

PLANNING & DEVELOPMENT OF RIVER CORRIDOR BETWEEN BHEDAGHAT AND JABALPUR

Bachelor of Planning

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PLANNING & DEVELOPMENT OF RIVER CORRIDOR BETWEEN BHEDAGHAT AND JABALPUR

A THESIS PROJECT

*A Report submitted in partial fulfilment of the requirements for the Award of degree
Bachelor of Planning*

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DECLARATION

I **JAGAN RAJ M** Scholar No **2211002121** hereby declare that the thesis titled Planning & Development of River corridor Between Bhedaghat and Jabalpur submitted by me in partial fulfilment for the award of degree of Bachelor of Planning, at Maulana Azad National Institute of Technology, Bhopal, India, is a record of Bonafide work carried out by me. The matter/result embodied in this thesis has not been submitted to any other University or Institute for the award of any degree or diploma.

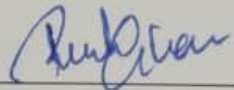
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This is to certify that the declaration made by **JAGAN RAJ M** is true to the best of my knowledge and that the student has worked under my guidance for one semester in preparing this thesis.

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ABSTRACT

Rivers play a crucial role in shaping urban and regional landscapes; however, increasing urban expansion has led to significant ecological degradation and spatial conflicts along river corridors. This study focuses on the Narmada River corridor between Bhedaghat and Jabalpur, aiming to analyze the physical, environmental, and developmental dynamics influencing the river-edge settlements.

The research adopts a spatial planning approach using GIS-based analysis, including slope, contour, natural drainage, road network, land use land cover (LULC), and vegetation assessment through NDVI. Temporal analysis of LULC (2015–2025) indicates a substantial increase in built-up areas, accompanied by a decline in vegetation cover, highlighting growing development pressure. The study further identifies environmentally sensitive zones, flood-prone areas, and conflicts arising from encroachment within designated river buffer zones, guided by URDPFI guidelines, RRZ norms, and NGT regulations.

Based on the analysis, the river corridor is classified into three distinct stretches—Bhedaghat (ecologically sensitive), middle stretch (transitional), and Jabalpur (urban influence zone). A zoning-based planning framework is proposed to regulate development and conserve the river ecosystem. The proposal emphasizes controlled development in urban areas, promotion of eco-friendly activities in transition zones, and strict conservation measures in sensitive regions.

The study contributes to sustainable river corridor planning by integrating spatial analysis with policy frameworks, providing practical guidelines for balancing development and environmental conservation. The proposed strategies aim to enhance ecological resilience, reduce conflicts, and support long-term sustainable development along the Narmada River corridor

सारांश

नदियाँ शहरी एवं क्षेत्रीय परिदृश्यों के निर्माण में महत्वपूर्ण भूमिका निभाती हैं, किन्तु तीव्र शहरी विस्तार के कारण नदी तटों के साथ पारिस्थितिक क्षरण और स्थानिक संघर्षों में वृद्धि हुई है। यह अध्ययन भेड़ाघाट से जबलपुर के मध्य नर्मदा नदी कॉरिडोर पर केंद्रित है, जिसका उद्देश्य नदी तट के आसपास के क्षेत्रों में भौतिक, पर्यावरणीय तथा विकासात्मक गतिशीलताओं का विश्लेषण करना है।

इस शोध में GIS आधारित विश्लेषण पद्धति अपनाई गई है, जिसमें ढाल, कंटूर, प्राकृतिक जल निकासी, सड़क नेटवर्क, भूमि उपयोग/भूमि आवरण, तथा NDVI के माध्यम से वनस्पति विश्लेषण शामिल है। 2015 से 2025 के बीच LULC के समयगत विश्लेषण से निर्मित क्षेत्र में उल्लेखनीय वृद्धि तथा वनस्पति में कमी पाई गई, जो विकास के बढ़ते दबाव को दर्शाती है। अध्ययन में URDPFI दिशानिर्देश, RRZ मानदंड तथा NGT विनियमों के आधार पर नदी बफर क्षेत्र में अतिक्रमण, बाढ़-प्रवण क्षेत्रों तथा पर्यावरणीय संवेदनशील क्षेत्रों की पहचान की गई है।

विश्लेषण के आधार पर नदी कॉरिडोर को तीन भागों में विभाजित किया गया है—भेड़ाघाट (पर्यावरणीय रूप से संवेदनशील), मध्य क्षेत्र (संक्रमण क्षेत्र) तथा जबलपुर (शहरी प्रभाव क्षेत्र)। एक जोनिंग आधारित योजना ढांचा प्रस्तावित किया गया है, जो विकास को नियंत्रित करते हुए नदी पारिस्थितिकी का संरक्षण सुनिश्चित करता है। प्रस्ताव में शहरी क्षेत्रों में नियंत्रित विकास, संक्रमण क्षेत्रों में पर्यावरण-अनुकूल गतिविधियों को बढ़ावा, तथा संवेदनशील क्षेत्रों में सख्त संरक्षण उपायों पर जोर दिया गया है।

यह अध्ययन स्थानिक विश्लेषण और नीतिगत ढांचे के एकीकरण के माध्यम से सतत नदी कॉरिडोर नियोजन में योगदान देता है, तथा विकास और पर्यावरण संरक्षण के बीच संतुलन स्थापित करने हेतु व्यावहारिक दिशा-निर्देश प्रदान करता है। प्रस्तावित रणनीतियाँ नर्मदा नदी कॉरिडोर में पारिस्थितिक संतुलन को मजबूत करने, संघर्षों को कम करने तथा दीर्घकालिक सतत विकास को समर्थन देने में सहायक होंगी।

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ABBREVIATION	FULL FORM
ESZ	Environment Sensitive Zone
GIS	Geographic Information System
GPS	Global Positioning System
Ha	Hectare
km	Kilometer
LULC	Land Use Land Cover
MDR	Major District Road
m	Meter
NDVI	Normalized Difference Vegetation Index
NGT	National Green Tribunal
NH	National Highway
RCC	Reinforced Cement Concrete
RRZ	River Regulation Zone
STP	Sewage Treatment Plant
URDPFI	Urban and Regional Development Plans Formulation and Implementation

CHAPTER 1

1.1 Background

In recent decades, rivers have re-emerged as a central focus of national and urban development discourse in India. Rapid urbanization, population growth, and infrastructure expansion have exerted increasing pressure on river systems, leading to issues such as ecological degradation, encroachment of riverbanks, altered hydrology, and declining environmental quality. Recognizing these challenges, the Government of India has initiated multiple policy frameworks, missions, and programmes aimed at river conservation and river-centric development.

Major initiatives such as Namami Gange Programme & River Centric Urban Planning Guideline, river rejuvenation missions, urban riverfront development projects, and integrated water resource management policies reflect a shift from viewing rivers merely as water channels to treating them as ecological, cultural, and spatial systems. These programmes emphasize pollution control, ecological restoration, public access, and integration of rivers with urban development.

Planning Gap

Policy intent frequently fails to translate into tangible spatial outcomes on the ground, particularly in the context of urban river corridors. Although policy frameworks often articulate objectives related to conservation, sustainable development, and integrated management, their implementation tends to remain fragmented across departments and jurisdictions. This disjointed execution weakens coordinated action and dilutes the overall impact of river management strategies. Moreover, the absence or inadequacy of robust physical planning controls—such as land use zoning, buffer demarcation, and development regulation along riverbanks—further exacerbates spatial inconsistencies. As a result, urban expansion often proceeds in direct conflict with river ecology, leading to encroachments, habitat degradation, and increased vulnerability to flooding. These challenges highlight the critical gap between policy formulation and spatial planning practice, particularly within rapidly urbanizing river corridors.

River-adjacent settlements grow without integrated land-use and environmental planning (Urban and Regional Development Plans Formulation and Implementation (URDPFI) Guidelines, 2014, National Water Policy, 2012, Namami Gange Programme & River Centric Urban Planning Guideline, Ramaswamy R. Iyer (2007) NIUA (National Institute of Urban Affairs).

1.2 Introduction

Rivers have historically played a critical role in shaping human settlements, economic activities, and cultural landscapes. In India, river corridors have functioned not only as ecological systems but also as lifelines for urban growth, providing water, fertile land, transport routes, and spiritual value. However, rapid urbanization, unregulated land development, infrastructure expansion, and tourism-oriented projects have increasingly altered natural river systems, leading to ecological degradation, flood vulnerability, and spatial conflicts between built and natural environments.

The Narmada River, one of the major perennial rivers of central India, holds immense ecological, cultural, and regional significance. The stretch between **Bhedaghat and Jabalpur** is particularly important due to its unique geomorphological features such as marble rock formations, waterfalls, religious ghats, tourism infrastructure, and expanding urban settlements. Over the years, this river corridor has experienced growing pressures from urban expansion, tourism-related construction, transport infrastructure, and informal settlement growth along the riverbanks.

Despite multiple policies and guidelines related to river conservation, floodplain management, and urban development, river corridors in Indian cities often lack integrated spatial planning. Development

activities frequently occur in isolation, focusing either on beautification or economic utilization, without addressing ecological continuity, land-use regulation, disaster resilience, and long-term sustainability. In this context, the Bhedaghat–Jabalpur River corridor presents a critical case for studying how physical planning can guide balanced river-centric development.

1.3 Aim of the Study

The aim of the study is to assess the impact of existing settlements and emerging expansion on the Narmada River corridor between Bedaghat and Jabalpur, and to develop a comprehensive physical planning proposal for river-corridor development.

1.4 Objectives

The specific objectives of the study are:

- To study the existing physical, ecological, and settlement characteristics of the Bhedaghat–Jabalpur River corridor. To analyse land-use patterns, settlement growth, and urban expansion trends along the river edge
- To identify environmentally sensitive zones, flood-prone areas, and development constraints within the corridor
- To assess policy provisions related to river management, urban development, environmental protection and other Guidelines applicable to the study area
- To evaluate conflicts between river ecology and existing development practices
- To propose spatial planning and development strategies for river corridor development.

1.5 Scope of the Study

The scope of the study is confined to the river corridor stretch between Bhedaghat and Jabalpur, including the immediate river influence zone on both banks. It primarily concentrates on physical planning dimensions such as land use patterns, settlement structure, infrastructure networks, open spaces, and environmental buffer zones. The study covers the river edge and adjoining built-up areas, encompassing urban, peri-urban, and tourism-influenced zones to capture the diverse spatial dynamics operating along the corridor. Analysis is carried out at both the corridor scale and the zone level to ensure a comprehensive understanding of settlement impacts and development pressures. However, the research does not extend to detailed hydraulic modelling or structural engineering design. Instead, considerations related to floodplains and ecological sensitivity are addressed through secondary data sources and spatial analysis techniques, aligning the study firmly within the domain of physical planning.

1.6 Need for the Study

The Narmada River functions not only as a vital ecological and cultural asset but also as a fundamental structuring element guiding settlement development in central India. The stretch between Bhedaghat and Jabalpur is currently undergoing rapid spatial transformation driven by urban spillover, expanding tourism activities, and incremental settlement growth. Despite its strategic importance, the river corridor

faces multiple challenges, as highlighted in the Jabalpur Development Plan, including unregulated riverbank development, encroachment into floodplains, degradation of water quality and riparian ecology, and increasing vulnerability to flooding and environmental stress. The lack of an integrated, river-corridor-based physical planning framework has led to fragmented development decisions that inadequately respond to river dynamics, rural–urban transitions, and long-term sustainability concerns. In this context, the study becomes essential to systematically assess existing spatial and environmental impacts and to propose informed planning interventions that achieve a balance between developmental pressures and ecological preservation.

1.7 Study Area

The study area encompasses the stretch of the Narmada River from Bhedaghat to Jabalpur showed in Figure 1&2, situated within Jabalpur district in Madhya Pradesh. Bhedaghat is widely recognized as a prominent tourist and religious destination, while Jabalpur serves as a major urban center in the region. This corridor demonstrates a clear spatial transition from relatively undisturbed natural river landscapes to dense urban development, making it an appropriate and meaningful context for examining river–urban interactions and planning interventions. The total length of the study stretch is approximately 21 kilometers, covering an area of about 2,845 hectares (28.54 sq. km), thereby providing a substantial spatial framework for corridor-level and zone-level analysis.

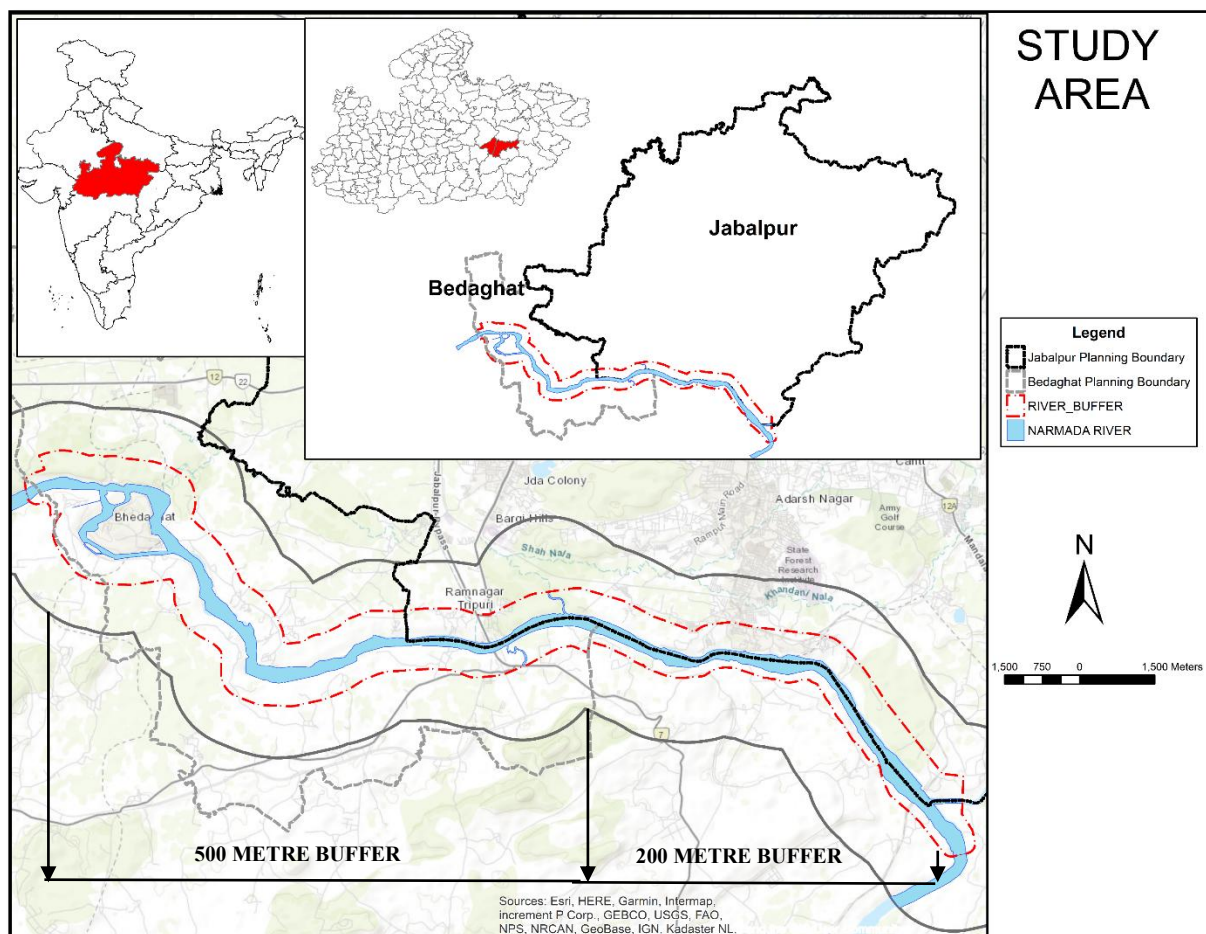


Figure 1 Study Area Location

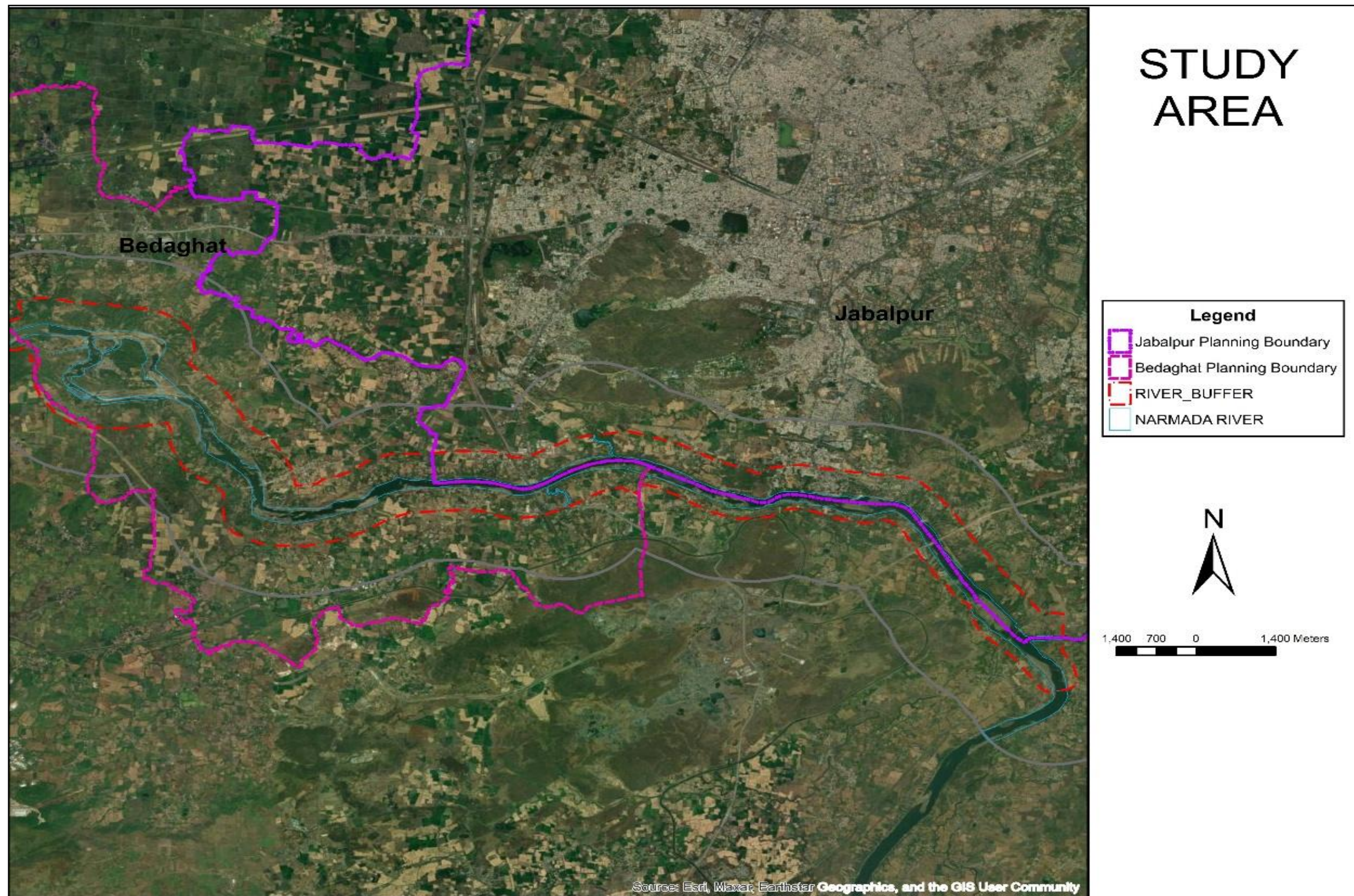


Figure 2 Study Area



Figure 3 Study Area 3D Map

1.8 Methodology

The research methodology is structured into four systematic stages to ensure a comprehensive and evidence-based planning approach for the Narmada river corridor between Bhedaghat and Jabalpur.

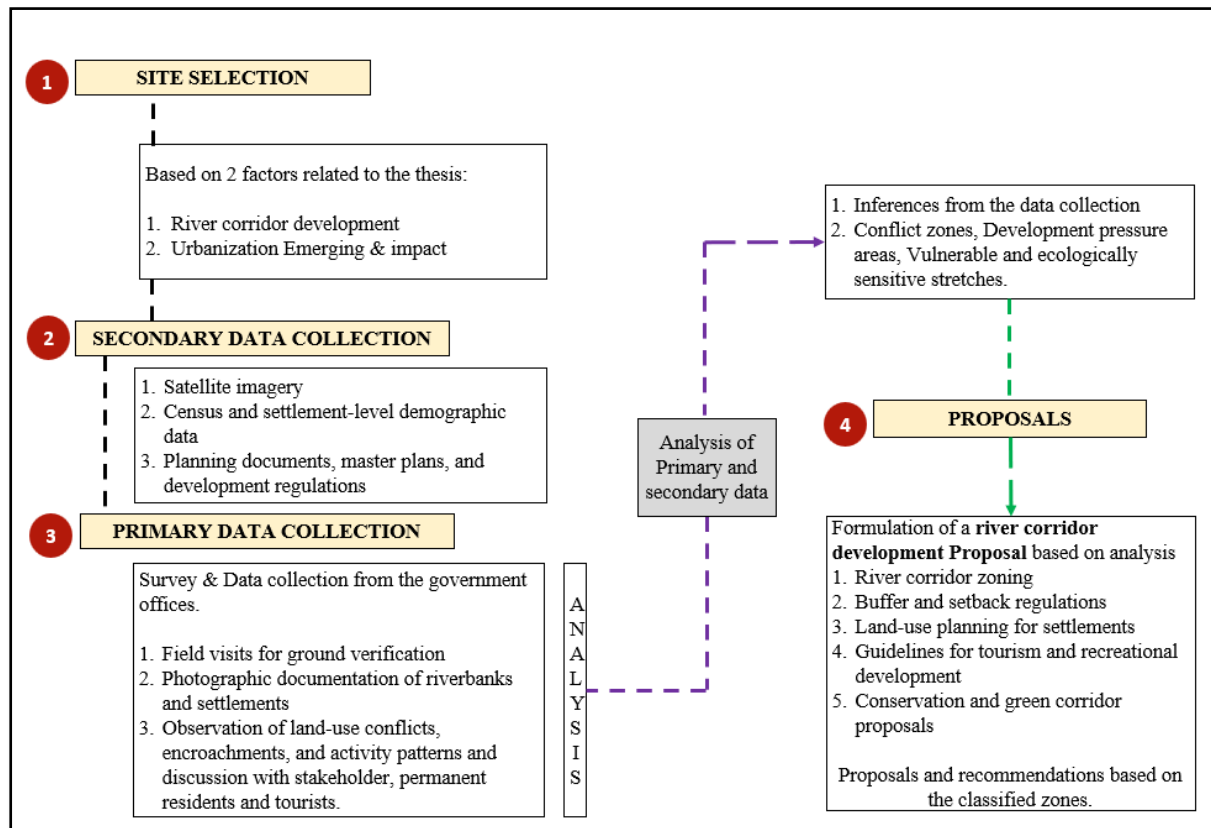


Figure 4 Methodology Map

Stage 1: Literature Review and Policy Review involves an extensive review of national, state, and local policies related to river planning, urban development, and environmental management. It also includes the study of Indian and international case studies on river corridor planning and river-sensitive urban development. This stage helps in identifying key planning parameters for analysis, understanding best practices, and assessing the broader impacts of urbanization on rivers.

Stage 2: Study Area Delineation, Base Map Preparation, and Impact Assessment focuses on delineating the river corridor from Jabalpur to Bhedaghat using satellite imagery and administrative boundaries. Base maps are prepared showing river alignment and width, settlement boundaries, transport networks, and land-use patterns. This stage also assesses the impacts of existing settlements and urban expansion on riverbanks, floodplains, natural drainage systems, riparian vegetation, and open spaces. The outcome of this stage is an accurate base map for spatial analysis along with an issues map highlighting key planning concerns.

Stage 3: Data Collection, Spatial Analysis, and Issues Identification integrates both secondary and primary data. Secondary data includes satellite imagery, land-use data, census and demographic information, and relevant planning documents such as master plans and development regulations. Primary data is collected through field visits for ground verification, photographic documentation of riverbanks and settlements, and on-site observations of land-use conflicts, encroachments, and activity patterns, along with discussions with stakeholders, tourists, and permanent residents. GIS-based spatial analysis is then conducted, including land-use and land-cover analysis, settlement growth and proximity

analysis, river buffer and floodplain mapping, and identification of environmentally sensitive and high-impact zones. This process enables the identification of conflict zones, development pressure areas, and vulnerable ecological stretches, resulting in thematic maps that illustrate existing conditions and problem areas.

Stage 4: Planning and Development Proposals builds upon the analytical findings to formulate a comprehensive river corridor development proposal. This includes river corridor zoning, buffer and setback regulations, land-use planning for settlements, guidelines for tourism and recreational development, and conservation and green corridor proposals. These components are integrated into a conceptual spatial plan for the entire corridor, culminating in a final river corridor development plan that balances ecological protection with sustainable urban growth.

1.9 Analytical Tools

The study employs a combination of analytical tools to ensure a systematic and evidence-based assessment of the river corridor. GIS-based spatial analysis is used to examine land-use patterns, settlement growth, buffer zones, and environmentally sensitive areas in a spatially integrated manner. Satellite image interpretation supports the identification of physical features, changes in land cover, and patterns of urban expansion over time. Detailed land-use mapping is undertaken to understand existing development distribution and its interaction with the river system. In addition, policy analysis is conducted to evaluate the relevance, gaps, and implementation challenges of existing regulatory frameworks. A comparative review of national and international case studies further strengthens the analysis by identifying transferable best practices and contextual lessons applicable to the Narmada River corridor.

1.10 Expected Outcomes

The expected outcomes of the study include:

1.10.1 Comprehensive understanding of physical and spatial dynamics

This refers to a detailed analysis of the corridor's land use structure, settlement morphology, ecological patterns, topography, river morphology, and growth trends. It means understanding how natural systems (river channel, floodplain, riparian zones) interact with human systems (settlements, roads, tourism, institutions). For your Bhedaghat–Jabalpur stretch, this is crucial because it represents a transition from a natural gorge landscape to an expanding urban fabric.

1.10.2 Identification of key issues affecting river corridor development

This includes recognizing problems such as floodplain encroachment, unregulated peri-urban growth, tourism pressure, ecological fragmentation, policy gaps, and governance conflicts. The outcome ensures that the proposal is problem-driven rather than only concept-driven.

1.10.3 Spatially defined river corridor zoning proposals

This means delineating the corridor into functional zones based on ecological sensitivity, flood risk, development suitability, and land-use compatibility. For example, conservation zones, controlled development zones, tourism management zones, and urban integration zones.

1.10.4 Planning guidelines for river edge development, conservation, and urban integration

These would be regulatory and design-based guidelines that inform building setbacks, permissible land use, buffer width, landscape treatment, access control, and infrastructure integration. The focus is on balancing ecological preservation with urban development.

1.10.5 Conceptual physical planning proposals

This refers to corridor-scale spatial strategies such as green buffer systems, ecological restoration nodes, regulated tourism clusters, mobility linkages, and settlement restructuring concepts. These proposals guide long-term development rather than providing only theoretical recommendations.

1.11 Conclusion

The study seeks to contribute to the growing discourse on river-centric planning in Indian cities by demonstrating how physical planning tools can be applied to manage development pressures while safeguarding river ecology. The Bhedaghat–Jabalpur corridor offers a valuable opportunity to develop a context-specific planning framework that can inform future river corridor development initiatives in similar urban settings.

CHAPTER 2 LITERATURE REVIEW

2.1 Introduction

River corridor planning represents a highly complex, interdisciplinary domain that operates at the intersection of urban design, hydrological management, ecological conservation, and socio-economic governance ((Ali et al., 2025); (Kirthika & Priyan, 2024). In the contemporary era of rapid global urbanization, inland aquatic systems—particularly rivers and floodplains—are subjected to unprecedented anthropogenic pressures, leading to severe spatial and morphological degradation (Amoateng et al., 2018). The dynamic nature of transitional river corridors, where natural ecological gradients abruptly interface with expanding urban frontiers, presents a critical spatial planning challenge. These corridors are not merely aquatic conduits; they are intricate socio-ecological systems that require planning frameworks capable of balancing intensive human activity with the preservation of vital environmental services.

The Narmada River corridor between Bhedaghat and Jabalpur in Central India exemplifies this transitional complexity. Spanning from the ecologically and culturally sensitive natural marble gorge of Bhedaghat to the rapidly expanding municipal limits of Jabalpur, the corridor features a fragile gradient of natural, rural, and urban land uses. Managing such a corridor necessitates moving beyond fragmented, piecemeal urban development. Instead, it requires a comprehensive physical planning approach that rigorously assesses the impacts of existing settlements, identifies environmental constraints, and reconciles emerging urban expansion with riverine ecology.

To establish a robust theoretical and methodological foundation for this thesis, a systematic review of 31 selected academic papers was conducted. These studies encompass a wide spectrum of Indian and international contexts, utilizing diverse geospatial, hydrological, and qualitative policy-analysis methodologies. To facilitate a critical synthesis, the reviewed literature has been categorized into seven distinct analytical themes: (A) River Corridor Planning, (B) Urban Expansion & Land Use Change, (C) Riparian Ecology & Environmental Sensitivity, (D) Floodplain & Risk Management, (E) River Governance & Policy Framework, (F) GIS and Spatial Analytical Methods, and (G) Conflict between River Ecology and Development.

2.2 Thematic Synthesis

2.2.1 River Corridor Planning

The conceptual paradigm of urban riverfronts has undergone a profound evolution. Historically, during the industrial era, urban riverfronts were viewed predominantly through a utilitarian lens, functioning as logistical hubs and, subsequently, as dumping grounds for urban waste and sewage (Simons et al., 2024). However, modern urban planning has shifted towards the concept of Integrated Riverside Development (IRD), a holistic approach that seeks to embed the river into the urban fabric sustainably while elevating the economic, social, and ecological quality of life for residents (Kirthika & Priyan, 2024).

A critical debate within the reviewed literature is the distinction between localized "riverfront development" and broader "river corridor planning." While traditional riverfront projects often prioritize hardscaped promenades, beautification, and commercial vitality—sometimes at the direct expense of natural hydrology and riparian ecology—corridor-scale approaches demand a comprehensive spatial understanding (Simons et al., 2024). For instance, the Sabarmati Riverfront Development in India successfully created vibrant public spaces and economic value, but drew criticism for heavily channelizing the river with concrete retaining walls, thereby altering its natural flow and ecological character (Simons et al., 2024). Conversely, a corridor-scale approach, as advocated in recent landscape urbanism frameworks, emphasizes the longitudinal continuity of the river, lateral riparian

buffers, and the integration of blue-green infrastructure to maintain the river's natural geomorphology (Ali et al., 2025; Li et al., 2026).

Theoretical perspectives on river corridor planning rely heavily on adaptive models and spatial identity. According to (Ali et al., 2025), the urban river landscape is a complex system of physical elements (water flow, riverbanks, green spaces) and urban elements (skyline, land use, pedestrian access). Successful integration requires translating these dimensions into actionable urban interventions, such as interconnected green corridors and multifunctional public nodes, rather than simply constructing rigid boundaries between the city and the water (Ali et al., 2025).

To operationalize these corridor-scale approaches, contemporary studies propose advanced spatial zoning paradigms. (Li et al., 2026) utilized a "Three-Zone Space" theory to categorize the highly compressed Yangtze River corridor into distinct ecological, agricultural, and urban functional zones. This macro-level theoretical guidance allows planners to implement differentiated management strategies—such as qualitative intensification in urban cores and absolute protection in ecological zones. Similarly, (Kirthika & Priyan, 2024) developed a land-use matrix technique for the Adyar River in Chennai, calculating eco-sensitivity to classify river stretches into development-prohibited, development-restricted, and development-optimized zones.

These zoning frameworks and the shift from hardscaped riverfronts to ecologically integrated blue-green corridors hold immense significance for the Bhedaghat–Jabalpur study. They provide the theoretical justification for proposing customized, eco-sensitive spatial regulations that can accommodate Jabalpur's urban pressures while strictly preserving the natural geomorphology and cultural heritage of the Bhedaghat gorge.

2.2.2 Urban Expansion and Land Use Change

The literature extensively demonstrates that rapid urbanization is the primary driver of river-edge degradation, fundamentally altering settlement morphology and peri-urban landscapes. (Amoateng et al., 2018) critically analyze the loss of inland aquatic systems in Kumasi, Ghana, revealing a staggering eighty-three percent reduction in floodplains driven by unregulated urban sprawl. This pattern of peri-urban transformation is mirrored in the Indian context, where (Kam et al., 2006) document a fifty percent reduction in the Mithi River's width in Mumbai due to the aggressive conversion of mudflats into built-up areas. These studies collectively argue that traditional land-use conversion prioritizes economic and residential expansion over hydrological preservation, leading to severe morphological constriction. Furthermore, (Odongo et al., n.d.) employ the Orfeo Toolbox open-source classifier to assess the Nairobi River, demonstrating how human-induced land-cover transitions systematically deplete riparian reserves.

When comparing spatial analytical techniques, a methodological evolution is evident across the literature. While studies like (Sharma & Khanal, 2024) successfully utilize macro-level datasets, such as the National Land Cover Database, to quantify a decade of forest-to-urban transitions in South Carolina, such medium-resolution approaches often fail to capture complex urban encroachment typologies in developing nations. Addressing this limitation, (Mishra et al., 2024) deploy high-resolution Unmanned Aerial Vehicle (UAV) photogrammetry along the Assi River in Varanasi. Their research reveals hidden micro-encroachments within immediate five-meter buffers that traditional satellite imagery overlooks. This methodological distinction is highly relevant for the Bhedaghat–Jabalpur thesis, as assessing the dense, informal settlement growth along the Narmada's rocky terrain will require high-precision spatial analysis to accurately identify encroachment typologies and formulate effective physical planning proposals.

2.2.3 Riparian Ecology and Environmental Sensitivity

Riparian buffers are consistently identified as critical ecological corridors that mitigate habitat fragmentation and sustain environmental flows. (Majumdar & Avishek, 2025) provide a comprehensive systematic review of riparian buffer zone degradation, critiquing the prevalent implementation of fixed-width buffers. They argue that rigid statutory lines fail to accommodate site-specific ecological continuities, advocating instead for an adaptive framework that adjusts buffer widths based on slope gradient, soil erodibility, and vegetation structure. This perspective is supported by (Olokeogun & Kumar, 2020), who utilize Google Earth Engine to map the vulnerability of riparian ecosystems in Dehradun, demonstrating that unplanned human disturbance severely compromises vegetation cover density and biodiversity indicators.

Ecological assessment frameworks across the literature emphasize the transition from passive conservation to active restoration prioritization. (Atkinson & Lake, 2020)) introduce a robust spatial modeling approach using the Water Quality Corridor Management for Restoration (WQCM-R) framework. By evaluating soil, slope, and land use, their model quantitatively prioritizes degraded riparian corridors in urbanizing Texas watersheds, allowing planners to target specific ecological interventions effectively. Synthesizing these studies reveals a strong consensus: effective riparian management requires integrating localized topological data rather than applying generic protective radii. For the Bhedaghat–Jabalpur corridor, which features a highly sensitive transition from a natural marble gorge to agricultural plains, employing an adaptive ecological assessment framework will be paramount for accurately delineating environmentally sensitive zones and preventing further habitat fragmentation.

2.2.4 Floodplain and Risk Management

Research on floodplain zoning and risk management underscores the catastrophic hydrological consequences of unchecked riverfront development. (Kasim et al., 2022) examine urban expansion into the wetlands of Lagos, Nigeria, concluding that the destruction of natural detention basins exponentially enhances flood risk. This is corroborated by (Zope et al., 2016) and (Zope et al., 2017) in their hydrological modeling of Mumbai's Oshiwara and Poisar River basins. Utilizing the HEC-HMS and HEC-RAS modeling suites, these studies demonstrate that land-use changes have increased peak flood discharges by over twenty percent, while the strategic preservation of natural detention ponds drastically mitigates inundation hazards. The methodological rigor of coupling hydrodynamic models with geographic information systems provides a defensible basis for evaluating urban flood vulnerabilities.

Further advancing flood risk mapping, (Tomar et al., 2021) employ linear regression of precipitation and gauge levels combined with spatial overlay analysis to demarcate precise flood boundaries along the Yamuna River in Delhi. Their research identifies specific vulnerable assets within the 207-meter and 208-meter high-flood levels, exposing how structural encroachments exacerbate backwater effects. A critical assessment of these methodologies reveals that while hydrodynamic models provide high accuracy, their reliance on extensive historical gauge data often limits their application in data-scarce developing regions. For the Narmada River corridor, where seasonal monsoon variations and upstream dam regulations dictate the flow, integrating spatial flood vulnerability mapping with topographical analysis will be a critical objective to identify development constraints and propose safe physical planning limits.

2.2.5 River Governance and Policy Framework

The evaluation of river basin governance models consistently exposes severe institutional fragmentation and policy-implementation gaps. (Piper, 2005) and Lerner and (Lerner & Holt, 2012) review river corridor management in the United Kingdom, arguing that while partnership models theoretically pool resources, they frequently fail due to a reliance on voluntary participation and a lack of unified statutory backing. In the Global South, these governance failures are often exacerbated by socio-economic

pressures. (Mwasenga & Mjemah, 2023) highlight the socio-economic unfeasibility of enforcing a strict sixty-meter riparian buffer law in Northern Tanzania, revealing that widespread poverty, urbanization, and a lack of public awareness render regulatory instruments entirely ineffective.

A significant consensus across the literature is the need to transition from top-down regulatory enforcement to evidence-based, participatory governance. (Urbanič et al., 2022) critique European riparian policies, advocating for a knowledge co-creation approach that integrates field managers, scientists, and local stakeholders into the policy formulation process. Similarly, (Majumdar & Avishek, 2025) note a profound policy vacuum regarding small and medium rivers in India, where national frameworks overlook local watershed dynamics. These insights directly inform the thesis objective of assessing policy provisions for the Bhedaghat–Jabalpur stretch, suggesting that proposed spatial planning strategies must bridge the disconnect between rigid state-level town planning regulations and the complex, on-the-ground socio-ecological realities of the local community.

2.2.6 GIS and Spatial Analytical Methods

The synthesis of spatial analytical methods reveals a sophisticated integration of remote sensing with multi-criteria decision analysis to resolve complex river corridor planning challenges. (Hazarika et al., 2015) utilize historical topographic maps and Landsat imagery within a GIS environment to quantify riverbank migration and erosion-driven land-use changes in the Brahmaputra plains. Moving beyond basic change detection, contemporary research employs advanced spatial modeling to construct ecological security patterns. (Chen et al., 2025) demonstrate this in Fuzhou, China, by coupling landscape pattern analysis software (Fragstats) with the Minimum Cumulative Resistance (MCR) model to mathematically map optimal green space networks and protect vital ecological corridors from urban fragmentation.

The integration of big data and zonation frameworks represents the forefront of spatial planning methodologies. (Li et al., 2026) formulate a structural-functional suitability assessment for the Yangtze River waterfront utilizing Point of Interest (POI) data combined with the Analytic Hierarchy Process (AHP) and Entropy weighting. Their framework rapidly classifies the riverbank into ecological, agricultural, and urban zones, exposing spatial mismatches between current land use and inherent ecological suitability. By synthesizing these diverse spatial tools—from UAV buffer analysis and morphological change detection to POI-driven multi-criteria zonation—a comprehensive methodological toolkit emerges. Applying these advanced spatial analytical techniques will directly empower the thesis to systematically evaluate the Narmada corridor, ensuring the spatial planning proposals are grounded in defensible, empirical spatial intelligence.

2.2.7 Conflict Between River Ecology and Development

The intersection of river ecology and urban development is characterized by profound socio-ecological tensions, particularly concerning tourism pressure, infrastructure expansion, and strivareal estate influence. (Srivastava & Sinha, 2025) critically analyze the impacts of urbanization on the sacred heritage zones of Varanasi, revealing that mass tourism and unchecked concrete infrastructure have severely degraded the natural vegetation and disrupted the ritualistic geography of the ghats. This tension is further explored by (Simons et al., 2024) in their comparative study of the Sabarmati and Patna riverfronts. They critique the Sabarmati model for relying on heavy concretization and channelization to maximize real estate and commercial value at the expense of ecological health, contrasting it with the Patna project, which successfully integrates soft engineering and community-centric ecological restoration.

Furthermore, the literature highlights how the built environment dictates human-river interaction. (Han et al., 2025) utilize machine learning algorithms to decipher how spatial environments influence physical activity along Shenzhen's waterfronts, proving that poor accessibility and over-commercialization alienate public engagement. (Dhandapani & Serrano, n.d.) echoes this in Chennai,

arguing that the Cooum River has been reduced to a polluted backyard due to institutional neglect and slum encroachment, entirely severing the socio-cultural connection between the city and its water. Comparing these conflict resolution approaches reveals that successful river corridor planning must synchronize economic vitality with social inclusivity and environmental sustainability. For the Bhedaghat–Jabalpur corridor, heavily influenced by religious tourism and encroaching real estate, resolving these tensions through eco-sensitive, inclusive spatial design will be the ultimate benchmark of the thesis proposal.

2.3 Identification of relevant papers

The selection of the core literature was driven by five stringent criteria. First, alignment with the thesis aim of assessing settlement impacts and developing physical planning proposals. Second, corridor-scale relevance, prioritizing studies that analyze continuous river stretches rather than isolated sites. Third, the successful integration of ecological constraints with human settlement dynamics. Fourth, direct policy applicability to riverfront zoning and regulation. Finally, methodological robustness, favoring studies that utilize advanced spatial analytical frameworks capable of replication. Based on these criteria, the following seven papers are ranked and selected for detailed critical discussion.

The top five Indian papers are ranked as follows. First, (Majumdar & Avishek, 2025) is selected as the premier source for its unparalleled policy analysis and adaptive buffer framework for Indian rivers. Second, (Kirthika & Priyan, 2024) is chosen for providing a highly replicable, matrix-based spatial zonation framework specifically designed for urban Indian rivers. Third, (Simons et al., 2024) ranks third for its critical comparative analysis of major Indian riverfront projects, offering a vital perspective on balancing ecology and hardscape development. Fourth, (Srivastava & Sinha, 2025) is selected due to its exact contextual parallel regarding the conflict between religious tourism heritage and rapid urbanization along a sacred river. Fifth, (Mishra et al., 2024) is included for its methodological innovation, demonstrating the necessity of high-resolution UAV mapping to detect micro-encroachments in dense Indian riverfront settlements.

The top two international papers are selected to provide advanced spatial modeling perspectives. Ranked first internationally, (Li et al., 2026) offers a highly sophisticated, corridor-scale methodology utilizing Point of Interest data and the Three-Zone Space theory to resolve complex functional conflicts along the Yangtze River. Ranked second internationally, (Atkinson & Lake, 2020) provides a quantitative, GIS-based prioritization model from the United States that is highly adaptable for identifying and protecting ecologically sensitive zones within rapidly urbanizing watersheds.

Detailed Critical Discussion of Selected 7 Papers

(Majumdar & Avishek, 2025) conduct a rigorous systematic review and field validation study focusing on the structural design and policy interventions required for Riparian Buffer Zones across small Indian rivers. Operating at a national basin scale with specific field validations along the Danro River, the authors utilize a PRISMA-guided thematic synthesis alongside stakeholder interviews to evaluate buffer performance. A key finding is that conventional fixed-width buffer policies fundamentally fail to address the complex socio-economic and topological realities of India's diverse landscapes. As a planning tool, they propose a tiered, variable-width buffer framework ranging from ten to one hundred meters, adjusted dynamically based on slope gradient, soil erodibility, and adjacent land-use intensity. The primary strength of this paper lies in its explicit bridging of local environmental governance with global Sustainable Development Goals, creating a highly defensible policy argument. However, its limitation is a reliance on broad policy reviews rather than providing a highly detailed, site-specific spatial mapping methodology. For the Bhedaghat–Jabalpur corridor, this paper provides the direct theoretical justification to discard rigid, state-mandated buffer setbacks in favor of proposing adaptive, slope-based zoning regulations that respond to the unique topography of the marble rocks and the adjacent agricultural plains.

(Kirthika & Priyan, 2024) operate at the corridor scale, developing an integrated regulatory framework for the Adyar River in Chennai. The methodology relies heavily on the Land Use Matrix technique, combining primary survey data with government land-use records to calculate the eco-sensitivity of different river segments. Their research culminates in the classification of the river corridor into three distinct typologies: development-prohibited, development-restricted, and development-optimized zones. The application of the Land Use Matrix serves as a powerful spatial planning tool, allowing planners to quantitatively justify land-use restrictions. The paper's strength is its direct applicability to physical planning, offering a ready-to-use framework for mitigating urban encroachment while improving city-river connectivity. A minor limitation is its exclusive focus on eco-environmental and socio-economic parameters, briefly omitting complex hydrodynamic flood routing. This framework can be perfectly replicated in the Bhedaghat–Jabalpur study to map sensitive zones and propose a definitive physical zoning master plan, explicitly dictating where tourism infrastructure can be optimized and where the natural gorge must be strictly prohibited from development.

(Simons et al., 2024) present a corridor-scale comparative case study evaluating the ecological frameworks of the Sabarmati Riverfront in Ahmedabad and the Ganga Riverfront in Patna. Utilizing a mixed-methods approach of archive analysis and user surveys, the study critically assesses the alignment of these mega-projects with the United Nations Sustainable Development Goals. The findings reveal a stark contrast: while the Sabarmati project successfully generated economic vitality through heavy concrete channelization, it severely compromised the river's natural ecological integrity. Conversely, the Patna model utilized soft engineering, retaining riparian vegetation and creating eco-centers that better supported socio-ecological harmony. The study excels in providing a critical lens on the philosophy of waterfront design, though it is limited by a relatively small survey sample size. The direct takeaway for the Narmada thesis is the imperative to adopt the Patna model's soft-engineering philosophy. Given the ecological fragility of the Bhedaghat gorge, this paper strongly supports an argument against concretized embankments, guiding the physical planning proposal toward sustainable, eco-centric design strategies.

(Srivastava & Sinha, 2025) focus on the localized site scale of Varanasi's Heritage Zone 1, investigating the impacts of rapid urbanization on a highly sensitive cultural landscape. The methodology employs multi-temporal Landsat imagery and supervised classification to perform land use change detection over two decades. The study quantitatively reveals a significant increase in built-up surfaces at the direct expense of natural vegetation and water bodies, concluding that uncontrolled commercialization and mass tourism are actively displacing traditional ritual spaces and degrading the sacred geography. The use of change detection algorithms is a standard yet effective tool for urban planning. The paper's strength is its deep integration of cultural heritage with physical spatial data, though its reliance on medium-resolution Landsat imagery slightly limits its ability to capture micro-level architectural modifications. Because Bhedaghat shares a nearly identical profile as a sacred, tourism-heavy riverfront, this study provides the essential contextual framework for evaluating conflicts between river ecology, heritage preservation, and aggressive development practices.

(Mishra et al., 2024) examine river-edge settlement morphology at a highly localized scale along the Assi River in Varanasi. To overcome the limitations of traditional satellite imagery, the researchers utilize UAV photogrammetry to generate high-precision orthophotos and Digital Surface Models with a five-centimeter resolution. Through precise GIS buffer analysis, the study finds that small rivers are disproportionately choked by informal urbanization, with encroachments entirely consuming the river channel in certain stretches. The application of UAV technology as a primary planning tool is the study's greatest strength, providing irrefutable spatial evidence of hidden structural encroachments within dense urban fabrics. The primary limitation is the high cost and operational complexity of scaling this method across massive river basins. For the Bhedaghat–Jabalpur thesis, this study highlights exactly what is missing in standard macroscopic analyses. It mandates the use of high-resolution mapping techniques

to accurately assess the settlement growth and informal encroachment occurring directly on the river edge, thereby supporting precise physical planning interventions.

(Li et al., 2026) provide an internationally sourced, corridor-scale analysis of the Yangtze River's Yichang section. The methodology is highly advanced, integrating the macro-level Three-Zone Space theory with micro-level Point of Interest big data. By applying an Analytic Hierarchy Process combined with Entropy weighting, the study evaluates structural-functional suitability across the riverfront. The key finding is a distinct spatial gradient where ecological functions dominate upstream, clashing with intense agricultural and urban functions downstream, revealing significant spatial mismatches between current land use and environmental suitability. The integration of POI data with suitability modeling represents a highly robust, replicable planning tool. While its strength is its comprehensive, multi-criteria objectivity, a limitation is that POI data often fails to capture informal, undocumented socio-economic activities prevalent in developing nations. This methodology can be highly adapted for the Narmada corridor to systematically categorize the transition from the ecological zones of Bhedaghat to the urbanizing limits of Jabalpur, providing a scientific basis for the proposed spatial master plan.

(Atkinson & Lake, 2020) operate at the basin scale within Texas, prioritizing riparian corridors for ecosystem restoration. They utilize the GIS-based Water Quality Corridor Management for Restoration model to analyze vegetation, surface slope, and soil erodibility. The study finds that highly urbanized, steeply sloped sub-watersheds with highly erodible soils receive the lowest scores, indicating the most urgent need for restoration. The application of spatial Multi-Criteria Decision Analysis tools provides an excellent mechanism for urban planners to rapidly allocate conservation resources. The methodology is incredibly strong in its quantitative rigor, though it is contextually limited to the ecological and policy frameworks of the Global North. Nevertheless, the spatial modeling logic is universally applicable. The direct takeaway for the Bhedaghat–Jabalpur study is the replication of this vulnerability scoring system. By mapping slopes, soil types, and vegetation loss along the Narmada, the thesis can scientifically identify specific environmentally sensitive zones and flood-prone areas, fulfilling a core objective of the research.

Methodological insights for thesis design

The synthesis of the reviewed literature yields profound methodological insights that will directly shape the analytical framework of the Bhedaghat–Jabalpur thesis. To accurately study the existing physical and settlement characteristics, the thesis must transcend the limitations of medium-resolution satellite data. Drawing from (Mishra et al., 2024), the methodology should incorporate high-resolution spatial mapping, potentially utilizing UAV imagery or advanced digital elevation models, to accurately digitize settlement morphology and detect micro-encroachments along the immediate river edge. This high-fidelity data extraction is critical for analyzing the complex, organic growth of informal tourism and residential clusters that define the corridor.

To identify environmentally sensitive zones and development constraints, the thesis will adapt the spatial modeling tools demonstrated by (Atkinson & Lake, 2020; Li et al., 2026). A Multi-Criteria Decision Analysis framework within a GIS environment will be constructed. By overlaying topographical parameters such as surface slope, soil erodibility, historical flood boundaries, and current vegetation cover, the methodology will quantitatively score and map vulnerability across the corridor. Furthermore, integrating the Three-Zone Space theory will allow for the systematic categorization of the corridor into distinct ecological, agricultural, and urban transition areas.

For the formulation of spatial planning strategies and policy evaluation, the methodology will directly replicate the Land Use Matrix technique introduced by (Kirthika & Priyan, 2024). By calculating eco-sensitivity against economic development potential, the thesis will build a defensible zonation framework. This will enable the classification of the Bhedaghat–Jabalpur stretch into development-prohibited, restricted, and optimized zones. Additionally, following the policy analysis approach of (Majumdar & Avishek, 2025), the thesis methodology will critically cross-reference these spatial

findings with existing Madhya Pradesh town planning regulations, culminating in the proposal of an adaptive, corridor-scale master plan that utilizes variable-width riparian buffers to reconcile urban expansion with riverine ecology.

Research Gaps

Despite the extensive volume of literature dedicated to urban riverfronts and hydrological modeling, significant research gaps persist that directly justify the necessity of the proposed thesis. A primary gap exists in the geographical and morphological focus of current research. The overwhelming majority of Indian river corridor studies concentrate on coastal megacities, such as Mumbai and Chennai, or the vast alluvial plains of the Ganges and Yamuna. Consequently, there is a profound lack of academic investigation into the transitional, hard-rock peninsular river systems of Central India. Medium-tier, rapidly expanding cities like Jabalpur, which intersect with geologically unique and culturally sensitive landscapes like the Bhedaghat marble gorge, remain critically underrepresented in contemporary spatial planning discourse.

Furthermore, a significant disconnect persists between ecological research and actionable spatial planning. While numerous studies excel at quantifying land-use change and diagnosing riparian degradation, they frequently fail to translate these environmental assessments into tangible, corridor-scale physical planning frameworks. There is a weak integration of traditional socio-cultural settlement dynamics with modern ecological vulnerability mapping. Additionally, policy evaluations frequently highlight the failures of rigid, one-size-fits-all buffer regulations but rarely provide localized, spatially explicit zoning alternatives tailored to specific transitional gradients.

The Bhedaghat–Jabalpur corridor presents a unique amalgamation of these unaddressed complexities. It features aggressive peri-urban expansion, immense religious and tourism-driven developmental pressure, and a highly sensitive, constrained geomorphological environment. By developing a comprehensive, ecologically integrated physical planning proposal based on high-resolution spatial analysis and adaptive zoning techniques, this thesis will directly address the identified gap in corridor-scale planning for medium-sized Central Indian cities, offering a replicable paradigm for harmonizing urban growth with vital riverine ecosystems.

This synthesis of spatial dynamics, ecological vulnerabilities, and governance frameworks establishes a robust theoretical foundation for addressing the complexities of the Narmada River corridor. By critically analyzing the successes and failures of global and national riverfront interventions, the literature justifies the transition toward adaptive, spatially explicit planning models. Building upon these conceptual and methodological insights, the subsequent chapter will detail the precise geospatial techniques, data collection protocols, and analytical matrices employed to operationalize these theories within the Bhedaghat–Jabalpur study area.

2.4 Scope and Limitation of selected papers

2.4.1 Scope Of The Study

The spatial scope of this research is explicitly confined to the Narmada River corridor, stretching between the ecologically sensitive natural marble gorge of Bhedaghat and the rapidly urbanizing municipal limits of Jabalpur. Thematically, the study adopts a comprehensive physical planning approach that synthesizes seven critical domains: river corridor planning, urban expansion and land-use change, riparian ecology and environmental sensitivity, floodplain and risk management, river governance and policy frameworks, Geographic Information Systems (GIS) and spatial analytical methods, and the inherent conflicts between river ecology and developmental pressures. By integrating these dimensions, the research operationalizes the concept of integrated riverside development, moving beyond isolated waterfront beautification to effectively address the socio-ecological complexities of this transitional landscape ((Kirthika & Priyan, 2024)).

The analytical focus is systematically directed towards quantifying land-use transformations, mapping the vulnerability of riparian ecosystems, identifying high-risk flood-prone areas by assessing spatial topography (Tomar et al., 2021), and critically evaluating existing river governance policies (Amoateng et al., 2018; Zope et al., 2016). To achieve these objectives, the study employs advanced methodological tools, utilizing GIS and remote sensing to perform spatial analysis, land-cover change detection, and multi-criteria eco-sensitivity zonation (Atkinson & Lake, 2020; Li et al., 2026). Furthermore, the research evaluates the morphological impacts of river-edge settlements and encroachment typologies to understand the spatial conflicts threatening the corridor's ecological integrity and cultural heritage (Mishra et al., 2024; Srivastava & Sinha, 2025). Ultimately, the planning outcomes of this investigation culminate in the formulation of context-specific development control strategies, adaptive spatial proposals, and robust conservation frameworks designed to harmonize Jabalpur's urban expansion with the Narmada River's natural dynamics. For instance, the spatial proposals will incorporate variable-width riparian buffer designs and structural-functional suitability models to regulate human activity along the riverbanks sustainably (Majumdar & Avishek, 2025).

2.4.2 Limitations Of The Study

While this research provides a comprehensive spatial planning framework, certain methodological and contextual limitations define its boundaries. Primarily, the study relies heavily on secondary data sources, including medium-resolution satellite imagery and historical hydrological records. Such data may possess inherent temporal limitations or constrain the detection of micro-level informal encroachments that are often hidden beneath tree canopies or within dense, organically grown urban fabrics (Mishra et al., 2024; Tomar et al., 2021). Furthermore, the spatial boundary is deliberately restricted to a corridor-level assessment rather than a macro-scale river basin analysis. Although a basin-wide hydrodynamic model would offer broader hydrological insights, the corridor scale is utilized to facilitate actionable, micro-level physical planning and functional zoning (Li et al., 2026).

Additionally, the evaluation of riparian ecology is constrained by limited primary ecological field data; consequently, the research relies on established geospatial indicators, such as vegetation cover density and slope gradient, to assess environmental sensitivity (Kumar et al., 2019; Olokeogun & Kumar, 2020). The study also acknowledges institutional data accessibility constraints, particularly regarding fragmented municipal land-use records and uncoordinated statutory policies across different administrative jurisdictions (Majumdar & Avishek, 2025). Finally, the proposed spatial strategies face inherent policy implementation uncertainty, as translating academic frameworks into enforced governance requires overcoming substantial administrative, financial, and socio-economic barriers (Mwasenga & Mjemah, 2023; Piper, 2005). Despite these defined boundaries, the methodological integration of robust geospatial analysis and adaptive zonation ensures that the study remains academically rigorous and practically highly relevant for sustainable riverfront management.

Table 1 Literature review of selected Paper

S.No	Author(s) & Year	Title of Paper	Study Area	Type (Indian / International)	Key Focus	Core Finding	Inference for My Thesis	Application in My Study (Bhedaghat–Jabalpur)
1	Kirthika & Priyan (2024)	Integrated Riverside Development Along Adyar River, Chennai	Adyar River, Chennai	Indian	River zoning and regulatory framework development.	A Land-Use effectively categorizes river edges into prohibited, restricted, and optimized zones.	Method: Land Use Classification technique for eco-sensitivity vs. economic potential.	Formulate a Zonal Master Plan separating Bhedaghat's restricted ecological gorge from Jabalpur's optimized urban edge. & Methodology
2	Majumdar & Avishek (2025)	Mitigating riparian buffer zone degradation through policy interventions and learnings from best practices	Danro River, Jharkhand	Indian	Adaptive Riparian Buffer Zone (RBZ) policy formulation.	Fixed-width buffers fail; adaptive widths (10–100m) based on slope, soil, and land use are essential.	Concept: Context-specific adaptive buffer framework based on topographical variables.	Delineate variable buffer widths (narrow/strict at rocky gorge, wider at agricultural plains) instead of generic setbacks.
3	Mishra et al. (2024)	Assessment of Encroachment along the Urban River using Unmanned Ariel Vehicle	Assi River, Varanasi	Indian	UAV-based micro-encroachment mapping in urban rivers.	High-resolution mapping reveals "hidden" structural encroachments missed by traditional satellite imagery.	Method: High-precision spatial mapping for informal river-edge settlements.	Utilize high-resolution spatial data to accurately digitize settlement morphology and map encroachments at Bhedaghat ghats.

4	Simons et al. (2024)	Assessing the impacts of ecological framework of Indian riverfront revitalization projects	Sabarmati (Ahmedabad) & Ganga (Patna)	Indian	Ecological impact evaluation of riverfront revitalization.	Soft engineering (Patna) sustains ecology significantly better than hard concrete channelization (Sabarmati).	Idea: Ecological riverfront design prioritizing softscapes and riparian retention over hardscapes.	Propose green terraces and natural riparian edges over concrete embankments to preserve the Narmada's natural character.
5	Srivastava & Sinha (2025)	Analyzing the Impacts of Urbanization on the Cultural Heritage of Varanasi City Heritage Zone 1, India	Heritage Zone 1, Varanasi	Indian	Urbanization impact on sacred riverfront heritage.	Unregulated commercialization and infrastructure expansion severely degrade natural vegetation and ritual spaces.	Concept: "Heritage-Sensitive Zoning" integrating cultural landscape protection with urban planning.	Design specific "Ritual/Heritage Zones" in Bhedaghat to balance high tourist influx with ecological and cultural conservation.
6	Li et al. (2026)	Structural-Functional Suitability Assessment of Yangtze River Waterfront in the Yichang Section: A Three-Zone Spatial and POI-Based Approach	Yangtze River, China	International	Structural-functional suitability assessment of large river corridors.	Combining "Three-Zone Space" theory with POI data effectively resolves functional land-use conflicts.	Concept: "Three-Zone Space" theory for macro-level spatial categorization and conflict resolution.	Map the entire continuous corridor into distinct Urban, Agricultural, and Ecological management units.

CHAPTER 3 ANALYSIS & FINDINGS

3.1 Introduction

This chapter presents a comprehensive spatial and analytical assessment of the Narmada River corridor between Bhedaghat and Jabalpur, with the objective of examining the interactions between natural systems and anthropogenic interventions within the study area. Building upon the methodological framework established in the previous chapter, the analysis integrates geospatial techniques, field observations, and secondary data sources to evaluate the existing physical, ecological, and settlement characteristics of the river corridor.

The analytical approach is structured around a series of thematic investigations, including land-use and land-cover distribution, settlement morphology, transportation networks, environmental sensitivity, and river-edge dynamics. Geographic Information System (GIS)-based spatial analysis forms the core of this assessment, enabling the identification of spatial patterns, growth trends, proximity relationships, and areas of conflict between development activities and riverine processes. Satellite imagery interpretation and ground-truthing further enhance the accuracy and reliability of the analysis.

A critical component of this chapter is the delineation of environmentally sensitive zones, flood-prone areas, and development constraint regions, which are essential for understanding the carrying capacity of the river corridor. In addition, the analysis evaluates the extent and nature of settlement expansion, particularly in peri-urban and tourism-influenced areas, highlighting patterns of encroachment, land-use transformation, and pressure on riparian ecosystems.

The findings presented in this chapter aim to identify key spatial issues and conflict zones arising from the interface between river ecology and existing development practices. These include unregulated riverbank development, loss of natural buffers, fragmentation of ecological corridors, and increasing vulnerability to flooding. By systematically synthesizing these insights, the chapter establishes a strong empirical foundation for the subsequent formulation of river corridor zoning and physical planning proposals.

Overall, this chapter serves as a critical bridge between data-driven spatial analysis and the development of context-specific planning interventions, ensuring that the proposed strategies are grounded in a rigorous understanding of on-ground realities and spatial dynamics.

3.2 Existing Features

The contour analysis of the Narmada River corridor highlights the variation in elevation and terrain morphology across the three segments—Bhedaghat, middle stretch, and Jabalpur—indicating differences in geomorphological character and development suitability. Figure 5 shows the spatial distribution of elevation across the study area, ranging approximately from 290 m to 380 m, reflecting the river valley structure and surrounding terrain.

The Bhedaghat stretch is characterized by closely spaced contours and significant elevation variation, generally ranging between 300 m and 330 m. This indicates a highly undulating and rugged terrain associated with marble rock formations and dissected landforms. The dense contour pattern reflects steep slopes and abrupt elevation changes, making this segment geomorphologically sensitive and unsuitable for intensive development. The terrain conditions reinforce its ecological importance and the need for strict conservation measures.

The middle stretch exhibits a relatively moderate terrain with elevations ranging from 320 m to 350 m. Figure 5 indicates that this segment acts as a transitional zone, where contour spacing varies between

moderate and wide, representing a mix of gentle slopes and localized elevated ridges. This variability suggests that certain areas may support controlled development, while others remain constrained due to slope and drainage characteristics. The terrain in this stretch provides a balance between stability and sensitivity.

The Jabalpur stretch is characterized by comparatively uniform and gently sloping terrain, with elevations generally ranging from 320 m to 340 m. Figure 5 further illustrates widely spaced contours in this segment, indicating gradual elevation change and relatively stable land conditions. These characteristics have facilitated urban expansion and infrastructure development. However, the presence of lower elevation zones near the river continues to pose potential flood risks, particularly where natural terrain has been modified.

Overall, the contour analysis emphasizes the transition from a highly sensitive and rugged natural landscape in Bedaghat to a relatively stable and urbanized terrain in Jabalpur. This variation underscores the need for segment-specific planning approaches, where Bedaghat is prioritized for conservation, the middle stretch for controlled development, and the Jabalpur stretch for managed urban growth with appropriate flood mitigation strategies.

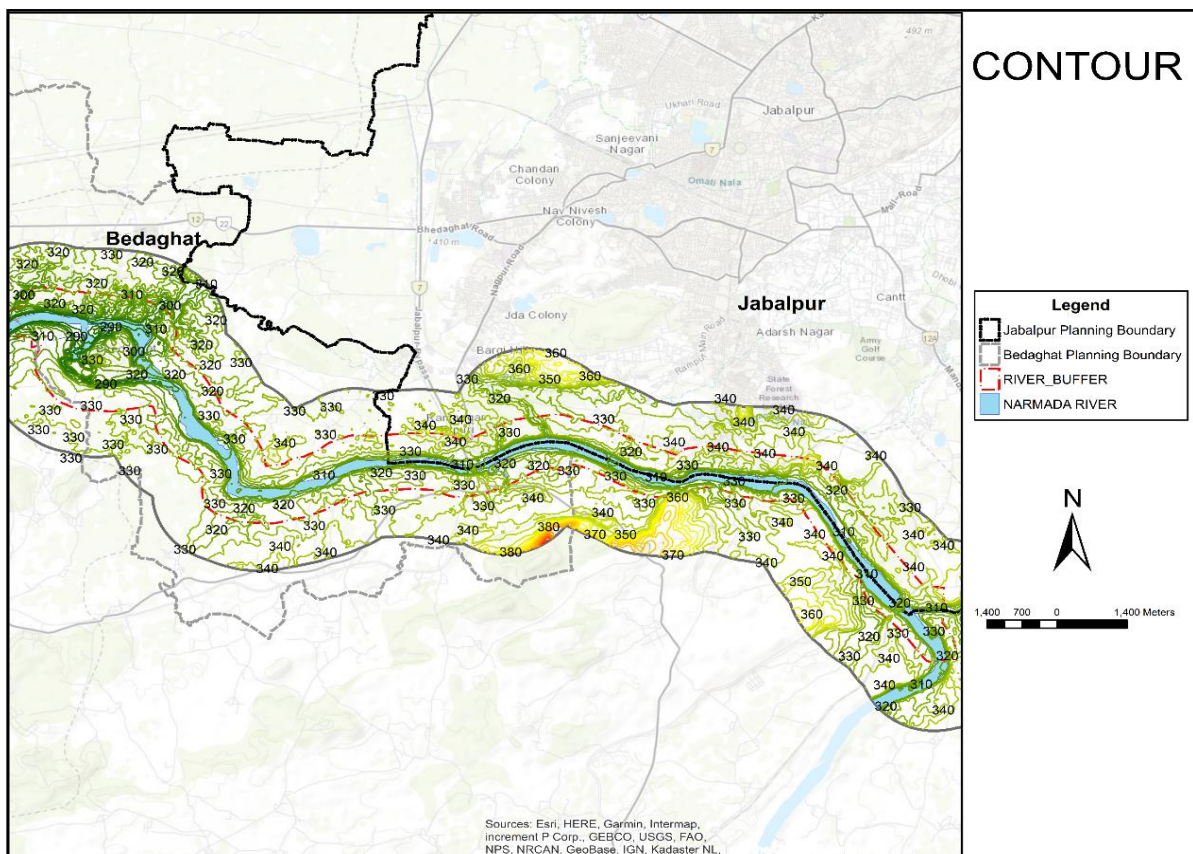


Figure 5 Contour Map

The slope analysis of the Narmada River corridor provides important insights into the physical characteristics of the study area and helps in understanding terrain suitability for conservation, development, and infrastructure planning. Slope is one of the most critical physiographic parameters in river corridor planning, as it directly influences land stability, erosion susceptibility, drainage behavior, construction feasibility, and ecological sensitivity. The spatial analysis carried out within the defined

river buffer reveals a clear variation in slope characteristics across the three major segments of the study area—Bhedaghat, the middle stretch, and Jabalpur. As illustrated in Figure 6, slope values in the corridor range from nearly flat terrain of 0–3% to steep slopes of 25–60%, reflecting the diverse geomorphological conditions that exist along the river system. This variation plays a crucial role in determining the carrying capacity of the landscape and forms an essential basis for identifying suitable planning interventions.

The slope distribution clearly indicates a strong spatial differentiation from upstream to downstream sections of the corridor. The upstream Bhedaghat segment is dominated by steep slopes and rugged terrain, the middle stretch exhibits moderate and transitional terrain conditions, while the downstream Jabalpur segment is characterized by relatively flat topography associated with urban expansion. This gradual transition reflects both natural geomorphological processes and human-induced landscape modifications over time. The analysis not only highlights areas suitable for future development but also identifies environmentally sensitive zones where intervention must be carefully regulated.

The Bhedaghat stretch emerges as the most topographically sensitive section of the corridor. The slope map indicates that a large portion of this segment falls within the higher slope categories of 15–30%, 30–45%, and in certain locations even 45–60%, represented by orange and red zones. These steep slopes correspond to the region's distinctive marble rock formations, deeply incised river channels, rocky escarpments, and gorge-like landforms that define the unique landscape character of Bhedaghat. The river has carved through hard geological formations over millions of years, creating a highly dissected terrain with abrupt elevation changes and unstable slope conditions. Such physical characteristics make the area ecologically fragile and highly sensitive to anthropogenic disturbances.

From a planning perspective, these steep slopes impose significant limitations on intensive development. Construction activities in such terrain require substantial slope modification, cutting, and stabilization measures, which may disturb the natural geological structure and increase the risk of landslides, rockfall, and soil erosion. The presence of steep gradients also reduces accessibility and increases infrastructure development costs. Moreover, disturbance of vegetation cover on steep slopes can accelerate surface runoff and sediment transport, negatively affecting river water quality and downstream ecosystems. Therefore, the Bhedaghat stretch is identified as highly unsuitable for conventional urban development or large-scale infrastructure expansion. Instead, this segment requires a conservation-oriented planning approach focused on protecting its geological heritage, ecological integrity, and landscape aesthetics. Low-impact interventions such as eco-tourism facilities, nature interpretation centers, scenic viewpoints, and controlled pedestrian infrastructure may be considered, provided they are designed with minimal ecological disturbance.

The middle stretch of the corridor presents a contrasting terrain profile and functions as a transitional zone between the steep upstream landscape and the relatively flat urbanized downstream section. The slope analysis indicates that this segment is dominated by low to moderate slope categories ranging from 3–8% and 8–15%, represented by green and yellow zones in Figure 6. Although isolated patches of higher slopes are present, the overall terrain is comparatively stable and less constrained by extreme topography. This transitional character reflects a gradual reduction in terrain ruggedness and an increase in alluvial and gently undulating landforms.

The moderate slope conditions of the middle stretch offer comparatively better suitability for planned development. Areas within this range generally support agricultural activities, rural settlements, and limited infrastructure development with relatively lower engineering challenges. However, the presence of localized slope variations and drainage channels requires careful site-specific evaluation before introducing new development. Unregulated construction or excessive land modification in these areas may disrupt natural drainage patterns, increase runoff concentration, and trigger localized erosion. Therefore, although this segment shows potential for development, it should be guided by controlled planning principles. Land-use activities such as agroforestry, eco-tourism, community-based recreation,

and low-density development may be accommodated, provided that environmental safeguards and slope-sensitive design guidelines are incorporated.

The downstream Jabalpur stretch is predominantly characterized by gentle slopes ranging from 0–3% to 3–8%, represented by the extensive green zones visible in the slope map. These low slope gradients indicate relatively flat terrain with minimal topographical constraints, which has historically supported urban growth, transportation infrastructure, institutional development, and settlement expansion in and around Jabalpur. The flat terrain facilitates ease of construction, accessibility, and utility provision, making it highly attractive for urban development. Consequently, this segment exhibits the highest concentration of built-up areas and anthropogenic interventions within the corridor.

However, while gentle slopes enhance development suitability, they also introduce a different set of environmental challenges. Low-gradient terrain often experiences slower surface runoff, which increases the risk of water stagnation, drainage congestion, and flood vulnerability, particularly in areas located close to the river or within natural floodplains. The study indicates that several parts of the Jabalpur stretch have undergone extensive land modification, including road construction, settlement expansion, and drainage alteration, which may have reduced the efficiency of natural hydrological systems. In the absence of adequate stormwater management and flood-resilient infrastructure, these areas remain vulnerable to seasonal flooding and waterlogging. Therefore, future planning in this segment must prioritize integrated drainage management, floodplain protection, permeable surface design, and restoration of natural water channels to ensure long-term urban resilience.

A comparative assessment of all three segments clearly demonstrates that slope plays a decisive role in shaping development patterns and ecological sensitivity within the river corridor. The steep and fragile terrain of Bhedaghat demands strict environmental conservation and minimal intervention; the moderately sloping middle stretch offers opportunities for controlled and context-sensitive development; and the flat Jabalpur stretch supports urban growth but requires robust flood and drainage management measures. This spatial variation confirms that a uniform planning approach cannot effectively address the diverse physical conditions of the corridor.

Overall, the slope analysis provides a strong scientific foundation for terrain-based zoning and decision-making within the river corridor. By integrating slope characteristics with land use, drainage, soil, and ecological parameters, planners can identify suitable zones for conservation, regulated development, and urban management. The findings emphasize the importance of adopting differential planning strategies that respect the natural carrying capacity of each segment while balancing environmental protection with developmental needs. Such an approach is essential for ensuring the long-term sustainability, resilience, and ecological integrity of the Bhedaghat–Jabalpur river corridor.

The natural drainage analysis of the Narmada River corridor reveals a well-defined hydrological network that is closely aligned with terrain and river morphology across the three segments—Bhedaghat, middle stretch, and Jabalpur. Figure 7 shows the spatial distribution of natural drainage channels, including primary tributaries and secondary nalas, converging towards the main river channel. The overall drainage pattern is predominantly centripetal, indicating that the Narmada River acts as the principal drainage spine, receiving runoff from the surrounding catchment.

The Bhedaghat stretch exhibits a dense and intricate drainage network, driven by its undulating and dissected terrain. Numerous small tributaries feed into the river, enhancing surface runoff and channel formation. This directly aligns with the study objective of identifying environmentally sensitive zones, as the high drainage density signifies increased susceptibility to erosion and ecological disturbance. Any alteration in this segment can disrupt natural flow regimes and negatively impact the fragile geomorphology.

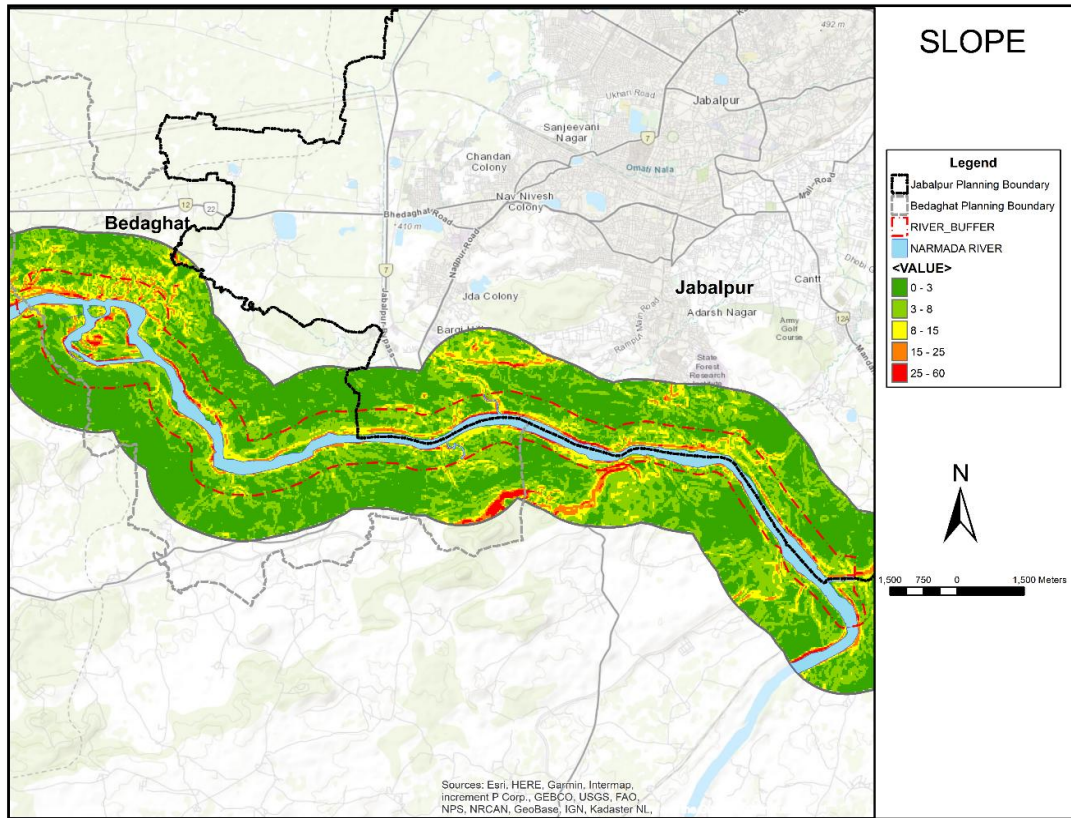


Figure 6 Slope Map

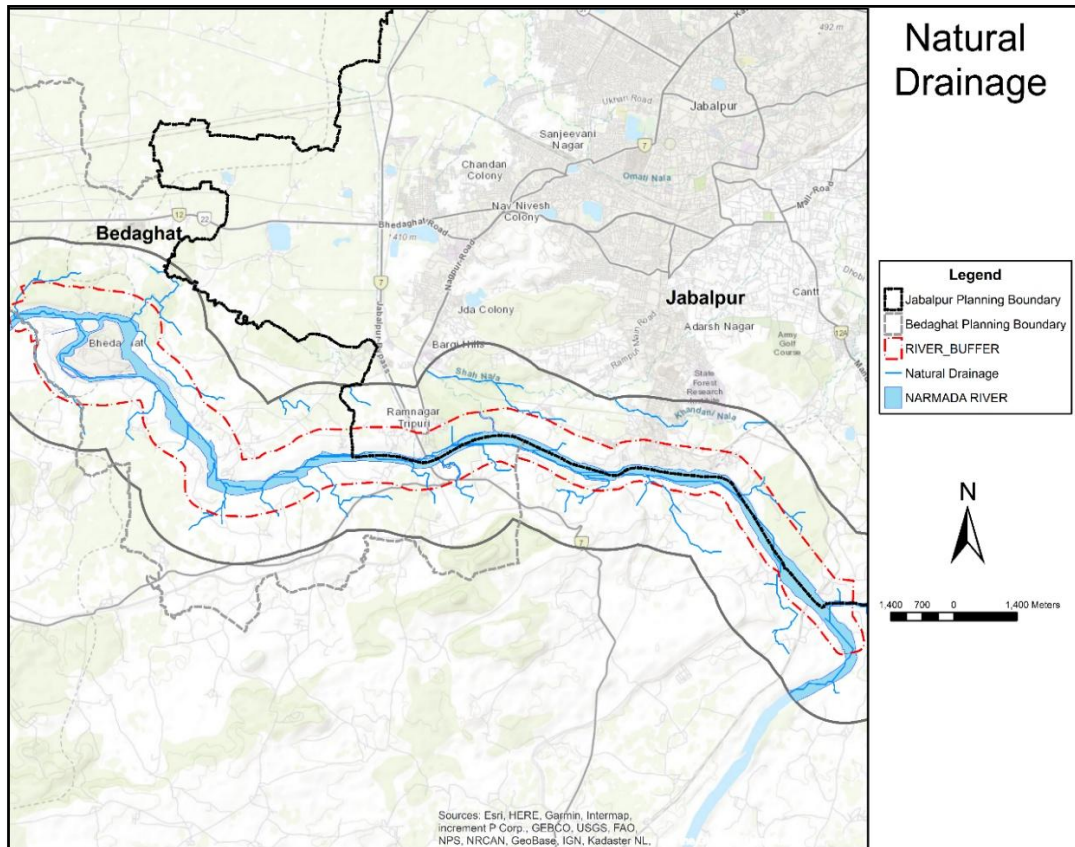


Figure 7 Natural Drainage Map

The middle stretch demonstrates a moderately dense and structured drainage system, where multiple secondary nalas intersect the river buffer zone. Figure 7 indicates strong hydrological connectivity between upland areas and the river corridor. In relation to the study objectives, this segment is critical for identifying development constraints and conflict zones, as these drainage paths often overlap with areas experiencing land-use transition. Unregulated development in such zones may obstruct natural drainage, leading to waterlogging and localized flooding.

The Jabalpur stretch shows a comparatively less dense but functionally significant drainage network, particularly within urban and peri-urban areas. The natural nalas are aligned with low-lying zones and act as key stormwater channels. This corresponds with the objective of evaluating conflicts between river ecology and development, as increasing urbanization in this segment has the potential to encroach upon or modify these natural drainage systems, thereby increasing flood vulnerability and disrupting hydrological balance.

Overall, the drainage analysis highlights the importance of hydrologically responsive planning, where the preservation and integration of natural drainage systems are essential to achieve ecological protection, minimize flood risks, and guide sustainable development along the corridor.

The road network analysis of the Narmada River corridor highlights the variation in accessibility, connectivity, and development intensity across the three segments—Bedaghat, middle stretch, and Jabalpur. Figure 8 shows the hierarchical distribution of transportation infrastructure, including national highways, major district roads (MDRs), and local roads, in relation to the river buffer and surrounding settlements.

The Bedaghat region is characterized by a relatively sparse and discontinuous road network, with limited connectivity primarily through local and minor roads. This low level of accessibility reflects the geomorphological constraints and ecological sensitivity of the area. In relation to the study objectives, this segment supports the identification of environmentally sensitive zones, where restricted accessibility has contributed to controlled development and preservation of natural landscapes. However, it also indicates limited infrastructure support for tourism and local mobility.

The middle stretch demonstrates moderate connectivity, primarily facilitated by major district roads (MDRs) and secondary road networks. Figure 8 indicates that this segment functions as a transitional connectivity zone, linking rural settlements with urban centers. This aligns with the objective of assessing land-use patterns and development trends, as improved connectivity in this stretch supports peri-urban growth, agricultural activities, and emerging development pressures. At the same time, increasing road penetration in proximity to the river may lead to potential conflicts with natural systems if not regulated.

The Jabalpur region exhibits a dense and well-developed road network, including the presence of national highways and an extensive local road system. This high level of connectivity enhances accessibility and supports intense urban development. In the context of the study objectives, this segment highlights areas of conflict between river ecology and development practices, as road infrastructure often encroaches upon the river buffer and influences land-use transformation.

A key observation is that several major roads run parallel to or intersect the river buffer zone, indicating strong interaction between transportation infrastructure and the river system. This has direct implications for planning, as such alignments may disrupt natural drainage, increase encroachment risks, and alter the ecological character of the river edge.

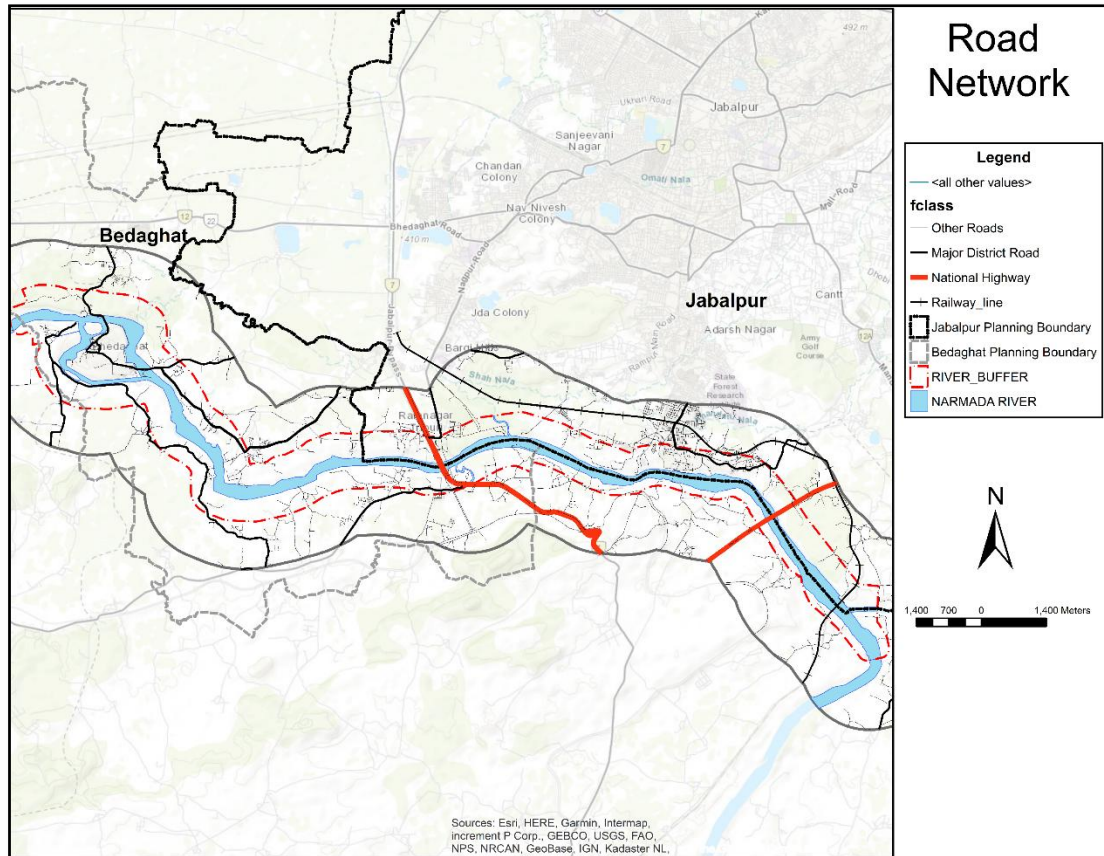


Figure 8 Road Network Map

. Increased accessibility also contributes to higher development pressure along the river corridor.

3.3 Existing Scenarios

The land use and land cover (LULC) analysis of the Narmada River corridor provides a comparative assessment of spatial transformation between 2015 and 2025, highlighting the changing dynamics of natural and built environments within the study area. Figure 9&10 shows the spatial distribution of major land use categories—agriculture, forest, built-up, and water bodies—while the accompanying charts quantify their proportional changes over time.

The analysis indicates that agriculture and forest land dominate the corridor, collectively accounting for the majority of land use in both time periods. In 2015, agriculture constituted approximately 45% and forest 44%, reflecting a predominantly natural and agrarian landscape. By 2025, these shares slightly declined to 42% (agriculture) and 41% (forest), indicating gradual land transformation. This reduction suggests increasing pressure on natural and productive landscapes due to expanding human activities.

A significant change is observed in the built-up area, which increased from 2% in 2015 to 7% in 2025, representing a substantial growth over a decade. This expansion is primarily concentrated along the river corridor, particularly in the Jabalpur stretch and parts of the middle stretch, where accessibility and infrastructure availability are higher. In relation to the study objectives, this trend directly supports the identification of urban expansion patterns and land-use transformation, highlighting areas experiencing development pressure and potential encroachment into ecologically sensitive zones.

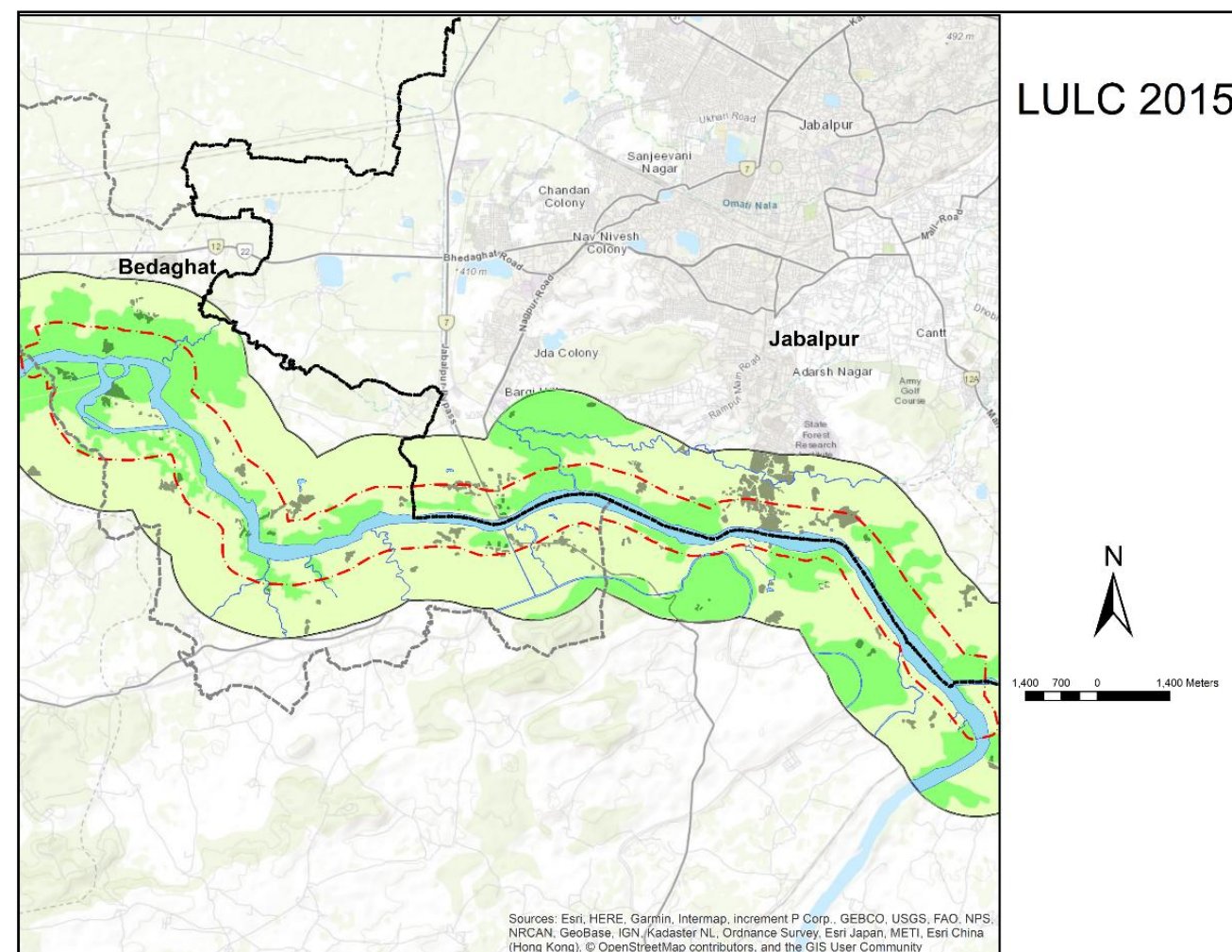


Figure 9 LULC MAP 2015

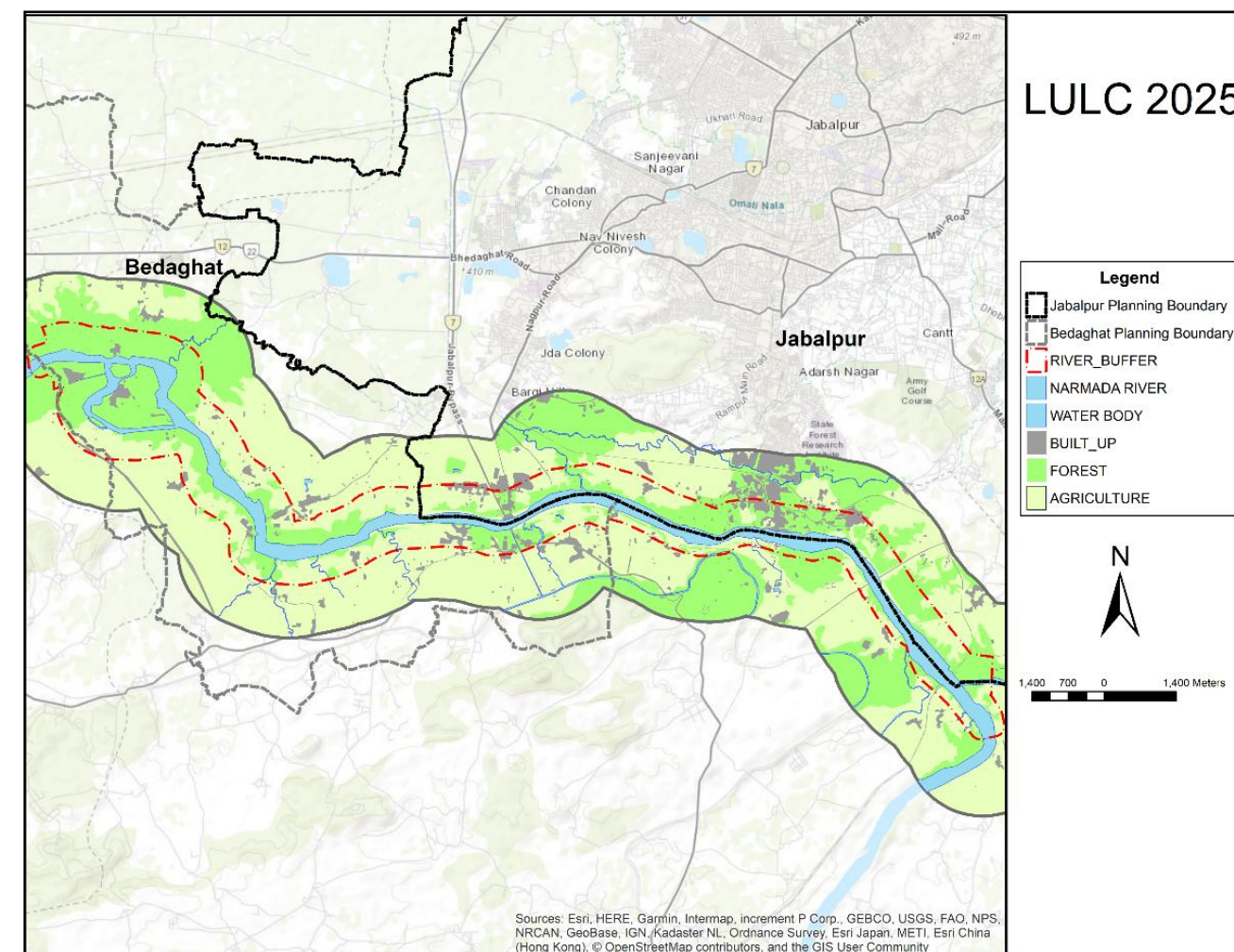
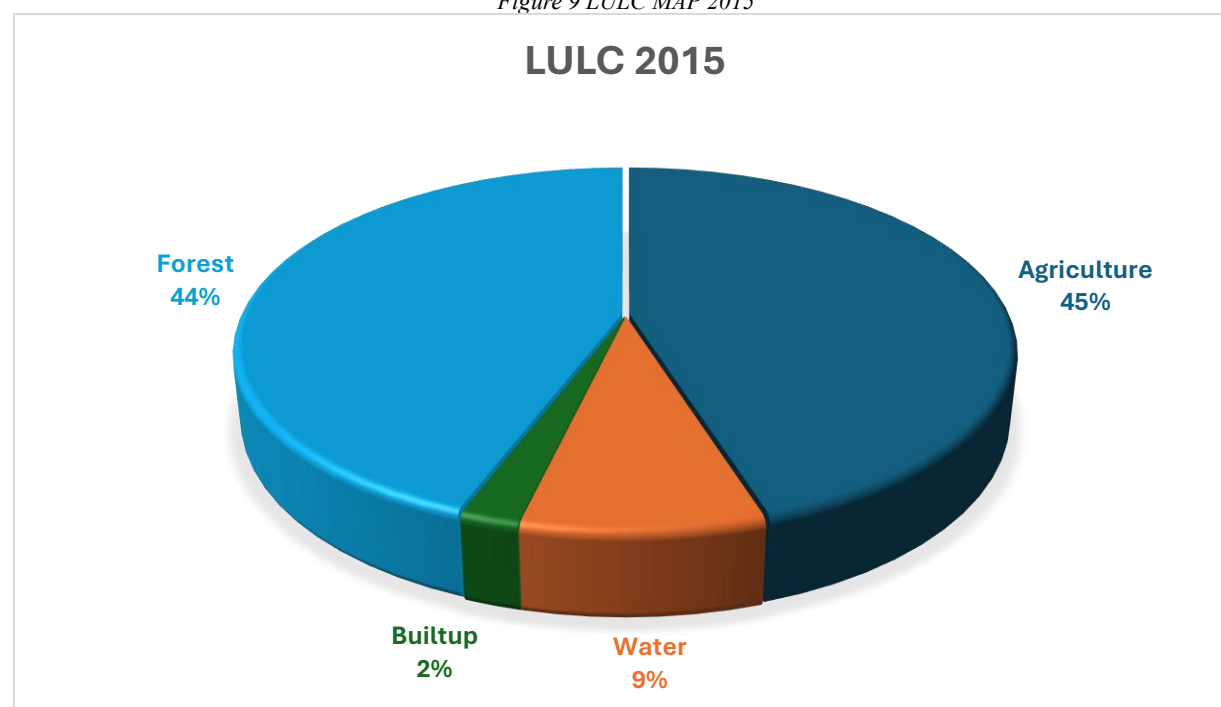
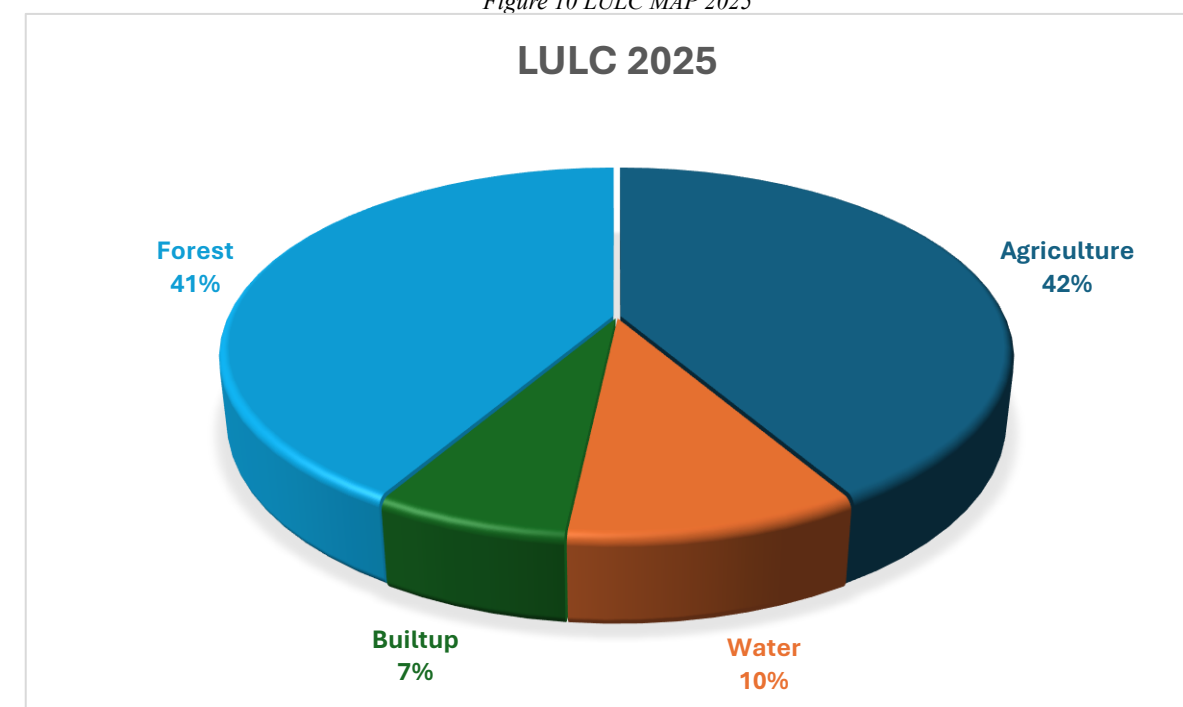


Figure 10 LULC MAP 2025



The water bodies category shows a marginal increase from 9% to 10%, which may be attributed to seasonal variations, improved mapping accuracy, or slight expansion of river and associated water features. However, this change remains relatively stable compared to other land use categories.

Spatially, the Bedaghat stretch continues to retain a higher proportion of forest and natural land cover, indicating limited anthropogenic disturbance and aligning with the objective of identifying environmentally sensitive zones. The middle stretch exhibits a mixed land-use pattern with increasing built-up patches, reflecting transitional peri-urban growth and emerging development conflicts. The Jabalpur stretch, on the other hand, shows a clear intensification of built-up areas, driven by urban expansion and infrastructure development, thereby highlighting significant conflict between river ecology and development practices.

A critical observation from the analysis is the encroachment of built-up areas within the river buffer zone, which poses risks to ecological integrity, natural drainage systems, and floodplain functionality. This directly relates to the objective of evaluating development constraints and environmental conflicts, emphasizing the need for stricter regulation and planning control.

Overall, the LULC analysis demonstrates a clear shift from a predominantly natural and agricultural landscape towards increasing urbanization within the river corridor. This transformation underscores the urgency for sustainable spatial planning strategies, including controlled development, protection of ecological zones, and regulation of land use within the river buffer to ensure long-term environmental and spatial balance.

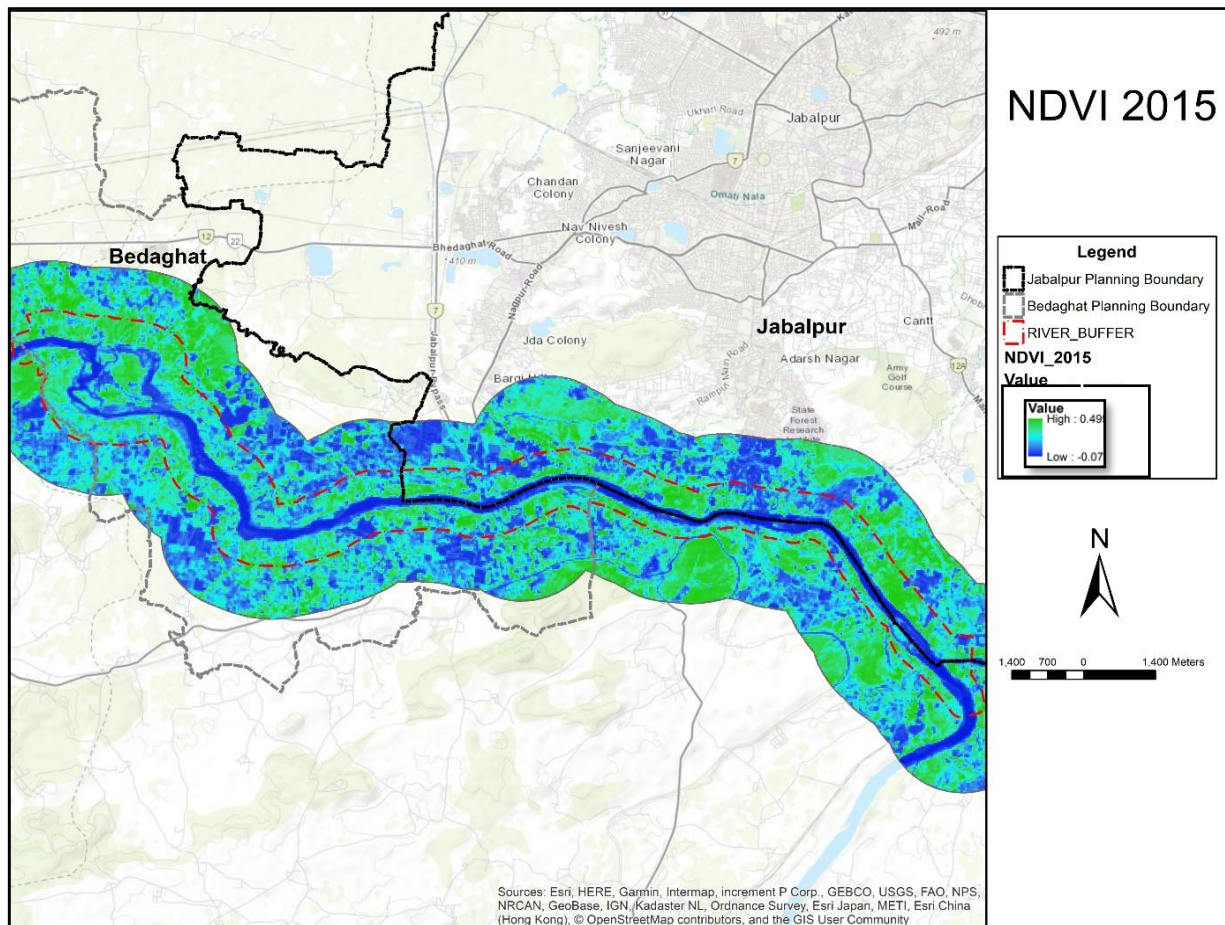


Figure 11 NDVI MAP 2015

The NDVI (Normalized Difference Vegetation Index) analysis provides a quantitative assessment of vegetation health and spatial distribution within the Narmada River corridor over time. Figure 11&12 shows the NDVI values for 2015 and 2025, ranging from approximately -0.07 to 0.49 , where higher values represent dense and healthy vegetation, while lower values indicate built-up areas, barren land, or water bodies

In 2015, the corridor exhibited a relatively higher presence of moderate to dense vegetation, particularly along the riverbanks and adjoining areas. The spatial pattern shows continuous green patches, indicating a stable and well-connected riparian ecosystem. This condition reflects minimal fragmentation and supports the ecological integrity of the river corridor. In relation to the study objectives, this aligns with the identification of ecologically stable zones, where vegetation cover plays a critical role in maintaining biodiversity, soil stability, and hydrological balance.

By 2025, a noticeable shift in NDVI values is observed, with a reduction in high NDVI zones and an increase in areas with lower NDVI values (blue regions). This indicates a decline in dense vegetation and a transition towards fragmented and discontinuous green cover. The spatial distribution suggests that vegetation loss is more prominent in areas experiencing development pressure, particularly in the middle and Jabalpur stretches. This directly supports the objective of assessing land-use transformation and environmental degradation, highlighting the impact of urban expansion and anthropogenic activities on natural ecosystems.

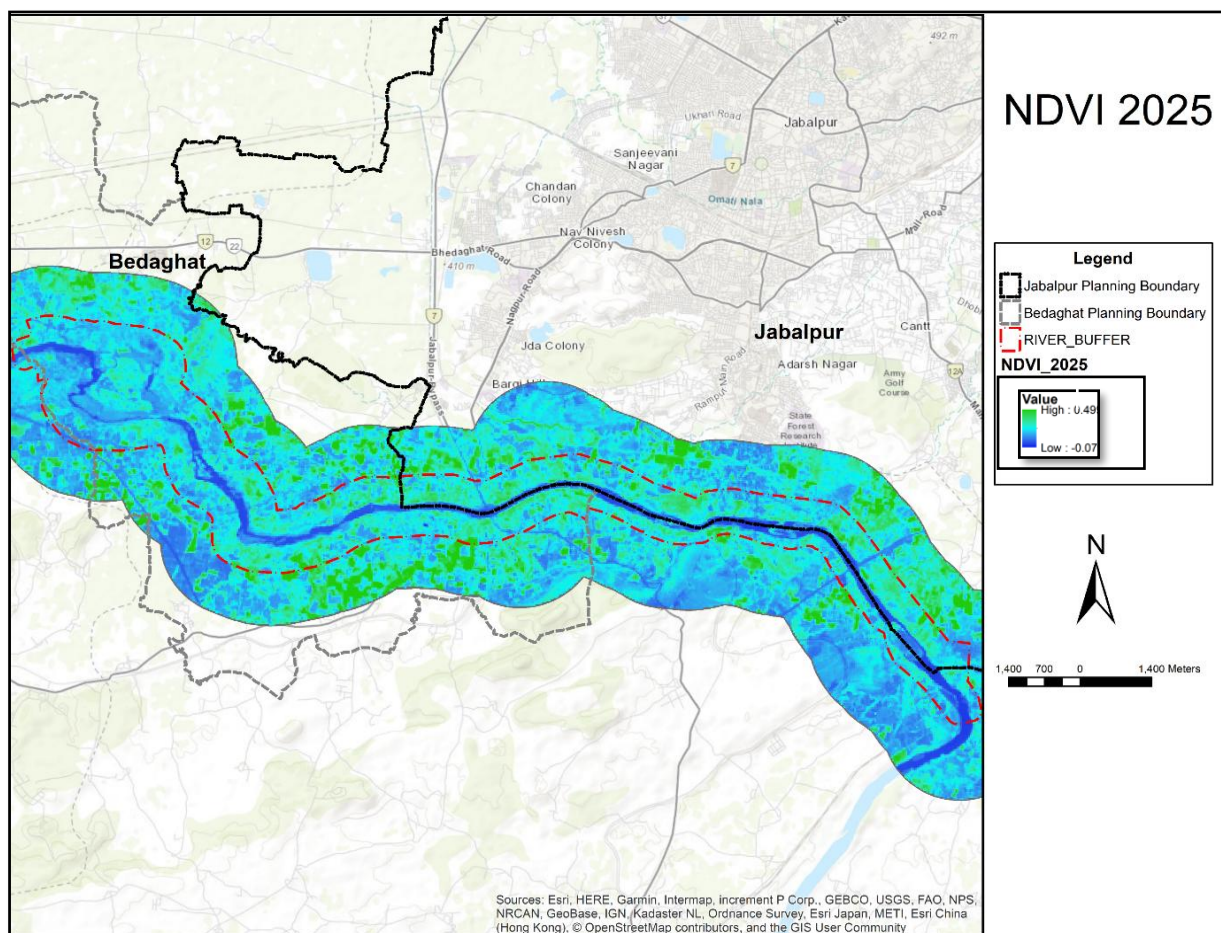


Figure 12 NDVI 2025

A critical observation is the fragmentation of vegetation along the river buffer zone, where previously continuous green corridors are now interrupted by patches of low NDVI. This has significant ecological implications, including reduced habitat connectivity, increased erosion risk, and weakened natural buffering capacity of the river edge. Such changes also contribute to higher vulnerability to flooding and environmental stress.

From a planning perspective, the NDVI analysis strongly reinforces the need for ecological conservation and restoration strategies, particularly in areas where vegetation loss is evident. It directly supports the objective of identifying environmentally sensitive zones and conflict areas, and provides a scientific basis for proposing green buffers, riparian restoration, and controlled development regulations.

Overall, the NDVI comparison highlights a clear trend of declining vegetation health and increasing ecological fragmentation within the corridor over the decade, emphasizing the urgency for integrating green infrastructure and conservation measures into future river corridor planning.

3.4 Conflict Area

The conflict area analysis, when examined in conjunction with existing policy and regulatory frameworks, reveals a significant mismatch between prescribed buffer regulations and on-ground development patterns within the Narmada River corridor. The identified conflict zones primarily occur where ecologically sensitive areas—such as floodplains, drainage channels, and riparian buffers—are subjected to increasing anthropogenic pressure.

As summarized in Table 1, the URDPFI Guidelines (2014) recommend a minimum setback of 30–100 m for rivers, allowing only limited and non-intensive development within this zone. However, the analysis indicates that several built-up areas, particularly in the Jabalpur and middle stretches, have extended into or are located in close proximity to these buffer zones. This encroachment contradicts the intended objective of protecting floodplains and maintaining ecological flow, thereby contributing significantly to conflict areas.

Table 2 Policy/Guideline Recommended Buffer

Policy / Guideline	Water Body Type	Recommended Buffer / Setback	Construction Permission	Purpose
URDPFI Guidelines 2014	Rivers	30–100 m minimum setback depending on river width and floodplain	Limited development such as parks, walkways, utilities; no dense construction	Protect floodplain, maintain ecological flow, prevent encroachment
URDPFI Guidelines 2014	Lakes / tanks	30 m buffer from edge of water body	Landscaping and recreation allowed; permanent buildings restricted	Protect water quality and recharge
URDPFI Guidelines 2014	Nala / drains	9–30 m buffer depending on drain width	No structures within the buffer; maintenance corridor required	Flood management and drainage protection
National Green	Major rivers	100–300 m or full floodplain protection	Permanent construction	Flood risk reduction and river

Tribunal Floodplain rulings	(Ganga, Yamuna etc.)	depending on local floodplain width	prohibited; only eco-friendly temporary activities allowed	ecosystem conservation
River Regulation Zone Policy	River corridors	Three regulatory zones (RRZ-1, RRZ-2, RRZ-3) based on distance from river	RRZ-1: No construction; RRZ-2: restricted development; RRZ-3: controlled development	Sustainable riverfront development and floodplain protection

Furthermore, as indicated in Table 2, URDPFI guidelines prescribe a 9–30 m buffer for nalas and drainage channels, with no construction permitted within this zone. The spatial analysis of natural drainage reveals that multiple tributaries intersect the river corridor, and in several instances, these drainage paths are either encroached upon or modified due to nearby development. This leads to disruption of natural hydrological systems, increasing the risk of waterlogging and localized flooding, and intensifying environmental conflicts.

The National Green Tribunal (NGT) floodplain regulations, also presented in Table 1, recommend a 100–300 m buffer or full floodplain protection, with strict prohibition of permanent construction. In contrast, the observed increase in built-up area—from 2% in 2015 to 7% in 2025—indicates a clear trend of development pressure within or near floodplain regions. This deviation highlights a critical gap between regulatory provisions and actual land-use practices.

Table 3 RRZ Development Control Guideline

Zone	Distance from River	Development Control
RRZ-1	0–50 m (or core river edge / active floodplain)	No construction permitted; only ecological conservation, river restoration, and essential utilities allowed
RRZ-2	50–100 m (or buffer transition zone)	Restricted development; low-impact activities such as parks, open spaces, walkways, and eco-tourism allowed; no permanent or dense construction
RRZ-3	Beyond 100 m (controlled development zone)	Controlled development permitted; regulated residential, commercial, and institutional uses with proper planning norms and environmental safeguards

Additionally, the River Regulation Zone (RRZ) framework, as outlined in Table 3, proposes a zonation-based approach with three categories—RRZ-1 (no construction), RRZ-2 (restricted development), and RRZ-3 (controlled development). However, the current spatial patterns suggest that development activities are not aligned with this framework. Built-up expansion and infrastructure development are observed even in areas that correspond to highly sensitive zones, thereby intensifying conflicts between river ecology and human interventions.

Table 4 Development plan Buffer Recommendation

Jabalpur Development Plan	30m Buffer from riverbank for urban development & and 300m buffer in protected areas
Bhedaghat Development Plan	300m buffer from riverbank

From a statutory planning perspective, the preparation and implementation of regional and local development plans play a critical role in regulating land use, guiding infrastructure growth, and ensuring environmentally sustainable development. In the context of the Narmada River corridor between Bedaghat and Jabalpur, the statutory frameworks represented by the Jabalpur Development Authority development plans—namely the Bhedaghat Development Plan and the Jabalpur Development Plan, as referenced in Table 4—provide a formal spatial framework for controlling urban expansion, protecting environmentally sensitive areas, and managing land use transitions. These plans identify specific land-use zones, development restrictions, infrastructure corridors, tourism zones, and environmentally regulated areas intended to maintain a balance between ecological conservation and developmental needs. However, the spatial conflict analysis conducted as part of this study reveals considerable discrepancies between planned statutory regulations and the actual patterns of development observed on ground.

The comparative analysis between planning provisions and existing land-use conditions indicates that although regulatory mechanisms are formally established, their implementation on the ground remains inconsistent across different sections of the river corridor. This mismatch is particularly evident in areas experiencing rapid urbanization, tourism-driven commercialization, and informal land conversion. The analysis demonstrates that several ecologically sensitive zones, natural drainage channels, riparian buffers, and flood-prone lands are increasingly subjected to developmental pressure, resulting in spatial conflicts between ecological functions and urban growth.

The Bedaghat stretch of the study area presents a relatively controlled development pattern when compared to the urbanized Jabalpur segment. This can largely be attributed to the unique geomorphological characteristics of the Bedaghat region, including steep rocky escarpments, marble formations, gorge systems, and highly undulating terrain, which naturally limit extensive construction activities and large-scale urban expansion. These physical constraints act as an inherent development control mechanism, restricting the intensity of anthropogenic interventions within immediate riverfront areas. However, despite these natural limitations, the analysis identifies emerging localized conflicts associated with increasing tourism activities. The growing popularity of Bedaghat as a major tourist destination has resulted in the expansion of tourism-related infrastructure such as hotels, parking facilities, commercial establishments, access roads, recreational spaces, and temporary vendor settlements. In several locations, these developments are found to be occurring in close proximity to environmentally sensitive zones, thereby posing localized threats to slope stability, riverbank integrity, vegetation cover, and overall landscape character.

In contrast, the Jabalpur stretch exhibits significantly higher levels of spatial conflict due to rapid urban expansion and increasing developmental pressure. As a major urban center, Jabalpur has experienced substantial population growth, infrastructure development, residential expansion, and industrial activity over the past decades. The conflict analysis indicates that these urbanization processes are increasingly extending toward the river corridor, often encroaching upon ecologically sensitive zones, floodplains, riparian buffers, and natural drainage corridors. In multiple locations, built-up developments including residential colonies, transportation infrastructure, institutional campuses, and commercial establishments are observed within areas that are identified as environmentally regulated or hydrologically significant under statutory planning provisions. Such encroachments not only reduce the ecological resilience of the river system but also disrupt natural hydrological processes, increase surface runoff, intensify erosion risks, and reduce groundwater recharge potential.

The spatial comparison between planned land-use regulations and existing development patterns further reveals that the issue is not merely the absence of policy frameworks, but rather the limited effectiveness of implementation, enforcement, and inter-agency coordination. Although multiple regulatory instruments—including the Ministry of Housing and Urban Affairs issued URDPFI Guidelines (2014), proposed River Regulation Zone norms, state-level environmental regulations, and local development

plans—provide planning provisions for ecological protection and development control, their translation into enforceable spatial actions remains fragmented. As highlighted in Table 1, Table 2, and Table 3, overlaps between institutional jurisdictions, lack of integrated spatial databases, weak monitoring mechanisms, and inconsistent enforcement practices have created implementation gaps that allow unauthorized development and gradual encroachment within environmentally sensitive areas.

The conflict area analysis undertaken for the Narmada River corridor provides a spatially explicit assessment of these implementation gaps by identifying the extent of built-up encroachments within designated river buffer zones. The analysis incorporates relevant statutory and policy provisions derived from the URDPFI Guidelines (2014), River Regulation Zone norms, and applicable development plans to establish regulatory buffer thresholds for environmental protection. Using GIS-based spatial overlay techniques, built-up land-use layers were compared against delineated river buffer zones to identify areas of direct conflict between existing development and prescribed environmental setbacks.

To capture variations in regulatory sensitivity and planning scenarios, three buffer distances—30 meters, 100 meters, and 300 meters—were considered in the analysis. The 30-meter buffer represents the minimum immediate protection zone intended to safeguard riverbank stability and prevent direct physical intrusion. The 100-meter buffer represents an intermediate ecological management zone aimed at preserving riparian vegetation, drainage continuity, and hydrological functions. The 300-meter buffer represents a broader ecological influence zone intended to regulate urban growth, control land-use intensity, and maintain long-term environmental sustainability within the river corridor.

The spatial outputs generated through this analysis, as illustrated in Figure 13, Figure 14, and Figure 15, clearly demonstrate increasing levels of land-use conflict across all three buffer scenarios. While the 30-meter buffer highlights direct encroachments along immediate river edges, the 100-meter and 300-meter scenarios reveal a substantially larger extent of urban influence, particularly in the Jabalpur segment where built-up expansion has penetrated deep into environmentally sensitive areas. The results indicate that conflict intensity is not uniformly distributed across the corridor but is concentrated in zones characterized by high accessibility, transportation connectivity, and urban development pressure.

Overall, the conflict analysis strongly supports the study objective of evaluating existing policy provisions and identifying discrepancies between statutory planning intentions and actual development practices within the Narmada River corridor. The findings reveal that despite the presence of multiple regulatory frameworks, significant gaps persist in implementation, monitoring, enforcement, and spatial integration of policies. These challenges highlight the urgent need for a context-specific and enforceable river corridor planning framework that integrates ecological sensitivity, geomorphological constraints, urban development controls, and institutional coordination. Such a framework is essential not only for protecting the ecological integrity of the Narmada River system but also for guiding future development in a manner that ensures long-term environmental resilience and sustainable regional growth.

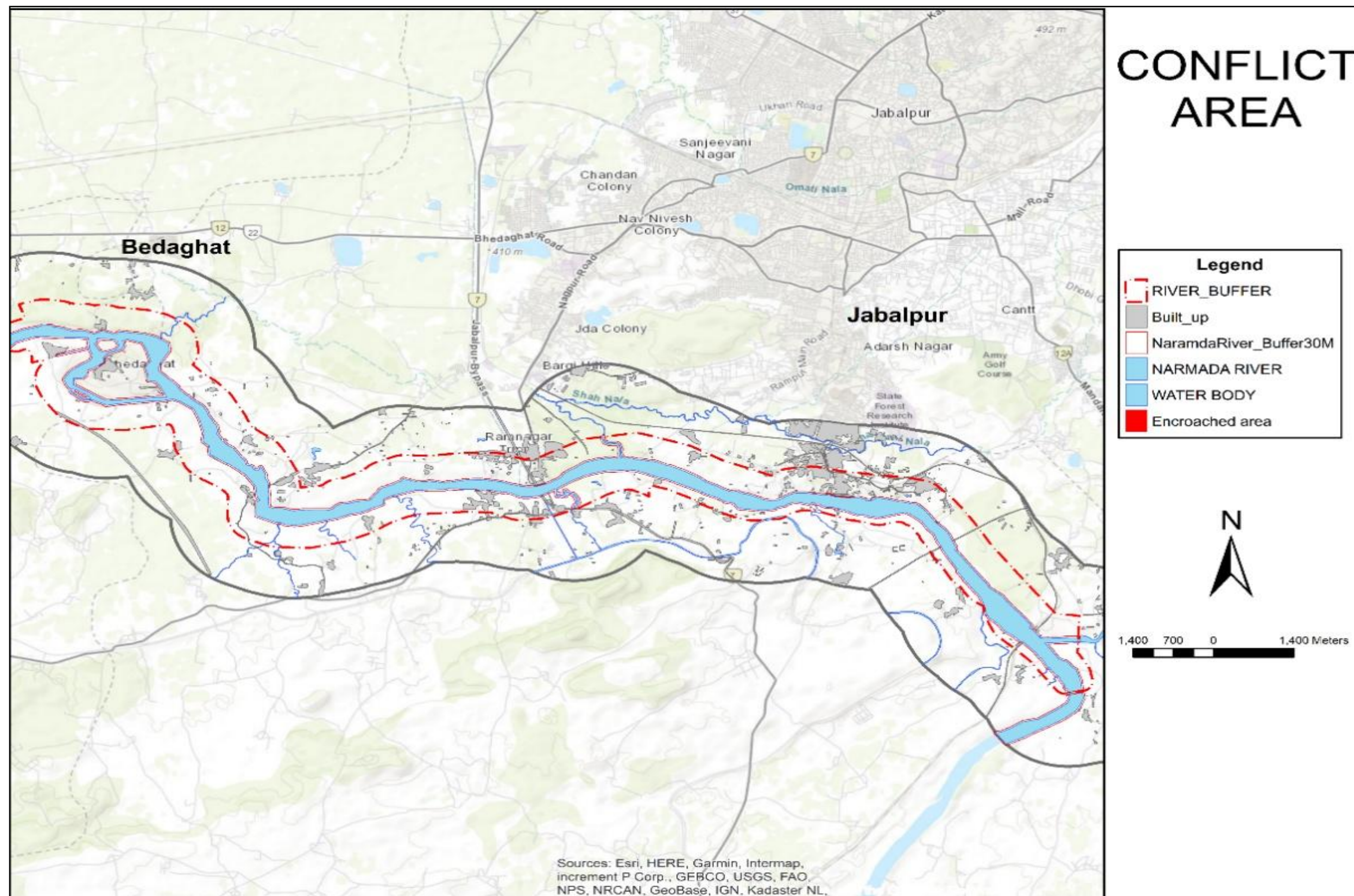


Figure 13 Conflict area 30 metre buffer

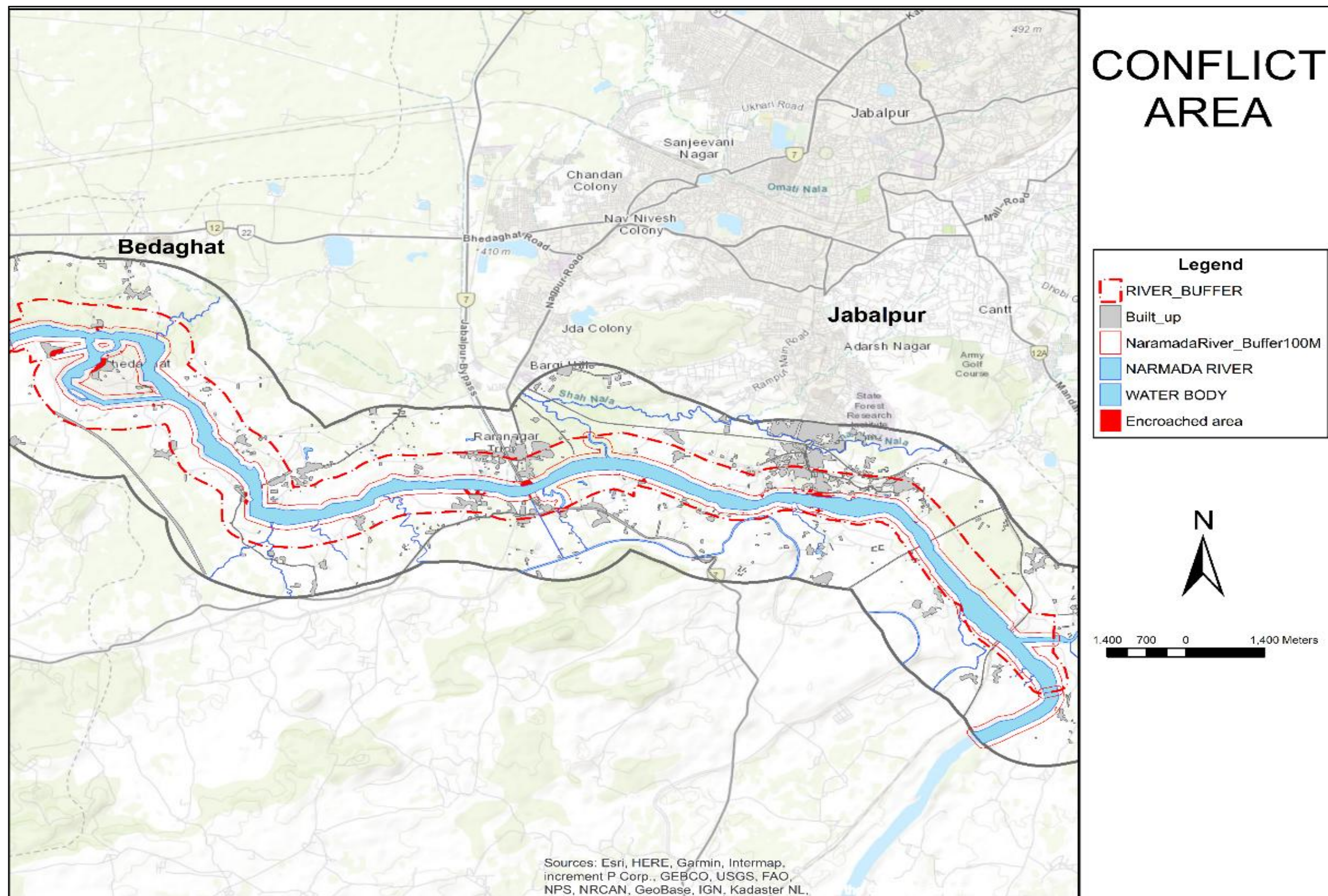


Figure 14 Conflict area 100 metre buffer

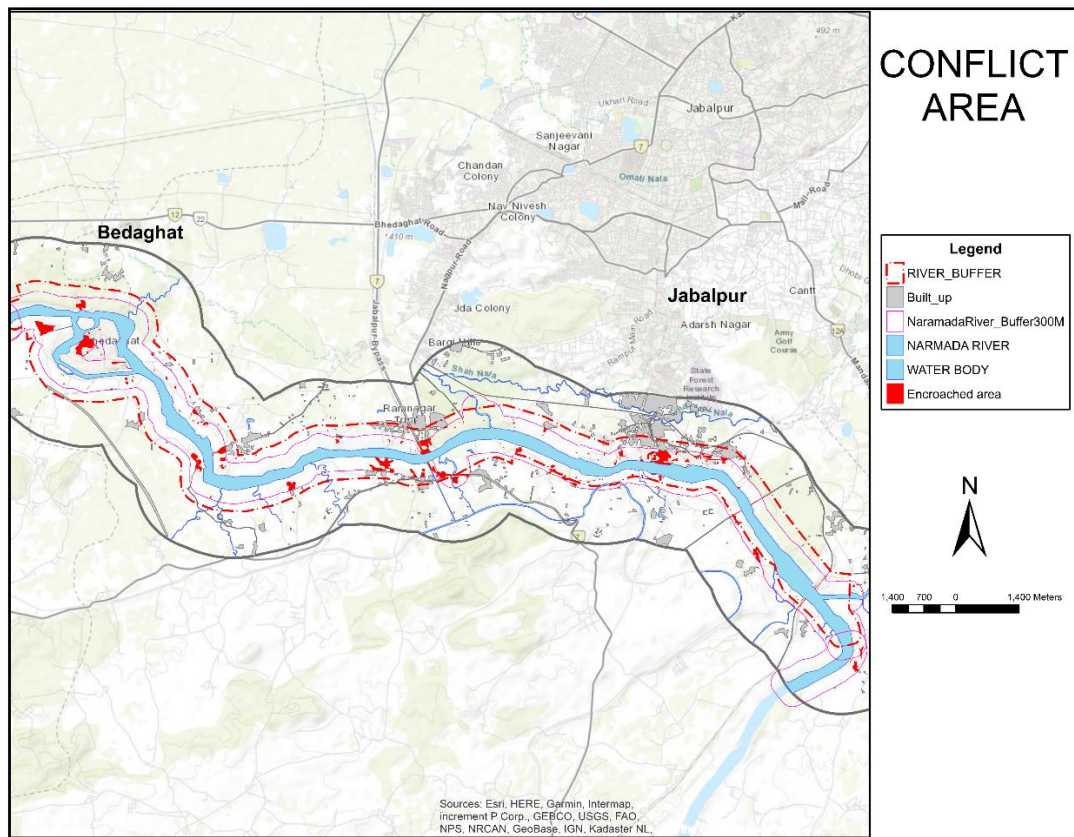


Figure 15 Conflict area 300 metre buffer

The analysis indicates that the required buffer ranges from 30 m to 300 m, depending on river characteristics, floodplain width, and ecological sensitivity. However, spatial overlay reveals that a substantial portion of built-up development has occurred within these regulated zones, leading to direct conflicts between river ecology and urban expansion.

Within the 30 m buffer, approximately 10 hectares of built-up area is identified as encroached, representing immediate intrusion into the active river edge and riparian zone. These areas are highly sensitive, as they directly affect riverbank stability, ecological flow, and natural processes.

The 100 m buffer shows a higher level of encroachment, with nearly 32 hectares of built-up area falling within this zone. This indicates increasing development pressure extending beyond the immediate river edge into the transitional buffer area, which is intended for restricted and low-impact uses.

The most significant impact is observed within the 300 m buffer zone, where approximately 105 hectares of built-up area is affected. This corresponds to nearly 20% of the total built-up development within the study area, highlighting the extent of urban expansion into floodplain and ecologically sensitive regions. Such encroachment poses serious risks, including disruption of natural drainage systems, increased flood vulnerability, and degradation of riparian ecosystems.

Spatially, the intensity of conflict is highest in the Jabalpur stretch, where dense urban development overlaps with all buffer categories. The middle stretch exhibits moderate conflict, primarily due to expanding peri-urban development and infrastructure growth. In contrast, the Bhedaghat stretch shows relatively limited but highly sensitive conflicts, largely associated with localized tourism activities and development near the river edge.

Overall, the analysis demonstrates a clear divergence between planned buffer regulations and actual development patterns, as illustrated in Figure 13,14&15. This directly supports the study objective of

identifying conflict zones and evaluating development pressures within the river corridor, emphasizing the need for stricter enforcement and a context-specific zoning framework to regulate future growth.

The drone-based photographic analysis provides critical ground validation of the identified conflict areas along the Narmada River corridor. Figure 16 shows a series of geo-referenced drone images integrated with the spatial conflict map, illustrating the on-site conditions of encroachment, land-use transformation, and river-edge modifications across different stretches.

The imagery clearly highlights the physical manifestation of encroachments within the river buffer zones, particularly in the form of built-up structures, informal settlements, agricultural expansion, and tourism-related activities along the riverbanks. These observations strongly corroborate the GIS-based findings, where significant portions of development were identified within restricted buffer limits.

In the Bedaghat stretch, drone images reveal localized but sensitive interventions near the river edge, including tourism infrastructure and access paths developed within close proximity to the river. Given the steep terrain and ecological fragility of this segment, even limited disturbances are observed to alter natural landforms and riparian conditions, reinforcing its classification as a high-sensitivity zone.

The middle stretch exhibits a mix of rural and peri-urban characteristics, where drone imagery shows agricultural encroachment, scattered built-up patches, and alterations to natural drainage channels. These areas demonstrate transitional conflicts, where increasing human activities are gradually transforming the natural landscape and interfering with hydrological systems.

In the Jabalpur stretch, the drone analysis captures intensive urban encroachment, including dense built-up areas, road infrastructure, and riverfront activities extending into the buffer zone. Several locations show direct occupation of low-lying floodplain areas, which increases vulnerability to flooding and disrupts the ecological continuity of the river corridor.

A key observation from the drone imagery is the fragmentation of the riparian buffer, where continuous natural edges are replaced by discontinuous patches of development. Additionally, visible alterations such as land leveling, bank modification, and informal access routes indicate increasing anthropogenic pressure on the river system.

Overall, the drone-based documentation provides strong visual evidence supporting the identified conflict zones, bridging the gap between spatial analysis and ground reality. It reinforces the study objective of validating conflict areas and assessing on-ground impacts, and highlights the urgent need for strict buffer enforcement, restoration of encroached zones, and sustainable river corridor management strategies.

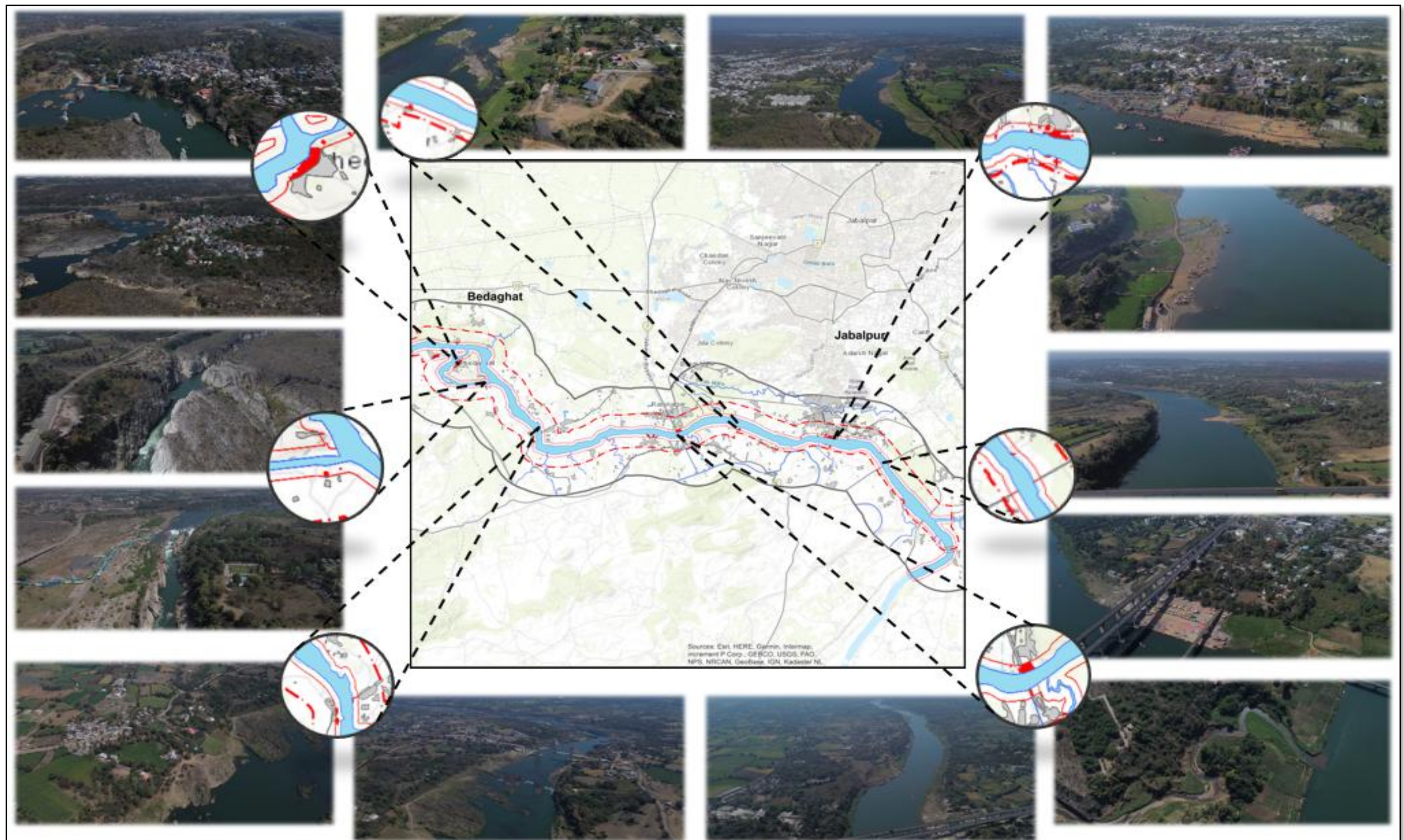


Figure 16 Conflict area Photographs Using Droneshots -by primary survey

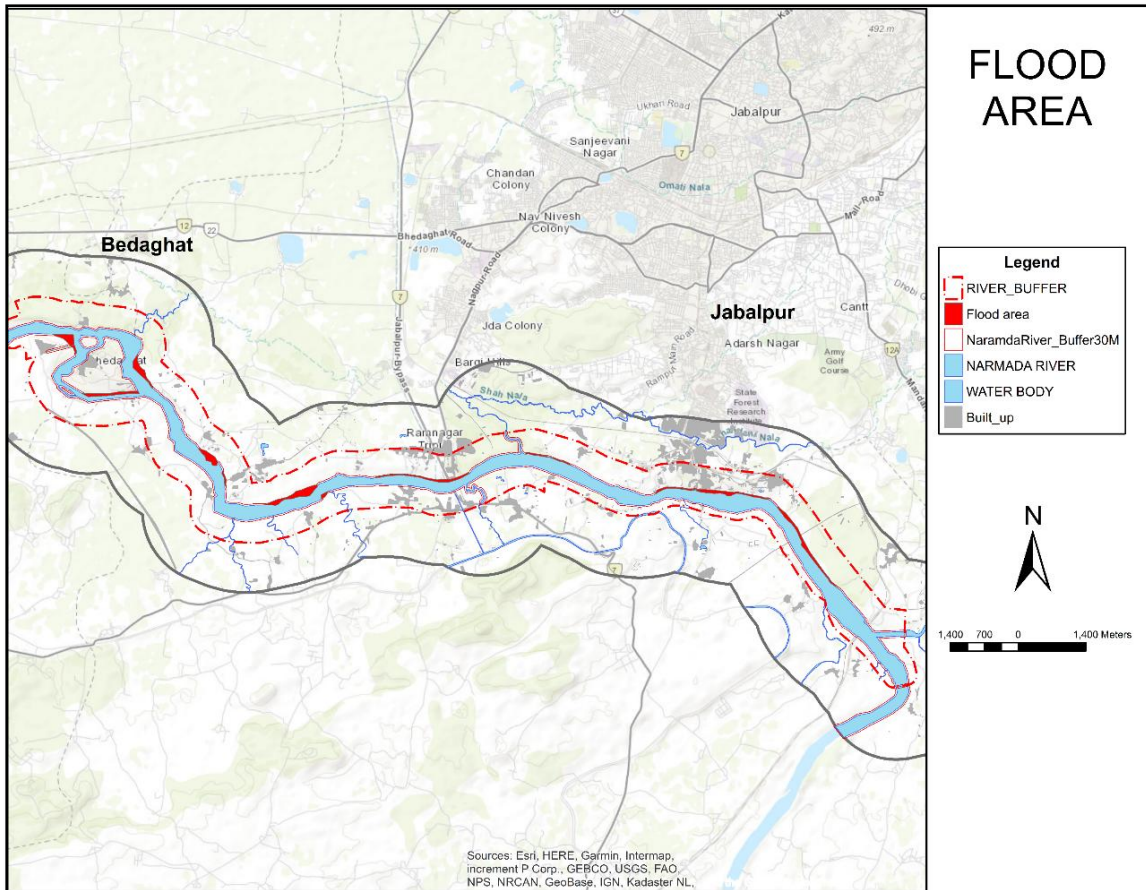


Figure 17 Flood Area Map

The flood susceptibility analysis of the Narmada River corridor highlights the spatial variation in flood-prone areas influenced by terrain, river morphology, and land-use characteristics across the three segments—Bedaghat, middle stretch, and Jabalpur. Figure 17 shows the delineation of flood-affected zones in relation to the river channel, buffer area, and existing built-up regions.

The Bedaghat region exhibits relatively limited flood spread, primarily due to its steep terrain and confined river channel. The narrow Ghat-like formations and higher gradients restrict lateral water expansion, resulting in a more controlled flood behaviours. However, despite lower flood extent, this area remains sensitive due to its geomorphological fragility, where sudden flow variations can still pose localized risks.

The middle stretch demonstrates a moderate flood spread, particularly along the meandering sections of the river. The relatively flatter terrain compared to Bedaghat allows water to extend laterally during high flow conditions. Additionally, the presence of multiple drainage channels and tributaries contributes to increased water accumulation in certain pockets. In relation to the study objectives, this segment represents a transitional risk zone, where both natural processes and emerging development patterns influence flood dynamics.

The Jabalpur region shows the widest extent of flood-prone areas, largely due to its gentle slope and expansive floodplain conditions. The reduced gradient facilitates the lateral spread of water during peak discharge events. Furthermore, urban expansion, encroachment within buffer zones, and increasing impervious surfaces significantly intensify flood risk by reducing natural infiltration and obstructing drainage pathways. This directly aligns with the objective of identifying conflict between urban development and natural systems, as built-up areas within flood-prone zones are highly vulnerable.

A key observation from the analysis is that several flood-prone areas overlap with existing built-up zones and river buffer regions, indicating inadequate adherence to floodplain regulations. This increases the likelihood of waterlogging, infrastructure damage, and environmental degradation, especially in the Jabalpur stretch.

Overall, the flood area analysis emphasizes the need for flood-resilient planning strategies, including strict control of development within flood-prone zones, restoration of natural drainage systems, and reinforcement of buffer regulations. The findings strongly support the study objective of identifying hazard-prone areas and integrating risk-sensitive planning into river corridor development.

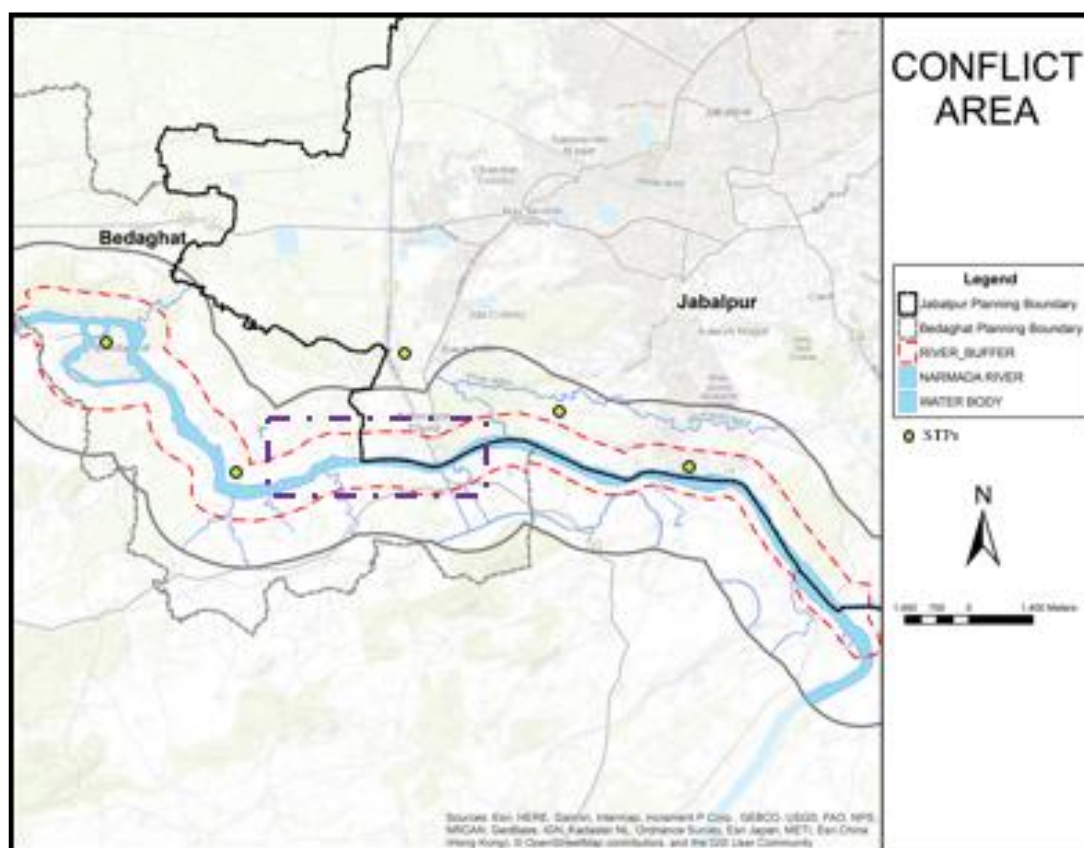


Figure 18 Conflict area of Discharge

The analysis of wastewater discharge patterns and the interaction between natural drainage systems and built-up development within the Narmada River corridor reveals significant spatial variations in environmental pressure across the three identified segments—Bhedaghat, the middle stretch, and Jabalpur. By integrating settlement distribution, drainage networks, river buffer zones, existing wastewater infrastructure, and built-up land-use patterns through GIS-based spatial analysis, the study identifies potential pollution hotspots and hydrological conflict zones that directly influence the ecological health of the river system. Figure 18 illustrates the spatial relationship between settlements, drainage channels, and the river buffer, highlighting potential locations where untreated or partially treated wastewater may enter the river system, while Figure 19 shows the interaction between natural drainage networks and built-up areas, indicating zones where development interferes with natural hydrological processes.

The Bhedaghat region exhibits comparatively minimal environmental pressure in terms of wastewater discharge and drainage conflict. This is primarily due to low settlement density, limited urban infrastructure, and the dominance of relatively undisturbed natural landscapes. The steep topography,

rocky escarpments, and confined river channel naturally restrict large-scale development and reduce the intensity of anthropogenic activities within immediate riverfront areas. As a result, the likelihood of direct wastewater inflow into the river remains low, and natural drainage systems continue to function with minimal physical disturbance. The limited interaction between built-up areas and drainage networks helps preserve hydrological continuity, slope stability, and ecological balance within this environmentally sensitive segment. These findings reinforce the importance of maintaining strict development control in the Bedaghat region to preserve its geomorphological and ecological integrity.

In contrast, the middle stretch of the corridor represents an emerging zone of environmental stress and hydrological conflict. This segment is characterized by scattered rural settlements, agricultural activities, and partially modified landscapes located in close proximity to natural drainage channels and tributary systems. The analysis identifies several instances of direct wastewater discharge into the river and its associated drainage network, primarily originating from small settlements lacking formal sewer infrastructure, wastewater collection systems, or treatment facilities. In the absence of planned sanitation infrastructure, untreated domestic wastewater, greywater discharge, and agricultural runoff containing sediments, fertilizers, and other pollutants are directly conveyed into nearby drainage channels, eventually reaching the river system.

This not only contributes to localized water quality degradation but also indicates significant infrastructure deficiencies in rural service provision. Furthermore, agricultural expansion and unregulated land-use practices have resulted in partial obstruction, diversion, and modification of natural drainage paths. In several locations, drainage channels intersect with cultivated land or settlement areas, reducing their natural carrying capacity and altering flow characteristics. These interventions create localized hydrological issues such as waterlogging, soil erosion, sediment deposition, and disruption of downstream connectivity. The middle stretch therefore functions as a transitional conflict zone where increasing human intervention begins to alter the natural hydrological behavior of the river corridor, directly supporting the study objective of identifying emerging environmental and service-level deficiencies.

The Jabalpur segment exhibits the highest level of anthropogenic pressure, reflecting the complex interaction between urban infrastructure, wastewater generation, and natural drainage systems. As a major urban center, Jabalpur possesses relatively more structured wastewater management infrastructure, including Sewage Treatment Plants (STPs), which contribute significantly toward reducing direct sewage discharge into the river system. However, despite the presence of such infrastructure, the analysis identifies continued environmental risks associated with untreated or partially treated wastewater inflows. These risks may arise due to limitations in treatment capacity, operational inefficiencies, aging infrastructure, or the existence of unconnected settlements and peripheral urban areas that remain outside the formal sewer network.

Additionally, several stormwater drains within the urban fabric appear to carry mixed flows consisting of surface runoff, domestic wastewater, and other pollutants, ultimately discharging into the river or its tributary drainage channels. These drainage corridors act as critical conduits for both point and non-point sources of pollution, particularly where they intersect with river buffer zones. Simultaneously, rapid urban expansion has increased the overlap between built-up areas and natural drainage systems, leading to channel encroachment, flow obstruction, and reduction in infiltration potential due to extensive impervious surfaces.

A key observation from the combined wastewater and drainage analysis is that multiple drainage channels across the middle and Jabalpur stretches serve not only as hydrological pathways but also as carriers of environmental pollutants. This creates cumulative ecological pressure on the river system and increases the vulnerability of the corridor to water quality deterioration, flooding, and habitat degradation. Overall, the analysis demonstrates a clear transition from low-impact natural conditions in Bedaghat to increasing anthropogenic pressure in the rural and urban segments. These findings

emphasize the urgent need for integrated wastewater management, improved sewer connectivity, drainage-sensitive land-use planning, and strict monitoring of discharge points to ensure sustainable management of the Narmada River corridor and long-term ecological resilience.

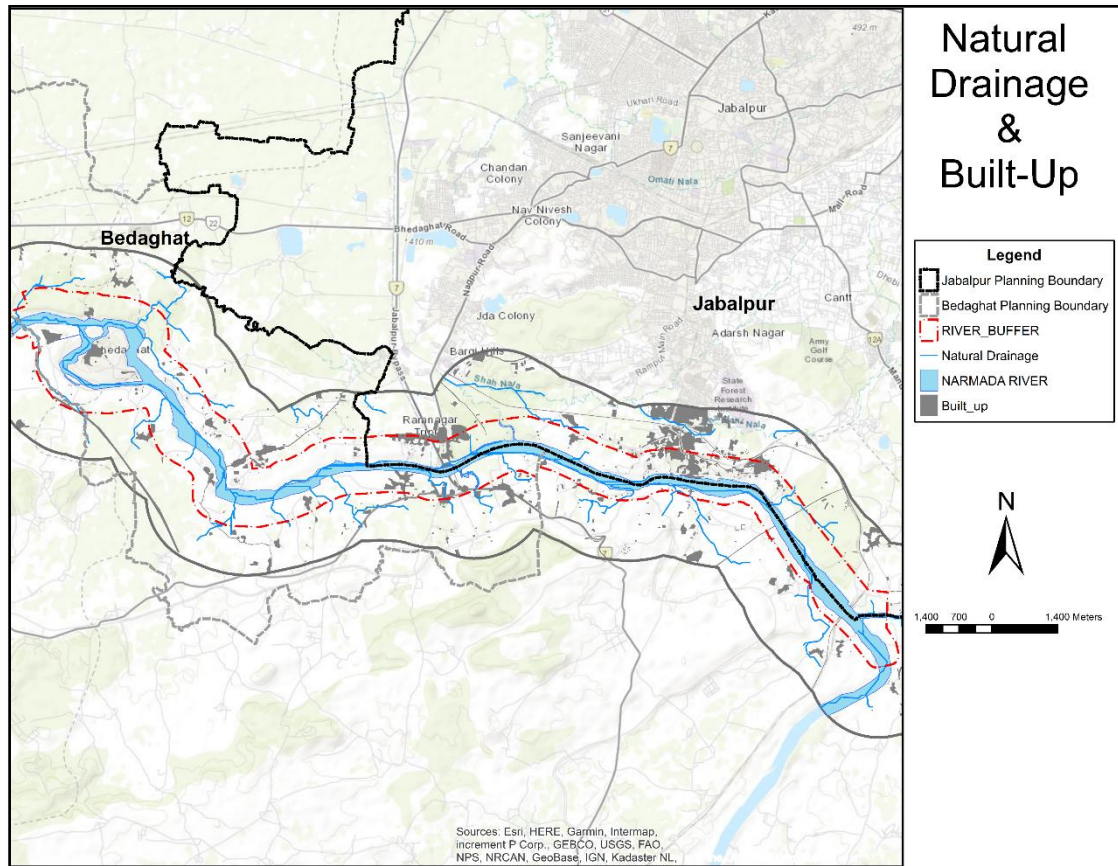


Figure 19 Conflict area Of Natural Drainage and Builtup Area Map

The spatial analysis of the Narmada River corridor reveals significant variations in the interaction between urban development, natural drainage systems, and environmentally sensitive landscapes across the study area. By integrating drainage network mapping, built-up land-use analysis, terrain characteristics, vegetation cover, and flood susceptibility layers, the study identifies critical conflict zones where existing development patterns intersect with natural hydrological systems and ecologically important landscapes. The findings provide important insights into the spatial implications of unregulated growth and support the broader objective of developing an environmentally responsive river corridor planning framework.

The Jabalpur region demonstrates the highest intensity of spatial conflict, characterized by dense urban development extending into designated river buffer zones, flood-prone areas, and natural drainage corridors. As one of the major urban centers within the study corridor, Jabalpur has experienced rapid population growth, infrastructure expansion, residential densification, and commercial development over recent decades. The spatial overlay analysis reveals that a significant proportion of built-up areas have expanded toward the riverfront and adjoining low-lying landscapes, often occupying areas that historically functioned as natural drainage paths, seasonal runoff channels, and flood absorption zones.

A major observation emerging from the drainage conflict analysis is the direct overlap between urban expansion and the natural drainage network, particularly within the Jabalpur stretch. Several primary and secondary drainage channels, including local nalas, seasonal streams, and minor tributary connections, show evidence of encroachment, channel modification, diversion, or partial obstruction

due to surrounding built-up development. In multiple locations, drainage corridors have either been narrowed by adjacent construction activities or physically altered to accommodate transportation infrastructure, residential layouts, and institutional development. Such modifications disrupt the natural hydrological continuity of the landscape and significantly affect the efficiency of surface water movement.

The encroachment upon drainage systems has multiple environmental and hydrological consequences. The reduction in open permeable surfaces due to increasing impervious cover, such as roads, paved areas, rooftops, and built structures, substantially limits infiltration and groundwater recharge processes. As a result, rainfall runoff that would otherwise be absorbed into the soil is rapidly converted into surface flow, increasing peak discharge within urban drainage systems. Simultaneously, the obstruction of natural channels reduces the carrying capacity of the drainage network, creating localized bottlenecks during monsoon events. This combination of reduced infiltration, increased runoff, and restricted drainage capacity significantly elevates the risk of urban flooding, waterlogging, soil erosion, and downstream environmental degradation. Consequently, the Jabalpur segment emerges as one of the most hydrologically vulnerable and environmentally stressed zones within the study corridor.

A critical finding from this analysis is the extent to which urban growth has directly overlapped not only with the river system itself but also with its associated drainage infrastructure. This interaction creates complex conflicts between anthropogenic development and natural ecological processes. The alteration of drainage patterns affects sediment transport, groundwater recharge, riparian moisture regimes, and floodplain functionality, thereby reducing the ecological resilience of the river corridor. Furthermore, the fragmentation of natural drainage systems weakens the ability of the landscape to absorb climatic variability and extreme rainfall events, making urban areas increasingly vulnerable to environmental hazards.

These findings highlight the urgent need for drainage-sensitive urban planning, wherein natural water systems are recognized as critical spatial infrastructure rather than residual open spaces available for development. Preservation and integration of drainage corridors within urban development frameworks are essential to maintaining hydrological efficiency, ecological connectivity, and long-term environmental sustainability. The analysis directly supports the study objective of identifying conflict zones and emphasizes the importance of regulating built-up expansion in relation to drainage systems and river buffer zones to ensure sustainable river corridor management.

In addition to drainage conflicts, the environmental sensitivity analysis of the Narmada River corridor identifies areas requiring varying degrees of ecological protection based on terrain characteristics, vegetation cover, hydrological conditions, geomorphological features, and existing development pressure. Using GIS-based spatial assessment, multiple environmental indicators were integrated to delineate environmentally sensitive zones across the corridor. Figure 20 illustrates the distribution of these environmentally sensitive areas in relation to the river buffer, highlighting zones where ecological vulnerability is particularly high and where development interventions require careful regulation.

The Bedaghat region emerges as the most environmentally sensitive segment within the study corridor. This high sensitivity is primarily attributed to its distinctive geomorphological character, steep topography, rocky escarpments, dissected terrain, and relatively dense vegetation cover. The presence of the famous marble rock formations associated with the Narmada River gorge system creates a unique geological landscape of both ecological and cultural significance. The steep slopes and exposed rock surfaces in this region are highly susceptible to erosion, slope instability, and irreversible landscape alteration if disturbed by construction or intensive human activity.

Furthermore, the ecological value of the Bedaghat landscape extends beyond its geomorphology. Vegetative cover along slopes and riparian zones contributes to slope stabilization, moisture retention, habitat continuity, and microclimatic regulation. Any form of unplanned intervention, including road

widening, tourism infrastructure, commercial expansion, or quarry-related disturbances, has the potential to significantly disrupt the natural equilibrium of this fragile environment. Therefore, the Bedaghat segment requires strict conservation measures, controlled visitor management, and minimal physical intervention. These findings directly align with the study objective of identifying ecologically critical areas that require maximum protection within the river corridor.

The middle stretch of the corridor exhibits moderate environmental sensitivity and represents a transitional landscape between the highly protected Bedaghat region and the urbanized Jabalpur segment. This area is characterized by a combination of agricultural land, open vegetation, natural drainage channels, scattered settlements, and partially modified landscapes. The coexistence of farming activities and hydrological systems creates a dynamic land-use environment where anthropogenic interventions can directly influence ecological processes.

Agricultural practices in this stretch contribute to both productive land use and environmental pressure. Changes in cropping patterns, irrigation practices, land leveling, and conversion of open spaces can alter surface runoff characteristics, soil permeability, and sediment transport. Simultaneously, natural drainage channels play a critical role in maintaining hydrological connectivity between upland areas and the river system. Any disruption to these drainage pathways may lead to localized flooding, reduced recharge, and ecological degradation. While this segment demonstrates potential for controlled development and productive land-use integration, careful regulation is necessary to ensure that future interventions do not compromise natural systems. This supports the study objective of identifying zones suitable for regulated development while maintaining ecological balance.

The Jabalpur region shows localized pockets of environmental sensitivity despite its relatively high degree of urbanization. These sensitive areas are primarily associated with low-lying flood-prone lands, remnant vegetation patches, riparian buffers, wetlands, and areas in close proximity to the river. Although urban development has transformed much of the landscape, several ecologically important patches continue to perform critical environmental functions, including flood attenuation, groundwater recharge, habitat support, and water quality regulation.

However, these environmentally sensitive pockets are under increasing pressure from urban expansion, infrastructure development, land reclamation, and informal encroachment. The reduction of vegetation cover, fragmentation of open spaces, and conversion of flood-prone land into built-up areas threaten the ecological stability of these urban-sensitive zones. Without appropriate planning controls, these pressures may result in irreversible ecological degradation and increased vulnerability to climate-related risks.

A key observation emerging from the environmental sensitivity analysis is the spatial overlap between ecologically sensitive zones and areas experiencing significant development pressure, particularly within the middle and Jabalpur stretches. This overlap identifies critical conflict zones where ecological priorities and developmental interests directly intersect. Such zones require strategic planning interventions to balance environmental conservation with urban growth demands.

Overall, the environmental sensitivity analysis emphasizes the necessity of adopting a graded conservation approach within the Narmada River corridor. Highly sensitive landscapes such as Bedaghat require strict protection and conservation-oriented management. Moderately sensitive transitional zones should be managed through carefully controlled development and sustainable land-use practices. Urban-sensitive ecological pockets within the Jabalpur stretch require targeted regulatory measures, ecological restoration, and integration within urban planning frameworks. These findings directly support the study objective of incorporating ecological sensitivity into river corridor planning and establishing a sustainable, context-specific framework for future development.

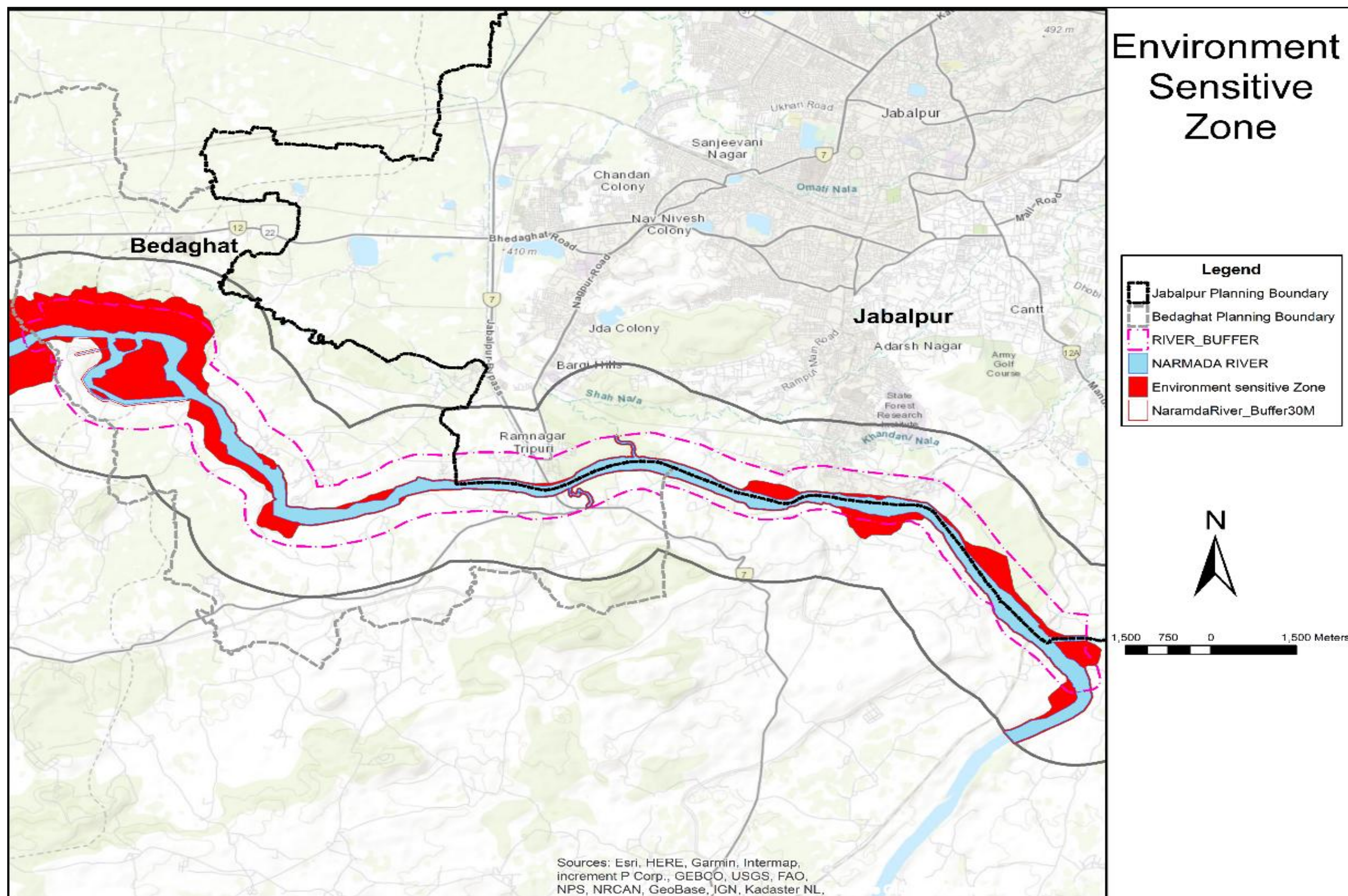


Figure 20 Environment Sensitive Zone M

CHAPTER 4 PROPOSALS

4.1 Proposal for Zoning

The proposal for the Narmada River corridor is formulated based on the synthesis of physical analysis, conflict identification, environmental sensitivity, and policy guidelines, aiming to achieve a balance between ecological conservation and sustainable development. The approach adopts a zonal planning framework integrating RRZ principles, buffer regulations, and on-ground realities identified through spatial and field analysis.

The proposal envisions the river corridor as an integrated ecological and urban system, where the river, its floodplain, drainage network, and surrounding land uses function cohesively. Based on the analysis, the corridor is structured into three primary planning zones—conservation, regulated development, and controlled urban development, aligned with RRZ-1, RRZ-2, and RRZ-3 concepts.

The Bedaghat stretch is proposed as a strict conservation zone, given its high environmental sensitivity, steep terrain, and unique geomorphological character. Development in this segment is limited to eco-friendly and non-intrusive activities such as controlled tourism, nature trails, and viewpoint development. Any form of permanent construction or land alteration within the immediate river buffer is restricted to preserve the natural landscape and ecological balance.

The middle stretch is identified as a regulated development zone, where controlled land use is permitted with strict adherence to environmental safeguards. Proposals in this segment focus on agro-based development, eco-tourism, and low-density settlement planning, while ensuring the protection of natural drainage systems and river buffers. Restoration of encroached nalas, creation of green buffers, and implementation of decentralized wastewater management systems are key interventions to reduce emerging conflicts.

The Jabalpur stretch is designated as a controlled urban development zone, where existing urban pressures are managed through planned interventions. The proposal emphasizes riverfront development with ecological sensitivity, improvement of sewage treatment infrastructure, and strict enforcement of buffer regulations. Built-up areas within flood-prone zones are to be regulated, and green corridors along the river are to be developed to enhance resilience and reduce environmental degradation.

Across the entire corridor, the proposal integrates **key strategic interventions**, including:

- **Strengthening river buffer zones** (minimum 30–100 m, extendable up to 300 m based on floodplain conditions)
- **Restoration of natural drainage networks** and prevention of encroachments
- **Riparian vegetation enhancement and green buffer development**
- **Flood-resilient planning and restriction of development in high-risk zones**
- **Improvement of wastewater management systems**, especially in peri-urban and rural stretches
- **Promotion of sustainable tourism and community participation**, particularly in Bedaghat

A critical component of the proposal is the establishment of a context-specific zoning regulation framework, ensuring that development permissions are directly linked to ecological sensitivity and risk assessment. This aligns with national guidelines (URDPFI, NGT, RRZ) while adapting them to local conditions.

Overall, the proposal aims to transform the Narmada River corridor into a resilient, ecologically balanced, and well-managed spatial system, where development is guided by environmental capacity and long-term

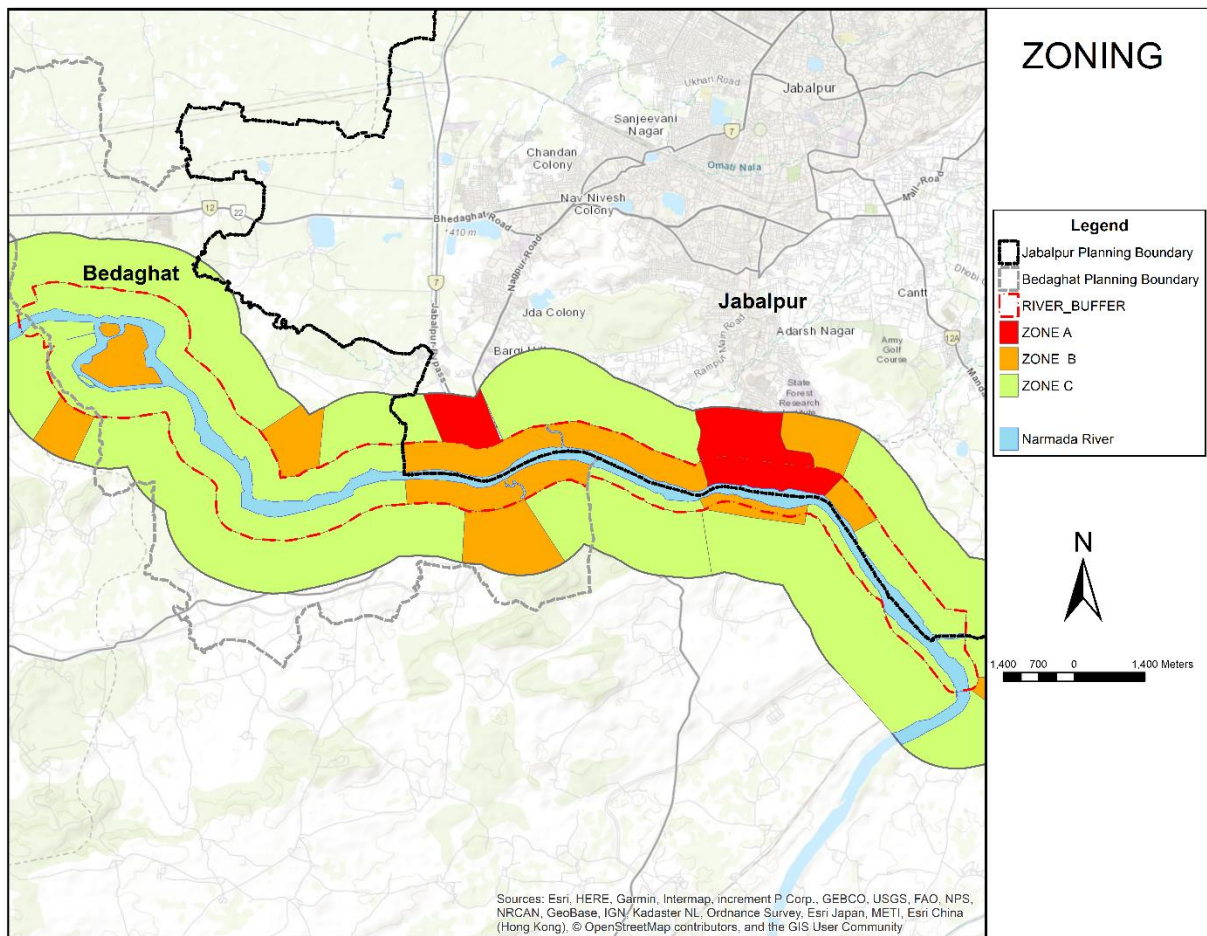


Figure 21 Zoning for proposal

The zoning framework for the Narmada River corridor is derived from the integration of physical analysis, environmental sensitivity, conflict zones, and policy guidelines (URDPFI, RRZ, NGT). The objective is to establish a spatially differentiated planning approach, where each stretch is assigned a specific role based on its ecological capacity and development pressure. Figure 21 shows the proposed zoning classification into three Zones—A, B, and C.

The zoning structure reflects a gradient from conservation to controlled development, ensuring that highly sensitive areas are protected while accommodating necessary growth in less vulnerable zones.

The Zone A (Red Zone) corresponds primarily to the Jabalpur segment, characterized by high urbanization, dense built-up areas, and significant conflict with the river buffer. This stretch is identified as a controlled urban intervention zone, where development already exists but requires strict regulation. The area is marked by flood risk, drainage obstruction, and encroachment within buffer limits. Therefore, the proposal focuses on riverfront redevelopment, strengthening of sewage infrastructure, removal of critical encroachments, and creation of green buffers to mitigate environmental impact.

The Zone B (Orange Zone) represents the middle transitional stretch, exhibiting moderate development pressure and emerging conflicts. This zone acts as a regulated development corridor, where controlled growth is permitted with strict environmental safeguards. The area is dominated by agricultural land, scattered settlements, and active drainage systems. The proposal emphasizes low-density development,

agro-based land use, protection of drainage networks, and promotion of eco-tourism, ensuring that natural systems are not disrupted.

The Zone C (Green Zone) corresponds to the Bedaghat region, which is highly sensitive due to its unique geomorphology, steep slopes, and ecological significance. This stretch is designated as a strict conservation zone, where development is highly restricted. Only eco-sensitive activities such as controlled tourism, nature trails, and conservation initiatives are permitted. The primary objective is to preserve the natural landscape and prevent any irreversible environmental degradation.

Table 5 Stretch Wise Area Distribution

ZONE	AREA (Ha)
Zone A	136
Zone B	680
Zone C	1426

The proposed zoning regulations are formulated to ensure a balanced approach between development and ecological protection along the Narmada River corridor. Based on the spatial classification of stretches, Table 5 presents the permitted and restricted activities for each zone, aligning with environmental sensitivity, existing land use, and policy guidelines.

Table 6 The permitted and restricted activities for each zone

ZONE	ALLOWED	RESTRICTED
Zone A (Urban Influence)	- Regulated residential & commercial development - Riverfront public spaces (ghats, walkways) - Infrastructure with proper sewage treatment	- High Impact Construction within core river buffer - Direct discharge of wastewater - Encroachment on floodplain
Zone B (Transition Zone)	- Low-density development - Agro-based activities - Eco-tourism (controlled)	- High-density construction - Blocking natural drainage - Conversion of buffer areas
Zone C (Semi-Natural)	- Sustainable agriculture - Plantation & green buffers - Low-impact rural activities	- Urban expansion - Industrial development - Vegetation clearing near river

Based on the spatial analysis of land-use conflicts, drainage interactions, environmental sensitivity, development pressure, and statutory planning gaps identified across the study area, a zone-based regulatory framework has been proposed for the Narmada River corridor between Bedaghat and Jabalpur. The zoning framework aims to establish a context-specific planning mechanism that balances ecological conservation with development requirements by defining permissible and restricted activities according to environmental sensitivity, urban influence, and hydrological significance. The proposed zoning strategy creates a gradual transition from urbanized areas toward highly protected ecological landscapes, ensuring that development intensity responds appropriately to the carrying capacity of each segment while minimizing future land-use conflicts.

Zone A – Urban Influence Zone

Zone A represents the Urban Influence Zone, primarily located within the Jabalpur stretch, where development pressure, population concentration, infrastructure demand, and land-use transformation are most intense. This zone is characterized by dense built-up areas, expanding urban settlements, transportation corridors, institutional development, and significant interaction between urban growth and the river system. Considering the strategic importance of this segment for urban development, the proposed planning approach focuses on regulated growth supported by strong environmental safeguards.

Within this zone, controlled residential, mixed-use, commercial, and public infrastructure development may be permitted, provided that all development complies with prescribed environmental regulations and river buffer controls. Riverfront public spaces, recreational landscapes, pedestrian corridors, open spaces, and urban amenities may also be developed to enhance public access while maintaining ecological continuity. Infrastructure projects such as roads, utilities, public institutions, and tourism-support facilities may be allowed only when integrated with adequate environmental mitigation measures, including stormwater management systems, green infrastructure, permeable surfaces, and mandatory sewage treatment mechanisms.

At the same time, specific high-risk activities are strictly restricted within this zone to prevent further ecological degradation. High-impact construction within the core river buffer, permanent structures in flood-prone areas, direct discharge of untreated wastewater, reclamation of low-lying lands, obstruction of drainage corridors, and any form of encroachment upon the floodplain are prohibited. These restrictions are essential for maintaining flood absorption capacity, reducing urban runoff, protecting water quality, and enhancing climate resilience within the urban riverfront. Thus, Zone A promotes planned urban growth while ensuring that environmental carrying capacity is not exceeded.

Zone B – Transition Zone

Zone B functions as the Transition Zone, forming an intermediate spatial buffer between urbanized areas and ecologically sensitive natural landscapes. This zone is primarily associated with the middle stretch of the corridor, characterized by agricultural land, scattered rural settlements, natural drainage systems, open landscapes, and moderate development pressure. Due to its transitional nature, this zone plays a critical role in absorbing urban expansion while preserving hydrological and ecological connectivity.

The planning approach in Zone B emphasizes low-density, environmentally compatible, and landscape-sensitive development. Activities such as agro-based economic uses, sustainable farming practices, horticulture, community-level eco-tourism, nature-based recreation, educational tourism, and small-scale rural infrastructure may be encouraged, provided they maintain the ecological integrity of the landscape. Limited residential expansion and essential public infrastructure may also be permitted under strict density and setback regulations.

However, to prevent this segment from becoming a future conflict zone, several development controls are imposed. High-density construction, large-scale land conversion, industrial activities, obstruction or diversion of natural drainage systems, excessive earth cutting, and permanent encroachment within designated buffer areas are strictly restricted. The preservation of natural water channels, riparian vegetation, agricultural productivity, and open landscapes remains a key planning priority in this zone. By functioning as both an ecological and developmental buffer, Zone B ensures a gradual transition between urban systems and protected landscapes while reducing the risk of uncontrolled expansion.

Zone C – Semi-Natural / Conservation Zone

Zone C represents the Semi-Natural and Conservation Zone, primarily corresponding to the Bedaghat stretch, which exhibits the highest ecological sensitivity within the study corridor. This zone is characterized by steep terrain, geomorphologically significant landscapes, dense vegetation patches, rocky escarpments, natural drainage systems, and culturally important riverfront environments. Due to its fragile environmental character, this segment requires the highest level of protection and the most restrictive development controls.

The planning approach in Zone C prioritizes ecological conservation, landscape preservation, and sustainable land-use practices. Activities such as sustainable agriculture, organic farming, plantation development, habitat restoration, soil conservation, afforestation, ecological research, environmental education, and green buffer creation may be permitted, provided they involve minimal physical intervention and do not disturb natural systems. Low-impact eco-tourism activities, guided interpretation trails, and conservation-based visitor infrastructure may also be allowed under strict environmental supervision.

Conversely, urban expansion, industrial development, quarrying, large-scale tourism infrastructure, road widening without environmental assessment, vegetation clearing near the river, and permanent construction within ecologically sensitive areas are strictly prohibited. Such restrictions are necessary to prevent erosion, habitat fragmentation, landscape alteration, and degradation of hydrological processes. As this stretch represents the most environmentally critical segment of the river corridor, Zone C functions as the primary conservation landscape within the proposed zoning framework.

Overall, the proposed zoning framework establishes a clear and enforceable regulatory structure that transitions from controlled urban development in Zone A, to managed and environmentally compatible growth in Zone B, and finally to strict ecological conservation in Zone C. By aligning development intensity with ecological sensitivity and hydrological significance, the zoning proposal provides a practical planning mechanism for reducing land-use conflicts, strengthening environmental protection, improving river health, and ensuring the long-term sustainability of the Narmada River corridor.

4.2 Proposal for Eco-Tourism Development Node

4.2.1 Land Suitability Analysis

The land suitability analysis was undertaken to systematically identify appropriate locations for eco-tourism development within the Bhedaghat–Jabalpur river corridor. Considering the ecological sensitivity of riverine environments and increasing development pressure, it was necessary to adopt a scientific and spatial approach to guide sustainable development. The objective of this analysis is to ensure that proposed interventions are located in environmentally suitable, physically feasible, and accessible areas, while avoiding ecologically sensitive zones such as floodplains, forest areas, and steep slopes.

A GIS-based Multi-Criteria Evaluation (MCE) method was adopted for the analysis, integrating multiple spatial parameters with assigned weights based on their relative importance. The assigned weights and ranking criteria are summarized in Table 6.

Table 7 Criteria, Weights and Ranking for Suitability Analysis

Theme	Theme Weight	Class	Rank Weight
Land use	35	Agriculture	7
		Built-up	1
		Wasteland	9
		Forest	0
		Railway	0
Transport	25	>500 M	4
		250-500 M	6
		100-250 M	7
		< 100 M	9
Water Body	20	>500 M	9
		200-500 M	8
		100-200 M	5
		50-100 M	2
		< 50 M	1
Slope	10	0-1	9
		2-3	8
		4--5	8
		6--10	6
		11--15	2

		16-35	1
		> 35	0
River Proximity	10	100 M	9

Table 8 Land Suitability Classification area

ID	Name	Sum Area (in Ha)
1	Highly Suitable	195
2	Moderate Suitable	1065
3	Low Suitability	505
4	No Development Zone	1080

To identify suitable areas for future interventions within the Narmada River corridor, a GIS-based multi-criteria suitability analysis was carried out by integrating spatial, environmental, and accessibility-related parameters. The analysis follows the principles of Multi-Criteria Decision Analysis (MCDA), which provides a systematic framework for evaluating alternative locations based on multiple spatial variables with varying levels of importance. The methodological approach adopted in this study is derived from the work of Jacek Malczewski, which establishes the theoretical foundation for spatial decision-making using weighted overlay techniques in GIS environments. Additional methodological reference was drawn from the study by Kirthika and Priyan (2024), which applied integrated suitability assessment for riverfront planning along the Adyar River in Chennai, demonstrating the relevance of combining ecological and development-oriented criteria in river corridor planning.

Based on the physical characteristics of the study area, planning objectives, and insights obtained from conflict analysis, environmental sensitivity assessment, and development pattern evaluation, five key spatial parameters were selected for the suitability analysis: land use, transport accessibility, proximity to water bodies, slope, and river proximity. These parameters collectively represent the major environmental, physical, and infrastructural factors influencing development suitability within the corridor.

Among all selected parameters, land use was assigned the highest weight of 35 percent, reflecting its direct influence on both development feasibility and environmental sustainability. Land-use characteristics determine the existing ecological condition of the landscape, the extent of human intervention, and the level of compatibility for future development. Areas classified as agricultural land and wasteland were considered relatively more suitable for planned interventions, as these landscapes generally exhibit lower ecological sensitivity, greater adaptability for land-use modification, and fewer constraints related to existing infrastructure commitments. Agricultural areas, particularly those with lower productivity or transitional use patterns, provide opportunities for controlled development when integrated with environmental safeguards. Similarly, wasteland parcels represent underutilized land resources that can accommodate appropriate interventions with comparatively limited ecological disturbance.

In contrast, areas classified as forest cover, dense vegetation, and existing built-up land were assigned lower suitability scores. Forested areas perform critical ecological functions, including biodiversity support, soil stabilization, carbon sequestration, and hydrological regulation, making their conservation essential within the river corridor. Development within such areas could result in habitat fragmentation,

vegetation loss, and increased environmental vulnerability. Existing built-up areas were also considered less suitable due to current land-use commitments, infrastructural saturation, limited expansion flexibility, and the potential for intensifying urban conflicts. Similarly, environmentally sensitive open spaces and riparian vegetation zones were assigned restricted suitability due to their ecological significance.

The weighting of land use at 35 percent reflects its dominant role in influencing both environmental carrying capacity and planning feasibility. By prioritizing land-use characteristics within the suitability model, the analysis ensures that future development proposals are directed toward areas that can support intervention with minimal ecological disruption while avoiding zones requiring conservation or restoration. This approach aligns with established MCDA principles proposed by Malczewski (1999) and supports contemporary river corridor planning methodologies demonstrated by Kirthika and Priyan (2024), thereby ensuring that the suitability assessment is both scientifically grounded and contextually relevant to sustainable riverfront development.

4.2.2 Soil Suitability Analysis

Soil characteristics play a significant role in understanding the physical suitability, ecological sensitivity, and development potential of river corridor landscapes. In the present study, soil analysis was carried out for the Narmada River corridor between Bedaghat and Jabalpur to understand variations in soil composition and their implications for land-use planning, environmental conservation, and future development interventions. The spatial distribution of soil types within the study area is illustrated in Figure 22. The soil data used for this analysis was obtained from the Department of Geology and subsequently processed and integrated within the GIS environment for spatial interpretation.

The analysis identifies two major soil and geological formations within the study corridor: fine loam soil distributed across the majority of the river stretch, and marble rock formations concentrated primarily in the Bedaghat segment near the river edge. The spatial variation of these formations reflects the diverse geomorphological character of the corridor and significantly influences both ecological sensitivity and development suitability.

The predominant soil type observed throughout the middle and Jabalpur stretches is fine loam soil. This soil is generally characterized by a balanced mixture of sand, silt, and clay particles, resulting in moderate permeability, good moisture retention capacity, and relatively high fertility. Due to these physical properties, fine loam soil supports agricultural productivity, vegetation growth, and groundwater recharge, making it suitable for both ecological functions and controlled development activities. The presence of fine loam along extensive portions of the river corridor has contributed to the development of agricultural land, riparian vegetation, and rural settlements in the middle stretch. From a planning perspective, these areas offer moderate to high suitability for carefully regulated land-use interventions, provided that natural drainage systems and river buffer zones are adequately protected. However, because fine loam soils may become vulnerable to erosion under excessive surface runoff or inappropriate construction practices, proper soil stabilization and drainage management remain essential for sustainable development.

In contrast, the Bedaghat region exhibits a distinctly different geological character, marked by exposed marble rock formations located near the river edge. These marble deposits are a defining geomorphological feature of the region and contribute significantly to the unique landscape identity of Bedaghat. The hard rock structure creates steep slopes, narrow gorges, and highly dissected terrain, limiting the extent of buildable land and naturally restricting urban expansion. While these formations provide structural stability and resistance to surface erosion under natural conditions, they also represent highly sensitive geological assets that can be permanently altered by excavation, construction, or uncontrolled tourism-related activities.

The presence of marble rock near the river edge enhances the ecological and cultural significance of the Bedaghat segment but simultaneously increases its planning sensitivity. Any physical intervention in this area has the potential to disturb slope stability, alter natural drainage patterns, and affect the visual and geological integrity of the landscape. Therefore, this segment requires strict conservation-oriented planning with minimal structural intervention. Activities such as large-scale construction, intensive infrastructure development, quarrying, or vegetation clearing should be carefully regulated to preserve the natural geological character of the area.

A key observation from the soil analysis is the clear relationship between soil characteristics and development patterns across the corridor. Areas dominated by fine loam soil, particularly in the middle and Jabalpur stretches, exhibit greater agricultural activity, settlement growth, and development pressure due to relatively favourable physical conditions. In contrast, the marble-dominated Bedaghat segment remains comparatively less urbanized due to topographical and geological constraints. This spatial variation highlights the importance of integrating soil characteristics into river corridor planning and zoning decisions.

Overall, the soil analysis supports the study objective of understanding the physical characteristics of the river corridor and identifying environmentally suitable zones for future interventions. The findings suggest that while fine loam areas may accommodate controlled development and agricultural activities, marble rock zones require strict environmental protection and conservation-focused planning. Integrating soil characteristics into the planning framework will help ensure sustainable land-use decisions, reduced environmental conflicts, and long-term ecological resilience within the Narmada River corridor.

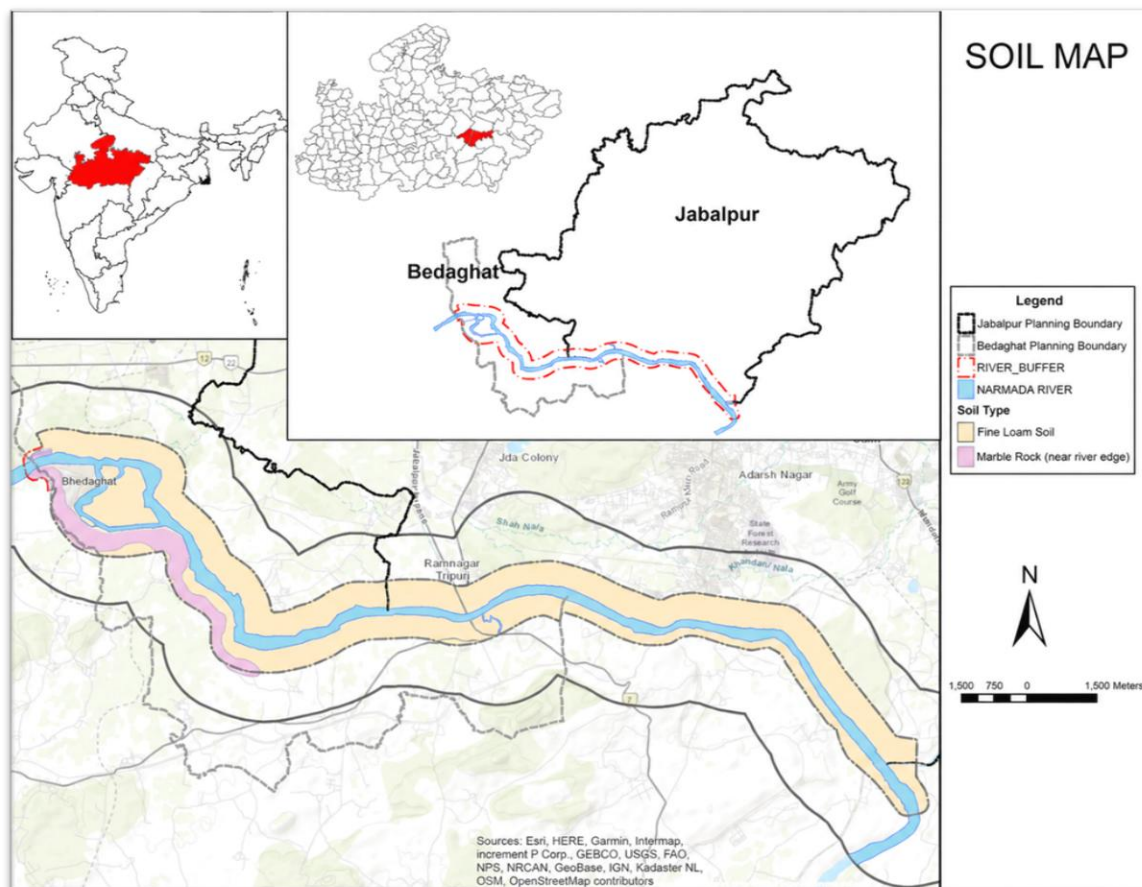


Figure 22 Soil Map of study area

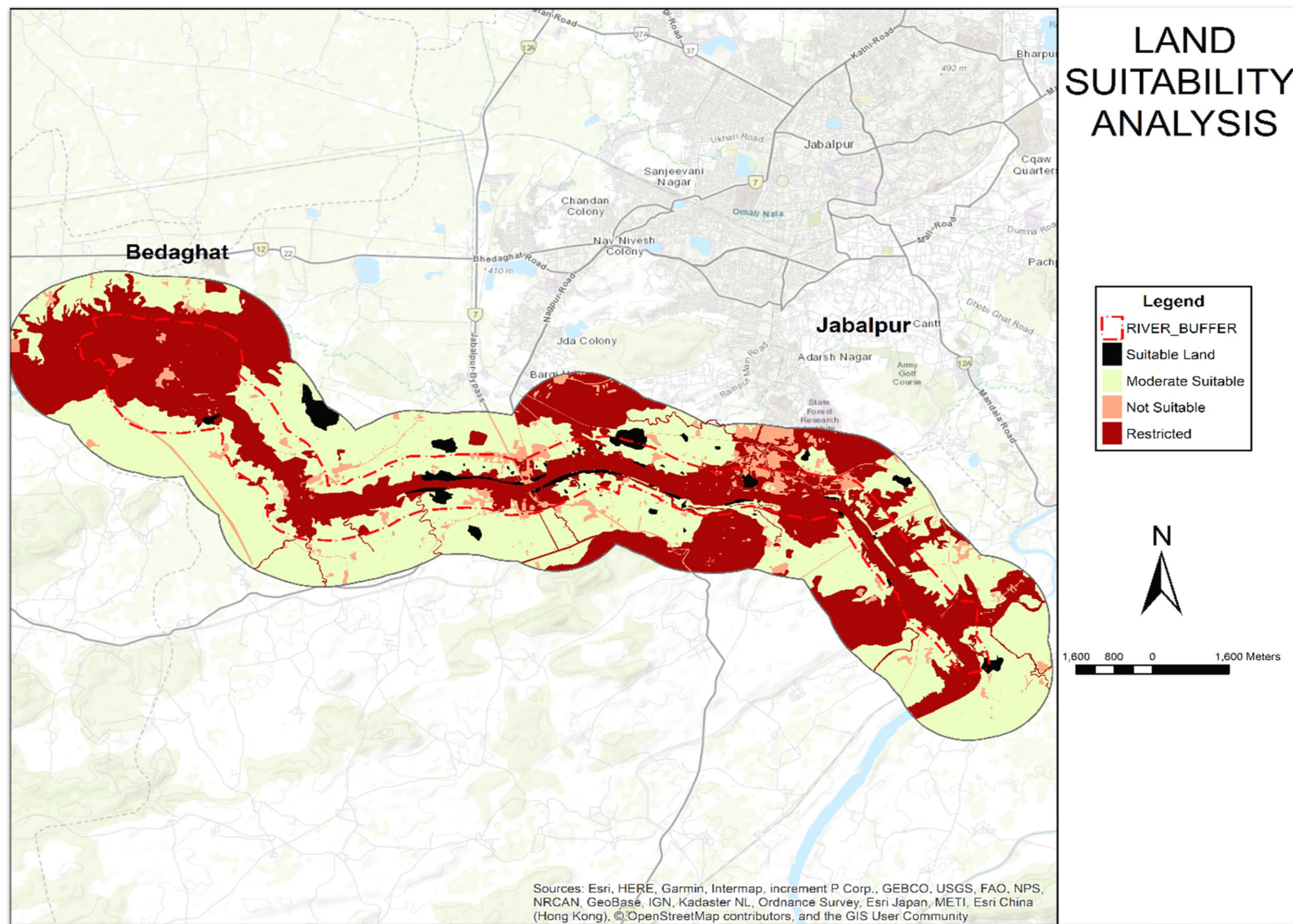


Figure 23 Land Suitability Map for Eco-Tourism Development

Transport accessibility was assigned a weight of 25%, highlighting the importance of connectivity in eco-tourism development. Areas located closer to major roads, particularly within 100–250 meters, were ranked higher due to ease of access, while remote areas were considered less suitable. Proximity to water bodies was given a weight of 20%, as water-based scenic value enhances tourism potential. However, areas too close to water bodies (<50 m) were considered unsuitable due to flood risk and environmental sensitivity, while moderate distances were found to be optimal.

Slope and river proximity were assigned weights of 10% each. Gentle slopes (0–5%) were identified as highly suitable due to ease of construction and stability, whereas steep slopes were considered unsuitable due to erosion risk. Similarly, areas at a moderate distance from the river were preferred, as they provide visual access while maintaining ecological buffers.

Each parameter was classified into suitability classes and assigned rank values, as shown in Table 6. These layers were then integrated using a weighted overlay analysis in GIS to generate a composite land suitability map, presented in Figure 23. The resulting map categorizes the study area into four suitability classes: highly suitable, moderately suitable, low suitability, and no-development zones.

The results of the analysis reveal a clear spatial distribution of suitability across the corridor. As summarized in Table 7, only 195 hectares fall under the highly suitable category, indicating limited availability of optimal development land. A larger portion, approximately 1065 hectares, is classified as moderately suitable, representing areas with potential for controlled and low-intensity development. Around 505 hectares fall under low suitability due to various physical and environmental constraints.

Notably, the largest share of land, approximately 1080 hectares, is categorized as a no-development zone. These areas correspond to ecologically sensitive regions, including dense vegetation, forest cover, steep slopes, and flood-prone zones along the river. The dominance of this category highlights the environmental significance of the corridor and reinforces the need for strict development control in these areas.

Based on the suitability analysis, the proposed eco-theme park site has been strategically selected within a highly suitable zone, as indicated in Figure 23. The site meets all critical criteria, including favourable land use, gentle slope, and strong transport connectivity, being located within 200 meters of a national highway. Additionally, it is situated outside flood-prone and restricted zones, ensuring minimal environmental impact.

The analysis clearly demonstrates that development within the river corridor should be spatially concentrated rather than dispersed. By limiting development to highly suitable areas, the proposal reduces ecological disturbance and prevents unregulated expansion along the riverbanks. This approach aligns with sustainable planning principles by balancing environmental conservation with tourism development.

In conclusion, the land suitability analysis provides a strong scientific basis for identifying appropriate development zones within the river corridor. It supports informed decision-making by integrating environmental, physical, and accessibility parameters. The results not only guide the selection of eco-tourism sites but also contribute to broader planning strategies such as zoning, buffer regulation, and conservation planning. This analysis forms a critical foundation for the subsequent proposal of eco-tourism development and river corridor management.

4.2.3 Theme Park proposal – Eco tourism

The eco-tourism development node is proposed as a strategic intervention within the Bhedaghat–Jabalpur River corridor to manage increasing tourism pressure while ensuring ecological conservation. Based on the land suitability analysis, a highly suitable site has been identified for the development of

an eco-theme park, which aims to concentrate tourism activities within a controlled and planned environment. This approach helps in reducing unregulated and scattered development along the riverbanks, thereby minimizing environmental degradation and preserving the natural character of the Narmada River corridor.

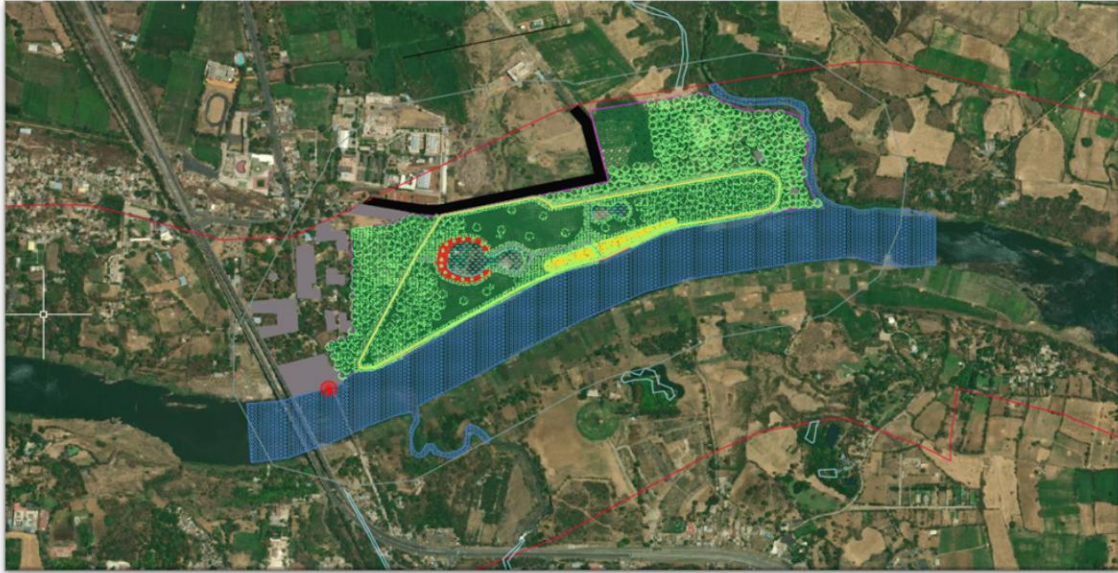


Figure 24 Location of Proposed Eco-Tourism Development Node

The location of the proposed eco-theme park is shown in Figure 24, which illustrates its spatial relationship with the river, surrounding land uses, and connectivity to the National Highway (NH-34). The site is strategically positioned within 200 meters of the highway, ensuring high accessibility for visitors while maintaining a safe and sustainable distance from the river edge. The total area of the proposed park is approximately 56 hectares, making it a significant node for eco-tourism development within the corridor.

The conceptual layout of the eco-theme park is presented in Figure 25, which highlights the zoning of different activity areas within the site. The planning concept is based on the principle of low-impact development, where built interventions are minimized and integrated with the natural landscape. The site is divided into three primary zones: Passive Recreation Zone, Controlled Activity Zone, and Public Interaction Node. The Passive Recreation Zone includes landscaped open spaces, walking trails, and seating areas designed for relaxation and nature appreciation. The Controlled Activity Zone accommodates limited recreational activities such as cycling, eco-friendly play areas, and guided nature experiences. The Public Interaction Node includes facilities such as amphitheatres, gathering spaces, and visitor amenities, designed to handle higher footfall in a controlled manner.



Figure 25 Conceptual Layout and Zoning of Eco-Theme Park



A continuous eco-sensitive buffer of 50–100 meters is maintained along the river edge, as indicated in Figure 25. This buffer zone acts as a protective layer between development and the river, where no permanent construction is allowed. Only soft landscape elements such as pathways, vegetation, and

natural restoration measures are permitted in this zone. This ensures the protection of riparian ecology, prevents soil erosion, and maintains the natural flow and character of the river.

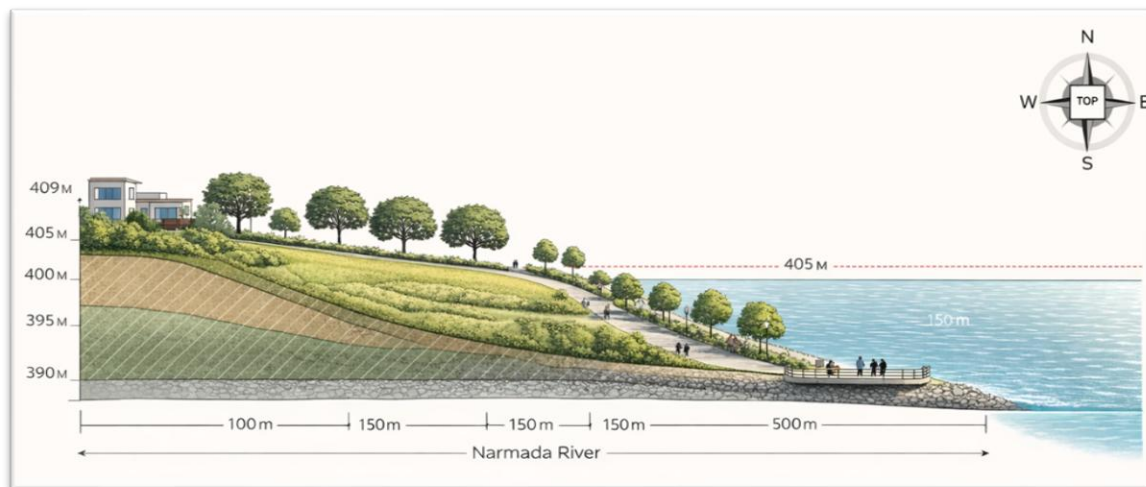


Figure 26 Cross Section of Eco-Tourism Development Proposal

The cross-sectional profile of the proposed development is illustrated in Figure 26, which demonstrates the relationship between built areas, landscape zones, and the river edge. The section clearly shows a gradual transition from developed spaces to natural riverbanks, incorporating vegetation buffers and permeable surfaces. This design approach minimizes surface runoff, enhances groundwater recharge, and reduces the risk of flooding. The use of elevated and lightweight structures in certain areas further ensures resilience against seasonal variations in water levels.

The planning guidelines for the eco-tourism node emphasize sustainability and environmental sensitivity. Only low-impact development is permitted, with strict control on construction activities. The use of permeable materials for pathways and open spaces is encouraged to maintain natural drainage patterns. Native plantation strategies are adopted to enhance biodiversity and ensure ecological compatibility. Additionally, visitor capacity is regulated to prevent overuse of the site and maintain a balance between tourism and conservation.



Figure 27 Material Palette and Landscape Elements Used

Material selection plays a crucial role in reinforcing the eco-sensitive nature of the development. As shown in Figure 27, materials such as permeable paving, bamboo structures, and locally available vegetation species are proposed. Trees such as Neel Mohor and Ashoka are incorporated to provide shade, improve microclimate, and enhance the visual quality of the landscape. Bamboo viewing decks are proposed as lightweight, eco-friendly structures that allow visitors to experience the river without causing significant disturbance to the natural environment.

The proposed eco-tourism node offers multiple benefits at both local and corridor levels. By concentrating tourism activities within a designated area, it reduces pressure on ecologically sensitive stretches of the river. It also enhances public access to the river in a controlled manner, providing opportunities for recreation, education, and community interaction. At the same time, the proposal supports local economic development by creating opportunities for eco-tourism-based activities and employment.

Furthermore, this intervention acts as a model for sustainable river corridor development, demonstrating how tourism and ecology can coexist through careful planning and design. The integration of zoning, buffer management, and low-impact infrastructure ensures that development remains within the carrying capacity of the environment. This approach aligns with broader planning objectives of river conservation, flood risk reduction, and sustainable urban growth.

In conclusion, the eco-tourism development node represents a balanced and context-sensitive planning solution for the Bhedaghat–Jabalpur River corridor. By combining accessibility, environmental protection, and controlled development, the proposal addresses key challenges identified in the analysis stage. It not only enhances the recreational and tourism potential of the corridor but also contributes to long-term ecological sustainability and resilience.

4.2.4 Case Studies, Costing and Funding Mechanism

The eco-tourism development proposal for the Bhedaghat–Jabalpur River corridor is supported by the analysis of selected case studies and a detailed assessment of project costing and funding mechanisms. This approach ensures that the proposal is grounded in practical planning experience while also being financially feasible and implementable.

4.2.4.1 Case Study Analysis

A set of national and international case studies was examined to understand best practices in riverfront development, ecological restoration, and integrated planning. These include Sabarmati Riverfront (Ahmedabad), Cheonggyecheon Stream (Seoul), Bishan-Ang Mo Kio Park (Singapore), and Kochi Metro–Water Metro Integration. Each case study provides important insights into different aspects of river corridor planning.

The Sabarmati Riverfront project demonstrates the importance of controlled edge development, provision of public access, and strong zoning regulations. It shows how riverfronts can be transformed into active public spaces through structured planning. However, it also highlights the need to carefully balance development with ecological considerations. The key learning from this case is the necessity of clearly defined development zones and regulated public access.

The Cheonggyecheon Stream project represents a major shift from hard infrastructure to ecological restoration. The removal of concrete structures and restoration of natural stream conditions improved environmental quality and urban livability. This case emphasizes the importance of prioritizing ecological functions over rigid development approaches.

The Bishan-Ang Mo Kio Park project in Singapore illustrates how naturalized river edges can be integrated with urban landscapes. The project successfully combines flood management with recreational use through soft engineering techniques. It highlights the role of flood-resilient design and ecological integration in riverfront planning.

Similarly, the Kochi Metro and Water Metro integration project demonstrates a multi-modal and eco-sensitive development approach. It focuses on improving accessibility while minimizing disturbance to the water system. The key takeaway is the importance of integrating infrastructure development with ecological systems.

Based on these case studies, the proposed eco-tourism development adopts a soft-edge approach, emphasizes ecological buffers, and promotes controlled public access. These principles ensure that development remains environmentally sensitive while enhancing user experience and accessibility.

4.2.4.2 Costing of Eco-Tourism Development

The financial feasibility of the eco-tourism project is assessed through a detailed costing framework, including land acquisition and development costs. The total area of the proposed eco-theme park is approximately 56 hectares.

The land acquisition cost is estimated based on prevailing peri-urban land values in the Jabalpur region, calculated at ₹2 crore per hectare. Accordingly, the total land acquisition cost amounts to ₹112 crore.

The development cost includes various components such as site development, pathways, public infrastructure, plantation, and utilities. A detailed cost breakdown is provided below

Table 9 Development Cost Breakdown

Component	Estimated Cost (₹ Cr)
Site development (grading, landscape)	18 (5,60,000sqm)
Pathways & cycling tracks	11 (50,000sqm)
Amphitheatre & public node	6 (24,000sqm)
Viewing decks & eco-structures	5 (4Nos)
Plantation & buffer development	8
Parking & entry infrastructure	8 (2 entry & exits)
Utilities (water, lighting, sewage)	16
Total Development Cost	~72 Cr

The total development cost is estimated at approximately ₹72 crore, resulting in an average development cost of about ₹1.3 crore per hectare.

Table 10 Total Project Cost

Component	Cost
Land Acquisition	₹112 Cr
Development	₹72 Cr
Total Estimated Cost	₹184 Cr

The total project cost is estimated at ₹184 crore, which can be rounded off to approximately ₹190–200 crore for planning and implementation purposes.

4.2.4.3 Funding Mechanism and Revenue Generation

To ensure financial sustainability, the project proposes a mixed funding model that combines government funding, public-private partnerships (PPP), and revenue generation mechanisms. Government funding can be sourced from schemes such as the Smart Cities Mission, AMRUT, and state tourism development programs. These schemes can support infrastructure development, ecological restoration, and public facilities.

The PPP model is proposed for activity zones within the eco-tourism park, where private stakeholders can invest in recreational and commercial facilities. A revenue-sharing mechanism can be adopted to ensure financial viability and shared benefits. Revenue generation is expected through multiple sources, including entry fees, parking charges, events, and eco-tourism activities. These revenue streams will support the operation and maintenance of the project in the long term.

2.3.4 Learning Integration into Proposal

The learnings from case studies and costing analysis are directly integrated into the proposed eco-tourism development strategy. The proposal adopts soft-edge development techniques, ecological buffers, and controlled access systems to minimize environmental impact. It also ensures financial feasibility through a balanced funding model combining public investment and private participation.

Overall, the integration of planning principles with financial analysis ensures that the eco-tourism development is sustainable, practical, and aligned with the broader objective of river corridor conservation and development.

4.3 Proposal for Riparian Agroforestry Corridor and Green Buffer Strategy

The proposed riparian agroforestry corridor and green buffer strategy is a key component of the river corridor development plan for the Bhedaghat–Jabalpur stretch of the Narmada River. This proposal aims to establish a continuous ecological buffer along the river, ensuring environmental protection while integrating sustainable land-use practices. The spatial extent and zoning of the proposed green corridor are illustrated in Figure 28, which shows the continuous buffer along both banks of the river.

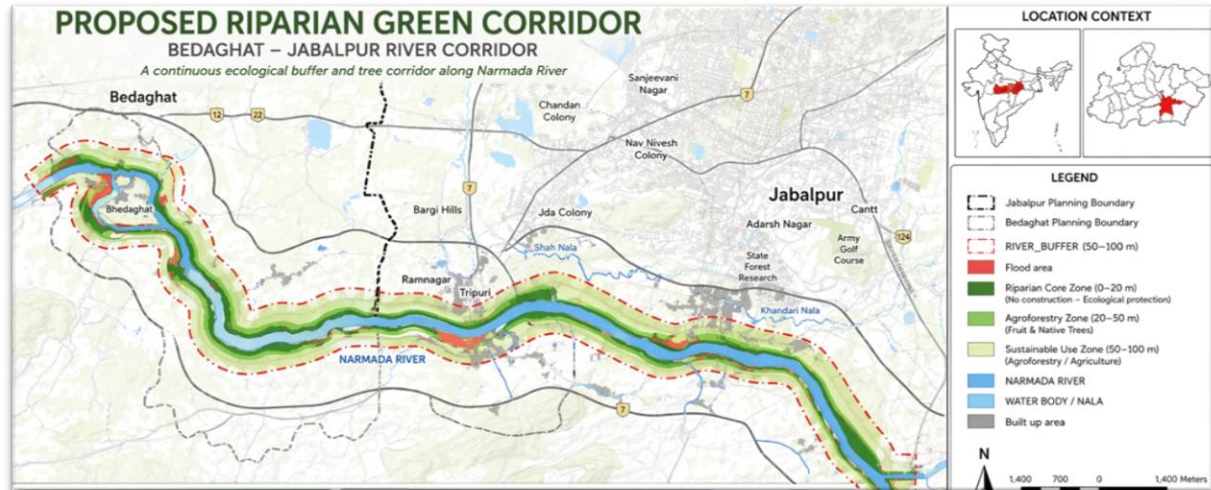


Figure 28 The spatial extent and zoning of the proposed green corridor

The primary objective of this strategy is to restore and protect the riparian ecosystem while addressing issues such as soil erosion, encroachment, water quality degradation, and loss of biodiversity. The river corridor currently faces increasing pressure from unregulated development, agricultural expansion, and tourism-related activities. In this context, the introduction of a structured green buffer acts as a natural defense system, improving ecological resilience and maintaining the functional integrity of the river system.

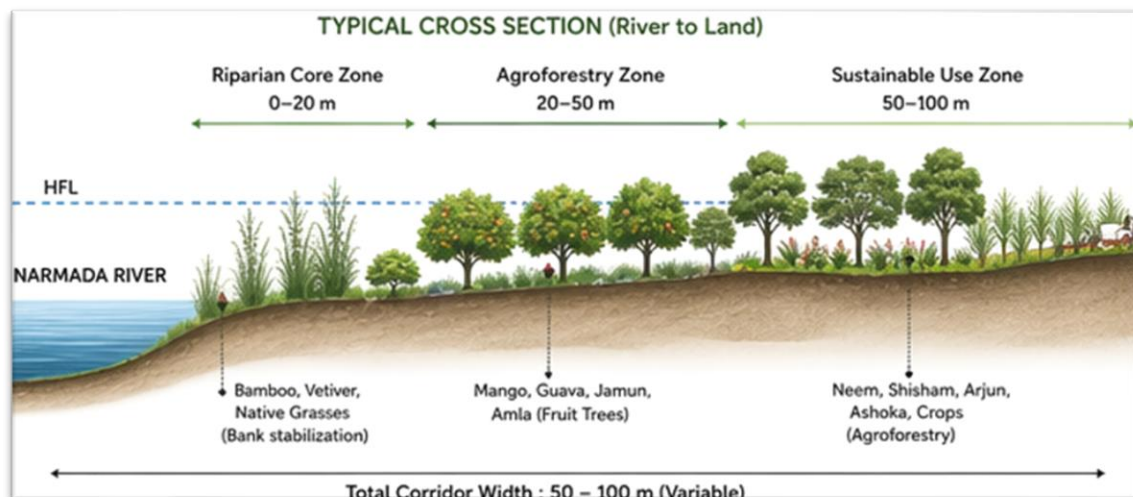


Figure 29 Typical cross-sectional view of the Proposed Riparian corridor

The proposed corridor is designed with a variable buffer width ranging from 50 to 100 meters, depending on local conditions such as topography, flood levels, and land availability. This buffer is divided into three functional zones: Riparian Core Zone, Agroforestry Zone, and Sustainable Use Zone.

The zoning structure and its spatial arrangement are represented in Figure 28, which provides a typical cross-sectional view of the corridor from the river edge towards the inland areas.

The Riparian Core Zone, extending approximately 0–20 meters from the riverbank, is designated as a strictly protected area where no construction or human intervention is permitted. This zone is reserved for natural vegetation, bank stabilization, and habitat protection. Native species such as bamboo, vetiver grass, and local shrubs are recommended to strengthen the riverbanks and reduce erosion. This zone plays a critical role in maintaining river ecology, filtering pollutants, and supporting aquatic and terrestrial biodiversity.

The Agroforestry Zone, extending from approximately 20–50 meters, serves as a transition area where controlled human activity is allowed in the form of agroforestry practices. This zone integrates agricultural productivity with ecological conservation by promoting the plantation of fruit-bearing and native tree species such as mango, guava, jamun, neem, and arjun. Agroforestry not only improves soil fertility and microclimatic conditions but also provides an additional source of income for local farmers. This approach ensures that conservation efforts are economically beneficial and socially inclusive.

The Sustainable Use Zone, extending from 50–100 meters, allows for low-intensity land-use activities such as agriculture, agroforestry, and limited rural development. However, strict regulations are imposed to prevent high-impact construction and ensure that land use remains compatible with ecological objectives. This zone acts as a buffer between the core ecological areas and human settlements, reducing direct pressure on the river system.

The cross-sectional design of the corridor, as shown in Figure 29, illustrates the gradual transition from the river edge to inland areas, incorporating vegetation layers, agroforestry plantations, and sustainable land-use practices. This layered approach enhances ecological continuity, improves landscape aesthetics, and ensures functional integration between natural and human systems.

The environmental and socio-economic benefits of the proposed green corridor are significant. The strategy helps in reducing soil erosion and sedimentation, improving water quality, enhancing biodiversity, and increasing green cover along the river. Additionally, it provides livelihood opportunities for local communities through agroforestry and sustainable agriculture. The corridor also acts as a carbon sink, contributing to climate change mitigation and improving overall environmental resilience.

An important aspect of the proposal is the transformation of the river corridor from its current degraded condition to a restored and sustainable landscape. The “before and after” scenario, depicted in Figure 30, clearly demonstrates the potential impact of the intervention. The existing condition is characterized by sparse vegetation, erosion-prone banks, and unregulated land use. In contrast, the proposed scenario shows a well-defined green corridor with continuous vegetation, stabilized banks, and organized land-use patterns.

The implementation strategy for the green corridor is based on a collaborative approach involving government agencies, local bodies, and farmers. The project can be implemented through a Public-Private Partnership (PPP) or cooperative model. Government support is essential for policy implementation, funding, and technical guidance, while local communities play a key role in plantation, maintenance, and monitoring activities.

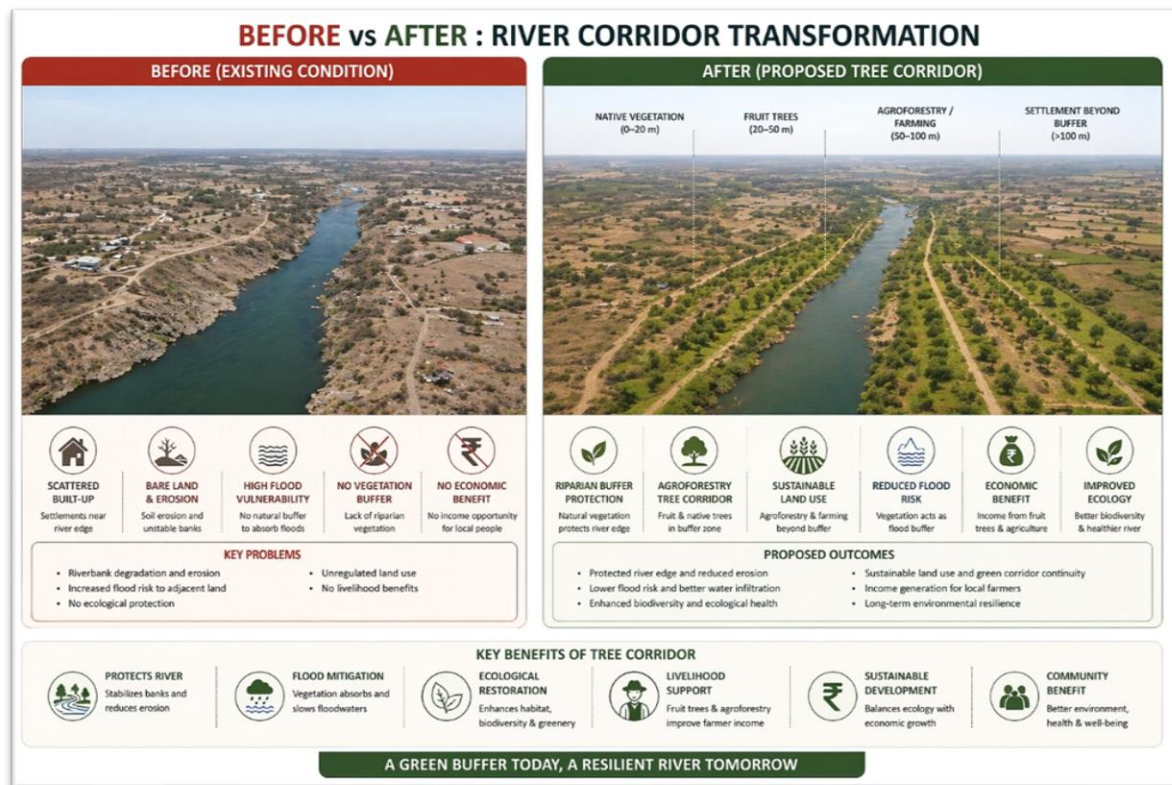


Figure 30 The “before and after” scenario of Proposed Riparian Corridor

The proposal is aligned with existing policy frameworks such as the National Green Tribunal (NGT) guidelines and River Regulation Zone (RRZ) norms, which emphasize buffer protection and restricted development along riverbanks. The policy framework, shown in Figure 31, includes buffer zone regulations, land-use control mechanisms, and support measures such as incentives for farmers, agroforestry promotion, and market linkages. These measures ensure that the proposed strategy is not only environmentally sustainable but also economically viable and socially acceptable.

From a financial perspective, the riparian agroforestry corridor is a low-cost, high-impact intervention. The plantation cost is estimated at ₹3–5 lakh per hectare, with relatively low maintenance requirements. This makes it a feasible solution for large-scale implementation across the river corridor. Compared to heavy infrastructure-based interventions, this nature-based approach provides long-term ecological and economic benefits at a lower cost.

The expected outcomes of the proposed strategy include improved river ecology, reduced encroachment, enhanced biodiversity, increased farmer income, and the creation of a continuous green corridor along the river. These outcomes contribute to the overall goal of sustainable river corridor development by balancing environmental conservation with socio-economic development.

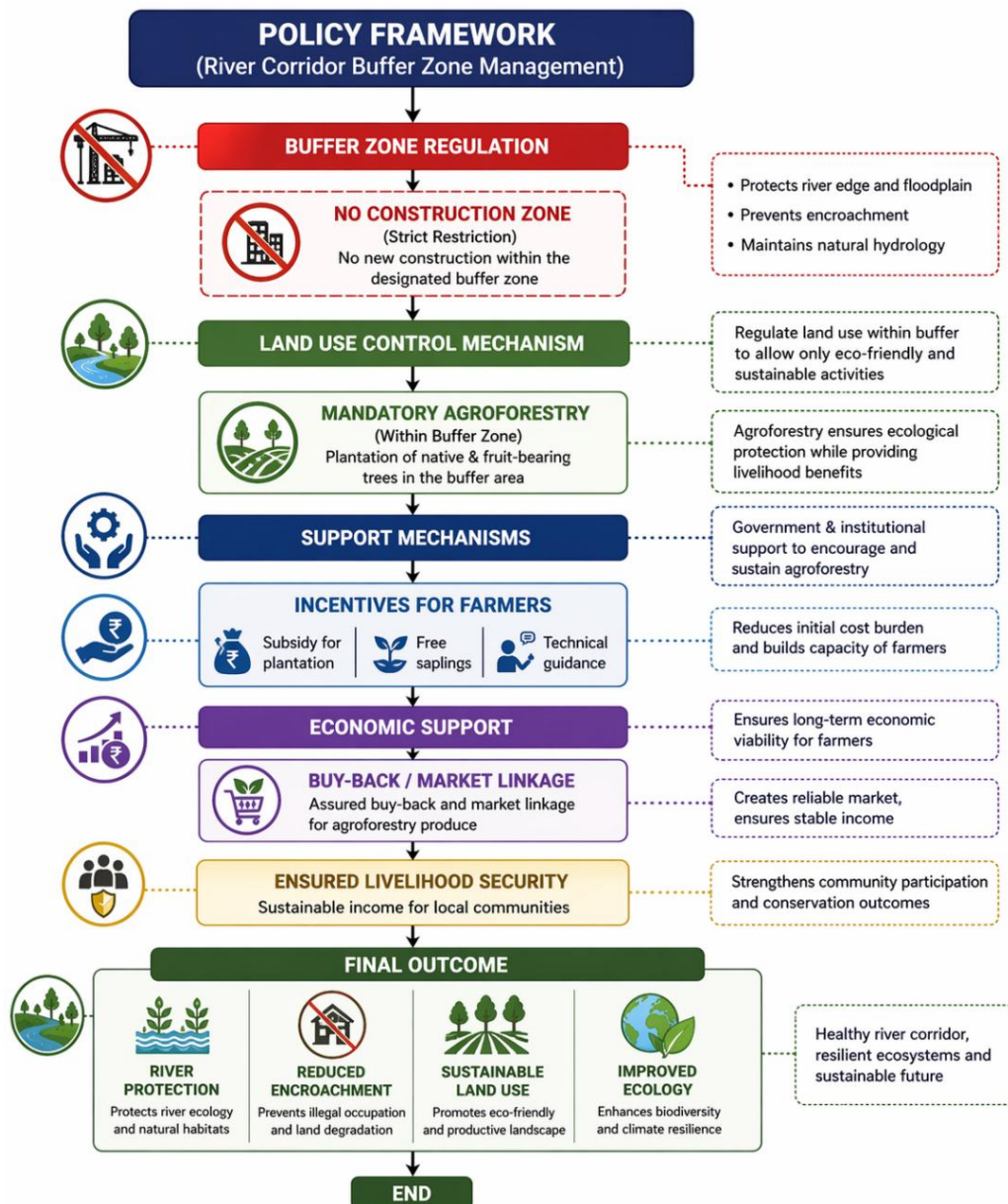


Figure 31 The policy framework for proposed Riparian Corridor

In conclusion, the riparian agroforestry corridor and green buffer strategy provides a holistic and sustainable approach to river corridor management. By integrating ecological restoration with livelihood generation and policy support, the proposal addresses multiple challenges simultaneously. It ensures the protection of the river ecosystem while promoting sustainable land use and community participation. This strategy serves as a crucial link between environmental conservation and development planning, making it an essential component of the overall river corridor development framework.

4.4 Proposal for Eco-Sensitive River Edge Development and Tourism Strategy – Bhedaghat Island

The eco-sensitive river edge development proposal for Bhedaghat Island represents a site-specific intervention within the larger river corridor planning framework. The island, located along the Narmada River near Bhedaghat, is characterized by its unique geomorphology, scenic landscape, and cultural significance. However, increasing tourism pressure and unregulated activities pose a threat to its ecological integrity. Therefore, the proposal aims to develop the island as an eco-sensitive tourism destination through a low-impact planning approach that prioritizes conservation while enhancing visitor experience.

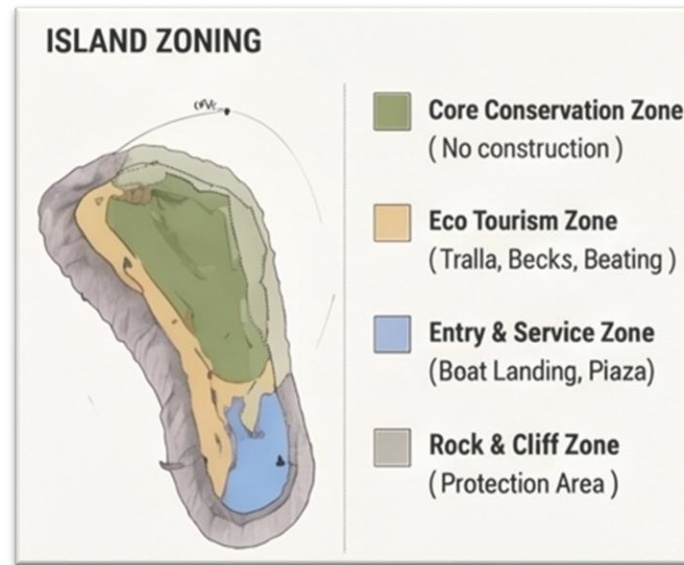


Figure 32 Layout and zoning of the Bhedaghat island for Eco Tourism Development

The overall spatial layout and zoning of the island are presented in Figure 32, which illustrates the distribution of activity areas, conservation zones, and circulation networks. The island is divided into four major zones: Core Conservation Zone, Eco-Tourism Zone, Entry and Service Zone, and Built-up/Settlement Zone. The Core Conservation Zone is strictly protected, with no construction permitted, ensuring the preservation of natural vegetation and landscape. The Eco-Tourism Zone accommodates controlled visitor activities such as nature trails, viewing decks, and rest areas. The Entry and Service Zone is located near the boat landing point and includes basic visitor facilities, while the Built-up Zone represents the existing settlement area that is retained with minimal intervention.

The planning concept is based on the principle of low-impact development, which focuses on minimal disturbance to natural systems. As highlighted in Figure 33, the design preserves the natural topography, vegetation cover, and rock formations of the island. Construction activities are restricted in steep and erosion-prone areas, and all interventions are designed to blend with the existing landscape. The use of local materials and lightweight structures ensures that the visual and ecological character of the island is maintained.

Circulation within the island is carefully planned to ensure safe and controlled movement of visitors. A network of nature trails, as shown in Figure 33, connects key nodes across the island, including viewpoints, rest areas, and interpretation points. These trails are designed along the natural contours to avoid unnecessary cutting of terrain and to minimize environmental disturbance. Elevated pathways and cliff walks are proposed in selected areas to provide panoramic views of the river while ensuring visitor safety.



Figure 33 Conceptual Map for Eco Tourism Proposal in Bhedaghat island

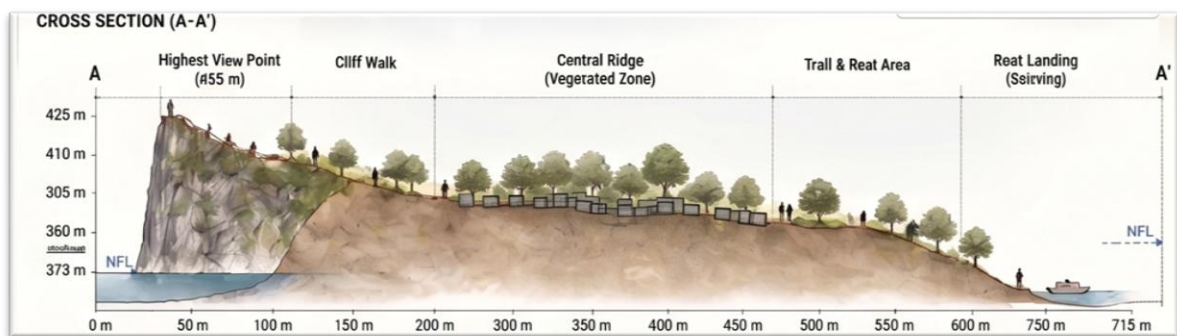


Figure 34 The cross-sectional profile of the Proposed Eco Tourism Bhedaghat island

Key activity nodes are strategically located across the island to enhance visitor experience without overloading any particular area. These include viewing decks at high points, rest and seating areas, eco-interpretation centres, and designated boat landing points. The cross-sectional profile of the island, illustrated in Figure 33, highlights the variation in elevation and the placement of different activity zones. The highest viewpoint (approximately 425 m) provides a panoramic view of the river corridor, while lower areas are used for passive recreation and interpretation activities.

The proposal also emphasizes ecological restoration and conservation. Native vegetation is preserved and enhanced through plantation strategies, particularly in degraded areas. Rock outcrops and natural features are retained as integral elements of the landscape. Buffer zones are maintained along the edges to prevent erosion and protect the river ecosystem. These measures ensure that tourism development does not compromise the ecological health of the island.

A key aspect of the proposal is the transformation of the island from its current state to a well-managed eco-tourism destination. The “before and after” transformation is depicted in Figure 35, which illustrates the shift from unorganized and degraded conditions to a structured and sustainable landscape. The proposed transformation includes improved vegetation cover, organized pathways, designated activity

zones, and enhanced accessibility, all while maintaining ecological balance.

BHEDAGHAT ISLAND – ECO TOURISM TRANSFORMATION

From a Natural Landscape to a Sustainable Eco-Tourism Destination

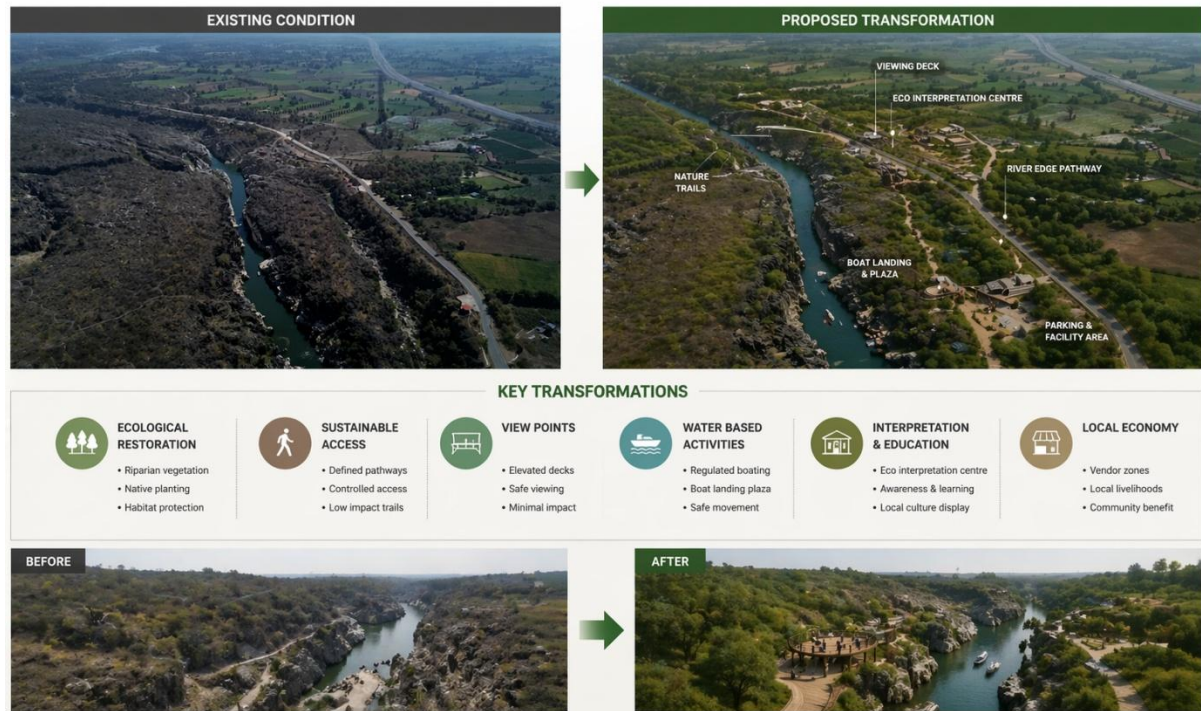


Figure 35 The “before and after” transformation of Proposed Eco Tourism Bhedaghat Island

From a design perspective, the proposal follows a set of clear planning controls to regulate development. These include restrictions on construction within the core conservation zone, provision of controlled access pathways, regulation of boating activities, and the use of eco-friendly materials. These controls ensure that development remains within the carrying capacity of the island and does not lead to environmental degradation.

The financial aspect of the proposal is relatively modest compared to large-scale infrastructure projects, as it focuses on low-impact interventions. The major components include pathways and eco-trails (approximately 3.7 km), viewing decks (4 units), and an eco-interpretation centre (100–150 sqm). The estimated cost for these components ranges between ₹7.5 crore to ₹12.5 crore, making it a cost-effective solution for sustainable tourism development.

The expected outcomes of the proposal are multi-dimensional. Environmentally, it ensures ecological protection, restoration of degraded areas, and preservation of natural landscapes. Socially, it improves accessibility, enhances visitor experience, and promotes awareness about conservation. Economically, it supports local livelihoods through eco-tourism activities and related services. Additionally, it strengthens the identity of Bhedaghat as an eco-sensitive tourism destination.

In conclusion, the eco-sensitive development strategy for Bhedaghat Island demonstrates how tourism can be integrated with conservation through careful planning and design. By adopting a low-impact approach, regulating visitor movement, and preserving natural features, the proposal achieves a balance between development and environmental protection. This intervention not only enhances the tourism potential of the island but also contributes to the overall sustainability of the river corridor. It serves as a model for similar eco-sensitive tourism developments in fragile landscapes, where the primary focus is on conservation-driven planning.

CHAPTER 5 CONCLUSION AND WAY FORWARD

The present study, titled “*Planning and Development of River Corridor between Bhedaghat and Jabalpur*,” was undertaken with the objective of understanding the spatial, ecological, and developmental dynamics of the river corridor and preparing an integrated physical planning framework for its sustainable development. River corridors represent highly sensitive landscapes where natural systems, human settlements, economic activities, and cultural values interact continuously. In the Indian context, where rapid urbanization and infrastructure expansion increasingly exert pressure on natural ecosystems, river corridor planning has become a critical area of research and policy intervention. The selected study area, located along the Narmada River between Bhedaghat and Jabalpur, presents a unique planning context due to its combination of ecological sensitivity, tourism significance, cultural importance, and increasing developmental pressures. Through a systematic integration of geospatial analysis, field observations, policy review, and planning interventions, this study attempts to address these complexities and propose a balanced framework for future development.

The findings of the study clearly establish that river corridors should not be viewed merely as linear geographical features but as dynamic socio-ecological systems that require integrated planning and management. The analysis of land use and land cover changes over the study period demonstrates significant transformation within the corridor, primarily driven by urban expansion, tourism-related development, transportation infrastructure, and agricultural modifications. The spatial comparison between historical and recent land use datasets reveals a substantial increase in built-up areas, particularly near urban influence zones around Jabalpur, accompanied by a corresponding reduction in vegetation cover and open natural landscapes. Such changes indicate growing anthropogenic pressure on the river ecosystem and highlight the urgent need for planned intervention to prevent ecological degradation and unregulated development. The study confirms that if current trends continue without strategic regulation, the ecological carrying capacity of the corridor may be severely compromised in the future.

The environmental analysis carried out as part of the study provides critical insights into the physical constraints and ecological vulnerabilities of the corridor. Terrain analysis indicates that large portions of the Bhedaghat stretch consist of steep slopes, rugged topography, and fragile geological formations, particularly the marble rock landscapes for which the area is nationally recognized. These physical characteristics make the region highly sensitive to intensive development activities. Similarly, the analysis of floodplains, riparian zones, and drainage networks reveals that many parts of the corridor are naturally prone to seasonal flooding and hydrological fluctuations. Such areas perform essential ecological functions, including groundwater recharge, sediment transport, habitat support, and flood mitigation. However, the encroachment of human activities into these environmentally sensitive zones has increased the vulnerability of the landscape. The findings strongly suggest that planning interventions in river corridors must be informed by physical suitability and ecological sensitivity rather than solely by economic or urban development considerations.

One of the major contributions of this research lies in the identification and spatial mapping of conflict zones within the corridor. Using GIS-based overlay analysis, multiple parameters including land use, slope, accessibility, drainage proximity, and environmental sensitivity were integrated to identify areas where development pressures conflict with ecological constraints. The results reveal significant spatial conflicts, particularly in areas where built-up development has expanded within environmentally sensitive buffer zones. Encroachments were observed within 30-meter, 100-meter, and in some cases even 300-meter buffer zones from the river edge, indicating a clear violation of recommended regulatory standards. This not only disrupts natural hydrological processes but also increases flood vulnerability, erosion risks, and habitat fragmentation. Such findings validate the initial hypothesis of

the study that the river corridor is experiencing increasing spatial conflicts due to weak implementation of planning regulations and fragmented development control mechanisms.

The policy review conducted under the study further highlights the gap between regulatory intent and ground-level implementation. Existing frameworks such as the Ministry of Housing and Urban Affairs's URDPFI guidelines, river buffer regulations, environmental protection norms, and river regulation principles provide a strong policy foundation for sustainable river corridor management. However, the spatial analysis reveals that many of these provisions are inadequately enforced at the local level. The absence of integrated institutional coordination, limited monitoring mechanisms, and lack of site-specific development controls have allowed incompatible land uses to emerge within ecologically sensitive zones. The study therefore emphasizes that policy effectiveness depends not only on the existence of regulations but also on their translation into spatial planning frameworks supported by monitoring, enforcement, and stakeholder participation.

Another important finding of the research relates to the degradation of natural ecological systems within the corridor. The analysis of vegetation cover using NDVI and field-based observations indicates a gradual decline in riparian vegetation continuity, particularly in areas affected by urban expansion and tourism activities. Fragmentation of green corridors has reduced ecological connectivity, affecting biodiversity and weakening natural resilience. Similarly, drainage analysis reveals that several natural water channels have been obstructed, modified, or encroached upon by development activities, resulting in localized flooding and altered surface runoff patterns. These findings underline the critical role of ecological infrastructure in maintaining the health of river systems. The study demonstrates that sustainable river corridor planning must integrate green infrastructure, riparian restoration, and hydrological conservation as core planning components rather than optional environmental measures.

In response to the identified issues, the study proposes a comprehensive planning framework based on spatial zonation. The river corridor is classified into three major planning zones: Conservation Zone, Regulated Development Zone, and Controlled Urban Development Zone. This zonation approach is designed to align future development with the ecological carrying capacity and physical characteristics of each stretch. The Conservation Zone, primarily covering the Bhedaghat region, is proposed to remain under strict environmental protection, permitting only low-impact activities such as ecological tourism, scientific research, and landscape conservation. The Regulated Development Zone, located in the transitional middle stretch, allows controlled low-density development integrated with agro-based activities, community participation, and eco-tourism initiatives. The Controlled Urban Development Zone, largely associated with the Jabalpur urban influence area, focuses on managing existing urban pressures through infrastructure improvement, redevelopment strategies, and strict enforcement of environmental buffers. This zonation framework provides a practical and context-specific mechanism for balancing environmental conservation with developmental needs.

A major strength of this research is the integration of site-specific proposals within the broader corridor-level planning framework. Rather than limiting the study to theoretical recommendations, practical interventions have been developed to address localized challenges. The proposed eco-tourism development node aims to organize tourism activities in designated areas, thereby reducing unregulated visitor pressure on ecologically sensitive zones. The riparian agroforestry corridor introduces a nature-based solution that combines environmental restoration with livelihood generation, promoting sustainable land management while supporting local communities. Similarly, the eco-sensitive development strategy for Bhedaghat Island demonstrates how tourism infrastructure can be designed with minimal ecological disturbance by integrating low-impact design principles, controlled accessibility, and landscape-sensitive architecture. These proposals collectively illustrate how site-level interventions can complement corridor-level planning objectives.

From an environmental perspective, the proposed strategies offer multiple long-term benefits. Restoration of riparian vegetation and the introduction of green buffers will enhance biodiversity,

improve water quality, reduce soil erosion, and strengthen ecological connectivity. Protection of natural drainage systems will improve hydrological resilience and reduce flood risks. The incorporation of climate-responsive planning principles ensures that the corridor remains adaptive to future environmental uncertainties, including changing rainfall patterns and extreme weather events. Thus, the study contributes not only to current environmental management but also to long-term climate resilience planning.

From a socio-economic perspective, the study demonstrates that environmental conservation and economic development are not mutually exclusive. Sustainable tourism, agroforestry initiatives, local entrepreneurship, and community-based resource management can generate livelihoods while preserving natural and cultural heritage. By promoting inclusive development strategies, the proposed framework ensures that local communities become active stakeholders in corridor management rather than passive beneficiaries. Such participation is essential for the long-term success of planning interventions and for building local ownership of conservation efforts.

Despite its significant contributions, the study acknowledges certain limitations. The analysis primarily relies on secondary spatial datasets, medium-resolution satellite imagery, and limited temporal datasets, which may restrict the identification of micro-level changes and informal encroachments. Additionally, detailed hydrological simulations and climate modeling were beyond the scope of the current research. Nevertheless, the integration of GIS-based spatial analysis, field validation, and planning synthesis ensures that the findings remain robust and applicable for strategic planning purposes. Future research may incorporate high-resolution UAV mapping, real-time environmental monitoring, hydrodynamic modeling, and participatory planning tools to enhance the precision and implementation potential of the proposed framework.

In conclusion, this study successfully demonstrates that river corridor planning requires a holistic, multidisciplinary, and ecologically sensitive approach that integrates physical planning principles with environmental stewardship. The Bhedaghat–Jabalpur stretch of the Narmada River serves as an important case study representing the challenges faced by many transitional river systems in India. Through systematic spatial analysis, policy evaluation, conflict identification, and strategic planning proposals, the study provides a practical and replicable framework for sustainable river corridor development. The proposed strategies not only address present-day challenges but also establish a long-term vision for a resilient, environmentally balanced, and socially inclusive river corridor. Ultimately, this research reinforces the principle that rivers must be planned as living ecosystems—protected, respected, and integrated into the broader framework of sustainable regional development for future generations.

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