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Groundwater Investigation by Resistivity Method In The Drought-Prone Kuchinda and Bamra Blocks, Sambalpur District, Odisha, India

N MAHANTA

P.G. Department of Earth Sciences, Sambalpur University, Jyoti Vihar, Burla – 768019, India

***Email:** nandita.mahanta12@gmail.com*

Abstract: *Hydrogeological studies in drought-prone Kuchinda and Bamra blocks of Kuchinda Subdivision in northern part of Sambalpur district has indicated predominance of consolidated formations lacking primary porosity. Groundwater occurs both under unconfined and semiconfined conditions in the weathered and fractured zones. Although, there is underdevelopment of groundwater resources in the subdivision as a whole, localized scarcity is found in many places as evidenced from dry wells in summer and increase in the depth of water table over the years. Resistivity survey in 26 locations of the area has indicated 3 to 5 layer cases in the disposition of subsurface rocks. The second and third layers are suitable for groundwater storage and movement and hence can be developed for groundwater. The potential fracture zones are restricted to a depth of 27 to 174.5 m below the ground level.*

Keywords: *Vertical electrical sounding, consolidated formation, Darjing Group*

1. Introduction

Because of rapid growth in population, urbanization, industrial and agricultural activities, water needs have been increased to a considerable extent. This problem has been compounded because of uncertain and erratic rainfall as a result of which people have started looking at groundwater as a viable resource instead of surface water. However, one of the problems encountered by people of India in developing groundwater resources is the declining trend of the dynamic water table. In the western part of Odisha, where there is predominance of hard rocks, the bore wells become unproductive and dug wells go dry particularly in the summer months. Even deep bore wells dug to tap deep seated fractures do not yield required result.

1.1 Study area

The study area lies between longitudes 84^0 15′ and 84^0 42′ E and latitudes 21^0 37′ and 22^0 13′N in Survey of India toposheet numbers 73 B/8,73 C/5, C/6, C/8, C/9, C/10 and C/12. The study area comprises of two administrative blocks such as Bamra and Kuchinda in Kuchinda Subdivision of Sambalpur district, Odisha with a total area of 1321. 64 sq.km. The area of study is a highly undulating terrain with maximum height of 736 m above MSL (Bamlo Pahar) and minimum height of 221 m above MSL. The rainfall is quite erratic since the average annual rainfall in 2009 in Bamra block is 1190 mm as against 1737 mm in 2008. Similarly in Kuchinda block the average annual rainfall in 2009 is 1200 mm as against 1662 mm in 2008. The major drainage system of the area is controlled by the major river Bheden with streamlets and nalas like Purtola nala, Kharla nala, Lamdora nala, Tabko Jharan, Lohrangi nala, Sian Jhor etc. The drainage pattern is dendritic and influent in nature. The main soil type of Kuchinda block is alfisols, which include red sandy, red loamy, red in the low lying flat terrains which serve as the cultivated lands. The thickness of the soil zone varies from less than 1m to about 3.5m. The lateritic soil is restricted to the high land and foot hill regions. The sandy soil is exposed along the course of the Bheden River and Kharla nala. The clay loam is found in the low lying flat terrains which serve as the cultivated lands.

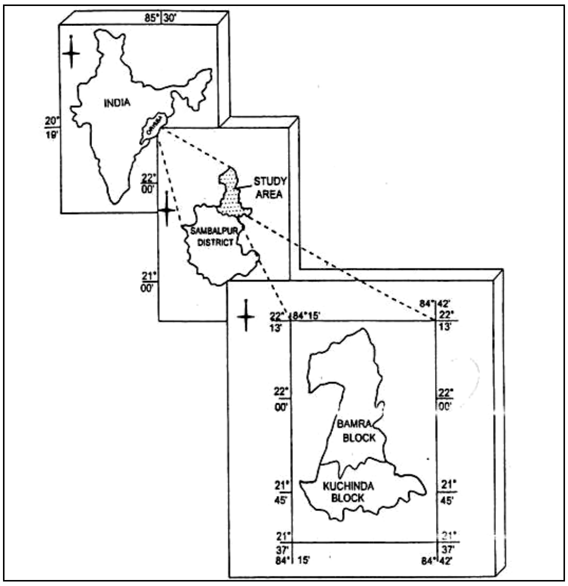

Fig. 1. *Location map of the area of study*

1.2 Geology

A number of lithologic units belonging to various stratigraphic horizons are exposed in the area of

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study. These include rocks like garnetiferous biotite-quartz schist belonging to Older Metamorphic Group, quartzite belonging to Deogarh Group, Birtola Formation and Jalda Formation belonging to Darjing Group, quartzite belonging to Kunjar Group, in addition to metavolcanics, mafic/ ultramafic sills and dykes, granitoids(Bamra granite), laterite, alluvium etc. The Birtola Formation comprises of quartzite and conglomerate whereas the Jalda Formation comprises of staurolite schist, calc-gneiss, garnetiferous mica schist etc. The oldest lithounit of the area belong to Older Metamorphic group which have been intruded by granitoids. It is overlain by metavolcanics and quartzites belonging to Deogarh Group. These are overlain by Bamra granite which forms the base for the rocks of Darjing Group. The contact of the Bamra garanite and Darjing Group represents an unconformity which is assigned an age of 2700 Ma (Mahalik, 1987, [1]; (Mahalik, 2006) [2]. The Kunjar basin has been developed over the 2700 Ma granitic basement during the Meso-Proterozoic period (Chaki et al., 2005) [3]. The rocks of the area are affected by different phases of folding complicating the geological set up of the area with development of folds of different generations, faults, joints etc. On the other hand, the structural disturbances are responsible for creating secondary porosities in the hard rock's helping in the storage and movement of groundwater.

1.3 Hydrogeology

The area is underlain predominantly by hard rock's comprising of 85% of the study area. The rocks lack primary porosity and the groundwater is present in these rocks in weathered, fractured, sheared, jointed zones etc. The hydrogeomorphic units in the study area include residual hills, structural hills, denudational hills, intermontanne valleys, pediment etc. The area is also characterized by a number of lineaments and faults which are of great importance to control groundwater storage and movement.

The Hydrogeological frame work of the study area is quite divergent due to diverse lithological formations along with meteorological condition. On the basis of water bearing and water yielding characteristics, the aquifer systems can be broadly classified into two categories i.e. consolidated formations and unconsolidated formations. The major part of the area is underlain by consolidated formations comprising Precambrian rocks like garnetiferous biotite-quartz schist, quartzite,granite, staurolite schist, along with mafic/utramafic sills or dykes and metavolcanics. Groundwater occurs under unconfined conditions in the weathered residuum but under semi confined and rarely under confined conditions in structurally disturbed zones like fractured and jointed rocks at deeper levels. The yield in the consolidated formation varies from 1 to 10 litres per second depending on the nature of weathering and fracturing. The unconsolidated formations on the other hand are constituted of laterite and alluvium. This formation is of limited areal extension and depth in the area of study and do not play any significant role in the hydrogeoloical scenario of the area.

The well inventory study of the area from 25 wells indicates that depth of the water table varies from 2.44 m below ground level (bgl) to 8.23 m bgl in pre-monsoon season and 0.91 m bgl to 6.7 m bgl in post-monsoon season. In pre-monsoon and postmonsoon seasons the variations in the depth of water table are > 6.5 m and > 5.0 m respectively. The stage of groundwater development in Kuchinda block is 17.29% whereas in Bamra block it is only 13.99% indicating the fact that huge resources of water is still to be utilized, but it has to be done location-wise vis-à-vis the availability of the resource.

1.4 Electrical resistivity investigations

Resistivity survey and remote sensing studies are two such tools which can provide valuable information on the groundwater condition of a particular area. The resistivity survey because of its simplicity in investigational and interpretational survey in addition to remote sensing study can be very successful in areas where a shallow soil and weathered zone overlies a fractured zone and bed rock.

Twenty six (26) Vertical Electrical Soundings (VES) were carried out in the area of study (Fig.2). A direct current resistivity meter was used in the field adopting Schlumberger electrode configuration. A maximum current electrode separation of 250m was maintained but in most of the cases it was restricted to 150m because of lack of space. The recorded apparent resistivity values with the half of current electrode spacing were plotted on standard transparent curves published by European Association of Exploration Geophysicists (Rajakshwatersaat, 1975) [4] and auxiliary charts given by Orellana and Mooney (1966) [5] and Bhattacharya and Patra (1968) [6]. Some of the field data were also interpreted by the computer programme to verify the accuracy in manual interpretation which is found to be comparable.

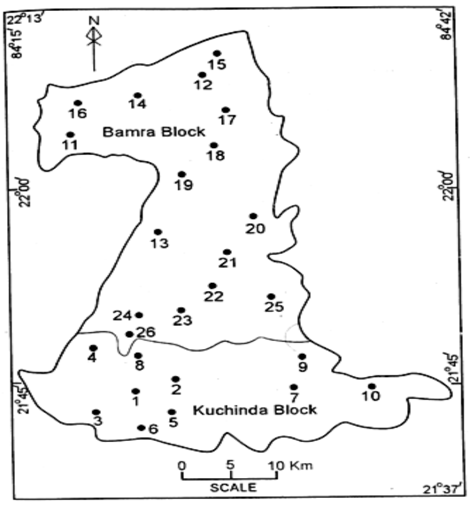

***Fig. 2**. VES Location map of the study area*

The interpretation of the resistivity curve indicates that, there are three to five layer situations with the first layer represented either by the top soil or lateritic horizon. The second layer is represented mostly by weathered to highly weathered rock, the third layer by partially weathered to fractured rock and the fourth layer by partially fractured rocks and the fifth layer invariably by massive and hard rocks. The interpreted results of the resistivity curves are given below.

Table 1: *Location of Vertical Electrical Sounding (VES)*

Sl. No.	Location
1	Kuchinda
2	Mantrimunda
3	Kira
4	Khandakota
5	Niktimal
6	Boxma
7	Kukum
8	Soida
9	Kusumi
10	Jandha
11	Gobindpur
12	Gorpos
13	Solboga
14	Lolobira
15	Sagra
16	Sargidihi
17	Kinabaga
18	Nuapali
19	Rangiatikra
20	Kholbilung
21	Jarabaga
22	Jarabahal
23	Mahulpali
24	Ardabahal
25	Banke
26	Paruabhari

1.4.1. Result and Discussion:

First layer: This layer is composed of sand mixed with varying content of clay and lateritic material. Its thickness varies from 0.4 to 6.3 m. The resistivity value of this layer varies from 8.0 ohm- m to 663.0 ohm- m except one location where value of 1130 ohm-m is noticed. This layer is relatively a dry layer and groundwater in this zone occurs in very limited quantities.

Second layer: This layer represents laterite in a few cases but highly weathered granite and other rocks in most of the cases. In a few localities, it comprises of clay, sandy loam and sandy clay. The thickness of this layer varies from 0.9 to 16.7 m. The resistivity of this layer varies from 3.0 to 169.6 ohms- m. Groundwater occurrence in this layer is very good.

Third layer: It represents highly weathered and fractured granite and other hard rocks in four layer cases and sometimes hard and nonporous rocks in three layer cases. The thickness ranges from 1.9 m to infinity. The resistivity value of this layer ranges from 29 ohm- m to very high (2290 ohm- m). Groundwater in fractured and weathered zones occurs in large quantities and can be considered as potential aquifers.

Fourth layer: It represents partly fractured rocks, weathered to partly weathered granite and other hard rocks. The thickness of this layer varies from 6.2 m to infinity. The resistivity varies from 12.5 to 6740 ohm-m. Groundwater occurs only in fractured and weathered zones in limited quantities.

Fifth layer: This layer is present only in a few cases representing hard rocks, which lack porosity in them as a result of which the groundwater occurs in very less amount. This layer extends indefinitely below the fourth layer and has very high resistivity values. The resistivity data obtained from VES Studies is applied to prepare isoresistivity maps for 1st, 2nd and 3rd layers of the whole area. From the study of the isoresistivity map of the 1st layer (Fig. 3), it is found that the top layer is usually soil with sand mixed with varying contents of clay and laterite with resistivity ranging from < 200 ohm- m to > 600 ohm- m.

About 70% of the area comprises of sandy soil with resistivity less than 200 ohmm. Resistivity value ranging from 200 to 399 ohm- m is located at Gobindpur, Jarabahal, Jarabaga, Gorpos, Ardabahal, Mantrimunda and Soida. Resistivity value ranging from 400 to 599 ohm- m is located at Kuchinda, Khandakota etc. The resistivity value of more than 600 ohm- m is located in the southern part of the area at Niktimal and Kukum due to presence of hard rocks at very shallow depths. The isoresistivity map of the second layer (Fig. 4) indicates that the resistivity value ranges from less than 30 ohm- m to more than 120 ohm- m. Resistivity values of more than 120 ohm- m are located at Gobindpur, Sagra and Jarabaga whereas values within 90 to 120 ohm- m are located at Mantrimunda, Niktimal and Gorpos.

Groundwater occurrence is very good in these areas due to presence of laterite, highly weathered granite and sometimes clay, sandy loam and sandy clay. The isoresistivity map of the third layer (Fig. 5) indicates a large variation in resistivity values from less than 500 ohm- m to more than 2000 ohm- m indicating presence of quite varied rock types such as weathered granite and other crystallines, fractured granite and sometimes other hard rocks. About 40% of the area has resistivity value less than 500 ohm- m and other areas have a value varying either from 500 – 1000 ohm- m, 1000 – 1500 ohm- m, 1500 – 2000 ohm- m and more than 2000 ohm- m as shown in the diagram.

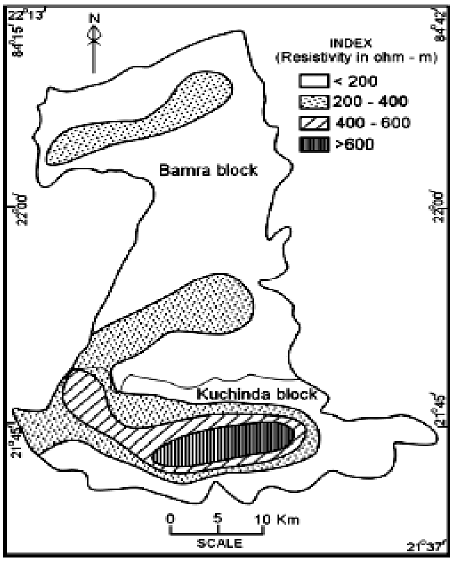

Fig. 3: *Isoresistivity map of First layer*

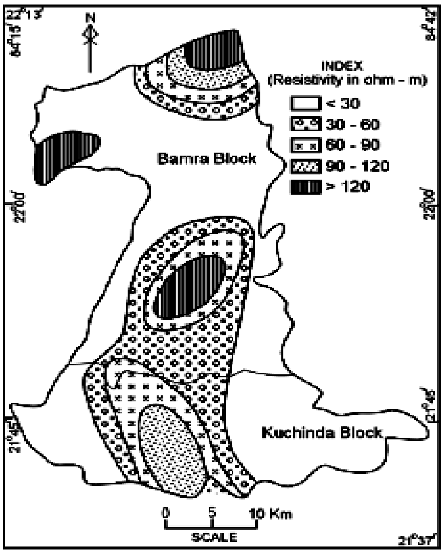

Fig. 4: *Isoresistivity map of Second layer*

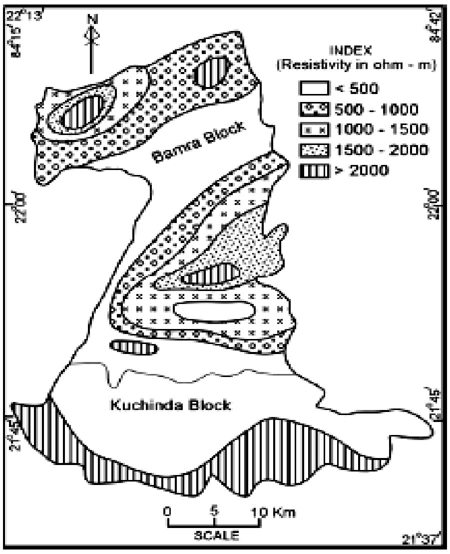

Fig. 5*. Isoresistivity map of third layer*

The interpretation of resistivity values of two locations (Boxma and Gorpos) from VES data is compared with that of the drilling data of Central Ground Water Board and it is found that both the results are comparable(Fig. 6) and hence the interpretations of the resistivity data can be taken as reliable. The interpretation of the resistivity values in terms of lithologic units and thickness of different layers for some locations are taken to prepare fence diagram (Fig. 7) indicating thickness of the aquifers and presence/absence of groundwater.

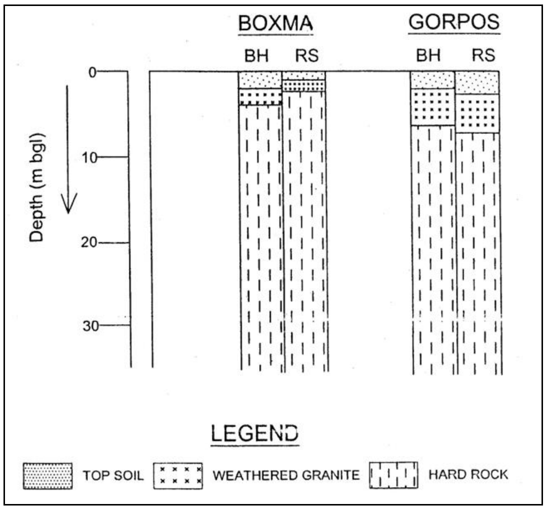

Fig. 6*. Comparison of Bore hole thickness data (BH) of CGWB with that of thickness derived from resistivity survey*

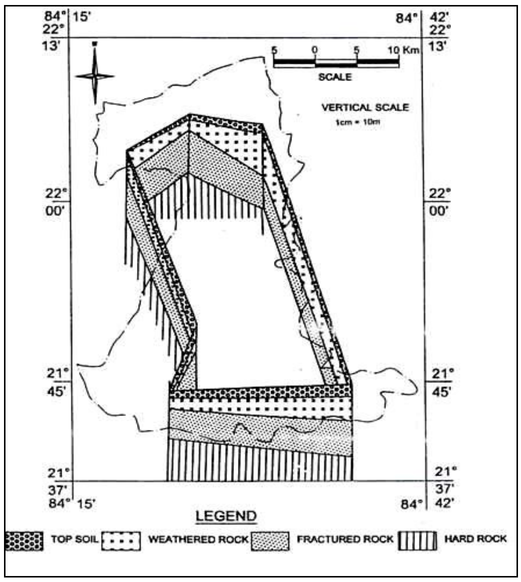

Fig. 7*. Fence diagram showing different layers*

1.5 Conclusions

Vertical electrical sounding undertaken in the area of study at 26 locations has revealed 3 – 5 layer cases. Since the area is predominantly underlain by hard, consolidated and nonporous rocks, groundwater condition is poor to moderate in the entire area. However it is essential to find out areas affected by large scale weathering and fracturing to get substantial amount of groundwater. Although, the groundwater development is low in the area, people of some localized areas suffer either due to lack of water or due to over-exploitation. To find out groundwater rich regions in a hard rock terrain like that of the present area in a large scale, surface geophysical prospecting method coupled with remote sensing method is most ideal. It is also recommended to suggest water harvesting structures at appropriate places from remote sensing inputs. Conjunctive practices to use both surface and groundwater resources with proper management techniques for utilization of water resources should be adopted.

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