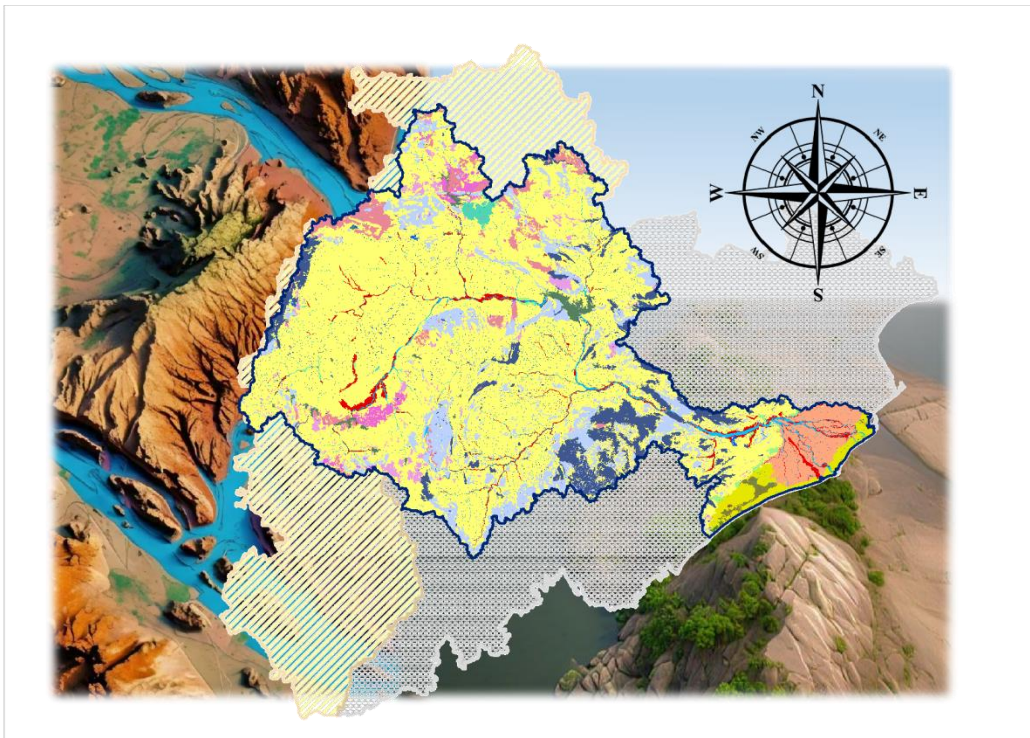
National River Conservation Directorate
Ministry of Jal Shakti,
Department of Water Resources,
River Development & Ganga Rejuvenation
Government of India

Geomorphological Mapping

Mahanadi River Basin



December 2024

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National River Conservation Directorate (NRCD)

The National River Conservation Directorate, functioning under the Department of Water Resources, River Development & Ganga Rejuvenation, and Ministry of Jal Shakti providing financial assistance to the State Government for conservation of rivers under the Centrally Sponsored Schemes of 'National River Conservation Plan (NRCP)'. National River Conservation Plan to the State Governments/ local bodies to set up infrastructure for pollution abatement of rivers in identified polluted river stretches based on proposals received from the State Governments/ local bodies.

www.nrcd.nic.in

Centres for Mahanadi River Basin Management Studies (cMahanadi)

The Centres for Mahanadi River Basin Management Studies (cMahanadi) is a Brain Trust dedicated to River Science and River Basin Management. Established in 2024 by NIT Raipur and NIT Rourkela, under the supervision of cGanga at IIT Kanpur, the centre serves as a knowledge wing of the National River Conservation Directorate (NRCD). cMahanadi is committed to restoring and conserving the Mahanadi River and its resources through the collation of information and knowledge, research and development, planning, monitoring, education, advocacy, and stakeholder engagement.

www.cmahanadi.org

Centre for Ganga River Basin Management and Studies (cGanga)

cGanga is a think tank formed under the aegis of NMCG, and one of its stated objectives is to make India a world leader in river and water science. The Centre is headquartered at IIT Kanpur and has representation from most leading science and technological institutes of the country. cGanga's mandate is to serve as think-tank in implementation and dynamic evolution of Ganga River Basin Management Plan (GRBMP) prepared by the Consortium of 7 IITs. In addition to this, it is also responsible for introducing new technologies, innovations, and solutions into India.

www.cganga.org

Acknowledgment

This report is a comprehensive outcome of the project jointly executed by NIT Raipur (Lead Institute) and NIT Rourkela (Fellow Institute) under the supervision of cGanga at IIT Kanpur. It was submitted to the National River Conservation Directorate (NRCD) in 2024. We gratefully acknowledge the individuals who provided information and photographs for this report.

Disclaimer

This report is a preliminary version prepared as part of the ongoing Condition Assessment and Management Plan (CAMP) project. The analyses, interpretations and data presented in the report are subject to further validation and revision. Certain datasets or assessments may contain provisional or incomplete information, which will be updated and refined in the final version of the report after comprehensive review and verification.

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Preface

In an era of unprecedented environmental change, understanding our rivers and their ecosystems has never been more critical. This report aims to provide a comprehensive overview of our rivers, highlighting their importance, current health, and the challenges they face. As we explore the various facets of river systems, we aim to equip readers with the knowledge necessary to appreciate and protect these vital waterways.

Throughout the following pages, you will find an in-depth analysis of the principles and practices that support healthy river ecosystems. Our team of experts has meticulously compiled data, case studies, and testimonials to illustrate the significant impact of rivers on both natural environments and human communities. By sharing these insights, we hope to inspire and empower our readers to engage in river conservation efforts.

This report is not merely a collection of statistics and theories; it is a call to action. We urge all stakeholders to recognize the value of our rivers and to take proactive steps to ensure their preservation. Whether you are an environmental professional, a policy maker, or simply someone who cares about our planet, this guide is designed to support you in your efforts to protect our rivers.

We extend our heartfelt gratitude to the numerous contributors who have generously shared their stories and expertise. Their invaluable input has enriched this report, making it a beacon of knowledge and a practical resource for all who read it. It is our hope that this report will serve as a catalyst for positive environmental action, fostering a culture of stewardship that benefits both current and future generations.

As you delve into this overview of our rivers, we invite you to embrace the opportunities and challenges that lie ahead. Together, we can ensure that our rivers continue to thrive and sustain life for generations to come.

Centre for Mahanadi River Basin
Management Studies (cMahanadi)
NIT Raipur & NIT Rourkela

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Abbreviations and Acronyms

cMahanadi	Centre for Mahanadi River Basin Management and Studies
CWC	Central Water Commission
DEM	Digital Elevation Model
GEE	Google Earth Engine
GIS	Geographic Information System
GRBMP	Ganga River Basin Management Plan
GSI	Geological Survey of India
IB	Ib River
IIT	Indian Institute of Technology
MRB	Mahanadi River Basin
NIT	National Institute of Technology
NRCD	National River Conservation Directorate
NRCP	National River Conservation Plan
RS	Remote Sensing
SAR	Synthetic Aperture Radar
SRTM	Shuttle Radar Topography Mission

1. Preamble

The Mahanadi River, one of the major river systems of peninsular India, originates from the Sihawa Hills in the Dhamtari district of Chhattisgarh at approximately 442 meters above sea level. It traverses a significant portion of central and eastern India before emptying into the Bay of Bengal. The river has a total length of about 851 kilometers and drains an expansive basin of over 141,600 square kilometers, encompassing parts of Chhattisgarh, Odisha, Jharkhand, and Maharashtra. The Mahanadi River Basin is known for its rich biodiversity, fertile alluvial plains, and intricate network of tributaries, making it an essential lifeline for the millions of people residing within its boundaries.

Geomorphological mapping is a critical scientific approach for understanding landforms, surface processes, and the geological features that shape the Earth's terrain. By systematically categorizing and analyzing landscape elements, this method provides valuable insights into the dynamic interactions between climate, hydrology, tectonic activity, and anthropogenic influences (Bishop, 2007). Such mapping not only reflects the present-day topographic configuration but also sheds light on the historical evolution of landscapes, making it an indispensable tool for both academic research and practical applications (Summerfield, 1991).

The Mahanadi River Basin, extending across eastern and central India, presents a diverse geomorphic setting characterized by floodplains, deltas, river terraces, and dissected plateaus. The basin supports a vast population through agriculture, biodiversity, and water resources, and its geomorphology is shaped by a combination of natural processes—including fluvial erosion, sediment transport, and tectonics—as well as human interventions like dam construction (Sharma & Ghosh, 2004). These factors contribute to the basin's complex and evolving geomorphic identity.

Recent advances in geospatial technologies have significantly enhanced the precision and scope of geomorphological investigations. Tools such as high-resolution digital elevation models (DEMs), remote sensing, and GIS-based analyses enable detailed terrain characterization and spatial pattern recognition (Drusch et al., 2012). In particular, data from Sentinel-1 and Sentinel-2 satellites have become instrumental in flood mapping and hydrological assessments within the basin. These datasets allow for the identification of flood-prone areas, monitoring of water extent during flood events, and post-flood evaluations, thereby facilitating a comprehensive understanding of the relationship between geomorphic features and hydrological dynamics (Bary & O'Conner, 2021).

Table 1. Geomorphological Characteristics and Features

S. No.	Aspect	Descriptions
1.	Lithology	In Chhattisgarh, the upper basin is dominated by the hard rocks of Vindhyan and Satpura ranges (e.g., sandstone, shale), which shape steep channels and constrain erosion (Directorate General of Hydrocarbons, 2015; cMahanadi, 2025). As the river enters Odisha, lithology shifts to Deccan Traps and widespread alluvium, resulting in broader floodplains and amplified sediment transport (India-WRIS, 2018; cMahanadi, 2025).
2.	Fluvial Processes	Active channel erosion in the upper reaches of Chhattisgarh is driven by rugged terrain and resistant rocks (PMF IAS, 2018; cMahanadi, 2025). In Odisha's central and lower basin, sediment transport and deposition intensify across the alluvial plains and delta regions, chiefly near Cuttack and Paradeep (CORE, 2020; IGNOU, 2020).
3.	Erosional Landforms	Major erosional landforms such as gorges and waterfalls occur in hard rock terrains in Chhattisgarh (Directorate General of Hydrocarbons, 2015; Chakrapani et al., 1993). Structural river terraces are observed in both Chhattisgarh and western Odisha, reflecting tectonic uplift and river incision (Subrahmanyam & Rao, 2008; Chakrapani et al., 1993).
4.	Depositional Landforms	Floodplains, natural levees, and river islands are especially extensive in the Odisha plains, with the delta continuing to the coast at Paradeep (CORE, 2020; Panda, 2016; IGNOU, 2020). The region is marked by active and abandoned distributaries and sediment-rich bars (Panda, 2016; IGNOU, 2020).
5.	Floodplain Dynamics	Annual monsoon flooding in Chhattisgarh and Odisha enables regular sediment deposition, nutrient renewal, and habitat development along the floodplains (CORE, 2020; Department of Water Resources, Odisha, 2018). Odisha's deltaic floodplains are especially rich and support intensive agriculture (cMahanadi, 2025; Department of Water Resources, Odisha, 2018).
6.	River Terraces	River terraces, shaped by tectonic activity and episodic incision, are present in the upland regions of Chhattisgarh and some parts of Odisha, indicating past shifts in base level (Subrahmanyam & Rao, 2008; INPE, 2009; Chakrapani et al., 1993).
7.	Channel Patterns	Low-energy depositional environments, most prominent in coastal Odisha, show meandering and braided channel patterns that reflect active sedimentation and shifting flow paths (Panda, 2016; Naik, 2022; Gyanganga, 2022).

Furthermore, the Mahanadi River Basin holds strategic importance in the context of climate variability, hydrological change, and increasing anthropogenic pressures. Integrating geomorphological mapping with satellite-based flood analysis provides a powerful framework for assessing erosion zones, sedimentation patterns, and land degradation risks (Sahoo & Patra, 2018; Naylor & Groves, 2013). These insights are vital for developing informed strategies for disaster risk reduction, landscape conservation, and sustainable resource management.

2. Study Area

The Mahanadi River, one of the major river systems of peninsular India, originates from the Sihawa Hills in the Dhamtari district of Chhattisgarh at approximately 442 meters above sea level. It traverses a significant portion of central and eastern India before emptying into the Bay of Bengal. The river has a total length of about 851 kilometers and drains an expansive basin of over 141,600 square kilometers, encompassing parts of Chhattisgarh, Odisha, Jharkhand, and Maharashtra. The Mahanadi River Basin is known for its rich biodiversity, fertile alluvial plains, and intricate network of tributaries, making it an essential lifeline for the millions of people residing within its boundaries.

In its initial course, the river flows through Chhattisgarh, where it is joined by prominent tributaries such as the Seonath, Hasdeo, Mand, and Jonk. The Seonath River, the longest tributary, originates from the Maikal Hills and significantly contributes to the flow of the Mahanadi. The Hasdeo River, originating from the dense forests of the Chhattisgarh hills, also plays a crucial role in the hydrological dynamics of the basin. As the river progresses into Odisha, it receives additional tributaries, such as the IB, Ong, and Tel, further augmenting its volume. These tributaries, arising from the Eastern Ghats and surrounding highlands, contribute to the basin's geomorphic diversity and hydrological complexity.

The basin encompasses various landscapes, ranging from rugged plateaus and forested regions in its upper reaches to expansive floodplains and deltas in its lower course. As the Mahanadi approaches the coastal plains of Odisha, it forms a sprawling delta before merging with the Bay of Bengal near Paradip. Fertile soils, intricate distributary networks, and significant socio-economic activities, including agriculture and aquaculture characterize this deltaic region. The basin's rich geomorphology, influenced by tectonic activity, fluvial processes, and human interventions, makes it a prime area for detailed geomorphological mapping and hydrological studies. Understanding this dynamic river system is crucial for water resource management, disaster mitigation, and sustainable development in the region.

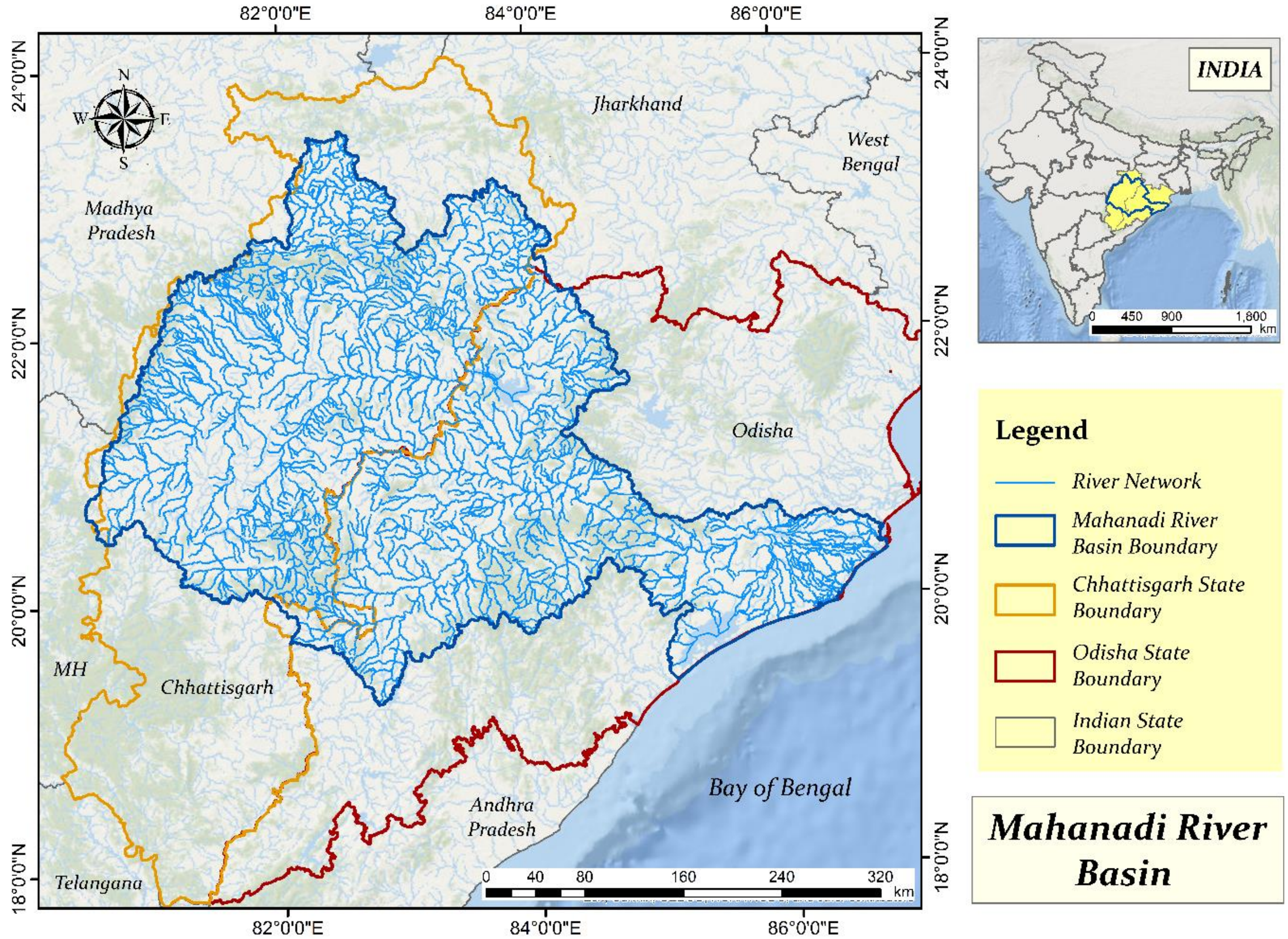


Figure 1. Location Map of Mahanadi River Basin

3. Data Used and its Sources

The data for geomorphological mapping combines field data and Remote Sensing (RS) data from Sentinel satellites. The field investigation was made to identify the grain size distribution of river bed material in the entire stretch of Mahanadi river including its tributaries.

In addition, Sentinel satellite data, particularly from Sentinel-1, is utilized for flood mapping. This data helps identify flood-prone areas, monitor water extent during flood events, and assess post-flood impacts. By integrating these datasets, a comprehensive understanding of the river's geomorphological features and flood behaviour is achieved, supporting effective resource management and disaster planning.

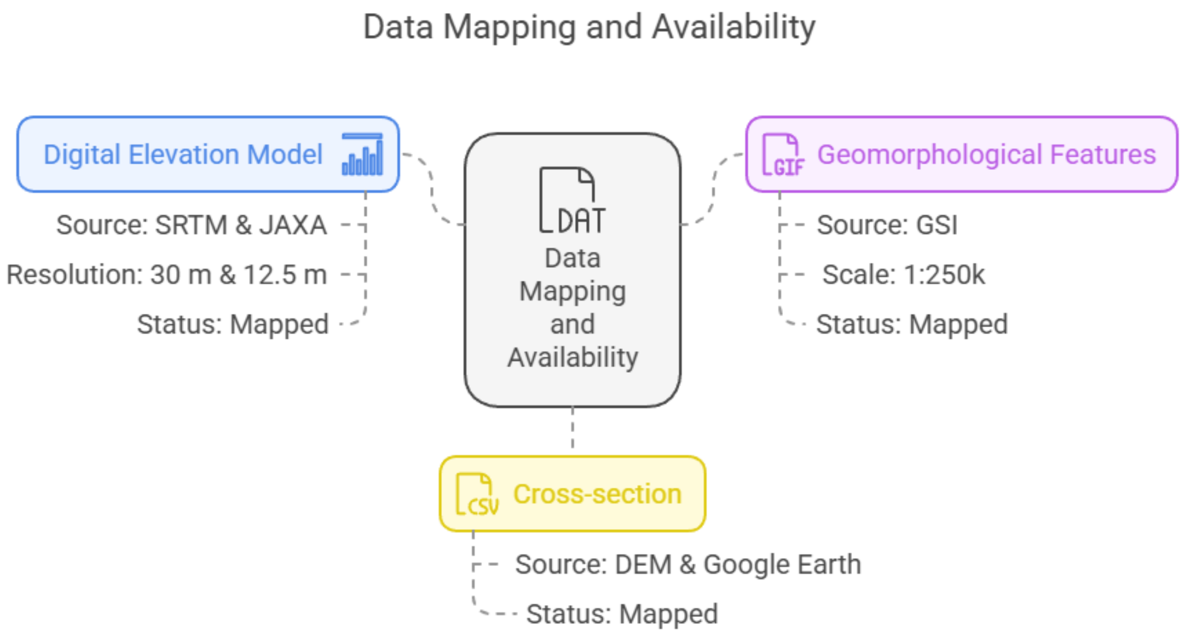


Figure 2. Data Mapping and Availability for Mahanadi River Basin

3.1 Sentinel Data

Flood mapping for the Mahanadi River Basin leverages high-resolution Sentinel-1 synthetic aperture radar (SAR) data, processed using Google Earth Engine (GEE). Sentinel-1 SAR data is particularly effective for flood mapping because it can penetrate cloud cover and capture surface water features even during heavy rainfall. This capability ensures reliable and accurate detection of flood events in real-time. Using GEE, Sentinel-1 imagery is processed to identify active flood extents using techniques such as thresholding and water classification indices. These methods highlight inundated areas, making it possible to monitor and assess flood progression dynamically. The data also facilitates year-on-year comparisons of flood extents to analyze changes in flood behaviour and the impacts of geomorphological and anthropogenic factors. Historical Sentinel-1 datasets archived in GEE are used to map previous flood events, providing a baseline for comparison. These comparisons help identify trends such as changes in flood frequency, intensity, and spatial distribution. Additionally, they offer insights into the influence of land-use changes, deforestation, or infrastructure development, such as dam construction, on flood patterns within the basin.

Integrating Sentinel-1 data with GEE's computational tools allows for rapid processing and visualization, enabling timely flood assessments critical for disaster response and mitigation planning. Analyzing multi-temporal flood data ensures a comprehensive understanding of flood dynamics, aiding in better floodplain management, infrastructure planning, and community resilience-building efforts in the Mahanadi River Basin.

3.2 SRTM (Shuttle Radar Topography Mission) data

It is widely used in geomorphological mapping to define basin boundaries and identify water-covered areas. The digital elevation model (DEM) generated from SRTM helps map the extent of the Mahanadi River Basin by accurately outlining its watershed. This is important for studying the flow of water and understanding the basin's drainage system.

SRTM data is also useful for detecting and mapping water bodies, such as rivers, lakes, and flood-affected areas, by analyzing elevation and terrain features. It helps in understanding how water moves through the basin and identifying areas prone to flooding. The elevation information from SRTM makes it easier to study the landscape and its features, such as river channels and floodplains. This data supports geomorphological mapping and water resource planning.

3.3 CWC Data

An essential component of a comprehensive geomorphological mapping approach is the integration of hydrological datasets, particularly those provided by the Central Water Commission (CWC). The CWC conducts extensive hydrological and hydraulic surveys across various spatial scales, typically ranging from 10 km to 30 km intervals in flood-prone river stretches. These surveys provide valuable cross-sectional profiles, river discharge measurements, and sediment load data, which are critical for analyzing channel morphology, bank stability, and floodplain dynamics. By incorporating CWC data into geomorphological mapping, researchers can enhance the spatial accuracy and hydrological relevance of terrain classification, especially in regions susceptible to seasonal flooding. This integration enables the delineation of flood-prone zones, identification of erosion- and deposition-prone areas, and assessment of channel migration patterns. The alignment of remote sensing and GIS-based mapping with CWC's ground-based observations ensures a more robust and data-driven understanding of fluvial processes and landscape evolution. Thus, CWC datasets serve as a vital empirical foundation for developing a scientific and scalable geomorphological mapping framework for dynamic river basins such as the Mahanadi.

3.4 Geospatial cloud computing technology

Cloud computing platforms such as Google Earth Engine (GEE) have significantly advanced the capabilities of geomorphological mapping, especially for large-scale water body extraction and monitoring. GEE provides access to an extensive repository of satellite datasets, including Sentinel-2 optical imagery and Sentinel-1 Synthetic Aperture Radar (SAR) data. Sentinel-2 delivers multispectral data at 10–20 m spatial resolution with high temporal frequency, making it ideal for detecting surface water and monitoring seasonal variations. In contrast, Sentinel-1 SAR data is highly effective for mapping water bodies under cloud-covered or monsoonal conditions due to its all-weather, day-and-night imaging capability (Drusch et al., 2012; ESA, 2021).Using GEE's cloud-based computational infrastructure, users can apply water indices such as the Normalized Difference Water Index (NDWI) (McFeeters, 1996) and Modified NDWI (MNDWI) (Xu, 2006), or implement thresholding techniques for SAR backscatter to extract surface water features efficiently across large regions and long time periods.

These techniques facilitate the identification of both permanent and ephemeral water bodies, flood inundation mapping, and the analysis of fluvial and hydromorphological dynamics. The integration of GEE-derived water body layers into geomorphological mapping enhances spatial accuracy and provides valuable insights into floodplain processes, channel evolution, and landscape-water interactions—crucial for flood risk assessment, hydrological modeling, and sustainable watershed management (Gorelick et al., 2017; Pekel et al., 2016)

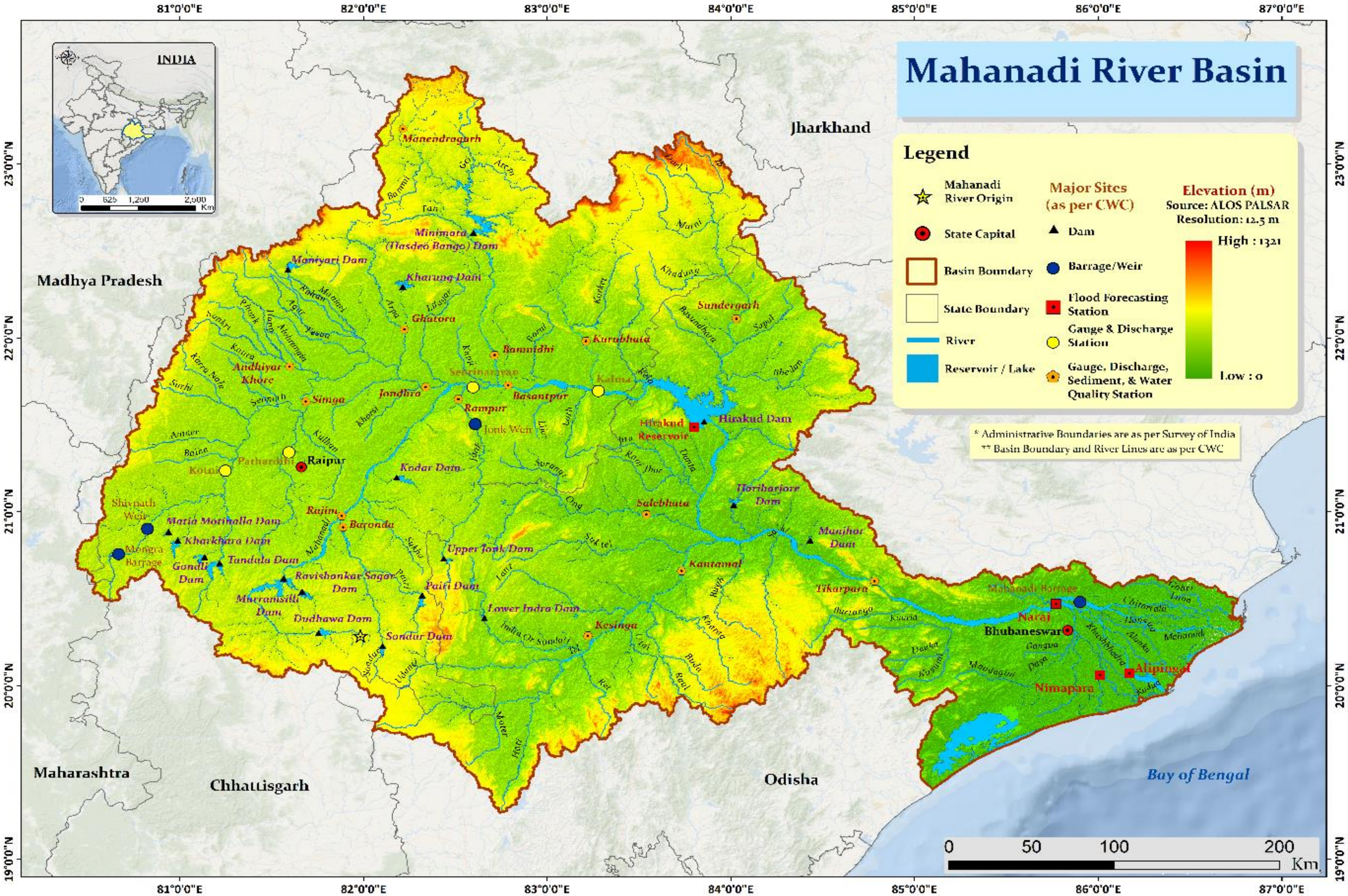


Figure 3. Digital Elevation Model (DEM) of Mahanadi River Basin

3.5. Geomorphological Parameters

The geomorphological map of the Mahanadi River Basin, derived from the 1:250,000 scale dataset available on the Bhukosh portal of the Geological Survey of India (**https://bhukosh.gsi.gov.in/Bhukosh/MapViewer.aspx**), provides critical insights into the basin's terrain characteristics, landform assemblages, and surface processes. This region, dominated by the Mahanadi main channel and major tributaries such as the Seonath, Hasdeo, Jonk, Mand, and Pairi rivers, exhibits a complex interplay of fluvial, structural, and denudational landforms. The GSI-based geomorphological data reveals a gradational landscape from structurally controlled uplands and dissected plateaus in the upper catchments **to** broad alluvial plains, floodplains, and valley fillsin the central and lower reaches. The fluvial landforms, such **as** meander belts, point bars, oxbow lakes, floodplains, and paleochannels, are clearly mapped and indicate zones of active sedimentation and lateral channel migration, particularly in the unconfined reaches of the basin. In the upper and middle reaches, especially along the Seonath and Hasdeo rivers, the presence ofpediplains, structural hills, and residual uplands points to long-term tectonic activity and erosion processes. The Bhukosh-derived geomorphological layers serve as a foundational dataset for regional geomorphic interpretation, flood hazard assessment, and basin management, and when integrated with remote sensing and hydrological data, they significantly enhance our understanding of the landscape evolution and river dynamics in the Chhattisgarh segment of the Mahanadi Basin.

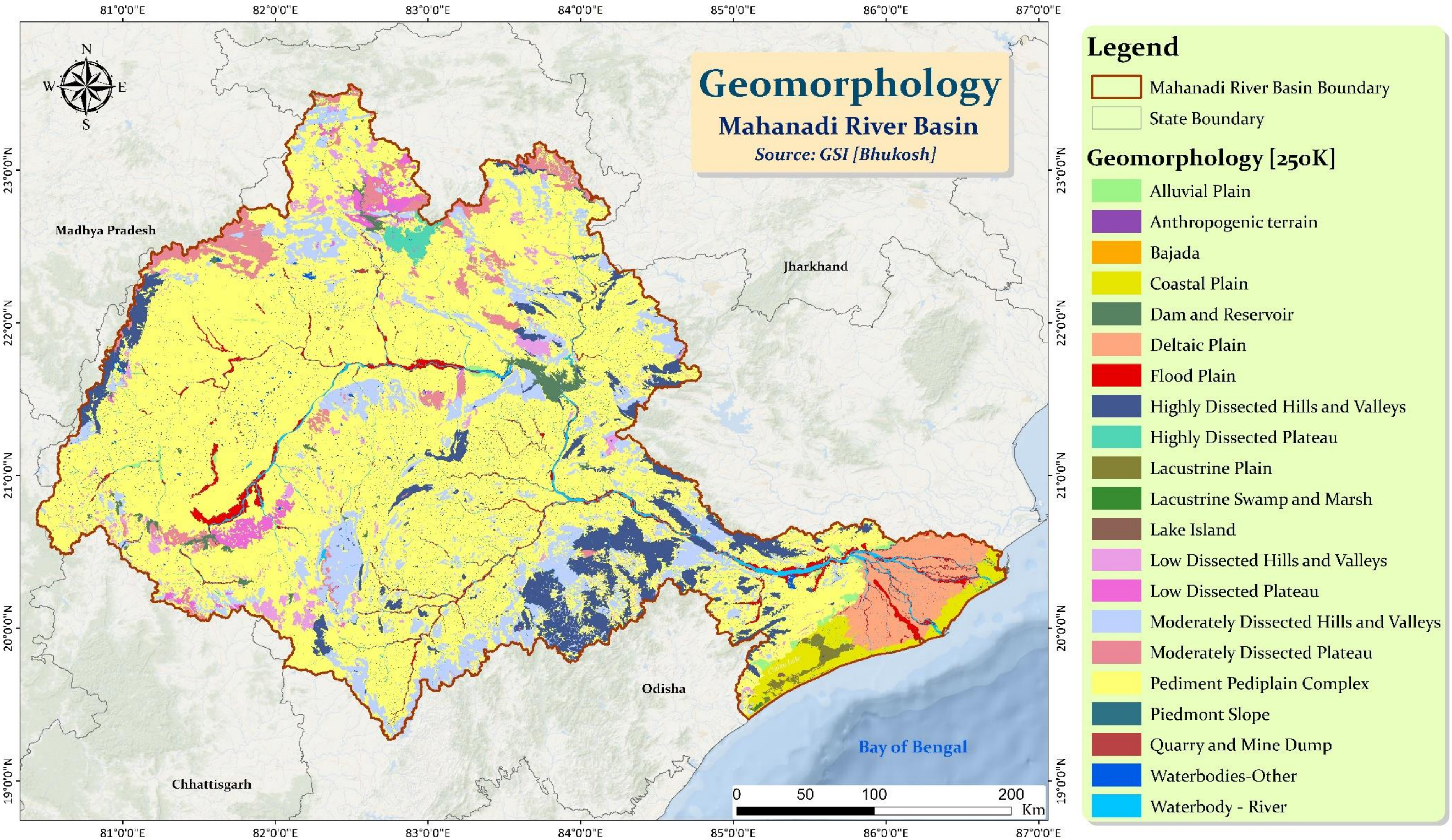


Figure 4. Geomorphology of Mahanadi River Basin based on GSI

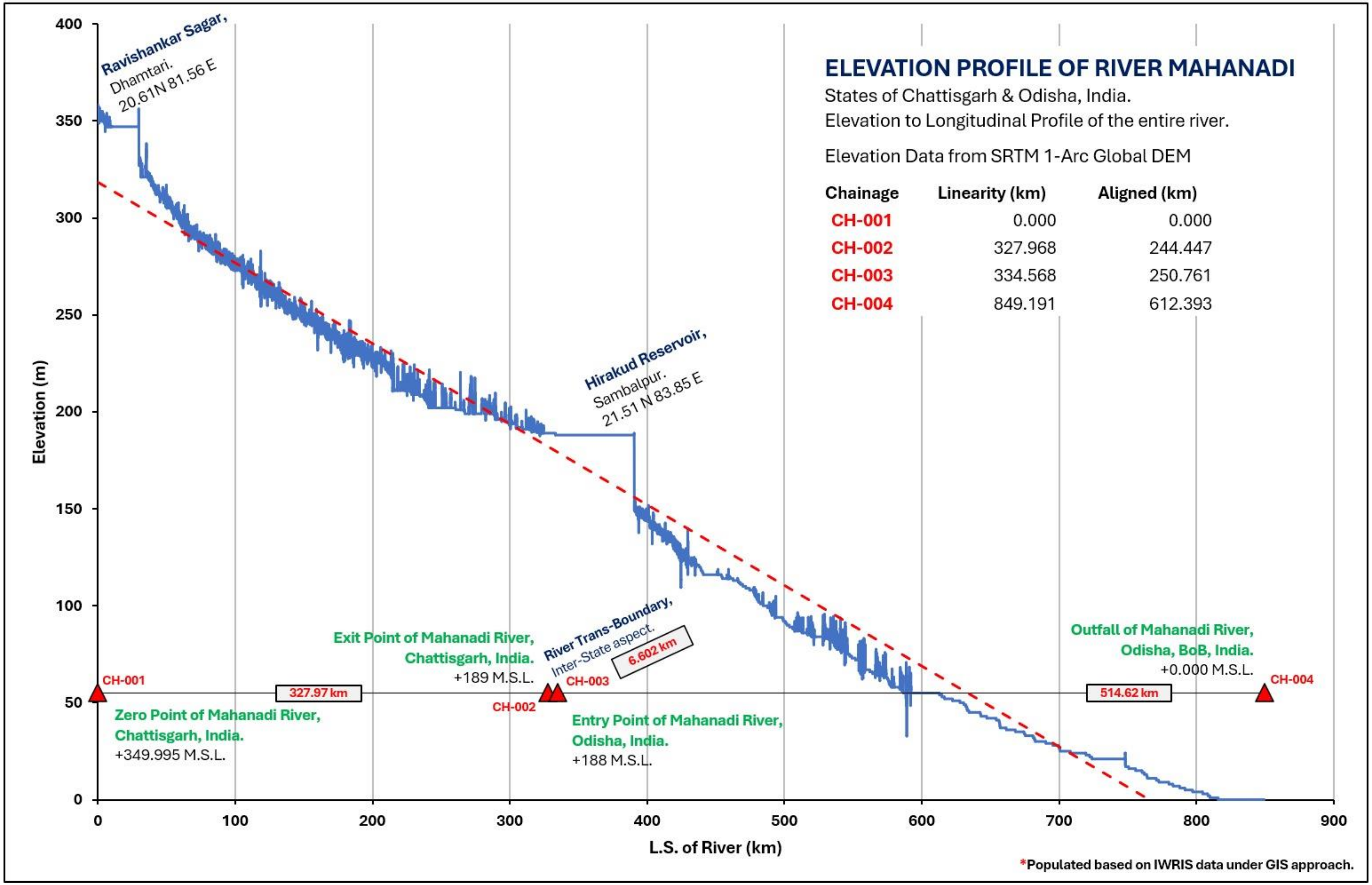


Figure 5. Elevation Profile of Mahanadi River

4. Landscape/ Valley setting:

The Mahanadi River is one of the major rivers in central India, originating from the Sihawa Hills in the state of Chhattisgarh. It traverses through diverse landscapes and geomorphological features as it moves towards its confluence with the Bay of Bengal. The geomorphology of the Mahanadi River is shaped by the regional topography, geological structure, and climatic conditions of the catchment area. This has formed the basis for differentiating the Mahanadi River into distinct River Styles.

4.1. Mahanadi River Basin under Chhattisgarh State:

Landscape setting is readily identifiable from topographic features with a characteristic pattern of landforms through which the river flows. In the Sihawa Hills, the river initially flows through deep gorges formed by tectonic and erosional processes. The steep-sided valleys create a confined channel, limiting lateral movement. These valleys have V-shaped profiles, indicative of the river's erosive power in carving its path through the hard rock formations. They are: -

a. **Upland Bedrock Terrain:** when the river is flowing through the Sihawa Hills range in the Dhamtari district (small stream cutting through rocky terrains). The region is underlain by bedrock of Precambrian age, primarily composed of gneisses and granites.

- **Location**: The upper reaches of the Mahanadi River Basin, particularly the **Chhattisgarh Plateau** and **Eastern Ghats**, are dominated by **bedrock** landscapes (Chakraborty, 2014).
- **Description**: This region is characterized by ancient, hard, and resistant rock formations, such as **granite**, **basalt**, and **schist**, which make up the foundational bedrock. The river's upper course is confined within these bedrock terrains, where it has cut through deeply eroded valleys and gorges (Pillai et al., 2015).
- **Key Features**:
    - The river flows through **narrow gorges** and **rugged valleys**, often constrained by steep, **rocky cliffs**.
    - The gradient is steep in this region, contributing to **higher energy** in the river’s flow, which results in **erosion** and the formation of deep valleys (Saha& Sharma, 2018).

   - This area often experiences **tectonic uplift**, leading to **ridges** and **rocky outcrops** along the riverbanks (Kundu&Samanta, 2017).
- **Geological Significance**: The bedrock terrain provides crucial evidence of the region's ancient geological past, marked by the stability of the Indian **craton** and the complex tectonic history of the **Eastern Ghats** (Saha& Sharma, 2018).

b. **Piedmont and Valley Interfluve (Transition Zone):** As the river descends from the hills, it enters a piedmont zone characterized by gently sloping terrain at the base of the uplands. The area between smaller tributary valleys forms valley interfluves, which act as divides.

- **Location**: As the river descends from the **Chhattisgarh Plateau** and enters the **Raipur Plateau**, it crosses a **piedmont zone**, where the steep slopes of the plateau meet the flatter alluvial plains (Rathore et al., 2020).
- **Description**: The **piedmont** is an area of transition between the **mountainous** or **hilly terrain** and the flat plains below. This zone is shaped by **erosion** from the higher lands and **sediment deposition** as the river loses energy (Yadava et al., 2016).
- **Key Features**:
   - The river exhibits **broad valleys** and begins to meander more as the gradient flattens out.
   - **Sediment deposition** from the mountain runoff forms **coarse material** such as **gravel**, **sand**, and **clay** in **alluvial fans**.
   - The **piedmont region** often includes **terraces** that are formed by ancient river terraces left by past erosional stages.
- **Geomorphic Importance**: The **piedmont zone** is critical for sediment transport, as it marks the transition between erosive processes in the mountains and deposition in the plains, shaping the river's ongoing landscape (Pillai et al., 2015).

c. **Alluvial Valley (middle course):** Moving downstream, the Mahanadi enters broader alluvial valleys with extensive floodplains. The terrain here is predominantly flat, with deep layers of silt, sand, and clay deposited by the river.

- **Location**: As the Mahanadi continues downstream, especially in the **lower reaches**, the river passes through wide **alluvial valleys** that are subject to flooding during the monsoon season (Rathore et al., 2020).

- **Description**: The **alluvial valley** is characterized by **flat, fertile floodplains** that have been shaped by continuous sediment deposition by the river. The Mahanadi deposits large amounts of **sand**, **silt**, and **clay** along its course, creating extensive floodplains (Saha& Sharma, 2018).
- **Key Features**:
  - The river meanders through the valley, creating **meanders**, **oxbow lakes**, and **sinuous river channels**.
  - **Floodplain areas** often contain **sandbars**, **deltas**, and **natural levees** formed by sedimentation during floods.
  - The valley is extremely fertile and supports agricultural activities due to the rich alluvial deposits.
- **Hydrological Impact**: The **alluvial valley** is crucial for the river's water dynamics, as it acts as a buffer for floodwaters and helps recharge groundwater levels during seasonal floods (Yadava et al., 2016).

d. **Craton Margin:** a low-lying plain where the river is flowing through an area that is flanked or underlain partly by the Indian cratonic basement rock and partly by its own alluvium.

- **Location**: The **craton margin** occurs at the boundary between the older, more stable crystalline rocks of the Indian craton and the younger, sedimentary formations in the lower part of the basin (Kundu&Samanta, 2017).
- **Description**: The **craton margin** is marked by a shift in geological characteristics, where the **hard, resistant crystalline rocks** meet **younger, more erodible sedimentary rocks** in the lower reaches.
- **Key Features**:
  - The region is marked by **structural deformations** such as **faults**, **folds**, and **fractures** that affect river flow and drainage patterns.
  - The **Mahanadi** in this region may be influenced by geological features such as **tilted layers** and **tectonic activity**, leading to **changes in river course**.
- **Geomorphic Importance**: The **craton margin** marks a critical boundary in the basin's geological history, influencing the river's path and sediment distribution (Chakraborty, 2014).

e. **Valley-Interfluve:** when the river flows through an alluvial terrain that has been deposited in the interfluve region of the two major river valleys.

- **Location**: These areas are typically found between the valleys of the Mahanadi and its tributaries, especially in the **Raipur Plateau** and **Sambalpur Plateau** regions (Yadava et al., 2016).
- **Description**: **Valley interfluves** are the higher ground areas that separate the main river valleys. These upland regions are often characterized by **gently undulating landscapes** and **plateau-like** features.
- **Key Features**:
  - Interfluves are often made up of **sedimentary deposits** that have been elevated by tectonic forces, creating **plateaus** and **ridges** between valleys.
  - These areas typically have **gentle slopes**, with **terraces** that reflect past river levels.
- **Agricultural Significance**: Many of these interfluves are used for agriculture due to their slightly elevated positions and good soil conditions (Saha& Sharma, 2018).

f. **Fan-Interfan:** when the river emerges from mountain front and flows out onto a more gently sloping plain resulting into a distinct landform called fans.
The area between two fans is called interfan.

- **Location**: The **fan-interfan** occurs where the Mahanadi receives tributaries from the **Raipur Plateau** and other highlands, forming fan-shaped deposits along its course (Pillai et al., 2015).
- **Description**: The river receives **sediment-laden waters** from several tributaries, which, upon meeting the main channel, spread out into **fan-shaped alluvial deposits**.
- **Key Features**:
  - **Alluvial fans** are often formed at the confluence of the Mahanadi and its tributaries.
  - The sediments in these fans range from **coarse gravels** to **finer sands and silts**, depending on the distance from the river.
  - The region is prone to **sedimentation** during high-flow events, which can lead to **shifting channels** and the formation of **new river branches** (Yadava et al., 2016).

g. **Badland:** this is typical for the Yamuna and Chambal rivers that flow through the Vindhyans creating ravines. Badlands are highly dissected regions.

- **Location**: In some areas of the Mahanadi Basin, especially in the **Eastern Ghats** and **Chhattisgarh Plateau**, regions experience intense erosion, forming **badlands** (Chakraborty, 2014).
- **Description**: **Badlands** are characterized by highly **eroded** and **rugged landscapes** where softer, unconsolidated rocks are exposed and eroded by wind and water.
- **Key Features**:
  - These areas are dominated by **gullies**, **ravines**, and **steep slopes**, with **minimal vegetation**.
  - The erosion results in highly dissected terrain, with **sharp ridges** and **deep valleys** that are often **difficult to cultivate**.
- **Hydrological Impact**: Badland areas typically experience **rapid runoff**, contributing to **flash floods** during the monsoon season (Rathore et al., 2020).

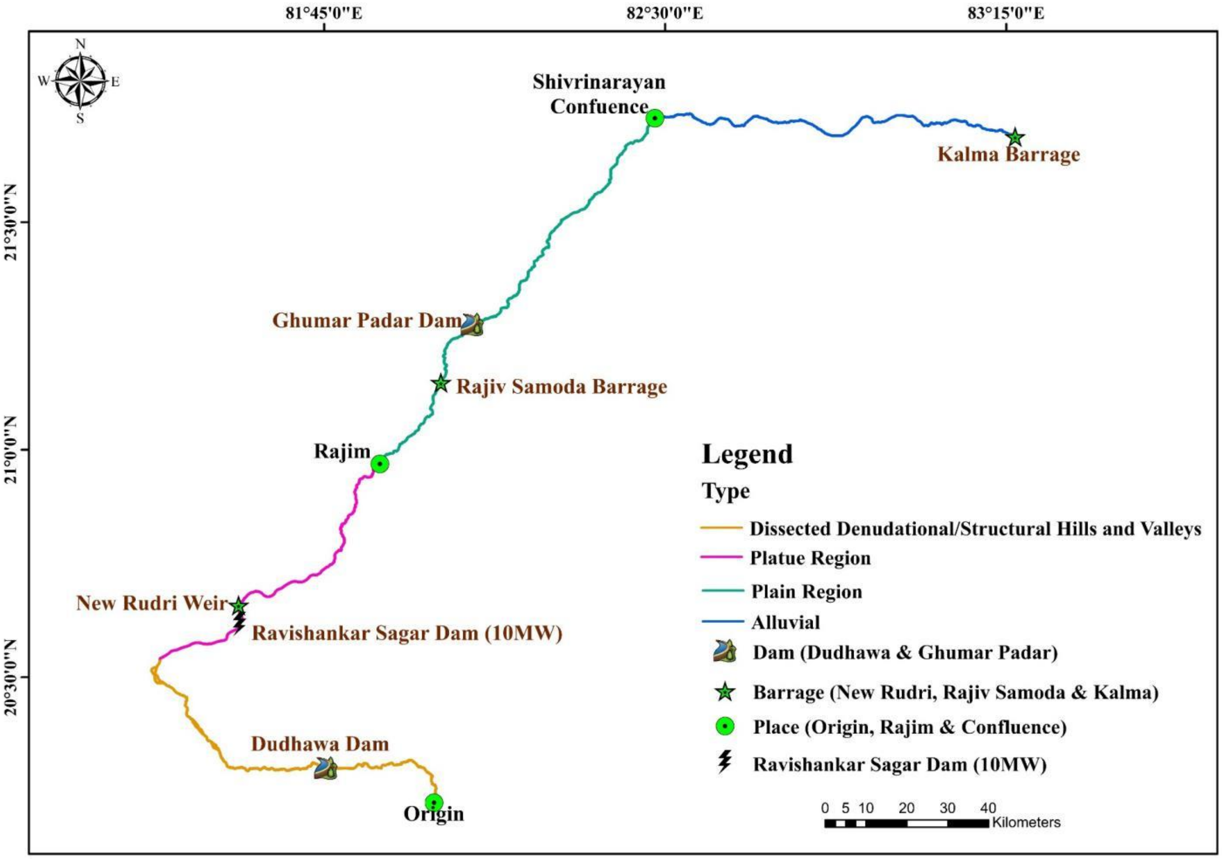


Figure 6. Landform of Mahanadi River Basin under Chhattisgarh State

4.2. Mahanadi River Basin under Odisha State:

According to the Geomorphological Landforms Map by the Geological Survey of India (GSI @1:250K), the basin can be broadly divided into four zones:

a) Upland and Highland Zone (Western & Northwestern Basin) Dominated by highly to moderately dissected hills and plateaus, including:

- Highly Dissected Hills and Valleys
- Moderately Dissected Hills and Valleys
- Moderately Dissected Lower Plateau
- Moderately Dissected Upper Plateau
- Highly Dissected Lower Plateau

These features are predominant in Sambalpur, Deogarh, and northern Subarnapur, formed primarily on Precambrian rock.

b) Transition Zones (Central Basin) Transitional units between hard rock terrains and alluvial plains, composed of:

- Pediment and Pediment Slope zones
- Piedmont–Pediplain Complex
- Residual Hills and Cuesta features

Found in western Angul, Boudh, and southern Subarnapur regions.

c) Alluvial Plains (Eastern Basin) Dominated by depositional features including:

- Older Alluvial Plain
- Younger Alluvial Plain
- Older Floodplain
- Active Floodplain

Spread across Cuttack, Jagatsinghpur, and Puri, where sedimentation dominates over incision.

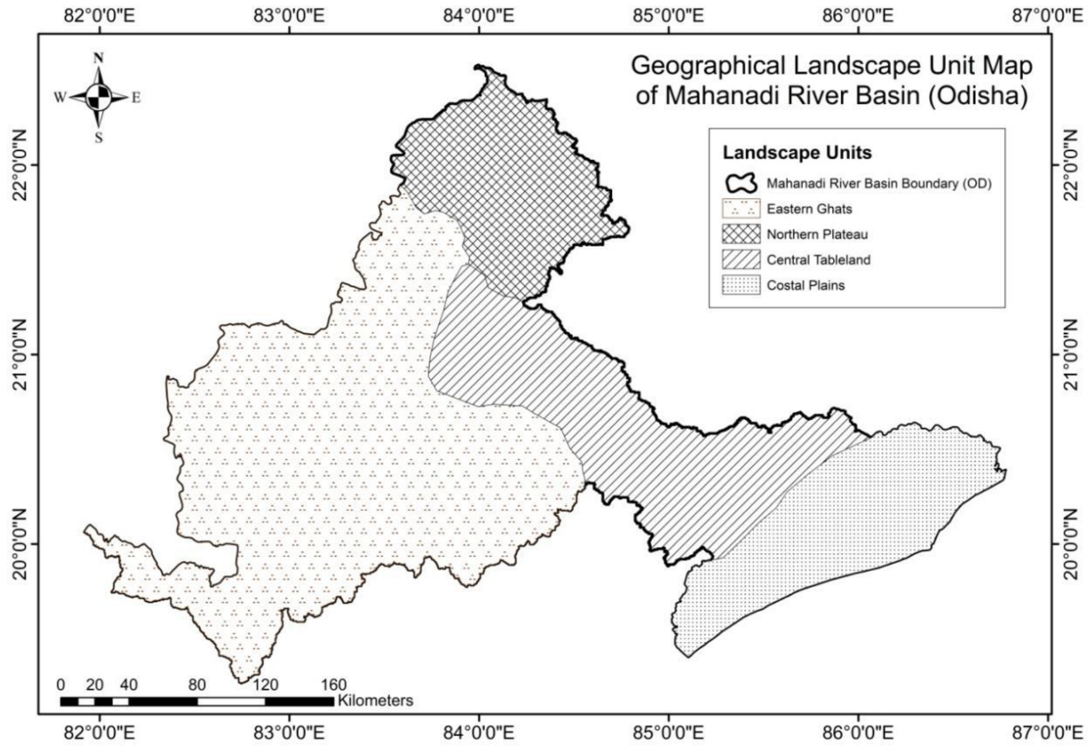
d) Deltaic and Coastal Zone (Mahanadi Delta) Key units include:

- Younger and Older Deltaic Plains
- Beach Ridge–Swale Complex, Tidal Flat, Mudflat, and Mangrove Swamp

Prominent in Kendrapara, Jagatsinghpur, and coastal Khordha districts.

Table 2: Major Geomorphological Units Based on GSI Map

Zone	Description	Dominant Districts
Upland	Dissected Hills & Plateaus	Sambalpur, Deogarh, Nuapada
Transition	Slopes, Residuals, Cuesta	Boudh, Angul
Alluvial	Floodplain and Alluvial Plains	Subarnapur, Cuttack
Deltaic	Delta, Coastal features	Jagatsinghpur, Puri



Source: Das, B., Satapathy, T., Kar, S. K., & Hazra, R. K. (2014). Genetic structure and Wolbachia genotyping in naturally occurring populations of Aedes albopictus across contiguous landscapes of Orissa, India. PLoS One, 9(4), e94094.

Figure 7. Geographical Landscape Unit Map of Mahanadi River Basin (Odisha)

4.3. Major Fluvial Landforms in the Mahanadi Basin

The fluvial geomorphology of the Mahanadi Basin,as classified by GSI, includes various depositional and erosional landforms shaped by river dynamics. Some of the most prominent types found in the GSI legend are:

a) Depositional Features:
- Braid Bars and Channel Bars: Identified across mid-Mahanadi near Subarnapur and in the Ib River.
- Natural Levees & Meander Scrolls: Common in the Cuttack-Jagatsinghpur delta.
- Flood Basins and Back Swamps: Associated with the active and older floodplains.

b) Erosional and Structural Features:
- River Terraces: Mapped along upper Mahanadi and Tel valleys.
- Residual Hills, Buttes & Inselbergs: Present within dissected terrain.
- Cuesta & Hogbacks: Mapped in transition zones between plateaus and plains.

1.1 River Islands

River islands form through the deposit of sediment in areas where water velocity decreases, suchas meanders or low-flow zones. As the river's flow slows, sediment (sand, gravel, silt) is carried by thecurrent settles, gradually building elevated landforms. Over time, these deposits accumulate to createislands, with vegetation typically stabilizing the surface. The size and shape of river islands areinfluenced by seasonal flow fluctuations; floods can cause erosion and reshape the islands, while lowerwater levels may expose or enlarge them. This process is driven by sediment dynamics, hydrology, andriver morphology. In the Lower Mahanadi River, three prominent river islands exist (Island Near Chiplima, Boudh and Naraj).

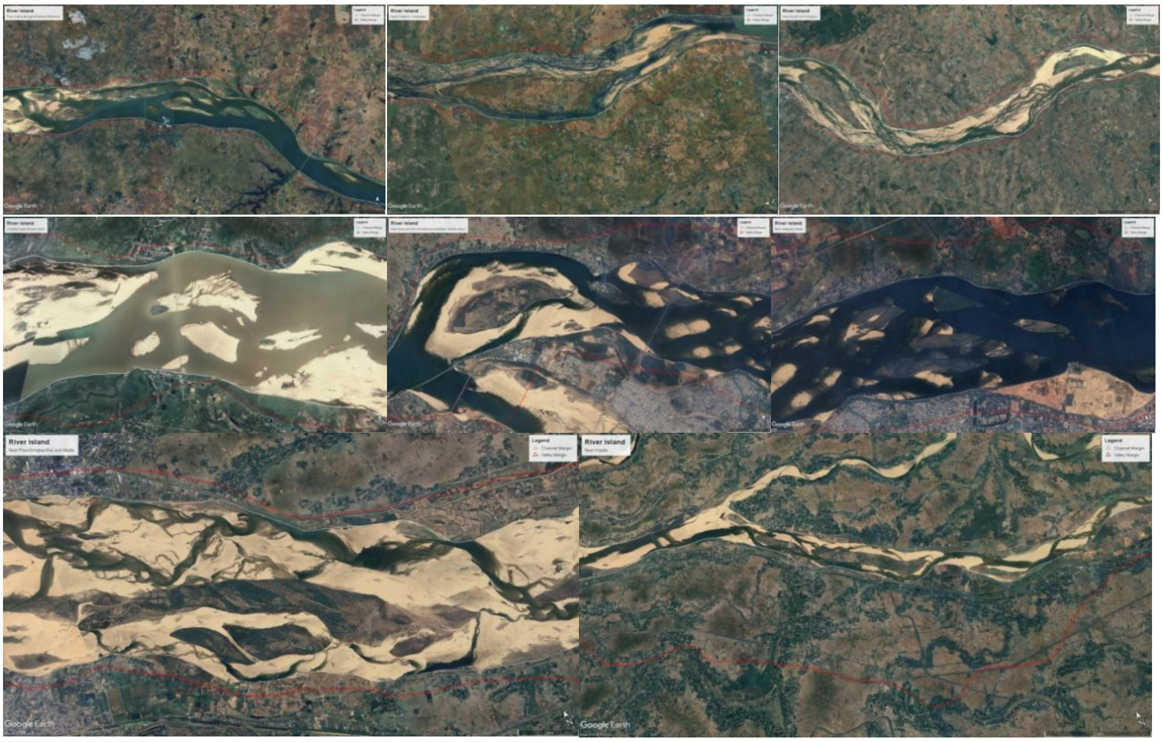


Figure 8. Major Fluvial Landforms in the Mahanadi Basin

4.3.1 Alluvial Floodplains

The alluvial floodplains of the Mahanadi River and its tributaries such as the Seonath, Hasdeo, Mand, and Jonk rivers are among the most prominent fluvial features in the Chhattisgarh region. . The alluvial floodplains of the Mahanadi River and its major tributaries in Odisha form primarily by quaternary alluvial deposits, these floodplains extend from the upper piedmont zones near Sambalpur down to the coastal deltaic tract near Cuttack and Jagatsinghpur. These floodplains are primarily composed of fine-grained alluvium—silt, clay, and sand—deposited by repeated flooding events over geological time. They exhibit flat to gently undulating topography and are highly fertile, making them ideal for intensive agricultural use. The floodplain width varies significantly, being broader in the central plains and narrower near hilly terrains. These features also play a crucial role in groundwater recharge and in maintaining the hydrological balance of the region (Sharma & Ghosh, 2004; Kale & Gupta, 2001).

4.3.2. River Terraces

River terraces are step-like landforms that occur above the current river level and represent abandoned floodplains formed during earlier phases of river activity. In the Mahanadi Basin's

Chhattisgarh portion, both strath and fill terraces are observed, especially along the Mahanadi and Seonath rivers. In Odisha portion these terraces occur prominently along the Mahanadi main stem and the major tributaries—Ib, Ong and Tel interfluve where valleys transition from bedrock-dominated uplands to broader alluvial plains. These terraces suggest alternating periods of river incision and lateral erosion, often associated with tectonic uplift or climatic fluctuations. Their presence indicates the historical evolution of fluvial processes and the vertical dynamics of the river system. In some locations, multiple terrace levels can be identified, reflecting different episodes of geomorphic adjustment (Singh et al., 2014).

4.3.3 Meander Scars and Oxbow Lakes.

The middle reaches of the Mahanadi and its tributaries show extensive development of meandering patterns due to their low gradient and high sediment load. This meandering gives rise to features such as meander scars—abandoned curves of old river channels—and oxbow lakes, which are formed when a meander loop is cut off from the main river course. Along the Mahanadi main stem, extensive scar fields are present downstream of Sambalpur, near Sonepur, and across the Cuttack–Kendrapara floodplains. These scars represent historic channel positions abandoned during cutoffs caused by high flood events, sediment choking, or natural neck narrowing. These landforms provide evidence of lateral channel migration and indicate active fluvial dynamics in the region. Oxbow lakes are often filled with water and support aquatic vegetation and biodiversity, playing a role in wetland ecology and acting as natural flood buffers (Sinha & Friend, 1994).

4.3.4 Point Bars and Channel Bars

Point bars are depositional features that form on the inner bends of meandering rivers, while mid-channel bars (or braid bars) appear in multi-threaded river channels. In the Chhattisgarh portion of the basin, these features are commonly seen in active sediment-transport zones. They are composed of sand and gravel and are highly dynamic in nature, often changing shape and size with seasonal flow variations. In Odisha point bars are prominent along meandering reaches of the Mahanadi, especially between Sambalpur–Boudh–Sonepur and further downstream toward Cuttack. Formed by lateral accretion during medium-to high-flow seasons, these bars consist mainly of well-sorted sands with interlayered silts. Their development is associated with active channel migration, bank undercutting on the outer bends, and steady deposition on inner bends. These bars not only reflect sediment transport mechanisms but also influence channel morphology and flow velocity. Their presence is a strong indicator of the ongoing sedimentation and hydrodynamic processes in the basin (Kale & Gupta, 2001).

4.3.5 Natural Levees and Backswamps

Natural levees are raised embankments formed parallel to the riverbanks as a result of sediment deposition during overbank flooding. These levees are typically composed of coarser sediments that settle quickly when floodwaters spill over the channel. Behind these levees lie backswamps—low-lying, poorly drained areas where fine sediments like clay and silt accumulate. In the Chhattisgarh region, such features are well-developed along the major rivers and play an essential role in controlling floodwater distribution and maintaining wetland ecosystems. Broad natural levees occur along the Mahanadi's middle and lower reaches, especially between Sambalpur, Sonepur, and the deltaic transition zone north of Cuttack. During high flows, coarser suspended sediments primarily sand and silt are deposited adjacent to the channel margins as floodwaters spill over the banks. Over time, these deposits build elevated ridges parallel to the river. Levees often act as natural flood barriers, while backswamps can function as temporary flood storage zones (Sharma & Ghosh, 2004).

4.3.6 Incised Valleys and Gorges

In regions where the river flows over resistant lithologies or where tectonic uplift has occurred, the Mahanadi and its tributaries have carved narrow, steep-sided valleys or gorges. These incised valleys are typically found in the eastern and southeastern margins of Chhattisgarh, where elevation increases and geological structure exerts a strong control on river morphology. The Mahanadi basin in Odisha contains several incised valleys and gorge segments formed through long-term fluvial erosion, most prominent bedrock incision occurs in the Satkosia Gorge, one of the most celebrated gorges in eastern India. The Mahanadi enters this narrow, steep-walled segment after leaving the broad Hirakud–Sambalpur plains and continues for nearly 22 km between Angul and Boudh districts. The incision depth reaches 200–300 m, with vertical cliffs on both sides. The gorge represents a classic antecedent river feature, where the

Mahanadi maintained its course while the Eastern Ghats Block uplifted, carving deeply into the rising terrain. These features are the result of vertical erosion and river rejuvenation, indicating tectonic or climatic changes that have increased the river's erosive power. The presence of such gorges suggests phases of landscape instability and adjustment within the basin (Singh et al., 2014; Kale & Gupta, 2001).

5. Flood Plain Mapping in Mahanadi River Basin

Advanced floodplain mapping relied on Sentinel-1 SAR data processed via the Google Earth Engine cloud platform, utilizing shapefiles for precise basin delineation. SAR's all-weather monitoring capability was crucial, especially during cloud-covered monsoon floods when optical sensors are ineffective. Focused on VV polarization (most sensitive to water bodies), high-resolution imagery (10 m) underwent change detection against a dry-season reference composite, yielding accurate spatial-temporal flood masks. Flooded areas were determined by pixels with ≥1.5 dB backscatter reduction, iteratively mapped for each major event from 2014 to 2024. The worst-case flood scenario was quantified by aggregating all events in a maximum composite and converting raster results to polygons for GIS application and reporting. The method's strengths include reproducibility, large volume historical coverage, and suitability for basin-scale analysis, despite limitations in vegetated or urban zones, as well as dependence on satellite revisit schedules. Integration with optical remote sensing and hydrodynamic models can improve accuracy—vital for climate change adaptation and disaster planning.

5.1 Upper Mahanadi Basin and Source Region Flooding

The Mahanadi River originates in the Sihawa hills (Dhamtari district), traversing undulating terrain with numerous rocky outcrops and shallow alluvial valleys, which generate significant monsoon flooding. Annual peak flows rise from low dry-season volumes (50–100 m^3/s) to extreme flood discharges (>8,000 m^3/s), inundating farmlands, villages (over 150), and affecting up to 800 km^2 of land. The upper basin floods are characterized by a dendritic drainage pattern; floodwaters spread over 2–5 km from the main channel. Climate predictions and recent studies (Science Direct, 2022) highlight increasing flood frequency and severity under future climate change scenarios, making this region India's worst flood-prone area according to the Central Water Commission and multiple hydrological surveys.

5.2 Sheonath River System and Flood Dynamics

Sheonath (Shivnath) River, Chhattisgarh's longest tributary (290 km), drains a large corridor before joining the Mahanadi. Floods are driven by the region's steep catchment, rapid runoff, and deforestation, with significant ENSO-related variability. Monsoonal peak flows in the Sheonath can reach 8,000–12,000 m^3/s, inundating a corridor of 18–25 km and affecting over 300 villages. Hydrological records from CWC indicate steep flood hydrographs, with peaks often aligning with Mahanadi main stem events, amplifying downstream impacts. Telemetry and streamflow network analysis show that flash floods and synchrony of tributary/main channel peaks exacerbate flood risks in Raipur and Durg districts.

5.3 Pairi River Tributary Flood Contribution

The Pairi River's steep gradient and modest catchment (~2,800 km^2) make it a critical flash-flood contributor. During monsoon, it produces early flood peaks (arriving 6–8 hours before main Mahanadi crest) and rapid runoff, contributing ~15–20% of upper basin flood volume during severe events. The affected corridor (8–12 km wide) primarily includes agricultural areas in Raipur/Gariaband, with depths up to 2–3 m. Local studies emphasize the river's pivotal role in upper basin flood wave formation and complex hydraulic responses at confluence zones.

5.4 Mand River Tributary Impact Zone

Mand River (catchment 3,200 km^2) originates in Chhattisgarh's southeast hills, characterized by a forested, steep upper basin and more meandering lower reaches. Its confluence near Sirpur creates a secondary accumulation zone, prolonging flood duration and increasing sediment deposition. Flood corridors reach 8–12 km, impacting Mahasamund and Janjgir-Champa especially during kharif season. Frequency analysis and historical records show extreme floods every 3–4 years, with major events once per decade. Agricultural and infrastructural losses remain high.

5.5 Jonk River Confluence and Middle Basin Dynamics

Jonk River, draining ~4,500 km^2, adds significant discharge and shapes flood propagation in the middle Mahanadi basin. Its steep, forested catchment delays peak flood arrival, increasing overlap with main stem events and flood duration (10–15 days in major floods). The width of inundated areas can reach 12–18 km, with depths up to 4–5 m, particularly in Janjgir-Champa and Bilaspur's lowlands. Poor drainage and small tributary convergence aggravate local vulnerability—an important factor for flood mitigation efforts.

5.6 Hasdeo River Major Tributary System

Hasdeo River (catchment 13,500 km^2), flowing from Korba plateau through mining/industrial zones, is the basin's largest flood contributor. At its confluence with Mahanadi, backwater effects extend up to 25 km upstream, and peak flood discharge can double main stem flow. Downstream flooding spans up to 25 km, impacting critical infrastructure such as power plants and mines. Sediment loading due to mining operations has noticeably altered river morphology, diminishing channel conveyance and increasing flood frequency.

5.7 Kalma Barrage Approach and Cumulative Basin Effects

Located 350 km downstream from the source, Kalma Barrage regulates aggregate flows from all upper basin tributaries. During extreme events, peak discharges over 25,000 m^3/s are common, with maximum modeled flood extents of 3,650–4,200 km^2 and depths reaching 31–39 m. Barrage operation modulates flood peaks within a 40 km stretch, with regulated pools sometimes inundating up to 30 km upstream, affecting villages and infrastructure in Sambalpur and Cuttack. Flood forecasting and management here require coordinated reservoir releases and robust telemetry for real-time decision-making. Future climate projections suggest increased inundation and flood depths under CMIP6 scenarios.

5.8 Ib River Confluence and Upper–Middle Basin Flood Dynamics

Ib River (catchment ~12,000 km^2) originates in the hills of Jashpur and flows through coal-bearing and industrial zones of Chhattisgarh and Odisha before joining the Mahanadi upstream of Hirakud Reservoir. High monsoon runoff from steep upper slopes makes Ib a fast-responding tributary. During peak inflow conditions, the river contributes substantial volume to Hirakud's flood pool, often dictating reservoir gate operations. Mining-related sediment inflow has led to localized aggradation in feeder channels, reducing conveyance and intensifying bank instability along downstream settlements.

5.9 Ong River Tributary Influence Zone

Ong River (catchment ~5,100 km^2) drains predominantly agricultural landscapes with moderate slopes. While less flashy than the Ib, its broad alluvial reaches allow wide overbank spreading during high-intensity rainfall events. At its confluence with the Mahanadi upstream of the deltaic transition zone, Ong inflows can compound downstream flood routing challenges, especially when coinciding with high releases from Hirakud. Sediment deposition at meander inflections has progressively reduced channel depth, increasing the frequency of floodplain inundation in adjacent villages.

5.10 Tel River Major Flood Contribution Corridor

Tel River (catchment ~22,000 km^2) is the largest southern tributary and provides major monsoon discharge to the lower Mahanadi system. Its basin includes forested uplands transitioning to fertile plains, producing rapid early-season runoff followed by sustained high flows. At the confluence near Sonepur, Tel inflow can markedly raise the lower Mahanadi stage, limiting the channel's ability to convey peak discharges toward the delta. Morphological shifts—particularly lateral erosion and bar formation—have been observed where Tel's sediment-rich flow merges with the main stem.

5.11 Mahanadi Delta and Distributary Flood Response Region

The Delta Region downstream of Naraj (where the Mahanadi bifurcates) is highly sensitive to backwater effects generated by synchronous high flows from the Ib–Ong–Tel system. When combined with tidal influence from the Bay of Bengal, the lower distributaries (Kathajodi, Kuakhai, Devi) experience amplified flood stages. Reduced sediment transport capacity in the main trunk, contrasted with heavy upstream sediment input, has promoted shoaling and reduced conveyance in delta channels. This has increased the frequency and severity of urban and peri-urban flooding in Cuttack, Jagatsinghpur, and adjacent low-lying zones.

5.12 Past Decedal Flood Plain Mapping

Over the last 10 years (2015–2024) satellite-based mapping put the high-susceptibility portion of the basin at roughly ~20% of the basin (around 25–30 thousand km^2). Geographically, the lower basin and delta in Odisha are the places most frequently inundated in big events coastal and low-lying districts such as Cuttack, Jagatsinghpur, Kendrapara, Khordha and Puri, plus extensive agricultural floodplain in districts like Sambalpur, Bargarh, Subarnapur (Sonepur), Boudh, Angul, Nayagarh and parts of Balangir, Kalahandi, Nuapada during major monsoon floods (Figure 9B).

In Chhattisgarh the flood signal is concentrated in upper and mid-basin catchments that generate the runoff districts such as Raipur, Dhamtari, Mahasamund, Janjgir-Champa, Raigarh, Korba and neighbouring areas see intense monsoon runoff and localized inundation, and they contribute the major peaks that flood the downstream plains.

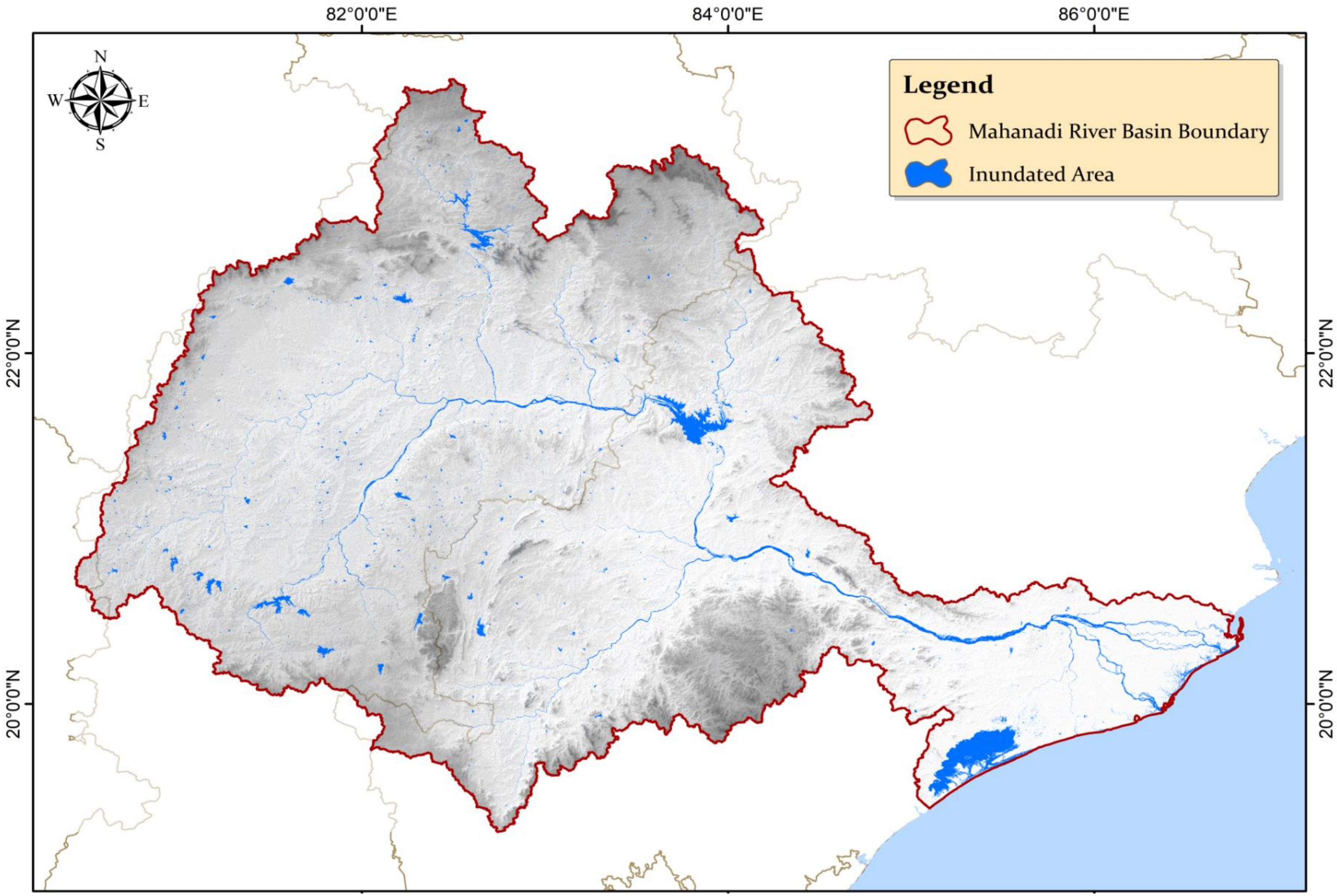


Figure 9 (a). Flood plain mapping in the Mahanadi Basin

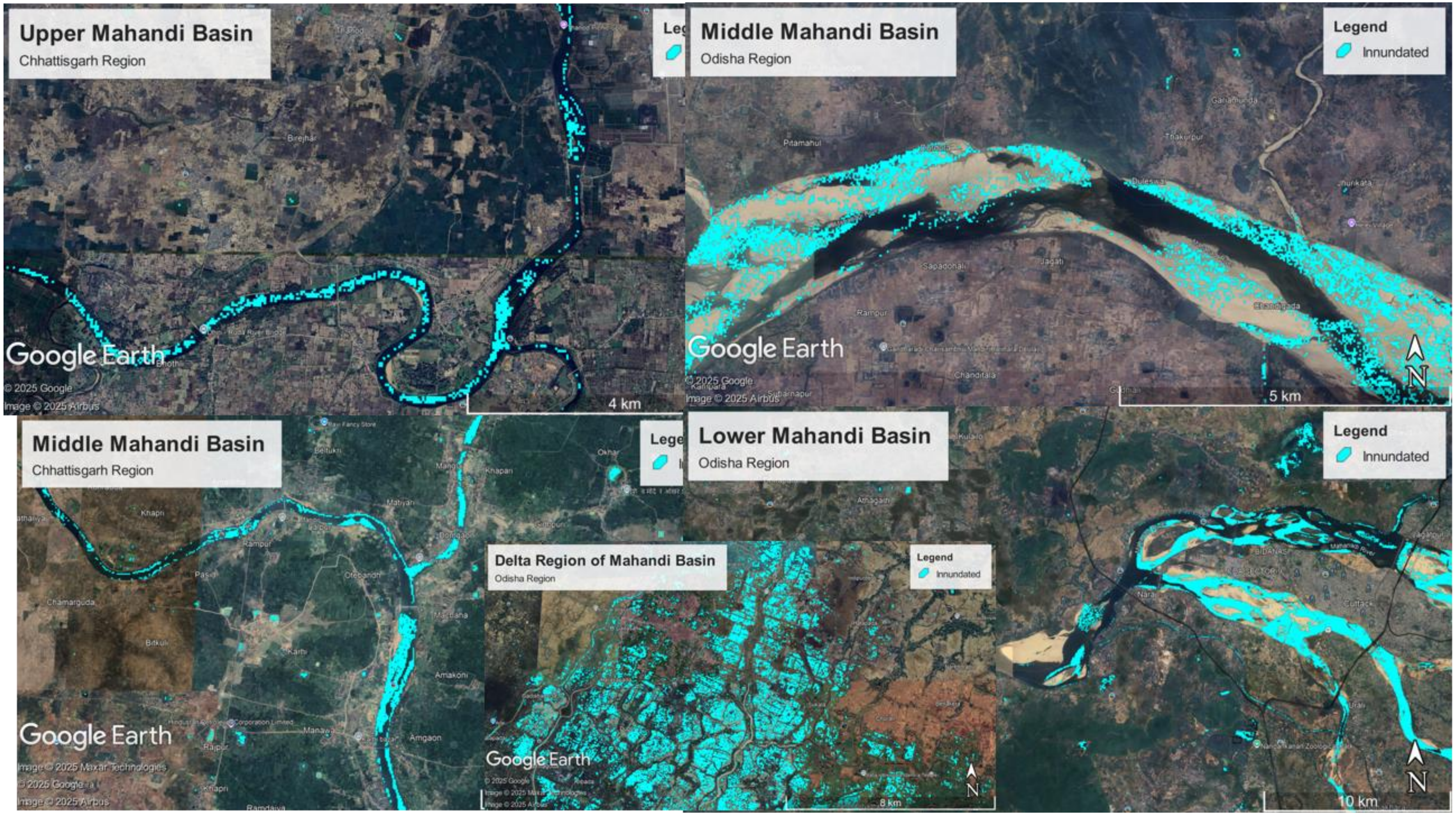


Figure 9 (b). Flood plain mapping in the Mahanadi Basin

6. Island Mapping

6.1 Cultural and Regional Significance of Maa Nathaldaai Temple

Maa Nathaldaai Temple, situated on a serene river island near Chandrapur in Chhattisgarh, is a sacred shrine dedicated to Goddess Durga, who is revered locally as Maa Nathaldaai. The temple holds great religious and cultural significance for the people of the region, attracting thousands of devotees throughout the year, especially during Navratri when special rituals, traditional folk songs, and devotional gatherings take place. This temple is not only a place of faith but also a center of local traditionsand community identity, where cultural heritage is preserved through festivals, folkpractices, and rural customs.

Located amidst the natural surroundings of a rural landscape, the temple also influences the agricultural lifestyle of nearby villages. Farmers from the region offer their first harvest to Maa Nathaldaai as a mark of gratitude and to seek blessings for prosperity and good rainfall. The river surrounding the island supports irrigation andagriculture, making the temple region agriculturally productive and self-sustained. Many local fairs (melas) are organized around the temple premises, which promote rural economy and handicrafts, providing livelihood opportunities to villagers.

For Chhattisgarh, Maa Nathaldaai Temple is not only a center of devotion but also a symbol of regional spirituality and cultural unity. It promotes religious tourism and showcases the rich heritage of the state. The site reflects the deep connection between nature, faith, and rural life, which is a core essence of Chhattisgarh's socio-cultural identity

Figure 10. Island at Maa Nathaldaai Temple, Chhattisgarh

6.2 Cultural and Regional Significance of Dhabaleswar Temple

Dhabaleswar Temple is a renowned Shiva shrine situated on an island in the Mahanadi River near Cuttack, Odisha. The temple's name and significance come from a legend where Lord Shiva turned a black stone white, symbolizing purity and absolution for a devotee's guilt.

The temple is revered across Odisha, Chhattisgarh, West Bengal, and Jharkhand. It preserves Odisha's spiritual traditions with unique rituals and draws large crowds during festivals like Bada Osha and Kartik Purnima, when the island is beautifully lit with thousands of oil lamps. Dhabaleswar Temple dates back to the 10th–11th centuries and features historic stone carvings in the Kalinga architectural style. Its island setting and the suspension bridge (jhula pul) over the Mahanadi add to its tourist and pilgrimage appeal.

The temple supports local livelihoods through regular fairs, trade, and artisan activity. It has become a hub for religious and rural tourism, enhancing economic development and fostering community bonds in Cuttack district.

Dhabaleswar Temple stands as a symbol of Odisha's spiritual heritage, blending religion, culture, and local economy while uniting communities in traditional faith.

Figure 11. Island at Dhabaleswar Temple, Odisha

7. Geomorphology of the Basin

- The basin's landforms are shaped by fluvial processes, variable sediment load, and lithology, producing diverse features along the Mahanadi and its tributaries: Pari, Seonath, Jonk, Mand, Hasdeo, Ib, Ong and Tel.
- Riverbed material ranges from coarse sand to silt and gravel, influencing alluvial soils in floodplains and varying soil textures along meanders and terraces.
- The Mahanadi shows high lateral mobility, especially in central plains, creating well-developed meanders, point bars, mid-channel bars, and vegetated islands due to monsoonal sediment deposition.
- Channel confinement varies: in upper incised valleys (source regions), the river is laterally constrained; in central plains, it becomes partially confined with room to meander; and in lower reaches, it flows in unconfined wide floodplains with active migration.
- Tributaries like Seonath show broad meandering floodplains; Hasdeo has partially confined channels with gorges; Jonk and Mand flow through terrains transitioning from confined to unconfined tracts downstream.
- Both active floodplains (seasonally inundated) and older, abandoned floodplain features (paleochannels, levees) are evident, reflecting long-term fluvial adjustments.
- The region's landscape is shaped by ongoing erosion and deposition, making it an important area for geomorphological research

7.1. River Styling

- The Mahanadi and its chief tributaries (Pairi, Jonk, Sheonath, Hasdeo, Mand, Ib, Ong) show three distinct valley types: confined (upper reaches with bedrock), partially confined (mid-reaches with intermittent floodplains), and unconfined (lower basin with alluvial plains supporting channel migration and meandering).
- Bed material gradation is evident—from coarse boulders and cobbles in the headwaters, moving downstream to gravel/coarse sand in transitional zones, and fine sand/silt in lower basin alluvial areas.
- Left bank tributaries (Hasdeo, Mand) mainly flow through the Chhota Nagpur plateau, resulting in more confined or partially confined channels controlled by resistant rock and limited lateral movement.

- Right bank tributaries (Sheonath, Ib, Tel) show a range of forms: confined upper reaches transition to unconfined, broader plains as channels exit the Deccan plateau and enter the Indo-Gangetic alluvium.
- Channel capacity, planform, and sediment transport vary by confinement zone: confined reaches display step-pool and armored beds, partially confined sections show riffle-pool morphologies and mixed sediments, unconfined reaches feature point bars, meander scrolls, and fine floodplain deposits.
- Overall, these geomorphic and sediment features critically shape local river management strategies.

7.1.1. River Style of Main Mahanadi River

The Mahanadi River originates from the Sihawa Hills in Dhamtari district of Chhattisgarh (20°18′44.69″ N, 81°55′11.08″ E) near Pharsiya village and flows eastward across Chhattisgarh and Odisha before draining into the Bay of Bengal. Along its course, the river exhibits 21 distinct river styles—ranging from straight and sinuous to meandering, braided, and anastomosing—as summarized in the morphological classification (Table 1).

7.1.2. River Style of Pairi River

The Pari River originates in the undulating terrain of Dhamtari district and is regulated by the Sikasar Dam, supporting irrigation and water storage for agriculture. Along its course, the Pari River exhibits diverse geomorphic features and river styles shaped by local terrain and regulation. The Sondur River joins the Mahanadi further downstream, increasing discharge and sediment load within the basin. In combination, the Pari and Sondur rivers, along with the Sikasar Dam influence, play key roles in shaping the fluvial geomorphology, flow pattern, and sedimentary environment of the left-bank tributary system of the upper Mahanadi.

7.1.3. River Style of Jonk River

The Jonk River originates in the Khariar (Sunabeda) hills of Odisha and flows through both Odisha and Chhattisgarh, joining the Mahanadi near Shivrinarayan. In its upper reaches, the Jonk flows through confined bedrock channels, while downstream, its valley widens and develops meandering, bar-dominated alluvial segments. The river's regime is regulated by the Patora Dam near Nuapada, which serves for irrigation, water supply, and flood moderation. The dam and other small irrigation structures influence the sediment transport, flow variability, and geomorphic evolution of the channel, contributing to diverse river forms and fluvial processes within the Mahanadi basin.

7.1.4. River Style of Seonath River

The Seonath River originates in the Panabaras hills (Rajnandgaon, Chhattisgarh) and joins the Mahanadi near Seorinarayan, traversing the extensive central plains. In its upper basin, the river features straight, confined channels, while in the middle and lower reaches, it transitions to meandering and bar-dominated alluvial segments. The river's flow regime and sediment dynamics are strongly influenced by the Mongra (Mongora) Dam, a key irrigation and water supply project, alongside smaller hydraulic structures. These interventions regulate discharge, support agriculture, and modify sediment transport and variability, shaping the Seonath's geomorphic and hydrological behavior before its merger with the Mahanadi.

7.1.5. River Style of Hasdeo River

Hasdeo River originates in the hills of Sonhat, Koriya district, Chhattisgarh, and flows southward through coal-bearing and forested regions before joining the Mahanadi near Seorinarayan. The river exhibits confined and partially confined channel styles in its upper reaches, transitioning into meandering and bar-controlled alluvial segments downstream. Hasdeo Bango Dam, located in Korba district, is an important earthen dam that provides irrigation, flood control, water supply, and hydroelectric generation. The dam has significantly altered the river's flow regime and sediment delivery, impacting ecological processes and geomorphic dynamics along its course within the Mahanadi basin.

7.1.6. River Style of Mand River

The Mand River originates in the Surguja district of Chhattisgarh, traversing forested and hilly terrain before joining the Mahanadi near Chandarpur in Raigarh district. The river exhibits confined bedrock channels in the upper basin, transitioning to meandering alluvial stretches with bar formation in the middle and lower reaches. Its basin is notable for coal and mineral resources, with hydrological regimes modified by small barrages and irrigation project. By contributing discharge and sediments, the Mand River is a key factor in shaping the fluvial dynamics of the middle Mahanadi catchment.

7.1.7. River Style of IB River

The IB River originates in the hills of Jashpur district and flows through Jharkhand, Chhattisgarh, and Odisha, eventually joining the Mahanadi near Jharsuguda. It traverses coal-rich and forested areas, contributing substantial discharge and sediment load to the main channel.The basin features significant industrial and mining activity, impacting water quality and flow regimes. Morphologically, the IB River exhibits partially confined and meandering channel styles, with local sediment deposition and bar formation particularly marked in the middle and lower reaches.

7.1.8. River Style of Ong River

The Ong River originates from the hills of Nuapada district and flows entirely within Odisha before joining the Mahanadi near Sonepur. Its seasonal flows are vital for agriculture, supported by several small dams and barrages that regulate water supply and irrigation. The river displays straight to slightly sinuous channels in upper reaches, shifting to meandering alluvial segments downstream, where sediment deposition and bar formation occur. The Ong's contribution to Mahanadi discharge becomes most significant during monsoon, supporting downstream flow and basin hydrology.

7.1.9. River Style of Tel River

The Tel River originates in Nabarangpur district and flows through Kalahandi, Balangir, and Boudh districts, joining the Mahanadi at Sonepur. Its basin is highly productive for agriculture, supported by several irrigation structures including barrages and medium-scale projects. The river exhibits meandering alluvial channels, with occasional bar-controlled stretches in its lower reaches. With its large catchment area and substantial seasonal discharge, the Tel River is a vital contributor to Mahanadi's hydrology and sediment regime, especially during the monsoon.

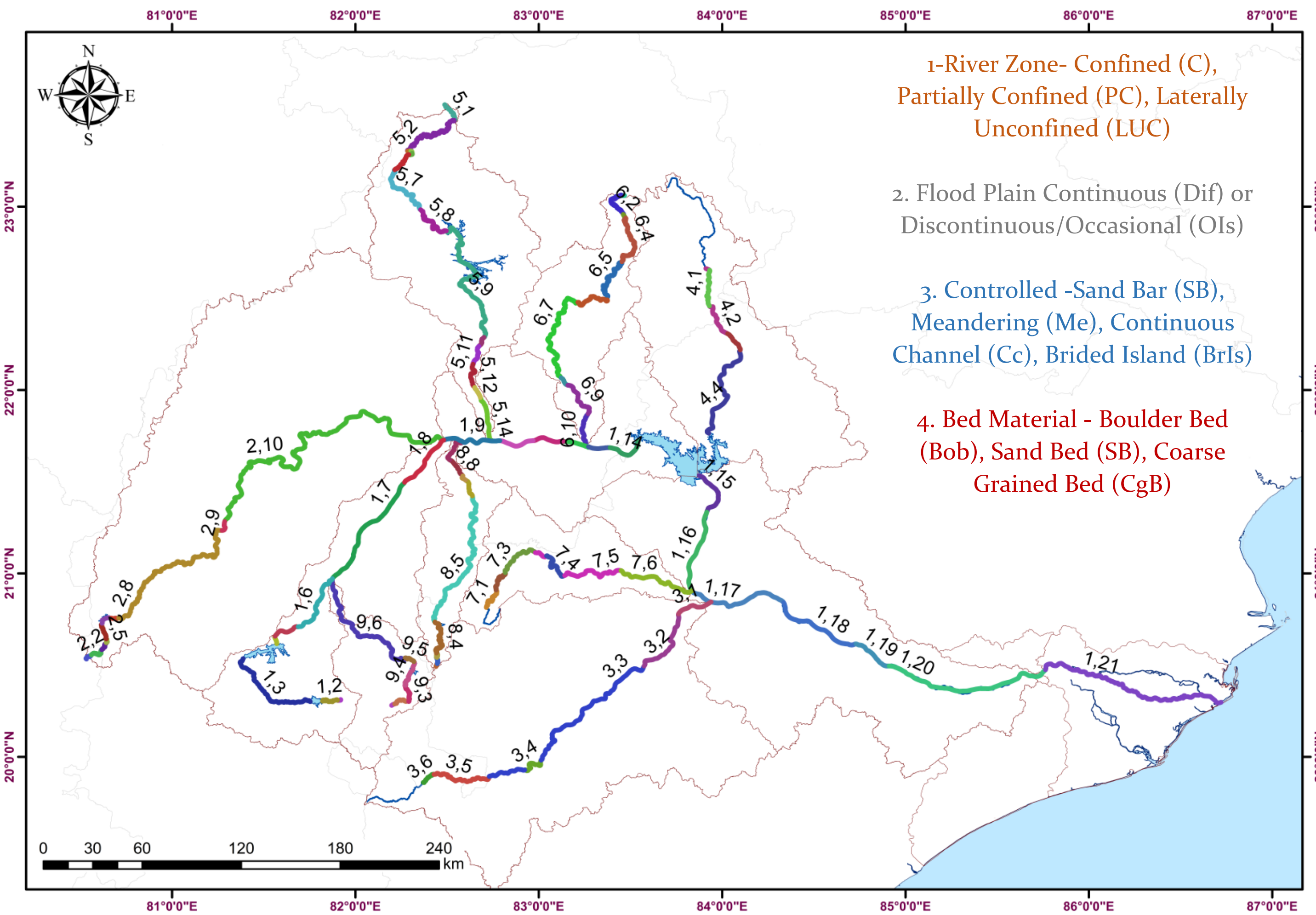


Figure 12. Geomorphological Map of Mahanadi River Basin

Table 3A. River style description of Mahanadi River Channel

S No.	Name of River Style	Description	Stretch Length	Average Slope	Sinuosity
1	PC-DiF-BRF-BoB	Partially Confined- Discontinuous Flood Plain - Back River Flow- Boulder Bed	2.24	0.13%	1.00
2	LUC-DiF-Cc-BoB	Laterally Unconfined- Discontinuous Flood Plain- Continuous Channel- Bolder Bed	11.45	0.12%	1.01
3	LUC-OF-Cc-SB	Laterally Unconfined- Occasional Flood – Continuous Channel- Sand Bed	59.99	0.12%	1.01
4	LUC-AF-Cc-CgB	Laterally Unconfined- Active Flood Plain- Continuous Channel- Coarse Grained Bed	4.74	0.60%	1.11
5	LUC-Si-DiF-CgB	Laterally Unconfined- Sinus- Discontinuous Flood Plain- Coarse Grained Bed	15.86	0.08%	1.21
6	LUC-Bd-Me-SB	Laterally Unconfined - Braided -Meandering - Sand Bed	40.59	0.04%	1.34
7	LUC-Bd-St-SB	Laterally Unconfined - Braided - Straight - Sand Bed	74.48	0.04%	1.71
8	LUC-SC-Me-BoSB	Laterally Unconfined - Sand Controlled - Meandering - Boulder and Sand Bed	35.03	0.02%	1.21
9	LUC-Cc-Me-SB	Laterally Unconfined – Continuous Channel - Meandering – Sand Bed	34.29	0.02%	1.29
10	LUC-Cc-BrIs-SGB	Laterally Unconfined – Continuous Channel - Braided Island – Sand and Gravel Bed	20.28	0.05%	1.03
11	LUC-Br-OIs-SPB	Laterally Unconfined – Braided - Occasional Island – Sand and Pebbles Bed	18.12	0.05%	1.02
12	LUC-Cc-OIs-SB	Laterally Unconfined -Continuous Channel - Occasional Island - Sand Bed	14.62	0.11%	1.00
13	PC-OF-SbC-FgB	Partially Confined - Occasional Floodplain - Sandbar Controlled - Fine Grained Bed	12.40	2.25%	1.03
14	PC-Si-OIs-FgB	Partially Confined – Sinous - Occasional Island - Fine Grained Bed	22.30	0.25%	1.36
15	C-BrC-Si-BoB	Confined - Bed Rock Controlled - Sinous - Boulder Bed	30.20	1.45%	1.33
16	PC-BrM-OIs-BoB	Partially Confined - Bed Rock Margin - Occasional Island - Boulder Bed	50.90	0.55%	1.05
17	UC-DiF-OSb-BrCB	Lateral Unconfined - Sand Bar Controlled - Occasional Island - Bedrock Core Bar Bed	59.60	0.55%	1.15
18	UC-SbC-OIs-BrCB	Lateral Unconfined - Discontinuous Floodplain - Occasional Sand Bar - Bedrock Core Bar Bed	52.90	1.10%	1.10
19	C-OF-Gr-SB	Confined - Occasional Floodplain – Gorge – Sand Bed	24.20	1.80%	1.05
20	UC-SbC-SB	Laterally Unconfined - Sandbar Controlled – Sand Bed	98.10	0.65%	1.10
21	UC-FpC-AnSg-SB	Laterally Unconfined Floodplain Controlled – Anastomising - Sand Bed	84.10	0.12%	1.10

Table 3B. River style description of Pairi River Channel

S No.	Name of River Style	Description	Stretch Length	Average Slope	Sinuosity
1	C-BrM-DiC-GB	Confined - Bed Rock Margin - Discontinue Channel - Grave Bed	1.98	0.91%	3.60
2	PC-Si-Me-GB	Partially Confined – Sinus - Meandering – Gravel Bed	11.69	0.27%	1.09
3	PC-Si-BrM-GB	Partially Confined – Sinus- Bed Rock Margin - Gravelly Bed	11.79	0.39%	1.03
4	C-BrMt-Me-GB	Partly Confined- Bed Rock material – Meandering- Gravelly Bed	17.35	0.57%	1.19
5	C-BrMt-St-GS	Confined- -Bed Rock Martial- Straight - Gravelly Soil	6.22	0.64%	1.04
6	PC-SbC-Me-OIs-SB	Partly Confined- Sand Bar Controlled – Meandering - Occasional Island - Sand Bed	82.62	0.09%	1.04

Table 3C. River style description of Jonk River Channel

S No.	Name of River Style	Description	Stretch Length	Average Slope	Sinuosity
1	C-BrM-DiC-GB	Confined - Bed Rock Margin - Discontinue Channel - Grave Bed	2.69	0.41%	1.15
2	LUC-Si-Me-RcBM	Laterally Unconfined – Sinus – Meandering – Rocky Bed Material	5.07	0.28%	1.20
3	PC-Si-Me-RcBM	Partially Confined – Sinus – Meandering – Rocky Bed Material	4.62	0.35%	1.06
4	C-Si-Me-RcBM	Confined – Sinus – Meandering – Rocky Bed Material	32.20	0.91%	1.07
5	LUC-SbC-Me-SSlB	Laterally Unconfined – Sand Bar Controlled – Meandering – Sand and Silt Bed	102.52	0.07%	1.02
6	PC-RcBM-Me-RcB	Partially Confined – Rocky Bed Material – Meandering – Rocky Bed	11.37	0.07%	1.01
7	C-RcBM-St-BoPB	Confined – Rocky Bed Material – Straight – Boulder and Pebbles Bed	3.65	0.11%	1.01
8	LUC-Rc-Me-SSlB	Laterally Unconfined Rocky – Meandering – Sand and Silt Bed	12.98	0.04%	1.02
9	LUC-SbC-St-SSlB	Laterally Unconfined – Sand Bar Controlled – Straight – Sand and Silt Bed	17.84	0.14%	1.03

Table 3D. River style description of Seonath River Channel

S No.	Name of River Style	Description	Stretch Length	Average Slope	Sinuosity
1	C-DiC-Me-RcB	Confined - Discontinue Channel - Meandering - Rocky Bed	5.84	0.70%	1.16
2	LUC-Cc-Me-RcB	Laterally Unconfined - Continuous Channel - Meandering - Rocky Bed	10.48	0.20%	1.08
3	PC-Cc-Me-RcB	Partially Confined - Continuous Channel - Meandering - Rocky Bed	5.85	0.19%	1.04
4	LUC-Cc-Me-CrSB	Laterally Unconfined - Continuous Channel - Meandering – Coarse Sand Bed	3.53	0.08%	1.07
5	LUC-Cc-Me-RcB	Laterally Unconfined - Continuous Channel - Meandering - Rocky Bed	11.46	0.18%	1.03
6	PC-Cc-Me-RcB	Partially confined - Continuous Channel - Meandering - Rocky Bed	7.35	0.07%	1.02
7	LUC-Cc-OIs-CrSB	Laterally Unconfined - Continuous Channel – Occasional Island – Coarse Sand Bed	4.60	0.22%	1.01
8	LUC-Cc-Me-RcSB	Laterally Unconfined - Continuous Channel – Meandering– Rocky and Sand Bed	109.38	0.04%	1.01
9	LUC-Cc-DiF-RcB	Laterally Unconfined - Continuous Channel – Discontinuous Floodplain – Rocky Bed	6.58	0.02%	1.01
10	LUC-Cc-Me-CrSB	Laterally Unconfined - Continuous Channel – Meandering – Coarse Sand Bed	220.58	0.12%	1.13

Table 3E. River style description of Hasdeo River Channel

S No.	Name of River Style	Description	Stretch Length	Average Slope	Sinuosity
1	C-DiC-Me-GBoB	Confined - Discontinue Channel - Meandering - Gravel and Boulder Bed	14.12	1.17%	1.13
2	LUC-Cc-Me-CoPB	Laterally Unconfined - Continuous Channel - Meandering – Cobbles and Pebbles Bed	57.65	0.35%	1.11
3	PC-Cc-OIs-SB	Partially Confined - Continuous Channel – Occasional Island - Sand Bed	1.88	0.90%	1.02
4	LUC-Cc-Me-BoB	Laterally Unconfined - Continuous Channel - Meandering – Boulder Bed	1.91	0.05%	1.06

5	C-Cc-St-BoB	Confined - Continuous Channel - Straight - Boulder Bed	2.78	0.86%	1.07
6	LUC-SbC-Me-SB	Laterally Unconfined – Sand Bar Controlled - Meandering - Sand Bed	14.62	0.55%	1.06
7	LUC-Cc-OIs-BoSB	Laterally Unconfined - Continuous Channel – Occasional Island – Boulder Sand Bed	40.76	0.12%	1.07
8	LUC-SbC-Me-SSlB	Laterally Unconfined - Sand Bar Controlled – Meandering - Sand and Silt Bed	29.54	0.09%	1.12
9	LUC-SbC-OIs-SCyB	Laterally Unconfined - Sand Bar Controlled – Occasional Island – Sand and Clay Bed	101.37	0.09%	1.09
10	LUC-SbC-Me-BoSB	Laterally Unconfined - Sand Bar Controlled – Meandering – Boulder and Sand Bed	6.81	0.12%	1.08
11	LUC-SbC-Me-FgB	Laterally Unconfined - Sand Bar Controlled – Meandering – Fine Grain Bed	12.94	0.03%	1.08
12	PC-SbC-OIs-RcSB	Partially Confined – Sand Bar Controlled – Occasional Island – Rocky and Sand Bed	17.10	0.08%	1.03
13	LUC-SbC-OIs-RcB	Laterally Unconfined – Sand Bar Controlled – Occasional Island – Rocky Bed	6.97	0.03%	1.03
14	LUC-BrC-OIs-RcSB	Laterally Unconfined – Bed Rock Controlled – Occasional Island – Rocky and Sand Bed	28.59	0.03%	1.08

Table 3F. River style description of Mand River Channel

S No.	Name of River Style	Description	Stretch Length	Average Slope	Sinuosity
1	C-DiC-Me-CoPB	Confined - Discontinue Channel - Meandering - Cobbles and Pebbles Bed	2.28	0.07%	1.02
2	LUC-DiC-Me-CoPB	Laterally Unconfined - Discontinuous Channel - Meandering – Cobbles and Pebbles Bed	24.92	0.45%	1.14
3	LUC-SbC-St-SSlB	Laterally Unconfined – Sand Bar Controlled - Straight – Sand and Clay Bed	2.71	0.22%	1.05
4	C-BrM-Me-BoB	Confined – Bed Rock Margin - Meandering – Boulder Bed	41.32	0.16%	1.11
5	PC-BoC-Me-SCyB	Partially Confined – Boulder Controlled - Meandering – Sand and Clay Bed	41.50	0.27%	1.10
6	C-SbC-Me-SCyB	Confined – Sand Bar Controlled - Meandering – Sand and Clay Bed	23.93	0.67%	1.06
7	LUC-SbC-OIs-SCyB	Laterally Unconfined – Sand Bar Controlled – Occasionally Island – Sand and Clay Bed	73.71	0.06%	1.09
8	C-SbC-St-SCyB	Confined – Sand Bar Controlled - Straight – Sand and Clay Bed	6.62	0.06%	1.09
9	LUC-SbC-OIs-SCyB	Laterally Unconfined – Sand Bar Controlled – Occasionally Island – Sand and Clay Bed	25.74	0.03%	1.09
10	PC-OF-Me-SCyB	Partially Confined – Occasionally Flood - Meandering – Sand and Clay Bed	23.20	0.21%	1.20

Table 3G. River style description of Tel River Channel

S No.	Name of River Style	Description	Stretch Length	Average Slope	Sinuosity
1	UC-BrCbC-OF-SB	Laterally Unconfined - Bedrock Core bar Controlled Occasional - Floodplain - Sand Bed	19.30	1.60%	1.08
2	UC-BrCBC-OSb-SB	Laterally Unconfined - Bedrock Core bar Controlled - Occasional Sandbar - Sand Bed	43.70	0.40%	1.18
3	PC-SbC-OF-FgB	Partially Confined - Sandbar Controlled - Occasional Floodplain - Finegrained Bed	95.00	0.55%	1.16
4	LUC-Cc-Me-BoB	Laterally Unconfined - Continuous Channel - Meandering – Boulder Bed	22.40	0.75%	1.08
5	PC-SbC-OF-Si-CgB	Partially Confined - Sandbar Controlled - Occasional Floodplain - Sinous – Coarsegrained Bed	17.40	0.50%	1.56
6	PC-BrCbC-OSb-CgB	Partially Confined - Bedrock Core bar Controlled - Occasional Sandbar - Boulder Bed	38.70	0.90%	1.22

Table 3H. River style description of Ong River Channel					
S No.	**Name of River Style**	**Description**	**Stretch Length**	**Average Slope**	**Sinuosity**
1	UC-BrC-OBrCb-Si-BoB	Laterally Unconfined - Bedrock Controlled - Occasional Bedrock Core bar - Sinous - Boulder Bed	16.7	2.60%	1.39
2	PC-BrCbC-OSb-Si-BoB	Partially Confined - Bedrock Core bar Controlled - Occasional Sandbar - Sinous - Boulder Bed	15.5	3.95%	1.33
3	PC-SbC-OBr-Si-SB	Partially Confined - Sand bar Controlled - Occasional Bedrock - Sinous - Sand Bed	27.2	2.40%	1.3
4	UC-BrC-OBrCb-BoB	Laterally Unconfined - Bedrock Controlled - Occasional Bedrock Core bar - Boulder Bed	7.65	3.30%	1.16
5	PC-SbC-OF-Si-CgB	Partially Confined - Sandbar Controlled - Occasional Floodplain – Sinous – Coarsegrained Bed	39.6	1.65%	1.23
6	PC-BrM-OSb-Si-CgB	Partially Confined - Bedrock margin - Occasional Sandbar – Snous - Coarsegrained Bed	22.3	2.55%	1.42

Table 3I. River style description of Ib River Channel					
S No.	**Name of River Style**	**Description**	**Stretch Length**	**Average Slope**	**Sinuosity**
1	UC-BrC-OBrCb-BoB	Laterally Unconfined - Bedrock Controlled - Occasional Bedrock Core bar - Boulder Bed	2.34	4.15%	1.08
2	PC-BrCbC-OSb-Si-BoB	Partially Confined - Bedrock Core bar Controlled - Occasional Sandbar – Sinous - Boulder Bed	22.7	1.95%	1.12
3	PC-BrCbC-OSb-CgB	Partially Confined - Bedrock Core bar Controlled - Occasional Sandbar – Coarsegrained Bed	21.3	2.35%	1.12
4	PC-BrCbC-OSb-FgB	Partially Confined - Bedrock Core bar Controlled - Occasional Sandbar - Finegrained Bed	12.5	2.95%	1.04

These variations reflect differences in valley confinement, slope, sediment characteristics, and fluvial processes that govern channel morphology.The river is also extensively regulated by hydraulic infrastructure. In the upper catchment, the Dudhawa Dam (constructed in the 1960s) and the Gangrel Dam (also known as Ravishankar Sagar Dam, commissioned in 1979) serve as key irrigation and water supply structures (Wikipedia, 2025a; Wikipedia, 2025b). Further downstream, the Hirakud Dam, one of the longest earthen dams in the world, impounds Asia's largest artificial reservoir and plays a crucial role in flood moderation, irrigation, and hydroelectric power generation (Wikipedia, 2025c; Ramsar, 2020). In addition, several small barrages and weirs contribute to water diversion and sediment regulation across the basin (Water Conflict Forum, 2018; Mongabay, 2021). Together, these geomorphic and anthropogenic controls shape the hydro-geomorphological evolution of the Mahanadi River from its upland source to its deltaic outlet.

Figure 13 (a). Certain glimpse of Field Visit photographs while taking observations of Mahanadi River Basin

Figure 13 (b). Certain glimpse of Field Visit photographs while taking observations of Mahanadi River Basin

Figure 13 (c). Certain glimpse of Field Visit photographs while taking observations of Mahanadi River Basin

Figure 13 (d). Certain glimpse of Field Visit photographs while taking observations of Mahanadi River Basin

8. Findings/ Summary

The report finds that the Mahanadi basin is a highly diverse, fluvially dominated system where lithology, tectonics, and monsoon hydrology together create a clear upstream–downstream transition in landforms, flood behaviour, and river styles, with significant human modification by dams and barrages. It concludes that systematic geomorphological and floodplain mapping using GSI datasets, SRTM DEM, Sentinel-1/2 and CWC data provides a robust base for risk-informed basin management, but also highlights growing flood susceptibility, sedimentation issues, and the need to integrate these insights into planning, infrastructure design, and conservation.

8.1. Key findings

- The upper basin in Chhattisgarh is dominated by hard-rock uplands (Vindhyan/Satpura, cratonic basement), steep confined valleys, gorges and bedrock-controlled channels, transitioning through piedmont and fans into broad alluvial valleys and craton-margin plains. The lower basin in Odisha shifts to dissected plateaus, extensive alluvial plains, and a large deltaic–coastal tract with active and older floodplains, levees, bars, islands, tidal flats, and mangroves.
- Geomorphological mapping from GSI (1:250k), combined with SRTM and fieldwork, shows a continuum from structural hills and pediplains in upper catchments to meander belts, point bars, oxbow lakes, terraces, paleochannels and valley fills in the central and lower reaches, especially along Seonath, Hasdeo, Jonk, Mand and Tel. Riverbed materials grade from boulders/cobbles in headwaters to gravel–sand in transitional zones and fine sand–silt–clay in lower alluvial tracts.
- Sentinel-1 SAR (2014–2024) processed on Google Earth Engine maps multi-year flood extents at 10 m, showing that roughly about one-fifth of the basin (≈25,000–30,000 km^2) is repeatedly flood-susceptible, with the most frequent and extensive inundation in the Odisha delta and lower plains (Cuttack, Jagatsinghpur, Kendrapara, Khordha, Puri) and major floodplain belts in Sambalpur, Bargarh, Subarnapur, Boudh, Angul and adjacent districts. Upper and mid-basin districts in Chhattisgarh (Raipur, Dhamtari, Mahasamund, Janjgir-Champa, Raigarh, Korba) act as primary runoff generators and show intense monsoon flooding and local inundation.

- Tributary-wise flood analysis indicates very high contributions and complex wave interactions: Sheonath and Hasdeo can reach peak discharges of several thousand m^3/s and strongly control downstream flood magnitudes; Pairi, Mand and Jonk act as important flash-flood or delay-wave contributors, shaping duration and synchrony with the main stem, with mapped inundation corridors often exceeding 10–25 km in width in major events.
- River style classification identifies 21 distinct styles along the main Mahanadi and multiple styles on major tributaries, spanning confined, partially confined and laterally unconfined valleys with combinations of straight, sinuous, meandering, braided and anabranching patterns and a wide spectrum of bed materials and bar/island configurations. This diversity is closely tied to valley confinement, slope and lithology, as well as to hydraulic infrastructure such as Dudhawa, Gangrel, Hasdeo Bango and Hirakud, which collectively alter flow regime, sediment delivery and channel morphology.
- The mapping also documents culturally important river islands (e.g., Maa Nathaldaai and Dhabaleswar temple islands), illustrating how geomorphic features underpin religious tourism, local economies and community identity in both Chhattisgarh and Odisha.

8.2. Concise summary

The report undertakes basin-wide geomorphological mapping of the Mahanadi using GSI geomorphology, SRTM-derived DEMs, Sentinel-1/2 data, CWC cross-sections and targeted field surveys to characterise landforms, river styles and floodplains from source to delta. It demonstrates a systematic upstream–downstream transition from bedrock-confined, high-energy reaches to low-slope, alluvial and deltaic plains with complex depositional systems, and quantifies flood susceptibility over the last decade through SAR-based floodplain mapping. By classifying main-stem and tributary river styles and relating them to lithology, slope, confinement, sediment and infrastructure, the study builds a process-based template that links geomorphology with hydrology, hazards, ecology and socio-cultural values across the basin.

9. Recommendations:

- Use the geomorphological and river-style maps as constraint layers in basin planning, dam/barrage operation rules, and alignment of new infrastructure (roads, embankments, bridges, intakes) to avoid active migration corridors, high-erosion banks and paleochannels that are prone to reactivation.
- Integrate the Sentinel-1 floodplain products into flood forecasting, zoning and land-use regulation, particularly in the mapped high-susceptibility tracts of the Odisha delta and key tributary confluences, and link these with CWC gauge data for real-time decision support.
- Prioritise river reaches with high lateral mobility, bar-dominated patterns and intense mining/land-use pressures (e.g., Hasdeo, IB, industrial belts) for detailed reach-scale studies, sediment budget assessments and restoration measures to recover channel capacity and reduce aggradation-driven flood risk.
- Recognise culturally and economically important islands and floodplain units as special management zones where maintenance of natural flow variability and sediment supply is essential to sustain both geomorphic stability and socio-cultural functions.
- Expand the geomorphological mapping framework to a periodically updated, operational tool by automating satellite-based monitoring (Sentinel-1/2, future missions) and routinely coupling it with climate-change–informed hydrological and hydraulic modelling for scenario analysis and long-term adaptation in the Mahanadi basin.

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