Planning for River Sensitive Developments in Cities: A Case Study of Varanasi

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Abstract

Rapid urbanization and population growth have exerted escalating pressure on cities, thereby triggering discord in the intricate relationship between urban environments and rivers. Cities, often accused of contributing to the degradation of rivers and water bodies, are now being urged to adopt a fresh perspective—that of becoming "river-thinking" cities. This paper delves into the case of Varanasi, focusing on the Rivers Varuna and Assi, which were once the vital lifelines of the city. Despite their historical significance, the city missed the opportunity of addressing the deteriorating state of these rivers. The research explores opportunities for Varanasi to shift from having a negative impact on rivers to actively contributing to their health.

Conducted at three levels—city, river fringe area, and the river—the study identifies issues and constraints. The Urban River Management (URM) index is calculated in two scenarios: considering only the Rivers Varuna and Assi and considering all three rivers—Ganga, Varuna, and Assi. Complemented by the on-ground studies, including reconnaissance surveys, observations, site documentations, and activity mapping, the research evaluates the real-world challenges that are faced by the rivers, such as pollution, untapped drains, sewerage overflow, waste disposal, and flood impacts on the local population.

The findings reveal that Varanasi falls short in adequately addressing the river issues, and the URM index suggests that only an elementary level of urban river management is being done by the city. This paper contends that cities worldwide should recognize the urgency of adopting a 'nature first' approach to urban planning. By analyzing planning tools at different levels, this research advocates a paradigm shift in urban planning towards sustainable practices that prioritize the well-being of rivers and the natural ecosystems.

Keywords: Conservation, Nature-first, Planning, River Health, River Thinking, Urbanization

Introduction

The bond between rivers and cities, embodied in a symbiotic relationship, has been the hallmark of civilizations. Unfortunately, over the years, increased development pressures on cities have caused discord in this relationship. Today, rivers in India are in a crisis and face threats on multiple fronts. There are concerns regarding pollution of the rivers, drying up of river stretches, encroachment onto the floodplains, loss of river-related biodiversity, and several others. There is need for new river-centric thinking in planning for "river cities" on their banks, as the city master plan, at present, does not adequately address this. If we continue to pollute rivers the way we are doing currently, then our future might face a serious water crisis. So, there is a need for river-sensitive development, which should be a mix of engineering and planning-related approaches. Initiatives need to be taken to make people empathize with the riverine ecosystems that could restore the health of these water bodies.

Problems faced by rivers within the city boundaries:

- **Poor drainage:** At present, rain falls on hard surfaces which quickly drains into the river system, thus increasing storm flows and runoff and raising the risk of flooding.
- **Encroachment on floodplains:** Development of housing, industry, infrastructure, and agriculture all contribute to increased flood risk, habitat loss, and biodiversity loss.
- **Over-abstraction of water:** Obtaining water from rivers, canals, reservoirs, lakes, or subterranean aquifers for use in agriculture and industry. This could cause watercourses and marshes to dry up, and water levels may sink.
- **Pollution:** Dumping of waste, industrial chemicals, sediments, agricultural pesticides and fertilizers, and oil-contaminated road drainage all contribute to river pollution, which results in the loss of water quality and biodiversity.

Seeing the problem that is being faced by rivers in cities, proper urban river management is the need of the hour for conservation, development, and restoration of river resources within the administrative extent of a city. This aims to achieve a careful balance between the ecological, infrastructural, social, recreational, and economic functions of a river within the city. This should ensure that the river is environmentally sensitive, economically viable, and socially inclusive within the city boundary (NIUA, 2020).

Significance and Need for the Study in Varanasi

Varanasi holds a great religious and historical significance for Hindus in Uttar Pradesh, since it is marked by the convergence of three rivers—Ganga, Varuna, and Assi. Unfortunately, Rivers Assi and Varuna face severe pollution, particularly River Assi which has been reduced to just a drain. Addressing pollution in these tributaries is essential for any meaningful effort to clean River Ganga. Despite their historical importance, these rivers are under threat and demand immediate attention.

River Assi has also fallen prey to unauthorized constructions, thus significantly altering its original character. The encroachments have eliminated the freshwater sources, and the riverbanks are unlawfully occupied. This degradation of the floodplains has not only led to loss of the river's identity but has also hampered the recharging of groundwater. River Varuna, once the lifeline of Varanasi, now faces flooding issues, thus affecting many due to the unauthorized constructions in the flood-prone areas. These rivers, crucial to Varanasi's existence, are now grappling with serious challenges which necessitates a comprehensive city development plan for their restoration and prominence.

The study focused on the impact zone extending 500–1 km from both rivers, and was determined by factors such as city growth, population density, economic activities, social, cultural, and recreational aspects, as well as environmental considerations.

Objectives

The objective of this research paper is:

- To understand the various diameters of a river sensitive planning process and urban river management indexing as part of good practices from cities in India and abroad.
- To analyse and assess the current situation at three levels: city level, river fringe level, and the river level at Varanasi.
- To evaluate the situation and identify the issues in Varanasi with the help of different parameters and from the Urban River Management (URM) Index.
- Formulation of strategies, recommendations, and regulations at all the three levels for river-sensitive development in Varanasi.

Research Methodology

The research methodology for this study has employed a multi-level approach, conducted at the city level, river fringe area level, and river level, with the following key steps:

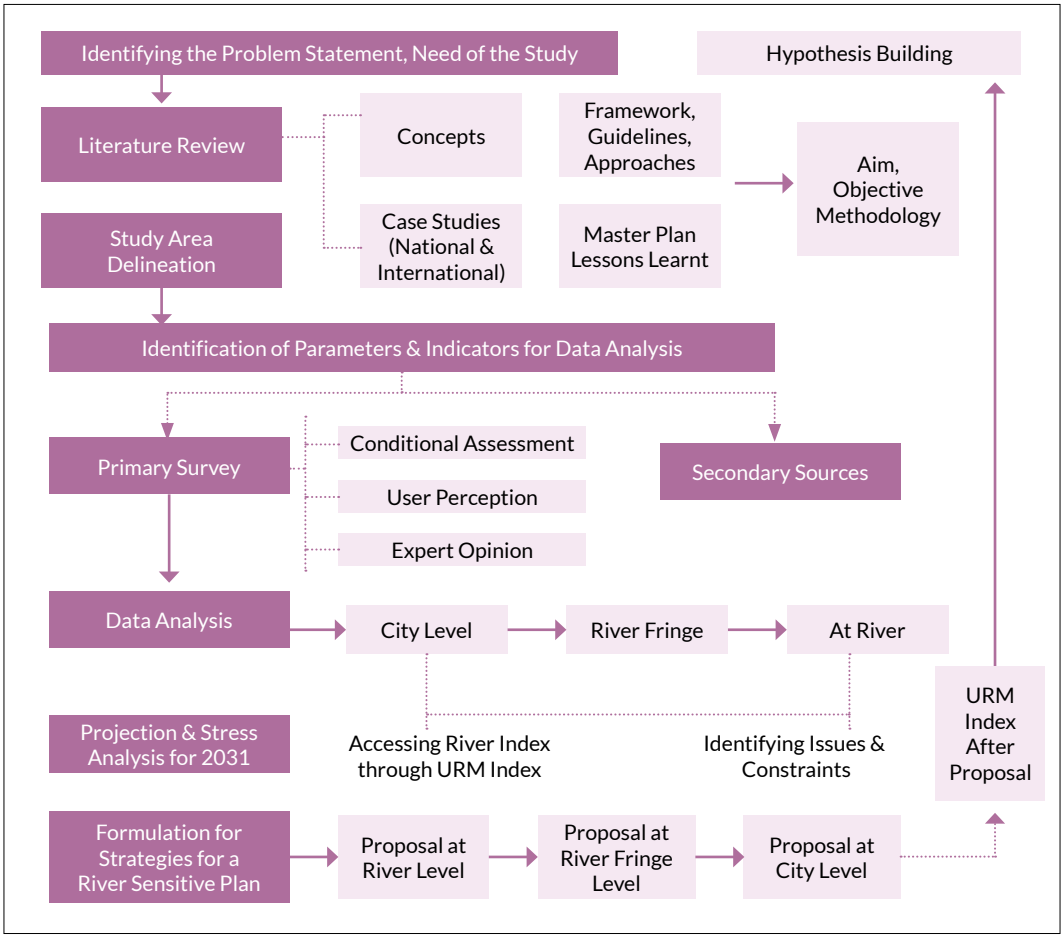
Literature review: The study undertook an extensive review of the existing literature to comprehend the context and necessity of the study. It analyzed various concepts, regulations, and relevant case studies from around the world to identify the best practices. From the literature review it derived the parameters and indicators for data analysis.

Data collection: To gather comprehensive information, data was collected from various authorities. Field studies were conducted by incorporating reconnaissance surveys to assess the overall river and city environment. Current conditions and potential areas for improvement were observed and documented along with site documentation, and activity mapping. A primary survey was also conducted which used a structured questionnaire to capture insights into the public and

expert perceptions of river-related issues, people's engagement with the river, and activities that were being carried on near the river.

Data analysis: Based on various identified indicators from the survey and data collection, analyses were conducted at three levels: at the city level, at the river fringe area, and at the river level. The assessment was done on various parameters such as floodplain management, riparian buffer, eco-friendly riverfront, revival of water bodies, river economy, citizen sensitization, citizen engagement, flood impacts, and quality of living. Based on the analysis, issues and constraints were identified. The calculation of the Urban River Management (URM) Index was done in two scenarios: considering only Rivers Varuna and Assi and considering all three rivers (Ganga, Varuna, and Assi).

Figure 1: Research Methodology



Source: Author, 2022

Projections and strategy formulation: To anticipate future scenarios, projected findings for the year 2031 were declared. Strategies for a river-sensitive approach at the river level, river fringe area level, and city level were developed. Strategies were formulated based on the assessment results. To validate the effectiveness of the proposed strategies, the URM index was planned to be calculated post the formulation of strategy.

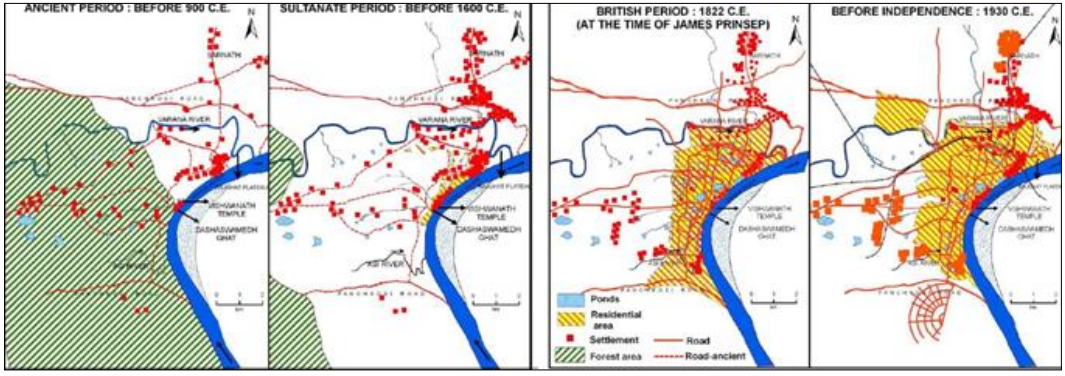
Hypothesis testing: A comparative analysis of the URM Index before and after the strategy formulation was conducted. It was assessed how the developed strategies justified the initial hypothesis.

Study Area

Historical Parlance of Varanasi

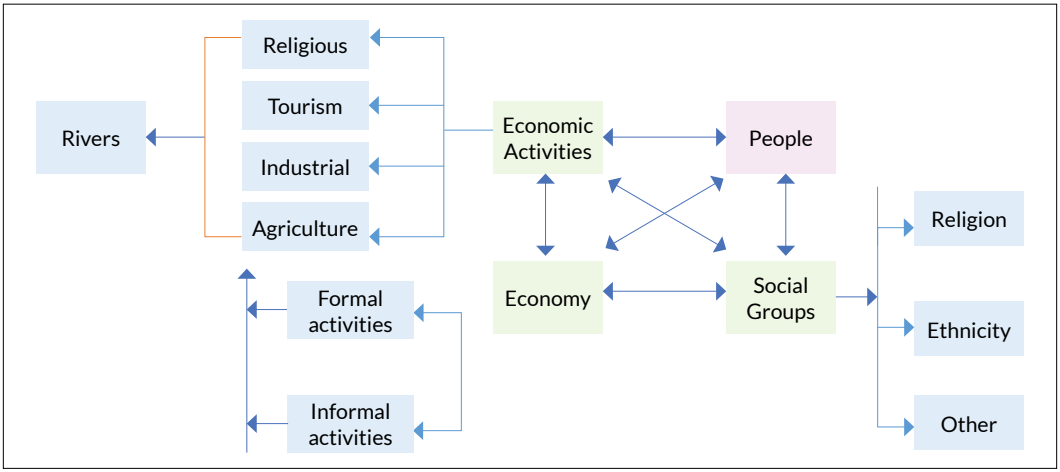
Rivers have always existed for settlements. Varanasi, too, was settled along the river. Varuna and Assi are non-perennial rivers that receive their water from rainfall, whereas the River Ganga is a perennial river. The initial settlement in the city was around River Ganga which was driven by the establishment of textile industries, agriculture, crafts, and mercantile groups along its banks. Over time, the transportation of goods along the river became a significant factor in attracting people to settle in the area. Subsequently, the population gradually shifted towards the northern area near River Varuna and expanded southwards along the River Assi. In the later stages, colonial settlements emerged in close proximity along the River Varuna, and away from the traditional core (Singh and Rana, 2018). The Ganga River area became densely populated and congested.

Figure 2: Growth of Varanasi along Rivers



Source: Singh, 2018

Figure 3: River, People, and the City Connect

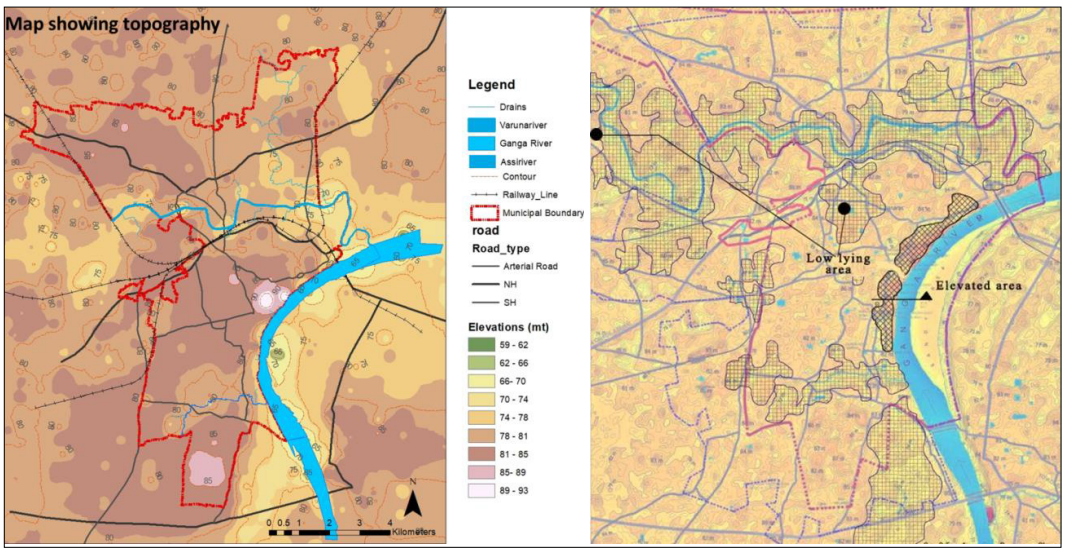


Source: Author

Topography

The city features a soft undulating terrain, with the ground elevation ranging from 71m to 80m above the river level. The highest point reaches 93m, while the lowest fluctuates around 59m. Due to this topography, the regions around the Rivers Varuna and Assi are characterized by lower elevations which result in flooding during the monsoon season.

Map 1: Topography and Low-Lying Areas in Varanasi



Source: Author

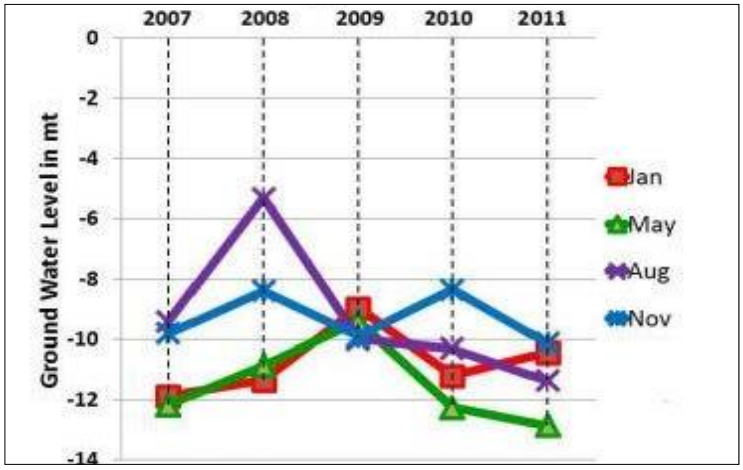
City Level Analysis

To comprehend the underlying reasons for the challenges that are encountered by the river and to suggest a workable remedy, an in-depth examination of the diverse sectors and parameters was conducted at the city level, in this section.

Groundwater

Groundwater serves as a crucial resource and is the foundation for the development of water supply and drainage infrastructure, with its quality directly impacting human health. In the city, groundwater depletion occurs at the rate of 23 cm per year, and the southern part experiences faster depletion, primarily due to extensive extraction by DLW and BHU. In the Trans Varuna area, there is significant reliance on groundwater, with deep tubewells, hand pumps, and private borewells serving as primary sources for water extraction (Gautam, 2013).

Figure 4: Groundwater Table in Varanasi



Source: Central Groundwater Board - Division-III, Varanasi

Water Supply System

The water supply and sewage system in Varanasi were established in 1892 and have now been in operation for over a century. Groundwater extraction constitutes the primary source (62%), followed by the Ganga (38%). The city relies heavily on groundwater, with a yearly depletion rate of 23cm. The Water Treatment Plant (WTP) has a capacity of 330 MLD (millions of litres per day) but treats only 120 MLD, necessitating an upgrade. Municipal water faces contamination from sewers due to their deterioration, and close proximity of the intake well to the Assi Nallah which results in elevated levels of coliform bacteria (School of Planning and Architecture, 2015).

Existing Sewerage Analysis

Regarding the existing sewerage system, it was originally designed for domestic sewage, the traditional layout of open drains in the core city allows stormwater to directly enter the trunk sewer or through manholes and branch sewers. This creates significant pressure on the sewerage network, especially during monsoons. The combined system renders the Sewage Treatment Plants (STPs) ineffective in the rainy season, thus contributing to increased pollution in the Rivers Ganga and Varuna.

Areas that are not covered by the sewer network discharge sewage directly into the Rivers Ganga, Varuna, or in the Assi Nallah, thereby further contaminating the rivers. Varanasi has a total of five STPs with a combined capacity of 399 MLD, and three new STPs (Dinapur new STP, Goithaha STP, and Ramana STP) were established by Namami Gange to cater to the current and projected populations by 2030. Except for Ramana STP, the others are currently operating at full capacity.

Table 1: Total Sewage Generation-Existing Scenario in Varanasi

Total population of Varanasi city 2021	16,36,168
Adding Floating Population 6%	18,27,732
Total water supply @150 lpcd + UFW	343.61MLD
Total sewage/sullage generation @80% of supply	280 MLD

Source: Primary Survey, 2022

Table 2: District-wise Sewage Generated and Gap Analysis in Varanasi, 2021

Sewerage District	POP 2021	Total Water Supply @150+UFW	Total Sewerage generation @ 80%supply	Total STP	GAP
District 1	675845	126.72	101	80+140 MLD= 220 MLD	
District 2	566432	106.25	846		
District 3	229036	42.94	34.35 +198 (Nagwa drain)	50	113.65 MLD
District 4	396108	74.24	59.46	120	

Source: Jal Kal, Bhagwanpur, Varanasi and Primary Survey, 2022

At present, there is a deficiency in sewage treatment for the waste generated in District 3. Many areas lack branch lines which leads to direct discharge of waste into rivers such as the Trans Varuna. Open defecation is observed along the Rivers Varuna and Assi. There also exists significant untapped potential for reuse of the treated wastewater.

River Sensitive Urban Planning for Varanasi: Situational Analysis

To make a city river-sensitive, various planning dimensions need to be addressed in the master plan of that city (NIUA, 2020). Table 3 depicts the planning dimensions addressed in the Varanasi Master Plan 2030. Out of 10 planning parameters, Varanasi Master Plan for river-sensitive has adopted only one, which shows that the city lacks in river-sensitivity in the implementation of the master plan.

Table 3: River Considerations in Master Plan

Planning Dimensions	Varanasi Master Plan 2031		
	Mentioned in Detail	Mentioned without Detail	Not Mentioned
River Sensitive Vision/Objective			
River Background			
River Zone Delineation			
Urban Flooding			
Land Use, Use Premises			
Development Control Regulations			
Groundwater Augmentation			
River Water Extraction for City Use			
River Pollution			
River Navigation			

Source: Master Plan Varanasi 2031-Varanasi Development Authority

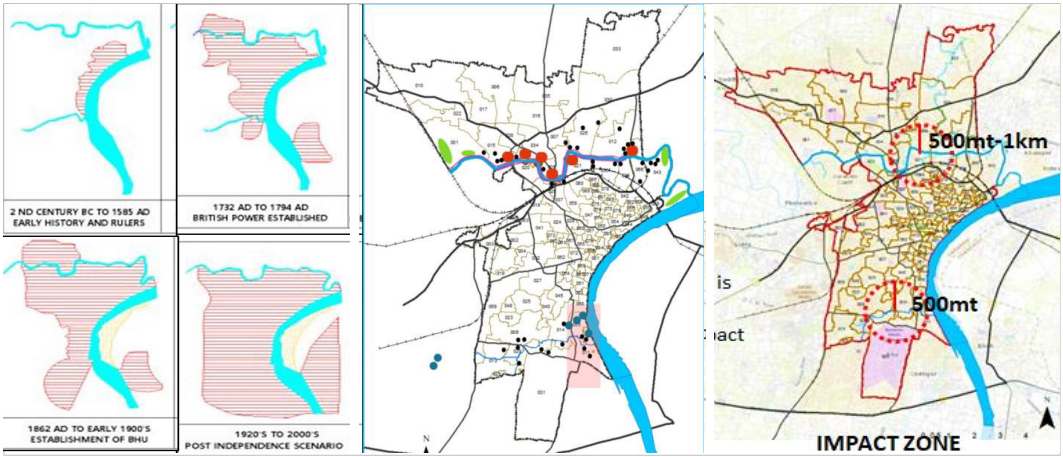
Urban River Zoning Regulations

For river zoning regulations, no active flood plain area has been demarcated. There is provision for a green belt along the Rivers Varuna (50m) and Assi (25m) on both sides, where no development is permitted. Other uses, activity control permits, and prohibited activity zones have been designated for only River Ganga. There is no such provision for Rivers Varuna and Assi.

Delineation of the River Fringe as an Impact Zone

The river fringe, situated in close proximity to the river, holds considerable influence. To identify the most affected zone that surrounds the river, the river fringe was defined based on six parameters. Each parameter underwent analysis, and the cumulative impact zones were demarcated. The six parameters that were considered include the growth of the city, population density, economic activities, social, cultural, and recreational aspects, environmental considerations, and slope contour. After evaluating these parameters, the impact zones for the Rivers Varuna and Assi were established to be within 500–1 km.

Map 2: Delineation of River Impact Zone in Varanasi



Source: Based on Primary Survey, 2022

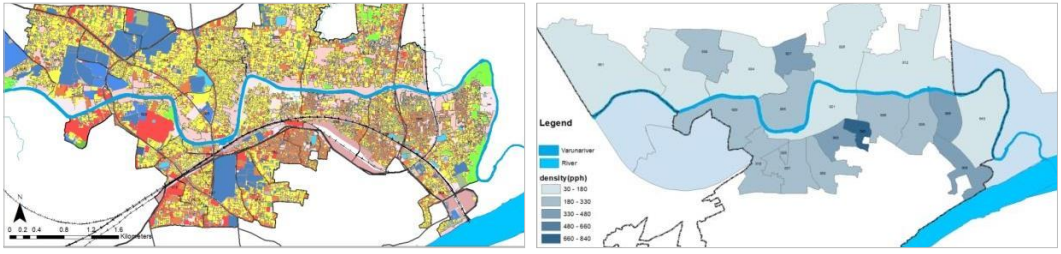
Analysis of the Varuna River Fringe (Impact Zone)

The River Varuna, a minor tributary within the Ganga River system, originates from Mailhan Jheel in Phulpur tehsil of Prayagraj district. After coursing approximately 200 kilometres, it converges with the Ganga River just northeast of Varanasi, the capital of Uttar Pradesh. The river traverses through the districts of Prayagraj, Bhadohi, and Varanasi, covering a total length of 11.58-km within the city limits of Varanasi. Currently, groundwater recharge is limited, and the primary source of water is industrial and domestic wastewater that is discharged into the Varuna River system.

Profile of the Varuna Fringe Area

The Varuna River fringe area encompasses a total of 20 wards which extend within a buffer zone of 500–1 km on both sides of the river. As of 2021, the population in this area was 275,670, with a population density of 231 people per square mile. Map 3 illustrates the distribution of land use and density along the Varuna River fringe area (500–1 km).

Map 3: Land Use and Density along River Varuna



Source: Author, 2022

Slum and Industrial Area in the Outskirts of Varuna River

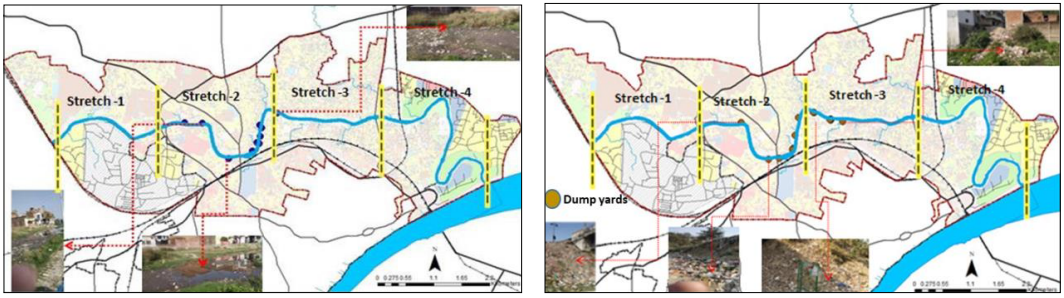
There are eight slums on the outskirts of River Varuna. With a total population of 8970, these slums are well served by community toilets around the area. When we surveyed the slum, the problem faced by a few of them was that those within 50 meters of the river were badly affected during flood time and had to shift to other places. In the Varuna Fringe Area, there are small-scale household dyeing industries of Banarasi Sarees, handlooms in Jalalipura and Kazzakpura, and automobile industries in Raza Bazar, which release effluents into the drains.

Major Issues in the Varuna River Fringe Area

Sewerage and Solid Waste Analysis

As per the primary survey it was found that drains and small scale industries out of which automobile are discharging effluent in Raza Bazar drain which trapped but small household industries are going into sewer which is directly discharge into Varuna. There are few stretches where sewerage overflow is there in the vicinity of River Varuna hence polluting the river. Dump yards near the river is another cause for the pollution of the river. Below, Map 4 depicts the sewerage overflow and dump yard location near the river

Map 4: Sewerage Overflow (Left) and Dump Yard Location (Right) on the Outskirts of River Varuna



Source: Primary Survey, 2022

Total 24 drains within the River Varuna catchment area were identified as discharging directly into the river. The wastewater from these connected drains is directed to the Sewage Treatment Plants (STP) at Dinapur and Goithaha. Conversely, the discharge from untapped drains, amounting to approximately 88 MLD, is directly released into the River Varuna. Survey results indicate that the primary factor that is negatively affecting the water quality of the Varuna River is sewage discharge, followed by urbanization, waste disposal, agricultural runoff, and other factors, as illustrated in Table 4. Some people have also stated that hotels are directly discharging their wastewater into the river.

Table 4: Existing Drain Details on the Outskirts of River Varuna

Name of Drain	Drain Meeting River Varuna	Status	Types of Drains	Observation (Primary Survey)
Phulwaria Nallah	Right Bank	Untapped	Domestic	7.6MLD flow is diverted to STP Dinapur, while 140 MLD & excess flow is discharging into River Varuna
Sadar Bazar Nallah	Right Bank	Untapped	Domestic	Flow is diverted to STP Dinapur
Raja Bazar Nallah	Right Bank	Tapped	Mixed	Flow is diverted to STP Dinapur
Telia Nallah	Right Bank	Tapped		Flow is diverted to STP Dinapur
Nakki Nallah	Right Bank	Tapped		Flow is diverted to STP Dinapur
Central Jail Nallah	Left Bank	Untapped	Domestic	Tapping provision provided but drains directly meeting in River Varuna, slightly blackish green water observed with slight flow
Chamarutha Nallah	Left Bank	Tapped	Mixed	Drain is directly meeting River Varuna
Banaras Nallah	Left Bank	Untapped	Domestic	Discharged into River Varuna
Orderly Bazar Nallah	Left Bank	Untapped	Domestic	Waste water containing slaughtering activity observed
Khajuri Colony Nallah	Left Bank	Untapped	Domestic	Tapping provision was found but damaged during inspection however, drain was directly meeting River Varuna due to choking of bar screen
Hukulganj Nallah	Left Bank	Untapped	Mixed	Drain was directly meeting River Varuna as the tapping provision is in a damaged condition
Nai Basti Nallah	Left Bank	Untapped		Drain directly meeting in River Varuna
Sarang Talab Nallah	Left Bank	Partially Tapped		Flow is diverted to STP Goithaha but currently in a damaged condition.
Narokha Nallah	Left Bank	Partially Tapped		On ground it is discharging into the river
New Drain Identified (Primary Survey)				
Drain 1	Right Bank	Untapped	Mixed	Drain is directly meeting in River Varuna (Hotel wastewater)
Drain 2	Right Bank	Untapped	Mixed	Drain is directly meeting in River Varuna (Hotel wastewater)
Drain 3	Right Bank	Untapped	Domestic	Drain is directly meeting in River Varuna
Drain 4	Right Bank	Untapped	Domestic	Drain is directly meeting in River Varuna
Drain 5	Right Bank	Untapped	Domestic	Drain is directly meeting in River Varuna

Name of Drain	Drain Meeting River Varuna	Status	Types of Drains	Observation (Primary Survey)
Drain 6	Right Bank	Untapped	Domestic	Drain is directly meeting in River Varuna
Drain 7	Right Bank	Untapped	Domestic	Drain is directly meeting in River Varuna
Drain 8	Left Bank	Untapped	Domestic	Drain is directly meeting in River Varuna
Drain 9	Left Bank	Untapped	Domestic	Drain is directly meeting in River Varuna
Drain 10	Left Bank	Untapped	Domestic	Drain is directly meeting in River Varuna

Source: Primary Survey, 2022; Jal Kal Varanasi

Flood and Associated Vulnerability Assessment

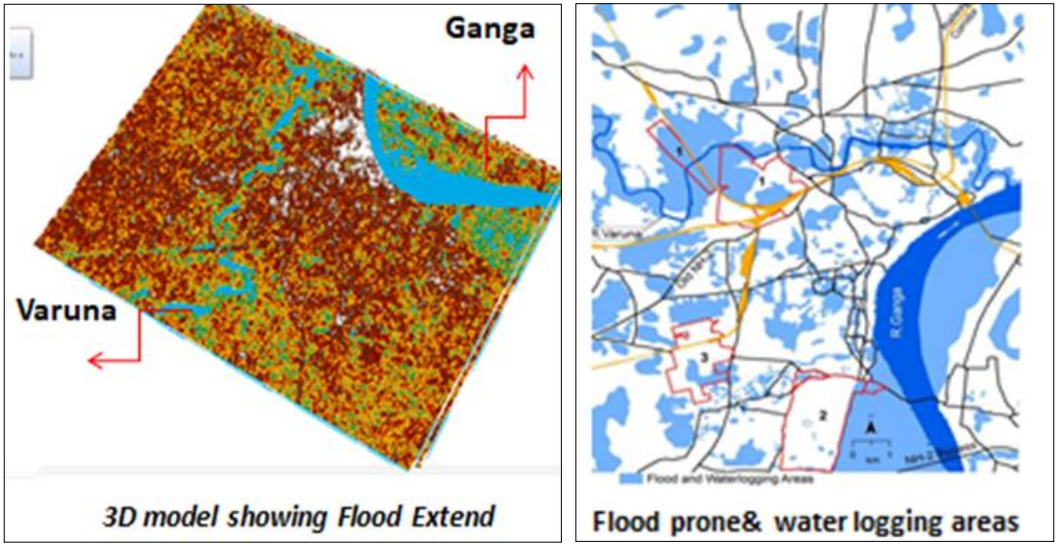
Varanasi experiences annual flooding, with the Highest Flood Level (HFL) reaching 74 meters for the Ganga River. Since the Varuna River flood is influenced by the backflow from the River Ganga, the flood level remains consistent. The danger level is set at 71 meters; however, data from Table 5 reveals that in the past decade, the flood level has surpassed the established danger level.

Table 5: Showing Highest Flood Level in Varanasi

Year	2013	2016	2018	2019	2020	2021
HFL	72.63	72.56	70.18	71.95	71.69	72.32

Source: Irrigation and Water Resource Department, Varanasi

Map 5: Flood Prone Areas around Varuna River



Source: Author, 2022

Moreover, through the modeling assessment that was conducted approximately 200 meters from the River Varuna stretch, identified significant areas as highly susceptible to flooding, while others exhibited moderate vulnerability. Table 6 presents the flood-affected regions on the outskirts of the Varuna River, along with the total population at risk. Additionally, during the survey, when

individuals were asked about the impact of floods on their income, 66% reported an adverse effect, while 33% claimed no impact. Those experiencing income impacts were predominantly farmers whose agricultural lands get submerged during floods.

Table 6: Showing Vulnerable Population in the Fringe Area of River Varuna

Flood Zone Elevation (in m)	Area (Sq km)	Population Affected
70-74 m	0.35	1350
74-75 m	10.99	8420

Source: Primary Survey, 2022

Assessment of the Quality of Living in the Varuna River Fringe Area

Furthermore, the quality of life for residents in the Varuna River Fringe area was evaluated by using parameters that were related to river issues derived from the ease of living index. Each parameter received a score out of 5 points, and the overall score was calculated. A score of 1 indicated poor quality of life, 2 signified fair quality, and 3 suggested excellent quality. The assessment conducted at the Varuna stretch revealed that the quality of living in the Varuna River Fringe area is fair.

Table 7: Quality of Life Assessment of River Varuna Fringe Area

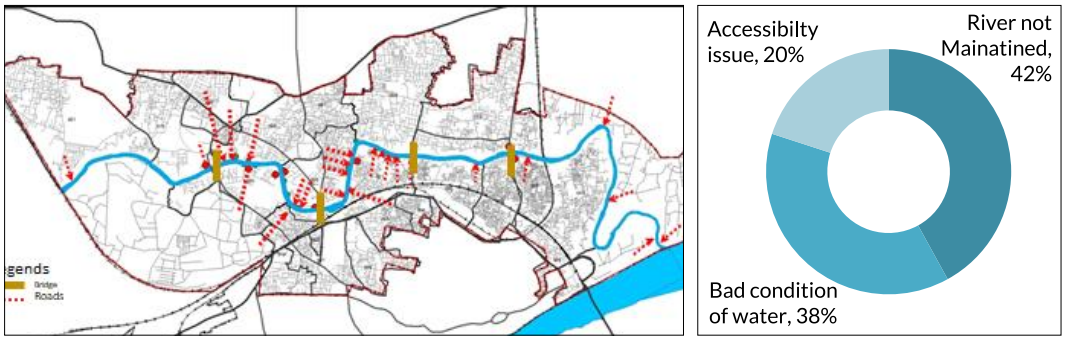
Quality of Living	Scoring
1. WASH & SWM	
Households Connected to Sewerage Network	3
Amount of Wastewater Treated	1
Households with Piped Water Supply	4
2. SUSTAINABILITY	
2.1 Environment	
Water Quality	3
Hazardous Waste Generation	2
2.2 City Resilience	
Has the City Implemented Local Disaster Reduction Strategies	2
Number of Deaths due to Disasters	5
3. HEALTH	
Prevalence of Diseases	
Water-borne Diseases (Jaundice, Typhoid)	3
Vector-borne Diseases (Malaria, Dengue)	3
TOTAL SCORE	1.833

Source: Primary Survey, 2022

Accessibility Analysis in Fringe Area of River Varuna

Map 6 illustrates the roads that are accessible from the river, but a majority of these are katcha roads, with only two ramp roads throughout the stretch. There are four bridges connected on each side. When respondents were asked about accessibility during the visit, 20% reported issues, while 38% attributed poor water and river conditions as reason for disconnecting from the river. Concerning the condition of roads in the area, only 10% considered them to be in good condition, and merely 12% reported the presence of street lights.

Map 6: Accessibility in the Fringe Area of River Varuna



Source: Primary Survey by the Author, 2022

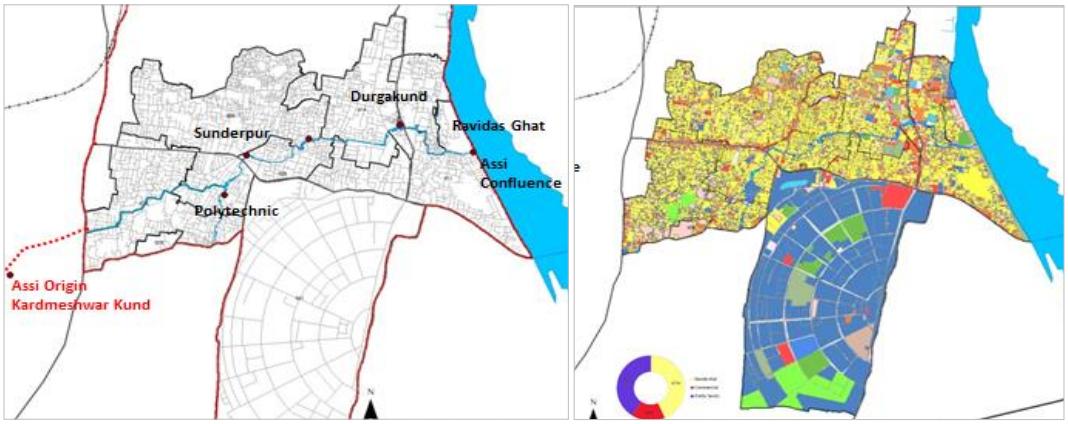
Analysis of the Assi River Fringe (Impact Zone)

The Assi River is believed to originate from Kardmeshwar Kund in the vicinity of Kandwa in Varanasi city, flowing approximately 5.5-km through an unconstructed channel before merging into the River Ganga. The average width of the Assi River is 5.50 meters which is subject to variations due to unauthorized encroachments. Historically, it used to confluence with the River Ganga at Assi Ghat, but presently, it is diverted through Nagwa Mohalla to safeguard Assi Ghat from the impacts of direct pollution. Passing mainly through residential areas towards Ganga, the Assi River traverses the city's historical section, encompassing Assi Ghat and BHU, surrounded by renowned kunds and ponds.

Profile of Assi Fringe Area

Total population of the area in 2021 was 118,871, and the density was 231 pph, as shown in Map 7. Population density is higher near the Assi River. The total number of wards in the area are seven. Total slums in the area are seven with a population of 4597. The eastern part of the stretch has maximum tourist footfalls because of the presence of the Durga Temple, Sankat Mochan, and BHU, as shown in Map 7. The famous Pachkoshi Yatra trail also follows the Assi River.

Map 7: Origin and Land Use of Catchment Area of Assi



Source: Author, 2022

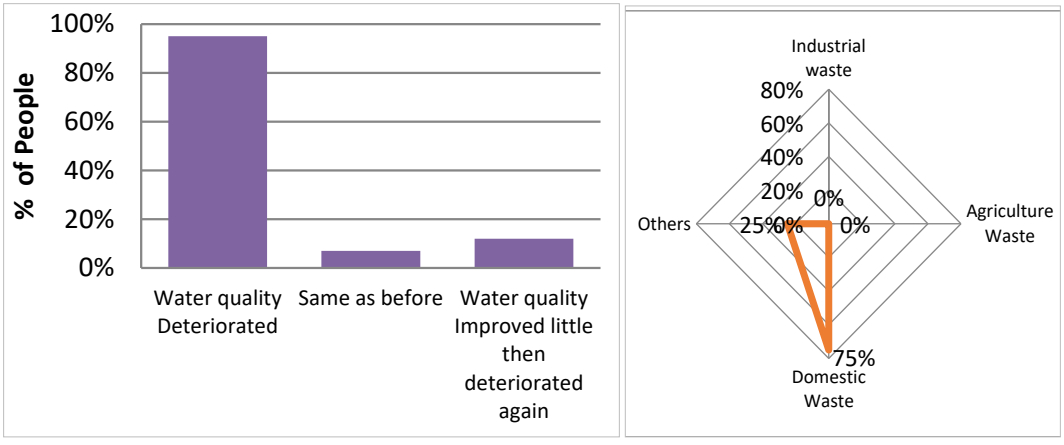
Existing Drainage Condition

The Assi River is served by 13 drains, as illustrated in Map. These drains predominantly carry domestic waste, thus contributing to a total discharge of 198 MLD. The primary characteristic of the Assi River is its course through residential and historical areas of the city, with a width of 5.5-meters.

Situational Analysis: Findings from Primary Survey

In the River Assi area, a comprehensive survey of 124 samples revealed that 91% of respondents believed that the water quality had deteriorated over time. Additionally, 12% acknowledged that the government efforts had initially improved the water quality, but due to a lack of sustained efforts, the water has degraded again.

Figure 5: Condition of the Water Quality of Assi River



Source: Primary Survey, 2022

During the survey, 43% participants described the water quality as very poor, while 58% deemed it poor. When asked about the reasons for this assessment, 75% attributed it to domestic waste, highlighting that houses discharged their wastewater and disposed their garbage into the river. Solid waste is reported to be uncollected within the streets.

Quality of Living in the Assi River Fringe Area: An Assessment

An assessment of the quality of life of the residents in the Assi River Fringe area utilized parameters related to river issues from the ease of living index. Each parameter received a score out of 5 points, and the final score was calculated accordingly. A score of 1 indicates a poor standard of living, 2 signifies fair quality of life, and 3 suggests an excellent quality of life. Table 8 illustrates the assessment that was conducted in the River Assi stretch, revealing that the quality of living in the Assi River Fringe area is fair.

Table 8: Quality of Living in the Fringe Area of River Assi

QUALITY OF LIVING	Scoring	After
1. WASH & SWM		
Households Connected to Sewerage Network	3	5
Amount of Wastewater Treated	2	4
Households with Piped Water Supply	4	5
2. SUSTAINABILITY		
2.1. Environment		
Water Quality	2	4
Hazardous Waste Generation	4	4
2.2. City Resilience		
Has the City Implemented the Local Disaster Reduction Strategies	2	4
Number of Deaths due to Disasters	5	5
3. HEALTH		
Prevalence of diseases		
Water-borne Diseases (Jaundice, Typhoid)	3	5
Vector-borne Diseases (Malaria, Dengue)	3	5
Total Score	2.5	3.2

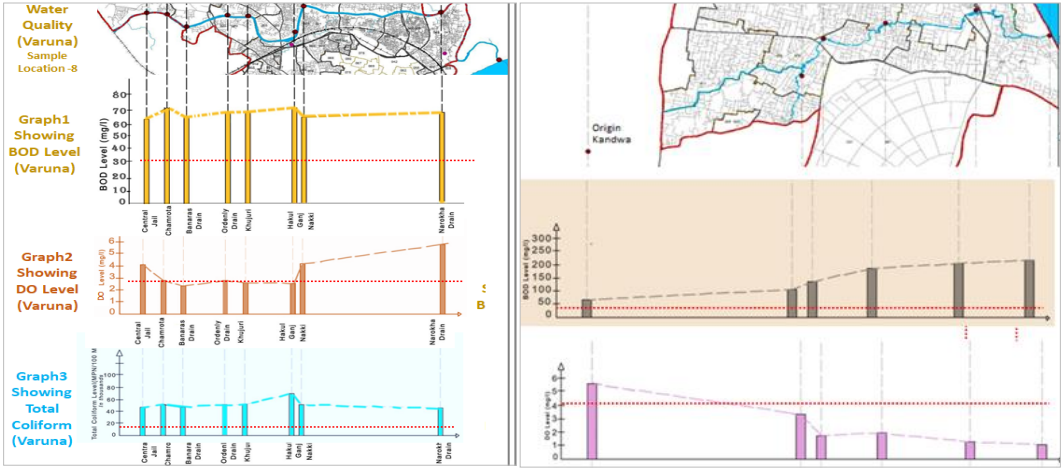
Source: Author, 2022

River Level Analysis

Water Quality Analysis of Rivers Varuna and Assi

Total eight sample locations were surveyed for the water quality analysis shown in Figure 6. Various water quality assessment parameters were considered, like pH value, BOD, DO, and COD. This is the average value of 12 months.

Figure 6: Sample Location and its Parameter Values at Varuna and Assi Rivers



Source: Author, 2022

As per standards, the Biological Oxygen Demand (BOD) for drinking water should be less than 5 mg/L, and in treated wastewater that is disposed in water bodies it should be below 30 mg/L. However, all sample locations in the Varuna stretch exhibit values higher than the standard. Healthy water has Dissolved Oxygen (DO) concentrations above 6.8–8 mg/L and DO levels below 3 mg/L are generally concerning. The survey identified four sample locations in Varuna where the DO levels were less than 3, indicating an unsuitable environment for aquatic plants and animals. Coliform count, between the desirable limit of 500 and the maximum permissible limit of 2,500 Most Probable Number (MPN) per 100 MLD, was observed in both the rivers. Similarly, for Assi River, all parameters surpass the standard values. Consequently, the water quality in the Assi River is more degraded than in the Varuna River, necessitating improvement in the water quality of both the rivers.

Urban River Management (URM) Index for Varanasi

The Urban River Management (URM) Index, measured on a scale of one to five, serves as a snapshot of the situation, which aids in monitoring the URMP implementation and developing overall strategies and policies for improvement (NIUA, 2020b). Various indicators, as depicted in Figure 7, have been considered for Varanasi, assessing how the city manages both the rivers, aside from River Ganga, where numerous interventions have already been implemented.

Figure 7: Indicators for URMP

Source: NIUA, 2020b

In this case, two scores were computed: one with integrated values for all the three rivers and the other considering only Rivers Varuna and Assi. Subsequently, the scoring was conducted for all 10 indicators, as shown in Figure 8.

Figure 8: Urban River Management Index for Varanasi

Indicator 1: floodplain management score

SNO.	Desirable Features	Flood Plain Points	Scenario 1 (All 3 River) A	Scenario 2 (Varuna & Assi B
1	Floodplain boundaries clearly demarcated	15	5	3
2	Floodplain boundaries protected through embankments, roads, or other means	5	4	3
3	Demarcation of no development zone adjacent to the river in the active floodplain	5	4	4
4	Strict enforcement in no development zone	10	5	2
5	Updated database of existing land use in floodplain available	10	8	1
6	Master Plan has clearly indicated permissible and non-permissible activities in the floodplain/river zone	15	5	2
7	All regulations in the Master Plan are enforced (10 points if at least 50% of the regulations are enforced)	15	10	7
8	Presence of river friendly landscaping (e.g. constructed wetlands, bios wales, etc.)	5	1	2
9	Strict monitoring mechanism in place	5	3	2
10	No solid waste dumping on river banks	10	5.5	1
11	Only organic farming practiced in river zone	5	2	2
		Total	52.5	30
	I1=Floodplain Management score =		*3*	*1*

Indicator 2:Net Dissolved Oxygen (DO) score

$$\text{Net DO} = \frac{\text{DO outlet} - \text{DO inlet}}{\text{DO inlet}} \times 100 \text{ where } DO_{outlet} = \text{DO at outlet; } DO_{inlet} = \text{DO at inlet}$$

Scenario 1= -0.111 , Scenario 2 B= -5.2

I2 = Net Dissolved Oxygen (DO) Score 2 = 3

Indicator 3:: Water Body Revival Score

How to measure the indicator:

$$\text{Water body revival factor} = \frac{\text{Number of water bodies in acceptable condition}}{\text{Total number of water bodies}} \times 100$$

= water body revival factor = 25.68

I3 Water Body Revival Score = *score = 1*

Indicator 4: Riparian buffer score

Note:-Only riparian buffer of width greater than 7.5m shall be considered in the analysis of this indicator

I4: Riparian buffer score =0

Indicator 5: wastewater reuse score

$$\text{Wastewater reuse factor} = \frac{\text{Wastewater reused annually}}{\text{Wastewater generated annually}} \times 100$$

= 20.022

= wastewater reuse factor scenario 1 = 20.22 , scenario 2=0

I5: wastewater reuse score s1 =1 , s2=0

Indicator 6: Return flow score

$$\text{Return flow factor} = \frac{\text{Actual annual return flow} - \text{Committed annual return flow}}{\text{Committed annual return flow}} \times 100$$

Indicator 7 :Eco-friendly riverfront score

S.no	Desirable Features	Eco-Friendly Riverfront points	Scenario 1	Scenario2
1	The riverfront project is a source of revenue for the ULB	15	6	1
2	The riverfront project supports commercial activities like shops, stalls,	15	8	8
3	The riverfront project has a footfall of more than 100 people/day	10	9	9
4	The riverfront project is listed as an attraction spot on travel-related websites	15	12	2
5	The riverfront project has good waste management facilities	15	8.5	8
6	The riverfront project is made up of predominantly natural material	10	3	2
7	The riverfront project has soft landscaping elements	10	1	5
8	The riverfront project does not block the natural path of the river	10	6	4
		Total	53.5	39
	Eco-friendly riverfront score =		3	2

Urban River Management Index for Varanasi Analysis

Indicator 8: River economy score

S.no	Desirable Features	Scenerio1	Scenario 2
1	The river is used for navigation (inland or inter-city) or cruises	Only ganga	NA
2	The river is used for water sport activities	(only ganga)	NA
3	The river supports livelihoods of fisher folk	30%	40%
4	The river support livelihoods of farmer	20%	40%
5	The river supports religious and/or cultural tourism	80%	Partial 20%
6	Any other economic use that can be verified	-	-
	I8= River economy score =	5	4

If the river has 3 or more economic uses	river economy score = 5
If the river has 2 economic uses	river economy score = 4
If the river has 1 economic use	river economy score = 2
If the river has no economic use	river economy score = 1

Indicator 10: Citizen Engagement score

S.no	Desirable Features	Scenario 1	Scenario 2
1	Participation of citizens in river health monitoring	2	1
2	Participation of citizens in river clean-up activities	3	2
3	Presence of citizen groups for river conservation	2	1
4	Presence of citizens in committees related to river decisions	1	1
5	CSR funds invested in river-related projects	1	1
6	Any other citizen engagement modality that can be verified	1	1
	I10= Citizen engagement score =	2	1

Urban River Management Index

$$URM_{index} = \frac{I_1 + I_2 + I_3 + I_4 + I_5 + I_6 + I_7 + I_8 + I_9 + I_{10}}{10}$$

A= 2.44 (All three rivers)
B= 1.5 (Only Varuna & Assi)

Indicator 9:Citizen sensitization score

S.no	Desirable Features	Citizen Sensitization points	Scenerio1	Scenario 2	
1	Dedicated Information, Education and Communication (IEC) programme for the river-related aspects	20	18	14	s2
2	River related sensitization is part of existing citizen awareness raising programmes	15	12	5	s1
3	Presence of a dedicated website for river-related aspects	5	0	0	
4	Use of traditional sensitization media (e.g. hoardings, murals, competitions, radio)	10	6	3	
5	Use of social media for river-related sensitization	10	4	1	
6	A dedicated river day for the city	10	8	1	
7	Earmarked budget for citizen sensitization	15	6	4	
8	Sensitization of school children through special events	10	7	7	
	Total		61	35	
	I9 Citizen sensitization score =		*4*	*3*	

URM_{index}	Interpretation	What it means
<1.5	Poor level of urban river management	The city is incapable of meeting the basic requirements for effective urban river management. The river is neglected and used indiscriminately without proper planning and management. There are serious concerns for all dimensions of urban river management.
1.6-2.5	Elementary level urban river management	Basic actions required to ensure urban river management are evident. However, there are still major gaps and serious concerns with regards to almost all dimensions of urban river management.
2.6-3.5:	Average level urban river management	The city has a satisfactory urban river management system. However, some dimensions of urban river management are still a cause of concern.
3.6-4.5	High level of urban river management	The city is well-placed with most of the dimensions of urban river management. The dimensions may not be at par with each other, but the overall situation is still nonetheless satisfactory.
4.6-5.0	Ideal level of urban river management	The city is an ideal example of urban river management. There are evidences of exemplary actions against every dimension of urban river management, suggesting that the plans and policies in regards to urban river management are working well.

Source: Author, 2022

The URM Index is calculated by adding all scores of the ten indicators:

$$URM_{index} = \frac{I_1 + I_2 + I_3 + I_4 + I_5 + I_6 + I_7 + I_8 + I_9 + I_{10}}{10}$$

A = 2.44 (all three rivers)
B = 1.5 (only Varuna and Assi).

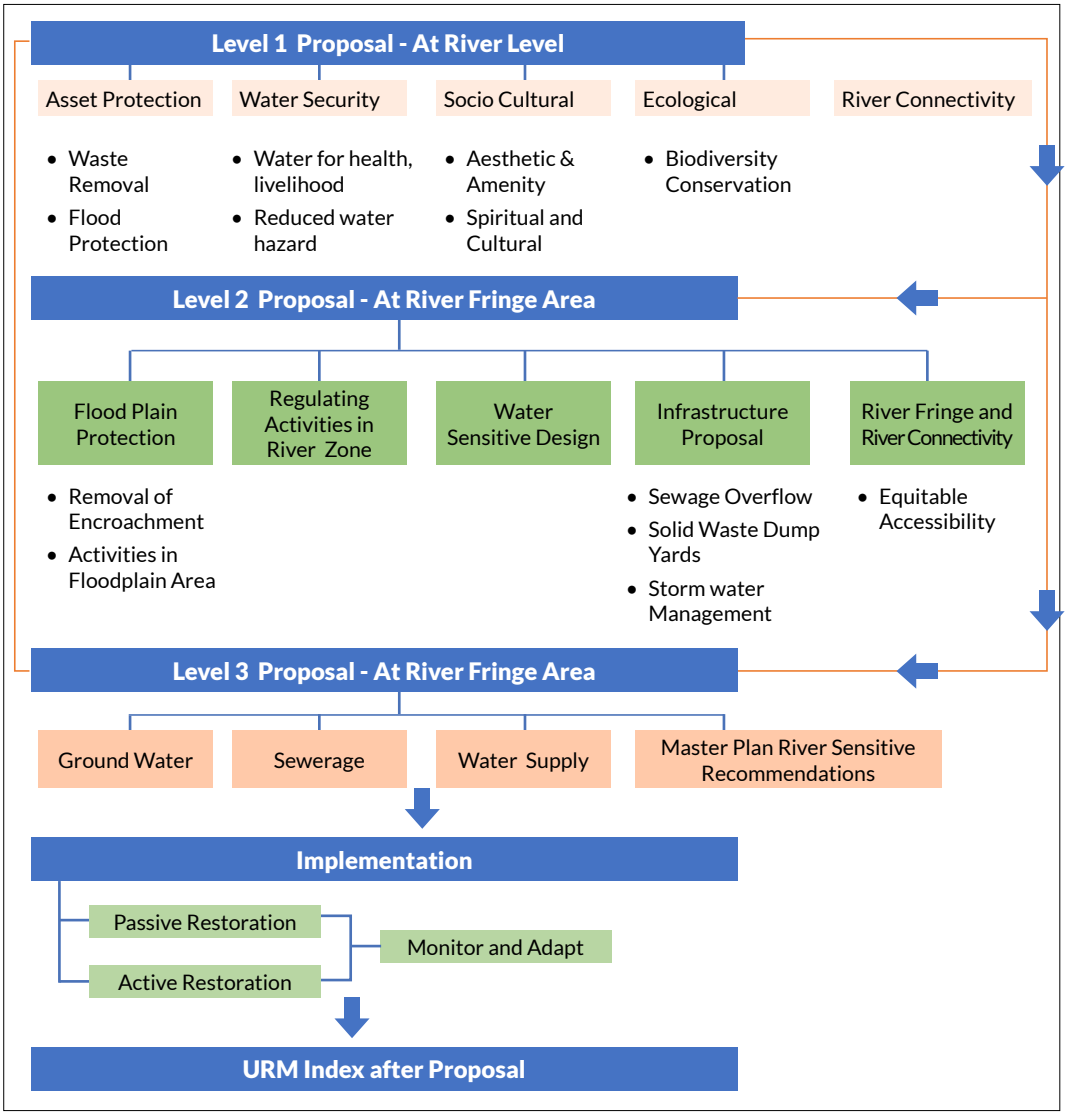
The URM Index for the city considering all three rivers shows that elementary-level urban river management is being done, whereas the URM Index considering only Rivers Assi and Varuna shows poor-level of urban river management.

The Proposal

The proposal is planned with the vision of creating an ecologically sensitive, resilient, recreational space along the Rivers Varuna and Assi that is accessible with clean water flowing through them. The overarching goal is to transform Varanasi into a city that prioritizes environmental sensitivity. The proposal takes into consideration a diverse range of parameters, encompassing physical, social, economic, environmental, and managerial aspects. The strategic solution has been outlined in Figure 9, where the recommendations are presented at three levels: river, river fringe, and the city. Implementation will occur at two levels: active restoration which will require field-level

interventions, and passive restoration which will involve policy-level recommendations. Table 9 shows the proposed interventions for both the rivers.

Figure 9: Approach for the Proposal



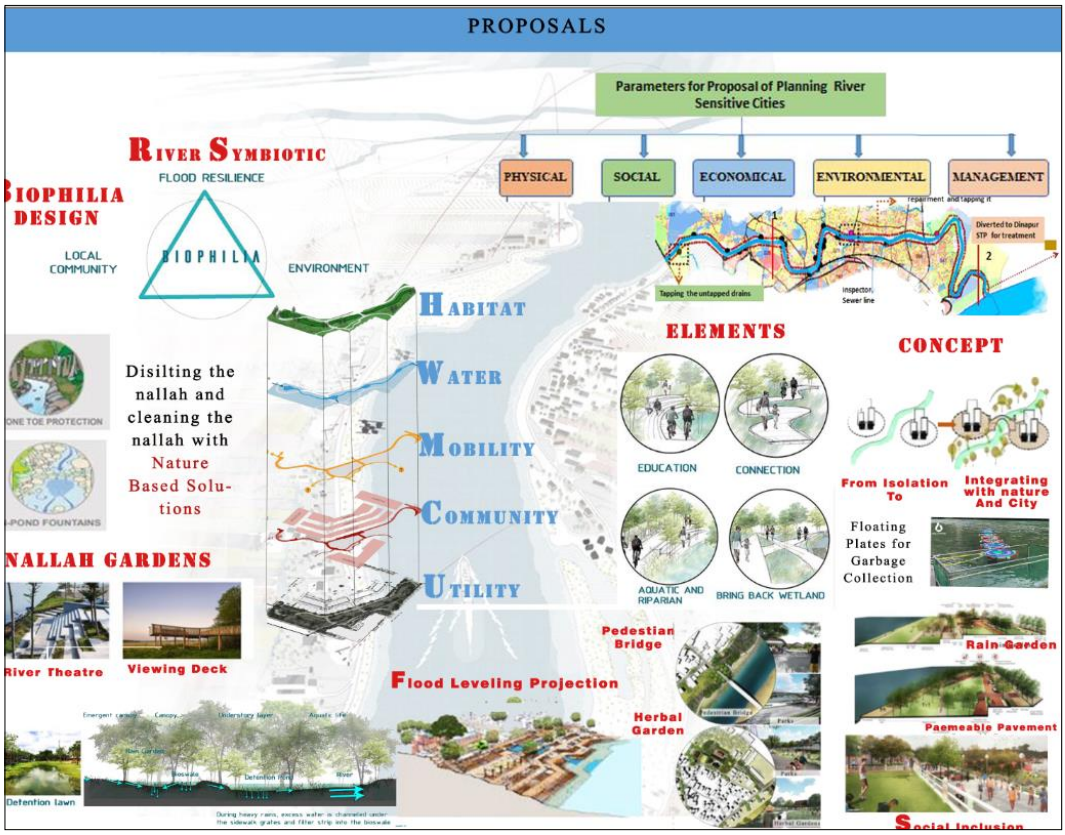
Source: Author, 2022

Table 9: Proposals

Proposals	
At the River Level	
AT VARUNA	**AT ASSI**
Untapped drains would be tapped and diverted to Dinapur STP, which is currently not practised	Nallah Gardens—Cleaning of the Nallah (Technique)
Desilting of rivers and strengthening embankments using desilted material	Construction of Wetlands - Four wetland projects have been proposed along River Assi
Vegetation Development and Microfiltration at the Embankments	Vegetation Development and Microfiltration at the Embankments
Channelizing the river and maintaining its width of 44 m.	
To accommodate extra spillover water, the river to be dredged and its depth to be increased.	
Ghats Amenities (toilets) and ritual spaces at the rest of the 5 ghats.	
5 Pedestrian bridges to connect one end of the river to the other and to connect temples.	
At River Fringe Area Level	
AT VARUNA	**AT ASSI**
Strategies to manage the floodplains	
• Assign a separate use zone category for the river and the floodplains. • According to the highest flood plain level, a prohibited zone of upto 50-75m from the Varuna River, a regulated zone of upto 100m, and a restricted zone of upto 150m are proposed.	Proposal for No Development Zone of 25m along both sides of the river, a green buffer of 25m width, a pedestrian walk zone and a green vegetation buffer with seating is proposed.
At City Level	
Sewerage Proposal	
Immediate Phase (2021–2026) - Renovation phase of the existing sewer pipelines, desilting to be done.	
Phase 2 (2026–2031) - Intercepting the drains, a new sewer line would be laid in district 4 and STP 141 MLD would be constructed in district 3	
Phase 3 (2031–2041) - Installation of smart sensor manholes and SCADA system, Upgradation of Dinapur STP and sewer network of 112km in district 4	

Source: Author, 2022

Figure 10: Various Interventions



Source: Author, 2022

Figure 10 illustrates multiple interventions that have been suggested at different levels. The proposed parameters for these interventions are derived from five indicators: physical, social, economic, environmental, and management.

Proposal for Fringe Area at River Varuna

Removal of Encroachments

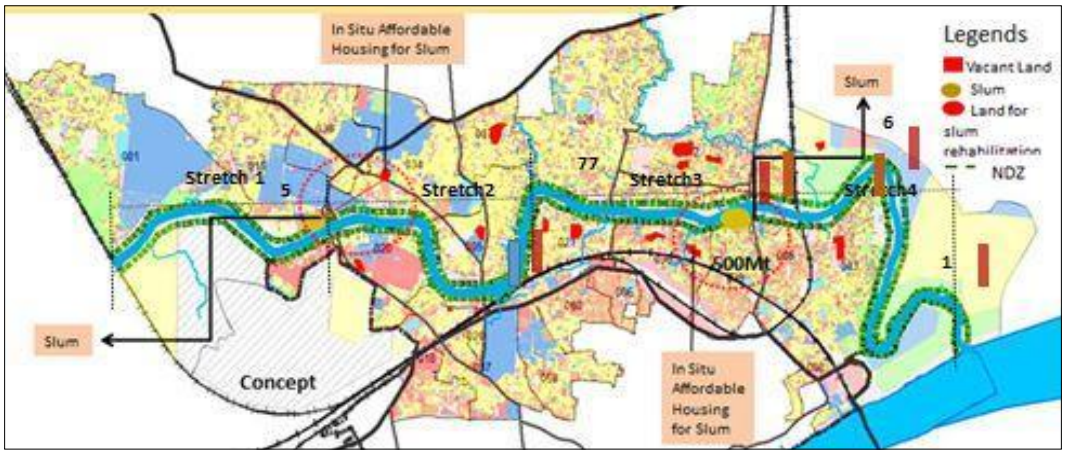
All development in the 50m NDZ will be removed. In situ Rehabilitation (Affordable housing) of three slums in the area (within range of 500m from their work area) has been proposed. The rest of the development will be resettled within 500-1km of their work space. Fourteen hotels cannot be removed so for them regulations will be imposed like no discharge of wastewater and water into the rivers.

Table 10: Encroachment and its Resettled Distance

Stretch	Encroachment on Left Bank	Encroachment on Right Bank	Resettled With Range of:
Stretch 1	22	52	200m
Stretch 2	90	45	1-km
Stretch 3	112	123	500m
Stretch 4	13	22	500m

Source: Author, 2022

Map 8: Proposed Location for Resettlements

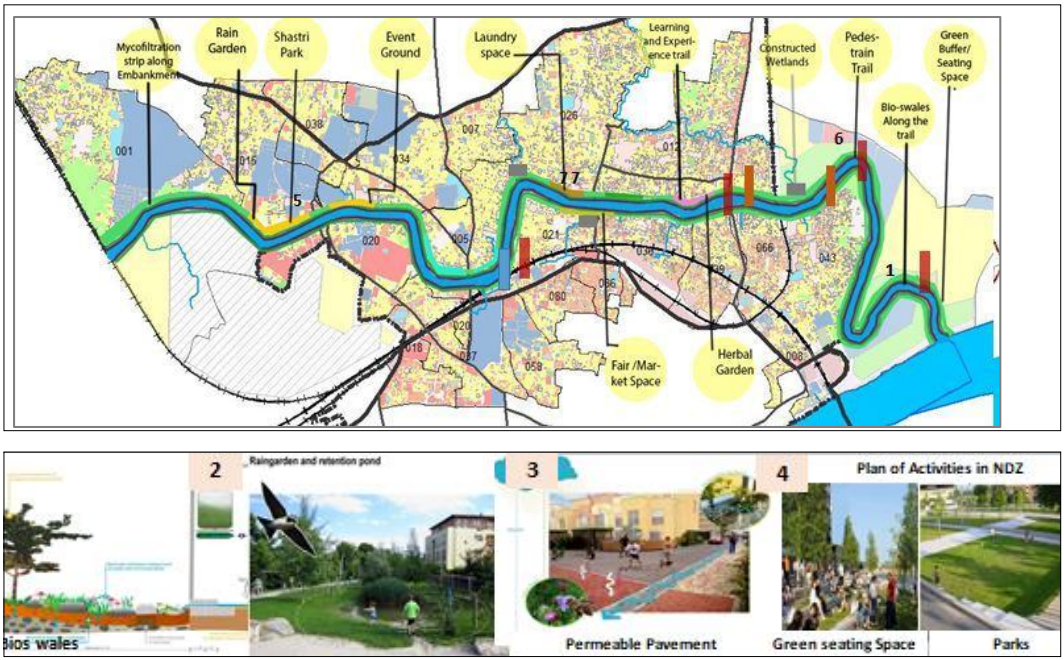


Source: Author, 2022

Proposal for Riverfront Development

Various activities along the riverfront have been proposed as permissible within the river zone. Suggestions include the establishment of parks to serve as leisure spaces for nearby residents, an event ground for temporary activities, and a learning space for educating people about nature, water, and its importance. Herbal gardens are also a part of the proposal. Instead of the previous unorganized fair market, a well-structured field and market space are now available for the residents of Chaukaghat area. Small dhobi ghats have been replaced with a systematic laundry space. Additionally, a rain garden has been incorporated to collect groundwater, and filter strips and bioswales are provided along the pedestrian trail. Permeable pavement is utilized for pathways, facilitating the percolation of water into the ground.

Map 9: Proposed River Front Activities



Source: Author, 2022

River Fringe Area Proposal for River Assi

Removal of Encroachments

All development within the 25-meter No Development Zone (NDZ) will be eliminated. In Situ Rehabilitation which involves the establishment of affordable housing, has been planned for two slums within a distance of 500 meters to 1.5 kilometres from their work area. The remaining developments will be relocated within 500 metres to 1 kilometre of their workplace. Resettlement will follow a model similar to the Kashi Vishwanath Corridor Project which offers both land and incentives to individuals. Table 11 outlines the extent of encroachment on both sides of the river and the corresponding range of resettlement.

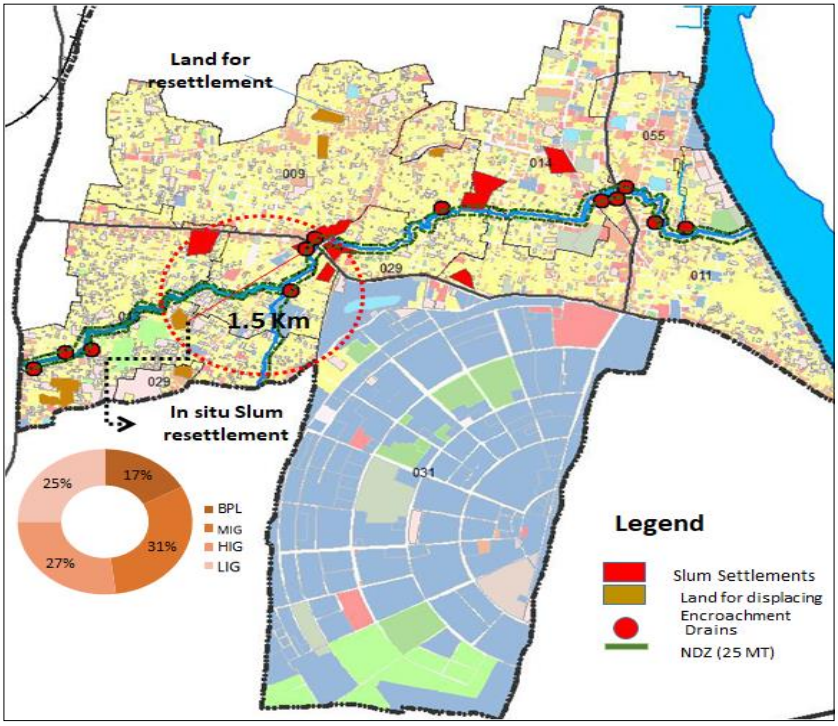
Table 11: Encroachment and its Resettled Distance

Encroachment	Encroachment on Left Bank	Encroachment on Right Bank	Resettled with Range of:
Assi	146	104	2-3 km
Slum	2		1.5 km

Source: Author, 2022

The plan encompasses activities within the 25-meter belt. It proposes a green buffer followed by a pedestrian pathway, and then provides a vegetation buffer with seating spaces.

Map 10: Proposed Location of Resettlements of Slums and Settlements



Source: Author, 2022

City Level Proposal

Proposal for Reuse of Treated Wastewater

As of now, the utilization of treated wastewater is minimal and restricted solely to gardening purposes. Table 11 outlines the sewage generated, with only 70-75 percent, equivalent to 263.25 MLD, undergoing treatment.

Table 11: Quantity of Sewerage Received and Treated Wastewater

Quantity of sewerage received	351	MLD
Quantity of treated wastewater generated for reuse (70-75% of sewerage)	263.25	MLD

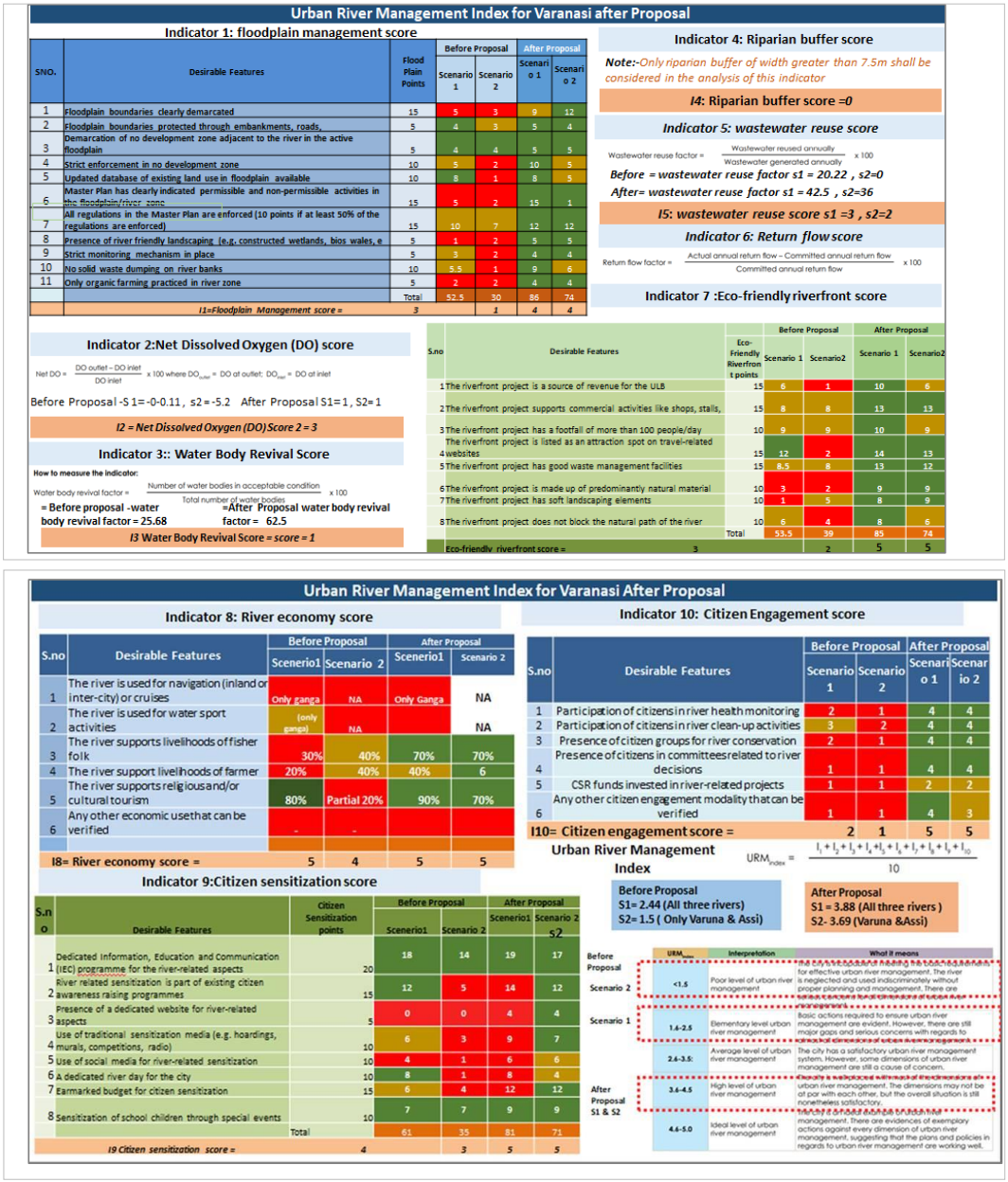
Source: Primary Survey, 2022

Following a priority-based approach, the treated water is then allocated among industrial, agricultural, and gardening purposes. The breakdown for treated water usage is: 89.5 MLD for industrial purposes, 123.7 MLD for agricultural purposes, and 50 MLD for gardening purposes.

Urban River Management Index for Varanasi after the Proposal

The URM Index has been recalculated to assess Varanasi's performance in river management post the proposed interventions. The indexing process was carried out by utilizing the following 10 indicators. Figure 11 shows the calculation of the index by various indicators after the proposal.

Figure 11: URM Index After Proposal



Source: Author, 2022

Urban River Management Index

Each indicator has a value between one and five. An average of all the indicators will yield the URM_{index}.

$$URM_{index} = \frac{I_1 + I_2 + I_3 + I_4 + I_5 + I_6 + I_7 + I_8 + I_9 + I_{10}}{10}$$

After the proposal:

URM Index score A= 2.44 (All three rivers before proposals)
URM Index score B= 3.88 (All three rivers after the proposals)

The URM Index for the city after considering the existing conditions shows that elementary level urban river management is being done, whereas the URM Index after the proposal shows that the city is well placed with most of the dimensions and is managing the river properly. Hence, the hypothesis created is justified: if any city manages its rivers with proper strategies and solutions, then the rivers will not face the issues that they are facing now.

Conclusion

Urban areas contribute significantly to the adverse effects on rivers. Therefore, it is crucial to design cities in a manner that minimizes these impacts by emphasizing a mutually beneficial relationship between urban areas and rivers. This study examined the assessment of Varanasi by highlighting various parameters for river management. It was concluded that the Urban River Management Index for the city, considering the existing condition, shows that elementary-level urban river management is being done, but after proposing interventions with respect to every parameter, the URM Index shows that the city is well placed with most of the dimensions and is managing the river properly.

It is essential for cities to align their development plans with consideration for the rivers by acknowledging the natural disturbance threshold. Worldwide, cities are increasingly recognizing the importance of prioritizing a 'nature first' approach for planning, which significantly influences the overall liveability of the urban spaces. At this juncture, the shift towards Nature-based Solutions is imperative.

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Conflict of Interest

Authors have no conflict of interest to declare.

Bibliography

Adam Rybka1, R. M. (2018). The river as an element of urban composition. INFRAEKO.

Gautam, J. (2013). Ground Water Brochure of Varanasi Districts, Uttar Pradesh. Retrieved from https://www.cgwb.gov.in/sites/default/files/2022-10/varanasi.pdf

Maciukenaite, J. (2013). The Role of the River in the City Centre and its Identity, Journal of Sustainable Architecture and Civil Engineering, 4 (5), DOI:10.5755/j01.sace.4.5.4820.

Calovi, M., Seghieri, C. (2018). Using a GIS to support the spatial reorganization of outpatient care services delivery in Italy, BMC Health Serv Res, 18, 883, https://doi.org/10.1186/s12913-018-3642-4.

NIUA (2020a). Mainstreaming Urban River Management into Master Plans, New Delhi.

NIUA (2020b). A Strategic Framework for Managing Urban River Stretches in the Ganga River Basin (URMP), New Delhi.

School of Planning and Architecture (2015). Sustainable development of Heritage city, Varanasi.

Singh, R. P. B., Rana, Prem Bahadur (2018). Urbanisation in Varanasi and interfacing Historic Urban Landscapes: a special lecture, at Conference: National Seminar on "Urbanization in Indian History": 5–6 January 2018.

WWF (n. d.). Managing Rivers Wisely: Lessons from WWF's work for integrated river basin management, Retrieved from https://wwfeu.awsassets.panda.org/downloads/managingriversintroeng.pdf as on May 7, 2023.

WWF (2018). Valuing Rivers: How the diverse benefits of healthy rivers underpin economies - Guide to Preparing River Basin Management Plans for Medium and Minor Rivers.

Indian National Trust for Art and Cultural Heritage (INTACH) (2020). Making Rivers Flow, New Delhi.