Sponsored Thesis Project Competition on

"RE-IMAGINING URBAN RIVERS"

Season- 3

Project Title : Leveraging River-Centric Planning for Rejuvenation of Eutriphicated Segment of Yamuna River in Mathura City through Citizen Engagement and Self-Financing Model of Urban Planning

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PREFACE

Throughout human history, rivers have played an indispensable role, deeply intertwined with cities. Cities have reaped substantial advantages from rivers, including reliable water supply and effective flood control, while also contributing to the preservation of rivers' natural integrity. However, urbanization and industrialization have compounded the challenges. The proliferation of impermeable surfaces disrupts the hydrological cycle, diverting pure rainwater away from groundwater replenishment and directly into polluted rivers. To understand this relationship, the Yamuna River has been extensively studied. The assessment reveals that the water quality in the Himalayan and Upper Segment of the Yamuna River meets established standards and is deemed to be satisfactory. However, as the river flows downstream from the Delhi Segment to the Eutriphicated Segment, a large number of drains discharge untreated or partially treated domestic and industrial waste directly into the river, significantly degrading its water quality. This highlights the pressing need to address pollution sources along the river's course to safeguard its ecological well-being and the associated benefits it provides to cities and communities.

To ensure effective resource allocation and the implementation of an action plan, the Analytic Hierarchy Process (AHP) technique is utilized to prioritize the most vulnerable city along the Yamuna River between Delhi and the Eutriphicated segment. Mathura emerges as the city with the highest vulnerability based on the influence of twenty-six urban drivers contributing to river pollution. In response, a comprehensive study is conducted in Mathura, employing a handlebar survey and user perception analysis to identify and map various pain points experienced by the river. These pain points encompass issues such as holy bathing, lack of recreational spaces, garbage deposition, cremation activities on riverbanks, limited connectivity, drainage outlets, cleanliness concerns, parking constraints, and dilapidated surrounding buildings. Addressing these challenges through targeted strategies and interventions will promote the preservation and enhancement of the Yamuna River in Mathura, ensuring ecological well-being, improved quality of life, and a sustainable riverfront environment.

Following a thorough assessment of the current conditions and an evaluation of existing design patterns along Mathura's Yamuna River, a sustainable preservation strategy is proposed. This strategy revolves around a river-centric, multi-purpose riverside development that incorporates nature-based solutions to address the various challenges endangering the cultural heritage of the Yamuna. The proposed design includes diverse amenities such as recreational spaces, a pontoon bridge, ghat development, boating facilities, and a captivating light and sound show. Complemented by relevant policies and guidelines, the design aims to achieve ecological restoration, enhance water quality, preserve the cultural and historical significance of the area, provide public access and recreational opportunities, and foster economic development. The financial feasibility and cost recovery period of the proposed design are also meticulously evaluated. By implementing this design, decision-makers can embark on a financially sustainable project to revitalize and rejuvenate the river, benefiting both the environment and the community.

Key words: Rivers, Urbanization, Hydrological Cycle, Nature-based Solutions, Ecological Restoration, Cultural Heritage, Economic Development.

ACKNOWLEDGEMENTS

Firstly, my most resounding and sincere praises to Almighty God, for showering his blessings on me and giving me strength to accomplish my research work.

I would like to express my sincere gratitude to my guide **Dr. Chetan R. Patel**, Assistant Professor, Department of Civil Engineering, for giving me the opportunity to participate in Student Thesis Competition on Reimagining Urban Rivers. I am extremely grateful to sir for the valuable suggestions, and insightful thoughts that helped me put the ideas in a rational way to proceed with the research work. Sir's dynamism and skill to do multitasking has always inspired me to constantly improve my work. I am indebted for his constant support and inputs at all stages of research. With a deep sense of gratefulness, I am thankful to **Dr. Ravin M. Tailor**, Assistant Professor and PG In charge, Urban Planning section, Department of Civil Engineering and **Dr. Krupesh A. Chauhan**, Professor and Section Head, Department of Civil Engineering.

I would like to extend my gratitude to my NIUA mentor **Mr. Lovlesh Sharma** from NIUA for his guidance and encouragement. I would like to extend my sincere thanks to the entire team of **NIUA** and **NMCG** for giving me the golden opportunity to be a part of this esteemed competition.

From the bottom of my soul, I solemnly thank my father **Mr. Sudhir Bhargava** and mother **Mrs. Varsha Bhargava** for the affection, care, blessings and sacrifices they have made for educating me and making me who I am today. This endeavor wouldn't have been possible without the sustenance of family members. All the mental support and endurance came from the inspiring words of them that helped me work persistently in accomplishing the research work.

I would also like to thank my friends and classmates for their constant support. My deepest gratitude and appreciation to **Vipul Jain**, **Dhanashree Bedke**, **Shivani Kulshrestha,** and **Mikil Vankawala** for helping me whenever I got stuck with their inspiring words and constant help. I would thank my senior **Ms. Shivalika Arora** for giving healthy critics that helped me shape the dissertation work in a better way. A huge thank you to everyone who has supported me directly or indirectly.

VIDHISHA BHARGAVA

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ABBREVATIONS

AHP – Analytic Hierarchy Process
BOD – Biological Oxygen Demand
COD – Chemical Oxygen Demand
CETP – Common Effluent Treatment Plant
CGWB – Central Ground Water Board
CPCB – Central Pollution Control Board
CWC – Central Water Commission
DO – Dissolved Oxygen
EIA – Environmental Impact Assessment
ETP – Effluent Treatment Plant
FSI – Floor Space Index
GAP – Ganga Action Plan
GPI – Grossly Polluting Industries
HFL – High Flood Level
MoEFCC – Ministry of Environment, Forest and Climate Change
MVDA – Mathura Vrindavan Development Authority
NBS – Nature-based Solutions
NDCZ – No Development and Construction Zone
NGT – National Green Tribunal
NIUA – National Institute of Urban Affairs
NMCG – National Mission for Clean Ganga
NNMV – Nagar Nigam Mathura Vrindavan
NRCP – National River Conservation Plan
NWMP – National Water Quality Monitoring Programme
NWP – National Water Policy
RBF – River Bank Filtration
RCA – River Cities Alliance
RFP – Request for Proposal
SDG – Sustainable Development Goals
SEIA – Socio-economic Impact Assessment
SOR – Schedule of Rates
STP – Sewage Treatment Plant
SWM – Solid Waste Management
TDR – Transferable Development Rights
ULB – Urban Local Body
UPBTVP – Uttar Pradesh Braj Tirath Vikas Parishad
URMP – Urban River Management Plan
YAP – Yamuna Action Plan

GLOSSARY OF TERMS

Term	Definition
Biodiversity	The variety and abundance of living organisms in a specific habitat or ecosystem, including the variety of species present.
Ecological Restoration	Ecological restoration is the deliberate process of aiding the recovery and renewal of damaged or degraded ecosystems to bring them closer to their original, healthier, and more sustainable state.
Erosion	The wearing away of land and soil by natural agents, such as water flow, which can lead to changes in riverbeds and banks.
Hydrology	The scientific study of the distribution, movement, and properties of water in the Earth's atmosphere and on its surface, including rivers and other water bodies.
Non-point Source Pollution	Pollution that comes from diffuse sources, such as agricultural runoff or urban stormwater, which can negatively impact river water quality.
Riparian Zone	The interface between land and a river or stream, characterized by unique vegetation and ecological functions that are crucial to river health.
River Basin	The geographical area drained by a river and its tributaries, encompassing all land and water resources that contribute to the river's flow.
River-Centric Planning	An approach to river management and conservation that prioritizes the health, well-being, and sustainability of the river ecosystem as the central focus.
Riverside Development	Riverside development involves planning and constructing projects along riverbanks to create attractive urban spaces that benefit communities while preserving the natural ecosystem.
River Ecology	River ecology is the study of the interrelationships between living organisms and their environment within river ecosystems.
River Health	The overall ecological condition and resilience of a river system, assessed through various indicators like water quality, biodiversity, and habitat structure.
River Pollution	River pollution refers to the contamination of rivers with harmful substances, adversely affecting water quality and the health of aquatic ecosystems.
River Rejuvenation	The process of restoring or revitalizing a river's natural hydrological and ecological functions to enhance its health and sustainability.
River Zone Regulation	River zone regulation refers to the management and control of specific areas or zones along riverbanks, often through zoning laws and regulations, to promote sustainable development and protect the environment and communities.
Urbanization	The process by which an increasing proportion of a country's population becomes concentrated in urban areas (cities and towns).
Water Quality	The chemical, physical, and biological characteristics of water, which are critical for assessing river health and supporting diverse aquatic life.

CHAPTER 1: INTRODUCTION

1.1 General

Rivers have been playing a significant role in the history of civilization. Cities and rivers are connected inherently in so many ways. Cities receive numerous tangible and intangible advantages from rivers, such as a guaranteed water supply, flood regulation, and more. On the other hand, cities also help in preserving the natural character and profile of rivers. This intrinsic connection between rivers and cities have always been fulfilled by rivers but cities on the other hand fail to match this commitment (Strategic Guidelines for Making River-Sensitive Master Plans, 2021).

Urbanization is anticipated to have a negative, considerable impact on river hydrology. Increased paved areas cause the peak flow to occur in a relatively short period of time, which causes drainage networks to get congested and rivers to flood. The declining capacity of the basin to retain water may be the cause of the rising tendency of higher peak floods. While flooding is frequent in the river during the monsoon season, the river's flow during the dry season is insufficient to meet the basin area's demand for water (Kumar et al., 2020).

With an area of more than 366,223 km^2, the Yamuna basin is a highly fertile and grain-yielding region, especially the areas in Haryana and western Uttar Pradesh (Kumar et al., 2020). It starts from Yamunotri Glacier and is around 1370 kilometers long overall and joins the Ganges at Allahabad (Misra, 2010). The Yamuna is important to the Indian economy. Rapid industry, urbanization, and agricultural activity have over-utilized basin resources (Kumar et al., 2020). Yamuna River has been categorized into five sections based on hydrological and ecological factors: the Himalayan, Upper, Delhi, Eutriphicated, and Diluted segments, given in Table 1. The water quality of the Yamuna River is satisfactory and meets established standards in the Himalayan Segment. However, as the river progresses downstream from the Delhi Segment to the Eutrophicated Segment, numerous drains discharge untreated or partially treated domestic and industrial waste into the river (Misra, 2010).

Table 1: Segments of River Yamuna (Misra, 2010)

River Segments	Segment Area	Approx. Segment Length
Himalayan Segment	From origin to Tajewala Barrage	172 km
Upper Segment	Tajewala Barrage to Wa-zirabad Barrage	224 km
Delhi Segment	Wazirabad Barrage to Okhla Barrage	22 km
Eutriphicated Segment	Okhla Barrage to Chambal Confluence	490 km
Diluted Segment	Chambal Confluence to Ganga Confluence	468 km

The primary focus of this research is to prioritize the most vulnerable city between Delhi and Eutriphicated segment of Yamuna River using AHP technique by ranking them based on the basis of twenty-six urban drivers that contribute to river pollution. The study reveals that Mathura is the most vulnerable city. Subsequently, in Mathura, a handlebar survey and user perception study are

conducted to identify and map the various pain points faced by the river. These challenges include lack of recreational spaces, waste deposition, no parking space, cremation activities on riverbanks, holy bathing, polluted drains, etc. To mitigate these challenges, a sustainable preservation strategy is proposed in the form of a river-centric multi-purpose riverside development using nature-based solutions.

The proposed design encompasses various amenities, such as recreational spaces, a pontoon bridge, ghat development, boating facilities, a light and sound show, etc. along with some policies and guidelines. This design aims to facilitate ecological restoration, improve water quality, preserve the cultural and historical significance of the area, provide public access and recreational opportunities, and support economic development. Furthermore, it is evaluated that total project cost using nature-based solutions is 47,58,76,138.9 which will be recovered in 6 years without taking any grants from government. The implementation of this proposed design will assist decision-makers in developing a self-financially viable project for the rejuvenation of rivers.

1.2 Need of study

In order to clean up Yamuna River, government has launched several programmes such as Namami Gange, Yamuna Action Plan, etc. These programmes blocked almost all the drains, dumping untreated effluent into the river, resolving Yamuna's local issue, but still there are some issues which are global in nature. To understand the global problem of Yamuna pollution, a user perception survey was conducted in Mathura city. During survey, it was found that 70% people consider river as active and vibrant, 100% people believes that main source of pollution for river is industrial discharge and upstream Delhi segment. 80% people see river Yamuna as clean and beautiful as it is their holy mother whereas 20% consider it dirty and drain. Moreover, 80% people believe that places like Vishram ghat and connecting spaces need to be strengthened and more recreational spaces should be provided. 20% people says that some connectivity should be provided between Durwasa Rishi Temple and Vishram Ghat. During the study, a very peculiar characteristics was observed for Yamuna River that no one was throwing garbage into the river as it is their holy mother but when they were asked whether they may drink its water, they were quite hesitant because they believe the river contains some kind of industrial pollution.

Furthermore, it was discovered that there was formerly biodiversity in the river, but they are no longer present owing to ecological imbalance and presence of pollutants. The prime cause for bad quality of River Yamuna water in Mathura is Delhi segment. Untreated or partially treated domestic and industrial effluents get discharge into the river, degrading its water quality. This polluted water flows downstream, entering the Eutriphicated Segment (Misra, 2010). Although, people are not throwing garbage into the river, but site such as Dhruv Tila has lots of waste. There were further concerns with the rivers, such as on the occasion of "Yum-Dwitiya", a special bath is organized on the Vishram Ghat of Mathura, where lakhs of devotees come to take bath. There is lack of recreational spaces and large areas to accommodate pilgrims, where they can enjoy, etc.

Also, as per the report of CPCB 2021, the dissolved oxygen (DO) content should be greater than 5 mg/L, whereas at Upstream Mathura, it is reported to be average 2.45 mg/L. The biochemical oxygen demand (BOD), as per the CPCB standards should be less than 3 mg/L and it is reported

as average 18.65 mg/L at Upstream Mathura. The fecal chloroform should be less than 2500 MPN/100 mL and it is reported as average 460200 MPN/100mL at Upstream Mathura. These standards shows that the water quality in Yamuna River in Mathura is very poor and makes it unfit for drinking (Central Pollution Control Board, 2021).

Thus, it is needed to rejuvenate the river, provide recreational spaces and techniques for effective stormwater management to reduce the load on ground water, provide non-motorized connectivity between two sides of the river and riparian zones for ecological restoration and promote activities for generating river-based economy.

1.3 Study Area

The two main segments considered for research are Delhi and Eutriphicated Segment, as shown in Figure 1. Among these two segments, the research focuses on identifying the most vulnerable city based on various urban drivers polluting the river. On the basis of this ranking, Mathura city is selected for providing city-specific proposals, for river rejuvenation and generation of river-based economy.

Mathura, a city in Uttar Pradesh, is situated about 50 km north of Agra, 145 km southeast of Delhi, around 11 km away from the town of Vrindavan, and 22 km from Govardhan, occupying an area of 28.5 km^2. The Mathuraites consider the Yamuna River in Mathura as a sacred river (*About District | District Mathura, Government of Uttar Pradesh | India*, 2023).

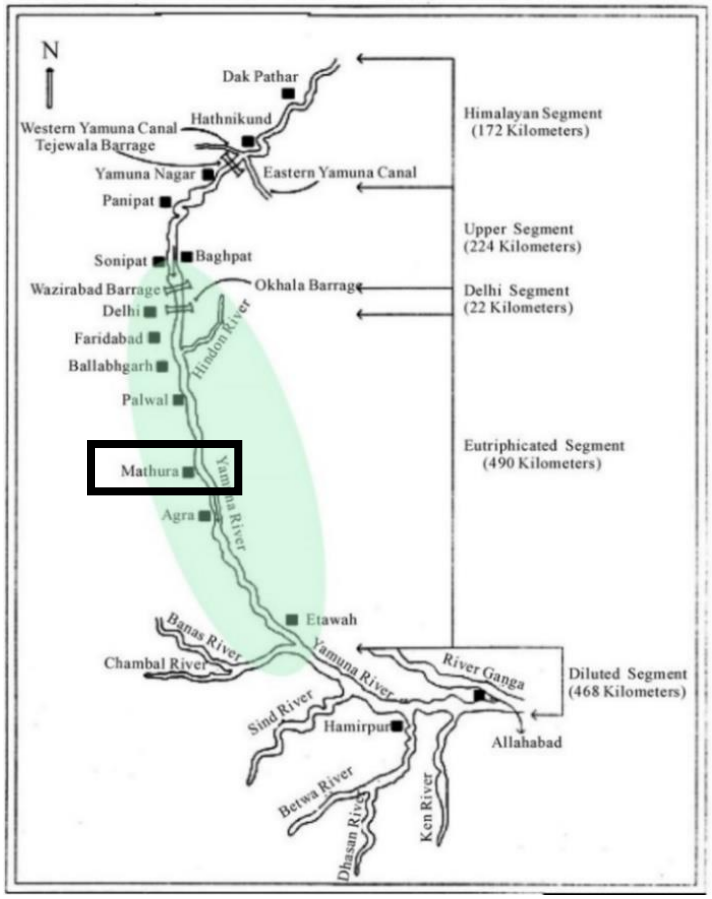


Figure 1: Study Area (Misra, 2010)

1.4 Aim & Objectives

The aim of this dissertation is to propose and assess the financial feasibility of a river-centric multi-purpose riverside development using nature-based solutions for the most vulnerable city of Delhi and Eutriphicated Segment of Yamuna River.

The Objectives to achieve the mentioned aim includes:

- To study the characteristics of Yamuna River by studying various literatures and conducting handlebar survey and user perception study.
- To identify the most vulnerable city in Delhi and Eutriphicated segments of Yamuna on the basis of various urban drivers polluting river along with identification and mapping of pain points in that city.
- To propose a river-centric plan in the form of a multi-purpose riverside development considering nature-based solutions for Yamuna River in Mathura.
- To assess the financial feasibility of the proposed river-centric planning of Yamuna River in Matura through innovative principles of self-financing tool and citizen engagement.

1.5 Scope

The research will focus on studying two segments of River Yamuna, namely the Delhi Segment and Eutriphicated Segment, along with conducting a detailed study of Mathura city to provide city-specific proposals. Furthermore, the financial feasibility of the proposed design will also be assessed. However, socio-economic impact assessment (SEIA), environmental impact assessment (EIA), details of testing of BOD, COD, etc. are not covered in this study and can be carried out as future scope of study.

1.6 Methodology

The flow chart shown in Figure 2 depicts the methodology adopted to achieve the objectives.

- Defining aim, objectives, need, and scope for the study.
- Various literatures including research papers, guidelines, norms, acts, and policies will be studied to identify the factors affecting river and most polluted segments of river Yamuna.
- Then prioritization of most vulnerable city among selected segments will be carried out using AHP technique on the basis of weights of various urban drivers polluting river.
- On the basis of these studies, proposals in the form of multi-purpose riverside development, river-centric plan, nature-based solutions, river-based economy, self-sustaining financial model, and policies and strategies, will be proposed, followed by assessing the financial feasibility of the proposed project.
- Then, stakeholder consultation will be carried out and review and feedback will be taken from various stakeholders. After incorporating required changes, proposals will be finalized and suggestions would be given to ULBs for improvement.

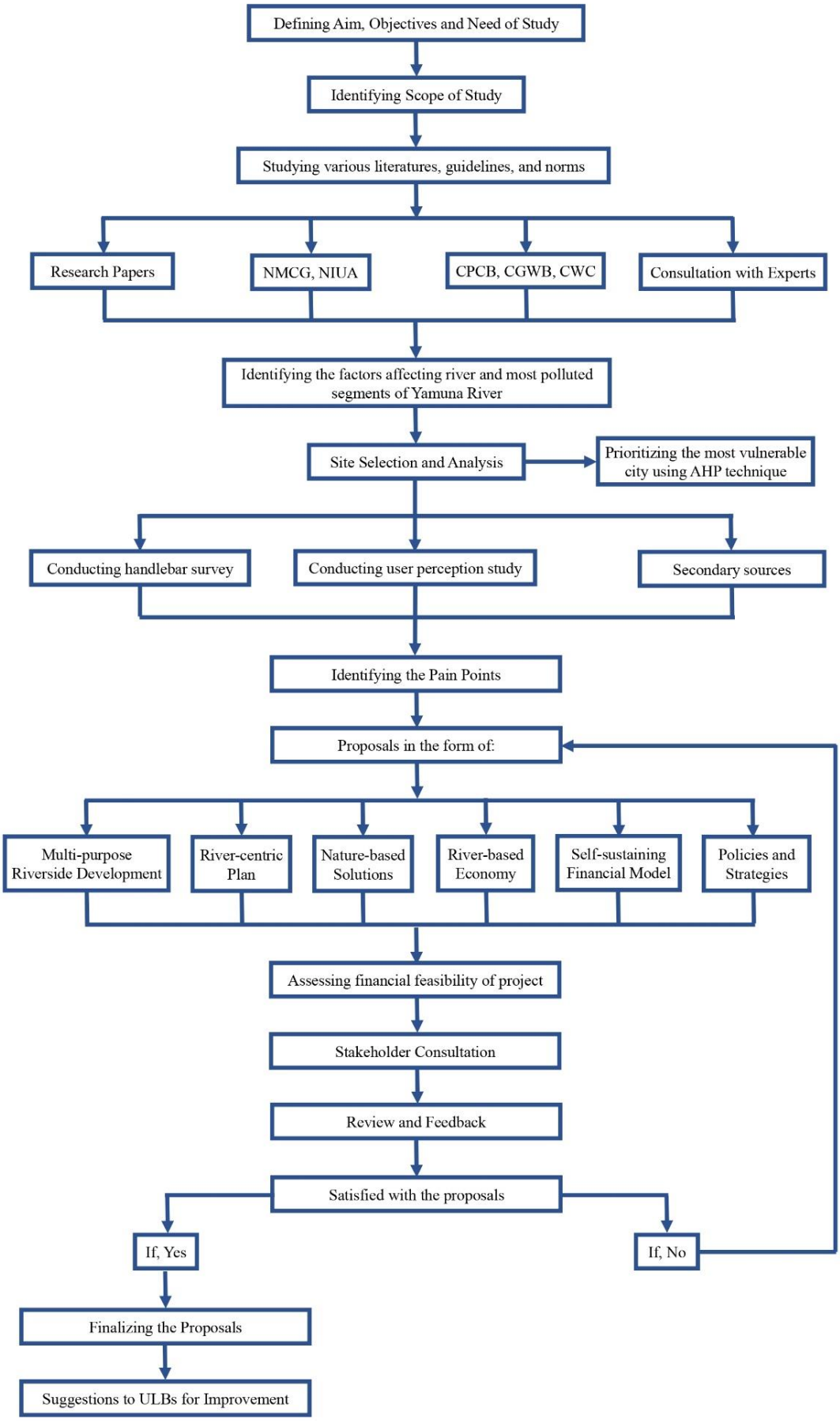


Figure 2: Line of Action to be Followed

1.7 Chapterization

- **Chapter 1: Introduction**

This chapter includes general information about Yamuna River pollution and the threats and challenges faced by it. It also includes need of study, aim, objectives, scope of study, methodology and chapters organization.

- **Chapter 2: Literature Review**

This chapter includes review of various research papers, journal papers and documents that were referred to study river ecology, pollution of rivers, policies and guidelines, strategies for conservation of river, and components of river-centric plan.

- **Chapter 3: Study Area Profile**

This chapter gives the detailed overview of the site selected for study i.e., Mathura city and Delhi and Euthriphicated Segment. The location, demography, climatic conditions, water quality standards, etc. for Mathura city have been discussed.

- **Chapter 4: Prioritization of Most Vulnerable City along River Yamuna**

This chapter includes the prioritization of most vulnerable city in Delhi and Euthriphicated segment along river Yamuna. This prioritization is carried out using weights of various urban drivers polluting river.

- **Chapter 5: Data Collection for Mathura City and Mapping of Pain Points**

This chapter includes collection of data for Mathura city through user perception study, and handlebar survey, along with identification and mapping of pain points.

- **Chapter 6: Proposals**

This chapter provides proposal for the selected region / area according to need and function. This includes the policy framework, design of site and envisaged outcomes.

- **Chapter 7: Financial Feasibility of Project**

This chapter delves into assessing the financial feasibility of the proposed design. It provides detailed information on expenses, revenue sources, and cost recovery strategies for the project.

- **Chapter 8: Conclusion and Future Scope of Study**

This chapter provides the overall summary of existing and proposed condition, with some concluding remarks on design and its accuracy. Future scope of this research is also discussed in this chapter.

CHAPTER 2: LITERATURE REVIEW

2.1 General

This chapter will include a details study about history of rivers, river ecology, river pollution, sources of pollution of River Yamuna, various guidelines formed in this direction such as, guidelines on National River Conservation Plan, guidelines on River-centric Urban Planning, guidelines on Urban River Management Plan and guidelines on River City Alliance, thorough study of all the components to conserve the river, etc.

2.2 History of Rivers

Rivers are bodies of water that have been channelized to flow in a specific direction, having an impact on our culture and civilization. In the beginning of human evolution, rivers were the only supply of water. Throughout history, many civilizations, were established along the riverbanks due to the benefits they provide. Even in today's technologically advanced and scientifically advanced world, several cities, including Haridwar, Rishikesh, Ayodhya, and Varanasi, are only well-known because of the rivers that flow through them. Celebrating festivals such as Kumbh Mela and Makar Sankranti by taking a dip in rivers not only serves as a form of celebration but also serves as a means for ordinary people to preserve a tradition and safeguard the rivers, which play a crucial role in human survival. Later, men developed a daily genetic bond with the river, and as a result, rivers came to represent our culture and way of life. Consequently, they are viewed as our mother and as lifelines (Singh, 2018).

2.2.1 River System of India

According to (D. Sen Singh, 2018), three river systems exist in North India, including

1. Ganga River System

These rivers serve as drainage for various regions of the Ganga Plain, which is one of India's primary physiographic zones located between the Peninsular Plateau in the south and the Himalayas in the north. This region is highly populated, accounting for almost 40% of India's population due to its fertile soil, accessible water, flat terrain, and favorable climate. Groundwater is the primary source of water for household, agricultural, and industrial applications. However, the quality of both surface and underground water is being degraded by industry.

2. Indus River System

The Indus/Sindhu, which is the longest river in Asia, originates near Mansarovar Lake and flows through the Karakoram in Tibet, the Ladakh Himalaya, and Nanga Parbat in the western Himalaya, all of which are regions with active tectonics. After covering a distance of around 3180 kilometers, it finally flows into the Arabian Sea.

3. Brahmaputra River System

Brahmaputra River crosses the border of for major countries including, Bangladesh, Bhutan, India, and China. It comes from the Chemayungdung Glacier and drains into the Bay of Bengal after crossing 3000 kilometres.

2.3 River Ecology

According to (Srivastava, 2007), a river possesses both abiotic and biotic characteristics. Abiotic factors include anything non-living in the vicinity that still has an impact on the river. The temperature of the river, its oxygen content, its pH, and how quickly or slowly it moves, are some of the examples of abiotic features of river. On the other hand, biotic factors are the living organisms, along with plants, living in the river. The biotic components include planktons, macro zoobenthos, fishes, mammals, algae, etc.

According to their geographical locations and origins, (Srivastava, 2007) described the two categories of rivers. These are categorized as

(a) Himalayan Rivers and

(b) Peninsular River

While peninsular rivers are entirely monsoon fed, the rivers in the Himalayas are perennial and nourished by glaciers.

2.3.1 Perennial Rivers

The perennial rivers of the Himalayas in India are comprised of three main river systems: the Ganga, Brahmaputra, and Indus. These river systems have diverse catchments and offer different microhabitats from their headwaters to their mouths. The Ganga River system includes major tributaries like the Yamuna, Ghghara etc. The Brahmaputra River system includes major tributaries like the Dibang, Lohit, etc. Similarly, the Indus River system has the Beas and Sutlej as major tributaries. However, only a small part of the Indus river's drainage basin is located within Indian territory while the majority of the river flows through Pakistan.

2.3.2 Peninsular Rivers

The hydrological characteristics of peninsular rivers can vary significantly, including water level, current velocity, and discharge, depending on the rainfall in their individual watersheds. Most peninsular rivers flow along the east coast and discharge into the Bay of Bengal, while a small number of west coast rivers, such as the Narmada, Tapi, Sabarmati, and Luni, flow in the opposite direction and discharge into the Arabian Sea. The flow of all peninsular rivers is determined by the monsoonal pattern, which can result in minimal flow to severe flooding and consequent changes in ecological and biological conditions.

2.4 River Pollution

(Hassan Al-Taai, 2021) emphasized that water is synonymous with life for all living organisms, and it is unimaginable for life to exist on earth without it. Water also serves as agriculture, food,

drink, and energy, all of which are essential to human existence and growth. It suffices to point out that water is a necessary component of life because it makes up at least 75% of the human body and 90% of plants. Water played a vital role in the advancement and affluence of ancient human societies. Historical evidence indicates that many civilizations flourished and developed near rivers. Water also plays a crucial role in tying various marine modes of transportation together, linking many regions of the world. The fact that water pollution leading to its depletion is a pressing issue pointed by (Hassan Al-Taai, 2021). Additionally, 88 developing countries, housing 40% of the world's population, face water scarcity as a major obstacle to their social and economic growth.

(Khan et al., 2021) correctly stated that most industries and commercial areas are situated close to water sources, such as rivers, oceans, etc., to make water more readily available as a lot of water is needed for both domestic and industrial uses. According to (Hudda, 2019), our rivers are now significantly more polluted than they were previously as a result of the country's rapid industrialization to support its expanding population and economy. Numerous water pollution sources combine to lower the overall quality of river water. Nearly all of India's rivers have been contaminated by industrial and home sewage as well as agricultural trash. The majority of these rivers now function as sewer drains. In India nowadays, illnesses are frequently caused by water-borne diseases. The negative effects of river pollution do not just affect people, but the animals, fish, and birds too. The ability of animals and fish species to reproduce in rivers is severely hampered by pollution, which will eventually lead to their extinction. There is no indication that river contamination is slowing down. It keeps growing every day.

There are instances where rivers have caught fire as a result of heavy pollution. This demonstrates the extreme pollution in our rivers. The presence of floating dead fish in a river, discolored river water, or a foul odor emanating from the river are all indications of river pollution (Hudda, 2019). The following factors may contribute to river pollution:

2.4.1 Acid rain

According to (Hassan Al-Taai, 2021), acid rain is primarily caused by the production of sulfuric and nitric acids, which are formed when sulfur and nitrogen oxides interact within raindrops. Some natural occurrences, like volcanoes, are blamed for the development of acid rain. Additionally, (Hudda, 2019) asserts that when acidic rainwater reaches the ground, it has a variety of impacts. It can cause the soil to emit dangerous elements like aluminum and heavy metals. These are typically harmless and inert, but under acidic conditions, many chemicals become poisonous to both plant and animal life. They can destroy fish and other aquatic life when they are washed into rivers, lakes, and streams.

2.4.2 Industrial pollution

According to (Hassan Al-Taai, 2021), factories are responsible for 60% of all pollutants found in oceans, lakes, and rivers. These pollutants include lead, mercury, copper, and tanning products. Most factories in developed and developing nations alike disregard industrial drainage regulations and dump their trash into the water. It should be emphasized that conventional water purification techniques do not get rid of pesticides, inorganic pollutants, or industrial pollutants. Using water

from rivers and lakes for cooling is one of the ways in which factories and power plants contribute to industrial pollution. Aquatic organisms and metabolic processes are negatively impacted by the rise in water temperature. (Hudda, 2019) mentioned that failure to regulate some industrial wastes quickly and rigorously could result in high future costs of dealing with their dangerous effects.

2.4.3 Agricultural pollution

According to (Hudda, 2019), heavy metal contamination has resulted from the extensive use of chemicals in agriculture, including pesticides and fertilizers. These contaminants, that lead to various health problems including cancer can be ingested by humans through the food they consume due to water pollution. The presence of chemicals or liquid manure in rivers results in a decrease of oxygen levels in the water. Insufficient oxygen levels make it impossible for any form of life to exist in the water body. Consequently, the river's character is permanently changed. Along with heavy metals, nitrate is another dangerous agricultural pollutant. Chemicals used in agriculture include nitrate, which enters rivers from the runoff of agricultural crops.

2.4.4 Oil Pollution

(Hudda, 2019), claimed that pouring substances like used motor oil and paint into rivers can also cause pollution that can be detrimental to aquatic life. When oil enters a river that is running slowly, it coats the entire surface with a rainbow-colored coating that keeps oxygen from reaching the water. Since the river lacks oxygen, it is biologically inert.

2.4.5 Dumping of Human Waste

According to (Hassan Al-Taai, 2021), toxic substances are released into rivers when human waste, animal carcasses, sewage, untreated factory waste, and garbage are dumped there. Moreover, the dumping of shipwrecks has led to the seepage of petroleum and chemical contaminants into seas and oceans. Another issue is the growth of weeds and aquatic plants in waterways, which can restrict the flow of water. Schistosomiasis and other diseases are caused by the stagnation and proliferation of snails.

2.4.6 Sources of sanitation

According to (Hassan Al-Taai, 2021), due to the lack of an integrated sanitation network in the majority of nations, sewage water is one of the biggest threats to public health. The main issue is that untreated effluent is being discharged into river, which poses a major health risk. Public health is also negatively impacted by the use of shit holes in places without a sanitation system. Particularly when it is left exposed or dumped in areas close to homes, it attracts mosquitoes and flies that spread numerous diseases.

2.5 Source of Pollution for River Yamuna

(Khan et al., 2021) highlighted the Yamuna River's extreme pollution. Domestic sources are responsible for more than 85% of the waste which is discharged altogether. The Yamuna River is heavily polluted due to various sources such as untreated sewage from residential and commercial areas, industrial waste, disposal of solid wastes, and immersion of idols. This pollution has resulted in the death of the river's ecological life and it can be considered as practically dead. Yamuna River

has primarily become an open drainage due to development and industrialization in the area. Haryana sends significant amounts of waste into the Yamuna River, along with other states, and is the primary cause of the river's pollution. Without effective waste treatment, 58% of Delhi's waste is dumped into rivers (Khan et al., 2021). Different heavy metals are present in pollutants that are released from residential and industrial sources. The current state of the river is a matter of great concern and immediate and strict measures need to be taken to clean up the river and reduce pollution. By the time the river reaches Uttar Pradesh, it is barely visible due to the extensive pollution, which has resulted in a hazardous foam covering most of its surface.

(Kumar et al., 2020) further added that Delhi is the largest contributor to pollution in the river, accounting for 79% of it. Agra, Mathura, and Panipat each contribute 9%, 4%, and 3% respectively, while Sonipat and Bhagpat add an additional 2%. The pollution in the river is mainly caused by solid waste, agricultural residue, washing of clothes, bathing, and open defecation in the catchment area. This has led to a decline in the quality of both surface and ground water. A tributary of the Yamuna called the Sahibi River was turned into the Najafgarh drain as a result of urbanization. Many researchers have emphasized on the quantification and classification of Yamuna River pollution, they are broadly classified as under:

2.5.1 Domestic Pollution

According to (Misra, 2010), Yamuna River, especially in the Delhi region, is one of the most polluted rivers globally, mainly due to the massive discharge of wastewater. (Kumar et al., 2020) emphasized that domestic waste makes up around 85% of the entire pollutant load. More than 0.4 mg/L of ammonia has frequently been detected in Delhi's Yamuna River, especially during the summer. Due to the ongoing dumping of residential wastewater from Palla to Etawah, the river has become severely contaminated.

According to (Bhargava, 2006), the city of Mathura, which has a population of approximately 3.5 lakh, is mostly located across the Yamuna River and has a natural slope in that direction. Only around 50% of the city is sewered. About 43 mld of wastewater are produced overall in the city of Mathura (million litres a day). Although 23 drains in Delhi have been tapped to pump wastewater through 5 pumping stations to sewage treatment plants with a total capacity of 28 mld (oxidation pond type) as part of the "Yamuna action plan," a considerable amount of the city's wastewater still flows directly into the river due to reasons such as overload, shock loads, rain, power outages, clogged drains, failed pumps, and poor management, etc.

2.5.2 Industrial Pollution

(Kumar et al., 2020) emphasized that Yamuna basin has experienced extensive industrialization. Several significant industrial cities, are located in the Yamuna basin. According to (Misra, 2010), the Yamuna River is a mailee (filthy) river with an endless supply of industrial facilities that discharge a massive volume of untreated water into the Yamuna. (Kumar et al., 2020) further added that wastewater from various industries such as sugar, distilleries, textile, food processing, chemicals, etc., is discharged into rivers through different types of drains, both treated and untreated.

According to (Bhargava, 2006), around 166 micro and small enterprises that involve in activities like saree printing, and manufacturing of metal products, located between Mathura and Vrindavan, release harmful chemicals, dyes, and other substances into the Yamuna with or without proper pre-treatment. Additionally, some local inhabitants carry out small-scale industrial activities in their homes, leading to the seepage of dangerous waste into the groundwater, which then flows into open drains that ultimately end up in the river.

2.5.3 Agriculture Pollution

(Kumar et al., 2020) highlighted the importance of agriculture as primary economic activity in the Yamuna basin. During the dry season, a significant amount of the riverbed is used for agriculture. (Misra, 2010) claims that agricultural activities such as groundwater and surface water irrigation are significant sources of contamination in the Yamuna River. Pesticides, fertilizers, and animal husbandry waste also contribute to water pollution. The washing of vegetables and disposal of farming waste also have a significant impact on the quality of water in the river. The presence of salt from irrigation water and agricultural waste are among the major factors that lead to pollution in the Yamuna.

(Bhargava, 2006) emphasized that the left bank of the Yamuna in the Mathura area is mainly utilized for farming purposes. To increase output and improve quality, farmers employ excessive amounts of chemical fertilisers, insecticides, etc. Thus, a significant amount of commercially produced fertilizers and pesticides used in agriculture end up in the river, thus polluting it.

2.5.4 Social Reasons

(Bhargava, 2006) emphasized that the Yamuna in Mathura is renowned for being a holy river. Devotees immerse poly bags filled with various holy items such as desecrated photographs, flowers, puja (worship) samagree (material), etc. into rivers at various ghats of Mathura such as Vishram Ghat, Swami Ghat, etc., adding to the ugliness and pollution by increasing the floating materials (organic, inorganic, and poisonous) in it. Additionally, (Kumar et al., 2020) noted that dead animals and adult human bodies are frequently discarded into rivers, which heightens the pathogenic contamination.

2.5.5 Solid Wastes

According to (Misra, 2010), solid wastes are undesired and discarded items that are in solid form; hence, proper management of these wastes is essential. One of the main issues with the Yamuna River is the dumping of solid waste and garbage. The main causes of this are the city's dense population and the disposal of solid waste and untreated wastewater into the river. Human faeces and cow dung are the main components of solid waste, which is produced by both authorized and unauthorized colonies in these cities.

(Bhargava, 2006) underlined that due to lack of disposal facilities, the problem of disposing solid waste (both residential and industrial) has grown extremely in Mathura. In the city, solid waste is piled everywhere, which also stops wastewater from discharging into the drains. As a result, the drains overflow, and the excess wastewater flows directly into the river rather than being treated. On the river banks near Old and New Bridge and even on the bathing ghats such as Jindal Ghat,

solid waste is frequently thrown. The unregulated disposal of solid waste results in unpleasant and unappealing scenes, and when it rains, the stormwater carries all the solid waste into the river. As per Nagar Nigam Mathura, 180-200 ton/day waste is collected from door to door in 70 wards of Mathura, but there is still lots of waste on the bank of river Yamuna in Mathura.

2.5.6 Mass Bathing by Devotees – Jindal Ghat

(Bhargava, 2006) highlighted that mass bathing at Mathura (on the Yamuna's right bank) occurs frequently throughout the year, particularly during "Yum-Dwitiya," when a large number of devotees bathed in the Yamuna River at Vishram Ghat. Unfortunately, there are no sanitary facilities along the river's banks. Due to this, a significant proportion of the transient population resorts to open defecation in the river catchment areas. Consequently, during heavy rains and overflow of drains, pathogenic and organic pollutants from the catchments enter the river. Furthermore, according to (Kumar et al., 2020), washing clothes near the Yamuna River causes an increase in inorganic, organic, and biological pollutants, leading to foaming. The presence of foam reduces the river's biological activity and slows down the rate of oxygen diffusion in the water.

2.5.7 Other Sources

According to (Misra, 2010), the Yamuna River is surrounded by multiple cities and small towns. The majority of these small villages and cities lack sanitary services. As a result, the majority of people use river catchment areas for defecation, which pollutes the river with pathogens and organic matter. (Bhargava, 2006) added that there are other major sources of pollution for the Yamuna at Mathura, including ongoing issues with silt buildup and erosion of the riverbanks, high pollution levels from the upper Delhi segment, excessive withdrawal of fresh water from the river, and consequently, insufficient dilution.

2.6 Government Guidelines and Policies

Initiatives to conserve rivers and water are continuously undertaken by the Central Government and several other organizations and are included in a number of schemes and programmes. Table 2 provides a detailed description of these policies, schemes, guidelines, and acts.

Table 2: Details of Government Actions for River and Water Conservation

Sr. No.	Policy/ Act/ Guidelines/ Schemes	Formulated By	Year of Implementation	Main Objective
1.	Water (Prevention and Control of Pollution) Act	CPCB, MoEFCC, GOI	1974, amended in 1988	To ensure the purity of the nation's water and to prevent and regulate water pollution, measures are taken.
2.	Water (Prevention and Control of Pollution) Cess Act	CPCB, MoEFCC, GOI	1977, last amended in 2003	To make provisions for the imposition and collection of an excises on water used by individuals who operate and engage in specified categories of industrial activity.

3.	National Water Policy	Ministry of Water Resources, GOI	1987, updated in 2002 and 2012	To create regulations for the efficient utilization and development of water resources. NWP, 2012 aims to treat water as an *economic good*.
4.	Yamuna Action Plan	GOI and Japan	Phase I – 1993 Phase II – 2003 Phase III – 2011	This program aimed for employing a variety of strategies and plans to safeguard and preserve the Yamuna River from pollution.
5.	National River Conservation Plan	MoEFCC, GOI	1995	To implement measures for controlling emissions to enhance the water quality of the major water sources of the country, such as rivers.
6.	National Lake Conservation Plan	MoEFCC, GOI	2001	Aims to fully conserve and restore wetlands and lakes to achieve the desired increase in water quality as well as the biodiversity and ecology.
7.	National Green Tribunal Act	Parliament of India	2010	To make it possible to establish a special tribunal to deal with the rapid resolution of conflicts involving environmental issues.
8.	Namami Gange	Ministry of Jal Shakti	2014	The goal is to effectively reduce pollution while protecting and rejuvenating the National River Ganga.
9.	Act for the Protection, Conservation, Regulation and Management of Groundwater	Ministry of Jal Shakti	2016	This Act's primary goal is to guarantee that groundwater is safeguarded, preserved, regulated, and managed.
10.	National Hydrology Project	Ministry of Jal Shakti	2016	To increase the quantity, quality, and accessibility of information about water resources and to boost the capability of specific Indian agencies responsible for their management.
11.	Jal Jeevan Mission	Ministry of Jal Shakti	2019	To provide clean drinking water to every home in all of India's remotest communities by 2024.
12.	Atal Bhujal Yojana	Ministry of Jal Shakti	2019	The objective of the scheme is to improve groundwater management in seven states of India, namely Gujarat, Haryana, Karnataka, Madhya Pradesh, Maharashtra, Rajasthan, and Uttar Pradesh
13.	Urban River Management Plan	NMCG and NIUA	2020	Put a focus on teaching people about responsible urban development that respects the river.

14.	River City Alliance	NMCG and NIUA	2021	To provide a platform for member cities to engage in discussions and exchange information regarding crucial aspects of urban river management for long-term sustainability.
15.	River-Centric Urban Planning Guidelines	MoHUA, GOI	2021	To provide a template for river zone regulations that states and UTs can use.

2.6.1 River Centric Urban Planning Guidelines, MoHUA, GOI, 2021

The document published by Ministry of Housing and Urban Affairs, GOI regarding the River Centric Urban Planning guidelines for the betterment of the river zones, to regulate them, and which can be adopted by various States/UTs was published in the year 2021. It emphasizes mainly on the objectives, river regulations, strategies for urban river conservation, framework for River Zonal Development Plan, etc.

Objectives

- Establish zoning and development guidelines for riverfront development and devising a strategy for the preservation of river water and the development of the riverfront.
- Emphasize the importance of river-centric master planning and provides suggestions to cities and municipalities on urban river management and development.
- One of the components of sustainable urban planning and development is to provide appropriate planning solutions to manage river water and develop riverfront areas.

River Regulations

The river regulation zones have also been categorized into three groups based on the permission granted to undertake developmental activities. These may include:

- Prohibited activities zones are those that are up to 500 metres from the highest flood level in the last 50 years, whereas
- Restricted activities zones have an outer boundary of one kilometre, and
- Regulated activities zones have an outer limit of three kilometres.

Permitted Activities

Household animal grazing, conventional capture fishing, organic farming, the release of treated domestic waste waters, the extraction of ground water using a hand pump, and leisure activities that don't require boat jetties are just a few examples.

Non-permitted Activities

Repackaging, the disposal of solid waste, new embankments construction, the reclamation of land, the storage of combustible and poisonous materials, and the withdrawal of water for industrial, commercial, or agricultural enterprises are all prohibited.

Strategies for Urban River Conservation

The guidelines listed three strategies for planned city and town growth with the goal of preserving the flood plains of the rivers going through them, including

- River ecology conservation plan
- Integrated Development Scenario
- Post channelization development scenario

Objectives and Framework for the River Zonal Development Plan

The following goals may be addressed in a zoning development plan for the river that runs through the city:

a) increasing water supply;
b) reducing pollution;
c) managing land use; and
d) promoting eco-friendly development.

The following issues are of utmost importance for river area development:

- Instead of adding to the pollution in the river area, development should restore a wholesome environment.
- Even at the highest flood stage, any type of development ought to be protected from flood damage.
- By developing land along a riverbed, the resource requirement is accomplished while maintaining environmental standards.
- It is important to identify the stretches that need to be developed first, don't require a lot of money, or are vulnerable to encroachment.
- Reduce the restrictions on land allocation for public and semi-public uses in the river's adjacent areas, particularly on its banks.

Urban River Zoning Regulations

The guidelines for River Centric Urban Planning provide lateral river bank zonation.

- Active Flood Plain: The area between two embankments, between existing highways on each side of a river functioning as an embankment, or in other entrenched or embanked lengths of a river, including the river channel(s).

- No Development and Construction Zone (NDCZ): The competent authority should establish a NDCZ on either bank of each river, larger than Active Flood Plain of river.
- High impact and medium impact zones: Keeping in mind local topographical conditions, the competent authority shall define and establish sufficient distance(s) from the NDCZ on either bank, to be known as high impact and medium effect zones. These distances from the NDCZ must not be less than 1 and 3 km, respectively, in regions where the topography of the river is reasonably flat.

Permitted Activities

Under this category, amenities like parks, gardens, playgrounds, sports stadiums, swimming pools, cemeteries, and crematories are allowed. Parking for these facilities must be supplied in accordance with the Master Plan's guidelines, and ancillary uses such as restaurants, stalls, sheds for storage, etc. may be allowed on up to 2% of the total land area with a FAR of 0.50 and G+1 building (TCPO & MoUHA, 2021).

2.6.2 Urban River Management Plan, NMCG & NIUA, 2020

URMP guidelines released by NMCG and NIUA in 2020 emphasized a concept of responsible urban development that respects the river. It demonstrates how a city and river should interact, as depicted in the Figure 3. The river is pollution-free owing to the proper treatment and disposal of all wastewater, as seen in the figure.

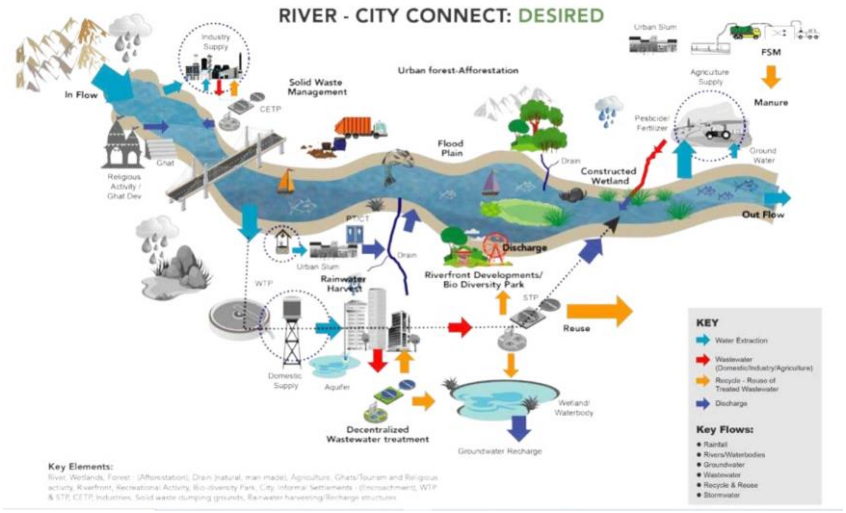


Figure 3: Desired River-City Connect *(NMCG & NIUA, 2020)*

The river is not under as much stress because there is enough wastewater recycling and reuse. The management of the city's sanitation system uses both centralized and decentralized approaches.

Design Principles

The URMP framework is based on three fundamental principles of sustainable development, namely the environment, economy, and society. It has been developed using the design concepts shown in Figure 4.

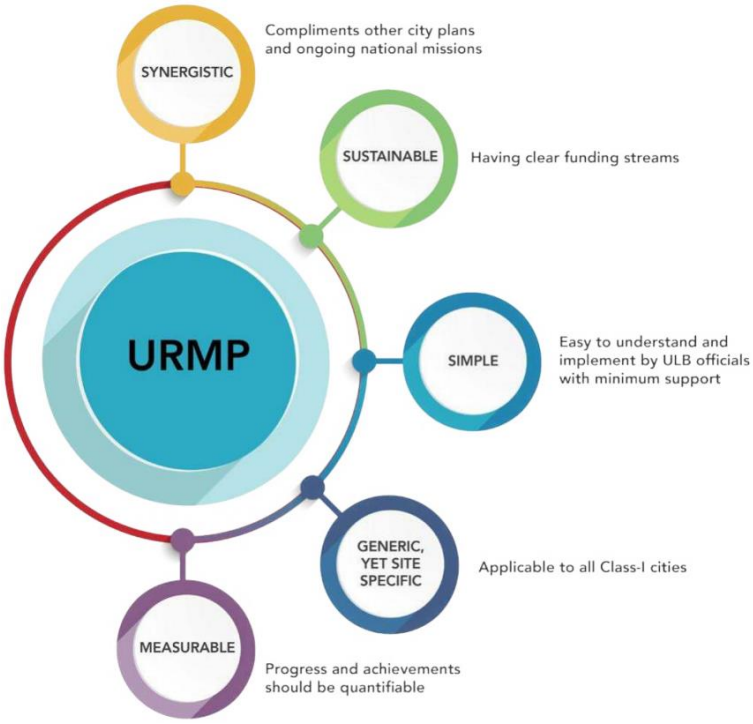


Figure 4: Design Principles of the URMP Framework *(NMCG & NIUA, 2020)*

Benefits of URMP

The URMP offers a city a number of benefits, including the following:

1. Environmental benefits include increased groundwater levels, clean air, clean water, and a rich biodiversity.
2. Economic benefits include better chances for employment, an increase in tourism, and alluring outside investment.
3. The URMP framework also takes into consideration the social benefits that can be derived from the sustainable development of urban rivers, such as providing spaces for religious, cultural, and recreational events, as well as creating peaceful and scenic picnic areas.

Objectives

The URMP framework essentially has ten goals to accomplish the vision. These goals take into account the social, economic, and environmental aspects of the URMP. The goals will be accomplished by different projects' worth of actions, activities, and interventions. The URMP guidelines list a few interventions that can be used to achieve each goal, as shown in Table 3.

Table 3: Objectives of the URMP Framework *(NMCG & NIUA, 2020)*

DESIGN PHILOSOPHY	Environmentally responsible	Economically beneficial	Socially inclusive
ELEMENT	ENVIRONMENTAL	ECONOMIC	SOCIAL
VISION	The river will be able to support a habitat for biodiversity to thrive	The river will provide opportunities for economic development	The river will be celebrated among the citizens
OBJECTIVES	1. To ensure effective regulation of activities in the floodplain 2. To keep the river free from pollution 3. To rejuvenate waterbodies and wetlands in the city 4. To enhance the riparian buffer along river banks 5. To adopt increased reuse of treated wastewater 6. To ensure maximum good quality return flow from the city into the river	7. To develop eco-friendly riverfront projects 8. To leverage on the economic potential of the river	9. To inculcate river-sensitive behaviour among citizens 10. To engage citizens in river management activities

Incorporating River Considerations in a City's Master Plan

A city's master plan specifies the general directions that the city's future growth will take. It is a long-term strategic blueprint. It is a legal document that outlines the city's goals for a specific time frame and recommends the tactics the city should use to realize those goals. The normal duration of a master plan in India is 20 years, although some cities may have plans with 15 or 25-year horizons. Integrating river-centric approaches into a master plan involves recognizing the river as an essential component of the city's long-term vision and developing a dedicated plan for it. The master plan offers various tools to tackle urban river issues, as depicted in Figure 5 (NMCG & NIUA, 2020).

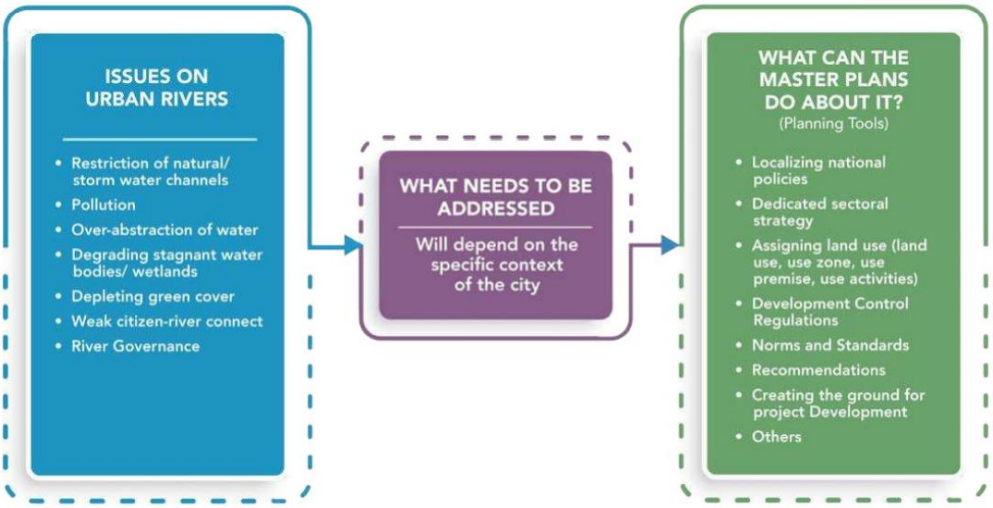


Figure 5: Master Plan Tools for River Management *(NMCG & NIUA, 2020)*

2.6.3 Yamuna Action Plan, 1993

This plan called for using a number of different strategies and initiatives to safeguard and preserve the Yamuna River from pollution. The Yamuna Action Plan (YAP) was a collaborative effort between the Governments of India and Japan aimed at restoring the Yamuna River. The YAP was one of the largest river restoration initiatives in India and was funded by a grant of 17.7 billion yen from the Japanese government to the Japanese Bank for International Cooperation. The project was executed with the involvement of the National River Conservation Directorate, the Government of India, and the Ministry of Environment and Forests.

Phases of Yamuna Action Plan

- YAP Phase I

Between 1993 and 2003, the first phase of the Yamuna Action Plan (YAP) saw the construction of 29 sewage treatment facilities, which had a combined treatment capacity of 725.79 MLD. The project was carried out in three states, with 402.79 MLD of capacity in Uttar Pradesh, 303 MLD in Haryana, and 20 MLD in Delhi. Further details about YAP – Phase I is shown in Figure 6.

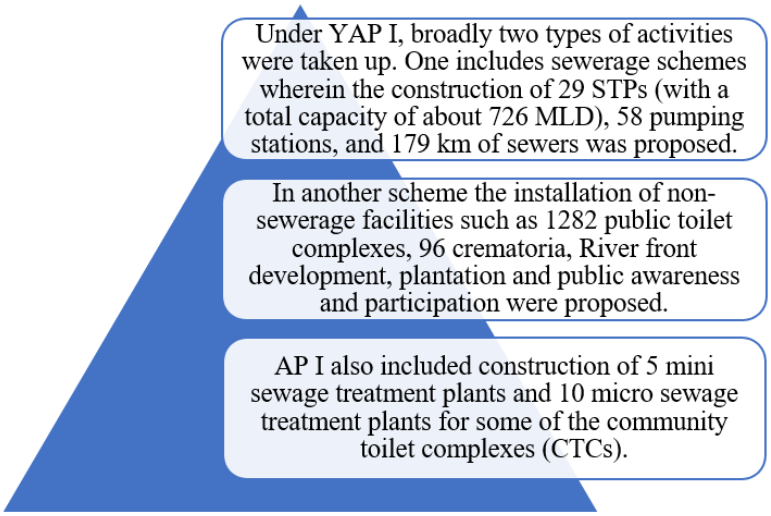


Figure 6: Yamuna Action Plan - Phase I

- YAP Phase II

During the second phase of the YAP, which began in 2003, an additional 189 MLD of sewage treatment capacity was constructed (54 MLD in UP and 135 MLD in Delhi), and 273 MLD of existing sewage treatment capacity in Delhi was renovated. Further details about YAP – Phase II is shown in Figure 7 (D. Sharma & Kansal, 2011).

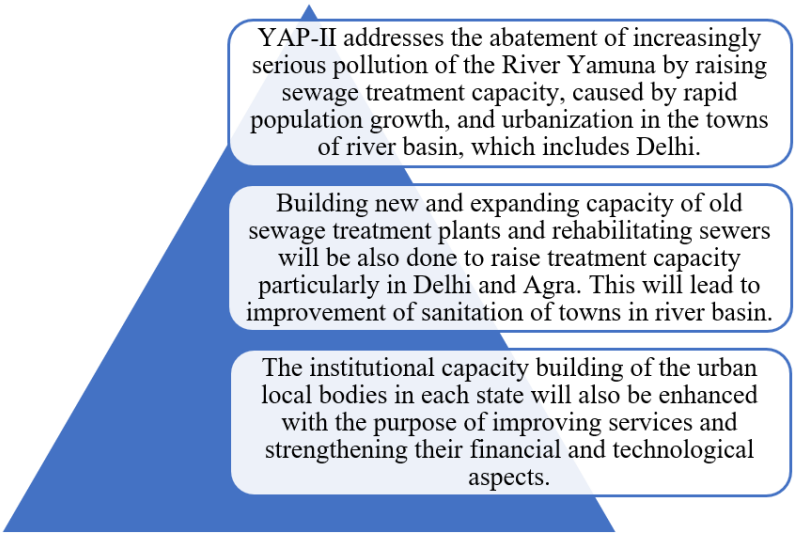


Figure 7: Yamuna Action Plan - Phase II

- YAP Phase III

The third phase of the Yamuna Action Plan (YAP) took place from 2011 to 2018, and was implemented by the Delhi Jal Board, which operates under the supervision of the Department of Urban Development of the Government of the National Capital Territory (NCT) of Delhi. Further details about YAP – Phase III is shown in Figure 8 (A. Sharma, 2018).

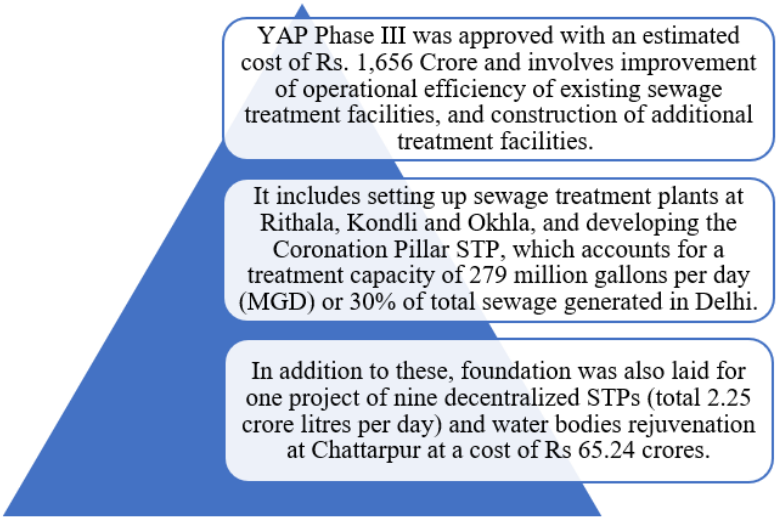


Figure 8: Yamuna Action Plan - Phase III

2.6.4 River Cities Alliance, NMCG & NIUA, 2021

The River Cities Alliance (RCA) was launched by the National Mission for Clean Ganga (NMCG) and the National Institute for Urban Affairs (NIUA) in 2021. The primary objective of the RCA is to provide a platform for member cities to exchange information and discuss issues related to sustainable management of urban rivers, share best practices, and promote innovation. The RCA focuses on three key areas, namely networking, capacity building, and technical support. Initially, the alliance consisted of 30 cities, including Mathura. At present, the alliance has 110 cities associated with it.

RCA is intended to serve as a platform that will facilitate the beginning of river-sensitive planning and development. Through its complete and thorough structure, Namami Gange has been trying to revitalise the Ganga River basin. The River Cities Alliance will assist cities as they begin implementing the river-sensitive development agenda so that they may share lessons learned and encourage others to take up progressive action in this area.

Objectives

- To give member cities a forum for discussion and information sharing on topics essential for the sustainable management of urban waterways.
- To promote the adoption and localization of national policies and programmes that have important river-related objectives.
- To prepare city-specific sectoral strategies and urban river management plans that are necessary for sustainable urban river management.

Significance

- It will provide cities the chance to share successes and shortcomings and connect people to the rivers.
- It can be a key component in reuniting cities with their rivers and serve as an example for other communities in the Basin and beyond.
- It provides chances for cities to improve the governance of river cities, increase their liveability to draw in outside financial investments, gain access to cutting-edge frameworks and knowledge, and take on the role of host for one-of-a-kind demonstration projects (*River City Alliance*, 2022).

2.6.5 National River Conservation Plan, MoEFCC, 1995

The Ganga Action Plan (GAP), which was introduced in 1985, served as the catalyst for the country's river cleaning initiative. In 1995, the National River Conservation Plan (NRCP) added additional rivers to the Ganga Action Plan. The Center Government and State Governments split the costs of implementing the pollution abatement measures. Several initiatives have been launched to combat different forms of pollution in India. These initiatives comprise the enhancement of wood-based cremation systems, the collection, transportation, and treatment of municipal sewage, the development of riverfronts, and the installation of low-cost sanitation facilities and electric cremation systems. Industrial pollution prevention and control is handled by the Central and State Pollution Control Boards/Pollution Control Committee. The National River Conservation Plan (NRCP) has implemented numerous pollution reduction programs aimed at enhancing the water quality of major rivers in the country (*National River Conservation Plan*, 1995).

2.7 Policies and Strategies for Conserving River

2.7.1 Industrial Waste Water Management

(Bhargava, 2006) emphasized that the population growth in Mathura city has been closely linked to the unstructured expansion of small and large industries. To address this issue, it is crucial to

implement in-plant techniques that minimize the amount and severity of pollutants. Industries should also adhere to planning regulations, land use restrictions, and consent policies for treated effluent discharge. To reduce the amount of wastewater generated, methods such as material recovery systems, effluent reuse, and wastewater treatment should be employed. Other practices that can be adopted include,

- alterations to the way of using raw materials;
- modifications in the process of waste generation;
- wastewater load equalization to cut down on peak flows;
- neutralizing wastewater before discharging it;
- segregating different types of industrial waste for particular treatment such as evaporation, incineration, pumping into deep soakage wells;

In Mathura, the Namami Gange Program aims to address industrial wastewater pollution by setting up common effluent treatment plants in clusters of small industries, with the assistance of the Pollution Control Board. Additionally, the program will install effluent treatment plants for individual industries to treat their wastewater.

2.7.2 Wastewater Treatment and Sewerage System Management

(Bhargava, 2006) suggests that all the wastewater generated and collected in Mathura city should undergo primary and secondary sewage treatment processes before being discharged into the Yamuna River, which should take place at a distance of 3 to 5 kilometers downstream.

Namami Gange has installed five STPs for this purpose and has proposed the construction of an additional 60 MLD STP to treat the wastewater produced in the city.

Additionally, to improve the availability of sewage to STPs for treatment, (Kumar et al., 2020) recommended installing sewer lines in areas that were not currently sewered. In order to reduce the need and consumption of fresh water, wastewater must be treated for both non-potable and recreational uses.

2.7.3 Solid Waste Management

According to (Misra, 2010), solid waste that is unwanted, harmful, or outdated can be recycled and reused in daily life. These materials are generated from human and animal activities. The solid waste that is recyclable can be cleaned and segregated, and turned into fully or partially recycled goods. Cities such as Sonipat, Panipat, Delhi, Noida, Mathura, Agra, and Etawah generate significant amounts of solid waste, which is a major contributor to the pollution of the Yamuna River. The solid waste disposal issue in these areas can be addressed by establishing more recycling facilities.

(Bhargava, 2006) continued by stating that some of the identified major generation points make it convenient to collect the majority of Mathura's biodegradable waste. He then suggested a few strategies for effective solid waste management.

- Solid waste can be collected from households and sorted into three categories - biodegradable, recyclable, and mixed waste.
- Vermiculture biotechnology, which uses earthworms to convert organic solid waste into vermicomposting, can be used to manage solid waste.
- Fuel pellets, which have calorific values comparable to coal, can be used as a substitute for petroleum products in homes and industries.
- Pyrolysis, which is the thermal decomposition of solid waste in an inert atmosphere, is a viable alternative to incineration. It produces a smaller volume of waste gases, resulting in less air pollution.

2.7.4 Improving agriculture practices

(Misra, 2010) emphasized that farmers use a lot of chemical fertilizer, insecticides, and pesticides without knowing the precise amounts needed to maintain soil productivity or boost short-term crop yields. The excessive use of fertilizers has adverse effects on the soil, groundwater, and surface water bodies. During the rainy season, fertilizer runoff pollutes lakes, ponds, and rivers, leading to eutrophication, which can reduce dissolved oxygen levels and threaten the health of aquatic organisms and plants. To prevent these issues, it is essential to promote the use of bio-fertilizers with minimal chemical components and take steps to prevent soil erosion through vegetation cover, especially along the river basins.

2.7.5 River Zone Regulation

(Kumar et al., 2020) recommended creating risk maps and segmenting the land into development, restricted construction, and no construction zones. These zones would then have construction regulations such the use of waterproof materials and higher plinths than design flood levels. To avoid encroachment, pollution, and unauthorized/illegal sand mining in the embanked stretch of the river, stringent application of river zone regulations, including river policing, is required.

(V. K. Sharma & Priya, 2001) highlighted the case of River Zone Regulation at Patna, Bihar. More than 60% of Bihar is flood-prone, although North Bihar makes up 80% of the state's flood-affected land. The state capital of North Bihar, Patna, faced frequent floods during the monsoon season, causing harm to the city's residents and property.

When the channel's capacity is exceeded by the flow, residents of low-lying areas experience flooding on a more frequent basis. If there is a drainage issue in the area itself, this problem gets worse. Poor drainage causes flooding and water logging, which opens the door for environmental pollution and health risks. Therefore, adequate planning and zoning rules are necessary to direct urban development in a metropolis that is prone to flooding towards more favourable patterns.

Flood plain zoning/zoning ordinance

Flood zoning is a strategy for managing flood-prone areas by designating them as different zones with specific usage regulations aimed at reducing flood damage. The effectiveness of flood zoning depends on several factors, including the probability of flooding in the designated area, the

topography of the land, and the permitted activities in surrounding areas. Areas can be prioritized differently based on the level of flood risk they face.

Recommendations for each zone

Zone 1

1. This zone is considered to have the highest risk of flooding, with a greater likelihood of flooding occurring first and resulting in significant material and financial losses.
2. In addition to areas with high flood risk, zones with extremely high population densities that would be severely impacted by flooding have also been included in this zone.
3. The actions listed below should be completed immediately in these regions, which can be considered Action Areas:
    i. prepare detailed contour/slope interpretation layouts;
    ii. create area-level plans and strategies for flood management;
    iii. identify low-lying areas and lowest points for instant rescue operation;
    iv. using the lowest points as storage spaces, play areas, gardens, etc.;
    v. enhancing current drains and channels;
4. All unused land in this zone, including parks, playgrounds, and other waterfront construction plans, should be prohibited from future use. The following applications shouldn't be allowed: any residential development; heavily trafficked business districts like CBDs and district centres; and any significant transit hubs or nodes that draw commuting traffic.

Zone 2

1. This zone is categorized as having a medium level of risk. In the event of heavy rainfall, this area experiences flooding conditions. However, the losses in terms of property and money are smaller compared to Zone 1. The locations in this zone are relatively more elevated.
2. These locations could potentially become high-risk zones if particular drainage augmentation guidelines are not strictly followed.
3. Given that there is a chance of flooding in this area, rigorous adherence to building rules is also necessary.
4. The population density in these places needs to be under control.
5. This zone has relatively low risk and can accommodate low-density commercial, residential, and public amenities such as community centers, exhibition grounds, and public libraries.
6. High density residential, public utilities including ESS, pumping stations, TV centers, and hospitals should be avoided in this zone to minimize the potential risks associated with flooding.

Zone 3

1. This area is the least dangerous. This zone hardly ever experiences flooding. Losses in terms of money and property are minimal. These locations are elevated and benefit from good drainage conditions.

2. These regions ought to be used for construction of any kind, particularly high-density housing, office buildings, important commercial hubs, TV stations, etc.

2.7.6 River Bank Filtration

According to (Patil, 2017), describes Riverbank Filtration (RBF) as a method that draws water from borewells drilled along river's banks. River water infiltrates and permeates the sediments of the riverbed while being pumped. Dissolved and suspended pollutants, as well as pathogens, may be eliminated or greatly decreased in number as the raw surface water moves toward the RBF well due to a mix of physical, chemical, and biological processes.

Water is extracted from one or more wells close to a river or lake in an RBF system. RBF wells are normally bored within a few hundred metres away from a body of surface water in order to allow surface water to be drawn through the underlying sediments when the well is pumped. Wells can be either vertical or horizontal. River water and groundwater are forced to flow through the porous riverbed sediments when an RBF well is pumped, which lowers the groundwater potential.

(Sandhu et al., 2011) suggest that RBF could be a viable long-term solution that could reduce the need for expensive infrastructure investments. Bank filtration uses natural attenuation processes to effectively remove various contaminants. It also helps in reducing the concentration of adsorbable substances, stabilizes temperature changes, and concentrations of dissolved constituents in the bank filtrate, resulting in a better quality of water as compared to direct surface water abstraction.

According to (Sandhu et al., 2011), River Bank Filtration is used in many Indian cities, including Haridwar, Delhi, Mathura, Ahmedabad, Nainital, Medinipur, Kharagpur, Srinagar, Patna, Dehradun, Rishikesh, Vadodara, along with some more potential river bank filtration sites.

(Sandhu et al., 2011) highlighted a case of Nainital where RBF is currently used. Uttarakhand is home to Lake Nainital. Nainital, as a town and its lake, are renowned among visitors as attractive destinations. The town's main source of drinking water is Lake Nainital. Prior to 2006, Nainital's population was thought to be around 42,500. An average of 100,000 people is temporarily added to this area each year by the seasonal tourist inflow. Between 1990 and 2007, seven tube wells were installed near Lake Nainital, with depths ranging from 22.6 to 36.7 meters. These tube wells are currently used to pump 24.1 million liters of water per day (MLD) to higher altitude reservoirs by UJS to pressurize the water distribution system through gravity feed. Massive debris dumps cover the level to mildly sloping ground surrounding the tube wells. The slopes above the wells are where the deposits are found. Shale/slate rock pieces make up the

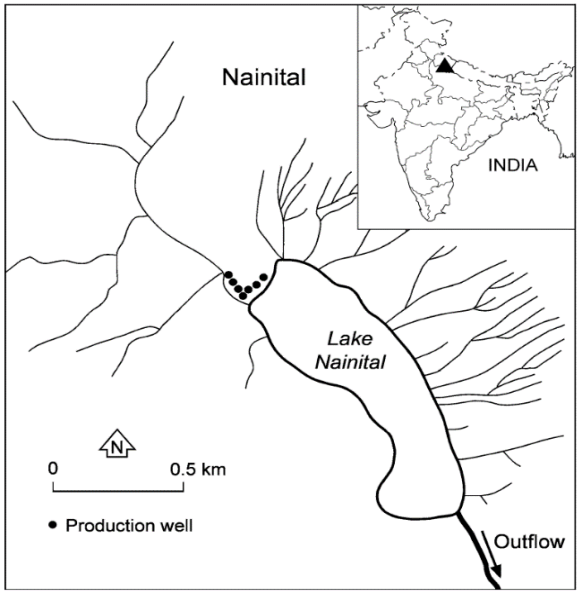


Figure 9: Nainital Lake (Sandhu et al., 2011)

majority of the material, with minor amounts of medium - grained coarse sand and clay. Studies have shown that water extracted from the tube wells near Lake Nainital has better bacteriological quality compared to water taken directly from the lake using sand filter units. This water is relatively free of coliform bacteria and does not require chlorination (Sandhu et al., 2011).

2.7.7 Development of a Park Area

According to (Bhargava, 2006), the right bank of the Yamuna River has the potential to be transformed into a park with various amenities, such as fountains, play areas, water sports, green spaces, and plantations. This park would also act as a barrier between the river and the city, reducing pollution levels in the Yamuna River. Developing riverbank parks in locations such as Mathura, could prevent people from unintentionally dumping solid waste on the river banks while providing a pleasant view of the river. Additionally, these parks could be utilized to construct artificial aeration facilities to increase the dissolved oxygen levels and help the river purify itself. Existing structures in the Yamuna River, such as old ghats, bridges, and wells, could also be renovated to aid in stream aeration.

(Halajova et al., 2019) highlighted the case of Rose Park reconstruction at Trnavka River, Trnava. The author faces a significant challenge in finding a balance between preserving flood protection levels and improving the ecological condition of the river during the design phase. This challenge is more difficult when there is limited space in the riparian zone. The suggested measures for river restoration have two primary goals: to improve the aesthetic quality of the restoration design in relation to the nearby public space, the Rose Park, and to implement biotechnical measures that will enhance the environmental conditions and management capabilities of the Trnavka River.

The major objectives of the initiative are: to reduce water pollution, create shady places, create a haven for ichtyofauna, make it possible for people to interact with the river through pier design, and raise the aesthetic quality of the riverscape.

Figure 10: Visualization and plan view of the Rose Park Reconstruction (Halajova et al., 2019)

2.7.8 Afforestation along the Yamuna River bank

According to (Bhargava, 2006), planting trees along riverbanks would reduce erosion, pesticide and fertilizer-rich agricultural runoff, siltation, and other environmental problems. The creation of forests may provide habitat for several species that can assist clean the river. The Banyan tree, also known as Bargad or Vut, is best suited for planting along riverbanks because of its long lifespan and strong ability to bind soil. In particular during the heat, this would give the pilgrims refuge. According to (Misra, 2010), planting trees and vegetation along the Yamuna River can have a positive impact on the river's temperature and oxygen levels. By providing shade, the trees can help to lower the temperature of the water, which can be beneficial for aquatic life. The vegetation can also contribute to oxygenation of the water, which can further support the river's ecosystem.

(Mohini & Gharge, 2016) highlighted the case of the Mutha River in Pune, which originates in the Western Ghats and runs eastward before merging with the Mula River in the city of Pune. At the Sangam, Mula joins the Mutha, and the two of them go to Bhima as the Mula-Mutha. The river has a designated river regulation zone along the lines of the CRZ, which can be used as a green belt.

2.7.9 Development of a Holy Pond

(Bhargava, 2006) asserts that it is challenging to prevent the disposal of holy items into rivers through legislation and penalties. As a solution, the author suggests building holy Yamuna ponds filled with Yamuna water to immerse the holy items collected from various sites. The purified water from the ponds can be released back into the river after receiving primary treatment. The pond sediments can be utilized as manure, and lotus plants can be grown in the pond as a heavy metal sorbent. To facilitate the collection of holy materials, holy pots can be positioned throughout the river bank at all bathing ghats, close to temples, and both sides of bridges to provide pilgrims with a convenient disposal option for their holy materials.

(Misra, 2010) continued by stating that the Yamuna River is considered holy by many in India, and mass bathing is a common practice. However, this mass bathing has a negative impact on the river's water quality, which can cause health problems for both those who bathe in it and downstream communities that use the water for drinking and bathing. To address this issue, holy bathing ponds could be constructed next to the ghats and filled with river water, using artificial ground water recharge techniques. This approach not only prevents river pollution but also helps replenish the groundwater supply.

2.7.10 Construction of Public Toilets

According to (Misra, 2010), between 30 and 40 percent of the urban population lives in slums without access to sanitary services in big towns like Delhi, Agra, Mathura, and Etawah. The Yamuna River's water quality is continuously declining as a result of the widespread practise of open defecation and sewage discharge by residents of these areas. Several diseases are brought on by water polluted with faeces. The best way to stop further deterioration is to establish public sanitation facilities, particularly in the slum neighbourhoods located close to either side of the river.

(Bhargava, 2006) further added that that bathing ghats and public restrooms should be constructed for the benefit of devotees and the underprivileged in the densely populated areas along the banks of the Yamuna River in Mathura.

2.7.11 Legislation and Fines

(Misra, 2010) claims that in order to stop the Yamuna River's pollution from getting worse, rigorous rules and regulations must be created and fully implemented. The river's major pollution areas should begin to be monitored right away. Domestic waste and other polluting materials should not be dumped in rivers. Instead, a fine and a prison sentence of six months to a year should be imposed, and depending on how well a river can absorb waste and purify itself, the appropriate effluent standards should be determined separately for each polluter.

2.7.12 Public awareness and participation

(Bhargava, 2006) claims that the Indian populace is largely ignorant of issues and ramifications related to pollution. (Misra, 2010) continued by stating that without public involvement, it would be impossible to prevent Yamuna River pollution. Therefore, it's crucial to educate the public about river pollution, how it happens, and the consequences that follow. People need to learn about many strategies they might use to lower the rising river pollution levels. Therefore, public awareness campaigns should be developed through conferences, the media, and NGOs. According to (Kumar et al., 2020), ensuring that the general public actively participates through awards, financial aid, and incentives will considerably improve the situation.

2.7.13 Creation of Yamuna Basin Board

(Kumar et al., 2020) emphasized that there are numerous state and national organizations with varying responsibilities pertaining to the land, flow, and quality of the Yamuna River. They propose the establishment of a distinct board for the entire Yamuna basin to improve coordination and prevent duplication, regulating water distribution and land use activities. A comprehensive and integrated management strategy for the entire river catchment area is also required, which must be periodically revised and adjusted. To effectively implement such a strategy, concerned agencies must enhance their capacity through the adoption of the latest technologies and training programs.

2.8 Components of River-Centric Plan

Through the various literature studied, various components of River-Centric Plan have been identified. These components include establishing a functional riparian ecosystem, enabling designated public access, rejuvenation of water bodies, managing riverine infrastructure, preventing river pollution, enhancing citizen-river connect and river-based economy. Various activities which need to be carried out under respective component, along with the stakeholders involved, is highlighted in Table 4.

Table 4: Components of River-Centric Plan

Sr. No.	Component of River-centric Plan	Activities to be Carried Out	Stakeholder
1.	Establish a Functional Riparian Ecosystem	• Biodiversity parks • Miyawaki forests • Plant a continuous buffer of vegetation along the river banks, choosing appropriate species for the soil conditions, water depth, native species, and ground profile. This will provide erosion control, water filtration, and wildlife habitat. • Connecting the vegetation buffer to other significant habitats and migration routes along tributaries would create a network of habitats for various species to move and migrate freely. • Improve water quality and add measures like fish passages, ladders, and riffle pools to support aquatic life and maintain a healthy ecosystem.	• Private sector • Community-based organizations • ULBs • Local People • Boatman • Fisherman
2.	Enable Designated Safe Public Access	• Provide safe access to the water and establish a flood warning system. • Create a variety of public spaces in "reclaimed" areas of the channel. • Use alternate "greening" techniques in areas where concrete is necessary for flood damage prevention. • Develop non-motorized transportation and recreation elements like bike and pedestrian paths.	• Community-based organizations • ULBs • Local people • NGOs
3.	Rejuvenation of Water Bodies	• Clean water bodies through bio-remediation, de-silting, and removal of invasive species. • Properly fence the shoreline and strengthen the inlet and outlet of water bodies. • Undertake catchment area treatment such as afforestation and stormwater drainage management.	• Private sector • Community-based organizations • ULBs • Local People • Other governmental agencies
4.	Managing Riverine Infrastructure (Ubing C et al., 2017)	• Ghat development • Stormwater management • Drainage services • Bridges and barrages construction • Space for bathing, crematoria activities, and offering flowers • Floodplain encroachment regulation • River zone regulation	• ULBs • Private sector • Community-based organizations
5.	Preventing River Pollution	• Prevent untreated wastewater discharge into water channels. • Limit disposal of solid waste into water channels and designate land use categories for waste disposal and treatment facilities. • Developing a community composting centre. • Developing a constructed wetland.	• Private sector • Community-based organizations • ULBs • Local People

6.	Citizen-River Connect	• Develop an IEC strategy for river management. • Allow eco-sensitive religious activities in designated ghat areas. • Encourage public recreation activities with landscape features that respect the existing natural habitat. • Establish community groups to monitor the river's health and organize river clean-up drives.	• Community-based organizations • ULBs • Local People • NGOs
7.	River-based Economy	• Promote tourism activities like water sports and navigation activities with dock stations and jetties. • Riverside and floating markets • Promenades • Recreational plazas • Boating clubs • Cultural theme parks	• Private sector • Local Boatman • Tourists • ULBs • Local People • Fisherman

2.9 Research Paper wise study (Matrix)

A detailed matrix of various research papers referred for study is given in Table 5.

Table 5: Matrix of Research Papers

Sr. No.	Year of Publication	Study Area				Planning Level			Impacting Factors			Pollution Related Parametres Adressed		Parameters Included in the study to Improve River Health						
		Whole River	2 or More Cities along the River	Single City along the River	Micro-level Stretch of River	Neighbourhood	City	Regional	Citizens	ULBs	Central/ State Government	Yes	No	River-Centric Planning	Policies and Strategies	River	River	River Ecology	Pollution Control	Pollution Measurement
1.	(Misra, 2010)	✓						✓	✓	✓		✓			✓		✓		✓	
2.	(A. Sharma, 2018)	✓					✓				✓		✓			✓			✓	
3.	(Yadav & Rajawat, 2011)			✓			✓		✓				✓							✓
4.	(Patil, 2017)					✓				✓			✓		✓				✓	
5.	(Krishan et al., 2017)		✓				✓			✓			✓							✓
6.	(Kumar et al., 2020)	✓						✓	✓	✓	✓	✓			✓		✓		✓	✓
7.	(NMCG & NIUA, 2020)			✓			✓		✓	✓	✓	✓		✓	✓	✓	✓		✓	
8.	(TCPO & MoUHA, 2021)			✓			✓			✓	✓	✓		✓	✓	✓	✓	✓		
9.	(Bhargava, 2006)			✓			✓		✓	✓		✓			✓		✓		✓	✓
10.	(Walling et al., 2016)			✓			✓		✓				✓							✓
11.	(Hassan Al-Taai, 2021)						✓		✓			✓			✓		✓		✓	
12.	(Khan et al., 2021)	✓					✓		✓	✓	✓	✓								
13.	(Nishat & Singh, 2018)	✓						✓	✓				✓					✓		
14.	(Tewari, 2018)								✓				✓					✓		
15.	(Hudda, 2019)	✓					✓		✓	✓		✓			✓		✓		✓	

16.	(Srivastava, 2007)								✓	✓		✓			✓		✓	✓	✓	
17.	(NIUA & NMCG, 2021)			✓			✓		✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	
18.	(Sinha et al., 2013)								✓				✓		✓		✓	✓		
19.	(D. Sen Singh, 2018)								✓			✓			✓			✓		
20.	(D. Sharma & Kansal, 2011)		✓				✓			✓	✓	✓			✓		✓		✓	
21.	(Upadhyay & Rai, 2013)	✓						✓	✓	✓		✓			✓				✓	
22.	(Sandhu et al., 2011)				✓	✓				✓			✓		✓		✓			
23.	(Ministry of Jal Shakti, 2022)		✓				✓			✓	✓		✓		✓	✓	✓		✓	
24.	(Mohini & Gharge, 2016)			✓			✓		✓	✓		✓			✓	✓	✓		✓	
25.	(Halajova et al., 2019)				✓	✓			✓	✓			✓			✓				
26.	(V. K. Sharma & Priya, 2001)			✓		✓	✓		✓	✓	✓		✓		✓		✓			
27.	(Youssef & Ali, 2017)	✓					✓		✓	✓	✓	✓			✓	✓	✓		✓	
28.	(Middelkoop, 2000)	✓					✓		✓			✓								✓
29.	(*'RHINE 2040'*, 2020)	✓					✓		✓	✓	✓		✓		✓	✓	✓	✓	✓	
30.	(Havinga, 2020)	✓					✓			✓	✓		✓	✓	✓	✓	✓	✓		
31.	(Environment Agency, 2022)	✓				✓	✓		✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	
32.	(Antuono, 2019)			✓			✓		✓				✓							
33.	(Scoccolo, 2019)			✓			✓		✓	✓	✓	✓			✓	✓	✓		✓	
34.	(C. Singh & Saini, 2019)				✓	✓			✓	✓			✓		✓			✓		
35.	(Koziupa, 2021)				✓	✓			✓	✓			✓		✓			✓		
36.	(Manuel, 2020)				✓	✓			✓	✓			✓		✓			✓		
40.	(MoEFCC, 1995)	✓					✓			✓	✓		✓		✓		✓		✓	
41.	(Tattoni, 2016)				✓	✓			✓	✓			✓			✓	✓			
42.	(Rathore & Jadon, 2019)				✓	✓			✓	✓			✓			✓	✓	✓	✓	
43.	(Albert et al., 2021)				✓	✓			✓	✓	✓		✓		✓	✓	✓	✓	✓	
44.	(Basak, 2020)				✓	✓			✓	✓	✓		✓		✓		✓		✓	
45.	(A. Singh & Omar, 2021)				✓	✓			✓	✓	✓		✓		✓	✓	✓	✓	✓	
47.	(NMCG, 2021)				✓	✓			✓	✓	✓		✓		✓	✓	✓	✓	✓	

CHAPTER 3: STUDY AREA PROFILE

3.1 General

The river Yamuna has its source at Yamunotri Glacier at an elevation of around 4500 m on the southwestern slopes of Bandrapunch peaks in Uttarakhand. It merges with the River Ganga at Triveni Sangam in Allahabad. The river has been divided into five segments, including the Himalayan Segment, Upper Segment, Delhi Segment, Eutrophic Segment, and Diluted Segment (Misra, 2010).

3.2 River Yamuna

River Yamuna is an important river in India that flows through several states, including Uttarakhand, Himachal Pradesh, Uttar Pradesh, Haryana, and Delhi. It has a total length of 1376 km and a basin area of 3,66,223 km2. The river has been divided into five segments details of which is given in Table 6, and in order to divert river water, six barrages have been built, namely the Dakpathar Barrage, Hathni Kund Barrage, Wazirabad Barrage, ITO Barrage, Okhla Barrage, and Gokul Barrage (Kumar et al., 2020). The water quality of the Yamuna River is good in the Himalayan Segment, but as it flows downstream towards the Delhi Segment, untreated or partially treated domestic and industrial effluents are discharged into the river through several drains. This 22 km stretch in the Delhi Segment, which is less than 2% of Yamuna's total length, contributes to around 80% of the total river pollution. The polluted water then flows downstream and enters the Eutriphicated Segment, where the river water is the primary source of municipal drinking water (A. Sharma, 2018).

Table 6: Details of Segments of River Yamuna (Kumar et al., 2020)

Stretch of Yamuna	Distance (km)	Source of discharge	Abstraction of water (approx. quantity in MLD)	Purpose of abstraction
Yamunotri–Hathnikund	172	Melting of glaciers (Kamal, Giri, Tons, Bata and Asan Tributries)	Shakti (Dakpatthar) & Asan canal (Asan Barrage) 20,000 (WYC & EYC)	Hydro power, Irrigation & Drinking
Hathnikund–Wazirabad	224	Ground water accrual, Delhi share from WYC by drain No. 2, small tributaries (Som Nadi & Choti Yamuna)/drains (6&8).	1100 (Wazirabad water works)	Drinking
Wazirabad–Okhla	22	Treated/untreated waste water from 17 drains. Water of WYC by NG Drain and Hindon cut canal.	5000 (Agra canal)	Irrigation
Okhla–Gokul Barrage	152	Shahdara Out Fall drain, Ground water accrual, Hindon & Gambhir river and Mathur, Varandavan drain water.	400 (Mathura water works)	Drinking and Industrial use.
Gokul Barrage–Allahabad	806	Ground water accrual, Chambal, Sind, Pahuj, Kumari Betwa Ken & Agra drain waste water.	4000 (Agra and Allahabad water works)	Drinking & Industrial use, confluence to Yamuna.

Therefore, the two main segments considered for research are Delhi and Eutriphicated Segment, as shown in Figure 11. Among these two segments, the research focuses on identifying the most vulnerable city based on various urban drivers polluting the river. On the basis of this ranking, Mathura city is selected for providing city-specific proposals, for river rejuvenation and generation of river-based economy.

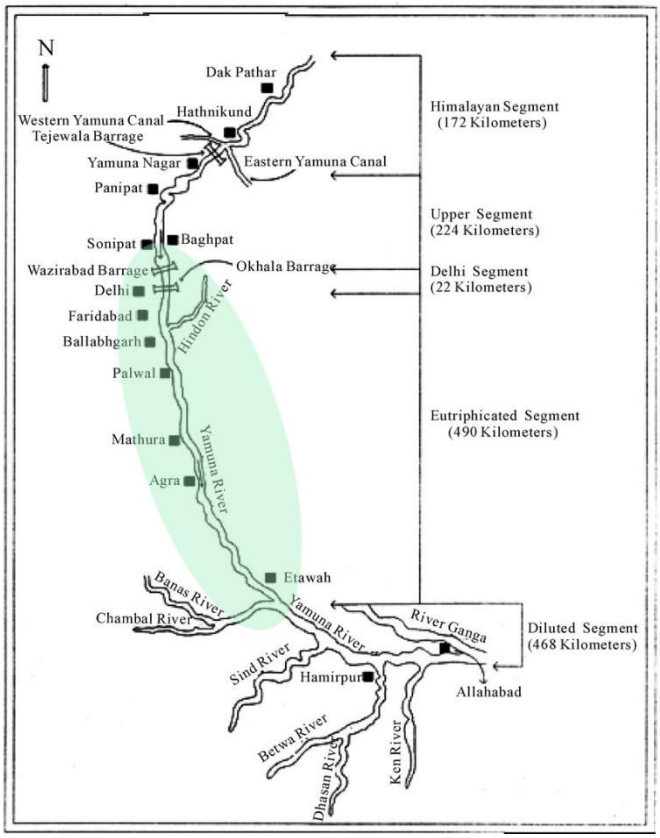


Figure 11: Study Area - Segments and City (Misra, 2010)

As stated earlier, the most vulnerable city in these two segments will be identified by ranking them on the basis of various urban drivers polluting river. Thus, understanding the basic characteristics of the cities in these two segments is required. Table 7 details about the various information, including population, population density, percentage share of Yamuna, and land use adjacent to river Yamuna of these cities.

Table 7: Detail of Various Cities in Delhi and Eutriphicated Segment

Sr. No.	City	Population, Census 2011	Population Density (population/km^2)	Percentage Share of Yamuna	Land use adjacent to River Yamuna
1.	Delhi NCT (source – census 2011)	1,67,87,941	11,320	22 km (1.6%)	Industrial, residential, commercial, recreational, public & semi-public, government
2.	Faridabad (census 2011 & Disaster Faridabad)	15,94,839	8,398	490 km (35.6%)	Agriculture, village abadi, residential, defence land, open spaces
3.	Ballabhgarh (census 2011 & Disaster Faridabad)	2,14,894	698		Agriculture, village abadi, residential
4.	Palwal (source - census 2011)	1,28,730	3,218		Agriculture, village abadi

5.	Mathura (source – slum free)	3,49,336	12,257		Industrial, religious, residential, commercial, agriculture, government, recreational
6.	Agra (source – slum free)	15,74,542	11,166		Agriculture, forest, residential, commercial, recreational, tourism, educational, industrial
7.	Etawah (source – slum free)	2,56,838	6,886		Agriculture, forest, sewage farm, recreational, cantonment area

3.3 About Mathura City

Mathura city is the administrative headquarters of Mathura District, located in Uttar Pradesh, about 50 km north of Agra and 145 km southeast of Delhi. It is situated approximately 11 km from the town of Vrindavan and 22 km from Govardhan, with an area of 28.5 km^2. The river Yamuna in Mathura has been acclaimed as Holy River by the Mathuraites. On the occasion of "Yum-Dwitiya", also known as "Bhai-dooj", a special bath is organized on the Vishram Ghat of Mathura, where lakhs of devotees from all over the country come to take bath. Brothers and sisters who join together in this special bath wish to attain salvation (*About District | District Mathura, Government of Uttar Pradesh | India*, 2023).

Mathura city has an area of 28.5 km^2, with a population of 3,49,336 as per census 2011. Table 8 shows the population of Mathura city for the year 2001 – 2031. The city has a decadal growth rate of 32.99% for the year 2021.

Table 8: Population of Mathura (Slum Free City Plan of Action Mathura)

Sr. No.	Year	Population	Decadal Growth Rate (%)
1.	2001	3,02,770	33.56
2.	2011	3,49,336	15.37
3.	2021	4,64,615	32.99
4.	2031	6,22,584	33.99

In addition to the census population, Mathura has a large amount of floating population as it is a religious centre. Table 9 shows the floating population of Mathura city for the year 2015 – 2019. The floating population consists of both Indian and international tourists.

Table 9: Floating Population of Mathura (Masterplan Mathura 2031)

Sr. No.	Year	Indian	International	Total
1.	2015	66,26,000	25,000	**66,51,000**
2.	2016	66,30,000	25,100	**66,55,100**
3.	2017	72,26,700	26,606	**72,53,306**
4.	2018	76,60,300	27,910	**76,88,210**
5.	2019	82,40,400	29,960	**82,70,360**

3.3.1 Location

Mathura district is located in the north-central region of India, in the state of Uttar Pradesh. The district is situated along the banks of the river Yamuna and is home to the historic city of Mathura, which serves as its administrative headquarters. There are five tehsils in Mathura district. Mathura is located at 27.28°N 77.41°E and has an average elevation of 174 meters (*About District | District Mathura, Government of Uttar Pradesh | India*, 2023).

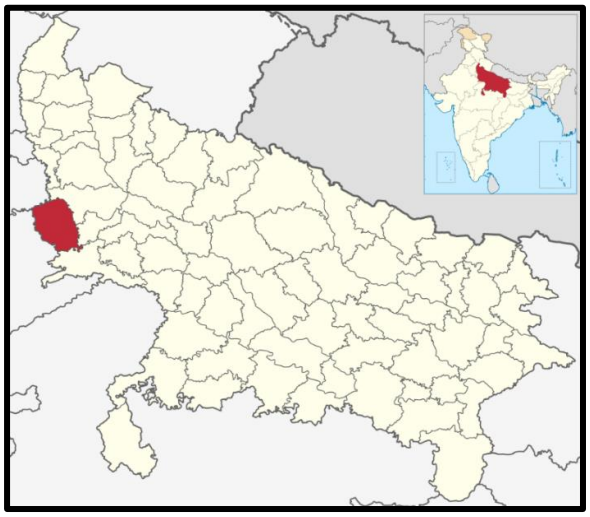


Figure 12: Location of Mathura in Uttar Pradesh

3.3.2 Climate

Table 10 shows the average maximum and minimum temperature, precipitation, humidity, rainy days, and sunny hours for every month. January and June are the months with lowest and highest average temperature respectively, with a difference of 19.5°C. November is the driest month with just 6 mm rainfall whereas July has maximum rainfall of 227 mm, leading to a difference of 221 mm between the driest and wettest months. August and April are the months with highest (78%) and lowest (29%) relative humidity respectively (Mathura climate: Temperature Mathura & Weather by Month - Climate-Data.org, 2021).

Table 10: Monthly Climatic Data for Mathura (Mathura climate: Temperature Mathura & Weather by Month - Climate-Data.org, 2021)

	January	February	March	April	May	June	July	August	September	October	November	December
Avg. Temperature °C (°F)	14 °C (57.2) °F	17.5 °C (63.5) °F	23.3 °C (74) °F	29.7 °C (85.4) °F	33.2 °C (91.8) °F	33.5 °C (92.2) °F	30 °C (86.1) °F	28.7 °C (83.6) °F	28.1 °C (82.6) °F	25.8 °C (78.5) °F	21 °C (69.8) °F	15.8 °C (60.5) °F
Min. Temperature °C (°F)	7.9 °C (46.2) °F	10.9 °C (51.6) °F	15.7 °C (60.3) °F	21.4 °C (70.6) °F	25.9 °C (78.7) °F	28.3 °C (82.9) °F	26.9 °C (80.5) °F	25.9 °C (78.6) °F	24.3 °C (75.7) °F	19.5 °C (67.1) °F	14.5 °C (58.1) °F	9.5 °C (49.2) °F
Max. Temperature °C (°F)	20.4 °C (68.7) °F	24.3 °C (75.7) °F	30.8 °C (87.4) °F	37.4 °C (99.3) °F	40.1 °C (104.1) °F	38.6 °C (101.6) °F	33.7 °C (92.6) °F	32.1 °C (89.7) °F	32.5 °C (90.4) °F	32.4 °C (90.3) °F	27.9 °C (82.2) °F	22.6 °C (72.6) °F
Precipitation / Rainfall mm (in)	15 (0)	22 (0)	14 (0)	9 (0)	14 (0)	82 (3)	227 (8)	221 (8)	111 (4)	16 (0)	6 (0)	7 (0)
Humidity(%)	68%	61%	46%	29%	32%	46%	71%	78%	71%	56%	55%	63%
Rainy days (d)	2	2	2	2	3	7	15	15	9	2	1	1
avg. Sun hours (hours)	8.5	9.6	10.6	11.5	12.1	11.7	9.4	8.7	9.2	10.0	9.6	9.0

Figure 13 shows the speed and direction of wind for Mathura city. The length of spoke shows the amount of time wind blows in that particular direction and the color depicts the wind speed. For

Mathura city, the wind blows in the W-NW direction mostly (*Simulated Historical Climate & Weather Data for Mathura - Meteoblue*, 2022).

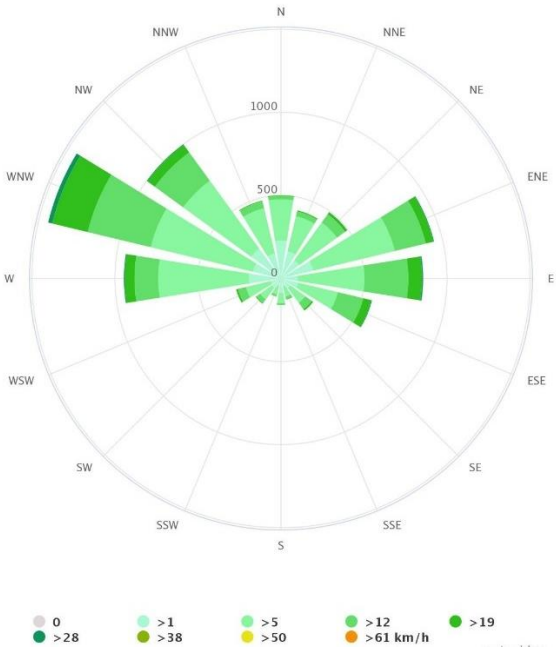


Figure 13: Wind Rose Diagram for Mathura *(*Simulated Historical Climate & Weather Data for Mathura - Meteoblue, *2022)*

3.4 Yamuna at Mathura

According to Indian mythology, the Yamuna River is considered a sacred river, revered as the second most important river after the Ganga. At Vishram Ghat, performing the ritual of Yamuna aachaman, which involves washing one's mouth with its holy water, is believed to be the most certain way of attaining redemption. People from distant places like Gujarat carry its holy water in sealed pots for use in religious ceremonies. In Mathura, candidates running in elections consider Yamuna poojan (worship) as an essential practice. On auspicious occasions, pilgrims perform traditional bathing rituals at the ghats to honor the gods in temples. However, most ghats are either destroyed or about to disappear. Every year, a significant number of devotees and pilgrims come to Mathura, the ancient city and birthplace of Lord Krishna, to take a holy dip in the Yamuna at Mathura during various festivals and religious events (Bhargava, 2006).

Vishramghat in Mathura is a year-round destination for millions of tourists. People visit this location to take a plunge and to carry holy water. Following the brutal execution of Mathura's King Kansa, Lord Krishna took a break (vishram) at Vishramghat. Therefore, this ghat's name is Vishramghat. On the second day after Dipawali, the auspicious day of Bhaiya Doj, the Lord of Death, is said to have given his sister Yamuna the blessing that "if a man would take bath at Vishramghat on the auspicious day of Bhaiya Doj, he will not travel to my realm" (*Yamuna - The Enviro-Litigators - College of Liberal Arts - Auburn University*, 2019).

3.4.1 Site Details

Yamuna travels in Mathura for a distance of about 12.5 km covering an area of approximately 25.5 km^2. There are total 25 ghats in Mathura. The river stretch from Gau Ghat to Sudarshan Ghat is

selected for research with a length of 2 km and width ranging from 167 m to 270 m. The proposal is given along both the banks of river with the width of bank ranging from 40 m to 78 m. The area between these two location consitis of a number of land uses including residential, commercial, mixed land use, agricultural, vegetation, etc. Figure 14 shows the area selected for research.

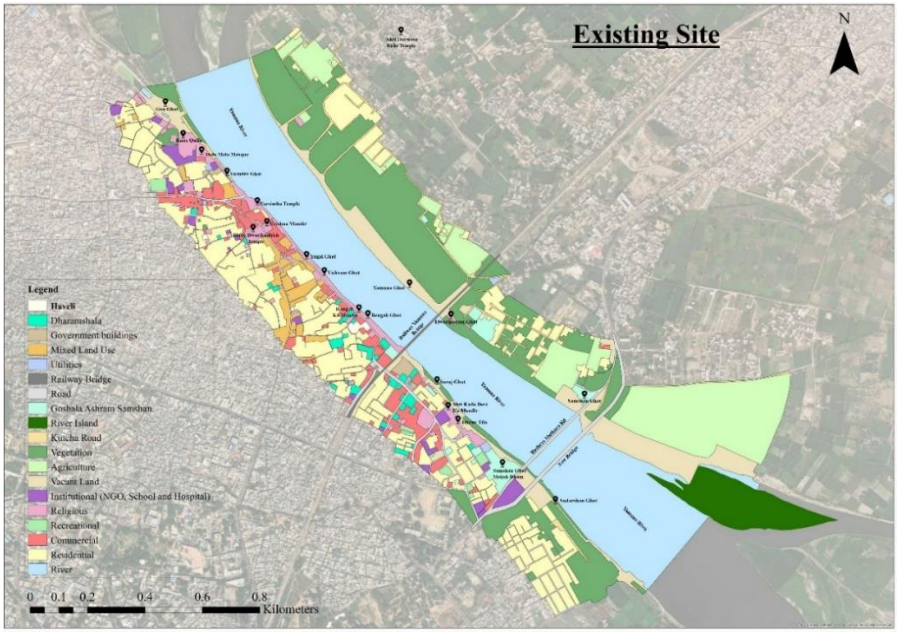


Figure 14: Study Area with Major Landmarks

The site is located at a distance of 4.6 km from Mathura Railway Station, 2.9 km from Bhuteshwar Railway Station, 1.5 km from Old Bus Stand, and 2.7 km from New Bus Stand.

3.4.2 Site Proximity

The vicinity of Vishram Ghat encompasses various transportation facilities such as bus stands and railway stations, all situated within a 3 km radius. Furthermore, all significant hospitals are also conveniently positioned within this 3 km range. Figure 15 displays the proximity of locations at distances of 1 km, 2 km, and 3 km from the site.

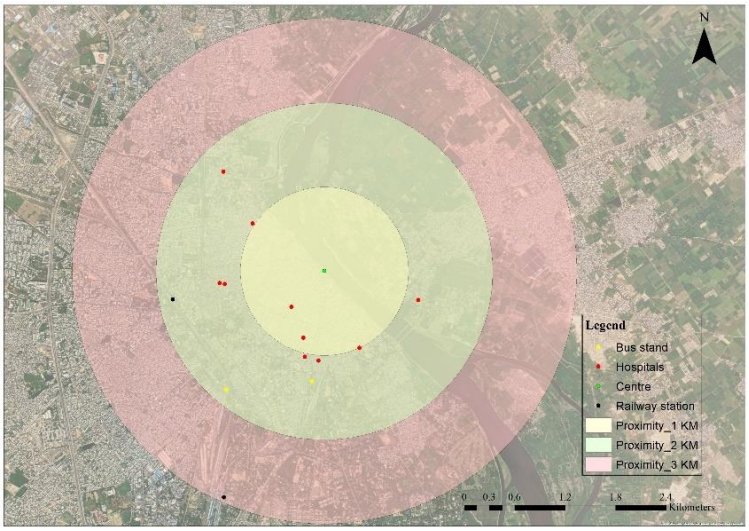


Figure 15: Site Proximity

3.4.3 Tourism

Mathura holds a significant place in Hinduism, being a revered religious site due to its historical and religious importance. It is home to several important religious sites, as well as many nearby towns of religious significance. The twin city of Mathura is Vrindavan. The little village, which is said to have been Krishna's childhood home, is home to several temples from different Hindu sects that declare Krishna in a variety of shapes and avatars (*Tourism | District Mathura, Government of Uttar Pradesh | India*, 2023). Among the fascinating locations are Shri Krishna Janambhoomi, Vishram Ghat, Dwarkadhish Temple, Birla Mandir, Kans Quila, Bengali Ghat, Durvasa Rishi Temple, etc.


Figure 16: Tourism in Mathura

3.4.4 Industries

Mathura plays a significant role in the economy of Uttar Pradesh, with industries being a major contributor. The production of silver jewellery and textile printing, including sari printing and fabric dyeing, are the primary industrial activities in the region. Silver sculptures of Krishna and jewellery for gods and goddesses are the main products in the silver industry. Besides, the area also houses manufacturing facilities for water taps and home furnishings. The city is renowned for its milk-based sweets, with Mathura Pedas and burfis being the most popular. Milk trading centers in Mathura sell fresh milk in any quantity, with prices fluctuating every few minutes, similar to stock prices. The count and investment of various industries are mentioned in Table 11 (*Mathura Industries*, 2013).

Table 11: Detail of Micro and Small Industries in Mathura-Vrindavan Development Area

Sr. No.	Type of Industry	No. of Units	Investment (in crores)
1.	Agro-based	3	1.07
2.	Cotton fabric	2	0.85
3.	Ready-made Garments	1	0.1
4.	Wooden Furniture	1	0.4
5.	Paper and Paper Production	3	0.48
6.	Rubber, Plastic and Petrochemical	2	0.5
7.	Metal-based Streel Furniture	19	5.25
8.	Engineering Units	1	0.28
9.	Service Provider	127	4.445
10.	Other	7	0.35
	Total	**166**	**13.725**

3.5 Water Quality Standards

One of the major causes for pollution of Yamuna River is Gokul Barrage, located 7 km downstream from Mathura. Its construction was completed in March 2003. As a result of construction of the barrage, the flow of the Yamuna has been diminished, and the water downstream of Mathura has become increasingly filthy owing to a lack of flushing. Along with this, a total of 23 drains falls into river Yamuna at Mathura. Table 12 shows the name and discharge capacity of each drain.

Table 12: List of Drains Falling into River Yamuna at Mathura

Sr. No.	Drain	Discharge Capacity (MLD)
1.	Jaisinghpura Nala	1.7
2.	Masani Nala	16.82
3.	Shahganj Nala	0.88
4.	Chakratirath Nala	0.79
5.	Ectaya Post Nala	1.95
6.	Kishanganga Nala	0.36
7.	Gau Ghat Nala	0.1
8.	Chintaharan Nala	0.26
9.	Dola Mola Ghat Nala	1.71
10.	Rani Ghat	0.05
11.	Swami	0.27
12.	Ashkunda Ghat	0.27
13.	Vishram Ghat	0.21
14.	Bengali Ghat	0.5
15.	Dhruv Ghat	0.13
16.	Amba Ghat Nala	26.49
17.	Satrangi Nala	1.75
18.	Mahadev Ghat	2.46
19.	Cantt	2.29
20.	Dairy Farm	0.17
21.	Kala Pathar	7.64
22.	Aurangabad Downstream	1.98
23.	Aurangabad Upstream	1.46
	Total	**70.24**

Due to heavy discharge of untreated domestic and industrial waste into the river in Delhi segment, river water quality at Eutriphicated segment is characterized by offensive odour and ugly look (Bhargava, 2006). CPCB regularly conducted water quality monitoring and analysis of Yamuna River. As per the report of CPCB 2021, the minimum and maximum temperature at Upstream Mathura, where water from Delhi segment is entering Eutriphicated segment, is 14° and 32° Celsius, respectively. The dissolved oxygen (DO) content should be greater than 5 mg/L, whereas at Upstream Mathura, it is reported to be average 2.45 mg/L. The biochemical oxygen demand (BOD), as per the CPCB standards should be less than 3 mg/L and it is reported as average 18.65 mg/L at Upstream Mathura. The fecal chloroform should be less than 2500 MPN/100 mL and it is

reported as average 460200 MPN/100mL at Upstream Mathura (Central Pollution Control Board, 2021).

Figure 17: Garbage along Riverside Polluting River

Figure 18: Polluted Water Body near River Yamuna

As per the **National Water Quality Monitoring Programme (NWMP)** under CPCB, water quality of Yamuna at Mathura falls under **category "D"** (CPCB | Central Pollution Control Board, 2021). Table 13 shows the water quality standards as per the Central Pollution Control Board for the year 2021.

Table 13: CPCB Water Quality Standards, 2021 (Central Pollution Control Board, 2021)

S No.	Location Name	State Name	Temperature °C		Dissolved Oxygen mg/L		pH		Conductivity (µmhos/cm)		BOD mg/L		Fecal Coliform MPN/100mL		Total Coliform MPN/100mL	
			Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max
Primary Water Quality Criteria for outdoor bathing					>5 mg/L		6.5-8.5				< 3 mg/L		< 2500 MPN/100 mL			
17.	Okhla After Meeting of Shahdara Drain	Delhi	15	33	BDL	5.6	7.2	7.8	499	1773	7.7	114.0	68000	7900000	490000	35000000
18.	Agra Canal at Madanpur Khadar	Delhi	15	31	BDL	1.4	7.1	7.8	573	1541	11.4	32	330000	4900000	1100000	24000000
19.	Mazawali	Uttar Pradesh	14		BDL	2.3	6.4	8.1	978	1719	8.7	59.0	680	4900000	3300	9200000
20.	Shahpur	Uttar Pradesh	14	32	4.6	6.9	7.1	7.5	_	_	5.8	10.0	31000	85000	53000	110000
21.	Kesighat, Vrindavan	Uttar Pradesh	15	32	4.0	7.6	7.1	7.6	_	_	6.0	10.4	24000	65000	46000	88000
22.	Mathura U/S	Uttar Pradesh	13		BDL	4.6	6.5	8.5	1096	1816	7.3	30.0	400	920000	1100	9200000
23.	Vishramghat, Mathura	Uttar Pradesh	14	32	4.1	7.4	6.9	7.6	_	_	6.8	12.0	31000	92000	54000	140000
24.	Mathura D/S	Uttar Pradesh	12		1.6	6.8	6.5	8.3	1195	1903	6.9	21.0	1700	170000	2200	1400000

3.6 Result and Discussion

To address all the relevant issues like pollution from upstream, connectivity for pilgrims, lack of recreational spaces, disturbance in ecology, etc., it is necessary **to study the peculiar characteristic of Yamuna River at Mathura and rejuvenate it.** This will help in reducing pollution, preserving the ecology of area, encouraging people participation through citizen-river connect, providing connectivity to pilgrims and generating river-based economy through recreational activities, etc.

CHAPTER 4: PRIORITIZATION OF MOST VULNERABLE CITY ALONG RIVER YAMUNA

4.1 General

This chapter includes prioritization of most vulnerable city along river Yamuna on the basis of various drivers polluting the river.

River Yamuna is majorly divided into five segments with a number of cities located on its bank. It starts from Himalayan Segment and after travelling a distance of 172 km, it enters Upper Segment where it travels a distance of 224 km. Invariably till the Upper Segment the water quality of River Yamuna is reasonably "good", but when it enters the Delhi Segment, several drains discharge untreated or partially treated domestic and industrial effluents into the river. This polluted water then flows downstream, entering the Eutriphicated Segment, where river water is the main source of municipal drinking water (A. Sharma, 2018). Therefore, to determine the appropriate allocation of funds and prioritize the action plan, the Analytic Hierarchy Process (AHP) technique is employed. This involves selecting seven cities from Delhi and the Eutriphicated segments for analysis, and ranking them based on the impact of 26 urban drivers that contribute to the river pollution. The city that receives the highest ranking is subsequently chosen for the development of proposals.

4.2 Prioritization using AHP Tool

Due to the poor water quality of Yamuna River after it enters Delhi Segment, seven cities from Delhi and Eutriphicated Segments along river Yamuna have been selected. These cities include Delhi, Faridabad, Ballabhgarh, Palwal, Mathura, Agra and Etawah. Among these cities, the most vulnerable city is prioritized using AHP tool.

4.2.1 About AHP

Making decisions is a necessary aspect of life, and to make excellent judgements, decision makers need the right tools. So, it is challenging to apply standard methodologies to unstructured difficulties and challenges where decisions must be made based on a variety of factors. In light of this, Professor Thomas Saaty created the Analytic Hierarchy Process in the 1970s, which resulted in a milestone. This technique uses both math and psychology to organize and evaluate difficult decisions. Three aspects of the problem are examined using the AHP technique. The AHP (Analytic Hierarchy Process) technique involves three key components. The first component involves identifying the problem that needs to be solved. The second component is identifying potential alternatives or solutions to the problem. The third and most important component of the AHP technique is the criteria used to evaluate and assess the different solutions (What is Analytical Hierarchy Process (AHP) and How to Use it, 2020). AHP provides a rational structure for making crucial decisions by assigning numerical values to the decision criteria and possible outcomes, and linking them to the primary objective (*What Is the Analytic Hierarchy Process (AHP)? | Passage Technology*, 2019).

4.2.2 How does AHP works?

There are four steps in the AHP:

- Clearly state the decision's possibilities and requirements.
- Compare items in pairs.
- Figure out the important weight assigned to each criterion.
- Use a concept known as utility to determine the optimal choice.

Decision, Options, and Criteria

Which option is best for you? is the first question that guides every choice. The AHP can be used, for instance, to choose the institution you want to attend. In this case, you may choose to select the finest university for you from your top three choices (Universities A, B, or C). You choose the criterion to take into account after fully comprehending the issue and the available alternatives. Pairwise comparisons can start once you've determined these criteria.

Pairwise Comparisons

Then, matrices are created by grouping the crucial criteria. Information is organized in rows and columns on a grid called a matrix. Each criteria have a row and column of its own in AHP matrices. The generated square matrices enable pairwise comparison of all potential criterion combinations.

Importance Weights

The relevance weights for each criterion are then determined using the completed matrix, and this information is utilized to make decisions. A criterion's impact on the decision-making process increases with its significance weight.

Utility

Utility assessment is the AHP's last stage. Utility is a metric that quantifies the usefulness of something and aids in choosing the optimal course of action. The higher the utility of a criteria, the more advantageous or helpful it is. For each criterion, utility may be evaluated in a variety of ways (Jagoda et al., 2020).

4.2.3 Urban Drivers Polluting River

As per (Arora, 2022), there are 26 urban drivers responsible for river pollution. Some of them are point source pollution while some are non-point source pollution. As the population is increasing the burden on rivers is also rising and it is getting degraded due to anthropogenic activities induced due to human interventions. Table 14 shows the list of drivers along with their final weights. The final weight of each driver represents its criticalness towards river pollution. More the final score, more critical is the driver. The final weight for each driver is calculated using FAHP (Fuzzy Analytic Hierarchy Process) technique.

Table 14: Urban Drivers with their Final Weights (Arora, 2022)

Sr. No.	Urban Drivers	Final Weights
1.	Exponential population growth leads to over withdrawn of surface & ground water	0.0192
2.	Lack of awareness amongst people regarding waste disposal	0.0332
3.	Human greed to over exploit water resources on upstream of the river	0.0255
4.	Competitive nature of development amongst states along or on river catchment	0.0191
5.	Direct or partially treated effluent discharge from industries	0.0537
6.	Rapid increase in number of Grossly Polluting Industries (GPIs) in Yamuna basin	0.0525
7.	Dumping of hazardous industrial waste near water bodies	0.0688
8.	Slums & squatters located near water bodies directly discharge their domestic waste	0.012
9.	Superstitious nature of people leads to direct discharge of floral, organic waste, mass bathing & crematorium activities at river ghats	0.015
10.	Partially or untreated municipal sewage discharge in rivers	0.0257
11.	Landfill sites located near to the water bodies	0.0284
12.	Hydropower & barrage projects	0.0326
13.	Construction projects leads to either flooding or drying of local water bodies as per site situation	0.0771
14.	Riverfront projects degrade riverine ecosystem & changes in LULC along river critically affects riparian zones	0.088
15.	Lack of Priority and Vision and Mission for cleaning of river at ULB level	0.0371
16.	Dearth of dispute resolving mechanism	0.0234
17.	Lack of know-how and poor Tech savvy level of Government	0.0496
18.	Insufficient funds for implementing innovative techniques/ infrastructure	0.0543
19.	Meagre state of regulations & policies to safeguard rivers	0.0325
20.	Poor surveillance by authorities	0.0523
21.	Intra operability of laws amongst various states	0.0563
22.	Leniency in taking strict actions against GPIs	0.0385
23.	Intensive use of fertilizers & pesticides for steadfast production of crops & aquaculture activities	0.0273
24.	Deforestation leads to soil erosion	0.023
25.	Poor working of STPs, under or over utilization of STPs hampers their performance	0.0388
26.	Polluted stormwater drains, nallas & tributaries gets merged with river	0.0458

The required data for listed urban drivers is collected for selected seven cities. It is then multiplied with respective final weight. The summation of all the values obtained for a single city gives the required ranking.

4.3 Data Collection for Selected Cities

The data regarding all the urban drivers polluting rivers for each city is collected through a number of sources. These may include official documents, newspaper articles, direct interview, website of cities, etc. Figure 19 shows the sources used for collecting the required data.

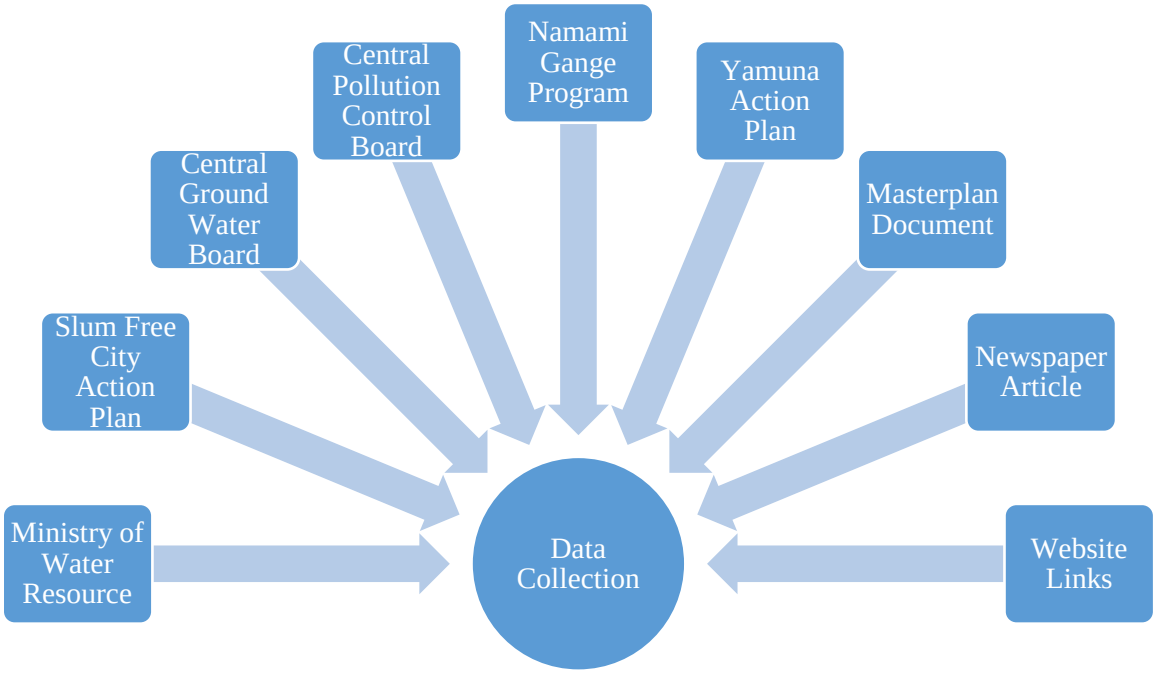


Figure 19: Sources of Data Collection

Table 15 shows the data collected for selected cities against each urban driver, which are both qualitative and quantitative in nature. The parameters which are addressed while collecting the data are also mentioned in the table. The quantitative parameters include population density of the area, Swachh Survekshan Score for the year 2022, different types of construction projects including riverfront projects, irrigation projects, number of GPIs, number of hazardous wastes generating industries and waste generated by them, etc. While on the other hand, the qualitative parameter includes the cities which have any river related programme such as Namami Gange or Yamuna Action Plan working upon them for cleaning of ghats and other activities have good condition of ghats and nearby areas. The cities are then given the score of 1 or 0 depending upon the situation asked. A detailed description of these parameters is shown in Table 15.

Table 15: Data Collection for Selected Cities

Sr. No.	Cities	Delhi	Faridabad	Ballabhgarh	Palwal	Mathura	Agra	Etawah	Parameters Addressed
	Urban Drivers								
1.	Exponential population growth leads to over withdrawn of surface & ground water	11,320	8,398	698	3,218	12,257	11,166	6,886	Population density (in person/km2)
2.	Lack of awareness amongst people regarding waste disposal	949.96	4007.06	4007.06	4680.04	2603.37	3058.7	4424.65	7500 (the score is given out of 7500) less Swachh Survekshan Score (More difference means Dirty city)
3.	Human greed to over exploit water resources on upstream of the river	26	12	0	12	13	9	15	Numbers of Ground water Wells as per CGWB
4.	Competitive nature of development amongst states along or on river catchment	13	3	0	1	5	5	1	Number of Riverfront projects, ERM projects, Biodiversity projects and Functional Barrages along River
5.	Direct or partially treated effluent discharge from industries	2654	286	0	163	103	29	3	Number of Hazardous Waste Generating Industries (Source CPCB)
6.	Rapid increase in number of Grossly Polluting Industries (GPIs) in Yamuna basin	267	106	3	8	39	5	1	Number of Grossly Polluting Industries
7.	Dumping of hazardous industrial waste near water bodies	23,649	1969.03	0	2485.637	4276.5	494	0	Quantity of Hazardous Waste generated as per Annual Return (Metric Tonne) (Source CPCB)
8.	Slums & squatters located near water bodies directly discharge their domestic waste	1500	50	2	22	98	255	39	Number of Slums

9.	Superstitious nature of people leads to direct discharge of floral, organic waste, mass bathing & crematorium activities at river ghats	1103	6	0	0	28	15	1	Number of Religious and Crematoria ghats
10.	Partially or untreated municipal sewage discharge in rivers	3330	236.04	31.8	19.05	51.7	233.03	38.01	As per CBCB, the sewage generation is estimated as 80% of 185 lpcd for the population of respective city
11.	Landfill sites located near to the water bodies	3	0	0	0	0	1	0	Number of Landfill Sites
12.	Hydropower & barrage projects	3	0	0	0	1	0	0	Number of Functional Barrages on Yamuna taken
13.	Construction projects leads to either flooding or drying of local water bodies as per site situation	3	2	0	0	3	3	1	Number of ERM projects and Irrigation Projects (Source - Ministry of Water Resource) Delhi - Biodiversity parks
14.	Riverfront projects degrade riverine ecosystem & changes in LULC along river critically affects riparian zones	7	1	0	1	1	2	0	Number of Riverfront projects along river
15.	Lack of Priority and Vision and Mission for cleaning of river at ULB level	1	1	1	0	1	1	1	The cities which have any river related programme such as Namami Gange or Yamuna Action Plan working upon them for cleaning of ghats and other activities have good condition of ghats and nearby areas. Such cities are awarded a score of 1.
16.	Dearth of dispute resolving mechanism	1	1	1	0	1	1	1	
17.	Lack of know-how and poor Tech savvy level of Government	1	1	1	0	1	1	1	
18.	Insufficient funds for implementing innovative techniques/ infrastructure	1	1	1	0	1	1	1	

19.	Meagre state of regulations & policies to safeguard rivers	1	1	1	0	1	1	1	
20.	Poor surveillance by authorities	1	1	1	0	1	1	1	
21.	Intra operability of laws amongst various states	1	1	1	0	1	1	1	
22.	Leniency in taking strict actions against GPIs	1	1	1	0	1	1	1	
23.	Intensive use of fertilizers & pesticides for steadfast production of crops & aquaculture activities	247	1100	1100	1050	2614.45	2587	1222.52	Net Irrigated Area (in sq. km)
24.	Deforestation leads to soil erosion	0.44	0.71	0.71	0.41	0	0	0	Forest Cover for year 2021 less Forest Cover for year 2019 (in sq. km.)
25.	Poor working of STPs, under or over utilization of STPs hampers their performance	537.07	35	0	9.05	23.09	41.75	10.5	Installed Capacity of STP less Actual Utilization of Installed Capacity (in MLD)
26.	Polluted stormwater drains, nallas & tributaries gets merged with river	156	2	1	2	23	8	134	Number of drains discharging water into Yamuna taken

4.4 Normalization of Data

The raw data collected for different cities for each urban driver through various sources cannot be compared with each other. Normalizing the data is one way to get comparable results in a given dataset. Thus, the collected raw data is normalized to get the values between 0 and 1. The general formula used for normalizing the data is:

$$\text{Normalization of Data} = \frac{X - X\,min}{X\,max - X\,min}$$

Where, X is the required data which needs to be normalized,

X_{min} is the least value in the dataset for a particular driver, and

X_{max} is the highest value in the dataset for a particular driver.

Table 16 shows the normalized data for each urban driver for selected cities.

4.5 Ranking of Cities

Table 17 shows the final ranking of cities along with their score. The normalized data calculated in Table 16 in section 4.4 is multiplied with the final weights of respective driver, mentioned in sub-section 4.2.3 to get the final score and ranking of cities. The final score for each city is calculated as –

Final Score for Each City = Σ Final weight of driver X Normalized value of collected data for that respective driver

Table 16: Normalized Data for Each City

Sr. No.	Cities / Barriers	Delhi	Faridabad	Ballab-hgarh	Palwal	Mathura	Agra	Etawah
1.	Exponential population growth leads to over withdrawn of surface & ground water	0.91894	0.66615	0	0.21801	1	0.90561	0.53534
2.	Lack of awareness amongst people regarding waste disposal	0	0.81958	0.81958	1	0.44326	0.56533	0.93153
3.	Human greed to over exploit water resources on upstream of the river	1	0.46154	0	0.46154	0.5	0.34615	0.57692
4.	Competitive nature of development amongst states along or on river catchment	1	0.23077	0	0.07692	0.38462	0.38462	0.07692
5.	Direct or partially treated effluent discharge from industries	1	0.10776	0	0.06142	0.03881	0.01093	0.00113
6.	Rapid increase in number of Grossly Polluting Industries (GPIs) in Yamuna basin	1	0.39474	0.00752	0.02632	0.14286	0.01504	0
7.	Dumping of hazardous industrial waste near water bodies	1	0.08326	0	0.10511	0.18083	0.02089	0
8.	Slums & squatters located near water bodies directly discharge their domestic waste	1	0.03204	0	0.01335	0.06409	0.16889	0.0247
9.	Superstitious nature of people leads to direct discharge of floral, organic waste, mass bathing & crematorium activities at river ghats	1	0.00544	0	0	0.02539	0.01360	0.00091
10.	Partially or untreated municipal sewage discharge in rivers	1	0.06554	0.00385	0	0.00986	0.06463	0.00573
11.	Landfill sites located near to the water bodies	1	0	0	0	0	0.33333	0
12.	Hydropower & barrage projects	1	0	0	0	0.33333	0	0
13.	Construction projects leads to either flooding or drying of local water bodies as per site situation	1	0.66667	0	0	1	1	0.33333
14.	Riverfront projects degrade riverine ecosystem & changes in LULC along river critically affects riparian zones	1	0.14286	0	0.14286	0.14286	0.28571	0
15.	Lack of Priority and Vision and Mission for cleaning of river at ULB level	1	1	1	0	1	1	1
16.	Dearth of dispute resolving mechanism	1	1	1	0	1	1	1
17.	Lack of know-how and poor Tech savvy level of Government	1	1	1	0	1	1	1

18.	Insufficient funds for implementing innovative techniques/ infrastructure	1	1	1	0	1	1	1
19.	Meagre state of regulations & policies to safeguard rivers	1	1	1	0	1	1	1
20.	Poor surveillance by authorities	1	1	1	0	1	1	1
21.	Intra operability of laws amongst various states	1	1	1	0	1	1	1
22.	Leniency in taking strict actions against GPIs	1	1	1	0	1	1	1
23.	Intensive use of fertilizers & pesticides for steadfast production of crops & aquaculture activities	0	0.36030	0.36030	0.33918	1	0.98841	0.41206
24.	Deforestation leads to soil erosion	0.61972	1	1	0.57746	0	0	0
25.	Poor working of STPs, under or over utilization of STPs hampers their performance	1	0.06517	0	0.01685	0.04299	0.07774	0.01955
26.	Polluted stormwater drains, nallas & tributaries gets merged with river	1	0.00645	0	0.00645	0.14194	0.04516	0.85806

Table 17: Final Ranking of Cities

Sr. No.	**Cities**	**Delhi**	**Faridabad**	**Ballab-hgarh**	**Palwal**	**Mathura**	**Agra**	**Etawah**
	Barriers							
1	Exponential population growth leads to over withdrawn of surface & ground water	0.01764	0.01279	0	0.00419	0.0192	0.01739	0.01028
2	Lack of awareness amongst people regarding waste disposal	0	0.02721	0.02721	0.0332	0.01472	0.01877	0.03093
3	Human greed to over exploit water resources on upstream of the river	0.0255	0.01177	0	0.01177	0.01275	0.00883	0.01471
4	Competitive nature of development amongst states along or on river catchment	0.0191	0.00441	0	0.00147	0.00735	0.00735	0.00147
5	Direct or partially treated effluent discharge from industries	0.0537	0.00579	0	0.00330	0.00208	0.00059	6.07E-05
6	Rapid increase in number of Grossly Polluting Industries (GPIs) in Yamuna basin	0.0525	0.02072	0.00039	0.00138	0.0075	0.00079	0
7	Dumping of hazardous industrial waste near water bodies	0.0688	0.00573	0	0.00723	0.01244	0.00144	0

8	Slums & squatters located near water bodies directly discharge their domestic waste	0.012	0.00038	0	0.00016	0.00077	0.00203	0.0003
9	Superstitious nature of people leads to direct discharge of floral, organic waste, mass bathing & crematorium activities at river ghats	0.015	8.16E-05	0	0	0.00038	0.00020	1.36E-05
10	Partially or untreated municipal sewage discharge in rivers	0.0257	0.00168	9.90E-05	0	0.00025	0.00166	0.00015
11	Landfill sites located near to the water bodies	0.0284	0	0	0	0	0.00947	0
12	Hydropower & barrage projects	0.0326	0	0	0	0.01087	0	0
13	Construction projects leads to either flooding or drying of local water bodies as per site situation	0.0771	0.0514	0	0	0.0771	0.0771	0.0257
14	Riverfront projects degrade riverine ecosystem & changes in LULC along river critically affects riparian zones	0.088	0.01257	0	0.01257	0.01257	0.02514	0
15	Lack of Priority and Vision and Mission for cleaning of river at ULB level	0.0371	0.0371	0.0371	0	0.0371	0.0371	0.0371
16	Dearth of dispute resolving mechanism	0.0234	0.0234	0.0234	0	0.0234	0.0234	0.0234
17	Lack of know-how and poor Tech savvy level of Government	0.0496	0.0496	0.0496	0	0.0496	0.0496	0.0496
18	Insufficient funds for implementing innovative techniques/ infrastructure	0.0543	0.0543	0.0543	0	0.0543	0.0543	0.0543
19	Meagre state of regulations & policies to safeguard rivers	0.0325	0.0325	0.0325	0	0.0325	0.0325	0.0325
20	Poor surveillance by authorities	0.0523	0.0523	0.0523	0	0.0523	0.0523	0.0523
21	Intra operability of laws amongst various states	0.0563	0.0563	0.0563	0	0.0563	0.0563	0.0563
22	Leniency in taking strict actions against GPIs	0.0385	0.0385	0.0385	0	0.0385	0.0385	0.0385
23	Intensive use of fertilizers & pesticides for steadfast production of crops & aquaculture activities	0	0.00984	0.00984	0.00926	0.0273	0.02698	0.01125
24	Deforestation leads to soil erosion	0.01425	0.023	0.023	0.01328	0	0	0
25	Poor working of STPs, under or over utilization of STPs hampers their performance	0.0388	0.00253	0	0.00065	0.00167	0.00302	0.00076
26	Polluted stormwater drains, nallas & tributaries gets merged with river	0.0458	0.0003	0	0.0003	0.0065	0.00207	0.0393
	Total	**0.9589**	**0.5342**	**0.40454**	**0.09876**	**0.55745**	**0.54681**	**0.47891**
	Final Ranking	**1**	**4**	**6**	**7**	**2**	**3**	**5**

Figure 20 shows the final ranking of cities on the basis of various urban drivers polluting river Yamuna. It has been analyzed that river Yamuna in Delhi is most polluted, but a large number of works under Yamuna Action Plan, Namami Gange, etc. has been carried out here to clean up the river. Thus, the second city where river Yamuna is most polluted, which is Mathura, has been selected for carrying out the study. City-specific proposals, including ghat and riverfront development for river rejuvenation and generation of river-based economy will be proposed for Mathura City.

Figure 20: Pie Chart showing Ranking of Cities

Since Mathura is considered as most vulnerable city along Yamuna River in these two segments, the top five drivers leading to pollution in the river there are identified. Figure 21 shows the weight of all 26 drivers polluting river Yamuna in Mathura. The major threat to Yamuna River there is due to construction projects leading to either flooding or drying of local water bodies as per site situation, which accounts to 13.83%. This is followed by intra operability of laws amongst various states, accounting to 10.10%. Insufficient funds for implementing innovative techniques/ infrastructure and poor surveillance by authorities holds the position of third and fourth driver polluting the river, with 9.74% and 9.38%, respectively. The fifth driver leading to pollution of river Yamuna is Lack of know-how and poor Tech savvy level of Government, which accounts to 8.90%.

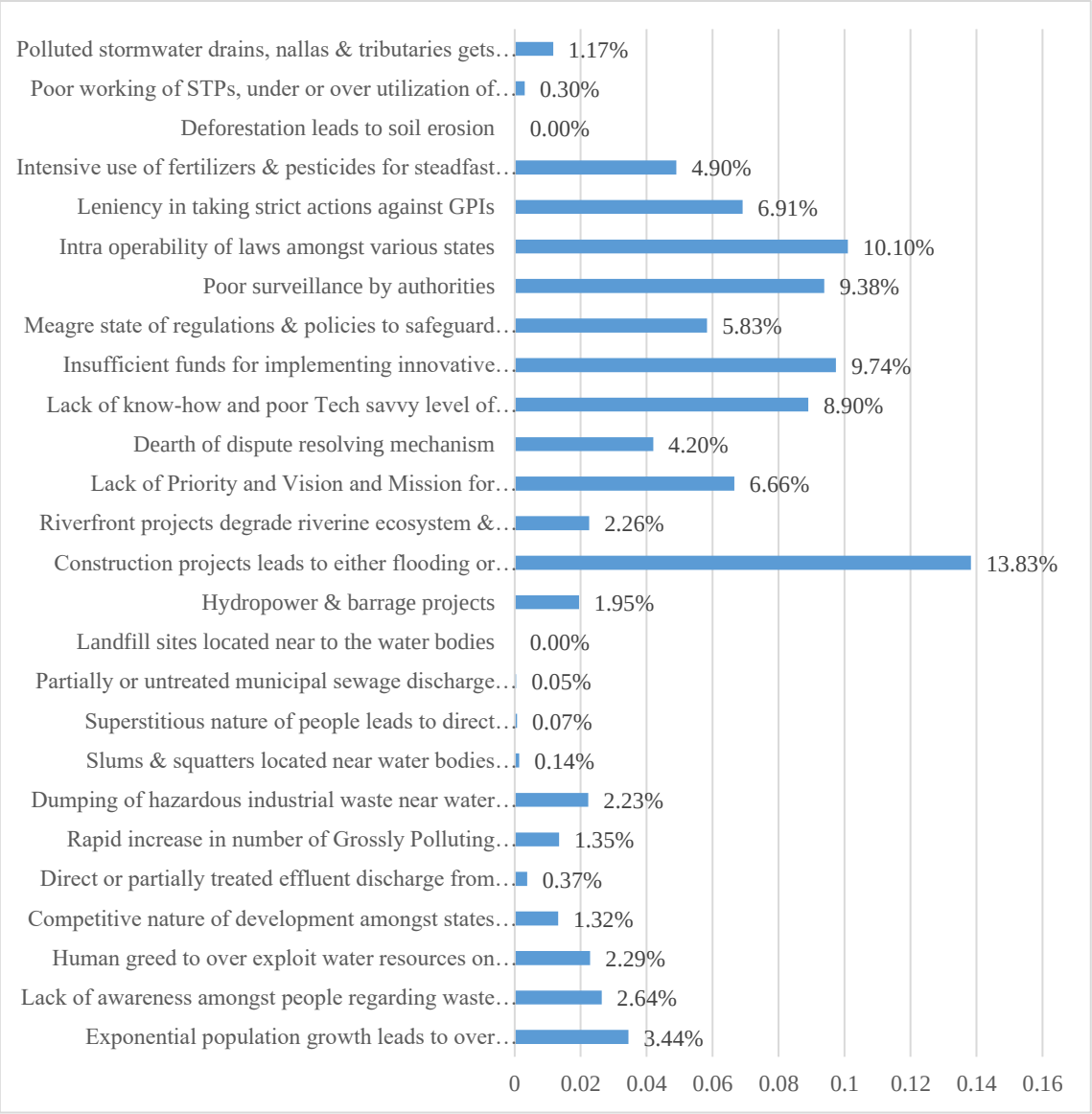


Figure 21: Percentage of Different Drivers Polluting Yamuna River in Mathura

Thus, the proposals should be given in such a way to minimize the impact of these factors in polluting the river Yamuna at Mathura. These proposals will be in the form of physical planning as well as policies and guidelines.

CHAPTER 5: DATA COLLECTION FOR MATHURA CITY AND MAPPING OF PAIN POINTS

5.1 General

This chapter includes data collection through various methods such as preliminary survey, interview of stakeholders, discussion with government officials, questionnaire, etc. It will be followed by presentation of data in the form of graphs, pie charts, bar charts, etc. and extracting relevant inferences from it.

5.2 Data Collection

The required data for carrying out the research have been collected through primary, secondary, and site survey.

5.2.1 Primary Survey

A primary survey is be carried out for analyzing the need of the people there. A set of questionnaires is made for various stakeholders including local residents of Mathura city, tourists, and government organizations. The questionnaire for local residents, floating population, and government organizations is given in ANNEXURE I.

5.2.2 Secondary Survey

During secondary survey, various governmental organizations including Nagar Nigam Mathura Vrindavan (NNMV), Mathura Vrindavan Development Authority (MVDA), Uttar Pradesh Braj Tirath Vikas Parishad (UPBTVP), and Irrigation Department, MVDA had been visited and details about various aspects had been collected as described in the section below.

Issues at the Study Stretch as per Nagar Nigam Mathura Vrindavan (NNMV)

- Drains falling into river Yamuna, specifically Masani Drain – a major cause of pollution, degrading its water quality.
- The main cause of pollution is industrial waste and not municipal waste because chemicals released from industries have a high impact on COD, BOD, DO, etc.
- The Choubey Para area (area adjacent to the river) has narrow roads, which makes it difficult for collecting and transporting waste.
- On the occasion of Yum-Dwitiya, 15 lakh devotees came, but there is no facility for them.
- Encroachment issue – people made their homes over drains, which makes it difficult to clean them, widen them, and set up of STPs.

Details about Drains Falling into River Yamuna at Mathura

As stated in Chapter 3: Study Area Profile, a total of 23 drains are falling into the river Yamuna at Mathura. Out of these 23 drains, six drains are untapped and one drain is partially tapped. For these

two types of drains, the process of bioremediation is carried out. After this process, the water is directed into the Yamuna River.

For this process, structures are created to increase the retention period of water, and dozing is carried out (some chemicals are added to the water). The chemical falls into the water drop by drop. The chemicals then get dissolved into the retained water and it gets cleaned. PCBC is responsible for testing the quality (BOD, COD, DO) of this water, before and after the treatment.

Detail about STPs

There is a total of 6 STP in Mathura and Vrindavan, out of which 5 were made under Namami Gange. Two new STP are proposed by Namami Gange for the tapping of remaining drains. One is in Mathura, near Gokul Branch, Aurangabad – capacity 60 MLD, cost 292.56 Cr with 15 years O/M. The other is in Vrindavan – capacity 13 MLD. Four drains will be tapped through 60 MLD STP at Mathura, a detail of which is shown in Table 18.

Table 18: Drains Tapped from 60 MPD STP

Sr. No.	Drain	Discharge Capacity (MLD)
1.	Amba Ghat Nala	26.49
2.	Kala Pathar	7.64
3.	Aurangabad Downstream	1.98
4.	Aurangabad Upstream	1.46
	Total	**37.57**

The Figure 22 below shows how wastewater in the selected study area goes to STP.

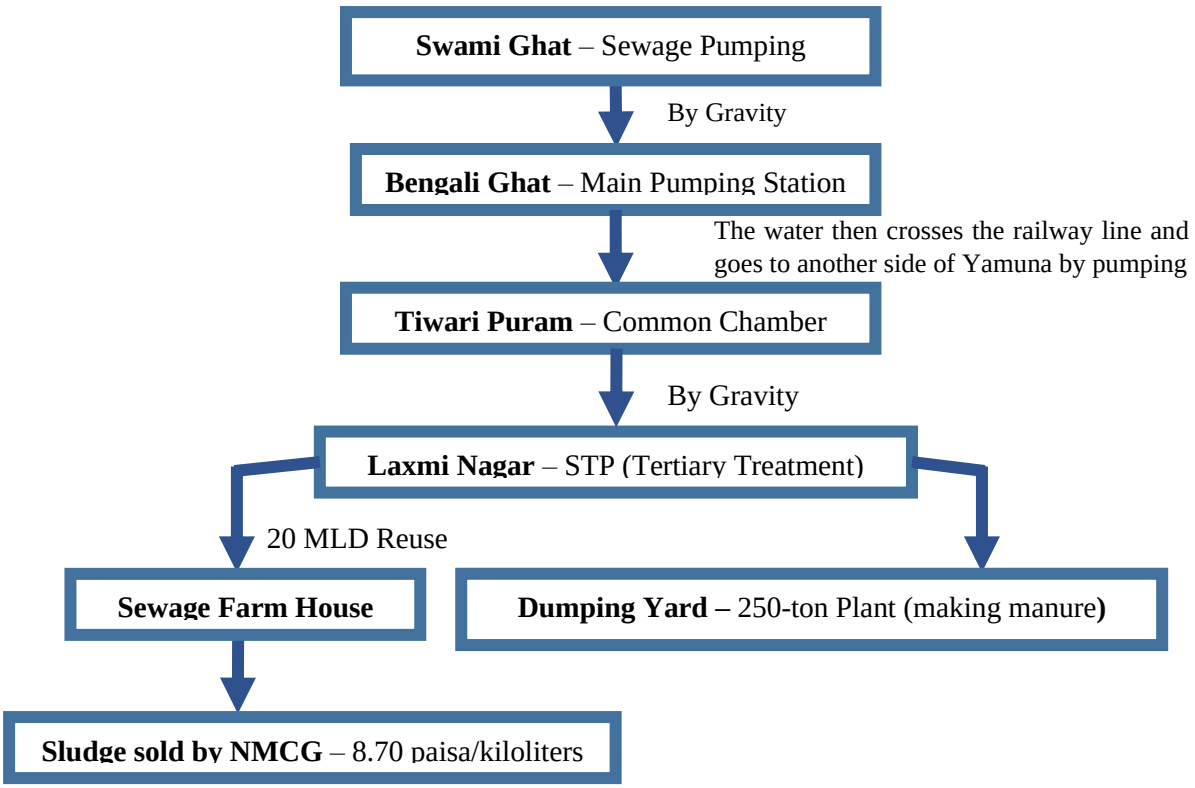


Figure 22: Process of Wastewater Treatment coming from Various Ghats

Vision for Development

- Control waterlogging
- No inter-locking roads
- Water flow should be proper as because of Gokul Barrage, water remains stagnant. Due to this, waste is deposited in water which seems dirty and has a bad odor.

Projects as per Nagar Nigam Mathura Vrindavan (NNMV)

- Water from various drains should go into the river after proper treatment.
- Industries wastewater treatment – made by Namami Gange
    - CETP – Common Effluent Treatment Plant for the cluster of industries
    - ETP – Effluent Treatment Plant for a single industry
- The water from the Delhi segment should flow downstream after tertiary treatment.
- Personal ETPs for industries.
- Under Namami gange –
    - Ghat cleaning
    - STPs
    - Rejuvenation projects
- Transformation from traditional STP to conventional STP.

Projects as per Mathura Vrindavan Development Authority (MVDA)

- Local area plan (under AMRUT) is prepared for old core areas which includes road beautification, heritage conservation. The area selected for preparing the LAP is Holy Gate area.
- ASI for Kans Quila.
- Connecting Corridor is proposed for people coming from Yamuna Expressway to Mathura Cut by constructing an outer peripheral by-pass. which connects Mathura to Vrindavan to the main highway. An elevated road will be made by NHI.

Projects as per Uttar Pradesh Braj Tirath Vikas Parishad (UPBTVP)

- DPR is prepared for 25 ghats for the development/beautification of ghats, changing room, washroom, water facilities, garbage collection & disposal.
- Inland Waterways is proposed by the Government of India which includes proposing a jetty system with a transportation system from Gokul Barrage to Vrindavan. Various tourist places at different locations with amenities such as parking, restaurants, etc. will be proposed with stops at major locations including Vishram Ghat, Swami Ghat, Sudarshan Ghat.
- Suspension bridge across both ends of the river is proposed for providing connectivity from Dwarkadhish Temple to Durvasa Rishi Temple with parking facilities (people coming from Yamuna Expressway parks on side, visit various places across the bridge, such as Janam bhumi and return).
- Heritage conservation for old buildings.

Information gathered from Irrigation Department, MVDA

- HFL for Yamuna River at Mathura is 169.73 m (1978) given by Central Water Commission. No permanent construction is allowed in this zone.
- As per NGT, no construction is allowed up to 100 m from river bank.
- Present the history of Vrindavan and Mathura as some proposal.

Funding

- 12 Crore/month through state finance for the salary, and pension of government officials of Mathura and Vrindavan.

5.2.3 Site Survey

A site survey is conducted to gather the detailed information about the existing condition of the area where research work is to be carried out. For this purpose, a detailed site survey was carried out at the study area and various pain points have been mapped as shown in Figure 23.

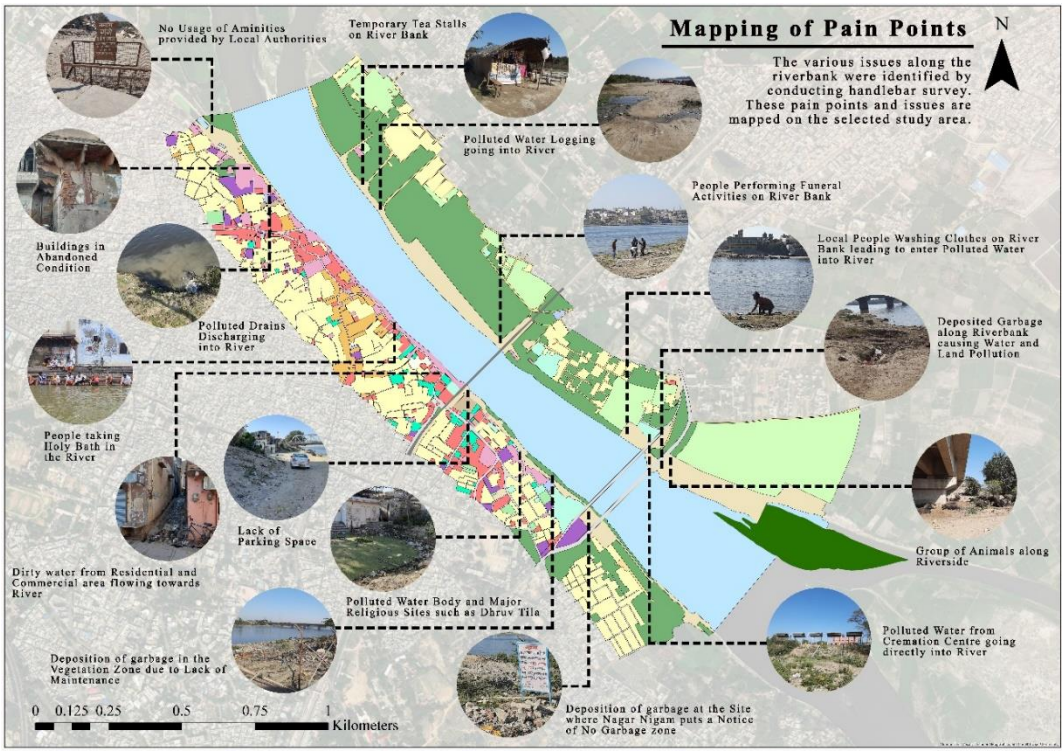


Figure 23: Pain Points at Study Area

The various pain points highlighted during the survey includes:

- Abandoned conditions of buildings.
- Polluted drains discharging wastewater into river.
- People taking holy bath in the river.
- Lack of parking space.
- Polluted water bodies present near major landmarks such as Dhruv Tila, Gau Ghat.
- Deposition of garbage in vegetation zone.

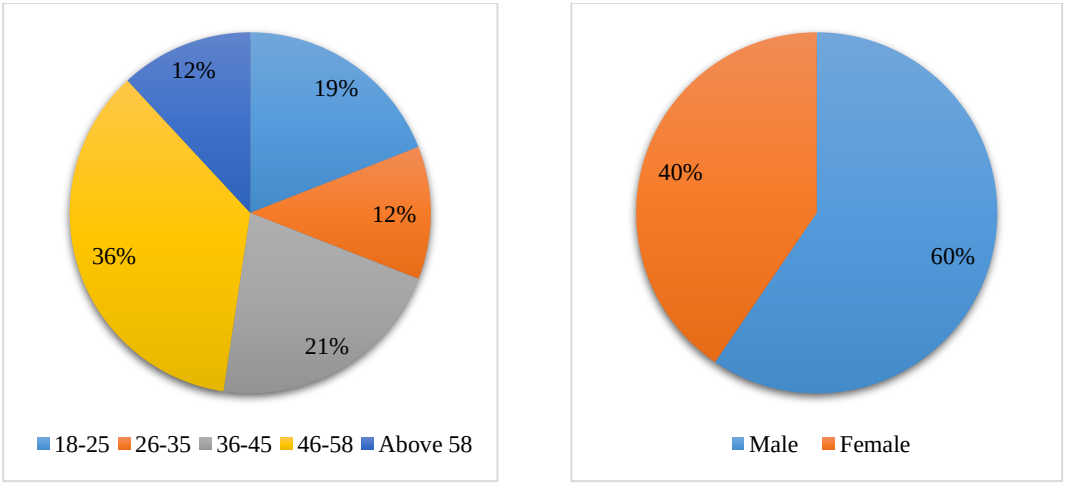
- Illegal stalls on riverbank.
- People performing cremation activities along riverbank.
- Local people washing clothes on riverbank.
- Group of animals roaming around riverside.
- No connectivity between two riverbanks.

5.3 Data Analysis

The data collected through primary surveys gives a large amount of information from sizable sample in a fast, efficient, and inexpensive manner. The survey was carried out for local residents of Mathura as well as people visiting there. The section below gives a detailed analysis about the various aspects including sources of pollution, infrastructure requirements, and their expectations for Yamuna River in future.

5.3.1 Analysis of Data Collected from Local Residents

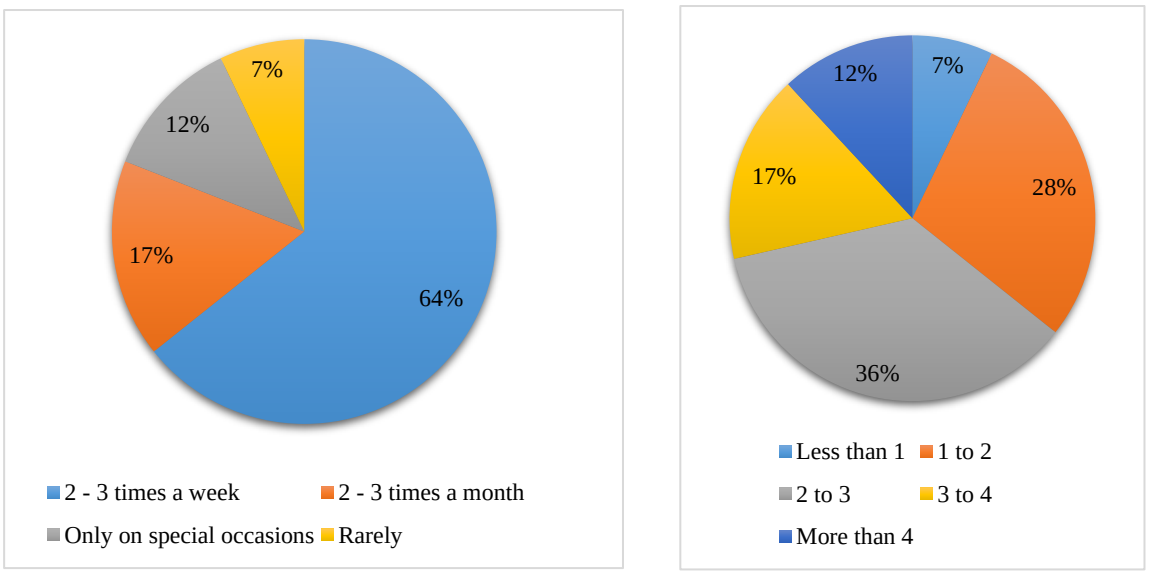
As shown in the Figure 24 (a), users from almost all age groups visit river Yamuna. Among these, the highest percentage, which is 36%, is from the age group of 46 to 58 years. Out of these people, 60% are male while 40% are female, as shown in Figure 24 (b).



(a) (b)

Figure 24: Age (a) and Gender (b) of Local Residents of Mathura

Around 64% of people visits the river 2 – 3 times a week, followed by 17% people who visits it 2 – 3 times a month as shown in Figure 25 (a), most of which spends around 2 to 3 hours there as depicted in Figure 25 (b). The people visit the river for a number of reasons as shown in Figure 26. Out of these reasons, religious purpose holds the highest weightage with 80.95%, followed by recreational purpose with 64.29% for visiting it. This depicts the importance of Yamuna River among the people of Mathura who consider it as their holy mother which they worship.



(a) (b)

Figure 25: Frequency of Visiting (a) and Time Spent – in hours (b) at River and Ghats by Local Residents of Mathura

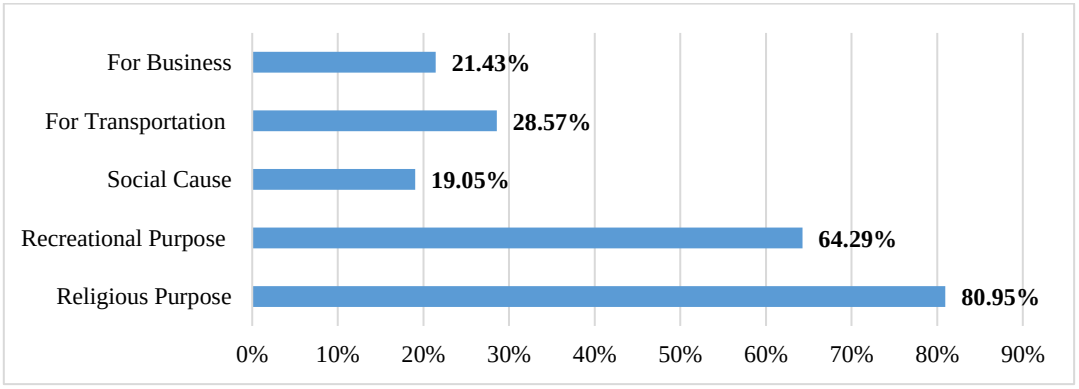


Figure 26: Local Resident's Purpose for Visiting River Yamuna

When they were asked about their perception of how they see river Yamuna, 71.43% people consider it as dirty and drain. Only 14.29% see it as clean and beautiful as shown in Figure 27. This represents a very peculiar characteristics of Yamuna River that though people consider it as their holy mother but they hesitate to drink its water because they believe the river contains some kind of industrial pollution.

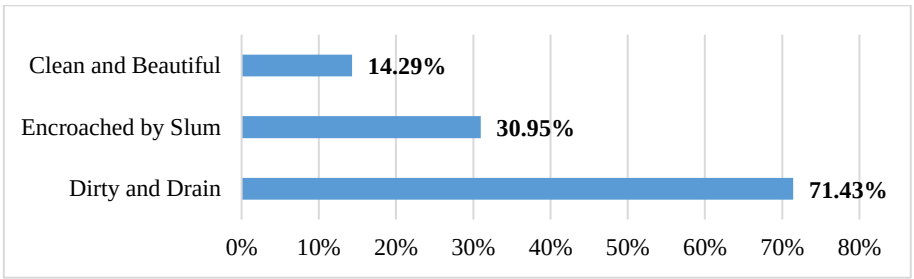
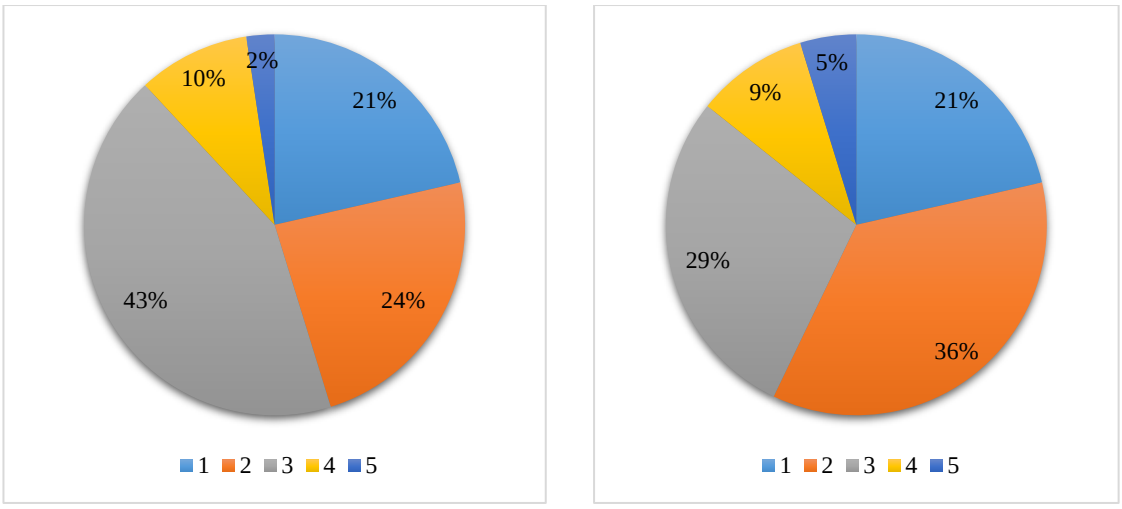


Figure 27: Perception of Local Residents about River Yamuna

Apart from this, 71% of people consider Yamuna River as active and vibrant because they believe that it is attached to them with moral and traditional values. It provides them with the very basic

need for a healthy lifestyle, which is water. Additionally, they consider the river as their holy mother and worship it.

43% of people believes that the existing condition of ghats at Yamuna River is 3, followed by 24% people who consider it only 2 on a scale of 1 to 5 as shown in Figure 28 (a). The case gets opposite when they were asked about the existing condition of river infrastructure at that place. 36% of people gives a score of 2, followed by 29% people who gives a score of 3 on a scale of 1 to 5 to the existing condition of river infrastructure as shown in Figure 28 (b). This necessitates the major need of developing these areas.



(a) (b)

Figure 28: Existing Condition of Ghats (a) and River Infrastructure (b) at River Yamuna according to Local Residents of Mathura

54.76% of the people visiting river believes that there is no recreational space near any stretch of river. Apart from this, the one who believes that there are few recreational spaces available, won't go there for a number of reasons, out of which lack of maintenance of these spaces holds the highest weightage with 50% followed by presence of lots of garbage around them with 47.62% as depicted in Figure 29.

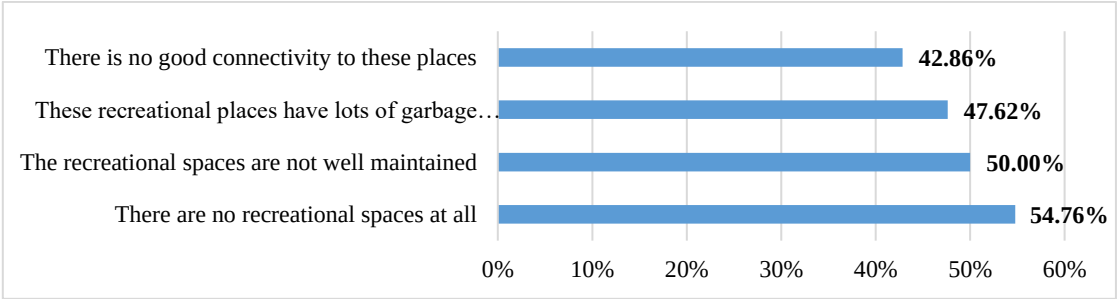


Figure 29: Reasons for not using Any River Stretch as Recreational Space by Local Residents of Mathura

A number of pain points as shown in Figure 30 were coined at the users which are associated with Yamuna River, among which outlet of drainages opening into river possesses the major threat to it accounting to 92.86%. This is followed by throwing garbage and waste deposition in and around the river with 83.33% and 78.57% respectively. Dirty places and no cleanliness with 71.43% each

add further to the issues faced by river. As a result of these issues, 88% people believe that improvement is needed for the river, its surrounding infrastructure, and Yamuna Ghats at Mathura.

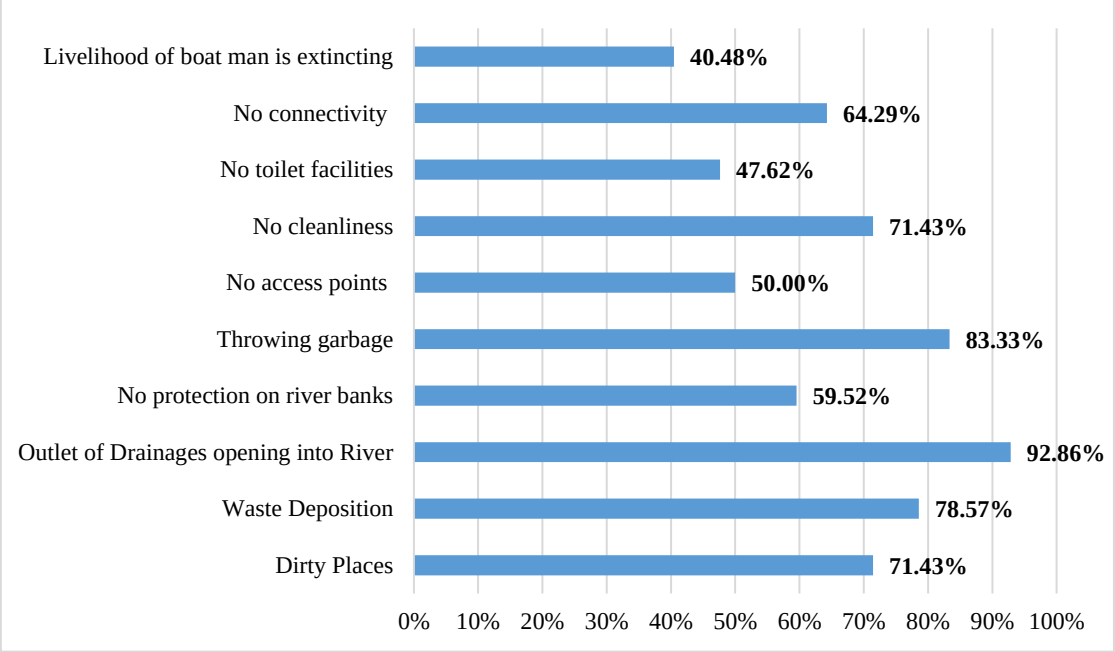


Figure 30: Pain Points Associated with River Yamuna at Mathura as per the Perception of Local Residents of City

According to Figure 31, the primary cause of pollution in the Yamuna River at Mathura, as reported by local residents, is the release of untreated or partially treated effluents from industries. This is reported by 100% people. The second most significant source of pollution is waste dumping into the river with 95.24%. Upstream in the Delhi segment, there are a large number of industries located on the bank of the Yamuna River that discharge untreated or partially treated domestic and industrial effluents into the river. This polluted water flows downstream and enters Mathura in the Eutriphicated Segment, leading to the degradation of water quality in the river. This particular source of pollution accounts for 88.10% of the pollution in the Yamuna River at Mathura.

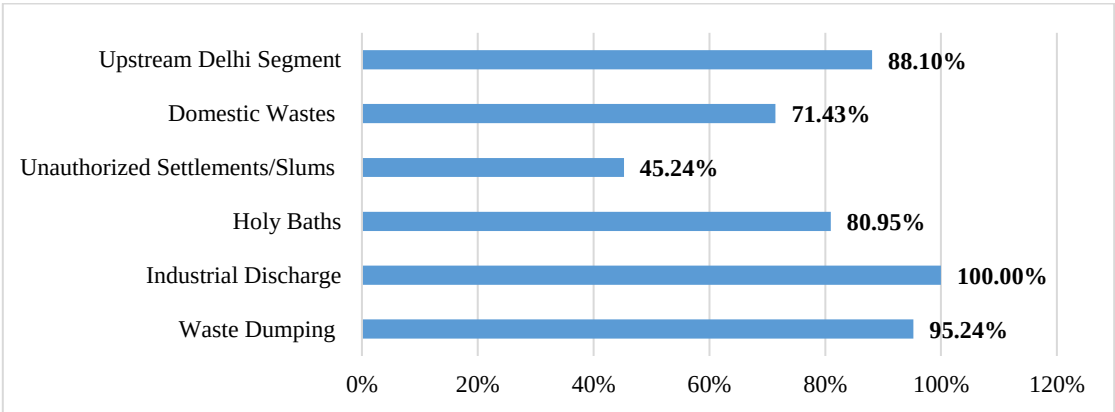


Figure 31: Major Source of Pollution for River Yamuna at Mathura according to Local Residents of City

Figure 32 shows the facilities and improvements people of the city want around the banks of river Yamuna at Mathura. 92.86% people pointed that they need larger number of recreational spaces, followed by public amenities and cleanliness pointed by 90.48% people. In addition to this,

83.33% people also want more riparian zones along the river banks. Riparian zone will help in maintaining the ecology of the place along with providing habitat to the species there.

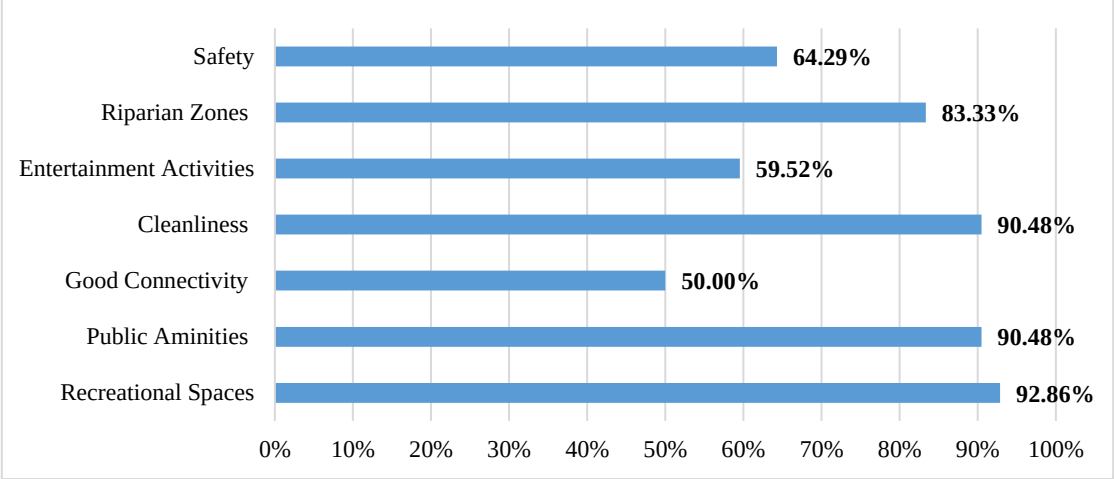


Figure 32: Facilities/Improvements required by Local Residents at River Yamuna

When the people were asked whether they can be a part of improvement for enhancing the condition of Yamuna River and its surroundings, 69% people agreed to it. Figure 33 shows the ways and suggestions through which one can be a part of improving the condition of Yamuna River and area around it. 64.29% people agreed to pay charges for various places they will visit. This will generate economy, which can be used for development of the area. This is followed by monitory participation with 47.62% people in which they can look around the things and check whether everything is up to date. Physical participation holds the third place with 45.24% in which people can do physical activities such as watering plants, cleaning walkways, etc. to maintain the place. 35.71% people also agreed to give donations for development of the area.

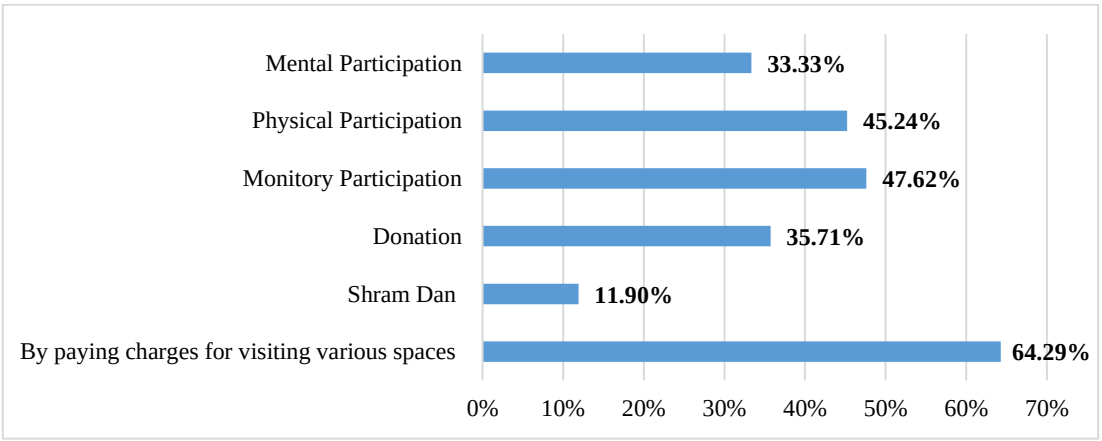


Figure 33: Suggestions for being Part of Improvement

At last, the people were asked about their future vision for Yamuna River of how they want to see it. Figure 34 shows the qualities for Yamuna River people wants to see. An active and vibrant river is the first vision of 95.24% people for their holy mother. 92.86% people want to see river pollution free which will appear clean and beautiful.

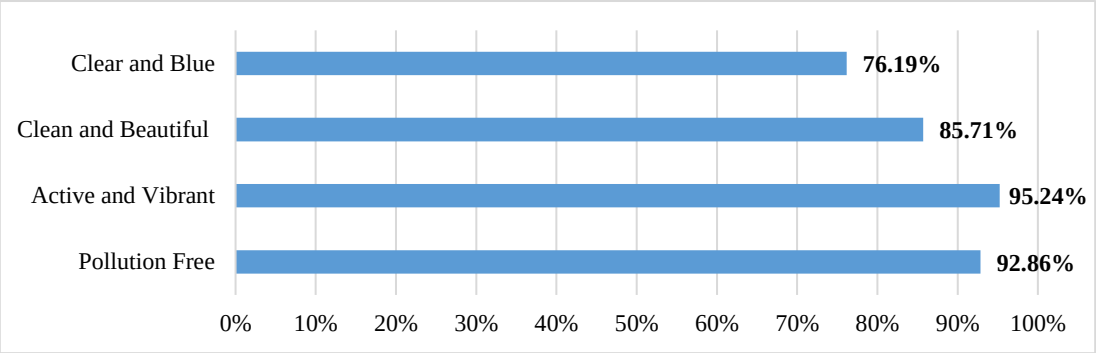


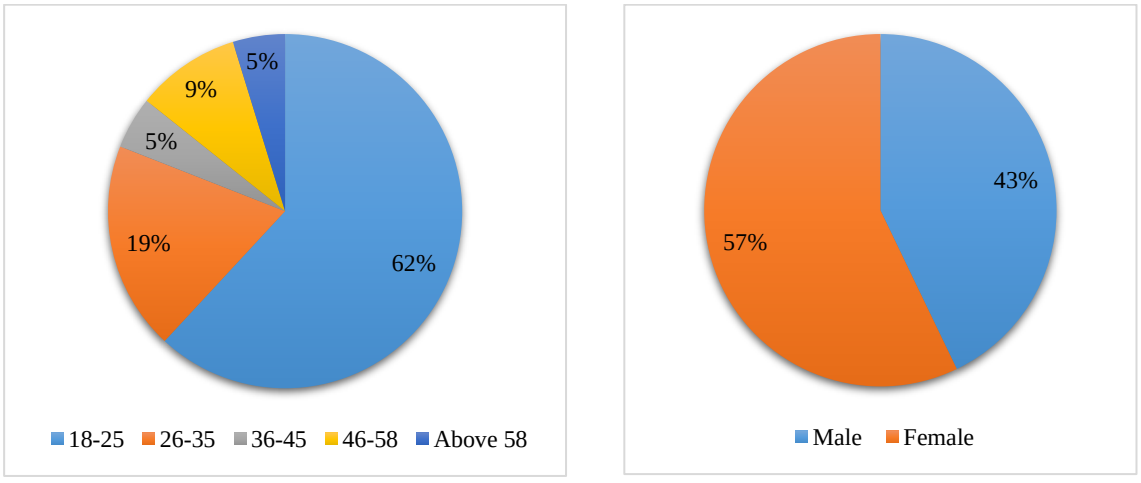
Figure 34: Local Resident's Future Vision for River Yamuna

Apart from these things, few more things were observed. One of them includes the absence of any rejuvenation centre there. Mathura is a place of tourism, especially the stretch taken for study has a number of ghats and temples over there. Thus, the people visiting there needs a place where they can relax and enjoy. This necessitates the need of a rejuvenation centre at that place. Along with this, some sites were also identified where people go for recreational purpose, which are in not so good condition and they want to improve it. These locations include Gau Ghat, Kans Quila, Vishram Ghat, Bengali Ghat, Swami Ghat, Dhruv Tila, Old bridge, new bridge, Sudarshan Ghat, Opposite bank of river Yamuna, Durwasa Rishi Temple etc. A list of activities is also prepared which the people want to do near Yamuna banks. These includes walking, cycling, jogging, eating, spiritual practices, boating, shopping, river-sporting, sitting and relaxing, etc. The people also want that there should be connectivity between two river banks, from Kans Quila to Durwasa Rishi Temple.

This sums up the analysis of data collected from local residents of Mathura.

5.3.2 Analysis of Data Collected from Floating Population

As shown in the Figure 35 (a), users from almost all age groups visit river Yamuna. Among these, the highest percentage, which is 62%, is from the age group of 18 to 25 years. This shows the interest of younger generation towards this holy place. Out of these people, 43% are male while 57% are female, as shown in Figure 35 (b).



(a) (b)

Figure 35: Age (a) and Gender (b) of Floating Population

Around 57% of people visits Mathura and river Yamuna rarely, only to special festivals such as Holi, Janmashtami, Yum Dwitiya, etc., followed by 19% people who are visiting there once in a year as shown in Figure 36. The people visit the river for a number of reasons as shown in Figure 37. Out of these reasons, religious purpose holds the highest weightage with 100%, followed by recreational purpose with 42.86% for visiting it. This depicts that Mathura and Yamuna River are a sacred place and people visits there for worshipping it.

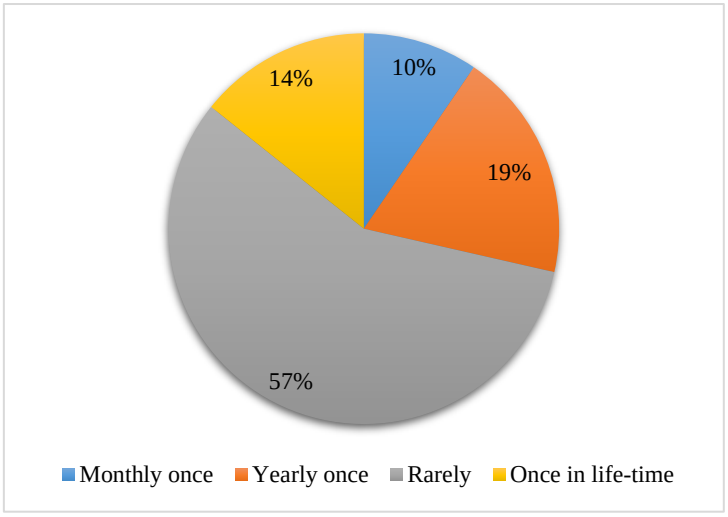


Figure 36: Frequency of Visiting River and Ghats by Floating Population

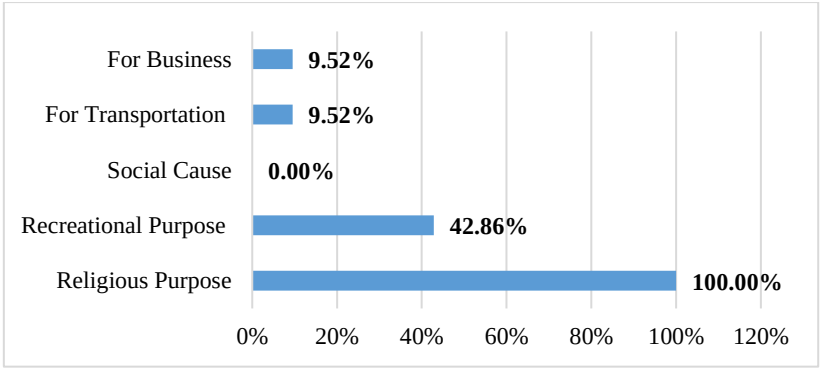


Figure 37: Floating Population's Purpose for Visiting River Yamuna

When the visitors were asked about their perception of how they see river Yamuna, 71.43% people consider it as dirty and drain. Only 14.29% people see it as clean and beautiful as shown in Figure 38. This necessitates the need for cleaning the river, reducing its pollution and make it clean and beautiful.

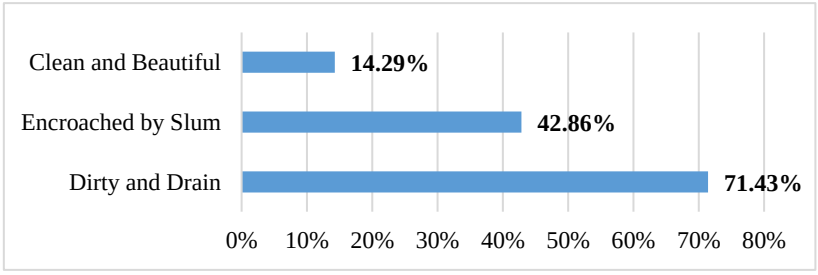
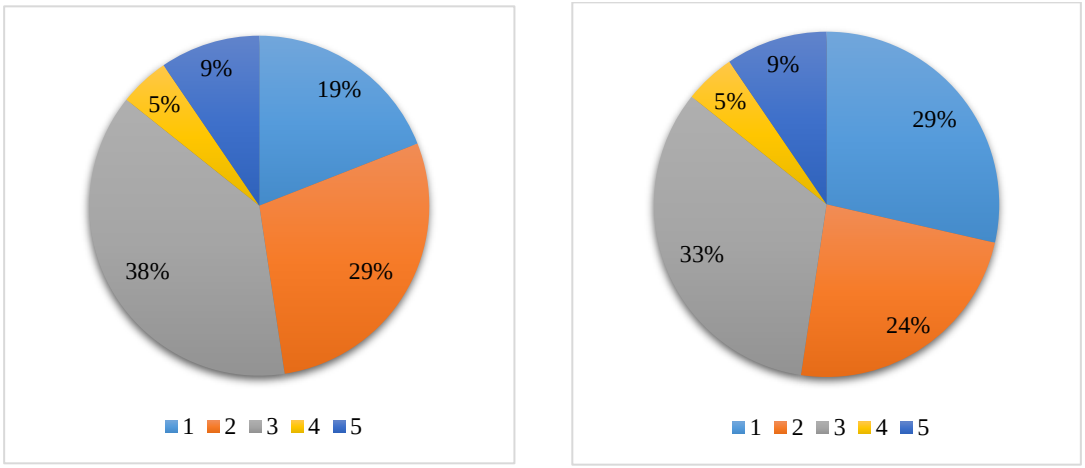


Figure 38: Perception of Floating Population about River Yamuna

Apart from this, 62% of people visiting there consider Yamuna River as active and vibrant because they believe that it is located in the middle of the city and is main source of people residing nearby. It also plays a major role for the development of its surroundings.

38% of people visiting there believes that the existing condition of ghats at Yamuna River is 3, followed by 29% people who consider it only 2 on a scale of 1 to 5 as shown in Figure 39 (a). The case remains almost same when they were asked about the existing condition of river infrastructure at that place. 33% people gives a score of 3, followed by 29% people who gives a score of 1 on a scale of 1 to 5 to the existing condition of river infrastructure as shown in Figure 39 (b). This necessitates the major need of developing these areas.



(a) (b)

Figure 39: Existing Condition of Ghats (a) and River Infrastructure (b) at River Yamuna according to the Floating Population

52.38% people visiting river believes that the recreational spaces available near river banks are not well maintained and have lots of garbage around them. Thus, they don't prefer to use them. Apart from this, 42.86% people believes that there is no recreational space near any stretch of river as shown in Figure 40.

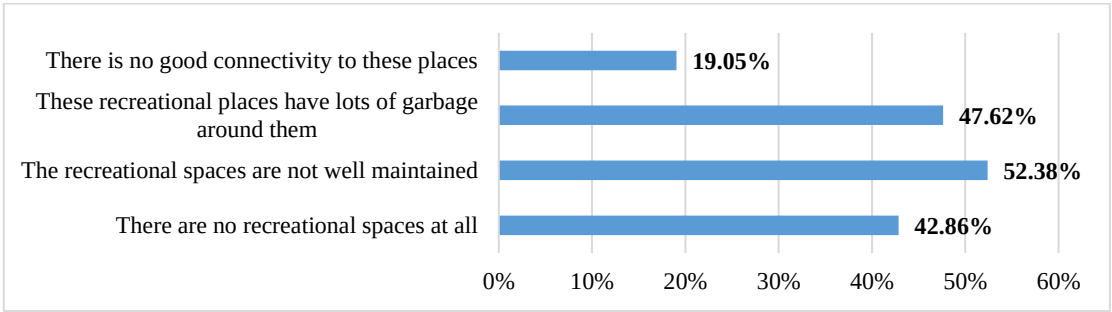


Figure 40: Reasons for not using Any River Stretch as Recreational Space by the Floating Population

A number of pain points as shown in Figure 41 were coined at the people visiting river Yamuna and adjoining ghats, among which throwing garbage and waste deposition in and around the river possesses the major threat to it with 80.95% each. This is followed by outlet of drainages opening into river, no protection on river banks, and no toilet facilities in the surrounding area with 66.67% each. Dirty places and no cleanliness with 57.14% and 52.38% respectively, add further to the

issues faced by river. As a result of these issues, 81% visitors believe that improvement is needed for the river, its surrounding infrastructure, and Yamuna Ghats at Mathura.

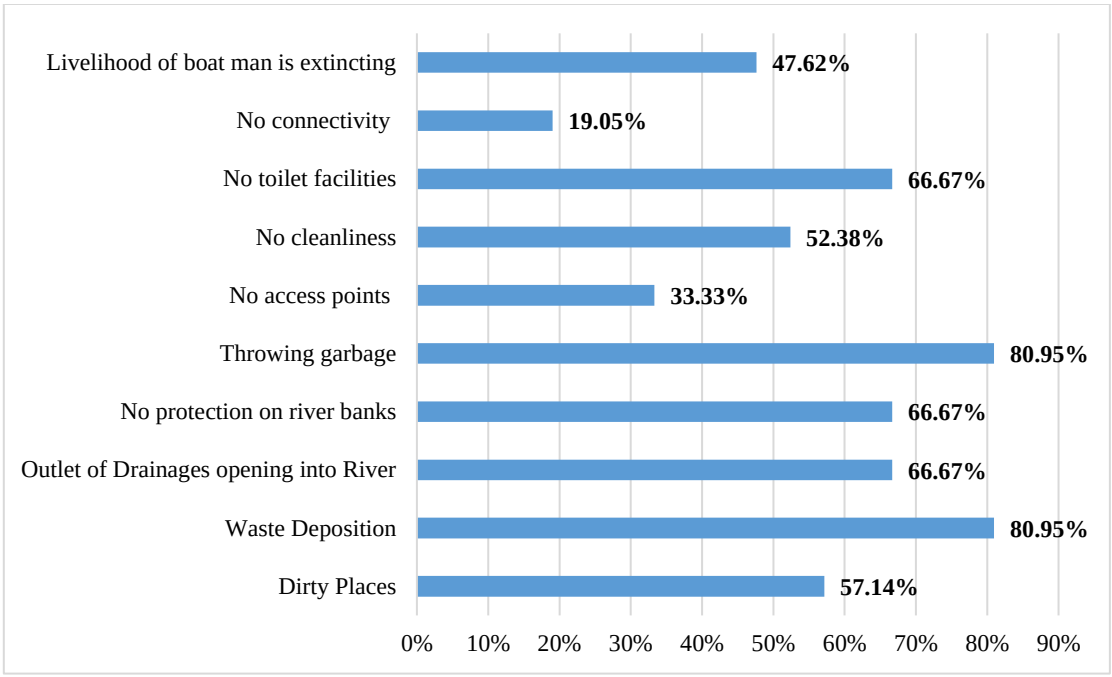


Figure 41: Pain Points Associated with River Yamuna at Mathura as per the Perception of Floating Population

Figure 42 shows the major source of pollution for river Yamuna at Mathura according to the floating population. Out of these, dumping of waste into the river hold the highest weightage with 90.48%. This is followed by discharge of untreated or partially treated effluents from industries with 80.95%. Another major source of pollution for river Yamuna at Mathura is upstream Delhi Segment accounting to 57.14%. A large number of industries are located on the bank of river Yamuna in Delhi. Untreated or partially treated domestic and industrial effluents get discharge into the river, degrading its water quality. This polluted water flows downstream, entering Mathura in the Eutriphicated Segment and polluting river there.

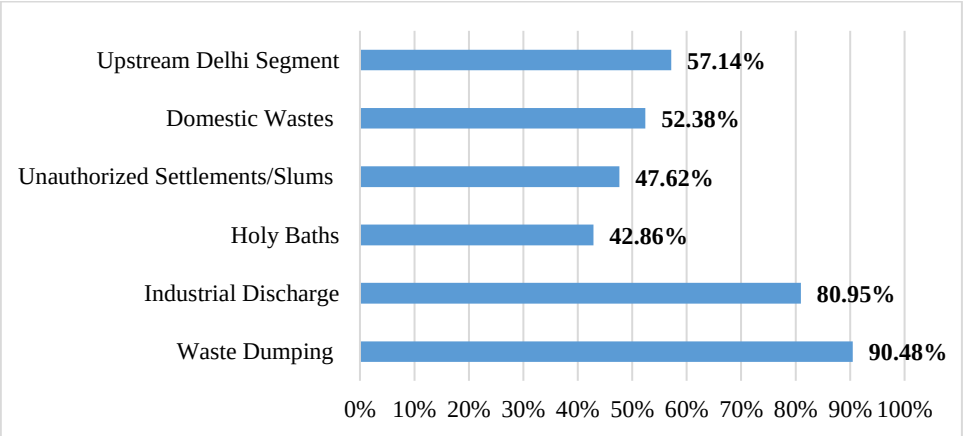


Figure 42: Major Source of Pollution for River Yamuna at Mathura according to Floating Population

Figure 43 shows the facilities and improvements people visiting the city want around the banks of river Yamuna at Mathura. 95.24% people wants a larger number of recreational spaces and cleanliness around them, followed by public amenities and safety with 80.95% and 57.14%

respectively. In addition to this, 38.10% people also want more entertainment activities where they can relax and enjoy with their family and friends. Such activities may include boating, river-sporting, etc.

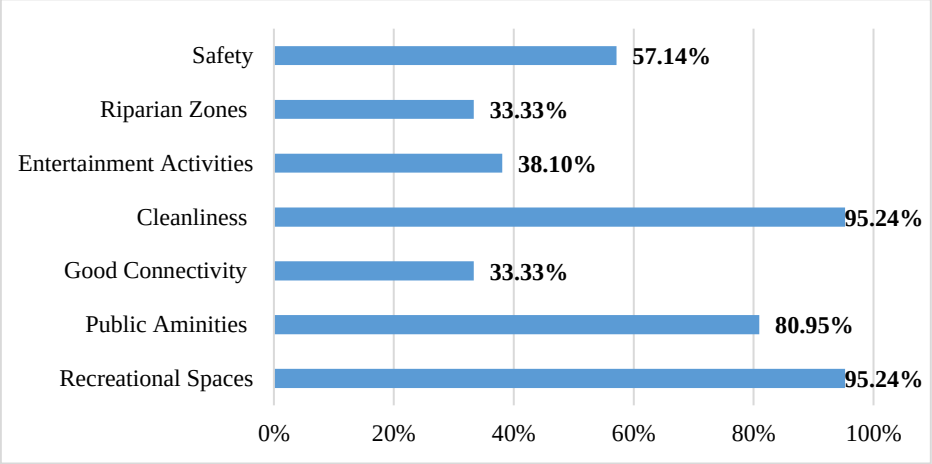


Figure 43: Facilities/Improvements required by Floating Population at River Yamuna

At last, the visitors were asked about their future vision for Yamuna River of how they want to see it. Figure 44 shows the qualities for Yamuna River people wants to see. Seeing a clean and beautiful Yamuna is the first vision of 100% visitors visiting there. 80.95% people want to see river pollution free which will make it active and vibrant.

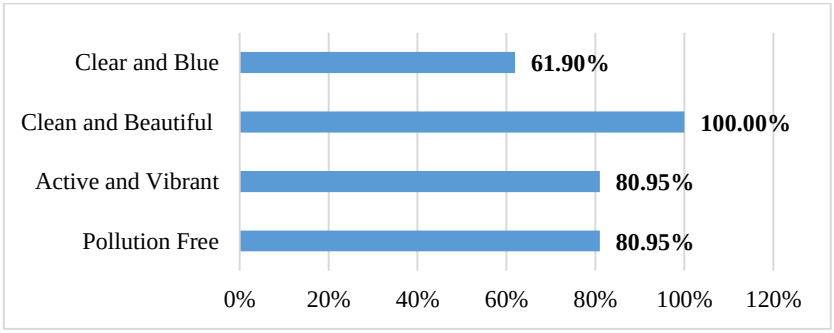


Figure 44: Floating Population's Future Vision for River Yamuna

Apart from these things, some sites were also identified where people go for recreational purpose, which are in not so good condition and they want to improve it. The main reason for going to these sites is because they are easily approachable from Holi gate. These locations include Gau Ghat, Kans Quila, Vishram Ghat, Bengali Ghat, Swami Ghat, Dhruv Tila, Opposite bank of river Yamuna, Durwasa Rishi Temple etc. They like to perform various recreational activities including water sporting, yoga, sitting at riverside, eating, walking, boating, performing spiritual activities, shopping in riverside markets, organizing awareness programmes, etc. there. Some more suggestions to improve the riverside area were coined by the visitors, including availability of parking space and toilets, connectivity between Kans Quila and Durwasa Rishi Temple, cleanliness around ghats, awareness programmes through nukkad natak, waste management, riverside development, open gyms, parks and gardens, etc.

This sums up the analysis of data collected from floating population of Mathura.

5.4 Result and Discussion

The preliminary survey can be used to extract useful information for betterment of the area. This information may include people's present and future perception about Yamuna River, major issues faced by them, main sources of pollution, requirements and facilities needed by people, preferred location for these services and activities they want to do at these locations.

People visit river mainly for religious purpose and presently see it as dirty and drain. They want to see it pollution free, active and vibrant, and clean and beautiful in future. They faced various issues while visiting river and ghats including outlets of drainage opening into river, waste deposition, lack of recreational spaces, throwing of garbage, lack of protection on riverbanks, dirty places, lack of cleanliness and connectivity. According to them the major source of pollution for river is industrial discharge, waste dumping, upstream Delhi Segment, along with holy baths. They believe that availability of more recreational spaces, cleanliness, public amenities, riparian zones, and entertainment activities will make the place livelier. The sites preferred by them for development of these services includes ghat area from Kans Quila to Sudarshan Ghat and opposite bank of river Yamuna. They want to carry out various activities at these locations which may include walking, boating, jogging, river-sporting, yoga, spiritual activities, shopping in riverside markets, etc. The people are also willing to be a part of improvement by paying charges for visiting various places along with monitory and physical participation.

This result and discussion will be followed by a number of proposals which will fulfill the requirements of people and improve the condition of river as well as infrastructure surrounding it.

CHAPTER 6: PROPOSALS

6.1 General

The chapter focusses on resolving the issues identified at the site along with addressing the top five urban drivers leading to pollution of Yamuna River at Mathura and the proposal of a river-centric multi-purpose riverside development using nature-based solutions to overcome these issues. The proposals are presented in various forms including drawings, visuals, policies, and guidelines. The visuals will enable the readers to grasp the intended transformations with greater clarity and envision the future state of the site. The proposal may be carried out in two phases, with the first phase focussing on vacant spaces and the second phase focussing on whole area development. The physical planning in the first phase is based on the theme of Shri Krishna and various major landmarks along both the banks of Yamuna River are rejuvenated.

In addition to the presentation, the chapter delves into the benefits and advantages of the proposed activities. It details out the positive impact of the implementation of these proposals, which are extended to different stakeholder, including the local community, tourists, government organizations, businesses, and the environment. In summary, this chapter aims to lay a solid foundation for transforming the site into a more sustainable, functional, and aesthetically pleasing environment.

6.2 Multi-purpose Riverside Development

Multi-purpose riverside development refers to creating spaces that serves multiple functions and fulfil the needs of different stakeholders. It integrates various elements and activities to maximize the potential and value of the riverside area. Figure 45 shows the components of multi-purpose riverside development.

- **Recreation and Leisure**: The riverside development proposed in this study includes designing of areas for recreational activities such as parks, gardens, viewing deck, and open spaces where people will engage in leisure activities, exercise, and socialize. These spaces accommodate activities such as picnicking, cycling, walking, jogging, and yoga spaces.
- **Cultural and Artistic Spaces**: The proposed design also incorporates spaces for cultural events, performances, and exhibitions that celebrate the local heritage and traditions of the place. It will enhance the know-how and cultural value of that place among its citizens.
- **Commercial and Retail Areas**: The design proposed in this study has spaces such as food outlets, bazaars, riverside markets, sport activities, etc., which will attract visitors and offer opportunities for local businesses. It helps in generating economy for that area that can be utilized for the upliftment of that place.
- **Education and Interpretation**: The designed multi-purpose riverside development proposed in this study encourages educating visitors about the river's ecology, history, and cultural significance. It is carried out by creating spaces for environmental education, visitor information centre, etc. These spaces will help in creating interactive exhibits, guided tours,

and educational programs for all age groups, promoting environmental awareness and appreciation.

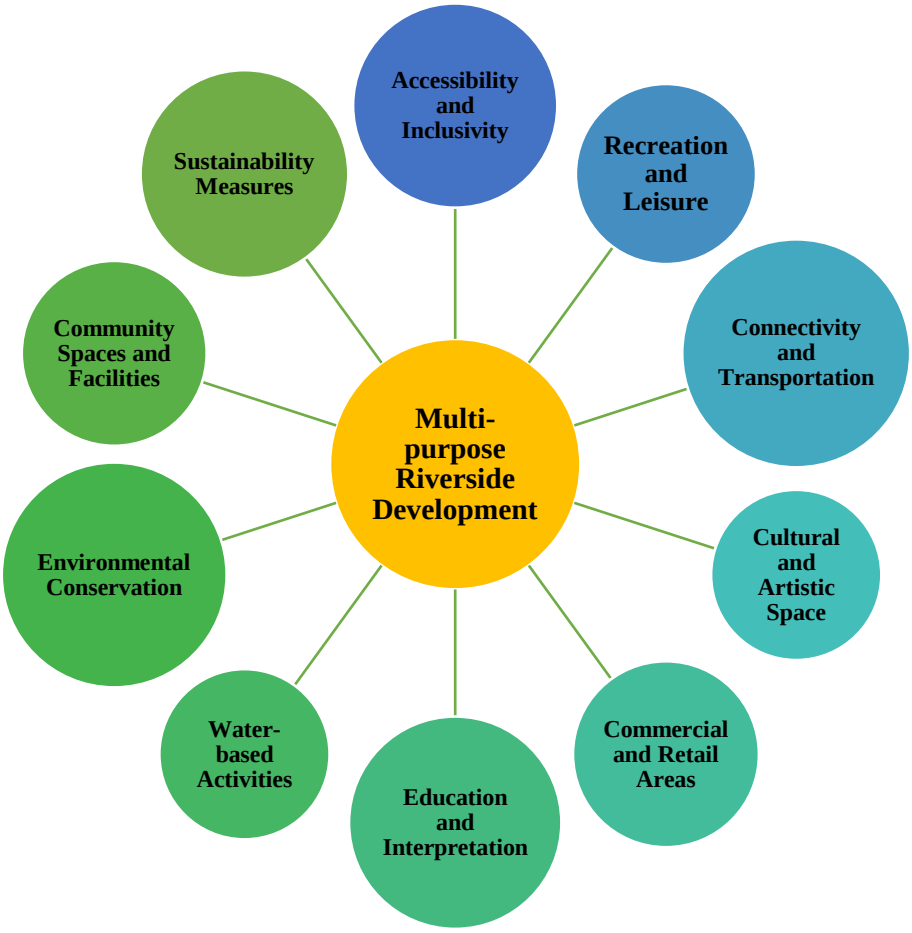


Figure 45: Components of Multi-purpose Riverside Development

- **Accessibility and Inclusivity**: The proposed design ensures that the riverside development is accessible and inclusive to people of all ages and abilities. Universal design principles, such as accessible pathways, seating, and facilities, are incorporated in the design to provide equal opportunities for everyone to enjoy and benefit from the designed spaces.
- **Environmental Conservation**: The proposed design integrates elements such as green infrastructure, bioswale channels, riparian buffer, and wildlife habitats, that will promote environmental conservation and sustainability. These elements enhance the ecological value of the river and its surroundings while providing opportunities for environmental education and research.
- **Connectivity and Transportation**: The design proposed in this study enhance connectivity with the surrounding areas by integrating pedestrian and cycling pathways, and public transportation access points. These connections facilitate seamless movement and encourage sustainable transportation options.
- **Community Spaces and Facilities**: The design proposed in this study include community gathering spaces, event plazas, amphitheatres, and multipurpose areas that can be used for community events, markets, or performances. These spaces serve as focal points for community engagement, fostering social cohesion and a sense of belonging.

- **Sustainability Measures**: The proposed design incorporates sustainable design principles, such as energy-efficient lighting, green building practices, water conservation measures, and waste management systems. These measures minimize the environmental impact of the riverside development and promote long-term sustainability.
- **Water-based Activities**: The proposed riverside development includes water-based activities such as boating. It allows the visitors to enjoy the recreational opportunities offered by the river and will help in revenue generation as well.
- By integrating these components, the proposed multi-purpose riverside development creates vibrant, inclusive, and sustainable spaces that cater to various activities and interests. It will enhance the quality of life for the community, fosters economic development, and promotes the appreciation and conservation of the river and its surrounding environment.

6.3 Nature-based Solutions for Rejuvenation of River

Nature-based solutions for rejuvenation of river involve integrating natural elements and processes to address environmental challenges and promote sustainability. Figure 46 shows the nature-based solutions to be considered for river rejuvenation.

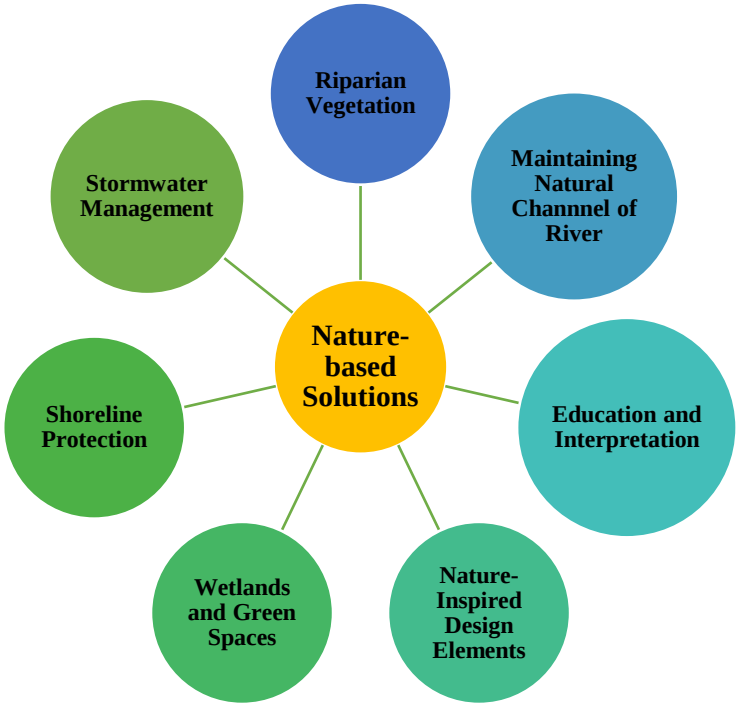


Figure 46: Nature Based Solutions for Rejuvenation of River

- **Riparian Vegetation**: A three-segment riparian zone with 5 m width each is proposed in the designed area. These segments are classified as streamside zone, middle zone, and outer zone. Native vegetations of Mathura city are planted in these zones to stabilize the soil, enhance biodiversity, and improve water quality. Name of the native plant species to be planted in the three zones, pertaining to Mathura's climatic condition is given below:
  - Streamside Zone: Neem, Amaltas, Jamun, Pilu, Kareel, Ashoka, Babul. Aak
  - Middle Zone: Tulsi, Sadabahar, Giloy, Ratti, Hingota
  - Outer Zone: Doobghas, Van Haldi, Curcuma aromatica

- **Wetlands and Green Spaces**: In the proposed design, the riverside development incorporates the establishment of wetland areas and green spaces. Wetlands act as natural filters, purifying water and improving its quality. They also provide habitats for various plant and animal species. Green spaces offer recreational opportunities, improve air quality, and provide a buffer between urban areas and the river.
- **Shoreline Protection**: Bioengineering techniques such as planting native trees along riverbank, and using local materials for construction are implemented in the proposed design to control erosion. These techniques contribute to stabilize the shoreline and reduce the impact of water currents.
- **Stormwater Management**: The proposed riverside is designed in such a way to incorporate natural stormwater management techniques, such as riparian buffers, bioswales, and permeable pavements. These features help capture and filter rainwater, reducing runoff and pollution entering the river.
- **Maintaining the Natural Channel of River**: The proposed design maintains the natural channel of the river, allowing for a healthy flow pattern and the restoration of natural river processes. This approach is essential for preserving the ecological balance, facilitating sediment transport, and providing habitats for aquatic organisms. By preserving the natural channel, the design promotes the overall health and functionality of the river ecosystem.
- **Education and Interpretation**: Educational signage, guided tours, and interactive installations are proposed in the design to inform visitors about the importance of the river ecosystem, local flora and fauna, and conservation efforts. This will foster a sense of stewardship and promote sustainable behaviours among visitors.
- **Nature-Inspired Design Elements**: Nature-inspired design elements, such as using natural materials, organic shapes, and colours that mimic the river's surroundings are incorporated in the proposed design. This creates a visually appealing and harmonious environment that blends with the natural landscape.

By incorporating these nature-based solutions, riverside development can not only enhance the ecological health and resilience of the waterbody but also provide valuable recreational and educational opportunities for the community and thus will help in rejuvenation of river.

6.4 Design Particulars

Based on the findings of the site survey, several key issues have been identified along with the top five urban drivers polluting rivers. In order to address these issues and align with the components of the river-centric plan, the proposed development will incorporate nature-based solutions. The development will be carried out in **two phases**, with the first phase focusing on the vacant land and the second phase involving the built-up area.

During the **first phase, the development and rejuvenation of available vacant land will be of the primary focus** involving physical proposals. This phase will not involve any land acquisition and will primarily focus on the design, implementation, and financial feasibility of various infrastructure and measures to mitigate the urban drivers polluting rivers. For instance, stormwater management systems are incorporated to capture and treat runoff, preventing pollutants from entering the rivers. Green spaces, such as parks and gardens, are established to promote natural

filtration and biodiversity. Additionally, the development also includes the creation of wetlands, and riparian buffers which will act as natural filters and provide habitat for aquatic species. It also includes activities such as exhibitions, maze garden, light and sound show, craft bazaar, etc. which will support the local economy.

The **second phase of the development will primarily focus on the built-up area**. In this, the development of entire area will be carried out on long-term basis including the dilapidated buildings, and land acquisition will be conducted to manage the required land. During this phase, **policies and guidelines will be formulated to ensure the long-term sustainability and environmental compatibility of the built environment**. These policies will encompass regulations for efficient waste management, drainage, waterlogging, dilapidated buildings, finances, street widening, water conservation, etc. By integrating these policies into the development process, the goal is to minimize pollution sources and promote environmentally responsible practices among residents and businesses.

Throughout both phases, the development will remain aligned with the components of the river-centric plan. This alignment ensures that the proposed solutions not only address the immediate pollution issues but also contribute to the broader objectives of river rejuvenation, ecological restoration, and sustainable development. The nature-based solutions integrated into the design will enhance the ecological integrity of the area, promote the health of the rivers, and create a harmonious relationship between the built environment and the natural surroundings.

By implementing the development in two distinct phases, the proposed approach allows for a comprehensive and staged solution. This phased approach enables a well-planned and coordinated implementation that maximizes the effectiveness of pollution reduction efforts and supports the overall objectives of the river-centric plan.

6.5 Phase I – Physical Proposal

This section elaborates various details about the proposed design including design theme, vision for designing, design concept, design features, detailed drawings, visuals, etc.

6.5.1 Design Theme

Flowing Serenity: A Riverside Development Inspired by the Life of Lord Krishna.

The selection of the Shri Krishna theme aims to preserve the hereditary culture by imparting a sense of appreciation for our rich heritage among the younger generation. The objective is to enable them to experience the beauty of our cultural traditions.

6.5.2 Vision

The goal is to proficiently develop versatile and environmentally conscious riverside spaces by employing nature-based solutions to ensure long-term sustainability.

6.5.3 Design Concept

In Hindu mythology and the Bhagavad Gita, Lord Krishna is often depicted as having a deep connection and love for nature. His reverence for the natural world is evident in various aspects of his life and teachings. Some of the key aspects highlighting Krishna's love for nature are listed below:

- **Cowherd and Nature Lover**: Krishna is commonly depicted as a cowherd, spending his childhood and early youth in the forests of Vrindavan. He would graze cows, play with his friends amidst the lush greenery, and immerse himself in the natural beauty of the surroundings. This portrayal reflects his affinity for the natural world. In the design of the riverside, a parallel connection to Krishna's affinity for nature is established through the careful integration of each component, aiming to provide distinct advantages and benefits comparable to the significance of cows. This includes proposals such as promoting biodiversity through the use of native vegetation, incorporating recreational spaces for stress relief, providing yoga and other activity spaces for better health, and integrating commercial areas to stimulate economic activity.
- **Raslila and Dance with Nature**: Just as Krishna's divine dance with the gopis symbolizes his profound connection with nature and the harmonious rhythm of life, the designed riverside features spaces like amphitheaters, exhibition areas, gardens, and parks. These spaces serve as venues for entertainment, physical activities, and cultural events, embodying a similar sense of harmony and enjoyment in tune with the surrounding environment.
- **Govardhan Hill**: One of the most famous incidents associated with Krishna's love for nature is the lifting of the Govardhan Hill. According to the legends, Krishna protected the people of Vrindavan by lifting the hill on his little finger to shield them from torrential rains and floods. This showcases the power and strength of nature. In a similar vein, the entire design of the riverside is imbued with a connection to nature, offering visitors a sense of power and strength through their interaction with the natural elements present.
- **Flute Playing**: Krishna's flute playing, known for its enchanting melodies, holds profound symbolic meaning. The music is believed to captivate not only humans but also animals, birds, and the elements of nature, signifying Krishna's ability to communicate and establish connections with all forms of life. Similarly, the proposed design incorporates numerous green spaces, native vegetation, biodiversity parks, and entertainment areas, creating an environment that soothes the minds of visitors and attracts more birds and animals. This harmonious integration with nature enhances the biodiversity of the place and fosters a sense of interconnectedness with all living beings.

The love for nature portrayed by Lord Krishna can be linked to both nature-based and sustainable riverside development, as they share common principles and goals. This link can be explained with following points:

- **Ecological Balance**: Lord Krishna's love for nature signifies the importance of maintaining ecological balance. Similarly, the proposed sustainable riverside development aims to restore and preserve the natural ecosystem of the river, promoting biodiversity, water quality, and

overall environmental health. By incorporating nature-based solutions, such as riparian vegetation, wetlands, native vegetation, sustainable infrastructure, and natural channel design, the proposed riverside development will mimic the natural flow and beauty of river Yamuna, enhancing its ecological balance and overall aesthetics.

- **Conservation and Preservation**: Lord Krishna's role as a protector of nature encourages to design sustainable riverside development that prioritize environmental conservation and preservation. Sustainable practices, such as stormwater management, responsible waste management, shoreline protection, and the restoration of natural habitats, are implemented in the riverside development which will contribute to the well-being of the surrounding ecosystems, ensuring their long-term sustainability.
- **Spiritual and Cultural Significance**: Lord Krishna's association with rivers, forests, and natural landscapes underscores their spiritual and cultural significance. Similarly, the proposed design incorporates elements such as statues, art installations, exhibitions, and spiritual gathering spaces, that celebrate the local culture and history of the place and enhance the spiritual and cultural connection between people and the riverside environment.
- **Education and Awareness**: Krishna's flute playing and divine dance symbolize the ability to connect with nature on a deeper level. Similarly, the designed nature-based riverside will provide opportunities for education and awareness about the importance of rivers, environmental conservation, and sustainable practices. Proposed interpretive signage, and interactive installations will help the visitors to develop a deeper appreciation and understanding of the river ecosystem, fostering a sense of stewardship and love for nature.

By integrating Lord Krishna's love for nature with nature-based riverside design principles, a riverside space can be created that not only provide aesthetic beauty and recreational opportunities but also promote environmental sustainability, cultural enrichment, and a deeper connection with the natural world.

6.5.4 Aligning the Design Concept with NIUA Theme

The project is carried under the theme of **Rejuvenating Water Bodies**. In order to successfully restore water bodies, it is crucial to consider their surrounding basin areas. Therefore, adopting a bottom-up approach is essential for rejuvenation. Thus, when contemplating the rejuvenation of water bodies, careful consideration should be given to the planning and development of the basin area. One specific initiative within this approach is the proposal for a sustainable riverside development along the bank of the Yamuna River in Mathura. This proposal aimed to not only revitalize the water body but also incorporate various best practices to control river pollution, aligning with the main focus of the National Institute of Urban Affairs (NIUA).

6.5.5 Design Features

The objective of the riverside development is to cater to different needs and provide a range of facilities. The site plan for the proposed project is shown in Annexure II. The intricate plan is illustrated through several blow-up diagrams. Figure 47 provides a closer look at the specific details outlined as blow-up detail A. Within this blow-up, amenities such as an exhibition area, maze garden, garden of flowers, craft bazaar, yoga space, children's park, activity park, food stalls,

viewing deck, flag hosting area, riparian zone, recreational zone, as well as basic facilities like toilets and water coolers are depicted.

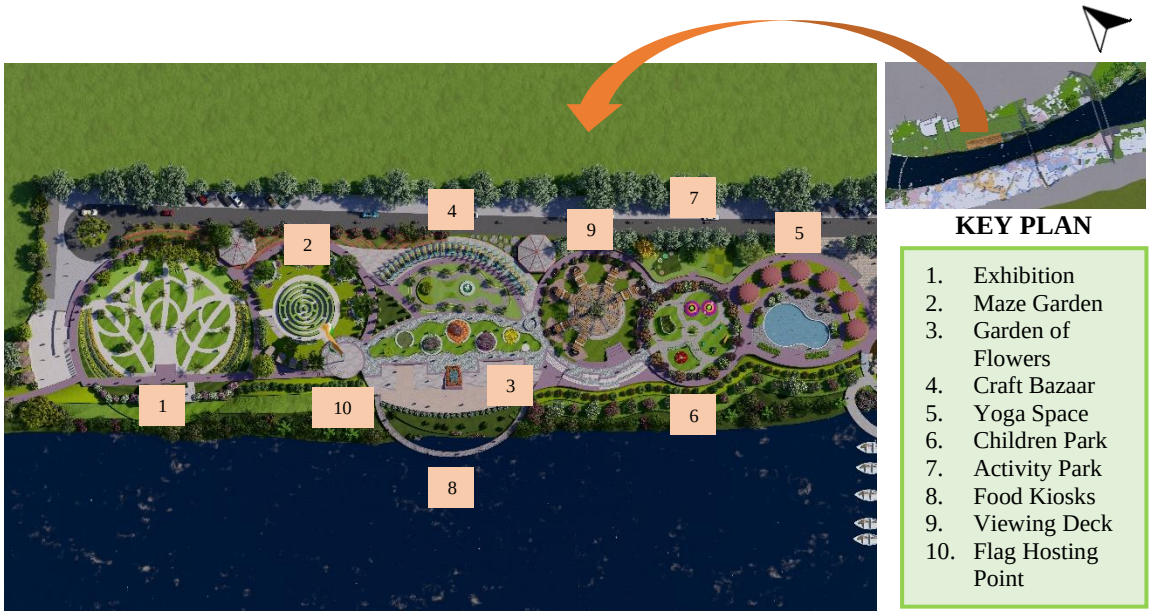


Figure 47: Blow-up Detail A

Blow-up detail B is presented in Figure 48, highlighting additional amenities in the riverside development. These include boating facilities, an amphitheatre for performances, light and sound show area, chanting open-air theatre (OAT), food stalls, dedicated cycle track, walking/jogging trail, bioswale channel (a sustainable drainage feature), riparian zone, recreational zone, and parking facilities.

Figure 48: Blow-up Detail B

Blow-up detail C is depicted in Figure 49, showcasing various amenities in the riverside development. These amenities include a holy bath area (ghat development) where people can perform religious rituals, flea market for shopping, riparian zone, recreational zone, rejuvenated water body, and essential facilities like toilets, changing rooms, water coolers, etc.

Figure 49: Blow-up Detail C

Figure 50 displays blow-up detail D, presenting a range of amenities envisioned in the design, including a Miyawaki forest, which comprises a dense and diverse forest ecosystem, bamboo jali, and a designated space for pre-cremation activities.

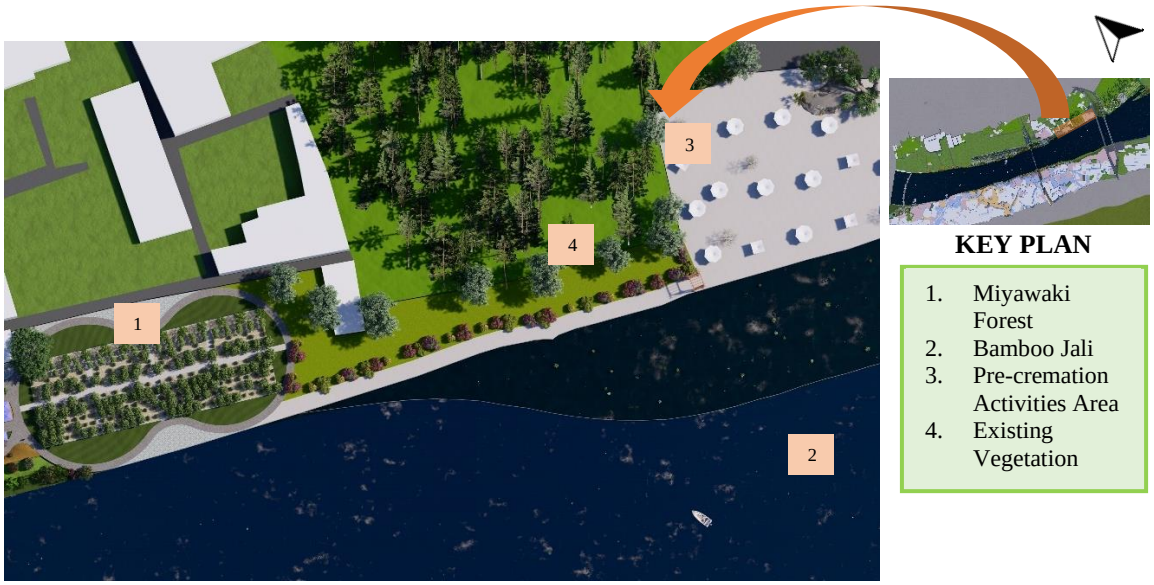


Figure 50: Blow-up Detail D

Figure 51 displays blow-up detail E, presenting a range of amenities envisioned in the design, including a biodiversity park, comprising different spaces such as bird nesting area, butterfly garden, fruit yielding area, recreational spaces, etc., which aims to promote and preserve the diverse flora and fauna in the area. Additionally, it provides space for organic farming, and agro-forestry, emphasizing sustainable and environmentally friendly approaches to agriculture.

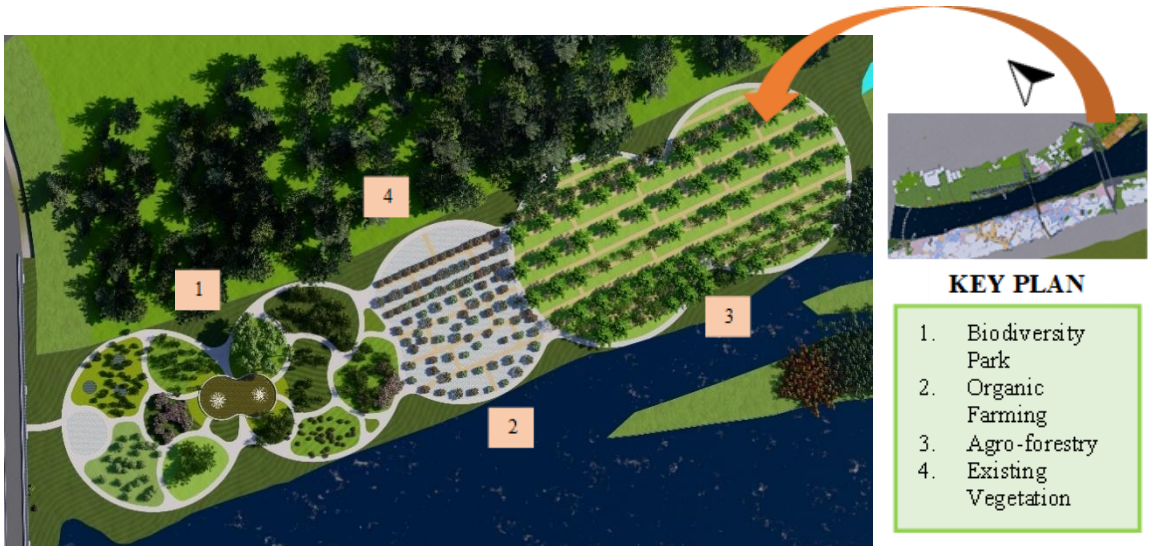


Figure 51: Blow-up Detail E

Blow-up detail F is presented in Figure 52, revealing various amenities in the riverside development. These amenities encompass a pontoon bridge for pedestrian access, constructed water bodies, recreational zone, boating facilities, bamboo jali, food kiosks, children's play area, as well as essential amenities such as toilets, water coolers, parking facilities, etc.

Figure 52: Blow-up Detail F

6.5.6 Design Visuals

This section provides visual representations of the various amenities proposed in the design. This will help readers to understand and visualize the proposed features in the riverside development project.

Figure 53: Exhibition Area

Figure 54: Maze Garden

Figure 55: Craft Bazaar

Figure 56: Garden of Flower

Figure 57: Children's Park

Figure 58: Food Stalls

Figure 59: Amphitheatre

Figure 60: Light and Sound Show

Figure 61: Holy Bath (Ghat Development)

Figure 62: Flea Market

Figure 63: Pontoon Bridge

Figure 64: Recreational Space

6.5.7 Best Practices Adopted

This section will describe about the best practices adopted in thesis for controlling river pollution and rejuvenating the river. The activities are listed below:

- **Bamboo Jali**: A bamboo jali barrier has been implemented along a section of the river to address river pollution. This barrier effectively prevents solid particles from entering the river, particularly in an area where holy rituals and cremation activities take place. By utilizing the bamboo jali, the aim is to minimize the impact of solid waste and other particles on the river's water quality. The barrier acts as a filter, physically blocking solid particles and preventing them from polluting the river. This intervention contributes to the cleanliness and overall health of the river ecosystem, creating a more sustainable and environmentally friendly environment.
- **Riparian Buffer**: A three zone riparian buffer is provided on both banks of the river. This zone will help in reducing sedimentation, controlling runoff, improving water quality, enhancing biodiversity, and promoting the overall health and resilience of the river ecosystem. Additionally, the riparian buffer will offer recreational opportunities, create green spaces for the community, and contribute to the aesthetic value of the area. Kanpur URMP serves as a noteworthy example of providing a riparian zone along the riverside.
- **Bio-sanitizer Ecochips:** To maintain cleanliness in the holy bath area, bio-sanitizer ecochips are used. These eco-friendly chips contain beneficial microorganisms that work to break down organic matter, eliminate odors, and degrade pollutants. Integrating these bio-sanitizer ecochips in the design will ensure a cleaner and more hygienic environment for individuals participating in the holy bath, and promotes a positive and refreshing experience for them. The utilization of bio-sanitizer ecochips for cleaning Powai Lake in Mumbai serves as an excellent example for implementation of this practice.

- **Bioswale Channel:** Bioswale channels are proposed at selected locations along the river in the design. These vegetated channels effectively manage stormwater runoff and enhance water quality. They are lined with native plants, and bioswales filter pollutants, which absorb excess water, and facilitate natural infiltration. By incorporating bioswale channels, the design mitigates the effects of runoff, reduces erosion, and improves water quality. This sustainable approach supports ecological health, providing wildlife habitat and promoting biodiversity in the surrounding area. A good example of bioswale channels can be seen in Mackey Arena Redevelopment Master Plan.
- **Biodiversity Park:** A biodiversity park is proposed, featuring various elements to support and enhance local wildlife and natural habitats. The park includes a butterfly garden, designed to attract and nurture these delicate creatures, creating a vibrant ecosystem for pollinators. Additionally, a bird nesting area is designed to provide safe spaces for birds to breed and raise their young. An aquatic garden is integrated, serving as a habitat for aquatic plants and species, fostering a thriving aquatic ecosystem. Alongside these natural elements, recreational spaces are incorporated to allow visitors to enjoy the beauty of nature and engage in outdoor activities. A successful story where, proposing biodiversity park attracting number of native birds can be seen in Surat.
- **Waste Management:** To ensure responsible interaction with the river, a viewing deck is included in the design, supported with railings. The viewing deck allows people to have a visual experience of the river without direct contact. This approach serves a dual purpose: it prevents the indiscriminate disposal of waste into the river supporting waste management and discourages littering on the river bank. By providing a designated area for observing the river, the design promotes environmental consciousness and encourages visitors to appreciate the natural beauty of the river while minimizing any negative impacts.
- **Sustainable Water Management:** Green spaces and permeable pavers with grasses are incorporated in the pathway design, providing multiple benefits including rainwater harvesting. The presence of green spaces allows for natural absorption and retention of rainwater, reducing runoff. Permeable pavers, along with grasses, facilitate the infiltration of rainwater into the soil, helping to replenish groundwater reserves. This combination of features promotes sustainable water management practices while creating an aesthetically pleasing environment for visitors to enjoy.

6.5.8 Design Benefits

The designed riverside offers both intangible and tangible benefits. In terms of **intangible benefits**, it provides visitors with a sense of mental peace and tranquillity through its green rejuvenating spaces. Being surrounded by nature promotes a soothing environment that fosters relaxation and well-being. Additionally, the riverside design helps inculcate cultural values among visitors, allowing them to connect with the heritage and history of the place. Visitors can develop a deeper understanding and appreciation for the significance of the location.

On the other hand, the **tangible benefits** of the riverside design are also notable. The development of the riverside can lead to an increase in the land prices of nearby areas due to enhanced desirability and improved amenities. This rise in land prices can stimulate economic growth and

attract investment opportunities. Moreover, the development can encourage landowners to contribute their land for further development, enabling the expansion and enhancement of the riverside project. These tangible benefits contribute to the overall prosperity and sustainable development of the surrounding areas.

These benefits can be summarized in the form of following outputs:

1. **Ecological Restoration**: Spaces for various areas including riparian buffer, miyawaki forest, biodiversity park, agro-farming, organic farming is provided in the design. It will focus on restoring and preserving the natural ecosystem of the waterbody. Native vegetation will be planted in these areas which will reintroduce local wildlife to support biodiversity.

2. **Water Quality Management**: Various practices including natural filtration systems, buffer zones with vegetation to reduce pollution runoff, and responsible waste management are promoted in the surrounding areas to improve water quality. Innovative materials such as bio-sanitizer ecochips are used in holy bath area to purify its water.

3. **Provision of Basic Amenities**: Basic amenities such as toilets, drinking water stations, dustbins, seating spaces, lighting, signage and information boards, wi-fi and charging stations, first-aid stations, parking and cycling and pedestrian facilities are provided at the riverside to ensure the comfort and convenience of visitors and also promoting cleanliness and environmental sustainability. These amenities will be regularly maintained and monitored to ensure their functionality and cleanliness.

4. **Public Access and Recreation**: The riverside is designed in such a way to provide public access and recreational opportunities to public. It includes various activities such as walking and cycling paths, picnic areas, playgrounds, children park, amphitheatre, flag hosting point, yoga space, viewing deck, boat launches, and light and sound show. Universal accessibility is ensured in the design to make the riverside spaces inclusive for people of all abilities.

5. **Cultural and Historical Preservation**: To preserve the religious importance of river, holy bath and designated space for cremation and pre-cremation activities is proposed which will be barricaded by bamboo jali to prevent discharge of any solid particle into the river. Various elements that celebrate the local culture, history, and heritage are incorporated in the design. These elements involve public art installations, interpretive signage, and design features that reflect the unique identity of Mathura city.

6. **Sustainable Infrastructure**: Sustainable infrastructure is integrated into the riverside design. This involve using bio-digester toilets, permeable pavements, bioswales, and improved land management.

7. **Community Engagement**: The local community is involved in the planning and design process to ensure that their needs and aspirations are considered. For this, a questionnaire has been prepared to assess the needs of the local community.

8. **Economic Development**: Opportunities for sustainable economic development along the riverside are explored. For this, various spaces such as light and sound show, flea market, craft bazaar, food outlets, maze garden, exhibitions, garden of flowers are proposed that can attract visitors and support the local economy.

9. **Continuous Monitoring and Maintenance**: A long-term monitoring and maintenance plan is established to ensure the sustainability of the riverside development. Regular assessment of river and ecosystem health, addressal of any required maintenance will be carried out.

6.6 Phase II – Heritage Local Area Plan

The second phase of the development will primarily focus on the built-up area. In this, the development of whole area will be carried out on long-term basis including the dilapidated buildings, and land acquisition will be conducted to manage the required land.

The development will address the pain points shown in Figure 65 which remain unaddressed during Phase – I. These challenges majorly include solid waste management, drainage, waterlogging, dilapidated buildings, finances, street widening.

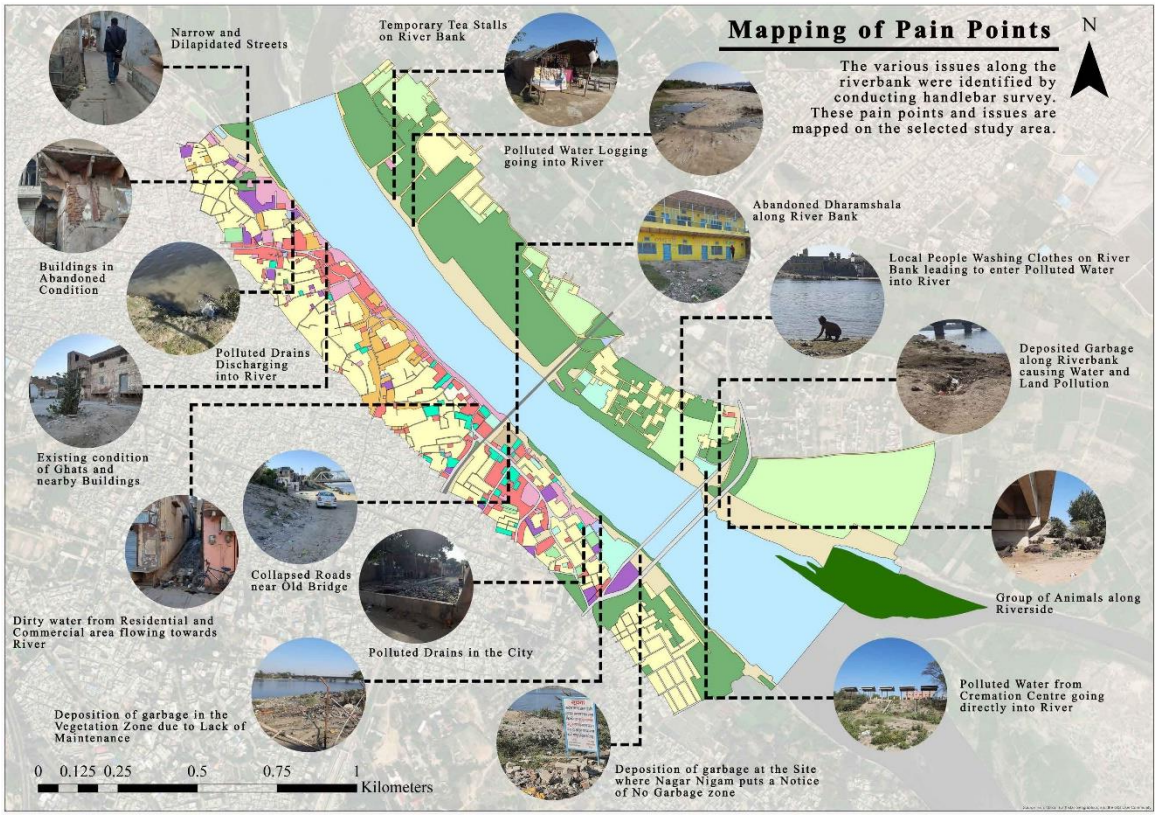


Figure 65: Pain Points at Site

Therefore, it is crucial to develop a long-term plan that will address these challenges. To tackle this, a comprehensive approach is required, which can be achieved through the formulation of a **Heritage Local Area Plan**. This plan would involve the restoration of heritage buildings and the removal of dilapidated structures, allowing for the utilization of the vacant space for redevelopment. By implementing this plan, the entire area can be developed holistically, taking into consideration the following activities:

1. **Preparation of a long-term land use redevelopment plan**: This involves creating a plan that outlines the optimal land use for the area, considering factors such as infrastructure requirements, public spaces, and commercial zones.

2. **Planning and implementation of a Heritage Local Area Plan**: By carrying out the development activities under this plan, the focus will be on preserving and enhancing the heritage value of the area. This can include restoring historic buildings, promoting traditional architecture, and preserving cultural elements.

3. **Development of the entire area along the river**: A key aspect of the plan would be the revitalization of the riverfront area. This involve designing the area in a manner that not only enhances its aesthetic appeal but also takes into account the environmental impact and promotes a river-centric urban plan.

4. **Development while maintaining heritage**: Throughout the process, the preservation of the area's heritage should be a priority. This will be achieved by integrating modern infrastructure and amenities while respecting and conserving the historical significance of the city.

By implementing these proposed activities, the development of the entire area can be undertaken comprehensively and simultaneously. This approach aims to minimize the city's impact on the river while achieving the objective of a river-centric urban plan.

In addition to the aforementioned plan, several additional policies have been drafted to address the remaining unaddressed challenges:

- It is crucial to address the quality of water entering Mathura from upstream areas, particularly from Delhi. Implementing tertiary treatment measures for the water before it reaches Mathura can significantly improve its quality and reduce pollution levels. This would involve implementing advanced treatment technologies to remove contaminants and ensure that the water entering Mathura is of a higher standard.
- It is important to establish provisions for effluent treatment plants (ETPs) and common effluent treatment plants (CETPs) in industrial areas. This ensures that industries in Mathura are equipped with the necessary infrastructure to treat their wastewater before releasing it into water bodies. ETPs and CETPs play a vital role in minimizing the pollution caused by industrial effluents and maintaining the overall water quality in the region.
- **The Sustainable Construction Materials Policy** is framed to address the issue of construction projects impacting rivers by promoting the use of local vernacular and green materials. This policy aims to minimize the adverse effects of construction projects on river ecosystems and mitigate the risks of flooding or drying up. The key elements of the policy include using local vernacular materials such as stone, bamboo, etc. for construction, adoption of green materials and technologies, advocating natural drainage system, integrating construction projects with natural landscape, and educating people about sustainable construction practices.
- **The Inter-State Legal Framework Policy** is formulated to address the issue of intra-operability of laws among various states. This policy aims to establish a framework that enables seamless coordination and consistency in legal matters across state boundaries. The

key elements of this policy include harmonization of laws, standardization of legal processes, establishing inter-state legal forums, information sharing and collaborations, dispute resolution mechanism, and training and capacity building.

- **The Innovative Technologies and Infrastructure Funding Policy** is framed to address the issue of insufficient funds for implementing innovative technologies and infrastructure projects. This policy aims to foster financial support and investment opportunities for the development and deployment of cutting-edge technologies and infrastructure. The key elements of this policy include public-private partnerships (PPPs), government grants and funding programs, tax incentives and subsidies, venture capital and investment funds, crowdfunding and community financing, international cooperation and funding, and innovation clusters and incubators.
- **A Surveillance Enhancement Policy** is formulated to address the issue of poor surveillance by authorities and improve overall surveillance capabilities. The policy will focus on infrastructure upgrades, increased personnel and training, enhanced monitoring and analysis, collaboration and information sharing, regular audits and quality control, and public engagement and transparency.
- **The River Technology Capacity Building Policy** is implemented to address the issue of lack of know-how and poor tech-savvy levels within the government regarding river management and conservation. This policy aims to enhance the technological capabilities and expertise of government officials specifically in the context of river-related matters. The key components of this policy include river technology training programs, collaboration with river experts and organizations, technology demonstration projects, river technology support centres, data sharing and collaboration platforms, regulatory framework for technology adoption, and monitoring and evaluation mechanism.

By incorporating these measures, the project can address the issue of water quality from upstream sources and establish sustainable practices for industries in Mathura. This holistic approach will contribute to the rejuvenation of Yamuna River in Mathura and promote a healthier and more environmentally friendly ecosystem in the region.

6.7 Design Enhancements

6.7.1 Resolving Site Issues

To effectively solve the issues at the site, the design takes into account various factors such as water quality, ecosystem health, safe public access, cleanliness, and community needs. It incorporates innovative approaches and technologies that target specific challenges, such as water pollution, habitat degradation, and unsustainable land use practices. By implementing measures such as efficient wastewater treatment systems, stormwater management strategies, and eco-friendly infrastructure, the design tackles pollution at its source and seeks to improve the overall health and functionality of the water bodies.

6.7.2 Pollution Reduction

In terms of pollution reduction, the design goes beyond mere compliance with environmental regulations. It embraces a proactive and holistic approach that integrates pollution prevention and mitigation strategies throughout the project. For example, it incorporates green infrastructure elements such as green spaces, bioswales, vegetated buffers, and biofiltration systems that help naturally filter and purify stormwater runoff, reducing the influx of pollutants into the water bodies. Additionally, the design highlights the need of sustainable practices within the surrounding community, such as waste management initiatives, educational programs, and awareness campaigns, to further reduce pollution sources and foster a culture of environmental stewardship.

6.7.3 Linking with River-centric Plan

Table 19 shows proposed activities for different components of River-centric Plan. The design aligns with the core principles of the river-centric plan, which typically include objectives such as ecological restoration, safe public access, rejuvenation of water body, managing riverine infrastructure in a sustainable way, community engagement, and generating river-based economy. This alignment facilitates a coordinated and synergistic approach towards the rejuvenation of the water bodies, promoting long-term sustainability and resilience.

Table 19: Proposed Activities for Various Components of River-centric Plan

Sr. No.	Component of River-centric Plan	Activities Provided	Design Benefits
1.	Establish a Functional Riparian Ecosystem	• Biodiversity parks • Miyawaki forests • A continuous buffer of vegetation along the river banks, choosing appropriate species for the soil conditions, water depth, native species, and ground profile. This will provide erosion control, water filtration, and wildlife habitat. • Organic farming • Agro-farming	• Relaxing and Soothing Environment • Ecological Restoration
2.	Enable Designated Safe Public Access	• Safe access to the riverside spaces with proper transport connectivity. • Non-motorized transportation including cycle track, walking and jogging trail.	• Public Access and Recreation
3.	Rejuvenation of Water Bodies	• Cleaning of water body through bio-remediation, bio-sanitizer ecochips, riverbank filtration, and removal of invasive species. • Proper fencing of the shoreline. • Provision of bioswale channels, afforestation and stormwater management.	• Water Quality Management • Ecological Restoration
4.	Managing Riverine Infrastructure	• Ghat development • Stormwater management • Bridge provision • Space for bathing, crematoria activities, and offering flowers	• Increase in Land Prices • Economic Development • Community Engagement • Provision of Basic Amenities

		• Basic amenities including parking, water, toilet, telephone booth, WIFI, charging stations. • Floodplain encroachment regulation • River zone regulation	
5.	Preventing River Pollution	• Preventing discharge of solid particles into river using bamboo jali and metal sheet. • Provision of green infrastructure including grass, bioswales, vegetative buffers.	• Water Quality Management • Ecological Restoration • Relaxing and Soothing Environment
6.	Citizen-River Connect	• Provision of eco-sensitive religious activities in designated ghat areas. • Encouragement of public recreation activities with landscape features that respect the existing natural habitat. • Establishment of community groups to monitor the river's health and organize river clean-up drives.	• Community Engagement • Cultural and Historical preservation • Increase in Land Prices • Economic Development
7.	River-based Economy	• Provision of water-based activities such as boating. • Flea Market • Light and sound show • Exhibition area • Food stalls • Craft bazaar • Maze garden • Garden of flowers • Viewing deck	• Increase in Land Prices • Economic Development • Community Engagement

6.7.4 Linking with SDGs

This section showcases how each meticulously crafted feature is intricately linked to the overarching principles of sustainable development goals (SDGs). By connecting the proposed design to the sustainable development goals, this section underscores the inherent value and comprehensive nature of the design. It demonstrates how the design goes beyond immediate aesthetic considerations, embracing a holistic approach that encompasses social, economic, and environmental dimensions. Through its ample benefits, the design sets a new benchmark for responsible and purposeful design that prioritizes the well-being of individuals, communities, and the planet. Here are some ways in which sustainable riverside development can align with specific SDGs:

1) **SDG 6: Clean Water and Sanitation**: The designed nature-based riverside will contribute to improve water quality and ensuring access to clean water by implementing green infrastructure, riverbank filtration, stormwater management systems, and natural filtration mechanisms.
2) **SDG 11: Sustainable Cities and Communities**: The proposed design has green spaces, pedestrian-friendly pathways, and recreational areas along the riverside, which will enhance the overall liveability and well-being of the community. It promotes the development of inclusive, safe, resilient, and sustainable cities and communities.

3) **SDG 13: Climate Action**: The proposed nature-based riverside development will help mitigate and adapt to climate change impacts. It includes the restoration of riparian ecosystems, and green spaces, which will act as carbon sinks, improve air quality, reduce urban heat island effects, and enhance resilience to extreme weather events.
4) **SDG 14: Life Below Water**: The proposed sustainable riverside development will support SDG 14 by incorporating measures to protect and restore aquatic ecosystems. Restoring riparian zones will contribute to the conservation of biodiversity and the sustainable use of marine and freshwater resources.
5) **SDG 15: Life on Land**: The proposed nature-based solutions in riverside development will promote SDG 15 by preserving and restoring terrestrial ecosystems. Incorporating native vegetation, reforestation efforts, and riparian corridors along the riverside will enhance biodiversity, support wildlife habitats, and contribute to the overall ecological balance.

By aligning sustainable riverside development with the SDGs, riverside spaces are created that address multiple dimensions of sustainability, contribute to the well-being of communities, and promote the protection and conservation of natural resources. This integrated approach ensures that riverside developments contribute to the global efforts towards achieving the SDGs and creating a more sustainable and equitable future.

CHAPTER 7: FINANCIAL FEASIBILITY OF PROJECT

7.1 General

The chapter extensively focuses on analyzing and evaluating the financial aspect of the project. It provides a comprehensive examination of the project's financial components, encompassing various facets such as expenditure, fund pooling mechanism, income generation, and cost recovery. The chapter delves into intricate details, including the breakdown of expenses incurred, sources of revenue generated, and approaches employed to recoup costs invested in the project. By thoroughly exploring these financial aspects, the chapter aims to provide a comprehensive understanding of the project's financial viability and sustainability.

7.2 Expenditure for Project

Two categories of expenditure details are determined for the proposed design: one based on the implementation of nature-based solutions and the other based on traditional methods. The estimated project cost by implementing nature-based solutions is ₹ 47,58,76,138.9, while the estimated cost under traditional methods is ₹ 99,10,88,667.5.

The detailed expenditure for nature-based solutions and traditional methods is given in Table 20 and Annexure III, respectively. The total expenditure encompasses both capital cost of construction as well as the annual operation and maintenance (O/M) expenses. The per square meter (sq. m) cost for each component is sourced from the Request for Proposal (RFP) and Schedule of Rates (SOR) of various projects. Table 20 gives a comprehensive overview of the financial allocations associated with the project, enabling a better understanding of the specific costs involved in construction and ongoing maintenance.

The operation and maintenance (O/M) cost for the project is calculated on a variable basis. In the first year, it is set at 1% of the construction cost. For each subsequent year, there will be an incremental increase of 0.2% in the O/M cost. This gradual increase in the O/M cost accounts for the factors that may affect the expenses associated with the ongoing operation and maintenance of the project over time.

7.2.1 Fund Pooling Mechanism

The overall funding needed for the project includes both the construction costs and the annual operation and maintenance expenses. Through perception studies, it was observed that people were willing to contribute financially towards the development of the project. Therefore, it is possible to fulfill the construction fund requirements through grants from government and donations from people.

In the event that grants and donations do not fully meet the funding demands, an alternative community-sharing mechanism can be implemented. This mechanism involves dividing the designated area into clusters, which will then be auctioned among wealthy individuals who are willing to contribute funds for construction. In return, their family name will be associated with

the specific space, which is considered a matter of pride due to the project's cultural and religious significance. This particular culture of attaching names with cultural and religious sites is prevalent in Mathura, which is why this mechanism is adopted. As a reward for their contribution, these individuals will receive incentives such as benefits and rewards in the form of reduced GST and taxes.

On the other hand, the funding required for the project's annual operation and maintenance will be sustained through the income generated from rent and fees. The subsequent section provides a detailed description of the income generation aspects associated with the project.

7.3 Income Generation

Table 21 provides a comprehensive overview of the income generated through various sources, including rent and fees. The project offers different rental opportunities, such as shops for craft bazaar, food kiosks, shops in the flea market, and boating facilities. These rental spaces will contribute to the overall income generation.

In addition to the rental income, the project will also generate revenue through entry fees, exhibition fees, and fees for the light and sound show. The calculation of these fees is based on the floating population data for the year 2019. It is assumed that a certain percentage of the floating population will visit the designed space during different years of the project's operation. Specifically, for the first and second year, 10% of the floating population is expected to visit. For the third and fourth year, it increases to 15% of the floating population, and for the fifth and sixth year, it further rises to 20% of the floating population. This estimation allows for a more accurate projection of the income generated through fees, taking into account the expected number of visitors during different phases of the project's implementation.

To analyze the project feasibility, the income generated from both nature-based solutions and traditional methods is assumed to remain constant.

7.4 Project Feasibility

Table 22 presents the detailed cost recovery analysis of the proposed project implemented with nature-based solutions, without considering grants from the central and state governments. It assesses the project's financial feasibility by analyzing the recovery of costs over time. The initial year involves higher capital expenditure, but subsequent years witness net profits that recover the initial investment. For nature-based solutions, the project becomes financially feasible by the end of the 6^{th} year without any government grants, while for traditional methods, feasibility is achieved by the end of the 12^{th} year. However, if government grants are secured, the project's feasibility period would be shorter than the calculated timeframe. The detailed cost recovery analysis of the proposed project implemented with traditional methods is given in Annexure II. The risk factor for the feasibility of project will be compensated by grants from the government.

Additionally, the project offers numerous tangible and intangible benefits, such as its climate responsiveness and contribution to the river's rejuvenation. This comprehensive perspective renders the project feasible in all aspects, not just financially.

Table 20: Expenditure Details of Proposed Project using Nature-based Solutions

Capital Cost											
Sr. No.	**Component**	**Area (sq. m.)**	**Rate (per sq. m)**	**Total Cost**	**Year 0**	**Year I**	**Year II**	**Year III**	**Year IV**	**Year V**	**Year VI**
1	Pontoon Bridge	804.74	50000	40237000	40237000	0	0	0	0	0	0
2	Boating	802.46	10000	8024600	8024600	0	0	0	0	0	0
3	Pathway I	1622.03	2700	4379481	4379481	0	0	0	0	0	0
4	Pathway II	1767.51	3000	5302530	5302530	0	0	0	0	0	0
5	Pathway III	1171.53	2500	2928825	2928825	0	0	0	0	0	0
6	Pathway IV	875.76	3000	2627280	2627280	0	0	0	0	0	0
7	Pathway V	1696.96	2700	4581792	4581792	0	0	0	0	0	0
8	Pathway VI	1404.94	2900	4074326	4074326	0	0	0	0	0	0
9	Pathway VII	3919.74	2700	10583298	10583298	0	0	0	0	0	0
10	Artificial Lake	1703.93	25000	42598250	42598250	0	0	0	0	0	0
11	Road	4236.98	2500	10592450	10592450	0	0	0	0	0	0
12	Parking	6063.42	2500	15158550	15158550	0	0	0	0	0	0
13	Bioswale Channel	339.12	1500	508680	508680	0	0	0	0	0	0
14	Holy Bath	4828.47	16000	77255520	77255520	0	0	0	0	0	0
15	Cycle Track	993.89	5500	5466395	5466395	0	0	0	0	0	0
16	Walking Trail	992.86	2700	2680722	2680722	0	0	0	0	0	0
17	Green I	4210.18	100	421018	421018	0	0	0	0	0	0
18	Green II	4933.9	110	542729	542729	0	0	0	0	0	0
19	Green III	4504.5	120	540540	540540	0	0	0	0	0	0
20	Green IV	3395.71	130	441442.3	441442.3	0	0	0	0	0	0
21	Green V	4320.14	140	604819.6	604819.6	0	0	0	0	0	0
22	Green (OAT)	1131.82	150	169773	169773	0	0	0	0	0	0
23	Biodiversity Park	9587.38	5000	47936900	47936900	0	0	0	0	0	0
24	Agro-forestry	9672.23	3500	33852805	33852805	0	0	0	0	0	0
25	Organic Farming	3897.19	3500	13640165	13640165	0	0	0	0	0	0
26	Open Exhibition	1841.07	2500	9602675	9602675	0	0	0	0	0	0
27	Amphitheatre	1989.23	12000	23870760	23870760	0	0	0	0	0	0

28	Children Park	695.9	5000	3479500	3479500	0	0	0	0	0	0
29	Activity Park	542.27	5000	2711350	2711350	0	0	0	0	0	0
30	Miyawaki Forest	2915.25	1500	4372875	4372875	0	0	0	0	0	0
31	Garden of Flowers	421	5000	2105000	2105000	0	0	0	0	0	0
32	Maze Garden	241	3500	843500	843500	0	0	0	0	0	0
33	Flea Market	690.93	2500	1727325	1727325	0	0	0	0	0	0
34	Stair and Ramps	2108.28	5000	10541400	10541400	0	0	0	0	0	0
35	Pebbles	218.48	750	163860	163860	0	0	0	0	0	0
36	Stone Masonry	650.79	3000	1952370	1952370	0	0	0	0	0	0
37	Railing	32.14	1200	38568	38568	0	0	0	0	0	0
38	Shrub Planting Area	3682.17	1000	3682170	3682170	0	0	0	0	0	0
39	Tree Planting Area	5007.87	1500	7511805	7511805	0	0	0	0	0	0
40	Toilet	773.08	10000	7730800	7730800	0	0	0	0	0	0
41	Water Cooler/ Telephone Booth	15	50000	750000	750000	0	0	0	0	0	0
42	Kiosk	503.04	11000	5533440	5533440	0	0	0	0	0	0
43	Wooden Deck	791.77	5000	3958850	3958850	0	0	0	0	0	0
44	Light and Sound Show	1	50000000	50000000	50000000	0	0	0	0	0	0
45	Dustbin	100	1500	150000	150000	0	0	0	0	0	0
	Total Cost	**101981.66**		**475876138.9**	**475876138.9**	**0**	**0**	**0**	**0**	**0**	**0**
Operation and Maintenance Cost											
1	Assuming the O/M cost for 1st year as 1% of project cost and increasing by 0.2% every year				0	4758761.39	5710513.67	6662265.94	7614018.22	8565770.5	9517522.78

Table 21: Income Generation through Project

Rent										
Sr. No.	**Component**	**Quantity**	**Rent (per month)**	**Year 0**	**Year I**	**Year II**	**Year III**	**Year IV**	**Year V**	**Year VI**
1	Shops	37	5000	0	2220000	2220000	2220000	2220000	2220000	2220000
2	Flea Market	36	3000	0	1296000	1296000	1296000	1296000	1296000	1296000
3	Boating	1	200000	0	2400000	2400000	2400000	2400000	2400000	2400000
Fees										
Sr. No.	**Component**	**Amount**	**Floating Population for year 2019**	**Year 0**	**Year I @ 10% Floating Population**	**Year II @ 10% Floating Population**	**Year III @ 15% Floating Population**	**Year IV @ 15% Floating Population**	**Year V @ 20% Floating Population**	**Year VI @ 20% Floating Population**
1	Entry Fee	20	8270360	0	16540720	16540720	24811080	24811080	33081440	33081440
2	Exhibition	20	8270360	0	16540720	16540720	24811080	24811080	33081440	33081440
3	Light and Sound Show	30	8270360	0	24811080	24811080	37216620	37216620	49622160	49622160
	Total Income			**0**	**63808520**	**63808520**	**92754780**	**92754780**	**121701040**	**121701040**

Table 22: Cost Recovery of Project

Sr. No.	**Component**	**Year 0**	**Year I**	**Year II**	**Year III**	**Year IV**	**Year V**	**Year VI**
1	Net Profit for each year	0	59049758.61	58098006.33	86092514.06	85140761.78	113135269.50	112183517.22
2	Cumulative Profit	-475876138.9	-416826380.29	-358728373.96	-272635859.90	-187495098.12	-74359828.62	37823688.60

CHAPTER 8: CONCLUSION AND FUTURE SCOPE OF STUDY

8.1 Conclusion

Rivers have been playing a significant role in the history of civilization. Cities and rivers are connected inherently in so many ways. Cities receive numerous tangible and intangible advantages from rivers, such as a guaranteed water supply, flood regulation, and more. On the other hand, cities also help in preserving the natural character and profile of rivers. This intrinsic connection between rivers and cities have always been fulfilled by rivers but cities on the other hand fail to match this commitment.

To understand the connection between cities and rivers, Yamuna River is taken for this research. The water quality of river is good till Upper Segment, but when it flows in downward direction, a large number of industries discharge their untreated or partially treated wastewater into the river, polluting Delhi and Eutriphicated Segment. A lot of work has been done for rejuvenation of river Yamuna, but it is still not in good condition. Thus, to determine the appropriate allocation of funds and execute the action plan, the Analytic Hierarchy Process (AHP) technique is employed to prioritize the most vulnerable city in these two segments by ranking them on the basis of weights of 26 urban drivers that contribute to the river pollution. On the basis of final ranking, it has been analyzed that river Yamuna in Delhi is most polluted, but a large number of works under Yamuna Action Plan, Namami Gange, etc. are carried out here to clean up the river. Thus, the second city where river Yamuna is most polluted, which is Mathura, has been selected for carrying out the research. For Mathura city, top five urban drivers polluting rivers are identified and a user perception study has been carried out to map the pain points faced by river. These pain points include people taking holy bath in river, no recreational spaces, deposition of garbage, cremation activities performed by people on riverbanks, no connectivity between two riverbanks, outlets of drainage opening into river, lack of cleanliness, parking space issue, and abandoned condition of surrounding buildings.

Thus, to address and resolve these challenges, a river-centric multi-purpose riverside development using nature-based solutions is proposed. The proposal may be carried out in two phases, with the first phase focussing on vacant spaces and the second phase focussing on entire area development including the dilapidated buildings. The first phase of development includes designing of various amenities such as light and sound show, maze garden, garden of flowers, ghat development, amphitheaters, craft bazaar, food kiosks, boating, riparian zone, Miyawaki forest, biodiversity park, etc., whereas the second phase includes the formulation of a **Heritage Local Area Plan**. This plan would involve the restoration of heritage buildings and the removal of dilapidated structures, allowing for the utilization of the vacant space for redevelopment. Land acquisition technique can be employed for second phase of development to meet the required land demand. A number of best practices is also employed in the design including bamboo jali. bioswale channels, bio-sanitizer ecochips, sustainable water management, riparian buffer, etc.

The designed riverside offers both intangible and tangible benefits. In terms of **intangible benefits**, it provides visitors with a sense of mental peace and tranquillity through its green

rejuvenating spaces. The riverside design helps inculcate cultural values among visitors, allowing them to connect with the heritage and history of the place. On the other hand, the **tangible benefits** include an increase in the land prices of nearby areas due to enhanced desirability and improved amenities. In addition to these benefits, the proposed design will help in ecological restoration, improves the water quality, preserve culture and history of the place, provide public access and recreational opportunities, and support economic development.

The financial feasibility of the project is also carried out by encompassing various facets such as expenditure, fund pooling mechanism, income generation, and cost recovery period. The estimated project cost by implementing nature-based solutions is ₹ 47,58,76,138.9, with a cost recovery period of 6 years through income generation without taking any grants from central or state government.

The implementation of this prototype model would change the microclimate of the area and if incorporated for more stretches the entire city would benefit specially during scorching summers as dense vegetation along the river bank would cool down the climate.

8.2 Future Scope of Study

- The present research primarily focuses on Phase I planning, involving the vacant land. Detailed planning for Phase II, which includes the development of entire area, resolving the issue of water logging, solid waste management (SWM), street widening, dilapidated buildings, etc. can be conducted in the future to propose a water-sensitive urban design.
- For the development of Phase II, land acquisition techniques will be employed to acquire land from various individuals. A comprehensive policy framework can be established in the future to provide appropriate compensation to landowners. The compensation may take the form of monetary compensation, Floor Space Index (FSI), or Transferable Development Rights (TDR) based on feasibility.
- The Socio-economic Impact Assessment (SEIA) of the proposed project has not been addressed in this research and can be conducted in the future. This assessment will help understand the potential range of impacts associated with the proposed design and the responses of all stakeholders affected by that design.
- An Environmental Impact Assessment (EIA) of the proposed project can also be conducted in the future to evaluate the significant effects of the development on the environment.
- The testing of parameters such as Biological Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Dissolved Oxygen (DO), etc., after the proposed development has not been performed in this research. Conducting such tests in the future will help assess the improvement in water quality in the Yamuna River at Mathura.
- Considering the rapid pace of technological advancements, provisions have been made to incorporate new techniques in the future. This includes the potential inclusion of innovative stormwater filtration and organic waste decomposition methods as they become available.

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ANNEXURE I

Questionnaire for Local Residents

1. Age (in years)
   ☐ Under 18 ☐ 18-25 ☐ 26-35 ☐ 36-45 ☐ 46-58 ☐ Above 58
2. Gender
   ☐ Male ☐ Female ☐ Other
3. How do you see River Yamuna?
   ☐ Dirty and Drain ☐ Encroached by Slum ☐ Clean and Beautiful
4. What are the various problems (pain points) associated with river Yamuna inMathura?
   ☐ Dirty Places ☐ Livelihood of boat man is extincting ☐ No connectivity
   ☐ Waste Deposition ☐ No toilet facilities ☐ No protection on river banks
   ☐ Outlet of Drainages opening into River ☐ Throwing garbage
   ☐ No access points ☐ No cleanliness
5. Do you think improvement is needed for the recreational spaces and YamunaGhats?
   ☐ Yes ☐ No ☐ Maybe
6. Which area along the river stretch needs more improvement?

   _____

7. What more facilities/improvement you want at Yamuna?
   ☐ Recreational Spaces ☐ Riparian Zones ☐ Safety ☐ Cleanliness
   ☐ Public Amenities ☐ Good Connectivity ☐ Entertainment Activities
8. Would you like to be a part of this improvement?
   ☐ Yes ☐ No ☐ Maybe
9. How will you participate as part of improvement?
   ☐ Shram Dan ☐ Donation ☐ Monitory Participation
   ☐ Physical Participation ☐ Mental Participation
10. In which part of river stretch, you go for recreational purpose and why?

    _____

11. How much time you spent at that location? (In hours)
    ☐ Less than 1 ☐ 1-2 ☐ 2-3 ☐ 3-4 ☐ More than 4
12. If you are not using any stretch of river for recreational purpose, why?
    ☐ There are no recreational spaces at all.
    ☐ The recreational spaces are not well maintained.
    ☐ These recreational places have lots of garbage around them.
    ☐ There is no good connectivity to these places.
13. Which part of river stretch you want to develop as recreational hub (including Ghats, water sports, parks, etc.)?

    _____

14. Which activity you prefer the most at that stretch?

15. How often do you visit the river?
☐ Very often ☐ Once a week ☐ Once a month ☐ Rarely
16. Why do you visit the river?
☐ Religious Purpose ☐ Recreational Purpose ☐ Social Cause
☐ For Transportation ☐ For Business
17. How satisfied are you with the existing condition (infrastructure) of this place?
Very dissatisfied ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 Very satisfied
18. How often do you visit Yamuna Ghats?
☐ 2-3 times a week ☐ 2-3 times a month ☐ Only on special occasions ☐ Rarely
19. How satisfied are you with the existing condition of Ghats?
Very dissatisfied ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 Very satisfied
20. Do you consider Yamuna as Active and Vibrant River?
☐ Yes ☐ No ☐
21. If yes, why?

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22. What is the major source of pollution for river?
☐ Waste Dumping ☐ Industrial Discharge ☐ Unauthorized Settlements/ Slums
☐ Holy Baths ☐ Domestic Wastes ☐ Upstream Delhi Segment
23. How do you want to see River Yamuna in future?
☐ Pollution Free ☐ Active and
☐ Clear and Blue ☐ Clean and Beautiful
24. Is there any rejuvenation centre for common people?
☐ Yes ☐ No ☐
25. If yes, where?

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26. Suggestions for Improvement.

✻ ✻ ✻ THANK YOU ✻ ✻ ✻

Questionnaire for Floating Population

1. Age (in years)
☐ Under 18 ☐ 18-25 ☐ 26-35 ☐ 36-45 ☐ 46-58 ☐ Above 58
2. Gender
☐ Male ☐ Female ☐ Other
3. How often do you visit the river?
☐ Monthly once ☐ Yearly once ☐ Rarely ☐ Once in a lifetime
4. How do you see River Yamuna?
☐ Dirty and Drain ☐ Encroached by Slum ☐ Clean and Beautiful
5. What are the various problems (pain points) associated with river Yamuna inMathura?
☐ Dirty Places ☐ Livelihood of boat man is extincting ☐ No connectivity

☐ Waste Deposition ☐ No toilet facilities ☐ No protection on river banks
☐ Outlet of Drainages opening into River ☐ Throwing garbage
☐ No access points ☐ No cleanliness

6. Why do you visit the river?
☐ Religious Purpose ☐ Recreational Purpose ☐ Social Cause
☐ For Transportation ☐ For Business
7. Do you think improvement is needed for the recreational spaces and YamunaGhats?
☐ Yes ☐ No ☐ Maybe
8. What more facilities/improvement you want at Yamuna?
☐ Recreational Spaces ☐ Riparian Zones ☐ Safety ☐ Cleanliness
☐ Public Amenities ☐ Good Connectivity ☐ Entertainment Activities
9. How satisfied are you with the existing condition (infrastructure) of this place?
Very dissatisfied ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 Very satisfied
10. How satisfied are you with the existing condition of Ghats?
Very dissatisfied ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 Very satisfied
11. Do you consider Yamuna as Active and Vibrant River?
☐ Yes ☐ No ☐
12. If yes, why?

_____

13. What is the major source of pollution for river?
☐ Waste Dumping ☐ Industrial Discharge ☐ Unauthorized Settlements/ Slums
☐ Holy Baths ☐ Domestic Wastes ☐ Upstream Delhi Segment
14. How do you want to see River Yamuna in future?
☐ Pollution Free ☐ Active and
☐ Clear and Blue ☐ Clean and Beautiful
15. In which part of river stretch, you go for recreational purpose and why?

_____

16. If you are not using any stretch of river for recreational purpose, why?
☐ There are no recreational spaces at all.
☐ The recreational spaces are not well maintained.
☐ These recreational places have lots of garbage around them.
☐ There is no good connectivity to these places.
17. Which part of river stretch you want to develop as recreational hub (including Ghats, water sports, parks, etc.)?

_____

18. Which activity you prefer the most at that stretch?

_____

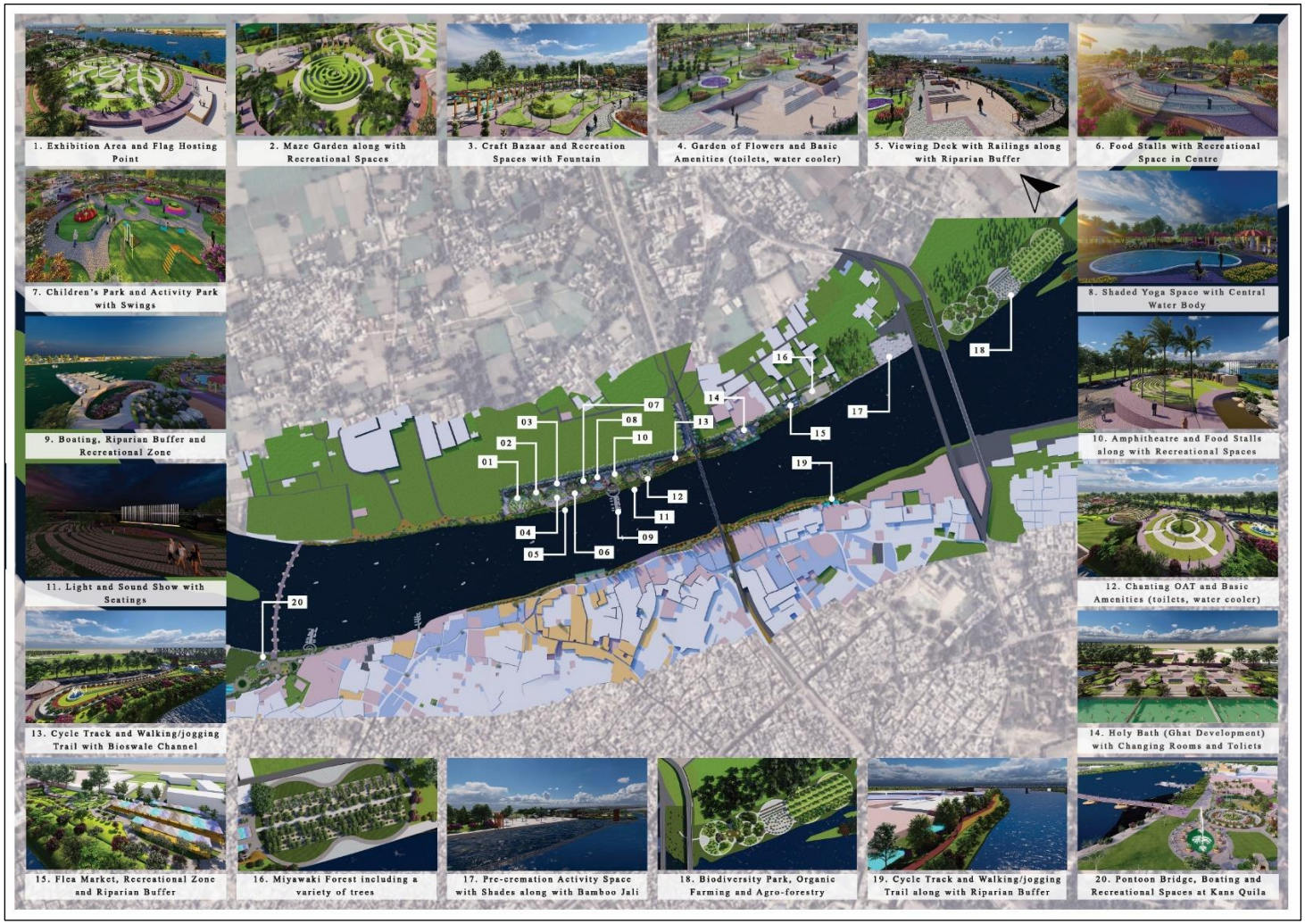
19. Suggestions for Improvement.

_____

* * * THANK YOU * *

ANNEXURE II

Site Plan



ANNEXURE III

Expenditure Detail of Proposed Project using Traditional Methods

Capital Cost																	
Sr. No.	**Component**	**Area (sq. m.)**	**Rate (per sq. m)**	**Total Cost**	**Year 0**	**Year I**	**Year II**	**Year III**	**Year IV**	**Year V**	**Year VI**	**Year VII**	**Year VIII**	**Year IX**	**Year X**	**Year XI**	**Year XII**
1	Pontoon Bridge	804.74	50000	40237000	40237000	0	0	0	0	0	0	0	0	0	0	0	0
2	Boating	802.46	20000	16049200	16049200	0	0	0	0	0	0	0	0	0	0	0	0
3	Pathway I	1622.03	6000	9732180	9732180	0	0	0	0	0	0	0	0	0	0	0	0
4	Pathway II	1767.51	6000	10605060	10605060	0	0	0	0	0	0	0	0	0	0	0	0
5	Pathway III	1171.53	6000	7029180	7029180	0	0	0	0	0	0	0	0	0	0	0	0
6	Pathway IV	875.76	6000	5254560	5254560	0	0	0	0	0	0	0	0	0	0	0	0
7	Pathway V	1696.96	6000	10181760	10181760	0	0	0	0	0	0	0	0	0	0	0	0
8	Pathway VI	1404.94	6000	8429640	8429640	0	0	0	0	0	0	0	0	0	0	0	0
9	Pathway VII	3919.74	6000	23518440	23518440	0	0	0	0	0	0	0	0	0	0	0	0
10	Artificial Lake	1703.93	50000	85196500	85196500	0	0	0	0	0	0	0	0	0	0	0	0
11	Road	4236.98	10000	42369800	42369800	0	0	0	0	0	0	0	0	0	0	0	0
12	Parking	6063.42	10000	60634200	60634200	0	0	0	0	0	0	0	0	0	0	0	0
13	Bioswale Channel	339.12	5000	1695600	1695600	0	0	0	0	0	0	0	0	0	0	0	0
14	Ghar Development	4828.47	20000	96569400	96569400	0	0	0	0	0	0	0	0	0	0	0	0
15	Cycle Track	993.89	12000	11926680	11926680	0	0	0	0	0	0	0	0	0	0	0	0
16	Walking Trail	992.86	6000	5957160	5957160	0	0	0	0	0	0	0	0	0	0	0	0
17	Green I	4210.18	150	631527	631527	0	0	0	0	0	0	0	0	0	0	0	0
18	Green II	4933.9	150	740085	740085	0	0	0	0	0	0	0	0	0	0	0	0
19	Green III	4504.5	150	675675	675675	0	0	0	0	0	0	0	0	0	0	0	0
20	Green IV	3395.71	150	509356.5	509356.5	0	0	0	0	0	0	0	0	0	0	0	0
21	Green V	4320.14	150	648021	648021	0	0	0	0	0	0	0	0	0	0	0	0
22	Green (OAT)	1131.82	150	169773	169773	0	0	0	0	0	0	0	0	0	0	0	0
23	Biodiversity Park	9587.38	10000	95873800	95873800	0	0	0	0	0	0	0	0	0	0	0	0
24	Agro-forestry	9672.23	10000	96722300	96722300	0	0	0	0	0	0	0	0	0	0	0	0
25	Organic Farming	3897.19	15000	58457850	58457850	0	0	0	0	0	0	0	0	0	0	0	0
26	Open Exhibition	1841.07	50000	97053500	97053500	0	0	0	0	0	0	0	0	0	0	0	0
27	Amphitheatre	1989.23	20000	39784600	39784600	0	0	0	0	0	0	0	0	0	0	0	0

28	Children Park	695.9	10000	6959000	6959000	0	0	0	0	0	0	0	0	0	0	0	0
29	Activity Park	542.27	10000	5422700	5422700	0	0	0	0	0	0	0	0	0	0	0	0
30	Miyawaki Forest	2915.25	2000	5830500	5830500	0	0	0	0	0	0	0	0	0	0	0	0
31	Garden of Flowers	421	5000	2105000	2105000	0	0	0	0	0	0	0	0	0	0	0	0
32	Maze Garden	241	5000	1205000	1205000	0	0	0	0	0	0	0	0	0	0	0	0
33	Flea Market	690.93	5000	3454650	3454650	0	0	0	0	0	0	0	0	0	0	0	0
34	Stair and Ramps	2108.28	8000	16866240	16866240	0	0	0	0	0	0	0	0	0	0	0	0
35	Pebbles	218.48	2500	546200	546200	0	0	0	0	0	0	0	0	0	0	0	0
36	Stone Masonary	650.79	8000	5206320	5206320	0	0	0	0	0	0	0	0	0	0	0	0
37	Railing	32.14	3000	96420	96420	0	0	0	0	0	0	0	0	0	0	0	0
38	Shrub Planting Area	3682.17	2000	7364340	7364340	0	0	0	0	0	0	0	0	0	0	0	0
39	Tree Planting Area	5007.87	5000	25039350	25039350	0	0	0	0	0	0	0	0	0	0	0	0
40	Toilet	773.08	20000	15461600	15461600	0	0	0	0	0	0	0	0	0	0	0	0
41	Water Coller/ Telephone Booth	15	50000	750000	750000	0	0	0	0	0	0	0	0	0	0	0	0
42	Kiosk	503.04	20000	10060800	10060800	0	0	0	0	0	0	0	0	0	0	0	0
43	Wooden Deck	791.77	10000	7917700	7917700	0	0	0	0	0	0	0	0	0	0	0	0
44	Light and Sound Show	1	50000000	50000000	50000000	0	0	0	0	0	0	0	0	0	0	0	0
45	Dustbin	100	1500	150000	150000	0	0	0	0	0	0	0	0	0	0	0	0
	Total Cost	**101981.66**		**991088667.5**	**991088667.5**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Operation and Maintenance Cost																	
1	Assuming the O/M cost for 1st year as 1% of project cost and increasing by 0.25 every year				0	9910886.68	11893064.01	13875241.35	15857418.68	17839596.02	19821773.35	19821773.35	19821773.35	19821773.35	19821773.35	19821773.35	19821773.35

Income Generation through Project

Rent																
Sr. No.	**Component**	**Quantity**	**Rent (per month)**	**Year 0**	**Year I**	**Year II**	**Year III**	**Year IV**	**Year V**	**Year VI**	**Year VII**	**Year VIII**	**Year IX**	**Year X**	**Year XI**	**Year XII**
1	Shops	37	5000	0	2220000	2220000	2220000	2220000	2220000	2220000	2220000	2220000	2220000	2220000	2220000	2220000
2	Flea Market	36	3000	0	1296000	1296000	1296000	1296000	1296000	1296000	1296000	1296000	1296000	1296000	1296000	1296000
3	Boating	1	200000	0	2400000	2400000	2400000	2400000	2400000	2400000	2400000	2400000	2400000	2400000	2400000	2400000

Fees																
Sr. No.	**Component**	**Amount**	**Floating Population for year 2019**	**Year 0**	**Year I @ 10% Floating Population**	**Year II @ 10% Floating Population**	**Year III @ 15% Floating Population**	**Year IV @ 15% Floating Population**	**Year V @ 20% Floating Population**	**Year VI @ 20% Floating Population**	**Year VII @ 20% Floating Population**	**Year VIII @ 20% Floating Population**	**Year IX @ 20% Floating Population**	**Year X @ 20% Floating Population**	**Year XI @ 20% Floating Population**	**Year XII @ 20% Floating Population**
1	Entry Fee	20	8270360	0	16540720	16540720	24811080	24811080	33081440	33081440	33081440	33081440	33081440	33081440	33081440	33081440
2	Exhibition	20	8270360	0	16540720	16540720	24811080	24811080	33081440	33081440	33081440	33081440	33081440	33081440	33081440	33081440
3	Light and Sound Show	30	8270360	0	24811080	24811080	37216620	37216620	49622160	49622160	49622160	49622160	49622160	49622160	49622160	49622160
	Total Income			**0**	**63808520**	**63808520**	**92754780**	**92754780**	**121701040**	**121701040**	**121701040**	**121701040**	**121701040**	**121701040**	**121701040**	**121701040**

Cost Recovery of Project

Sr. No.	**Component**	**Year 0**	**Year I**	**Year II**	**Year III**	**Year IV**	**Year V**	**Year VI**	**Year VII**	**Year VIII**	**Year IX**	**Year X**	**Year XI**	**Year XII**
1	Net Profit for each year	0	53897633.33	51915455.99	78879538.66	76897361.32	103861443.99	101879266.65	101879266.65	101879266.65	101879266.65	101879266.65	101879266.65	101879266.65
2	Cumulative Profit	-991088668	-937191034.18	-885275578.19	-806396039.53	-729498678.21	-625637234.23	-523757967.58	-421878700.93	-319999434.28	-218120167.63	-116240900.98	-14361634.33	87517632.32

ANNEXURE IV

Site Photographs








CERTIFICATE OF COMPLETION

This is to certify that this thesis project titled "**Leveraging River-Centric Planning for Rejuvenation of Eutriphicated Segment of Yamuna River in Mathura City through Citizen Engagement and Self-Financing Model of Urban Planning**" was carried out by Ms. **Vidhisha Bhargava**, a student of **M. Tech – Urban Planning**, at the **Sardar Vallabhbhai National Institute of Technology, Surat**. The research for this project was undertaken under the guidance of the afore-mentioned institute and completed during the period of **2 January 2023** to **19 June 2023**.

This project was shortlisted under the *Sponsored Thesis Project Competition on "RE-IMAGINING URBAN RIVERS" (Season- 3)* hosted by the National Institute of Urban Affairs (NIUA) and the National Mission for Clean Ganga (NMCG).

This report has been submitted by the student as a final deliverable under the competition. All parts of this research can used by any of the undersigning parties.

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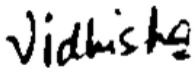
Signature - 

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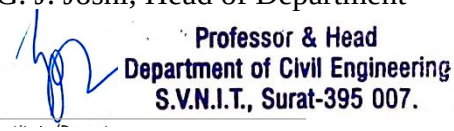
Signature - 

3. Sponsors

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