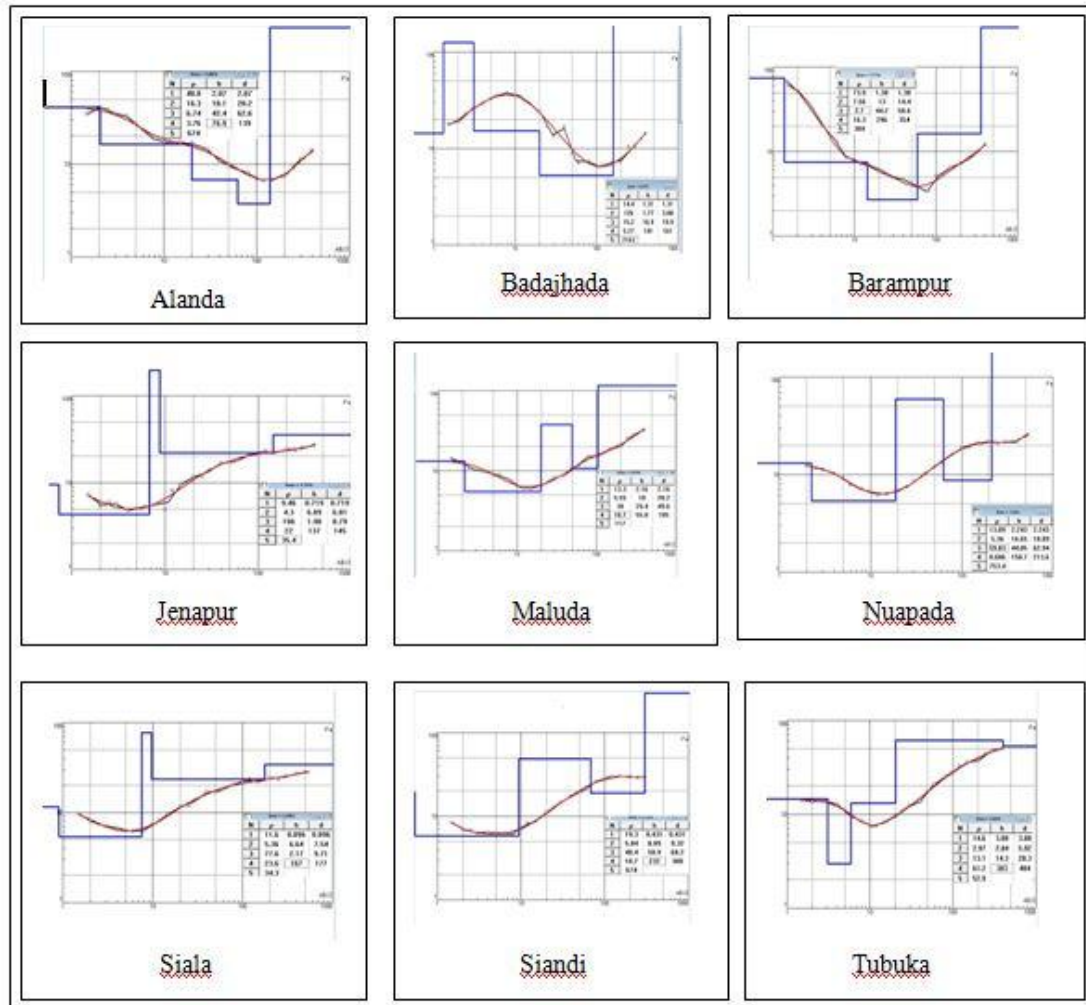


Figure 2: VES field curve of nine location of Krushnaprasad Block.

The second layer from the top corresponds to an apparent resistivity of ρ_2 with corresponding thickness of h_2 . Out of nine points, seven points have registered one digit resistivity value, more especially close to a value of 5 Ωm . Such low values of resistivity are only due to presence of high amount of salt in the aquifer medium. This indicates that the aquifer is intruded by salt water from the adjacent sea. Only two points (No.-1) and (No.-2) have recorded double digit ρ value. This is due to the fact that the locations are away from sea and seawater intrusion has not occurred.

The third layer has the resistivity ρ_3 and the thickness of strata is h_3 . At all the places, the value of ρ_3 is a double digit number except location 1 and location 3. The resistivity values at seven locations are found to be in the range of 13.1 Ωm to 196 Ωm . The resistivity value indicates the presence of highly compact clayey material that gives tough resistance to the flow of electricity. The thickness of this layer (third layer) varies from 1.98 m to 58.9 m. Most of the strata have large thickness as

compared to the previous two layers. From the ρ values, it is pertinent that this layer is free from saline intrusion.

The fourth layer at all the places show large thickness of material as compared to the previous three layers. The ρ values at all the places vary from 3.76 Ωm to 61.2 Ωm . The ρ values at the first two locations are comparatively low with the values of 3.76 Ωm and 5.27 Ωm respectively. That indicates presence of saline water which may be due to saline intrusion from the sea.

Higher resistivity value (9.46 to 73.9 Ω meter) was observed in Bramhapur and Tubuka and the average value is 23.38 Ω meter. Lower resistivity value was observed (0.43 to 3.08 Ωm) in Tubuka and Siandi and the average is 1.58 Ωm .

From the data, it has been observed that 20% of study area show “KHK” type curve. Another 20% of the study area shows “HAA” and “KQQ” type curve and 60% “HAK” and “HKH” type curve. The overall tendency of these curves indicate alternate resistivity conductivity and conductibility reflectivity layers indicating highly unconsolidated nature of formation characterized by clay, shale and sand horizon. The resistivity of topsoil ranges between minimum and maximum of 9.46 and 73.9 Ωm with an average of 23.38 Ωm . In the second layer, the maximum and minimum thickness of the strata are 2.97 and 126.2 Ωm respectively and its average is 19.93m and the corresponding apparent resistivity varies from 2.84 to 18.2 Ωm with an average of 10.24 Ωm . In the third layer, the maximum and minimum thickness of strata are 2.7 and 196 meter with an average of 50.84m and the corresponding apparent resistivity (1.98 to 58.9 Ωm) along with its average 28.25 Ωm . In the fourth layer, the maximum and minimum thickness of strata are 3.76 and 61.2m and its average is 18.91m; the corresponding apparent resistivity is 5.8 to 383 Ωm with an average of 182.15 Ωm . Similar studies have been undertaken by Raut. (2011) in the irrigation command areas of Odisha.

From the above discussion, it has been confirmed that the second layer is clay and fine sand which has been demarcated as a shallow aquifer belonging to Quaternary age. A similar study has been undertaken by (Gopinath and Srinivasamoorthy, 2014 and 2015). The third layer is dominated by sandy silt and sandy clay. Since lower resistivity values are seen at most of the points, they indicate salt water intrusion. The fourth layer is having low resistivity values at some points near to the sea. However, at some other points it has high values indicating absence of salt water. However, due to nearness of the sea, salt water intrusion is imminent in near future. This layer is consisting of compact clay as per the litholog information.

The concentration of all the major ions ranged between wide limits. Chemical analysis results indicate that the concentration of Ca^{++} , Mg^{++} , Na^+ and K^+ ions varied from 8 mg/l to 100 mg/l, 12.24 mg/l to 78.0 mg/l, 135.8mg/l to 1600.19mg/l and 21.29 mg/l to 374.60 mg/l respectively. On the other hand, the anions such as Cl^- , HCO_3^- , and SO_4^- showed variation from 72.74 mg/l to 2493.39 mg/l, 119.1824 mg/l to 2332.61 mg/l, and 12.0 mg/l to 150.0 mg/l, respectively. The concentration of Na^+ at Fatepur, Adalabad, Ora, Hunda, Gilinasi, Kanheipur, Biripadar, Balijagannathpur, Deulaparha, Patharakata, Bhabanipur, Parala, Baghamunda, Banamalipurpatna, Nathpur, Bankijal, Baulapatana, Alupatana, Naubarhi, Porhadhihi, Gangadharpur,

Mirzapur, Gabakund, Bhagabanpur locations Showed higher values than what is recommended by WHO as Maximum Permissible Limit for drinking water.

Total hardness (TH) indicates the trend in the concentration of Ca^{++} and Mg^{++} with a value ranging from 160 mg/l to 650 mg/l. The total dissolved solids (TDS) values, representing the total salt content in the water, ranged between 676 mg/l and 4539 mg/l, amongst which at locations Fatepur, Adalabad, Ora, Hunda, Gilinasi, Kanheipur, Biripadar, Balijagannathpur, Deulaparha, Patharakata, Bhabanipur, Parala, Baghamunda, Banamalipurpatna, Nathpur, Bankijal, Baulapatana, Alupatana, Naubarhi, Porhadhihi, Gangadharpur, Mirzapur, Gabakund, Bhagabanpur the values were higher than the recommended value of 1000 mg/l, the maximum permissible limit for water.

Drinking water standards are generally based on two main criteria (Davis and De Wiest, 1966)⁶: (1) presence of objectionable tastes, odor, and color and (2) presence of substances with adverse physiological (health effects) characteristics. The chemical analysis results showed that the groundwater in the landward locations of the study area is potable, but waters close to shrimp ponds are unfit for drinking as they contain objectionable levels of TDS, Na^+ and Cl^- .

CONCLUSION:

VES was conducted at nine different locations to find out information regarding disposition of different layers. The interpreted resistivity values together with the stratum thickness information indicate a disposition of five layers. The thickness of first layer varies from 9.46 to 73.9 Ωm meter consisting of alluvium. This layer is characterized by moderate resistivity. There is no sight of salt water intrusion. The thickness of second layer varies from 2.97 to 126.2 Ωm and is consisted of fine sands which makes up a shallow aquifer. This layer is characterized by low resistivity which indicates salt water intrusion. The thickness of third layer varies from 2.84 to 18.2 Ωm consisting of sandy silt and sandy clay. This layer is characterized by moderate to high resistivity. Hence there is no salt water intrusion in this layer. The thickness of fourth layer varies from 3.76 to 61.2 Ωm consisting of compact clay. This layer has also low resistivity values at most of the points; that indicate towards salt water intrusion. The fifth layer has no thickness value as per the data fed into the software.

In a nutshell, it can be summarized that two layers (2nd and 4th later) in subsurface area of the study area has been affected by saltwater intrusion. The bore wells and tube wells drawing water from these two layers may not be fit for drinking as well as for irrigation. The other two horizons (1st and 3rd layer) are risk free locations for drinking and irrigation purpose. However, nearness to the sea may lead those other two horizons towards salt water intrusion. So chemical analysis of groundwater may be carried out regularly to know the quality of groundwater for drinking and irrigation purposes.

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