Artificial Recharge Basin Siting: Verification of GIS Approach Through Geophysical Investigations

G. M. Shah[1], H. M. Nafees Ahmad[2], Asghar Hussain[3] and Abdul Razzaq[4]

ABSTRACT

Water is an essential commodity to mankind. The largest source of fresh /reusable water lies underground. Due to limited availability of surface water the demand of usable groundwater is increasing day by day. This demand includes the requirements of domestic, drinking, agricultural and Industrial needs. The exploitation of fresh groundwater in bulk, without any planning/program, has resulted in lowering of groundwater level in many areas. This lowering of water level has alarmed the mankind to think and act for providing the artificial recharge to groundwater. Rechna Doab area is one of those areas where water level is going down rapidly. To maintain its level, it was felt to select a suitable piece of land that could be used as artificial recharge basin on the availability of excessive surface water, especially during the monsoon period. This paper discusses the results of electrical resistivity survey – a geophysical technique that was conducted at two different sites (identified through GIS) in the project area to demarket the presence of clay layer(s) between the land surface and water level for using the appropriate methods for artificial recharge. The interpretation of field data has helped in selection of artificial recharge basins. The results show good agreement between the GIS approach and geophysical investigations.

INTRODUCTION

Excessive exploitation of groundwater at a rate greater than replenishment causes declining groundwater levels over the long term and, if not corrected, lead to contamination and eventual mining of groundwater. Haider (2000) reported 59 billion m^3 as annual groundwater pumpage in the year 1999. Due to the increasing water demand, in Punjab province alone, more than 500,000 tube wells have been installed by the private sector (PPSGDP, 2000). To maintain the groundwater levels and to prevent contamination of groundwater, artificial recharge of groundwater is becoming increasingly important in groundwater management and, particularly, in the conjunctive use of surface and groundwater resources.

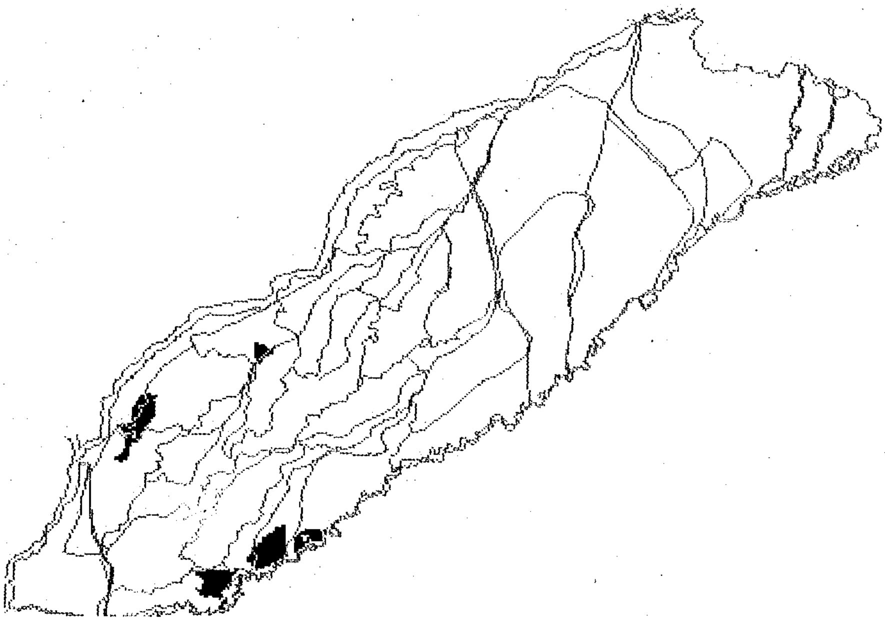
The purpose of artificial recharge to groundwater is to reduce, stop, or even reverse declining levels of groundwater; to protect underground freshwater aquifer against saltwater intrusion/ upconing, and to store surface water, including flood or other surplus water and imported water, for future use. Three common methods of managed recharge are water spreading basins, pits, and wells. The main

[1] Director, PCRWR, Lahore, Pakistan
[2] Senior Researcher, PCRWR, Lahore, Pakistan
[3] Spatial Data Analyst, International Irrigation Management Institute (IWMI), Lahore, Pakistan
[4] Deputy Director, PCRWR, Lahore, Pakistan

theme of this paper is to evaluate the artificial recharge basin sites, which were identified through GIS approach, by electrical resistivity survey at the spot. In respect of site selection through GIS, a set of criteria acceptable for siting a recharge basin was established for transmitting layer and storing layer. A transmitting layer is defined here as the unsaturated soil profile in the basin area having conditions for infiltrating and conveying acceptable quality water to the aquifer system. Its evaluation is based on soil texture and salinity. The storing layer is the aquifer system having capability of storing percolated water and recovery by wells. This layer is evaluated on the basis of history of depth to water table, aquifer parameters and groundwater quality. The physiography, irrigation subdivision and storm water drainage network maps covering Rechna Doab were superimposed to determine the adequacy of siting of the artificial recharge basin.

Five areas (Figure 1) were identified in Lower Rechna Doab in the vicinity of Chenab and Ravi rivers, ranging from two to eleven thousand hectares in size. These areas fulfil the set of developed criteria/requirements i.e. water level should be more than six meters and subsoil should have porous texture.

Figure 1: Suitable sites identified through GIS for artificial recharge. Geophysical investigations – electrical resistivity survey



Geophysical investigations involve the measurement of the apparent resistivity of soils and rock as a function of depth or position to study the sub-surface hydrological set up of the area. The objective of electrical resistivity survey is to map the sub-surface changes in earth resistivity and correlate them with the hidden geological formations. The resistivity of any formation is mainly dependent on two factors, viz. the porosity of the formation and the salinity of the solution held in the pores. In water bearing formations the current is carried entirely by the dissociated ions of the salt held in solution.

Electrical Resistivity Survey can be used profitably for solving various groundwater problems such as:

i. To determine qualitatively the type of water bearing formation, e.g., clay, sand, sandstone or gravel provided conditions are favorable and not complicated by abrupt lateral changes in lithology.

ii. To differentiate between saline and fresh water aquifers, provided the lithology of the aquifer is uniform.

Terrameter SAS 300 B was used in the area to collect the field data. This instrument works on the basis of Ohm's law. SAS stands for single averaging system, a method whereby consecutive readings are taken automatically and results are averaged continuously until the Geophysicist is satisfied with the stability of the results. SAS results are more reliable than those obtained using single short systems. SAS comprises of a battery powered deep penetration resistivity meter. Ratio of potential and current (V/I) is calculated automatically and displayed in kilo-ohms, ohms or milli-ohms.

FIELD PROCEDURE

On the basis of recommended basins by GIS, geophysical investigations through electrical resistivity survey were done at two sites i.e. Jamal Pahar near Kamalia and Chak No.55 Mamu Kanjan. The sites were selected having dimension of 300 × 300 meters (9 ha) and 300 × 200 meters (6 ha). The field performa was so designed that maximum field data should be collected to get information on subsurface set up of formations within twenty five to thirty meters. The Spacing between Vertical Electrical Sounding (VES) was kept 100 meters. In all, twenty-eight VES were established in the two areas Fig-2 & 3.

Figure 2: Geophysical survey (probe location map) of Jamal Pahar area, Kamalia

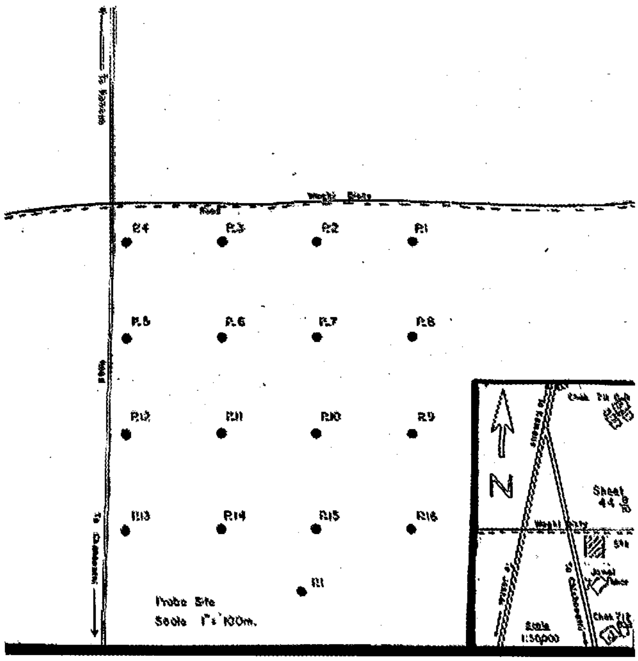
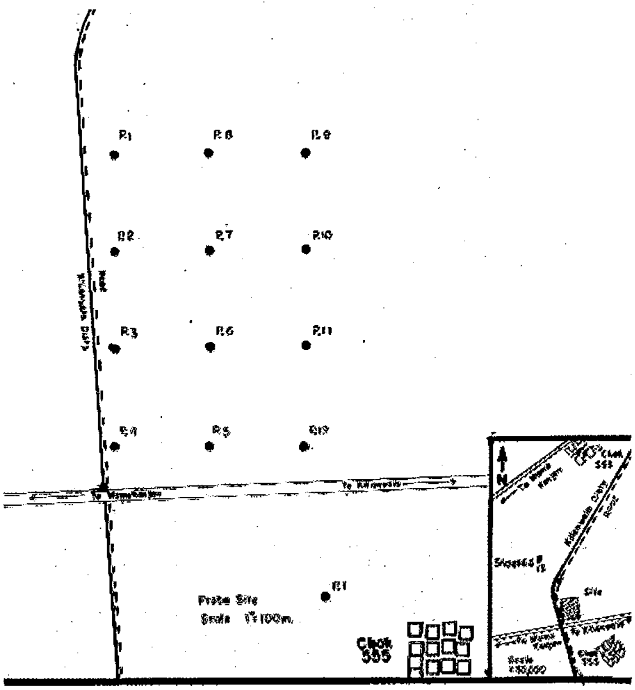
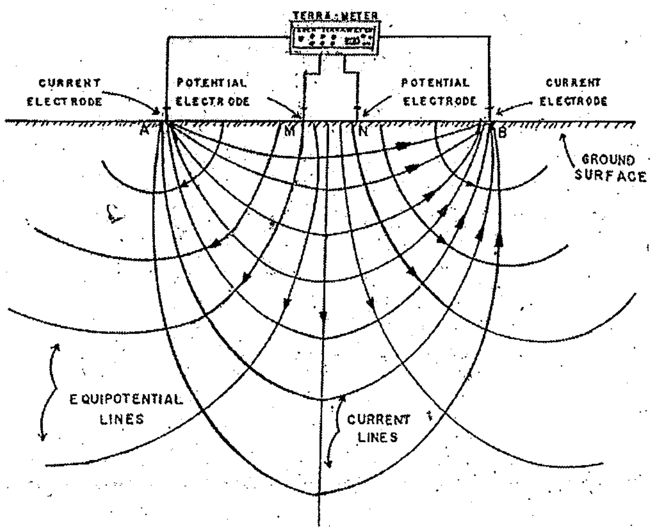


Figure 3: Geophysical survey (probe location map) of Chak 555, Mamun Kanjan.



The Schlumberger electrode configuration (Figure 4) was used during fieldwork for conducting the electrical resistivity survey keeping AB ≥ 5 MN. The earth was energized by using the battery pack at various electrode spacing at one VES station. The instrument displayed value of V/I when multiplied by the constant

Figure 4: Setting of current and potential electrodes by Schlumberger electrode configuration.



'K', the apparent resistivity value for each electrode spacing was obtained. To know the true resistivity of various sub-surface layers field curves were plotted for further analysis. Apparent resistivity values were plotted against corresponding current electrode spacing i.e. AB/2 on log-log graph paper (base 62.5 mm) for further processing the field data.

INTERPRETATION

The aim of geophysical interpretation (Qualitative and Quantitative) of resistivity sounding data is to determine the thickness and resistivity of different horizons from a study of the VES field curves and to use these results for obtaining a picture of subsurface hydrogeological set up of the investigated area.

QUALITATIVE INTERPRETATION

In this regard, apparent resistivity contour maps at the value of AB/2 = 3 & 8 meters in respect of two areas have been prepared (Figure 5 & 6) to know the existence & trend of clay layer above the water level. It reveals that clay layer(s)/lens are present in the area and its thickness varies & disappears after reaching the depth of nine meters.

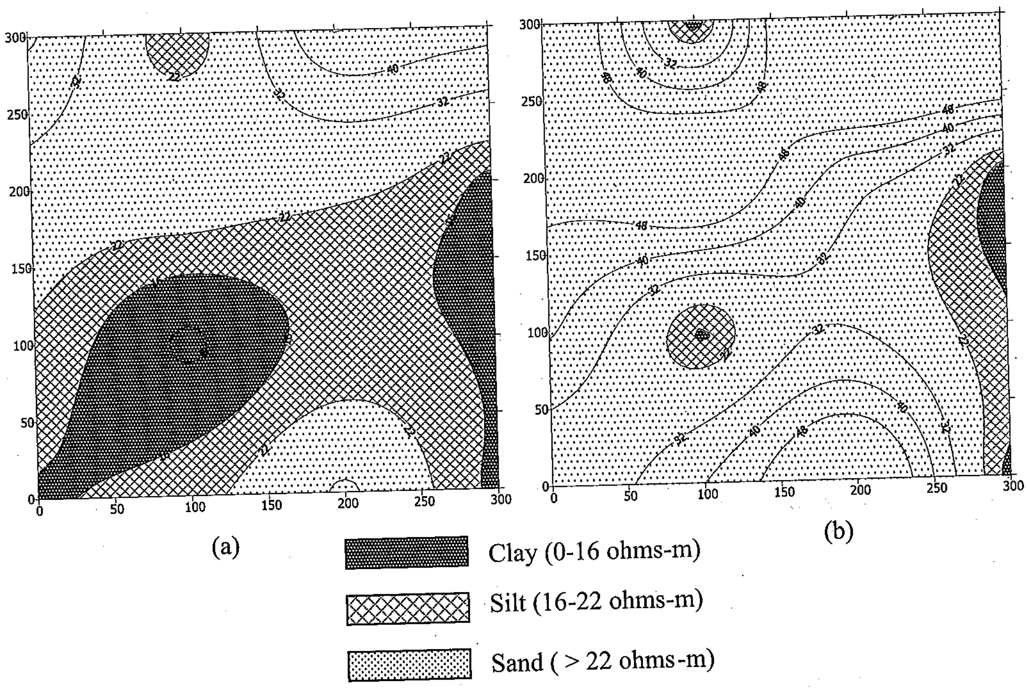


Figure 5: Apparent resistivity contour map at (a) AB/2 = 3m & (b) AB/2 = 8m Jamal Pahar, Kamalia

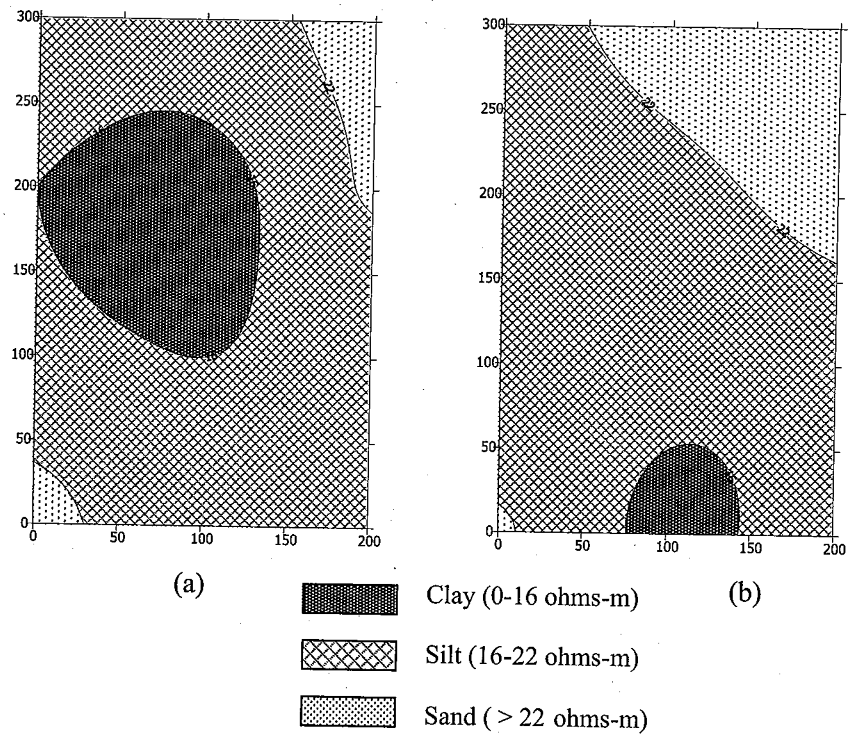


Figure 6: Apparent resistivity contour map at (a) AB/2 = 3m & (b) AB/2 = 8m Chak 555, Mamun Kanjan

QUANTITATIVE INTERPRETATION

Field curves were matched with the curves made by the computer for each VES and final interpretation was made. Lithological columns based on this interpretation are drawn and presented in Figures 7 & 8 for Kamalia and Mamun Kanjan areas respectively. The subsurface formations on the basis of electrical characteristics are classified into four distinct zones:

i.	Low Resistivity Zone	0-15 Ohm-meter
ii.	Medium Resistivity Zone	16-40 Ohm-meter
iii.	High Resistivity Zone	41-100 Ohm-meter
iv.	Very High Resistivity Zone	> 100 Ohm-meter

LOW RESISTIVITY ZONE

This zone reveals the presence of impervious material like clay and silty clay with minor sand.

MEDIUM RESISTIVITY ZONE

This is interpreted as the presence of thin alternate layers of impervious and pervious material like clay and sand or sand with poor to marginal quality of water.

Figure 7: Lithological columns showing quantitative interpretation based on VES data for Kamalia area.

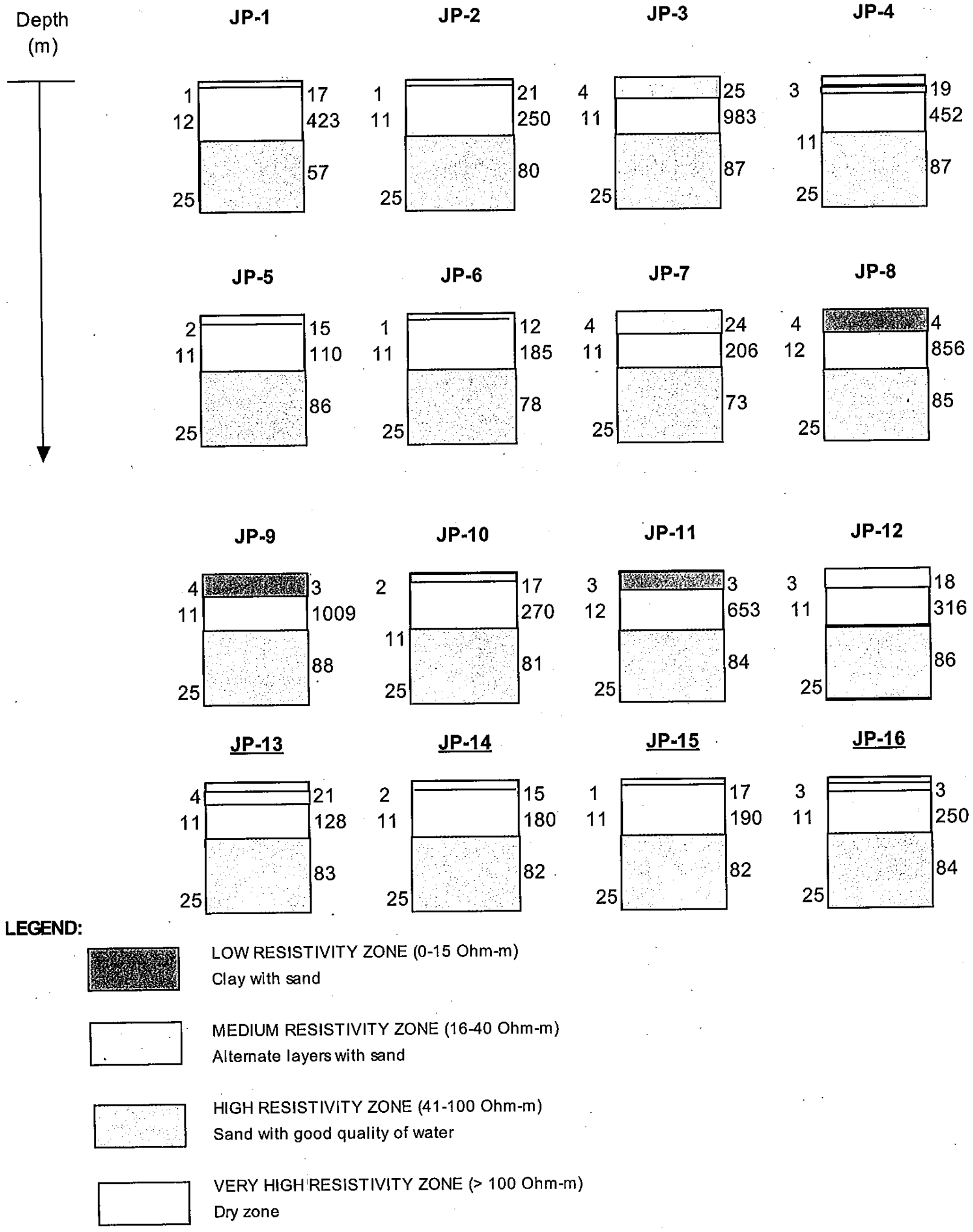
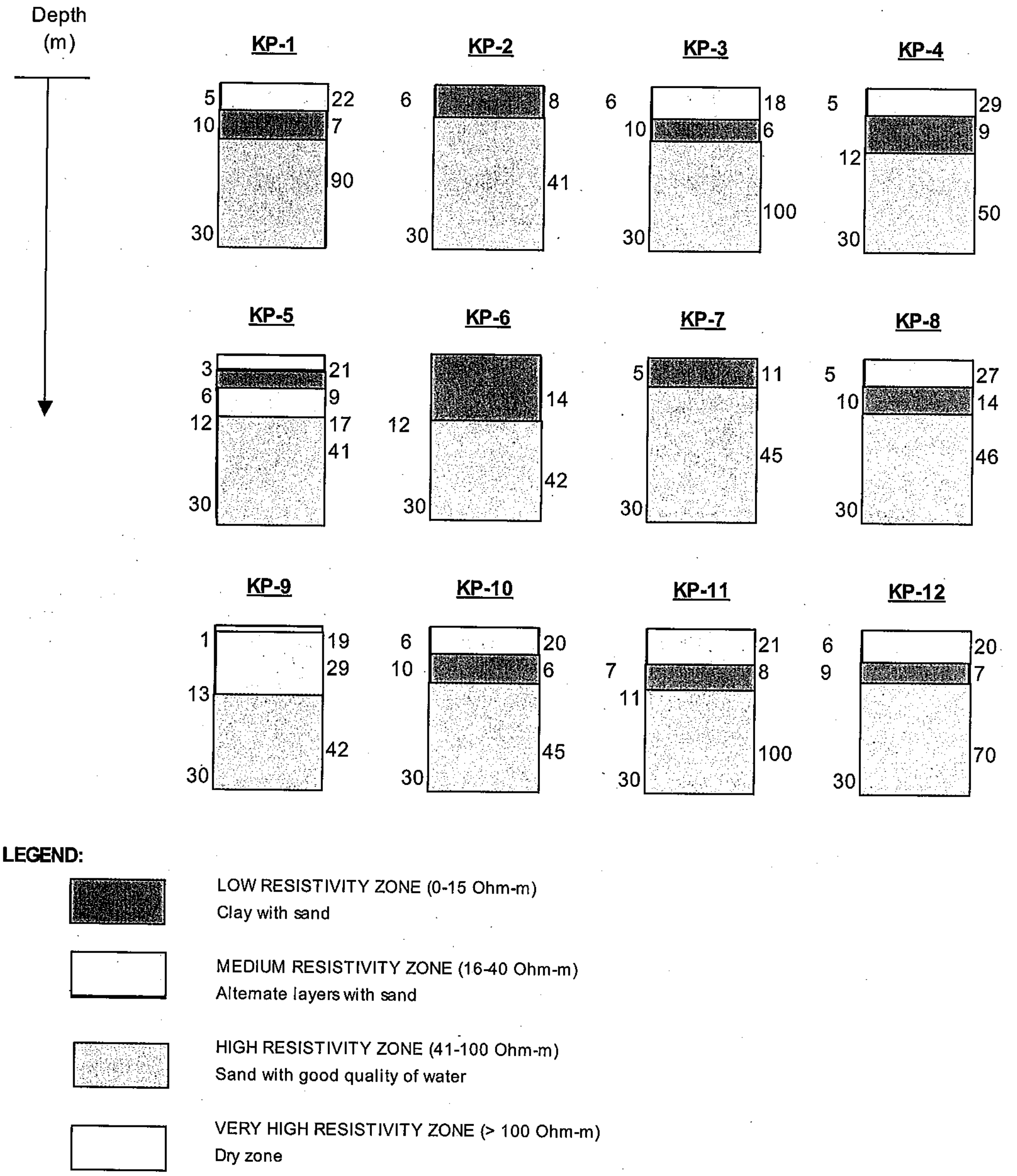


Figure 8: Lithological columns showing quantitative interpretation based on VES data for Mamun Kanjan area.



HIGH RESISTIVITY ZONE

This zone reveals the existence of pervious material like sand, gravel and kankres with rare impervious material like clay/silty clay having good quality of water.

VERY HIGH RESISTIVITY ZONE

This zone represents the existence of dry zone.

Based on the interpretation results it is concluded that Jamal Pahar area comes under medium to high resistivity zone with increasing depth whereas Mamun Kanjan area has very high to high resistivity zone. The groundwater level in Jamal Pahar, Kamalia area is about thirteen meters where as in Mamun Kanjan area groundwater depth is about seventeen meters. The apparent resistivity contour maps at the value of AB/2=3 & 8 meters show that there are clay lenses starting from 3m depth and disappearing almost at the depth of 8m at both the sides.

CONCLUSION AND RECOMMENDATIONS

Following conclusions are drawn from this study:

- The electrical resistivity survey results supplement/support the findings of GIS.
- In general, sand formation exists in the area.
- There are thin clay lenses, which start from 3m depth and almost disappear at 8m depth at both the sites.
- The groundwater level exists within thirteen and seventeen meters in Kamalia and Mamun Kanjan areas respectively.
- Keeping in view the existence and extend of sand formation, Northern part of Jamel Pahar - Kamalia and southern part of Mamu Kanjan investigated areas are recommended to be used for recharge basins.
- Water spreading and pits techniques be applied in Jamal Pahar area, whereas dug well (up to 10 meters depth) technique be applied in Mamun Kanjan area for recharge purpose.

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