GEOHYDROLOGICAL INVESTIGATION USING VERTICAL ELECTRICAL SOUNDING AT BANARAS HINDU UNIVERSITY CAMPUS, VARANASI, U.P, INDIA

R. Kumar[1], A. K. Tiwari[1], G.S. Yadav[1], N.P. Singh[1]

[1]*Department of Geophysics, Faculty of Science, Banaras Hindu University, Varanasi 221005, U.P., India*

Abstract

Geohydrological investigations are performed to assess the groundwater parameters for locating suitable sites for groundwater exploration and resource management in the main campus of Banaras Hindu University, Varanasi, U.P., India. Nine vertical electrical soundings (VES) using Schlumberger configurations were carried out at selected locations in the main campus of the university. The interpretation of sounding data has been accomplished using both curves matching as well as computer assisted automatic iterative resistivity sounding technique. On basis of interpreted sounding results, four geoelectrical cross sections have been generated along the profiles. The interpretation of data revealed four layers, generally one top thin layer overlying the other three thick layers. Interpreted results are corroborated with the borehole data. The results depict proper geohydrological conditions for existence of good aquifers suggesting continued supply of groundwater in the campus for extended period.

Keywords: *Geohydrological investigations, Vertical electrical sounding, Groundwater, Borehole, Geoelectrical cross section*

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1. INTRODUCTION

Groundwater is very important natural resources for sustainable development of a region. It is the only viable source of water in many areas where development of surface water is not economically viable. Groundwater in alluvial and sedimentary rocks occurs in pore spaces between grains, while in hard rocks, it is largely due to secondary porosity and permeability resulting from weathering, fracturing, jointing and faulting activities.

The area of investigation is the main campus of Banaras Hindu University, Varanasi, the great seat of learning founded by Pt. Madan Mohan Malviya in 1916 as a national University during the freedom struggle with donation from both the rich and poor. The foundation stone of this largest residential University of Asia was laid by Lord Hardinge on Feb 04, 1916; then Viceroy and Governor General of British ruled India. This vast central university presently has 3 institutes, 14 faculties and over 130 departments [1] and the University campus spreading over 1,300 acres of land areas, having well maintained roads and greenery all around the campus. It houses more than 20,000 people inside the campus. The recent expansion activities in the university campus following the implementation of increased admission seats and faculties in various departments under the central government rule, has resulted in increased developmental activities and shrinking of green area in the campus.

With increased infrastructure development and irregularity and failure of monsoon, it has been vaguely reported that the groundwater level in the campus is depleting fast. Therefore, with aim of examining the groundwater level and locating the potential aquifers for their management, we have performed geohydrological investigations at suitably chosen sites in the campus. In this study, we have carried out vertical electrical sounding (VES) at nine sites in the main campus of the university and have interpreted the results for estimating the parameters which may be useful for management of groundwater aquifers in the campus to cope with the sustained development of the university campus.

2. STUDY AREA

2.1. Geographical Location of Study Area

The area of investigation lies in the main campus of Bananas Hindu University in the Varanasi district of Uttar Pradesh, India (Figure 1). It is located 5 km south of Varanasi city on the western bank of sacred Ganga river (25º18' 00" N, 83º 1'00" E), on a leveled topography at 76 m above the mean sea level [2]. The area is covered under the toposheet No.63K/15 and 63K/16 of the Survey of India. The profiles lines along which vertical electrical sounding (VES) have been carried out are shown by VES-1 to VES-9 in the location map of study area (Figure 1).

2.2 Geological and Metrological Aspect of Study Area

The study area is a part of Indo-Gangetic plain which is underlain by Quaternary alluvial sediments of Pleistocene to Recent age. In the area, the unconsolidated sediments form a sequence of clays and sands of various grades. The nodular calcareous concretions (kankars) intercalated with the sands at many places, form potential aquifers at various depths. Shallow aquifers occur principally in the clay kankar and meander river deposits, while the deep aquifers occur in thick sand layers and have good potentials for groundwater [3].

The soil is of alluvial type formed by the deposition of sediments of river Ganga, which is fertile with sandy loam texture. The climate is tropical monsoon type with three distinct seasons; the cold (November to February), the hot (March to mid-June), and the rainy (mid-June to September), while October is regarded as transitional month.

The diurnal temperature variation averages between 13 and 14.5ºC in the cold and hot months. The highest monthly temperature is recorded in the May, varying between 32 and 44ºC. The annual rainfall is around 1000 mm of which nearly 90% occurs in the rainy season [4].

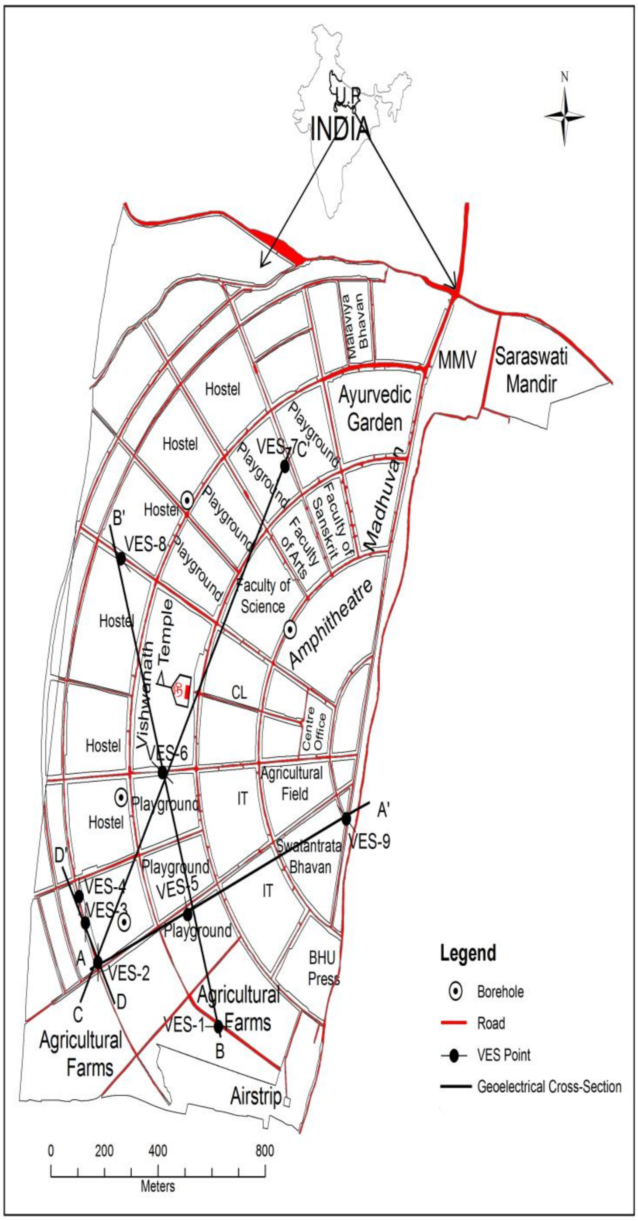

Fig 1. Location map of the study area (B.H.U. Main-campus)

3. MATERIALS AND METHODS

In this study, vertical electrical sounding (VES) method has been adopted and VES surveys have been carried out at nine locations in the area (Figure 1) using Schlumberger electrode configuration [5]. For resistivity sounding using Schlumberger array, the current electrodes are spaced much farther apart as compared to the potential electrodes [6-7]. Although, a number of electrode arrangements for current electrodes (A, B) and potential electrodes (M, N) have been suggested for this purpose, we used the symmetrical Schlumberger arrangement for the VES survey. In symmetrical arrangement the points A, M, N, B are taken on a straight line such that points M and N are symmetrically placed about the centre 'O' of the spread (Figure 2).

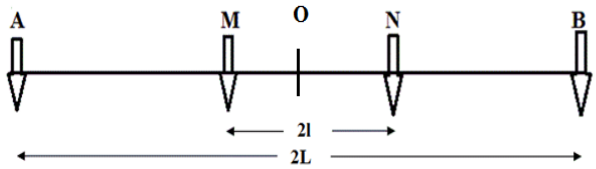

Fig 2. Symmetrical Schlumberger Electrode Arrangement

Here the separation between two current electrodes A and B is $2L$ and the separation between the two potential electrodes is $2l$. For Schlumberger array, the relation between potential drop (ΔV), current flow (I), apparent resistivity (ρ_a) and the distance between current electrodes and potential electrodes can be given by [8-9].

$$\rho_a = \frac{\pi}{2}\frac{(L^2 - l^2)}{l}\frac{\Delta V}{I} \quad (1)$$

In case of Schlumberger sounding the above mathematical relation (1) is used however, in the actual sounding survey the separation between the current electrodes AB ($2L$) is always taken five times greater than the separation between the potential electrodes MN ($2l$) [10].

A Terrameter SAS 1000 (ABEM, Sweden) have been used for conducting electrical resistivity sounding survey. The apparent resistivity values obtained from the field have been plotted against half current electrode spacing on a log-log graphical sheet. The interpretation for layer parameters are initially obtained using initial curve matching technique [6, 9, 11] and auxiliary point charts [12]. Later on, automatic iterative technique has been used for the final interpretation of the sounding data. The examination of evaluated layer parameters reveal fluctuations in resistivity values of the top layer due to the variations of moisture content and also due to change in the surface conditions from place to place [13]. Therefore, the interpreted results of the vertical electrical sounding data are represented in the terms of thickness of alluvial cover above the resistant substratum and thickness of the aquifer zone as given in Table 1.

4. RESULTS AND DISCUSSIONS

For better understanding, the results of investigation are usually presented in the form of geoelectrical cross-sections, contour map of resistant substratum and isopach map of aquifer [14]. Therefore, in accordance with above fact, four geoelectrical cross-sections (Figure 3-6) are prepared along AA', BB', CC' and DD' shown in the study area map (Figure 1) and are interpreted as following.

4.1. Geoelectrical Cross-Section AA'

The cross section AA' is drawn, based on evaluated electrical layer parameters of the three vertical electrcal soundings (VES-2,VES-5 and VES-9), and is presented in Figure 3. This profile lies to the north of the Airstrip and south of the Vishwanath temple. The cross-section incorporates the lithological information deduced from the existing borehole in the surrounding between the soundings VES-2 and VES-5. From cross section, it can be noticed that lithological information obtained from the borehole are in agreement with those interpreted from veritical electrical sounding data. The upper layer is present along all the profiles. It also represents approximatly the depth of water table. The resistivity of this layer varies due to variation in the moisture content and the type of the soil layer. The maximum thickness of this layer is approximatly 2.21 m at the sounding point VES-2. Below this layer the clayey formaion is present with varying thickness along the profiles. The third layer with higher resistivity value indicates a sandy formation. The maximum thickness occurs at sounding point VES-9 and gradually descreases towards the sounding point VES-2. The thick sandy formation is present in between the sounding VES-2 and VES-5 which is suitable for the formation of good aquifers.

4.2 Geoelectrical Cross-Section BB'

The cross section BB' based on interpreted results of the four vertical electrcal soundings (VES-1,VES-5, VES-6 and VES-8) is prepared and shown in Figure 4. This profile lies to the west of Vishwanath temple. The lithological information from the existing borehole between the soundings VES-5 and VES-6 , are in agreement with the lithological information deduced from the veritical electrical sounding results. The thin upper layer is present with approximatly uniform thickness along all the profiles having an average thickness of about 1.71 m. The resistivity of this layer is not uniform due to the variation in moisture content and the type of soil. Below this layer, the clayey formaion is present with varying thickness and resistivity along the whole profile. The variation in resistivity of clayey formation is expected due to the presence of some sand particles. The maximum thickness is present at sounding point VES-8, which gradually descreases toward the sounding point VES-6 and again gradually increases toward the sounding point VES-1. Below this layer, the sandy formation is present with varying thickness in between sounding point VES-1 and before the sounding point VES-8 along the profile. The variation in resistivity of this formation is expected due to the admixture of clay. The maximum thickness is present at sounding point VES-6, which gradually descreases toward both sides, i.e. VES-1 and before the sounding point VES-8. The thick sandy formation indicate good potential of ground water in between the sounding point locations VES-5 and VES-6, which is expected to form the very good aquifers.

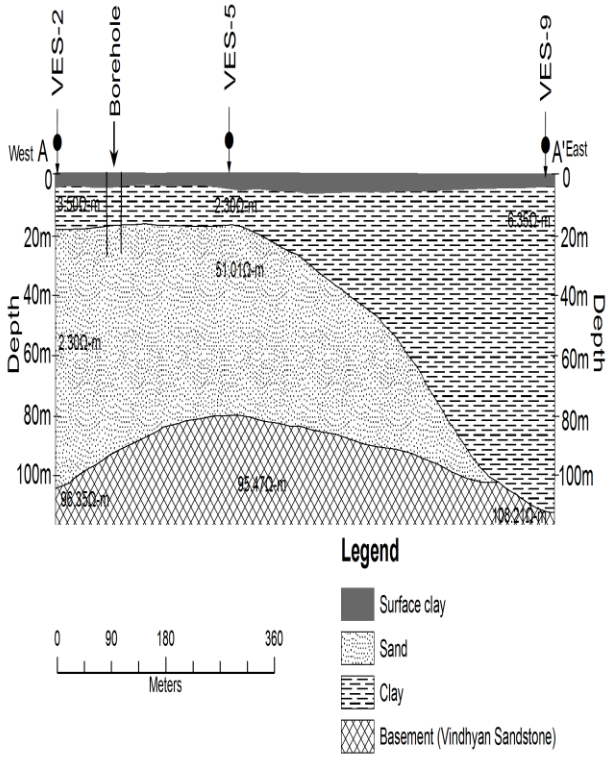

Fig 3. Geoelectrical cross-section along the line AA'

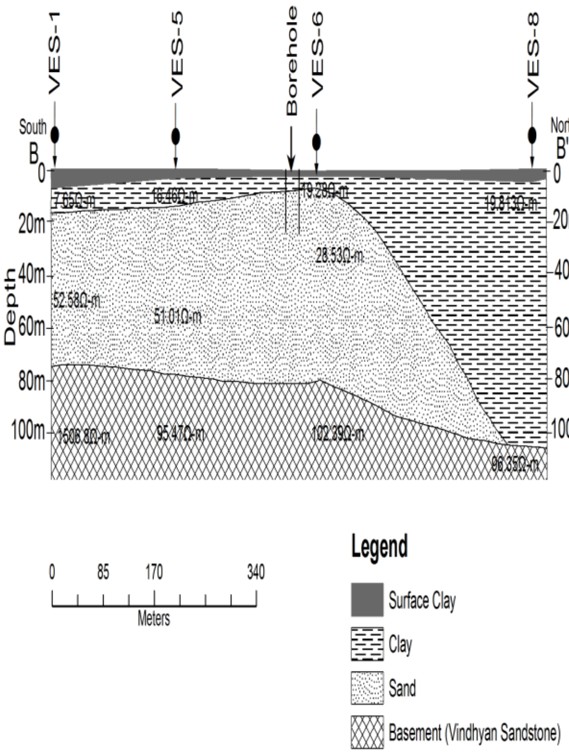

Fig 4. Geoelectrical cross-section along the line BB'

4.3. Geoelectrical Cross-Section CC'

The geolectrical cross section CC' based on the results of three vertical electrical soundings (VES-2, VES-6 and VES-7) is shown in Figure 5. This cross section lies to the east of the Vishwanath temple. This section also incorporates the lithological information from the existing borehole lying between the sounding points VES-2 and VES-6. From the section it is obvious that the lithological information revealed by the vertical electrical soundings are in agreement with the information obtained from the borehole data. The thin upper layer is present all along the profile with varying thickness.

The average thickness of this layer is 2.18 m. The resistivity of this layer varies due to variation in the moisture content and type of the soil layer. The clayey formaion is present with varying thickness in between VES-2 and VES-6 below the topmost surface layer. Below this layer the sandy formaion with admixture of clay is deposited above the bedrock along the profile. The thick sandy formation is present all along the profile and is approximatly of uniform thickness. The sandy formation is present in between VES-2 and VES-6 with admixture of clay. This thick uniform sandy formation suggest good potential of groundwater and is expected to form the very good aquifers.

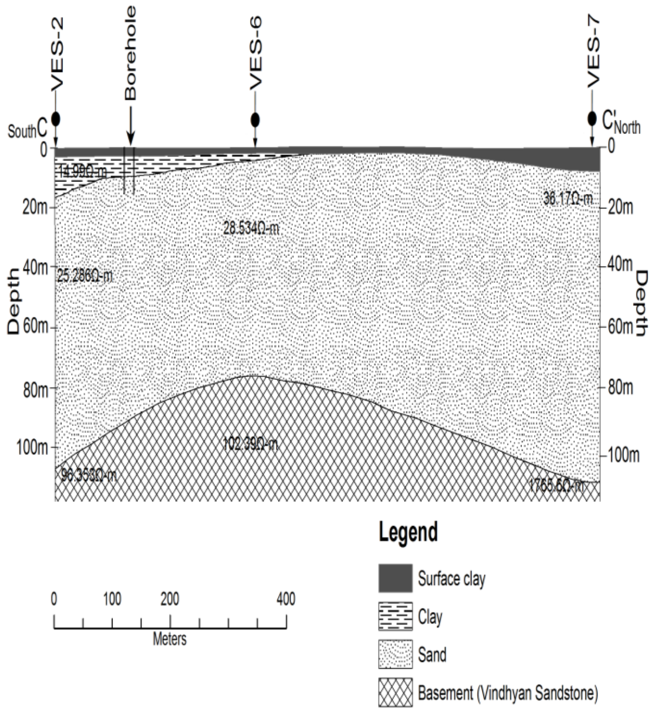

Fig 5. Geoelectrical cross-section along line CC'

4.4. Geoelectrical Cross-Section DD'

The cross section DD' (Figure 6) is drawn based on the results of the three vertical electrical soundings (VES-2 to VES-4). This cross section lies to the west of cross-section BB' and in the east of the university agricultural farm. The thin upper layer is present with approximatly uniform thickness. The average thickness of this layer is 2.50 m. The resistivity of this layer varies due to variation in moisture content and soil type. The clayey formaion is present with varying thickness all along the profile below the topmost surface layer. Below this layer thick sandy formaion is deposited above the bedrock all along the profile. The thick sandy formation present in between VES-2 to VES-3 with admixture of clay is expected to form good aquifers that can be exploited for the water supply in the campus.

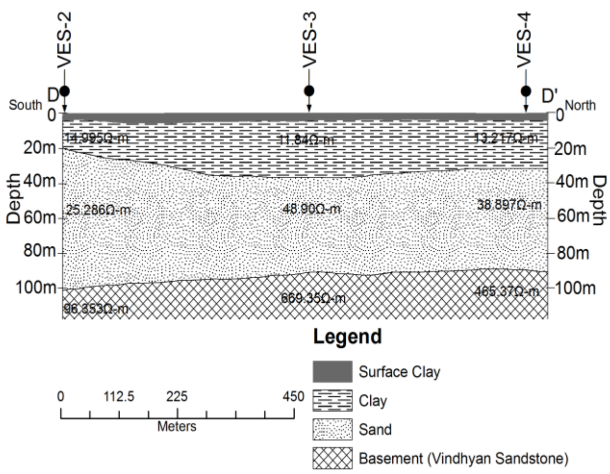

Fig 6. Geoelectrical cross-section along profile line DD'

On basis of vertical electrical soundings (VES-1 to VES-9) and corresponding geoeletrical cross sections (AA', BB', CC' & DD'), the interpreted results are summarized in Table 1.

Table 1: Total thickness of alluvial cover above the resistive substratum and thickness of aquifer zones

VES No.	Total thickness alluvial cover (in m)	Total thickness aquifer (in m)
VES-1	72.09	55.53
VES-2	106.49	90.83
VES-3	90.14	53.59
VES-4	85.43	54.83
VES-5	80.51	66.55
VES-6	75.04	72.50
VES-7	109.17	88.61
VES-8	107.70	-
VES-9	113.67	-

5. CONCLUSIONS

This paper contains the results of geoelectrical soundings conducted at selected locations in the main campus of Banaras Hindu University, Varanasi, India for assessing the geohydological parameters related with delineation, management and expolitation of the groundwater to cope with the enormous expansion activities in the campus. The vertical electrical sounding data have been interpreted using curves matching, auxiliary point charts and computer assisted automatic iterative techniques. On the basis of sounding results, four geoelectrical cross sections (AA', BB', CC' and DD') have been developed to illustrate the lithological changes and geological structures related to the groundwater accumulation and geohydrological conditions in the campus. The interpreted sounding results are correlated with the borehole data.

From sections, it is obvious that four distict layers are present in the area. The topmost layer is present all along the area, and indicates approximatly the depth to the water table. The resistivity of this layer varies due to variation in the moisture content and type of soil layer. Below this layer the clayey formaion is present with varying thickness in some parts of the area. The third layer with higher resistivity value indicates a sandy formation above the basement. The lithological information interpreted from geoelectrical cross sections are in agreement with the borehole data. The sounding results depict suitable geohydrological conditions for the existence of good aquifers ensuring proper supply of the groundwater over an extended period in the campus. These results can be used as preliminary information for further potential assessment and management of groundwater for sustainable development in the main campus of the university.

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