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Rejuvenation Stratgeis for Water Bodies in Raipur

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Abstract

The shrinking of water bodies is a significant environmental concern with far-reaching consequences. This thesis provides an overview of the factors contributing to the shrinking of water bodies, its impact on ecosystems and communities, and the potential solutions to address this critical issue.

Water bodies, including lakes, rivers, and wetlands, are experiencing a decline in their size and volume due to various factors. Climate change plays a significant role, with rising temperatures causing increased evaporation rates and altering precipitation patterns. Deforestation and land degradation further exacerbate the problem by disrupting natural water cycles and reducing water retention capacity. Additionally, human activities such as excessive water extraction, pollution, and encroachment on water bodies' boundaries contribute to their shrinkage.

Addressing the shrinking of water bodies requires a multi-faceted approach. Mitigating climate change through reducing greenhouse gas emissions is crucial to minimize the impact of rising temperatures and altered precipitation patterns. Sustainable land management practices, including afforestation, reforestation, and erosion control, can help restore natural water cycles and reduce sedimentation. Additionally, implementing effective water resource management strategies, such as responsible water extraction, pollution control measures, and protected area designations, are necessary to preserve and restore water bodies.

Local communities, governments, and international organizations should work together to raise awareness about the importance of water bodies and their conservation. Encouraging community participation, implementing regulations, and promoting sustainable practices are essential steps towards protecting and restoring shrinking water bodies. Furthermore, integrating water management into broader sustainable development plans can ensure long-term preservation and equitable access to this vital resource.

Keywords: Waterbody Shrinkage, Encroachment, Climate Change, Waterbody Conservation, Urbanization

सारांश

जल निकायों का सिकुड़ना दूरगामी परिणामों के साथ एक महत्वपूर्ण पर्यावरणीय चिंता है। यह थीसिस जल निकायों के सिकुड़ने में योगदान करने वाले कारकों, पारिस्थितिक तंत्र और समुदायों पर इसके प्रभाव और इस महत्वपूर्ण मुद्दे को हल करने के संभावित समाधानों का एक सिंहावलोकन प्रदान करती है।

विभिन्न कारकों के कारण झीलों, नदियों और आर्द्रभूमि सहित जल निकायों के आकार और मात्रा में गिरावट आ रही है। जलवायु परिवर्तन एक महत्वपूर्ण भूमिका निभाता है, बढ़ते तापमान के कारण वाष्पीकरण दर में वृद्धि होती है और वर्षा के पैटर्न में बदलाव होता है। वनों की कटाई और भूमि का क्षरण प्राकृतिक जल चक्र को बाधित करके और जल

धारण क्षमता को कम करके समस्या को और बढ़ा देता है। इसके अतिरिक्त, अत्यधिक जल निकासी, प्रदूषण और जल निकायों की सीमाओं पर अतिक्रमण जैसी मानवीय गतिविधियाँ उनके सिकुड़ने में योगदान करती हैं।
जल निकायों के सिकुड़ने को संबोधित करने के लिए बहुआयामी दृष्टिकोण की आवश्यकता है। बढ़ते तापमान और परिवर्तित वर्षा पैटर्न के प्रभाव को कम करने के लिए ग्रीनहाउस गैस उत्सर्जन को कम करके जलवायु परिवर्तन को कम करना महत्वपूर्ण है। वनीकरण, पुनर्वनीकरण और कटाव नियंत्रण सहित स्थायी भूमि प्रबंधन प्रथाओं से प्राकृतिक जल चक्र को बहाल करने और अवसादन को कम करने में मदद मिल सकती है। इसके अतिरिक्त, प्रभावी जल संसाधन प्रबंधन रणनीतियों को लागू करना, जैसे जिम्मेदार जल निष्कर्षण, प्रदूषण नियंत्रण उपाय, और संरक्षित क्षेत्र पदनाम, जल निकायों को संरक्षित और पुनर्स्थापित करने के लिए आवश्यक हैं।
जल निकायों के महत्व और उनके संरक्षण के बारे में जागरूकता बढ़ाने के लिए स्थानीय समुदायों, सरकारों और अंतर्राष्ट्रीय संगठनों को मिलकर काम करना चाहिए। सामुदायिक भागीदारी को प्रोत्साहित करना, नियमों को लागू करना, और टिकाऊ प्रथाओं को बढ़ावा देना सिकुड़ते जल निकायों की रक्षा और बहाली की दिशा में आवश्यक कदम हैं। इसके अलावा, जल प्रबंधन को व्यापक सतत विकास योजनाओं में एकीकृत करने से इस महत्वपूर्ण संसाधन के लिए दीर्घकालिक संरक्षण और समान पहुंच सुनिश्चित हो सकती है।

1. Executive Summary

The concept of waterbody shrinkage refers to the diminishing size, volume, or surface area of natural water bodies such as lakes, rivers, wetlands, and reservoirs. It is a result of various factors, including human activities and environmental changes, which can have significant impacts on ecosystems, biodiversity, and human populations.

Waterbody shrinkage in India is a significant environmental issue that has been observed in various parts of the country. Several factors contribute to the shrinking of water bodies, including population growth, urbanization, industrialization, agricultural practices, and climate change.

Several factors contribute to the shrinkage of water bodies:

- **Climate Change:** Rising temperatures and altered precipitation patterns associated with climate change can lead to increased evaporation rates, reduced snowfall, and changes in water availability, causing water bodies to shrink.
- **Water Extraction:** Excessive water extraction for various purposes, including agriculture, industry, and domestic use, can deplete water bodies, especially in areas with limited water resources. Over-pumping of groundwater can also lead to the depletion of underground aquifers connected to surface water bodies.
- **Deforestation and Land Use Changes:** Deforestation and land degradation disrupt natural water cycles, reducing water retention capacity and increasing soil erosion. This can result in sedimentation and the filling of water bodies, reducing their size and depth.
- **Pollution:** Pollution from industrial discharge, agricultural runoff, and improper waste disposal can contaminate water bodies, making them unsuitable for use and affecting aquatic ecosystems. In extreme cases, severe pollution can lead to the death of aquatic life and the loss of biodiversity.
- **Channelization and Damming:** Altering natural water flow patterns through channelization or the construction of dams and reservoirs can disrupt the equilibrium of water bodies. This can change the water levels, alter habitats, and affect downstream ecosystems.

According to the Union Ministry of Urban Development (MoUD), 31 per cent of the country was urbanized in 2011. The ministry says almost 50 per cent of the country will be urbanized by 2050.

MoUD data also suggests a 54 per cent increase in the number of cities and towns between 2001 and 2011. Natural streams and watercourses, formed over thousands of years due to the forces of flowing water in the respective watersheds, have been altered because of urbanization.

Waterbody shrinkage is a growing concern in India, with various lakes, ponds, and reservoirs experiencing a significant reduction in their size over the years. This problem poses a threat to ecosystems, biodiversity, and human livelihoods. This problem statement aims to identify the causes of waterbody shrinkage, assess its impacts on society and the environment, and explore potential solutions to mitigate the issue.

Aim

Aim of the research is to identify the causes of waterbody degradation and shrinking and develop effective rejuvenation strategies for the same.

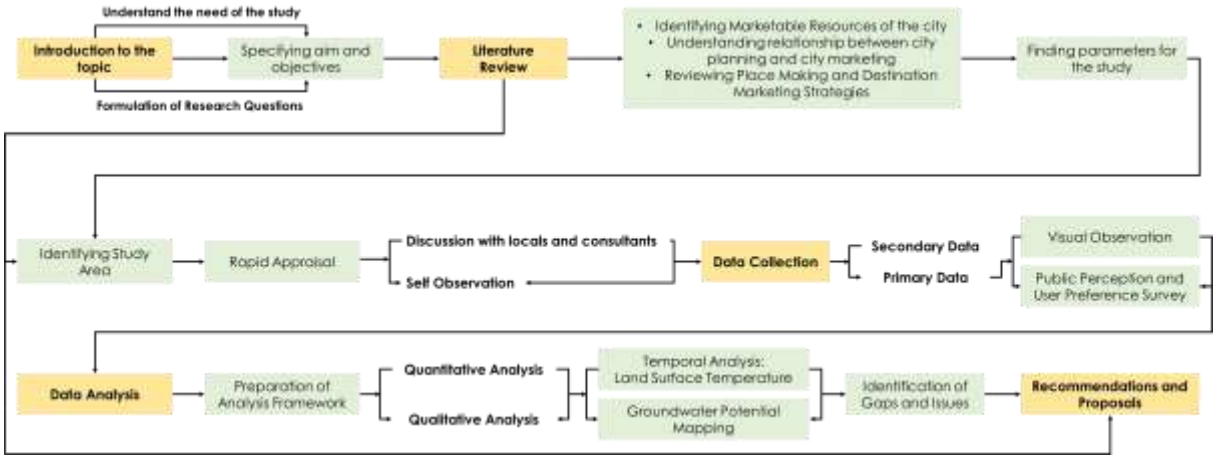
Objectives

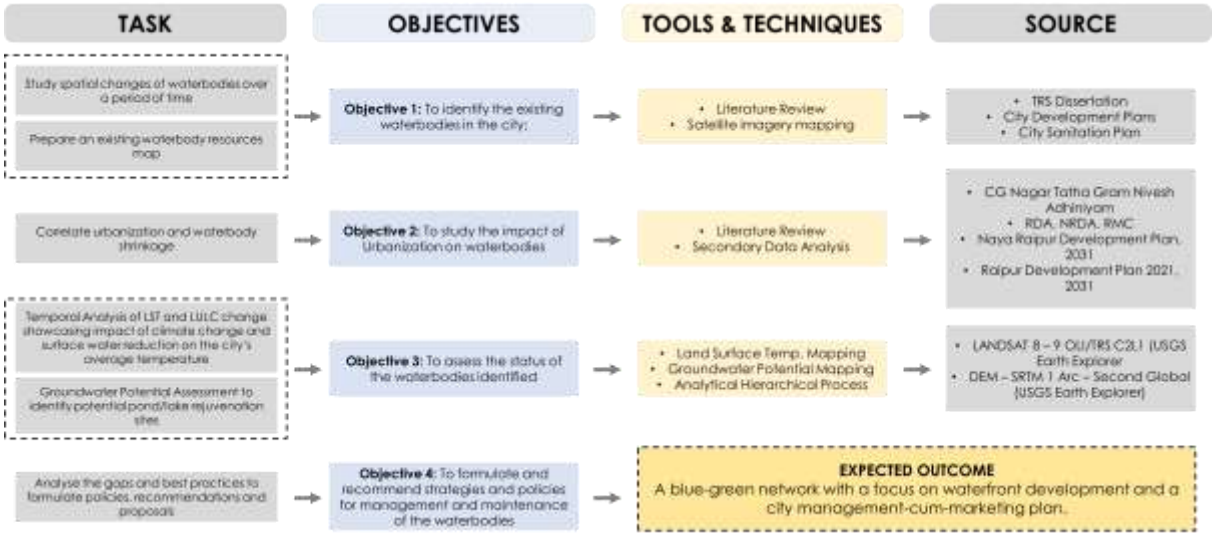
1. To identify the existing waterbodies in the city;
2. To study the impact of Urbanization on waterbodies;
3. To assess the status of the waterbodies identified;
4. To formulate and recommend strategies and policies for management and maintenance of the waterbodies.

Scope and Limitation(s)

- The scope of the study would cover the study and analysis, majorly qualitative, of inland fresh waterbodies and People/Public Perception Survey.
- The outcome of the study would be Policy Recommendations and Strategies for the city level with a few area based development proposals for a few waterbodies of significance.
- The study area is limited to the Raipur Planning Area.

Methodology





Introduction to the Study Area

Raipur is a district in the state of Chhattisgarh. Raipur is the capital of the state of Chhattisgarh. Raipur is the largest district in the state of Chhattisgarh in terms of population.

The headquarters of the district is Raipur. Raipur Municipal Corporation was ranked 6th in the year 21 for best governance and administrative practices in India. It was a part of Madhya Pradesh before the state of Chhattisgarh was formed on 1 November 2000. It has exponential industrial growth, and has become a major business hub in central India.

The city has 3 governing bodies namely:

- Raipur Municipal Corporation (RMC)
- Raipur Development Authority (RDA)
- Naya Raipur Development Authority (NRDA)

It is spread across an area of 226 sq. km. and has a population of nearly 11 lakhs as per 2011 census.

Justification for Selection of Site

Raipur, like many rapidly developing urban areas, has experienced loss and degradation of its water bodies due to various factors. The expansion of urban infrastructure, encroachments, pollution, and inadequate management practices have contributed to the decline of water bodies in the city. Here are some key aspects related to waterbody loss in Raipur:

- **Encroachments and Land Use Changes:** Unplanned urbanization has resulted in encroachments and unauthorized constructions on water bodies and their catchment areas. Illegal settlements and commercial activities have encroached upon lakes, ponds, and wetlands, leading to their shrinkage or complete disappearance.
- **Pollution and Waste Disposal:** Water pollution from industrial effluents, untreated sewage, and solid waste dumping has severely impacted water bodies in Raipur. Discharge of pollutants and improper waste disposal practices degrade water quality, affecting aquatic life and ecosystem health.
- **Drainage System and Stormwater Management:** The inadequate drainage system in Raipur, coupled with improper stormwater management, leads to the accumulation of rainwater in low-lying areas. This results in the flooding and subsequent siltation of water bodies, reducing their capacity and degrading their ecological value.

- **Agricultural Practices:** Inefficient irrigation practices and excessive use of agrochemicals in the agricultural areas surrounding Raipur contribute to water pollution and the degradation of water bodies. The runoff of pesticides, fertilizers, and sediment from agricultural fields can contaminate nearby water bodies.

At its peak, Raipur had over 200 lakes and ponds spread across the city, but in the last 70 years, it has lost more than 100 of its waterbodies to various developmental activities.

Analysis

The major studies conducted were:

1. People Perception and User Preference Survey

The major outcome of this survey was to identify what are the major resources Raipur has to offer that can be judiciously utilized to help the city grow economically. Based on the Perception survey, 37% of the sample size (365) voted for Raipur to be developed as a Waterfront City owing to its numerous waterbodies.

2. Footfall Survey

The Footfall Survey was done for 4 major Lakefronts in the city namely:

Budhapara Talab, Swami Vivekananda Sarovar, Katora Talab and Telibandha Talab

Telibandha Talab is the busiest spot with at least 3600 people visiting the lakefront development everyday followed by Swami Vivekananda Sarovar and Budhapara Talab with each 2000+ visitors and lastly Katora Talab with just a little under 1000 visitors a day.

The peak hour during the weekdays in generally seen from 16:00 hrs. up until 21:00 hrs. post which majority of the public facilities at these lakefront developments start to close.

3. Land Use Analysis (2011, 2021)

The table below gives the gist of the LUA:

Land Use	2011	2011%	2021	2021%	% Change (2011-2021)
Residential	2050	55%	8088	51%	2.95
Commercial	180	5%	1370	9%	6.61
Industrial	430	12%	1451	9%	2.37
Public Semi-Public	450	12%	1506	9%	2.35
Recreation	100	3%	1610	10%	15.10
Transportation	500	13%	1975	12%	2.95
Total	**3710**	**100%**	**16000**	**100%**	

4. LULC Analysis

The Land Use Land Cover trend of Raipur for the last ten years shows an abrupt change in the urban vegetation which reduced from 29% in 2018 to a mere 4% in 2023. The major reason for this as per the RMC is the population growth and expansion of the built-up area and lack of funds for the recreation department.

The waterbody area has increased from 2% back in 2013 to 3% in 2023 owing to numerous lake rejuvenation schemes.

5. Land Surface Temperature (LST) Analysis

The LST Analysis shows that the average temperature of the city has been 30°C with maximum temperatures rising up to 40°C during summers and being the main reason for drying of the local lakes.

Even in February we can see that the maximum LST is 40.1°C which is way above the winter average of 23°C.

The central area of the city shows a cool LST owing to an abundance of lakes to balance and cool the surrounding temperature.

6. Groundwater Potential Mapping

The GWP Mapping helped identify the potential zones where major interventions can be taken throughout the city. The table below gives the areas of GWP Zones with varying GWP Capacities:

Zone	Area (in sq. km.)
Poor	0.35
Fair	84.10
Moderate	99.46
Excellent	1.00

7. Waterbody Status Assessment

Waterbody Status Assessment was conducted for 58 major waterbodies that are still present in the city based on the following parameters:

SIZE

>1.5 Ha

USE AND FUNCTIONS

Irrigation

Recreation and Tourism

Religious Activities

Drinking, Washing, etc.

SOURCE OF WATER AND POLLUTION

Domestic and Industrial Effluents

Stormwater and Agricultural Run Off

Cattle-wading, dumping waste, etc.

Rain Run Off

Through Interconnection of Lakes

The study concluded that **35% of the 58 waterbodies are highly polluted.**

3 waterbodies are further selected from the above analysis for area-based rejuvenation strategies, viz.:

- Ramkund
- Raja Talab
- Tikrapara Talab

Issues and Potentials

	PAST STATUS	PRESENT STATUS
SIZES AND NUMBERS	There used to be more than 178 waterbodies which were bigger than most of the existing ones and most of them even being filled with due course of urbanization, for example, Rajbandha Talab which was 3.2 Ha in size but is inexistent now	Urbanization has led to decrease in the number and sizes of the waterbodies evidently and only 108 of them survive of which mostly are on the verge of completely diminish in the near future if not notified and conserved immediately
USES AND FUNCTIONS	Watrbodies used to find major role in socio-economic activities of the city such as lotus farming, cattle wading, agriculture, religious activities, etc.	Various factors like increase in construction activities has resulted in an increase in the sediment flow, chemical used for bathing and laundry, religious activities, sewage and solid waste disposal, etc. have led to a degraded quality of water.
SOURCES OF WATER AND POLLUTION	Sources of water to the lakes were predominantly watershed, rainfall and ground water aquifers. Pollution sources were limited only to religious activities, bathing, cattle wading, etc.	Urbanization has also led to construction of roads intersecting watershed channels and also encroachment along them has drastically changed the catchment area of the lakes thereby leading to decreased water levels
GROUND WATER LEVEL	Assuming the uses were limited, the ground water level was good	With an increase in population and density around the waterbodies, the demand also flew high resulting in unaccounted withdrawal of water both

		from open sources, specially from surface waterbodies, and also, groundwater usage had led to a decrease in the GWT.
URBANIZATION IMPACT ON LAKES	Unlike now, urbanization growth rate was only 12%.	Impact of urbanization has led to degradation of many waterbodies, potable surface water sources because of pollution which in course pollutes the groundwater by infiltration and thus, leads to common epidemic.

ISSUES	**CAUSES**	**IMPACT**
Decreasing Ground Water Table	change in drainage pattern due to unplanned construction	Reduced ground water recharge Drying of lakes in summer
	Drainage channel being obstructed by civil structures like roads and buildings	The empty lake sites converted into dumping grounds
	Stormwater runoff getting mixed with sewage and dispossed off via drainage network	over loading/malfunctioning of waste water treatment plants
Water Pollution	Dumping of industrial waste into the lakes	Contamination of aquifers
	Non-point source pollution from village and nearby settlements	

	Disposed off waste water/sewer from nearby settlements through piped/network open channel	Loss in economic value of water stored as it cannot be used for any purposes
	Disposal of household refuse	unhygienic living condition in the surrounding settlements threat to water borne diseases
Encroachment	Availability of unclaimed/vacant land	blockage of the natural drains
	Improper demarcation of the waterbody	Increases ground elevations in the periphery resulting in flooding
	Absence of any monitoring agency/fencing to prevent unauthorized occupation of the waterbodies	
Dependency on Long distance water	less water collection in lakes unaccounted discharge of water	unhygienic living condition in the surrounding settlements threat to water borne diseases
Negligence of Authorities	Absence of interdepartmental coordination Data regarding Sewerage network is also not available with the RMC	No treatment process by any authority

Proposals

1. **RIPARIAN BUFFER**

- **KHARUN RIVER**

- 300m Riparian buffer along Kharun river:
- Ideal Situation: 18.65 sq. km.; 62.15 Km running stretch
- Realistic Situation: 4.75 sq. km.; 16.18 km running stretch

- **WATERBODIES**

- 50 M Riparia Buffer around the waterbodies
- Total of 3.5 sq. km of waterbody buffer; 137.1 km stretch throughout the city

- **STREAMS AND NATURAL DRAINS**

- Total 9.1 sq. km. Riparian Buffer; 181.7 km stretch throughout the city

- **PLANNING THE BUFFER**

- **SITE PREPARATION**
- Removal of all invasive vegetation to reduce competition to new native species and shrubs.

- **BUFFER WIDTH**
- There is no one size fits all buffer width in the riparian corridor. The buffer width is largely dependent on the terrain and incline of the slope. The recommendations given are based on gradual slopes and steep inclined slopes.

2. POLICY PROPOSALS

a. Short Term Proposals

- Demarcating waterbody boundaries with fencing
- Reviving the waterbody's utility and value
- Stoppage on unauthorized dumping and debris disposal in the waterbodies
- Cleaning, dredging, removing weeds and agricultural run-offs, construction embankment, etc.
- Control of indiscriminate cultural activity on lakes
- Regular de-silting and removal of sediment from the lake area is required
- Rainwater harvesting to be taken up in the first order catchment area
- Providing STP for waterbodies bigger than 20 Ha
- Treated water could be disposed into the lakes as they have good nutrient value which would be beneficial for the fishes and aquatic life to flourish

b. Medium Term Proposals

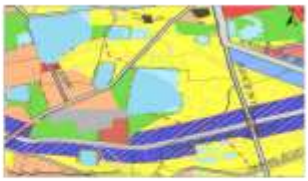
- To establish Lake Development Authority, which timely monitor the condition of the lake and give timely guidance in the maintenance and improvement of the lakes
- A strong monitoring system with laboratory support should be developed
- Formation of Lake Development Authority - for Regular monitoring O/M of lakes and
- Public private partnership to develop lake front
- No discharge from domestic, commercial or industrial to be done without treatment (and bring them to the CECB recommended BOD and COD level)
- Strictly enforcing 15m no construction along the edge of the lakes
- Abutting plots to setback by 15m Row and pathway along the lakes

- Institutions to give pathways and plant trees along the lake side (this could be used as access by the pedestrian and cyclist)
- No litter zone; Bund trees; Separate waste collection (Dry/Wet)

c. Long Term Proposals

- Zonal and Regional plan should demarcate lakes as notified water intake point
- Surface area or Lake storage area both minimum and maximum should be demarcated in Lake Rejuvenation Plan
- Catchment area should be recorded for water sensitive design and planning for sustainability of lakes as a source of water supply
- Peripheral areas of the lakes(100M) should be declared as 'Protected zones
- 15 M immediate buffer around lake should be under "No Construction Zone
- Rain water harvesting & Solid waste management practice to be adopted
- ElA should be done for all development projects in lake and its catchment
- NGO and Public participation should be incorporated in lake restoration
- Utilizing the lakes for the purpose of education and research
- Provision of treatment plants in the industries (if preferred give single treatment plant for 2-3 nearby industries)
- No construction on the natural drainage
- Reclaim the slum area abutting the lakes till 15m from the river edge

3. AREA BASED PROPOSALS

	RAMKUND		RAJA TALAB		TIKRAPARA TALAB
					
RECOMMENDATIONS	1 De-silting of pond	1	De-silting of pond	1	De-silting of pond
	2 Buffer of 50 MT along the waterbody shoreline	2	Buffer of 50 MT along the waterbody shoreline	2	Buffer of 50 MT along the waterbody shoreline
	3 Creation of shore ecotones around the waterbody	3	Improvement of Inlet Drains should be done	3	Dumping of garbage, domestic and agricultural waste should be completely restricted
	4 Biological control of weed through aquaculture	4	Fountains and aerators to be proposed for aeration in waterbodies	4	Floating wetlands to be introduced to take control of eutrophication
	5 Fountains and aerators to be proposed for aeration in waterbodies; helps in the improvement physical characteristics of the waterbody.	5	Provision of trash cans and waste processing facility		
	6 Sewage treatment plant is needed for disposal of treated water	6	Cattle-wading, washing of clothes need to be restricted	5	Pisciculture should be encouraged for improving the production function of the waterbody
		7	Removal of encroachment from waterbody shoreline		

4. GUIDELINES FOR STAKEHOLDERS

GUIDELINES FOR STAKEHOLDERS		
GOVERNMENT	**DEVELOPERS**	**PUBLIC/COMMUNITY**
Ensure continuous monitoring and initiating suitable corrective measures	Follow properly the planning restrictions, standards and codes	Realize and respect the value of environment and ecosystem services
Advocating and promoting Lake restoration according to the Plan	EIA to be done for all projects to be undertaken	Keep waterbodies clean and avoid pollutants such as detergents in the streams and ponds
Establish standards, building codes and other regulations	Ensure that all the development activities are unobstructive and do not interfere with the natural ecosystem	Water-saving practices, RWH should be employed
Recognize and award. the developers and to the citizens who actively participate in the lake restoration process.	All developmental activities in the waterbody restoration should be done in harmony with the local environment	Actively participate in the planning process of Lake Restoration and also help in implementing the plan
Launch training programmes on lake restoration for administrators, Planners, Developers and the general public.	Involve local community to the extent possible in various activities and vocations	Realize and react to the potential threat of investors who see opportunities in development but lack sensitivity to local ethos
Publishing simple brochures or a set of brochures on lake restoration		

Chapter 1

INTRODUCTION

Water body shrinkage refers to the process by which the size, volume, or surface area of a water body, such as lakes, rivers, and wetlands, decreases over time. It is a phenomenon that can have significant environmental, social, and economic implications. Water body shrinkage can occur due to various natural and human-induced factors, and its consequences can be far-reaching.

Natural factors that contribute to water body shrinkage include changes in precipitation patterns, evaporation rates, and natural geological processes. Climate change plays a crucial role in altering these factors. Shifts in regional climate patterns can result in reduced rainfall or changes in the timing and distribution of precipitation, leading to decreased water inflow into lakes and rivers. Additionally, rising temperatures can increase evaporation rates, further depleting water bodies.

Human activities also play a significant role in water body shrinkage. The construction of dams and reservoirs for water storage and hydroelectric power generation can lead to the flooding and subsequent loss of natural water bodies. Channelization and diversion of rivers for irrigation, industrial use, or water supply purposes can disrupt the natural flow of water, leading to reduced water availability downstream. Additionally, urbanization and the expansion of agricultural practices can increase the number of impervious surfaces, such as concrete and asphalt, which prevent rainwater from infiltrating the ground and replenishing water bodies.

The consequences of water body shrinkage are multifaceted. Ecologically, it can result in the loss of critical habitats for various plant and animal species, affecting biodiversity and disrupting ecosystems. Reduced water availability can impact the livelihoods of communities dependent on these water bodies for agriculture, fisheries, and drinking water supply. It can also lead to conflicts over water resources among different user groups, particularly in regions where water scarcity is already an issue.

Efforts to mitigate water body shrinkage and its associated impacts include sustainable water management practices, such as water conservation measures, restoration of wetlands, and the implementation of integrated water resource management strategies. Addressing the underlying causes, such as reducing greenhouse gas emissions to mitigate climate change and promoting responsible water use, is crucial for long-term solutions.

1.1. Background

Waterbody shrinkage in India is a significant environmental issue that has been observed in various parts of the country. Several factors contribute to the shrinking of water bodies, including population growth, urbanization, industrialization, agricultural practices, and climate change.

Dams, diversions, and inter-basin water transfers affect river flows, causing water body decrease in India. The erection of dams for purposes such as irrigation, hydropower generation, and water supply frequently result in the inundation of areas upstream and modifies the typical flow patterns downstream, ultimately leading to a decrease in water accessibility and the contraction of rivers and their associated water reservoirs.

Over-extraction of groundwater, especially in agricultural areas, is another problem. The overexploitation of groundwater for various purposes, including irrigation, has resulted in the exhaustion of aquifers, thereby impacting the water levels of interconnected water bodies such as lakes, wetlands, and rivers. Consequently, numerous aquatic systems are undergoing desiccation or encountering diminished water quantities.

Water body encroachment and urbanisation also contribute. The swift expansion of urban areas has resulted in the erection of edifices, thoroughfares, and infrastructure on top of lakebeds and wetlands, thereby diminishing their dimensions and modifying their hydrological characteristics. The issue of flood management is compounded by encroachments and unauthorised constructions along riverbanks, which result in the reduction of natural floodplains and obstruction of water flow.

1.1.1. Global Scenario

A paradoxical phenomenon has been identified by a worldwide investigation, wherein our water resources are diminishing concurrently with the escalation of more concentrated precipitation due to climate change.

1.1.1.1. The Caspian Sea

The Caspian Sea is the world's largest inland water body when measured by surface area. But new satellite imagery shows that it's shrinking - and quickly. (NASA, 2022)

Figure Error! No text of specified style in document.**.1: The Caspian Sea, 2006 - 2022**

Source: (NASA, 2022)

1.1.1.2. The Aral Sea

The gradual shrinking of the Aral Sea -- the world's 4th-largest inland waterbody -- has set alarm bells ringing in the Central Asian states that once formed part of the Soviet Union. (NASA, 2018)

Figure **Error! No text of specified style in document.**.2: The Aral Sea, 2001, 2010, 2018

Source: (NASA, 2018)

1.1.2. Indian Scenario

As per the statistics provided by the Union Ministry of Urban Development (MoUD), the urbanisation rate of India stood at 31% in the year 2011. According to the ministry, it is projected that approximately 50% of the nation's population will reside in urban areas by the year 2050.

According to data from the Ministry of Urban Development (MoUD), there was a 54% rise in the quantity of cities and towns from 2001 to 2011.

The process of urbanisation has resulted in the modification of natural streams and watercourses that have been shaped over an extended period by the forces of flowing water within their respective watersheds. (Down To Earth, 2020)

1.2. Problem Statement

Waterbody shrinkage is a growing concern in India, with various lakes, ponds, and reservoirs experiencing a significant reduction in their size over the years. This problem poses a threat to ecosystems, biodiversity, and human livelihoods. This problem statement aims to identify the causes of waterbody shrinkage, assess its impacts on society and the environment, and explore potential solutions to mitigate the issue.

1.2.1. Major Causes of Water body shrinkage

- **URBANIZATION AND INDUSTRIALIZATION**
  - Rapid urbanization and industrial growth lead to increased demand for land, resulting in the encroachment and conversion of waterbodies for developmental purposes

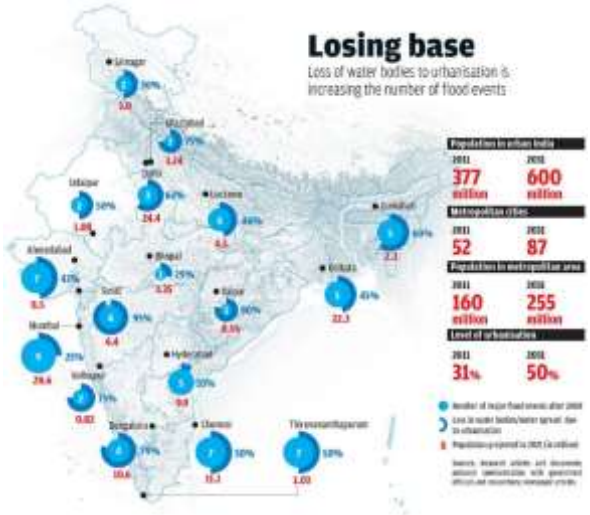


Figure Error! No text of specified style in document.**3: Water body Loss in Major Cities due to Urbanization ((Down To Earth, 2020)**

- **DEFORESTATION & LAND USE CHNAGE**
  - Clearance of forests and changes in land use patterns contribute to soil erosion, sedimentation, and reduced water retention capacity, leading to the shrinkage of waterbodies
- **UNREGULATED EXTRACTION**
  - Uncontrolled extraction of groundwater and excessive water consumption for agriculture, industries, and domestic purposes deplete water sources, reducing inflows into waterbodies
- **CLIMATE CHANGE**
  - Altered precipitation patterns, rising temperatures, and changing weather conditions impact water availability, affecting the size and volume of waterbodies

1.2.2. Impacts of Water body shrinkage

- **Ecological Consequences**
  - Waterbody shrinkage disrupts aquatic ecosystems.
- **Water Scarcity and Quality**
  - Decreased water availability exacerbates water scarcity issues, and conflicts over water resources.
- **Socio-economic Challenges**

- It can result in economic losses, migration, and social unrest in affected communities.

1.3.Aim

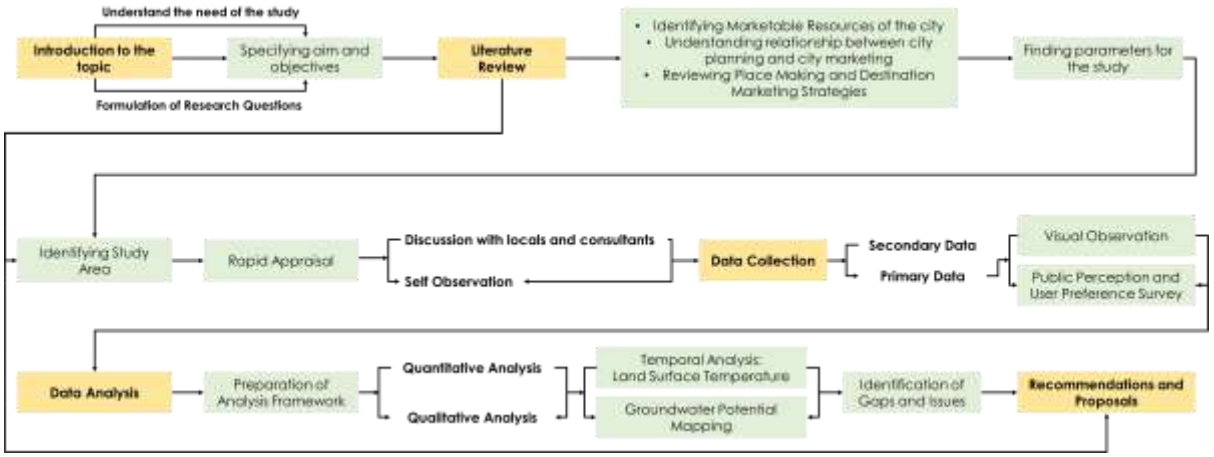
Aim of the research is to identify the causes of waterbody degradation and shrinking and develop effective rejuvenation strategies for the same.

1.4.Objectives

1. To identify and assess the status of water bodies;
2. To study the impact of Urbanization on water bodies;
3. To study the institutional mechanisms & analyze the issues and potentials;
4. To formulate and recommend strategies and policies for management and maintenance of the water bodies.

1.5.Research Methodology

Figure Error! No text of specified style in document.**.4: Research Methodology**



1.6. Scope and Limitation(s)

The scope of the study would cover the study and analysis, majorly qualitative, of inland fresh water bodies and People/Public Perception Survey.

The outcome of the study would be Policy Recommendations and Strategies for the city level with a few area-based development proposals for a few water bodies of significance.

Chapter 2

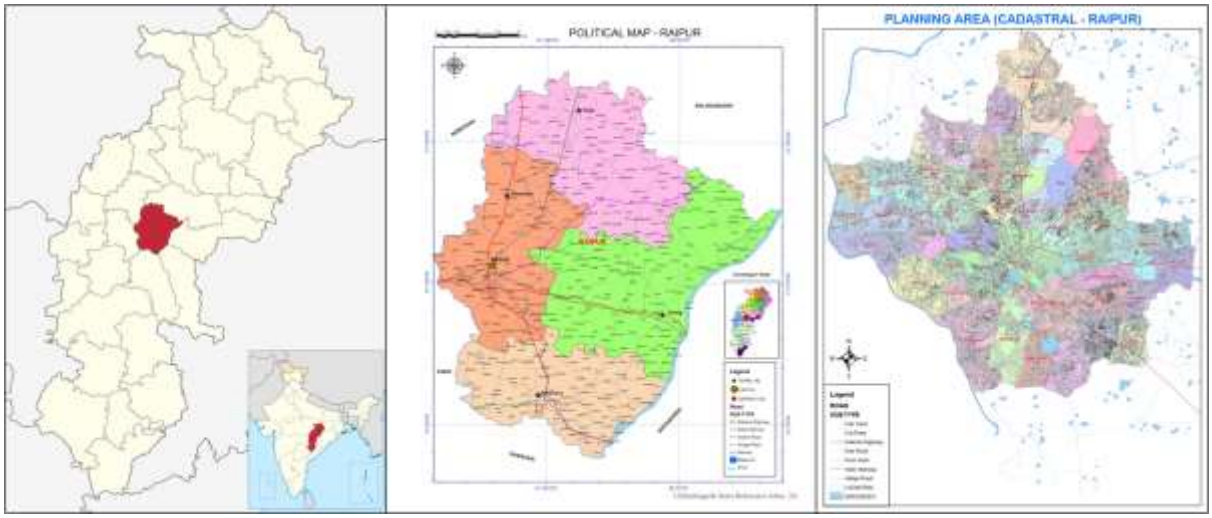
STUDY AREA PROFILE

Raipur is a district in the state of Chhattisgarh. Raipur is the capital of the state of Chhattisgarh. Raipur is the largest district in the state of Chhattisgarh in terms of population. The headquarters of the district is Raipur. Raipur Municipal Corporation.

The city has 3 governing bodies namely:

- Raipur Municipal Corporation (RMC)
- Raipur Development Authority (RDA)
- Naya Raipur Development Authority (NRDA)

Map Error! No text of specified style in document.**.1: Raipur Regional Setting**



Source: Raipur Municipal Corporation

1.7. Demographic Profile

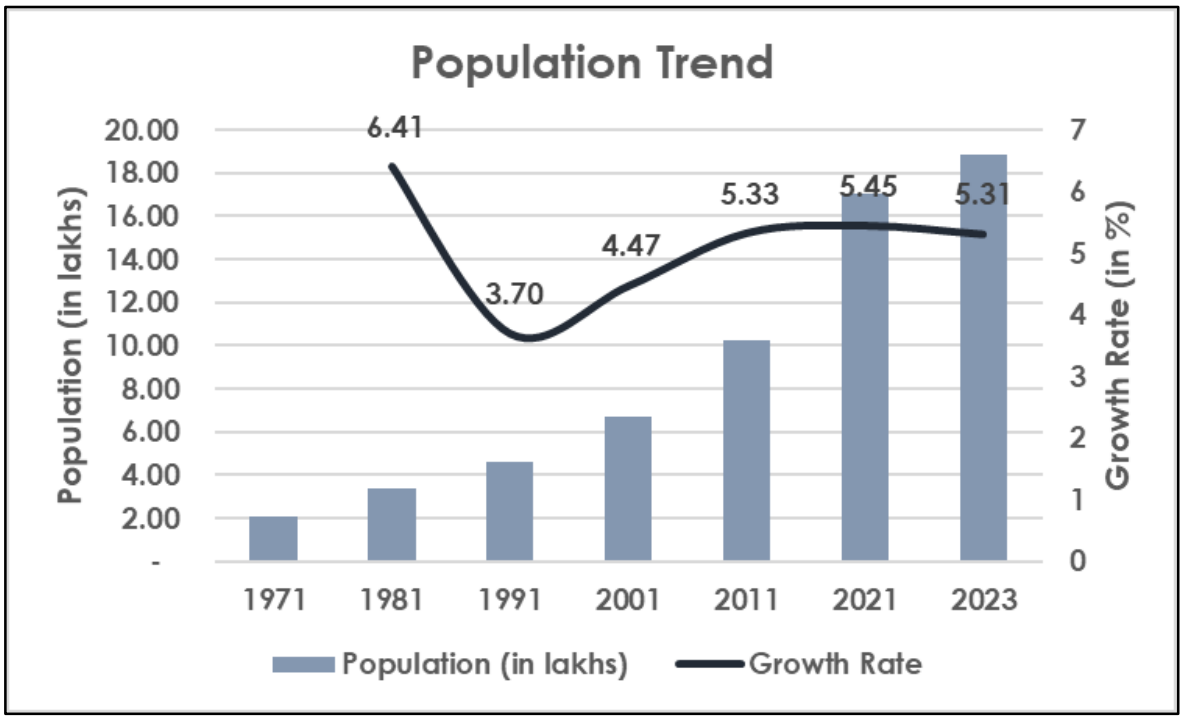
The table below shows the population and growth rate of Raipur from 1971 till 2023.
The populations for the years 2013 – 2023 were estimated based on CAGR.

Table Error! No text of specified style in document.**.1: Raipur Demographic Profile**

RAIPUR U/A DEMOGRAPHIC PROFILE			
Year	**Population**	**Increment**	**Annual Growth Rate**
1971	2,06,000		
1981	3,38,000	1,32,000	6.41
1991	4,63,000	1,25,000	3.70
2001	6,70,000	2,07,000	4.47
2011	10,27,000	3,57,000	5.33
2013	11,36,153	1,09,153	5.31
2018	14,62,523	3,26,370	5.75
2021	17,01,775	2,39,252	5.45
2023	18,82,645	1,80,870	5.31

Source: Census 1971 – 2011, Raipur CDP

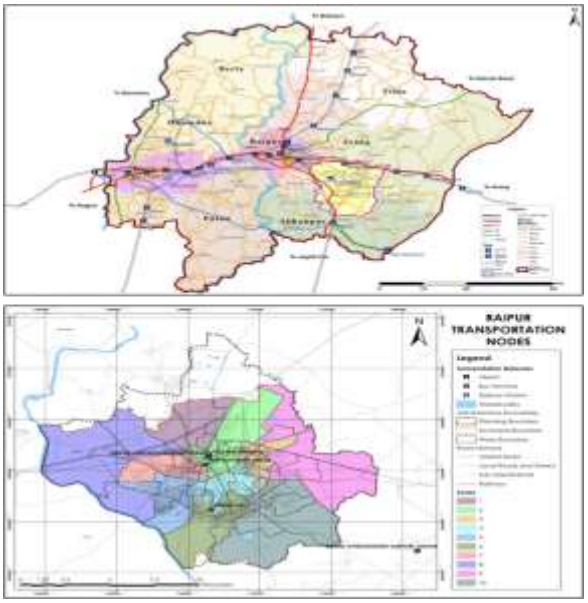
Graph Error! No text of specified style in document.**.1: Raipur Population Growth Trend**



1.8. Regional Connectivity

Major regional linkages in Raipur include:

- **Roadways**
  - Some major roads in Raipur are National Highway 53 (NH-53), National Highway 30 (NH-30), Great Eastern Road, Pandri Road, Baloda Bazar Road, Nardha Raipur Road, VIP Road, and Atal Path Expressway.
- The Raipur–Naya Raipur Expressway, also known as Atal Path Expressway, is a 12.7 km (7.9 mi) access-controlled expressway connecting Raipur to Naya Raipur.



Map Error! No text of specified style in document.**.2: Raipur Regional Connectivity**

- **Railways**

- Raipur Junction railway station is the primary railway station of the city, which is situated on the Howrah-Nagpur-Mumbai line of the Indian Railways, running through the cities of Bhusawal, Nagpur, Gondia, Bilaspur, Rourkela and Kharagpur.
- It is categorized in the A-1 category of railway stations by the Indian Railways.

- **Air**

- Swami Vivekananda Airport, or Mana Airport, is the primary airport serving the state of Chhattisgarh. The airport is located 15 km (9.3 mi) south of Raipur and 10 km (6.2 mi) from Naya Raipur. The airport is well-connected, having daily direct flights to Mumbai, Delhi, Kolkata, Bangalore, Pune, Chennai, Goa, Lucknow, Indore, Jaipur, Patna, Ahmedabad, Bhopal, Bhubaneswar, Hyderabad, Prayagraj, and Jagdalpur, operated by Alliance Air, IndiGo and Vistara airlines.

1.9. Administrative Jurisdictions of Raipur

The major administrative jurisdictions of the city include the:

- Planning Area
- Municipal Area
- Zones
- Wards

The following maps show the various administrative jurisdictions in the city:

Map Error! No text of specified style in document.**.3: Raipur Administrative Jurisdictions (Source: Author)**

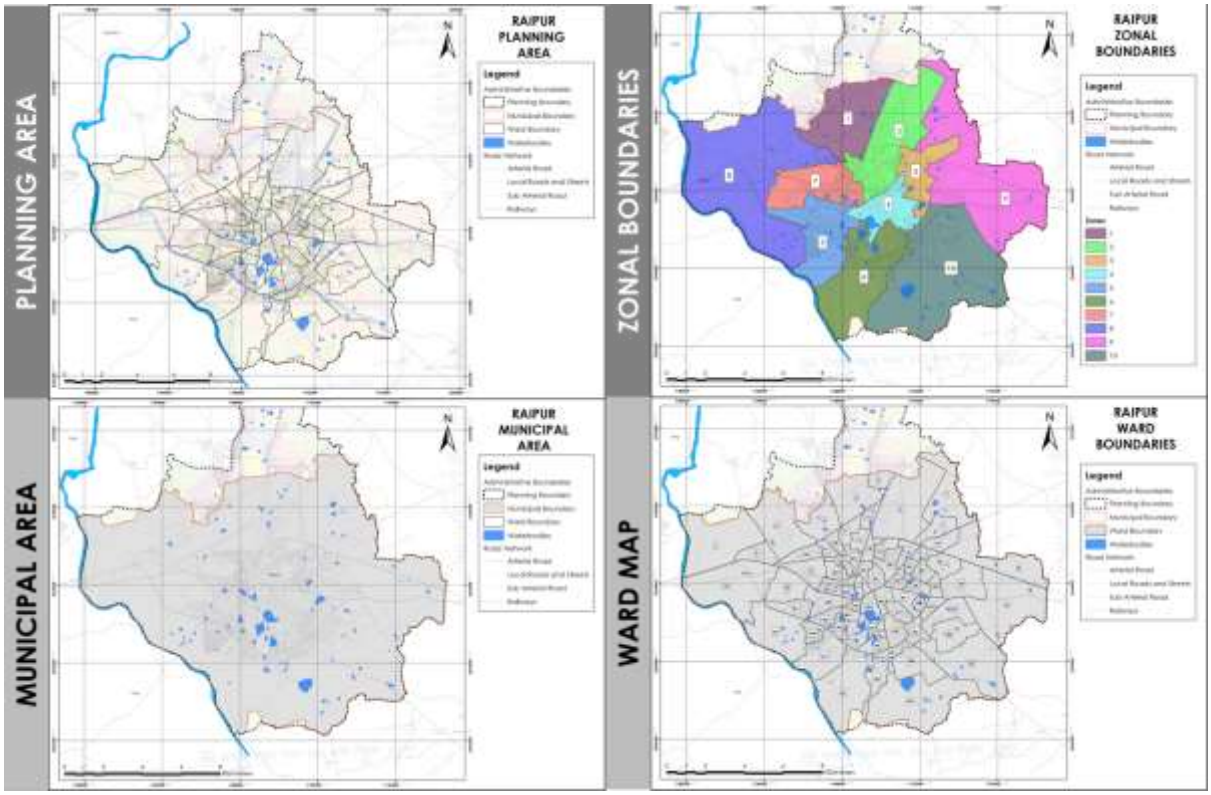


Figure Error! No text of specified style in document.**.5: Justification for Site Selection**

- The total planning area: 189.67 sq. km.
- Total Municipal area: 163.32 sq. km.

- Total Zones: 10
- Total Wards: 70

1.10. Justification for Site Selection

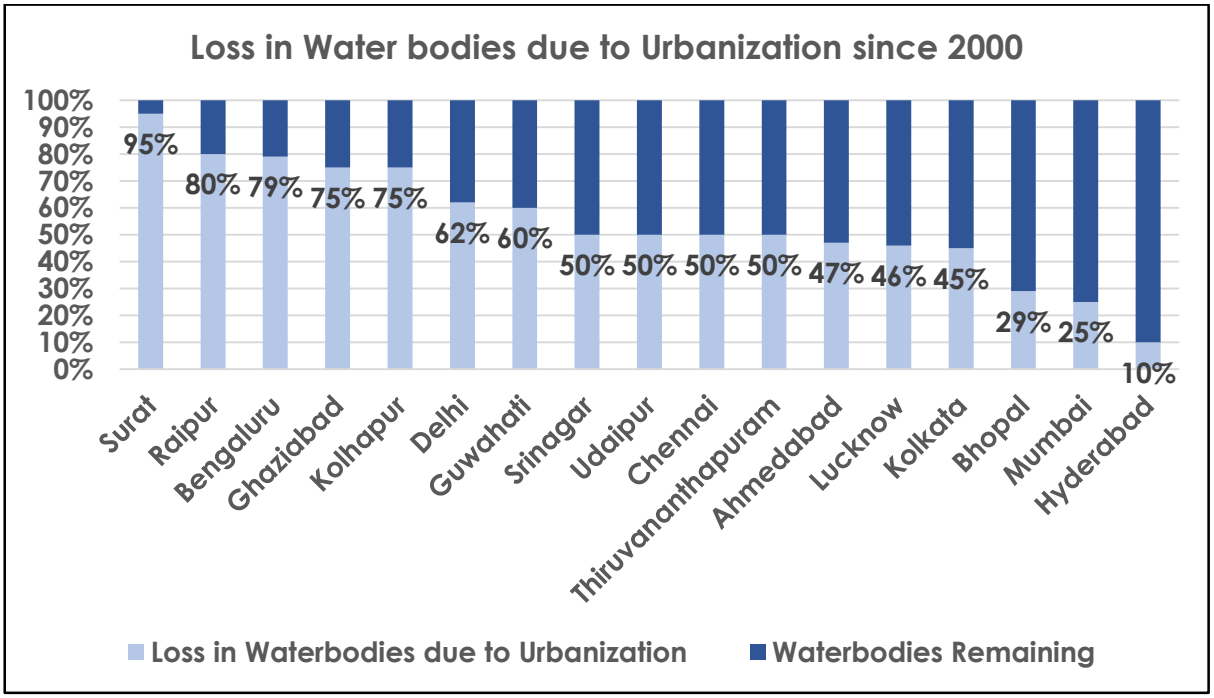
The city of Raipur is endowed with over 200 lakes, which are commonly referred to as "Talabs". However, only 85 of these Talabs are presently in existence.

In the past, Raipur was endowed with a total of 200 Talabs, which were either naturally formed or constructed by human agency. However, at present, only 58 Talabs have managed to endure. Fifty-eight surface water bodies, with sizes ranging from 2800 to 402000 square metres, cover a combined surface area of 2.83 square kilometres, equivalent to approximately 2.27% of the city's total area.

Present-day Raipur is markedly different from its historical antecedents, as it currently boasts a mere 40 extant lakes, a significant number of which are in imminent danger of disappearing altogether. According to official data, the urban area has experienced a loss of over 100 lakes within the last 25 years, equating to an average of four lakes per annum. The causative factors are attributed to unanticipated and swift urbanisation, coupled with governmental indifference. The topography of the urban area, previously conducive to the existence of these bodies of water, has been subjected to infringement by architectural structures, resulting in the absence of adequate room for fluid circulation. According to Ninad Bodhankar, a faculty member of the Department of Geology at Raipur University, the encroachment of lakes results in flooding during the monsoon season.

The following graph shows the status of water body shrinkage due to urbanization in various cities since 2000:

***Graph** Error! No text of specified style in document..2: Loss in Water bodies due to Urbanization since 2000 (Source: (Down To Earth, 2020)*

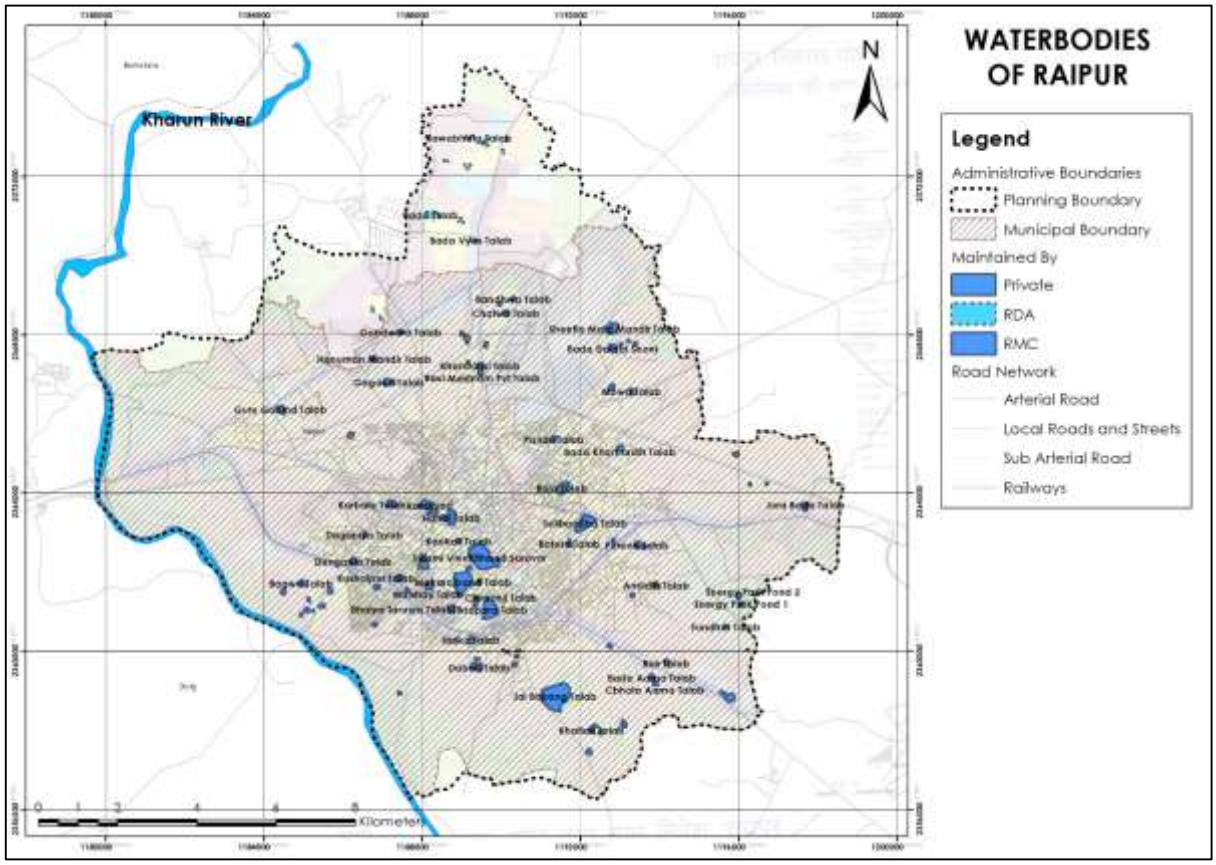


The development of residential and commercial infrastructure in proximity to water bodies has resulted in a reduction of soil coverage, thereby causing a decline in percolation and an increase in surface runoff. This phenomenon has been identified as a contributing factor to the occurrence of floods. The escalation in the application of inorganic fertilisers throughout the terrain, particularly in the rural vicinities adjacent to Raipur, has resulted in the phenomenon of eutrophication in surface water bodies.

1.11. Water Bodies of Raipur

The following map shows all the 108 waterbodies present in the Raipur Planning Area based on their ownership:

Map Error! No text of specified style in document.**.4: Water bodies of Raipur (Source: Author)**



Out of the total 108 water bodies:

- 73 are owned and maintained by the RMC
- 15 are owned and maintained by the RDA
- 20 are owned and maintained by private authorities and/or individuals

The table below enlists all the water bodies in the city:

Table Error! No text of specified style in document.**.2: List of Water bodies in Raipur (Source: Google Earth Imagery, RMC)**

Sr. No.	Name	Area (in Ha)	Ownership
1	Bada Khamardih Talab	2	RMC
2	Pandri Talab	1	RMC
3		2	RMC
4	Mowa Talab	1	RMC

5		1	RMC
6		0	RMC
7	Daldal Seoni	0	RMC
8	Bada Daldal Seoni	3	RMC
9	Sheetla Mata Mandir Talab	5	RMC
10	Gagaon Talab	4	RMC
11	Hanuman Mandir Talab	1	RMC
12	Gondwara Talab	1	RMC
13		1	RDA
14		1	RDA
15	Chhota Vyas Talab	1	RDA
16	Bada Vyas Talab	1	RDA
17		2	RDA
18	Sheetla Talab	1	RDA
19	Bada Talab	4	RDA
20		2	RDA
21		1	RDA
22		2	RDA
23		1	RDA
24		1	RDA
25	Rawabhata Talab	2	RDA
26		1	RDA
27		1	RDA
28	Khamtarai Talab	1	RMC
29	Ravi Meshram Pvt Talab	2	Private
30		0	Private
31		1	Private
32		3	Private
33	Chatwa Talab	2	RMC
34	Darri Talab	1	RMC
35	Bandhwa Talab	1	RMC
36		2	RMC
37	Khallari Talab	1	RMC
38		1	RMC
39		1	RMC
40		2	RMC
41		1	RMC
42		4	RMC
43	Chhota Aama Talab	1	RMC
44	Bada Aama Talab	2	RMC
45	Boir Talab	2	RMC
46	Jai Bajrang Talab	35	RMC
47		0	Private
48	Fundhar Talab	1	RMC
49	Energy Park Pond 1	1	RMC
50	Energy Park Pond 2	0	RMC
51		2	Private
52	Jora Bada Talab	2	RMC

53		2	Private
54		0	Private
55		0	Private
56		1	RMC
57	Amlidih Talab	2	RMC
58		1	RMC
59	Purena Talab	2	RMC
60	Purena Dabri Talab	1	RMC
61	Mukti Dham Talab	1	RMC
62	Katora Talab	1	RMC
63	Telibandha Talab	11	RMC
64	Raja Talab	5	RMC
65		1	Private
66		1	Private
67		1	Private
68		1	Private
69		1	Private
70	Bandhawa Talab	2	RMC
71	Dabari Talab	2	RMC
72	Halka Talab	2	RMC
73	Tikrapara Talab	14	RMC
74	Chiraunji Talab	1	RMC
75	Chiraunji Talab	1	RMC
76	Bhaiya Taraiya Talab	3	RMC
77		1	Private
78	Maharajband Talab	18	RMC
79	Hazrat Burhan Shah Talab	1	RMC
80	Swami Vivekanand Sarovar	28	RMC
81	Kankali Talab	1	RMC
82	Handi Talab	6	RMC
83		1	Private
84		1	RMC
85		1	RMC
86		1	RMC
87		1	RMC
88		0	RMC
89		1	RMC
90		1	RMC
91		1	RMC
92	Bagwa Talab	2	RMC
93	Changorabhata Talab	1	RMC
94	Dangania Talab	2	RMC
95	Malshay Talab	3	RMC
96	Khokho Talab	4	Private
97		2	Private
98	Khadan Talab	0	RMC
99	Kushalpur Talab	2	RMC
100	Daganiya Talab	1	RMC

101	Kari Talab	1	RMC
102		2	Private
103	Ramkund	3	RMC
104	Amatalab	2	RMC
105	Amatalab	0	RMC
106	Karbala Talab	3	RMC
107		2	Private
108	Guru Gobind Talab	3	RMC

All the blank cells are unnamed water bodies.

1.11.1. Major Water Bodies of Raipur

1.11.1.1. Budhapara Talab

***Figure** Error! No text of specified style in document..6: Budhapara Talab*

This marvellous lake is one of the main attractions in Raipur. Basically, this lake was created by King Brahmadeo, one of the Kalchuri emperors, in 1402. This lake is a quite alluring destination of Raipur and therefore, one could see hordes of people at this lake every moment.

1.11.1.2. Telibandha Talab

***Figure** Error! No text of specified style in document..7: Telibandha Talab*

Located at the busiest road of Raipur, named The GE Road, Telibandha Talab is one of the most attractive spots of Raipur. This Talab is recognized as a religious site more than a tourist place. Loads of Hindus come here to perform rituals with great pious and faith every year from every nook of the state. Therefore, Telibandha talab is one of the most demanding attractions in Raipur.

Figure** Error! No text of specified style in document.**.8: Swami Vivekanand Sarovar

1.11.1.3. Swami Vivekanand Sarovar

This talab is located in Puranibasti of Raipur and is quite appealing. There is a mind-boggling island located in the middle of the talab enclosed with lush vegetation and green gardens enhanced with colourful flowers.

Chapter 3
LITERATURE STUDY

Water bodies can be classified into various categories based on different criteria. Here are some common classifications of water bodies:

- **Oceans:** The largest water bodies on Earth, oceans cover about 71% of the planet's surface. The five major oceans are the Pacific Ocean, Atlantic Ocean, Indian Ocean, Southern Ocean, and Arctic Ocean.
- **Seas:** Seas are generally smaller than oceans and are partially enclosed by land. Examples include the Mediterranean Sea, Caribbean Sea, and Red Sea.
- **Lakes:** Lakes are inland bodies of water that are usually freshwater, although some lakes can be saline. They are typically surrounded by land and can vary in size from small ponds to large bodies of water like the Great Lakes in North America.
- **Rivers:** Rivers are flowing bodies of water that usually originate from mountains or highlands and flow into lakes, seas, or oceans. They play a crucial role in the water cycle and are essential for drainage and transportation.
- **Reservoirs:** Reservoirs are human-made water bodies created by constructing dams across rivers. They are used to store water for various purposes such as drinking water supply, irrigation, hydroelectric power generation, and flood control.
- **Ponds:** Ponds are small, shallow water bodies that are typically found in agricultural or rural areas. They support a diverse range of plant and animal life.
- Wetlands: Wetlands are areas where the land is saturated with water, either permanently or seasonally. They include marshes, swamps, bogs, and estuaries. Wetlands provide habitat for many species and play a vital role in water filtration and flood regulation.
- **Glaciers:** Glaciers are large masses of ice and snow that accumulate over time in cold regions. They are important sources of freshwater and contribute to the formation of rivers.
- **Estuaries:** Estuaries are partially enclosed coastal bodies of water where freshwater from rivers mixes with saltwater from the ocean. They are characterized by high biodiversity and serve as breeding grounds for many marine species.

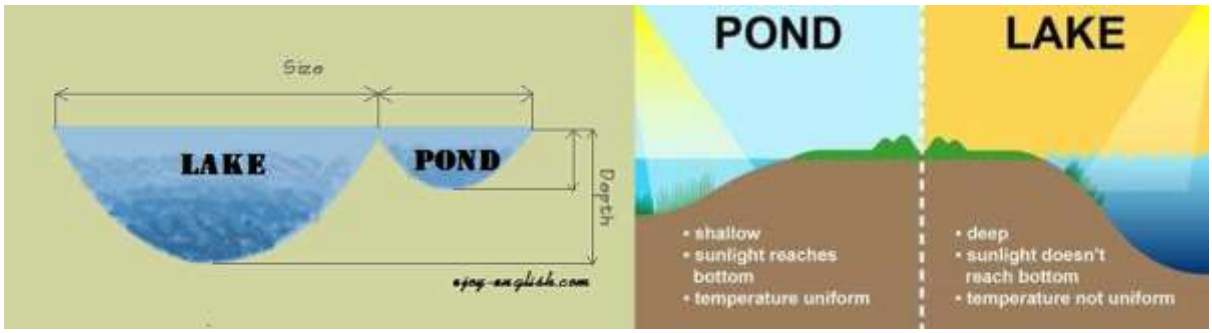
- **Bays and Gulfs:** Bays and gulfs are partially enclosed coastal areas that are usually larger than coves and smaller than seas. Examples include the Bay of Bengal, Gulf of Mexico, and San Francisco Bay.

These classifications provide a general overview, but it's important to note that there can be overlap and variations within each category. Additionally, there are other types of water bodies, such as lagoons, fjords, and coral reefs, that represent specific geological or ecological features.

1.12. Lakes v/s Ponds

Lakes and ponds are sometimes used as connotations but they vary vastly based on their depth, catchment and size.

Figure Error! No text of specified style in document.**..9: Difference between Lake and Pond**



Source: (Darlene, 2019) (Tabitha, 2022)

Table Error! No text of specified style in document.**..3: Difference between Lakes and Ponds**

	Lakes	**Ponds**
	Lake is an area filled with water, localized in a basin, not connected to the sea except by rivers or streams. A lake can be natural or artificial. Artificial lake is constructed for industrial or agricultural use, for hydro-electric power generation or domestic water supply, or for aesthetic, recreational purposes, etc.	Pond is an area of water surrounded by land, either natural or artificial, usually smaller than a lake. A pond is usually human-constructed for habitat restoration, decoration, commercial breeding (of fish, shrimp, etc.), or architectural features, etc.
Depth	20 – 40,000 ft	4 – 20 ft
Outlet	Open	Closed
Size	200+ acres	<200 acres

Source: (Stacy, 2023)

1.13. Functions of Water Bodies

Functions of water bodies can be categorised in 4 services, viz.:

1. **Provisioning Services**

a. **Water Supply:** Water bodies, particularly lakes, rivers, and reservoirs, serve as essential sources of freshwater for human societies. They provide water for drinking, irrigation in agriculture, industrial processes, and energy production through hydropower.

2. **Regulatory Services**

a. **Water Filtration and Purification:** Wetlands and other water bodies act as natural filters, purifying water by removing pollutants and contaminants. They trap sediments, absorb nutrients, and facilitate the breakdown of organic matter, improving water quality.

b. **Nutrient Cycling:** Water bodies play a crucial role in nutrient cycling within ecosystems. They receive and distribute nutrients, such as nitrogen and phosphorus, which are essential for the growth of aquatic plants and organisms. These nutrients are cycled through processes like sedimentation, decomposition, and uptake by organisms, maintaining the overall balance of the ecosystem.

c. **Climate Regulation:** Water bodies, particularly oceans, influence global climate patterns. They act as heat sinks and absorb and store large amounts of solar energy, moderating temperature extremes. Oceans also play a significant role in the global water cycle, influencing precipitation patterns and atmospheric circulation.

d. **Flood Control:** Water bodies, especially rivers and wetlands, play a critical role in flood control. They act as natural buffers, absorbing excess rainfall and slowing down the flow of water. Wetlands, in particular, can store and retain water, reducing the risk of downstream flooding.

e. **Erosion Control and Sediment Regulation:** Water bodies help control erosion by dissipating the energy of flowing water and trapping sediment. Vegetation along rivers and wetlands can stabilize banks and prevent excessive erosion, while estuaries and deltas capture sediment, maintaining coastal landforms.

3. **Cultural Services**

a. **Recreation and Tourism:** Water bodies offer recreational opportunities and serve as popular tourist destinations. Activities such as swimming, boating, fishing, snorkelling, and diving attract people to coastal areas, lakes, and rivers, contributing to local economies and leisure activities.

b. **Cultural and Spiritual Significance:** Water bodies hold cultural and spiritual significance for many communities around the world. They are often associated with traditional practices, ceremonies, and beliefs, representing a deep connection to nature and providing a sense of identity and heritage.

4. **Supporting Services**

a. **Habitat and Biodiversity:** Water bodies provide habitats for a wide range of aquatic plants and animals. They support diverse ecosystems, including fish, invertebrates, birds, mammals, and amphibians. Water bodies serve as breeding grounds, nurseries, and feeding areas for many species, contributing to overall biodiversity.

b. **Transportation and Trade:** Rivers, seas, and oceans have historically been crucial transportation routes for trade and commerce. They allow for the movement of goods, people, and resources, facilitating economic activities and cultural exchange between regions.

1.14. Water Body Rejuvenation: Frameworks, Policies, Initiatives, Tools and Techniques

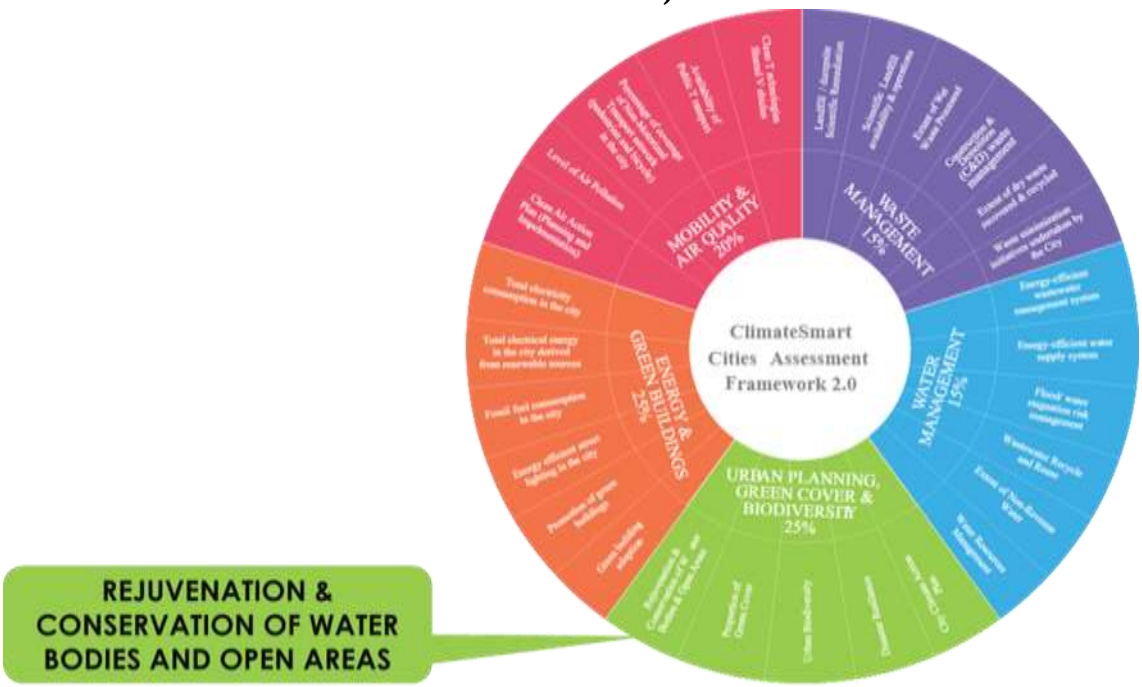
Water bodies, open spaces, and built-up area are all components of the urban environment. All three aspects are of crucial importance from the perspective of climate adaptation and mitigation. Water bodies play a crucial role in serving as repositories for potable water, as well as retention basins for the purpose of groundwater recharge. Additionally, they serve as a protective measure in the event of floods and are instrumental in preserving biodiversity. The presence of nearby sources of unpolluted water reduces the reliance on energy-intensive pumping mechanisms.

1.14.1. CSCAF: ClimateSmart Cities Assessment Framework 2.0

The ClimateSmart Cities Assessment Framework is a tool that helps cities evaluate their climate resilience and sustainability efforts. It provides a structured approach to assess a city's performance in various areas related to climate change mitigation, adaptation, and overall environmental sustainability. The framework is designed to assist cities in identifying their strengths, weaknesses, and priority areas for improvement. While there are various versions and variations of the ClimateSmart Cities Assessment Framework, here are some common components and aspects it may cover: (National Institute of Urban Affairs)

- **Greenhouse Gas Emissions:** The framework assesses a city's emissions inventory and reduction strategies. It evaluates the city's efforts to mitigate greenhouse gas emissions through measures such as energy-efficient buildings, renewable energy deployment, public transportation systems, waste management practices, and sustainable land use planning.
- **Climate Change Adaptation:** This component focuses on a city's preparedness and ability to adapt to the impacts of climate change. It examines initiatives related to climate risk assessments, infrastructure resilience, water resource management, emergency response planning, and public health considerations.
- **Urban Planning and Design:** The framework assesses how cities plan and develop their urban areas with climate resilience and sustainability in mind. It evaluates factors such as compact and mixed land use, green infrastructure, walkability, bikeability, public spaces, and access to essential services.

Figure Error! No text of specified style in document.**.10: CSCAF 2.0 (Source: (National Institute of Urban Affairs)**



- **Energy and Water Management:** This component focuses on a city's efforts to promote energy efficiency, renewable energy integration, and sustainable water management practices. It evaluates initiatives related to energy conservation, smart grid implementation, water conservation, wastewater treatment, and water reuse.

- **Waste Management:** The framework assesses a city's waste management practices, including waste reduction, recycling programs, waste-to-energy initiatives, landfill management, and circular economy approaches.
- **Transportation and Mobility:** This component evaluates a city's transportation systems and policies with a focus on reducing emissions and promoting sustainable mobility options. It assesses initiatives related to public transportation networks, non-motorized transportation infrastructure, electric vehicle adoption, and traffic management strategies.
- **Governance and Policy:** The framework considers the city's governance structure and policy framework for climate action and sustainability. It evaluates the existence of climate action plans, sustainability targets, regulatory frameworks, stakeholder engagement mechanisms, and funding mechanisms to support climate initiatives.
- **Community Engagement and Social Equity:** This component assesses the city's efforts to engage and involve the community in climate resilience and sustainability initiatives. It considers inclusivity, social equity, public participation, education and awareness campaigns, and the integration of social considerations in decision-making processes.

By using the ClimateSmart Cities Assessment Framework, cities can gain a comprehensive understanding of their current performance and identify areas where improvements can be made to enhance their climate resilience and sustainability efforts. This framework provides a roadmap for cities to set targets, prioritize actions, and monitor progress towards building more sustainable and resilient urban environments.

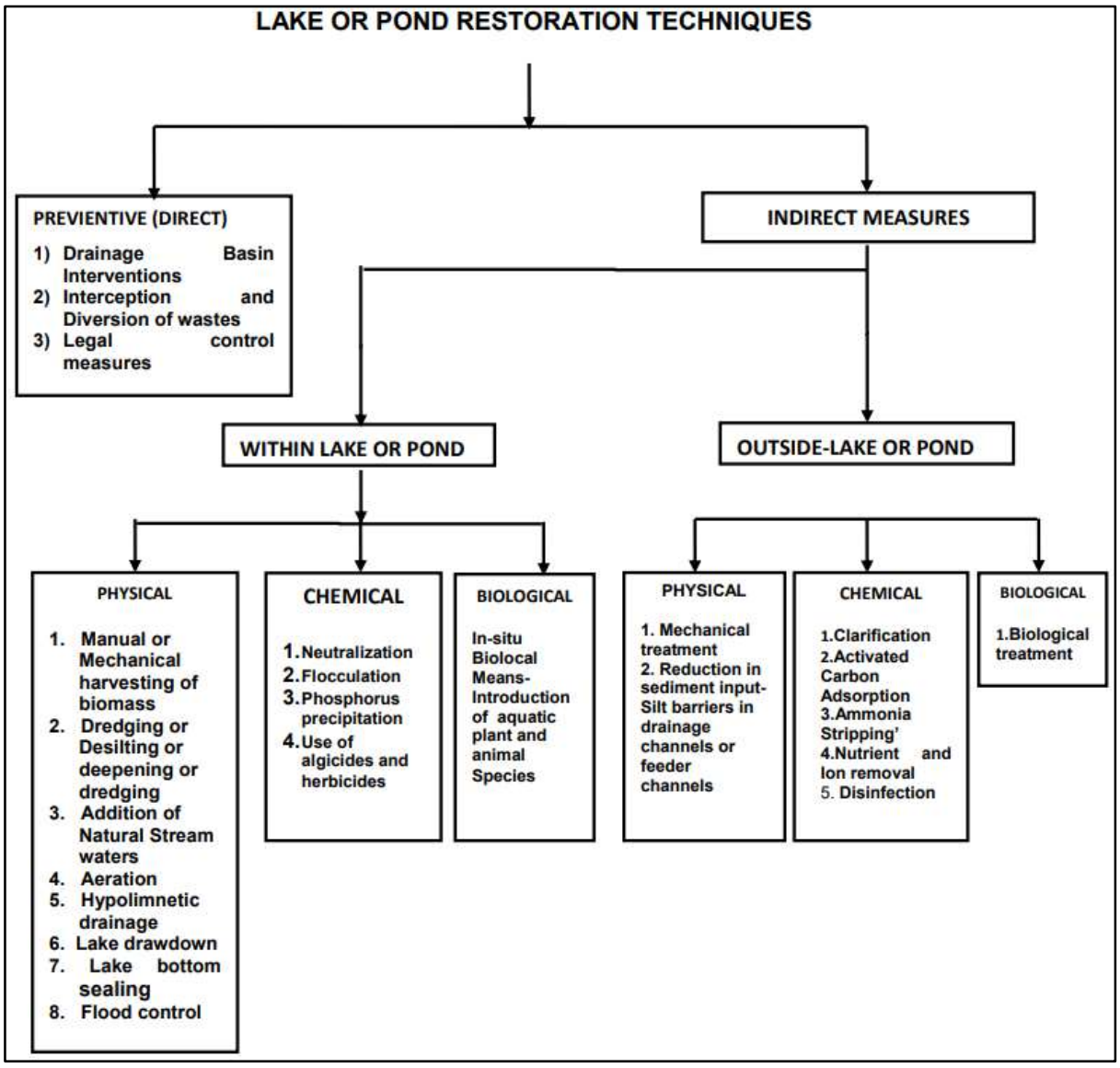
1.14.2. Jal Jeevan Mission

The Jal Jeevan Mission endeavours to achieve universal access to safe and adequate drinking water for every rural household in India through the provision of individual household tap connections by the year 2024. The programme will integrate mandatory measures for source sustainability, such as grey water management, water conservation, and rainwater harvesting, with the aim of encouraging recharge and reuse.

1.14.3. Water Body Rejuvenation Framework

Given below is a framework for rejuvenation and restoration of lakes and ponds as per the Rejuvenation and Conservation of Water Bodies and Open Areas Training Manual:

Figure Error! No text of specified style in document.**.11: Water body Rejuvenation Framework**



Source: (Awasti, Suchita;, 2021)

1.14.4. Water Body Rejuvenation Tools and Techniques

1. **Area Treatment**
   - Afforestation, storm water drainage management, silt traps
   - Removal of obstructions in the inlet & outlet
   - Plantation of trees along the sides of water bodies
   - Removal of encroachment
   - Bunds, fencing/re-fencing
   - Wetland plantation
2. **In-Situ Conservation**
   - De-silting and De-weeding
   - Bio-manipulation
   - Bioremediation
   - Green Bridge
   - Sedimentation Basin

- Rainwater Harvesting

3. Quality Monitoring

- Prevention of any outfall of domestic/industrial sewage
- Ensuring only treated effluent disposal
- Monitoring of water quality by the concerned ULB
- A separate tank for religious/cultural festivities

4. Restrictions and Awareness

- Delineation of eco-sensitive areas
- Ban on uses of "potable water" for proposes other than drinking
- Walking track along the water bodies to increase public awareness
- Promote community participation

1.15. Existing Acts and Laws

At present, there exists no specific legal provision aimed at safeguarding Lakes and Wetlands. Numerous legislative measures implemented in the past comprise pertinent clauses aimed at the preservation of said natural resources. Numerous instances can be cited as illustrations: (Tamil Nadu Water Supply and Drainage Board)

The legislative measures that were enacted to address environmental concerns in India include the Forest Conservation Act of 1980, the Wildlife Act of 1972, the Water (Prevention and Control of Pollution) Act of 1974, and the Environment (Protection) Act of 1986.

Furthermore, some states have established unique legislative structures at the state level to protect and conserve their lakes and other bodies of water.

The primary objective of the National Environment Policy (NEP) of 2006 is to institute a legally binding regulatory structure that safeguards and conserves lakes and wetlands, with the ultimate goal of averting their deterioration.

Until a specific regulatory framework for lakes and wetlands is established, the conservation of lakes may be governed by the provisions of current central and state legislations, which are as follows:

- **The Water (Prevention & Control of Pollution) Act of 1974**, as revised, provides a comprehensive framework for addressing water-related concerns. The aforementioned legislation confers authority upon the Government to uphold the purity and soundness of the country's aquatic resources. The Act stipulates a prohibition on the utilisation of streams, which encompasses both natural and artificial inland water bodies, as well as wells, for the purpose of disposing of polluting substances and other similar materials. The Act empowers the Government, in collaboration with the Central and State Pollution Control Boards, to establish standards and implement measures for monitoring and ensuring compliance. It also includes provisions for penalising those who violate the Act.
- **The 1986 'Environment (Protection) Act'** confers upon the Central Government the authority to undertake actions aimed at safeguarding and enhancing the environment, encompassing water, air, and land, as well as the interdependencies that exist among these elements and between them and human beings, other organisms, flora, microorganisms, and assets.
- **The National Environment Policy (NEP) of 2006** acknowledges the ecological benefits provided by bodies of water such as lakes and wetlands. According to the NEP, wetlands, including lakes, are facing a multitude of challenges such as drainage and conversion for agricultural and human settlement purposes, as well as pollution. The failure to consider the depreciation of the economic worth of environmental services and the health-related expenses associated with pollution when utilising them

as a disposal site is a significant concern. The NEP outlines a course of action for the preservation of these aquatic ecosystems, which involves the development of strategies for conservation and responsible usage, the incorporation of wetland and lake conservation into poverty alleviation and livelihood improvement plans, the creation of eco-tourism strategies to foster collaboration among multiple stakeholders, and most importantly, the establishment of a legally-binding regulatory framework for these water bodies.

1.16. Case Studies

1.16.1. Rajokri Lake, New Delhi

The Delhi administration faced a significant water crisis in the metropolitan area during the year 2018. One potential solution was the restoration of urban water bodies, with the Rajokri Lake serving as a convenient pilot case. The revitalization of this 2.33-acre lake has been achieved through the implementation of decentralised natural treatment methods, in conjunction with the utilisation of sustainable energy sources and rainwater collection techniques. The project was founded on the principles of sustainability and scalability. (CDD Society, 2019)

The Rajokri Lake is situated in the suburban village of Rajokri, which is in close proximity to the Delhi Gurgaon Border. In 2018, the Delhi Jal Board (DJB) undertook the task of restoring the lake. Previously, the lake served as a breeding habitat for mosquitoes and communicable illnesses that afflicted the semi-rural populace residing in the vicinity of the lake. The wastewater emanating from the adjacent residential localities was directed through the uncovered conduits and accumulated in the lake. (CDD Society, 2019)

The lake holds great significance for the indigenous community, as it serves a symbolic function in the observance of Chhath Puja, a culturally significant festival. The Member of Legislative Assembly (MLA) demonstrated proactive efforts in advocating for the revitalization of the aforementioned lake, resulting in its selection as a pilot project by the Delhi Jal Board (DJB). (CDD Society, 2019)

1.16.1.1. Institutions Involved

The rejuvenation of Rajokri Lake was a collaborative endeavour between the Delhi Jal Board (DJB) and the Department of Irrigation and Flood Control. The project's conceptualization and design were attributed to DJB, while its practical implementation was carried out by Irrigation and Flood Control (I&FC). Several smaller private organisations and trusts provided pro-bono services for specific components of the work. The initiative also involved the participation of the Chhath Puja Committee. (CDD Society, 2019)

Figure Error! No text of specified style in document.**.12: Rajokri Lake Rejuvenation**

Source: (CDD Society, 2019)

1.16.1.2. Key Initiatives at Rajokri Lake

- **Preparatory Interventions**
  - Desilting of the lake for removal of sludge and solid waste for enhancement of the water holding capacity
- **Lake Recharge & Wastewater Treatment Interventions**
  - Scientific Wetland System with Active Bio - Digester (SWAB) of 0.6 MLD treatment capacity
  - Installation of 40 floating wetlands.
  - Creation of Bio swales
  - Gravel Pathways
  - Plantation of Bioremediation grasses
- **Biodiversity Enhancement Interventions**
  - Plantation inside the lake premises
- **Allied Interventions**
  - Creation of a children's play area and open gym
  - Space for conducting Chhath Puja

1.16.1.3. Inferences

1. The strength of the wastewater that is being discharged into the lake can be classified as moderate. Typically, the strength of wastewater conveyed through open channels is moderate to low.

Nonetheless, in the event that the water is in motion within an enclosed conduit, such as a sewer line, it could potentially possess greater potency.

The water flow in Rajokri has been redirected to operate within a confined system as a result of the high concentration of residential structures in the area.

2. The parameters of COD and BOD indicate a consistent reduction in the organic content of water. The results indicate a reduction of 67% in biological oxygen demand (BOD) from the primary inlet to the SWAB inlet, subsequent to the completion of secondary treatment. Additionally, a further decrease of 56% in BOD is observed within the SWAB. In general, it is evident that there is an approximate reduction of 85% in Biological Oxygen Demand (BOD) from the point of entry to the point of discharge of processed water into the lake. The decrease in quantity can be attributed to the utilisation of both anaerobic and aerobic systems in conjunction.
3. The lake is equipped with a treatment mechanism in the form of floating wetlands. Floating wetlands facilitate the process of converting ammonia into nitrates. The process of conversion is facilitated by the microorganisms that exist in the plant's root system, in conjunction with the media that is aerated on its surface.
4. A comprehensive evaluation of all parameters has not been conducted, therefore a definitive statement regarding the quality of water cannot be rendered. According to the limited parameters that were examined, the composition of the lake water aligns with the characteristics of Class E as per the best use classification system designated by the Central Pollution Control Board (CPCB). This indicates that the water is appropriate for purposes such as controlled waste disposal, industrial cooling, and irrigation.

1.16.2. Mansagar Lake, Jaipur Rajasthan

The amalgamation of landscapes and water has the potential to captivate the attention and stimulate the imagination of any individual. The Jal Mahal, which is encompassed by the Mansagar Lake, effectively accomplishes this task. The process of rehabilitating the aforementioned ecosystem entails increased accountability and intricacy due to a consistent influx of visitors to the heritage location. However, it is important to note that the environmental system that sustains the Mansagar Lake is considerably more expansive than the tourist infrastructure. (CDD Society, 2019)

Mansagar Lake was created through human intervention under the direction of Maharaja Mansingh I. The process involved the construction of a dam to impound the flow of River Drabhavati and Nagatalai drain in the year 1610. The expansion of Jaipur city had a detrimental impact on the condition of the lake, which was further exacerbated by the decision of the Jaipur administration to redirect the city's sewage into the lake via the Brahmapuri and Nagtalai drains. (CDD Society, 2019)

The proliferation of water hyacinth resulted in the encroachment upon the indigenous flora of the lake, ultimately leading to the degradation of the aquatic ecosystem. Over time, avian species that engage in seasonal migration ceased to frequent the aforementioned body of water. The deposition of silt caused by soil erosion and sewage sludge led to increased eutrophication, ultimately resulting in the obstruction of the lake. (CDD Society, 2019)

The Mansagar Lake has been identified as a highly susceptible area to the impacts of urbanisation and tourism. In December 2002, the ecological restoration of the Lake was carried out in accordance with the National Lake Conservation Plan (NLCP), which was funded through a 70:30 pattern between the Central and State Government, amounting to Rs. 24.72 Crore. (CDD Society, 2019)

1.16.2.1. Institutions Involved

The rejuvenation of Mansagar Lake was a collaborative endeavour between the Jaipur Development Authority and the Jaipur Nagar Nigam, facilitated by the National Lake Conservation Programme, which is sponsored by the central government. Considering the inherent attributes and features of the project, the adoption of a Public Private Partnership (PPP) framework was deemed advantageous for the perpetuation of lake upkeep. The maintenance contract was awarded to Kothari Group, a Mumbai-based consortium, following a competitive bidding process. Therefore, the establishment of Jal Mahal Resorts Private Limited was undertaken with the objective of developing a 100-acre land for tourism purposes on a 99-year lease. A Public Interest Litigation (PIL) has been filed in the Rajasthan High Court, and the case is currently under judicial consideration.

Currently, the JDA is responsible for the upkeep of the lake, whereas the management of the lakefront and STPs falls under the purview of JNN. (CDD Society, 2019)

Figure Error! No text of specified style in document.**.13: Mansagar Lake Rejuvenation**

Source: (CDD Society, 2019)

1.16.2.2. Key Initiatives at Mansagar Lake

- **Preparatory Interventions**
  - Manual de-weeding
  - Mechanised dredging
  - Realignment of drains
  - Construction of a sedimentation basin
- **Lake Recharge & Wastewater Treatment Interventions**
  - Construction of a 27 MLD STP that can treat wastewater up to the secondary level.

- Construction of a 7 MLD Tertiary Treatment Plant (TTP)
- Construction of contour trenches and dykes
- Construction of loose rubble check dams
- Constructed Wetlands
- Diffusors for aeration

- **Biodiversity Enhancement Interventions**
- Creation of nesting Islands for residential and migratory birds
- Afforestation

- **Allied Interventions**
- Creation of Lake Front Promenade and walking track

1.16.2.3. Inferences

1. All the storm water inlets to the lake are carrying low to medium strength wastewater indicating contamination along the drains.
2. Aeration as a standalone treatment mechanism is helping reduce the organic content by approximately 78%.
3. High ammonia and phosphate concentration indicate eutrophic conditions in the lake.
4. All parameters have not been analysed hence a conclusive remark on the water quality cannot be made. But based on the few parameters that were analysed, the lake water resembles CLASS E of the designated best use classification system which makes it suitable for irrigation, industrial cooling and controlled waste disposal.

1.16.3. Summary of the Case Studies

Table Error! No text of specified style in document.**.4: Case Studies at a Glance**

	Preparatory Interventions	Lake Recharge & Wastewater Treatment Interventions	Biodiversity Enhancement Interventions	Allied Interventions
RAJOKRI LAKE, DELHI	• Desilting of the lake for removal of sludge and solid waste for enhancement of the water holding capacity.	• Scientific Wetland System with Active Bio-Digester (SWAB) of 0.6 MLD treatment capacity • Installation of 40 floating wetlands. • Creation of Bio swales • Gravel Pathways • Plantation of Bioremediation grasses	• Plantation inside the lake premises	• Creation of a children's play area and open gym • Space for conducting Chhath Puja
MANSAGAR LAKE, JAIPUR	• Manual deweeding • Mechanised dredging • Realignment of drains • Construction of a sedimentation basin	• Construction of a 27 MLD STP that can treat wastewater up to the secondary level. • Construction of a 7 MLD Tertiary Treatment Plant (TTP) • Construction of contour trenches and dykes • Construction of loose rubble check dams • Constructed Wetlands • Diffusors for aeration	• Creation of nesting islands for residential and migratory birds • Afforestation	• Creation of Lake Front Promenade and walking track

Source: (CDD Society, 2019)

Chapter 4
ANALYSIS

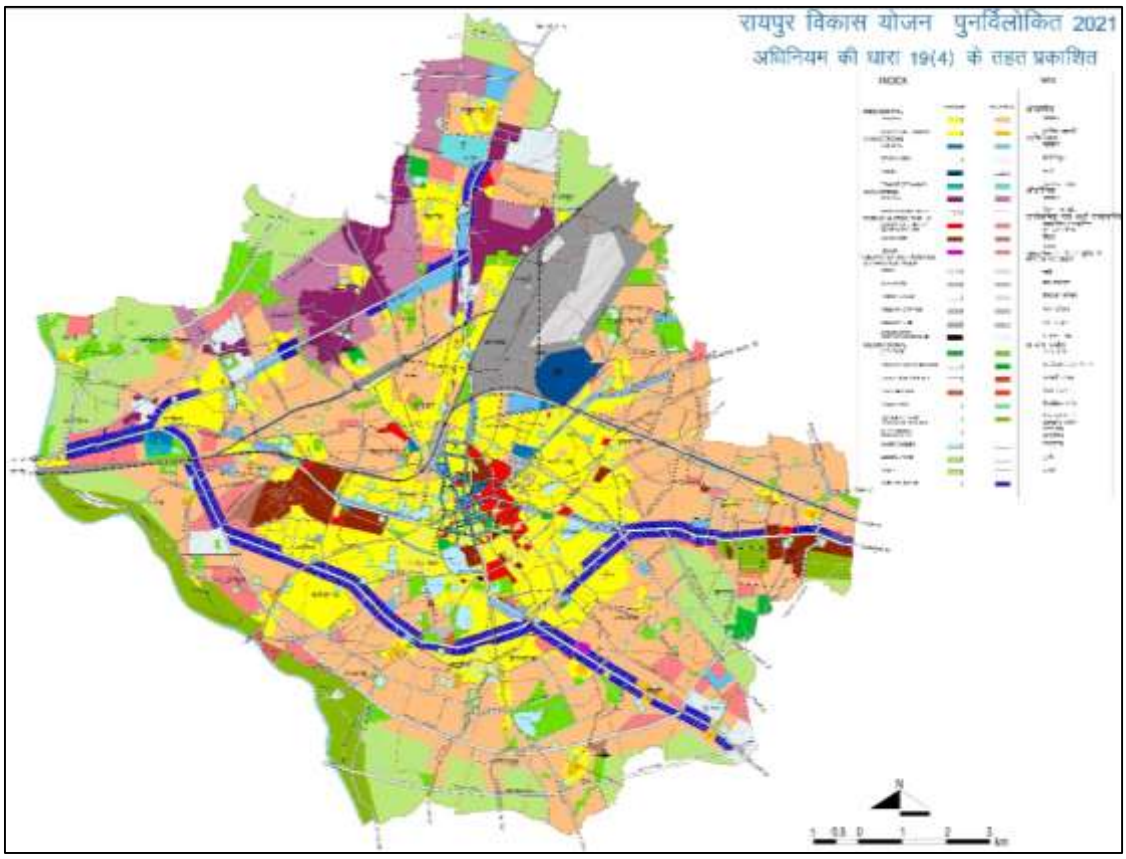
The major analysis and studies conducted are:

1. Land Use Analysis
2. LULC Analysis
3. LST (Land Surface Temperature) Analysis
4. GWP (Ground Water Potential) Zone Mapping
5. Status Assessment of the water bodies

1.17. Land Use Analysis

The Land Use Analysis was done for land uses of 2011 and 2021 as per the Raipur Development Plans. Following is a map of the Raipur Development Plan, 2021:

Map Error! No text of specified style in document.**.5: Raipur Development Plan, 2021 (Source: TNCP, RMC)**



The following table shows the change in land use of Raipur between 2011 and 2021:

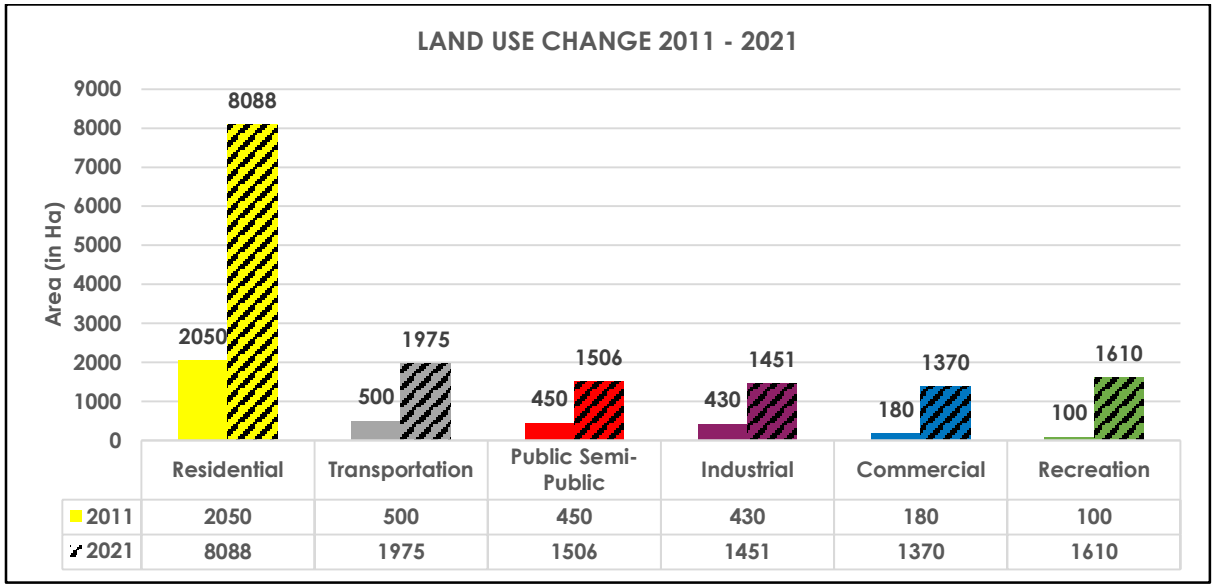
Table Error! No text of specified style in document.**.5: Raipur Land Use Distribution: 2011, 2021**

Land Use	2011	2011%	2021	2021%	% Change
Residential	2050	55%	8088	51%	2.95
Commercial	180	5%	1370	9%	6.61
Industrial	430	12%	1451	9%	2.37
Public Semi-Public	450	12%	1506	9%	2.35
Recreation	100	3%	1610	10%	15.10
Transportation	500	13%	1975	12%	2.95
Total	**3710**	**100%**	**16000**	**100%**	

Source: Raipur Development Plan 2021

Below is a graphical representation of the table above:

Graph Error! No text of specified style in document.**.3: Raipur Land Use Change (i)**



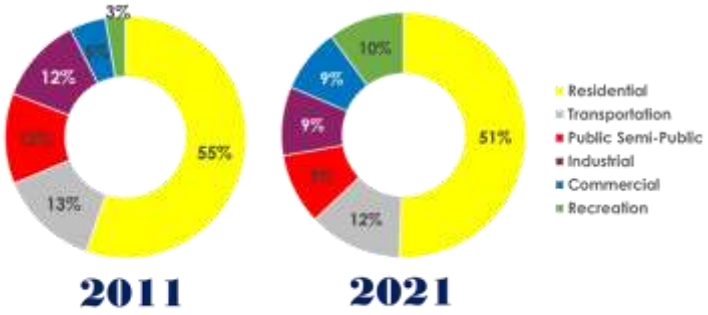
As per the analysis, the existing land use distribution is more even compared to that of 2011.

1.18. Land Use Land Cover Analysis

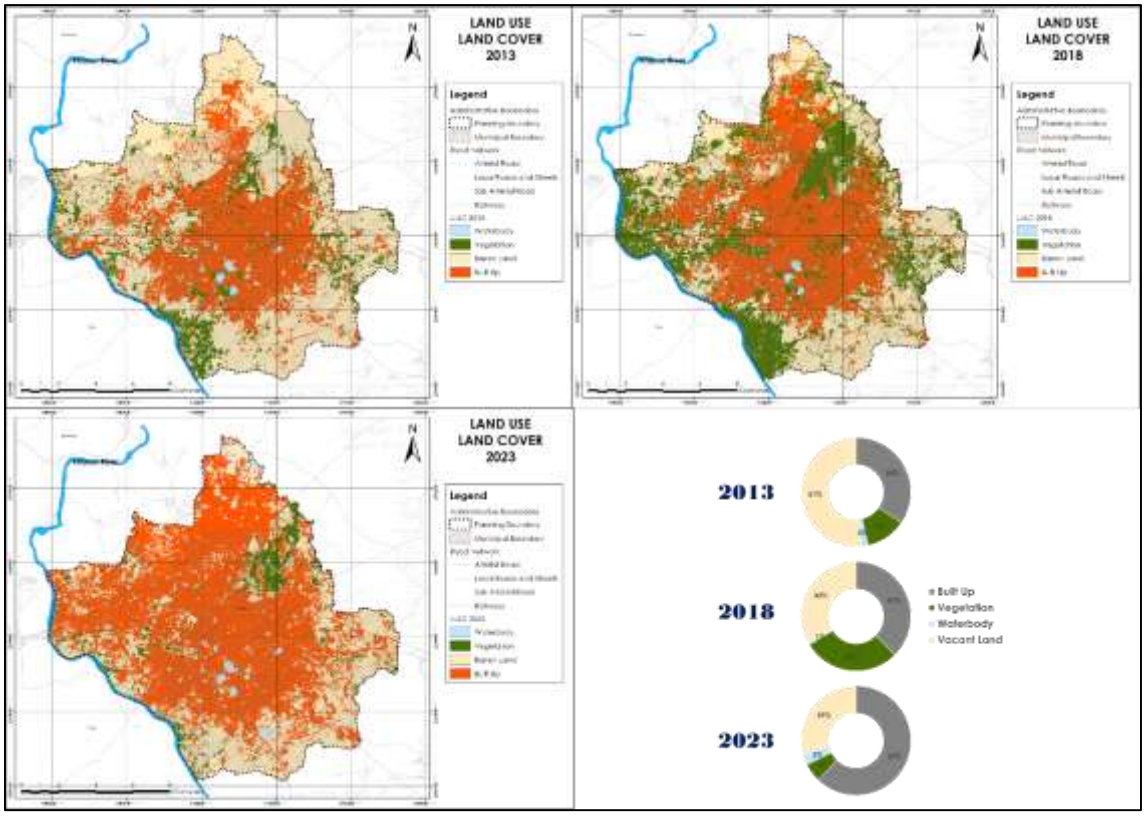
The Land Use Land Cover trend of Raipur for the last ten years shows an abrupt change in the urban vegetation which reduced from 29% in 2018 to a mere 4% in 2023. The major reason for this as per the RMC is the population growth and expansion of the built-up area and lack of funds for the recreation department.

The waterbody area has increased from 2% back in 2013 to 3% in 2023 owing to numerous lake rejuvenation schemes.

The maps below showcase the LULC for the years 2013, 2018, and 2023:



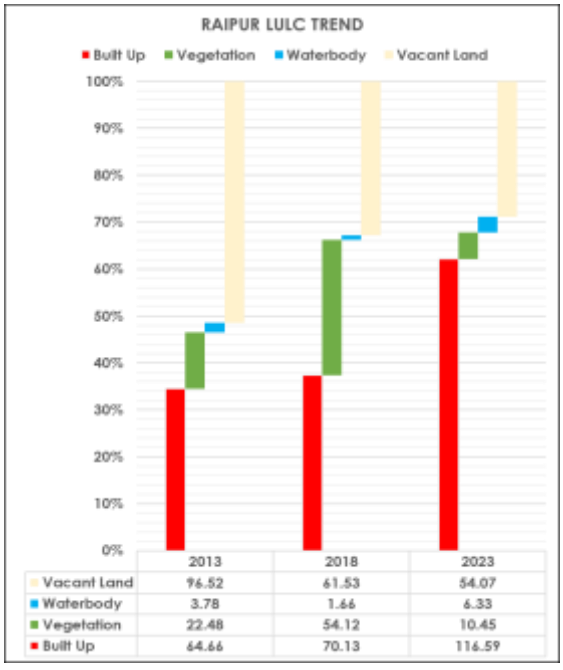
Map** Error! No text of specified style in document.**.6: Raipur LULC: 213, 2018, 2023



Source: Author

As per the analysis, the Land Use Land Cover trend of Raipur for the last ten years shows an abrupt change in the urban vegetation which reduced from 29% in 2018 to a mere 4% in 2023. The major reason for this as per the RMC is the population growth and expansion of the built-up area and lack of funds for the recreation department.

The waterbody area has increased from 2% back in 2013 to 3% in 2023 owing to numerous lake rejuvenation schemes.



	2013	2018	2023
Vacant Land	96.52	61.53	54.07
Waterbody	3.78	1.66	6.33
Vegetation	22.48	54.12	10.45
Built Up	64.66	70.13	116.59

Graph Error! No text of specified style in document.**..4: Raipur LULC Trend: 2013, 2018, 2023**

The adjacent graph represents the change in Raipur's LULC for the abovementioned years:

1.18.1. Availability of Open Spaces

The table below shows the availability of open spaces in Raipur per 1000 persons for the year 2013, 2018, and 2023:

Table Error! No text of specified style in document.**.6: Availability of Open Space**

Year	Population	% of Open Space (as	% of open space per
2013	11,36,153	26.26	2%
2018	14,62,523	55.78	4%
2023	18,82,645	16.78	1%

The table shows a drastic reduce in the availability of open spaces (urban green open spaces, water bodies, urban open spaces, etc) from 4% per thousand persons in the year 2018 to only 1% per thousand persons in the year 2023.

The diminution of available open areas may yield diverse implications for both the ecosystem and human welfare. The following are plausible outcomes:

- **Loss of Biodiversity:** Parks, woods, and natural areas support various plant and animal species. Reduced or fragmented open areas can destroy habitats, ecological networks, and biodiversity.
- **Ecosystem Services Degradation:** Open areas purify air and water, regulate temperature, and fertilise soil. Reduced open areas can harm these services, including air pollution, urban heat island effect, water pollution, and soil erosion.
- **Increased Urban Heat Island Effect:** Open areas minimise surface temperatures by providing shade and greenery. Reduced open spaces raise urban temperatures, causing discomfort, greater cooling costs, and health hazards.
- **Reduced Recreation and Leisure:** Open places allow individuals to exercise, relax, and connect with nature. Reducing open areas reduces leisure and recreation, affecting people's health.
- **Loss of Cultural and Aesthetic Value:** Open spaces often have cultural and aesthetic significance, contributing to the identity and heritage of a place. When open spaces are diminished, there can be a loss of cultural landscapes, scenic views, and community gathering spaces, affecting the overall quality of life in a locality.
- **Increased Stormwater Runoff and Flooding:** Green spaces and wetlands absorb and store precipitation, decreasing stormwater runoff and flooding. Reduced open areas increase impervious surfaces like pavement and buildings, which can exacerbate stormwater runoff, drainage concerns, and floods.
- **Health decline:** Open places boost mental and physical wellbeing. They promote well-being by offering exercise, stress relief, and nature. Reduced open space may reduce these advantages, affecting public health.
- **Increased Urbanisation and Loss of Natural Landscapes:** Open spaces decrease as urbanisation increases. This can reduce a place's aesthetic attractiveness, ecological connectedness, and community identity.

1.19. Land Surface Temperature Analysis

India with its diverse agroclimatic and morphological zones is particularly affected by climate change. According to the initial national communication to the United Nations Framework on the Convention on Climate Change, the predicted impacts of climate change in India include a surface air temperature rise up to 4° Celsius by 2100, up to 30 per cent decline in yield in rain-fed areas for some crops and an increase in incidences of extreme events, such as droughts, floods and cyclones.

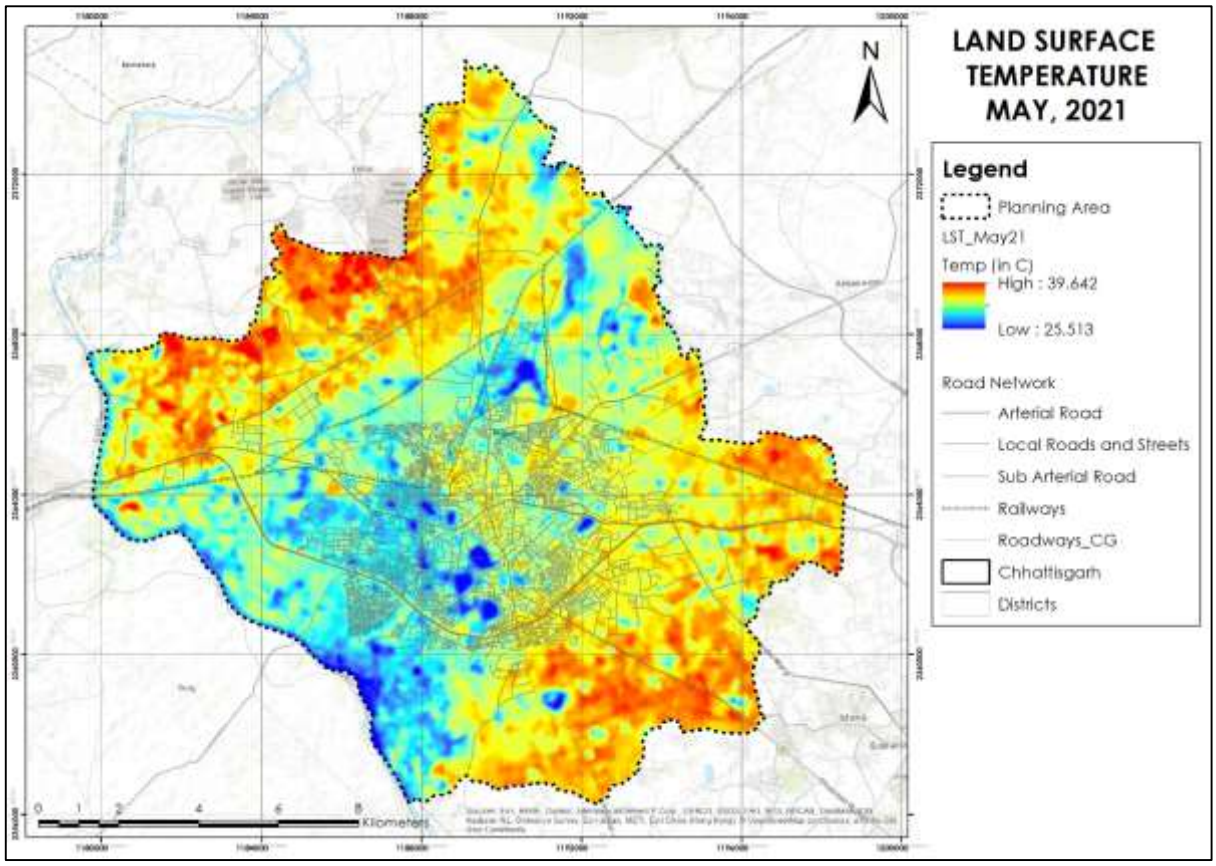
To understand how the LST of the city of Raipur has changed in the past few years will help us understand the impacts of climate change and undertake necessary mitigation strategies to counter the adverse impacts on the remaining waterbodies of the city which are prone to drying.

The following maps depict the peak summer (May) and peak winter (December) LSTs of Raipur for the period of 2021 – 2022 and 2023's LST for the month of February:

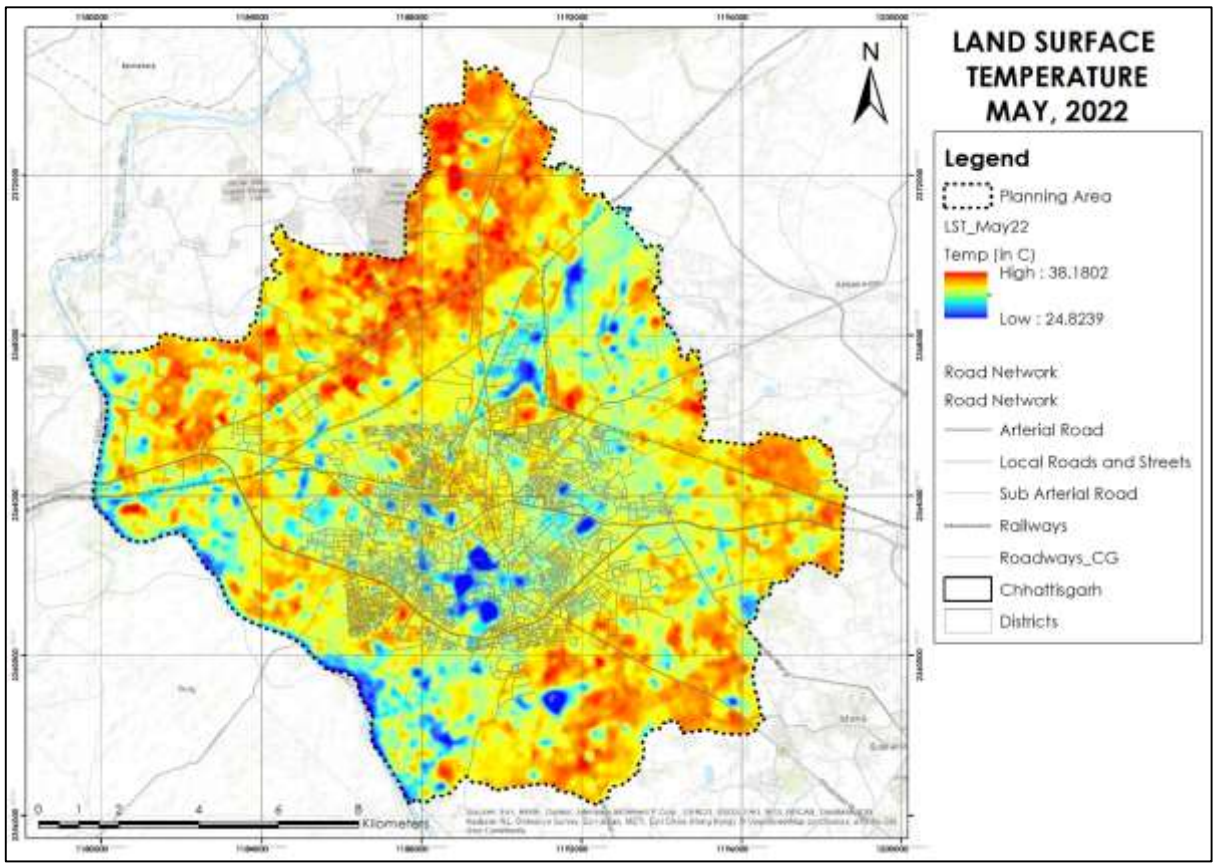
1.19.1. Peak Summer: May – 2021 and 2022

The maps below show Raipur's LST for the month of May for the years 2021 and 2022. We can see that albeit 2022's maximum and minimum temperatures (38.18°C and 24.82°C respectively) being less than that of the year 2021, the Urban Heat Island is more prominent in 2022 majorly towards the west, north – west, and central parts of the city.

Map Error! No text of specified style in document.**.7: Raipur LST, May 2021**



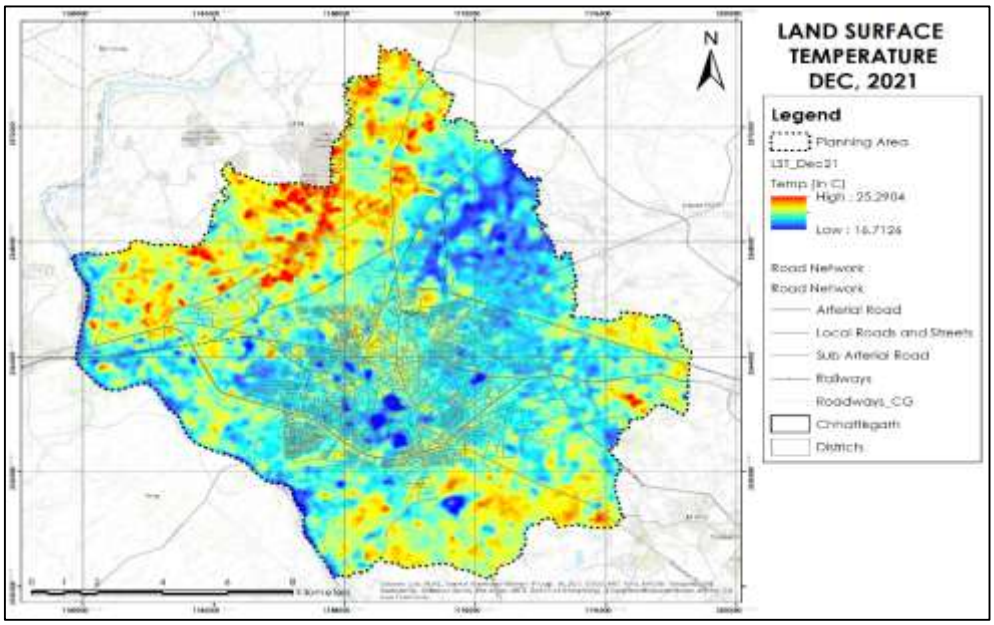
Map Error! No text of specified style in document.**.8: Raipur LST, May 2022**



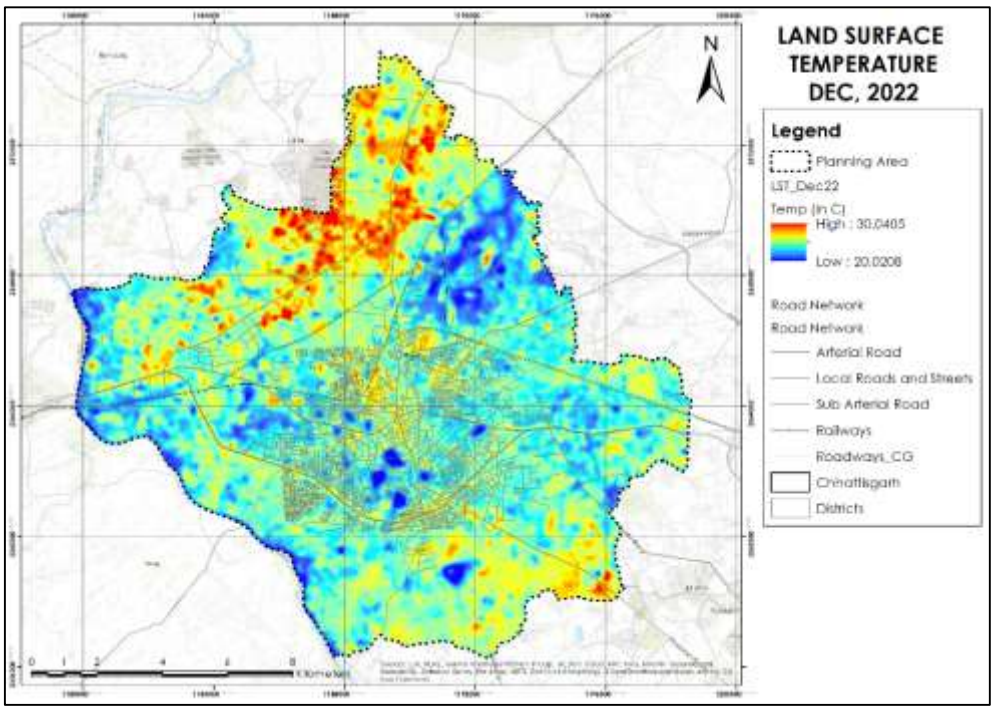
1.19.2. Peak Winter: December, 2021 – 2022

The maps below show Raipur's LST for the month of Decemebr for the years 2021 and 2022. We can see that 2022's maximum and minimum temperatures (30.04°C and 20.02°C respectively) are higher than that of the year 2021 (25.29°C and 16.71°C respectively). The UHI is more majorly towards the north – west parts of the city in both the cases.

Map** Error! No text of specified style in document.**.9: Raipur LST, Dec 2021



Map Error! No text of specified style in document.**.10: Raipur LST, Dec 2022**

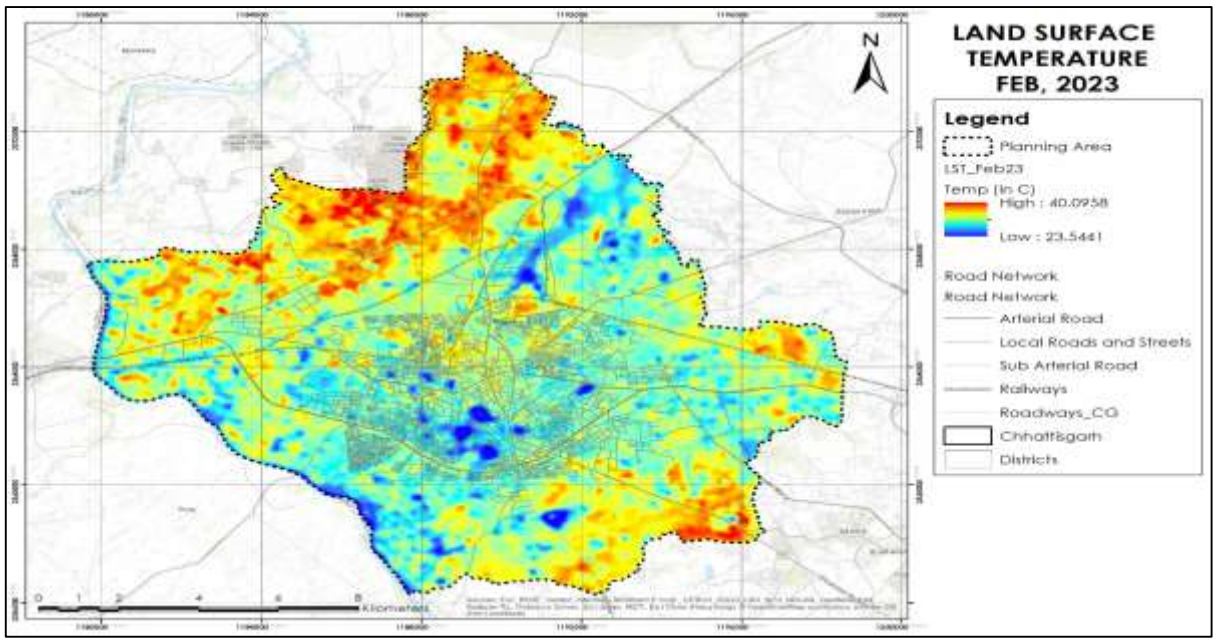


1.19.3. Current Year: February, 2023

The LST Analysis shows that the average temperature of the city has been 30°C with maximum temperatures rising up to 40°C during summers and being the main reason for drying of the local lakes. Even in February we can see that the maximum LST is 40.1°C which is way above the winter average of 23°C.

The central area of the city shows a cool LST owing to an abundance of lakes to balance and cool the surrounding temperature.

Map Error! No text of specified style in document.**.11: Raipur LST, Feb 2023**



The average temperature of the city has risen by 0.7°C which is an alarming number for a city like Raipur.

1.19.4. Climate Change and Potential Impacts on Cities

Table Error! No text of specified style in document.**..7: Climate Change and Potential Impacts on Cities**

Parameter	Impact	Urban Planning Consequence
Increased Temperatures	Ground water depletion, Water Shortage	Water Shortage Distress migration to cities/towns due to droughts in rural areas
	Drought, Degraded air Quality (smog)	Interruption of food supply networks and higher food prices Potential energy price increases Exaggerated urban heat island effect, increased energy demands for cooling Need for higher and/or additional wastewater Treatment Population health impacts, increased mortality due to heat waves, decreased access to food/nutrition
Increased Precipitation	Increased risk of landslides or mudslides on hazard slopes	Interruption of food supply networks Property damage Disruption of livelihoods and city economies Damage to infrastructure, not designed to standards of occurrences being experienced by rural areas Displacement and population movement from informal settlements, built on steep slope hazard lands, etc. More favorable breeding grounds for pathogens and disease vectors like mosquitoes, flies etc. Population health impacts (increased incidences of water-borne diseases like cholera) Increased risk of landslides or mudslides, hazard slopes

Source: (Urban Climate Change Research Network, 2015)

1.20. GWP Zone Mapping

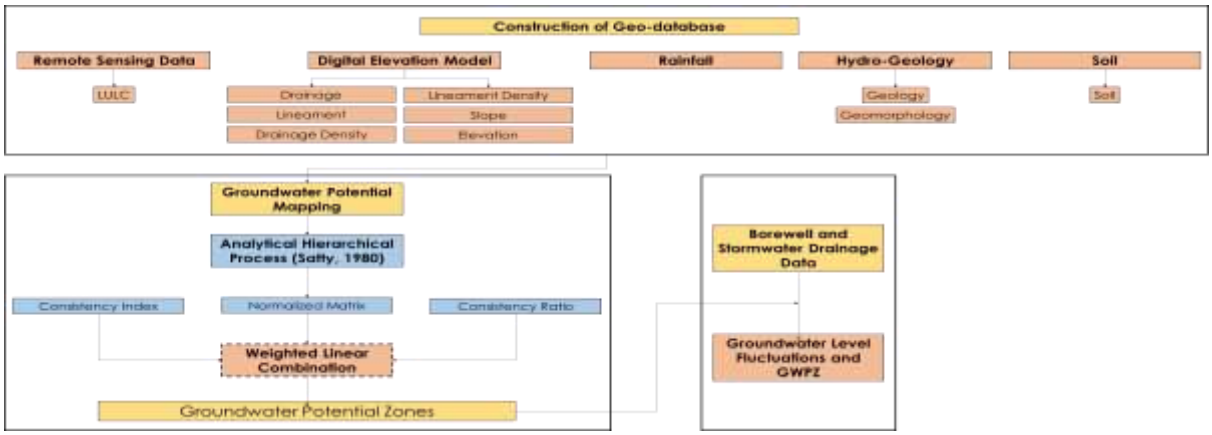
The process of mapping potential groundwater zones involves the identification and delineation of regions that are highly probable to possess substantial groundwater resources. The process entails the amalgamation of diverse geospatial data and analytical methodologies to evaluate the determinants that impact the incidence and accessibility of groundwater.

The study was conducted by taking into account nine distinct layers, namely geomorphology, drainage density, lineament density, slope, elevation, geology, land use and land cover, soil, and rainfall. The aforementioned data were gathered from various sources and subsequently underwent processing within a GIS environment in order to generate the database. Geological and geomorphological maps were acquired from the Survey of India (SOI) Toposheet at a scale of 1:50,000. Digital Elevation Model (DEM) data was obtained from LANDSAT 8 OLI at a resolution of 30 metres. This data was utilised to generate layers for slope, elevation, and drainage density. The cartographic representation of soil is derived from

the National Bureau of Soil Survey (NBSS) at a scale of 1:50,000. At present, the collection of precipitation data remains outstanding.

1.20.1. Methodology

Figure Error! No text of specified style in document**..14: GWP Zone Mapping Methodlogy**

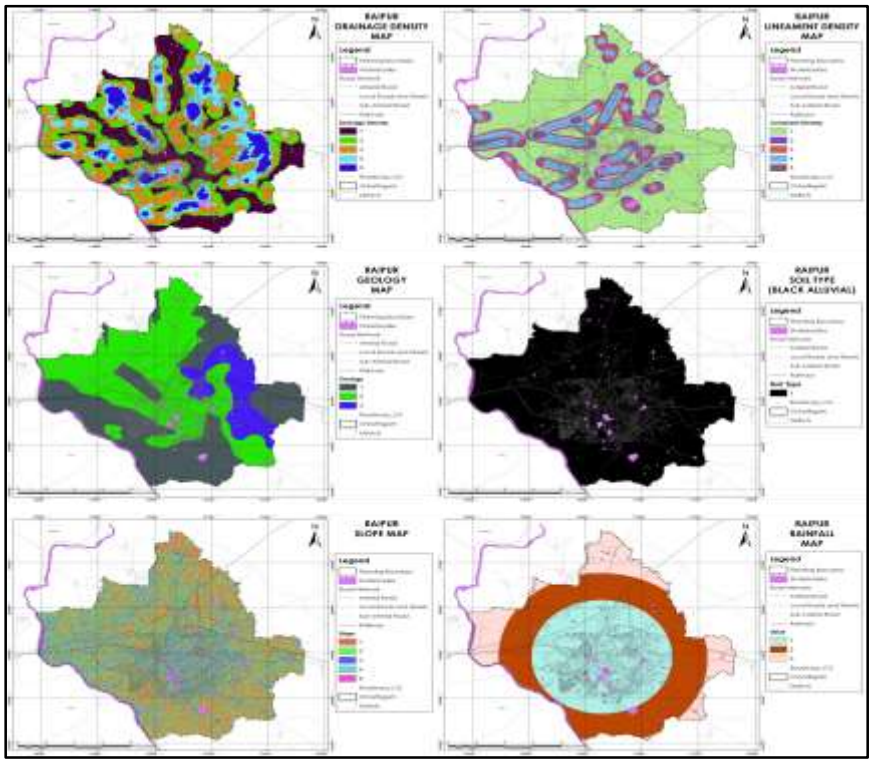


1.20.2. Base Layers

The following parameters were used as base layer for the identification of major GWP Zones in the city:

1. Drainage Density
2. Lineament Density
3. Geology
4. Soil Type
5. Slope
6. Rainfall Intensity

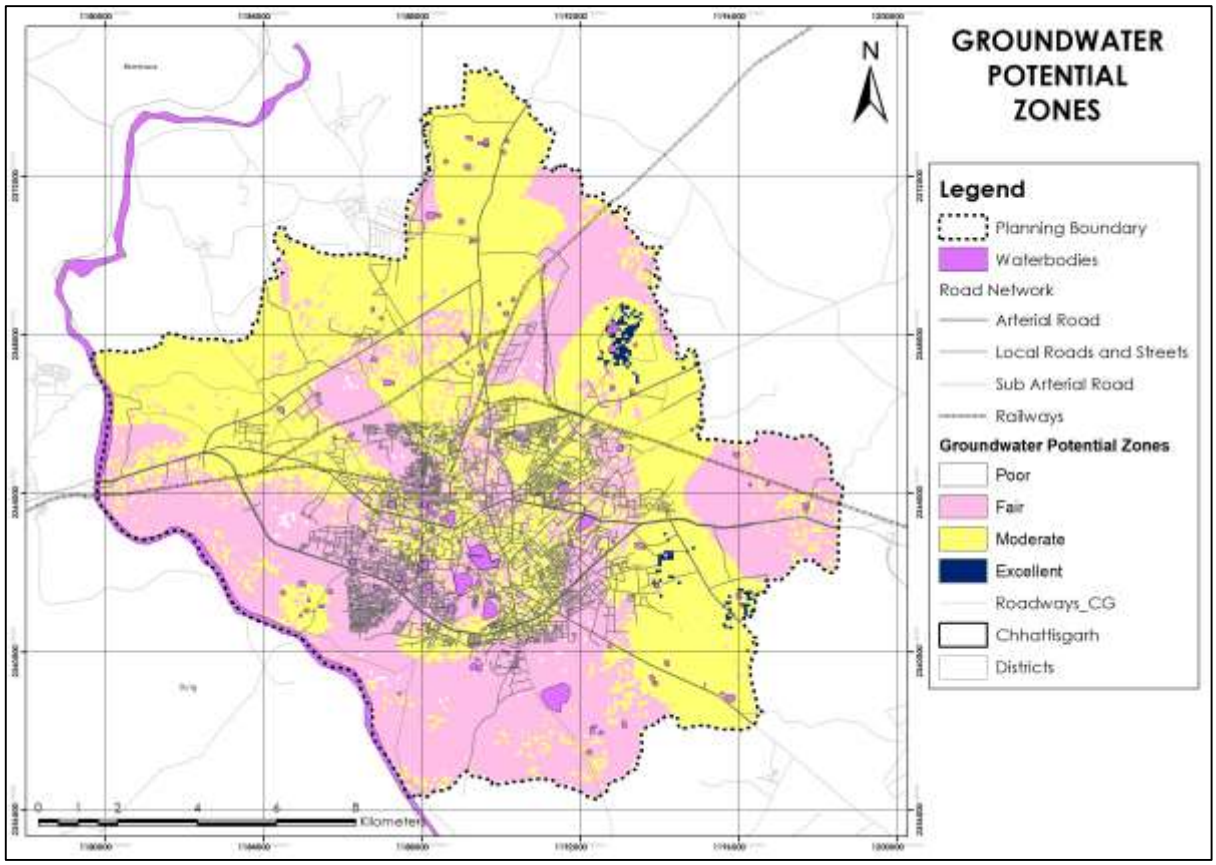
Map Error! No text of specified style in document**..12: Base Layers for GWP Zone Mapping**



1.20.3. Groundwater Potential Zone Map

The following map depicts the various Groundwater Potential Zones in Raipur:

Map Error! No text of specified style in document.**.13: GWP Zones of Raipur**



Source: Author

Table Error! No text of specified style in document.**.8: Raipur GWP Zones**

Zone	Area (in sq. km.)	Percentage share
Poor	**0.35**	**0%**
Fair	**84.10**	**45%**
Moderate	**99.46**	**54%**
Excellent	**1.00**	**1%**

1.21. Status Assessment of the water bodies

Status Assessment of the water bodies was conducted for 58 major waterbodies that are still present in the city based on the following parameters:

- **SIZE**
  - >1.5 Ha
- **USE AND FUNCTIONS**

A. Irrigation
B. Recreation and Tourism
C. Religious Activities

D. Drinking, Washing, etc.

- **SOURCE OF WATER AND POLLUTION**
  - Domestic and Industrial Effluents
  - Stormwater and Agricultural Run Off
  - Cattle-wading, dumping waste, etc.
  - Rain Run Off
  - Through Interconnection of Lakes

1.21.1. Past and Present Status of the water bodies

Figure Error! No text of specified style in document**..15: Existing Status of Water Bodies of Raipur**

The table below gives the general status of the water bodies in the city:

Table Error! No text of specified style in document**..9: Past and Present Status of Raipur's Water Bodies**

	PAST STATUS	PRESENT STATUS
SIZES AND NUMBERS	There used to be more than 178 water bodies which were bigger than most of the existing ones and most of them even being filled with due course of urbanization, for example, Rajbandha Talab which was 3.2 Ha in size but is inexistent now	Urbanization has led to decrease in the number and sizes of the water bodies evidently and only 108 of them survive of which mostly are on the verge of completely diminish in the near future if not notified and conserved immediately
USES AND FUNCTIONS	Water bodies used to find major role in socio-economic activities of the	Various factors like increase in construction activities has resulted in

	city such as lotus farming, cattle wading, agriculture, religious activities, etc.	an increase in the sediment flow, chemical used for bathing and laundry, religious activities, sewage and solid waste disposal, etc. have led to a degraded quality of water.
SOURCES OF WATER AND POLLUTION	Sources of water to the lakes were predominantly watershed, rainfall and ground water aquifers. Pollution sources were limited only to religious activities, bathing, cattle wading, etc.	Urbanization has also led to construction of roads intersecting watershed channels and also encroachment along them has drastically changed the catchment area of the lakes thereby leading to decreased water levels
GROUND WATER LEVEL	Assuming the uses were limited, the ground water level was good	With an increase in population and density around the water bodies, the demand also flew high resulting in unaccounted withdrawal of water both from open sources, specially from surface water bodies, and also, groundwater usage had led to a decrease in the GWT.
URBANIZATION IMPACT ON LAKES	Unlike now, urbanization growth rate was only 12%.	Impact of urbanization has led to degradation of many water bodies, potable surface water sources because of pollution which in course pollutes the groundwater by infiltration and thus, leads to common epidemic.

1.21.2. Status Assessment

Table Error! No text of specified style in document.**.10: Status Assessment of Water bodies of Raipur**

Sr. No.	Name	Area (Ha)	Use	Accessibility	Quality of Water	Surrounding Landuse	Pollution Level
1	Chiraunji Talab	1.68	4	DEFINED	MODERATE	RESIDENTIAL (ENCROACHMENT)	M
2	Halka Talab	1.51	2	DEFINED	MODERATE	RESIDENTIAL	L

3	Bandhwa Talab	2.78	3	NOT DEFINED	GOOD	RESIDENTIAL (ENCROACHMENT)	M
4	Mathpurena Dabri Talab	1.95	2	NOT DEFINED	GOOD	RESIDENTIAL	M
5	Rooprela Talab	5.61	3	NOT DEFINED	GOOD	RESIDENTIAL	M
6	Bhahiyaa Talab	2.07	3	DEFINED	MODERATE	RESIDENTIAL	L
7	Anchi Talab	6.38	2	DEFINED	MODERATE	RESIDENTIAL	H
8	Gaadhi Talab	1.68	2	NOT DEFINED	MODERATE	PUBLIC USE	M
9	Raipura Bandhwa Talab	2.23	2	NOT DEFINED	GOOD	RESIDENTIAL	M
10	Sarona Talab	3.8	4	NOT DEFINED	POOR	PUBLIC USE	H
11	Chuiya Talab	1.78	2		POOR	PUBLIC USE	M
12	Makti Talab	3.08	2	NOT DEFINED	GOOD	RESIDENTIAL	L
13	Bhavndha Talab	2.63	2	NOT DEFINED	GOOD	RESIDENTIAL	M
14	Gogaon Talab	2.23	2	NOT DEFINED	GOOD	RESIDENTIAL	M
15	Sondongari Talab	1.5	2	DEFINED	POOR	RESIDENTIAL	H
16	Gondwara Talab	1.99	2	DEFINED	POOR	RESIDENTIAL	L

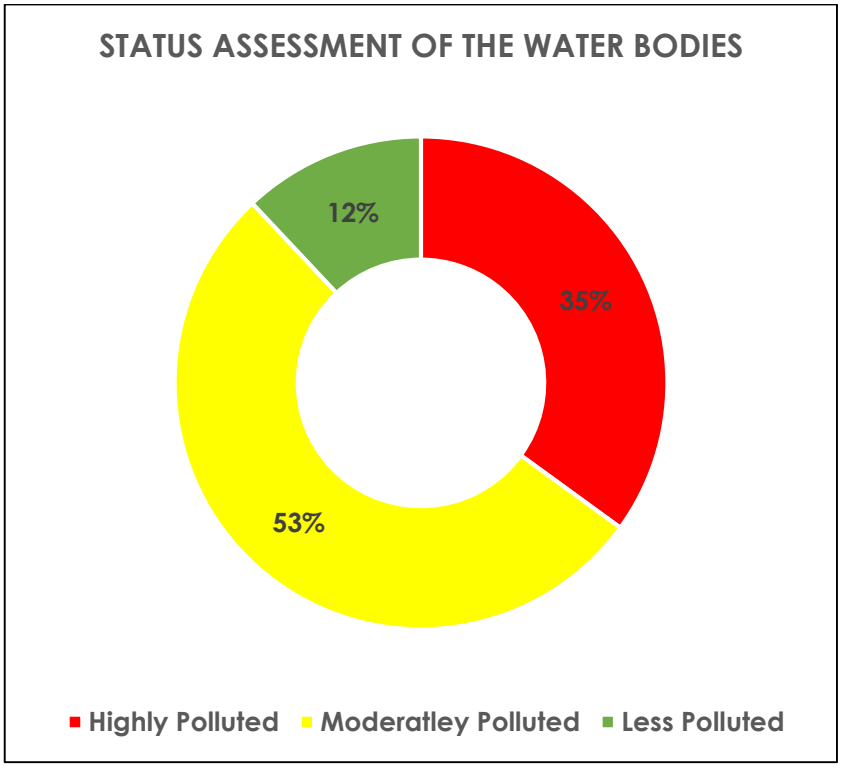
17	Chantwa Talab	1.72	2	NOT DEFINED	MODERATE	RESIDENTIAL	L
18	Bhanpuri Talab	3.16	3	NOT DEFINED	GOOD	RESIDENTIAL (ENCROACHMENT)	H
19	Mathiya Talab	1.62	2	DEFINED	MODERATE	COMMERCIAL	M
20	Mowa Bada Talab	1.52	2	DEFINED	MODERATE	RESIDENTIAL	L
21	Mayya Talab	2.23	3	NOT DEFINED	MODERATE	RESIDENTIAL	M
22	Daldal Seoni Bandhwa Talab	3.14	3	DEFINED	GOOD	RESIDENTIAL	H
23	Thakur Diya Talab	5.17	3	DEFINED	POOR	RESIDENTIAL	H
24	Pethu Talab	2.04	2	NOT DEFINED	MODERATE	RESIDENTIAL	M
25	Lachi Talab	2.06	2	DEFINED	POOR	RESIDENTIAL	M
26	Durga Talab	1.85	2	NOT DEFINED	MODERATE	RESIDENTIAL	H
27	Amaldih Talab	2.77	2	DEFINED	POOR	RESIDENTIAL	M
28	Bade Talab	2.01	2	DEFINED	MODERATE	RESIDENTIAL AND COMMERCIAL (ENCROACHMENT)	M
29	Danganiya Talab	1.82	3	DEFINED	GOOD	PUBLIC USE	H
30	Dumar Talab	14.23	3	DEFINED	POOR	RESIDENTIAL	H

31	Aama Talab	3.06	4	NOT DEFINED	POOR	RESIDENTIAL	M
32	Machi Talab	2.15	3	DEFINED	MODERATE	RESIDENTIAL	L
33	Darri Talab	2.02	2	NOT DEFINED	MODERATE	RESIDENTIAL	H
34	Dhaba Talab	1.78	2	NOT DEFINED	POOR	COMMERCIAL AND PUBLIC USE	M
35	Kota Mahant Talab	2.07	2	DEFINED	GOOD	RESIDENTIAL (ENCROACHMENT)	H
36	Mahant Talab	2.3	2	DEFINED	MODERATE	RESIDENTIAL (ENCROACHMENT)	M
37	Kota Darri Talab	3.18	2	DEFINED	MODERATE	RESIDENTIAL (ENCROACHMENT)	M
38	Khamtarai Nistari Talab	1.84	3	NOT DEFINED	POOR	RESIDENTIAL	H
39	Chotwa Talab	2.49	2	NOT DEFINED	POOR	RESIDENTIAL (ENCROACHMENT)	M
40	Raja Talab	7.33	4	DEFINED	POOR	RESIDENTIAL AND PUBLIC USE (ENCROACHMENT)	H
41	Khanto Talab	1.62	2	NOT DEFINED	MODERATE	SEMI-PUBLIC USE	M
42	Khamardih Talab	2.17	2	NOT DEFINED	MODERATE	RESIDENTIAL	M
43	Katora Talab	1.85	2	DEFINED	POOR	RESIDENTIAL AND COMMERCIAL (ENCROACHMENT)	M
44	Telibandha Talab	16.51	4	DEFINED	POOR	RESIDENTIAL AND COMMERCIAL (ENCROACHMENT)	M

45	Tikrapara Sarjubandha Talab	13.27	3	DEFINED	POOR	RESIDENTIAL (ENCROACHMENT)	H
46	Tikrapara Talab	1.85	2	NOT DEFINED	POOR	RESIDENTIAL	M
47	Dabri Talab	1.69	2	DEFINED	MODERATE	RESIDENTIAL (ENCROACHMENT)	M
48	Khadan Talab	1.78	2	NOT DEFINED	MODERATE	RESIDENTIAL	M
49	Gajrajbandh Talab	20.55	4	DEFINED	POOR	SEMI-PUBLIC USE	H
50	Budha Talab	27.26	4	DEFINED	POOR	RESIDENTIAL AND COMMERCIAL (ENCROACHMENT)	H
51	Sarjubandha Talab	6.12	4	DEFINED	MODERATE	RESIDENTIAL (ENCROACHMENT)	M
52	Phaladwa Talab	2.43	2	NOT DEFINED	MODERATE	RESIDENTIAL	M
53	Pethu Kho Talab	6.78	4	NOT DEFINED	POOR	RESIDENTIAL	H
54	Kho Kho Talab	3.74	2	NOT DEFINED	MODERATE	RESIDENTIAL (ENCROACHMENT)	H
55	Pahari Talab	2.15	2	DEFINED	MODERATE	COMMERCIAL	M
56	Malsaya Talab	2.66	2	NOT DEFINED	POOR	RESIDENTIAL	L
57	Karbala Talab	3.28	2	DEFINED	MODERATE	RESIDENTIAL	H
58	Ramkund	2.94	3	DEFINED	POOR	RESIDENTIAL	H

Source: CGWB, SPCB. RMC

Graph Error! No text of specified style in document.**.5: Status Assessment of Water Bodies**



As per the analysis, 35% of the water bodies are highly polluted with three of them being critical, namely:

- Ramkund
- Raja Talab
- Tikrapara Talab

These three water bodies have been further selected for area-based interventions.

Site Specifications

Table Error! No text of specified style in document.**.11: Site Specifications for Area-based Analysis**

Parameters	Name of Waterbody		
	Ramkund	Raja Talab	Tikrapara Talab
Area Details			
Area of Waterbody	2.94 Ha	5.29 Ha	14.2 Ha
Depth of Waterbody	4.6 mt	3 mt	4.2 mt
Catchment Area (Ha)	96.20	148.76	44.24
Physical Structure			
Surrounding Land Use	North: Residential East: Residential South: Residential and PSP West: Residential	North: Residential East: Residential South: Residential, PSP West: Residential	North: Residential East: Residential South: Composite Use West: Village Settlement
			
Major Functions	Religious Utility Cultural Utility	Domestic Use	Irrigation Recreation
Condition of Existing Structural Measures	Boundary is demarcated Bunds need repair Controlling religious exploitation	Boundary is not demarcated No bunds available Organic pollutant leaching needs to be controlled	Boundary is demarcated Bunds in satisfactory state
Inlet Source	Rain water	Rain Water	Rain Water, Ground Water Aquifer
Chemical Structure			
Outcome of water quality analysis	Low DO level bacterial and fungal growth high turbidity pH is not suitable for aquatic flora and fauna	very low DO Level hyper-eutrophication high turbidity pH is not suitable for aquatic flora and fauna	DO level is good organic build up is in control low turbidity pH is suitable for aquatic flora and fauna
Changes to be undertaken	de-silting of lake bottom lowering pH level Increase DO Level Decrease Turbidity levels	de-silting of lake bottom lowering pH level Increase DO Level develop pisciculture	
Trophic Status	eutrophic	hyper-eutrophication	Oligotrophic
ISSUES	Contamination due to religious and cultural processions	Hyper-eutrophication due to domestic use	Majorly unutilized leading to economic loss
POTENTIAL	To be converted into a designated religious procession site with proper management of religious waste processing	To be revived and rejuvenated for pisciculture	To be retrofitted and utilised for local tourism and economy generation through ancillary activities.

1.21.2.1. Past and Present Status Assessment of the sites

Table Error! No text of specified style in document**..12: Status Assessment of Selected Water bodies**

ASPECT	NAME OF WATERBODY	PAST	PRESENT
SIZE	**Ramkund**	Was almost 7.5 Ha	It is reduced to a mere 2.94 Ha owing to it being divided by road networks and residential encroachment
	Raja Talab	was 7.1 Ha	Reduced to 5.29 Ha with 2.07 Ha under intense eutrophication
	Tikrapara Talab	was 27.9 Ha	Reduced to a mere 14.2 Ha with residential and commercial encroachment
USES AND FUNCTIONS	**Ramkund**	It was used for religious processions	It is still used for religious processions especially during Chhat Puja
	Raja Talab	It was used fro bathing, washing, cattle wading	It currently remains mostly unutilised, washing clothes and for cattles to bathe in
	Tikrapara Talab	It was used as a source of drinking water and irrigation	It is still currently used as water supply for irrigation purposes and as an occasional recreation spot
SOURCES OF WATER AND POLLUTION	**Ramkund**	Source of water: Rainfall, Natural Drains and other lakes. Sources of Pollution: Idol immersion	Source of water: Rainfall, Natural Drains and other lakes. Sources of Pollution: Idol immersion
	Raja Talab	Source of water: Rainfall, Natural Drains and other lakes. Sources of Pollution: domestic waste, cattle wading	Source of water: Rainfall, Natural Drains and other lakes. Sources of Pollution: Domestic Waste, Cattle wading, organic waste inflow, eutrophication
	Tikrapara Talab	Source of water: Rainfall, Groundwater Aquifers. Sources of Pollution: agricultural chemical flow	Source of water: Rainfall, Groundwatr Aquifers. Sources of Pollution: sewer opening, construction

			waste, agricultural chemical flow
GROUND WATER LEVEL	**Ramkund**	Assuming the uses were limited, the ground water level was good	Moderate GWP Zone
	Raja Talab	Assuming the uses were limited, the ground water level was good	Fair to Low GWP Zone
	Tikrapara Talab	Assuming the uses were limited, the ground water level was good	Fair to Low GWP Zone
URBANIZATION IMPACT	**Ramkund**	Urbanization was limited up until 2011	Impact of urbanization has led to degradation of lake, and it is also polluting the GWL
	Raja Talab	Urbanization was limited up until 2013	Impact of urbanization has led to degradation of lake, and the construction and other organic pollutants have led towards hyper-eutrophication
	Tikrapara Talab	Man-made lake constructed in the early 70s so pretty sparse urbanization	It is still used as water supply for irrigation purposes. Urbanization impact is pretty less.

1.22. Issues, Causes and Impacts

Table Error! No text of specified style in document**..13: Issues, Causes and Impacts**

ISSUES	CAUSES	IMPACT
Water Pollution	Dumping of industrial waste into the lakes	Contamination of aquifers
	Non-point source pollution from village and nearby settlements	
	Disposed off waste water/sewer from nearby settlements through piped/network open channel	Loss in economic value of water stored as it cannot be used for any purposes

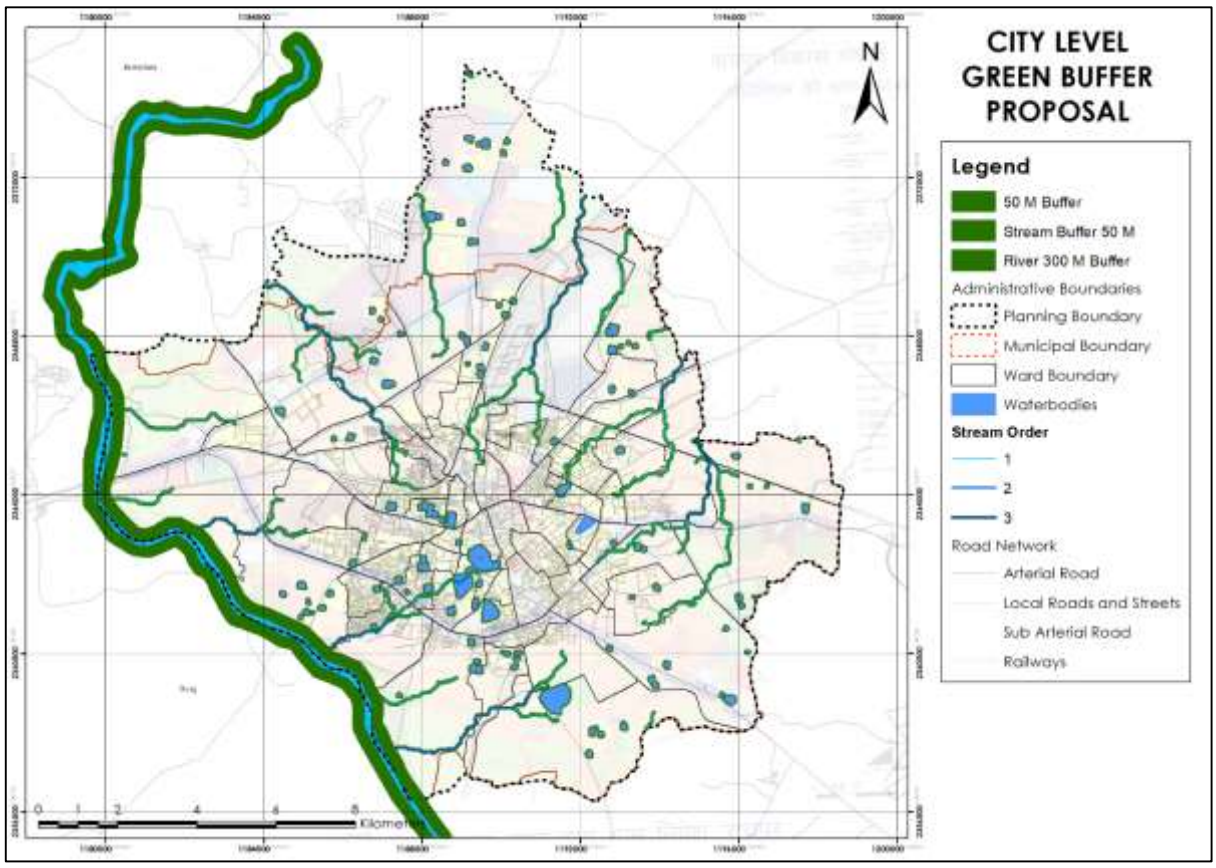
	Disposal of household refuse	unhygienic living condition in the surrounding settlements threat to water borne diseases
Encroachment	Availability of unclaimed/vacant land	blockage of the natural drains
	Improper demarcation of the waterbody	Increases ground elevations in the periphery resulting in flooding
	Absence of any monitoring agency/fencing to prevent unauthorized occupation of the water bodies	
Dependency on Long distance water	less water collection in lakes unaccounted discharge of water	unhygienic living condition in the surrounding settlements threat to water borne diseases
Negligence of Authorities	Absence of interdepartmental coordination Data regarding Sewerage network is also not available with the RMC	No treatment process by any authority

Chapter 5
PROPOSALS, STRATEGIES AND POLICY RECOMMENDATIONS
City Level Proposal: Riparian Buffer

A city level riparian buffer has been proposed.

A riparian buffer is a region next to a lake, stream, or wetland that has a mix of trees, shrubs, and/or other permanent plants and is maintained differently from the area's surroundings, mostly to aid conservation. Although it is less frequent, riparian buffers may be maintained to contain plants and shrubs that provide a harvestable crop in addition to the conservation advantages. In agricultural, row crop, range, suburban, and urban situations, buffers are employed. The development of riparian forest buffers on public and private property is supported by a broad range of state and federal programmes.

Map Error! No text of specified style in document.**.14: Riparian Buffer Proposal**



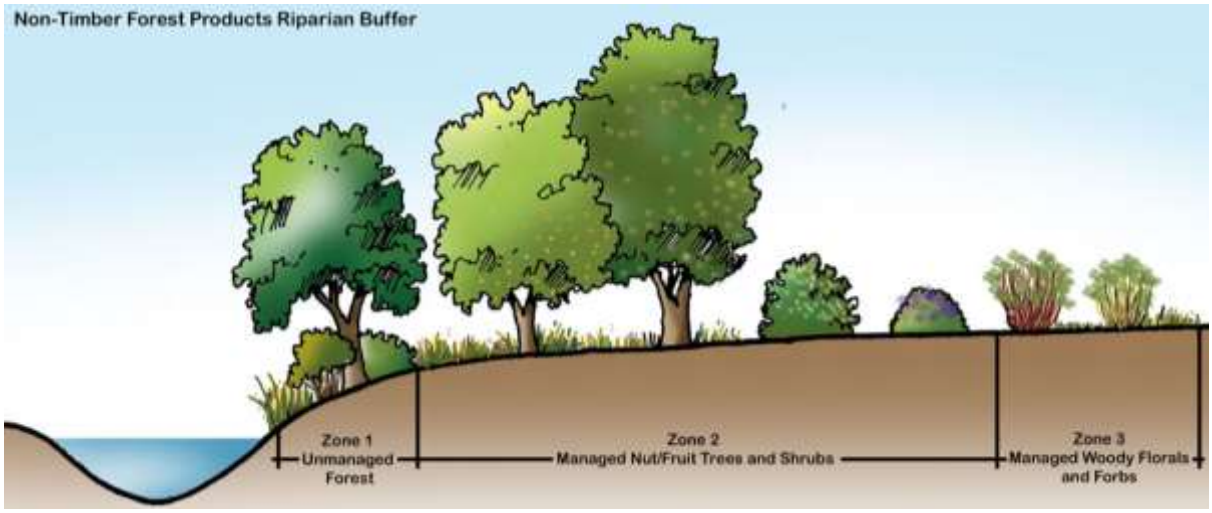
1.22.1. Specifications

- **KHARUN RIVER**
- 300m Riparian buffer along Kharun river:
- **Ideal Situation: 18.65 sq. km.; 62.15 Km running stretch**
- **Realistic Situation: 4.75 sq. km.; 16.18 km running stretch**
- **WATER BODIES**
- 50 M Riparia Buffer around the water bodies
- Total of 3.5 sq. km of waterbody buffer; 137.1 km stretch throughout the city
- **STREAMS AND NATURAL DRAINS**
- Total 9.1 sq. km. Riparian Buffer; 181.7 km stretch throughout the city
- **PLANNING THE BUFFER**

  SITE PREPARATION
- removal of all invasive vegetation to reduce competition to new native species and shrubs.

  BUFFER WIDTH
- There is no one size fits all buffer width in the riparian corridor. The buffer width is largely dependent on the terrain and incline of the slope. The recommendations given are based on gradual slopes and steep inclined slopes.

Figure Error! No text of specified style in document.**.16: Riparian Buffer**



1.22.2. Proposed Vegetation

Table Error! No text of specified style in document.**.14: Proposed Vegetation for the Riparian Buffer**

TREE/PLANT	SECTION	DISTANCE (from wet zone)	HABIT	FLOWERING PERIOD	CO2 SEQUESTRATION RATE (tonnes/year)
Mangifera indica Wild mango	Upper section/ Middle section	0-50m	Evergreen tree	February – March	0.06
Syzygium heyneanum River Jamun	Middle section/ Lower section	0-30m	Evergreen tree	March – April	4.14
Salix tetrasperma Indian Willow	Middle section/ Lower section	0-30m	Deciduous tree	January – February	0.03
Scleropyrum pentandrum Hard Pear Tree	Upper section/ Middle section	20- 50m	Evergreen species.	January – March	1.23
Pongamia pinnata Indian Beech Tree	Upper section/ Middle section	10- 30m	Deciduous tree	March – April	0.07

Homonoia riparia Willow- leaved Water Croton	Lower section/ Middle section	0-5m	Semi-aquatic Shrubs	March – April	-
Phyllanthus ebmlica Indian Gooseberry	Lower Section/ Middle Section	0-5m		September – November	1.30
Crinum viviparum River Crinum Lily	Lower section	0 m	Emergent Aquatic Plant	September-November	-

1.22.3. Carbon Sequestration

The amount of CO2 a tree sequesters varies based on the growth rate, age, and species of the particular tree.

For trees in Tropical/Sub-tropical regions CO2 sequestration rate: 3.2 to 10 tonnes/tree/ha/year

1.22.3.1. Ideal Situation

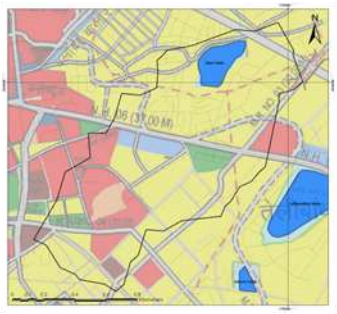
- Average no. of trees per hectare: 1000 trees/ha*
- Total Area: 3125 Ha
- Total Trees: 3,125,000 trees
- CO2 sequestration rate of the proposed riparian buffer:
- 3,125,000 trees x 3.2 tonnes/tree/ha/year = **10 million tonnes/ha/year – 31.25 million tonnes/ha/year**

1.22.3.2. Realistic Situation

- Average no. of trees per hectare: 1000 trees/ha*
- Total Area: 1735 Ha
- Total Trees: 1,735,000 trees
- CO2 sequestration rate of the proposed riparian buffer:
- 1,735,000 trees x 3.2 tonnes/tree/ha/year = **5.5 million tonnes/ha/year – 17.35 million tonnes/ha/year**

1.23. Area Based Proposals

Table Error! No text of specified style in document.**.15: Area Based Proposals**

	RAMKUND		RAJA TALAB		TIKRAPARA TALAB	
						
RECOMMENDATIONS	1	De-silting of pond	1	De-silting of pond	1	De-silting of pond
	2	Buffer of 50 MT along the waterbody shoreline	2	Buffer of 50 MT along the waterbody shoreline	2	Buffer of 50 MT along the waterbody shoreline
	3	Creation of shore ecotones around the waterbody	3	Improvement of Inlet Drains should be done	3	Dumping of garbage, domestic and agricultural waste should be completely restricted
	4	Biological control of weed through aquaculture	4	Fountains and aerators to be proposed for aeration in water bodies	4	Floating wetlands to be introduced to take control of eutrophication
	5	Fountains and aerators to be proposed for aeration in water bodies; helps in the improvement physical characteristics of the waterbody.	5	Provision of trash cans and waste processing facility		
	6	Sewage treatment plant is needed for disposal of treated water	6	Cattle-wading, washing of clothes need to be restricted	5	Pisciculture should be encouraged for improving the production function of the waterbody
			7	Removal of encroachment from waterbody shoreline		

1.24. Policy Based Proposals

Table Error! No text of specified style in document.**.16: Policy Proposals**

POLICY PROPOSALS		
SHORT TERM PROPOSALS	**MEDIUM TERM PROPOSALS**	**LONG TERM PROPOSALS**
Demarcating waterbody boundaries with fencing	To establish Lake Development Authority, which timely monitor the condition of the lake and give timely guidance in the maintenance and improvement of the lakes	Zonal and Regional plan should demarcate lakes as notified water intake point
Reviving the waterbody's utility and value	A strong monitoring system with laboratory support should be developed	Surface area or Lake storage area both minimum and maximum should be demarcated in Lake Rejuvenation Plan
Stoppage on unauthorized dumping and debris disposal in the water bodies	Formation of Lake Development Authority - for Regular monitoring O/M of lakes and	Catchment area should be recorded for water sensitive design and planning for sustainability of lakes as a source of water supply
Cleaning, dredging, removing weeds and agricultural run-offs, construction embankments, etc.	Public private partnership to develop lake front	Peripheral areas of the lakes(100M) should be declared as 'Protected zones
Control of indiscriminate cultural activity on lakes	No discharge from domestic, commercial or industrial to be done without treatment (and bring them to the CECB recommended BOD and COD level)	15 M immediate buffer around lake should be under "No Construction Zone

Regular de-silting and removal of sediment from the lake area is required	Strictly enforcing 15m no construction along the edge of the lakes	Rain water harvesting & Solid waste management practice to be adopted
Rainwater harvesting to be taken up in the first order catchment area	Abutting plots to setback by 15m Row and pathway along the lakes	ElA should be done for all development projects in lake and its catchment
Providing STP for water bodies bigger than 20 Ha	Institutions to give pathways and plant trees along the lake side (this could be used as access by the pedestrian and cyclist)	NGO and Public participation should be incorporated in lake restoration
Treated water could be disposed into the lakes as they have good nutrient value which would be beneficial for the fishes and aquatic life to flourish	No litter zone; Bund trees; Separate waste collection (Dry/Wet)	Utilizing the lakes for the purpose of education and research
		Provision of treatment plants in the industries (if preferred give single treatment plant for 2-3 nearby industries)
		No construction on the natural drainage
		Reclaim the slum area abutting the lakes till 15m from the river edge

1.25. Guidelines for Stakeholders

Table Error! No text of specified style in document.**.17: Stakeholder Guidelines Proposals**

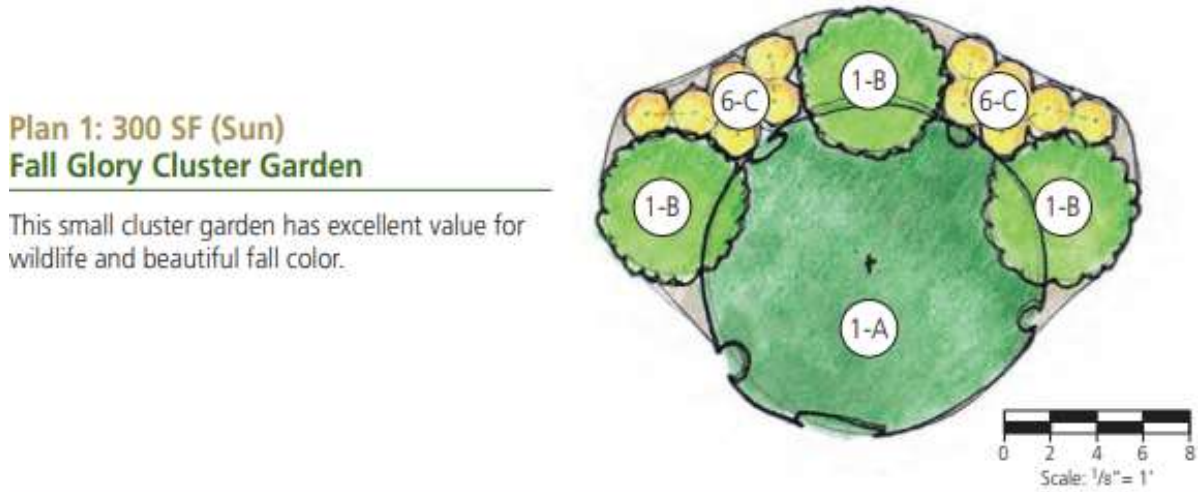
GUIDELINES FOR STAKEHOLDERS		
GOVERNMENT	**DEVELOPERS**	**PUBLIC/COMMUNITY**
Ensure continuous monitoring and initiating suitable corrective measures	Follow properly the planning restrictions, standards and codes	Realize and respect the value of environment and ecosystem services
Advocating and promoting Lake restoration according to the Plan	EIA to be done for all projects to be undertaken	Keep water bodies clean and avoid pollutants such as detergents in the streams and ponds
Establish standards, building codes and other regulations	Ensure that all the development activities are unobstructive and do not interfere with the natural ecosystem	Water-saving practices, RWH should be employed
Recognize and award. the developers and to the citizens who actively participate in the lake restoration process.	All developmental activities in the waterbody restoration should be done in harmony with the local environment	Actively participate in the planning process of Lake Restoration and also help in implementing the plan
Launch training programmes on lake restoration for administrators, Planners, Developers and the general public.	Involve local community to the extent possible in various activities and vocations	Realize and react to the potential threat of investors who see opportunities in development but lack sensitivity to local ethos
Publishing simple brochures or a set of		

brochures on lake restoration		

1.26. Open Green Space Recommendations

1.26.1. Plan 1

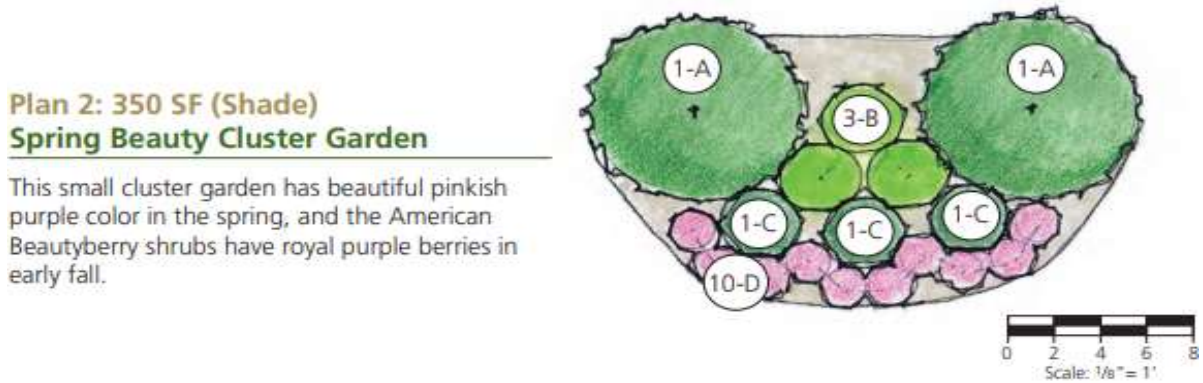
Figure Error! No text of specified style in document**..17: Open Green Space Recommendation (i)**



Symbol	Common Name	Scientific Name	Size	Plant Type	Total Number	Credit
A	Red Maple	*Acer rubrum*	¾-inch caliper	Canopy tree	1	N/A
B	Virginia Sweetspire	*Itea virginica*	3 feet	Large shrub	3	N/A
C	Butterfly Flower	*Asclepias tuberosa*	1 quart	Herbaceous plant	12	N/A

Plan 2

Figure** Error! No text of specified style in document**..18: Open Green Space Recommendation (ii)



Symbol	Common Name	Scientific Name	Size	Plant Type	Total Number	Credit
A	Eastern Redbud	*Cercis canadensis*	¾-inch caliper	Understory tree	2	N/A
B	American Beautyberry	*Callicarpa americana*	18 inches	Small shrub	3	N/A
C	Pink Azalea	*Rhododendron periclymenoides*	18 inches	Small shrub	3	N/A
D	Wild Geranium	*Geranium maculatum*	1 quart	Herbaceous plant	10	N/A

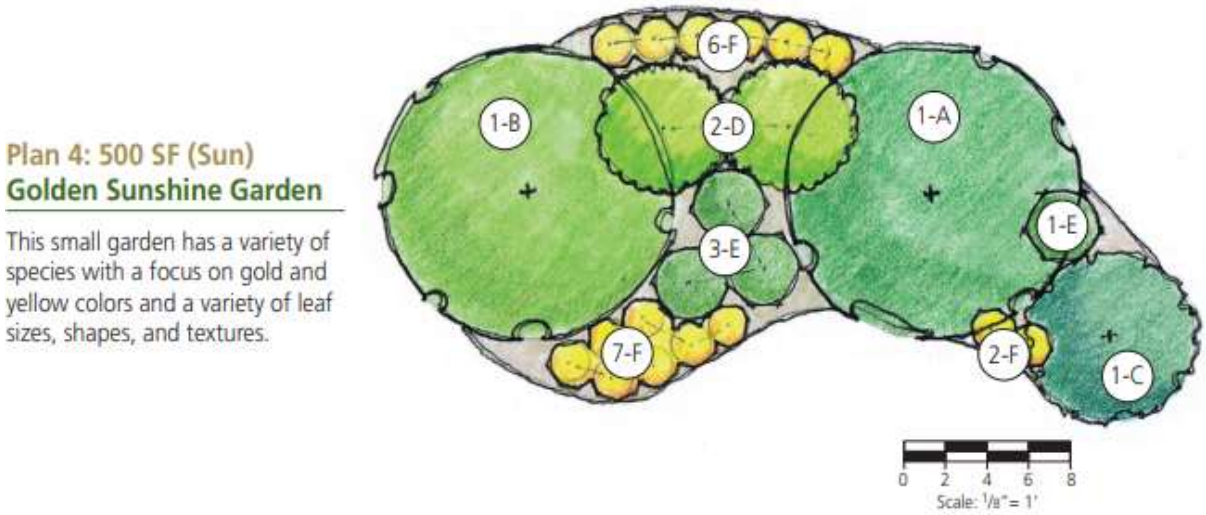
1.26.2. Plan 3

Figure Error! No text of specified style in document.**.19: Open Green Space Recommendation (iii)**

Symbol	Common Name	Scientific Name	Size	Plant Type	Total Number	Credit
A	River Birch	*Betula nigra*	¾-inch caliper	Canopy tree	1	100
B	Sweetbay Magnolia	*Magnolia virginiana*	¾-inch caliper	Understory tree	2	150
C	Red Chokeberry	*Photinia pyrifolia*	3 feet	Large shrub	2	100
D	Sheep Laurel	*Kalmia angustifolia*	18 inches	Small shrub	3	75
E	Virginia Spiderwort	*Tradescantia virginiana*	1 quart	Herbaceous plant	6	12
F	New England Aster	*Symphyotrichum novae-angliae*	1 quart	Herbaceous plant	6	12
G	Helmet Flower	*Scutellaria integrifolia*	1 quart	Herbaceous plant	5	10

1.26.3. Plan 4

Figure Error! No text of specified style in document.**.20: Open Green Space Recommendation (iv)**



Symbol	Common Name	Scientific Name	Size	Plant Type	Total Number	Credit
A	Southern Red Oak	*Quercus falcata*	¾-inch caliper	Canopy tree	1	100
B	American Beech	*Fagus grandifolia*	¾-inch caliper	Canopy tree	1	100
C	Sweetbay Magnolia	*Magnolia virginiana*	¾-inch caliper	Understory tree	1	75
D	Red Chokeberry	*Photinia pyrifolia*	3 feet	Large shrub	2	100
E	Maple-leaved Arrowwood	*Viburnum acerifolium*	18 inches	Small shrub	4	100
F	Black-eyed Susan	*Rudbeckia hirta*	1 quart	Herbaceous plant	15	30

Table Error! No text of specified style in document.**.18: Credit Allowance Specifications for Open Green Spaces**

Vegetation Type	Minimum Size Eligible for Credit	Credit Allowed (per Sq. Ft.)	Maximum Percent of Credit
Canopy tree	2-inch caliper	200	No maximum
Canopy tree	¾-inch caliper	100	No maximum
Understory tree	¾-inch caliper	75	No maximum
Large shrub	4 feet high	50	30%
Small shrub	18 inches high	25	20%

Herbaceous perennial	1-quart or based on the area covered by plugs or seed mix	2	10%
Planting cluster for Buffer establishment or mitigation planting less than ½ acre	1 canopy tree; and 3 large shrubs or 6 small shrubs	300	Not applicable
Planting cluster for Buffer establishment or mitigation planting less than ½ acre	2 understory trees; and 3 large shrubs or 6 small shrubs	350	Not applicable

1.27. General Recommendations

- **Reduce pollution:** Find and fix waterbody pollution sources. Industrial and agricultural runoff, waste management, and community responsibility may be needed.
- **Wetland restoration:** Wetlands filter water and house many species. Restoring and conserving nearby wetlands improves water quality and biodiversity.
- **Riparian zone management:** The riparian zone around a water body helps preserve water quality and avoid erosion. Shoreline vegetation buffers prevent sedimentation, filter pollutants, and stabilise soil.
- **Nutrient management:** Excess nitrogen and phosphorus may pollute water and create algal blooms. To reduce water body nutrient imports, utilise fertiliser properly and reduce agricultural runoff.
- **Controlling invasive species:** Invasive species may harm native plants and animals in water bodies. Create a strategy to control and manage invasive species surrounding the water body to restore ecological health.
- **Controlling erosion** prevents sedimentation and habitat loss. Improve water quality by stabilising shorelines using natural materials, planting plants, or building retaining walls.
- **Implement watershed management** for a comprehensive strategy. To maintain and restore the water body, evaluate the whole watershed and handle land use, stormwater management, and groundwater recharge.
- **Public engagement:** Educate the people about water body rejuvenation. Promote water conservation, garbage disposal, and habitat preservation. Volunteer, educational, and citizen science programmes may include the community in restoration.

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