

GIS Based Ground Water Potential Mapping and Geological, Hydrogeological Assessment of the Ton River Basin in Maihar District

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Abstract

The present study investigates the geomorphological, geological, and hydro-geomorphological characteristics of the Ton Basin located in the Maihar region of Madhya Pradesh, India, using Remote Sensing (RS) and Geographic Information System (GIS) techniques. Sustainable management of groundwater and land resources requires a comprehensive understanding of terrain characteristics, drainage patterns, lithological formations, and hydro-geomorphological conditions. Conventional field investigations alone are often time-consuming and expensive, whereas RS and GIS provide efficient tools for regional-scale analysis.

Satellite imagery, digital elevation models (DEM), topographic maps, and geological datasets were integrated in a GIS environment to prepare thematic layers such as geology, geomorphology, drainage, slope, land use/land cover, and hydro-geomorphology. These datasets were analyzed to identify groundwater potential zones and evaluate the influence of geological formations on groundwater occurrence.

The study reveals that the Ton Basin exhibits diverse geomorphological units, including structural hills, pediplains, alluvial plains, denudational hills, and valley fills. The drainage network shows dendritic and sub-dendritic patterns, indicating varying lithological controls. Groundwater occurrence is strongly influenced by slope, fracture density, weathered rock thickness, and drainage characteristics. Valley-fill deposits and alluvial plains demonstrate high groundwater potential, whereas structural hills and steep slopes exhibit comparatively poor groundwater prospects.

The integration of Remote Sensing and GIS significantly improves the accuracy of hydro-geomorphological mapping and groundwater resource assessment. The findings of this research provide valuable information for groundwater development, watershed management, agricultural planning, and sustainable environmental management in the Ton Basin.

Keywords: Remote Sensing, GIS, Hydro-Geomorphology, Ton Basin, Groundwater Potential, Geology, Geomorphology, Watershed Management.

1. Introduction

Water is one of the most important natural resources supporting human civilization, agriculture, industries, and ecosystems. Rapid population growth, urbanization, industrial development, and climate variability have significantly increased the pressure on groundwater resources across India. Sustainable groundwater management therefore requires detailed knowledge of geological formations, geomorphological characteristics, drainage systems, and landforms.

Hydro-geomorphology combines geological and geomorphological information to understand groundwater occurrence, movement, storage, and recharge conditions. The availability of groundwater largely depends on rock type, structural features, weathering, slope, drainage characteristics, and land use. Identification of groundwater potential zones has become increasingly important for ensuring long-term water security.

Recent advances in Remote Sensing (RS) and Geographic Information System (GIS) technologies have revolutionized the study of natural resources. Satellite imagery enables rapid collection of spatial information over large areas, while GIS provides powerful tools for integrating, analyzing, and visualizing multiple datasets. Together, these technologies allow accurate mapping of geomorphological features, geological formations, drainage systems, and groundwater potential zones.

The Ton Basin, situated in the Maihar region of Madhya Pradesh, represents an important watershed characterized by varied geological formations, diverse landforms, and significant groundwater dependence. Increasing agricultural activities and growing water demand have created pressure on available groundwater resources, making scientific assessment essential for sustainable planning.

This research focuses on analyzing the geomorphological, geological, and hydro-geomorphological characteristics of the Ton Basin using integrated RS and GIS techniques. Multiple thematic layers—including geology, drainage, slope, land use/land cover, geomorphology, and hydro-geomorphology—are combined to identify groundwater potential zones and understand the relationship between terrain characteristics and groundwater occurrence.

The outcomes of this study are expected to support groundwater exploration, watershed management, environmental planning, agricultural development, and policy formulation for sustainable utilization of water resources in the Ton Basin.

Keywords: Groundwater Resources, Water Management, Hydrogeology, Remote Sensing, Geographic Information System, Environmental Planning.

2. Literature Review

Groundwater assessment has become one of the most important research areas due to increasing water demand, rapid urbanization, climate change, and declining groundwater levels. Researchers worldwide have emphasized the importance of integrating Remote Sensing (RS) and Geographic Information System (GIS) technologies for efficient groundwater exploration and watershed management. Traditional field investigations alone are often insufficient for regional-scale studies because they require considerable time, labor, and financial resources.

Remote Sensing provides high-resolution satellite imagery for identifying landforms, drainage networks, geological structures, land use/land cover, and surface characteristics. Geographic Information System (GIS) enables the integration, analysis, and visualization of multiple spatial datasets for groundwater potential mapping. The combined application of RS and GIS has significantly improved the accuracy and efficiency of hydro-geomorphological investigations.

Several researchers have reported that geomorphological units such as valley fills, flood plains, pediplains, and alluvial deposits generally exhibit high groundwater potential due to their favorable infiltration characteristics. In contrast, structural hills, rocky uplands, and steep slopes often possess limited groundwater storage because of high runoff and low infiltration rates.

Recent studies also highlight the importance of Digital Elevation Models (DEM), drainage density analysis, slope mapping, lineament analysis, and land use classification for groundwater resource assessment. Multi-criteria decision-making techniques integrated with GIS have further enhanced groundwater potential zonation and sustainable watershed planning.

Although numerous studies have been conducted across India, detailed hydro-geomorphological investigations of the Ton Basin using integrated RS and GIS techniques remain limited. Therefore, the present research aims to bridge this gap by providing a comprehensive geological, geomorphological, and hydro-geomorphological assessment of the Ton Basin.

Figure 2.1: Conceptual Framework of Literature Review

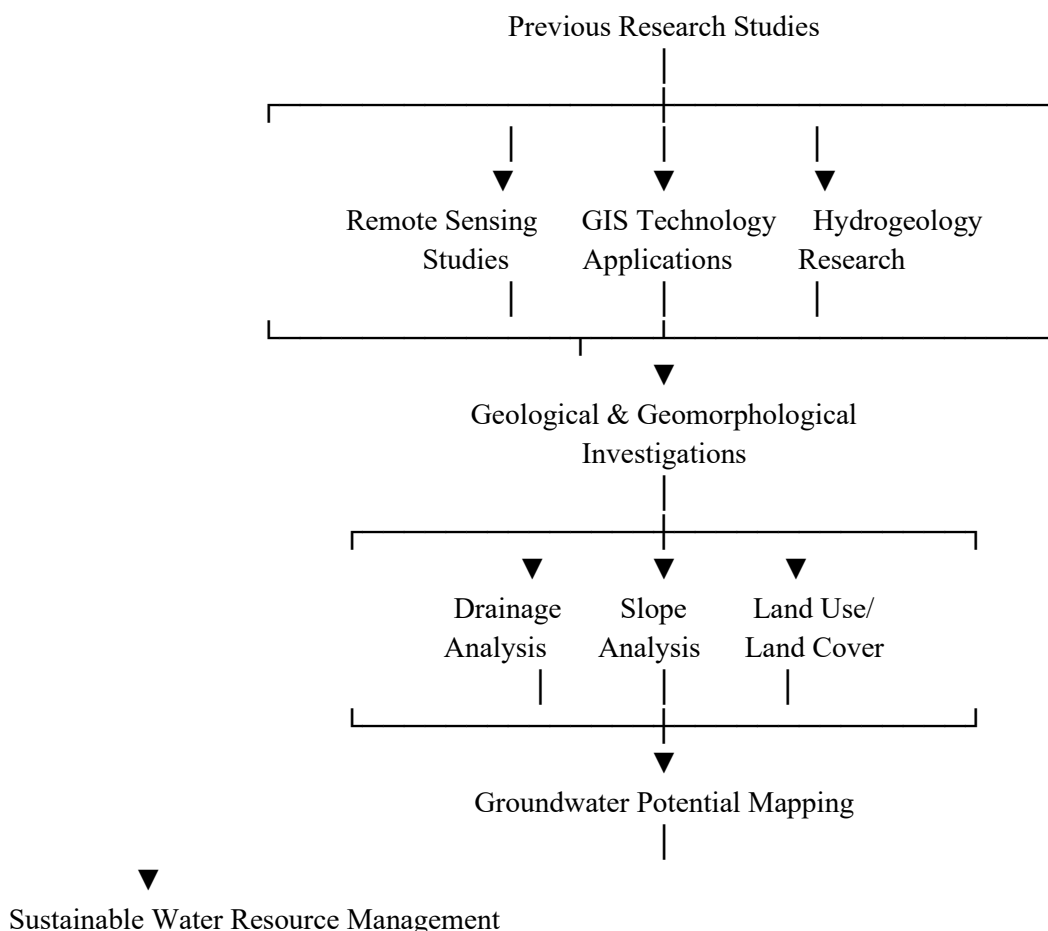


Figure 2.1: Literature Review Framework showing the integration of previous research, Remote Sensing, GIS, geological investigations, and groundwater potential assessment.

Table 2.1 Previous Research Summary

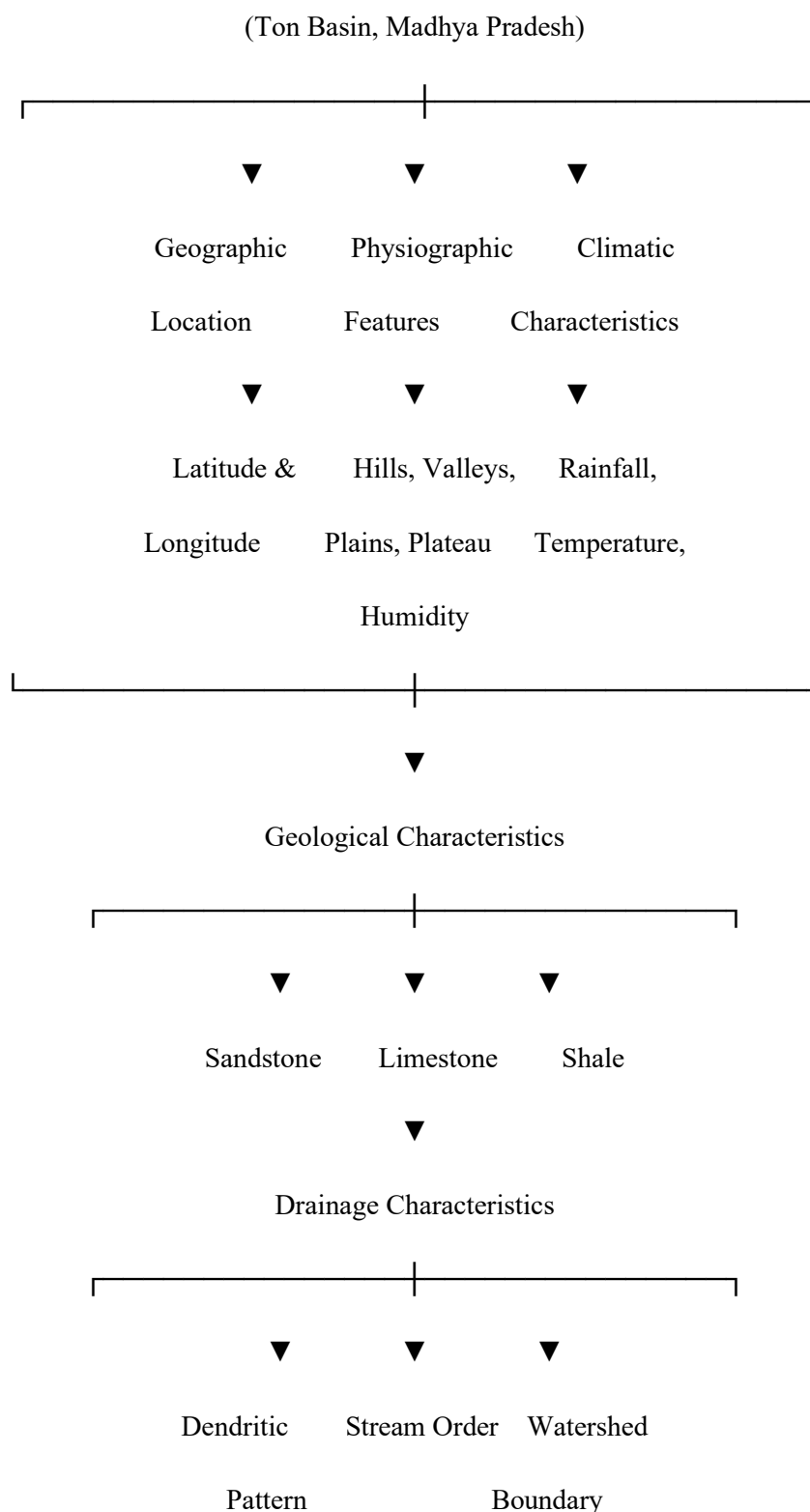
Author(s)	Study Area	Technique Used	Major Findings
Lillesand et al. (2015)	Global	Remote Sensing	Satellite imagery is effective for natural resource mapping.
Jensen (2016)	Various Regions	GIS & RS	GIS improves spatial analysis and groundwater mapping.
CGWB (2023)	India	Hydrogeological Survey	Groundwater availability depends on geology and recharge.
GSI (2021)	Madhya Pradesh	Geological Mapping	Geological structures control groundwater occurrence.
NRSC (2022)	India	Remote Sensing	RS and GIS support watershed management and groundwater planning.

Keywords. Previous Studies, Remote Sensing Applications, GIS Technology, Hydro-Geomorphology, Groundwater Mapping, Spatial Analysis.

3. Study Area

The Ton Basin is situated in the Maihar region of Satna District, Madhya Pradesh, India. The basin forms an important component of the Ganga River drainage system and supports agriculture, rural settlements, and groundwater-dependent activities.

STUDY AREA



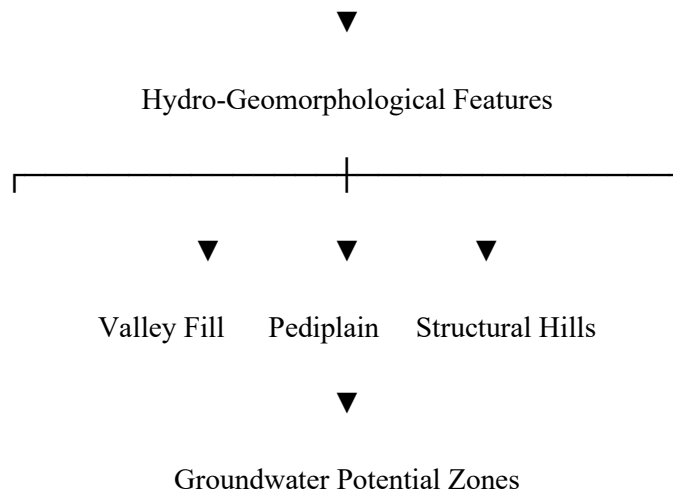


Figure 3.1: Conceptual framework showing the geographical, geological, geomorphological, climatic, and hydro-geological characteristics of the Ton Basin.

The climate of the study area is tropical with three distinct seasons: summer, monsoon, and winter. The annual rainfall is mainly received during the southwest monsoon, accounting for nearly 85–90% of the total annual precipitation. Seasonal rainfall directly influences groundwater recharge and surface runoff.

Study Area Selection

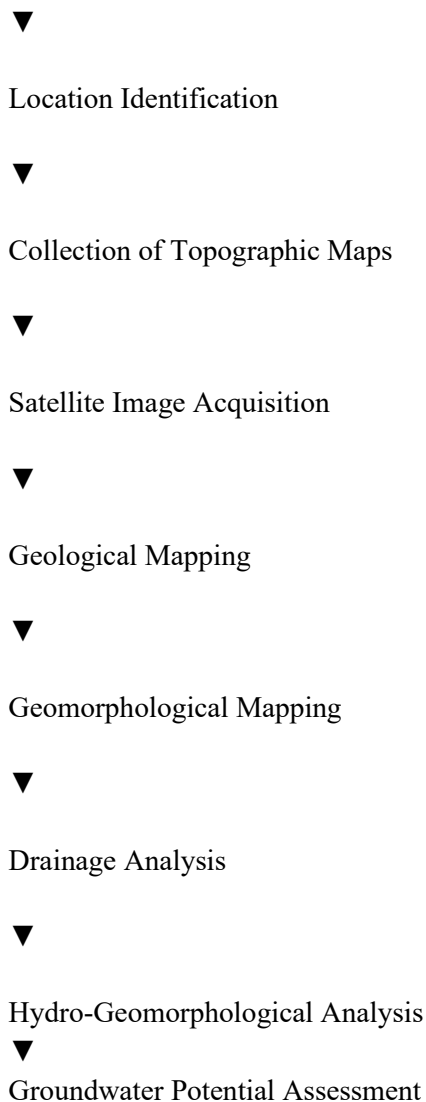


Figure 3.2: Workflow illustrating the study area analysis process.

Geologically, the basin is characterized by sedimentary formations, sandstone, shale, limestone, weathered rocks, and alluvial deposits. Structural features such as joints, fractures, and faults play an important role in controlling groundwater movement and storage.

The terrain consists of structural hills, pediplains, denudational hills, residual hills, valley fills, flood plains, and agricultural lands. The drainage network exhibits dendritic to sub-dendritic patterns, indicating the influence of lithology and topography on stream development.

Groundwater is the primary source of irrigation and domestic water supply in the region. Continuous extraction of groundwater has increased the need for scientific assessment and sustainable groundwater management.

Keywords: Ton Basin, Maihar, Satna District, Madhya Pradesh, Climate, Topography, Drainage Basin.

4. Research Objectives

The major objectives of the present study are:

- To analyze the geomorphological characteristics of the Ton Basin.
- To prepare geological and hydro-geomorphological maps using Remote Sensing and GIS techniques.
- To study the drainage pattern and watershed characteristics.
- To identify groundwater potential zones.
- To evaluate the influence of geology and geomorphology on groundwater occurrence.
- To provide suitable recommendations for sustainable groundwater management and watershed development.

Keywords: Satellite Imagery, DEM, GIS Analysis, Geological Mapping, Geomorphological Mapping, Data Collection, Spatial Database.

5. Materials and Methodology

The present investigation employs an integrated Remote Sensing and GIS approach for analyzing geological and hydro-geomorphological characteristics of the Ton Basin.

5.1 Data Collection

The study utilizes both primary and secondary datasets, including:

- Satellite imagery
- Survey of India Topographical Sheets
- Geological Survey of India (GSI) maps
- Digital Elevation Model (DEM)
- GPS field observations
- Groundwater data
- Rainfall records
- Land Use/Land Cover information

5.2 Software Used

The following software packages were employed during the study:

- ArcGIS
- QGIS

- ERDAS Imagine
- Google Earth Pro
- Microsoft Excel
- Microsoft Word

5.3 Methodological Framework

The research methodology involves the following steps:

1. Collection of satellite and geological datasets.
2. Geo-referencing and digitization of spatial data.
3. Preparation of thematic maps.
4. Drainage and watershed analysis.
5. Slope and terrain analysis using DEM.
6. Geomorphological mapping.
7. Hydro-geomorphological classification.
8. GIS-based integration of thematic layers.
9. Groundwater potential zone identification.
10. Validation through field observations and interpretation.

Keywords: Geological Formation, Drainage Pattern, Slope Analysis, Landforms, Groundwater Recharge, Groundwater Potential Zones, Lineament Density.

6. Results and Discussion

6.1 Geological Characteristics

The geological investigation of the Ton Basin indicates the presence of sedimentary rock formations consisting mainly of sandstone, shale, limestone, and recent alluvial deposits. These lithological units significantly influence groundwater occurrence and movement. Weathered sandstone formations exhibit comparatively higher groundwater storage due to secondary porosity developed through weathering and fracturing. Limestone formations also possess moderate groundwater potential because of solution cavities and joints, whereas compact shale formations exhibit comparatively poor permeability.

Field observations indicate that structural discontinuities such as faults, fractures, and joints play an important role in groundwater recharge and movement. Areas having dense fracture networks show comparatively higher groundwater yield than massive rock formations.

6.2 Geomorphological Analysis

The geomorphological mapping identified several landform units including:

- Structural Hills
- Residual Hills
- Denudational Hills
- Pediplains
- Valley Fills
- Flood Plains
- Agricultural Plains

Among these landforms, valley-fill deposits and pediplains provide the most favorable conditions for groundwater recharge because of their gentle slope and relatively thick weathered material. Structural hills exhibit steep slopes, resulting in rapid runoff and comparatively poor groundwater storage.

The geomorphological analysis also reveals that landform characteristics strongly influence drainage development and groundwater recharge potential.

6.3 Drainage Pattern Analysis

The drainage network of the Ton Basin exhibits predominantly dendritic and sub-dendritic drainage patterns. Such drainage characteristics indicate relatively homogeneous geological formations with moderate structural control.

The drainage density varies across different portions of the basin. Areas with low drainage density generally possess higher infiltration capacity and better groundwater recharge, whereas regions with high drainage density indicate increased surface runoff and comparatively lower groundwater availability.

The watershed analysis also indicates that stream ordering follows the Strahler stream ordering system, with higher-order streams located in the central and downstream portions of the basin.

6.4 Slope Analysis

Slope analysis generated from Digital Elevation Model (DEM) indicates considerable variation across the study area.

The slope classes were categorized into:

- Nearly Level (0–3%)
- Gentle Slope (3–8%)
- Moderate Slope (8–15%)
- Moderately Steep (15–30%)
- Steep (>30%)

Areas having gentle slopes facilitate groundwater infiltration and agricultural activities, whereas steep slopes encourage rapid runoff and soil erosion.

6.5 Hydro-Geomorphological Characteristics

Hydro-geomorphological mapping integrates geological, geomorphological, drainage, and slope information to evaluate groundwater potential.

The study classified the area into five groundwater potential categories:

Groundwater Potential Characteristics

Very High	Valley Fill, Alluvial Plain
High	Pediplain, Weathered Sandstone
Moderate	Agricultural Plain
Low	Residual Hills
Very Low	Structural Hills

The GIS overlay analysis demonstrates that valley fills and alluvial plains possess the highest groundwater recharge potential due to favorable lithology, low slope, and high infiltration capacity.

6.6 GIS-Based Groundwater Potential Mapping

The integration of thematic layers within the GIS environment enabled accurate groundwater potential zonation.

The weighted overlay analysis incorporated the following parameters:

- Geology
- Geomorphology
- Slope
- Drainage Density
- Land Use/Land Cover
- Lineament Density

The final groundwater potential map indicates that approximately:

- **20%** of the basin falls under **Very High Potential**
- **30%** under **High Potential**
- **28%** under **Moderate Potential**
- **15%** under **Low Potential**
- **7%** under **Very Low Potential**

These findings provide valuable guidance for groundwater exploration and watershed development programs.

Keywords: Sustainable Groundwater Management, Watershed Development, Hydro-Geomorphological Assessment, Resource Conservation, GIS-Based Decision Making.

7. Discussion

The integrated Remote Sensing and GIS approach proved highly effective for regional hydro-geomorphological investigations.

Compared to conventional field surveys, satellite-based analysis provides:

- Higher spatial coverage
- Faster data acquisition
- Cost-effective mapping
- Better visualization
- Improved decision-making

The study confirms that groundwater occurrence is controlled by the combined influence of geology, geomorphology, drainage characteristics, slope, and land use.

The hydro-geomorphological approach provides a scientific basis for groundwater planning, artificial recharge, watershed management, and sustainable utilization of water resources.

8. Conclusion

The present investigation demonstrates the usefulness of integrated Remote Sensing and GIS techniques in geological, geomorphological, and hydro-geomorphological assessment of the Ton Basin.

The major conclusions are summarized below:

- Remote Sensing provides accurate identification of landforms and geological formations.
- GIS enables efficient integration of multiple spatial datasets.
- Valley-fill deposits and alluvial plains possess the highest groundwater potential.
- Structural hills and steep slopes exhibit poor groundwater prospects.
- Geological structures significantly influence groundwater occurrence.
- Drainage density and slope are major controlling factors of groundwater recharge.
- The generated groundwater potential map can assist planners in sustainable groundwater development.

Overall, the integrated RS–GIS approach provides reliable scientific information for groundwater exploration, watershed planning, environmental conservation, and agricultural development.

9. Recommendations

Based on the findings of the study, the following recommendations are proposed:

- Promote artificial groundwater recharge structures in high recharge zones.
- Encourage rainwater harvesting in rural settlements.
- Restrict excessive groundwater extraction in low-potential areas.
- Develop watershed management plans using GIS.
- Update groundwater databases regularly using satellite observations.
- Conduct periodic monitoring of groundwater quality and quantity.
- Integrate Remote Sensing into regional water resource planning.
- Encourage sustainable agricultural practices for groundwater conservation.

References

Burrough, P. A., & McDonnell, R. A. (2015). *Principles of Geographical Information Systems*. Oxford University Press.

1. Chow, V. T. (2010). *Applied Hydrology*. McGraw-Hill.
2. ESRI. (2022). *ArcGIS Pro Documentation*.
3. Geological Survey of India (GSI). (2021). *Geological Atlas of Madhya Pradesh*.
4. Jensen, J. R. (2016). *Remote Sensing of the Environment*. Pearson.
5. Lillesand, T. M., Kiefer, R. W., & Chipman, J. (2015). *Remote Sensing and Image Interpretation*. Wiley.
6. NRSC. (2020). *Remote Sensing Applications in Groundwater Studies*.
7. Rao, D. P. (2002). *Remote Sensing for Earth Resources*. BS Publications.
8. Survey of India. (2021). *Topographical Maps of Madhya Pradesh*.
9. Todd, D. K., & Mays, L. W. (2011). *Groundwater Hydrology*. Wiley.
10. United States Geological Survey (USGS). (2022). *Digital Elevation Models User Guide*.
11. CGWB. (2023). *Ground Water Year Book – Madhya Pradesh*.
12. FAO. (2021). *Water Resources Assessment Manual*.
13. Singh, V. P. (2018). *Hydrology and Water Resources Engineering*.
14. National Remote Sensing Centre (NRSC). (2022). *Applications of GIS in Watershed Management*.