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Geoelectrical investigations for locating potable aquifers in parts of Agra District, U.P., India

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ABSTRACT
Heavy withdrawals of groundwater for irrigation and limited recharge due to recurrent drought resulted in acute scarcity of drinking water in Kheragarh and Kiraoli Tehsils of Agra district, U.P.

The geoelectrical methods comprising resistivity profiling and sounding aided by the hydrogeological data including litholog data of existing bore wells and chemical analysis data of water samples from a number of wells helped in delineating fresh water pockets underlying or overlying or at some places sandwiched between saline water zones.

INTRODUCTION

Agra district, located along southern fringe of the Indo-gangetic plain has a semi arid climate. Many villages in the district face severe scarcity of drinking water either due to poor yield of wells or salinity of available sources. In the alluvial covered areas of eastern part, the scarcity is primarily due to poor quality of groundwater pertaining mainly to salinity. The south westren part is covered by hard compact sandstones where the scarcity is mainly due to absence of weathered/fractured sand stone. Hence, the resistivity surveys were carried out to delineate the weathered/fractured rock in the westren part while in the eastern part, the target was delineation of freshwater pockets in a saline environment.

GEOLOGY

The study area is underlain by rocks belonging to Upper Bhander series of Upper Vindhyan system. These rocks are covered by thick alluvium at places. The geological sequence of the area is as follows:

Quarternary	Recent to Upper Pleistocene	Younger alluvium older alluvium laterite and clay
	Unconformity	
Precambrian	Upper Vindhyan system	Upper Bhander Sandstone Lower Rewa sandstone
	Unconformity	
	Delhi system	

HYDROGEOLOGY

Ground water occurs mostly in the unconsolidated sediments comprising of layers having different proportions of sand, clay and kankar. In sandstones, ground water occurs in weathered and fractured zones. Weathered aquifers are in unconfined condition where as fractured aquifers are in semi confined condition. According to Handa (1964), the area is characterized by low to moderate aquifer permeabilities, low rainfall and high evapo-transpiration losses resulting in the increase of brackishness of groundwater. Based on satellite imagery studies, Rajiv Mohan, Lakshman Rao & Hira Singh (1987) have reported Kiraoli Tehsil and surrounding areas as being strongly saline. Usually fresh water aquifers overlie the deeper brackish zone as seen in Chit village. At some locations fresh water pockets underlie the brackish water layers as observed in Mahuakhera village. A third case also exist where the multi layered freshwater and saline water pockets exist. The annual departure of rain fall is reported to be –265 mm. in Agra district (Kidwai & Mukherji 1988). They also reported that out of the 14 hydrograph stations monitored by CGWB in Agra district, 13 wells showed declining trend of groundwater table in the range of 0.24-1.88 meters while only one well showed raising trend of 2.2m during May 1986-and May 1987. The low rainfall led to the limited recharge to freshwater aquifers resulting in decline of ground water level. Kwarnadi and Utangan rivers form the major drainage of the area. Kwarnadi is ephimeral while Utangan is a perennial river.

Chemical Analysis: Chemical analysis of water samples was carried out at the laboratory of the U.P.

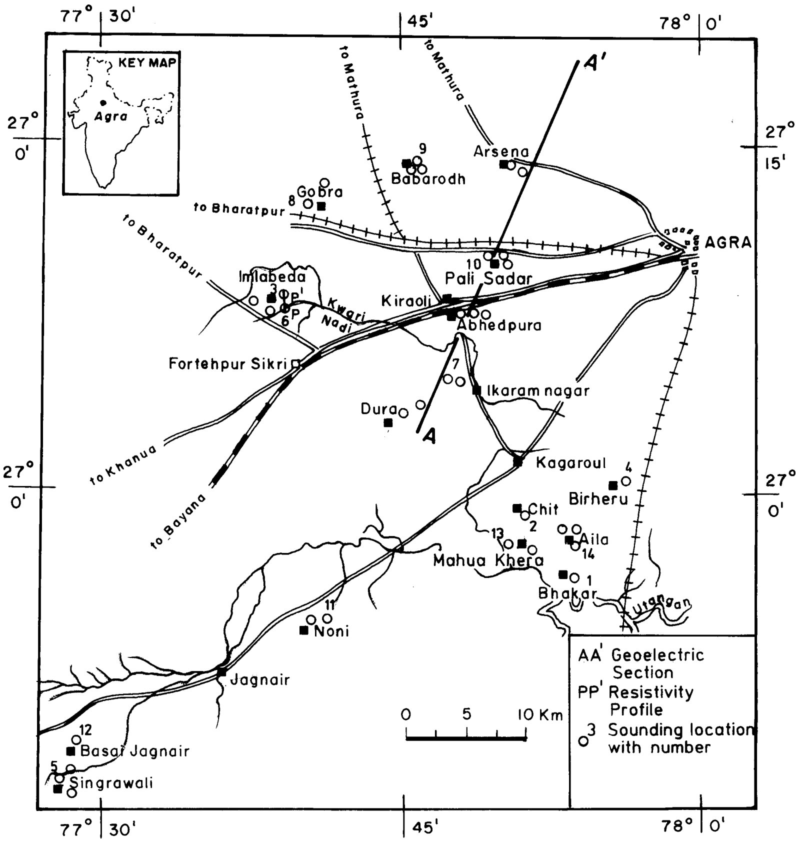

Figure 1. Location Map of villages covered by Geoelectrical surveys in Agra district.

Jalnigam at Agra to arrive at an approximate correlation between total dissolved solid (TDS) count of ground water and resistivity of the different geoelectric layers. The TDS count of the water samples varied from 500 mg/l to 3000mg/l (Table 1). While the safe limit for human consumption is about 1000 mg/l, people in some villages are forced to use water with higher TDS count also due to scarcity.

Geophysical studies: Geoelectrical surveys were carried out in twenty-five villages located in Kiraoli and Kheragarh tehsils of Agra district (Fig.1) to locate well sites for drilling. The results of resistivity surveys are correlated with hydrogeological data including litholog data of existing bore wells for estimating the characteristic resistivity ranges of various lithological units (Anjaneyulu et al. 1992). Resistivity profiling with an electrode separation of 30 m was carried out employing Wenner configuration to find out the lateral variation of the salinity of the shallow aquifer. The resistivity soundings with a maximum separation of AB=1000 m were carried out to find out the thickness of various sand, clay and sandy clay layers and their nature (with reference to salinity) employing Schlumberger configuration. The preliminary interpretation of the sounding data was done using the curve matching technique (Orellana & Mooney 1966) and further refined with the help of the inversion program (Jupp & Vozoff 1975).

QUALITATIVE APPRAISAL

The sounding curves at different locations of the study area show different trends. In general, K and Q type of curves or combinations of these types of curves are obtained over the region wherein the alluvial thickness is high or salinity of the deeper horizons is high. H and A type of curves are or combinations of these type of curves are obtained in the rest of the region where both depth to hard rock (sand stone) and salinity are less (Fig.3) showing an increasing trend in the resistivity for larger electrode separations.

Sounding curves obtained in north eastern part (ending with descending type of curves) indicated the last layer (depth probed by sounding) to have low resistivity compared to the over lying layer. (S1, S2, S4 and S9 in Fig.3). The alluvium overlying the bedrock has much lower resistivity due to high salinity and or clay content as revealed in these four sounding curves (Prabhakar Rao et al. 1993). However, the descending trend in the last part of curve S5 in

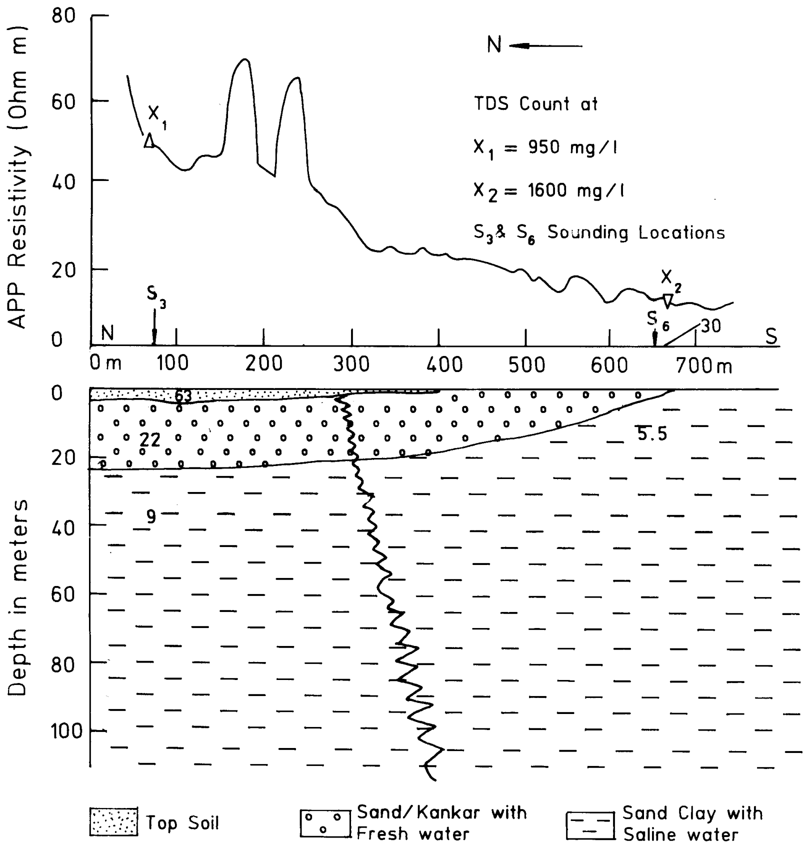

Figure 2. Wenner resistivity profile across fresh-saline Water transition zones at Imlabeda village.

Singrawali village of western part is due to fractured nature of the deeper formation in this region but not due to salinity. Second type of sounding curves show a marginal rise in resistivity at larger separations after the initial steep fall in resistivity which may be due to the presence of fresh water as seen at Palisadar and Gobra villages (S3, S8 and S10 in Fig.3). A third type of sounding curves are also obtained which end with an increasing trend (S6, S7, S10,S11 and S12 in Fig. 3.) corresponding to the bed rock which is sand stone of Bhander series.

QUANTITATIVE INTERPRETATION

Approximate resistivity ranges of various litho units has been obtained by correlation of interpreted layer parameters from the resistivity sounding data with lithology of the nearby existing wells (Dhar et al1995). Fig.4 shows such correlation of the sounding data at Dura village with litholog. Attempts are made to constrain to the extent possible, the interpreted thickness of the various lithological units to the thickness from drilling data. Clay encountered at a depth of 6-10m and clay and kankar at 10-15 m is represented by a resistivity of 7.3 and 24 ohm m. respectively. Below these two layers, a layer comprising hard clay with some amount of kankar and fresh water bearing sand layer are revealed with resistivities of 17 and 27 ohm m respectively. In this area the wells are drilled up to this type of sand layer to construct wells. It was recommended to stop drilling at depth of 22 m because below the depth of 25 m, occurrence of saline water zone is indicated as shown by a layer of 3.5 ohm m resistivity. The soundings (S2) carried out in Chit village shows fresh water pocket at shallow depth of 25 m only, below which brackish water was expected. Based on the above comparative study of the resistivity ranges of various formations and their salanity values, it has been approximately found that the resistivities below 10 ohm m correspond to aquifer with salinity and the resistivities above 10 Ohm m and below 50 ohm m correspond to clay and sand or weathered sand stone with fresh water. However, formations with resistivities close to 10 Ohm m may yield potable water but may turn into saline if excess pumping is carried out.

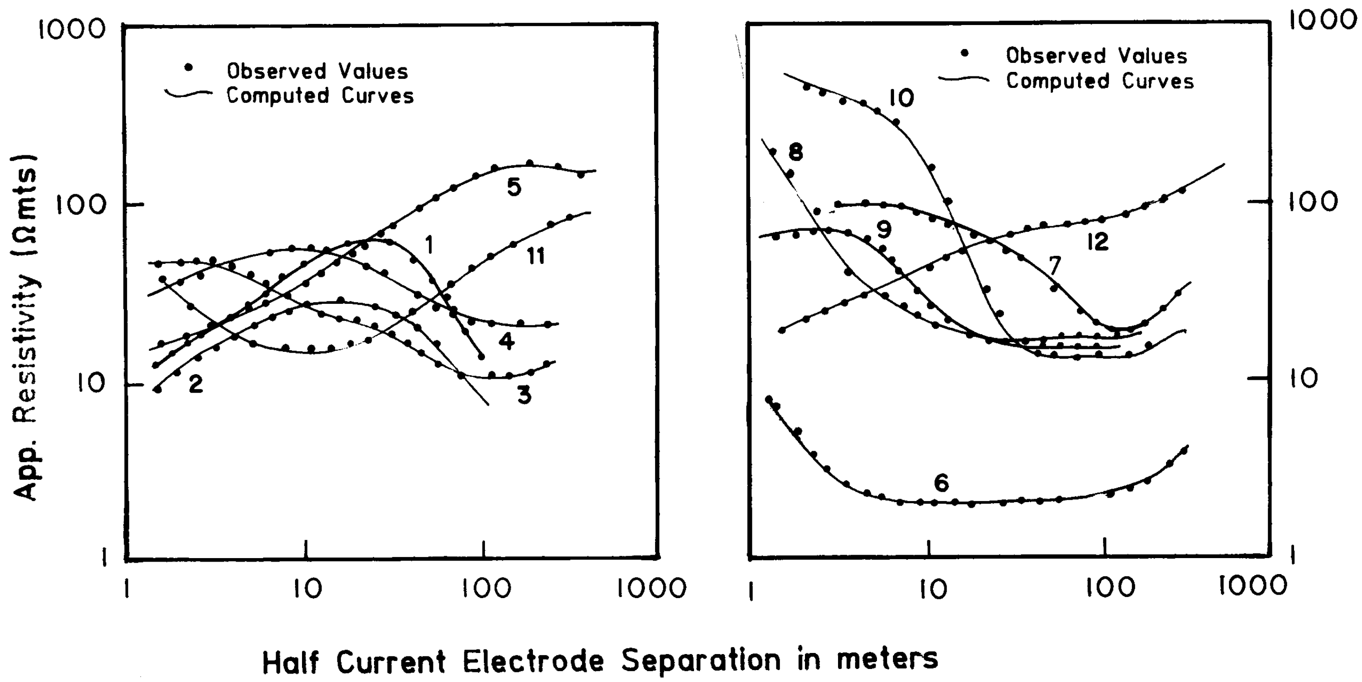

Figure 3. Some typical resistivity sounding curves along with computed curves.

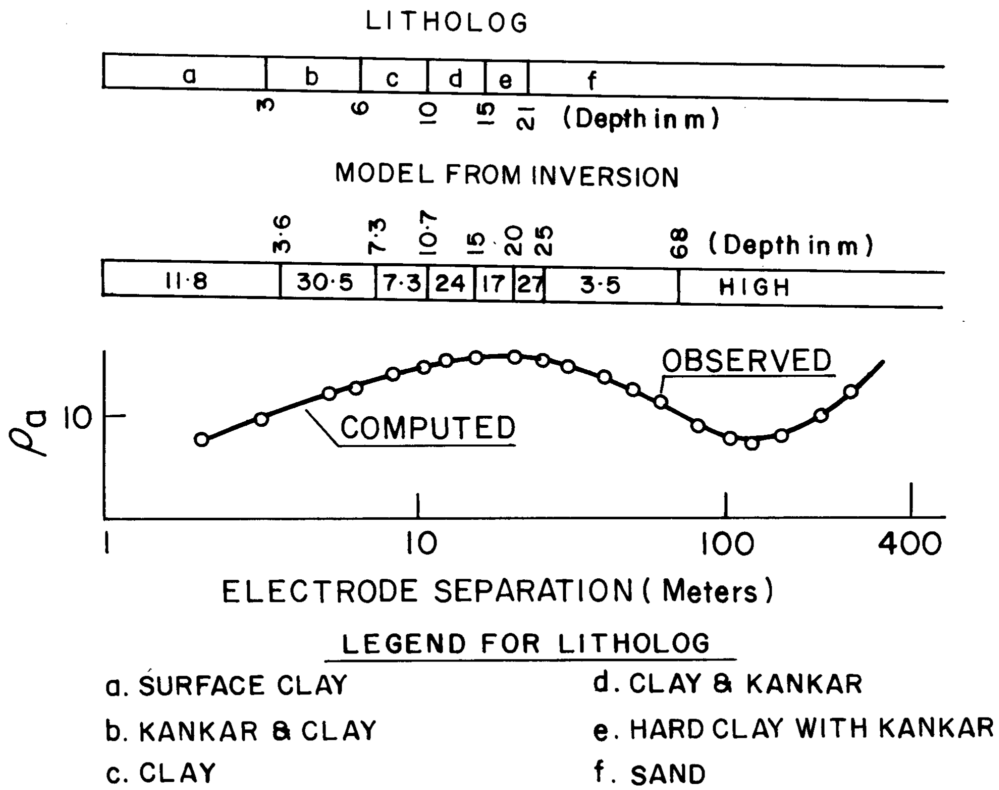

Figure 4. Correlation of layer parameter from sounding data with litholog.

DISTRIBUTION OF SALINE AND FRESH WATER AQUIFERS

(a) North-Eastern part of the surveyed area

Wenner profiling carried out in North-South direction near Imlabeda village has clearly brought out the lateral variation in salinity of the shallow aquifer. The depth of probing for electrode separation of 30m corresponds to the shallow aquifer in the area surveyed. The profile (Fig.2) shows a decrease in apparent resistivity from 70 ohm m to 8.5 ohm m. The TDS count of two water samples collected from wells falling near the profile is 950 and 1600 mg/l corresponding to apparent resistivities of 50 ohm m and 15 ohm m, respectively. In the northern part of the profile the salinity is less compared to southern part. Based on this profile, two resistivity soundings were carried out at the two ends of the profile to find out the vertical distribution of salinity. The sounding S3at the northern end shows no indication of brackishness up to 22 m (see table I). Below 22m depth a layer of 100 m thickness and 9 Ohm m resistivity is present. The sounding results at the southern end (S6 in Table I) clearly show the brackish layer right from the top with 5.5 Ohm m resistivity. But the TDS value of the water sample near S3 is also close to the upper safe limit of the TDS count (1000 mg/l) and the resistivity is close to the safe limit (about 10 Ohm m). The distance between the two sounding points being around 700 meters, it clearly shows that the lateral variation of salinity is very rapid or high in this area which gives a warning that even fresh water wells may turn saline if heavy pumping is carried out in excess to the capacity of the well.

Variation of litho units both laterally and vertically is seen in the Geoelectric section AA' (Fig.5). Top 20 m with a resistivity of 14 ohm m to 23 ohm m may comprise different proportions of clay, kankar and sand constituting top fresh aquifer. The underlying sediments are mainly saline from Dura to Abhedpura with entrapped potable aquifer zones at places. Saline aquifer is indicated by resistivity of 2.5 to 5 ohm m. while that of the fresh aquifer is 10-24 ohm m. Fresh water pockets occur at depths 20 to 35m at Dura and Ikaram nagar.In addition to the above fresh water zone another zone is expected at depth of 35 and 60m at Abhedpura and Ikaram Nagar respectively. The sounding results at Palisadar and Arsena are indicative of the occurrences of potable water through out the entire depth probed by the soundings with the likelihood of thicker granular zones at Arsena as indicated by layer of resistivity 28 Ohm m. This is well supported by the TDS count at Palisadar (500 mg/l) and Arsena (1000 mg/l). The variation in TDS is also reflected in the geoelectric section by the lateral variation in resistivity of the layer below the sand layer which is 12.5 ohm m. at Palisadar and 11 ohm m. at Arsena respectively. Water samples in Dura and Ikaramnagar villages showed TDS counts of 3000 mg/l and Abhedpura 2500 mg/l corresponding to clay and sand with brackish water as shown in geoelectric section (Fig.5). Depth to hard rock varies from about 70 to 120 m along this profile. Basement at Arsena could not be probed due to non-availability of space for larger electrode separations. Another reason could be that the current could not penetrate down due to high degree of salinity of the layer above the bed rock. Hence the interface is shown as dotted line in the geoelectric section (Fig.5).

(b) South eastern part of the Study area

The fence diagram (Fig.6) shows the variation of salinity in the area both laterally and vertically. Similar to the geo electric section, the fresh water occurs at shallow depth but the range of resistivity is higher (25-50 ohm m) to that of geoelctric section (20-30) ohm m. Both situations of fresh water overlying saline water and vice versa also exist in this area. At Mahuakhera, Bhaker and Aila villages, brackish water (6-8 ohm resistivity) is sandwiched between two aquifers. The top aquifer alone is fresh at chit while the aquifer at Birheru is potable all along within the probed depth. In the central portion of the surveyed area, there exist numerous alluvial patches and places with intermontane alluvial fills. Here, the overburden is less saline compared to that of the eastern most as revealed by resistivity of 10-25 ohm m. Here the lower range of resistivity is due to predominance of clay in the aquifer but not due to salinity. A well drilled at Noni on recommendation of present investigation has yielded potable water of about 8,000 gph. At this location, thin layers of sand sandwiched between layers of clay and kankar form the aquifer. A comparison of the sounding curve S11 (Fig 3) with the lithlog indicates the resistivity of clay and kankar to be of the order of 10-15 ohm m for clay and kankar. Because of less thickness of different layers compared to the depth of occurrence, layers of fine sand have not been revealed as separate layers in the sounding curve. Hard clay and sticky clay along with fine sand in different proportions has been indicated as s single layer represented by a resistivity of 16 ohm.m between a depth of 11-24 m followed by a of layer of resistivity of 10.5 ohm m below 24 m. The depth to bed rock at this location is estimated to be about 130 m but the well was drilled only up to 76 m. If the bore was drilled further deeper it could have met some more acquifers.

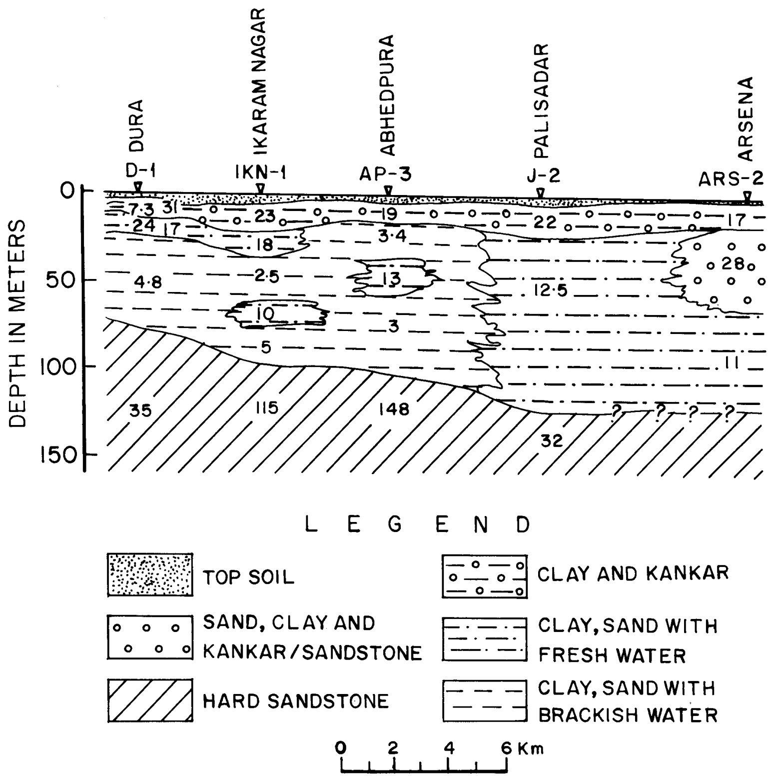

Figure 5. Depth section AA' between Dura and Arsena deduced from resistivity sounding data.

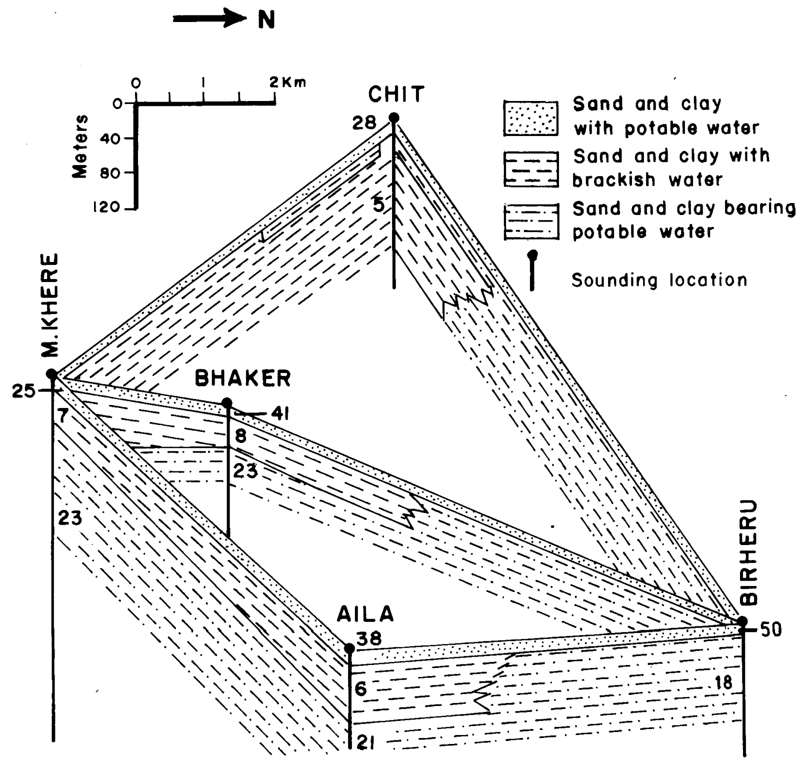

Figure 6. Fence diagram around Bhaker in Eastern alluvial part of Agra district showing possible Litho units derived from electrical sounding interpretation Numbers in layers represent Electrial resistivity of the deduced lithological units.

HARD ROCK COVERED WESTERN REGION

In the villages covered by hard rock, the source finding was comparatively much easier because of no salinity and existence of weathered and underlying fractured sandstone. The resistivity of compact sandstone is of the order of 150-300 ohm. m in most of the soundings in the region. The resistivity sounding carried out near an existing well near Singrawali village agress quite well with the well section. Weathered sand stone in the form of loose sand forms the aquifer in this bore well. The aquifer is struck at a depth of 38 m and yielded up to 46 m where the drilling was terminated. Another sounding in this village shows similar situation with a resistivity of 32 ohm.m for weathered sand stone which is expected from 50 m depth below ground level and continues up to 70m. The ground water prospects at Basai Jagnair (S12 in Fig.3) is even better because of a substantial thickness of (53 m) of a weathered/fractured layer as deduced from the sounding interpretation (Table 1). In all the villages in this area, the salinity problem is not prevalent which is also revealed by higher range of resistivities.

CONCLUSIONS

Electrical resistivity investigations aided by lithologs of the existing wells have made the delineation of fresh/saline water aquifers possible. Based on the above study, the area can be divided into two distinct parts namely the alluvial covered eastern and central part where the scarcity is mainly due to salinity and south western part which is mostly covered by hard sand stone. In the first part, the brackish-fresh water conditions have been revealed to be highly variable both laterally and vertically. The location of well sites was carefully done by comparing TDS count of water samples and resistivities of corresponding layers near the existing wells. Particularly, where the resistivity range of the aquifer falls near to the lower side of range (about 10 ohm m), care should be taken to select those sites with larger layer thickness. Another ambiguity is that the order of resistivities bordering 10 ohm m may correspond to sandy aquifer with brackish water and/or predominantly clayey horizon with potable water. Such problem could be solved with the help of information on the local hydrogeology and chemical analysis data. In the hard rock covered region, the success of the wells mainly depends on the weathered / fractured nature of the rock.

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Name of Villlage	Sounding (g No.)	No.Resistivities (Ohm-m.)							Thickness (m.)						T.D.S Count (mg./ litre)	Remarks
		p1	p2	p3	p4	p5	p6	p7	H1	h2	h3	h4	h5	h6		
Bhaker	1	41	8	23					7	32					——	
Chit	2	28	17	5					17	2					——	
Imalabeda	3	46	63	22	9	20			1	1	20	100	950			
Imalabeda	6	30	5.5	120					1	160					1600	Not Recommended
Birheru	4	19	50	18					1	9					——	
Singravali	5	12	27	270	88				1	7	42				——	Recommended upto 45m
Ikaram Nagar	7	46	23	18	2.5	10	5	115	5	17	15	26	11	32	3000	Bore well up to 45m
Gobra	8	270	20	35	13	17			1	1	3	10				Bore well up to 100 m.
Babarodh	9	55	95	15	8				1	2	130				1000	Bore well up to 90 m.
Palisadar	10	670	360	11	22	10	250		1	6	15	20	70		500	.
Noni	11	55	15	10	9999				1	23	107					Recommended & drilled successfully
Basai Jagnair	12	23	60	122					3	53						
Mahuakhere	13	25	7	23					12	32						Bore well upto 100m. Top aquifer may be brackish. Fresh aquifer expected below 50m depth.
Aila	14	16	38	6	21				1	10	63					Not recommended