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

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Abstract

Urban rivers worldwide face ecological degradation due to rapid urbanization, land-use encroachments, infrastructure expansion, and fragmented governance. The Nag River in Nagpur, India a historically significant urban waterbody has evolved from an ecological lifeline to a neglected, polluted drain owing to unregulated growth and ineffective planning. This research proposes an integrated Urban River-Oriented Development (U-ROD) framework as a planning paradigm to restore and reimagine rivers as strategic urban assets.

Developed through spatial analysis, policy review, hydrological modeling, and financial evaluation, U-ROD integrates eco-sensitive zoning, nature-based solutions, and participatory planning into the mainstream urban development process. The framework draws from national programs such as AMRUT, Smart Cities Mission, and URMP (Urban River Management Plan) while aligning with global agendas like the Sustainable Development Goals (SDGs) and the EU Water Framework Directive. It also explores innovative climate finance mechanisms such as green bonds, land value capture, and blended investment models.

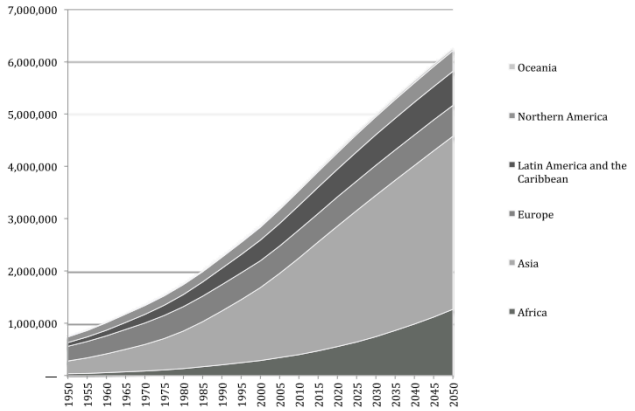
Through a case application on the Nag River, the study highlights context-specific interventions across layered influence zones, including riparian buffer delineation, inclusive housing, ecosystem restoration, and urban resilience infrastructure. The research offers a replicable model for urban river rejuvenation in emerging economies, contributing to regenerative urbanism, water-sensitive planning, and sustainable river basin governance.

Keywords: Urban river regeneration, nature-based solutions, climate finance, ecological zoning, U-ROD, Nagpur, riparian restoration, urban resilience.

1. Introduction

Urbanization in rapidly developing countries has resulted in unprecedented city expansion as populations surge and people migrate in search of better livelihoods. This growth places mounting pressure on environmental resources, demanding new infrastructure and intensifying consumption while also generating greater volumes of waste. These dynamics significantly threaten long-term urban sustainability. Urban rivers the arteries once central to settlement, economic growth, and cultural life are increasingly overlooked in contemporary urban planning. Far from being mere channels of water, urban rivers are vital for flood regulation, water supply, recreation, transportation, and biodiversity support. Throughout history, thriving cities have depended on their rivers for agricultural irrigation, trade, and

cultural expression, but with unplanned urban development, many rivers now face ecological degradation and the loss of their essential roles.



Within the urban fabric, rivers fulfil diverse and interconnected functions. They stimulate local economies, support public health, help preserve cultural and social identities, and sustain critical ecological processes. The presence of riparian zones—vegetated buffers along the banks—enhances ecosystem services by filtering pollutants, moderating floods, providing habitats for wildlife, and improving urban microclimates. Despite these functions, urban rivers are severely challenged by pollution, degradation of riparian buffers, and fragmented governance. In response, innovative strategies like Urban River-Oriented Development (UROD) are emerging. UROD advances a multidisciplinary approach that integrates ecological restoration, climate-adaptive infrastructure, inclusive public design, and sustainable financing tools in pursuit of resilient and livable cities. Examples from cities such as Seoul, Singapore, and Ahmedabad demonstrate how river-centered planning can simultaneously restore ecological integrity, revitalize public space, enhance economic opportunities, and reinforce community identity. Nevertheless, hurdles such as limited municipal budgets, complex funding requirements, and institutional fragmentation continue to impede progress. Strengthening partnerships, accessing climate finance, and activating green bonds are increasingly important to bridge these gaps. Achieving sustainable urban rivers ultimately depends on informed governance, coordinated action, and a holistic embrace of rivers as engines of urban resilience and vitality.

1.1. Multifaceted Role and Function of Urban Rivers

1.1.1. Ecological and Environmental Significance

Urban rivers support biodiversity corridors, recharge groundwater, moderate urban heat, and provide essential ecosystem services such as air and water purification. Riparian zones serve as natural filters, absorbing pollutants and reducing flood risks through increased rainwater infiltration (UNEP, 2021).

1.1.2. Socio-Economic and Cultural Value

Rivers have historically underpinned local economies by enabling trade, irrigation, and tourism. City riverfronts boost property values, attract investments, and foster recreation and civic life. Iconic rivers like the Thames, Seine, and Ganges exemplify how waterways are imbued with cultural symbolism and social functions (World Bank, 2022; UNESCO, 2022).

1.2. Threats Facing Urban Rivers

1.2.1 Urbanization and Loss of Riparian Buffers

Unplanned city growth and infrastructure expansion frequently encroach upon river space, resulting in the loss of natural buffers and habitats. Degraded riparian zones weaken ecosystem functions, amplify surface runoff, and increase flood and pollution risks (OECD, 2021).

1.2.2 Pollution and Fragmented Governance

Untreated sewage, industrial discharges, and solid waste are persistent threats, especially where governance is fragmented between multiple agencies. End-of-pipe technocratic solutions remain dominant, with insufficient integration of spatial, social, and ecological considerations (UN-Habitat, 2021).

1.3. River-Oriented Development (ROD): A Paradigm Shift

1.3.1 Concept and Rationale

River-Oriented Development (ROD) reimagines the role of rivers from city peripheries to vital organizing spines. This approach is inspired by Transit-Oriented Development but centers on natural waterways, prioritizing eco-restoration, adaptive design, public space creation, and multi-stakeholder governance (UN-Habitat, 2021; Kumar & Lee, 2022).

1.3.2 Global Precedents

Cities such as Seoul (Cheonggyecheon Stream Restoration), Singapore, and Ahmedabad (Sabarmati Riverfront) have implemented successful river-centric regeneration projects, demonstrating improvements not only in urban ecology but also public amenity and economic vibrancy (ADB, 2019; Kumar & Lee, 2022).

1.4. The Importance of Riparian Zones

1.4.1 Environmental Benefits

Vegetated riparian buffers contribute to water quality improvement, erosion control, urban cooling, and carbon sequestration. Their conservation is critical for maintaining healthy aquatic habitats and high-quality urban environments (IUCN, 2021; UNEP, 2020).

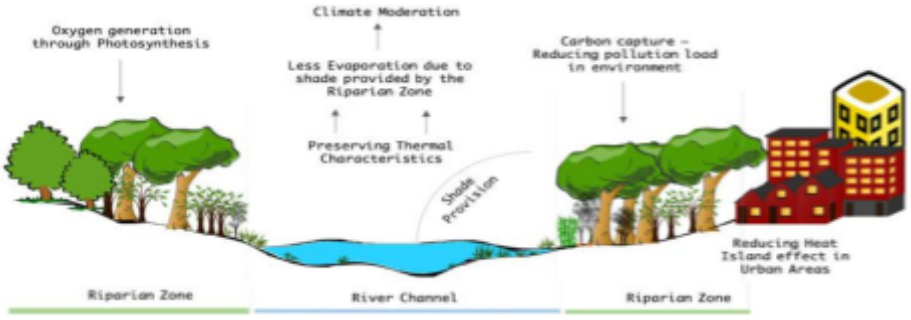


Figure SEQ Figure * ARABIC 2: Riparian Buffer zone in Urban Areas

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

1.4.2 Social and Recreational Roles

Riparian zones provide accessible green spaces, enhance urban aesthetics, and support mental and physical well-being. Urban parks along rivers are linked to increased property values and vibrant, inclusive communities (OECD, 2021).

1.5. Financial and Institutional Challenges

1.5.1 Constraints in Funding

Most cities face significant budgetary constraints, struggling to allocate sufficient resources for river restoration versus competing priorities. The high upfront cost of infrastructure and stewardship, alongside fragmented institutional arrangements, often stall progress (World Bank, 2021).

1.5.2 Innovative Financing Solutions

Climate finance mechanisms, green bonds, and public-private partnerships are emerging tools to bridge funding gaps. However, barriers such as eligibility requirements and limited local

technical capacity persist, underscoring the need for improved institutional coordination and access to financing instruments (ADB, 2022).

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

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

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

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.

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.

2.1. Nag River: Lifeline Under Threat

Nagpur, Maharashtra's third-largest city and geographic center of India, serves as a vital hub for trade, transportation, and administration. Its rapid urban expansion has spurred significant economic growth and infrastructure development but has also imposed severe environmental pressures, particularly on the Nag River. Historically, this river was a crucial freshwater

resource and ecological asset. Today, it faces immense strain from unregulated urbanization, pollution, and habitat loss, highlighting an urgent need for sustainable interventions.

The Nag River Basin Action Plan identifies key factors driving its decline, including altered hydrology due to unplanned urban growth, widespread discharge of untreated sewage, ineffective solid waste management, and increased impervious surfaces from expanding roads, residential, and industrial areas. The absence of a comprehensive conservation policy and weak regulatory enforcement have exacerbated the river's ecological degradation.

2.2. Challenges Faced by the Nag River

2.2.1. Threat of Periodic Floods

Seasonal flooding is exacerbated by floodplain encroachments and reduced natural drainage capacity. Built-up areas have replaced inundation zones, restricting stormwater dispersion, elevating flood risks, and causing regular urban flooding during monsoons due to inadequate drainage infrastructure.

2.2.2 Hydrological and Development Impacts

Rapid, unregulated urbanization along the riverbanks narrows the river channel, obstructing natural flow and limiting space for ecological restoration. The lack of river-sensitive urban planning facilitates urban sprawl directly onto the river edge.

2.2.3 Pollution from Sewage and Industrial Outfalls

Over 70% of sewage inflows remain untreated, significantly elevating biochemical and chemical oxygen demand and contaminating the river with heavy metals. Insufficient sewage treatment plants and wastewater management worsen pollution levels.

2.2.4 Polluted Stormwater Drains (Nallas)

Stormwater drains, originally intended for rainwater runoff, have become conduits for untreated domestic and industrial waste, effectively converting parts of the river into polluted

open sewers. Inadequate maintenance and improper solid waste disposal further degrade water quality and aquatic ecosystems.

2.2.5 Inaccessible Riverbanks

Unlike some Indian and global urban riverfronts, Nagpur lacks an integrated riverfront development plan. Most riverbanks are privately owned or occupied by informal settlements, restricting public access and ecological conservation. The absence of continuous pedestrian pathways, green buffers, and recreational spaces has resulted in fragmented, neglected river edges disconnected from the urban fabric.

2.3. The Nag River: Significance and Rationale for Study

The Nag River is intrinsic to Nagpur's cultural, historical, and ecological identity. Spanning approximately 68 kilometers, with about 17 kilometers traversing the city, its seasonal width and depth vary due to monsoon influence and urban runoff. Traditionally sourced from the ecologically rich Lava Hills, recent administrative redefinitions associated with real estate development have challenged the river's designated origin, raising ecological and legal concerns.

Rapid population growth has intensified pressure on land and water resources, resulting in floodplain encroachments, diminished riparian buffers, and elevated flood risks. The 2015 repeal of Maharashtra's River Regulation Zone policy eliminated protective buffer zones, accelerating industrial and residential encroachment and degrading the river's flood resilience and water quality.

2.4. Environmental Challenges

2.4.1 Pollution and Waste Management Deficiencies

Approximately 80% of the city's sewage is discharged untreated into the river, drastically reducing water quality and aquatic life viability. Industrial effluents and solid waste dumping compound the pollution problem, while existing sewage treatment and drainage infrastructure remain inadequate.

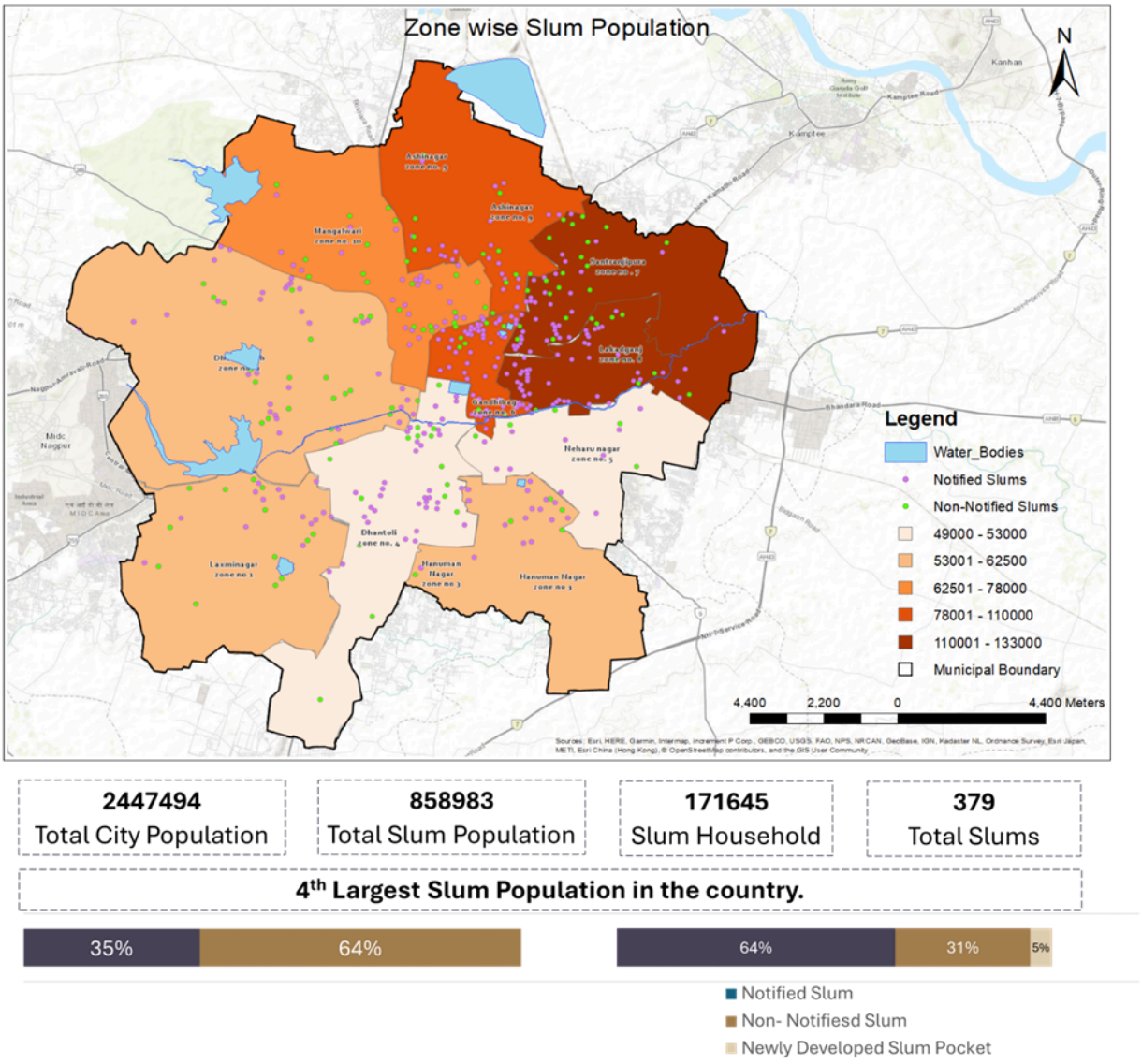


Figure 3 : Zone wise Slum Population Map

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

2.4.2 Habitat Loss and Encroachments

Informal settlements and unregulated construction along the riverbanks have led to habitat destruction, loss of vegetation, and narrowed floodplains, intensifying flood risk and disrupting ecological continuity vital for aquatic and riparian species.

2.4.3 Hydrological Disruptions

Urbanization has increased impervious surfaces that limit groundwater recharge, elevate surface runoff, and cause destructive flash floods. Excessive groundwater extraction has further destabilized the river's base flows, amplifying dry-season water scarcity.

3. Data Analysis

3.1. Urban Growth and Planning in Nagpur

Nagpur's development has historically centered around the Nag River, evolving from early settlements under the Gond and Bhonsle reigns reliant on the river for agriculture and trade, to a colonial city integrating transport and industrial infrastructure along the river corridor. Post-independence rapid urbanization and industrialization have resulted in significant spatial expansion and unregulated growth, severely impacting the Nag River's ecological health.

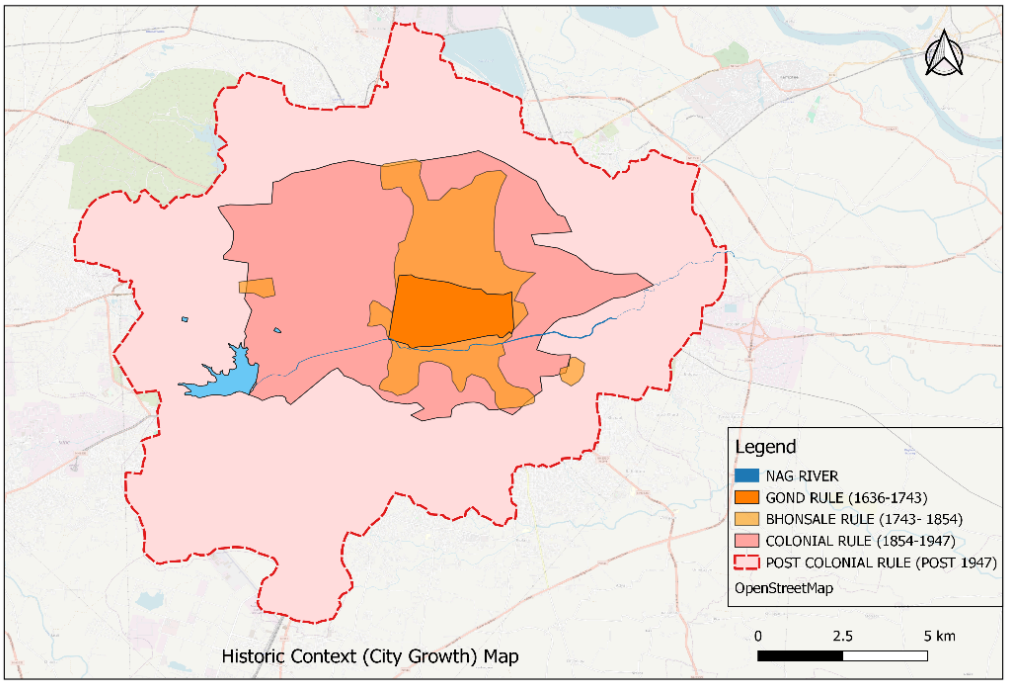


Figure 4: Evolution of Nagpur City Map

Source: Integrating Heritage in Urban Development, Nagpur, SPAV

Currently spanning 225.08 sq.km with a population of approximately 2.4 million (2011 Census), Nagpur faces immense pressure on infrastructure and natural resources. Urban sprawl, informal settlements, and commercial development have encroached on the riverbanks, resulting in pollution, loss of vegetation, decreased water flow, and increased flood vulnerability. The absence of buffer zones and river-sensitive planning has culminated in siltation, groundwater depletion, and weakening of urban ecological resilience.

3.2 Interdepartmental Gaps: A Key Factor in Nag River's Degradation

Fragmented governance critically hampers river restoration efforts. Coordination failures between agencies such as the Nagpur Improvement Trust (NIT) and Nagpur Municipal Corporation (NMC) have led to unclear accountability. Within the NMC, departments operate in silos: outdated planning maps hinder updating river buffer zones, while sewage management is treated apart from ecological and water quality concerns. Technical consultants possess valuable data but lack engagement in integrated restoration planning.

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

NIT	**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.

This compartmentalized approach causes delays, inefficiencies, and fragmented interventions inadequate to resolve the river's complex degradation. A unified inter-agency governance framework with coordinated planning, data sharing, and shared responsibilities is essential for effective river rejuvenation.

3.3 Riparian Restoration Zone of the Nag River Basin

The designated Riparian Restoration Zone, covering 37 municipal wards with a population over 600,000, is critical for intervention. It faces combined challenges of urban encroachment, pollution, habitat loss, and decreased floodplain capacity. Unregulated construction obstructs natural hydrology, while accumulation of untreated sewage, industrial effluents, and solid waste severely compromise water quality.

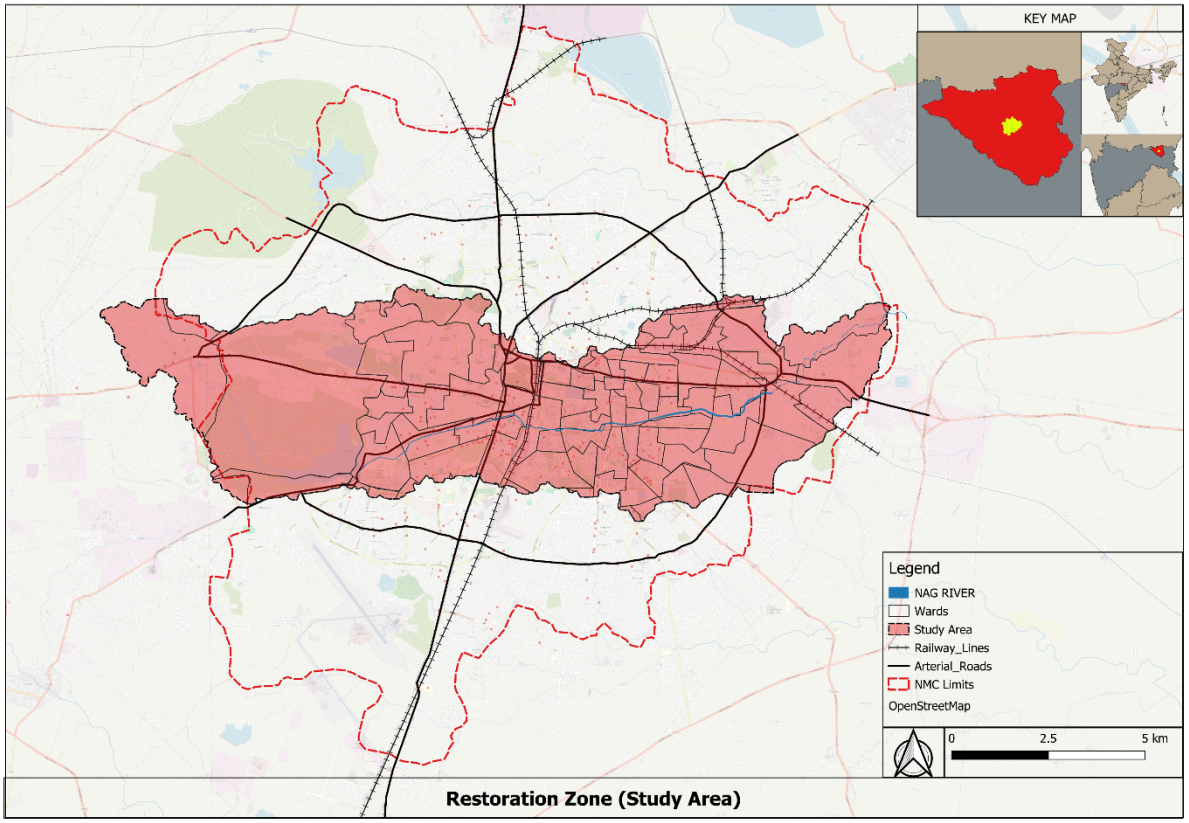


Figure 5: Nag River Restoration Zone

Source: Author

Slum settlements lacking sanitation infrastructure discharge untreated wastewater directly into the river, escalating ecological degradation and public health risks. Aquatic biodiversity dwindles as pollution and habitat fragmentation intensify, undermining the river's natural self-purification.

2.4 Hydrological and Environmental Analysis of the Nag Basin

Spatial and hydrological analyses reveal significant environmental stressors linked to urbanization. Western and central sub-basins maintain remnant vegetation supporting groundwater recharge and biodiversity, but eastern areas are heavily urbanized and fragmented, impeding natural drainage and increasing flood risk.

Land cover mapping shows significant loss of green space and riparian buffers from 1993 to 2021, replaced by impervious built-up areas. Wetlands, ponds, and water bodies have shrunk or vanished due to encroachment. These trends enhance urban heat effects, flood vulnerability, and reduce carbon sequestration capacity.

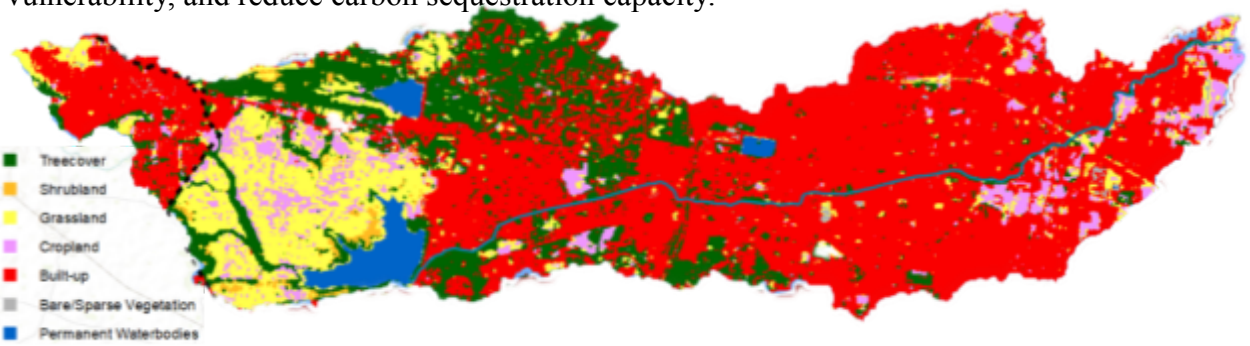
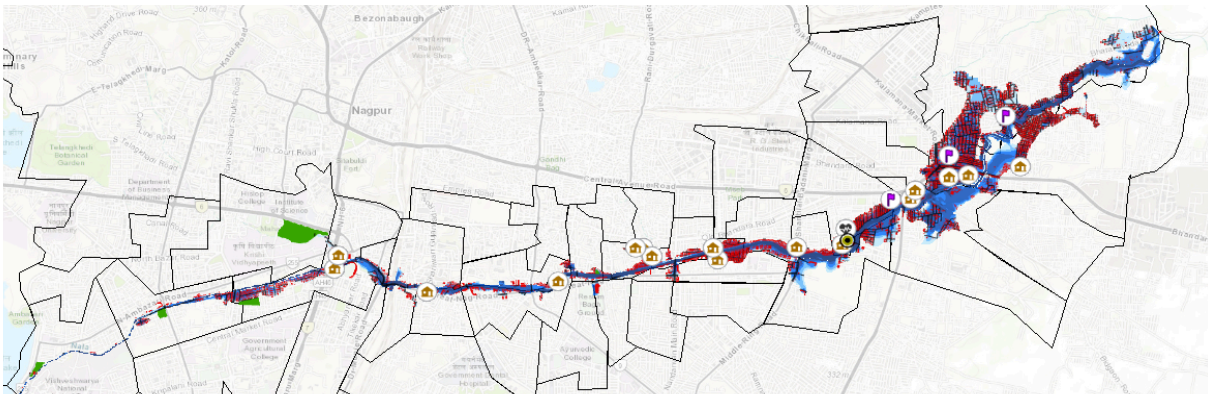


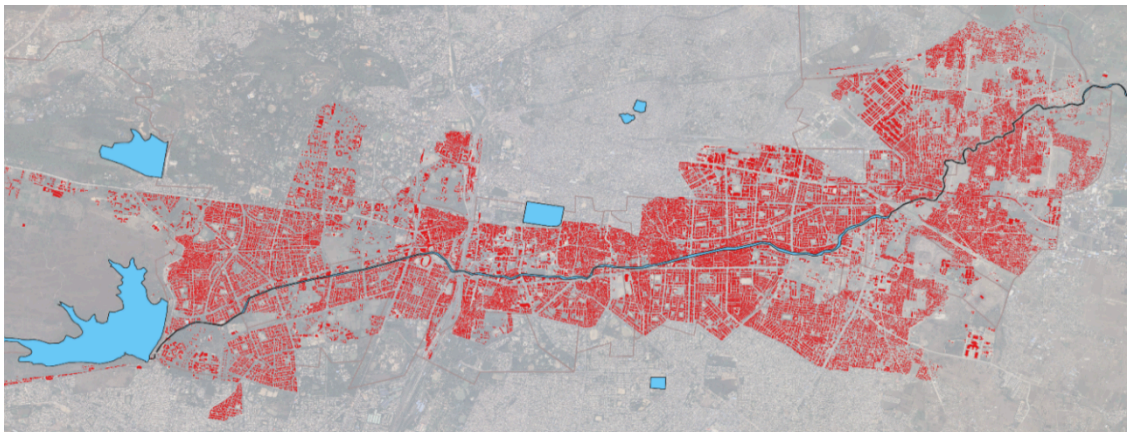
Figure 7: Land Cover Map

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.

Flood risk assessments predict continued exposure of residential, slum, public infrastructure, and sewage treatment plants to inundation, emphasizing the urgency of floodplain restoration and green infrastructure.



Source: ArcMap Online



Source: GEE

Building footprint and land use comparisons confirm extensive loss of buffer zones, unregulated settlements directly on riverbanks, and encroachment into floodplains, reinforcing the need for stringent zoning and ecological restoration.

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

4. PROPOSALS & INTERVENTIONS

4.1. 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.

4.1.1. Ecological & Environmental Components

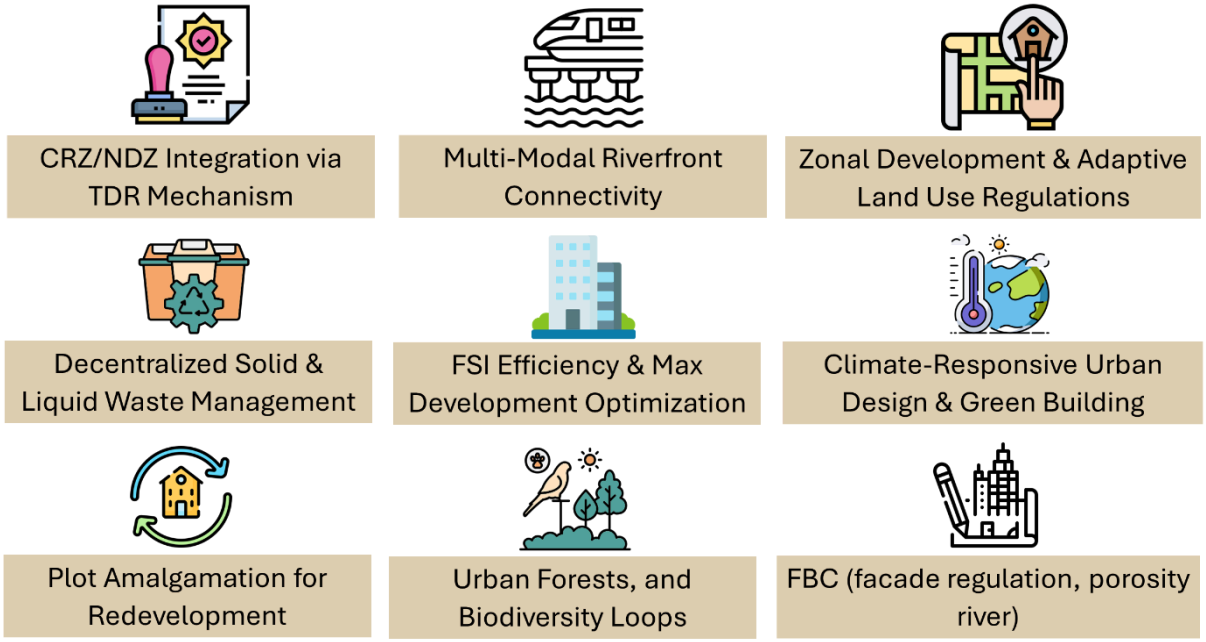
This component focuses on re-establishing the river's ecological integrity by restoring its natural functions and improving its interaction with the surrounding urban systems. The framework mandates the establishment of Riparian Buffer Zones and River Edge Setbacks ranging from 30 to 100 meters, in compliance 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.

4.1.2. 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.



4.1.3. 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.

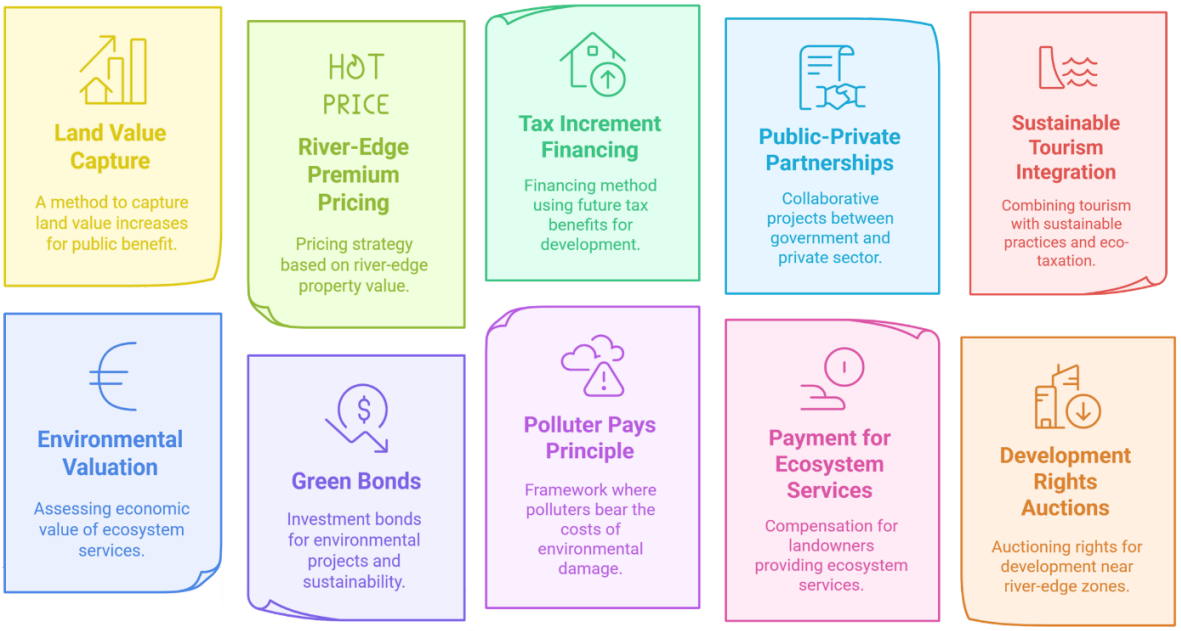


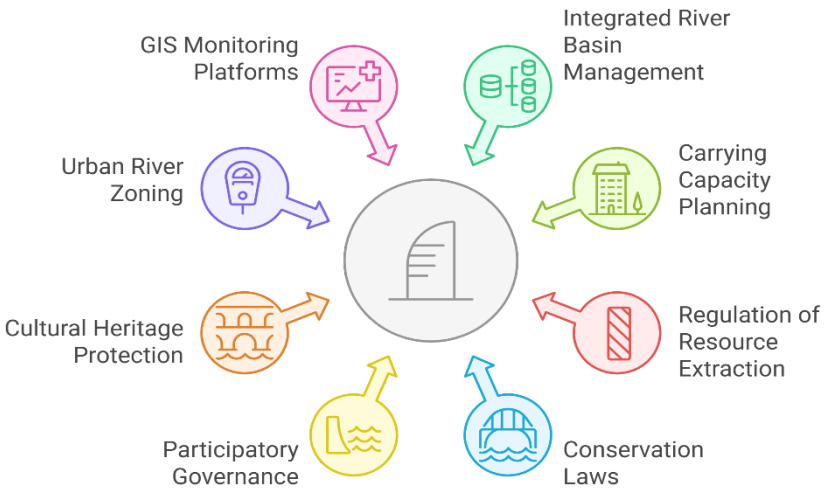
Figure 12: Financial and Economic Instruments

4.1.4. 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.



4.2. Spatial Sectoral Framework: Nag River Influence Zones

Reimagining the Nag River as a central spine for sustainable urban development requires a nuanced, layered zoning framework. This approach divides the river's surroundings into concentric influence zones based on ecological sensitivity, cultural significance, urban

regeneration potential, and transit connectivity. Rooted in Urban River-Oriented Development (UROD), the framework integrates national guidelines (MoEFCC River Regulation Zone, National Green Tribunal rulings) and international precedents (Danube River Basin, Cheonggyecheon restoration, Transit-Oriented Development models). The river is therefore segmented radially into four zones, each with tailored land use, planning policies, and intervention strategies.

4.2.1. Core Ecological Setback / No Development Zone (0–30 meters)

This innermost zone functions as the No Development Zone (NDZ), constituting a strict ecological buffer aligned with MoEFCC's Minimum Ecological Setback (MES) and reinforced through National Green Tribunal directives. All construction is prohibited here, ensuring preservation of riparian buffers to enhance natural filtration, flood mitigation, and habitat connectivity. The zone promotes large-scale riparian restoration via native vegetation planting, integration of bioswales and stormwater buffers, and application of nature-based solutions financed through green bonds. To address existing landowner rights, Transfer of Development Rights (TDR) mechanisms allow shifting entitlements to designated receiving zones, balancing conservation with social equity.

4.2.2. Primary Riverfront Zone (30–100 meters)

The Primary Riverfront Zone (PRZ) serves as the cultural and social interface, incorporating heritage sites, informal settlements, and community spaces. Planning within the PRZ uses Form-Based Codes to promote heritage-sensitive, contextually responsive urban regeneration prioritizing adaptive reuse over wholesale redevelopment. Inclusive in-situ upgrading of informal settlements enhances safety, sanitation, and flood resilience while protecting sacred riverfront features as part of a designated Cultural Protection Zone. Landscape and public realm design integrates low-impact materials, native planting, and water-sensitive urban design to reinforce both cultural identity and ecological function.

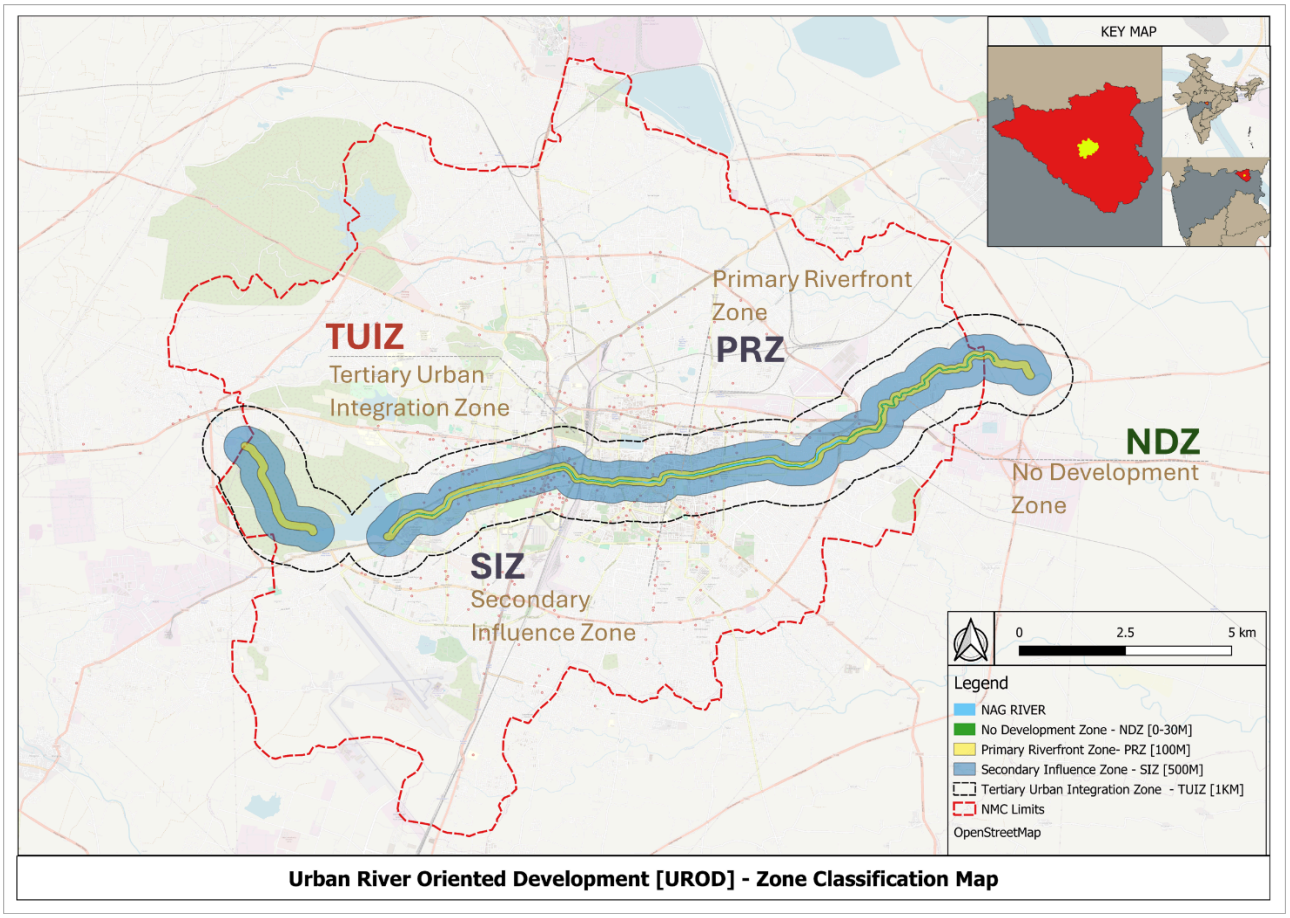
4.2.3. Secondary Influence Zone (100–500 meters)

Serving as the urban regeneration engine, the Secondary Influence Zone (SIZ) aligns with Transit-Oriented Development (TOD) principles, leveraging proximity to the Nagpur Metro Blue Line to foster dense, mixed-use, walkable neighborhoods. This zone receives TDR

credits from conservation zones, incentivizing ecological protection upstream while encouraging sustainable urban growth near transit. Vertical zoning permits stacked residential, commercial, and institutional uses governed by GIS-enabled FSI audits to optimize land utilization aligned with infrastructure capacity. Inclusive housing mandates and green mobility infrastructure support social equity alongside ecological sustainability.

4.2.4. Tertiary Urban Integration Zone (500 meters–1 kilometer)

The outermost Tertiary Urban Integration Zone (TUIZ) bridges the intensively planned riverfront with the broader metropolitan fabric. It comprises underutilized lands, fragmented parcels, and peri-urban areas suitable for inclusive mixed-use redevelopment via Public-Private Partnerships (PPP). Tools such as land pooling, value capture, and Tax Increment Financing (TIF) mobilize resources for infrastructure and public amenities development. The TUIZ incorporates climate-responsive zoning, green corridors to mitigate urban heat island effects, and multimodal transit access integrated with last-mile connectivity. Social infrastructure investments ensure affordable housing and community facilities, fostering social inclusion and connectivity. This zone exemplifies scalable, climate-adaptive urbanism extending river corridor benefits city-wide.



Urban River Oriented Development [UROD] - Zone Classification Map

This spatial sectoral framework establishes a comprehensive, multi-layered strategy to balance ecological preservation, cultural heritage, inclusive development, and transit-oriented urban regeneration—positioning the Nag River as the backbone for resilient metropolitan growth.

Table

: 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. 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.

5.1. 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.

5.2. 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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