ENHANCING RESILIENCE & IMAGEABILITY OF URBAN AREAS THROUGH ITS LAKE AND RIVER ASSETS- A CASE OF NAGPUR

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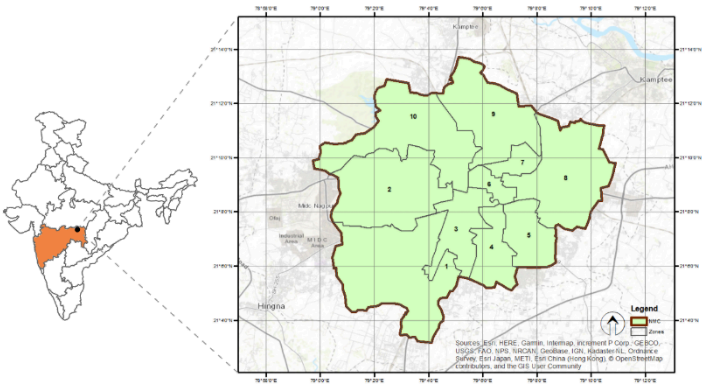
Abstract*— Across India, rapid urbanization has degraded many lakes and rivers, leading to frequent flooding and impacting the ecological balance and aesthetic value of urban areas. Floods are among the most destructive natural disasters, causing significant economic losses and human casualties. Nagpur, the third-largest city in Maharashtra, located at the geographical center of India, is a rapidly developing city with three rivers and approximately 11 lakes, tanks, and ponds. Established 322 years ago, Nagpur, with its profound history and cultural legacy has encountered significant flood occurrences since 1929 and the severity of their impact continues to escalate with each passing year, highlighting the need for effective flood risk assessment and management. The primary issue is the fragmented approach to water asset management and underutilization of water bodies, a problem prevalent in many Indian cities. This research envisions a holistic approach by recognizing the interconnectedness of these water bodies and addressing them as a unified system, focusing on enhancing urban resilience and imageability through strategic management of lake and river assets in the city. Flood vulnerability mapping has emerged as a critical tool for identifying areas prone to flooding and assessing the potential impacts of flood events on human populations, infrastructure, and the environment. The research is divided into 3 major steps: Firstly, Flood Vulnerability Mapping using multi-criteria decision-making (MCDM) method - Analytic Hierarchy Process (AHP). This method involves the integration of various physical and social factors that contribute to flood risk, such as topography, land cover, precipitation, population density, thematically layered in GIS. Secondly, application of Kevin Lynch's theory - "The Image of the City" to explore the relationship between urban elements and flood resilience. Thirdly, developing multifunctional strategies with co-benefits addressing flood resilience and imageability simultaneously, tackling issues such as degrading water bodies, encroachment, destroyed historic water networks, disturbed ecosystems, water pollution, and poor urban image. The research findings delineate strategies and recommendations for crafting a flood-resilient, secure, and visually captivating cityscape, where water bodies are acclaimed as lifelines and landmarks, enhancing the city's appeal and safeguarding its future.

***Keywords*— Resilience, Imageability, River, Flood vulnerability, Nagpur, AHP.**

I. INTRODUCTION

Floods are one of the most common and destructive natural disasters worldwide, causing significant economic losses and human casualties (Guha-Sapir et al., n.d.) According to the United Nations Office for Disaster Risk Reduction (UNDRR), floods affected more than 1.65 billion people globally between 2000 and 2019, resulting in over 104,000 deaths and $651 billion in economic damages (UNDRR, 2020). In India, floods are a recurring phenomenon that affects millions of people annually. Between 1953 and 2017, floods accounted for 26% of all natural disasters in the country, affecting an average of 18.6 million people per year and causing an estimated USD 54.3 billion in economic losses (Guha-Sapir et al., n.d.);(Mohapatra & Singh2, 2003).

Nagpur, the third largest city in Maharashtra and the 13th largest in India with over 2.4 million residents, has been plagued by flooding issues since 1929, with increasing severity. Despite recent infrastructure efforts utilizing the city's lakes, these attempts have faced conflict and failure, such as the unsuccessful rejuvenation of the Sonegaon and Pandhrabodi lakes. Flooding has caused significant human and economic loss, exemplified by the Rs. 150 crore loss in 2016 and Rs. 54 crore loss in 2023. This ongoing crisis, highlighted by the severe flood situation on September 23, 2023, necessitates re-imagining urban rivers to enhance resilience and imageability.

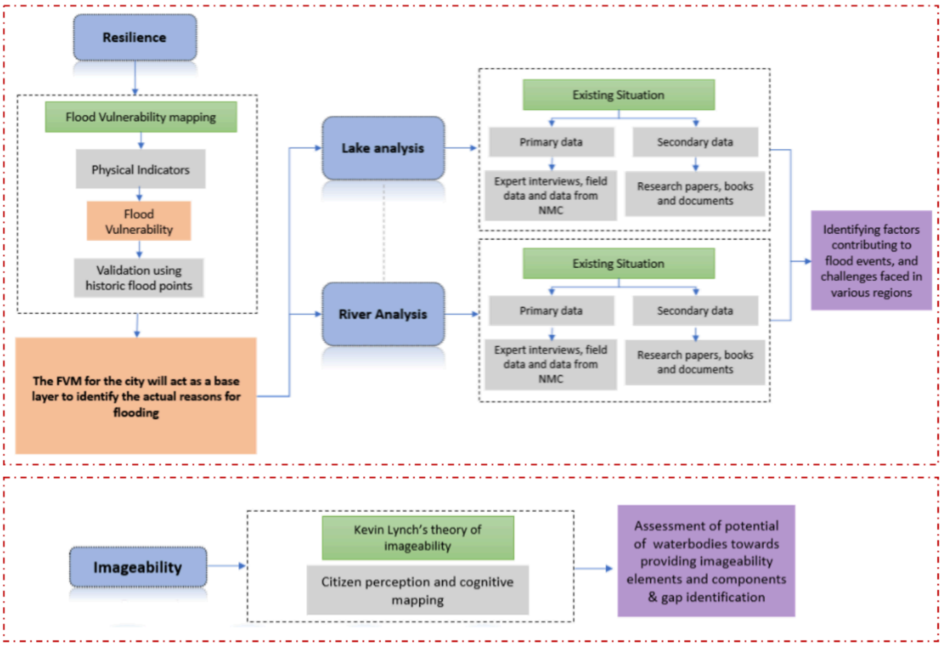


Flood Situation on 23rd September 2023 at Nagpur - (overflow of Nag River)

Water is a valuable resource with the potential to transform areas from small spaces to large cities and entire countries. It has so

much potential that we can utilize it in various ways. Presently, solutions for Rejuvenation of water bodies primarily aim any one function may it be preservation or recreational use or using to install Asia's biggest fountain , neglecting holistic restoration, Environmental and sustainability measures.
A water body is multifunctional, and the irony is that its potential for enhancing urban beauty and providing recreational spaces through imageability must go hand-in-hand with effective flood resilience measures to prevent it from becoming a source of devastation. A resilient city can better withstand climate impacts, ensuring the well-being of its population & Imageability contributes to a city’s identity, pride, and social cohesion.

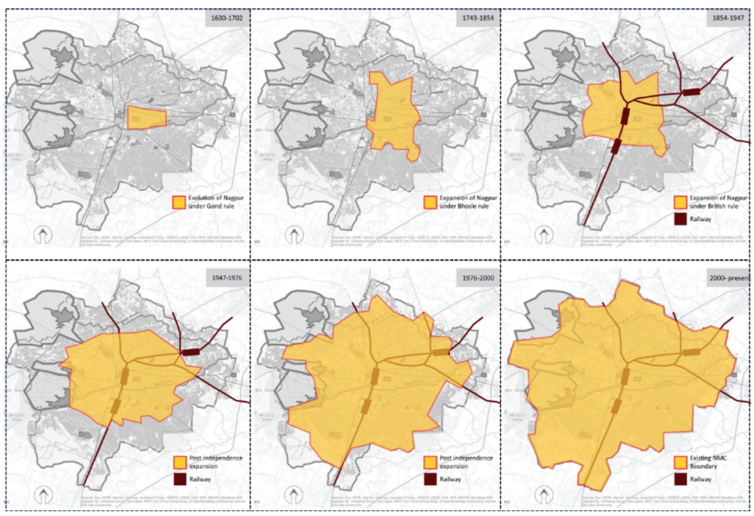
The conceptualization phase of re-imagining urban rivers in Nagpur involves five key steps. Step 1 includes a literature study on the history, significance, and profile of the city's water assets. Step 2 focuses on flood vulnerability mapping using the AHP



method, which serves as a base layer for identifying flood causes. Step 3 identifies the primary reasons for flooding in Nagpur. Step 4 assesses the potential and contribution of water bodies to the city's image through lake and river analysis, involving primary and secondary data. Step 5 formulates holistic strategies and proposals that integrate resilience and imageability, based on Kevin Lynch's theory and citizen perception.

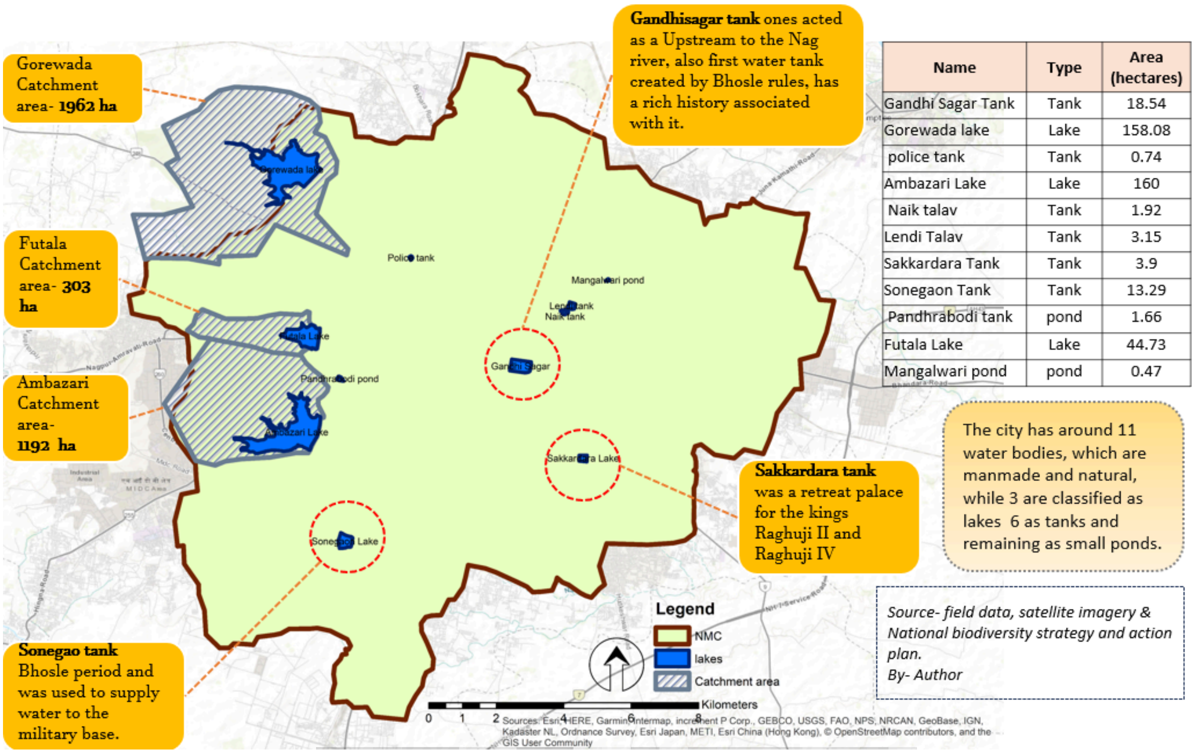
II. MAPPING THE ECOSYSTEM OF NAGPUR

The Nag River has been integral to Nagpur's history, providing water for agriculture, trade, and urban settlement. Various rulers and administrations recognized the importance of managing water resources, leading to the construction of dams, reservoirs, and artificial lakes These efforts aimed to regulate the flow of the Nag River and ensure a steady water supply for the growing population Notable water bodies in Nagpur include Ambazari Lake, Futala Lake, and Gorewada Lake, each with its own unique history and significance. These water bodies serve practical needs like irrigation and daily water supply, while also functioning as recreational spaces and landmarks within the city.



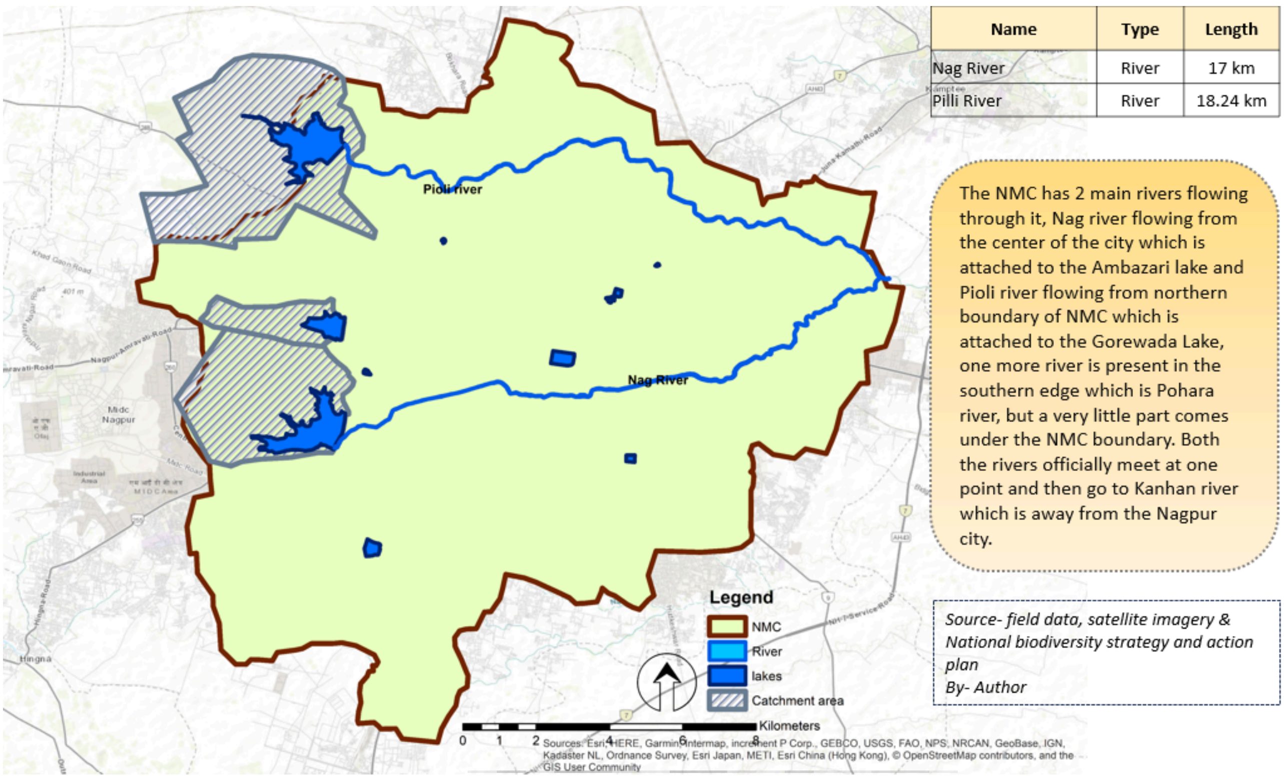
The city has around 11 water bodies, which are manmade and natural, while 3 are classified as lakes 6 as tanks and remaining

as small ponds.
3 lakes have its own catchment areas, these lakes were natural lakes formed due to geographical conditions and further were dammed and made as water reservoirs by the Bhosle kings before 300 years ago, the water was utilized for drinking and other day to day use.



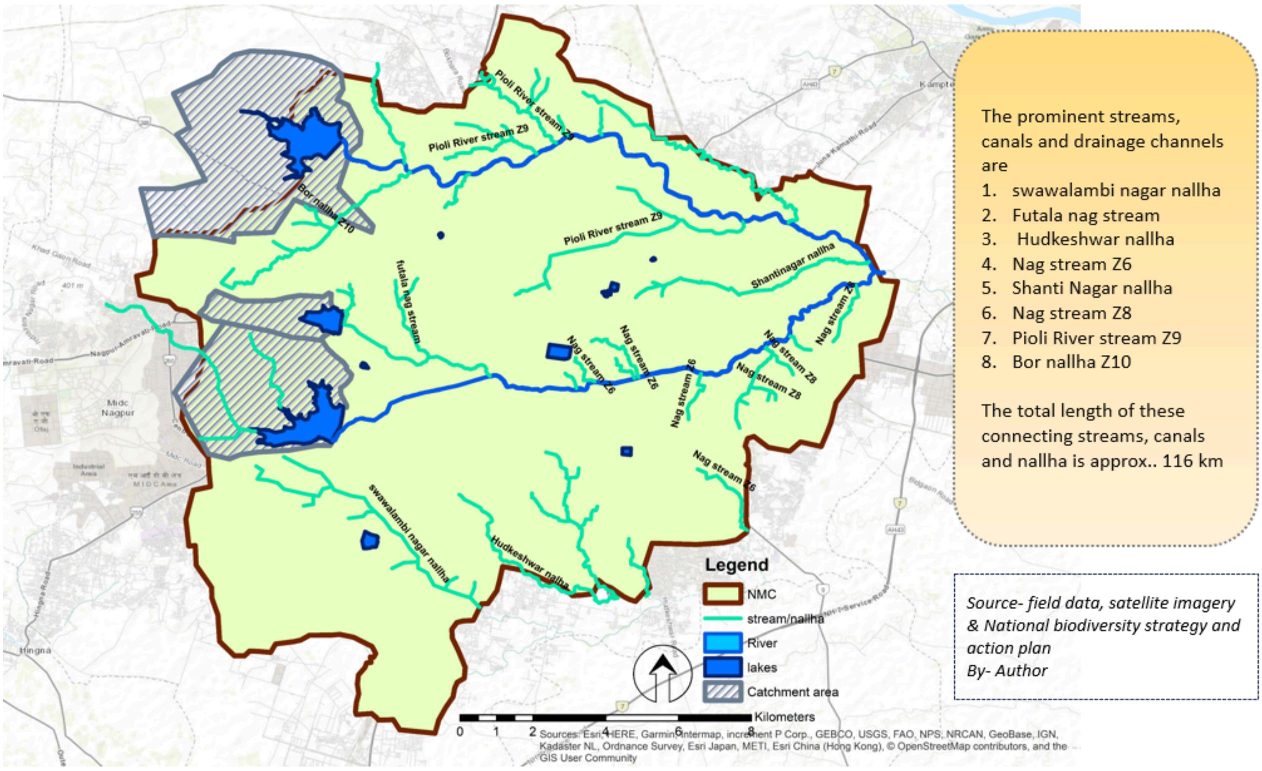
Name	Type	Area (hectares)
Gandhi Sagar Tank	Tank	18.54
Gorewada lake	Lake	158.08
police tank	Tank	0.74
Ambazari Lake	Lake	160
Naik talav	Tank	1.92
Lendi Talav	Tank	3.15
Sakkardara Tank	Tank	3.9
Sonegaon Tank	Tank	13.29
Pandhrabodi tank	pond	1.66
Futala Lake	Lake	44.73
Mangalwari pond	pond	0.47

The city has 2 main rivers flowing through it, Nag River flowing from the center of the city which is attached to the Ambazari lake and Pioli river flowing from northern boundary of NMC which is attached to the Futala Lake, one more river is present in the southern edge which is Pohara river, but a very little part comes under the NMC boundary. Both the rivers officially meet at one point and then go to Kanhan river which is away from the Nagpur city.

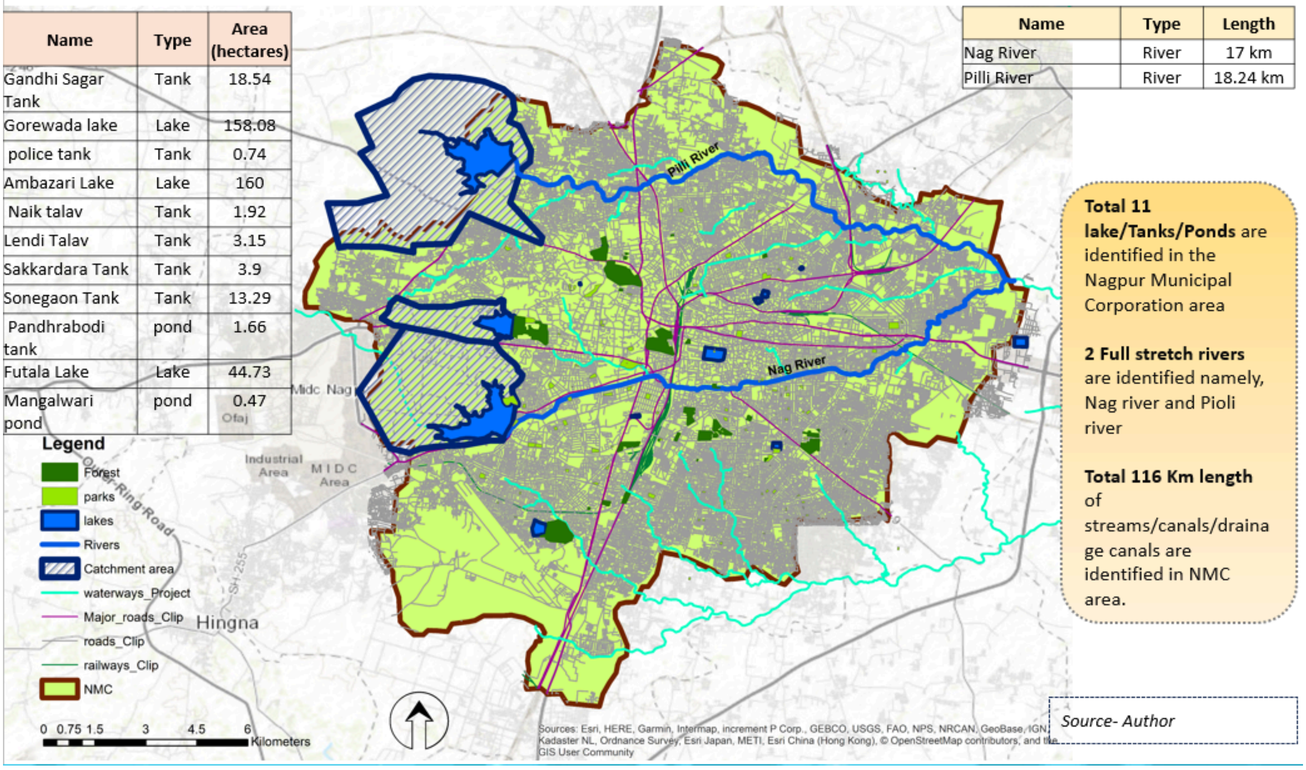


Name	Type	Length
Nag River	River	17 km
Pilli River	River	18.24 km

The prominent streams, canals and drainage channels are Swawalambi nagar nallha, Futala nag stream, Hudkeshwar nallha, Nag stream Z6, Shanti Nagar nallha, Nag stream Z8, Pioli River stream Z9, Bor nallha Z10, The total length of these connecting streams, canals and nallha is approx. 116 km.



Map 6- Streams Canals of Nagpur



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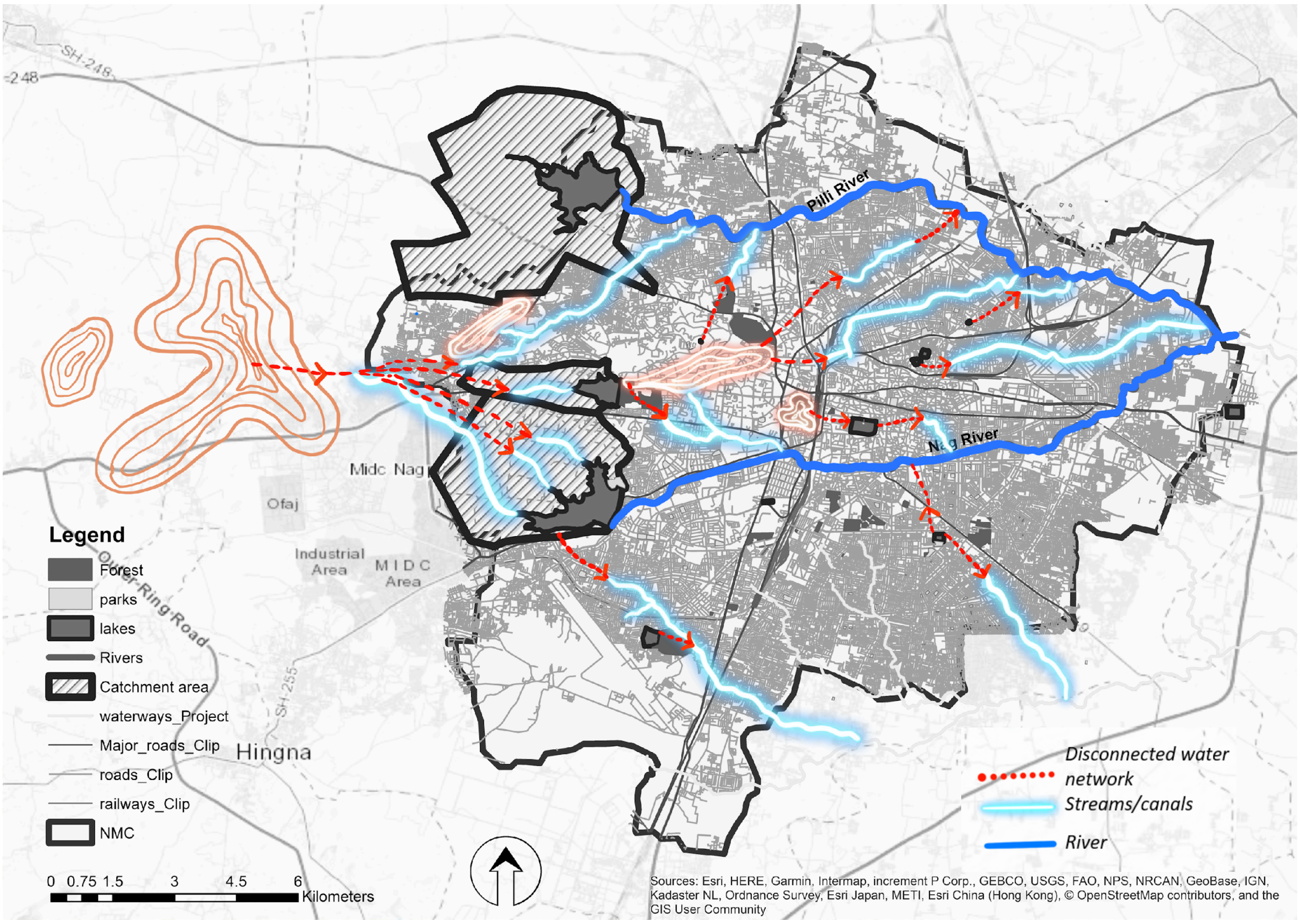
Map 7- Water assets of Nagpur

The rivers and lakes in Nagpur are interconnected due to their common origin, Ambazari and Gorewada lakes. Despite originating from the same source, the Nag and Pioli rivers are considered separate due to strategic damming. Overflow channels from tanks like Gandhisagar, Futala, and Sakkardara were strategically placed to feed Nag River and prevent flooding. These water assets, built by the Bhosle's 300 years ago, hold historical, religious, cultural, and social significance, evident in the heritage structures surrounding them.



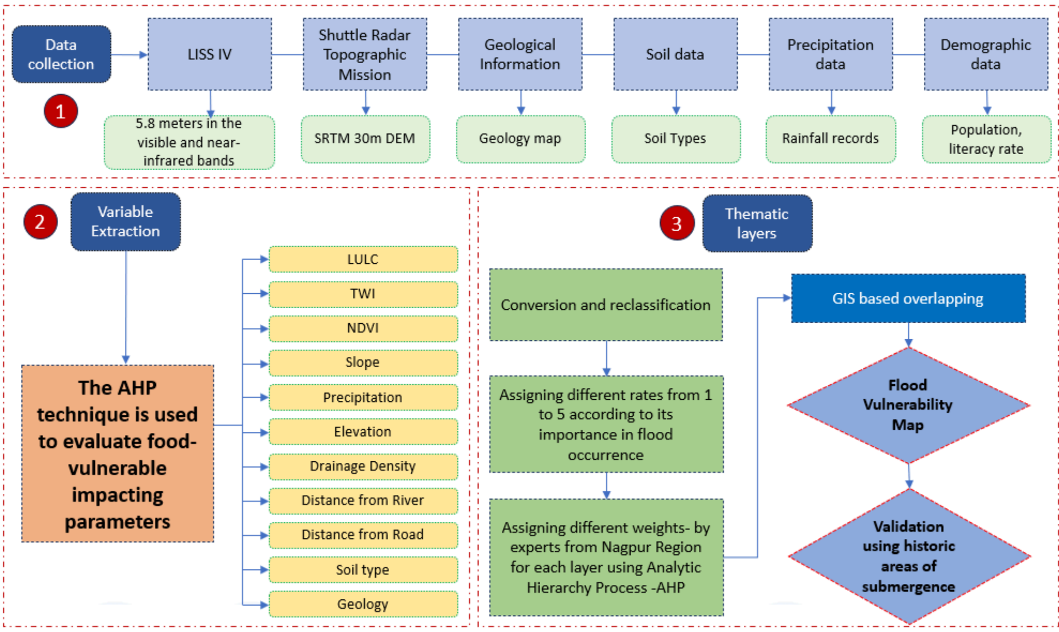
III. FLOOD VULNERABILITY MAPPING

The Analytic Hierarchy Process (AHP) is a multi-criteria decision-making method used to assign different weights to each thematic layer based on their relative importance in flood vulnerability (Saaty, 2008). The AHP involves the following steps:

a) Pairwise comparison: The thematic layers are compared pairwise to determine their relative importance using a scale of 1 to 9, where 1 represents equal importance and 9 represents extreme importance (Hoque et al., 2017). A pairwise comparison matrix is constructed based on expert knowledge and literature review (Morales & de Vries, 2021).
b) Consistency check: The consistency of the pairwise comparisons are checked using the consistency ratio (CR). A CR value of less than 0.1 indicates that the comparisons are consistent and acceptable (Yeboah Nyamah et al., n.d.).
c) Weight calculation: The weights of the thematic layers are calculated using the eigenvector method (Saaty, 2003). The eigenvector represents the relative importance of each layer in the pairwise comparison matrix.
The methodology is divided into 3 major parts,
Data collection, Variable extraction and Thematic layering, after which we will be doing a SWOT analysis based on the risk factor of the different parts of the city.

Data Collection
This study uses diverse data sources to develop a flood vulnerability map for Nagpur, India:

- **LISS-IV Satellite Imagery**: High-resolution (5.8m) multispectral images from ISRO's Resourcesat-2, used for land cover and NDVI calculations (NRSC, 2021).
- **SRTM Data**: Global DEM with 30m resolution from NASA, utilized for extracting topographic parameters like elevation, slope, and drainage density (NASA, 2021).
- **Geological Information**: Maps and data from the Geological Survey of India (GSI), essential for assessing lithology, infiltration capacity, and flood vulnerability (GSI, 2021).
- **Soil Data**: Acquired from the National Bureau of Soil Survey and Land Use Planning (NBSS&LUP) to characterize soil types and hydraulic properties (NBSS&LUP, 2021).
- **Precipitation Data**: 30 years (1990-2020) of daily rainfall data from IMD and satellite-derived estimates from the GPM mission (IMD, 2021; NASA, 2021).



Data Preprocessing and Preparation

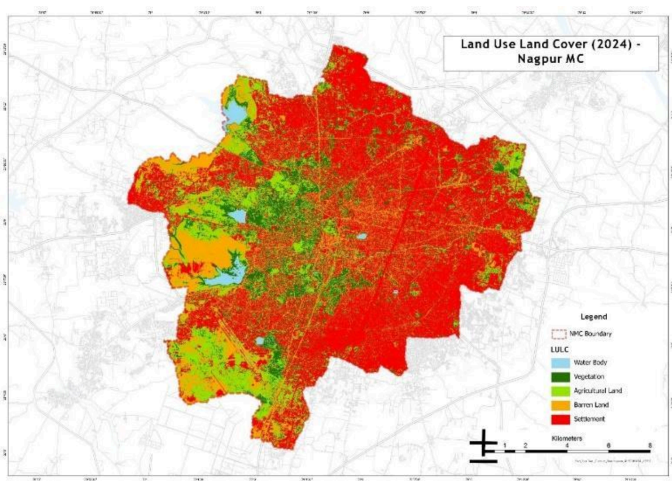
Data preprocessing involves:

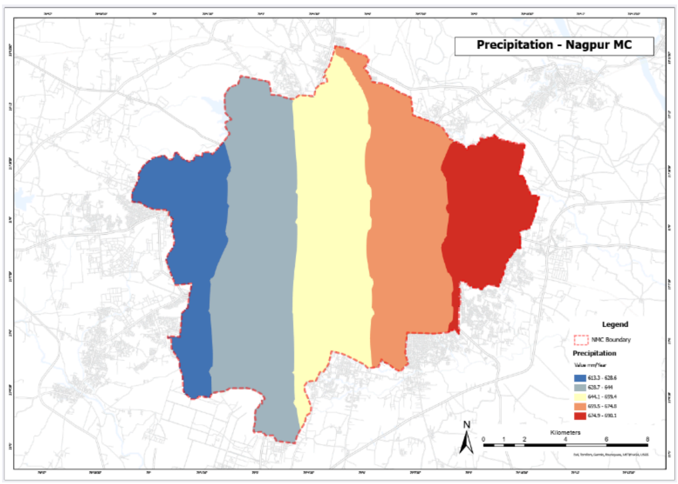
- **Geometric Correction**: Aligning LISS-IV imagery and SRTM DEM using GCPs.
- **Radiometric Correction**: Converting DNs to surface reflectance values using the FLAASH algorithm.
- **Image Mosaicking and Sub setting**: Ensuring datasets cover the study area with consistent spatial extent.
- **Data Harmonization**: Standardizing datasets to UTM Zone 44N, WGS84, and 5.8m resolution.
- **Quality Assessment**: Visual and statistical analysis to ensure data quality.

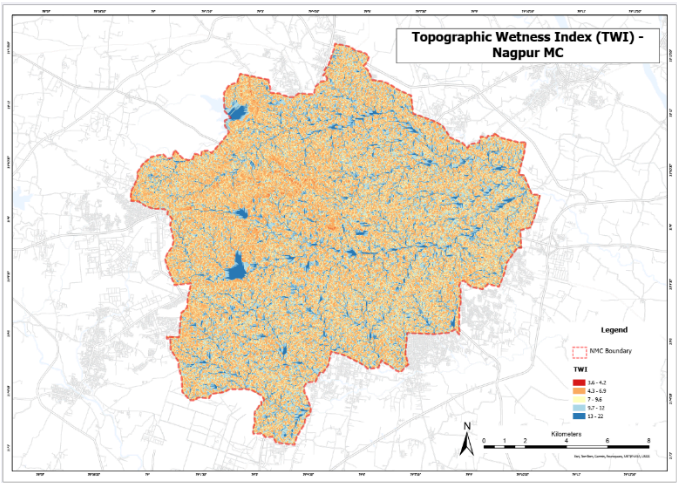
Variable Extraction

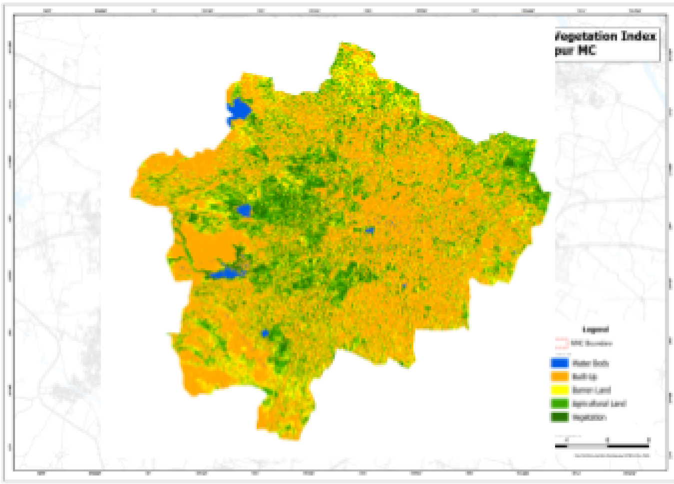
Indicators derived from preprocessed data include:

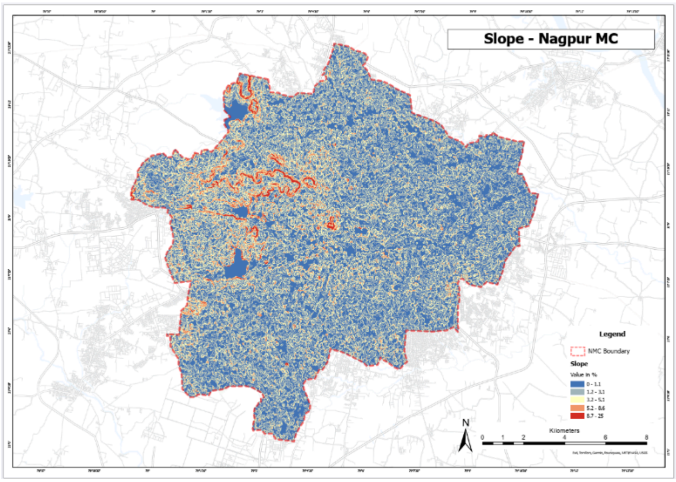
- **Land Cover**: Derived using OBIA and SVM classification to understand surface roughness and flood vulnerability.
- **Topographic Wetness Index (TWI)**: Measures potential water accumulation using the formula TWI=ln(a/tanβ)\text{TWI} = \ln (a / \tan \beta)TWI=ln(a/tanβ).
- **NDVI**: Calculated from LISS-IV imagery to assess vegetation density and its impact on runoff.
- **Slope**: Derived from SRTM DEM to determine surface runoff velocity.
- **Precipitation**: Characterized using IMD and GPM data for average annual rainfall and intensity.
- **Elevation**: Categorized from SRTM DEM to assess flood vulnerability.
- **Drainage Density**: Calculated from the stream network to understand runoff potential.
- **Distance from River**: Assessed using Euclidean distance to gauge proximity to water bodies.
- **Distance from Road**: Calculated to understand the impact of road infrastructure on flooding.
- **Soil Type**: Reclassified based on hydraulic properties from NBSS&LUP maps.
- **Geology**: Categorized based on permeability and water-holding capacity from GSI maps.

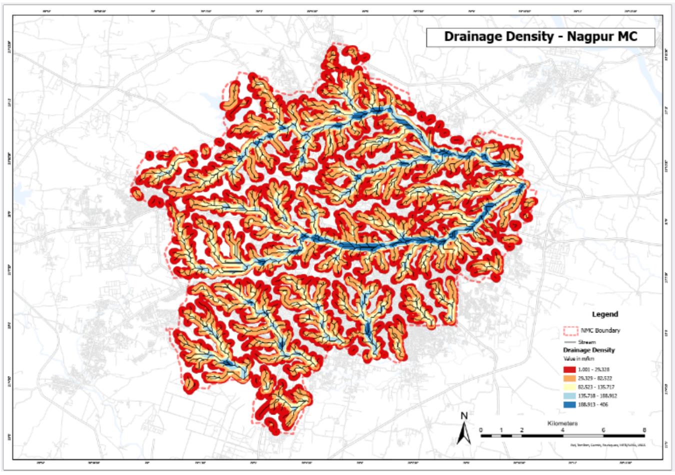


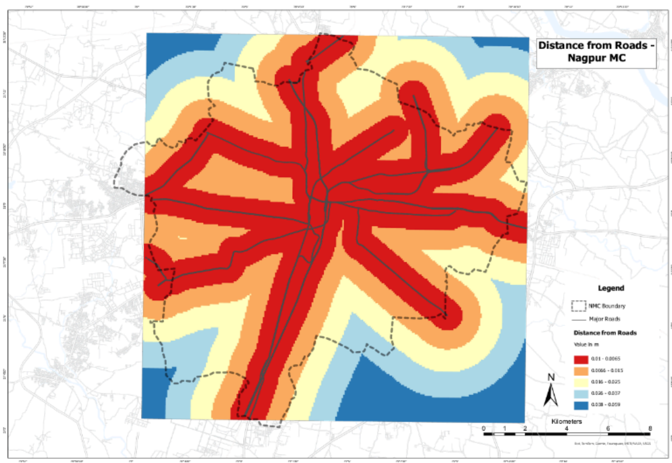


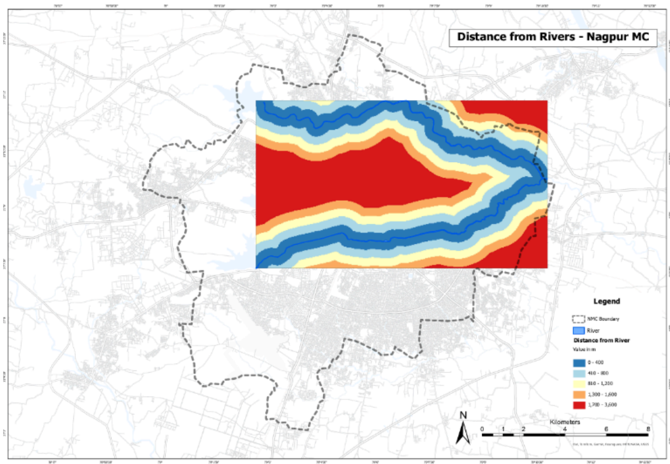

Topographic Wetness Index (TWI) - Nagpur MC
Legend
NMC Boundary
TWI
3.6 - 4.2
4.3 - 6.9
7 - 9.6
9.7 - 12
13 - 22
N
Kilometers
0 1 2 4 6 8

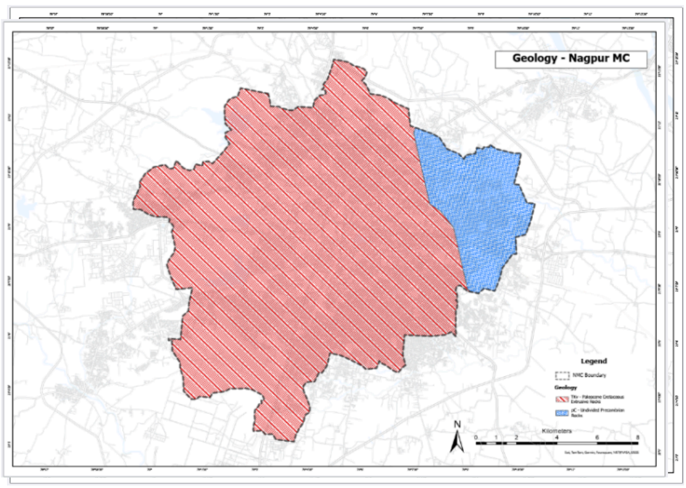


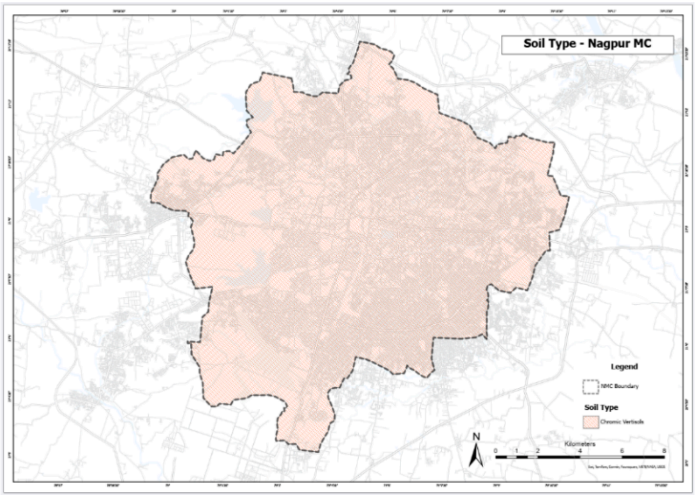

Slope - Nagpur MC
Legend
NMC Boundary
Slope
Value in %
0 - 1.1
1.2 - 3.1
3.2 - 5.1
5.2 - 8.6
8.7 - 25
N
Kilometers
0 1 2 4 6 8


Drainage Density - Nagpur MC
Legend
NMC Boundary
Stream
Drainage Density
Value in m/km
1.001 - 29.328
29.329 - 82.522
82.523 - 135.717
135.718 - 188.912
188.913 - 406
N
Kilometers
0 1 2 4 6 8


Distance from Roads - Nagpur MC
Legend
NMC Boundary
Major Roads
Distance from Roads
Value in m
0.01 - 0.0065
0.0066 - 0.015
0.016 - 0.025
0.026 - 0.037
0.038 - 0.059
N
Kilometers
0 1 2 4 6 8


Distance from Rivers - Nagpur MC
Legend
NMC Boundary
River
Distance from River
Value in m
0 - 400
410 - 800
810 - 1,200
1,300 - 1,600
1,700 - 3,600
N
Kilometers
0 1 2 4 6 8


Geology - Nagpur MC
Legend
NMC Boundary
Geology
TKv - Paleocene Cretaceous Extrusive Rocks
pC - Undivided Precambrian Rocks
N
Kilometers
0 1 2 4 6 8



Thematic Layering

Conversion and Reclassification

- **Thematic Layers**: Converted into intervals or categories based on their flood vulnerability influence.
- **Rates Assignment**: Each class in thematic layers is rated from 1 to 5 based on its importance in flood occurrence, using expert knowledge and literature review. For example, built-up areas may receive a rate of 5, while forests may receive a rate of 1 (Seejata et al., 2018; Das, 2018).

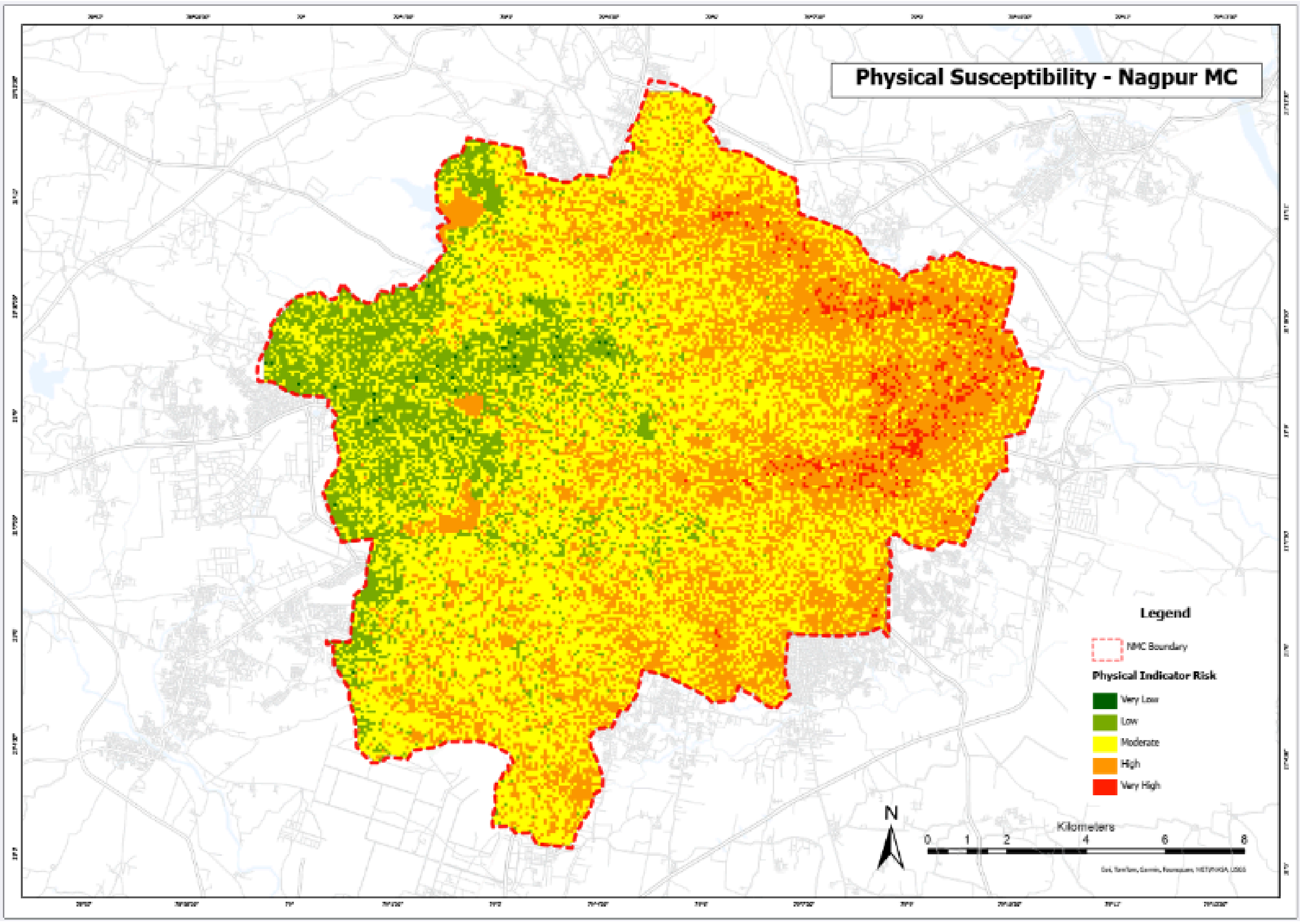
To create a flood vulnerability map for Nagpur, the Analytic Hierarchy Process (AHP) was employed to weight 11 indicators, based on the input from 9 experts familiar with Nagpur's geography and hydrology, including two from other cities. The process began with the finalization of indicators for assessing flood vulnerability, followed by the development of a detailed survey form tailored to Nagpur's specific context and flood history. Experts were identified and contacted through phone, social media, and personal visits to solicit their participation. The survey form, designed using Google Forms, was then circulated among the experts, who used Saaty's scale to prioritize the identified indicators. This structured approach ensured that the expert opinions were crucial in assigning weights to each indicator, providing a comprehensive and informed approach to flood vulnerability mapping.

The expert panel comprised individuals with extensive and diverse experience in urban planning, hydrology, and related fields. Among them were an Associate Professor in Urban Planning with 25 years of experience in GIS and Remote Sensing, a town planner at NMC with 8 years of expertise in technology, a practicing consultant and advanced GIS expert with 6 years of experience, a practicing urban designer with 11 years of experience, and a hydrology expert with 10 years of experience. Additionally, the panel included an Associate Professor in Architecture and Planning, an expert in structures with 22 years of experience, an architect and planner with 9 years of experience, a PhD holder in Architecture and Planning with 19 years of expertise in hydrology and GIS, and the NMC Hydrology Head with 30 years of experience. The diverse and experienced panel ensured a well-rounded and expert-informed assessment of flood vulnerability in Nagpur. The AHP-derived weights were used to combine the thematic layers and generate physical vulnerability maps. The consistency ratio of the expert judgments was 2.4%, indicating a high reliability of the results.

Matrix		TWI 1	Elevation 2	Slope 3	Precipitation 4	LULC 5	NDVI 6	Distance from river 7	Distance from road 8	Drainage density 9	Soil type 10	Normalized Principal Eigenvector
TWI	1	1	8/9	7/8	1 2/7	1 2/5	4/5	1 1/6	1	1	1	10.09%
Elevation	2	1 1/9	1	3 1/4	5/7	1 2/5	1	1 2/7	1	1	1	12.52%
Slope	3	1 1/7	1/3	1	1 8/9	1 1/6	1 4/5	1	4/5	1	1	10.59%
Precipitation	4	7/9	1 2/5	1/2	1	1	4/5	1 4/5	1 1/3	1	1	10.39%
LULC	5	5/7	5/7	6/7	1	1	1 1/5	1	7/8	1	1	9.69%
NDVI	6	1 1/4	1	5/9	1 1/4	5/6	1	3/4	1 1/9	1	1	9.41%
Distance from river	7	6/7	7/9	1	5/9	1	1 1/3	1	1	1	1	9.12%
Distance from road	8	1	1	1 1/4	3/4	1 1/7	1	1	1	1	1	9.59%
Drainage density	9	1	1	1	1	1	1	1	1	1	1	9.69%
Soil type	10	1	1	1	1	1	1	1	1	1	1	8.90%

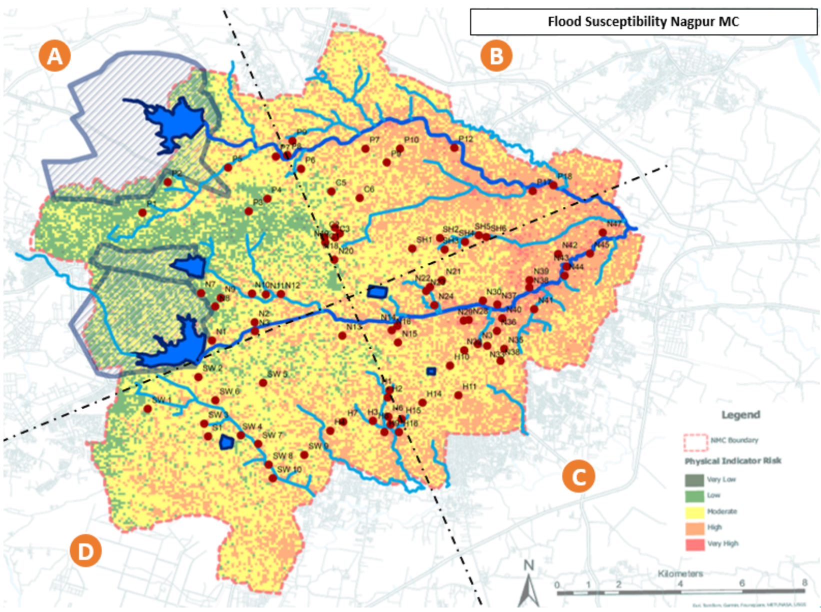
Output – Flood Vulnerability map for Nagpur City

Very Low Risk (Green areas): These zones are characterized by stable geological conditions with minimal susceptibility to physical disruptions like landslides, subsidence, or seismic activities.
Low to Moderate Risk (Yellow to Orange areas): Represent regions with moderate geological and environmental stability. While not immediately hazardous, these areas may require careful monitoring and preventive measures to manage potential risks.
High to Very High Risk (Red areas): Indicate critical regions with significant potential for physical disturbances. These areas are often characterized by complex geological structures, such



Validation using historic areas of submergence

The validation of the flood susceptibility map for Nagpur, produced using AHP and GIS, was conducted using historical flood data and points of submergence obtained from the Nagpur Municipal Corporation. The Corporation's disaster management report 2023 identified 89 submergence points across Nagpur's 10 zones. These points were overlaid onto the flood susceptibility map, allowing for visual analysis of their concentration. This approach effectively validated the map by correlating high-susceptibility areas with historical submergence points, ensuring its accuracy and reliability.



SWOT Analysis

Strengths

- The presence of significant catchment areas
- Low population density and better infrastructure
- Starting point of Nag & Pioli River
- D. Ongoing MIHAN development
- D. Presence of Sonegao catchment area

Weaknesses

- Encroachment and solid construction on the river and its stream
- B & C. High density of buildings and population
- B & C. Degradation of natural habitats
- D. The susceptibility of critical infrastructure

Opportunities

- Presence of dams
- D. Incorporating flood risk into airport planning
- B & C. Opportunity for effective community education and awareness campaigns
- B & C. Leveraging the river stretches, there is an opportunity to implement integrated water management solutions

Threats

- Breakage of dams
- Aging of infrastructure
- B & C. Existing socio-economic disparities
- D. Airport disruptions from floods
- Increasing frequency and intensity of extreme weather events due to climate change

Major reasons for flooding

- Encroachment along the river and corresponding streams.
- Legalized construction over the river.
- Narrow width of river from the starting point.
- Absence of riparian buffer along the river stretch.
- Presence of Slums on critical stretches of river.
- Sewage disposal in canals, streams and river directly.
- Weak abetment walls along the river stretch
- Loss of natural connectivity of water channels
- Increased impervious surface
- Construction on the water bodies (garden & fountain)

IV. LAKE ANALYSIS

Derived from various Literature studies on lake and its relation with floods 10 parameters were chosen to scale the lakes in Nagpur. The 10 parameters are as follows-

Sr No.	Analysis Parameters (Flooding Issues)	Likert Scale (1-3-5)	Justification
1	**Water Quality**		Assess the presence of contaminants, pH levels, turbidity.
		1 - Poor	Significant contamination, poor water quality.
		3 - Fair	Acceptable water quality, some minor issues.
		5 - Excellent	Excellent water quality, no significant contaminants.
2	**Presence of Catchment Area**		Assess the extent and definition of the catchment area.
		1 - None	No significant catchment area.
		3 - Moderate	Moderately defined catchment area.
		5 - Extensive	Well-defined and extensive catchment area.

3	**Catchment Health**		Assess vegetation and land management in the catchment.
		1 - Poor	Degraded vegetation, poor land management.
		3 - Fair	Acceptable vegetation and land management.
		5 - Excellent	Dense vegetation, excellent land management.
4	**Water Presence**		Determine the lake's seasonal water presence.
		1 - Intermittent	Water present only during the rainy season.
		3 - Seasonal	Water present reliably during specific seasons.
		5 - Perennial	Water present all year round.
5	**Connection to River or Major Stream**		Assess the connection to natural watercourses.
		1 - None	No connection to rivers or streams.
		3 - Moderate	Some connection to streams or minor rivers.
		5 - Excellent	Highly connected to major river systems.
6	**Water Storage Capacity**		Assess the volume of water the lake can store.
		1 - Low	Limited capacity to store water.
		3 - Moderate	Reasonable capacity to store water.
		5 - High	Large capacity to store significant water volumes.
7	**Riparian Vegetation & Buffer Zones**		Assess vegetation and buffer zones around the lake.
		1 - Poor	No significant vegetation or buffer zones.
		3 - Fair	Some vegetation and buffer zones.
		5 - Excellent	Dense, high-quality vegetation and effective buffer zones.
8	**Health of Feeder Streams**		Assess the quality of water entering the lake.
		1 - Poor	Highly polluted or non-existent feeder streams.
		3 - Fair	Moderately clean feeder streams.
		5 - Excellent	Very clean feeder streams with no significant pollution.
9	**Overflow Management & Infrastructure**		Assess the effectiveness of overflow systems.
		1 - Poor	Ineffective or non-existent overflow management.
		3 - Fair	Acceptable overflow management with some issues.
		5 - Excellent	Highly effective overflow management systems.
10	**Encroachment**		Assess the extent of encroachment on lake areas.
		1 - High	Significant encroachment affecting lake area.
		3 - Moderate	Some encroachment with limited impact.
		5 - None	No encroachment, lake area fully preserved.

Result of Lake Analysis

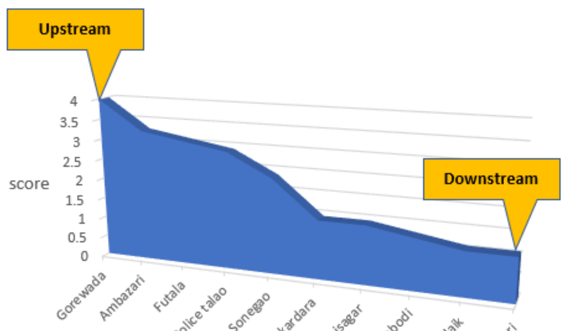
*Table SEQ Table * ARABIC 39- Summary table for lake analysis*

sr.no.	Lake/tank/pond	score
1	Gorewada	4
2	Ambazari	3.27
3	Futala	3.09
4	Police talav	2.91
5	Sonegao	2.36
6	Sakkardara	1.45
7	Gandhisagar	1.45
8	Pandhrabodi	1.27
9	[illegible]	[illegible]

High Potential for Flood Resilience (Scores ≥ 3.5)

Moderate Potential for Flood Resilience (Scores 2.5 - 3.5)

Low Potential for Flood



Major Gaps Identified

- **Overflow Management**: Most lakes have poor or inadequate overflow management systems.
- **Catchment Health**: Many lakes have unhealthy catchment areas, impacting water quality and flood resilience.
- **Feeder Stream Health**: Feeder streams are often polluted or degraded, reducing their effectiveness in supporting lake health.
- **Riparian Vegetation**: Inadequate vegetation around many lakes affects their ability to absorb and manage floodwaters.
- **Encroachment**: Significant encroachment issues affecting lakes, particularly Gandhisagar and Lendi & Naik.

V. IMAGEABILITY ANALYSIS

Water plays a crucial role in shaping the image of a city, supported by several proven theories that highlight its multifaceted benefits. Jay Appleton's Prospect-Refuge Theory (1975) explains that water bodies offer ex-pansive views (prospect) and sheltered areas (refuge), making them psychologically appealing. This is com-plemented by Rachel and Stephen Kaplan's Attention Restoration Theory (1980s), which suggests that nat-ural environments, including water features, help restore directed attention and reduce mental fatigue, en-hancing cognitive functioning. E.O. Wilson's Biophilia Hypothesis (1984) further supports the idea that humans have an innate tendency to seek connections with nature, making water a particularly attractive element in urban settings. Additionally, the Kaplans' Preference Matrix (1989) indicates that water bodies contribute to environmental coherence, legibility, complexity, and mystery, making them preferred ele-ments in urban landscapes.
Designing imageable cities with water using Kevin Lynch's (1960) theory of Imageability involves creating urban environments that are easily understood and remembered by their inhabitants and visitors. Lynch identified five key elements that contribute to a city's imageability: paths, edges, districts, nodes, and landmarks. Incorporating water into these elements can significantly enhance the city's legibility and aesthetic appeal.

Sr. No.	Analysis parameters (Flooding issues)	Ambazari	Futala	Gorewada	Sonegao	Sakkardara	Lendi & Naik	Pandhrabodi	Mangalwari	Police talav	Gandhisagar
1	**Paths**	5	5	3	5	5	3	3	3	3	5
2	**Edges**	5	5	5	5	5	3	3	3	5	5
3	**District**	5	5	3	3	3	1	3	1	3	5
4	**Nodes**	5	5	3	3	3	1	1	1	1	3
5	**Landmarks**	5	5	5	3	3	3	1	1	3	5
6	**Identity**	5	5	5	1	1	1	1	1	1	3
7	**Structure**	3	3	3	3	3	1	1	1	3	5
8	**Meaning**	5	3	3	3	3	3	3	3	3	5
Total		38	36	30	26	26	16	16	14	22	36
Score		**4.75**	**4.5**	**3.75**	**3.25**	**3.25**	**2**	**2**	**1.75**	**2.75**	**4.5**

Citizen Survey

For this thesis, the author conducted a perception survey with a sample size of 273 respondents, ensuring a 90% confidence level and a 5% margin of error. The survey employed a simple random sampling method, gathering samples from various public spaces such as markets, malls, parks, water bodies, and residential colonies both near and far from the area of interest. The survey was administered in two modes: offline and online via Google Forms (Appendix II). It was divided into two parts: the first part involved verbal interviews where cognitive mapping was conducted, and the second part required respondents to fill out the Google Form, providing specific information about particular water bodies and other necessary details.
Cognitive mapping results
During the cognitive mapping process, which involved creating a mental representation of one's surroundings, three main questions were posed, each related to different elements: mappability, identifiability, and attachment. The questions were as follows:

Mappability: "What are the city features that come to your mind when you think of the city?"
Identifiability: "If you can take five pictures of the city to describe it to someone who has never been to the city, what will they be?"
Attachment: "What are the five things about the physical environment you will miss if you have to leave the city tomorrow?"
Participants were not specifically prompted to think about water bodies in their responses. Instead, they were asked to focus on the physical environment in general. After collecting the responses, I analyzed how often water bodies were mentioned. The water assets were categorized as lake, river, tank, canal, and stream, and responses were further divided according to the three recall protocols: mappability, identifiability, and attachment.

Primary Questions:

Question 1: "Which water bodies have you visited in Nagpur so far?" This question aimed to identify the water bodies that people have seen or visited.

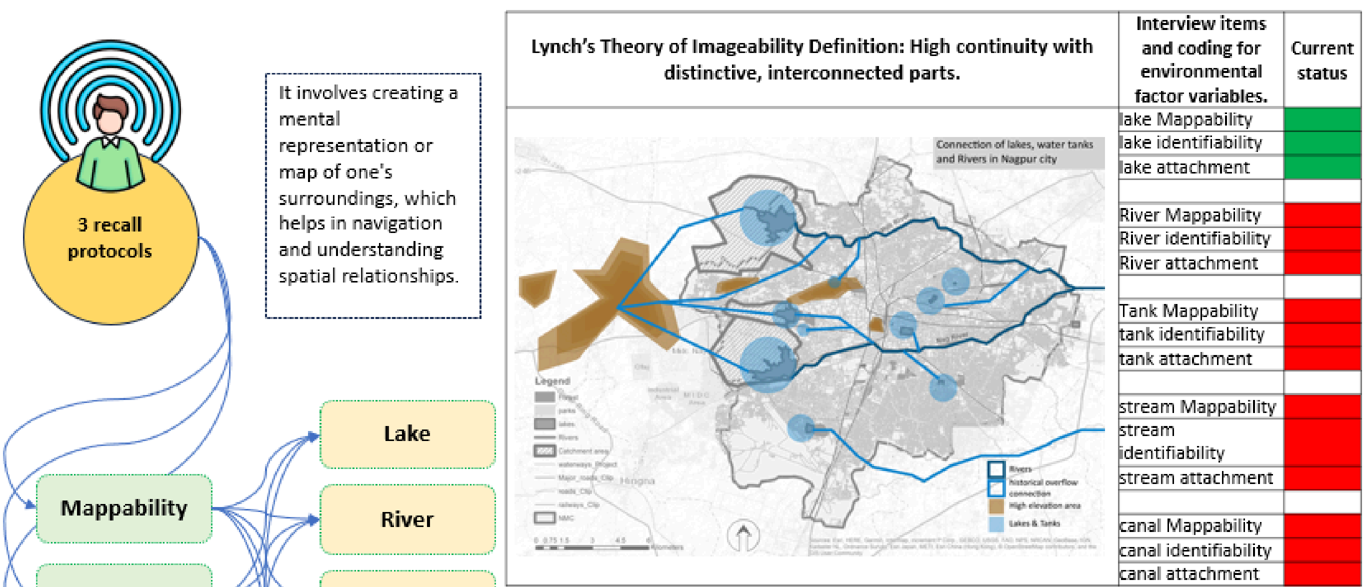
Question 2: "Which water body do you wish to visit in Nagpur city?" This question sought to understand the water bodies people desire to visit in the future.

Question 3: "Which water body would you not prefer visiting in Nagpur city?" This question aimed to identify the water bodies people avoid or have no interest in visiting.

Purpose of the Questions:

To assess people's perception of specific water bodies in Nagpur.
To determine which water bodies, have a positive image and are preferred by people.
To identify water bodies that are unrecognized, unvisited, or have a negative image.

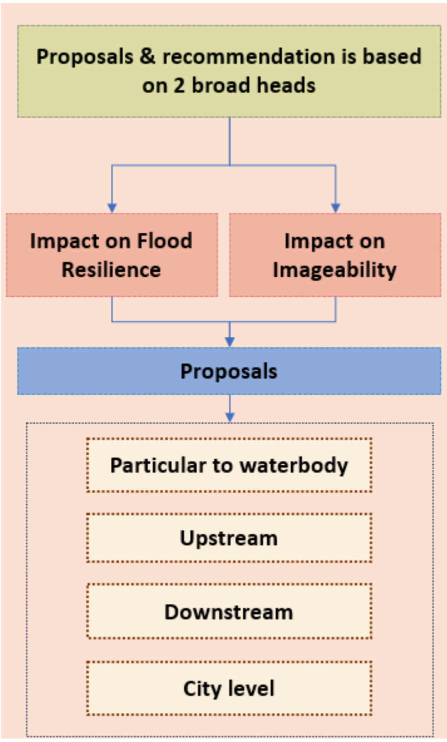
The results of the cognitive mapping revealed a significant finding: only lakes were consistently mentioned in terms of mappability, identifiability, and attachment. Rivers, tanks, streams, and canals were not mentioned at all in response to the three primary questions. This indicates a substantial gap in the perception of water bodies,
suggesting that people either cannot imagine or do not wish to recall water assets other than the primary lakes within the city. This was the key outcome of the cognitive mapping exercise. Figure 33 represents the mapping output.



Major gaps identified

The results of the cognitive mapping and perception surveys indicate a significant gap in the recognition and imagability of Nagpur's water bodies, with only primary lakes like Ambazari and Futala frequently mentioned. Most other water assets, including rivers, tanks, streams, and canals, are rarely thought about or visited by the residents. This finding highlights the need to enhance the visibility and appeal of these lesser-known water bodies to improve the overall imagability of Nagpur.

VI. PROPOSALS & RECOMMENDATIONS



The way forward for the thesis involves structuring proposals and recommendations based on two broad categories: impact on flood resilience and impact on imageability. These proposals will be divided into five parts:

Specific to a Water Body:

Proposals and interventions tailored to individual water bodies, addressing their unique challenges and potentials.

Upstream:

Strategies focusing on the upstream areas to manage water flow, prevent pollution, and enhance the ecological health of the entire watershed.

Downstream:

Recommendations aimed at improving the conditions and resilience of downstream areas, including flood management and habitat restoration.

City Level:

City-wide initiatives to integrate water bodies into the urban fabric, enhance accessibility, and promote sustainable urban water management practices.

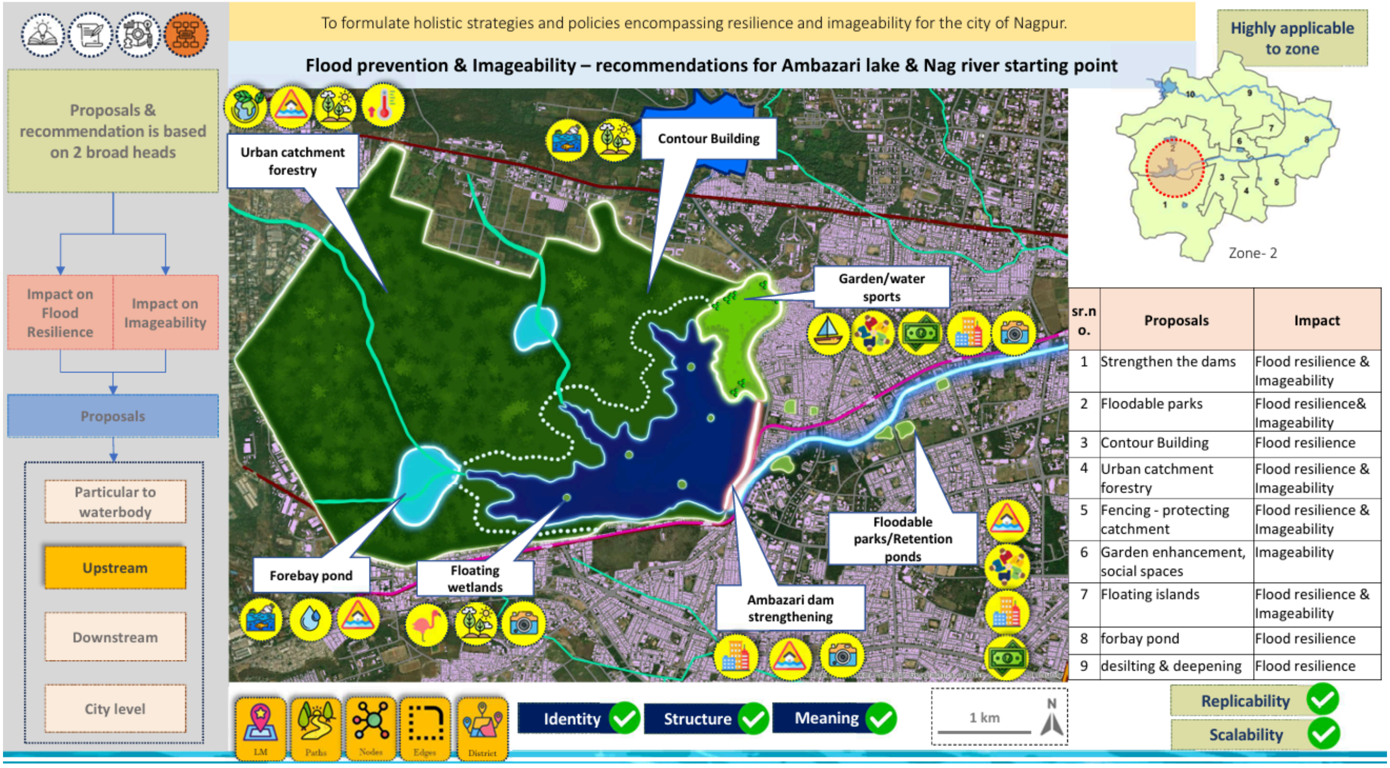
Proposal 1- Priority Function Classification of Lakes

Priority Function Classification of Lakes

Lake/Tank	Flood prevention	Cultural Recreational	Modern recreation	Economy generation	Unique identity	Catchment restoration	River flow management	Water supply	Ecosystem support	Convert to retention ponds (Increase water holding capacity)	Current water holding capacity (Million metric cube)
Gorewada lake	✓			✓	✓	✓	✓	✓	✓		8.82
Ambazari lake	✓		✓	✓		✓	✓		✓		7.54
Futala lake			✓	✓	✓		✓		✓		1.7
Gandhisagar tank	✓	✓		✓			✓		✓		0.6
Sonegao tank	✓		✓	✓	✓	✓		✓	✓		0.4
Lendi & Naik tank	✓		✓	✓					✓	✓	0.15
Sakkardara tank		✓		✓	✓				✓		0.07

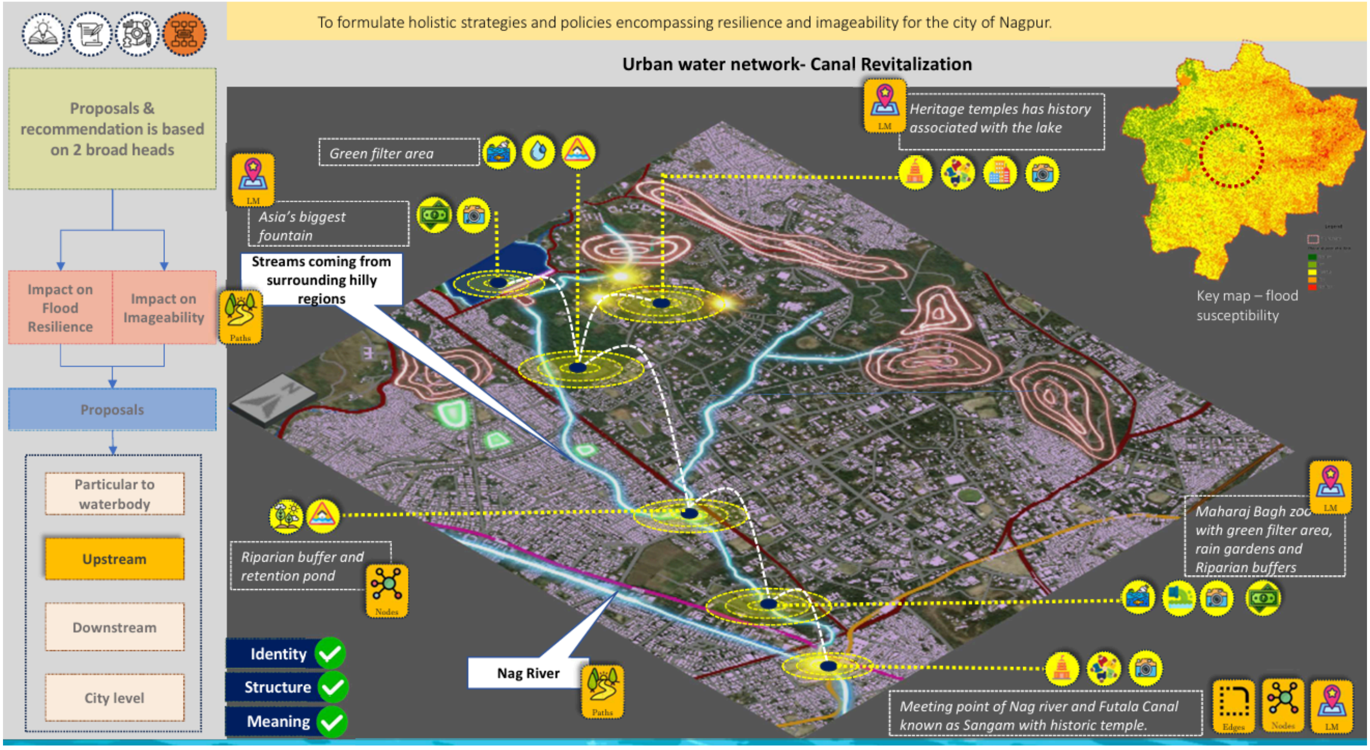
This proposal focuses on the priority function classification of lakes in Nagpur. This involves a comprehensive analysis of all 11 lakes within the city, assessing their potential to contribute to flood resilience and urban imageability. The analysis considers various parameters, such as the lakes' capacity to manage floodwaters, their ecological significance, and their role in enhancing the visual and recreational appeal of the urban landscape. Based on this evaluation, each lake is assigned a priority level, highlighting those that should be prioritized for conservation and development efforts to maximize their benefits for flood management and urban aesthetics. This classification aims to guide strategic interventions, ensuring resources are allocated effectively to the most impactful water bodies.

Proposal 2- Flood prevention & Imageability – Recommendations for Ambazari lake & Nag river



This proposal focuses on flood prevention and imageability in the upstream areas of Ambazari Lake and Nag River. It includes urban catchment forestry to restore the degraded catchment, creation of forebay ponds, floating wetlands, contour bunding, garden and water sports areas, and strengthening the Ambazari dam. These measures aim to enhance flood resilience and imageability, creating landmarks and paths, and leveraging the river-lake meeting point as a significant node, thus forming a distinct district identity. Additionally, the proposal addresses urban heat islands, polluted water, biodiversity, green spaces, social and economic aspects, and public infrastructure, providing multiple co-benefits.

Proposal 3- Canal Revitalization



This proposal involves revitalizing the canal from Futala Lake to the Sangam point, featuring six key hotspots. The downhill temples will be restored, and a green filter area near the lake will filter rainwater, which will then be stored and transferred via Asia's largest fountain. Riparian buffers and retention ponds will be added along the canal, and the Maharaj Bagh zoo will incorporate rain gardens and green filter areas to manage overflow water. Finally, the historic temple at the Sangam point will be redeveloped. This proposal with various co-benifits enhances flood prevention and significantly boosts the city's imageability by creating a major attraction that integrates water and heritage management.

Proposal 4- Identification of Hotspots in Downstream

NAG RIVER

Scale	River width	major encrochments	Confluence points	Riparian buffer	Flood Vulnerability	Score
	LOW = 1	LOW=5	LOW=5	LOW = 1	LOW=5	
	MEDIUM = 3	MEDIUM=3	MEDIUM=3	MEDIUM = 3	MEDIUM=3	
	HIGH = 5	HIGH=1	HIGH=1	HIGH = 5	HIGH=1	
A	1	1	5	3	5	3
B	1	1	5	3	5	3
C	1	1	5	1	5	2.6
D	1	1	5	1	3	2.2
E	1	3	5	3	3	3
F	3	1	1	1	3	1.8
G	3	1	5	1	3	2.6
H	3	3	5	3	3	3.4
I	5	1	3	1	3	2.6
J	5	3	3	1	3	3
K	5	3	3	1	1	2.6
L	5	3	5	1	1	3
M	5	3	1	1	1	2.2
N	5	3	5	3	1	3.4
O	3	1	1	3	1	1.8
P	3	3	1	3	1	2.2
Q	3	1	5	1	1	2.2
R	3	1	1	1	1	1.4

PIOLI RIVER

Scale	River width	major encrochments	Confluence points	Riparian buffer	Flood Vulnerability	Score
	LOW = 1	LOW=5	LOW=5	LOW = 1	LOW=5	
	MEDIUM = 3	MEDIUM=3	MEDIUM=3	MEDIUM = 3	MEDIUM=3	
	HIGH = 5	HIGH=1	HIGH=1	HIGH = 5	HIGH=1	
A	1	3	5	3	5	3.4
B	1	3	1	1	5	2.2
C	1	1	1	1	5	1.8
D	3	1	5	1	3	2.6
E	3	1	1	1	3	1.8
F	3	3	5	3	3	3.4
G	3	1	1	3	3	2.2
H	3	1	1	3	3	2.2
I	5	3	1	1	1	2.2
J	5	3	5	3	3	3.8
K	3	1	5	3	3	3
L	3	1	5	3	3	3
M	3	1	5	3	1	2.6
N	3	3	1	3	1	2.2
O	3	3	3	3	1	2.6
P	3	5	1	5	1	3
Q	3	5	5	5	1	3.8
R	3	5	1	5	1	3

VII. CONCLUSION

Urbanization and the neglect of water bodies have caused significant losses, not just in terms of water resources but overall urban health. However, there is still hope. Properly managing and respecting the city's water bodies can help Nagpur escape the suffocation of mismanagement. Healthy waters are synonymous with a healthy city; otherwise, persistent issues will remain unresolved. The goal is to create a flood-resilient, secure, and visually captivating cityscape where water bodies are recognized

as lifelines and landmarks, enhancing the city's appeal and safeguarding its future.
This model, developed for Nagpur, is scalable and replicable for many other Indian cities, particularly tier-1 and tier-2 cities with similar urban river and lake scenarios. It is crucial to understand that while the original functions of water bodies were for water supply, irrigation, and basic human needs, their importance remains even though these needs are no longer directly fulfilled by them. Keeping water bodies alive is essential for the city's vitality.
This thesis aims to highlight the need for a holistic approach to planning and implementing strategies for managing urban water assets—whether rivers, lakes, connecting streams, or canals. These systems are interconnected, and their multifunctional potential must be properly utilized. By addressing issues such as flooding and imageability together, we can create proposals that offer various co-benefits. Integrating flood resilience with enhancing the visual and recreational appeal of water bodies leads to better proposals that not only mitigate flood risks but also improve urban aesthetics, increase property values, and provide social and economic benefits.
Due to urbanization, many issues have arisen, but there is still hope if we handle things carefully. This integrated approach ensures that water bodies continue to contribute to the city's health and sustainability, addressing the broader implications and multifunctional aspects associated with them.