A GIS based Hydrogeomorphological Mapping of Basaltic Terrain: Implications for Water Resource Evaluation and Management

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Abstract:
Bhopal, the capital city of Madhya Pradesh having highest population density and situated over Malwa plateau. The area in and around Bhopal city faces acute water scarcity and chronically drought prone region. The present study was under taken to evaluate various hydrogeomorphological units of the area through the use of high resolution satellite data and field survey. The evaluated hydrogeomorphological units along with geological setup and topographic condition are integrated in GIS environment on the basis of contribution of particular factor in groundwater occurrence and movement. Digital image processing techniques were also applied for better understanding of the features which are helpful for identification of boundaries of various landforms and geology. The deeply and moderately weathered pediplains with shallow alluvial plains are the most potential zones for groundwater exploration and site for water management plan.

Keywards: Hydrogeomorphological mapping, Basaltic terrain, remote sensing & GIS, Bhopal, India.

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Introduction

Groundwater is a dynamic and replenishable natural resource for the survival of human beings and the development of society. Therefore accurate and reliable information was required for water resources assessment and management. One of the most concerning issues currently being faced by the society, is the growth of population and its impact on the water resources. A groundwater resource plays a fundamental role in the sustainability of livelihood and regional economies throughout the world. It is the primary safeguard against drought and plays a central role in food security at local, national as well as global levels.

Space borne remote sensing information with its unique capabilities of spatial, spectral resolutions and temporal availability covering large and inaccessible areas within short time has become a very versatile tool in natural resource mapping. Geographical Information System (GIS) is a powerful tool for collection; storing, retrieving, transforming and displaying spatial data from the real world (Brunner et al. 2007; Leblanc et al. 2007).Remotely sensed data provides is a rapid and cost-effective tool in generating valuable data on geology, geomorphology, land/ use, lineaments/structures and slope, etc. that helps in demarcating groundwater prospect zones over a conventional techniques of hydrological analysis (Singh et al. 2011). A systematic integration of these data with field information provides rapid and cost-effective tool for identification of groundwater prospect zones and management of water resources in hard rock areas (Singh, 2012, Imran et al. 2011).

The groundwater occurrence and movements in hard rock areas are depending on the underlying rock formation, thickness of weathered material, topography, secondary porosity (fold, fault, fractures and lineaments) and climatic conditions. It is well known that hard rocks are having very less prospect for groundwater storage due to hard in nature, diversify physiographic conditions and climate change resulting is a severe crisis of availability of portable drinking water.The available water resources are inadequate to meet all the water requirements as well as high cost of exploration make the serious concern to find out the groundwater prospect zones with cost-effective techniques especially in hard rock terrain.In this direction mapping and monitoring of existing groundwater resources and predicting the future scenarios are the major issues in hard rock areas such as basaltic terrains in India. The incorporation of various field information collected from several sources are the key input data for groundwater prospecting of hard rock area with sustainable manner (Jasmin et al. 2011; Singh et al. 2011; Jha et al. 2007).
The present study has been taken for the Bhopal area using remote sensing and GIS techniques for understanding the terrain for groundwater assessment and management.

STUDY AREA: Bhopal is the capital city of the state of Madhya Pradesh situated in the central part of India and widely known as a City of Lakes. The study area comes under latitudes 23^0 10' -23^0 20' N and longitudes $77^0$20'-77^0 30'E of Bhopal city (Fig.1). The average annual rainfall of city is 1270 mm. The southern part of the city receives more rainfall than northern part of the city. The maximum rainfall takes place during the month of July.The city form a part of Malwa plateau with undulating topography. The major part of the city is covered by Vindhyan hills and by Deccan trap basalt. There is no major river flowing through the Bhopal city except number of large and small lakes. The area is drained by small drains which are lastly contributed to the river Betwa in the downstream.

Bhopal has been sprawling a fast rate of urban development and industrialization, over the last decade population growth of the city has been change drastically and the rate of high urbanization have an severe impact on the available water resource. The Deccan Traps cover almost one third of the area followed by Vindhyan sandstone. In Deccan Trap basalts, aquifer is encountered at shallow depth and in vindhyan sandstone depth ranges more than 150 m bgl. The water supply to Bhopal city is mainly comes from surface water bodies and small amount by groundwater. Nowadays number of bore holes / tube wells area drilled in the area without consideration of hydrological status of the aquifer formation to meet the water requirement this unaware drilling has also lead to the declining trend of water level and also failure of well in successive years.

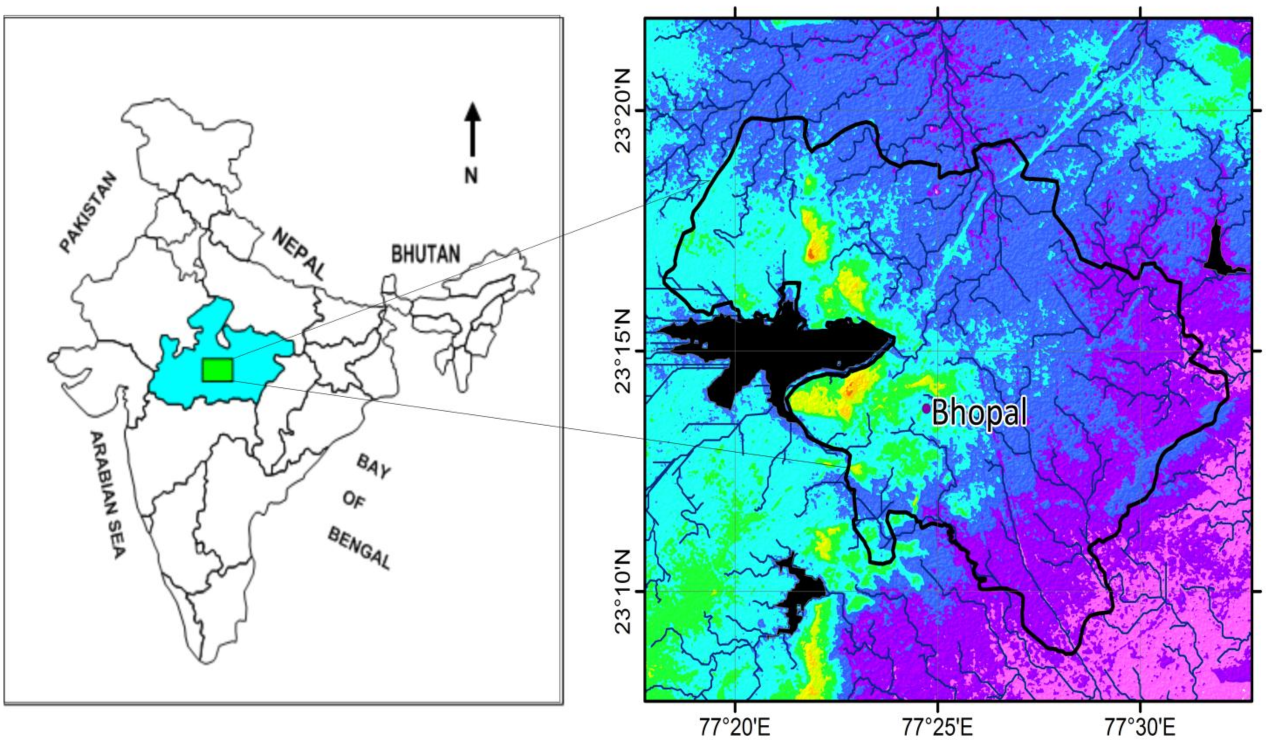

Fig. 1: Location map of the study area.

Geological and Hydrological status: The Deccan Traps sequence consists of multiple layers of solidified lava flows. It is more than 2000 m thick on its western margin and decreases in thickness eastward and occupies ~ 500,000 sq. km area spread over parts of Madhya Pradesh, Maharashtra, Gujarat, Andhra Pradesh and Karnataka. The Deccan Trap covers around 65% of the area of the city and Vindhyan sandstones inhabit 35% of the area. In Deccan Trap basalts, aquifers are encountered at shallow depth and in vindhyan sandstone aquifer zones are deep seated. The basaltic lava flows vary in color from dark grey to purple and pink. Each lava flow consists of an upper vesicular unit and a lower massive unit which may or may not be fractured/jointed. Two lava flows at some places are separated by intertrappean sedimentary beds. Therefore, unlike other hard rocks, the Deccan Traps behave as a multi-aquifer system, somewhat similar to a sedimentary rock sequence. Bhopal is occupied by the rocks of Vindhyan & Deccan trap Basalt and alluvial formations. Geologically area is divided in three major type's alluvium, Deccan trap and Vindhyan sandstones with small patches of shale which makes the major aquifers of the city. In the study area, Deccan traps are sporadically distributed mainly in the form of linear patches. On the satellite image, this rock type is seen with distinct grey color with rough texture. The derivatives of Deccan trap rock are the black soils, which are seen on the satellite image as dark grey tone with smooth texture.

Hydrologically major groundwater yielding aquifer zones are confined in shallow depths the groundwater .The shallow aquifer occurs in Alluvium, Weathered jointed and fractured Deccan traps and Weathered and jointed Vindhyan sandstone. Alluvium is deposited in patches along the major drainage channels and the yield is very limited due to very low thickness. The Deccan trap basalt forms good shallow aquifers zones due to high thickness of weathered deposits. Weathered basalts make the major water bearing horizon. Sometimes a layer of jointed basalt located at suitable geographic locations show very high permeability and supports high pumping through dug wells. In low lying areas the depth of weathering is greater and often a thick clay layer is also developed which confined the ground water at deeper levels. In general Deccan traps yield between 100 and 400 cum/day. (CGWB, 2011) Vindhyan sandstones being general orthoquartzitic in nature are resistant to weathering and do not favour development of thick weathered profile unless the area is predominantly shale. In sandstones groundwater occurs mainly in fractures and along bedding joints. The Vindhyan sandstones in the area occupy mainly higher ground where weathered profile is insignificant or. It acts as recharge for the low lying areas.

Data Used and Methodology

Assessment and management of groundwater from the remote sensing, field data and other published maps required a systematic methodology in which entire dataset support for the integration and analysis in GIS environment. For the groundwater resource evaluation of an area, a multiparametric data set comprising remote sensing data (IRS ID, ASTER), Survey of India toposheets and published geological map of GSI along with other published maps of the district.

The IRS –ID LISS III and PAN data were geometrically rectified and registered with SOI topographical maps using **ENVI image processing software** through map to image registration techniques. The digitally rectified images were spectrally merged by principle component analysis based on image fusion techniques. Image enhancement techniques have been applied for the preparation of hydrogeomorphological map on the basis of their image characteristics to enhance lithological boundary and landforms. Topographic analysis and generation of slope and aspect map has been derived from satellite borne ASTER DEM using ARC GIS surface analysis tools. ASTER is an advanced multispectral imager that was launched on board NASA's Terra spacecraft in December, 1999. ASTER covers a wide spectral region with 14 bands from the visible to the thermal infrared with high spatial, spectral and radiometric resolution. ASTER consists of three separate subsystems, each operating in a different spectral region, using separate optical systems.

Result and Discussion

In a methodical approach for groundwater resource assessment and management of any complex geological setup requires systematic guideline for hydrological evaluation. Availability of water as surface as well as Groundwater depends on various geo-climatic factors such rock type, geomorphology,structure / lineament, geophysical aspect in respect to aquifer type and their complexity, soil type and their thickness, landuse / land cover , drainage pattern and its density, slope and rainfall of the area. Once we approach the groundwater resource evaluation of any area than we have to discussed and prepare all these parameters before finalization of ground water resource evaluation plan of the terrain (Singh et al 2012, 2011; Saud, 2011).

In the present work A GIS based Hydrogeomorphological mapping of hard rock terrain has been discussed for Water Resource evaluation and management of Bhopal city based on geomorphological and topographic analysis for a primary level of investigation.

Slope

Slope is a critical parameter which directly control runoff and therefore on infiltration and also important in geomorphic evaluation.The topographic analysis has carried out using digital elevation models (DEM) from ASTER data using ARC GIS software (Fig.2). On the basis of topographic height, the study area is divided into nine topographic elevation classes. The highest topographic elevations (about 650 m MSL) exist in the central part of the area which encourage highest runoff and hence less possibility of rainfall infiltration. The low topographic elevations are observed in the southeast and southwest portions of the study area.The slope map of the study area has been grouped from 0-10 to 90 – 100 %. Higher degree of slope results in rapid runoff and increased erosion rate with less groundwater recharge potential. It can be seen from (fig.3**)** that the lowest slope exists in southeast and southwest portions of the study area which indicates almost flat topography. The highest slope exists in the central part of the area in the form of linear hills.

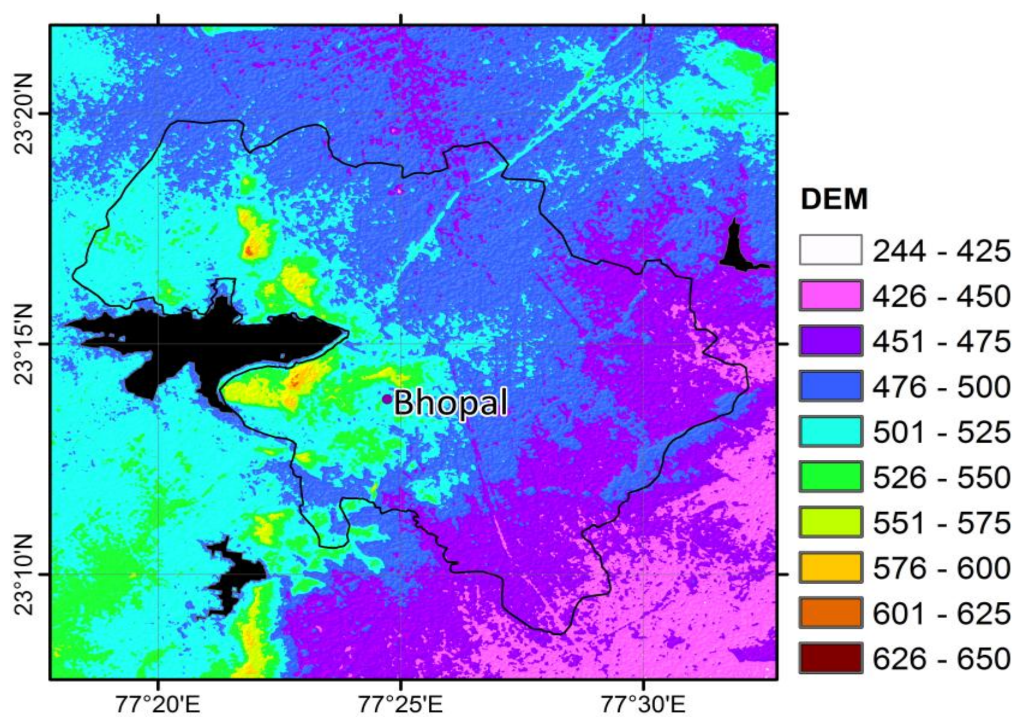

Fig 2: Digital Elevation Model of the Area.

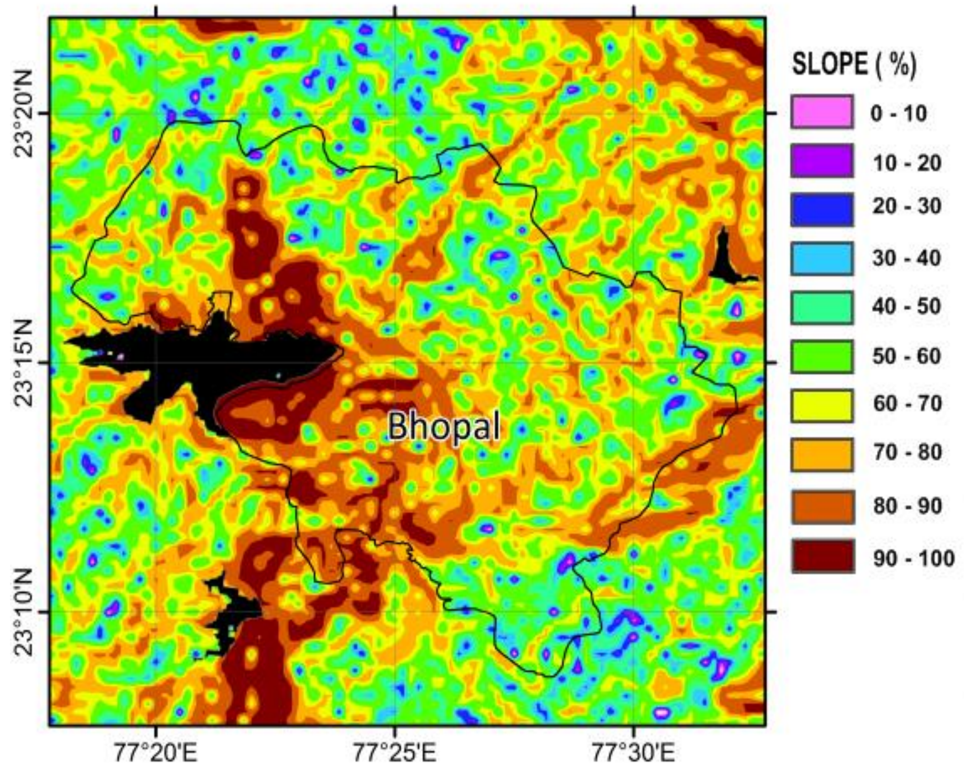

Fig. 3: Slope map of the study area.

Hydrogeomorrphology

Hydrogeomorphological map depicts a essential indication about the geomorphic units and landforms along with their underlying rock formation so the detail geomorphologic investigation provide an important input data for understanding the entire processes of deposition , lithology / structure and various geological controls responsible for the occurrence and movement of groundwater resources (Singh et al 2011 and Machiwal et al. 2011).

The major Hydrogeomorphic landforms demarcated in the study area are pediplains, pediments, denudation hill, and structural hill. Pediplains comprise gently undulating plains covered with weathered basalt materials, and are the most favourable zones for groundwater accumulation and movement (Fig.4). The groundwater storage depends upon the thickness of the weathered material and the soil cover. On satellite images, they have a yellowish-red colour and coarse texture. Pediplains are covered by thick vegetation and are characterized by low-lying flat terrain. On the basis of thickness and composition of weathered material, the pediplan have been classified into Shallow weathered buried Pediplain and moderate weathered buried covered with black soils most of the area cover under shallow pediplans hence this landform classified as moderate to good groundwater accumulation zones.Thin Alluvial deposits are also observed close to drainage channels and having highly porous and permeable alluvial deposits hence are characterized as ‘moderate’ zone for groundwater accumulation in upper level for dug well construction.

Denudational hills and pediments are the massive hills with resistant rock bodies that are formed due to differential erosion and weathering processes. These denudational hills occur in the central portion of with Vindhyan sandstone and mainly covered by the settlements and having high relief. On the satellite image, these landforms were identified by dark brownishred colour due to thick forest cover. They show steeply sloping topography with high relief developed over the Bhander sandstone. These hills are characterized by high surface runoff and are categorized as poor groundwater prospect zones in deeper level. Structural hills are represented by the presence of strong structural controls. They are located in the outer fringes of the area and are mainly composed of Bhander sandstone. These are characterized by red tone with rough texture on the satellite image. These hills are covered with dense forest cover.

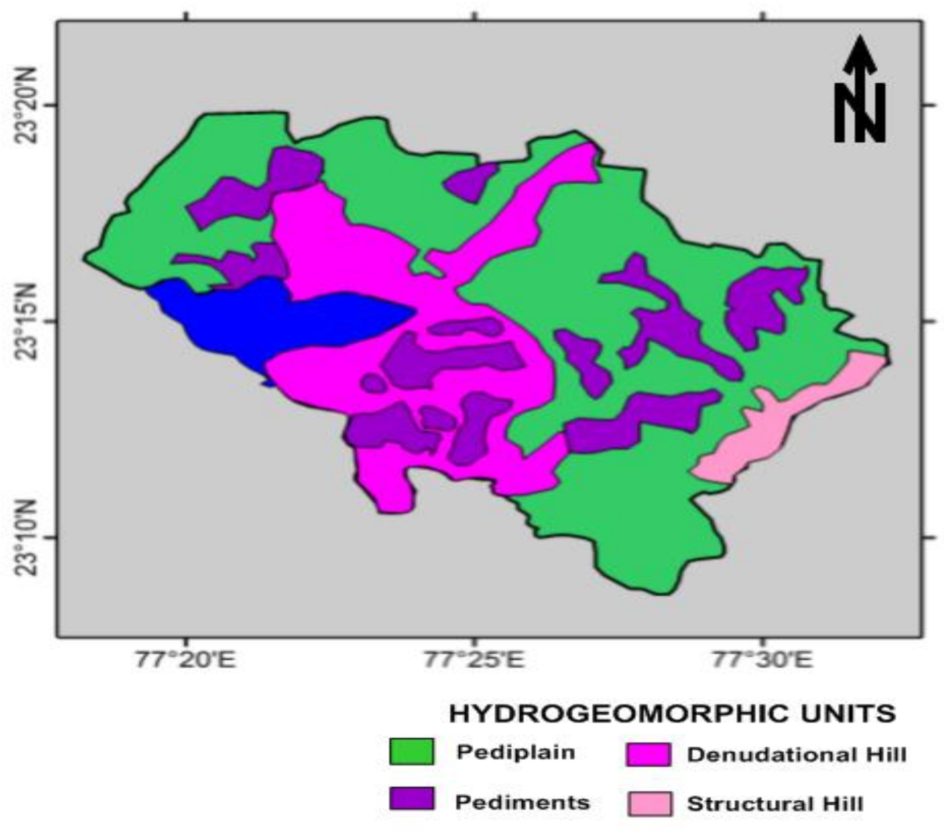

Fig. 4: Hydrogeomorphological map of the Study area.

Conclusion:

Bhopal and its surrounded physiographic conditions reveal a variety of hydrogeological and hydrogeomorphological complexity which are controlled and managed by variety of geofactors primarily hydrogeomorphology, geological conditions and topographic variation. In the present paper GIS based hydrogeomorphological evaluation and interpretation of different units shows the primary level of prospect for groundwater resource evaluation and management using satellite data. In Bhopal city most of the area is overlay by concrete and not having space for recharge to ground water system, roof top rain water harvesting is most suitable technique adopted in the city to recharge phreatic and semi-unconfined. The hydrogeomorphological units such

as pediplain are prospective zones for groundwater exploration and development in the study area. Denudational hills and pediments can be used for better water management plan for construction artificial recharge structures. The methodology may be useful in formulating effective groundwater exploitation strategies and predictive groundwater development and management. The results obtained can be used for sustainable management of groundwater resources inthe area in terms of artificial recharge.

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