Identification of Fresh Groundwater Areas Using Remote Sensing and GIS

Singh, K.K.  
Research Scholar  
e-mail: kunal_singh@iitb.ac.in

Bajpai, V.N.  
Professor  
e-mail: vnabajpai@yahoo.com

Department of Civil Engineering, IIT Bombay, Powai, Mumbai  
1Department of Geology, University of Delhi, Delhi

ABSTRACT

The National Capital Region, Delhi faces acute water scarcity and the available underground water is severely polluted. The groundwater resources in the area have been heavily exploited and also there is a huge demand of water in the city. With this in view the study was undertaken to evaluate the fresh groundwater prospects zones employing Remote Sensing and GIS techniques in the North Campus of University of Delhi, situated in the foothill region of North Delhi ridge. Efforts were made to merge the LISS III and PAN image in tandem with water table mapping to demarcate the fresh groundwater prospects zones. The study demonstrates that the merged image provides better results with more contrast than the corresponding individual images. It has also been observed that the fresh groundwater is restricted in the foothill region and in the fractured Quartzitic rocks of the North Delhi ridge.

1. INTRODUCTION

The study area, North campus of University of Delhi is located in the northern district of Delhi – National Capital Region (NCR) of India (Fig. 1). It lies between latitude 28° 41' 56"N and 28° 39' 57"N and longitude 77° 11' 50"E and 77° 14' 09"E and is included in Survey of India toposheet no. 53H/2NE on 1:25000 scale. The area has been selected because fresh groundwater availability in the Delhi-NCR is a matter of deep concern, as water is either not available or available at great depth (>1000m) and also the shallow water table is saline. The areas of limited fresh groundwater occurrence can be expected in the ridges and one of such ridge is the North Delhi ridge, where on its west foot hill region, the North campus, University of Delhi is situated.

Najafgarh drain is flowing in the west. The river Yamuna is flowing N to S in the eastern most part of the region. The general elevations of the land surface ranges from 200 m to 217 m above mean sea level (MSL) while the elevations of the ridge area vary from 215 m to 240 m above MSL. The climate of the area is marked by semi-arid with extreme winters (1-2°C) and summers (49-50°C) intervened by rainy season. The average rainfall in the region is about 700 mm. Geologically the area consists of quartzite of Delhi Supergroup of Precambrian age, overlain by Quaternary alluvium with intervening dunal sand. The alluvium has been deposited on an uneven basement, having sufficient storage of water in the subsurface, however, also causing water logging and salinity. The water logging has severely affected the heritage buildings of the university and requires the engineering treatment. It has been observed that the surroundings of the ridge have a boon of fresh water, which can be exploited for water supply. Since, the construction in the university campus is continuously going on, the demand of fresh water supply is accordingly increasing. The Municipal Corporation of Delhi (MCD) supply is many times not enough particularly in summer season, so, it is necessary to be self-dependent. Besides, the work undertaken by Department of Geology, University of Delhi, on different hydrogeological aspects (Paul Prabhakar, 1985; Reddy, 1989; Bajpai and Paul Prabhakar, 1993; Purohit, 2000; Bhardwaj, 2004), many researchers have also reported the
assessments of groundwater conditions made with remote sensing techniques (Baldev et al., 1991; Krishnamurthy et al., 1992; Krishnamurthy, et al., 1992; Krishnamurthy & Srinivas, 1995; Manavalan et al., 1993). But no detail study on the part of satellite data-based fresh groundwater prospects zone delineation for groundwater exploration and management is available at such a local scale. With this in view, the present work has been thus undertaken to have a better assessment of the situation in the university campus.

In the present work, the hydrogeomorphic classification of the terrain has been carried out on IRS LISS III image to understand the surface and subsurface distribution of water. The results are further substantiated on merged images of LISS III and PAN for better understanding and evaluation of water resources at local scales. There are several techniques for data fusion of multi-sensor images in the remote sensing literature (Yao and Gilbert, 1984; Chavez et al., 1991; Weydahl et al., 1995; Niemann et al., 1998; Saraf, 1999; Zhang, 1999; Gamba and Houshmand, 1999). Data fusion is capable of integrating different imagery to generate more information than can be derived from a single sensor image (Chen et al., 2003). The water table contour map has been prepared to indicate the direction of ground water flow in the study area and also to know the areas of high and low recharge. Water samples have been collected from the located bore wells (Fig. 1) and specific electrical conductance measurement has been done to demarcate the areas of fresh and saline groundwater. Also such areas have been demarcated on IRS FCC and merged images.

2. DATA USED AND METHODOLOGY
In the present work, the Indian Remote Sensing Satellite (IRS) LISS III sensor, multispectral band image and high resolution (5.8 m) panchromatic (PAN) band image have been procured from the National Remote Sensing Centre (NRSC), Hyderabad, India. The time of IRS LISS III data has been selected as 1st week March, which is suitable for vegetational differentiation. Comparison has been made from the Dec. month LISS III image, when the vegetation is on the reducing side.

This section also summarizes the spatial enhancement procedures to merge the IRS LISS III image and the PAN image. We used ERDAS Imagine 8.7, image processing software and ArcView 3.2-a, geographical information system (GIS) software, for the image processing and mapping steps. The FCC images are constructed by combining the blue, green and red colours (bands 2, 3 and 4) and then resolution merge, spatial enhancement technique has been applied following the principal component method and cubic convolution resampling techniques to merge the PAN and LISS III images. Further, hydrogeomorphic classification has been carried out based on visual and digital image classification techniques. Water table measurements have been done on the located wells in the area (Fig. 1) and water table contour map has been prepared using ArcView GIS. Also water samples have been collected from these bore wells and specific electrical conductance measurement has been carried out using the soil/water quality analyzer kit model DB-1206 (Decibel Scientific Industries, Chandigarh, India). Finally, fresh and saline groundwater areas have been identified and demarcated on the satellite images.

3. RESULTS AND DISCUSSION
Hydrogeomorphic Classification
Hydrogeomorphologically, the area has been classified into the rocky tract, the pediment, the alluvial plain and the valley fill. All these areas can be distinguished on IRS LISS III FCC image, however, with more contrast on PAN and merged images of LISS III and PAN. The maximum contrast for visualizing different type of features is on the merged image, because it has the higher spatial resolution of PAN image and multispectral characteristics of LISS III image. This has also been indicated earlier by mapping of furrows within the alluvium in the Golf links of Delhi region (Saraf, 1999).

The rocky tract appears as oval ridge, extending in NNE-SSW direction as visible on LISS III, PAN and merged image (Locations R, Figs. 3 a, b and 4 a). Rocky tract consists of Quartzite interbedded with schist of Delhi Supergroup. The rocks are highly fractured and show three sets of joints as NW-SE, E-W and NE-SW as prominent trends (Fig. 2 a). The beds dip in SE direction with an angle of 44°. The NE-SW trending joints are vertical to sub-vertical (Reddy, 1989). Within the rocky tract on merged image, the water bodies appear as bluish tone (Locations W, Fig.4 a), whereas, in PAN image as dark black tone (Locations W, Fig. 3 b), and the vegetated areas appears as reddish brown to red (Locations G, Fig.4 a). At certain places the joints are very deep and are exposed to water table making extensive lakes as Khunikhar (Location K Fig. 2 b) and Sarpakar Lake. These lakes provide recharge and water supply to ridge and pediment areas.

Fig. 2: (a) Fractured Quartzitic Rocks with Three Sets of Joints as NW-SE, E-W and NE-SW; (b) Khunikhar Lake

Fig. 3: (a) IRS LISS III Image, (b) PAN Image
In the rocky tract distinct dark brown depressions
The University Campus and surrounding areas appear to be fresh. The area shows typical buried microdrainage basin with pediment following the University road (Fig. 1) joining while the shallow pediment extends to a depth of about 30m, the constructed areas appear as white tone with their rectangular boundaries.

The pediment situated on the western side and in the immediate vicinity of the rocky tract, appears pinkish to yellowish red with network of roads in the northern part on merged image (Locations P, Fig. 4 a). The pediment is basically rock pediment covered by thickness of alluvium ranging from about 5m to 50m in the university campus. While, the shallow pediment extends to a depth of about 30m, the deep pediment extends to a depth of about 50m.

The water quality all along the contact of the rocky tract with pediment following the University road (Fig. 1) joining the Shankar Hall, Gwyer Hall, and St. Stephens College is fresh. The area shows typical buried microdrainage basin formed between the Ridge and the Najafgarh drain. This is indicated by several shadowy reddish pink areas within the region showing drainage flowing towards west and northwest shown by black lines on the merged image (Fig. 4 a). Thus, the University Campus and surrounding areas appear to be within an extensive pediment with channel network buried under urbanisation.

The valley fill is situated to the west of road (Patel Marg, Fig. 1) joining Miranda House and Patel Chest Institute gate. The area extends towards west approximately all along the Najafgarh drain which consists of mostly clay with saline water to a depth of about 200m, as found in geophysical surveys (deep resistivity and gravity) carried out by Bhanumurty et al., (1978). The Najafgarh drain appears dark grey on the merged image (Fig. 4 a), which otherwise appears light bluish scattered line on LISS III image (Fig. 3 a). The several shallow hand pumps in alluvial valley fill area yield brackish to saline water.

**Water Table Contour Map**

Water table contour map based on elevations of the water table for different locations has been depicted in figure 4 b). As evident from the map the contours are closer towards ridge indicating relatively higher hydraulic gradient, however, less hydraulic conductivity, away from the ridge. Such areas are situated on shallow buried pediment between University playground and the ridge (Location LP, Fig. 4 b). At selected locations within the ridge area the groundwater elevations are 217m and 219m (Fig. 4 b). Between the ridge area in the east and the Najafgarh drain in the west, the water table elevation contours range from 212m to 205m. A general observation is that contours in the Delhi University Campus area are widely spaced as depicted between 210m and 209m and between 208m and 207m. The wide spacing shows more hydraulic conductivity (Location HP, Fig. 4 b). Several shallow tubewell borings in the campus show fine to medium sand, which blankets the rock pediment. As mentioned earlier, the pediment area has a thickness to a maximum of about 50m. It is interesting to note that this area appears bright to dark red on the merged image (Locations P, Fig. 4 a). The dark red colour also indicates typical boundary characteristics of channel pattern directed towards W and NW. This is in conformity to the flow lines directed towards W and NW (Locations F1 and F2, Fig. 4 b) as indicated on the water table contour map.

**Specific Electrical Conductance**

Specific electrical conductance measurements show the conductivity values in the area range from 900µS/cm to 12,000µS/cm. In the rocky tract it ranges from 900µS/cm to 1500µS/cm indicating the occurrence of fresh and potable water. In the pediment area (onward from the foothill region of the ridge towards Geology department) the conductivity values range from 850µS/cm to 3500µS/cm. The conductivity value of 2000µS/cm in the dugwell in the University Playground indicates the presence of fresh water. The deep aquifer in the pediment region (aquifer in fractured quartzite; 55m - 80m of depth) at USIC gives the conductivity value of 2100µS/cm, which is fresh and potable water. Specific electrical conductance of water ranging from 900µS/cm to 12000µS/cm from the several borings along the Khalsa College, Miranda House and Patel Chest lines indicate that the water is from brackish to saline. In all these areas, the salt efflorescence patches are indicated by white tone in the grasslands and playgrounds (Location S,
Fig. 4 a). In all these areas the water of dynamic storage (infiltrated stored water to a shallow depth during monsoon; July-October) can be used for irrigation and drinking.

The deep valley fill is situated on either side of Najafgarh drain in its close vicinity. The subsurface material in this region consists of clay saturated with saline water. The artificial grassland squares in such areas do not develop to greater spread and are indicated by yellowish white tone (Locations, Y, Fig. 4 a). It may be mentioned here that wherever the palaeochannels meet the Najafgarh drain after passing through valley fill region, the areas can be expected of low conductivity (Locations L, Fig. 4 a).

4. CONCLUSIONS
High-resolution satellite data is useful for visual assessment of surficial features such as geomorphology, vegetation, water bodies, settlement etc. Hydrogeomorphic classification is better possible on merged image. A buried drainage system in the northern part of the area between the ridge and Najafgarh drain oriented towards west and northwest has been also discovered on the merged image on the basis of dark red to bright red channel boundary characteristics. In rest of the area, particularly towards south the bluish green tone does not indicate the presence of drainage. This study showed the usefulness of merged image for water quality assessments at a local scale. This type of information can be very useful in groundwater management to monitor and explore the fresh groundwater at local scale.

ACKNOWLEDGMENTS
The authors thank to University authorities especially, the Prof. C.R.Babu, the then Pro Vice Chancellor for providing funds and encouragement for such a work.

REFERENCES


