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Geophysical Studies for Assessment of Groundwater Potential in Old Amritsar, Jalandhar, Ludhiana and Muktsar Districts, Punjab

L. Surinaidu, J. Mahesh, G. Padalunaidu, R. Rajesh, P.S. Acharya*, V.S. Sarma and V.V.S. Gurunadha Rao
National Geophysical Research Institute, Uppal Road, Hyderabad
*NRDMS, Department of Science & Technology, New Delhi

Abstract : Intensive agriculture is prevalent in Punjab state. Amritsar, Jalandhar, Ludhiana and Muktsar districts of Punjab is drained by three perennial rivers Ravi, Beas and Sutlej. Most of the irrigation water met from groundwater as surface water in canals is dwindling during recent years. Early 70's and 80's shallow tube well irrigation is practiced. Recently farmers are switching over to deep well irrigation in Amritsar, Ludhiana and Jalandhar districts, which causing rapid depletion of the ground water levels ~ 50-60 cm/yr. In order to increase the agriculture productivity heavy dose of agriculture inputs like fertilizers and pesticides are being used, which may be causing groundwater contamination. The groundwater in Muktasr district is facing acute problems of water logging due to increasing salinity and sodicity. Integrated geophysical Surveys using the Electrical Resistivity Tomography (ERT) equipment has been carried out at 34 locations in the four districts for ascertaining thickness of unsaturated zone and water table conditions in the Amritsar, Jalandhar, Ludhiana and Muktsar districts. Interpretation of ERT images revealed that unsaturated zone thickness/dry sand is found varying from 14 to 34 m with a resistivity value of 200 to 350 Ohm-m in Amritsar, Ludhiana and Jalandhar districts. Large thickness of dry sand zones encountered near Beas River in Amritsar District represent heavy withdrawal of groundwater in Amritsar district. The ERT images in the Muktsar district clearly brought out the salinity condition in the top formations as indicated by very low resistivity < 8 ohm m which is extending up to 30 to 32 m depth.

Keywords: Unsaturated Zone, ERT, groundwater, Punjab

INTRODUCTION

In order to fulfill the water requirements for agricultural, domestic and industrial purposes, the dependency on groundwater in Punjab plains is rapidly increasing. Agriculture is the main source for livelihood of the rural population. The dependence on groundwater for irrigation is around 68% of the total irrigated area where as 28% on surface water during last decade. Major groundwater resource scarcity result from indiscriminate over-exploitation particularly for irrigation, and contaminant inputs from a variety of sources such as fertilizers used in agriculture. Punjab state is one of the prosperous agricultural productive regions in India and are producing three crops in a year. Increased production and productivity that characterized the green revolution of the 1970s and 1980s came about due to a combination of factors including expansion of irrigated areas by the development of surface and groundwater resources and increased use of inputs, such as fertilizers, herbicides and pesticides. Intensive agriculture in the central part of Punjab is mainly governed by over exploitation of groundwater and large use of fertilizers has created deterioration of the groundwater quality as well as quantity (Singh, 1999, 2000).

Indiscriminate use of nitrate fertilizers and over exploitation of the groundwater has resulted in change of land use pattern, mainly additional area brought under cultivation. Variations in groundwater recharge associated with land use changes can have negative impacts on groundwater quality and quantity because of thick unsaturated zones in semiarid and arid regions contain a reservoir of salts that accumulated over thousands

of years and can be flushed into underlying aquifers (Allison et al., 1990; Walvoord et al., 2003). Sustainable resource management and planning requires consideration of impacts of land use changes on both the quantity and quality of groundwater. A variety of approaches can be used to assess the impact of land use on subsurface hydrology. The most direct approach relating land use changes is the assessment of groundwater table fluctuations.

In the present study hydrogeophysical studies have been carried out to assess the impact of the overexploitation of the groundwater on aquifer properties for agriculture use in the old Amritsar, Jalandhar, Ludhiana and Muktsar districts of Punjab. Earlier Studies of IT-SAP project under TIFAC and studies by CGWB during recent years highlighted decline of Groundwater level by 50-60 cm/yr causing increase in thickness of Unsaturated zone.

GEOLOGY AND GEOMORPHOLOGY

The four districts in the central part of Pujab is underlain by formations of Quaternary age comprising of alluvium deposits belonging to vast Indus alluvial plains. The exploratory drilling wells describe that sub surface geological formations comprise of fine to coarse grained sand, silt, clay and kankar. Gravel associated with sand beds occurs along left bank of Ravi River. Thin beds of clay exist alternating with thick sand beds and pinches out at short distances against sand beds (CGWB report, 2007).

ELECTRICAL RESISTIVITY TOMOGRAPHY

Electrical Resistivity Tomography (ERT) investigations have been carried out using the Syscal pro – 96 System, capable of measuring apparent resistivity values with different electrodes configurations viz., Wenner – Schlumberger & Wenner electrode arrangement.

An inverse model Resistivity section was prepared using the Apparent Resistivity values and Interpretation was carried out using RES2DINV software (Loke, 1997). The out put of ERT Survey is viewed as subsurface tomographic images representing variation of resistivity along vertical Section. In recent years, the system has been used extensively used in environmental and engineering investigations and has proved to provide reliable data sets under difficult geological terrains (Bernstone and Dahlin, 1997). Among the geophysical methods, electrical resistivity methods have been found very suitable for such kind of environmental studies, due to the conductive nature of most the contaminants in groundwater. The use of electrical resistivity methods applied to environmental studies is well documented (Stanton and Schrader, 2001; Atekwana et al., 2000; Sauck, 2000; Karlik and Kaya, 2001). Electrical Resistivity Tomography (ERT) has been applied to major groundwater exploration problems and to the investigation of areas of complex geology (Griffiths and Barker, 1993; Dahlin and Owen, 1998). In this present study ERT techniques were used to delineate unsaturated and saturated zones in the alluvial aquifer at 34 locations covering 4 districts of Old Amritsar, Jalandhar , Ludhiana and Muktsar districts(Fig. 1).

INTERPRETATION OF ERT IMAGES

Geophysical methods are very effective tools for groundwater exploration as well as for environmental studies. To determination of depth, thickness and boundary of an aquifer, determination of interface between saline and fresh water, contamination of groundwater, porosity, hydraulic conductivity, transmissivity and specific yield of the aquifer. Contamination usually reduces the electrical resistivity of pure water due to increase of the ion concentration. However, the use of geophysics for both groundwater resource mapping and for water quality evaluations has increased dramatically over the last 10 years in large part due to the rapid advances in microprocessors and associated numerical

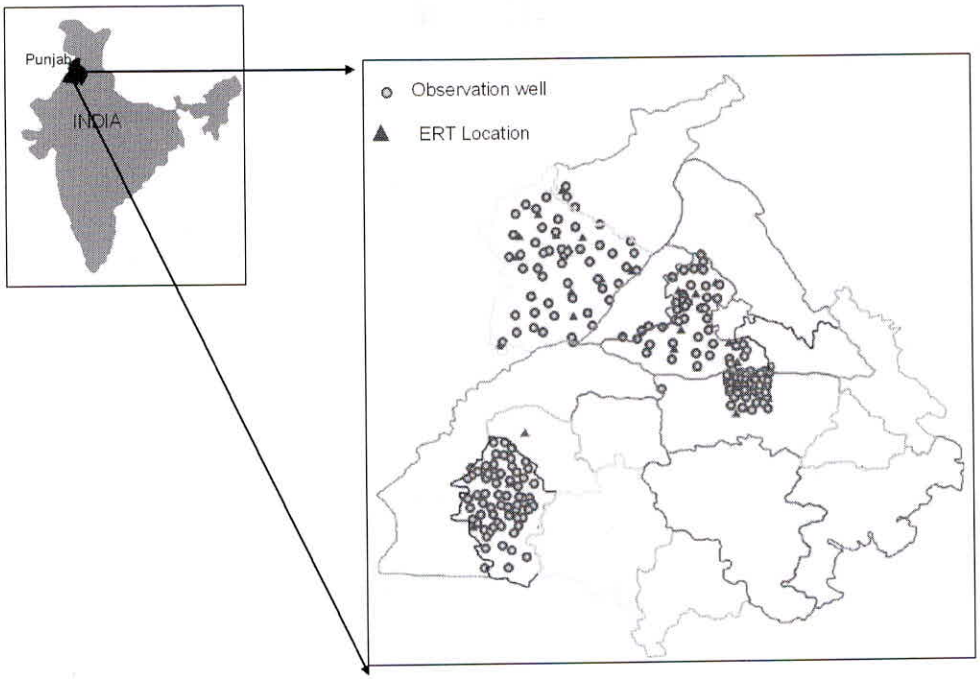

Fig. 1 : Observation wells and Location of Electrical Resistivity Tomography Survey, Parts of Punjab

modeling solutions. Electrical Resistivity Tomography technique has been used throughout the Amritsar, Jalandhar, Ludhiana and Muktsar districts to study the aquifer condition.

ERT images in Old Amritsar District

Interpretation of all ERT images has brought significant inferences regarding increasing thickness of unsaturated zone and groundwater condition upto about 50 m depth where most of the groundwater exploitation for agriculture is concentrated. The Vertical Cross Section of ERT images reveals 26 m thickness of dry sand with a resistivity of 200 to 450 Ohm-m indicating that over exploitation of the groundwater in and around the Beas village and also Amritsar city (Fig. 2). Saturation zone could be delineated around 40 m depth only with a resistivity value of 10 to 30 Ohm-m in Amritsar District. Further the groundwater monitoring carried out in the area during last two years has supported the view and revealed water levels are depleting a rapid way compared with other regions in Amritsar district. Where as Saturated zone was encountered at 30m depth with the resistivity value of < 4 Ohm-m indicates that slightly contaminated groundwater in the North east and North West parts of Amritsar district. The thickness of unsaturated zone with dry sands was delineated up to 12 m depth in these parts. Top soil is extending up to 5 m depth and because of good soil moisture condition a low resistivity (< 4 Ohm-m) was reported in the ERT image. Groundwater quality analyses in these parts also support elevated salinity which may be attributed to continuous addition of fertilizers for intensive agriculture. Saturated zones were encountered at shallow depth around 19 m due to influence of Ravi River and Upper Bari Doab Canal and the resistivity value was about 24 Ohm-m in the northern part of Amritsar. Occurrence of sandy clay with 5-6 m thickness in the top has

been inferred from the ERT image having resistivity in the range of 50 - 80 Ohm-m in the western part of the district along the border areas. Extension of dry sand /unsaturated zone extending from 5 m - 34 m depth with resistivity >200 Ohm-m below the clay zone has been inferred from the ERT image. The ERT image shows presence of saturated sands with fresh groundwater with the resistivity ranging from 10 to 32 Ohm-m below 34 m depth (Fig. 3).

ERT Images in Jalandhar District

The ERT images in the Jalandhar district present mixed scenario of agriculture and industrial areas. Occurrence of groundwater with elevated salinity could be seen in the ERT image with the resistivity <2 Ohm-m around 34 m depth in Nagar village east of Jalandhar city (Fig. 4). In this case the thickness of dry sand/ unsaturated zone extends up to 32 m depth indicating over exploitation of groundwater close to Sutlej River. The ERT image of Kalma village Near Jalandhar distributary canal indicated 34 m thickness of dry sand indicating that the replenishment from the canal water is enough for raising the water level and saturated zone was found 35 m depth in the central parts of Jalandhar city. The situation may be a representative case where the canal supplies are unable to replenish the groundwater regime, which may be explored further. Presence of fresh groundwater at the depth of 39 m possesses the resistivity value of 7 to 30 Ohm-m could be seen in the ERT image (Fig.5). The resistivity Image has indicated an unsaturated zone thickness of 26 m and the presence of fresh ground water was found around 34m depth with the resistivity value 14 - 30 Ohm-m at another ERT image in the Raipur village, north of Jalandhar city. In some

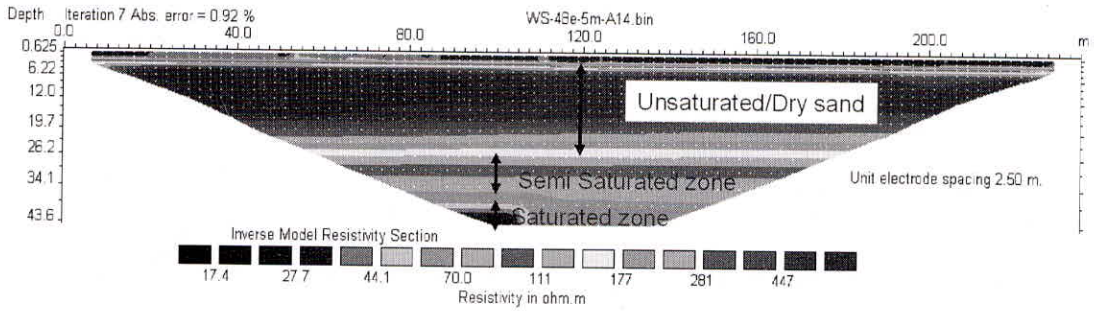

Fig. 2 Vertical Cross-Section of ERT Image in Beas, Amritsar district, Punjab

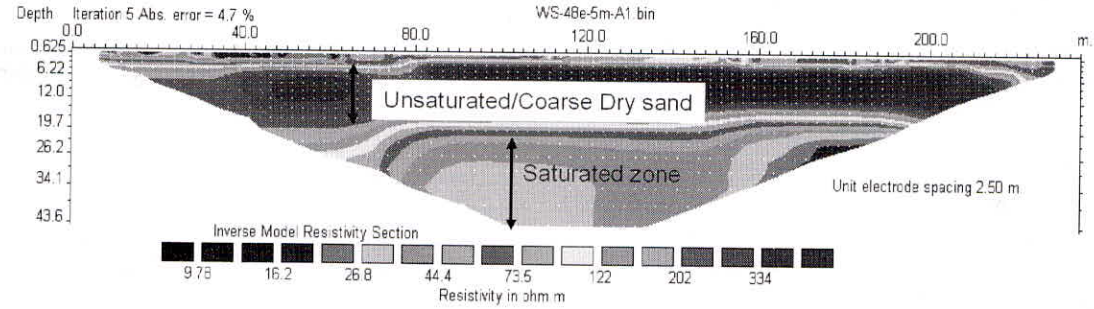

Fig. 3 Vertical Cross-Section of ERT Image in Attari, Amritsar district, Punjab

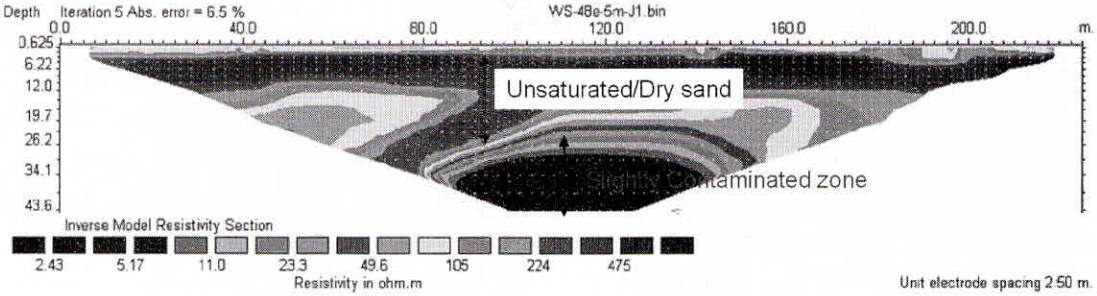

Fig. 4 Vertical Cross Section of ERT image in Nagar village, Jalandhar district, Punjab

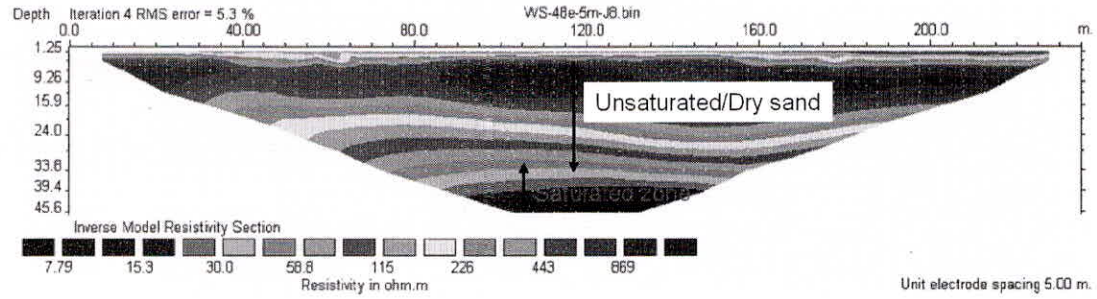

Fig. 5 Vertical Cross Section of ERT image in Kalma village, Jalandhar district, Punjab

other cases the groundwater contamination at depth has been found in the ERT images adjacent to the industrial development areas.

ERT Images in Ludhiana and Muktsar Districts

The typical ERT image in Dolon kalan village indicates occurrence of 5m thickness of sandy clays in the top, underlined by dry sand of about 28m thickness followed by presence of fresh groundwater at 34 m depth indicating over exploitation of groundwater for intensive agriculture in Ludhiana District (Fig. 6). Resistivity values in the ERT image indicating presence of thick saline soils up to a depth of 26 m with the resistivity <10 Ohm-m followed by highly saline groundwater zones with resistivity <2 Ohm-m in the Jassiana village in central part of Muktsar District (Fig.7). Due to the presence of highly saline soils in the surface and poor drainage conditions the water logging conditions are prevailing in the Muktsar district.

CONCLUSIONS

The Electrical Resistivity Tomography images were used to evaluate the sub-surface hydrogeological conditions and to estimate the thickness of the unsaturated zone and saturated zones in the central part of Punjab. Based on the interpretation of Resistivity image data, it was found that presence of 14 to 36m of thick unsaturated zone (dry sand), and mainly consists of sand and clay in the Amritsar and Jalandhar districts with the resistivity value ranges from 200 - 450 Ohm-m and fresh groundwater zones were delineated with 7 to

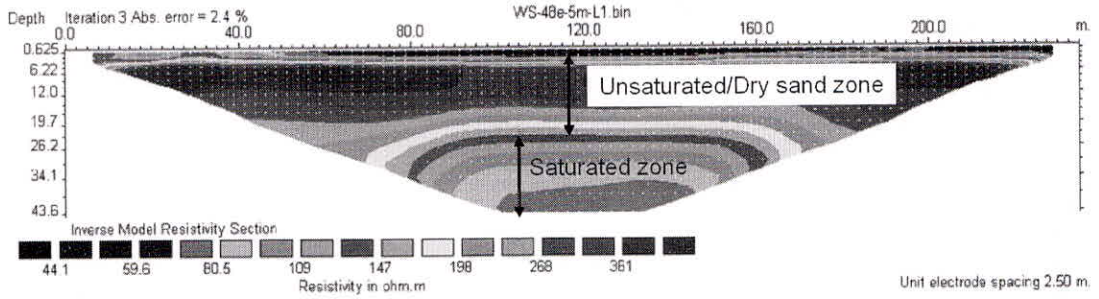

Fig. 6 Vertical Cross section of ERT image in Dolon Kalan village, Ludhiana district, Punjab

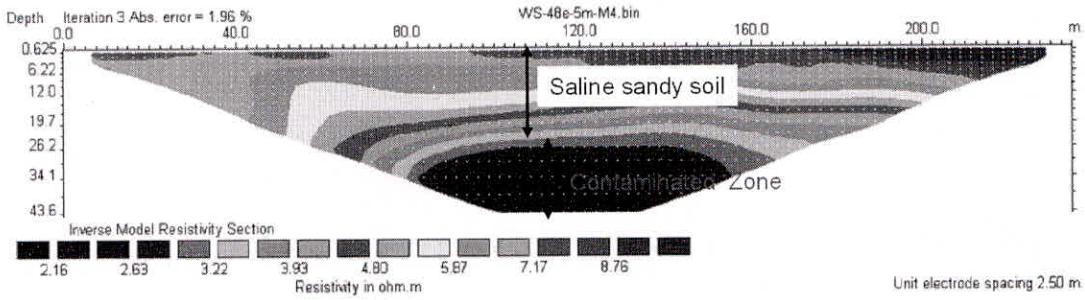

Fig. 7 Vertical Cross section of ERT image in Jassiana village, Muktsar district, Punjab

30 Ohm-m in the ERT images. Groundwater contamination has been identified with resistivity < 4 Ohm-m. In general the ERT images showed three sub-surface layers consisting of surface soil layer, thickness of the dry sand and saturated layers. Significantly large thickness of unsaturated zones have been reported in the canal command areas indicated imperative need for evaluation of functioning of the canal systems and monitoring the over exploitation of groundwater for intensive agriculture particularly in Central part of Punjab. In the Ludhiana district it was found that the fresh groundwater at the depth of 34m with the resistivity 40 to 80 Ohm-m and in Muktsar district it was found that existence of the contaminated groundwater with the resistivity value of < 2 Ohm-m at very shallow depth (< 2 m).

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