Journal of Spatial Hydrology
Vol.9, No.2 Fall 2009

An investigation of groundwater condition using geoelectrical resistivity method: A case study from some parts of Kaushambi district (U.P.) India

Virendra Bahadur Singh and Jayant Nath Tripathi*

ABSTRACT

Twelve Vertical Electrical Sounding (VES) were carried out using Schlumberger configuration in parts of Kaushambi district (latitude 25^o 15' 8'' and 25^o 39' 55'' N. and longitude 81^o 17' 5'' and 81^o 31' 5'' E) Uttar Pradesh to determine the nature and thickness of aquifer zone and necessary geoelectrical parameters. The data were interpreted with the help of three and two layer master curves and auxiliary point charts. Sounding curve suggests number of three layer geoelectrical sections H, A, K, Q type and some of four layer section of the KHA, QHA, HA, types. The study indicates that average depth of the top of the aquifer is 35 m and average thickness of the aquifer is 53 m. The bedrock is encountered at an average depth of 89m. This study indicates that the groundwater reservoirs are mainly confined to the alluvial aquifer.

Keywords: Groundwater/ Vertical Electrical Sounding (VES)/ Resistivity

Introduction

Water is generally accepted as one of the principal element of life. Groundwater is an important source of water throughout the world. Ground water prospecting is essentially a geological problem and the geophysical approach is dependent on the mode of the geological occurrence of water. Geophysical electrical resistivity methods were developed in the early 1900s and have been extensively used for groundwater investigation by many workers (Pal and Majumdar, 2001, Majumdar, et al. 2000, Yadava and Abelfazli, 1998, Stewart et al. 1983, Page, 1969) and considered to be the most suitable method for groundwater investigation in most geological occurrence (Bhattacharya and Patra, 1968, Ojelabi et al. 2001) due to simplicity of technique. This approach has been employed in this study to determine the groundwater potential of the area with a view to determining the nature and thickness of the aquifer zone and necessary geoelectrical parameters.

Study Area

The study area lies between Latitude 25^o 15' 8'' and 25^o 39' 55'' N and Longitude 81^o 17' 5'' and 81^o 31' 5'' E and covers a total area about 544 sq km. (Fig. 1). The study area is situated in the southeastern part of the Indo-Gangetic alluvium plain, and is more or less flat having a few conspicuous topographical features. The plains of the area have been formed by the sediments brought down by rivers of the Ganga and Yamuna system and deposited over undulating surface of the Vindhyans and suffered erosions to such an extent that it becomes peniplain. The plain area has slope from west to east. The area is situated in the drainage basin of the Yamuna and its tributary Kilanhigh and Sasur Khaderi rivers. These rivers are characterized by a slow tranquil flow wide flood plain and broad meander belts. The landforms observed in the alluvial plane are meander, point bars, back swamps etc (Singh, 1980). The altitude of the land surface varies between 88.69 m feet and 73.15 m above mean sea level.

Department of Earth and Planetary Sciences, Faculty of Science, Nehru Science Centre Building, University of Allahabad, Allahabad 211002, INDIA
** Corresponding Author E-mail: to.virendra@gmail.com*

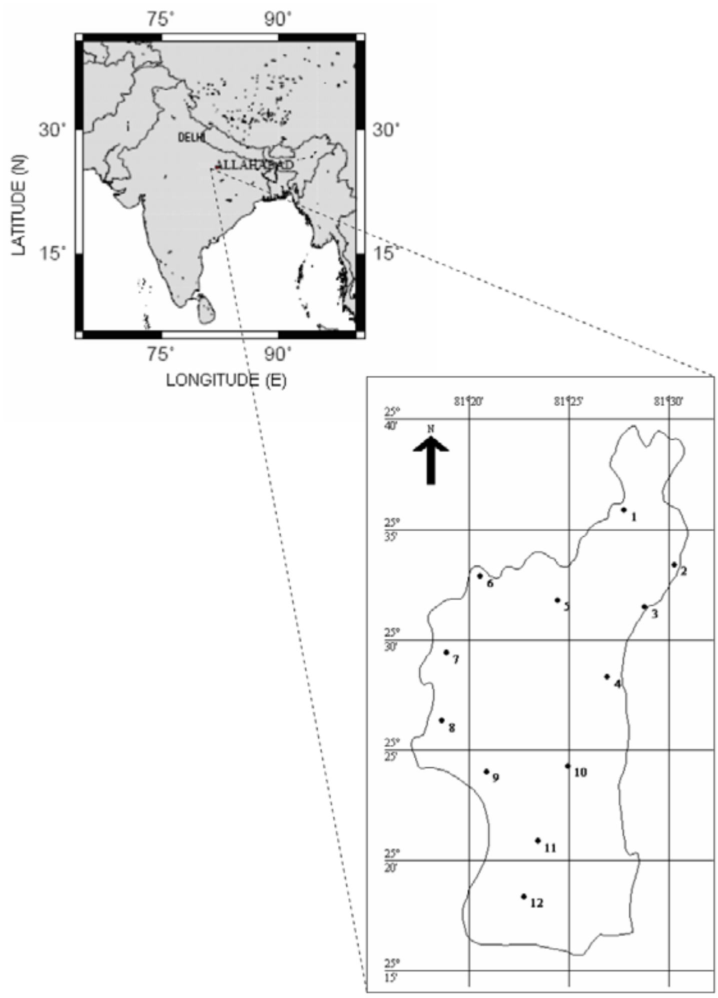

Fig. 1: Locations of Vertical Electrical Soundings

Geology of the Study Area

The study area is underlain by alluvial deposits of Pleistocene to Recent age. Of these Older Alluvium, believed to be Middle Pleistocene in age (Wadia, 1980) is not touched by highest flood level because it forms the high ground. The Newer Alluvium, which in general occupies the areas of lower altitude, is restricted to the present flood plains along river channels. The Older Alluvium belongs to Middle to Upper Pleistocene age while the Newer Alluvium belongs to upper Pleistocene to Recent age (Krishanan, 1956). The generalized stratigraphical sequence and water bearing character of the rock units are summarized in Table 1 (Pathak, et al. 1978). The rocks of the Vindhyan system comprising shale and limestone form the basement. These rocks are overlain by laterite and mottled clay, which are succeeded by the Gangetic alluvium and top soil. The thick beds of limestone are present at a depth of about 220 m below land surface. Limestones are hard, grey, fine grained and chert like in appearance. Shales are present at a depth of about 180 m to 190 m below the land surface. Shales are greenish gray in colour, moderately hard and cleavable. Some of the shale were sandy in nature indicating probably the presence of laminae of sandy shale in shale bed. Laterite and mottled clays – (clays of red, orange, pink, and yellow colour) - occur as a distinct zone above the bed rock (Vindhyans). The clays off this group, which are deeply coloured, are distinct from the clays of the older alluvium, which are earthy brown or buff coloured. The mottled clays containing varying amounts of quartz, sand and lateritic gravel are hard to soft and plastic to gritty. Some times the mottled clays are ochreous in nature enclosing, occasionally, a core of ferruginous material. The Older Alluvium comprising clay, silt, sandy clay, fine to very coarse grained sand, gravel, a small proportion of pebbles, kanakar and indurated sand occur immediately above the laterite and mottled clay group.

Table 1: The generalized stratigraphical sequence and water bearing character of the rock units of the area.

Group	System	Series	Thickness (meter)	Lithology	Water bearing properties
Quaternary	Recent to Upper Pleistocene	Newer Alluvium	Not precisely known	Top soil sand, silt and clay	Likely to yield small supply of water to wells
	Upper to Middle Pleistocene	Older Alluvium	125 to 128 m	Clay with kankar clay fine to coarse grained sand and gravel	Coarse texture facies yields moderate to abundant supplies of water to wells
Quaternary and Tertiary	Lower Pleistocene to Upper Pliocene	Upper Siwalik	51 to 102 m	Laterite and mottled clays, red pink and yellow coloured clays	Likely to yield meager to small supplies of water to wells
Proterozoic	Algonkian (Vindhyan)	Semri series	Total thickness not known	Limestone and shale	Likely to yield meager to very small supplies of water to wells.

Results and Discussion

A total of twelve Vertical Electrical Soundings (VES) were conducted over the study area using Schlumberger electrode array. VES locations are shown in Fig. 1. The instrument used was a DC Terrameter of Swiss make. Maximum and minimum current electrode separations (AB/2) were kept at 250 m and 2 m while those of potential electrodes (MN/2) were kept at 20 m and .5 m respectively. The sounding was carried along the NE-SW trend of the area. The results of apparent resistivity obtained at each VES location was plotted against electrode spacing (AB/2) on a log-log paper. The resistivity curve types KHA, QHA, HA, were obtained which are shown in Fig 2 and 3. These curves were interpreted using the partial curve matching technique using two and three layer master curves (Rijkwaterstata, 1966,

Orellana, and Mooney, 1966) and corresponding auxiliary curves (Campagine Generate De Geophysique,1975)[14] to obtain the resistivity and thickness of each of the layers delineated. The interpreted results of VES data are shown in Table 2. From the interpretation of VES curves, 4 to 5 subsurface layer indicated in the study area. The top layer (top soil) is composed of clay. The thickness of the top soil is usually 1.6 to 3.5 m thick. Average resistivity of the surface layer in the range 25-84. These data indicate that bedrock of the aquifer is same generally Shale). The higher resistivity in southeastern and central parts is due to existence of alluvial fans that consist of a mixture of gravel and sand. The lower resistivity in the northeastern parts is due to fine material of sand and silt mixed clay. Depth of the aquifer was measured in the range of 7.7-66.9 m and average thickness of the aquifer is about 53m. Using the interpreted results of the soundings a map has been prepared showing the depth to basement (Fig 4). The depth to basement is not uniform in the basin as depicted at VES-2 (149.2m) and VES-6 (48.4m). On the basis of sounding data alone it has been found that the depth to bedrock is found to be greater along the northeastern region and also at a few locations along west directions. Hence, these areas are more suitable for groundwater development.

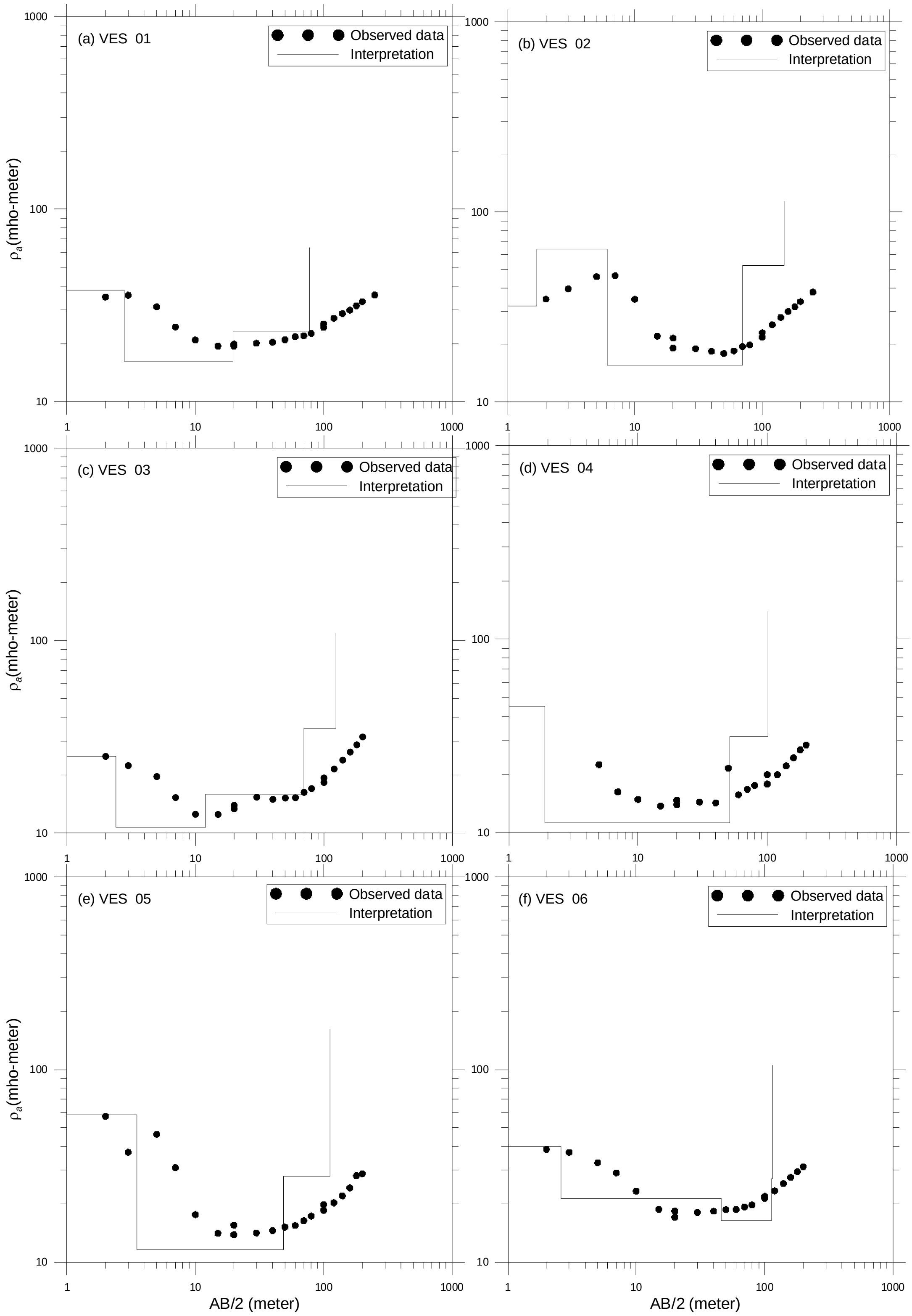

Fig. 2: Interpretation of Vertical Electrical Sounding Field Curves (VES 01 to VES 06)

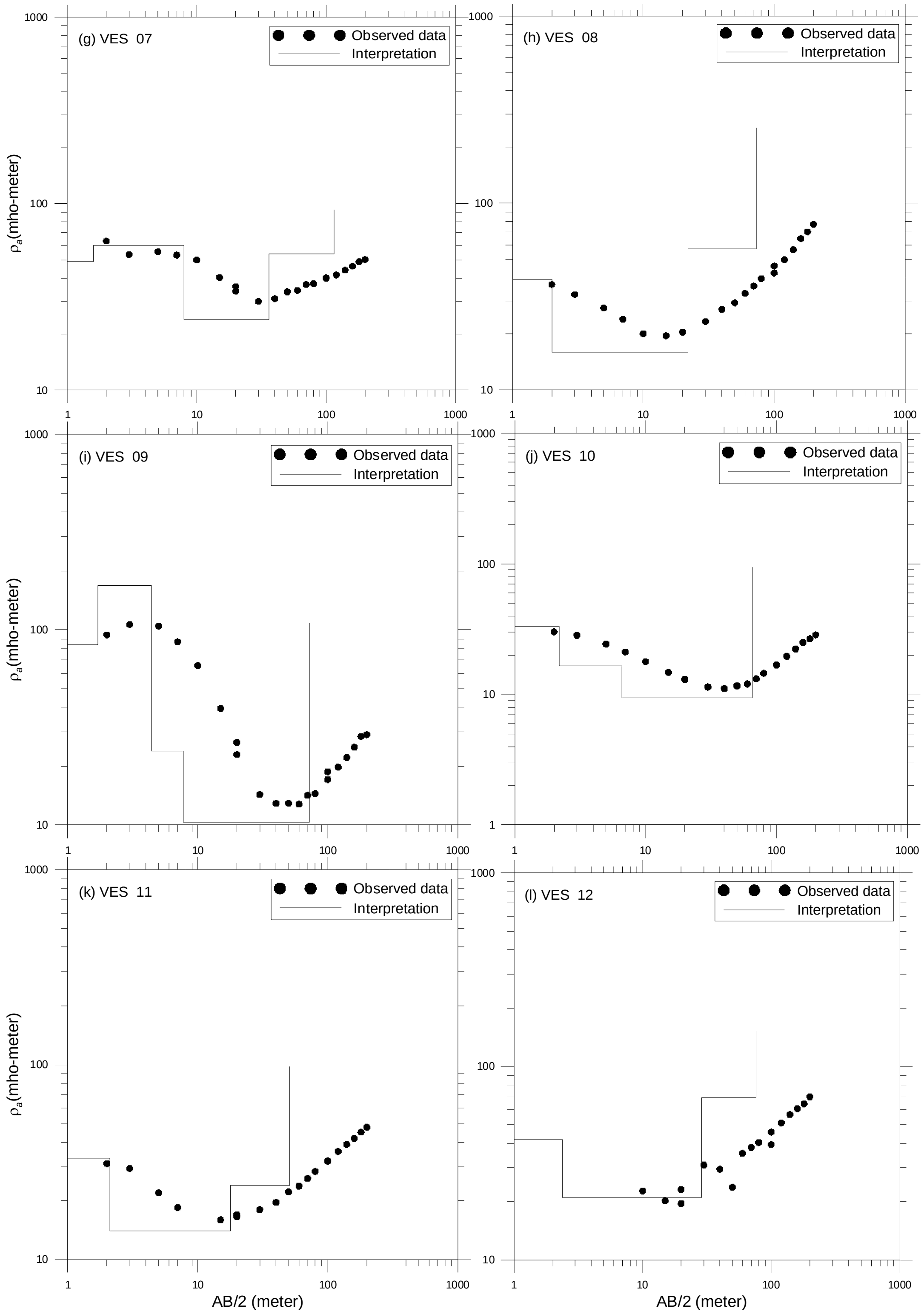

Fig. 3: Interpretation of Vertical Electrical Sounding Field Curves (VES 06 to VES 012)

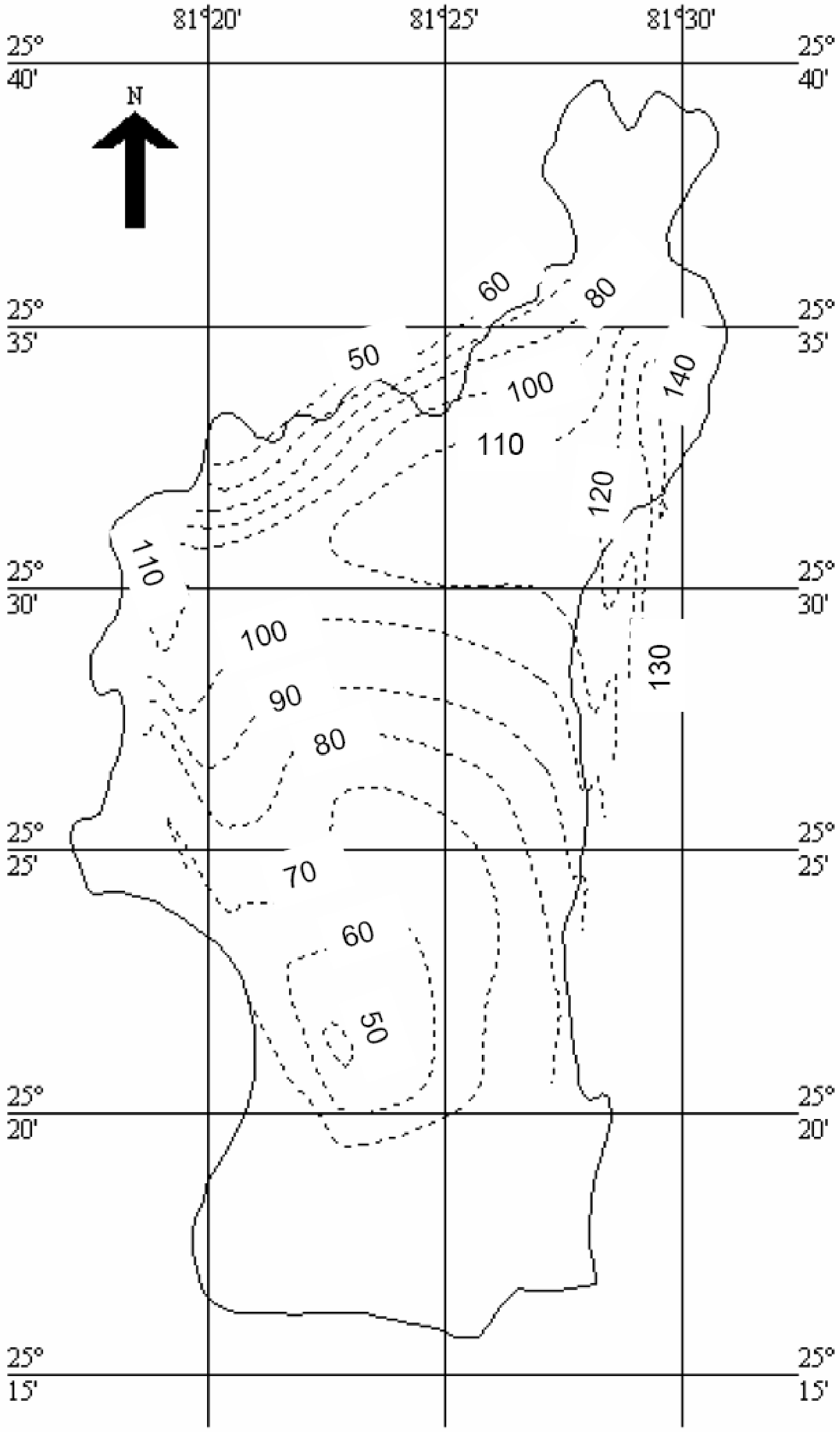

Fig. 4: Map showing inferred variation in depth to basement.

Table 2**:** Interpreted results of VES data

VES No.	**1st Layer Resistivity** ρ_1 (Ohm meter)	**2nd Layer Resistivity** ρ_2 (Ohm meter)	**3rd Layer Resistivity** ρ_3 (Ohm meter)	**4th Layer Resistivity** ρ_4 (Ohm meter)	**5th Layer Resistivity** ρ_5 (Ohm meter)	**h_1 (metrer)**	**h_2 (metrer)**	**h_3 (metrer)**	**h_4 (metrer)**	**Depth to basement in meters**
1	38	16.3	23.2	63		2.8	16.8	57.8		77.4
2	32	64	15.7	52.5	114	1.7	4.4	63.8	79.3	149.2
3	25	10.7	15.9	35	110	2.4	9.6	57.8	54	123.8
4	45	11.3	31.5	140		1.9	49.4	50		101.3
5	58	11.6	28	162		3.5	45.5	63		112
6	40	21.5	16.5	27	105	2.6	43.2	67	2	48.4
7	49	60	24	54	93	1.6	6.4	28.0	79.2	115.2
8	39	16	57	252		2	20	51.3		73.3
9	84	168	24	10.3	108	1.7	2.7	3.3	64.3	72
10	33	16.5	9.4	94.5		2.2	4.4	58.4		65
11	33	14	24	97.5		2.1	15.8	33		50.9
12	42	21	69	152		2.4	26.4	48		76.8

Conclusions

Twelve VESs curves have been used to evaluate the subsurface hydrogeological conditions to a depth of about 250 m. Based on the interpretation of geoelectrical data, the following conclusions are drawn:

1. Vertical electrical sounding results can be used for well siting as the resistivity obtained from different depths are indicative of nature of formation to be present at that depth.

2. Clay layer is present as top soil which acts as confining layers and hence, it has a significant role in the hydraulic behavior of the groundwater flow system as well as on groundwater potentiality.

3. Vertical electrical sounding survey shows four to five layers and groundwater occurs in alluvial acquifer.

4. Probable geological section of the area consists of clay at the top. Beneath surface clay, clay with kankar is present and below that fine to medium sand is encountered.

5. Interpretation of the VESs indicates the presence of an alluvial aquifer that mainly consists of mixture of clay, sand of various grades (fine to medium sand) and kankar.

6. The top of the aquifer at an average depth of 35m. The average thickness of the aquifer is found to be about 53m. The bed rocks are encountered on average about 89 m depth.

7. The depth to basement is not uniform in the basin as depicted at VES-2 (149.2m) and VES-6 (48.4m). At many places hard rock was not encountered even at the depth of 89 m. So it can be inferred that the aquifer continues beyond the depth of 89 m at such places.

On the basis of results obtained it can be concluded that the techniques of Vertical Electrical Sounding provides an inexpensive method for characterizing on the groundwater conditions of the region.

Acknowledgements
The author is thankful to the Mr. B. R. Verma Geophysicist U.P. Ground Water Board Division – 4, Allahabad for his help in performing the field measurement and interpretation of field data.

References

Bhattacharya, P. K. and Patra, H. P. (1968) Direct current geoelectric sounding, Elsevier: Amesterdam.

Campagine Generate De Geophysique (1975) Abaques de sondage electrique. (Master Curves). Geophysical Prospecting, v.3.

Krishana, M.S. (1956) Geology of India and Burma, The Associated printers: Madras

Majumdar, R. K, Majumdar, N. and Mukherjee, A. L. (2000) Geoelectric investigation in Bakreswar geothermal area, West Bengal, Indian Journal applied Geophysics, v.45 pp. 187-202.

Ojelabi, E. A., Fasunwo, O.O., Badmus, B. S, Onabajo, D.R. and Okunbanjo, O,O (2001) Geophysical and Chemical analysis of groundwater samples in Ago-Iwoyearea, Southwest Nigeria, African Jour, Environ, studies, v.2(1), pp. 77-80

Orellana, E. and Mooney, H.M (1966) Water table and curves for vertical electrical sounding over layered structures, Interetencia: Madrid, Spain.

Page, L. M. (1969) The use of the geoelectric method for investigating geologic and hydrologic conditions in Santa Clara County, California. Jour. Hydrology, v.7, no.2, pp.167-177.

Pal, S. K. and Majumdar, R.K. (2001) Determination of ground water potential zones using iso-resistivity maps in alluvial areas of Munger district, Bihar. Indian Journal Earth Sciences, nos. 1-4, pp. 16-26.

Pathak, B. D., Karanth, K. R., Dubey, M.C., Kidwai, A. L., Rao, A. P. and Bose, B.B., 1978 Geology and groundwater resources in parts of Allahabad, Sultanpur, Jaunpur, azamgarh, Ballia and Faizabad districts, Uttar Pradesh, Bulletin of the Geological survey of India. Series B-Engineering Geology and Groundwater No. 44, pp 77.

Rijkwaterstata (1966) Standard graphs of resistivity prospecting published by European association of exploration geophysicists. The Netherlands, pp.125-140.

Singh, R. (1980) depositional sedimentary environment. Springer-Verlag Berlin, Heidelberg.

Stewart, M., Layton, M. and Lizanec, T. (1983) Application of resistivity surveys to regional hydrologic reconnaissance. Ground Water v.21, no. 1, pp. 42-48.

Wadia, D.N. (1980) Geology of India. Macmillan and co Ltd St Martine street London.

Yadava, G.S. and Abelfazli, H. (1998) Geoelectric soundings and their relationship to hydraulic parameters in semiarid regions of Jalore, northwestern India. Journal applied Geophysics, v.39, pp.35-51.