Application of Remote Sensing and Geographic Information System for Groundwater Resource Mapping: A Preliminary Appraisal in Guwahati City, Assam

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***Abstract*- Availability of high resolution satellite data and advancement in Geographic Information System (GIS) together with GPS technology has provided powerful modern tools for large scale mapping, geospatial data analysis and integration enabling development of effective decision support system. Here we present a case study of ground water resource mapping in Guwahati city, Assam using these tools. It results in a fivefold prospect zoning of the city viz., very good, good, moderate, poor and very poor with different yield potential as estimated from aquifer characteristics and dugwell data.**

***Keywords*-Remote sensing, Geographic Information System, ground water, prospect zone, Guwahati**

I. INTRODUCTION

Groundwater provides about twenty percent of the world's fresh water supply and in India more than 90% rural population and nearly 30% of urban population depend on it for drinking water[1]. Groundwater is replenished by surface water from precipitation, streams and rivers. However, urbanization lead to high population growth and the consequent anthropogenic activities put pressure on both surface and subsurface water regime. High population growth also affects the hydrological processes with less infiltration into the ground and higher volumes of water entering the stream and river systems during storms [2], [3]. As such there is reduced replenishment than withdrawal which leads to geo-environmental problems. Availability of groundwater and aquifer development is influenced by the geological and geomorphic factors viz., lithology, structure, topography, drainage etc. besides precipitation. Thus, prospect evaluation for groundwater needs convergence of evidence approach taking into consideration of all the influencing factors. Availability of high resolution satellite images, high end computing systems together with the analytical capability of Geographic Information System (GIS) now provide a powerful tool for integration and analysis of geospatial data enabling identification of prospective areas for groundwater. Here we present the result of ground water prospect evaluation for Guwahati, the capital city of Assam using these modern tools.

II. STUDY AREA

Guwahati city is part of the Kamrup Metrodistrict of Assam spread over ~273 Sq. km in both the banks of the Brahmaputra River (26°4'45"N-26°13'33"N and 91°34'14"E-91°52'06"E). The main urban growth centers are concentrated on the south bank covering about 232 sq. km (Figure 1). At present Guwahati Municipal Corporation (GMC), Public Health Engineering Department (PHED) and Urban Water Supply agency are involved in distribution of domestic water supply in Guwahati mainly drawn from the Brahmaputra River that flows through the northern part of the city. However, these water supply schemes are grossly inadequate and only ~30% of the city is covered under piped water supply as on date. The total installed capacity of potable water generation under GMC area is around 98 MLD (Million Litre per Day)while the requirement for nearly 10 lakh population is as much as 132 MLD. The projected water demand in the existing Guwahati Municipal Area is further expected to grow to ~425 MLD in 2025[4].Although the Brahmaputra can supply entire requirement of water for the Guwahati city, due to inadequate capacity building of treatment plants over the years, major part of the city population now has to depend on groundwater. However, the aquifers are not uniformly developed in Guwahati and often during dry season the handpumps and deep tube wells go dry leading to acute scarcity of groundwater. This necessitates a proper delineation of groundwater prospect zones so that rational utilization of the natural resource can be ensured.

III. DATABASE AND METHODOLOGY

Satellite data and Survey of India (SoI) topographic maps (Table 1) were primarily used as spatial data source for extraction of pre field thematic information on geology, geomorphology and landuse. A Digital Elevation Model was prepared based on elevation information of SoI topographic map in 1:50000 scale. All database were brought into same projection and datum (UTM,WGS 84) in GIS environment followed by extraction of information in .shp format using ArcGIS 9.1. The sequence of steps followed is given in Figure 2. The thematic layers are integrated in GIS environment and union overlay analysis was performed to generate prospect map through convergence of evidence. The lithology, geomorphology and structural layers are integrated, taking utmost care in making the boundaries of geomorphic units and lithological units co-terminus to avoid sliver polygon. After the analysis two types units were derived namely, lithology-geomorphology controlled units by integrating the lithology and geomorphology layers and structurally controlled units. This overlay analysis on lithology and geomorphology layers were done to have better understanding on the parameters controlling the occurrence and movement of ground water. The prospect layer showing all the prospect zones based on integration of lithology geomorphology and structural elements is then integrated with the hydrology layer so that all the hydrological features occurring in each hydrogeomorphic unit gets delineated. The lithology-geomorphology controlled units have been assessed for their ground water prospects based on the analysis of hydrogeological characteristics of all the parameters controlling the occurrence and movement of ground water in association with the well inventory data collected during the field work.

Fig. 2 Methodology flowchart for groundwater prospect mapping

TABLE I

DATABASE USED IN THE STUDY

Data type		Description		
		Year of survey/ Date of acquisition	**Scale / Resolution**	**Index/ Path-Row**
SoIToposheets		1967-1968	1:50,000	78N/12, 78N/16
Satellite image	IRS P6 LISS-3	02-02-2010	23.5m	Path-110, Row-52
	Landsat ETM+	17-02-2002	30m (multispectral)	Path-137, Row-42
SRTM DEM		2000	3 arc sec (~90m)	Same extent as of Landsat ETM+
Collateral data		Published maps, data, paper etc.		

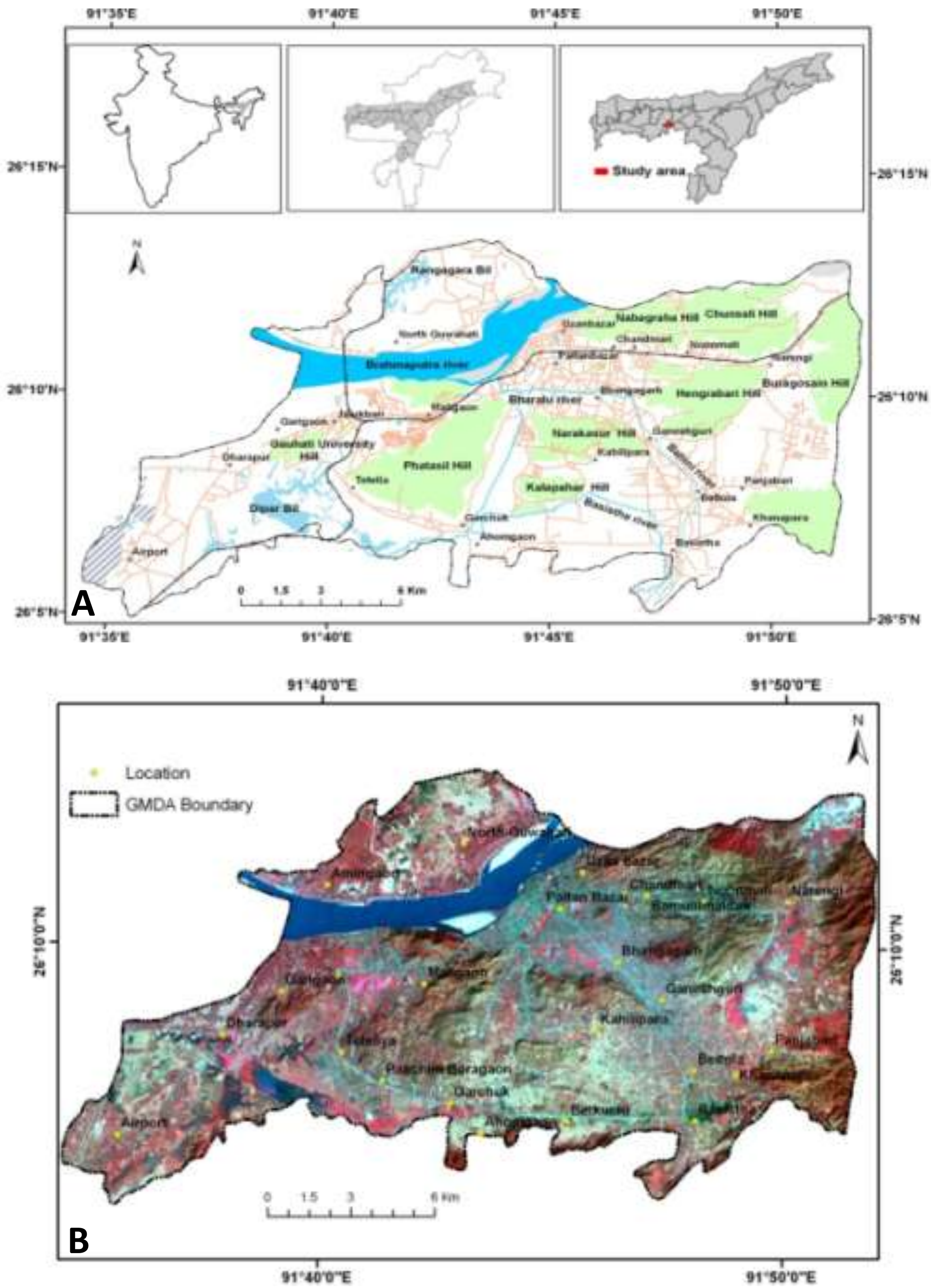

Fig.1. ALocation map of Guwahati city showing the communication network
B. Satellite image of the study area clipped along GMDA boundary

IV. THEMATIC LAYERS

The occurrence and movement of ground water is influenced by lithology, structure, geomorphology and drainage while replenishment is further affected by landuse, precipitation and infiltration rate.As such in this study, four thematic layers viz. lithology, structure, geomorphology and drainage have been generated for analysis and integration into a prospect map.

A. Lithology

The geology of the study area is represented by the Precambrian Gneissic Basement which is intruded by porphyritic granites in several localities (Figure 3). The basement complex is composed of granite gneiss, biotite gneiss, biotite schist and quartzite [5], [6], [7]. Quaternary alluvium and colluvial valley fills of varying thickness composed of unconsolidated sand, silt and clay are deposited over the basement Gneissic complex. The typical Brahmaputra sand with quartz, biotite and muscovite particles are found at a depth of 5-10 m in Bharalumukh, Machkhowa, Chatribari and 200 m or more at Ulubari [8].The deep bore holes drilled by Geological Survey of India in western part of the area at Azara reveal uninterrupted alluvial sediments up to bottom of the borehole and maximum thickness of 250-300m alluvium over basement has been inferred from Bhattapara, Palasbari and Airport areas. In DiparBil region i.e. on the western part of Guwahati, the top 10 m is represented by silty clay, clayey silt or sandy silty clay with ubiquitous litho-facies variations, while towards bottom i.e. invariably below 10 meter depth, fine to medium grained sand occasionally with intermittent silty clay and sand facies constitute the litho-package up to 30 meter [9].

B. Structure

Geological structures may act either as conduits or as barrier to flow of groundwater. Lineaments representing faults, fractures, shearzones etc. are the structural features that control the occurrenceand movement of groundwaterin hard rock terrain [10].The crystalline Precambrian rocks of the study area are traversed by a number of lineaments trending nearly E-W to NE-SW representing fracture zones and some showing semi circular pattern as in the Fatasil area. The dominant trend of these structures is NE-SW as shown in Figure 4. These structures also facilitate weathering and water seepage in hilly terrane of Guwahati.

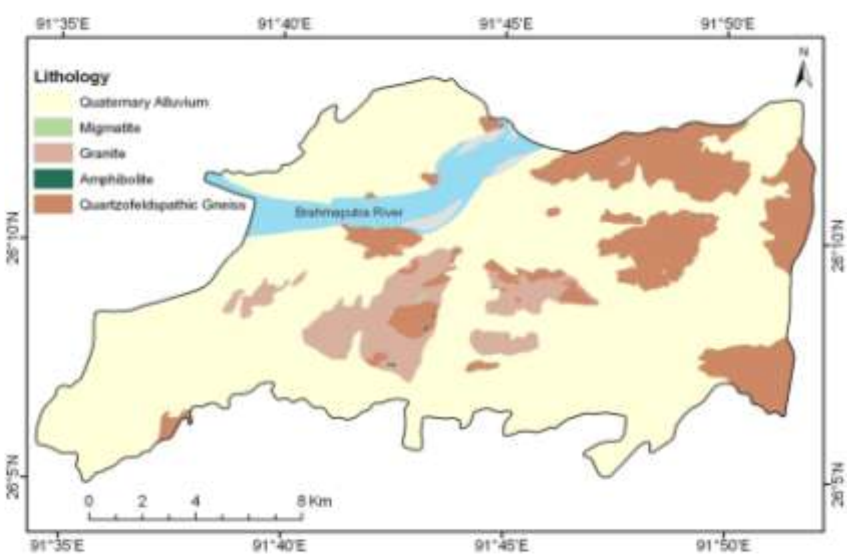

Fig. 3 Lithological map of the study area

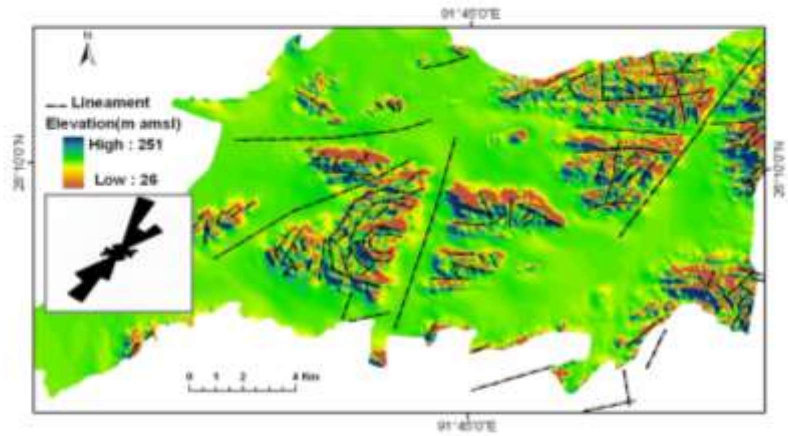

Fig. 4 Fracture pattern and their trend in Guwahati overlaid on a Digital Elevation Model

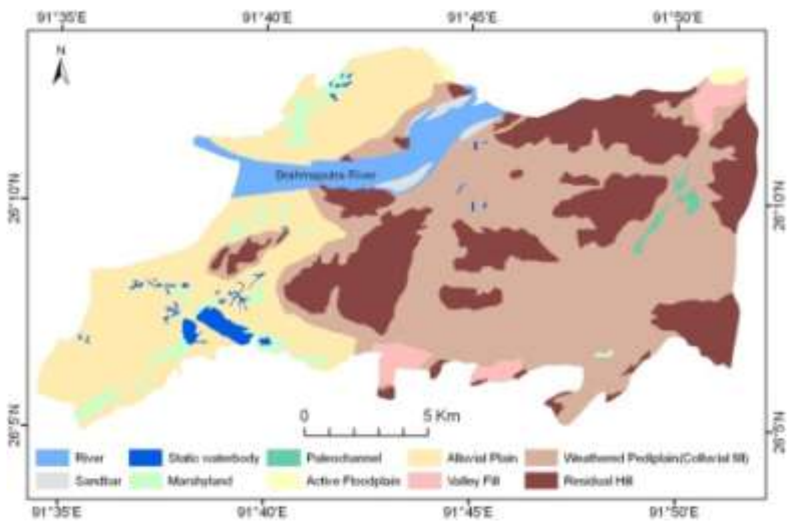

Fig. 5 Geomorphological map of Guwahati

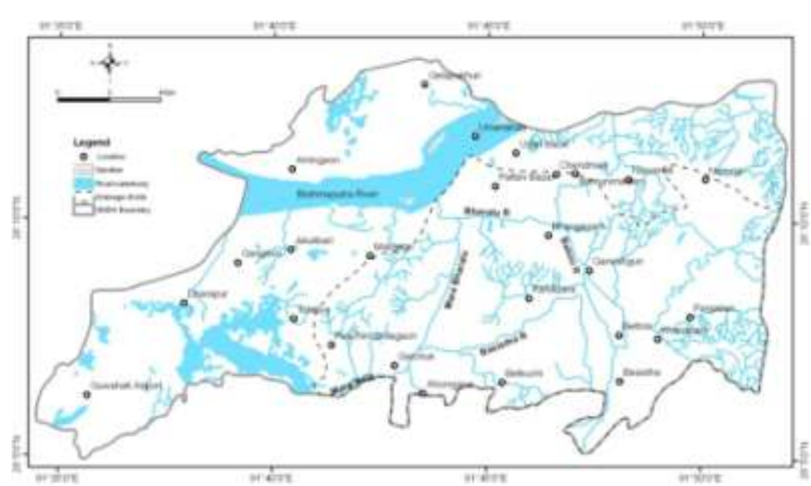

Fig. 6 Drainage network and wetland in Guwahati

C. Geomorphology

Guwahati presents an undulatory topography dotted with nineteen low lying hills interspersed with elongated valley fills. In this study the major geomorphic features viz., river, wetland, paleochannels, weathered pedeplain, active floodplain valley fill and residual hills (Figure 5) have been delineated from IRS LISS III FCC images. Common lithological and geomorphological boundaries were made co-terminus for avoiding inconsistencies of the polygons. These features were further verified in the field.

D. Hydrology

The hydrology layer of information consist of the surface drainage extracted from SoI topomaps, wetlands and the dug-wells (Figure 6). The Basistha-Bahini-Bharalu are the trunk channels in the city and alongwith their host of tributaries form the main conduit for surface water runoff. Besides, there are a number of wetlands locally known as ‘bil’ many of which are remnant of abandoned channels. However, most of these wetlands are now silted up and can be identified in satellite images from differential tone.

V. Result and discussion

Overlay analysis of the thematic information layers on lithology, structure, geomorphology and drainage has resulted in five ground water prospect zones (Figure 7, 8, Table 2) in Guwahati city, viz., very good, good, moderate, poor and very poor with different potential yield as approximated from the well data analysis. It is observed that all the hills composed of Precambrian crystalline rocks viz., granite gneiss, granite and quartzite have very poor prospect. However, there are isolated areas within these hills with good groundwater potential because of presence of fracture zones, although this is not reflected in the final prospect map (Figure 7). Therefore, a groundwater exploration strategy in these areas needs to take into account the fracture pattern. The pediment and foothills zones characterized usually by colluvial valley fills are in the poor category of prospect although during and immediately after monsoon these areas may provide good yield. Within the valley fills the area around Bharalu river get replenished from the river and are demarcated as moderate prospect zone. The alluvial plain which is well developed towards western part of the city has good groundwater prospect throughout the year while the paleochannelsof earstwhile anabranches of Brahmaputra along Sixmile-Chachal-Narengi and Dharapur-Boragaon-Jalukbari-Adabari-Pandu are found to be with very good yield potential. The areas with poor prospect cover as much as 42% area of the city while very poor, moderate, good and very good prospect areas cover 27%, 2%, 24% and 5% respectively.

VI. Conclusion

Analysis and integration of geospatial data for Guwahati in GIS environment enables fivefold prospect zoning of the city viz., very good, good, moderate, poor and very poor with different yield potential as estimated from aquifer characteristics and dug-well data. These prospect zones are found to be greatly influenced by geological factors viz., lithology and structure. This preliminary appraisal of prospect however need further large scale mapping and deterministic study through geophysical technique and detail well inventory for effective groundwater management.

TABLE II

Groundwater Prospect Zones and Estimated Yield

Sl. No.	Geomorphic Unit	Prospect	Yield
1	Marshyland	Very good	>75 Cu.m/day
2	Palaeochannel	Very good	>75 Cu.m/day
3	Alluvial plain	Good	50-75 Cu.m/day
4	Valley fill	Moderate	10-15 Cu.m/day
5	Weathered pediplain (colluvial fill)	Poor	1-3 Cu.m/day (10-15 Cu.m/day during Monsoon)
6	Residual hills	Very poor	< 1 Cu.m/day (10-15 Cu.m/day Borehole at fractured zone)

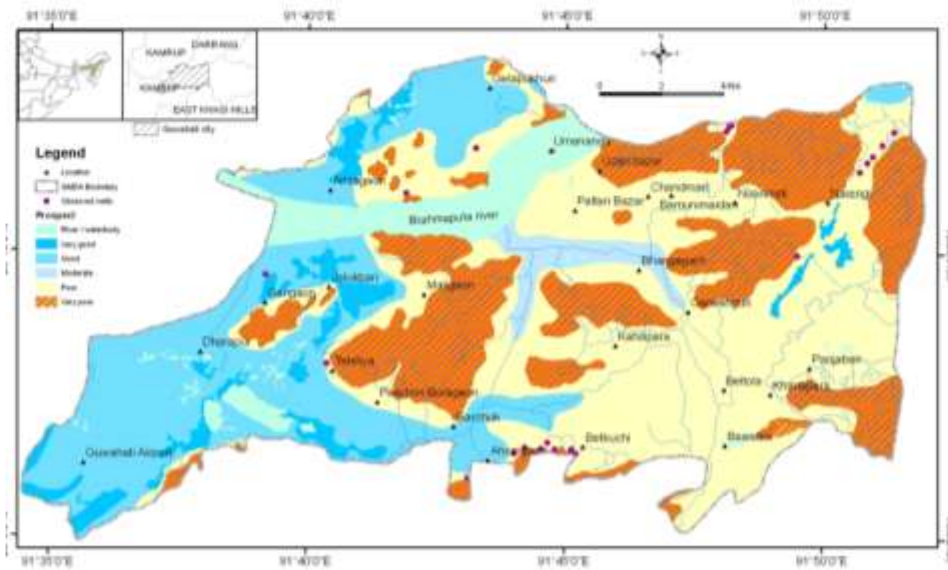

Fig. 7 Ground water prospect map of Guwahati city

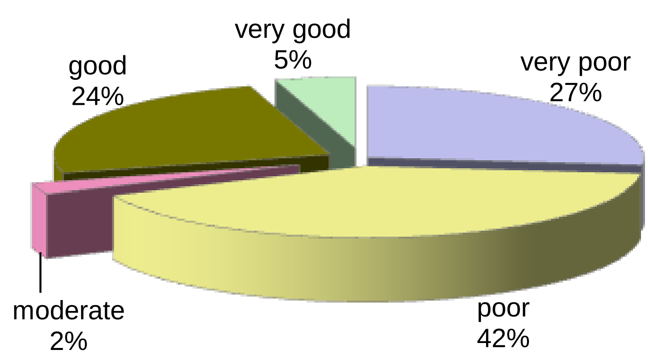

Fig. 8 Area coverage of different groundwater prospect zones in Guwahati city

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