



# Watershed Delineation of Tapi River Basin Using QGIS

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**Abstract:** Geographic Information Systems (GIS) have emerged as indispensable tools in the field of natural resource management, particularly in hydrological studies involving water harvesting and watershed analysis. This study focuses on delineating the watershed of the Tapi River basin using Digital Elevation Model (DEM) data processed through QGIS software. Algorithms and spatial plugins within QGIS were applied to extract and analyses the drainage network across three sub-catchments of the basin. The analysis produced accumulation maps, cut-and-fill maps, and thematic outputs that can inform decision-making related to ground and surface water resource distribution and management. The derived watershed data also facilitates computation of key hydrological and topographic parameters.

**Keywords:** Digital Elevation Model (DEM), Toposheets, QGIS, Watershed Management, Remote Sensing

## I. INTRODUCTION

Watershed modeling has long been recognized as one of the most practical applications of GIS technology, largely because it enables a comprehensive, systems-level simulation of hydrological processes — something that traditional models often fall short on. At the heart of any watershed model is the catchment area, which is the extent of land that contributes runoff to a specific outlet point. Broadly speaking, the terms watershed, catchment, and drainage basin are used interchangeably; all refer to a topographically defined area that gathers rainfall and channels it into a single outlet through the stream network [1,2].

Watershed delineation — the task of mapping the exact boundaries of a drainage area — relies heavily on

topographic data. In an ideal scenario, high-resolution topographic maps are available and current. However, in many parts of the world, including large sections of India, such maps are either difficult to obtain or outdated. Furthermore, when a study area spans multiple map sheets at varying scales, manual delineation becomes error-prone and laborious, especially in low-relief terrain where boundaries are not visually obvious [3,4].

This is where Digital Elevation Models (DEMs) combined with GIS tools offer a significant advantage. DEMs allow automated extraction of drainage networks, flow directions, and watershed boundaries with reasonable accuracy, depending on the resolution and quality of the elevation data. For this study, the open-source platform QGIS was chosen as the primary analysis environment, and a 90-metre resolution Cartosat-derived DEM was used to delineate the watershed of the Tapi River and map its stream network [5,6].

The reliability of any DEM-based analysis is directly tied to the quality of the elevation data and the algorithms applied. With this in mind, the study also aimed to evaluate how well a 90m DEM performs for watershed and stream network delineation when processed through QGIS. A

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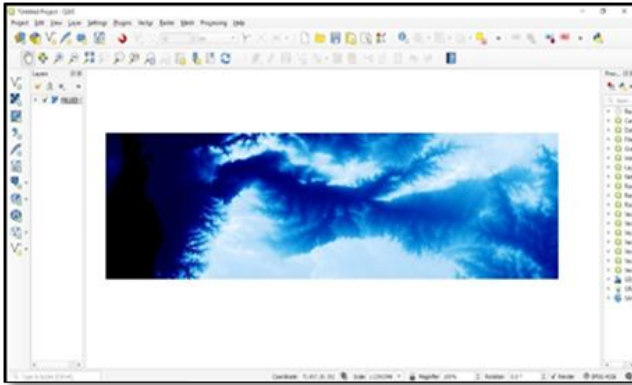
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consistent coordinate reference system — WGS 1984 UTM Zone 43N — was assigned to all datasets to ensure spatial accuracy throughout the workflow [7-9].



**Fig 1:** Digital Elevation Model (Tapi River)

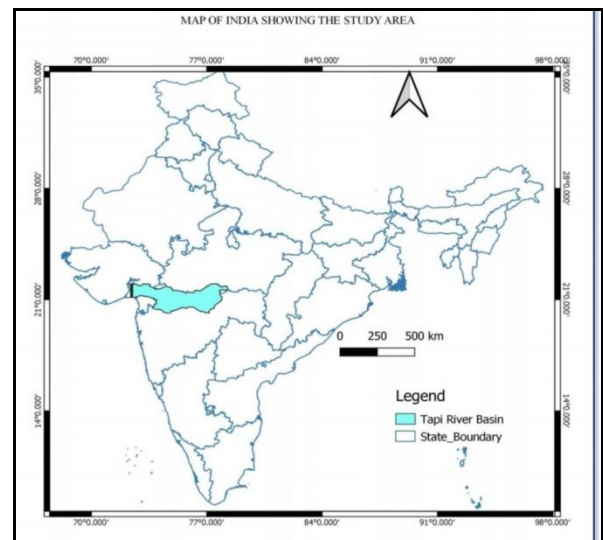
Earlier studies have contributed valuable insights in this area. Ingavale et al. [2] highlighted how DEMs serve as a foundational tool for extracting topographic information and enabling flow modelling across terrain. Rudra et al. [3] drew attention to the importance of global elevation datasets, noting that while they are essential for studying large-scale environmental processes, they inevitably carry errors stemming from the data acquisition methodology and subsequent processing steps. Umang et al. [5] reinforced the practical value of DEMs in hydrology, noting that their raster structure makes them particularly well-suited for automated delineation — more so than triangulated irregular networks (TINs), which are comparatively harder to process computationally.

Building on this body of work, the current study set out to achieve the following specific objectives:

- To compile and prepare GIS data layers for the study area, including Digital Elevation Models (DEMs), Digital Raster Graphic maps (DRGs), and administrative boundary datasets at the national, provincial, and district levels.
- To use the DEM to delineate watershed and sub-basin boundaries, and to derive morphometric parameters such as drainage area, watershed length, watershed slope, and flow length.

## II. CASE STUDY

The Tapi River holds the distinction of being the second-largest westward-draining interstate river on the Indian Peninsula. It originates at an elevation of 752 metres near the Multai Reserve Forest in the Betul district of Madhya Pradesh. Over its total course of 778 km, the river passes through three states before emptying into the Arabian Sea at the Gulf of Cambay. The first 282 km of its journey lie within Madhya Pradesh, of which approximately 54 km forms a shared boundary with Maharashtra. The river then travels 228 km through Maharashtra before crossing into Gujarat, where it covers a further 214 km and eventually flows past Surat city. Tidal influence is felt up to about 25 km upstream from the river mouth.



**Fig 2:** Index Map of the Study Area

The Tapi's major right-bank tributaries include the Suki, Gomai, Arunavati, and Aner rivers, while its left bank receives contributions from the Vaghur, Amravati, Buray, Panjhra, Bori, Girna, Purna, Mona, and Sipna. Collectively, the Purna and Girna account for close to 45 percent of the total catchment area of the Tapi basin.

Geographically, the basin spans longitudes 72°33' to 78°17' E and latitudes 20°N to 22°N. The total drainage area of the Tapi basin is 65,145 km<sup>2</sup>. Of this, 66.1 percent is agricultural or open land, and around 25 percent is under forest cover. Water bodies account for approximately 2.99

percent of the total area. Rainfall is heavily seasonal: around 90 percent of annual precipitation is received during the monsoon months, primarily in July and August.

### III. DATA ACQUISITION AND PROGRAM SETUP

Spatial datasets for this study were sourced from several open-access platforms. The primary sources included the BHUVAN portal (managed by ISRO), Diva-GIS, OpenDEM, and Google Earth. The specific datasets used were:

- Digital Elevation Model (DEM) — Sourced from the Cartosat-1 satellite (Cartodem Version 3R1), downloaded from [www.bhuvan.nrsc.gov.in](http://www.bhuvan.nrsc.gov.in)
- Administrative boundaries — Downloaded from <https://www.diva-gis.org>
- Waterway shapefiles (GIS\_OSM\_Water and GIS\_OSM\_Waterways) — Downloaded from <http://download.geofabric.de>, used for reference in understanding the spatial distribution of water features



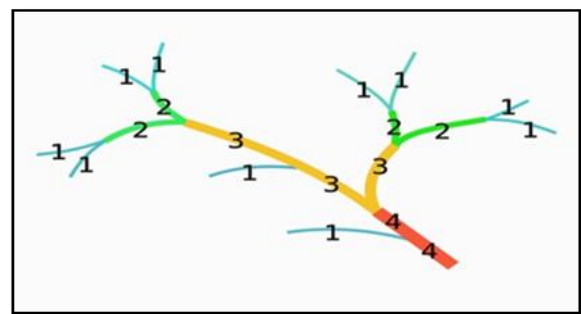
**Fig 3:** Software Used

Once all necessary datasets were gathered, they were loaded into QGIS 3.12.3 with GRASS 7.8.3 for processing. A critical preliminary step was assigning a consistent coordinate reference system to every dataset. The WGS 1984 UTM Zone 43N projection was applied uniformly across all layers to ensure accurate spatial alignment and reliable analysis output.

### IV. METHODOLOGY

The analysis followed a structured, step-by-step workflow to delineate the watershed and extract morphometric parameters for the Tapi River basin.

The process began with toposheets downloaded from the OpenDEM platform. These were processed in QGIS using the TIN (Triangulated Irregular Network) interpolation algorithm to generate a Digital Elevation Model of the study area. Stream ordering was then carried out following Strahler–Horton’s classification scheme: a stream with no tributaries upstream is classified as first order; where two first-order streams converge, the resulting stream becomes second order; two second-order streams meeting produce a third-order stream; and so on. All streams were counted and tabulated by order.



**Fig 4:** Strahler Stream Order

The drainage network and basin boundaries were digitised as line and polygon coverages, with each stream segment assigned a unique identifier corresponding to its order. The DEM from the BHUVAN portal was then brought into the QGIS environment and used to derive three key layers: stream segments, micro-watershed boundaries, and a basin accumulation map. These were all derived from the terrain elevation data. The resulting raster layers were subsequently converted to vector format using the raster-to-vector conversion tools in QGIS, enabling calculation of spatial parameters such as area, length, slope, and drainage direction. All computations were performed within QGIS 3.12.3 with GRASS 7.8.3.

The final outputs included thematic maps showing the delineated watershed, stream ordering, flow direction, and the overall drainage basin configuration.

### V. RESULTS AND DISCUSSION

The watershed of the Tapi River was successfully delineated with a computed area of 65,145 sq. km,

consistent with published data for the basin. Using the DEM as the primary input, the QGIS algorithms produced a comprehensive thematic map that captures the drainage network and stream ordering across the basin.

The morphometric parameters derived from the QGIS analysis are summarised in Table 1 below. These values were extracted based on stream segment lengths and numbers as computed from the DEM.

**Table 1.** Morphometric Parameters Derived from QGIS

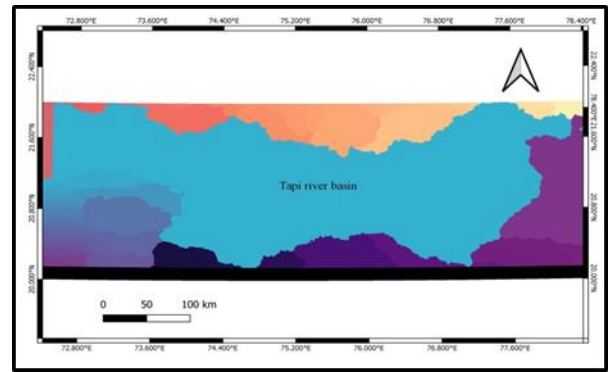
Parameter	Value
Area of Watershed	65,145 sq. km
Basin Extent	72°33' to 78°17' E   20°09' to 21°50' N
Basin Length	778 km
Highest Elevation	1,556 m
Highest Stream Order	7th Order
Water Resource Structures	Dams: 356   Barrages: 8   Lift Schemes: 13   Weirs: 11
Number of Sub-Basins	1. Upper Tapi 2. Middle Tapi 3. Lower Tapi
Length of Major Rivers	Tapi: 778 km   Purna: 379 km   Girna: 346 km   Aner: 74 km

## VI. OUTPUTS

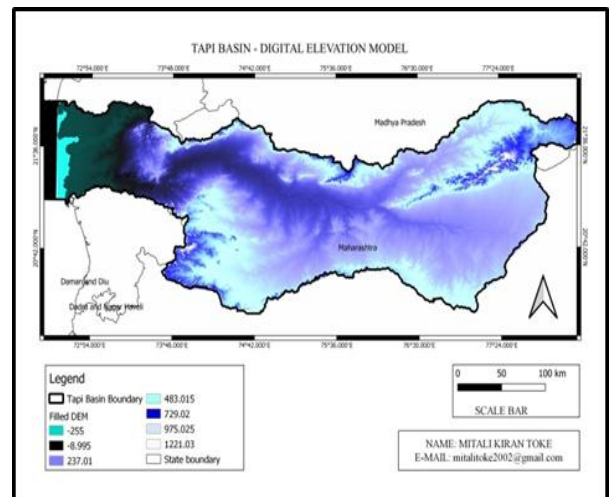
The following thematic maps were generated as outputs of the QGIS-based analysis:



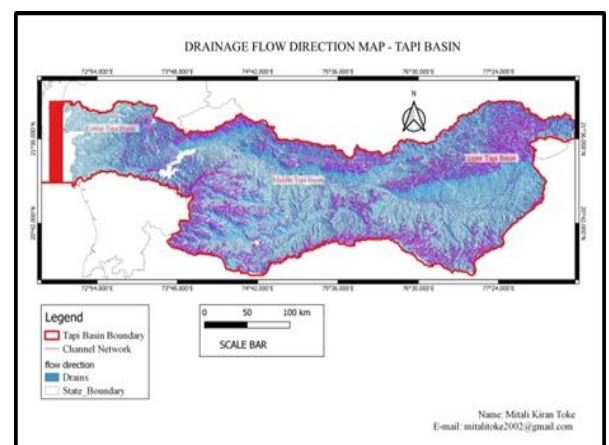
**Fig. 5:** DEMs downloaded from the BHUVAN Portal



**Fig. 6:** Tapi River Watershed (Vector Format)



**Fig. 7:** DEM in Raster Format



**Fig. 8:** Drainage Flow Direction Map

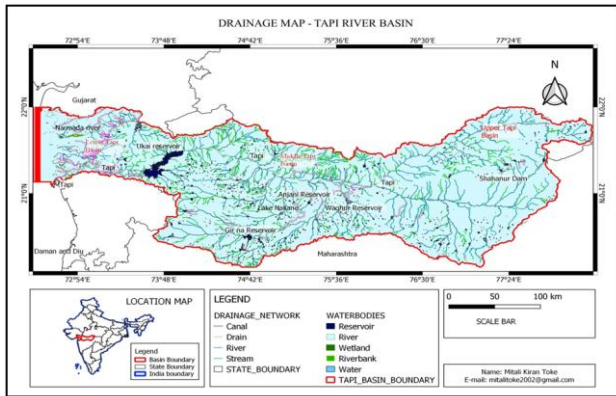


Fig. 9: Delineated Watershed of the Tapi River

## VII. CONCLUSION

This study demonstrated that the watershed of the Tapi River basin can be effectively delineated using QGIS with DEM data sourced from the BHUVAN portal. The analysis successfully extracted key spatial and hydrological attributes including flow direction, highest elevation, river network structure, catchment area, and the overall drainage pattern of the study area.

The DEM data was processed using GRASS 7.8.3 algorithms within QGIS 3.12.3, resulting in a set of thematic maps that clearly depict the watershed boundaries and stream hierarchy. The three sub-basins of the Tapi — Upper, Middle, and Lower — were delineated with morphometric parameters that provide a solid foundation for future hydrological investigations.

Looking ahead, the outcomes of this work can serve as a baseline for more detailed studies aimed at sustainable water resource management of the Tapi basin. Some areas that warrant further investigation include:

- Identifying the causes of discontinuities in the stream network and assessing the current condition of water bodies within the watershed.
- Conducting a detailed water budget analysis that accounts for varying consumption patterns across different sectors, as well as quantifying losses through evaporation, transpiration, infiltration, and depression storage.

- Estimating the costs associated with stream rejuvenation at different ordinal levels.

This work also reflects a broader trend: GIS-based analysis is increasingly finding its way into civil engineering practice, particularly in water resources planning, and is proving to be a valuable tool for achieving sustainable development of the nation's water resources.

## REFERENCES

- [1] P. Singh, A. Gupta, and M. Singh, "Hydrological inferences from watershed analysis for water resource management using remote sensing and GIS techniques," *The Egyptian Journal of Remote Sensing and Space Science*, vol. 17, no. 2, pp. 111–121, 2014, doi: 10.1016/j.ejrs.2014.09.003.
- [2] R. R. Ingavale, V. V. Jadhav, and P. D. Rout, "Studies on Watershed Management in Shivaji University, Kolhapur, India," *International Research Journal of Environmental Science*, vol. 2, no. 7, pp. 35–38, 2013.
- [3] R. Rudra, W. T. Dickinson, and D. N. Sharma, "Application of GIS in Watershed Management," *Journal of Water Management Modelling*, pp. 1–20, 1993, doi: 10.14796/jwmm.r175-21.
- [4] K. E. Viswanathan, M. Manikandan, and S. Bharanitharan, "Watershed Delineation for Varaha Nadi Basin using Open Source Geospatial Technology," *International Journal of Research and Scientific Innovation*, vol. 2, no. 6, 2015.
- [5] U. S. Visharolia, N. J. Shrimali, and I. Prakash, "Watershed Delineation of Purna River using Geographic Information System (GIS)," *International Journal of Advance Engineering and Research Development*, vol. 4, no. 5, pp. 1–20, 2017, doi: 10.21090/ijaerd.28223.
- [6] K. Basnet, R. C. Paudel, and B. Sherchan, "Analysis of Watersheds in Gandaki Province, Nepal Using QGIS," *Technical Journal*, vol. 1, no. 1, pp. 16–28, 2019, doi: 10.3126/tj.v1i1.27583.

- [7] K. V. Pandurang, S. S. Kulkarni, and V. A. Swami, “Watershed Management: Concept, Principles and Challenges to Improving Productivity, Resources and Livelihoods,” *International Manager’s Journal on Civil Engineering*, vol. 2, pp. 1–10, 2012, doi: 10.26634/jce.2.2.1833.
- [8] S. Aryal *et al.*, “Integrated Water Resource Management (IWRM): A Case Study of Durlung Watershed, Bagmati Zone, Nepal,” *Hydro Nepal: Journal of Water, Energy and Environment*, no. 18, pp. 47–54, 2016, doi: 10.3126/hn.v18i0.14645.
- [9] P. R. Reddy and V. Reddy, “Hydrology and Water Resource Engineering,” *International Journal on Earth Science and Engineering*, vol. 7, no. 2, pp. 394–399, 2014.