FROM NEGLECT TO TRANSFORMATION: ENVISIONING A SUSTAINABLE FUTURE FOR NAG RIVER, NAGPUR THROUGH URBAN RIVER-ORIENTED DEVELOPMENT (U-ROD)

BACHELOR OF PLANNING

(Department of Urban and Regional Planning)

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MAY 2025

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Thesis submitted in partial fulfilment of the requirements for the award of the degree of

BACHELOR OF PLANNING

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AARUL BHALEKAR

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Under the Guidance of

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Declaration

I, **Aarul Bhalekar**, Scholar No. **2021BPLN007**, hereby declare that the thesis entitled "**From Neglect To Transformation: Envisioning A Sustainable Future for Nag River, Nagpur through Urban River-Oriented Development (U-ROD)"** submitted by me in partial fulfillment for the award of **Bachelor of Planning (Urban and Regional Planning)**, at School of Planning and Architecture, Bhopal, India, in the department of URP 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.

Signature of the Student

Date: May 2025

Certificate

This is to certify that the declaration of **Aarul Bhalekar** is true to the best of my knowledge and that the student has worked under my guidance for one semester in preparing this thesis.

RECOMMENDED

_____ _____

Signature of the Co-Guide
Prof. Aparna Soni

Signature of the Guide
Prof. Mrunmayi Wadwekar

ACCEPTED

_____

Signature of the Head, Department of Urban and Regional Planning
Dr. Sheuli Mitra
May 2025
Bhopal

Acknowledgment

The past four years have been a transformative journey marked by continuous learning, exploration, and growth. This thesis is a reflection of the knowledge, skills, and critical thinking that I have cultivated through the academic program. Every experience—inside and outside the classroom—has contributed to shaping this research, and it stands as a testament to the academic rigor and intellectual curiosity fostered over the course of my education.

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Abstract

Urban rivers have historically shaped the spatial, ecological, and socio-cultural identities of cities. However, rapid urbanization, fragmented governance, and weak policy integration have led to their significant degradation. The **Nag River** in **Nagpur, Maharashtra**—once a vital ecological and cultural asset lending its name to the city—now faces severe challenges due to pollution, encroachment, altered hydrology, and urban neglect. As Nagpur emerges as a key tier-2 city, restoring the health of the Nag River becomes critical to its sustainable urban future.

This research formulates the **Urban River-Oriented Development (U-ROD)** framework, an interdisciplinary planning model that reimagines rivers as strategic urban assets and drivers of ecological resilience. U-ROD draws from spatial analytics, hydrological modeling, and flood vulnerability assessments to diagnose riparian land-use conflicts and environmental risks. It also explores innovative climate finance mechanisms—including green bonds, land value capture, carbon credits, and blended public-private investments—to mobilize resources for long-term restoration.

Aligned with national initiatives such as the **Urban River Management Plan (URMP)** under the **National Institute of Urban Affairs (NIUA)**, U-ROD integrates eco-sensitive zoning, participatory governance, and institutional reforms to mainstream river-centric urban development. It emphasizes nature-based solutions, community engagement, and cross-sectoral coordination as essential pillars for sustainable river management.

The study not only addresses the specific challenges of the Nag River but also offers a replicable, scalable model applicable to urban rivers across India, particularly in emerging cities. By repositioning rivers as dynamic, living corridors, the research contributes to global dialogues on sustainable infrastructure, water-sensitive planning, and regenerative urbanism—bridging critical gaps between ecological conservation, urban livability, and resilient futures.

Keywords: Urban River-Oriented Development (U-ROD); Sustainable Urban Development; Finance; Nature-Based Solutions; Eco-sensitive Zoning.

सारांश

शहरी नदियों ने ऐतिहासिक रूप से शहरों की स्थानिक, पारिस्थितिक और सामाजिक-सांस्कृतिक पहचान को आकार दिया है। हालांकि, तीव्र शहरीकरण, विखंडित शासकीय व्यवस्था और कमजोर नीति एकीकरण के कारण इन नदियों का गंभीर क्षरण हुआ है। महाराष्ट्र के नागपुर शहर की नाग नदी—जो कभी शहर की पहचान और एक महत्वपूर्ण पारिस्थितिक-सांस्कृतिक संपत्ति थी—आज प्रदूषण, अतिक्रमण, बदली हुई जलगतिकी और शहरी उपेक्षा जैसी गंभीर चुनौतियों का सामना कर रही है। नागपुर के एक प्रमुख द्वितीय श्रेणी (टीयर-2) शहर के रूप में उभरने के साथ, नाग नदी के स्वास्थ्य का पुनर्स्थापन इसके सतत शहरी भविष्य के लिए अत्यंत महत्वपूर्ण हो गया है।

यह शोध **"अर्बन रिवर-ओरिएंटेड डेवलपमेंट (यू-आरओडी)"** ढांचे को प्रस्तुत करता है, जो एक अंतर्विषयी नियोजन मॉडल है और नदियों को रणनीतिक शहरी परिसंपत्तियों तथा पारिस्थितिकीय पुनर्स्थापन के प्रेरक कारकों के रूप में पुनः कल्पित करता है। यू-आरओडी स्थानिक विश्लेषण, जलगतिकी मॉडलिंग और बाढ़ संवेदनशीलता आकलनों के माध्यम से नदी तटीय भूमि उपयोग संघर्षों और पर्यावरणीय जोखिमों की पहचान करता है। यह हरित बॉन्ड, भूमि मूल्य अधिग्रहण, कार्बन क्रेडिट तथा सार्वजनिक-निजी निवेश जैसी नवीन जलवायु वित्तीय व्यवस्थाओं का भी अन्वेषण करता है, जो दीर्घकालिक पुनर्स्थापन के लिए संसाधनों को जुटाने में सहायक हैं।

राष्ट्रीय शहरी कार्य संस्थान (NIUA) के अंतर्गत **शहरी नदी प्रबंधन योजना (URMP)** जैसी राष्ट्रीय पहलों के अनुरूप, यू-आरओडी पारिस्थितिक संवेदनशील क्षेत्र निर्धारण, सहभागी शासन प्रणाली और संस्थागत सुधारों को एकीकृत करता है, जिससे नदी-केंद्रित शहरी विकास को मुख्यधारा में लाया जा सके। यह प्रकृति आधारित समाधानों, सामुदायिक सहभागिता और बहु-क्षेत्रीय समन्वय को सतत नदी प्रबंधन के आवश्यक स्तंभों के रूप में रेखांकित करता है।

यह अध्ययन न केवल नाग नदी की विशिष्ट चुनौतियों को संबोधित करता है, बल्कि भारत भर के शहरी नदियों के लिए एक प्रतिरूपणीय और विस्तार योग्य मॉडल भी प्रस्तुत करता है, विशेष रूप से उभरते शहरों के संदर्भ में। नदियों को जीवंत और गतिशील गलियारों के रूप में पुनःस्थापित करते हुए, यह शोध सतत अवसंरचना, जल-संवेदनशील नियोजन और पुनर्जीवित शहरीवाद पर वैश्विक विमर्शों में महत्वपूर्ण योगदान देता है, तथा पारिस्थितिक संरक्षण, शहरी जीवन गुणवत्ता और लचीले भविष्य के बीच की महत्वपूर्ण खाइयों को पाटने का प्रयास करता है।

मुख्य शब्द: अर्बन रिवर-ओरिएंटेड डेवलपमेंट (यू-आरओडी); सतत शहरी विकास; जलवायु वित्त; प्रकृति आधारित समाधान; पारिस्थितिकीय संवेदनशील क्षेत्र निर्धा

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List of Abbreviations:

U-ROD – Urban River-Oriented Development

URMP – Urban River Management Plan

SPV – Special Purpose Vehicle

NDZ – No Development Zone

PRZ – Primary Riverfront Zone

SIZ – Secondary Influence Zone

TUIZ – Tertiary Urban Integration Zone

FSI – Floor Space Index

TDR – Transferable Development Rights

FBCs – Form-Based Codes

WSUD – Water-Sensitive Urban Design

GCF – Green Climate Fund

GRESB – Global Real Estate Sustainability Benchmar

1. INTRODUCTION

1.1. CONTEXTUAL BACKGROUND

Urbanization, especially in rapidly developing nations, has led to unprecedented growth in cities, driven by population increases and migration from rural to urban areas in search of better economic opportunities. As urban areas expand, the pressure on natural resources intensifies, creating challenges that threaten long-term sustainability. Urban environments, where a large portion of the world's consumers and waste producers are concentrated, contribute significantly to the depletion of natural resources. The rapid growth of urban areas demands the construction of infrastructure such as housing, roads, industrial and commercial facilities, and waste management systems, often resulting in the degradation of the environment.

One vital but frequently overlooked feature in urban planning is the riverine ecosystem. Rivers, especially in urban environments, are not merely watercourses but serve as crucial ecosystems, providing services such as water supply, flood regulation, transportation routes, and recreational spaces. Historically, cities have grown around rivers, with these water bodies supplying resources for agriculture, trade, and industry. However, with the pressures of urbanization, many urban rivers are now facing ecological degradation and the loss of their natural functions.

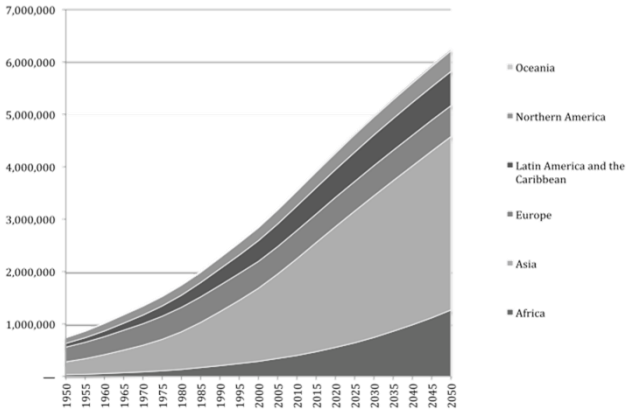


Figure 1: Total Urban Population by World Region (1950 – 2050)

Source: Integrating the Environment in Urban Planning and Management, UNEP (2013)

1.1.1. The Multifaceted Role and Function of Urban Rivers

City ecosystems are shaped by urban rivers, which also improve economic viability and enhance social and cultural life. Because rivers are vital conduits for trade, transportation, and food, cities have historically thrived along them (World Bank, 2022). Groundwater recharge, biodiversity preservation, and climate regulation are just a few of the vital ecosystem services that urban rivers offer (United Nations Environment Programme [UNEP], 2021). However, there is an urgent need for integrated and sustainable management frameworks due to the substantial degradation caused by rapid urbanization, industrial growth, and inadequate environmental governance (United Nations Human Settlements Programme [UN-Habitat], 2021; OECD, 2021).

Ecological and Climate Resilience Functions

Urban rivers are crucial in protecting cities from climate issues and supporting the environment. They act as natural barriers, soaking up extra rainwater to help prevent serious city flooding (Intergovernmental Panel on Climate Change [IPCC], 2021). The areas around these rivers, called riparian zones, support a variety of land and water life and naturally help clean water by filtering it (World Resources Institute, 2020). Urban rivers also store carbon, which is important for reducing greenhouse gases in the air (International Union for Conservation of Nature [IUCN], 2021). Maintaining these river environments is essential for supporting diverse plants and animals, improving air and water quality, and helping cities adapt to climate changes.

Economic Contributions and Revitalizing City Areas

Urban rivers are key to boosting local and regional economies. They enhance waterfront properties, attract tourists, support trade, and drive numerous business activities. Cities such as London, Paris, and Shanghai have historically grown by making smart use of their river systems. Nowadays, cities like Singapore and Seoul demonstrate how improving riverfront areas can combine ecological protection with economic growth. These projects transform urban spaces into dynamic, lively areas while safeguarding natural resources.

Urban rivers hold a special place in both culture and social life. They play important roles in religious, spiritual, and community activities for city residents (United Nations Educational, Scientific and Cultural Organization [UNESCO], 2022). Rivers like the Ganges in India and the Seine in France are far more than simple water flows. They stand as symbols of long histories and community identities (ADB, 2021). When riverfronts in cities are easy to reach and well maintained, they bring many benefits. These benefits include improving public health, providing fun areas for people, cooling down hot city zones, and making urban air cleaner (AIIB, 2022).

Integrated Approaches for Sustainable River Management

To protect city rivers for the future, we need a solid plan that involves everyone working together. This means doing things like fixing up rivers, saving wetlands, and adding green areas. It's also critical to get help from different groups like the government, businesses, and local communities so everyone is involved and decisions are better. We must invest in controlling pollution, treating wastewater, and making sure city designs can handle climate changes. These steps are key to making city rivers healthy and useful again in terms of ecology, economy, and society.

To address these challenges, an integrated river management framework is essential. This includes the adoption of nature-based solutions, such as river restoration projects, wetland conservation, and green infrastructure initiatives (OECD, 2021). Additionally, multi-stakeholder collaborations involving government agencies, private sector players, and community groups are crucial for ensuring sustainable urban river management (World Bank, 2021). Investments in wastewater treatment, pollution control measures, and resilient urban planning can restore and sustain urban rivers for future generations (ADB, 2022).

Urban rivers are indispensable assets for sustainable urban development, offering ecological, economic, and social benefits. Without comprehensive management and policy interventions, these rivers risk further degradation, undermining urban resilience and quality of life. By adopting a holistic and participatory approach, cities can maximize the potential of urban rivers, ensuring long-term environmental sustainability, economic prosperity, and improved urban livability (UNEP, 2021). Urban planners, policymakers, and local stakeholders must prioritize the conservation and

revitalization of urban rivers to create resilient, inclusive, and sustainable urban environments.

1.1.2. River-Oriented Development (ROD): Reimagining Urban Futures

From the very beginning, human beings have thrived around riverbanks. This is primarily because rivers serve numerous purposes, including trade routes, sources of agriculture, and cultural intersection points. Water is an essential part of life, as well as urban growth, witnessed during the rise of civilizations such as the Mesopotamia, Indus Valley, and Egypt regions (Mitra, 2019). In modern times however, cities and rivers have been systematically disconnected. The relationship between the two has become highly powerless, giving rise to fragmented governance, pollution, and illegal land use (Jain & Sharma, 2021). The socio-cultural and ecological value of the river is heavily overlooked in the current paradigm of urban growth. All that has been catered to are land-centric growth models alongside infrastructure development.

River-Oriented Development (ROD) seeks to advance an urban planning model where rivers are integrated into the development of cities in the same way that Transit-Oriented Development (TOD) uses transport hubs as focal points for development. ROD differs from mobility-centered TOD by viewing rivers as the core feature of a city's life, as spines instead of edges, putting rivers around ecology-focused urban planning. ROD strives to improve the integration and rehabilitation of river systems in cities in order to improve their resilience, ecosystem health, and societal benefits. Unlike TOD which revolves around public transportation-enabled mixed-used high-density residential areas, ROD is centred on enhancing the quality and presence of rivers through urban cores. This shift aligns with the global call for enhanced ecosystem-based solutions, infrastructure that embraces climate adaptability, and holistic design principles.

1.1.3. River-Oriented Development (ROD) & Its Benefits

Urban river-oriented development (U-ROD) is as an approach to planning that positions rivers as features of architecture to be integrated into cities alongside and with urban ecosystems, similar to how transit-oriented development (TOD) is centered around planning an urban area around a transit hub. U-ROD implements eco-heritage restoration, public space construction, culture integration, climate adaptive

infrastructure, and multifunctional development with a river focus. It focuses on improving the quality of life, while mitigating environmental harm and restoring neglected riverfronts (UN Habitat, 2021). This approach correspond with frameworks of sustainable urban development that endorse nature-based solutions, integrated land water planning systems, and holistic systems-thinking approaches (World Bank, 2021). Instead of containing rivers as back-of-city drains or barriers, ROD conceptualizes them as an open, front-facing public asset for biodiversity, urban connectivity, and community health.

The concepts of ROD are not as formally documented as TOD, but exist in global case studies on urban riverfront regeneration. The initiatives such as the Sabarmati Riverfront located in Ahmedabad or post-industrial streams like Cheonggyecheon in Seoul and even Los Angeles with the Los Angeles River Revitalization Project all showcase the efficacy of river-centered planning (ADB, 2019; Kumar & Lee, 2022). Rivers can serve as a catalyst for urban renewal, alleviate flood risk, and provide recreational and cultural facilities.

1.1.4. Riparian Zones Along Urban Rivers & Their Benefits

Riparian zones are effusively vegetated buffers of urban rivers which are important for the sustainable development of our enclaves. These multifunctional zones filter out river sediments and improve water quality by capturing harmful and unnecessary particles before they are released into the river (World Bank, 2021). They also provide habitats for various species which fosters urban biodiversity and enhances the productivity of ecosystems (International Union for Conservation of Nature [IUCN], 2021]). In addition, well-managed riparian zones increase urban adaptive capacity by alleviating the impacts of climate change, decreasing heat islands, and improving land use planning (United Nations Environment Programme [UNEP], 2020).

Additionally, riparian zones greatly assist in the regulation of water levels as they manage the recharge of ground silver (water) as well as oversee peak flow during torrential rains, thus assisting in the prevention of urban flooding (Miller et al., 2022). In addition, these zones augment the ability to sequester carbon dioxide thereby assisting in the prevention of adverse climatic change (Smith et al., 2019). These

zones function as buffers basing on their ability to trap atmospheric carbon dioxide, which augments the climates changing issues.

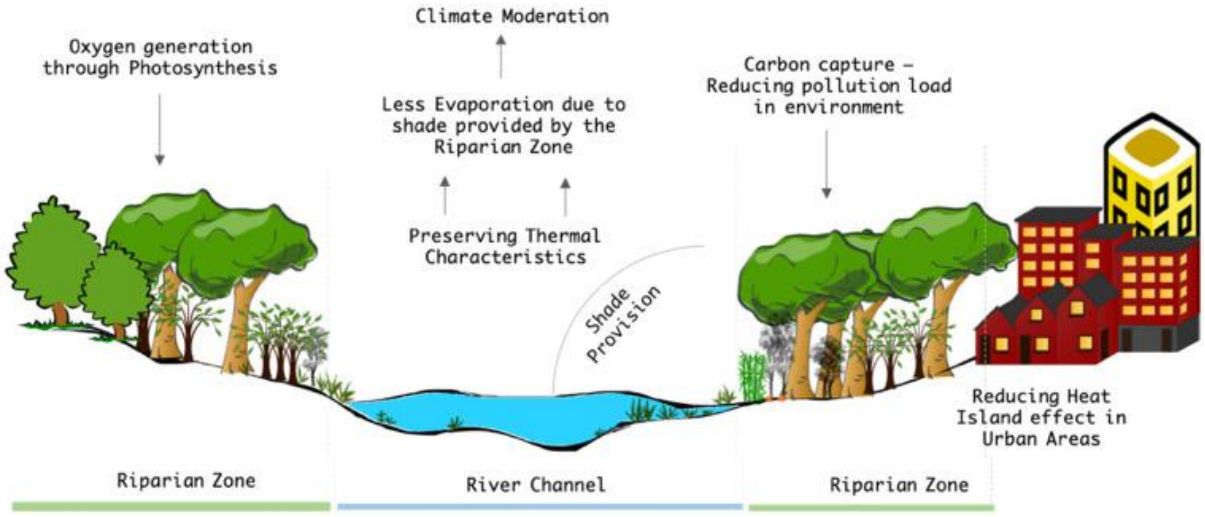


Figure 2: Riparian Buffer zone in Urban Areas

Source: Chapter 9: Enriching and Maintaining the Riparian Buffer Zone." Managing Urban Rivers: From Planning to Practice

1.1.5. Key Benefits of Riparian Zones:

- **Recreational & Aesthetic Value** – Riparian zones provide green spaces for public use, promoting mental well-being and fostering community engagement through parks, trails, and recreational activities (United Nations Human Settlements Programme [UN-Habitat], 2021). Urban waterfront development projects incorporating riparian zones have been shown to increase property values and attract tourism (OECD, 2021).
- **Flood Mitigation** – Vegetation in riparian zones absorbs excess stormwater, reducing flood intensity and protecting urban infrastructure from water-related damages (Intergovernmental Panel on Climate Change [IPCC], 2021). Studies have shown that urban areas with intact riparian buffers experience significantly lower flood damage costs compared to those with degraded buffers (Jones et al., 2020).

- **Water Quality Improvement** – These zones act as natural biofilters, removing pollutants such as heavy metals, nitrates, and phosphates, thereby enhancing river health and ensuring safer water resources (Asian Development Bank [ADB], 2022). Research indicates that riparian vegetation can reduce nitrogen levels in urban runoff by up to 80%, preventing eutrophication in rivers and lakes (Gomez et al., 2021).
- **Erosion Control** – Riparian vegetation stabilizes soil, preventing land degradation and minimizing sedimentation in urban rivers, which is essential for maintaining navigability and aquatic habitat integrity (Organisation for Economic Co-operation and Development [OECD], 2021). Root systems of riparian plants such as willows and reeds strengthen riverbanks and reduce soil loss due to water flow (Anderson & Green, 2018).

Riparian watersheds are important for the sustainability of urban communities, providing biodiversity and providing access to improved climate resilience and public spaces that are inclusive to the community. Denying riparian conservation through integrated urban planning can significantly improve the viability and resilience of cities as well as enhance long-term ecological sustainability (UNEP, 2020). Riparian restoration success in cities such as Melbourne, Singapore, Portland, and elsewhere serves as an example of how ecological preservation and urban development can be blended (Kumar & Lee, 2022). Policy makers, urban planners and community stakeholders must consider riparian conservation as necessary to protect the long-term viability of urban rivers and their benefits to people and nature.

1.1.6. Budgetary Constraints in Urban River Restoration and the Role of Funding Mechanisms

Urban river restoration is a core component of sustainable urban development, with significant environmental and socio-economic benefits including improved water quality, flood risk mitigation, biodiversity conservation and strengthening of urban resilience. Despite the obvious environmental and socio-economic benefits of urban river restoration, cities are often unable to implement large scale restoration projects due to serious financial constraints: limited public funding, competing priorities of

urban development and underdeveloped financial mechanisms contribute to delays, inefficiencies and continued ecological degradation in many urban river systems (World Bank, 2021; OECD, 2020).

One major obstacle is the large amount of capital necessary to install necessary infrastructure, pollution control and ongoing maintenance. In many developing countries, municipal budgets are heavily limited and geared towards short term demands including housing, transportation and sanitation, leaving little financial room for sustainable river rehabilitation. It is also frequently the case that fragmented governance structures and a lack of inter-agency coordination contribute to inefficient resource utilization and substandard restoration efforts (UN-Habitat, 2021; ADB, 2022). Lack of integrated financial planning is another impediment to local governments' commitment to sustainable rehabilitation of rivers.

Three important agencies are the national, sub-national and global governments, environmental organizations, landowners, business communities, and civil society that govern, plan, and finance urban river restoration: Nationwide Mission for Clean Ganga (NMCG) (division of Ministry of Jal Shakti) is responsible for restoring rivers such as the Ganga and its tributaries in India. State Pollution Control Boards (SPCBs) can manage river water quality and regulate industrial discharges into the river. Urban Local Bodies (ULBs) can manage solid waste and sewage infrastructure. Both these have an impact on the river health. Internationally, the World Bank (WB), Asian Development Bank (ADB), United Nations Habitat (UNHabitat) and other international institutions fund and provide technical assistance to urban water and ecosystem management projects, and multiple organizations such as the International Union for Conservation of Nature (IUCN) and World Resources Institute (WRI) contribute to policy formulation as well as on-ground action.

Against the backdrop of lack of funding, climate finance is becoming a key driving force for urban river revitalization. Many climate finance mechanisms such as the Green Climate Fund (GCF), Global Environment Facility (GEF) and other international institutions increasingly recognize nature-based solutions such as river restoration as approaches for climate adaptation, helping to bridge resource gaps and advance environmentally sustainable development (IPCC, 2021; UNEP, 2020). Additional

instruments that are emerging in recent years, such as green bonds, environmental impact funds, water tariffs, PPPs and other public-private partnerships, may also contribute to mobilizing financial support for urban water management and river ecology (OECD, 2021).

But despite the rising availability of climate finance for urban local authorities, many of them do not have access to these funds due to the stringent eligibility criteria, the complexities of the documentation process and lack of technical expertise. For many urban local authorities, producing well-structured, bankable proposals eviating relevance to global climate agendas is a barrier for external funding inflow. Reaching these gaps requires strengthening institutional capacity, creating inter-sectoral dialogue and linking river restoration with overall frameworks for climate resilience and urban development (World Bank, 2021; ADB, 2022).

Table 1: Comparative Overview of Key Urban River Restoration Funding Mechanisms

Funding Source	Type	Description	Key Example(s)	Challenges
National Government	Public	Allocated via Ministries (e.g., MoEFCC, NMCG)	Namami Gange (India)	Budget constraints, policy shifts
ULB/Municipal Finance	Public	Property taxes, water tariffs, development charges	Sewage network upgrades	Limited financial autonomy
Climate Finance	Multilateral	Grants/loans for climate-linked river projects	GCF, GEF	Inaccessible to many cities
PPP	Hybrid	Private investment in exchange for commercial rights or annuity	Sabarmati Riverfront (India)	Risk-sharing, regulation
Green Bonds	Market-based	Debt instrument for eco-projects	Pune Municipal Green Bond (2017)	Regulatory framework, credibility

Source: Compiled from World Bank (2021), ADB (2022), OECD (2021), UNEP (2020), UN-Habitat (2021)

To address these challenges, a multilateral approach is needed with an enhanced focus on climate finance, involving the private sector, and forging a framework for river restoration in national and local development policies. Cities must embrace innovative financing models and promote integrated urban water governance in order to unlock the full potential of urban rivers as climate resilient assets, protecting environment integrity in addition to contributing to economic viability and urban livability in the future (UN-Habitat, 2020).

1.2. PROBLEM STATEMENT

The Nag River, from which the city of Nagpur derives its name, has historically held ecological, cultural, and hydrological significance. However, decades of unregulated urbanization, encroachments, untreated wastewater discharge, and weak institutional frameworks have transformed this once-natural asset into a severely polluted urban drain (MPCB, 2022; CPCB, 2020). Despite its pivotal role in shaping the city's identity and environmental resilience, the river has been systematically excluded from urban planning and development priorities. This neglect is evident in the degradation of its riparian zones, declining biodiversity, and the socio-spatial disconnection between citizens and the riverfront (NIUA, 2021).

Current regeneration efforts under the National River Conservation Plan (NRCP) and the Nag River Pollution Abatement Project (NRPAP) focus primarily on end-of-pipe solutions such as sewage treatment and infrastructure upgrades. While necessary, these measures alone fail to address the systemic urban-river disconnect, land-use conflicts, and the lack of integrated, community-centric planning (CEEW, 2023). There is an urgent need to reframe the river not merely as an environmental liability but as a socio-ecological and economic opportunity through River-Oriented Development (ROD). This approach necessitates a shift from technocratic fixes to multi-functional, inclusive, and adaptive planning that can restore the river's ecological integrity, unlock real estate and recreational potential, and foster resilient urban growth.

The absence of localized, river-specific regulatory mechanisms and context-sensitive urban design frameworks for cities like Nagpur further exacerbates the problem. Without embedding the Nag River into the city's spatial and governance systems, sustainable transformation remains elusive. Therefore, this research seeks to explore

the potential of ROD in the Nag River context—assessing its feasibility, identifying barriers, and proposing a multi-stakeholder, policy-informed regeneration framework aligned with contemporary urban resilience and climate adaptation goals.

1.3. SIGNIFICANCE OF STUDY

1.3.1. Nag River: Lifeline Under Threat

Nagpur is the third-largest city in Maharashtra and in the geographic centre of India. It is a center for trade, transportation and administration. The winter capital of Maharashtra, it has developed rapidly and resulted in massive infrastructure expansion. This expansion has had great economic benefits and enhanced connectivity with other cities in the state, but it has also created numerous environmental challenges, with particular mention to the Nag River which flows through the city. The Nag River was an important source of water in the past and was considered as an ecological asset. However, the present flood of urban resources has put tremendous strain on the river's ecological system. Emerging pressures on urban resources require immediate sustainable and ecological interventions to rejuvenate and protect this critical river system.

The Nag River Basin Action Plan identifies five reasons for the decline of the Nag River: Rapid and unregulated urbanisation altered the natural hydrology of the river leading to increased pollution and ecological imbalance. The direct discharge of not treated sewage into the river, lack of effective solid waste management, and loss of green cover resulted in the widespread degradation of the river. Increased road infrastructure, residential development, and industrial zones further changed the land use patterns of the river, creating more impervious surfaces which interfere with natural groundwater recharge, and increase the rate at which surface runoff is contaminated. There was no comprehensive river conservation policy and lack of effective enforcement of existing regulations contributed to the decline of the Nag River.

1.3.2. Challenges Faced by Nag River

1. Threat of Periodic Floods

Figure 3: Floods in Nag River
Source:- Hitvada

The Nag River is highly vulnerable to seasonal flooding, primarily due to encroachments within the floodplain and the reduction of natural drainage capacity. The inundation zone, which should allow excess water to disperse during heavy rainfall, has been converted into built-up areas, limiting the river's ability to manage stormwater effectively. According to the Nag River Basin Action Plan, unauthorized construction along the riverbanks has significantly reduced its width, increasing water velocity and elevating flood risks. During the monsoon season, stormwater drainage systems in Nagpur remain inadequate, leading to frequent urban flooding and infrastructure damage (Hitavada, 2022).

2. Choked by Development

Figure 4: Development around Nag
Source: Times of India

Rapid urban expansion has severely altered the hydrological balance of the Nag River. Unregulated development along the riverbanks has resulted in the narrowing of the river channel, impeding its natural flow. Residential, commercial, and industrial projects have encroached upon the river's buffer zones, leaving little to no space for ecological restoration (TOI, 2022). The lack of river-sensitive urban planning policies has allowed urban sprawl to extend directly to the river's edge, further restricting its ability to function as a natural water system (Hitavada, 2023).

3. Polluted by Outfalls

Figure 5: Pollutants Outlets Nag River

Source: TOI (2021)

The Nag River has become a recipient of untreated sewage and industrial effluents, leading to severe water quality degradation. Numerous piped outfalls discharge untreated wastewater directly into the river, significantly raising levels of biochemical oxygen demand (BOD), chemical oxygen demand (COD), and heavy metal contamination (TOI, 2021). According to the Nag River Pollution Abatement Project, more than 70% of sewage discharged into the river is untreated, making the water unsuitable for any ecological or human use (Hitavada, 2023). The absence of adequate sewage treatment plants (STPs) and wastewater diversion mechanisms has exacerbated this issue.

4. Polluted Nallas

Figure 6: Polluted Nag River

Source: Hitvada

In addition to sewage discharge from piped outfalls, several stormwater drains (nallas) carry untreated domestic and industrial waste directly into the river. Originally designed to manage rainwater runoff, these nallas now serve as open drainage channels for solid and liquid waste. The lack of a well-maintained drainage infrastructure has turned the Nag River into a polluted urban waterbody, resembling an open sewer rather than a natural river system (TOI, 2022). This issue is further compounded by poor solid waste management, where plastic waste, industrial sludge, and organic debris accumulate in the river, disrupting aquatic ecosystems (Hitavada, 2022).

5. Inaccessible Banks

Figure 7: Inaccessible Banks to Nag River

Source: Hitavada (2022)

The Nag River's limited accessibility is another critical concern. Unlike other urban riverfront projects such as Ahmedabad's Sabarmati Riverfront or Seoul's Cheonggyecheon Stream, Nagpur lacks an integrated riverfront development plan. Most of the riverbanks are privately owned or occupied by unregulated settlements, restricting public access and ecological conservation efforts (Hitavada, 2022). The absence of pedestrian pathways, green buffers, and open recreational spaces has resulted in fragmented and neglected riverbanks, further alienating the river from the city's urban fabric (TOI, 2023).

1.4. AIM

To develop a comprehensive Urban River-Oriented Development (U-ROD) framework that leverages the potential of Nag River and its riparian zones to promote sustainable, river-centric urban growth in Nagpur.

1.5. OBJECTIVES

1. To assess the impact of urbanization on the riparian ecosystem of urban rivers.
2. To review existing policies and planning framework for riverine management.
3. To evaluate the potential of riparian buffer zones as a strategic approach for riverbank restoration and ecological enhancement through case example of Nag river Nagpur.
4. To formulate an Urban River – Oriented Development (U-ROD) Framework

1.6. SCOPE

Objective 1.

This objective focuses on evaluating the extent of ecological and physical degradation in the riparian zones of the Nag River due to rapid urbanization. It includes identifying illegal encroachments, loss of native vegetation and habitats, and disruptions to natural hydrological flows. The assessment will cover both spatial and temporal

changes using GIS tools, satellite imagery, and ground surveys. It will also consider the river's reduced ecological buffer capacity and its implications on urban flood vulnerability. This analysis aims to provide evidence for river-sensitive urban planning and restoration strategies.

Objective 2.

This objective aims to identify gaps in existing policies, planning frameworks, and institutional mechanisms that limit sustainable management of the Nag River's riparian zones. It involves a comparative analysis with cities that have successfully adopted river-centric planning—such as Ahmedabad's Sabarmati Riverfront—to draw contextual lessons. The study will also explore innovative financial mechanisms like Public-Private Partnerships (PPPs) and Environmental Valuation models to assess their applicability in funding long-term river conservation and restoration initiatives in Nagpur.

Objective 3.

This objective focuses on critically reviewing Nagpur's master plans, Development Control Regulations (DCRs), and urban policy frameworks to identify the lack of river-sensitive planning provisions. It will propose revised zoning guidelines and eco-sensitive policies that encourage sustainable development, green infrastructure, and proper floodplain management. Furthermore, the study will outline practical strategies for reforestation, erosion mitigation, improvement of water quality, and restoration of biodiversity in the Nag River's riparian corridor, aligning with urban ecological goals.

Objective 4.

This objective aims to explore national and global climate finance avenues applicable to riparian ecosystem restoration and resilient urban growth. It will identify viable funding sources such as green bonds, carbon trading mechanisms, and government-backed climate initiatives that can be leveraged for the Nag River. The study will develop an Urban River Oriented Development (U-ROD) framework that integrates climate finance with river-sensitive land use planning. Additionally, it will recommend institutional arrangements to embed river-compatible development into Nagpur's urban governance and planning systems.

1.7. LIMITATIONS

A significant limitation of this study is the limited availability of comprehensive and current ecological data concerning the Nag River and its surrounding riparian environment. This constraint may affect the depth and accuracy of the ecological analysis, thereby influencing the formulation of evidence-based restoration strategies. Additionally, integrating climate finance into urban planning presents institutional and procedural complexities, as climate finance mechanisms—such as green bonds, carbon credits, and international funding—are still evolving in terms of policy frameworks, accessibility, and implementation at the city level. These challenges may hinder the effective operationalization of a cohesive Urban River Oriented Development (U-ROD) framework within existing urban governance systems.

1.8. METHODOLOGY

The research adopts a multi-dimensional and mixed-methods approach to address the complex interactions between urbanization and riverine ecosystems in the context of the Nag River in Nagpur. Anchored around the four primary objectives, this methodology strategically blends spatial analysis, ecological assessments, policy reviews, and financial and institutional feasibility studies to arrive at an implementable Urban River-Oriented Development (U-ROD) framework. Each phase of the research is designed to build upon the previous one, ensuring a cohesive structure that responds to local urban realities while drawing from global best practices.

To fulfill the first objective—assessing the impact of urbanization on the riparian ecosystem—the research begins with a comprehensive analysis of the ecological degradation and physical transformations that the Nag River and its buffer zones have undergone over the past two to three decades. Using GIS mapping and temporal satellite imagery (Landsat, Sentinel, and CartoSAT), the study identifies the extent of urban encroachments, infrastructure-induced disruptions, and shrinking of natural buffers. These spatial datasets are layered with historical land-use records to visualize the loss of native vegetation, wildlife habitats, and floodplain areas. Additionally, field surveys and on-ground transect walks along different stretches of the river are conducted to ground-truth the remote sensing findings. Particular emphasis is placed on understanding the hydrological impacts of urban sprawl, including increased

surface runoff, blocked stormwater channels, and changes in groundwater recharge patterns. The research also involves water quality testing—analyzing parameters like Biological Oxygen Demand (BOD), Chemical Oxygen Demand (COD), and Dissolved Oxygen (DO)—to understand the extent of pollution and ecological stress. This phase aims to produce an evidence-based ecological profile of the Nag River, thereby informing restoration priorities and river-sensitive development policies.

In the second phase, the study critically reviews the existing policy and institutional frameworks that govern urban planning and river management in Nagpur. This includes an in-depth analysis of key urban planning instruments such as the City Development Plan (CDP), Master Plan, and Development Control Regulations (DCRs), along with policies related to water bodies, wetlands, and floodplain zoning. The review aims to identify the absence of river-centric planning principles and the fragmented nature of institutional responsibilities across bodies such as the Nagpur Municipal Corporation (NMC), Nagpur Improvement Trust (NIT), and Nagpur Metropolitan Region Development Authority (NMRDA). To draw comparative insights, case studies of successful urban riverfront management in cities like Ahmedabad (Sabarmati Riverfront), Seoul (Cheonggyecheon Stream), and Pune (Mula-Mutha River Rejuvenation) are examined. These case studies help highlight planning innovations, institutional mechanisms, and financial models such as public-private partnerships (PPPs), land value capture, and integrated development approaches. The policy review also explores the potential of environmental valuation tools and incentives like Transfer of Development Rights (TDR) and betterment charges to finance river rejuvenation projects. The goal of this phase is to identify planning gaps, institutional overlaps, and missed financial opportunities that hinder long-term, sustainable management of the Nag River.

Following this, the third phase focuses on exploring the potential of riparian buffer zones as a strategic and ecological tool for riverbank restoration. Drawing upon the spatial and policy insights from the earlier stages, this phase proposes the delineation of scientifically informed buffer zones categorized as primary (0–30 meters) and secondary (30–100 meters) based on topography, land use intensity, flood susceptibility, and ecological sensitivity. GIS-based suitability mapping is employed to

allocate specific interventions within these zones—such as reforestation, wetland creation, bioswales, permeable paving, and eco-parks. A critical evaluation of Nagpur's DCRs is undertaken to identify how current zoning and development norms can be restructured to accommodate these green infrastructure elements. The study further proposes modifications to building regulations and land-use classifications to ensure that no high-impact development occurs within these riparian zones. In addition, practical strategies for erosion control, improvement of water quality through decentralized wastewater treatment systems, and restoration of native biodiversity are outlined. These strategies aim not only to restore the river's ecological function but also to enhance its social, cultural, and recreational value in the urban context.

The final phase synthesizes the findings of the previous stages into the formulation of the Urban River-Oriented Development (U-ROD) framework for Nagpur. This framework aims to mainstream river-sensitive development within the city's broader planning ecosystem by aligning ecological restoration with urban resilience and financial sustainability.

The U-ROD framework incorporates four key components:

(1) Ecological & Environmental Components

(2) Infrastructure & Land Use Components

(3) Financial & Economic Instruments

(4) Governance & Policy Measures

It proposes the use of climate finance tools such as green municipal bonds, carbon credits, blue-green investment platforms, and central/state programs like AMRUT and Smart Cities Mission to fund large-scale restoration and conservation initiatives. The study recommends the establishment of a dedicated Riverfront Development Cell under NMC or NMRDA to implement the U-ROD framework, supported by inter-agency coordination committees. Furthermore, it emphasizes the need for participatory governance by involving citizens, educational institutions, NGOs, and the private sector in monitoring and maintaining riverfront projects. Community engagement tools such as participatory GIS platforms, mobile applications for pollution reporting, and educational campaigns are proposed to foster a sense of collective

responsibility for the Nag River. The final framework envisions a future where the Nag River is not a neglected urban drain, but a central spine of ecological balance, social equity, and economic opportunity—deeply embedded in the urban identity of Nagpur.

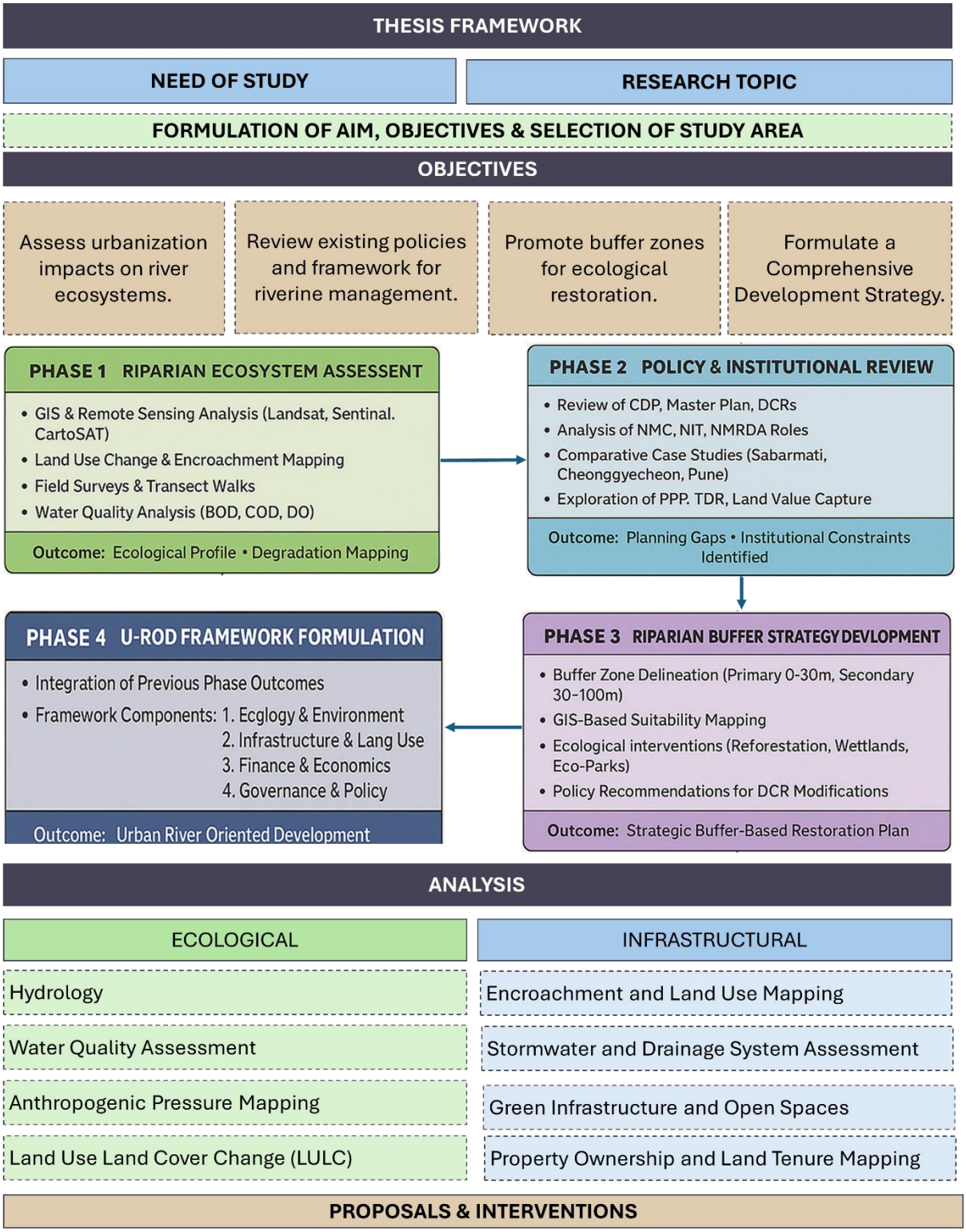


Figure 8: Methodology

2. LITERATURE REVIEW

This chapter presents a comprehensive review of existing literature related to urban river management, focusing on the ecological, planning, policy, and financial dimensions of riverine restoration. It explores how urbanization impacts riparian zones, evaluates current planning and regulatory frameworks, and highlights successful national and international case studies of riverfront development. Additionally, it delves into innovative funding mechanisms and climate finance instruments relevant to river-centric development. This review sets the foundation for developing a context-specific Urban River-Oriented Development (U-ROD) framework for the Nag River in Nagpur.

2.1. Riparian Zones and Urbanization

Riparian zones, the transitional interfaces between terrestrial and aquatic ecosystems, play a vital role in maintaining ecological balance, regulating hydrological processes, and supporting biodiversity. These areas function as natural buffers that filter sediments and pollutants, stabilize riverbanks, regulate stream temperatures, and provide critical habitat for both aquatic and terrestrial species (Capon et al., 2013). The vegetation in riparian corridors prevents erosion, facilitates nutrient cycling, and helps recharge groundwater aquifers. These zones also mitigate flood risks by absorbing and slowing down surface runoff, thereby reducing peak flow during storm events (Naiman & Décamps, 1997). Given their ecological importance, riparian zones are often considered keystone features of riverine landscapes and are integral to the resilience and functionality of urban ecosystems.

Despite their value, riparian zones are increasingly threatened by rapid and unplanned urbanization. Urban expansion often leads to the encroachment, fragmentation, and degradation of these areas, compromising their ecological functions and connectivity. The construction of impervious surfaces such as roads and buildings increases surface runoff, diminishes water infiltration, and introduces pollutants into nearby water bodies (Franklin et al., 2002; Liu et al., 2016). Studies have highlighted how anthropogenic interventions, including channelization, land reclamation, and infrastructural developments, have historically altered riparian ecosystems, particularly in urban contexts (Castonguay & Evenden, 2012). These pressures not only degrade water quality and biodiversity but also disrupt the thermal and

hydrological regimes essential for sustaining aquatic life (Bernhardt & Palmer, 2007). As such, the conservation and restoration of riparian zones must be a priority in urban planning, integrated through policies that recognize their multifunctional benefits and ecological significance.

2.1.1. The Role of Riparian Zones in Urban Ecosystem

Riparian zones, the transitional areas between terrestrial and aquatic ecosystems, serve as vital ecological buffers that maintain hydrological balance, support biodiversity, and mitigate the adverse impacts of urbanization. These zones deliver a range of ecosystem services, including water filtration, soil stabilization, stream temperature regulation, flood mitigation, and habitat preservation (Capon, 2019). Riparian vegetation reduces nutrient and pollutant loads entering water bodies, thereby enhancing water quality. It also prevents soil erosion, moderates streambank dynamics, and provides crucial habitats for diverse aquatic and terrestrial species.

Given these benefits, riparian buffer zones are increasingly recognized as essential components of sustainable urban planning. They act as natural defenses against urban runoff, sedimentation, and pollution—common consequences of rapid urban development. Guidelines for riparian buffer planning often advocate for clearly defined regulations based on the river's ecological sensitivity and surrounding urban density. For instance, high-density urban areas may necessitate wider buffer zones to better mitigate pollution and physical encroachment.

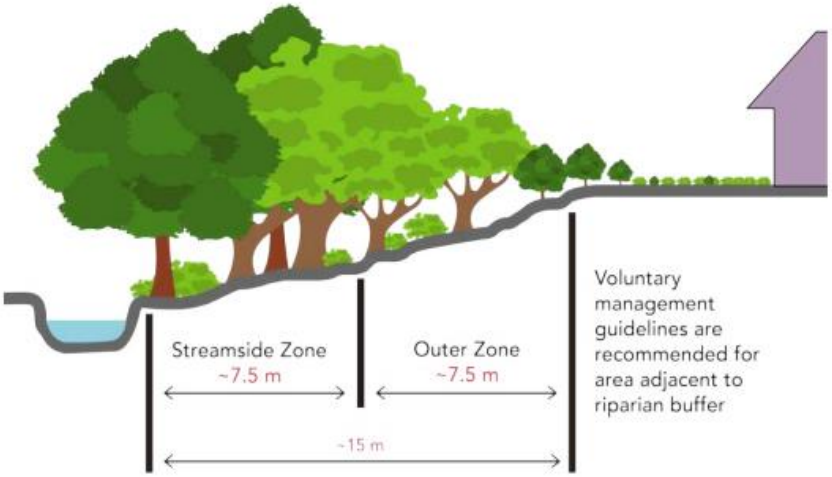


Figure 9: Riparian Buffer Zone

Source: Urban River Management Plan (URMP)

To address the challenges of balancing ecological protection with urban demands, the U.S. Environmental Protection Agency (EPA) recommends a two-zone riparian buffer model. This includes a streamside zone designated for strict ecological protection with minimal permissible activities (e.g., footpaths, limited flood control structures), and an outer zone designed for managed urban utilities like bike trails and stormwater infrastructure (US EPA, 2005). Restrictions typically include limitations on vegetation removal, soil disturbance, pesticide use, livestock grazing, and the construction of permanent structures. In some contexts, cities may implement a three-zone approach incorporating native flora, shrubs, and pedestrian pathways, tailored to the availability of land and specific urban needs. This strategic zoning approach enhances riverbank ecosystems while integrating urban mobility and recreational functions, ultimately ensuring a balance between ecological sustainability and urban development goals.

However, despite their ecological value, riparian zones remain highly vulnerable to anthropogenic pressures—particularly from unregulated or poorly planned urban expansion. Such pressures often result in the encroachment, fragmentation, or even complete loss of riparian areas, thereby compromising their capacity to provide critical ecosystem services and threatening the resilience of urban riverine systems (Bernhardt & Palmer, 2007). Effective urban riparian management must therefore incorporate legally enforceable buffer policies, spatial planning integration, and restoration strategies to safeguard these ecologically indispensable areas.and pathways, tailored to available land. This strategy balances ecological benefits with urban needs.

2.1.2. Impact of Urbanization on Riparian Ecosystems

Urbanization poses profound challenges to the sustainability of riparian ecosystems, which are critical for maintaining biodiversity, ecological balance, and ecosystem services. In a rapidly urbanizing world, understanding the impact of urbanization on these ecosystems is crucial for ensuring sustainable urban development that benefits both residents and nature. The migration of people from rural to urban areas, coupled with the global increase in urban population—surpassing 6.68 billion in 2019 and projected to reach 70% of the global population by 2050 (United Nations, 2012; 2019)—has accelerated the loss of natural ecosystems, including riparian zones (Camacho et al., 2021; Monk et al., 2019).

One direct consequence of urbanization is the proliferation of impervious surfaces such as roads and buildings, which reduce the infiltration of rainfall, increase surface runoff, and lead to the loss of original riparian habitats. This degradation is compounded by urban sprawl, which not only fragments habitats but also isolates riparian zones from other natural regions (Franklin et al., 2002; Liu et al., 2016). Additionally, urbanization introduces pollutants, heavy metals, and excessive nutrients into water bodies, negatively affecting water quality and aquatic habitats (Hassan et al., 2005).

The anthropogenic pressures on riparian zones often include extensive modifications such as channelization, land reclamation, and the construction of infrastructure to support urban growth. Historical accounts by Castonguay and Evenden (2012) demonstrate how urban rivers in Europe and North America were reshaped to accommodate expanding cities, frequently at the expense of ecological health. These interventions disrupt the natural structure and functionality of riparian ecosystems, resulting in habitat destruction, biodiversity loss, and altered hydrological regimes (Iakovoglou et al., 2013).

Despite these challenges, riparian zones remain ecological hotspots, supporting disproportionately high biodiversity relative to their extent in the watershed (Monk et al., 2019). These areas offer vital ecosystem services, including improved water quality, flood protection, recreational opportunities, enhanced aesthetics, and climate change mitigation (González et al., 2015). However, the sustainability of these benefits is contingent on active riparian restoration efforts. Such efforts often involve geomorphic restoration, re-establishment of natural floodplains, and the introduction of native plant species to revitalize the ecological balance of these zones (González et al., 2015).

As urbanization continues, it is imperative to integrate sustainable planning and restoration initiatives to mitigate the adverse effects on riparian zones. This requires a holistic approach that considers the intricate relationship between urban development, ecological health, and the critical ecosystem services provided by riparian areas.

2.1.3. Riparian Restoration in Urbanized Landscapes

Riparian restoration in urbanized areas focuses on rehabilitating degraded riparian zones to reinstate their ecological, hydrological, and social functions. In cities where riparian buffers have been replaced by built-up structures, innovative approaches are essential to address space constraints and mitigate environmental impacts. Restoration efforts begin with identifying and prioritizing degraded areas through detailed mapping, hydrological analysis, and pollution assessment (González et al., 2017). Strategies such as land use conversion, revegetation, and the introduction of green infrastructure are pivotal in reviving riparian ecosystems (Groffman et al., 2003).

Revegetation with native plant species is a cornerstone of riparian restoration, as it stabilizes riverbanks, enhances biodiversity, and improves water quality by filtering sediments and pollutants (Naiman & Décamps, 1997). Engineered solutions, including bioswales, rain gardens, and permeable pavements, are employed to manage urban runoff and restore natural hydrological processes. In areas where physical buffers are unattainable, alternative measures like floating wetlands provide ecological benefits by supporting aquatic habitats and reducing waterborne pollutants (González et al., 2017).

Restoration efforts also focus on re-establishing floodplain functionality to enhance resilience against flooding. This includes creating terraced embankments and other features that mimic natural floodplains. Integrating ecological goals with urban development, riparian restoration in urban areas requires collaboration between policymakers, urban planners, ecologists, and local communities. These interventions not only restore ecological health but also offer co-benefits such as improved aesthetics, enhanced recreational spaces, and climate resilience (Groffman et al., 2003).

2.1.4. Policy and Planning Frameworks for Integrating River Systems in Urban India

Riverine systems in India face increasing ecological degradation due to uncoordinated urban expansion and weak policy integration. Although various national and state-level frameworks address environmental conservation and urban development, a critical gap persists in river-sensitive planning and regulatory coherence. This section will explore the existing policy and regulatory landscape, identify shortcomings in master plans regarding river integration, and examine emerging frameworks such as River-Sensitive Urban Planning and the Urban River Management Plan (URMP). Ultimately, it aims to critically evaluate the vision, implementation, and funding mechanisms of these approaches to understand their potential for mainstreaming river restoration within urban governance.

Riparian zones—transitional interfaces between terrestrial and aquatic ecosystems—play a pivotal role in sustaining ecological integrity, water quality, and flood resilience. In the context of growing urbanization, the need for robust policy and regulatory frameworks to protect these fragile ecosystems has become increasingly critical. Effective governance mechanisms must ensure a balance between urban development, ecological sustainability, and disaster risk reduction. This underscores the urgency of establishing and enforcing policies specifically aimed at the conservation and sustainable management of these vital buffer areas.

Globally, several regulatory instruments underscore the importance of conserving riparian and wetland ecosystems. The Ramsar Convention on Wetlands provides an international framework for the conservation and wise use of wetlands, including riparian corridors. The European Union Water Framework Directive (WFD) is another landmark policy that mandates member states to achieve good ecological status for all water bodies. It requires the integration of riparian zone restoration and protection into national river basin management plans, promoting a holistic approach to water governance. These international examples highlight the recognized ecological significance of riparian zones and the policy approaches adopted elsewhere to safeguard them.

In India, riparian zone management is supported through a range of environmental legislations. The Environment (Protection) Act, 1986 empowers the central

government to regulate and restrict developmental activities in ecologically sensitive areas, including riverbanks. The Water (Prevention and Control of Pollution) Act, 1974 provides a statutory basis for monitoring and controlling water pollution in rivers and streams, indirectly supporting riparian health. Additionally, the National Green Tribunal (NGT) has issued multiple landmark directives reinforcing buffer zone maintenance, prohibiting encroachments, and mandating environmental clearance for projects affecting riverine areas. The Wetlands (Conservation and Management) Rules, 2017 also acknowledge the role of riparian and associated ecosystems in maintaining hydrological regimes, although implementation across states remains inconsistent. Thus, a suite of national laws and judicial pronouncements provides a foundational legal basis for riparian zone protection in India.

At the municipal level, urban planning instruments increasingly reflect the need for riparian conservation. City Master Plans often demarcate riverbanks as 'no-construction zones' and integrate setback requirements to establish buffer areas that can serve ecological, recreational, and flood management functions. The River Regulation Zone (RRZ) guidelines—modeled after the Coastal Regulation Zone (CRZ) norms—were proposed to introduce a uniform regulatory mechanism for urban riverbanks. Although still pending official notification at the national level, several state governments have adopted interim RRZ-like guidelines to control encroachment and pollution along urban watercourses. Moreover, emerging practices in integrated urban water management promote nature-based solutions such as riparian green belts, bioswales, and stormwater wetlands. Consequently, urban and local regulations are evolving to incorporate riparian conservation measures, although their consistent application and enforcement remain key challenges.

In conclusion, the policy and regulatory landscape in India concerning riverine and riparian zone management is a complex interplay of international conventions, national legislations, judicial directives, and evolving urban planning practices. While a legal and policy foundation exists, the identified issues of uncoordinated urban expansion and weak policy integration underscore the need for more coherent and effectively implemented frameworks, particularly those that are river-sensitive and promote the ecological integrity of riparian zones within urban contexts. The potential of emerging

approaches like River-Sensitive Urban Planning and the URMP lies in their ability to bridge these gaps and mainstream river restoration into urban governance.

2.2. Urban River Management and Planning Integration

The increasing ecological degradation of riverine systems in India, driven by uncoordinated urban expansion and weak policy integration, necessitates a focused examination of urban river management and planning. This section addresses this critical interface by first identifying gaps in prevailing master planning approaches regarding river integration. Subsequently, it explores nascent River-Sensitive Urban Planning Frameworks designed to foster greater ecological consideration. Finally, a detailed analysis of the Urban River Management Plan (URMP) is presented, encompassing its vision, implementation mechanisms, and funding strategies, to evaluate its potential for mainstreaming river restoration within the broader context of urban governance.

2.2.1. Current Gaps in Master Planning for River Integration

Urban master planning in India has historically marginalized riverine ecosystems, often treating rivers as infrastructural constraints rather than integral components of urban ecology. This oversight has led to the degradation of riparian zones, which are vital for flood mitigation, water purification, and biodiversity conservation. A study by the National Institute of Urban Affairs (NIUA) highlights that most urban master plans lack comprehensive strategies for river conservation, resulting in fragmented and reactive approaches to river management .

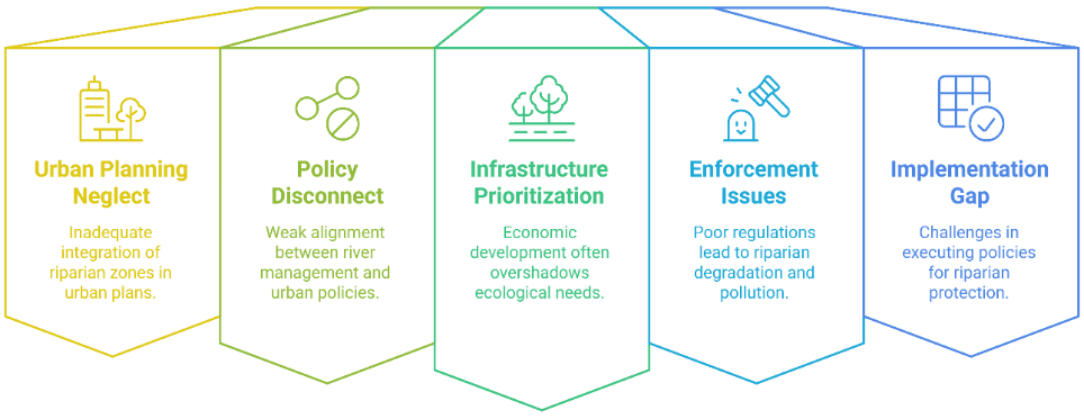


Figure 10: Gaps in the Master Planning Framework for Riverine Ecosystems

Source: River Sensitive Master Planning Framework, NIUA 2020

One significant gap is the absence of integrated watershed-based planning. Urban planning often occurs within administrative boundaries, disregarding the ecological continuity of river basins. This disjointed approach fails to address upstream and downstream impacts, leading to cumulative environmental degradation. Furthermore, land-use zoning regulations rarely delineate floodplains and riparian buffers, allowing for encroachments and unregulated development along riverbanks .

The prioritization of economic development over ecological considerations exacerbates these issues. Master plans tend to focus on infrastructure and urban expansion, often at the expense of natural ecosystems. Environmental Impact Assessments (EIAs), when conducted, typically evaluate projects in isolation without considering the broader ecological context. This siloed approach neglects the interconnectedness of urban development and river health.

Institutional fragmentation further hinders effective riverine ecosystem management. Multiple agencies with overlapping mandates lead to coordination challenges, while enforcement of existing regulations remains weak. The lack of clear guidelines and accountability mechanisms allows for continued degradation of river systems .

To address these gaps, there is a pressing need for the integration of river-sensitive strategies into urban master planning. This includes adopting watershed-based planning approaches, delineating and protecting riparian buffers, and ensuring inter-agency coordination. Incorporating ecological considerations into the core of urban planning can foster sustainable development and the restoration of degraded riverine ecosystems.

2.2.2. River-Sensitive Urban Planning Frameworks

Urban development in proximity to rivers necessitates a sensitive and integrated planning approach due to the ecological, hydrological, cultural, and economic significance of river systems. River-sensitive urban planning frameworks aim to harmonize urban growth with the preservation and revitalization of riverine ecosystems, ensuring long-term resilience and sustainability. These frameworks prioritize the health of river corridors while addressing urban challenges such as flood management, water quality, habitat protection, public access, and climate change adaptation (Sinha & Mishra, 2020).

A critical advancement in this domain is the inclusion of river management within statutory urban planning instruments. The publication Mainstreaming River Management in Master Plans (NIUA, 2020) provides a structured approach for embedding river health considerations into master planning processes. It outlines strategic interventions for zoning riverfront areas, conserving natural drainage systems, integrating blue-green infrastructure, and ensuring inter-departmental coordination for sustainable river governance. The framework encourages the adoption of River Health Assessment Indicators and Environmental Zoning Regulations within city master plans, thereby institutionalizing river sensitivity as a core urban planning principle.

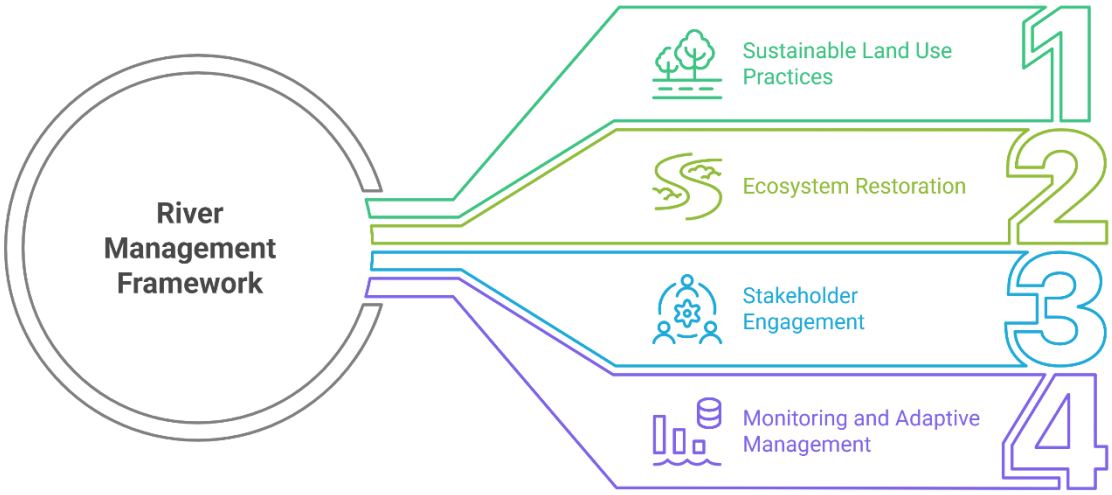


Figure 11: River Management Framework

Source: Mainstreaming River Management in Master Plans (NIUA, 2020)

Key components of river-sensitive planning include the delineation of river buffer zones, restoration of riparian habitats, implementation of sustainable drainage systems (SuDS), and integration of blue-green infrastructure. Buffer zones help to mitigate the impacts of urban runoff and provide space for rivers to meander naturally, reducing flood risks (Fletcher et al., 2015). SuDS, such as bioswales, rain gardens, and permeable pavements, are vital in managing stormwater and improving water quality before it enters river systems (Ashley et al., 2007).

Moreover, river-sensitive frameworks are increasingly being guided by participatory planning models that involve local communities, stakeholders, and indigenous

knowledge. Such inclusive processes foster stewardship and enhance the cultural relevance of planning outcomes (UN-Habitat, 2016). Integrated river basin management (IRBM) principles are also central, emphasizing the coordination between land use planning, water management, and ecological conservation across administrative boundaries (GWP, 2000).

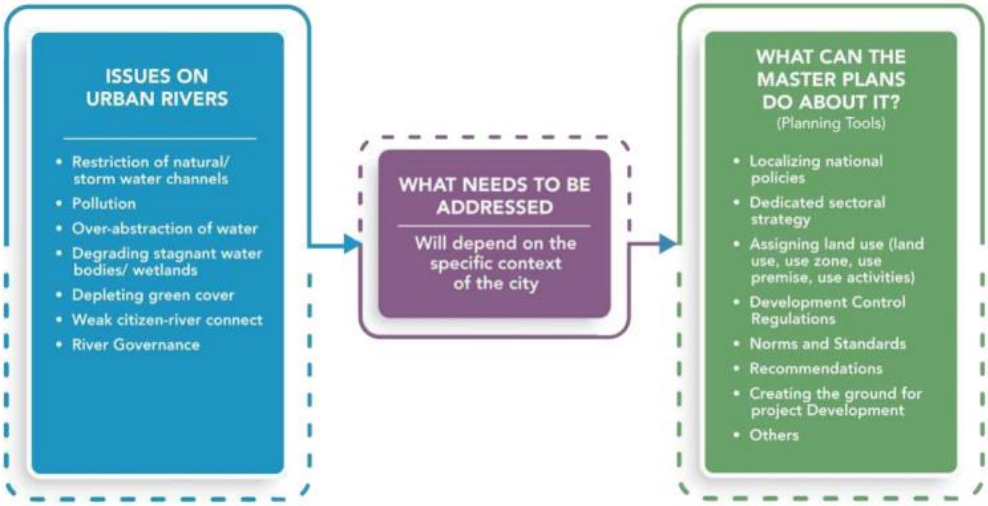


Figure 12: Integrating Urban River Concerns into Master Planning Frameworks

Source: Mainstreaming River Management in Master Plans (NIUA, 2020)

Successful international examples include the Cheonggyecheon Stream restoration in Seoul, South Korea, which transformed a once-polluted and covered urban stream into a vibrant public space, reducing urban heat and enhancing biodiversity (Cho, 2010). Similarly, the Isar Plan in Munich exemplifies multi-functional river planning that balances flood protection with ecological rehabilitation and urban recreation (Fischer et al., 2014).

The future of river-sensitive urban planning lies in adopting nature-based solutions and adaptive governance mechanisms that respond dynamically to climate variability and urban pressures. As emphasized by NIUA (2020), mainstreaming river management into urban master plans is not merely an environmental imperative but a socio-economic necessity for enhancing urban resilience, equity, and quality of life.

2.2.3. Urban River Management Plan (URMP)

The Urban River Management Plan (URMP) is a strategic and action-oriented planning framework aimed at the sustainable management of urban rivers within the broader context of city development and environmental resilience. As part of India's efforts to integrate water-sensitive planning into urban governance, the URMP provides cities with a structured approach to revive, conserve, and sustainably manage their river systems. It is an initiative supported by the National Mission for Clean Ganga (NMCG) in collaboration with the National Institute of Urban Affairs (NIUA), and has been piloted in several Indian cities under the River-Cities Alliance.

URMPs are designed to operate alongside statutory planning instruments such as city master plans and development plans. They provide a blueprint that aligns river management with urban priorities such as land use regulation, public health, climate change mitigation, biodiversity conservation, and equitable access to natural assets.

Vision and Objectives

The Urban River Management Plan (URMP) is envisioned as a transformative framework that redefines the relationship between cities and their river systems. Its overarching vision is to restore, protect, and sustainably manage urban rivers as dynamic ecosystems that contribute to urban resilience, environmental sustainability, and socio-cultural vitality. The plan perceives rivers not merely as hydrological entities, but as integral urban assets that shape the ecological and socio-economic fabric of cities. At its core, the URMP seeks to achieve multiple, interrelated objectives. These include ecological restoration through the rejuvenation of riverine habitats and biodiversity; pollution abatement by identifying and mitigating sources of contamination such as untreated sewage and industrial effluents; flood risk mitigation through integrated watershed management and climate-resilient infrastructure; and public engagement by enhancing community awareness, accessibility, and recreational opportunities along riverfronts. Additionally, the plan emphasizes institutional integration by mainstreaming river-sensitive planning principles into statutory urban planning frameworks, thereby ensuring that river health is considered in land use decisions, zoning regulations, and infrastructure development.

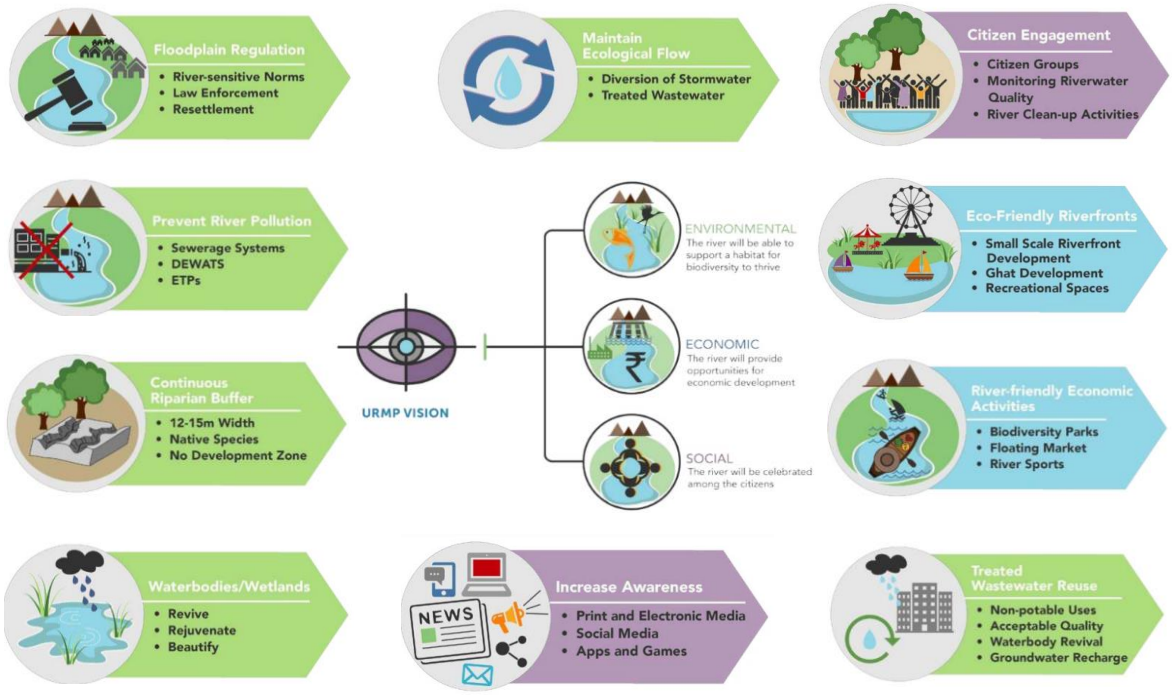


Figure 13: Urban River Management Plan Vision and Objectives

Source: Urban River Management Plan (NIUA, 2022)

Implementation Mechanisms

The effective execution of a URMP requires a comprehensive and multi-layered implementation strategy, involving coordination across sectors, institutions, and scales of governance. A critical first step involves the establishment of dedicated governance structures, such as a River Management Committee (RMC), which brings together urban local bodies, state pollution control boards, water resources departments, environmental experts, and civil society representatives. This body is responsible for guiding the implementation process, facilitating inter-agency coordination, and ensuring accountability. Technical components of implementation include the delineation of river buffer zones, preparation of river health assessments, GIS-based mapping of catchments and floodplains, and integration of river-related data into master plans and development control regulations. Moreover, city-specific river action plans are formulated, outlining short-, medium-, and long-term interventions such as the construction of decentralized wastewater treatment systems, restoration of natural drainage channels, solid waste management improvements, and the development of eco-sensitive riverfront infrastructure. The implementation framework is further supported by monitoring and evaluation systems, which track performance indicators

like water quality, biodiversity indices, and community participation metrics. The URMP also emphasizes capacity-building initiatives for municipal officials and planners to ensure institutional readiness and technical proficiency.

Funding Mechanisms

Financing the initiatives under a URMP necessitates a blended and adaptive funding model, capable of mobilizing resources from multiple sources and aligning them with project-specific requirements. Public sector funding constitutes the foundational layer, drawing on central and state government schemes such as the Namami Gange Programme, AMRUT (Atal Mission for Rejuvenation and Urban Transformation), Smart Cities Mission, and the Jal Shakti Abhiyan. Municipal corporations are also expected to allocate budgetary resources for river-related projects within their capital expenditure plans and annual budget cycles. In addition to public funding, the URMP framework encourages the use of Public-Private Partnerships (PPPs), particularly for infrastructure-heavy components like sewage treatment plants (STPs), riverfront beautification, and eco-tourism facilities.

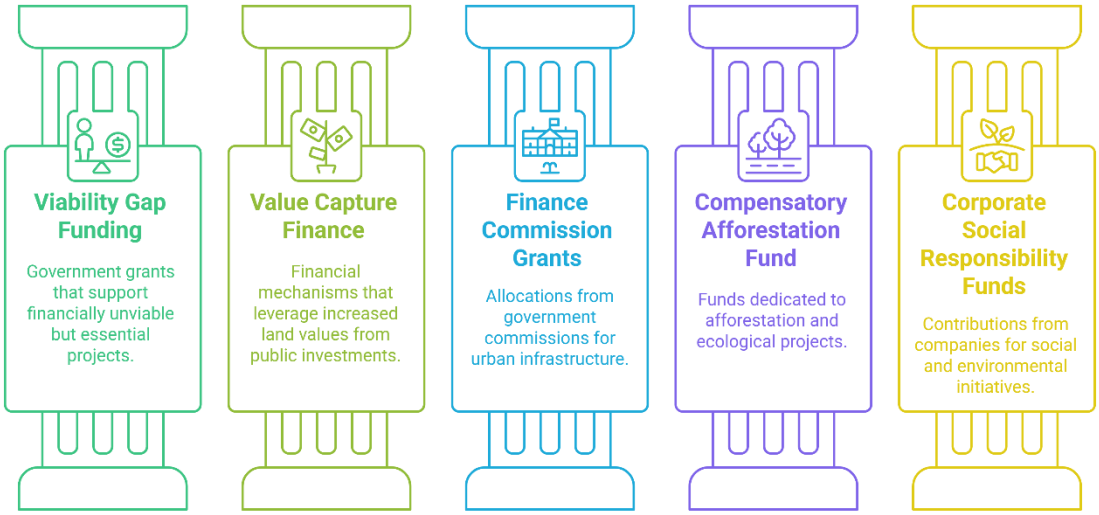


Figure 14: Different Financial Options

Source: Urban River Management Plan (NIUA, 2022)

Innovative financing instruments, such as municipal green bonds and climate adaptation funds (e.g., Green Climate Fund), provide additional avenues for resource mobilization, especially for projects with strong environmental and social co-benefits. Corporate Social Responsibility (CSR) contributions and philanthropic donations can

also be harnessed for community-based river stewardship programs. Furthermore, the URMP promotes participatory financing by involving local communities and resident welfare associations in small-scale initiatives such as urban gardening, cleanup drives, and the maintenance of public riverfront spaces. Together, these funding mechanisms aim to create a sustainable financial ecosystem that ensures the long-term viability of river management initiatives.

2.3. Case Studies of River Restoration

This section presents a comparative analysis of selected national and international case studies that illustrate diverse approaches to riparian restoration and riverfront development. These examples demonstrate how cities around the world have integrated ecological restoration, urban design, flood management, and public engagement into river-sensitive planning. Each case highlights unique contextual challenges, planning frameworks, stakeholder involvement, and outcomes, offering valuable insights and transferable lessons for urban river management. The case studies include both well-established models and evolving initiatives, providing a balanced perspective on strategic interventions and governance mechanisms.

2.3.1. Cheonggyecheon Stream Restoration, South Korea

The Cheonggyecheon Stream Restoration Project in Seoul is widely regarded as a transformative example of urban river regeneration. Undertaken between 2003 and 2005, the project replaced a decaying elevated highway with a revitalized stream corridor, re-establishing *a riparian ecosystem in the heart of one of the world's most densely populated cities. Led by the* Seoul Metropolitan Government and supported by public-private partnerships, the project represents a landmark shift in urban infrastructure planning towards ecological sustainability.

Major restoration interventions included the removal of concrete structures to reveal and rehabilitate the historic streambed, reintroduction of native plant and aquatic species, and development of pedestrian-friendly greenways along the corridor. These efforts created a vibrant urban ecosystem that improved air and water quality, reduced urban heat island effects, and provided valuable recreational space for residents.

Financially, the project was underpinned by innovative mechanisms such as the issuance of municipal green bonds and a land value capture (LVC) strategy. As property values along the revitalized corridor surged by 25–50%, the resulting tax revenues contributed to the project's financial viability (Kim, 2008). Furthermore, collaboration with private construction and engineering firms enabled resource mobilization and project delivery on a large scale. Cheonggyecheon stands as a global model of how urban waterway restoration can simultaneously drive ecological, economic, and social revitalization.

Figure 15: Cheonggyecheon River
Source: ArchDaily

2.3.2. Sabarmati Riverfront Development, Ahmedabad

The Sabarmati Riverfront Development Project in Ahmedabad is a pioneering example of urban riverfront transformation in India. Aimed at flood control, environmental restoration, and urban renewal, the project successfully reclaimed the riverfront from years of encroachment and degradation. It was executed by the Sabarmati Riverfront Development Corporation Limited (SRFDCL), a Special Purpose Vehicle (SPV) established by the Ahmedabad Municipal Corporation (AMC), which ensured focused governance and project delivery.

The development included the construction of embankments to regulate seasonal flooding, establishment of green public spaces to enhance ecological value, and installation of wastewater treatment plants (WWTPs) to improve water quality. These interventions not only restored the river’s ecological functions but also created inclusive recreational and commercial zones that benefited the city’s social and economic fabric.

The financing model was both innovative and robust. Land value capture played a central role, wherein redeveloped parcels along the riverfront were monetized to fund infrastructure development. Additionally, Public-Private Partnerships (PPPs) were leveraged to finance commercial spaces and amenities, ensuring ongoing revenue streams for maintenance. State government grants and municipal bonds provided

supplementary capital, making the project financially resilient (Sabarmati Riverfront Development Corporation, 2018). The Sabarmati case demonstrates how strategic planning, institutional innovation, and financial engineering can convert neglected urban rivers into thriving, multifunctional spaces.

Figure 16: Sabarmati River

Source: Urban Design Lab

2.3.3. Sabarmati Riverfront Land Disposal Policy, 2024: A Self-Sustaining Urban River Model

The *Sabarmati Riverfront Land Disposal Policy, 2024*, introduced by the Sabarmati Riverfront Development Corporation Limited (SRFDCL), marks a significant evolution in urban riverfront governance and management in India. Building upon the foundational success of the Sabarmati Riverfront Development Project, the policy outlines a structured, long-term strategy for monetizing reclaimed riverfront land while safeguarding public access and ecological integrity. It represents a pioneering approach in establishing a self-sustaining model for urban riverfront development.

A central pillar of the policy is its self-financing framework, wherein revenue generated from the lease and development of designated commercial land parcels is strategically

reinvested into the operation, maintenance, and enhancement of public infrastructure. This includes green open spaces, promenades, wastewater treatment facilities, and civic amenities. By leveraging land value capture and guided private investment, the model ensures financial sustainability without recurring dependency on public subsidies or external grants.

Equally important is the emphasis on public land use, with a substantial portion of riverfront land allocated for community-oriented spaces such as urban parks, walkways, gardens, and cultural zones. These spaces aim to provide inclusive access to the riverfront, promote environmental stewardship, and improve the overall quality of urban life. The policy enforces strict development regulations, with built-form guidelines and design controls ensuring that new construction aligns with the aesthetic, ecological, and socio-cultural vision of the riverfront.

A noteworthy environmental component of the policy is its commitment to biodiversity restoration through the large-scale plantation of 500,000 native trees using the Miyawaki afforestation method. This technique, characterized by dense multi-species planting, is designed to accelerate forest growth and enhance microhabitats within the urban landscape. The initiative seeks to improve air quality, reduce urban heat island effects, and strengthen riparian ecology.

Furthermore, the policy integrates transport and infrastructure planning, including the development of arterial roads, pedestrian linkages, and enhanced connectivity between the riverfront and the wider urban region. This holistic planning approach aims to decongest surrounding urban areas while facilitating greater public accessibility.

Overall, the *Sabarmati Riverfront Land Disposal Policy, 2024* embodies a comprehensive model of urban river-sensitive planning that harmonizes economic viability with ecological responsibility. By institutionalizing a revenue-generating yet environmentally conscious framework, the policy sets a national benchmark for sustainable riverfront governance and exemplifies how strategic urban land management can reinforce long-term ecological and civic resilience.

2.3.4. Yamuna O-Zone, Delhi – A Conflict Between Urban Expansion and Ecological Preservation

The Yamuna O-Zone in Delhi represents a critical ecological buffer zone designated to protect the floodplains of the Yamuna River. Defined under the Master Plan for Delhi (MPD) 2021 and reiterated in MPD 2041, this zone is officially a no-construction area meant to preserve the river's ecological integrity and mitigate flood risks. However, the O-Zone has become a battleground between environmental objectives and uncontrolled urban expansion, with more than 161 unauthorized colonies housing nearly 2.3 lakh households currently occupying this sensitive area (DDA, 2021).

Challenges to the zone's integrity are multifaceted. The Delhi Jal Board has struggled to extend basic sewerage infrastructure to these settlements due to narrow lanes, high densities, and regulatory delays. Weak enforcement of construction bans has allowed informal developments to proliferate unchecked for over two decades. In response, MPD 2041 introduces a dual-zoning system—O-I (strict conservation) and O-II (regulated development)—to balance ecological protection with urban pressures. Notably, the plan excludes the O-Zone from land regularization programs, signaling a firm policy stance against further encroachment.

This case underscores the urgent need for integrated governance models that reconcile urban growth with environmental sustainability. It reveals how planning lapses, regulatory ambiguity, and informal housing pressures can undermine riparian health, and highlights the importance of river-sensitive urban planning frameworks, such as Urban River Oriented Development (U-ROD), to guide future interventions (DDA, 2021).

2.3.5. Thames River Restoration, United Kingdom

The Thames River Restoration initiative is a long-standing and comprehensive program that exemplifies holistic riverine ecosystem management within an urban context. Led by the Thames River Restoration Trust, the initiative integrates biodiversity enhancement, riverbank stabilization, and invasive species control to rehabilitate one of the UK's most iconic water bodies. The restoration program emphasizes the ecological regeneration of the riparian corridor, while also contributing to urban flood management and climate adaptation.

Key ecological strategies include the reconnection of rivers with their floodplains to facilitate wetland restoration, bioengineering-based stabilization of riverbanks to minimize erosion, and the reintroduction of native plant species to support habitat diversity. These interventions have significantly improved the health of the aquatic and riparian ecosystems, while also enhancing the landscape's capacity to absorb floodwaters during extreme weather events.

The initiative's financial sustainability is ensured through a hybrid funding model. National government support is channelled through the UK's Environmental Protection Funds, while local authorities contribute through a specialized riparian conservation tax levied on communities along the Thames. Furthermore, international co-financing—particularly through the European Union's LIFE+ Program—has provided significant capital for integrated water resource management and ecosystem restoration. This model highlights the effectiveness of combining policy mandates, local accountability, and international cooperation in achieving sustainable river restoration (Thames River Restoration Trust, 2015).

2.3.6. Annandale Riparian Restoration Initiative, Virginia, USA

The Annandale Riparian Restoration Initiative in Virginia, USA, is a prominent example of a community-driven approach to ecological rehabilitation. Focusing on restoring native vegetation, improving water quality, and enhancing riparian biodiversity, the initiative is primarily led by grassroots environmental organizations in partnership with local schools, municipalities, and citizen volunteers. Its success lies in the deep involvement of the local community, which not only contributes to on-ground restoration efforts but also fosters long-term stewardship.

Community engagement activities include riparian planting programs, where schoolchildren and residents actively participate in afforestation drives along degraded riverbanks. Citizen science initiatives, such as water quality monitoring programs, enable local residents to measure sedimentation, pH levels, and biological health, reinforcing awareness and accountability. The initiative also employs extensive public outreach campaigns to promote environmental education and civic responsibility.

Institutionally, the program is supported through a combination of state-level environmental grants under the Chesapeake Bay Restoration Program and the

Virginia Clean Water Initiative. Private philanthropy, especially through organizations like the Chesapeake Bay Foundation, plays a vital role in funding restoration projects. Additionally, local businesses contribute via Corporate Social Responsibility (CSR) programs, further reinforcing the financial sustainability of the initiative. The Annandale model showcases how empowered communities, when supported by institutional frameworks and targeted funding, can play a pivotal role in urban riparian conservation (Chesapeake Bay Foundation, 2019).

2.3.7. Hampshire County Riparian Task Force, United Kingdom

The Hampshire County Riparian Task Force in the United Kingdom exemplifies a collaborative, multi-stakeholder approach to riparian zone restoration, driven by regional planning and ecological stewardship. Spearheaded by the Hampshire County Council, the initiative integrates sustainable land-use planning, environmentally conscious agricultural practices, and ecosystem-based restoration strategies to address pressing challenges such as water quality degradation, biodiversity loss, and increased flood risk. Operating under the UK's Water Framework Directive (WFD) and aligned with the National Ecosystem Assessment, the Task Force functions in coordination with key institutions including the Environment Agency and Natural England. Its governance framework ensures policy coherence and facilitates the implementation of region-specific environmental standards.

Core restoration strategies include the establishment of vegetated riparian buffer strips to filter runoff and stabilize riverbanks, promotion of no-till farming and cover crops to reduce soil erosion, and the reconnection of rivers with their natural floodplains to enhance hydrological resilience. These interventions not only improve water retention and habitat quality but also promote biodiversity conservation. The financial model for the initiative is multifaceted, relying on public grants through the UK's Countryside Stewardship Scheme, EU environmental funding, and targeted incentives for landowners. Farmers, in particular, benefit from subsidies for adopting conservation practices, while local municipalities allocate budgetary support from water management agencies. This integrated model underscores the effectiveness of aligning local policy, agricultural incentives, and ecological science to achieve measurable outcomes in riparian restoration (Hampshire County Council, 2021).

2.4. Financial Instruments for Riverine Restoration

Effective riverine restoration requires not only technical and ecological interventions but also a robust framework of financial and policy instruments. These tools serve as enablers for long-term ecological health, resilience against climate risks, and sustainable urban integration of river systems. The following subsections explore key mechanisms currently advancing riparian restoration efforts globally, delving into Climate Finance Mechanisms which channel funds towards climate-resilient ecological projects, innovative Business Models for Nature-Based Solutions that blend economic viability with ecological benefits, Tax Incentives and Eco-Friendly Policies designed to encourage sustainable practices, and the role of Environmental Valuation and ESG in Real Estate in recognizing and integrating the economic and sustainability value of healthy riverine ecosystems.

Table 2: Overview of Finance Mechanisms for Urban River Restoration

Finance Mechanism	Type	Key Instruments	Focus Areas	Relevance to River Restoration	Examples
Green Climate Fund (GCF)	Multilateral Fund	Grants, concessional loans, technical assistance	Climate adaptation, water resilience, NbS	Supports urban flood control, wetland restoration, infrastructure upgrades	India (urban water projects), Bangladesh (resilient cities)
Global Environment Facility (GEF)	Multilateral Fund	Blended finance, grants, co-financing	Biodiversity, land degradation, international waters	Co-finances riparian and wetland rehabilitation under NAPs & NDCs	Vietnam (Mekong Delta), India (Lake Conservation)
Adaptation Fund	UNFCCC Mechanism	Project grants, capacity building	Community-based adaptation, water management	Supports river-dependent livelihoods and green buffer creation	Rajasthan (India), Peru (ecosystem-based adaptation)

World Bank Climate Funds	Multilateral Lending	Investment loans, DPLs, CAT-DDO, blended climate funding	Resilient cities, watershed management	Finances green infrastructure and integrated urban water systems	Vietnam, India, Colombia
UN-Habitat Climate Action	UN Agency Program	Technical support, pilot projects, city capacity building	Urban resilience, flood mitigation	Integrates river restoration in city climate adaptation strategies	Kenya, Nepal, India (urban planning assistance)
Green Bonds	Market-Based Instrument	Debt instruments for eco-focused infrastructure	Sustainable water, energy, green buildings	Municipal green bonds fund sewerage, riparian and bioswale systems	Pune Municipal Green Bond (2017), Johannesburg (2014)

Source: *Adapted from GCF (2020), UNEP (2021), UN-Habitat (2019), World Bank (2020), OECD (2021)*

2.4.1. Climate Finance Mechanisms

Climate finance has emerged as a pivotal lever for supporting large-scale riverine and watershed restoration efforts, especially in the face of escalating climate risks and environmental degradation. International climate finance instruments such as the Green Climate Fund (GCF), Adaptation Fund, and Global Environment Facility (GEF) are central to this transformation. These mechanisms channel resources—through concessional loans, grants, and capacity-building support—toward climate-resilient projects that include nature-based solutions (NbS), such as floodplain restoration, wetland rehabilitation, and riparian afforestation (UNEP, 2021; GCF, 2020).

In urban contexts, climate finance has been instrumental in enhancing stormwater infrastructure, reducing flood vulnerability, and mitigating urban heat island effects through ecological restoration of riverbanks and adjacent floodplains. For example,

India and Bangladesh have accessed GCF support for integrated urban water management and resilient infrastructure in flood-prone cities (GCF, 2020; UN-Habitat, 2019). Similarly, Vietnam's Mekong Delta Climate Resilience Program, co-funded by the World Bank and GEF, demonstrates how international climate finance can underpin riparian restoration as part of national climate adaptation strategies (World Bank, 2020).

Importantly, integrating climate finance into riverfront development frameworks helps bridge the funding gap for environmental infrastructure and aligns restoration projects with nationally determined contributions (NDCs) under the Paris Agreement and National Adaptation Plans (NAPs). This alignment enhances both access to global funding and coherence in national climate policy, fostering long-term ecological and fiancial sustainability (UNFCCC, 2022).

2.4.2. Business Models for Nature-Based Solutions

Nature-Based Solutions (NbS) have gained prominence as effective, cost-efficient interventions for addressing environmental degradation, climate resilience, and urban livability. However, their successful implementation at scale depends heavily on innovative and viable business models that can secure long-term financing and stakeholder engagement. Among these, Public-Private Partnerships (PPPs), ecosystem service markets, and impact investment funds are increasingly leveraged to support riverine and riparian restoration initiatives (WWF, 2021; UNEP FI, 2021).

A key mechanism within this framework is the Payment for Ecosystem Services (PES) model, wherein downstream beneficiaries—such as water utilities, urban municipalities, or private landowners—compensate upstream actors for maintaining or restoring ecological functions. This approach has been successfully applied in watershed management programs in Latin America, Asia, and sub-Saharan Africa, linking financial incentives to conservation performance (FAO, 2019).

Another emerging financing model is the use of green bonds and blended finance structures, which combine concessional capital from development institutions with private sector funding. This approach not only reduces investment risk but also makes NbS projects more attractive to institutional investors and infrastructure developers (OECD, 2020). In riverfront restoration, such models help embed ecological objectives

within broader urban planning frameworks, enabling projects to yield both environmental and economic returns—such as improved water quality, enhanced biodiversity, and increased property values.

By internalizing the value of ecosystem services and aligning financial returns with ecological outcomes, these business models are redefining how riparian health is integrated into urban and regional development agendas. They represent a shift from donor-dependent conservation toward self-sustaining ecological infrastructure investment.

2.4.3. Tax Incentives and Eco-Friendly Policies

Fiscal incentives and regulatory instruments are increasingly recognized as strategic tools for mainstreaming river-sensitive urban planning and promoting sustainable land and water use. Through mechanisms such as tax rebates, deductions, and credits, governments can encourage developers, industries, and communities to adopt environmentally responsible practices that support riparian health and resilience (OECD, 2021).

Municipalities have begun implementing targeted incentives—such as reduced property taxes, development fee waivers, or density bonuses—for projects that incorporate green infrastructure features like riparian green buffers, permeable pavements, or urban biodiversity corridors. For example, U.S. cities such as Portland and Philadelphia offer stormwater fee reductions for property owners who implement green roofs or bioswales, which also contribute to improved water quality in nearby rivers and streams (EPA, 2020).

In parallel, eco-zoning regulations and Transfer of Development Rights (TDR) frameworks enable more flexible land-use planning while preserving ecologically sensitive areas along riverbanks and floodplains. TDR schemes have been applied in regions such as Florida and Karnataka (India) to protect riparian zones by allowing developers to acquire additional development rights elsewhere in return for conserving designated environmental areas (UN-Habitat, 2018).

At a broader scale, environmental tax reforms, including carbon pricing and pollution levies, generate fiscal space for green infrastructure while sending clear price signals

that align economic activities with environmental goals. By integrating these fiscal instruments into river governance frameworks, policymakers can link tax policies with measurable ecological outcomes, encouraging long-term stewardship and reducing dependence on ad hoc funding mechanisms (World Bank, 2022).

Ultimately, these financial and regulatory tools embed sustainability into the urban development process, making eco-friendly design and river-sensitive planning both economically viable and institutionally supported.

2.4.4. Environmental Valuation and ESG in Real Estate

Environmental valuation plays a pivotal role in bridging ecological restoration with economic planning, particularly in the context of riverine landscapes. Valuation tools such as Cost-Benefit Analysis (CBA), Multi-Criteria Decision Analysis (MCDA), and Natural Capital Accounting (NCA) are increasingly applied to quantify the ecological, social, and economic returns of riparian restoration initiatives (OECD, 2018; World Bank, 2021). These methodologies enable policymakers and urban planners to make evidence-based decisions by internalizing the value of ecosystem services—such as water purification, flood regulation, carbon sequestration, and recreational use—within conventional development appraisals.

In parallel, the rise of Environmental, Social, and Governance (ESG) frameworks in the real estate and infrastructure sectors has catalyzed a shift toward more sustainable riverfront development. ESG integration compels developers to assess and disclose environmental risks, including flood vulnerability, habitat degradation, and water quality impacts, thereby aligning development objectives with sustainability criteria (GRESB, 2022). Projects that incorporate green infrastructure, nature-based solutions, and biodiversity corridors are increasingly viewed as low-risk, future-resilient investments—especially under the scrutiny of institutional investors and financial regulators.

The financial implications are significant. ESG-compliant developments are more likely to attract green bonds, sustainability-linked loans, and funding from climate finance institutions, thereby expanding capital access while reducing borrowing costs (PRI, 2021). Moreover, real estate assets that demonstrate environmental stewardship and

community integration often enjoy higher occupancy rates, premium pricing, and regulatory incentives, reinforcing the business case for ecological restoration along urban rivers.

Together, environmental valuation and ESG alignment are transforming how urban riverfronts are conceptualized—not merely as public amenities or ecological buffers, but as integral components of sustainable urban growth, financial resilience, and long-term real estate value.

3. INTRODUCTION TO STUDY AREA

3.1. Nagpur: The Strategic Heart of India

Nagpur, commonly referred to as the “Orange City,” is one of India’s most prominent Tier-2 urban centers. Functioning as the winter capital and second administrative capital of Maharashtra, the city holds a critical position in the state’s political and governance framework. Its strategic location at the geographical center of India—marked by the historic Zero Mile Stone—has established Nagpur as a pivotal node in the country’s transportation, logistics, and trade networks. With accelerating urbanization, demographic expansion, and infrastructure modernization, Nagpur is emerging as a key player in India's smart city movement and regional economic development.

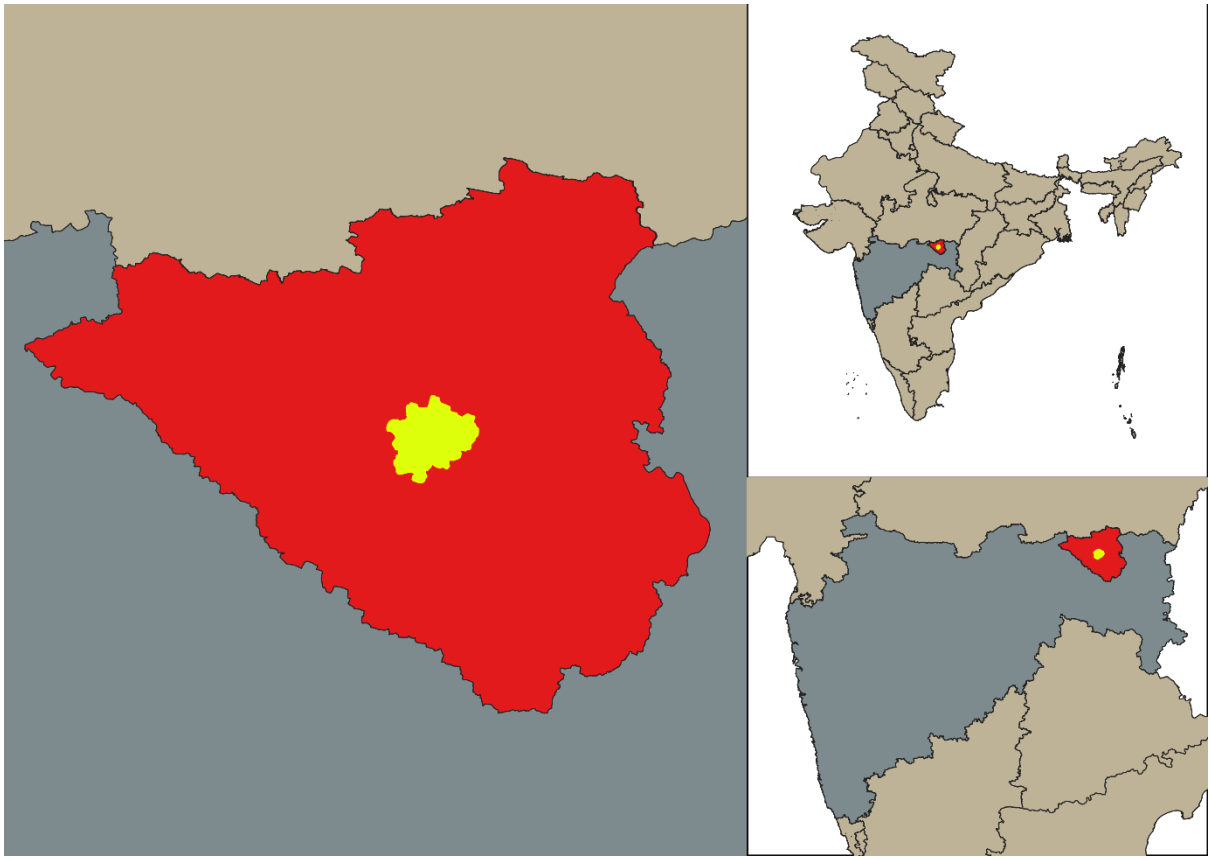


Figure 17: Location of Nagpur City Map

Source: Author

3.1.1. Geographical Significance

Nagpur's geographical centrality offers substantial advantages in national connectivity. It serves as a junction for multiple national highways (such as NH-44 and NH-53) and key railway corridors, linking northern, southern, eastern, and western regions of the country. This connectivity has reinforced the city's role as a logistics hub, fostering growth in sectors such as warehousing, transportation, and defense logistics. Additionally, its location has made it a natural choice for military establishments and emergency response coordination, further adding to its strategic relevance.

3.1.2. Administrative Role

The city's administrative prominence stems from the Nagpur Pact of 1953, which conferred upon it the status of Maharashtra's second capital. In accordance with this agreement, the state legislature conducts its annual winter session in Nagpur. This unique political arrangement has ensured consistent governmental investment in urban infrastructure, administrative institutions, and educational facilities. As a result, Nagpur has evolved into a regional governance nucleus, balancing both bureaucratic and civic functions.

3.1.3. Economic and Industrial Growth

In recent decades, Nagpur has experienced robust industrial and economic growth, driven in large part by the development of the Multi-modal International Cargo Hub and Airport at Nagpur (MIHAN). MIHAN is one of India's largest integrated logistics and aerospace projects, positioning the city as a strategic destination for cargo, warehousing, and aviation industries. Complementing MIHAN are established industrial zones such as Butibori and Hingna, which host a wide range of enterprises across sectors including information technology, pharmaceuticals, engineering, and education.

However, this rapid economic and spatial expansion has also intensified pressure on Nagpur's natural ecosystems. The Nag River, historically integral to the city's identity and ecology, has been significantly impacted by unchecked urban growth, pollution, and encroachments. This underscores the critical need for adopting sustainable urban

development frameworks that integrate ecological preservation with infrastructural advancement.

3.2. The Nag River: Significance and Rationale for Selection

The Nag River, from which the city of Nagpur derives its name, holds deep historical, cultural, and ecological significance. Once a vital freshwater resource for agriculture, domestic use, and local biodiversity, the river has gradually transformed into a heavily polluted urban drain. This transformation has been driven by unregulated urban expansion, unchecked discharge of sewage and industrial effluents, and encroachments along its banks. The deterioration of the Nag River exemplifies the broader challenges of urban river degradation in rapidly growing Tier-2 Indian cities, making it a highly relevant case study for examining the dynamics of urban hydrology, environmental policy, and sustainable restoration strategies.

3.2.1. Geographical Features and Origin

The Nag River extends approximately 68 kilometers from its source to its confluence with the Kanhan River, with around 17 kilometers flowing directly through the urban fabric of Nagpur. The river's width ranges from 12 to 40 meters, while its depth varies seasonally between 2 and 4.5 meters, influenced by monsoonal precipitation and urban runoff. Traditionally, the river is believed to originate from the ecologically sensitive Lava Hills, which host seasonal wetlands, springs, and dense vegetation. However, contemporary urban planning and real estate development interests have controversially repositioned the river’s origin near an urban dam, raising concerns about ecological accountability, legal ambiguities, and the manipulation of hydrological baselines to facilitate land conversion and infrastructure expansion.

3.2.2. Urbanization Impacts

The city’s rapid population growth, recorded at 2.4 million in the 2011 Census and projected to rise significantly, has intensified demands on both land and water resources. The spatial expansion of the Nagpur Metropolitan Region has led to widespread land-use changes, including the encroachment of floodplains, informal settlements, and unregulated construction along the riverbanks. These developments have severely disrupted the river’s ecological functions—diminishing its capacity for

natural drainage, elevating the risk of urban flooding, and exacerbating water quality deterioration due to increased surface runoff and pollutant loading. The weakening of riparian buffer zones and the loss of wetlands have further compromised the river's ability to support biodiversity and ecosystem services.

3.2.3. Policy Reversal and Buffer Zone Encroachment

A critical turning point in the river's ecological decline was the revocation of the Maharashtra River Regulation Zone (RRZ) Policy in 2015. The RRZ Policy, initially implemented in 2000, provided regulatory protection by restricting industrial and commercial developments within designated buffer zones of major rivers. Its repeal has allowed extensive real estate and industrial activity to penetrate previously safeguarded areas along the Nag River. This policy shift has legitimized construction in ecologically sensitive zones, accelerated the pace of encroachments, and further eroded the river's resilience to seasonal flooding and pollution stressors. The absence of stringent zoning laws and enforcement mechanisms has only amplified these trends, leading to irreversible land-use transformations and ecological degradation.

Given these intersecting challenges, the Nag River serves as an instructive example of the environmental trade-offs associated with urban development in mid-sized Indian cities. Its restoration offers critical insights into the formulation of integrated urban water management strategies, the role of policy and governance in ecological protection, and the potential for aligning urban planning with sustainable development goals. Accordingly, the river has been selected as the focal point of this study, with an emphasis on examining restoration interventions, regulatory frameworks, and climate-resilient planning models.

3.3. Environmental Challenges Along the Nag River

The Nag River is emblematic of the ecological degradation experienced by urban rivers in rapidly developing Indian cities. Once a natural freshwater channel integral to the city's environmental and cultural landscape, the river now faces multiple environmental stressors arising from unregulated urban growth, deficient infrastructure, and ineffective governance. This section identifies and analyzes the

primary environmental challenges that have compromised the river's health and functionality.

3.3.1. Pollution and Waste Management Deficiencies

One of the most pressing environmental concerns facing the Nag River is the acute level of pollution, largely attributed to systemic deficiencies in waste management. Approximately 80% of Nagpur's sewage—largely untreated—is discharged directly into the river, contributing to critically high levels of Biochemical Oxygen Demand (BOD) and Chemical Oxygen Demand (COD). These indicators reflect the presence of organic and chemical pollutants that have drastically reduced the river's oxygen levels, leading to the collapse of aquatic ecosystems. Additionally, indiscriminate dumping of municipal solid waste and the inflow of industrial effluents further exacerbate water quality deterioration. The absence of adequate sewage treatment plants (STPs) and the poor maintenance of existing drainage systems have effectively rendered the river ecologically lifeless in several segments, particularly within the urban core.

3.3.2. Habitat Loss and Encroachments

Encroachment along the Nag River's banks—primarily in the form of informal settlements and unregulated construction—has resulted in the large-scale loss of riparian habitats. Natural vegetation has been cleared to make way for housing and infrastructure, disrupting native flora and fauna and leading to a significant reduction in biodiversity. The river's floodplains, once acting as natural buffers against seasonal inundation, have been severely narrowed, increasing the risk of urban flooding during monsoons. Furthermore, habitat fragmentation caused by built structures impedes the movement and survival of aquatic and semi-aquatic species, undermining the ecological integrity of the river corridor.

3.3.3. Hydrological Disruptions

Urbanization has profoundly altered the hydrological cycle of the Nag River basin. The proliferation of impervious surfaces—such as roads, pavements, and buildings—has drastically reduced groundwater recharge and increased surface runoff, leading to flash floods during periods of heavy rainfall. Concurrently, excessive extraction of

groundwater for residential, commercial, and industrial uses has contributed to declining water tables, resulting in low or absent base flows during the dry season. These changes have destabilized the river's seasonal hydrology, with long dry stretches in summer and heightened flood risks during monsoons. This hydrological imbalance not only exacerbates water scarcity in surrounding areas but also undermines the river's role as a dynamic ecological system.

3.4. Slums and Informal Settlements in Riparian Zones

Nagpur is home to the fourth-largest slum population in India, with informal settlements accounting for an estimated 35% of the total city population. As per recent demographic data, the city houses 858,983 slum residents, spread across 379 slums, including 171,645 slum households. These settlements are unevenly distributed across administrative zones, with the Satranjipura and Lakadganj zones showing the highest slum densities—ranging from 110,001 to 133,000 individuals. These high-density zones are notably adjacent to the Nag River and its tributaries, making them critical to any riparian ecological restoration effort.

3.4.1. Spatial Distribution and Riparian Impact

The spatial analysis from the accompanying map highlights the concentration of both notified and non-notified slums along the Nag River corridor. Specifically, 42 notified and 12 non-notified slums fall within the riparian restoration zone, directly impacting the river through untreated domestic wastewater, solid waste discharge, and structural encroachments on the floodplain. The majority of these settlements lack proper sanitation, waste disposal systems, and piped water supply, further exacerbating riverine pollution and public health vulnerabilities.

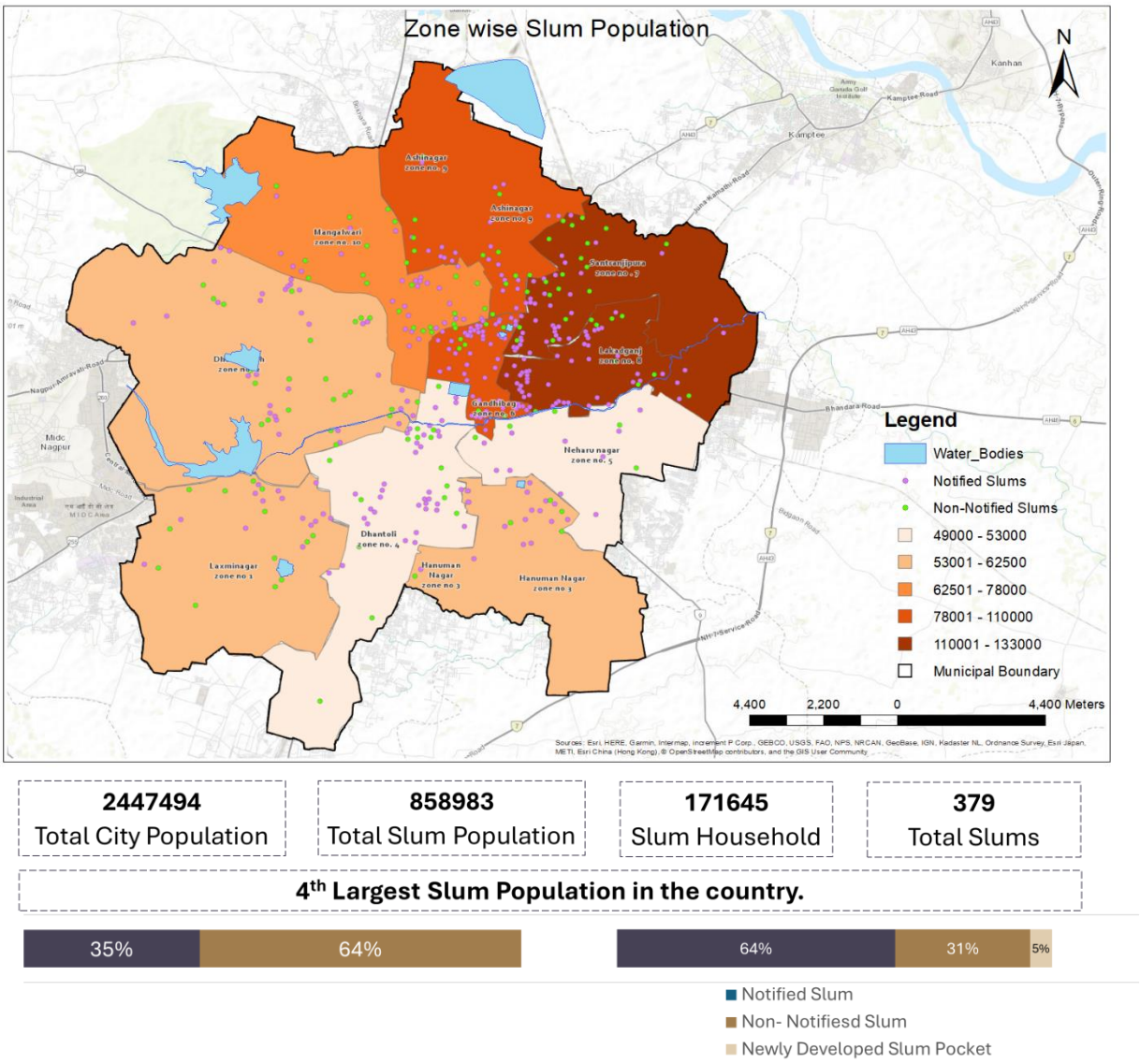


Figure 18: Zone wise Slum Population Map

Source: Climate Resilient City Action Plan Nagpur, ICLEI South Asia (2022)

Newly developed slum pockets, marked distinctly in the spatial dataset, are emerging in peri-urban zones such as Hanuman Nagar and Laxmi Nagar, indicating ongoing informal urban sprawl. These newer encroachments are particularly concerning, as they tend to develop in ecologically sensitive buffer areas where regulatory oversight is minimal following the rollback of the Maharashtra River Regulation Zone (RRZ) policy in 2015.

3.4.2. Socio-Economic Vulnerability and Environmental Risk

The physical proximity of informal settlements to the Nag River increases their exposure to environmental hazards, particularly seasonal flooding, vector-borne diseases, and water contamination. These risks are magnified by poor infrastructure and insecure land tenure, which prevent residents from accessing formal housing or insurance mechanisms. Despite the deployment of national housing and urban reform schemes like the Pradhan Mantri Awas Yojana (PMAY) and the Jawaharlal Nehru National Urban Renewal Mission (JNNURM), relocation and rehabilitation initiatives have been hampered by administrative delays, legal disputes over land ownership, and community resistance.

Furthermore, the slum population's high density and lack of integration into formal urban planning mechanisms pose significant challenges for effective implementation of the Nag River Rejuvenation Project. Without parallel efforts to address housing rights, provide in-situ infrastructure upgrades, and engage communities in participatory restoration planning, ecological interventions along the river will remain incomplete and unsustainable.

3.4.3. Environmental Degradation from Informal Settlements: Insights from CDP 2041

The Nagpur City Development Plan (CDP) 2041 provides a detailed assessment of the environmental challenges stemming from the proliferation of informal settlements, particularly those located along riparian zones of the Nag River. With approximately 35% of the city's population residing in slums, including 42 notified and 12 non-notified slums situated directly within the riparian restoration zone, the strain on the urban river system has reached a critical point. These settlements, often established without formal planning or infrastructure, lack basic services such as sewage networks, waste disposal mechanisms, and safe drinking water access—making them both contributors to and victims of ecological degradation.

According to the CDP 2041, continuous discharge of untreated domestic wastewater from these communities has led to excessive pollutant accumulation, manifesting in high levels of Biochemical Oxygen Demand (BOD) and Chemical Oxygen Demand

(COD) in the Nag River. Furthermore, unprotected riverbanks adjacent to informal settlements have exacerbated issues of siltation and flood vulnerability, especially during monsoon seasons, when runoff from densely built-up areas enters the river unchecked.

The absence of regulated development and enforcement in these areas has also resulted in encroachments into the floodplain, severely impairing the river's natural drainage and assimilation capacity. The lack of embankment stabilization and the use of impervious materials in informal housing further reduce groundwater recharge, leading to hydrological imbalances and seasonal waterlogging. This has a cascading effect on public health, particularly in densely populated slum clusters exposed to contaminated surface and groundwater sources.

The CDP emphasizes the urgent need for integrated planning approaches that align urban housing policies—such as the Pradhan Mantri Awas Yojana (PMAY)—with river conservation strategies. It recommends the enforcement of no-development zones, the legal protection of riparian corridors, and the implementation of Public-Private Partnership (PPP) models to support relocation, rehabilitation, and ecological restoration. Strengthening the institutional capacity of municipal authorities to monitor and enforce regulations is identified as essential to curbing further degradation of riverine ecosystems and ensuring long-term urban resilience.

4. DATA ANALYSIS

4.1. Urban Growth and Planning in Nagpur

Nagpur's urban growth has been shaped by a layered history of political regimes and spatial development, with the Nag River playing a pivotal role in its evolution. Situated at the geographical center of India, Nagpur has experienced distinct phases of expansion, each contributing to its transformation from a river-centric settlement to a major urban and industrial hub. Despite this growth, the ecological health of the Nag River—once the lifeline of the city—has declined significantly due to unregulated development and inadequate integration of environmental planning.

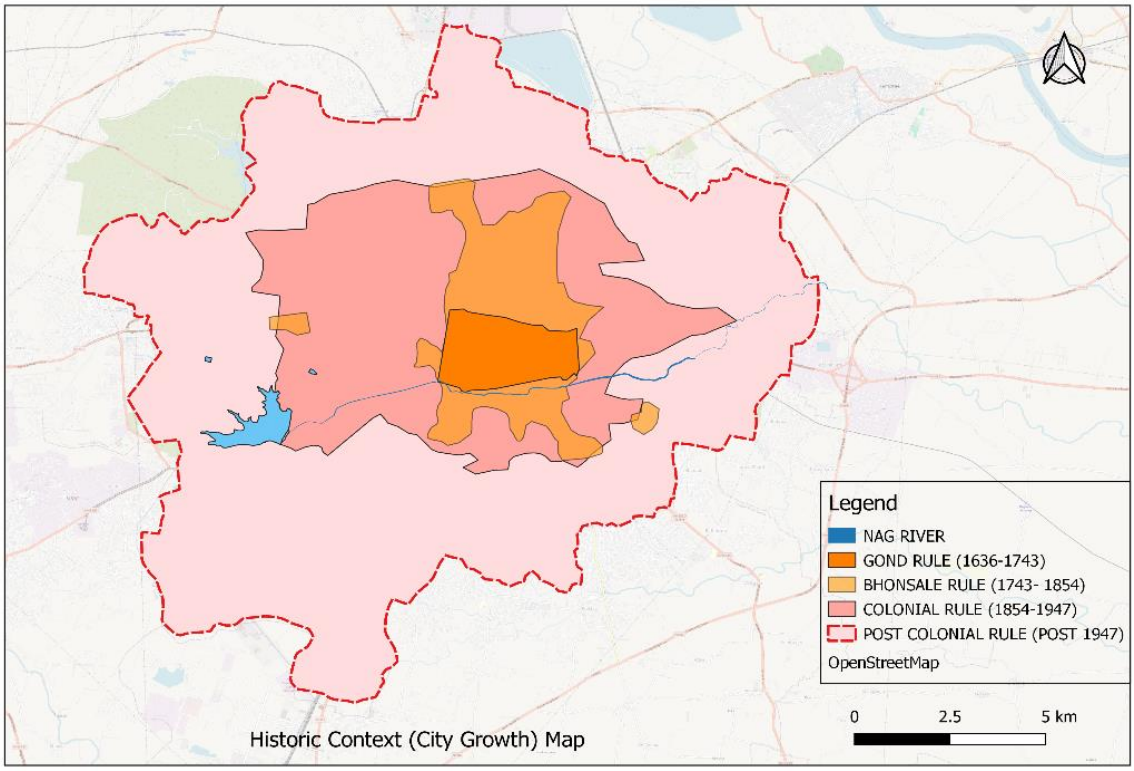


Figure 19: Evolution of Nagpur City Map

Source: Integrating Heritage in Urban Development, Nagpur, SPAV

Historically, the city's growth revolved around the Nag River, reflecting its geographical and cultural centrality. During the **Gond rule (1636–1743)**, the earliest settlements were established along the river, relying on its water for agriculture and sustenance.

This phase laid the foundation of the city's core. Under the **Bhonsale rule (1743–1854)**, Nagpur expanded outward with the construction of administrative centers, religious sites, and local markets, further reinforcing the river's centrality in trade and daily life. The **colonial period (1854–1947)** introduced structured urban planning, including transportation networks and industrial infrastructure, much of which followed the river's course. Post-independence, Nagpur witnessed rapid population growth and industrialization, resulting in extensive urban sprawl. While this expansion elevated the city's economic profile, it also led to widespread encroachments and environmental degradation of the river and its surrounding ecosystems.

Figure 20: Nagpur City Ward Boundary Map

Source: Nagpur Municipal Corporation

Today, Nagpur covers an area of **225.08 sq. km**, comprising **145 electoral wards** across **10 administrative zones**. The city's population stood at **2.4 million as per the**

2011 Census, creating substantial demands on infrastructure, housing, and natural resources. This rapid urbanization has significantly altered the landscape, with peri-urban growth, informal settlements, and high-density commercial areas encroaching upon natural features. The Nag River, once central to the city's formation, now faces severe ecological challenges, including pollution, reduced water flow, loss of riparian vegetation, and vulnerability to flooding.

One of the most critical consequences of this unregulated growth has been the environmental deterioration of the Nag River. With insufficient integration of river-sensitive planning, the city has witnessed unplanned construction along riverbanks, discharge of untreated sewage and industrial waste, and the conversion of riparian zones into urban land. As highlighted in the Nagpur City Development Plan (CDP) 2041, the absence of buffer zones and conservation policies has led to siltation, flood risks, and reduced groundwater recharge, thereby weakening the city's ecological resilience.

Moving forward, Nagpur’s urban planning must prioritize the ecological restoration of the Nag River as a foundational element of sustainable development. This includes enforcing no-development zones along the river, enhancing green infrastructure, implementing afforestation along riverbanks, and adopting integrated water resource management. By restoring the river's environmental health and re-establishing its role in urban life, Nagpur can balance future growth with long-term ecological sustainability.

4.2. Interdepartmental Gaps: A Key Factor in Nag River’s Degradation

The degradation of the Nag River is intricately linked to significant interdepartmental gaps among the various governmental and technical agencies involved in urban development, sanitation, and environmental conservation. Despite the presence of multiple stakeholders, the absence of an integrated governance framework has led to disjointed efforts, overlapping responsibilities, and a fragmented response to the river’s environmental challenges.

A prominent example of this disconnect is the lack of clear accountability between the Nagpur Improvement Trust (NIT) and the Nagpur Municipal Corporation (NMC). While

the NIT has distanced itself from the river rejuvenation efforts by asserting that the Nag River falls under the purview of the NMC, the NMC itself suffers from internal fragmentation. Within the NMC, critical departments such as the Directorate of Town Planning operate with limited coordination. Notably, the planning department continues to rely on outdated maps from the year 2000, despite the ongoing preparation of the 2041 Development Plan, which has yet to be integrated into river-specific planning processes such as defining buffer zones and demarcating flood lines.

Additionally, the Public Health Engineering Department within the NMC remains narrowly focused on the management of sewage flows, with little attention to ecological buffers or current water quality metrics—factors essential for long-term pollution mitigation. Moreover, the Project Management Consultant (PMC), Tata Engineering Consultancy (TEC), possesses valuable data sets such as water quality analyses and sewage outlet mappings. However, TEC's involvement remains limited to technical implementation, with minimal engagement in broader ecological restoration strategies.

Table 3: Interdepartmental Gaps: A Key Factor In Nag River's Degradation

NIT Since 1936	**Nagpur Improvement Trust** "We are not involved in the Nag River project. This is solely under the jurisdiction of Nagpur Municipal Corporation (NMC)."
	Nagpur Municipal Corporation (Directorate of Town Planning Department) •Not working on Nag River regarding **buffer zones, plotting, or development plans**. •**Development Plan 2041** report is published, but no finalized map exists. •Still using the **2000 Development Plan map**. •Hired personnel to create the 2041 map, which will take **2 more years**.
	Nagpur Municipal Corporation (Public Health Engineering Department) •Currently focused on **stopping sewage flow** into Nag River. •**Not addressing** buffer zones, RRZ, or flood lines (blue/red). •Lack of **latest water quality maps**. •Exploring the possibility of laying **interceptor lines**. •Only focusing on cleaning of the river. •Collaborating with **Tata Engineering Consultancy (TEC)** as PMC for sewage.
TATA CONSULTING ENGINEERS	**Tata Engineering Consultancy (TEC)** •Possesses **2019 water quality data** from NEERI (National Environmental Engineering Research Institute). •Has a **sewage outlet map**. •Exploring the potential for **buffer zones** but not actively working on it yet. •Only working for the pollution abatement- project.

Source: Primary Survey, FGD

This compartmentalized and siloed approach has resulted in operational delays, inefficiencies, and a piecemeal response that fails to address the river's degradation comprehensively. Without a unified framework for collaboration and data-sharing among all stakeholders, efforts to restore the Nag River are likely to remain fragmented and insufficient. A coordinated, inter-agency strategy is imperative to drive meaningful progress in river rejuvenation and environmental sustainability.

4.3. Riparian Restoration Zone of the Nag River Basin

The Riparian Restoration Zone (RRZ) delineated within the Nag River Basin represents a strategically significant area for ecological and hydrological rejuvenation. Encompassing 37 municipal wards, this zone lies directly within the river basin and serves as a focal point for interventions aimed at reversing environmental degradation caused by rapid urbanization. Restoration initiatives within this zone are driven by the need to reconcile urban development with the preservation and rehabilitation of the riverine ecosystem.

According to data from the 2011 Census, the total population residing within this zone is approximately 6.16 lakh, underscoring the intensity of human-environment interactions that influence the health of the river. Over the years, unplanned urban expansion and increased anthropogenic pressures have led to extensive encroachments on riverbanks, pollution from various sources, and the gradual disappearance of natural floodplains. These developments have necessitated the formulation of a comprehensive and sustainable restoration strategy focused on restoring the ecological integrity and resilience of the Nag River.

4.3.1. Key Challenges in the Riparian Restoration Zone

A detailed assessment of the Riparian Restoration Zone has revealed a number of interrelated challenges that compromise both the ecological health of the river and the well-being of surrounding communities

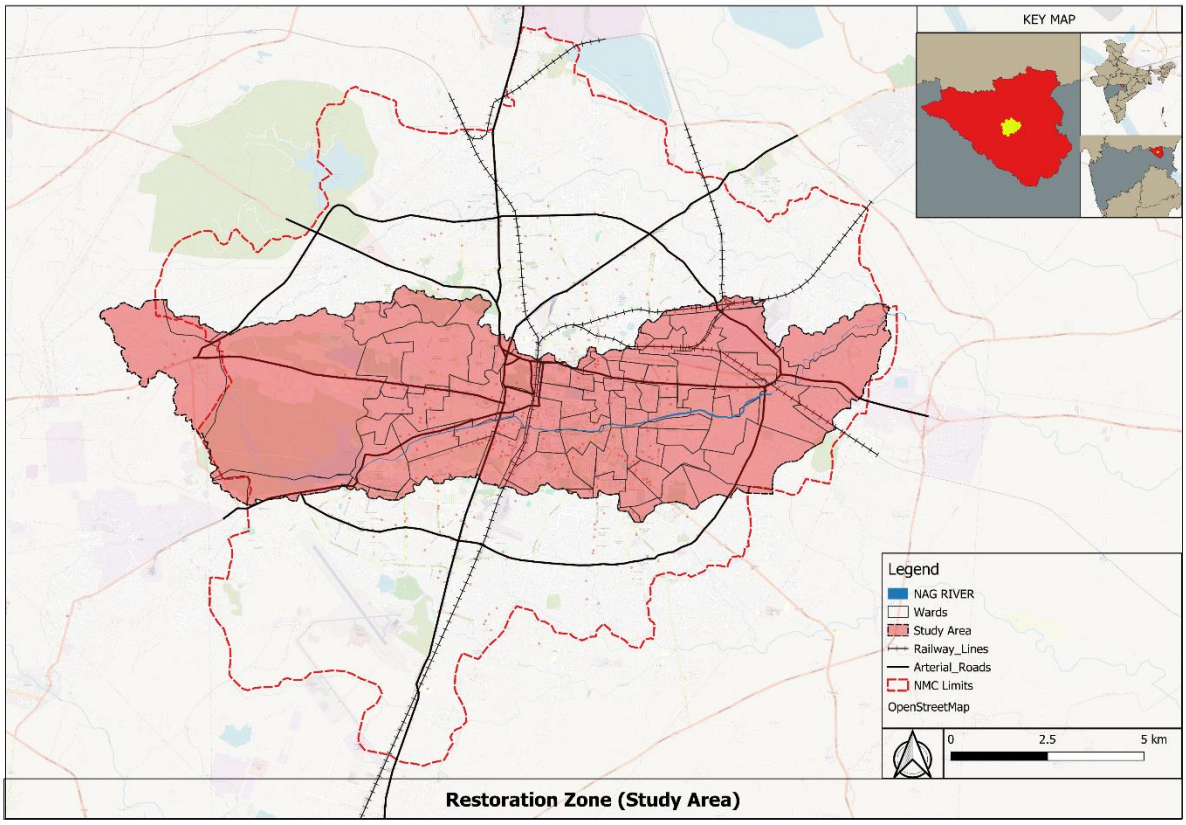


Figure 21: Nag River Restoration Zone

Source: Author

1. Urban Encroachment and Infrastructure Expansion

The unchecked proliferation of residential and commercial structures along the riverbanks has significantly altered the river's natural hydrological dynamics. Encroachments into the floodplain have not only increased the risk of urban flooding but have also contributed to the erosion of riverbanks and the destruction of native habitats. In many cases, unauthorized constructions have impeded the river's natural flow and reduced its capacity to absorb and retain stormwater, thus intensifying seasonal flood events.

2. Water Pollution and Solid Waste Accumulation

The Nag River has increasingly been subjected to severe pollution, acting as a conduit for untreated sewage, industrial discharges, and unregulated solid waste disposal. The

absence of robust waste management systems has led to the accumulation of plastic debris, organic waste, and hazardous effluents within the watercourse. Elevated levels of biochemical oxygen demand (BOD), chemical pollutants, and suspended solids have significantly deteriorated the river's water quality, threatening aquatic life and public health.

3. Slum Settlements and Lack of Sanitation Infrastructure

Informal settlements along the riparian corridor, often lacking basic sanitation and waste disposal infrastructure, further aggravate the river's pollution load. Many residents within these slum areas are dependent on the river for daily domestic needs, resulting in frequent instances of open defecation and direct discharge of greywater into the river. The absence of proper sewerage and drainage networks in these high-density settlements contributes to the systemic degradation of the riparian environment.

4. Loss of Aquatic Biodiversity and Ecological Degradation

Despite the adverse environmental conditions, isolated pockets of aquatic life persist in certain segments of the river, signaling the river's latent ecological potential. However, continued exposure to pollution, coupled with sedimentation and the destruction of vegetative cover along the banks, poses an existential threat to native fish species and riparian flora. The gradual disappearance of these natural ecological buffers has weakened the river's intrinsic self-purification mechanisms, making restoration both more urgent and more complex.

4.4. Hydrological and Environmental Analysis of the Nag Basin

A comprehensive hydrological and environmental analysis of the Nag River Basin provides critical insights into the current state of the ecosystem and highlights the impact of urbanization on the natural flow of water and ecological balance. Through detailed mapping and spatial analysis, this section explores key hydrological features, land cover changes, and the implications of urban expansion on flood risk, water quality, and biodiversity within the basin.

4.4.1. Sub-Basin Map: Understanding the Hydrological Framework

The sub-basins map serves as a vital tool for understanding the river's natural drainage system and the interconnection between water channels within the broader basin. It reveals that the western and central parts of the basin still maintain some degree of natural vegetation and open spaces, which function as crucial water recharge zones. These regions, characterized by their relatively intact hydrological systems, help to regulate water flow, contribute to groundwater recharge, and support local biodiversity.

Figure 22: Sub Basin Map

Source: Prepared by the author using SRTM DEM data (30m) from USGS Earth Explorer; processed in QGIS for sub-basin delineation

Conversely, the eastern sections of the basin are heavily urbanized, leading to significant fragmentation of the sub-basins. This urban sprawl disrupts the natural water flow, impedes groundwater percolation, and increases surface runoff. Such changes amplify the risk of flooding and waterlogging, especially during the monsoon season. The encroachment into riparian zones and the subsequent loss of natural water retention areas have exacerbated the basin's vulnerability to urban flooding, highlighting the need for careful land-use planning and ecological restoration to mitigate these hydrological challenges.

4.4.2. Land Cover Map (2021): Urbanization at the Cost of Green Spaces

The 2021 land cover map further accentuates the transformation of the basin, illustrating how rapid urbanization has encroached upon natural vegetation, agricultural land, and open spaces. Built-up areas, depicted in red on the map, have replaced vital ecosystems such as forests, wetlands, and permeable surfaces. These

green spaces once played an essential role in absorbing rainwater, facilitating groundwater recharge, and maintaining ecological balance.

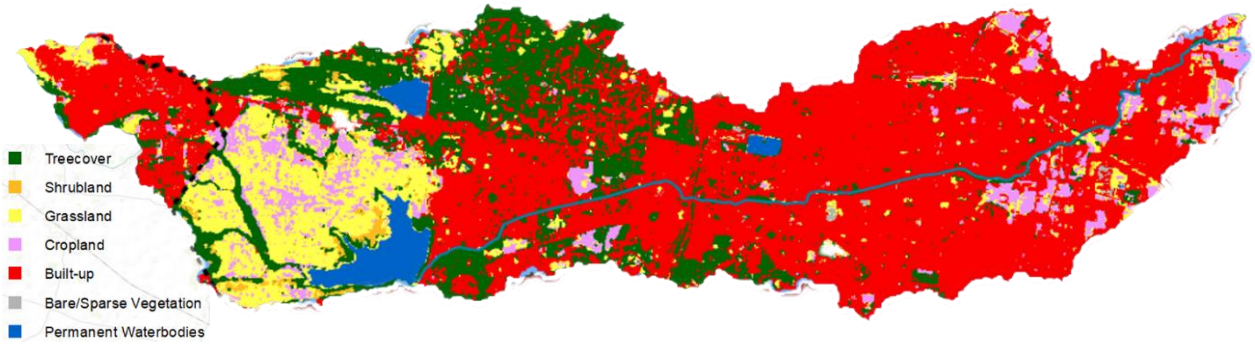


Figure 23: Land Cover Map

Source: Prepared by the author using Landsat imagery (1990–2020) from USGS Earth Explorer; classified in Google Earth Engine using supervised classification and validated in QGIS.

The fragmentation of green patches signals the decline of the basin's ecological health. Urban expansion has not been accompanied by adequate conservation efforts, leading to a diminished capacity for the environment to self-regulate and absorb excess water. Notably, the conversion of wetlands and riparian buffer zones into residential and commercial developments has not only increased the risk of flooding but has also contributed to escalating pollution levels in the river. The depletion of open water bodies, as indicated by the land cover map, reveals that numerous natural streams, ponds, and small lakes have either dried up or been encroached upon due to unregulated development, further stressing the river's ability to cleanse itself.

4.4.3. Built-Up Growth (1993–2021): The Alarming Expansion of Urbanization

The built-up growth map spanning from 1993 to 2021 provides a historical perspective on the pattern of urbanization in the Nag River Basin. During the early years (1993–2000), urban growth was confined to the core city areas. However, the period from 2000 to 2010 witnessed a rapid expansion into peri-urban areas, resulting in the encroachment of agricultural lands and open spaces.

The most concerning phase occurred between 2010 and 2021, during which unregulated urban growth surged along the riparian zones. This encroachment led to the loss of critical buffer zones, further exacerbating contamination levels in the river

and increasing the proportion of impervious surfaces, which in turn elevated surface runoff. The lack of effective enforcement of land-use regulations during this period has resulted in unplanned settlements, often in flood-prone regions, contributing to a significant rise in urban flooding risks. The unchecked sprawl depicted in this map highlights the inadequacy of urban planning frameworks in addressing both the demands of development and the need for environmental sustainability.

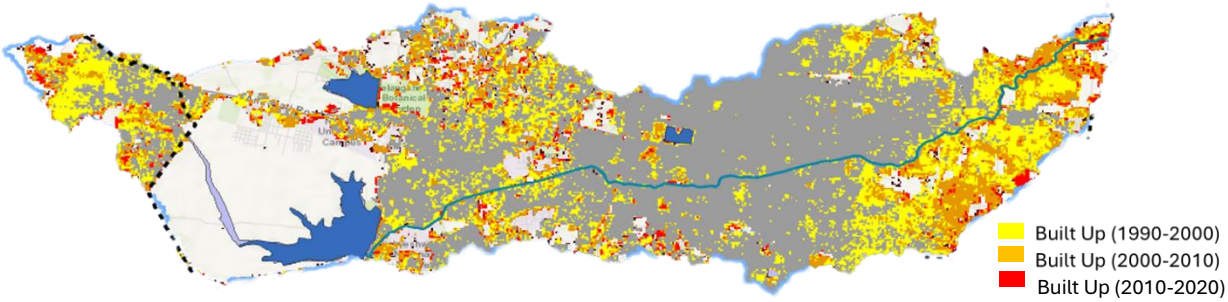


Figure 24: Built Up Growth Map

Source: Prepared by the author using Landsat satellite imagery (1990–2020) obtained from USGS Earth Explorer, analyzed through supervised classification and Normalized Difference Built-up Index (NDBI).

4.4.4. Topographic Wetness Index (TWI): Identifying High-Risk Flood Zones

The Topographic Wetness Index (TWI) map is instrumental in identifying areas prone to flooding and water stagnation within the basin. Regions marked by darker blue shades indicate areas with high water accumulation potential, which are more susceptible to flooding, especially during the monsoon season. These high-risk zones often coincide with densely urbanized areas, suggesting that urban expansion has encroached upon natural water retention zones, such as low-lying depressions and wetlands, that were once capable of absorbing excess rainfall.

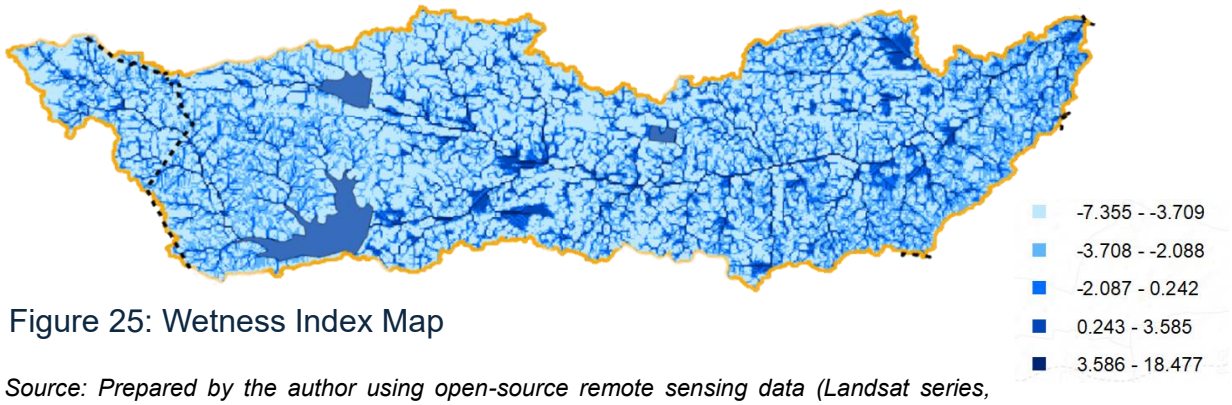


Figure 25: Wetness Index Map

Source: Prepared by the author using open-source remote sensing data (Landsat series, USGS Earth Explorer) and processed using Normalized Difference Wetness Index (NDWI).

The transformation of these naturally wet areas into residential or commercial properties has resulted in severe waterlogging during heavy rainfall. Furthermore, the absence of planned stormwater drainage systems in these areas has compounded the issue, leading to water accumulation in urban pockets rather than allowing for natural drainage into the river. The loss of wetland areas, as indicated by the TWI map, has not only heightened flood risks but also undermined the basin's ability to recharge groundwater and regulate water flow.

4.4.5. Analyzing Vegetation Trends in the Nag River Basin (1993–2021)

The vegetation trend map, covering the period from 1993 to 2021, provides a visual representation of the changes in green cover within the Nag River Basin. The map categorizes areas into zones of high, moderate, and low vegetation loss, as well as areas of vegetation gain. This trend is crucial for understanding the broader environmental impacts of urban expansion and the degradation of natural ecosystems.

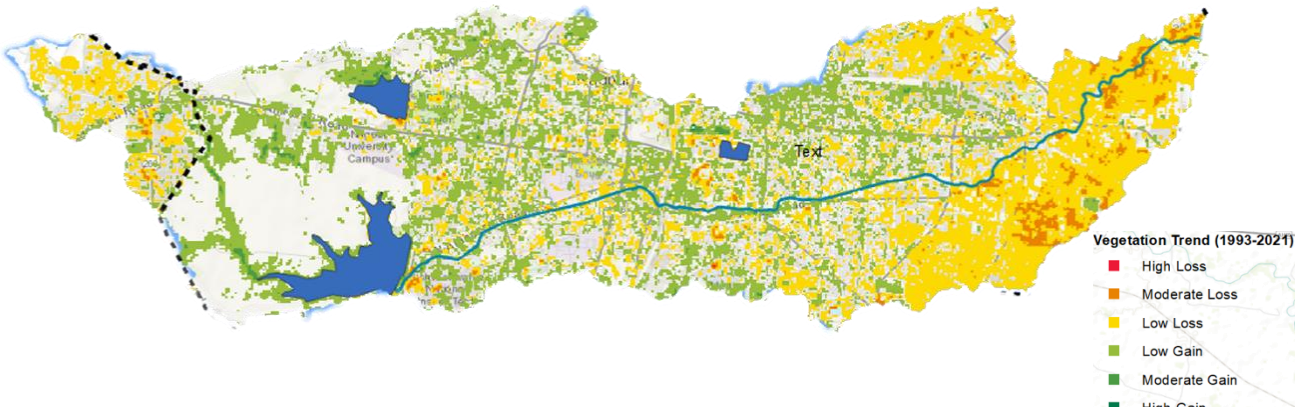


Figure 26: Vegetation Trend Map

Source: Prepared by the author using open-source remote sensing data from USGS Landsat archive (1993–2021) and processed using QGIS

Key Observations from the Vegetation Trend Map:

1. **Significant Vegetation Loss in Urban and Peri-Urban Areas:**
    - Areas marked in red (high loss) and orange (moderate loss) indicate substantial deforestation or conversion of green spaces into built-up areas, roads, and industrial zoneS.

- The encroachment into natural riparian buffer zones and the disappearance of tree cover in urban areas have contributed to increased surface runoff, reduced air quality, and a decline in biodiversity.
- The central and eastern parts of the river basin, where rapid urbanization has occurred, exhibit the most prominent vegetation loss.

2. **Moderate and Low Loss in Peripheral Areas:**
    - Yellow zones (low loss) suggest gradual degradation of vegetation, potentially due to the fragmentation of agricultural lands or conversion into barren land.
    - While these areas exhibit less severe loss compared to urban zones, they still face risks of further degradation without intervention and stricter land-use regulations.
3. **Vegetation Gain in Specific Pockets:**
    - Light green (low gain) and dark green (high gain) zones indicate areas where positive changes in vegetation cover have occurred, possibly due to afforestation efforts, reforestation programs, or natural regrowth.
    - Some wetland areas and water bodies show signs of rejuvenation, thanks to conservation initiatives or seasonal regeneration of aquatic plants.
    - Urban greening efforts, including tree plantation programs and the establishment of protected ecological zones, may also have contributed to these positive changes in select areas.

Impact on Hydrology and Microclimate:

- The significant loss of vegetation has altered the local microclimate, contributing to the urban heat island effect, higher temperatures, increased flooding risks, and a reduction in the basin's capacity for carbon sequestration.

- The disappearance of riparian buffers and wetland vegetation has weakened the river's natural ability to filter pollutants and regulate water flow, making the ecosystem more susceptible to contamination and fluctuations in water quality and quantity.

4.5. Building Footprint and Encroachment Analysis

The Building Footprint Mapping of the Riparian Zone provides a critical analysis of the urbanization trends along the Nag River, revealing significant encroachment that exacerbates flooding risks, environmental degradation, and challenges in water resource management. The analysis underscores the substantial impact of urban development on the river's ecosystem, highlighting the pressing need for effective land-use planning and regulatory measures.

One of the most concerning observations from the map is the absence of a dedicated buffer zone along the river. Ideally, riparian zones should incorporate an ecological buffer to help mitigate flooding, facilitate groundwater recharge, and preserve local biodiversity. However, the map indicates that urban developments have extended directly to the river's edge, leaving little to no space for natural flood management or ecological functions. This lack of a buffer zone has severe consequences: it heightens the risk of urban flooding by eliminating open spaces that could absorb excess rainwater, limits the capacity for groundwater recharge, and accelerates riverbank erosion, which further degrades the ecological health of the river.

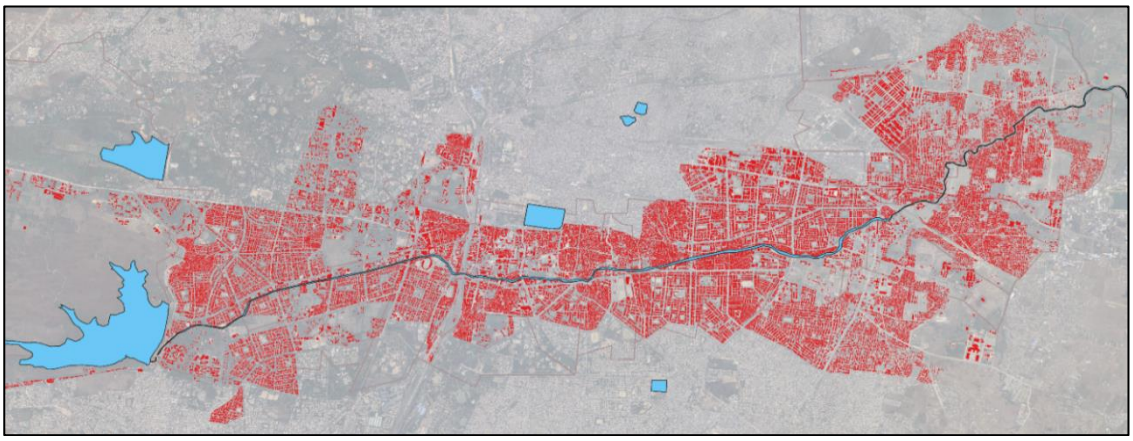


Figure 27: Built Up Footprint Map

Source: GEE

In addition, the map reveals high-density urbanization along the riverbanks, particularly in pockets of rapid development. These densely built-up areas result in extensive impervious surfaces, which impede water absorption and significantly increase surface runoff. This runoff carries pollutants, solid waste, and untreated sewage directly into the river, further deteriorating its water quality. The presence of unauthorized structures and informal settlements along the riparian zone exacerbates these issues, as these areas often lack basic sanitation and drainage infrastructure. Consequently, waste is frequently disposed of directly into the river, which not only degrades aquatic ecosystems but also heightens the risk of waterborne diseases for nearby communities.

This analysis highlights the urgent need for comprehensive planning and regulatory measures to address encroachment and restore the health of the Nag River, ensuring that future urbanization occurs in harmony with environmental sustainability and public health objectives.

4.6. Comparison of Land Use: Development Plan (2011) vs. Existing Land Use (2025)

The comparison between the 2011 Development Plan (DP) and the Existing Land Use (ELU) of 2025 offers a detailed overview of urban growth, land-use transformation, and emerging urban management challenges. This comparative analysis highlights both the intended land-use patterns outlined in the 2011 DP and the actual urbanization trends that have occurred by 2025. Understanding these differences is crucial for addressing gaps in planning and ensuring that future development aligns with sustainable growth principles.

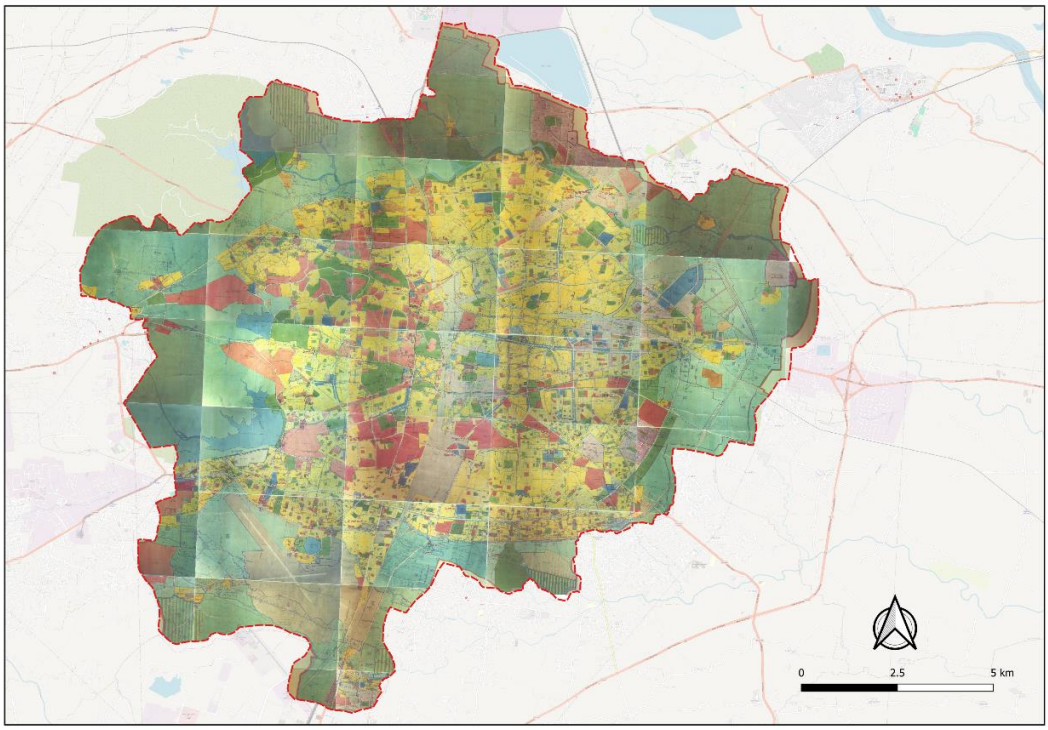


Figure 28: Nagpur Master Plan 2011

Source: Nagpur Municipal Corporation (NMC)

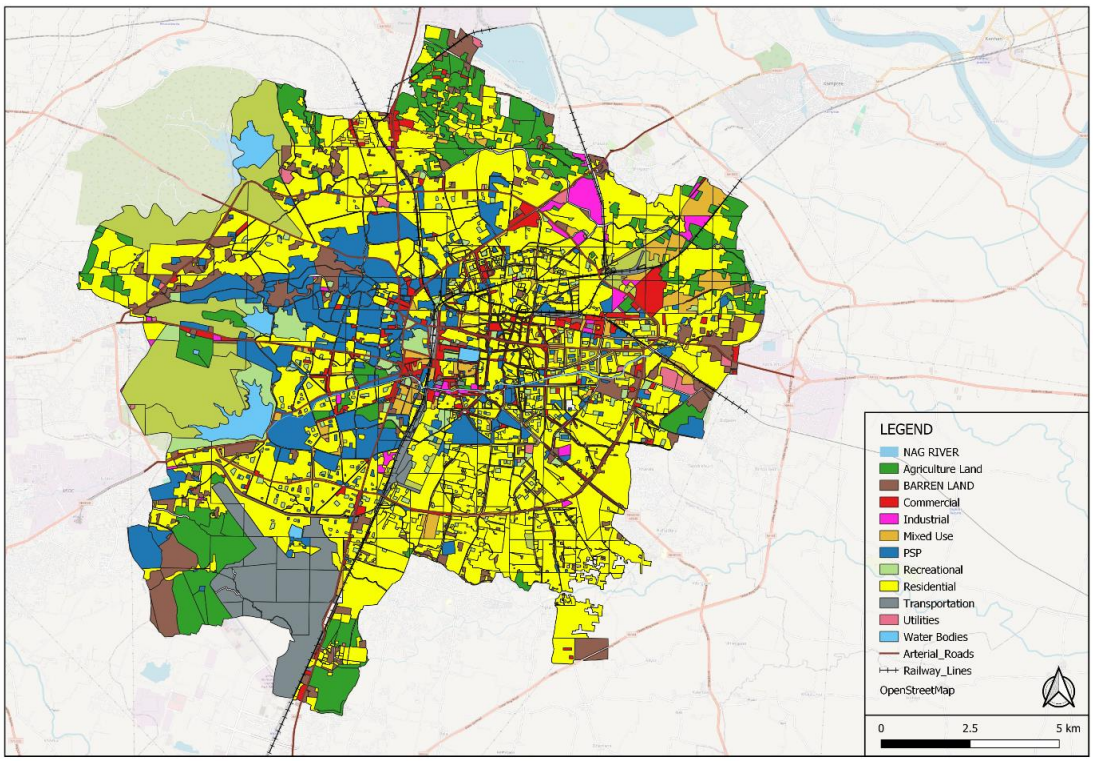


Figure 29: Nagpur Development Plan 2035

Source: Nagpur Municipal Corporation (NMC)

Key Observations from Land Use Maps

1. **Expansion of Urbanized Areas**

   The 2025 land-use map indicates a significant increase in urbanized areas when compared to the 2011 DP. Residential zones, represented by yellow, have expanded, reflecting rapid population growth and urban sprawl. Areas once designated for agricultural purposes in the 2011 plan have now been transformed into built-up zones, signifying unchecked urbanization at the periphery of the city.

2. **Growth of Commercial and Mixed-Use Developments**

   In 2025, there is a marked increase in commercial and mixed-use developments. What were once primarily residential areas in the 2011 plan are now seeing heightened commercial activity, especially in key corridors and intersections. This change indicates a response to growing urban demands for business spaces, retail centers, and mixed-use developments, which help accommodate the city's economic expansion.

3. **Industrial Expansion and Land Reallocation**

   Industrial land, shown in blue on the 2025 map, has grown in specific pockets, particularly on the outskirts of the city. This reflects a planned industrial expansion, likely influenced by economic policies or incentives. However, there may also be instances of unplanned industrial settlements, leading to conflicts in land use between industrial zones and residential areas.

4. **Reduction in Open Spaces and Green Areas**

   One of the most concerning trends in the 2025 land-use map is the significant reduction in open spaces and green areas. These zones have been increasingly encroached upon for development, reducing the availability of parks, agricultural land, and other natural spaces. This loss contributes to the environmental challenges of urbanization, such as increased urban heat island effects and diminished ecosystem services. The reduction in green spaces emphasizes the

importance of integrating ecological considerations into urban development strategies.

5. **Infrastructure and Transport Network Development**

   The 2025 land-use map reflects considerable progress in infrastructure, with new transportation corridors, roads, and urban mobility infrastructure. Areas that were low-density in 2011 have been transformed due to improved connectivity along major roads, spurring higher-density developments. The presence of planned transport hubs and corridors has significantly influenced urban expansion patterns, facilitating both residential and commercial growth along key transit routes.

6. **Informal and Unregulated Development**

   A notable concern in the 2025 land-use scenario is the rise in informal and unregulated development. While the 2011 DP anticipated structured growth, the ground reality shows deviations, including the expansion of slums, unauthorized commercial activities, and irregular urbanization in some areas. This informal development presents challenges for urban planners in managing public health, infrastructure, and environmental sustainability.

4.7. Existing Land Use 2025: Riparian Restoration Zone

The Riparian Restoration Zone along the Nag River plays a pivotal role in both ecological conservation and urban development. The Existing Land Use map of 2025 highlights how urban growth has significantly influenced the spatial distribution of land uses within the riparian zone, emphasizing the need for targeted restoration and urban planning effort.

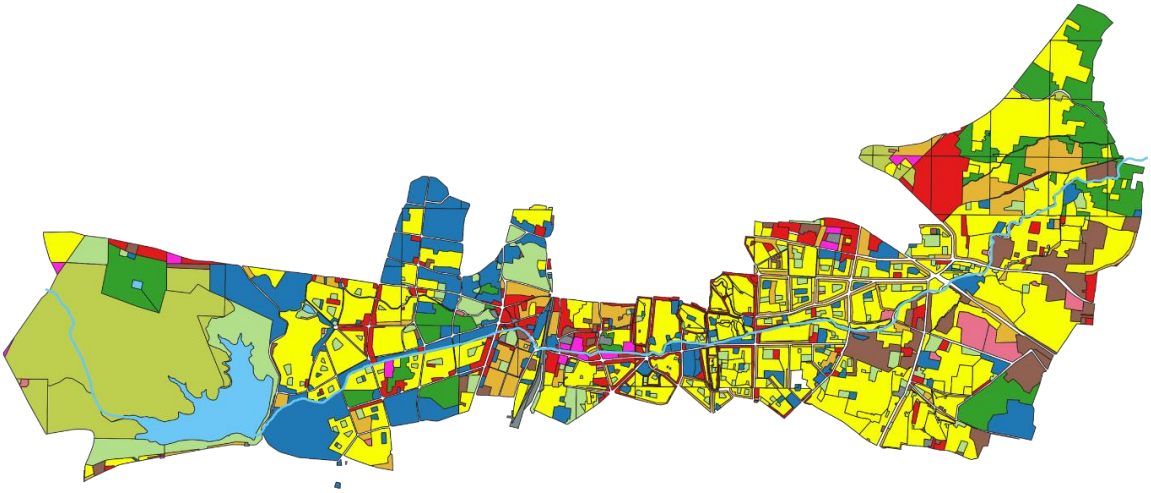


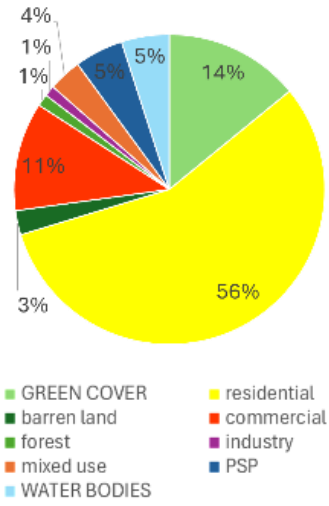
Figure 30: Land Use of Riparian Restoration Zone

Source: Nagpur Municipal Corporation

Key Land Use Observations

1. **Predominance of Residential Land Use (56%)**

   Residential areas account for more than half (56%) of the riparian zone, reflecting substantial urban encroachment along the riverbanks. This extensive settlement suggests high population density and informal housing growth, which pose environmental challenges such as waste disposal, sewage discharge, and river pollution. Addressing these issues requires enhanced urban planning and improvements in sanitation infrastructure.



2. **Limited Green Cover (14%)**

   Green cover, including parks, open spaces, and riparian buffer zones, represents only 14% of the land in the riparian zone. Given the ecological importance of riparian buffers for flood mitigation, groundwater recharge, and biodiversity, this low percentage raises concerns about the ongoing degradation of the river's ecosystem. Restoration efforts must focus on increasing green infrastructure and protecting natural habitats along the river.

3. **Water Bodies and River Channel (5%)**

   The Nag River and connected water bodies make up only 5% of the riparian zone in 2025. This shrinking of the river's width and encroachment on water bodies underscores the growing pressure on the river’s ecological health. Conservation measures are essential to maintain water flow, reduce pollution, and improve wastewater treatment to restore the river's vitality.

4. **Commercial and Mixed-Use Growth (3%)**

   Approximately 3% of the riparian zone is designated for commercial and mixed-use developments. While these areas contribute to the local economy, they can also increase waste generation and put further strain on the river ecosystem if not carefully managed. Future urban planning in this zone should prioritize sustainable, eco-friendly commercial growth that minimizes environmental harm.

5. **Industrial Presence and Potential Pollution (1%)**

   Industrial land use accounts for just 1% of the riparian zone, but its potential impact on the environment is significant. Industrial effluents and waste discharge can contribute to water pollution, affecting both aquatic life and public health. Stringent regulatory measures and pollution control strategies are needed to mitigate the environmental impacts of industrial activities.

6. **Institutional and Public-Semi-Public (PSP) Land (4%)**

   Public and semi-public institutions, such as government buildings, educational centers, and healthcare facilities, cover about 4% of the riparian zone. These land uses are vital for community welfare but should be carefully planned to avoid negative ecological impacts on the river. Urban planning should integrate these facilities into broader sustainability goals to prevent ecological degradation.

7. **Barren Land and Forest Cover (1% Each)**

   Barren land and forest cover each account for only 1% of the riparian zone. The limited forest cover underscores the need for conservation strategies, while barren land offers potential for green infrastructure development, community spaces, or ecological restoration projects. These areas should be strategically managed to enhance the ecological health of the river and its surrounding environment.

4.8. Flood Risk Assessment of the Nag River (2024–2038): Identifying Vulnerabilities

The Flood Risk Assessment Map (2024–2038) for the Nag River Basin provides a detailed evaluation of areas vulnerable to flooding over the next 25 years. The assessment identifies high-risk zones, including residential buildings, slums, roads, hospitals, schools, parks, and sewage treatment plants (STPs), which are crucial urban assets that could face severe impacts during flood events. The extent of flood-prone areas suggests that unregulated urban expansion, encroachment on floodplains, and inadequate drainage infrastructure have exacerbated flood risks, leading to a heightened need for mitigation strategies.

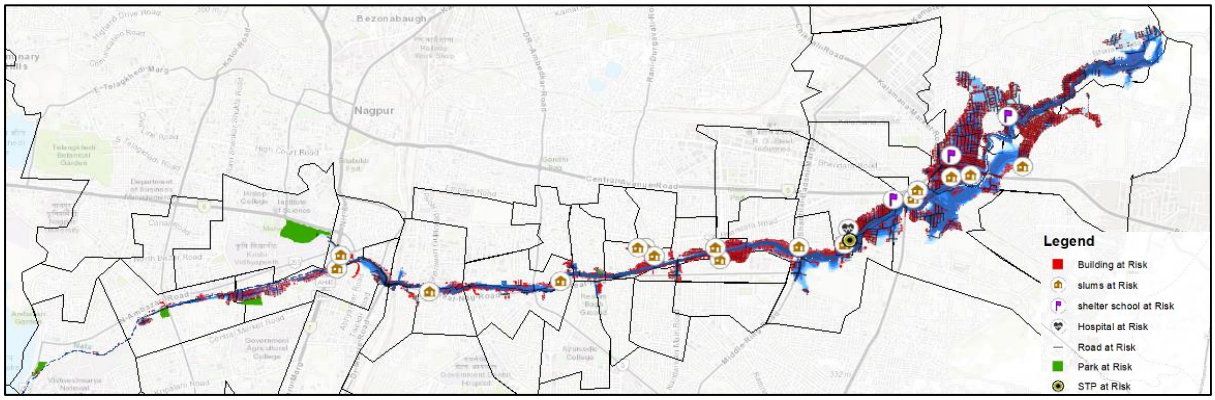


Figure 31: Flood Risk assesment Map

Source: ArcMap Online

One of the most critical issues highlighted in the map is the vulnerability of informal settlements (slums) situated in low-lying areas along the riverbanks. These settlements, often characterized by poor construction and lack of proper drainage, face

the highest risk of inundation, resulting in displacement, loss of livelihood, and severe health hazards due to water contamination. The presence of hospitals, schools, and public buildings within the flood-prone areas is particularly concerning, as their inaccessibility during extreme flood events could lead to service disruptions, compromised healthcare, and loss of educational continuity for affected communities.

The map also indicates that key transportation corridors, roads, and bridges are at risk, potentially hampering emergency response, evacuation efforts, and economic activities. The loss of connectivity during floods could isolate certain areas, making disaster response efforts more challenging. Additionally, Sewage Treatment Plants (STPs) located in flood-prone zones are susceptible to damage, increasing the likelihood of untreated wastewater contaminating the river, leading to long-term environmental and public health issues. The potential flooding of parks and open spaces could further impact urban biodiversity and recreational spaces, reducing overall urban resilience.

4.9. Result

This analysis underscores the urgent need for integrated flood management strategies that focus on improving drainage systems, enforcing stricter zoning regulations, restoring natural floodplains, and implementing nature-based solutions such as wetland conservation and afforestation. Additionally, adopting early warning systems, emergency preparedness plans, and climate-resilient infrastructure will be essential to mitigate the socio-economic impacts of future floods. Given the increasing frequency and intensity of extreme weather events due to climate change, a multi-disciplinary approach involving engineering solutions, policy reforms, and ecological restoration is imperative to enhance urban resilience and disaster preparedness.

The urban growth and planning of Nagpur have evolved over several historical phases, with the Nag River serving as a central element in the city's development. Initially, during the Gond and Bhonsale rule, the city’s core was established around the river, which played a vital role in sustaining agriculture, trade, and daily life. In the colonial period, structured urban planning integrated transportation and industrial infrastructure around the river, cementing its importance in shaping Nagpur's spatial development.

However, rapid urbanization post-independence, driven by population growth and industrialization, has led to uncontrolled urban sprawl, significantly impacting the river's ecological health. The once vital Nag River now faces severe challenges, including pollution, reduced water flow, and habitat loss, resulting from encroachments, inadequate waste management, and a lack of river-sensitive planning. This ongoing degradation underscores the urgent need for a shift in urban planning priorities, focusing on restoring the ecological balance of the river while accommodating future growth.

A key factor in the degradation of the Nag River is the lack of coordination between multiple governmental and technical agencies responsible for urban development, sanitation, and environmental conservation. Agencies such as the Nagpur Improvement Trust (NIT) and Nagpur Municipal Corporation (NMC) have failed to collaborate effectively, with fragmented responsibilities hindering the implementation of cohesive restoration strategies. For instance, the Directorate of Town Planning operates with outdated maps, while departments like Public Health Engineering focus solely on sewage management, neglecting the broader ecological considerations crucial to addressing water quality and river health. This fragmented approach has resulted in operational delays and inefficiencies, emphasizing the need for an integrated governance framework to ensure the success of river rejuvenation initiatives. Bridging these interdepartmental gaps and fostering collaboration is vital for creating a comprehensive strategy to restore the Nag River and mitigate environmental risks.

The Riparian Restoration Zone within the Nag River Basin represents a critical area for environmental rejuvenation, requiring targeted interventions to restore the river's ecological integrity. This zone, which encompasses 37 municipal wards, faces numerous challenges, including urban encroachment, pollution, and the loss of riparian buffers, which have exacerbated flooding risks and compromised water quality. The absence of adequate green infrastructure and conservation measures has contributed to the decline of aquatic biodiversity and the river's diminished ability to self-purify. Hydrological and environmental analyses, such as land cover and flood risk

assessments, indicate that unchecked urbanization, including the expansion of residential and commercial developments along the riverbanks, has further strained the river's ecological functions. To address these challenges, it is essential to implement strategic restoration initiatives, including afforestation, waste management improvements, and the creation of ecological buffers, to restore the river's environmental health and enhance its role in urban resilience

5. PROPOSALS & INTERVENTIONS

5.1. U-ROD Framework: Urban River-Oriented Development

The Urban River-Oriented Development (U-ROD) framework offers a transformative planning model aimed at integrating rivers into the urban fabric of Indian cities. This model is designed to foster ecological restoration, sustainable infrastructure, inclusive development, and robust governance, ensuring that rivers are not treated as peripheral or disposable, but as vital urban lifelines. Rooted in climate resilience, heritage conservation, and spatial equity, U-ROD merges environmental regeneration with adaptive planning tools to address the multifaceted challenges of urban river systems. The framework emphasizes a cross-disciplinary approach that brings together ecological wisdom, technical innovation, policy integration, and financial sustainability to promote long-term river health and liveable urban environments.

5.1.1. Ecological & Environmental Components

This component focuses on re-establishing the river's ecological integrity by restoring its natural functions and improving its interaction with the surrounding urban systems. The framework mandates the establishment of Riparian Buffer Zones and River Edge Setbacks ranging from 30 to 100 meters, in compliance with MoEFCC guidelines and NGT directives, to safeguard floodplains and prevent erosion. Nature-Based Solutions (NbS) such as bioswales, rain gardens, constructed wetlands, and vegetated channels are proposed to enhance infiltration, filter runoff, and manage stormwater sustainably. In addition, Floodplain Restoration and Reconnection aims to reintegrate urban rivers with their original hydrological paths, improving biodiversity and reducing flood risks.

Blue-Green Infrastructure strategies, inspired by the Sponge City model, are incorporated to manage runoff and replenish aquifers, while Eco-sensitive Riverfront Development leverages native vegetation, soft embankments, and green transitions to strengthen riverine ecosystems. Water Quality Management through decentralized wastewater treatment systems and phytoremediation is emphasized to tackle pollution at source. The use of Soil Bioengineering and Groundwater Recharge mechanisms such as bio-retention ponds and percolation tanks will contribute to aquifer recovery

and reduced surface runoff. Finally, Sediment and Siltation Management, through desilting operations, check dams, and riparian planting, will maintain hydraulic capacity and prevent riverbed degradation.

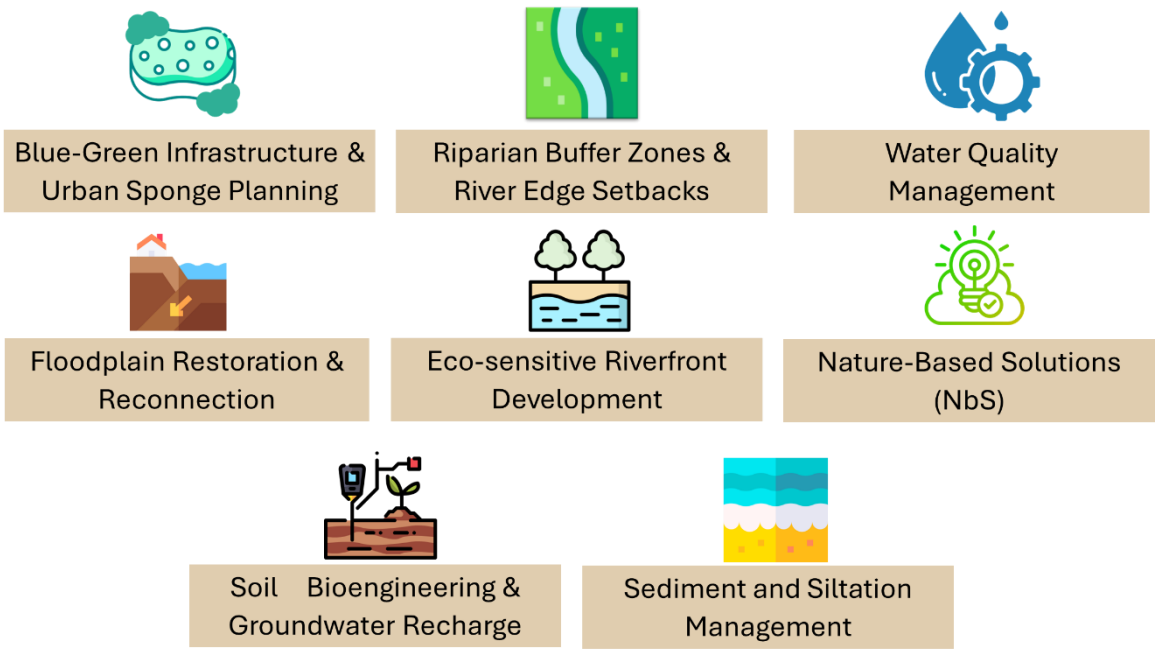


Figure 32: Ecological & Environmental Components

5.1.2. Infrastructure & Land Use Components

This section of the framework envisions integrated land use planning and infrastructure development that align with ecological goals and urban resilience. A core element is the demarcation of Zonal Development through adaptive land use regulations tailored for UROD zones, which allow mixed-use, low-impact urbanization. The framework also integrates Multimodal Riverfront Connectivity, encouraging non-motorized mobility with walkways, bicycle tracks, water taxis, and last-mile connections to metro or bus networks. The concept of Climate-Responsive Urban Design is embedded through shaded pathways, heat-reflective materials, and passive ventilation strategies.

To address the city's carrying capacity, FSI Optimization and TDR Mechanisms are proposed to redirect development away from ecologically sensitive areas while encouraging sustainable densities in designated zones. Decentralized Solid and Liquid Waste Management systems will ensure localized, circular waste processing through MRFs, composting, and faecal sludge treatment. Urban Forests and Biodiversity Loops, designed with native flora, will serve as green sponges and wildlife corridors, enhancing ecosystem continuity. Form-Based Codes (FBCs) will replace conventional zoning, regulating built forms to respect river morphology and promote porosity. Lastly, strategic interventions such as Plot Amalgamation for Redevelopment and river-facing green housing will ensure equitable and efficient land use.

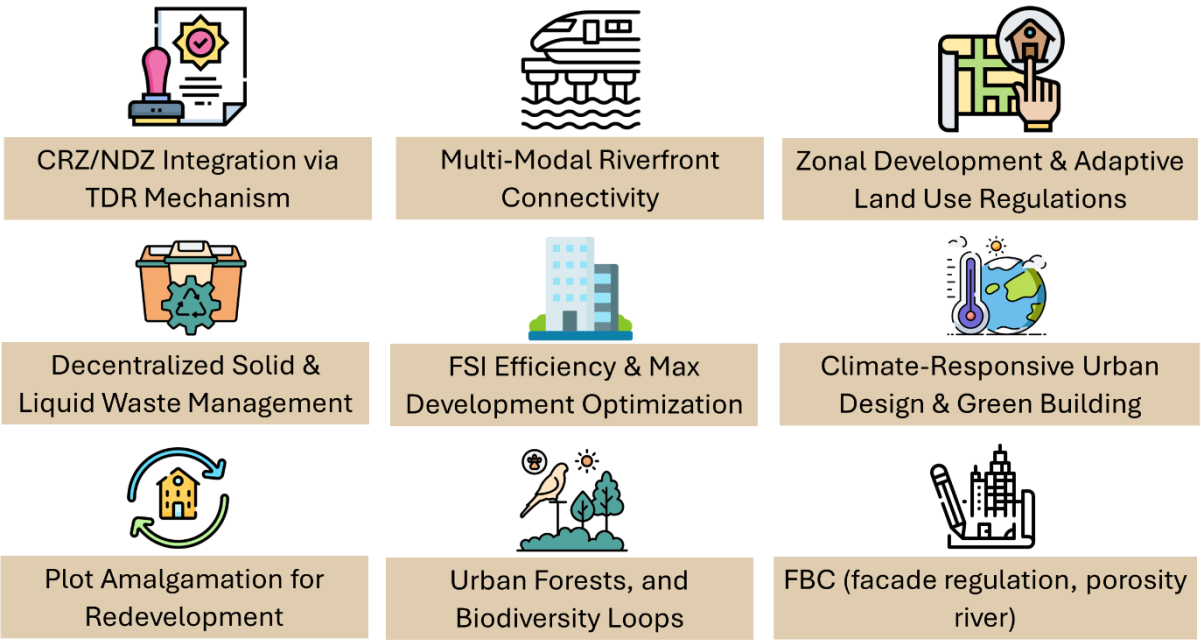


Figure 33: Infrastructure & Land Use Components

5.1.3. Financial & Economic Instruments

Ensuring financial viability is key to implementing U-ROD interventions at scale. The framework incorporates Land Value Capture (LVC) and River-Edge Premium Pricing to monetize land value appreciation arising from river rejuvenation and improved infrastructure. Tax Increment Financing (TIF) mechanisms will utilize anticipated rises in property tax revenue to fund current development needs along the riverfront. The

inclusion of Public-Private Partnerships (PPP) will facilitate investment in eco-tourism, affordable housing, and green infrastructure by sharing risks and responsibilities between public authorities and private stakeholders.

To reinforce environmental accountability, instruments such as Polluter Pays Principle and Eco-Taxation will impose penalties and levies on entities responsible for river degradation. Payment for Ecosystem Services (PES) will reward communities for preserving riparian buffers and sustaining ecosystem services. Environmental Valuation Tools like InVEST can be employed to quantify the economic benefits of restored ecosystems, aiding investment decisions. Financing mechanisms will also include Green Bonds and climate finance instruments regulated by SEBI for capital mobilization. Innovative tools such as Development Rights Auctions will allocate additional FSI in return for ecological performance, ensuring that development is aligned with sustainability goals.

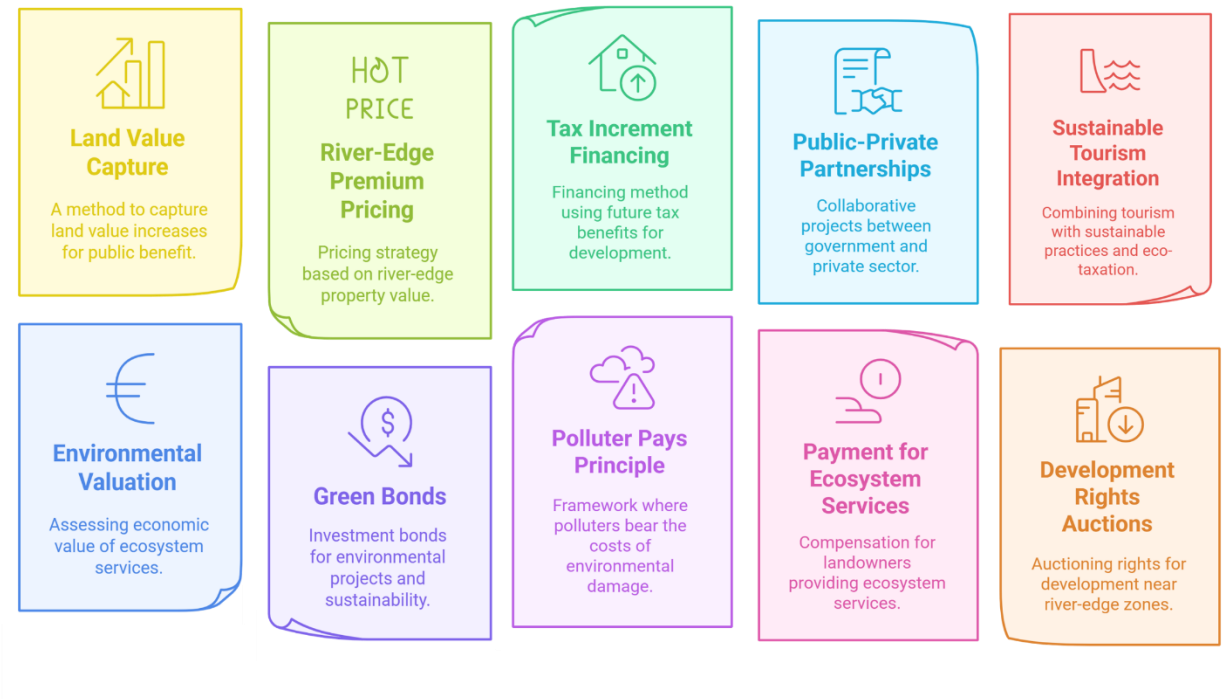


Figure 34: Financial and Economic Instruments

5.1.4. Governance & Policy Measures

Robust governance underpins the U-ROD framework, with an emphasis on integration, accountability, and community participation. Integrated River Basin Management (IRBM) aligns urban planning with watershed dynamics, ensuring upstream-downstream coordination and preserving the river's hydrological function. Carrying Capacity Planning sets quantifiable thresholds for land use, infrastructure load, and population density, avoiding overexploitation. GIS Monitoring Platforms and Drone Surveillance will be employed to track land use changes, encroachments, and pollution in real time, while Urban River Zoning within Development Control Regulations (DCRs) will institutionalize protective measures for river zones.

Participatory processes are key to legitimacy and sustainability. Participatory Governance Mechanisms, such as River Monitoring Committees with stakeholders from civil society, academia, and local government, will ensure transparency. The protection of Cultural Heritage Assets—including ghats, shrines, and sacred trees—will be integrated into planning through collaboration with heritage bodies like ASI and INTACH. The UROD framework also calls for the development of a dedicated UROD Planning Manual at the state level, akin to existing TOD policies, to standardize and guide city-level implementation. Conservation laws, strict regulation of resource extraction, and enforcement of Wetland Rules (2017) will further support ecological safeguards.

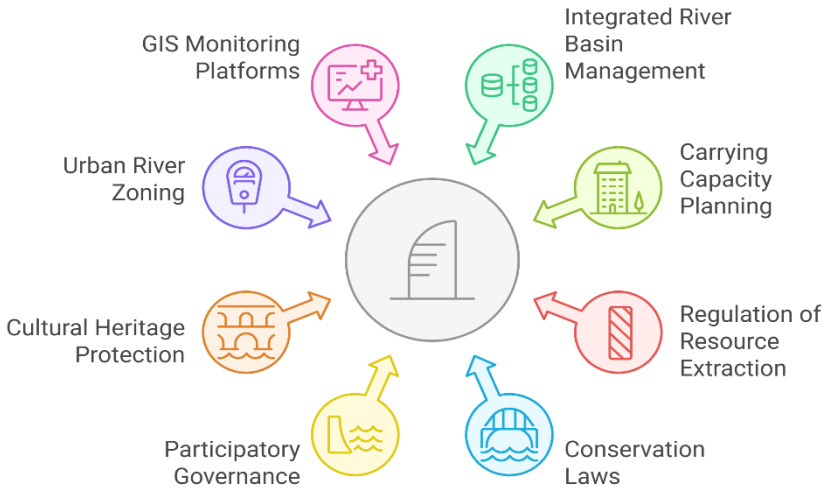


Figure 35: Governance and Policy Measures

5.2. Spatial Sectoral Framework: Nag River Influence Zones

Reimagining the Nag River as a central spine for sustainable urban development necessitates a layered and context-specific zoning framework. This framework classifies the river's surroundings into concentric influence zones based on ecological sensitivity, socio-cultural value, urban regeneration potential, and proximity to mass transit. The concept of Urban River-Oriented Development (UROD) introduced here is structured as a radial system, dividing the river influence area into four distinct zones—each with tailored policies, land use regulations, and design interventions.

The zoning logic draws upon a combination of Indian and international frameworks including the MoEFCC River Regulation Zone guidelines (2013), National Green Tribunal directives, Coastal Regulation Zone (CRZ) norms, and global riverfront planning precedents such as the Danube River Basin guidelines, Seoul's Cheonggyecheon restoration, and TOD strategies from Hong Kong and Copenhagen.

5.2.1 Core Ecological Setback (CES) / No Development Zone (NDZ): 0–30 meters

The Core Ecological Setback (CES), delineated as the No Development Zone (NDZ), encompasses the first 0–30 meters from the Nag River's edge and constitutes the most environmentally sensitive belt within the spatial zoning framework. This critical ecological buffer aligns with the Minimum Ecological Setback (MES) principle as advocated by the Ministry of Environment, Forest and Climate Change (MoEFCC) and reinforced through landmark National Green Tribunal (NGT) rulings, particularly the *Manoj Misra vs Union of India* case. The zone's design principles also draw from analogous planning approaches in Coastal Regulation Zone (CRZ-I and III) regulations, adapted here for an inland riverine context.

Historically, this corridor has been vulnerable to encroachments and informal development, primarily due to inadequate enforcement mechanisms and the lack of a clearly demarcated protective buffer. Nonetheless, it plays a pivotal role in enhancing the river's ecological resilience by serving as a natural filtration and flood absorption belt.

Planning and development within this zone adopt a strict preservationist stance, prohibiting all forms of construction and enforcing a zero Floor Space Index (FSI) policy. The core objective is to enable long-term ecological regeneration through interventions such as large-scale riparian restoration, with a focus on planting native species along the banks to rebuild habitat connectivity and improve riverine health. These interventions are to be supported through innovative green finance instruments, such as Green Bonds, ensuring financial viability for nature-based solutions.

In addition, bioswales, vegetated silt traps, and stormwater buffers will be strategically integrated to improve water quality, reduce surface runoff, and restore natural hydrological cycles. To address the concerns of existing landholders and mitigate resistance to restrictions, the zone is also designated as a TDR (Transfer of Development Rights) issuing zone. This allows private landowners whose properties fall within the NDZ to transfer their development potential to higher-density receiving zones further away from the river, thereby ensuring equity and incentivizing compliance.

By designating this 30-meter setback as a no-build ecological buffer, the framework sets a strong precedent for nature-based urban planning and ensures that the Nag River's restoration is not only environmentally sound but also socially and economically sustainable.

5.2.2 Primary Riverfront Zone (PRZ): 30–100 meters

The Primary Riverfront Zone (PRZ) spans from 30 to 100 meters from the edge of the Nag River and serves as the cultural and social interface of the river corridor. This zone accommodates a dense overlay of heritage ghats, shrines, informal settlements, and community spaces, representing a vivid confluence of sacred geography, vernacular architecture, and everyday urbanism. The spatial extent of the PRZ is informed by international and national planning precedents, particularly the European Water Framework Directive (WFD) and the India-WWF Urban River Management

Planning Guidelines (2018), both of which recommend a 50–100 meter multifunctional buffer to balance ecological and cultural riverfront values.

In this context, the PRZ becomes the fulcrum of heritage-sensitive regeneration and community-inclusive development. A Form-Based Code (FBC) regulatory framework will be employed to ensure that any new construction or redevelopment within this zone harmonizes with the existing architectural typologies, street patterns, and riverfront character. Rather than imposing modernist redevelopment models, the FBC approach will emphasize adaptive reuse, contextual design, and the integration of natural and built heritage, supporting a gradual, organic transformation of the river edge.

A central tenet of planning in the PRZ is the in-situ upgrading of informal settlements. These communities—often comprising vendors, pilgrims, and daily wage earners—are closely tied to the river's social economy and cannot be displaced without disrupting both livelihoods and place identity. Instead, targeted interventions will enhance structural safety, sanitation, flood resilience, and climate adaptation, ensuring that redevelopment remains both inclusive and environmentally responsive.

The PRZ is also proposed as a Cultural Protection Zone, safeguarding elements such as sacred trees, ritual bathing sites, and public ghats that form part of the city's intangible cultural heritage. These elements will be conserved and upgraded using climate-resilient, low-impact materials such as bamboo decks, stone platforms, and pervious pavements, thus reinforcing the ecological performance of the riverbank while celebrating its cultural significance. Landscape design will also incorporate passive shading, native vegetation, and water-sensitive urban design (WSUD) principles to enhance usability and microclimatic comfort.

In essence, the PRZ acts as a transitional layer—a space where ecology meets culture, and where urban regeneration is reimagined not through erasure, but through sensitive integration. It embodies a vision of riverfront planning that respects both people and place, contributing meaningfully to the identity and resilience of the Nag River corridor.

5.2.3 Secondary Influence Zone (SIZ): 100–500 meters

The Secondary Influence Zone (SIZ), covering a radial band from 100 to 500 meters from the Nag River, acts as the urban regeneration engine of the Urban River-Oriented Development (UROD) strategy. This zone is strategically aligned with principles of Transit-Oriented Development (TOD), leveraging proximity to high-capacity public transport—most notably the Nagpur Metro Blue Line—to drive compact, sustainable urban form. The delineation of this 100–500 meter band draws directly from the Ministry of Housing and Urban Affairs (MoHUA) TOD Guidelines (2017), which advocate for dense, walkable, and mixed-use neighborhoods within a 500-meter catchment of transit nodes. International parallels can be seen in successful river-city models like Singapore's Bishan, Copenhagen's Harbourfront, and Seoul's Cheonggyecheon, where mid-rise urbanism and integrated transit have catalyzed economic and ecological revival.

In this context, the SIZ becomes the receiving zone for Transfer of Development Rights (TDR) issued from the Core Ecological Setback (CES) and Primary Riverfront Zone (PRZ). This incentivizes conservation upstream while channeling development pressure into a managed, transit-accessible corridor. To enable such transformation, a system of vertical zoning will be adopted—enabling layered land use with stacked residential, commercial, and institutional functions within the same urban blocks. This will be governed by context-sensitive zoning overlays and real-time GIS-enabled FSI audits, identifying underbuilt parcels and optimizing floor space utilization in line with infrastructure capacity.

The SIZ will be designed to prioritize green, inclusive mobility, complementing transit infrastructure with shaded pedestrian boulevards, segregated cycle tracks, and e-mobility nodes for last-mile connectivity. These elements will create a human-scaled urban environment that fosters accessibility, reduces car dependency, and promotes environmental sustainability. Smart mobility hubs will serve as interchange points connecting the riverfront with key city destinations, further anchoring the SIZ in Nagpur's broader urban mobility network.

Crucially, the zone will advance the principle of inclusive densification. A mandated share of redevelopment projects will be reserved for affordable housing, particularly targeting the resettlement needs of communities displaced or upgraded from the PRZ. Incentives such as rental housing stock, micro-housing typologies, and public-private partnerships (PPPs) will be introduced to ensure social equity in the densification process. Mixed-use zoning will also enable diverse economic activities, fostering job creation, local entrepreneurship, and urban vibrancy without compromising liveability.

As a transformative corridor, the SIZ blends economic value capture with social and ecological responsibility, embodying a future-ready approach to riverfront urbanism. It not only absorbs development potential redirected from conservation zones but also ensures that such growth is resilient, accessible, and regenerative—firmly positioning the Nag River as a catalyst for sustainable metropolitan evolution.

5.2.4. Tertiary Urban Integration Zone (TUIZ): 500 meters – 1 kilometer

The Tertiary Urban Integration Zone (TUIZ), spanning a distance of 500 meters to 1 kilometer from the banks of the Nag River, marks the outermost layer of the Urban River-Oriented Development (UROD) framework. Functioning as a transitional interface between the intensively planned riverfront and the wider metropolitan fabric of Nagpur, this zone is pivotal in mainstreaming ecological resilience and inclusive urban expansion. The delineation of this buffer draws inspiration from contemporary urban planning practices in Latin America and Southeast Asia, where a radius of up to one kilometer from ecological or infrastructural corridors is often leveraged to foster equitable growth and integration.

TUIZ is envisioned not merely as a fringe buffer, but as a strategic urban frontier—a space for land-use experimentation, institutional innovation, and policy testing. The zone comprises a mosaic of vacant government parcels, underutilized brownfields, and peri-urban settlements, often characterized by fragmented landholdings and limited formal infrastructure. This presents a unique opportunity for planned redevelopment that is both inclusive and future-ready.

To activate this zone, the city will adopt Public-Private Partnership (PPP) models as the primary delivery mechanism for large-scale, mixed-use redevelopment. Instruments such as land pooling, plot amalgamation, and value capture financing will be utilized to overcome land fragmentation and create developable parcels with adequate public space ratios. A cornerstone financial strategy in TUIZ is the deployment of Tax Increment Financing (TIF)—a model wherein future increases in property tax revenue from redeveloped plots are earmarked for reinvestment in infrastructure, mobility, and basic services. This ensures that growth is self-financing and that the benefits of redevelopment are broadly distributed.

In terms of physical planning, the TUIZ will incorporate climate-responsive zoning, urban cooling corridors, and green networks that mitigate the heat island effect and improve ecological connectivity with the river system. Smart mobility hubs will anchor these green corridors, ensuring multimodal transit access to the riverfront, metro stations, and key employment centers. Last-mile transit options such as e-shuttles, non-motorized transit paths, and feeder services will further bridge the urban-rural divide often evident in peripheral zones.

Social infrastructure in the TUIZ will be critical for ensuring that development does not deepen existing inequalities. The zone will accommodate affordable housing clusters, public schools, health centers, and community facilities that support low-income and vulnerable populations. These interventions will ensure that TUIZ serves as a social integration buffer, not just a physical one—connecting diverse demographic groups to the economic and cultural opportunities unfolding along the Nag River.

Ultimately, the TUIZ anchors the scalability of the UROD model—demonstrating how thoughtful zoning, institutional partnerships, and innovative financing can extend the benefits of river-centric regeneration beyond the immediate waterfront. It represents a model for inclusive, climate-adaptive urbanism, positioning Nagpur as a pioneering city in river-based metropolitan planning.

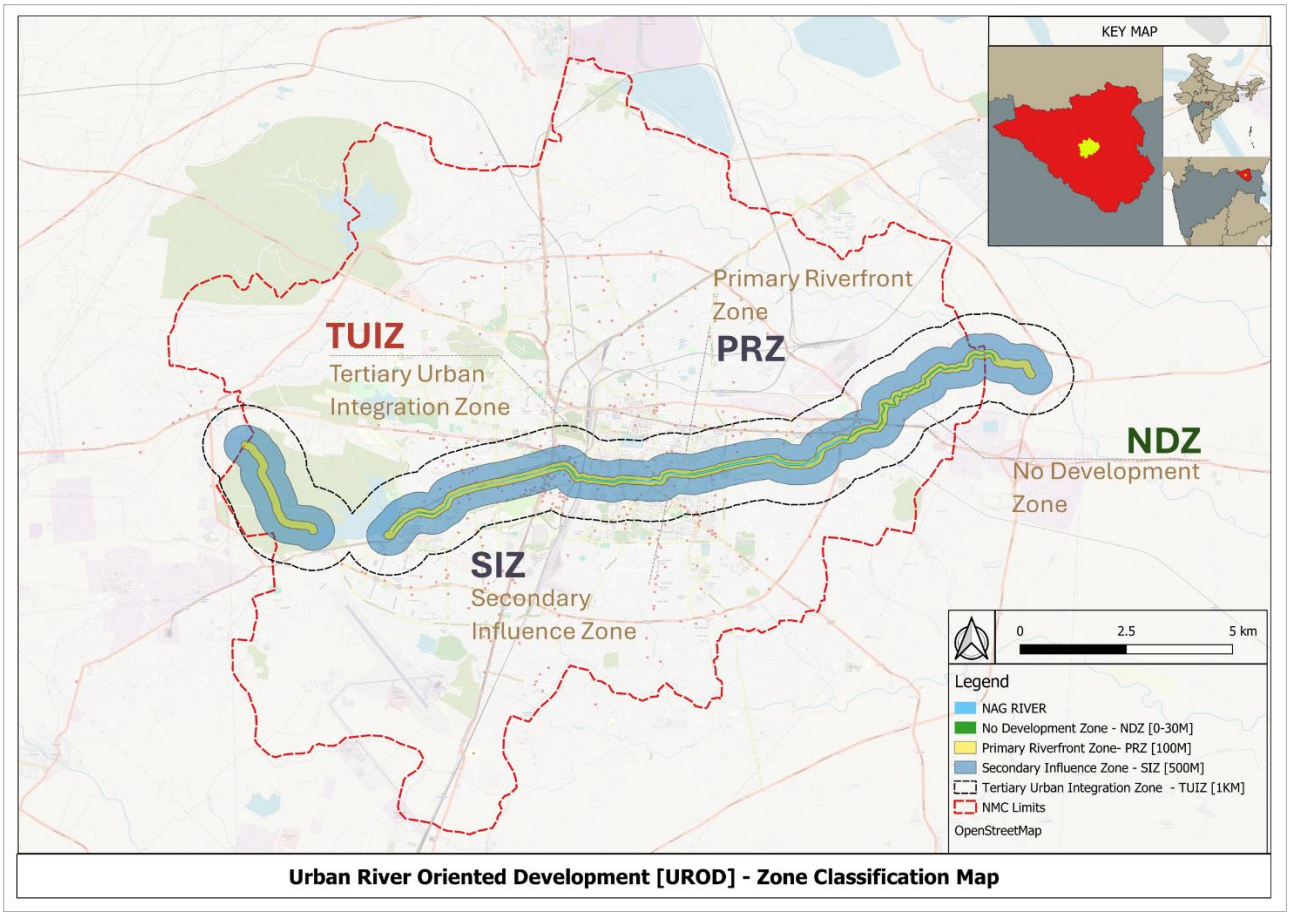


Figure 36: Nag River Influence Zones Map

Table 4: Spatial Zoning Framework for Urban River-Oriented Development (UROD) along the Nag River

Zone Name	Distance from River	Planning Focus	Key Characteristics	Key Interventions	Reference Guidelines
Core Ecological Setback (NDZ)	0–30 m	Ecological Preservation	MES/NDZ buffer, encroachments, riparian habitat	Native species restoration, bioswales, zero FSI, TDR issuance	MoEFCC MES Guidelines, CRZ-I/III norms, NGT (Manoj Misra case)

Primary Riverfront Zone (PRZ)	30–100 m	Cultural & Heritage Regeneration	Heritage ghats, shrines, informal settlements	Form-Based Code, in-situ upgradation, cultural protection, bamboo/stone decks	EU WFD Guidelines, India-WWF Urban River Management Planning (2018)
Secondary Influence Zone (SIZ)	100–500 m	Transit-Oriented Redevelopment	Metro Blue Line TOD, mixed land use	TDR receiving zone, FSI maxing, vertical zoning, affordable housing	MoHUA TOD Guidelines (2017), Global TOD models (Singapore, Seoul)
Tertiary Urban Integration Zone (TUIZ)	500 m–1 km	Urban Integration & Expansion	Underutilized govt land, brownfields, peri-urban edge	PPP pilots, TIF financing, smart mobility, plot amalgamation	Latin America & SE Asia inclusive buffer models

5.3. Micro-Level Nag River Sectoral Planning and Implementation Strategy

To facilitate the phased and context-sensitive execution of the Urban River-Oriented Development (UROD) framework, the Nag River corridor has been strategically divided into four Micro-Level Planning Sectors. Each sector presents a distinct set of spatial characteristics, patterns of land ownership, and socio-ecological challenges. This segmentation allows for a more localized, adaptive planning process that aligns with the overarching goals of river rejuvenation, inclusive redevelopment, and ecological urbanism. The sectoral approach enables the integration of site-specific

project typologies while maintaining a cohesive vision for the Nag River's transformation.

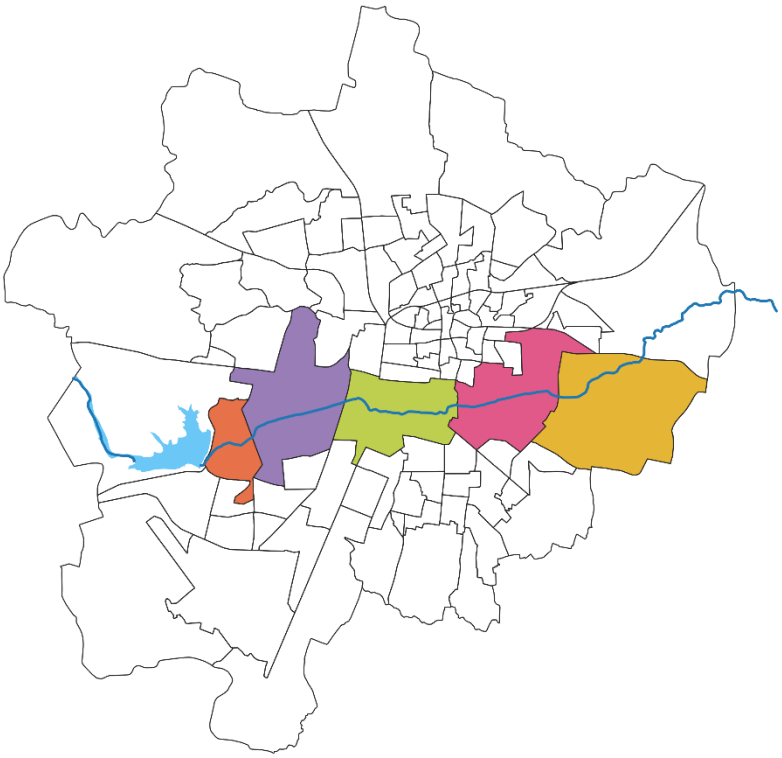


Figure 37: Nag River Micro-Level Planning Sectors

5.3.1. Sector 1: Ecological Edge Restoration and Community Integration

Sector 1 focuses on the restoration of ecological edges and the integration of surrounding communities along the Nag River. This zone includes significant areas falling within the Core Ecological Setback (No Development Zone or NDZ) and the Primary Riverfront Zone (PRZ), both of which are critical to preserving the river's ecological integrity. The area is characterized by the presence of informal settlements, slums along the NDZ, and widespread linear encroachments, which pose challenges to both environmental conservation and urban resilience. However, the presence of scattered government-owned land parcels offers a strategic opportunity for ecological regeneration and community-centric development.

The planning strategy emphasizes riparian rehabilitation through the use of sustainable and low-impact interventions such as bioswales, bamboo boardwalks, and vegetative buffer zones. These measures aim to restore the river's natural edge conditions, improve water quality, and create a continuous green corridor. A core

component of the strategy is the in-situ upgradation of slum settlements. This involves providing decentralized sanitation systems, solar-powered street lighting, and flood-resilient housing typologies that enhance living conditions without displacing residents.

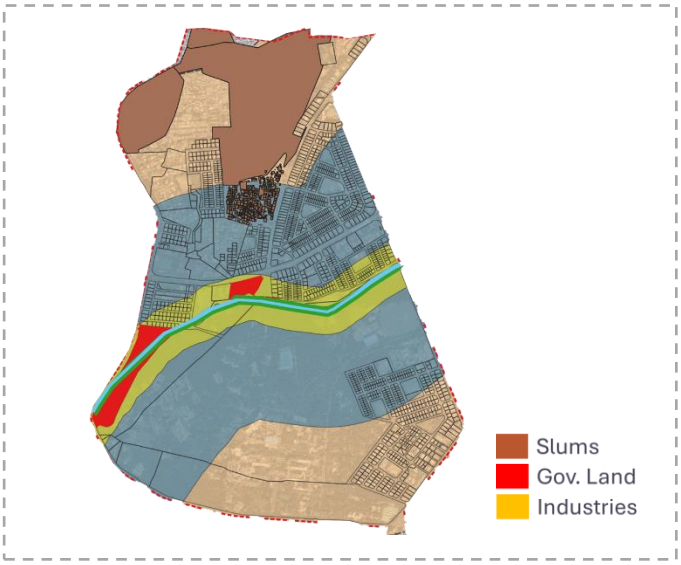


Figure 38: Sector 1 (Nag River Planning Sector)

To foster greater community engagement and environmental stewardship, the plan proposes the development of community parks and river learning centers on underutilized government plots. These facilities are envisioned as inclusive public spaces that reconnect local residents with the river ecosystem and promote awareness about sustainable living practices. Additionally, the sector identifies specific Transfer of Development Rights (TDR) transfer points. These are designed to incentivize landowners and developers to comply with no-build regulations in the NDZ by offering compensatory development rights in designated urban zones, thus ensuring a balance between ecological protection and urban growth.

5.3.2. Sector 2: Cultural Heritage Revitalization and Mixed-Use Spines

Sector 2 is envisioned as a key cultural and urban renewal zone within the Nag River corridor, emphasizing the revitalization of its rich heritage landscape and the strategic redevelopment of underutilized land. This sector includes a dense concentration of historic structures and religious nodes along the Primary Riverfront Zone (PRZ), which form a culturally significant urban fabric. Additionally, the area encompasses extensive

government-owned land within the Strategic Influence Zone (SIZ), offering high potential for vertical mixed-use redevelopment. The presence of obsolete industrial pockets adjacent to the river further necessitates targeted brownfield remediation and adaptive reuse strategies.

The planning approach in this sector prioritizes heritage-sensitive renewal through the application of Form-Based Codes. These codes ensure the preservation of key architectural elements, such as historic façades, while allowing adaptive reuse of structures. The strategy includes the restoration of riverfront ghats, development of cultural trails, and preservation of traditional urban morphology to reinforce the area's identity and sense of place. By weaving cultural preservation into urban design, the plan aims to celebrate the historical continuity of the river's relationship with the city.

Figure 39: Sector 2 (Nag River Planning Sector)

A significant component of the strategy is the transformation of decommissioned industrial areas into eco-creative hubs. These hubs are intended to support river-related economic innovation and cultural industries—such as arts, crafts, and small-scale green enterprises—thus promoting employment and sustainable livelihoods. TDR reception hubs are also planned within this zone, specifically on government land earmarked for vertical zoning. These hubs will accommodate affordable housing units and commercial retail spines, effectively balancing economic development with social inclusivity.

Furthermore, the concept of sacred ecology is a defining element of this sector. The strategy includes the revival of sacred groves, restoration of temple tanks, and rehabilitation of ritual spaces along the riverbank. These interventions aim to not only conserve ecological elements with cultural significance but also to reestablish the spiritual and communal ties between the river and the citizens. Overall, Sector 2 exemplifies a holistic integration of heritage conservation, ecological mindfulness, and inclusive urban regeneration.

5.3.3. Sector 3: Transit-Oriented Affordable Urbanism

Sector 3 represents a strategic urban intervention zone that aligns closely with the Nagpur Metro Blue Line, positioning it as a prime candidate for Transit-Oriented Development (TOD). The spatial profile of this sector includes several government-owned and industrial land parcels situated within the 100–500 meter belt of the Strategic Influence Zone (SIZ), making them ideal for high-density, transit-integrated redevelopment. At the same time, the sector encompasses multiple slum settlements located within the Primary Riverfront Zone (PRZ), many of which face pressing needs for structural improvements and essential service provisioning.

The core planning strategy focuses on TOD node densification, which involves the development of vertically integrated, mixed-use towers that combine residential, retail, and community functions. These vertical nodes are designed to maximize land efficiency and accessibility to transit infrastructure. Supporting infrastructure such as e-mobility hubs and pedestrian-friendly environments ensure seamless connectivity between metro stations, surrounding neighborhoods, and the riverfront. The approach integrates green transit loops—comprising cycle lanes and shaded walkways—to enhance non-motorized mobility and reinforce the environmental sustainability of urban transport.

A critical social component of this sector’s strategy is the in-situ upgradation of informal settlements. This includes introducing rental housing overlays and incremental tenure models that enable slum dwellers to remain in place while accessing improved housing and services. Such interventions aim to prevent displacement and support gradual, community-led improvements in living standards.

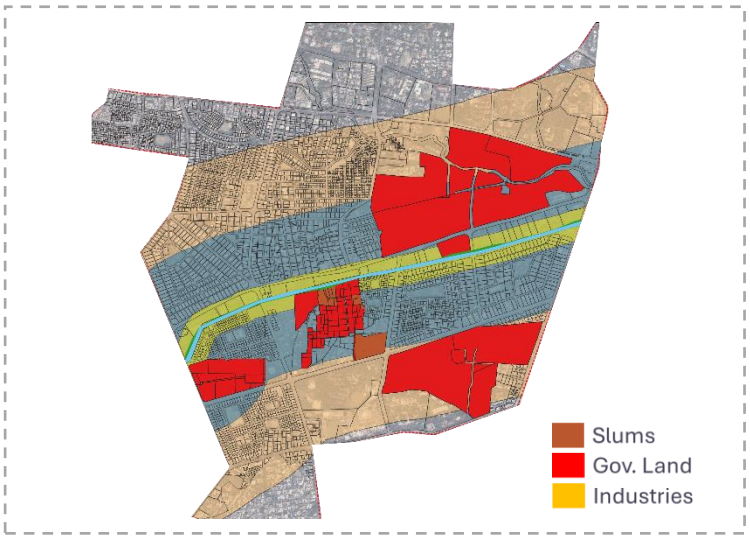


Figure 40: Sector 3 (Nag River Planning Sector)

To address the challenge of fragmented land ownership, particularly in areas targeted for TOD, the Land Pooling Model (LPM) is introduced as a key implementation mechanism. By consolidating small and irregular land parcels, LPM facilitates the creation of coherent development clusters that align with broader TOD principles. Overall, Sector 3 embodies a model of inclusive, affordable, and transit-integrated urbanism that strengthens the connection between the city, its people, and the river corridor.

5.3.4. Sector 4: Strategic Integration and Peri-Urban Transitioning

Sector 4 serves as a critical transitional zone between the urban core and the peripheral landscapes along the Nag River corridor. This zone encompasses predominantly slum lands located within the Secondary Influence Zone (SIZ) and Transitional Urban Influence Zone (TUIZ), approximately 200 meters to 1 kilometer from the river. Characterized by sparse settlement patterns this sector presents both challenges and opportunities for integrated urban expansion. The presence of low-lying, ecologically sensitive portions within the No Development Zone (NDZ) further necessitates a balanced approach that addresses environmental risks while enabling strategic urban growth.

The planning strategy for Sector 4 emphasizes the regeneration of underused industrial sites through pilot Public-Private Partnership (PPP) models. These initiatives aim to convert obsolete industrial land into residential or institutional developments, thereby optimizing land use without contributing to sprawl. To finance the necessary civic and infrastructure upgrades, the sector proposes the implementation of Tax Increment Financing (TIF). This mechanism allows future tax revenues generated by new developments to be ring-fenced and reinvested into the area, ensuring self-sustaining urban improvements.

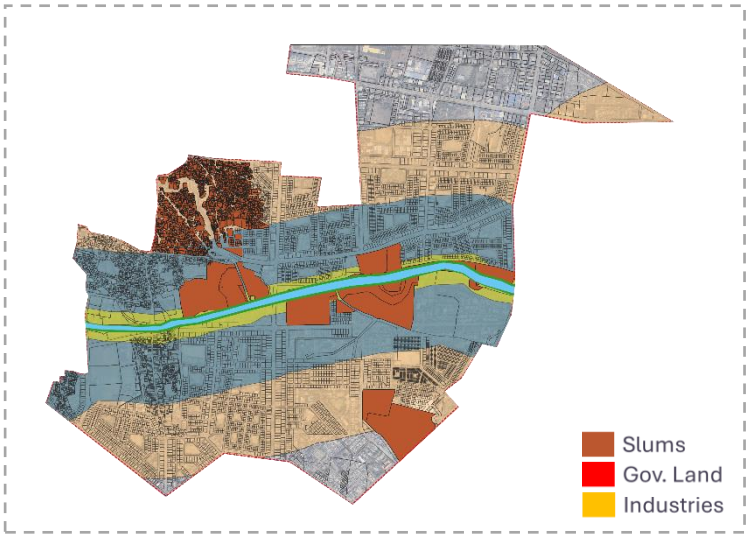


Figure 41: Sector 4 (Nag River Planning Sector)

Environmental resilience is a key focus in this peri-urban context. The strategy includes the development of green corridors and stormwater buffer zones at the urban edge, which serve to mitigate flood risk and reduce the urban heat island effect. These ecological interventions not only protect vulnerable landscapes but also create multifunctional open spaces that enhance the quality of life for future residents.

To support livability and connectivity, the sector integrates last-mile infrastructure planning, ensuring that essential services such as smart bus stops, neighborhood schools, and electric vehicle charging plazas are located within walkable five-minute radii. This approach promotes compact, accessible urban development and encourages sustainable mobility options. Sector 4 thus plays a pivotal role in ensuring that the growth of the Nag River corridor is environmentally responsible, economically

viable, and socially inclusive, particularly as the city transitions toward its expanding peripheries.

5.4. Pilot Project Typologies for River-Influenced Lands

5.4.1. Pilot Project Proposal 1 : Urban River Commons on Agricultural College Land (Zone 2 – SIZ & TUIZ)

As a demonstrative component of the Nag River Urban River-Oriented Development (UROD) framework, a pilot project is proposed on the government-owned land of the Agricultural College located in Zone 2 – Cultural Heritage Revitalization and Mixed-Use Spines. This site, situated entirely within the Secondary Influence Zone (100–500m) and Tertiary Urban Integration Zone (500m–1km), offers a rare opportunity for the development of a public ecological and cultural space inspired by the successful ASITA riverfront model of New Delhi.

Although the site is not directly adjacent to the river and does not fall within the No Development Zone (NDZ) or Primary Riverfront Zone (PRZ), it plays a critical supporting role in the larger river rejuvenation effort. The project aims to demonstrate how strategically located institutional lands can be reimagined as vibrant public commons that echo the spirit of river-centric planning even at a distance from the immediate river edge.

Project Vision and Concept

The proposed **Urban River Commons** will serve as a high-impact, accessible, and inclusive public space that integrates environmental education, cultural identity, and sustainable design. Its objective is to restore community engagement with the Nag River through symbolic and programmatic elements while enhancing the ecological and social value of an underutilized urban parcel. Designed as a contemporary reinterpretation of a river park, the project draws conceptual inspiration from Delhi's ASITA initiative, with a focus on climate resilience, cultural continuity, and urban wellness.

Key Design and Programmatic Components

1. Eco-Cultural Park and Promenade (SIZ: 100–500m)

The SIZ portion of the site will accommodate the core landscape and recreational elements, designed to promote passive and active use by a diverse urban population.

- Landscaped urban gardens with native vegetation and water-sensitive design strategies, including bioswales and rain gardens for stormwater management.
- Public spaces such as shaded walkways, cycling paths, rest plazas, and community lawns designed for inclusivity, safety, and universal access.
- An open-air amphitheatre and exhibition lawns for cultural programming, educational outreach, and seasonal events related to river heritage and ecology.
- Interactive river learning installations curated in partnership with local academic institutions to raise awareness about water systems, biodiversity, and sustainability.
- Small-scale built forms (e.g., pavilions, kiosks) for cafés, art displays, and recreational amenities designed in keeping with eco-sensitive architectural principles.

2. Institutional and Community Interface (TUIZ: 500m–1km)

The TUIZ area of the site will serve as a civic and educational extension of the park, leveraging the academic resources of the Agricultural College and linking surrounding peri-urban neighbourhoods.

- Establishment of an **Urban Ecology and Sustainability Resource Centre**, led by the college and open to local schools and community groups.
- Flexible use spaces for eco-workshops, crafts training, and local entrepreneurship in sustainable materials (e.g., bamboo, organic farming).
- Provision for smart last-mile mobility infrastructure including e-charging stations, bus stops, shaded pedestrian connectors, and cycle rental hubs.

- Landscape buffers and green corridors linking the park to nearby institutional zones and urban edges, supporting biodiversity and microclimate control.

Financing Mechanism

The financial model for this pilot project relies on a blended public-private approach, emphasizing scalable and realistic funding sources suitable for implementation in a mid-sized Indian city context. The strategy integrates Land Value Capture (LVC), Corporate Social Responsibility (CSR), and Public-Private Partnerships (PPP) as its three primary financing pillars.

- **Land Value Capture (LVC)**: As the park enhances the environmental quality and liveability of the surrounding area, land values are expected to appreciate. A portion of this uplift can be captured through betterment charges, development premiums on nearby real estate projects, or municipal bonds. This revenue will support both capital development and long-term park maintenance.
- **Corporate Social Responsibility (CSR)**: Contributions from local industries and institutions can be secured under CSR mandates, especially for components such as education centres, ecological landscaping, public sanitation, and clean energy installations. Partnerships with environment-focused foundations can also bring in grant-based support for biodiversity and awareness programs.
- **Public-Private Partnerships (PPP)**: Select elements such as kiosks, amphitheatres, cafés, and event spaces can be developed and operated through PPP models. Private partners may be incentivized through lease agreements or brand visibility opportunities, while ensuring adherence to design and ecological guidelines.

This multi-pronged financial strategy not only reduces the burden on municipal budgets but also builds stakeholder ownership and ensures operational sustainability over the long term.

Anticipated Outcomes and Impact

- **Environmental**: Transformation of over 15–20 hectares of underutilized urban land into a green, permeable, and ecologically functional public asset, contributing to improved air quality, stormwater management, and biodiversity.
- **Social**: Creation of a safe and inclusive space that serves as a community anchor for education, leisure, and wellness—accessible to students, local residents, and marginalized groups.
- **Cultural**: Reinforcement of Nagpur's historical relationship with the Nag River through public storytelling, events, and artistic expression.
- **Economic**: Generation of employment opportunities in park operations, event management, and eco-tourism, alongside long-term value appreciation in adjacent real estate.

Conclusion

The proposed **Urban River Commons on Agricultural College land** represents a realistic, adaptive, and scalable model for river-oriented public space development in constrained riverfront geographies. By working within the spatial parameters of the SIZ and TUIZ, and utilizing flexible financing mechanisms such as LVC, CSR, and PPP, this pilot project can catalyze broader community participation, institutional collaboration, and environmental stewardship. As a flagship initiative under the Nag River UROD framework, it offers a replicable template for creating river-connected urban commons even when direct access to riparian land is limited.

5.4.2. Pilot Project Proposal 2: Commercial Complex Development at Yashwant Stadium and Patwardhan Ground (Zone 3 – SIZ)

In line with the objectives outlined in the Nag River Urban River-Oriented Development (UROD) framework, a transformative pilot project is proposed for the available government lands surrounding Yashwant Stadium and Patwardhan Ground, both located within Zone 3: Transit-Oriented Affordable Urbanism. This area lies within the Secondary Influence Zone (SIZ) and benefits from proximity to the Nagpur Metro Blue

Line, positioning it within a Transit-Oriented Development (TOD) area. Given that the stadium is underutilized and in a deteriorating condition, coupled with the nearby Patwardhan Ground, which is located within municipal ownership, this proposal aims to repurpose these underutilized lands into a commercial complex that integrates modern retail, office, and leisure spaces while simultaneously enhancing access to the riverfront.

The proposed Commercial Complex will be a mixed-use development, combining retail spaces, offices, and recreational zones in a vertical format, with designated areas for river view functions, including outdoor terraces and cafes on the first and second floors. This development will maximize the potential of the site by offering diverse uses that meet both the growing demand for urban commercial spaces and the increasing need for public amenities along the river corridor. It will act as a catalyst for urban regeneration, creating a dynamic urban environment that brings together commercial, residential, and recreational elements in a transit-friendly and sustainable way.

Key Features of the Pilot Project:

- **Commercial Complex with River Views:**

  The building will include ground-floor retail spaces, first and second-floor office spaces, and terraces with stunning river views that can accommodate cafés, restaurants, and event venues. The structure will be designed with an open, modern aesthetic, providing flexible spaces for various types of businesses, including start-ups and eco-friendly enterprises.

- **Sustainable and River-Sensitive Architecture:**

  The design will prioritize eco-friendly construction techniques and incorporate green building principles such as passive solar design, rainwater harvesting, and energy-efficient systems. The terraces and open spaces will be landscaped with native plants and feature shaded seating areas to encourage outdoor interaction and relaxation.

- **Integration with TOD:**

  The development will capitalize on the site's connectivity to the Nagpur Metro Blue Line, ensuring easy access via the metro, buses, and pedestrian-friendly walkways. Shaded pedestrian pathways and cycle lanes will connect the commercial complex to the riverfront, creating a seamless transit experience for visitors and commuters. The complex will serve as a transit hub, linking commercial spaces with metro stations and facilitating seamless mobility.

- **Slum Upgradation and Affordable Housing Integration:**

  In line with the overarching goal of inclusive urbanism, a portion of the development will be dedicated to affordable housing and slum upgradation. This includes integrating rental housing options and creating community spaces that cater to low-income populations living in adjacent slum areas. The development will offer structured tenure models and incremental upgrades to enhance the quality of life for the existing residents.

- **Public Amenities and Riverfront Activation:**

  The development will include community spaces such as parks, recreational areas, and riverfront promenades. This will allow for public engagement and provide essential services to local residents. The river view areas will become a key attraction, offering the public access to leisure spaces while contributing to the revitalization of the riverfront.

Financing Mechanism:

The financing for the Commercial Complex at Yashwant Stadium and Patwardhan Ground will utilize a blend of Land Value Capture (LVC), Corporate Social Responsibility (CSR) investments, and Public-Private Partnerships (PPP). These financing mechanisms are aligned with the TOD framework and are designed to generate long-term revenue streams, ensuring the project's sustainability and financial viability.

1. **Land Value Capture (LVC):**

   The development will benefit from the inherent increase in land values due to its strategic location within a TOD zone. The project will capture this uplift through the sale of commercial spaces, office leases, and revenue from parking and retail outlets. These revenue streams will not only fund the construction and operational costs but will also contribute to long-term maintenance and further development initiatives. As the area around the metro station becomes more attractive to businesses and residents, the land's value will rise, providing a steady stream of income through both land appreciation and commercial leasing.

2. **Corporate Social Responsibility (CSR):**

   Companies with a focus on urban development, environmental sustainability, or community upliftment may be encouraged to participate through CSR investments. These contributions can be directed towards the development of sustainable infrastructure, eco-friendly building features, and public amenities such as parks and recreational spaces. Corporations could also sponsor educational programs, vocational training, or entrepreneurship workshops within the complex, further enhancing the development's social impact.

3. **Public-Private Partnerships (PPP):**

   A **PPP model** will be utilized for the construction and management of the commercial complex, ensuring private sector efficiency in building design, construction, and operations while maintaining public ownership of the land. The partnership will also facilitate the integration of affordable housing and slum rehabilitation within the larger development framework. The private sector will finance the development and contribute to its construction, while the public sector will retain control over the long-term operational and regulatory aspects, ensuring that the project remains aligned with urban planning goals and community needs.

4. **Revenue Generation:**

   The commercial complex will generate substantial revenue through various sources, including:

   - **Leasing of commercial spaces** (retail outlets, office spaces, restaurants, and event venues)
   - **Parking fees** for visitors to the complex, particularly those using the metro or attending events
   - **Revenue from public amenities**, such as cafés and recreational spaces, contributing to the upkeep of the complex
   - **Event hosting** in the river view areas, generating income from public and private events, markets, and festivals.

By leveraging these revenue streams, the project will not only become financially self-sustaining but also generate long-term value for both the community and investors. The **PPP model** ensures that the public sector retains oversight while benefiting from the efficiency of private-sector development.

Expected Impact:

- **Environmental:** The commercial complex will integrate sustainable design practices, including energy-efficient systems and green building materials. The riverfront promenade and recreational spaces will restore access to the river, enhancing local biodiversity and improving the urban microclimate.
- **Social:** The development will provide much-needed commercial spaces and amenities for the surrounding communities, including affordable housing for low-income residents. Public spaces will foster social cohesion, with recreational areas and riverfront access offering opportunities for leisure and community events.
- **Economic:** The project will stimulate local economic growth by providing new job opportunities in retail, hospitality, construction, and services. It will also

enhance the value of surrounding properties and attract new businesses to the area, contributing to long-term urban development and prosperity.

Conclusion:

The proposed Commercial Complex at Yashwant Stadium and Patwardhan Ground will serve as a catalytic development within the Transit-Oriented Development (TOD) framework, revitalizing underutilized land while generating significant social, environmental, and economic benefits. By using a combination of Land Value Capture (LVC), CSR, and PPP financing mechanisms, the project ensures financial sustainability and long-term success. This redevelopment will not only enhance the local urban fabric but will also contribute to the broader objectives of the Nag River Urban River-Oriented Development (UROD) framework, promoting a balanced and inclusive approach to riverfront revitalization.

5.4.3. Pilot Project Proposal: Inclusive Riverfront Redevelopment with Mixed-Income Housing (Zone 4 – PRZ)

In alignment with the objectives of the Nag River Urban River-Oriented Development (UROD) framework, a high-impact pilot project is proposed in Zone 4 – Strategic Integration and Peri-Urban Transitioning, targeting a large slum cluster situated directly along the Nag River in the Primary Riverfront Zone (30–100m). This zone is critically located from both ecological and planning standpoints, but currently faces challenges of informal encroachment, environmental degradation, and substandard living conditions.

The proposed redevelopment initiative focuses on transforming this informal settlement into a structured, mixed-income riverfront residential precinct, integrating social inclusion, ecological preservation, and land value enhancement. Through a combination of in-situ slum upgradation, strategic zoning tools, and innovative financing mechanisms, the project aims to deliver secure housing to slum dwellers while unlocking the real estate potential of river-facing parcels for broader urban regeneration.

Project Vision and Objectives

- To provide dignified, tenure-secure housing for existing slum residents without displacement.
- To reconfigure and optimize the land for river-facing mid-rise residential developments, promoting a vibrant, mixed-income neighborhood.
- To reclaim and ecologically restore the riverfront through regulated setbacks, landscape buffers, and public access corridors.
- To enhance urban form and value using tools such as Form-Based Codes, vertical zoning, and FSI optimization.

Key Development Components

1. **In-Situ Rehabilitation for Existing Slum Households (EWS):**
    - A minimum of 10% of the developed housing stock will be allocated to existing slum dwellers under the Economically Weaker Section (EWS) category.
    - Units will be built within the same redevelopment footprint, ensuring continuity of community ties and access to livelihoods.
    - Supportive infrastructure will include decentralized sanitation, piped water, solar lighting, and multi-purpose community centers.

2. **Mixed-Income Residential Development with Riverfront Orientation:**
    - The remaining 90% of the land will be utilized for river-facing residential blocks, planned with mid-rise vertical zoning (G+5 to G+10).
    - Form-Based Codes will guide building typologies, façade articulation, and public interface, ensuring architectural coherence and contextual sensitivity.

- Premium units on upper floors will be priced based on river-view valuation, capturing market demand and maximizing return on land potential.

3. **Public Realm and Ecological Buffer (NDZ Interface):**
    - The 30m No Development Zone (NDZ) adjacent to the river will be retained as a green, publicly accessible riparian corridor, featuring bioswales, native plantings, and shaded walkways.
    - This space will act as both a flood mitigation buffer and a public recreational asset, reconnecting the community with the river.
4. **Infrastructure and Access Improvements:**
    - The redevelopment will include upgraded internal roads, last-mile mobility infrastructure, and provisions for electric vehicle charging and cycle parking.
    - Smart waste management and water-sensitive urban design (WSUD) systems will be integrated across the site.

Financing and Regulatory Framework

The financial viability of this pilot project will be achieved through a multi-tiered mechanism combining planning incentives, environmental valuation, and real estate leveraging:

1. **Transferable Development Rights (TDR):**
    - The PRZ will act as a **TDR issuance zone**, wherein developers undertaking slum rehabilitation and NDZ restoration will receive TDR credits.
    - These rights can be monetized in designated **receiving zones** (such as SIZ in Zones 2 and 3), thus attracting private participation in the rehabilitation effort.

2. **FSI Maxing and Vertical Zoning:**
    - The project will apply **enhanced FSI allowances** (up to 3.0 in the PRZ) for mixed-income redevelopment to improve the financial return on investment.
    - Vertical zoning will allow higher FSI for market-rate residential units while maintaining scale-sensitive development along the river.
3. **Form-Based Codes (FBCs):**
    - FBCs will provide predictable and design-conscious regulatory guidance, ensuring flexibility for private developers while safeguarding the character and ecological integrity of the riverfront.
4. **Environmental Valuation:**
    - The ecological and public realm components (riparian buffers, green spaces) will be assigned environmental service values, which can be used to unlock funding via urban environmental trust funds, municipal green bonds, or sustainability-linked municipal incentives.
5. **Land Readjustment and Plot Reconstitution:**
    - A portion of the redeveloped land will be retained by the implementing authority or SPV (Special Purpose Vehicle), allowing for strategic land sales or lease models to generate long-term revenue.

Expected Outcomes and Impact

- **Social Inclusion:**

  Secure, formal housing provided to slum dwellers on-site with integrated amenities, improving their health, dignity, and access to services.

- **Environmental Restoration:**

  Restoration of riparian edges and creation of urban ecological infrastructure to support biodiversity and climate resilience.

- **Urban Regeneration:**

  A transformative shift in land use from informal encroachments to a planned, high-value, and inclusive urban precinct.

- **Revenue Generation:**

  Sale or lease of high-value river-facing apartments and monetized TDRs will finance project costs and provide surplus revenue for reinvestment into other UROD initiatives.

Conclusion

This pilot slum redevelopment initiative in Zone 4 offers a model for integrated, equitable, and financially sound riverfront transformation. By embedding EWS housing within a larger framework of real estate optimization, ecological resilience, and urban design, it exemplifies how slum land—when planned holistically—can contribute to inclusive growth, environmental restoration, and urban equity. The proposal stands as a replicable precedent for peri-urban riverfront redevelopment across similar Indian urban contexts.

5.5. Institutional Strategy Proposal: Formation of Nag Riverfront Development Corporation (NRDC)

To ensure effective governance, implementation, and long-term management of the Nag River Urban River-Oriented Development (UROD) initiative, the formation of a dedicated Special Purpose Vehicle (SPV) is proposed—titled the Nag Riverfront Development Corporation (NRDC). Inspired by successful models such as the Sabarmati Riverfront Development Corporation (SRDC) in Ahmedabad, this institutional mechanism will be structured to integrate urban planning, ecological restoration, infrastructure delivery, and public engagement under a unified administrative and financial framework.

The NRDC would function as a limited-liability, government-promoted company with equity participation from key stakeholders, including the Nagpur Municipal Corporation (NMC), Nagpur Improvement Trust (NIT), Maharashtra Urban Development Department, Maharashtra Pollution Control Board (MPCB), and potential private partners under a PPP structure. This body will serve as the nodal agency responsible for project planning, land management, capital mobilization, coordination with metro and transport authorities, and long-term operations and maintenance (O&M) of riverfront assets.

A core mandate of the NRDC will be to leverage land-based financing tools such as land value capture (LVC), FSI monetization, leasehold models, and environment-linked grants, along with access to green and municipal bonds. It will act as the custodian of riverfront zoning policies, manage public-private partnerships, and ensure adherence to ecological and heritage-sensitive design guidelines as outlined in the UROD framework.

By creating this institutional anchor, the NRDC will enable professional project management, fiscal discipline, and strategic continuity—de-risking investment and accelerating the delivery of riverfront projects. Its autonomous yet accountable structure will also ensure that citizen engagement, environmental compliance, and urban equity are upheld throughout the planning and implementation lifecycle. This model is essential for transforming the Nag River from a neglected drain into a resilient, inclusive, and catalytic.

6. CONCLUSION & WAY FORWARD

The Nag River Urban River-Oriented Development (UROD) framework represents a transformative vision for the regeneration of the Nag River corridor, weaving together ecological restoration, cultural revival, economic growth, and inclusive urbanism. As the thesis has outlined, the key takeaway from this comprehensive analysis is that a holistic, zonal, and sector-specific approach is essential to sustainably manage riverfront development. The proposed interventions, institutional structures, and financing mechanisms provide a roadmap for revitalizing not only the Nag River but also the broader urban ecosystem. However, successful implementation requires careful coordination, adaptive governance, and the mobilization of diverse resources. The way forward involves a clear focus on priority pilot projects, institutionalizing the planning process, and ensuring active community participation. By building on these foundations, Nagpur has the potential to serve as a model for other Indian cities, transforming its riverside into a vibrant, resilient, and integrated urban space that benefits both the environment and its people.

6.1. Key Takeaways

River as a Central Urban Spine

The Nag River, long perceived merely as an urban drain, has the potential to be repositioned as a vital ecological and cultural corridor that anchors Nagpur's urban form. The Urban River-Oriented Development (UROD) framework reconceptualizes the river as a regenerative urban spine that not only facilitates improved stormwater management and biodiversity restoration but also enhances civic life, mobility access, and cultural continuity. This new role of the river integrates nature with infrastructure, ensuring that urban growth aligns with environmental stewardship.

Zonal Differentiation Enables Targeted Interventions

One of the most important planning strategies adopted in this framework is the division of the river corridor into four spatial influence zones—No Development Zone (NDZ), Primary Riverfront Zone (PRZ), Secondary Influence Zone (SIZ), and Tertiary Urban Integration Zone (TUIZ). This zonal differentiation acknowledges the varying degrees

of proximity, ecological sensitivity, land use intensity, and redevelopment potential along the river. It enables planners to apply tailored interventions—ecological in the NDZ, cultural in the PRZ, high-density mixed-use in the SIZ, and peri-urban integration in the TUIZ—thus ensuring planning responses are context-sensitive and implementable in a phased manner.

Micro-Level Planning is Crucial

The thesis emphasizes the importance of disaggregated, sector-wise planning for effective riverfront rejuvenation. By dividing the entire river corridor into four micro-level sectors, each with unique spatial characteristics, the UROD approach enables precise interventions that are both spatially and socially grounded. From ecological edge restoration in slum-encroached areas to heritage-sensitive renewal near religious nodes, this granular level of planning facilitates practical and inclusive implementation, creating visible, site-specific improvements while remaining aligned with a larger strategic vision.

Institutional Innovation through NRDC Formation

A critical takeaway from the study is the need for robust institutional support. Drawing from the precedent of the Sabarmati Riverfront Development Corporation (SRDC) in Ahmedabad, the proposal recommends establishing the **Nag Riverfront Development Corporation (NRDC)** as a dedicated Special Purpose Vehicle (SPV). This institutional model would consolidate administrative functions, enable focused project management, and streamline multi-agency coordination. More importantly, it would allow the city to attract diversified capital sources, engage in long-term planning, and ensure accountability in both ecological and socio-economic outcomes.

Pilot Projects Anchor the Vision

To translate vision into action, the UROD framework identifies several pilot projects that act as anchors for broader transformation. These include the ASITA-inspired urban river park developed on government land in Zone 2, which showcases ecological restoration integrated with public amenities; a commercial complex and mobility node in Zone 3 aligned with Transit-Oriented Development (TOD) principles;

and a slum redevelopment scheme in Zone 4 that combines affordable housing provision with land value enhancement. These pilot projects not only demonstrate feasibility but also serve as proof-of-concept models for community benefit and financial viability.

Blended Financing is Essential for Sustainability

The study underscores the importance of innovative and diversified financing strategies to support the capital-intensive nature of riverfront development. Traditional public funding is complemented with mechanisms such as **Land Value Capture (LVC)**, **Public-Private Partnerships (PPP)**, and **Corporate Social Responsibility (CSR)** investments. These instruments allow for the monetization of redevelopment value, mobilization of private sector expertise, and alignment with social impact goals. The strategic use of zoning tools and value accruals ensures that development is not only sustainable but also self-financing over time.

Community and Cultural Anchoring is Central

Beyond physical infrastructure, the success of the riverfront revitalization hinges on the active integration of communities and the celebration of local heritage. The proposals strongly advocate for participatory planning processes, in-situ rehabilitation of slum dwellers, and design guidelines rooted in cultural context. Features such as cultural trails, river learning centers, and sacred ecology revival reinforce the river's historical identity and embed a sense of belonging in its users, thereby securing long-term stewardship and public support.

Replicability for Other Indian Cities

Finally, the UROD framework developed for the Nag River provides a flexible and scalable model that can be adapted to similar urban rivers across India. Its integrated approach—linking ecological health with urban resilience, cultural continuity with economic opportunity, and micro-planning with institutional reforms—offers valuable lessons for cities seeking to rehabilitate their neglected water bodies. With its clear zoning strategies, governance roadmap, and financing architecture, the Nag River

model demonstrates a replicable pathway toward sustainable and inclusive river-centric urban transformation.

6.2. Way Forward

The realization of the Urban River-Oriented Development (UROD) vision for the Nag River necessitates a multi-pronged and phased approach anchored in institutional readiness, land governance, and community engagement. The first and most critical step is the official delineation of river influence zones—namely the No Development Zone (NDZ), Primary Riverfront Zone (PRZ), Secondary Influence Zone (SIZ), and Tertiary Urban Integration Zone (TUIZ). This should be supported by a comprehensive land mapping and ownership assessment exercise, which will form the basis for zoning regulations, land value capture strategies, and development control mechanisms.

Subsequently, the formation of a dedicated Special Purpose Vehicle (SPV)—**Nag Riverfront Development Corporation (NRDC)**—should be prioritized. Drawing inspiration from successful precedents like the Sabarmati Riverfront Development Corporation, NRDC must be empowered with planning authority, financial autonomy, and operational flexibility to coordinate multi-agency efforts and attract diversified investments. This institution will be central to managing project pipelines, issuing tenders, monitoring implementation, and fostering public-private partnerships.

To build momentum and establish credibility, early-stage implementation of **pilot projects** is essential. These should be strategically selected for their visibility, ecological significance, and potential to catalyze public support—such as the **urban river park** proposed on Agricultural College land in Zone 2, and the **TOD-linked commercial redevelopment** at Yashwant Stadium in Zone 3. These pilots will serve as proof-of-concept for integrating ecological resilience, urban mobility, heritage, and inclusive public spaces within a coherent framework.

Simultaneously, **sector-specific Detailed Project Reports (DPRs)** must be prepared in consultation with local communities, heritage bodies, environmental experts, and planning authorities. These DPRs should translate the conceptual strategies into phased, costed, and regulation-compliant implementation roadmaps, ensuring socio-ecological sensitivity and spatial integration.

Finally, a robust **communication and stakeholder engagement strategy** should be embedded into the process to ensure that the riverfront transformation is not merely viewed as a construction project, but as a cultural and ecological renaissance of Nagpur. Digital platforms, public design workshops, academic collaborations, and outreach campaigns will be crucial in cultivating public trust and long-term stewardship.

The revival of the Nag River stands as a generational opportunity to reshape the interface between nature, infrastructure, and community in urban India. If driven with integrity, innovation, and inclusivity, the UROD framework can position Nagpur as a national exemplar in river-centric urban regeneration—redefining how Indian cities reconnect with their rivers as living systems and civic commons.

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