Sponsored Thesis Project Competition on

"RE-IMAGINING URBAN RIVERS"

Season- 2

Project Title: **Planning for Yamuna to mitigate pollution effects of wastewater flow on the river, Delhi**

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This thesis research is an effort to contribute to highlighting the issues present in the existing wastewater management system present in place in Delhi and how it has contributed to the decline of Yamuna's fragile health. It attempts to show various approaches to proper wastewater management in Delhi.

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Abstract

Rivers have been at the center of society's progress. All ancient civilizations of the world flourished on the banks of one river or another. As cities developed, rivers, which once were the most important sources of freshwater, became carriers of wastewater. Various sources of pollution suggest how rivers have incurred the cost of hasty economic and technological progress. Most rivers today are suffering from severe organic, inorganic, and/or pathogenic pollution along with the low water volume. The two most revered rivers of India— the Ganga and the Yamuna– are no exceptions, despite being considered goddesses by the Hindus. In both 2007 and 2017, the Ganga was listed as one of the world's top 10 'rivers at risk' (Wong 2007, Sawe 2017).

One of the most polluted tributaries of the river Ganga is the river, Yamuna. The pollution of this river has led researchers to declare that the Yamuna is 'about to die' (Misra 2010). Delhi NCR, the national capital region, generates approximately 76 percent of the total pollution load in the Yamuna (PTI, 2018), effectively turning the river into a 'sewage drain' (Datta, 1992). Delhi treats about 66 percent of the total sewage generated by its urban area and the untreated sewage mostly finds its way into the rivers or other surface water bodies. Nevertheless, approximately for the entire Delhi, the Yamuna remains pivotal to their livelihood and socio-cultural life. 70 % of Delhi's water needs are sufficient because of Yamuna alone and apart from this on Yamuna river, all forms of livelihood continue to depend: farmers still cultivate on the banks, fisher-folk fish, washer-folk wash, boatmen ply their boats and devotees take ritual baths.

There is no dearth of work focusing on the Yamuna's deteriorating water quality and its negative impact both on the biodiversity of the river The report attempts to demonstrate the interwoven nature of river water quality and ever-increasing issues related to wastewater, revealing the way each aspect is related to one another. It also attempts to show the potential of Decentralised Wastewater Management along potential of nature-based solutions can be a feasible approach for improving water quality as well as better community liveability with greater social benefits.

***Keywords**: Decentralised Wastewater Management, Nature-Based Solutions, Water Quality, Socio-Economic Impacts*

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Acronyms/ Abbreviations

BOD - Biological Oxygen Demand

CETP – Common Effluent Treatment Plant

CPCB - Central Pollution Control Board

COD - Chemical Oxygen Demand

DDA - Delhi Development Authority

DJB - Delhi Jal Board

DWWM – Decentralised Waste Water Management

DO - Dissolved Oxygen

FC – Fecal Coliform

HH – Household

GIM - Green India Mission

GNCTD – Government of NCT of Delhi

KLD - Kilo litres / Day

LULC – Land Use/ Land Cover

MCD - Municipal Corporation of Delhi

MLD - Millions of litre / Day

MPD - Master Plan Delhi

MoEF - Ministry of Environment and Forests

NAPCC - National Action Plan on Climate Change

NbS – Nature Based Solution

NCT - National Capital Territory

NMSA - National Mission for Sustainable Agriculture

SBM – Swachh Bharat Mission

STP – Sewage Treatment Plant

TDS – Total Dissolved Solids

TSS – Total Suspended Solids

UAC - Unauthorized Colonies

UNEP - UN Environment Programme

YAP – Yamuna Action Plan

Glossary of Terms

Agricultural Run-off: Water that flows from agricultural fields. Agricultural run-off is a major source of pesticides in water

Ecosystem-based management: An integrative and holistic approach to management based on the idea of systems in contrast to the traditional procedure of managing sectoral activities like fishing, shipping, or oil and gas development. This approach is intended not only to draw attention to linkages among the various components of complex systems but also to consider the non-linear dynamics of socio-ecological systems

Ecosystem services: The processes by which the environment produces resources that we often take for granted such as safe water, timber, and habitat for fisheries, and pollination of native and agricultural plants

Green technology: A continuously evolving group of methods and materials, from techniques for generating energy to non-toxic cleaning products. The goals that inform developments in this rapidly growing field include sustainability, "cradle-to-cradle" design, source reduction, innovation, viability, energy, green building, environmentally preferred purchasing, green chemistry, and green nanotechnology

Sewage: Organic waste and wastewater produced by residential and commercial establishments

Water pollution: Direct or indirect introduction by humans of substances or energy into the aquatic environment, resulting in harm to living resources, hazards to human health, hindrances to marine activities including fishing, impairment of the quality of water, and reduction of amenities

Wastewater: Wastewater is used water. It includes substances such as human waste, food scraps, oils, soaps and chemicals. In homes, this includes water from sinks, showers, bathtubs, toilets, washing machines and dishwashers. Businesses and industries also contribute their share of used water that must be cleaned

Water Quality: Physical, chemical, biological and organoleptic (taste-related) properties of water

I N T R O D U C T I O N

Chapter - I

CHAPTER I

1. Understanding the Context

Rivers have always been at the heart of society's development. All of the world's ancient civilizations thrived along the banks of one or more rivers. Rivers, which were once the most important sources of freshwater, became carriers of wastewater as cities grew. Rivers have paid the price for hasty economic and technological progress, according to various sources of pollution. Today's rivers are plagued by severe organic, inorganic, and/or pathogenic pollution, as well as low water levels.

According to a UNEP report titled 'A Snapshot of the World's Water Quality: Towards a Global Assessment,' one-third of all river stretches in Latin America, Africa, and Asia are affected by severe pathogenic pollution. Furthermore, severe organic pollution affects one-seventh of these river stretches, while salinity pollution affects one-tenth. Increased wastewater discharge into rivers has been identified as a primary source of water pollution (UNEP 2016).

Water is necessary for the survival of all living things, but it is becoming increasingly scarce as human populations grow and demand more high-quality water for domestic and commercial purposes. Freshwater scarcity is one of the most pressing environmental issues that India faces this century. The main obstacles to better water quality management in India are contamination and water quality issues caused by treated, partially treated, and untreated wastewater from urban settlements, industrial operations, and irrigation run-off, as well as poor municipal solid waste management.

As it transitions from a developing to a developed economy, India faces two challenges. On the one hand, there is a lack of infrastructure, and on the other, there is an ever-increasing metropolitan population. As a result, two self-perpetuating problems have emerged: water scarcity and sewage overflow. By 2050, it is expected that more than half of the country's population will live in cities and towns, creating a significant demand for infrastructure amenities and posing a challenge to urban planners and policymakers. Only 38% of sewage in India's cities is treated (CPCB, 2015).

According to a 2015 report by the Central Pollution Control Board (CPCB), India generates 61,948 million liters of urban sewage per day. The cities' installed sewage treatment capacity is only 38 percent of this. The treatment capacity of the country's major STPs is around - 66% of the installed capacity (CPCB, 2013). As a result, more than 38,000 million liters of wastewater are discharged into major rivers each day, with some even percolating into the ground. There is also industrial effluent to consider.

Despite being considered goddesses by Hindus, India's two most revered rivers, the Ganga and the Yamuna are no exceptions. The Ganga was named one of the world's top ten 'rivers at risk' in both 2007 and 2017 (Wong, 2007, Sawe, 2017). The river Yamuna is one of the most polluted tributaries of the Ganga. Researchers have declared that the Yamuna is 'on the verge of dying due to pollution (Misra, 2010).

Much research which mostly deals with the severity of pollution due to wastewater discharge and the existence of heavy metals in crops has revealed the bad influence on human health as well as riverine populations exposed to contaminated water bodies for an extended duration (Priyanie Amerasinghe, 2013).

Further, rivers connect numerous parts of socioeconomic life and the richness of this connectivity is the outcome of complexity in social organizations (Hannerz 1992). That is why rivers are molded not only by the hydrological cycle but are also de-shaped and remade by socio-cultural and political interventions and become a part of the hydro-social cycle opposing the idea of the nature-culture dichotomy. Thus, the worsening water quality of rivers has not only presented a threat to the river biota but has also damaged river-dependent people. However, most of the conformist interpretation of environmentalists has put the burden of river water pollution mostly on people who are dependent on it, which has led to coercive cultural change along the river (Baviskar, 2011).

The report through a comprehensive and exhaustive review of pre-existing literature including journal articles, national and international reports, etc. tries to provide a basic understanding of the significance of the Urban river for cities and riverine communities particularly, the impact of pollution on the communities, cause of degradation of urban river and parameters to identify the pollution status of a river. It further seeks to highlight the interconnected nature of river water quality and the health & livelihood of the riverine populations, revealing the way each component is tied to one another.

1.1. Need of the study

The discharge of untreated or partially treated sewage from cities/towns and industrial effluents into their respective catchments, problems in the operation and maintenance of sewage /

effluent treatment plants, lack of dilution, dumping of solid waste on river banks, and other non-point sources of pollution are the main causes of pollution in the country's rivers.

The situation has been exacerbated by rapid urbanisation and industrialization. According to a 2015 report by the Central Pollution Control Board (CPCB), India generates 61,948 million gallons of urban sewage each day. However, over 38,000 million gallons of wastewater every day is discharged into major rivers and even percolate into the earth. The disconnect between sewage generation and treatment continues to be a major source of river contamination.

Under the National Water Quality Monitoring Programme, the CPCB has been monitoring the water quality of rivers and other water bodies across the country through a network of monitoring stations in collaboration with Pollution Control Boards/committees in various states / Union territories.

CPCB had conducted river pollution assessments based on water quality monitoring findings regularly. According to the CPCB's most recent report, issued in September 2018, 351 contaminated stretches were detected on 323 rivers based on monitoring data in terms of biochemical oxygen demand, an indicator of organic pollution (Senapati, 2021) as shown below in the table.

BOD levels beyond a certain threshold are harmful to aquatic life. DO is digested by bacteria when significant biodegradable organics are present in water, as is the case with most wastewater. When this happens, the DO level falls below a certain threshold, which has a detrimental influence on life since they are unable to maintain regular life-sustaining functions like growth and reproduction.

Table 1 Urban Sewage Generation and Treatment (State of India's

STATES	Urban Sewage Generation (MLD)	Installed Treatment Capacity (MLD)	Polluted Stretches
Jammu and Kashmir	547	264.74	9
Himachal Pradesh	110	114.72	8
Punjab	1644	1245.45	2
Haryana	1413	852.7	2
Delhi	**4155**	2693.7	1
Uttarakhand	465	152.9	13
Bihar	1876	124.55	5
Assam	703	0.51	28
Uttar Pradesh	**7124**	2646.84	5
Jharkhand	1270	117.24	8
Sikkim	24	31.88	5
Rajasthan	2736	865.92	8
Gujarat	**4119**	3062.92	20
Madhya Pradesh	3214	482.23	21
West Bengal	**4667**	416.9	17
Nagaland	92	0	2
Chhattisgarh	951	0	5
Maharashtra	**8143**	5160.36	49
Daman & Diu	55	0	1

Telangana	1671	685.8	7
Karnataka	**3777**	1304.16	15
Goa	145	74.56	8
Andhra Pradesh	2871	247.27	6
Odisha	1121	385.54	12
Meghalaya	95	1	10
Tripura	154	0.02	2
Nagaland	92	0	3
Manipur	132	0	12

Furthermore, eutrophication is caused by the abundance of nitrogen-containing chemicals in many wastewater streams. This can cause algae blooms (the growth of plants in the aquatic ecosystem) and anoxic conditions, resulting in changes in dominant aquatic biota species, fish kills, and the spread of water-borne diseases such as cholera and typhoid (Joshua N. Edokpayi, 2017).

Pollutants also reduce the quantity of usable water, raise the cost of purification, pollute aquatic resources, and have an impact on food supplies. Pollution, in combination with human water demand, has an impact on biodiversity, ecosystem functioning, and the natural services provided by aquatic systems, all of which are important to society.

Thus, implementing effective management approaches for improved water quality and biota conservation is critical, as it also affects the health and livelihood of riverine populations that live close to dirty river water.

1.2. Research question

a. What proposals have been laid out in Master Plans to Control Yamuna'

b. Where mainly is wastewater generated and what is the status of its management?

c. How poor water quality of rivers is affecting the livelihood and health of the people in the site area?

d. What are the institutional responses and how effective are they?

e. What are the possible solutions for prevailing wastewater problems?

1.3. Aim

To assess the Pollution Effects of the Wastewater Flow on Water-Quality of Yamuna and suggest various methods to improve it.

1.4. Objectives

UNDERSTANDING (LIT): To critically understand the importance of urban rivers and the pollution status of Indian rivers.

ANALYSIS: To assess the existing wastewater management system and identify sources of pollution in the study area

ANALYSIS: To assess the water quality parameters spatially and detect the level of pollution in the study area.

ANALYSIS: To study the impact of river water quality on the livelihood of site area communities.

PROPOSAL: To propose/recommend strategies for the water quality improvement of Yamuna.

1.5. Scope

The research can help with wastewater management and its effects on water quality and riverine populations in the study area.

- The study can provide insights on wastewater management in relation to its impact on water quality in the study area at the city level.
- Especially critical focus is on the communities in the site area, who are dependent on and interact with the river on a daily basis.
- It also attempts to make a case for a more integrated spatial governance of the urban rivers at risk.

1.6. Limitations

- The study will be based on secondary data and limited primary data due to the present COVID – 19 scenarios.
- Primary Surveys conducted will be limited to a small stretch of the river only due to time constraints.

1.7. Methodology

P H A S E 1 *Formulation Stage*	***Aim & Objectives***	***Need of the study***	
P H A S E 2 *Literature Study*	***To critically understand the importance of urban rivers and their cause of degradation.***	1. Urban rivers significance for cities and riverine communities particularly 2. Impact of pollution on the communities 3. Cause of degradation of urban river 4. Parameters to identify the pollution status of a river 5. Assessing proposals regarding river pollution in Master Plans	**Delhi as a Case Study** Identify current issues Status of Water Pollution Impact on Communities
P H A S E 3 *Data Collection & Selection of Study Area* ***(Based on Literature)***	***To assess existing wastewater management systems & identify pollution sources in the study area.***	***LandUse/ LandCover Analysis*** *LULC approach* to capture the hydrological variability of the Yamuna and changes in the LULC pattern over the previous decade. **Pollution Source Analysis of -** 1. Sewered & unsewered area	*The overall study can help to find a link between rising pollution levels and the pressures of urbanization, which may be attributed to increased wastewater generation/discharge into the Yamuna.*

		2. 18 Drains falling into the Yamuna 3. STPs and other treatment infrastructure 4. CETPS & Industrial Clusters it caters **Wastewater Analysis** 1. Assess the treatment capacity of sewage treatment plants (Generation/Treatment Gap) 2. Pollution Analysis of Treated effluents (STPs, CETPs) 3. End Use of Treated Effluents from STPs	
PHASE 4 *Analysis*	***To assess the water quality parameters spatially & detect the level of pollution in the study area.***	1. To assess the river water quality for pollution parameters, field datasets of the National Water Quality Monitoring Programme (NWMP) from river water quality monitoring stations of the Central Pollution Control Board (CPCB) can be taken.	Based on water quality parameters, water quality across the whole river flow area will be assessed using ***IDW interpolation***.
PHASE 5 *Identification of Issues and Problems*	***To analyse the impact of river water quality on the livelihood & health of riverine communities***	Socio-economic Survey questionnaire 1. Questions related to habitation 2. Questions related to the basic facility in household 3. Livelihoods and Income: Questions related to Household Economy 4. Perception of river water /Awareness and opinion about river water quality 5. Questions related to health	Social research to evaluate the impact of pollution on various riverine communities' livelihoods and health is required.
PHASE 5 *Proposals*	***To propose strategies for water quality improvement of urban rivers.*** It will incorporate ecological and biodiversity concerns of poor water quality and will support urban river and livelihood improvements.		

CHAPTER II

2. Literature Review – Importance of Rivers

One-third of the world's drinking water comes from surface sources such as rivers, dams, lakes, and canals, making freshwater supply one of the world's most pressing concerns. These water sources also serve as excellent sinks for the disposal of household and industrial trash (Corcoran, 2010). The most serious threat to India's long-term water supply is pollution, which contaminates accessible water resources.

Apart from maintaining flora and fauna, increasing aesthetic and landscape quality, moderating climate, and providing a supply of electricity, rivers are significant resources for human civilizations because they meet water demand for many needs. For their daily supply and livelihood, many riverine villages in India still rely on untreated or inadequately treated water from surface resources such as rivers and lakes. They may not have or have limited access to sufficient sanitary facilities, putting them at risk of contracting waterborne infections.

Farmers have used it for irrigation, and fishermen make their living by harvesting fish from a variety of freshwater sources. It is a swimming pool that also functions as a tourist attraction. As a result, pollution should be avoided in surface water. The higher parts of the Yamuna River, for example, are determined to have good water quality due to fewer human impacts, but as it passes through semi-urban and metropolitan regions, it begins to receive pollution from numerous point and non-point sources as a result of anthropogenic activity. River flow is strongly dependent on climatic conditions and drainage patterns. Because of the prevailing stream and turbulence, vertical mixing is obtained. To draw water for diverse needs, urbanization and industries are created near rivers, but wastewater is frequently released without sufficient treatment, resulting in substantial river contamination. As a result, humans have used surface water for a variety of reasons (M.P. Sharma, 2008).

Raw and partially processed wastewater are major point sources of freshwater pollution. Increased freshwater pollution and loss of clean water resources have resulted from the discharge of home and industrial wastewater. Wastewater treatment is a serious concern in India, particularly in quickly increasing metropolitan regions. According to a 2015 report by the Central Pollution Control Board (CPCB), India generates 61,948 million gallons of urban sewage each day. Every day, however, over 38,000 million gallons of wastewater are discharged into major rivers and even percolate into the earth. There is also industrial wastewater to consider (Down to Earth, 2018).

Wastewater containing microbes, heavy metals, fertilizers, radionuclides, pharmaceuticals, and personal care items finds its way into surface water resources, causing irreversible damage to the aquatic ecosystem and humans by compromising the water's aesthetic and ecological value.

2.1. Polluting Sources

A major portion of water pollution in India is caused by domestic effluents. Untreated household effluents contaminate surface and groundwater sources. Cities, municipalities, and panchayats are responsible for water supply and sanitation, and they must adhere to national

water pollution legislation or minimum national norms (MINAS). Only about 30% of effluents are treated and the rest are sent into the environment untreated.

Water pollutants including biochemical oxygen demand (BOD), chemical oxygen demand (COD), suspended solids (SS), and pH are used by the CPCB to create pollution recommendations for companies. These industries have effluent treatment facilities (ETPs), however, they were found to be in breach of pollution regulations.

Ground and surface water sources are impacted by pesticide and fertiliser residue in agricultural run-offs. Water resources are negatively impacted by the use of fertilisers. An organism's ability to reproduce is facilitated by an increase in water channel feeding. Disease vectors or algae could be the source of these organisms. Sedimentation and the growth of organisms could be facilitated by the development of algae in waterways.

Table 2 Water Regulation Framework in India (*Rajaram and Das (2008)*)

Polluting Sources	Effect On Ecosystem	Specific Standards	Current Status
Domestic sewage from towns and cities	Organic pollution of rivers, eutrophication of lakes, waterborne diseases	MINAS	Out of 26,500 MLD of sewage from Class-I towns and cities treatment capacity exists only for about 7,000 MLD (26%). Out of 271 STPs inspected by CPCB only 150 (55%) were complying with MINAS
Industrial effluents (point discharges)	Organic and inorganic pollution, toxic chemicals in the food chain	MINAS (industry-specific)	No comprehensive statistics on compliance exist as it is dealt with mainly by SPCBs. Widespread damage to the ecosystem around industrial areas is well documented by CPCB
Industrial and mines run-off	Organic and inorganic pollution, toxic chemicals in the food chain	No standards/ legislation	No comprehensive study as stored hazardous waste, mine spoils, etc. contribute large quantum of contaminants which pollute surface and groundwater
Agricultural run-off	Fertilizers leading to eutrophication pesticides in the food chain	No standards/ legislation	Nation-wide studies have not been conducted, apart from regular news articles on pesticides in water and food items

Domestic wastes, agricultural wastes (fertilisers, pesticides, etc.) and inadequately disposed of industrial wastes are all found in soils and groundwater. Direct sources include effluent outfalls from factories, refineries, wastewater treatment plants, and other industrial facilities that leak

directly into urban water supplies; while indirect sources include toxins that enter the river through soils/groundwater and rain. The contamination potential in the Yamuna catchment area is determined by a variety of human activities and is divided into two categories:

(a) point sources of pollution, such as home sewage and industrial effluent; and

(b) diffuse sources of pollution, such as agricultural runoff. Agriculture runoff, in-stream water uses, bathing, livestock wading, open faeces, and clothes washing are all examples of non-point sources of pollution (after YAP 2008).

Other forms of river contamination include soil erosion, pollutant fallout in the atmosphere, unintentional shipments, and river damming effects.

2.2. Water Quality and the Index

Water quality refers to the chemical, physical, and biological qualities of water that influence its suitability for several applications as well as the health and integrity of water bodies (Corcoran, 2010). Natural and manmade processes both have an impact on water quality. Natural water quality varies widely from place to location, based on seasonal and climatic variations, as well as the types of soils, rocks, and surfaces it passes through. Agricultural activities, urban and industrial development, mining, and recreation all have a substantial impact on the quality of natural streams and their water use potential (M.P. Sharma, 2008).

With regard to the specific issue of drinking water supply, the first recorded Indian water quality index (WQI) was proposed for zoning and categorization of the river Ganga. In the Indian setting, an overall index of pollution for surface water based on the average value of all pollution sub-indices provides a basic classification method (Saraikistan Deshpande 2003).

When determining the contamination status of a river, the following water quality parameters are taken into account:

Physical Parameters

pH, temperature, turbidity, TSS, TDS, colour, taste and odour, and electrical conductivity, among other physical factors

Chemical Parameters

Inorganic waste: inert suspension, inorganic salts (e.g., Ca, Mg as CaCO3), acids and alkalis, toxic metals (As, Cd, Pb, Zn, Co, Cu, Cr, Fe, Ni), inorganic salts, oxides, and radioactive waste;

Organic waste: sewage (DO, BOD, COD), oils and grease, detergents, pesticides, and nutrients

Biological Parameters - Pathogens (total coliform & faecal coliform), algal toxins, and toxic compounds due to microbial activity.

Water quality is an important indicator for measuring environmental changes that have immediate social and economic implications. Two major difficulties that hamper socio-economic progress are the paucity of fresh water and the pollution of readily available water. Wastewater and effluents from industrial processes and commercial establishments, as well as domestic sources, pollute rivers.

Understanding the characteristics and methods of surface and groundwater contamination can help policymakers assess the success of water management strategies and build a climate conducive to long-term development.

2.3. Water Quality Requirement for Different Uses – CPCB

Any water body must have a certain level of purity in order to perform properly for the intended purpose. Drinking water should be as pure as possible. The concept of water quality management is becoming as important as water quantity management as the volume of water demand approaches the available supply.

Each water usage has distinct quality requirements. As a result, identifying the uses of water in a water body is critical to setting the standard for the desired quality of that water body. The Central Pollution Control Board (CPCB) in India has created the idea of designated best use. According to this, among a body's several uses of water, the one that requires the highest quality is referred to as the designated best use. There are five top uses that have been established. This classification aids water quality managers and planners in establishing water quality goals and developing appropriate restoration plans for distinct water bodies.

Table 3 Designated Best Use as per CPCB (Central Pollution Control Board, n.d.)

Designated Best Use	Class	Criteria
Drinking Water Source without conventional treatment but after disinfection	**A**	1.Total Coliforms Organism MPN/100ml shall be 50 or less
		2. pH between 6.5 and 8.5
		3. Dissolved Oxygen 6mg/l or more
		4. Biochemical Oxygen Demand 5 days 20 °C, 2mg/l or less
Outdoor bathing (Organised)	**B**	1.Total Coliforms Organism MPN/100ml shall be 500 or less
		2. pH between 6.5 and 8.5
		3. Dissolved Oxygen 5mg/l or more
		4. Biochemical Oxygen Demand 5 days 20 °C, 3mg/l or less
Drinking water source after conventional treatment and disinfection	**C**	1. Total Coliforms Organism MPN/100ml shall be 5000 or less
		2. pH between 6 and 9
		3. Dissolved Oxygen 4mg/l or more
		4. Biochemical Oxygen Demand 5 days 20 °C, 3mg/l or less
Propagation of Wild life and Fisheries	**D**	1. pH between 6.5 and 8.5
		2. Dissolved Oxygen 4mg/l or more
		3. Free Ammonia (as N)
		4. Biochemical Oxygen Demand 5 days 20 °C, 2mg/l or less
Irrigation, Industrial Cooling, Controlled Waste disposal	**E**	1. pH between 6.0 and 8.5
		2. Electrical Conductivity at 25 °C micro mhos/cm, maximum 2250
		3. Sodium absorption Ratio Max. 26

		4. Boron Max. 2mg/l
	Below-E	Not meeting any of the A, B, C, D & E criteria

Table 4 Colour coding frequently used to depict the quality of water on maps (Central Pollution Control Board, n.d.)

Bluewater	This water can be directly used for drinking, industrial use, etc.
Green water	Water contained in soil and plants is termed green water
White water	Atmospheric moisture is white water
Brown or grey water	Various grades of wastewater are shown by brown or grey colour

2.4. Environmental impact

Poorly treated wastewater can have a significant impact on the watershed it is discharged into. The harmful effects can be immediate or build up over time. Large levels of ammonia and chlorine, high loads of oxygen-demanding compounds, or hazardous quantities of heavy metals and organic pollutants are the most common causes of acute consequences from wastewater effluents. Cumulative effects result from the gradual accumulation of pollutants in receiving surface water, which only becomes apparent when a particular threshold is crossed (Weber S, 2006).

For optimal operation and survival, all aquatic creatures have a temperature range. Their reproductive cycle, growth, and life can be harmed or threatened when such parameters are abruptly altered. Discharged effluents from wastewater treatment plants normally add to the oxygen demand level of the receiving water due to the organic load of wastewater. In surface water that absorbs untreated wastewater, dissolved oxygen (DO) levels have decreased.

BOD and COD are commonly used to calculate the amount of organic contamination in water and wastewater. They are crucial wastewater quality metrics since they are used to assess the efficacy of most wastewater treatment plants. To support aquatic life, surface water should have low BOD/COD concentrations. BOD and COD levels above a certain threshold can be harmful to aquatic life, particularly fish. In river systems, low levels of BOD and COD indicate acceptable water quality, whereas high levels indicate polluted water. The levels of BOD/COD and DO concentrations have an inverse relationship. DO is digested by bacteria when significant biodegradable organics are present in water, as is the case with most wastewater. When this happens, the DO level falls below a certain threshold, which has a detrimental influence on life since they are unable to maintain regular life-sustaining functions like growth and reproduction. Fish and other aquatic species suffer as a result of this decline.

When nutrient-rich wastewater effluents are dumped into waterways, eutrophication can occur. Algae blooms and plant growth in the aquatic habitat may occur as a consequence of this. Whenever this happens, water turbidity rises, plant and animal biomass rise, sedimentation rate rises, species diversity declines, and anoxic conditions emerge, potentially leading to changes in dominant aquatic biota species, cholera outbreaks, and fish kills. In general, nitrogen-

containing compounds are common in many wastewater streams, and improper treatment might result in their entry into the receiving watershed, with the aforementioned implications.

Groundwater can be contaminated by the release of chemicals from wastewater. Pollutants that enter aquifers stay there for years and spread through the water, rendering groundwater unfit for drinking, irrigation, and other purposes across large areas.

Increased sediment impoundments and the presence of harmful and persistent chemicals pose a threat to riverbeds and wetlands. Pollution can remain for a long time after its source has gone. The presence of harmful compounds can have a negative impact on the aquatic ecosystem's health. This is made worse by the high number of pathogens in the water. Human health and society as a whole are harmed by the use of microbiologically polluted water for residential and other purposes (Joshua N. Edokpayi, 2017).

CHAPTER - III

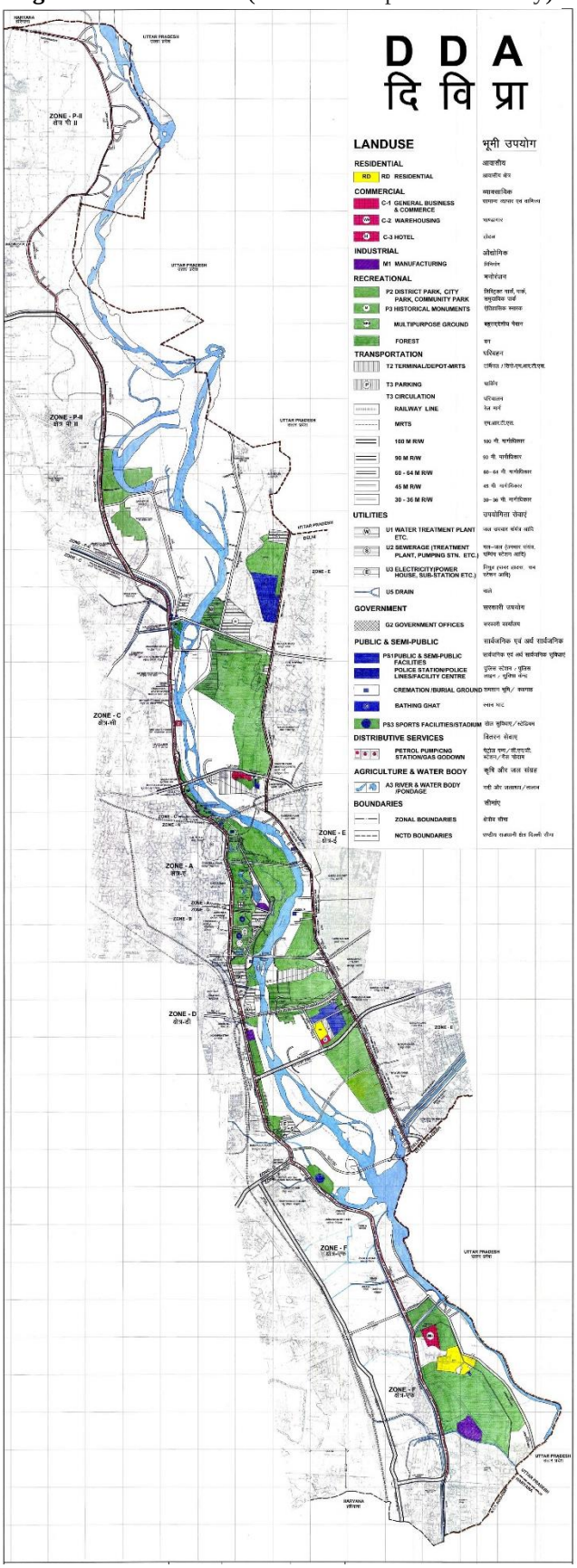
3. Case Study – Yamuna Stretch in Delhi

The Delhi National Capital Territory (NCT) has a total area of 1,483 square kilometres and is divided into 9 census districts and 27 sub-divisions (Tehsils). The urban area, including new settlements in rural habitations, accounts for approximately 525 square kilometres of this total. Delhi is governed by three bodies: the Municipal Corporation of Delhi (MCD), the New Delhi Municipal Council (NDMC), and the Delhi Cantonment Board (DCB).

The MCD is one of the world's largest municipal bodies, accounting for 94.22 per cent of the total NCT area. MCD has been subdivided into three sub-divisions: South Delhi Municipal Corporation (SDMC), East Delhi Municipal Corporation (EDMC), and North Delhi Municipal Corporation (NDMC) (NDMC).

According to the Delhi Development Authority's (DDA) Master Plan 2021, the National Capital Territory of Delhi has been divided into 15 Planning Zones / Divisions, of which 8 zones ('A' to 'H') are in the urban area and 6 zones ('J' to 'P' (Except 'I') are in the urban extension / rural area, and Zone 'O' is designated for the river Yamuna/Yamuna Front.

Figure 1 Zonal Plan 'O' (Delhi Development Authority)



3.1. River Yamuna

The River Yamuna, a major tributary of the Ganges, flows from the Yamunotri glacier near the Banderpoonch peaks in the Mussourie range of the Lower Himalayas, at an elevation of about 6387 metres above mean sea level in the district of Uttarkashi (Uttaranchal).

River Yamuna flows for about 200 kilometres from its source through a series of valleys in the Lower Himalayas before emerging into the Indo-Gangetic Plains. It draws water from several major streams in its upper 200 km stretch. The combined stream flows through the Shivalik range of hills in the Indian states of Himachal Pradesh and Uttaranchal before entering the plains at Dak Pathar in Uttaranchal, where the river water is regulated by a weir and diverted into a canal for power generation. It flows from Dak Pathar through the famous Sikh religious site of Paonta Sahib. Flowing through Paonta Sahib, it reaches Hathnikund/Tajewala in Haryana's Yamuna Nagar district, where it is diverted into the Western and Eastern Yamuna Canals for irrigation. It arrives in Delhi near Palla village after a 224-kilometre journey from Tajewala.

The river is tapped again at Wazirabad via a barrage to supply drinking water to Delhi. In general, no water is allowed to flow beyond Wazirabad Barrage during the dry season because the available water is insufficient to meet Delhi's water supply-demand. Untreated or partially treated domestic and industrial effluent from a number of drains flows downstream of the Wazirabad Barrage.

After 22 kilometres downstream of Wazirabad Barrage, there is another barrage, Okhla Barrage, which diverts Yamuna water into Agra Canal for irrigation. During the dry season, no water is allowed to flow through the barrage. Whatever water flows in the river beyond the Okhla barrage comes from domestic and industrial wastewater generated in East Delhi, Noida, and Sahibabad, which enters the river via the Shahdara drain. After receiving water from other important tributaries, the Yamuna joins the Ganga and the underground Saraswati at Prayag (Allahabad) after a 950-kilometre journey.

Between Wazirabad Barrage and Okhla Barrage, the River Yamuna has 18 major drains. Originally, these drains were intended to carry stormwater. However, raw sewage is discharged into the river due to a lack of sewerage system in many unauthorised colonies, rural villages, and planned colonies, as well as a non-functioning sewerage system in planned colonies. Other stakeholders contribute to the pollution in the river by open defecation by people living along the river's banks and the banks of drains. Industrial waste and garbage dumping directly into drains and the Yamuna River

The various human and industrial activities generate a large amount of garbage, which is directly discharged into the river without adequate treatment, lowering the river's water quality. The Yamuna flows through the National Capital Territory for only 22 kilometres (or less than 1.6% of its total length). However, the wastes and toxins dumped into that narrow swath account for roughly 80% of all pollution in the 1,376-kilometre-long river (Sharma, 2017).

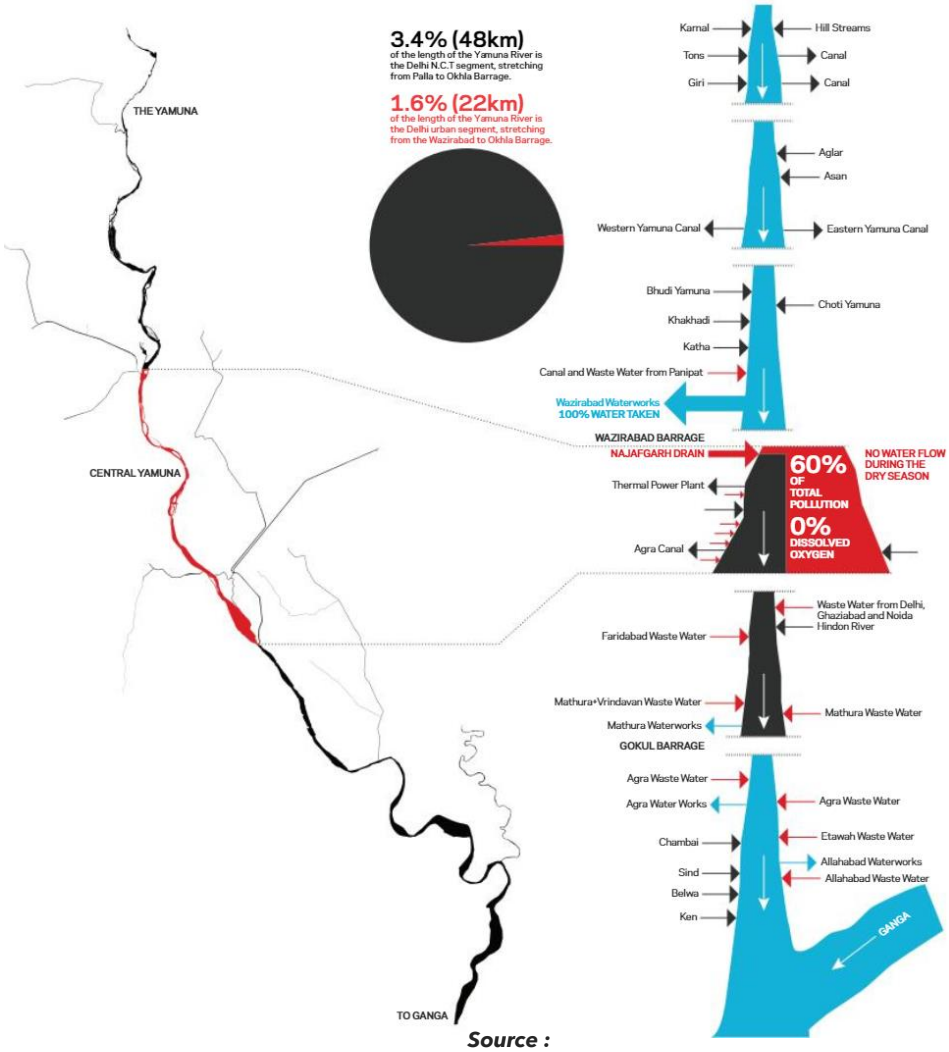
This heavy pollution load in the Yamuna River, which also emits foul gases, may cause serious problems for the environment and nearby residents. Polluted water also serves as a breeding ground for mosquitoes, exacerbating the problem during the recent 2011 Commonwealth Games. Due to Delhi's scarcity of water, polluted groundwater extracted via hand pumps or shallow tube wells may cause water-borne diseases, which could become epidemic and result in a disaster. As a result, river water quality has been reduced to the "E" category rather than the required "B" category (Bathing Standard).

3.2. Pollution Sources

The causes of the Yamuna's severe pollution levels are as follows (Sharma, 2017) –

a. The discharge of **18 sewage drains** into the river, the largest of which is the Najafgarh Drain. This section has been designated as the most polluted, and the United Nations has declared the river "dead" as a result of its pollution.

Figure 2 Najafgarh Drain and Other Flows in the Yamuna (Tulane University (2016))



b. Increasing the quantity of **water diverted** for the western and eastern Yamuna canals at the Hathnikund barrage. As a result, the quantity of water flowing downstream in the Yamuna has decreased, and much of the riverbed is now dry. During the dry season in Delhi, the Yamuna is primarily fed by small streams of sewage and waste runoff from the city.

c. **Industrial Effluent:** The Yamuna is more of an industrial drain because industrial units dump most of their untreated effluents into the river. According to the CPCB, approximately 359 industrial units discharge their effluents into the Yamuna, either directly or indirectly.

d. **Agriculture Pollution:** A lot of agricultural activities are carried out along the river's banks in Delhi, which pollutes the river directly or indirectly through ground and surface

water runoff from agricultural land during monsoon and non-monsoon rains, as well as seepage of irrigation water containing artificial fertiliser contaminants and farmyard waste (livestock excreta)

e. **Domestic Waste Water:** According to a CPCB survey, Delhi generates 23% of all wastewater produced by Class I cities (cities with more than 100,000 people).
f. **Development along the banks:** The DDA (west bank) and the U.P. Flood and Irrigation Department (east bank) had handed over large tracts of land along the river to private bodies in flagrant violation of the master plan for Delhi, which designated these lands as an ecological zone. When it came to allowing the construction of capital-intensive projects on the riverbed, there was no such environmental concern.

3.3. Proposals of the various Plans and Programs in view of Yamuna's Pollution

MPD - 1962

The entire land north and south of the Wazirabad Barrage was demonstrated as prone to floods, and it was suggested that on the west bank of the Yamuna River and south of the Wazirabad Barrage - District Parks, Playgrounds, and Open Spaces be developed.

MPD - 2001

Various efforts were to be taken to clean up the River Yamuna. On the vast expanses of its banks, significant recreational areas must be constructed and connected with other urban development so that the river becomes a physical and visual component of the city. It was suggested that the river be channelled, with the following procedures:

I. Once the results of the model studies for the channelisation of the river Yamuna are available, the development of the river front should be undertaken as a project of exceptional significance for the city, taking into account all ecological and scientific issues.
II. To maintain the river clean, the Water Pollution Act must be strictly enforced.

National Capital Region (NCR) - Regional Plan-2021

River zones have been designated as natural conservation zones in the Regional Plan-2021, and it is recommended to facilitate the free flow of water through keeping the water bodies free from encroachment/development . Building activity for human dwelling or any other supplementary purpose is prohibited. To keep the water body at a minimum flow/water level appropriate precautions must be implemented. In the natural conservation zone, the following activities have been suggested:

1. Agriculture and horticulture
2. Pisiculture
3. Social forestry/ plantation including afforestation
4. Regional recreational activity with no construction exceeding 0.5% of the area with the permission of competent authority.

MPD - 2021

1. River Yamuna rejuvenation through a variety of techniques, including ensuring adequate river flow by releasing water from riparian states, upgrading trunk sewers, treating drains, sewering of unsewered areas, treating industrial effluent, recycling treated effluent, and removing coliforms at STPs.
2. Natural elements such as forests, wildlife sanctuaries, the Yamuna River, and other bodies of water should be protected from unrestrained and unplanned urban expansion.
3. Designation and demarcation of acceptable land uses and aesthetics for the riverfront, which should be integrated with the city and made better physically, functionally, and visually accessible.

In the above proposals, all plans have focused on providing engineering solutions such as STPs or either restricting development by proposing appropriate land-use to promote aesthetics of the river front physically and visually. However, on ground various Mega projects have been approved in the name of 'recreation' land-use which doesn't conform with the land-use proposed. The section below explains in detail the change of use along Yamuna over the years.

Other Plans & Programs (km, 2019) –

YAP 1 (1993 to 2003)

1. Construction of 2.2 MGD capacity STP at the mouth of Delhi Gate Drain
2. Construction of 2.2 MGD capacity STP at the mouth of Dr. Sen Nursing Home Drain

YAP 2 (2003 onwards)

1. Construction of 30 MGD capacity STP at Okhla
2. Construction and 12 MGD capacity STP & Renovation of 20 & 40 MGD STPs at Keshopur
3. Providing Laying peripheral sewer on Wazirabad Road
4. Rehabilitation of Ring Road Trunk Sewer
5. Rehabilitation of Bela Road Trunk Sewer

YAP 3 (2011-2018)

1. It includes 9 projects of which eight are sewerage infrastructure projects under YAP-III - creation of 56.4 crore liters per day STP capacity at Okhla, rehabilitation and upgradation of 38.6 crore liters per day STP capacity; rehabilitation of trunk sewer and Rising main of 35 km length in Kondli and Rithala zones.
2. The sewerage projects are being taken up in four packages of Kondli (K1, K2, K3, K4), three packages of Rithala (R1a, R1b, R2) and Okhla zone (O). In addition to these, foundation was also laid for one project of 9 decentralized STPs (total 2.25

Crore litres per day) and water bodies rejuvenation at Chattarpur at a cost of Rs 65.24 Crores.

3. The project has got integrated as a component of Namami Gange Mission. Delhi Jal Board is the executing agency for all the projects.

Even after so much money has been invested, the plan's outcome is still unknown in Delhi. The project's feasibility study has played a minor role in the overall operation. As a result, the project fails to fulfil the purpose for which it was created.

The Teri study also stated that while the YAPs may not be 100% effective in enhancing water quality, the water quality has not deteriorated after their introduction (km, 2019).

3.4. Acts and Laws

There are currently no separate regulations or rules in place in the country for the proper management, transportation, and disposal of wastewater.

Water supply and sanitation are a state subject, according to the Indian Constitution (Items 5 and 6 of the 12th Schedule of Article 243 W). The 74th Constitution Amendment Act of 1992 establishes a framework and places responsibility for water supply and sanitation in urban areas on urban local body. Furthermore, state governments/urban local bodies and their agencies are responsible for the operation and maintenance of sewerage infrastructure, including treatment plants.

Even though state governments/urban local bodies are responsible for the construction of sewerage infrastructure for sewage disposal, central schemes such as the National River Conservation Plan, National Lake Conservation Plan, Jawaharlal Nehru National Urban Renewal Mission, and Yamuna Action Plan 1,2,3 supplement their efforts.

The Ministry of Environment and Forests (MoEF) offers technical and financial assistance to develop CETP for the treatment of effluents generated by clusters of Small Scale Industries. Existing policies for wastewater management regulation are based on environmental laws, policies, and legal provisions such as –

- Water Act, 1974
- Water Prevention and Control of Pollution Rules, 1975
- Environment (Protection) Act, 1986
- National Environment Policy, 2006
- National Sanitation Policy, 2008

CHAPTER - IV

4. Analytical Framework

OBJECTIVES	ANALYSIS TYPE	DATA REQUIRED	DATA TYPE	SOURCE
To critically understand the importance of urban rivers and their cause of degradation.	***Existing Literature Analysis*** ✓ 1. Urban rivers significance for cities 2. Cause of degradation of urban river 3. Assessing proposals regarding river pollution in Master Plans and Action Plans 4. Policies/ Schemes : to improve wastewater management	Sanitation policy of the Govt. Existing & proposed schemes & projects concerned Problems and issues of the city Environmental Issues due to sewerage	**Secondary**	Various
To assess existing wastewater management system & identify pollution sources in the study area.	***LandUse/ LandCover Analysis*** ✓ *LULC approach* to capture the hydrological variability of the Yamuna and changes in the **LULC pattern** over the previous decade.	Satellite Image of Delhi (2000, 2010, 2020) using **ARC GIS, QGIS**	**Secondary**	1. Earth Explorer 2. Bhuvan
	Pollution Source Analysis of - **1. Sewered & unsewered area** 2. 18 Drains falling into Yamuna ✓ 3. STPs and other treatment infrastructure ✓ 4. CETPS & Industrial Clusters it caters ✓ ***Wastewater Analysis*** 1. Assess treatment capacity of sewage treatment plants (Generation/Treatment Gap) ✓ 2. Pollution Analysis of Treated effluents (STPs, CETPs) ✓ **3. End Use of Treated Effluents from STPs**	Population and area covered under sewerage system. CETPs Location, Capacity and Area Served Treatment facilities available & proposed, level of treatment, their capacity, catchment and location. Locations for Discharge of treated waste water Process of effluent discharged, reuse of treated waste water (at city level and larger group housings) Drainage Lines, Capacity of Drains and Drainage Zones	**Secondary (Collect from the office)**	1. DJB 2. DPCC
To assess the water quality parameters spatially & detect the level of pollution in the study area.	***Water Quality Assessment Spatially*** ✓ Based on water quality parameters, water quality across the whole river flow area will be assessed using IDW interpolation.	Pollution parameters, field datasets of the National Water Quality Monitoring Programme (NWMP)	**Secondary**	1. Earth Explorer 2. NWMP
To analyze the sewage management and impact of river water quality on the livelihood of site area communities.	Social research to evaluate the impact of pollution in the site area ***Socio-economic Survey questionnaire*** ✓ 1. Questions related to habitation 2. Questions related to basic facility in household 3. Livelihoods and Income: Questions related to Household Economy 4. Questions related to health		**Primary**	-

4.1. City-Level Analysis

4.1.1. Land Use/ Land Cover Analysis – Impact of Urbanisation

In the late 1970s, for the Asiad '82, a section of the Yamuna's floodplain was diverted to build the Players' building, an athlete hostel, and the Indraprastha Stadium, which quickly fell into disuse. Thousands of construction workers settled along the western embankment (pushta). During the 1980s and 1990s, the encouragement of Congress politicians resulted in the expansion of swaths of settlement on both sides of the river's no-land. man's By 2004, nearly 350,000 poor squatters lived along Delhi's Yamuna River. In the year 2000, court orders forced the closure of thousands of small industrial firms across the city due to water pollution.

Although industrial effluents were reduced to 218 million litres per day, the river was still polluted by the unchecked discharge of domestic sewage, receiving an estimated 1,789 million litres per day of untreated wastewater (Baviskar, 2011). Further, defecation along the Yamuna by these settlers became the basis for their homes being demolished in 2004. Later on the construction of luxury high-rise apartments near the Yamuna in east Delhi as part of a complex to house athletes and officials during the Commonwealth Games 2010 was approved in July 2009.

Even though Yamuna Pushta settlers were squatting on land legally owned by the DDA (west bank) and the U.P. Flood and Irrigation Department (east bank), far larger tracts of these agencies' lands along the river had been handed over to private bodies in flagrant violation of the master plan for Delhi, which designated these lands as an eco-logical zone.

If the high court order of evicting poor squatters appeared to show some concern for the river's polluted state, no such environmental concern was evident when it came to permitting capital-intensive projects on the riverbed. This demonstrates how most conformist versions of environmentalism have placed the burden of river water pollution primarily on the people who rely on it, resulting in coercive socioeconomic change along the river (Baviskar, 2011). Table 7 below highlights the existing characteristics of Zone-O.

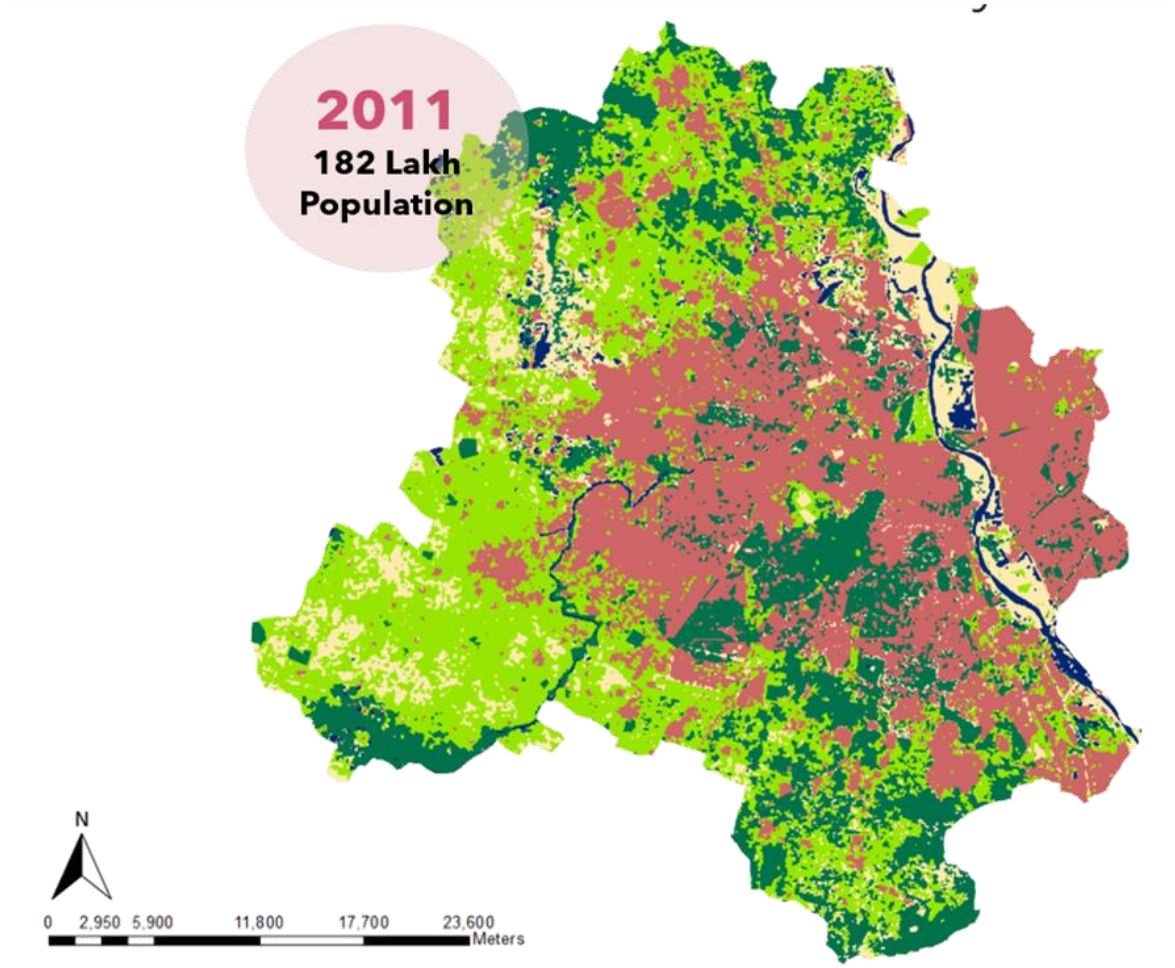
Table 5 Existing Development in Zone 'O' (Zonal Plan 'O')

Sub-Zone	Description of Area	Existing characteristics/ Developments in Zone 'O'	
		West	East
1	**NCTD Boundary to Wazirqabad Barrage**	Agriculture, Biodiversity park, Jagatpur village, Wazirabad Village, monuments, **Unauthorized colonies**, Wazirabad Water works, Ghats.	Agriculture, Water works, Facility centre, CRPF Camp, Delhi Police Firing range, **Unauthorized colony**.
2	**Wazirabad Barrage to ISBT Bridge**	**Unauthorized colonies**, **Unauthorized religious structures**, CNG station, Bathing ghat.	220 KV ESS(Electric Sub-Station), water ponds, grass farms, Marshes, Gurudwara & Agriculture.
3	**ISBT Bridge to Old Yamuna**	Nigam Bodh ghat, unauthorized growth of Yamuna Bazaar, Salimgarh fort, ghats, ESS.	Unauthorized colony, Agriculture, DMRC Depot, IT Park, PSP site.

	Rail cum Road Bridge		
4	**Old Yamuna Bridge to ITO Barrage**	Electric crematorium, Vijay ghat, Shanti van, Shakti sthal, Raghat, Gandhi Darshan, I.G. stadium complex, Power house, Delhi secretariat, Fly ash brick plant.	Agriculture, cremation ground.
5	**ITO Barrage to Nizamuddin Rly Bridge**	I P power house, Gas turbine power house, STP.	Agriculture, Forest, **Site for DMRC Depot & Station.**
6	**Nizamuddin Rly Bridge to N H 24**	Fly ash pond, **Fly ash brick plant**.	Agriculture, PSP(Public and Semi-Public) site, **Akshardham temple complex**, **Parking**, **CWG Village Complex**
7	**NH24 to Okhla Barrage**	Electric crematorium, Rajiv Gandhi Smriti Van, **unauthorized petrol pump**, **unauthorized encroachment**, Electric sub-station, site of underground water reservoir, unauthorised colonies.	Agriculture
8	**Okhla barrage to NCTD Boundary**	**Unauthorized colonies**, water body, agriculture, Madanpur Khadar resettlement scheme ,LPG bottling plant.	Agriculture & Water body

Ignoring the river-flood-plain interactions that play important roles in river ecology, most of the floodplain has been reclaimed by building high levels. Developments like the Akshardham temple and the Common-wealth Games – which consists of multi-story luxury apartments with a captive power plant – demonstrate how the government has actively encouraged new development by providing massive subsidies to corporate entities. Other concrete developments have followed suit, with the Akshardham temple acting as an anchoring point on the eastern bank and a network of flyovers and wider roadways being built parallel to the eastern river-front to accommodate the increased traffic.

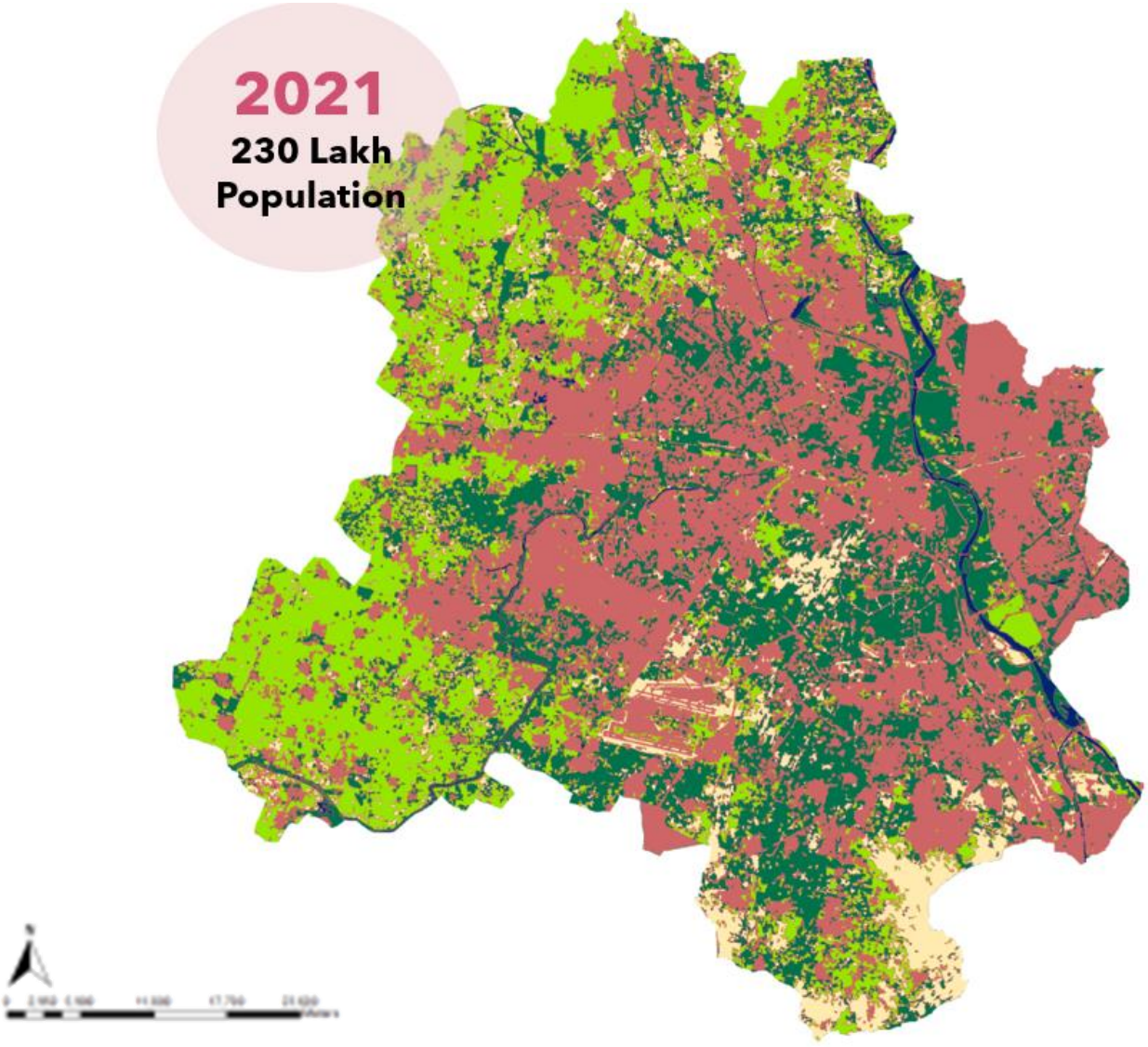
Figure 3 LULC Delhi – 2011 (Author, 2022)



Within 300 metres of the river, the Delhi Metro Rail Corporation (DMRC) has built a Yamuna bank station and a large train depot; Parsvnath Builders has built a retail mall near to the Games Village, and the remaining property along the river is earmarked for similar projects. The riverfront is being reimagined at a rapid rate. One can see the patchwork of agricultural land fast being replaced by elegant skyscrapers as one rides along the overhead metro line from central to east Delhi, passing the Yamuna on the new metro bridge.

Instead of the ecological zone established in MPD - 2021, these developments provide material expression to riverside development that reflects other western cities. This seemingly innocent initiative of transforming the riverside into a public place, with the potential to build a bond between the river and Delhi inhabitants, ignores fundamental socioeconomic and environmental challenges. One, this area will not truly be open to the "public," because the direction of its redistribution already favours corporate capital and private and elite public consumption modes. These new areas exclude the majority of city residents, as well as the land made available for the new buildings was stolen from farmers and thousands of poor slum-dwellers occupying the land were evicted.

Figure 4 LULC Delhi, 2021 (Author, 2022)



Further, LandUse/LandCover Analysis was performed for year 2011 & 2021 as shown in figure 3 & 4 respectively to highlight the pressure of haphazard development on the floodplains and urbanisation on the river Yamuna's water quality.

Table 6 LULC Change between 2011-2021 (Author, 2022)

Land Use	2011		2021		% Change (with respect to 2011)
	Area (m2)	Area %	Area (m2)	Area %	
Agriculture	545	36.62	405	27.24	-26
Built-Up	464	31.20	512	34.39	10
Barren Land	166	11.16	127	8.54	-23
Vegetation	277	18.65	424	28.51	53
Water Body	35	2.37	20	1.33	-44

The results showed that -

- The effects of rapid population growth and a changing economy have led to unprecedented rates of urbanization thus, acting as a major driver of LU/LC change.
- The major negative change can be observed in terms of the area of water bodies by 44%.

4.1.2. Wastewater Analysis - STP

As discussed in the previous section, Delhi Jal Board (DJB) is constituted under the Delhi Jal Board Act, 1998 and the responsibility for the production & distribution of water as well as collection, treatment, and disposal of domestic sewage in the NCT Delhi lies with it. DJB is working in a phased manner to provide sewerage facilities in all the unsewered areas and to cater the requirement of unprecedented growth of population up to the year 2031, firstly by extending the sewerage facilities in those command areas where outfall infrastructure exists.

Figure 5 Location of STPs in Delhi (Author, 2022)

Presently, Delhi generates around 744 million gallons of sewage a day -- 80 per cent of the 930 MGD water supply. The 35 sewage treatment plants operational at 20 locations across Delhi can treat up to 597.26 MGD of sewage.

Figure 6 Capacity of STPs (in MGD) (Author, 2022)

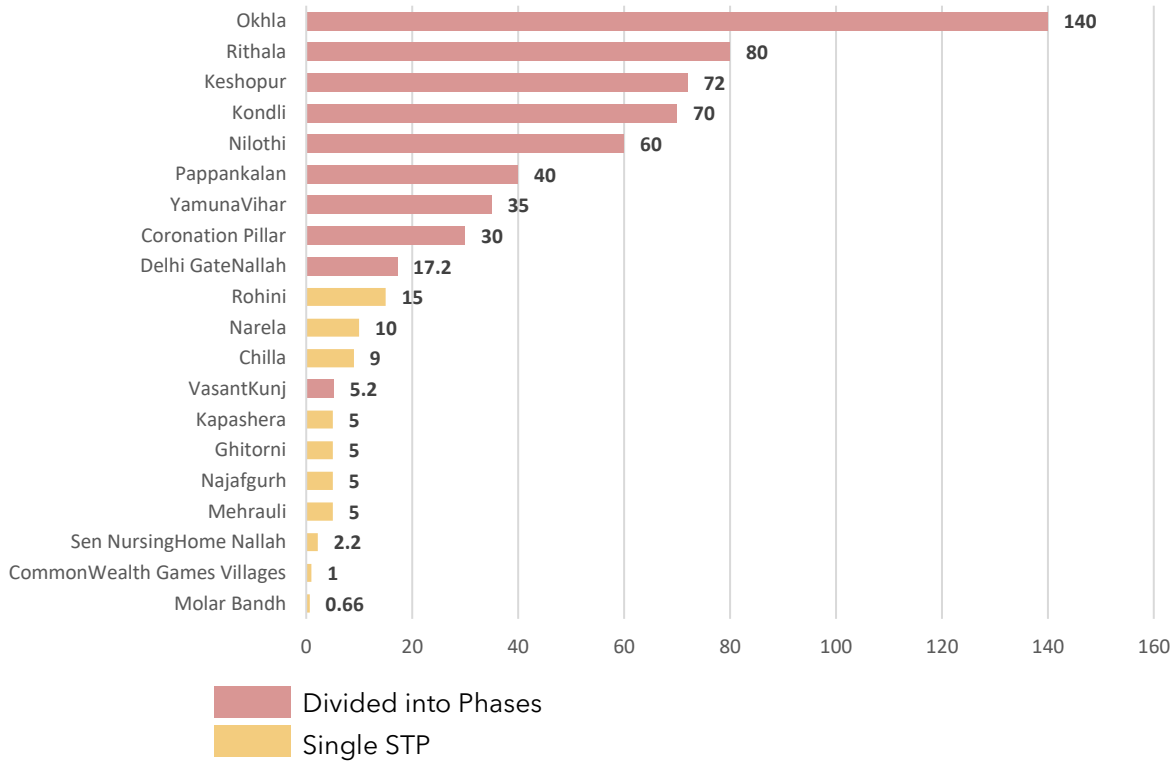


Table 7 Phase Wise Break-up of STPs (*Delhi Pollution Control Committee, July 2021*)

Location of STP	Phase wise break up	Capacity in MGD
Okhla	Phase-Il	12 MGD
	Phase- III	37 MGD
	Phase-IV	45 MGD
	Phase-V	16 MGD
	Phase-VI	30 MGD
Rithala	Phase-I	20 MGD
	Phase-Il	40 MGD
Kondli	Phase-Il	25 MGD
	Phase-IV	45 MGD
Keshopur	Phase -I(New)	12 MGD
	Phase-Il	20 MGD
	Phase-Ill	40 MGD
Yamuna Vihar	Phase-I	10 MGD
	Phase-Il	10 MGD
	Phase-Ill	25 MGD
Vasant Kunj	Phase-I	2.2 MGD
	Phase-Il	3 MGD
Coronation Pillar	Phase-I & II	20 MGD

	Phase-Ill	10 MGD
Nilothi	Phase-I	40 MGD
	Phase-Il	20 MGD
Pappankalan	Phase-I	20 MGD
	Phase-Il	20 MGD
Delhi Gate Nallah	Phase-I	2.2 MGD
	Phase-Il	15 MGD

STP Effluent Analysis

The environment ministry has strengthened rules for sewage treatment plants (STPs) that discharge waste water into rivers and other sites in order to tackle pollution. However, from the analysis it was observed that 23 STPs (70%) don't discharge treated water as per standards as shown in figure 8. Further, table 10 below compares the water quality parameter of discharged effluents with STP discharge standards in order to find parameters that are being violated most.

Table 8 STPs Effluent Discharge Quality (*Delhi Pollution Control Committee, July, 2021*)

Parameters		**pH**	**TSS**	**BOD**	**COD**	**Oil & Grease**	**Ammonical Nitrogen**	**Dissolved Phosphate as P**
STP Standards		**6.5-9.0**	**10 (mg/l)**	**10 (mg/l)**	**50 (mg/l)**	**10 (mg/l)**	**5 (mg/l)**	**2 (mg/l)**
Okhla	**Phase-II**	7.3	26	17	80	2	4.1	1.2
	Phase- III	7.3	24	16	85.3	1.2	4	1.9
	Phase-IV	7.4	28	20	96	1.6	4.3	1.5
	Phase-V	7.2	16	13	69.3	2.4	4.2	1.4
	Phase-VI	7.3	6	5	37.3	0.4	2.6	1.4
Rithala	**Phase-I**	*Under Rehabilitation*						
	Phase-II	7.4	10	8	36	0.8	3.2	1.4
Kondli	**Phase-II**	7.3	20	14	64	1.2	3.2	1.6
	Phase-IV	7.2	44	38	117.3	3.2	5.84	3.4
Keshopur	**Phase –I (New)**	7.2	10	10	37,3	1.6	3.8	1.6
	Phase-II	7	62	46	136	3.6	7.1	8.2
	Phase-III	7.8	58	40	152	2	6.6	4.8
YamunaVihar	**Phase-I**	7.3	12	14	58.6	0.6	2.8	2
	Phase-II	7.2	18	15	74.6	0.8	2.1	2.3
	Phase-III	7.2	30	24	88	1.2	3.2	3
VasantKunj	**Phase-I**	7.6	16	12	69.33	2.4	2.1	4.1
	Phase-II	6.8	12	8	64	1.2	3	2
Mehrauli		6.8	16	10	48	0.8	3.5	1.6
Coronation Pillar	**Phase-I & II**	7.4	36	21	80	2.4	6.8	3.1
	Phase-III	7.5	40	27	96	3.2	8.2	3.6

Narela		7.3	20	12	58.6	1.2	4.6	2
Nilothi	**Phase-I**	7.2	40	28	96	2	4.2	1.8
	Phase-II	7.3	10	6	36	1.2	3.4	1.2
Najafgurh		7.6	34	26	96	1.2	4.6	3.9
Pappankalan	**Phase-I**	7.4	32	26	85.3	4	4	1.8
	Phase-II	7	8	6	32	1.2	3.8	1.4
Sen Nallah		7.1	8	5	32	0.6	1.6	1.4
Delhi Gate Nallah	**Phase-I**	7.2	8	6	37.3	0.8	1.4	1.8
	Phase-II	7.3	6	5	32	0.4	1.8	1
Rohini		7.6	12	14	58.6	1.2	5.4	3.2
Ghitorni	*Not Available*							
Kapashera		7.3	10	8	32	0.8	4.2	1.2
Chilla		7.1	10	6	32	0.8	2.8	1.2
CWG Villages		7.2	4	2	26.6	0.6	0.6	1
Molar Bandh		7.4	32	18	80	1.2	2.9	2.2

It is found that the main parameters not conforming to the standards are TSS, BOD & COD. Higher levels of BOD & COD indicate a higher amount of organic waste or sewage in water/ wastewater.

Figure 7 Map of STPs Conforming Standards (Author, 2022)

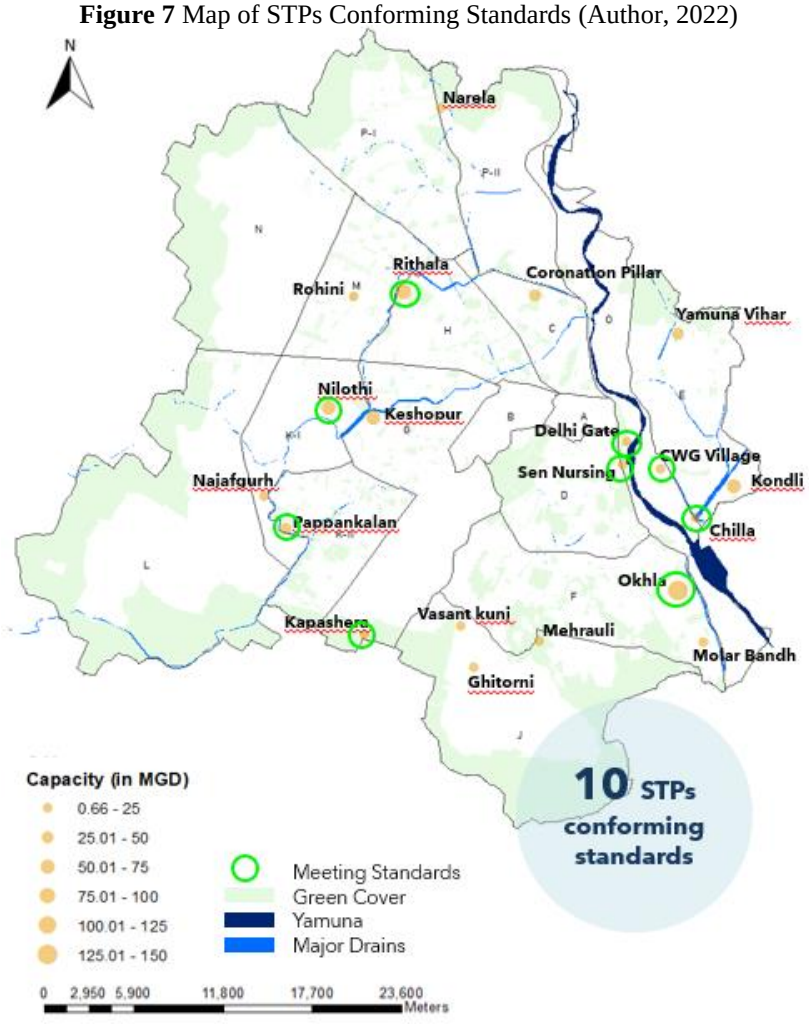


Figure 8 *Percentage of STPs conforming standards*
(Primary Analysis)

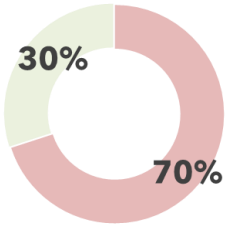


Table 9 *Most Non-Conforming Parameters*
(Primary Analysis)

pH	***0 (0%)***
TSS	***22 (67%)***
BOD	***20 (61%)***
COD	***22 (67%)***
Oil & Grease	***0 (0%)***
Ammonical Nitrogen	***6 (18%)***
Dissolved Phosphate	***12 (36%)***

4.1.3. Wastewater Analysis – CETP

DSIIDC is a Govt. Company has been assigned the function to establish, operate, maintain and manage Industrial Estates in Delhi. At present, 33 approved planned Industrial areas in Delhi exist. Out of 33 industrial clusters in Delhi, 17 are connected to 13 CETPs (treatment plants) which are marked in figure 9 below.

Figure 9 Map of CETPs in Delhi
(Author, 2022)

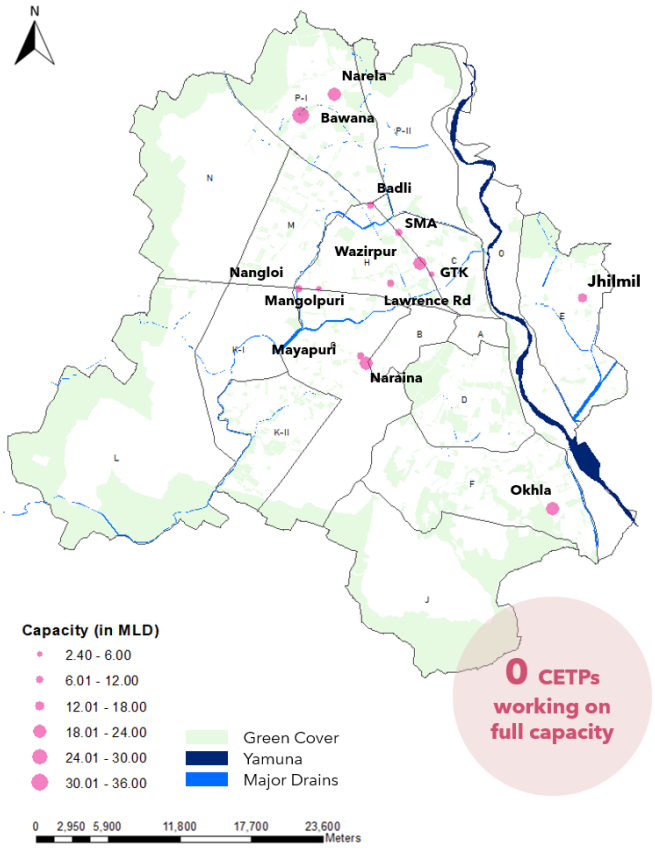
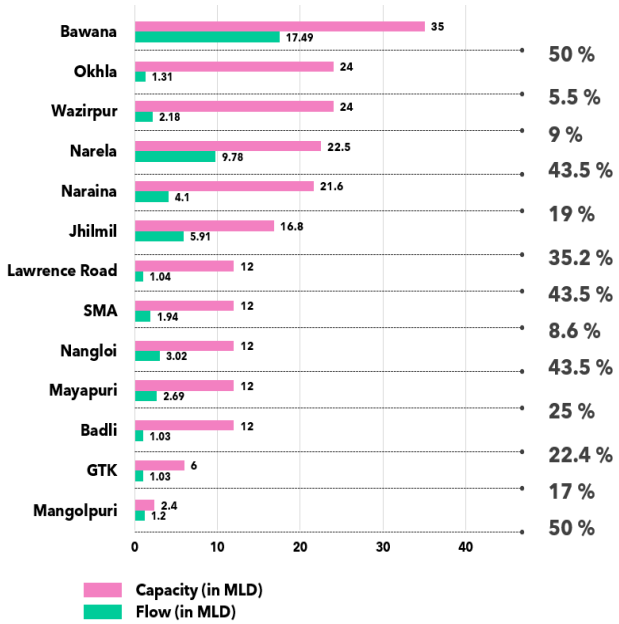


Figure 10 Utilization Efficiency of CETPs
(Primary Analysis)



Utilization Efficiency of CETP

The total Capacity of 13 CETPs in Delhi is around 212.3 MLD. However, the total effluent flow generated is only 52.72 MLD. This shows that the percent of utilization of CETPs is only 24.8 % as depicted in figure 10 above. This indicates that CETPs are not functioning up to the designed capacity probably because all industries have not taken any connection to the CETPs. Thus, industrial waste from all the industries is not being treated and is disposed of directly into the drains.

CETP Effluent Analysis

Environment Ministry has set standards for both influent and effluent discharge from CETP. However, none of the CETP conforms the standards if considering both inlet and outlet quality. Table 12 details the violating parameters in each CETP.

Table 10 CETPs Influent and Effluent Quality (*Delhi Pollution Control Committee, December, 2021*)

Parameters		pH	TSS	BOD	COD	TDS	Sulphide
EPA Standards	Inlet (in mg/l)	6--9	250				
	Outlet(in mg/l)	6--9	100	30	250	2100	2
Jhilmil CETP	Inlet	6.85	460	150	352	1630	6.4
	Outlet	7.46	60	27	112	1580	1.6
Badli CETP	Inlet	6.45	40	60	432	1230	5.6
	Outlet	7.42	42	35	80	980	2
Mayapuri CETP	Inlet	7.44	396	42	456	1720	10
	Outlet	7.4	40	35	108	1520	3.4
Mangolpuri CETP	Inlet	7.32	448	75	432	2500	15.2
	Outlet	7.76	120	25	104	1760	4.4
Wazirpur CETP	Inlet	3.98	240	120	325	1640	8.4
	Outlet	6.84	54	24	84	1300	6
Nangloi CETP	Inlet	7.51	316	75	432	2960	10
	Outlet	7.66	92	32	96	1380	5.6
SMA CETP	Inlet	6.84	136	30	75	1960	6
	Outlet	7.36	86	26	58.6	1720	3.2
Okhla CETP	Inlet	7.59	1308	80	112	1310	14
	Outlet	7.71	86	27	88	720	4
Narela CETP	Inlet	7.25	560	65	288	2340	6.2
	Outlet	7.54	46	16	68	1680	1.8
Bawana CETP	Inlet	7.01	716	80	304	2890	8.2
	Outlet	7.48	48	16	85	1690	1.4
Naraina CETP	Inlet	7.01	220	25	288	764	8
	Outlet	7.3	32	22	108	735	6
GTK CETP	Inlet	7.52	266	50	106	1990	4
	Outlet	7.85	58	27	80	878	2

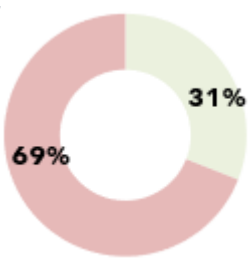
Lawrence Road CETP	**Inlet**	**6.98**	224	60	320	1720	8.8
	Outlet	**7.02**	**64**	48	**186.6**	**1720**	4.8

The main parameters not conforming to the standards are TSS in influent discharge and Sulphide & BOD in effluent discharge as shown in table 13 below. Higher levels of BOD indicate a higher amount of organic waste or sewage in water/ wastewater. However, in terms of effluent standards (outlet), 9 CETPs do not discharge treated water as per the standards as shown in figure 11 below.

Table 11 Most Non-Conforming Parameters in CETPs Primary Analysis

	Inlet	Outlet
TSS	9 (69 %)	0
BOD	-	4 (31%)
COD	0 (0%)	0 (0%)
TDS	0 (0%)	0 (0%)
pH	0 (0%)	0 (0%)
Sulphide	-	8 (62%)

Figure 11 Percentage of Non-Conforming CETPs Primary Analysis



4.1.4. Wastewater Analysis – Drains & UACs

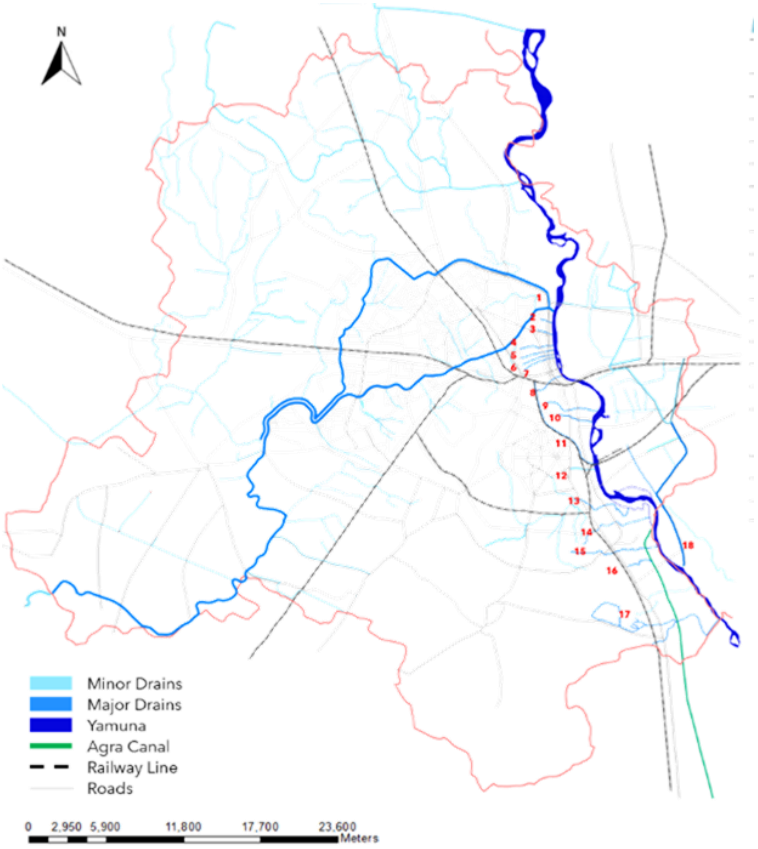
A total of 18 drains of Delhi, whose water flows into the Yamuna, create 80 per cent of pollution in the river (University of Virginia, 2018). A total of 3017 MLD is drained into the Yamuna through –

Main Discharge is by:

1. Najafgarh
2. Shahdara
3. Barapullah
4. Delhi Gate Drain

Furthermore in Delhi, out of 1,799 UACs, 31 % of Unauthorized Colonies have sewer lines laid till now that is only 561. In other either a septic tank is used or waste is drained openly into the drains.

Figure 12 Major Drain Outfall in Yamuna (Author, 2022)



4.1.5. Spatial Pollution Mapping

a. Dissolved Oxygen (DO)

Figure 13 Spatial Mapping of DO (2011-2021) (Author,2022)

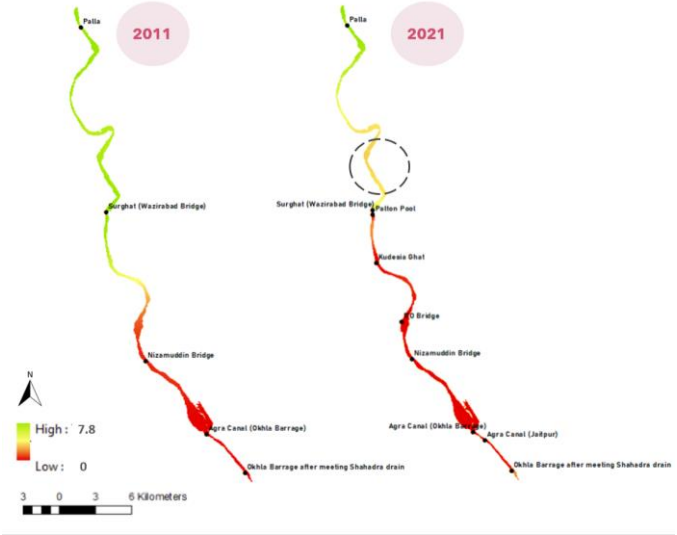
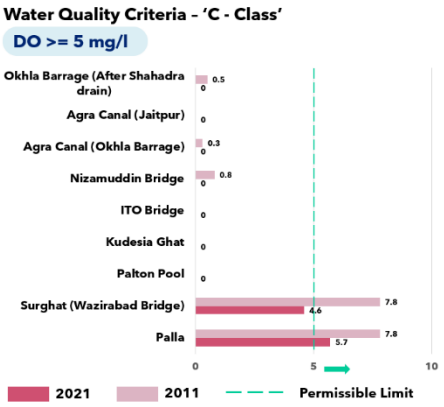


Figure 14 Change in DO Levels at Diff. Stations **(**Primary Analysis)



DO gives an estimate of organic pollution in water and wastewater. In 2021 Dissolved Oxygen level dropped so below the permissible limit of >= 5 mg/l as the Yamuna crosses the wazirabad barrage that it became non-detectable. Similarly, in 2010 DO levels remained close to 0 as shown in figure 14.

- As a result of the extreme decrease of oxygen levels in the water, fish kills take place.
- A river ecology requires DO levels of 6 or higher to survive.

b. Biological Oxygen Demand (BOD)

Figure 15 Spatial Mapping of BOD (2011-2021) *(*Author,2022)

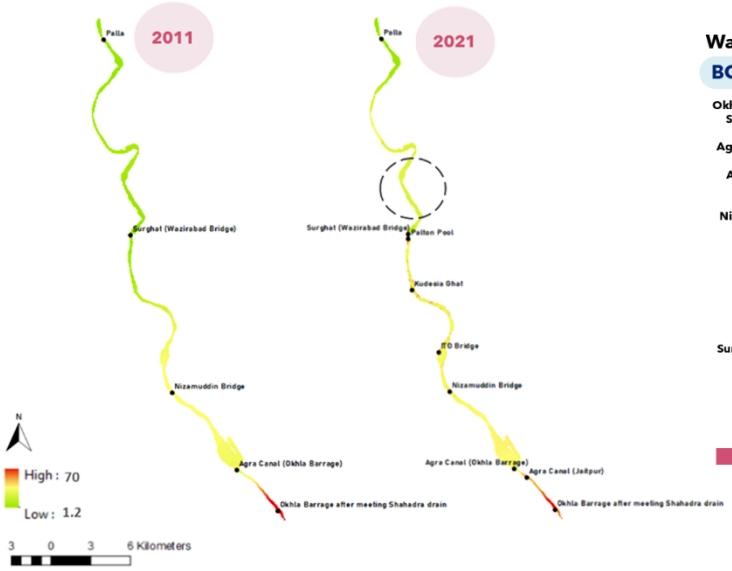
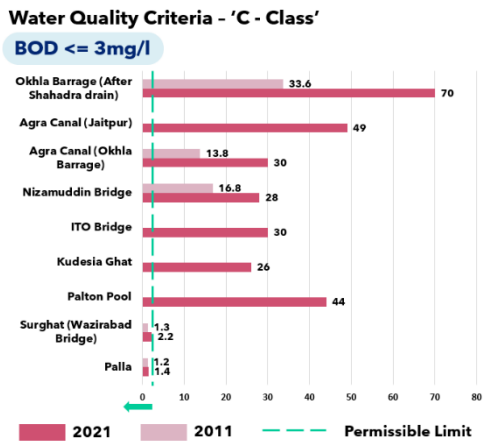


Figure 16 Change in BOD Levels at Different *S*tations *(*Primary Analysis*)*



BOD gives an estimate of organic pollution in water and wastewater. In both 2021 & 2011, BOD levels remain under the permissible limit only till the wazirabad barrage. Also, in figure 16 it can be seen that after the barrage values almost increase by 30 times as the river reaches the Okhla barrage in both 2021 & 2011.

- lead to decomposition of organic material and excess release of nutrients, such as N & P.
- Produce dense algal bloom lowering DO

c. Fecal Coliform (FC)

Figure 17 Spatial Mapping of FC (2011-2021) (Author,2022)

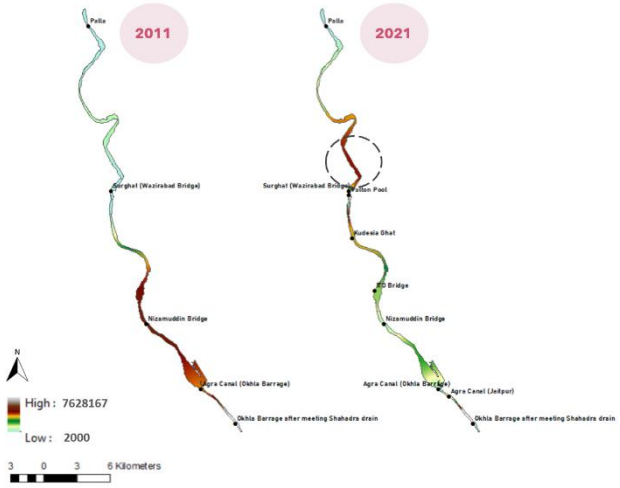


Figure 18 Change in FC Levels at Different Stations (Primary Analysis)

Fecal Coliform	2020	2010
Palla	2000	22260
Surghat (Wazirabad Bridge)	27000	3948
Palton Pool	3200000	-
Kudesia Ghat	920000	-
ITO Bridge	460000	-
Nizamuddin Bridge	170000	4893333
Agra Canal (Okhla Barrage)	140000	3541091
Agra Canal (Jaitpur)	310000	-
Okhla Barrage after meeting Shahadra drain	4500000	7628167

Fecal Coliform gives an estimate of biological pollution in water and wastewater. In both 2021 & 2011 Fecal Coliform is not within the permissible limit except palla (2020) as shown in figure 18. Contact with such waters can result in exposure to pathogenic bacteria and it is often associated with fecal contamination by fecal material of humans or animal sources.

- The presence of fecal coliform bacteria in rivers indicates that contamination by fecal material from human or animal sources has occurred
- Sources could be leaking sewage pipes or septic systems.

d. pH

Figure 19 Spatial Mapping of pH (2011-2021) (Author,2022)

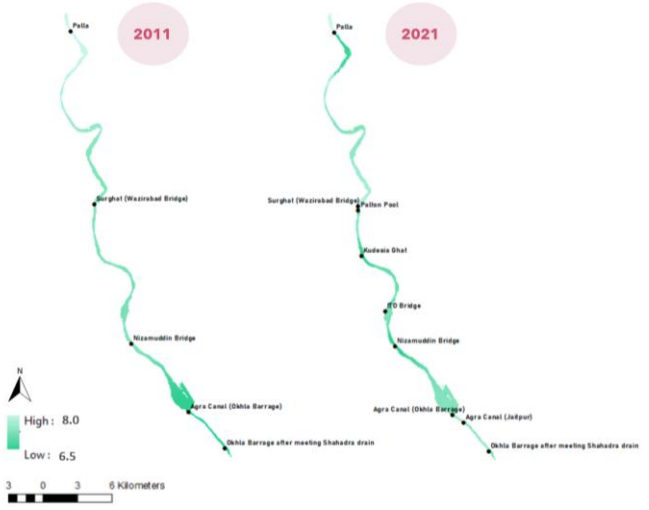
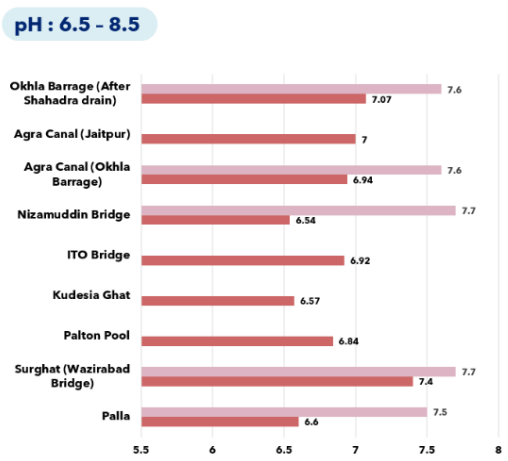


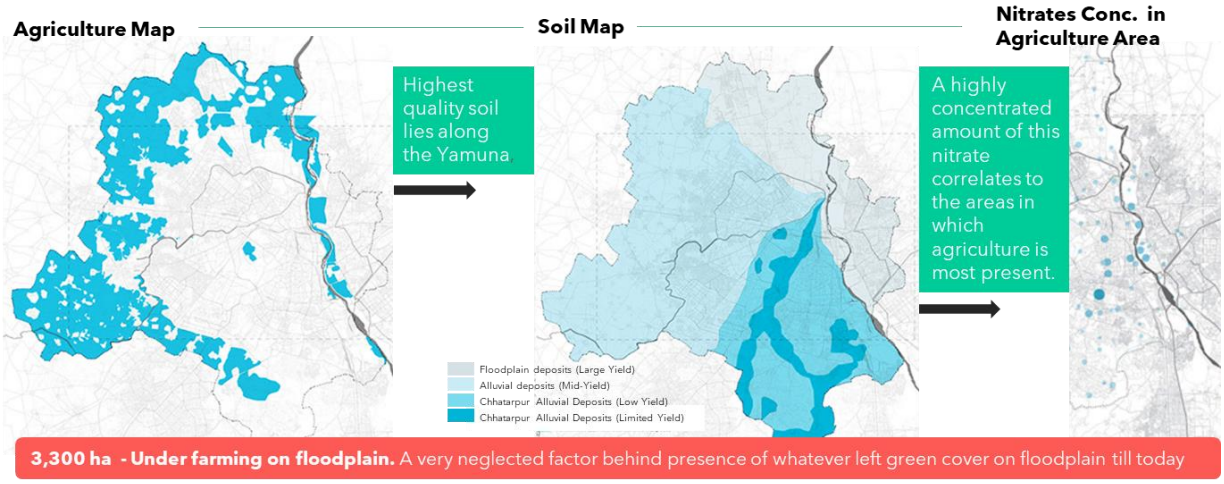
Figure 20 Change in pH Levels at Different Stations (Primary Analysis)



pH is a physical indicator of water quality. In both 2011 & 2021 pH was within the range of CPCB guidelines. The lowest Ph value is 6.5 reached in 2021 as shown in figure 20.

4.1.6. Wastewater Analysis – Agricultural Effluents

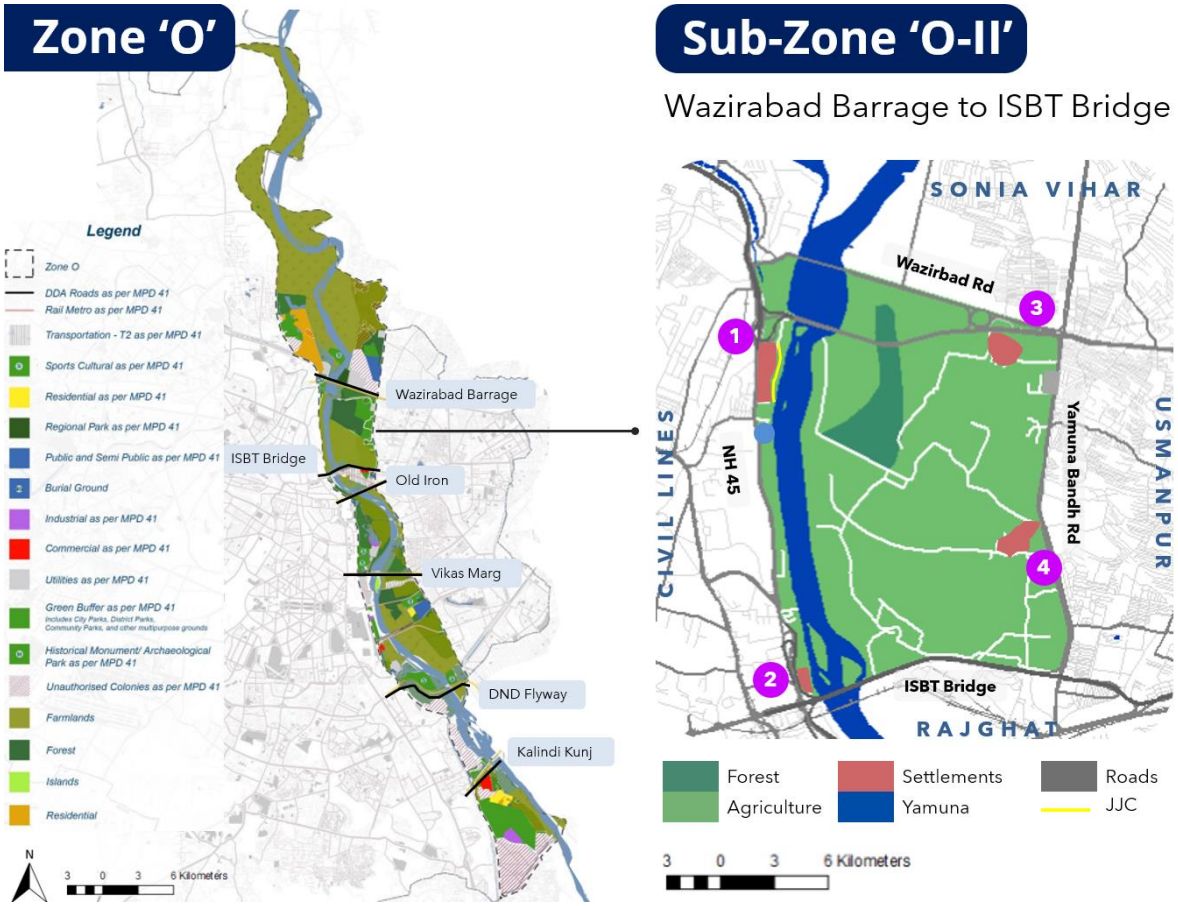
Figure 21 Agricultural along with its pollution mapping *(University of Virginia, 2018)*



While the highest quality soil lies along the Yamuna, most agricultural practices take place along the city's periphery and that too in low-quality soil because of the limited access to the river. As a result of industrial effluents and untreated sewage water, Delhi's soil is highly contaminated with heavy metals and pesticides creating concern for crop production and food safety. Contrarywise, contamination of Yamuna also occurs because soil contamination through agricultural pesticides, fertilizer residue, and farmland waste creates unhealthy runoff (University of Virginia, 2018).

4.2. Introduction to the Site

Figure 22 Site Area ((Social Design Collaborative, 2022), (Author, 2022))



Sub-Zone 'O-II' has been selected to conduct site-level research and it lies between Wazirabad barrage and ISBT bridge as shown in figure 21. It is located downstream of Najafgarh drain in Sub-Zone II which contributes about 60% of the total pollution to the river. The site consists of one residential colony that is New Aruna Nagar Colony and three unauthorised colonies that is -

1. Ladakh Vihar Colony
2. Gehri Mandu Village
3. New Usmanpur

New Aruna Nagar was selected for a detailed study because of the diverse socio-economic profile of the area. Further, systematic sampling was conducted in this colony. Every fourth household was surveyed with a sample size being of 100. In the river's floodplains behind New Aruna Nagar Colony, farmers are involved in agricultural activities. This community of farmers on the floodplains has also been taken for the research and all 15 households were surveyed.

4.3. Site-Level Analysis

4.3.1. Background

a. New Aruna Vihar Colony

1963 - Allocation of Majnu Ka Tila for the Tibetans to set up their settlements

2006 - Eviction threat and the demolition due to the 2010 commonwealth games and 2001 master plan of Delhi.

2013 - Status of "New Aruna Nagar" colony with court's mandate.

b. Riverine Communities

After Independence, the land on the floodplain was given to various farmers on lease by the DDA.

The 1960s - Most people have migrated from the neighboring states of U.P. & Bihar. After a few years, the system of giving land on lease stopped.

Present – Still farmers of Majnu Ka Tila had taken land on lease from Jagatpur farmers and depending upon the area and size they had to pay Rs 6k – 35k/year.

4.3.2. Basic Facilities in HHs

In New Aruna Nagar Colony, piped water supply was present for all. However, during the dry season water received is dirty and smells which forced them to buy bottled water. In terms of the sewer connection, there isn't any present at the moment. However, 1 in every 3rd household has a septic tank i.e. 47 % but due to lack of irregular pumping and proper drainage most systems aren't working properly (sludge continues to build). It can contaminate nearby water bodies as well as underground water. In terms of sanitation facility, 83% HHs have access to IHHL,15% uses community toilet while 2% didn't respond as shown in figure 22.

Figure 23 Latrine Facility in New Aruna Nagar **(**Primary Analysis)

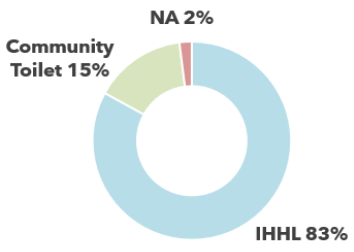
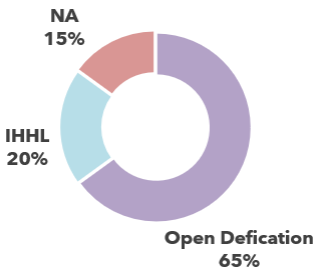


Figure 24 Latrine Facility in Riverine **(**Primary Analysis)



At the back of New Aruna Nagar Colony facing the west bank of the river, it was observed that farmers were living at the bare-minimum level. These farmers did not have access to a proper sanitation facility as shown in figure 23. They practiced open defecation at makeshift arrangements installed on narrow drains carrying wastewater from Majnu Ka Tila to the river. However, for drinking water purposes, they had a government tap installed. Though most of the farmers had a hand pump installed on their farmland, they were not using its water for

drinking because of the high concentrations of fluoride present in the groundwater. Every morning they fetch water from the government's public tap.

4.3.3. Awareness and Perception

a. Awareness about wastewater discharge

In New Aruna Nagar Colony, it was found that 55% of the respondents expressed that the wastewater from their homes is directly drained into the Yamuna. While 26% and 19% of respondents believed that wastewater goes into drains and septic tanks respectively as illustrated in figure 24.

However, farmer communities had a strong stand on the point that their entire wastewater generated goes directly to the Yamuna as shown in figure 25 below. This is predominantly due to lack of tenure, space, and economic constraints urban poor are unable to access safe sanitation.

Figure 25 HH Discharge Awareness - New Aruna Nagar **(**Primary Analysis)

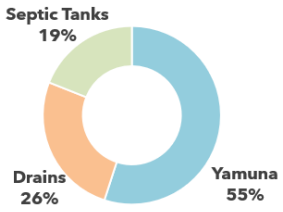
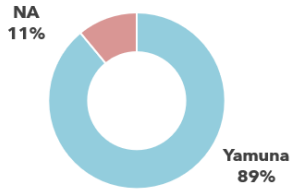


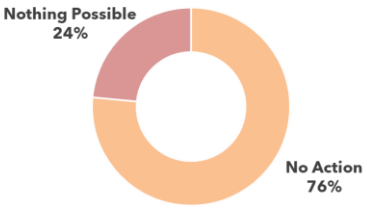
Figure 26 HH Discharge Awareness – Riverine **(**Primary Analysis)



b. Perception on Role of Communities in Managing Wastewater

When asked about govt. & community action? 76.47 % felt that as a community they did nothing or couldn't do anything. Participants were eager to help manage wastewater to safeguard the Yamuna River, but they had no idea where to begin. Furthermore, they said of government efforts, "This is all talk, no implementation!" What options do we have? Only the government has the ability to do so. We lack the authority to shut down the polluted drains."

Figure 27 Perception of communities about the possible change in the situation (Primary Analysis)



What role do they envisage themselves performing in wastewater management and river sanitation? "What can we possibly do?" was the general answer. They described their limited authority as "filing a complaint to the government about drain discharge" or "Sewer Connection".

4.3.4. Health, Occupation and Pollution Impacts

a. Occupation and Pollution Impacts

New Aruna Nagar Colony, has an extensive human activity like shops, eateries, vendors and vehicles spread all over as shown in figure 27. No Impact on their Business is mentioned as such because interaction with Yamuna is zero within this community with respect to occupation. However, restaurants and other businesses on the backside facing the Yamuna tend to face losses because of - a smelly & unhygienic environment.

Also, even though polluted river does not affect their occupation to a larger extent but these extensive human activities in return affect the pollution level in the Yamuna through discharging wastewater directly into it.

Figure 28 Occupation Type- New Aruna Nagar **(**Primary Analysis)

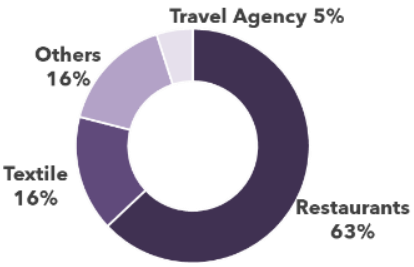
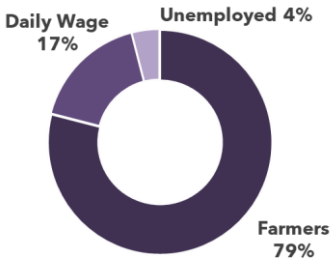


Figure 29 Occupation Type- Riverine **(**Primary Analysis)

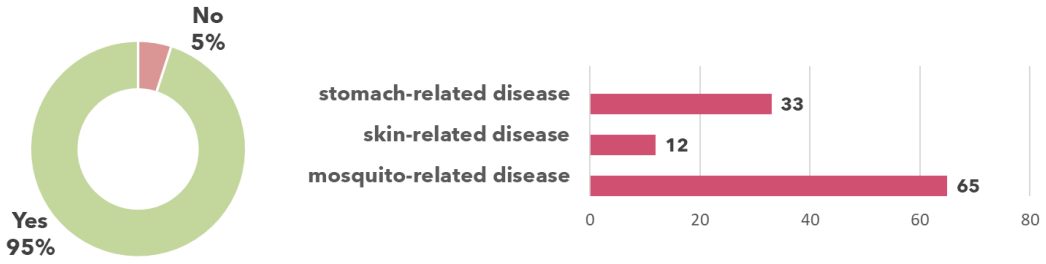


In farmer's communities, the major occupation source is farming which is around 79%. Major vegetables produced are cucumber, bottle gourd in summers & cauliflower, spinach, and lettuce in the winters. However, due to the lack of fresh and clean water sources for irrigation, the use of wastewater discharge from drains/ Yamuna is practiced. Because of this Crops irrigated by the Yamuna river spoil sooner and this requires a high use of fertilizers. Such conditions have also forced them to change the type of crop grown over the year. Thus, it has been 10 years since their last watermelon harvest.

b. Health and Pollution Impacts

In New Aruna Nagar Colony, when asked - the Yamuna river specifically had an impact on their health, all 95 % of respondents said that Yamuna's water quality had an impact on their health especially on children. Of these maximum cases recorded from the survey were of mosquito-related diseases followed by stomach and skin-related diseases respectively as shown in the figure 29 below.

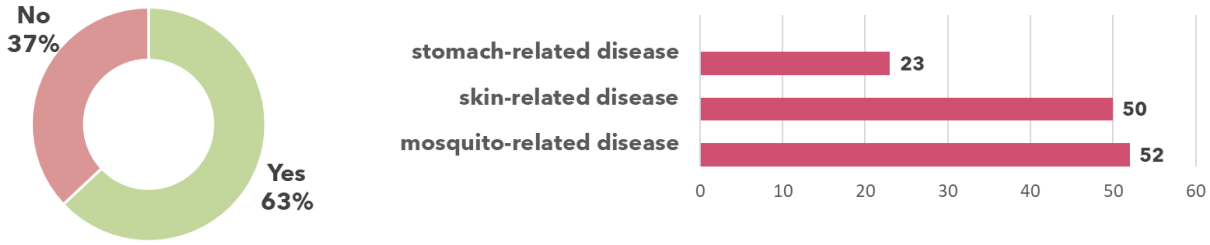
Figure 30 Yamuna's Water Impact on Health & the Types of Diseases Reported- New Aruna Colony (Primary Analysis)



In farming communities, when asked - the Yamuna river specifically had an impact on their health, half respondents did not answer. Only 34% of respondents said that Yamuna's water quality had an impact on their health as shown in figure 30.

This was mostly due to the fact that the majority of respondents were hesitant to think that river pollution could be the cause of any disease as they believed in the river's divinity. However, those who accepted responded that they suffer from mosquito related diseases frequently, followed by skin and stomach related diseases. This is because they remain in close contact with the wastewater and Yamuna's polluted water for irrigation purposes.

Figure 31 Yamuna's Water Impact on Health & the Types of Diseases Reported- Riverine (Primary Analysis)



4.3.5. Overall Issues

LandUse/ LandCover

Rapid urbanization has resulted in the reduction of vegetation and the Yamuna area significantly in the last 10 years only. This type of urban sprawl negatively impacts the quality of the river because more drains are built alongside these urban areas which outflow into the river.

STP & CETP Analysis

The existing sewerage treatment facilities in not sufficient –

- Inadequate sewerage coverage resulting wastewater flowing into open nalas causing pollution of River Yamuna (only 31% of UAC have sewer laid)
- 20% of waste water generated by domestic users is discharged directly into the river
- **23 STPs (70%)** don't discharge treated water as per standards
- **9 CETPs** do not discharge treated water as per effluent standards (outlet).

The **generation-treatment gap** will continue to increase because of rapid population growth

Community Assessment

- Due to lack of tenure, space, and economic constraints urban poor are unable to access safe sanitation.
- People who use river water for their livelihood are reporting diseases like joint pains, stomachache, nausea, etc.
- The pollution in the river water affected the crops yield and farmers were forced to rethink the types of crops for cultivation.
- In turn, heavy use of fertilizers is also being washed into the Yamuna because of the use of wastewater to irrigate the crops

CHAPTER - V

5. Collective Approach

A combination of decentralized & in-situ treatment systems can be planned through nature based solutions to achieve overall city sanitation.

What is Nature Based Solutions (NbS)?

Nature-based Solutions (NbS) are interventions designed around the management, conservation and enhancement of natural resources that yield multiple environmental, social and economic benefits and co-benefits. It is an umbrella term that encompasses various approaches that put nature at the centre of designing solutions that build climate resilience and create sustainable economies. Based on global practices that aim to simultaneously tackle environmental, social and economic issues, NbS are classified under the following three categories (IUCN):

1. **Nature Based**: Solutions based on nature that use the power of functioning ecosystems as infrastructure to provide natural services to benefit society and the environment.
2. **Nature Derived**: Wind, wave and solar energy — solutions to help fulfil our low carbon energy needs through production methods deriving from natural sources.
3. **Nature Inspired**: Solutions that involve innovative design and production of materials, structures, and systems that are modelled on biological processes.

Figure 32 Advantages of NbS (IUCN)

Nature-based solutions are emerging as powerful allies in addressing the global interconnected challenges of water pollution, biodiversity loss, and urban ecosystem degradation. Several cities have begun to change their approach to urban planning by harnessing the power of nature to provide environmental and societal benefits. The potential of incorporating nature in cities is now universally acknowledged; however, these must be seamlessly integrated with overall city development plans through a more linked and collaborative approach between several stakeholders.

Delhi recently unveiled its draft Master Plan 2041, a document that will guide the city's development over the next twenty years. The draft plan aims to make Delhi more environmentally sustainable, habitable, and economically and socially strong, with stronger attention to environmental protection. While attempting to address issues of water pollution and overall discordance with the natural environment as a result of rapid and unplanned urbanisation, the new Master Plan aims at the revitalization of the city's green and blue assets, which includes increasing forest and green cover as well as protecting and conserving water bodies.

Several cities are beginning to embrace nature's power and shifting urban planning approaches to place a greater emphasis on blue (such as rivers, and lakes) and green (such as trees, parks, and forests) spaces. Nature-based solutions can supplement efforts to reduce water pollution. Such solutions provide numerous co-benefits such as improved water quality, increased green cover and biodiversity, and the creation of healthy and balanced living spaces.

5.1. Interventions at Different Levels

1. **At Site Level to overcome the issue of connecting areas to centralised treatment plant**
   DWWT - In-Situ Treatment: The use of in-situ treatment to improve water in the industries and proposing DWWT as per the gap in generation/ treatment can bring back the flow in the rivers if such treatments work at their full capacity and efficiency

2. At **Flood Plain Level** to overcome the issue of changing floodplain Land-Use

Greenways

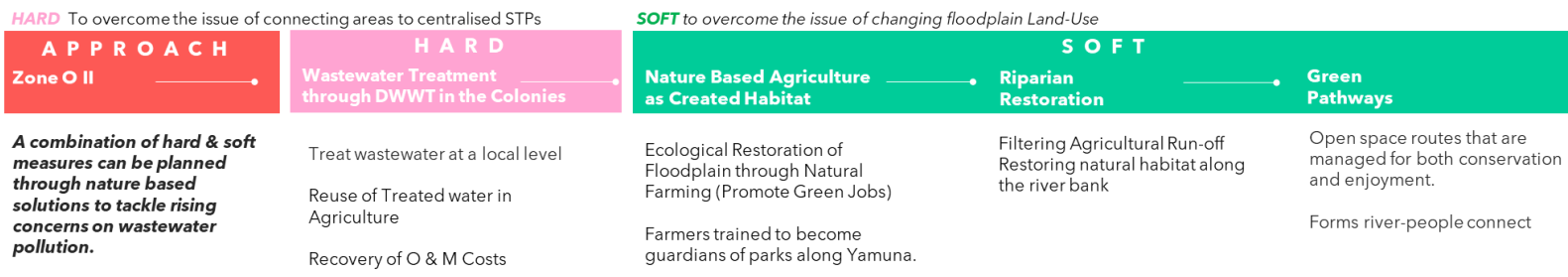
- Are protected open space routes that are managed for both conservation and enjoyment.
- They connect habitats and provide open space networks for people to explore and enjoy

Created Habitats

- Interventions that involve the protection or management of artificial ecosystems (agricultural, fishery, and livestock farming methods).
- Cover crops and water-smart agriculture are examples of related measures (cater to riverine communities)

Riparian Restoration

- Restoring natural habitat along the banks of a river, stream, or lake that serves as an interface between land and water.
- Riparian buffers on agricultural land can play a significant role in filtering runoff from fields



5.2. Site Level Proposals

Decentralized Wastewater Management Systems *(through nature-inspired technologies)*
Decentralized wastewater management (DWWM) as per MoUD Guidelines be defined as "the collection, treatment, and disposal/reuse of wastewater from individual homes, clusters of homes, isolated communities, industries, or institutional facilities, as well as from portions of existing communities at or near the point of waste generation" (Guidelines for Decentralised Wastewater Management , 2012).

Advantages (Guidelines for Decentralised Wastewater Management , 2012)**:**
Flows would remain small in the system at any point
Less environmental disturbances as smaller pipes would be installed during the construction process of the system
Without routing more flows to existing centers, new treatment centers can be added; making the expansion of the system easier
For laying down sewer pipelines, less investment is required
More efficient quality of treatment if compared to the traditional system
Efficient reuse of treated sewage for toilet flushing, irrigation, etc.
Easier sewerage system maintenance

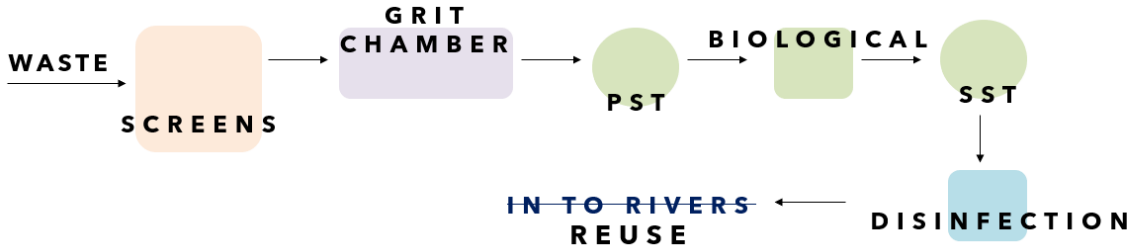
Planning Considerations
Detailed investigations carried out respect to (Guidelines for Decentralised Wastewater Management , 2012):

1. Population
2. Reuse potential
3. Topography
4. Wastewater quantity and quality
5. Details of existing on-site treatment systems
6. Presence of any drainage channel

Technologies Available
Several treatment options are available selected on the basis of wastewater characteristics. The treatment systems include (Guidelines for Decentralised Wastewater Management , 2012) :

6. Waste stabilization ponds
7. Constructed wetlands
8. Moving bed bio-film reactor
9. Activated sludge process
10. Extended aeration process

Figure 33 Process of DWWT (Guidelines for Decentralised Wastewater Management , 2012)



5.3.Selection of Technology

Various efficient technologies are present in India in order to treat wastewater at a local level. However, factors considered while selecting Technologies for DWWM are land required, capital cost and operation & maintenance cost as it is to be proposed in an unauthorized colony with available land being the biggest constraint to propose any kind of wastewater treatment system. On the basis of these factors CAMuS-SBT was selected for the site specifically as shown in table 33 below. Further, this DWWT technology is the most suitable prototype for the selected area which cannot be replicated as it is in other areas. In different areas on the basis of varied factors other suitable systems can be proposed.

Figure 34 Factors for selecting a Technology (Primary Analysis)

FACTORS	CAMuS-SBT (600 KLD)
Land required	420 sq.m.
Capital Cost	Rs. 62.1 Lakhs
Operation & Maintenance costs	Rs. 6 Lakhs

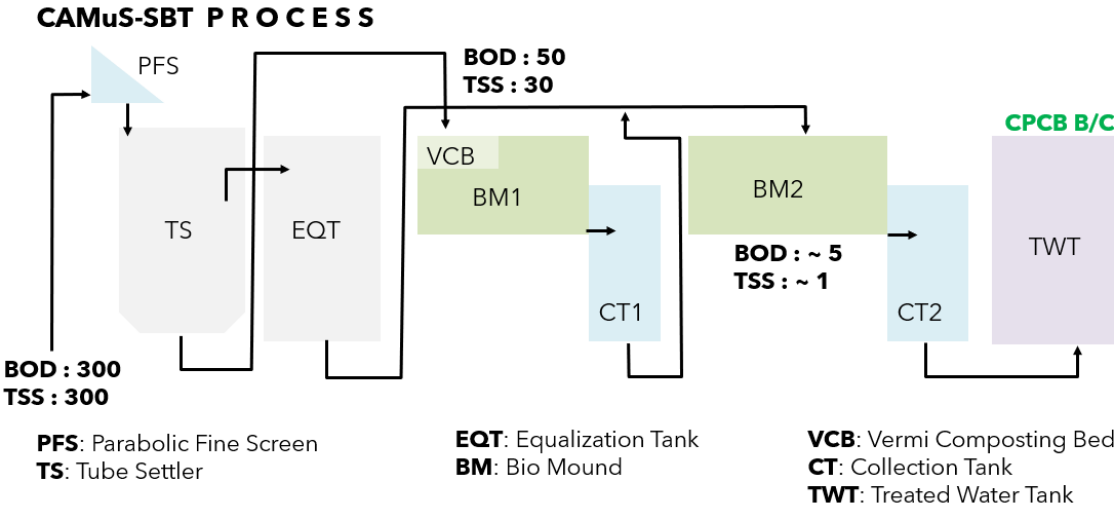
CAMuS-SBT

Continuous Advanced Multistage System – Soil Biotechnology (CAMUS-SBT) is an advanced SBT that uses only local supplies and is an oxygen supplying biological engine (can treat all wastewater - domestic, municipal & industrial). Media used in the bio-reactors creates a natural eco-system (ensures a min. life span - **25 year** for desired hydraulic & organic loading) (Center for Sceince and Environment).

Features (Center for Sceince and Environment)**:**

- It's a green/clean technology
- No Noise & Odour
- Optimal space usage
- No external aeration
- No bio-sludge formation
- One time media installation
- Low power consumption (1/3 of conventional STPs)
- Efficient removal of pollution
- Long life and creates green habitats

Figure 35 CAMuS-SBT Process (Center for Sceince and Environment)



Components (Shankar)**:**

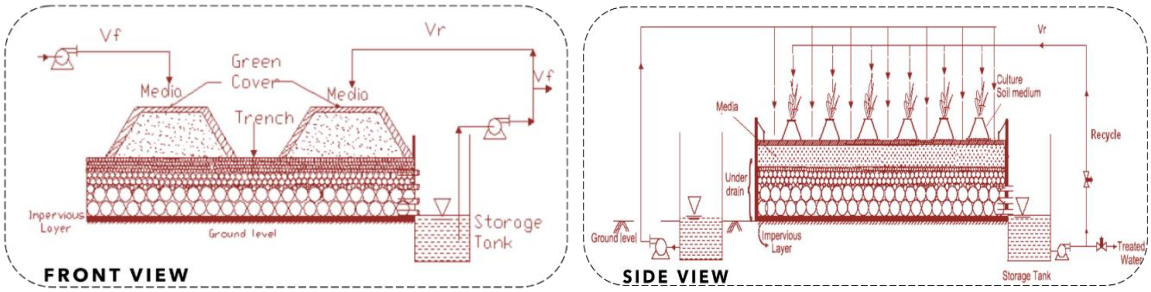
- **Media** : Partially weathered soil-like primary minerals of suitable particle size , composition, liquid hold up, hydraulics

- **Additives** : Formulated from natural materials for suited particle size and composition to provide sites for respiration, CO2 capture.

- **Culture** : Geophagus worm such as Pheretima Elongata and bacterial culture. Appropriate culture for special situations.

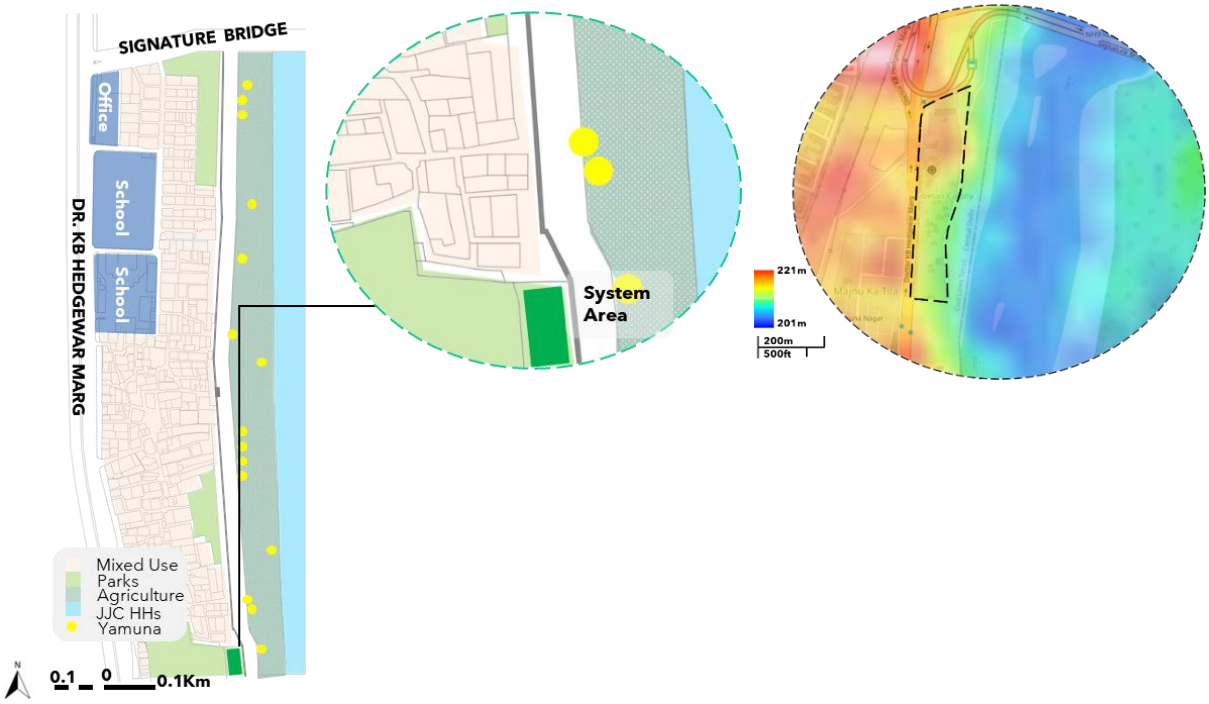
- **Plantations** : Selected Green plants particularly with tap root system

Figure 36 Sectional Plans (Shankar)



5.4.Site Selection for Technology

Figure 37 System Area of Technology in New Aruna Nagar (Author, 2022)



Design Considerations

Total Vacant Space – 9,300 sq.m. (0.93 Ha)
Area Requirement/ KLD - 0.7 sq.m.
Area Required for (600KLD)– 450 sq.m.
Flooding mark - 205.33 m
System Level – 213.47 m

Outcome Shown

BOD and COD are less than 5 with the removal efficiency of BOD and COD greater than 99%. Effluent can be used for Construction, Flushing, Plantation, and Irrigation as the discharged water is equivalent to CPCB designated Use Category 'B/C'.

COSTING

1,360Rs/ person treatment cost
120 Litre/ person treated water generated
1,26,000RS/month total revenue generated
@ **RS. 7.00** per kl from STPs (Delhi Jal Board, 2018)

SCOPE OF REUSE IN AGRICULTURE

Water Requirement for 1ha : **67,885 Gallon/ week = 256.9727 KL/ week**
Water Requirement for 5ha : **1,283 KL/ week (3.5 times treated wastewater generated)**
Cost to Farmers : **8,500/ week (@7 Rs)**

5.5.DWWM Recommendation at Policy Level

Table 12 Area-wise Interventions for DWWM (Author, 2022)

Areas of Intervention	**Possible Measures**
Recognition of DWWM by the government agencies responsible for urban sanitation planning	1. Specify role and scope of DWWM in national policies, City sanitation plans, master plans and zonal plans. 2. Create a unified database of DWWM, georeferenced data 3. Draw statistics on the contribution of DWWM to urban sanitation coverage, and introduction of DWWM category in the census
Effluent Standards	Develop effluent standards that are specific to DWWM and reuse purposes
Water reuse planning	1. Specify role and scope of DWWM in water reuse policies 2. Draw statistics on contribution of DWWM to water reuse

- These measures at policy level will not only help in establishing ***organised framework for DWWT*** but will also help in monitoring of such systems by the state boards.
- It can further ensure the ***participation of local bodies*** in effective wastewater management in the State.
- ***Institutional framework can also be strengthened*** that will actually support or facilitate the implementation of all the declared rules.

5.6.Floodplain Level Proposal: Delhi Master Plan 2041

The proposed Master Plan 2041 of the Delhi Development Authority places a strong emphasis on green belt development and improving people's engagement with the city's "green and blue resources". The "*Green-Blue strategy*" which focuses on water bodies and the land around it, offers to give the city a unique shape (Rajput, 2020).

What is Green-Blue infrastructure?

Rivers, canals, ponds, wetlands, floodplains, and water treatment facilities are examples of **'Blue'** infrastructure, while trees, lawns, hedgerows, parks, fields, and woods are examples of **'Green'** infrastructure. The term relates to urban planning in which water bodies and land are linked and flourish together, providing environmental and social benefits.

Through blue green infrastructure under MPD – 41, the draught plan establishes certain guidelines for cleaning the river and recovering dying water bodies, which is one of the most important components of the plan (Rajput, 2020) as shown below in the table –

Table 13 Proposals Laid out in MPD-2041 (Compiled by Author from Draft MPD 2041)

Draft Proposals	
A clear limit of the ***buffer zone near the river***, with directions on how to develop it as a hub of public usage for recreation only	So, a strong emphasis is on green belt development and improving people's engagement with the city's "green and blue resources". However, created habitats like agriculture can provide multiple benefits like reducing water pollution and
Creation of ***green mobility corridors*** for use as pedestrian walkways and cycle tracks along blue assets in the city	
Use of ***in-situ treatment*** to improve water quality will be implemented	
'Interactive zones' will be designated as specific sites and paths. These locations will be open to temporary activities such as active/passive recreation, exercise/yoga, nature classes, and so on	
Recognized ***farming as a permissible activity*** in floodplains	

Floodplain proposals based on MPD-41 Proposals

Vision : Integrating farming with existing/proposed parks, wetlands and public spaces to improve floodplain health in terms of Biodiversity, water quality and soil health.

Agriculture notified as a dedicated land use

- Reimagining riverine ecology along with riverine agriculture.
- Regularizing farming as a community-driven, sustainable urban livelihood - recognize long-standing ground realities.

Farmers of Zone O be given access to welfare schemes

- Peri-urban farmers in the NCT of Delhi are eligible for various benefits, subsidies, and insurance as per relevant policies of GoI and GNCTD, such as SBM Gramin, Paramparagat Krishi Vikas Yojana, Mukhyamantri Kisan Mitra Yojana, etc. (Kumar, 2017)

Farmers are reskilled in organic and sustainable practices

- Reskilling of farmers into organic and sustainable practices

Table 14 Universal Principles Of Natural Farming (Andhra Pradesh Community-Managed Natural Farming, n.d.)

Universal Principles Of Natural Farming	Soil To Be Covered With Crops 365 Days (Living Root)
Minimal Disturbance Of Soil	Increase Organic Residues On The Soil

Bio-stimulants As Necessary	No Synthetic Fertilizers, Pesticides, Herbicides
Catalysts Use Indigenous Seed	Pest Management Through Botanical Extracts

Figure 38 Multiple Level of Capacity Development (Author, 2022)

- Localized, contextual interventions by agricultural scientists, environmentalists, and planners.

Table 15 Nature Based Agriculture enhancing ecosystem services (Miralles-Wilhelm, 2021)

NbS	Biodiversity	Water	Soil
Conservation Agriculture	Agroforestry provides habitat for species & supports connectivity	Reduced agricultural water demands	Reduces soil erosion and redistribution maintaining soil depth and water retention
Cropland Nutrient Management	Increased fish species richness and abundance	Benefits associated with improves surface water quality. Increased opportunity for recreation & Health benefits	Better nutrient management maintains soil fertility
Riparian Buffer	Can create wildlife corridors and buffer areas that enhance biological conservation	Improved availability of water; avoided sedimentation and water regulation	Measured increase in soil fauna in reforested sites

Integration of riverfront development with farming

- Along with forests/marshes, farms are also ecologically beneficial uses of floodplains.
- Farmers are to be trained to become effective guardians of parks and biodiversity spheres.

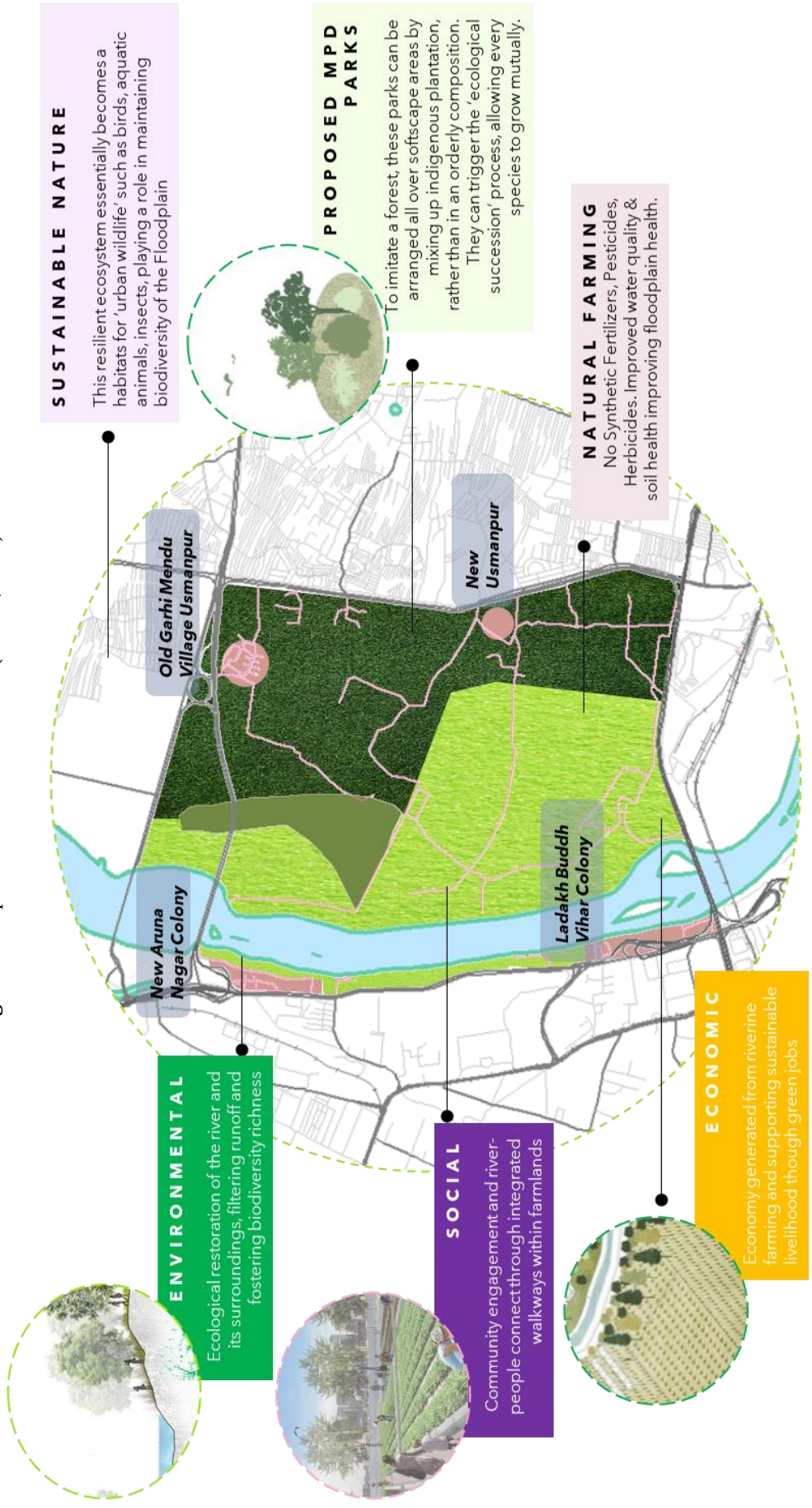


Figure 39 Proposed Sub-Zone 'O' II Plan (Author, 2022)

CHAPTER VII

6. Funding and Stakeholders

6.1. Funding Pattern
For Zonal Level Nature Based Interventions

The public sector is critical to the success of NbS in India, both as a key enabler of policy-driven transformation and as a source of large-scale funding. This section provides an overview of public funding for NbS activities in India's scenario.

National missions and programs - Under National Action Plan on Climate Change (NAPCC), two missions are most aligned with NbS activities conducted on land. These are, GIM and NMSA which are discussed below with their respective budget allocations and types of activities supported.

A. Green India Mission (GIM)

GIM aims to protect, restore, and improve India's forest cover by addressing climate change with a combination of adaptation and mitigation measures. It takes a holistic approach to greening and focuses on improving the provision of multiple ecosystem services, particularly biodiversity, water, and biomass, as well as the preservation of mangroves, wetlands, and critical habitats.

Table 16 Fund allocation under Green India Mission (Press Information Bureau, 2022)

Year	2021-22 (As on 24 -01-22) in Crores	More than 90% of the allocated budget has been utilised both in 2020-21 and 2021-22
Budget Allocated	220.00	
Expenditure	200.13	

B. National Mission for Sustainable Agriculture (NMSA)

NMSA's mission is to promote sustainable agriculture practises that make agriculture more productive, sustainable and profitable. By supporting three key areas that is agroforestry, rainfed agriculture, and bamboo cultivation promotion the mission focuses on farmland development and restoration.

Table 17 Fund allocation under the National Mission on Sustainable Agriculture (Ministry of Agriculture & Farmers Welfare, 2021)

NMSA Components	Financial Status (in Cr)	Activities aligned with land-based NbS
Sub-Mission on Agro-Forestry	39 (2021-2022)	Improved crop seeds, improved farm practices, agricultural insurance, access to market, livelihood diversification

For Site Level Decentralised Wastewater Treatment Intervention

The Delhi Jal Board (DJB) constituted under the Delhi Jal Board Act, 1998, is responsible for proper collection, efficient treatment and safe disposal of domestic sewage in the Capital.

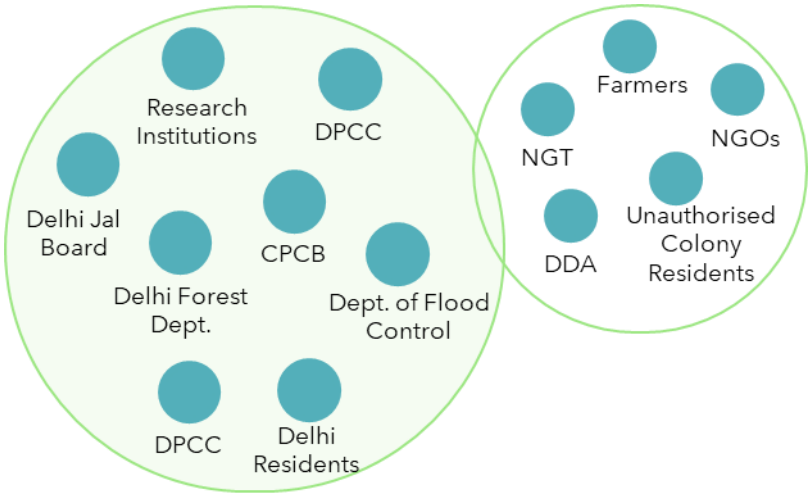
Table 18 Fund allocation under DJB Schemes (Delhi Jal Board)

Name of the Scheme	2020-2021 (in Lakhs)	2021-2022 (in Lakhs)
Sewerage facilities in Unauthorised Colonies	60,000	45,000
Rejuvenation of Yamuna and Water bodies	-	-
Environmental Greenery and Landscaping	200	200

6.2. Stakeholder Identification

Any planning vision for the Yamuna and its floodplains in Delhi must consider and reconcile the concerns and interests of all stakeholders.

Figure 40 Identified Stakeholder (Author, 2022)



For the successful implementation of projects stakeholder engagement is a main component on community based projects. It involves stakeholders in planning & implementation stages to achieve consensus and take into account their needs and interest. This allows all stakeholders to understand the potential impacts of a proposed activity on the community and the potential they have to contribute for better implementation of the project.

Figure 41 Stakeholders and their potential to contribute to the project (Author, 2022)

STAKEHOLDER CATEGORIES	THEIR MOTIVE	POTENTIAL TO IMPLEMENT
Authorities DJB CPCB DDA NMCG	1. Respect for laws and regulations 2. Public health 3. City Cleanliness 4. Conforming with Master plans and Other Plans	• Power for enforcement through the regulatory framework in terms of taking connections and safe disposal of treated wastewater, management of treatment units • Link with other authorizations can **help in land transfer.** • Training methods and materials developed with subject matter specialists and trainers to support integrated agro-ecosystem.
NGOs (Farmers Rights, Environmental Groups)	1. Clean environment 2. Capacity building Programs 3. Transparency & Public Participation	• Community awareness on the effect of **current practices** on farm. • **Conducting workshops** and creating awareness about Nature-Based Agriculture • Collaboration between researchers, and land users on the promotion productive and sustainable farming system.
Potential end-users for Reuse Farmers DDA FOREST Dept	1. Affordable and safe products 2. Yield increase	Increase DWWTs **revenue** through selling of end-products • For Irrigation • For maintaining green spaces under various agencies
Households (users and owners)	1. Clean environment	• Pressure on municipal authorities and service providers • Better management of onsite systems

CHAPTER VII

7. Conclusion

Although the river Yamuna's water quality is not up to par with that of a healthy river, this study clearly demonstrates that it is an important part of many people's life. The river's management in the city is more likely to create grey infrastructure and recreational areas in and around the river. However, the constant discharge of wastewater drains into the river has yet to be entirely addressed.

Delhi must address its unplanned urban growth and try to restore the river's natural ecological flow to allow waste water to be diluted between Wazirabad and Okhla. Furthermore, Delhi must decentralize wastewater management through in-situ treatment with a focus on soft infrastructure and local reuse, and mainstream septage control, as new, illegal growth will emerge by the time grey infrastructure covers existing areas that are unsewered.

This game of catch-up will continue until we acknowledge the problem, and move away from sewage and centralized systems and toward sanitation for all.

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National Mission for Clean Ganga (NMCG)
&
National Institute of Urban Affairs (NIUA)

Template for Submission of the Project Idea

Thesis Competition
on
Re-imagining Urban Rivers, Season 2

A competition for Bachelor's and Master's students

Annexure

Note: This template has two parts. The first part should be filled in by the student. The second part should be filled in by the student's Institute/School/University.

PART 1
To be filled up by the applicant

1. Proposed project title Planning for Nature-Based Solutions to Mitigate Pollution Effects of the Wastewater Flow on Water-Quality & Riverine Communities Maximum length: 300 characters, including spaces
2. Selected Theme Select any theme from the options below Theme 1: Reducing river pollution
3. Abstract Rivers have always been at the heart of societal development. All of the world's ancient civilizations thrived on the banks of one or more rivers. Rivers, which were formerly the most important supply of fresh water, became conveyors of effluent as cities grew. Various sources of contamination demonstrate how rivers have paid the price for fast economic and technical advancement. Despite being regarded as a goddess by Hindus, the Yamuna is no exception. The river Yamuna is one of the most polluted tributaries of the Ganga. Researchers have said that the Yamuna is "about to die" due to pollution (Misra 2010). Furthermore, the Delhi NCR contributes almost 76% of the overall pollution load in the Yamuna (PTI 2018), effectively turning the river into a 'sewage drain' (Datta 1992). Delhi processes around 66 per cent of all sewage generated by its metropolitan area, with the remainder entering rivers or other surface water bodies. Nonetheless, the Yamuna continues to be vital to many communities' livelihoods and socio-cultural lives. All types of livelihoods continue to rely on this 'about to die' (Misra 2010) river: farmers still cultivate on the banks, fisher-folk fish, and washer-folk wash. This study aims to contribute to a better understanding of the diversity of riverine communities along the Yamuna stretch in Delhi (such as farmers and fishermen) and the challenges they face as a result of river pollution by correlating water quality with socioeconomic factors that affect these riverine communities. To achieve greater water security and resilience in the future, as well as to reverse biodiversity loss and lay the groundwork for more sustainable societies (community liveability with greater social benefits), the thesis seeks to demonstrate how Indian cities can turn to nature-based solutions (NbS) to protect the urban rivers on which they rely, thereby contributing to improving environmental quality and the livelihood of riverine communities. Sources Datta, Chandan. 1992. "Yamuna River Turned Sewer." Economic and Political Weekly, 27, 2633-2636. Misra, Anil Kumar. 2010. "A River about to Die: Yamuna." J. Water Resource and Protection 489-500. PTI. 2013. Phase three of Yamuna Action Plan approved for Delhi. 10 December. Accessed November 2019. https://www.ndtv.com/delhi-news/phase-three-of-yamuna-action-planapproved-for-delhi-544037.

Maximum length: 300 words

4. Case study area

Provide a brief description of the study area and why it has been selected. Feel free to use figures/tables/maps/diagrams/sketches

Delhi: Yamuna River

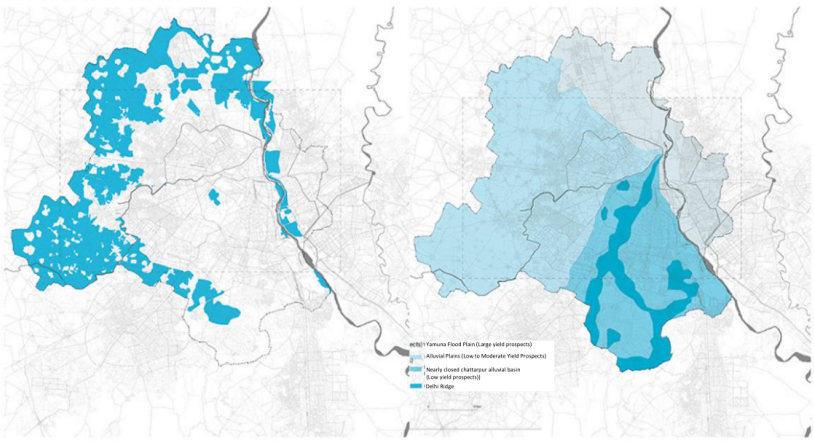
The Yamuna River is the Ganga River's longest and second-largest tributary. The main starting stream of the river originates from the Yamunotri glacier near Bandar Punch. The different human and industrial activities generate a large amount of garbage, which is directly discharged into the river without adequate treatment, lowering the quality of the river's water. However, only 22 kilometres (or less than 1.6 per cent) of the Yamuna pass through the National Capital Territory. However, the wastes and toxins dumped into that limited stretch contribute to about **80% of all pollution** in the 1,376-kilometre-long river.

Rapid population increase has rendered Delhi unable to properly handle the volume of sewage produced, while ageing infrastructure is unable to treat water at full capacity. The pristine Himalayan waters of the Yamuna River are nearly entirely diverted for use as drinking water just north of Delhi, at the Wazirabad Barrage. That flow is effectively replaced by the Najafgarh Drain's discharge, which is heavily contaminated by agricultural and industrial runoff, solid waste, and untreated home sewage. The diversion of clean water for drinking and agriculture has lowered the natural flow of the Yamuna and its tributary drains dramatically. The limited flow is unable to dilute the volume of solid waste and effluents dumped into the Yamuna, thereby transforming it into an open sewage drain.

As a result of the extreme decrease of oxygen levels in the water, large numbers of fish die, severely affecting fishing communities. A river ecology requires dissolved oxygen (the amount of oxygen in water) levels of 6 or higher to survive. A **DO** level of at least 4-5 is required for fish. The DO in the Delhi section of the Yamuna ranges from 0 to 0.4. Furthermore, the allowed **Biochemical Oxygen Demand (BOD)** threshold for river water is 2 mg/l, whereas the BOD level of the Yamuna exceeds 55mg/l, which is extremely high, and at this level, contamination becomes irreversible, rendering river water dangerous and unusable (Shalini Singh, 2020).

The Central Water Commission (CWC) declared that the water in the Yamuna River is unsafe for household, irrigation, fishing, and industrial usage. Similarly, agriculture communities along the river in Delhi have numerous challenges, primarily in terms of water quality and quantity, yield, and land availability.

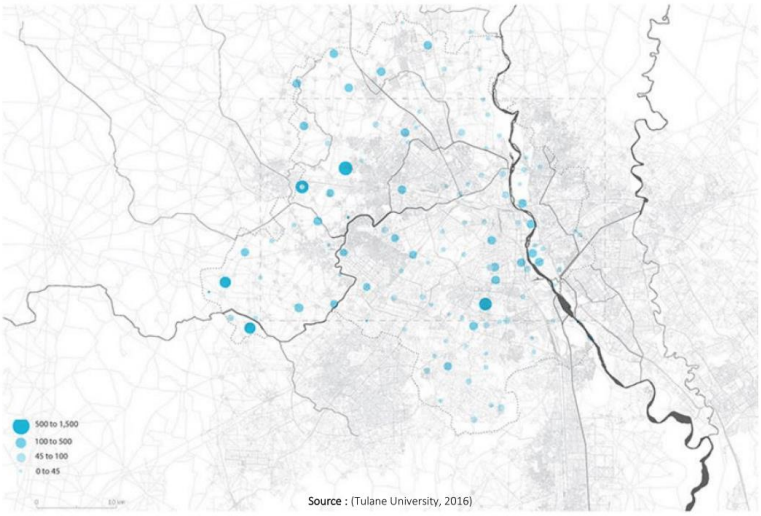
AGRICULTURE IN DELHI



Source : (Tulane University, 2016) Land used for Agriculture in Municipal Delhi Soil Map of Municipal Delhi

The greatest quality soil is found along the Yamuna, limited access to the river means that most agricultural output takes place on the city's outskirts, in poor quality soil. However, water contamination caused by agricultural pesticides, fertiliser residue, and agriculture waste, generate hazardous runoff and nutrient pollution, contaminating the Yamuna and Delhi's groundwater. This has not only impacted agricultural communities along the Yamuna river but others as well. As illustrated in the map below, agricultural runoff pollutes Delhi's groundwater in several regions, causing nitrate levels to rise.

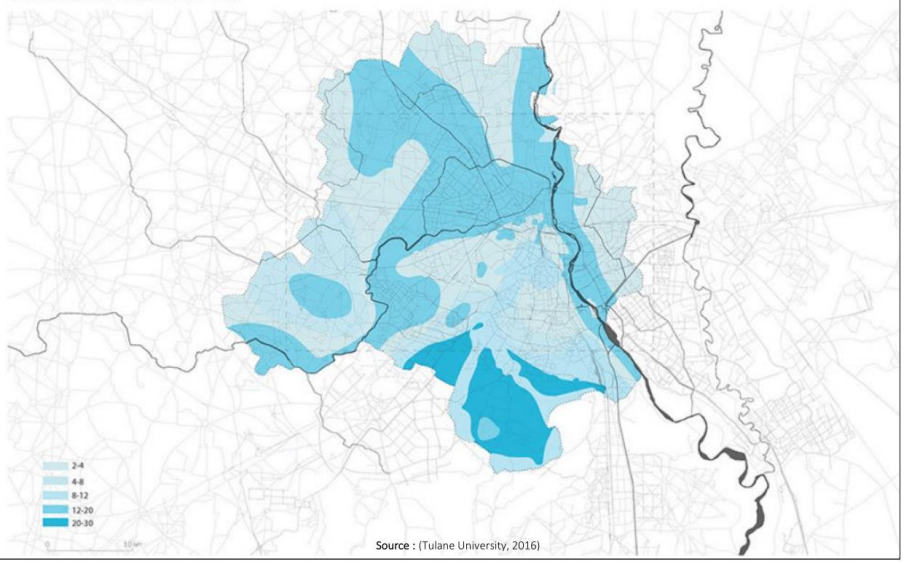
GROUNDWATER NITRATE LEVELS



Source : (Tulane University, 2016)

A high concentration of this nitrate corresponds to the places where agriculture is most prevalent. In Delhi, the groundwater table **dropped by 2 to 20 metres** (Tulane University, 2016). A heavy layer of sludge has accumulated at the Yamuna's bottom, preventing the water bodies from replenishing groundwater. This is extremely problematic for farmers' livelihoods, as groundwater is a vital source of crop irrigation.

GROUNDWATER DEPTH



Source : (Tulane University, 2016)

Nonetheless, the Yamuna continues to be vital to many communities' livelihoods and socio-cultural lives. Water pollution, on the other hand, has forcibly broken down nature-based economies, pushing labour, food, and manufacturing into energy and capital-intensive corporate cycle. Meanwhile, rivers continue to be used for trash disposal. As a result, poor river water quality has harmed not only river biota but also river-dependent populations.

The presence of varied communities along the Yamuna enables chances to invest in nature-based solutions, which is a fundamental component of the thesis to safeguard water resources. Nature-based solutions (NbS) entail collaborating with nature to address societal issues, thereby benefiting both human well-being and biodiversity. They are actions including the protection, restoration, or management of natural and semi-natural ecosystems, as well as the sustainable management of aquatic systems and working areas such as croplands. They are biodiversity-based initiatives that are created and implemented with the full participation and permission of local communities and Indigenous Peoples.

Sources
Tulane University. 2016. Yamuna River Project at the University of Virginia and Tulane University. https://yamunariverproject.wp.tulane.edu/2016/11/28/mapping-drinking-water-infrastructure/

Singh. Shalini. 2020. "When Yamuna's 'dead fish will be fresher." https://www.in.undp.org/content/india/en/home/climate-and-disaster-reslience/successstories/pari-undp-series/When_Yamunas_dead_fish_will_be_fresher.html

Maximum length: 700 words

4. Project concept

Provide a fairly detailed description of your project idea, highlighting its objective, and the method you will follow to achieve the objective. Feel free to use figures/tables/maps/diagrams/sketches

I. To critically understand the importance of urban rivers and their cause of degradation.

A comprehensive and exhaustive review of pre-existing literature including journal articles, national and international reports, etc. will be done to understand the issues of river pollution in cities in terms of-

- urban rivers significance for cities and riverine communities particularly
- impact of pollution on the communities
- cause of degradation of urban river
- parameters to identify the pollution status of a river

II. To assess the existing wastewater management system and identify sources of pollution in the study area.

- Assess treatment capacity of sewage treatment plants (Generation/Treatment Gap)
- Secondary data- Landsat 4-5 (TM) and Landsat 8 data from USGS Earth Explorer with a resolution of 30 metres will be used for LULC.
- The Supervised Classification approach will be used to classify the images to capture the hydrological variability of the Yamuna and changes in the LULC pattern over the previous decade. It can aid in identifying the point and non-point sources of pollution along the Yamuna River's course.
- The overall study can help to determine a link between rising pollution levels and the pressures of urbanisation, which may be attributed to increased wastewater generation/discharge into the Yamuna.

III. To assess the water quality parameters spatially and detect the level of pollution in the study area.

- To assess the river water quality for pollution parameters, field datasets of the National Water Quality Monitoring Programme (NWMP) from river water quality monitoring stations of the Central Pollution Control Board (CPCB) will be taken for years 2010 and 2020.
- The water quality parameters considered for the study will be pH, DO (mg/l), BOD (mg/l), and Faecal Coliform (MPN/100ml).
- Based on these parameters, water quality across the whole river flow area will be assessed using IDW interpolation.

IV. To study the impact of river water quality on the livelihood, occupation and health of riverine communities.

In addition to spatially mapping water quality and identifying pollution hotspots, social research to evaluate the impact of pollution on various riverine communities' livelihoods and health is required. As a result, a field visit will be planned. Riverine communities will be classified as those:

- Living within 'x' metres of the riverbanks
- People who are directly or indirectly interacting with the river water on a regular basis.

Primary method of data collection

Field observations, a standardised survey questionnaire, and in-depth interview schedules with riverine communities will be used in the primary study.

- Survey Questionnaire - Following a thorough assessment of the literature, a complete survey questionnaire will be prepared. The survey questionnaire will collect information about the impact of river pollution on their livelihood and health, as well as their role in reducing pollution in the river.
- In-depth Interview Schedules – will be held with informal representatives from various occupational groups in order to fill any gaps in the information gathered through the survey questionnaire.

Secondary method of data collection

The available relevant literature on the socioeconomic impact of river pollution will be studied in order to understand how various discourses about polluted water bodies have constructed and deconstructed opportunities and difficulties for riverine communities in particular. Reports and other works on river pollution and invasive species, as well as their influence on native flora and wildlife, will also be reviewed.

Data analysis

Odds ratios and descriptive statistics for survey responses will be calculated using a variety of software and programming languages such as Excel, R, JMP (Statistical Analysis Software), and SPSS (Statistical Package for Social Science).

V. To assess the potential for a selected range of nature-based solutions to mitigate diffuse pollution challenges and generate benefits for people and nature, when deployed at a scale.

Excess nitrogen and phosphorus in water can come from a variety of sources, including agriculture, industry, and households. Such sources might be found in discrete sites (point sources) or widely dispersed locations spread across broad areas (diffuse emissions).

When water bodies are contaminated with too much nitrogen and phosphorus, it can lead to excessive algal growth, decreased levels of Dissolved Oxygen (DO), and greater levels of Biochemical Oxygen Demand (BOD). This condition is known as eutrophication, and it has the potential to harm human health by impairing the use of water for irrigation, drinking, bathing, and fishing, as well as threatening the livelihoods of riverine populations.

Nature-based solutions (NbS) entail collaborating with nature to address societal difficulties, resulting in benefits for both human well-being and biodiversity. They are specific actions involving the protection, restoration, or management of natural and semi-natural ecosystems; the sustainable management of aquatic systems and working lands such as croplands or timberlands; or the creation of new ecosystems in and around cities. They are biodiversity-based initiatives that are created and implemented with the full participation and permission of local communities and Indigenous Peoples.

SITE SCALE

Land conservation is one method of sustaining interconnected networks of open space that support healthy communities. Prioritizing areas of land for acquisition is the first step in land conservation efforts.

Greenways are protected open space routes that are managed for both conservation and enjoyment. Greenways are frequently formed by rivers or other natural features. They connect habitats and provide open space networks for people to explore and enjoy.

Riparian restoration Restoring natural habitat along the banks of a river, stream, or lake that serves as an interface between land and water. For example, riparian buffers. Riparian buffers are short strips of land on either side of a river or stream that restore natural habitat. Riparian buffers on agricultural land can play a significant role in filtering runoff from agricultural fields, preventing silt and nutrients from entering the riparian area.

Floodplain Restoration Floodplains that have not been disturbed serve to maintain waterways healthy by holding floodwaters, minimising erosion, filtering water pollutants, and providing habitat. Floodplain restoration helps to restore some of these natural processes by reconnecting the floodplain to its waterway.

Waterfront parks Flood-prone locations along rivers can be purposefully engineered to flood during major occasions, lowering flooding elsewhere and improving water quality.

Created Habitats Interventions that involve the establishment, protection or management of artificial ecosystems. This encompasses the majority of agricultural, fishery, and livestock farming methods, as well as pastoralism. **Cover crops, contour farming, hedgerows, conservation tillage, agroecology, and water-smart agriculture** are examples of related measures.

The thesis outcome will be in a **"form of a landscape plan"** based on the mentioned NbS for a selected site (A section of the river) that will incorporate ecological and biodiversity concerns of poor water quality and will support urban river and livelihood improvements. Further, it will support implementation on the ground and replication in other landscapes.

Maximum length: 1000 words

5. Envisaged outcomes

Describe the expected outcomes of your project.

- Nature-based ecological restoration and pollution-reduction initiatives along the Yamuna River in Delhi can demonstrate positive results through **improved water quality** and **riverine communities livelihood**.
- **The added advantage of recreational space and improved public health**: Nature-based solutions such as waterfront parks and greenways maintain and enhance open space, allowing for greater recreational opportunities. Furthermore, nature-based solutions like greenways and green streets can expand possibilities for active transportation like biking and walking. These areas can also provide aesthetic benefits that contribute to better mental and physical wellness.
- **Green jobs:** Nature-Based Solutions generates new work opportunities in areas such as landscaping, pavement, and construction. Furthermore, smart green solutions can **support traditional local communities** occupations such as agriculture, fishing, and so on.
- As stated above, the thesis outcome will be in the **"form of a landscape plan"** based on the mentioned NbS for a selected site (A section of the river) that will incorporate ecological and

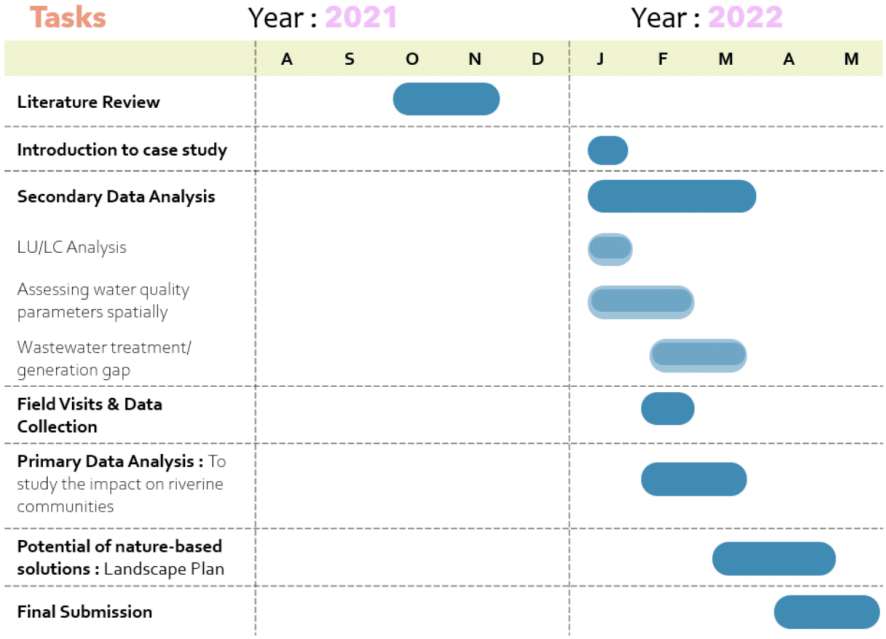
biodiversity concerns of poor water quality and will support urban river and livelihood improvements. Further, it will **support implementation on the ground** and **replication in other landscapes.**

Maximum length: 300 words

6. Proposed timelines

Provide a concise timeline for the project activities as a Gantt chart, in lines with the academic thesis timelines of your institution. Activities may include, literature review, site visit, data collection, analysis, and final submission.

In August and September topic selection took place. The timeline of the activities based on the decided topic is below -



7. Student's information

Name: Rupal Srivastava
Name of academic programme enrolled in: Bachelors of Planning
Name of university/school/institute: School of Planning and Architecture, New Delhi
Expected thesis/project period: November 2021 – April 2022
Email: rupal769bp18@spa.ac.in
Contact number: 9810390119

8. Institution's information

Name of the Institute: School of Planning and Architecture, New Delhi
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Name of Dean of Academics : Prof. Dr. Ashok Kumar
Email of Dean of Academics : akumar@spa.ac.in
Contact number of Dean of Academics : 9968076056

National Mission for Clean Ganga (NMCG)
&
National Institute of Urban Affairs (NIUA)

National Institute of Urban Affairs

9. **Supervisor's information** (assigned by the institute) Name: Prof. Dr. Ashok Kumar Designation: Dean of Academics Department: Department of Physical Planning Email: akumar@spa.ac.in Contact number: 9968076056
10. **Any other relevant information regarding the proposed project** Particular nature-based solutions described above might change or others will be introduced in the later stage of the thesis based on further study and discussions with the guide. Maximum length: 300 words

National Mission for Clean Ganga (NMCG)
&
National Institute of Urban Affairs (NIUA)

National Institute of Urban Affairs

PART 2
To be filled up by an Authorized Representative of the Institution/School/University

This is to affirm that Ms/Mr. Rupal Srivastava is enrolled in a Bachelors/Masters programmein Planning in this Institute.

The student has discussed the project idea with his/her assigned supervisor and Head of the Department, and will be allowed to take up this project idea as part of his/her academic thesis if he/she is selected for the thesis competition.

Details of the Authorized Representative

Name: Prof. Dr. MAHAVIR

Designation: Head of the Dept. of Physical Planning

Signature:

20.10.2021

Seal of the Institute/Department:

योजना तथा वास्तुकला विद्यालय School of Planning & Architecture नई दिल्ली NEW DELHI

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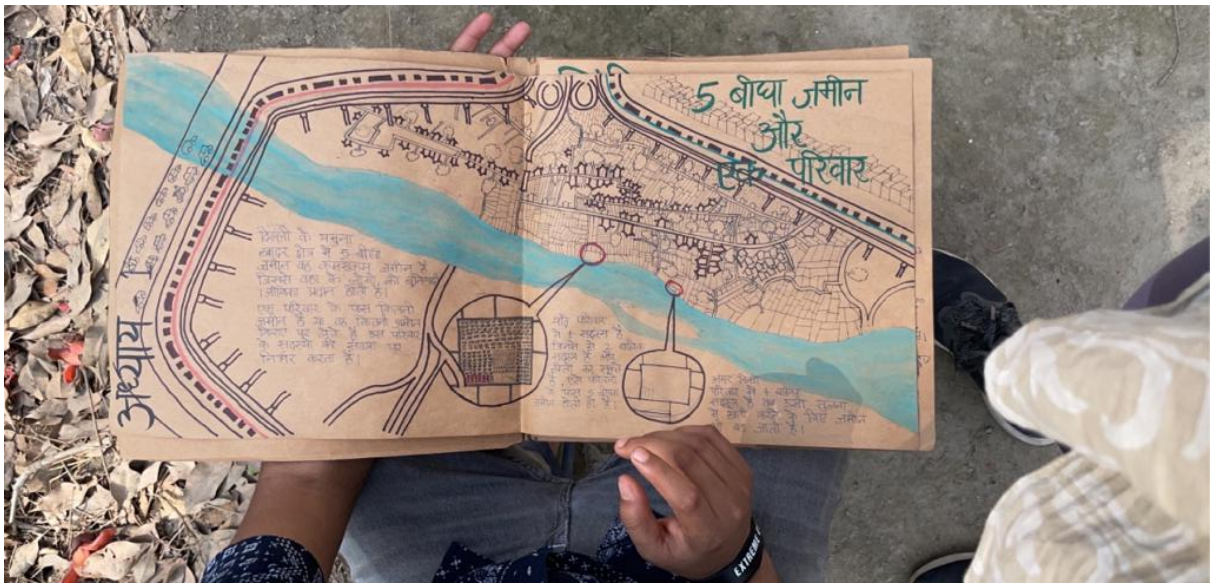
SITE VISIT PICTURES



CERTIFICATE OF COMPLETION

This is to certify that this thesis project titled "**Planning for Yamuna to mitigate pollution effects of wastewater flow on the river, Delhi**" was carried out by Smt. **Rupal Srivastava**, a student of **Bachelor of Planning**, at the **School of Planning and Architecture, New Delhi**. The research for this project was undertaken under the guidance of the afore-mentioned institute and completed during the period of **January, 2022** to **May, 2022**.

This project was shortlisted under the *Sponsored Thesis Project Competition on "RE-IMAGINING URBAN RIVERS" (Season - 2)* 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.

1. Student

Name - Rupal Srivastava
Signature -

2. Institute

Name - School of Planning and Architecture, New Delhi
Department - Bachelor of Planning
Authorized Representative - Mr. Rajeev Malhotra
Signature -

3. Sponsors

Name - National Institute of Urban Affairs
Authorized Representative - Hitesh Vaidya, Director
Signature -

Name - National Mission for Clean Ganga
Authorized Representative - G Asok Kumar, Director General
Signature -