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Hydrogeological Investigation of the Morna River Basin, Akola District, Maharashtra, India Using Remote Sensing and GIS Techniques for the Assessment of Groundwater Conditions

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ABSTRACT - Geographic Information Systems (GIS) technology has played critical roles in all aspects of watershed management, from assessing watershed conditions through modeling impacts of human activities on water quality and to visualizing impacts of alternative management scenarios. The field and science of GIS have been transformed over the last two decades. Once considered a Cinderella technology in selected disciplines and application domains, GIS has grown quite rapidly to become a multi-billion industry and a major player in the broader field of the ubiquitous information technology. Advancements in computer hardware and software, availability of large volumes of digital data, the standardization of GIS formats and languages, the increasing interoperability of software environments, the sophistication of geo-processing functions, and the increasing use of real-time analysis and mapping on the Internet have increased the utility and demands for the GIS technology. In turn, GIS application in watershed management has changed from operational support (e.g., inventory management and descriptive mapping) to prescriptive modeling and tactical or strategic decision support system.Groundwater constitutes an important source of water for various purposes. The conventional approach for groundwater investigation is ground based survey. Keeping this in view the present study attempts to map groundwater prospect map of the Morar river basin using remote sensing, GIS and geoelectrical techniques. Geomorphological, geology, lineaments and slope map has been prepared from satellite data. All the thematic maps maps are integrated in GIS environment and classified the area in four categories of groundwater prospects from poor to excellent groundwater potential zones. For the field verification of the result obtained from the integration of thematic maps are crossed checked with resistivity survey of the area. In this study, an attempt has been made to understand the hydrogeological characterstics of the Morna River basin and 'potential groundwater contributing zones' were delineated using geographic information system (GIS) and remote sensing (RS) analysis tools.

Keywords: hydrogeological characterstics, GIS and geoelectrical techniques, groundwater prospect map, 'potential groundwater contributing zones',

1.0 Introduction:

Water is the natural and basic essential need for survival of human beings and for other living beings including plants. Groundwater has and would continue to play a crucial role for food and fodder production, drinking water supply, drought mitigation and economic development of the country ,the groundwater being occult and subterraneous resource needs to be explored through sub surface techniques of groundwater exploration. As already stated water is the most vital natural resource for living and is the backbone of socioeconomic development of the country. The absence of water resulted in the absence of life on the moon. The planet earth has approximately 71% of the area covered with water in the form of ocean bodies.

The Maharashtra state is located within the peninsular shield area of the country with about 94% of its total geographical area underlain by hard rock formations and the remaining 6% with localized occurrences of sedimentary and alluvial deposits. About 80% area of the state is covered by basaltic lava flows with overlying alluvium confined to the areas in the vicinity of major rivers and the streams. The alluvial deposits of shallow thickness occurred extensively along the stream courses of consisting of gravely, sandy and clayey admixtures. The nature of formations viz. unconsolidated, semi consolidated and consolidated rocks are an important factor that governs the development of suitable drilling machine for the successful construction of a bore well or tube well. The groundwater exploration by drilling commences with selection and pinpointing of the site.

The first and extensive programme in Maharashtra for a systematic exploration of ground water by drilling i was started in 1995, in soft rock areas of Purna River basin. The Purna River is the principal tributary showing perenial nature with seasonal tributary, originating from the southern slope of Gavilgarh hill of Satpura ranges and flows westerly through Amaravati, Akola and Buldhana districts. The Purna basin covers an area of 7500 sq. km. of which 3500 sq. km. area in

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covered by saline ground water showing critical situation of drinking water. The basin shows complex geological set up which is traversed by east west and north south faults in the northern part.

1.1 Watershed Characterization and Assessment

GIS has been widely used in characterization and assessment studies which require a watershed-based approach. Basic physical characteristics of a watershed such as the drainage network and flow paths can be derived from readily available Digital Elevation Models (DEMs) and USGS's National Hydrography Dataset (NHD) program. This, in conjunction with precipitation and other water quality monitoring data from sources such as EPA's BASINS database and USGS, enhances development of a watershed action plan and identification of existing and potential pollution problems in the watershed. The groundwater salinity in the Purna basin is very crucial and has attracted the attention of many researchers.Wynne,(1889); Chatterjee, (1959); Adyalkar ,(1963) and Ayyangar, (1996) have provided possible causes for the salinity which might be due to remnants sea water transmission in the Geological past. Mutthuraman,(1992) and Ravishankar, (1987) have provided structural characters of the Purna River. Tiwari et. al., (1996) have indicated the geological and geo-morphological characters of the Purna river basin. Ayyangar, (1996) has provided the use of GIS in the management of saline tract. In addition, CGWB and GSDA have carried out various studies on the salinity problem of the Purna basin. The ground water salinity forms a crucial problem in the Akola district which needs a proper integrated study and management to cater the drinking water and agricultural needs.

The northern part of the Akola district is occupied by Purna alluvium which is saline in nature. The work done so for in establishing the systematic, stratigraphic, petrographic and hydrogeological and water resource management of Morna basin is very limited. The present study is aimed to understand some of the crucial problems of groundwater quality and management with the help of latest available techniques in an integrated manner. The proposed study will certainly fill the crucial gap of knowledge related to the salinity problem by providing detailed field and laboratory data with GIS analysis for proper interpretation. These results will provide geological, hydrogeochemical, petrological, stratigraphic, geophysical and environmental data based which is fundamental in resolving the salinity problem and also in locating potable sweet water zones within the saline tract. This study will certainly bring awareness among the common people regarding the various measures for controlling the salinity so as to improve the socioeconomic condition with the help the of multidisciplinary approach.

2.0 Study Area:

The Morna River basin which is a tributary of Purna River lies towards the northern and southern part of Akola district, and parts of Washim district, forming near about 190 to 200 meters thick lava flows covering an area of 941.39 sq. km. and lies between 76o45′38″ to 77o 5′ 26″ E longitude and 20o 25′ 7″ to 20o 29′ 34″ N Latitude and Survey of India Toposheet No. 55H/1,H/2, H/15, D/3, and 55D/15(Fig 1).

2.1 Physiography

Physiographically, the area consists of minor depositional and majority of erosional landforms. The topography is characterized by the presence of various land forms like Mesa, Butte, Lavahills, Lavaflats, Escarpment and Lava plateau. The highest point (480m) in the basin lies near village Nandkhed. The area is dominated by monotonous flat top terraces, which are results of lateral erosion of lava flows. The lowest point (240m.) in the basin lies in northern part of the area i.e. at the village Andura. The study area is drained by Morna River flowing south to north with almost dendritic to subdendritic drainage pattern.

Physiographically, the study area can be broadly divided into low lying plain towards the banks of the Morna River in the northeast and horizontal Deccan Trap flows with multiple scarps and abrupt cliffs towards the southern parts. The study area consists of various erosional surfaces in step-like terraces. The horizontal dispositions of the lava flows with a fair degree of uniformity in lithology have considerably simplified the changes brought by the secondary processes like weathering and denudation. Differential weathering forces has resulted in wiping out of thick lava pile. The result of geomorphic analysis indicates the predominance of erosional landforms over the depositional landforms. The study area can be interpreted as a moderate morphogenetic region. The contour map of the area is prepared with the help of Arc-GIS to show the physiography of the region; contour lines are defined as the lines joining the points of equal elevations. The southern part of the basin such as Patkhed, Rajanda, Waghjali, Mahagaon, upto Rajur the terrain represents positive relief features .The contour spacing is close in the southern part of the basin but in the middle it is more. The Patkhed hills have moderate slope, Rajanda hills have steep slopes. The drainage network of the Morna River basin demonstrates the hydrogeological conditions of the study area with the dominance of dendritic drainage pattern showing uniform lithology with the presence of Deccan Traps with the occasional presence of alluvial tract (Fig.2). In order to understand the hydrogeological conditions of the study area, detailed fieldwork for the collection of water samples at specific locations was conducted in pre and post monsoon periods to decipher the various physical and chemical hydro geological parameters of the Morna River basin to identify the aquifer characterstics and groundwater conditions of the water bearing horizons (Fig.3).

2.2 Hydrogeological Investigations

In the study area, the water table occurs under confined and unconfined conditions. The physico- chemical characteristics of groundwater in unconfined regime along with the mode of occurrence have been highlighted. The results of well inventory data analysis of wells for pre - monsoon and post-monsoon seasons demonstrate a consolidate range of fluctuations in the water level which can be divided into three groups such as low level fluctuation (1.5m bgl), moderate level flections (1.5-3 m bgl) and high level fluctuations (>3 m bgl). The probable reasons for the water level fluctuations are the distinct valuation in the rainfall and also the indiscriminately pumping of the groundwater in the region. In addition, two years data of groundwater fluctuations collected from various observation wells was computed to understand the nature of groundwater regime. Detailed climatological and meteorological data of past 20 years was computed to understand water level fluctuations and favorable sites for groundwater development, which might be due to the nature of topography, frequency of rainfall and withdrawal of the water from the aquifers.

This detailed study demonstrates various measures for improving the groundwater potential and water level fluctuations in the region with emphasis on environmental management. The area of investigation is characterized by the presence of alluvial zone showing saline tract towards the northern part and basaltic lava flows showing horizontal nature towards the southern part. The shallow unconfined aquifers, which are tapped by means of dug wells, are the largest producers of groundwater in the region. It is concluded that the salinity of the ground water is largely controlled by lithology with high salinities regulating from carbonates and evaporates.

Miller and Drover, (1977) showed various chemical relationships between soil, bedrock, lithology and runoff chemistry. They suggested that water chemistry is mainly dependent on slight alteration of host rock without development of chemical equilibrium involving secondary phases in soil zone. The area shows very good scope for the proposed study of hydrological investigation and watershed development with water resource management. The proposed work is quite significant as it has provided a detailed hydrological parameter with valuable clues for assessment of groundwater potential in the area and also to reconstruct the ground water flow path in the particular watershed which shall be useful for an optimum rational planning and management of groundwater resources in future with concern to groundwater resource management.

In the study area, the recharge of groundwater is controlled by topography, thickness of weathered zone, and infiltration capacity of soil and subsoil strata within the zone of aeration. The lava flows are separated by the horizons of red boles. Each part of the flow forms a separate unit, which differs from the other, based on variation in porosity and permeability of the flow units. The water bearing capacity of various lava flows depends on the flow nature and geomorphic expression. The massive portions are devoid of any openings due to low porosity and hence unproductive for groundwater. Whereas, the vesicular and amygdaloidal horizons of lava flows shows interconnected and uniformly distributed vesicles contributing to the groundwater potential due to high degree of porosity and permeability, which further intensifies due to differential weathering. Occasionally, the closely spaced interconnecting joints present in between the massive horizon may contribute towards the formational porosity can form productive zone. The size and number of vesicles, degree of weathering and jointing pattern mainly control the water productivity and yielding strength of aquifers in basaltic terrain. Hence, highly weathered zones of vesicular and amygdaloidal basalts are good producer of groundwater. The results of hydrogeochemical data demonstrate the role of chemical weathering causing water chemistry to remain unchanged in trapping area whereas the alluvial zone shows definite change in chemistry due to salinity problem. The variation of pH and TDS is controlled by lithology and climate. Bhatt and Saklani, (1996) have indicated that high velocity of river water may lead to excessive mass transport over a rock weathering which influences the quality. Chemical weathering plays major role in controlling water chemistry in the downstream temperate area.

It has been observed that the presence of poor water quality in the Northern saline tract of the alluvial zone which is not suitable for drinking and irrigation purposes. Whereas, the trap region shows fair to excellent quality for groundwater. In the study area the highly fractured, weathered and jointed horizons of Deccan trap have maximum yielded amount of water showing potential aquifers. The area of investigation is characterized by the presence of multiple aquifer system showing productive and unproductive zones due to the presence of alternating massive and vesicular units with lateral variation. The depth to water level studies indicates distinct zones and influence by irrigation methods showing recharge of groundwater table. The groundwater level fluctuation mainly depends on the difference in water levels of pre-monsoon and post-monsoon periods, which can be directly linked, to recharge and discharge of groundwater (Fig.4). In addition, SRTM map of the Morna river basin has been prepared using Arc GIS techniques to understand the hydrogeological regime of the river basin (Fig. 5).

2.3 Watershed Restoration

Watershed restoration studies generally involve evaluation of various alternatives and a GIS provides the perfect environment to accomplish that efficiently and accurately. GIS has been used for restoration studies ranging from relatively small rural watersheds to heavily urbanized landscapes. Coupled with hydrodynamic and spatially explicit hydrologic/water quality modeling, GIS can assist in unified source water assessment programs including the total maximum daily load (TMDL) program. As an example, alternatives for restoring a waterbody or a watershed can be studied by creating digital maps that show existing conditions and comparing them to maps that represent the alternative scenarios. GIS can also provide a platform for collaboration among researchers, watershed stakeholders, and policy makers, significantly improving consensus building and offering the opportunity for collaborative work on interdisciplinary environmental policy questions. The integrating capabilities of a GIS provide an interface to translate and emulate the complexities of a real world system within the confines of a digital world accurately and efficiently.

2.4 Watershed Policy Analysis and Decision Support

The field of watershed science, particularly watershed planning, is experiencing fundamental changes that are having profound impact on the use of computer-based simulation models in resource planning and management. On the one hand, the dramatically increased availability of powerful, low-cost, and easy-to-use GIS software, and more extensive spatially referenced data, are making GIS an essential tool for watershed planning and management tasks. However, with this increased use has come an increased realization that GIS alone cannot serve all the needs of planning and managing watersheds. This realization has renewed resource planners' interest in development of decision support systems that combine GIS, spatial and non-spatial data, computer-based biophysical models, knowledge-based (expert) systems, and advanced visualization techniques into integrated systems to support planning and policy analysis functions.

As a component of a spatial decision support system, GIS provides very powerful visualization facilities for display and manipulation, giving immediate intuitive evaluation capabilities to which a wide range of non-technical users and decision makers can relate to. Planning and management are based on a generic problem-solving process which begins with problem definition and description, involves various forms of analysis which might include simulation and modeling, moves to prediction and thence to prescription of the hydrogeological characters. In this study an attempt has been made to decipher the groundwater characterstics of the terrain using remote sensing and GIS techniques.

3.0 Conclusions:

Remote sensing and GIS approach has successfully used in the present investigation to obtain a detailed evaluation of groundwater conditions of the study area.The integrated maps were classified into four groundwater potential zones from excellent to poor. Based on the geomorphological mapping, lineament density and resistivity data, the following broad conclusion can be drawn. The present study brings out the close relationship among the geomorphic, geologic, hydrogeologic and geophysical parameters of groundwater. The ground water potential zones are also verifying with bore wells yield data of the study area. The comparison shows that the groundwater potential zones are in agreement with the bore wells yield data.

The above study has demonstrated the capabilities of using remote sensing, geoelectrical data and GIS for demarcation of groundwater potential zones, especially in diverse geological setup. This gives more realistic groundwater potential map of an area which may be used for any groundwater development and management plan. Geologically, the study area comprises deep alluvium, which is of basaltic and volcanic origin. Water quality was monitored at various locations along the stretch of Morna River, upstream and downstream, the assessment was carried during pre-monsoon, monsoon and post-monsoon seasons. The analytical results indicate higher concentrations of certain ions during pre-monsoon and post-monsoon seasons may be attributed to seepage of ground water from aquifer to surface water body and lower concentrations during monsoon may be due to dilution effect with surface runoff. The values of SAR, %Na and RSC indicate good to permissible quality of water as per the BIS standard for irrigation. This study is quite crucial and significant in the present day contest as it has provided a detailed hydrological regime of the Morna River basin with valuable clues for assessment of groundwater potential in the area and also to reconstruct groundwater flow path in Morna watershed which will be useful for an optimum national planning and management of groundwater resources in the entire region for the sustainable development in future.

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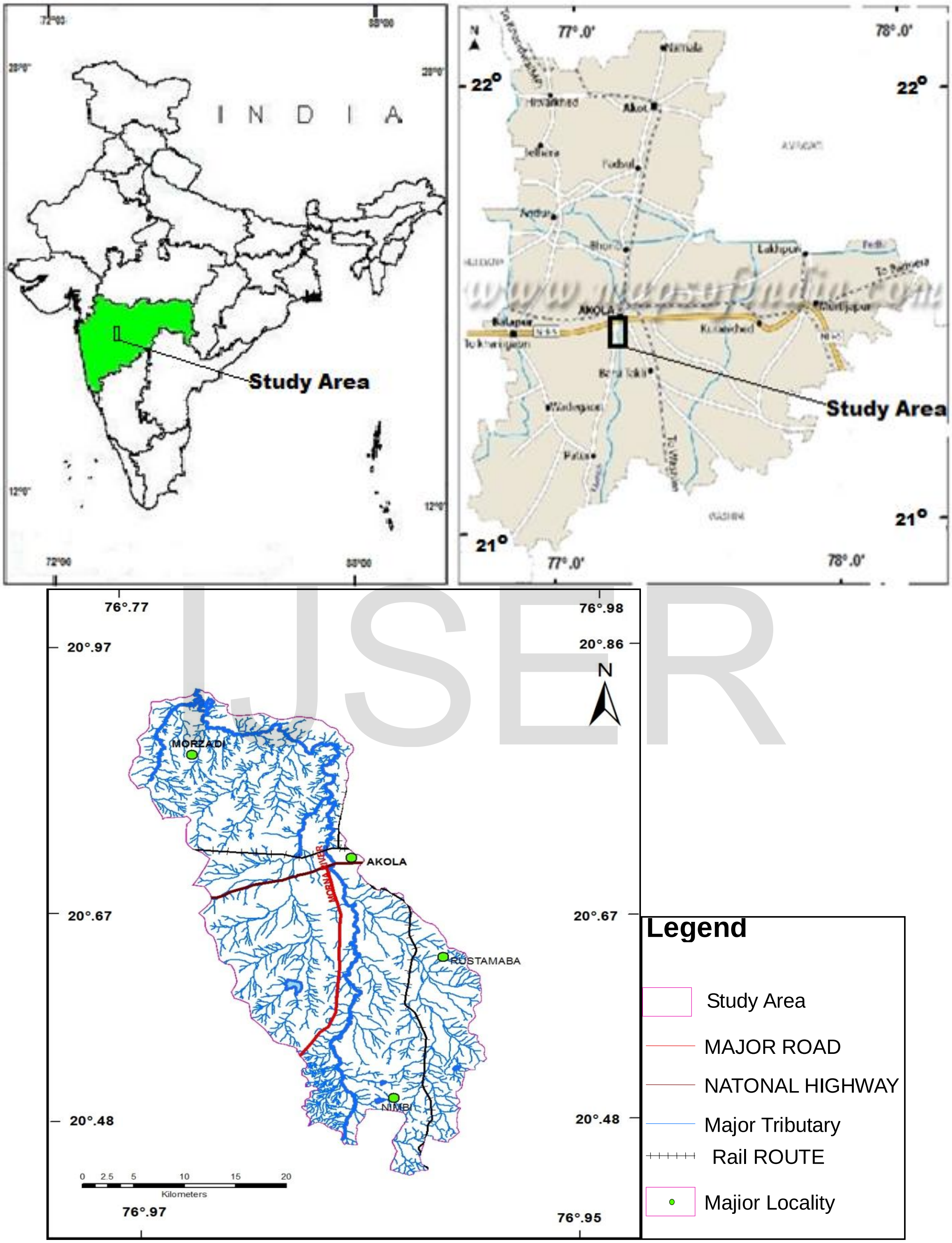

Fig.1 Location map of the Morna River Basin

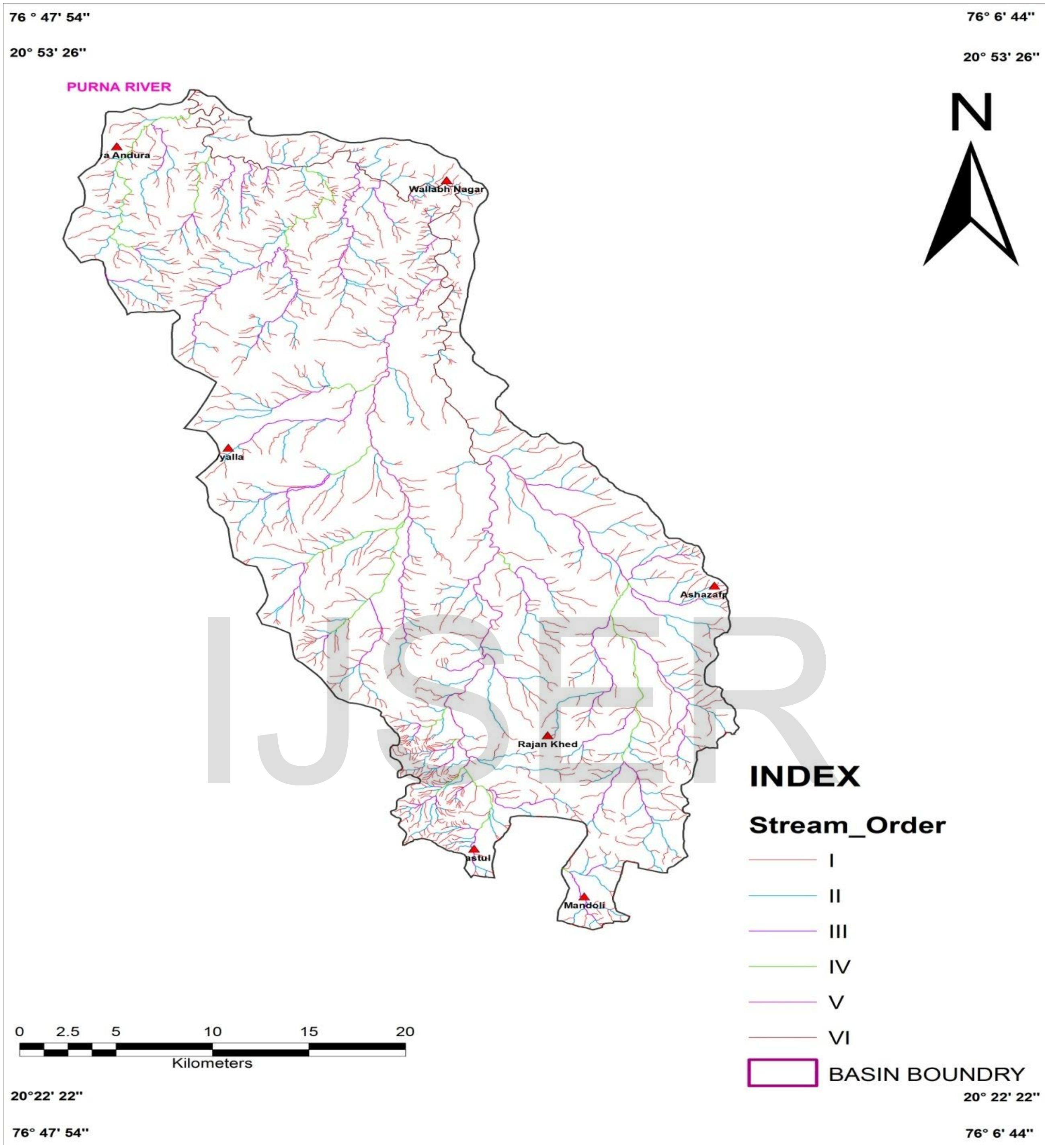

Fig. 2 Drainage network of the Morna River basin

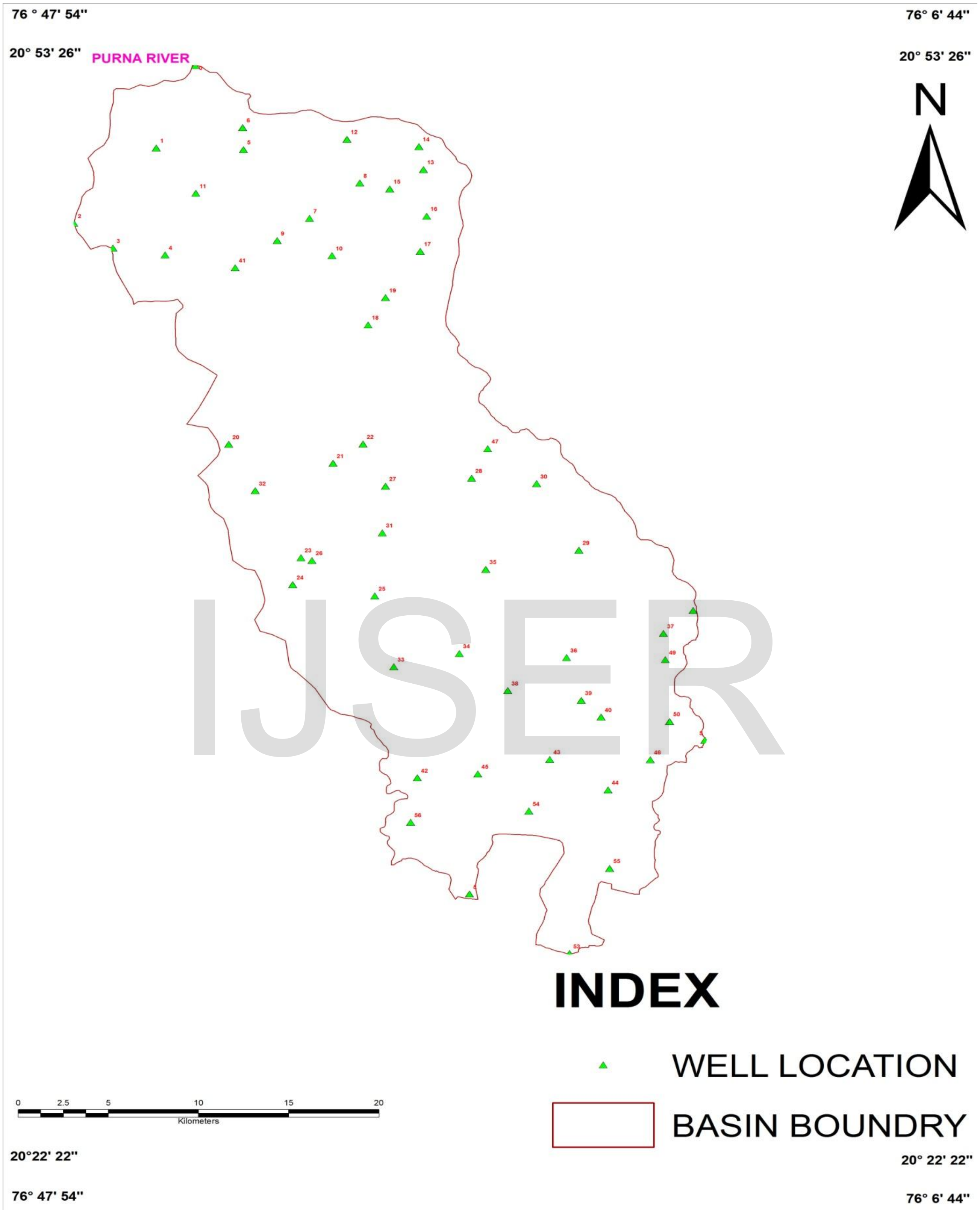

Fig.3 Well location map of the study area

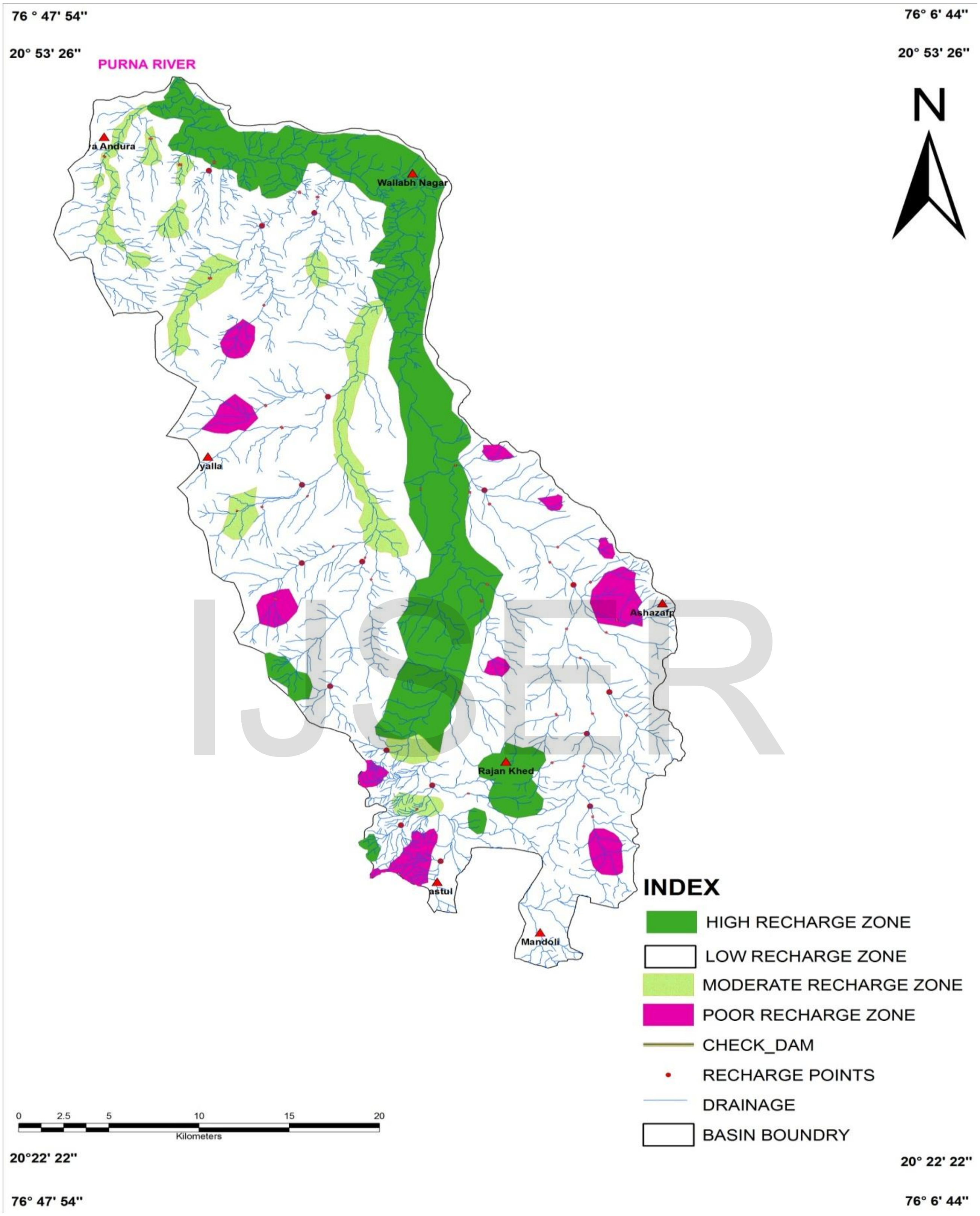

Fig.4 Identification of groundwater recharge zone through remote sensing and Arc GIS techniques

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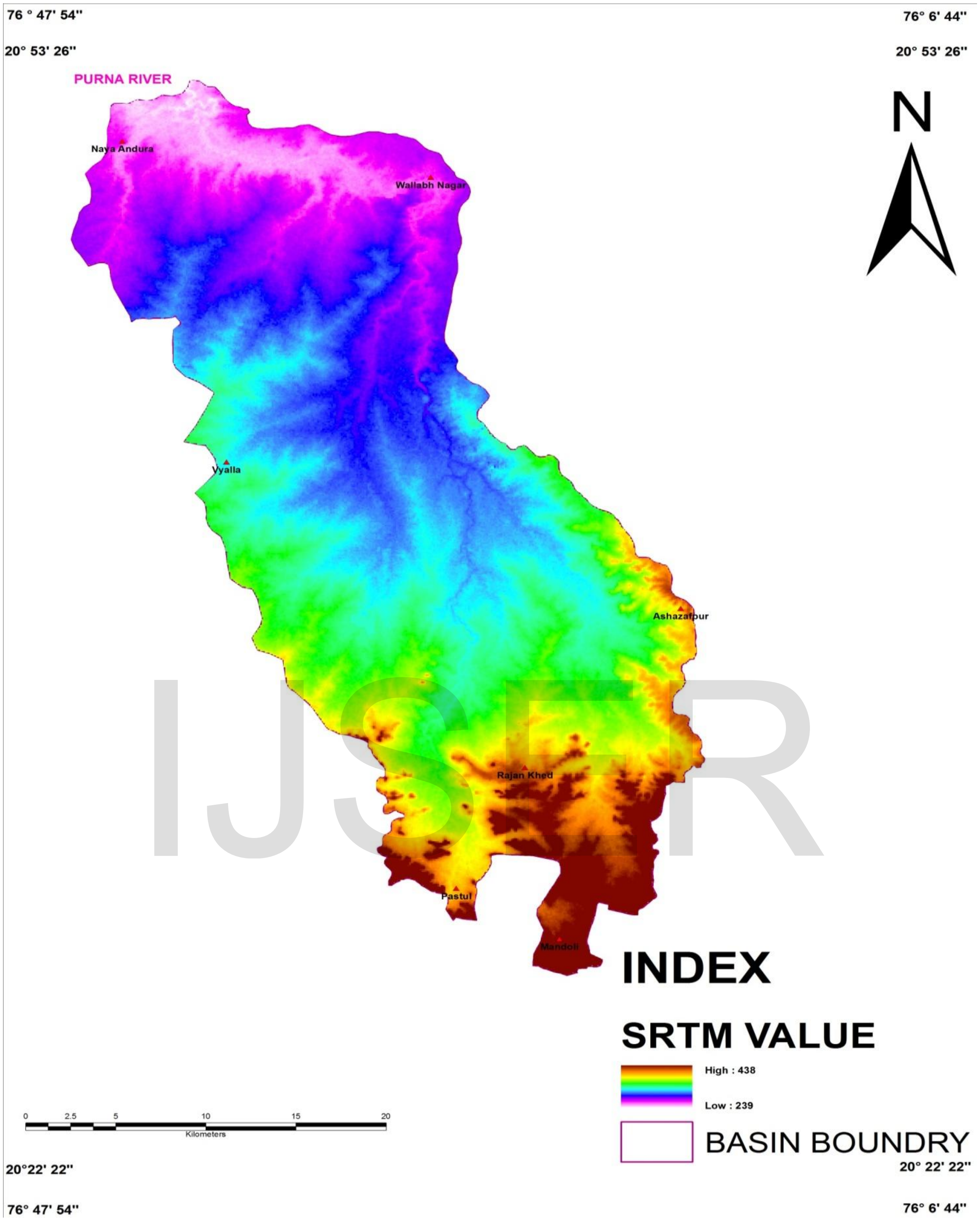

Fig.5 SRTM map of the Morna River basin

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