STRATEGY FOR FLOOD MANAGEMENT IN BHUBANESWAR CITY USING NATURE-BASED SOLUTIONS

Global EbA Fund

BHUBANESWAR MUNICIPAL CORPORATION BMC

NIUA National Institute of Urban Affairs

Acknowledgement

Title
Strategy for Flood Management in Bhubaneswar City using Nature-based Solutions

About the document
This document outlines a city-wide strategy for integrating ecosystem-based adaptation (EbA) approaches into the flood management agenda for Bhubaneswar city in the State of Odisha, India. The strategy aims to build long-term climate resilience by leveraging the city's existing ecosystems.

Advisor
Prof. Mukund Babel (Distinguished prof., the Asian Institute of Technology (AIT), Thailand)

Authors
Jyoti Verma, Banibrata Choudhury, Uday Bhonde, Victor R. Shinde,

Publisher
National Institute of Urban Affairs (NIUA), Ministry of Housing & Urban Affairs, GoI

Pictures credits
The pictures used in this document were taken by the authors, and some were used from web resources.

Disclaimer
This document is a knowledge product based on the compilation of various works. The publishers do not have any legal liability for the accuracy of data or the inferences drawn from the material contained herein or for any consequences arising from the use of this material.

This publication is prepared under the project "**Proliferating ecosystem-based adaptation practices in Indian cities (EPIC)**" supported by the Global EbA Fund.

Year of Publication
2025

TABLE OF CONTENTS

Dr. Debolina Kundu
Director,
National Institute of Urban Affairs (NIUA)

Integrating ecosystem-based approaches within the urban flood management strategy of a city is a paradigm shift in how Indian cities prepare for climate adaptation. This document on Bhubaneswar's strategy exemplifies NIUA's commitment to promote nature-based solutions (NbS) rooted in science, local knowledge, and community participation. We are convinced that leveraging natural ecosystems for urban infrastructure needs will ensure our cities become more resilient, inclusive, and sustainable.

Rajesh Patil, IAS,
Municipal Commissioner,
Bhubaneswar Municipal Corporation

Bhubaneswar has long been recognized for its cultural heritage and planned urban development. Yet, like many growing cities, it faces mounting challenges due to rapid urbanization and climate-induced vulnerabilities, especially urban flooding. This city strategy document reflects our ongoing efforts to address these issues using nature-based solutions that are not only sustainable but also inclusive.

Through initiatives such as the rejuvenation of natural drains, restoration of wetlands, and creation of community-friendly green spaces, the Bhubaneswar Municipal Corporation (BMC) is committed to ensuring that our development is in harmony with the ecosystems that support our city. This strategy has been shaped through technical assessments, community inputs, and inter-agency collaboration. I thank NIUA and our other partners for their contributions and reaffirm our commitment to creating a climate-resilient Bhubaneswar that places people and nature at its core.

List of Maps

List of Tables

Abbreviations

EPIC	Proliferating Ecosystem-based Adaptation Practices in Indian Cities
EbA	Ecosystem-based Adaptation
NIUA	National Institute of Urban Affairs
NAPCC	National Action Plan on Climate Change
SAPCC	State Action Plan on Climate Change
DRR	Disaster Risk Reduction
UNISDR	United Nations International Strategy for Disaster Reduction
BMC	Bhubaneswar Municipal Corporation
BDA	Bhubaneswar Development Authority
R&B	Roads and Buildings Department
IDCO	Industrial Infrastructure Development Corporation
NHAI	National Highways Authority of India
MUKTA	Mukhya Mantri Karma Tatpar Abhiyan
IDF	Intensity Duration Frequency
DEM	Digital Elevation Model
LULC	Land Use Land Cover
MCDA	Multi-Criteria Decision Analysis
AHP	Analytical Hierarchy Process
NDZ	No Development Zone
CDP	City Development Plan
CGWB	Central Ground Water Board
PHED	Public Health Engineering Department
CHHATA	Community Harnessing and Harvesting Rainwater Artificially from Terrace to Aquifer
RWH	Rain Water Harvesting
RWAs	Resident Welfare Associations
SHGs	Self-Help Groups
BOD	Biological Oxygen Demand
COD	Chemical Oxygen Demand
DO	Dissolved Oxygen
LID	Low Intensity Development
NbS	Nature-based Solution
CARTOSAT	Cartography Satellite
ISRO	Indian Space Research Organisation
TWI	Total Wetness Index
OSM	Open Street Map

CONTEXT

The strategy for flood management in Bhubaneswar city using nature-based solutions was developed under a project called "**Proliferating Ecosystem-based Adaptation Practices in Indian Cities (EPIC)**", executed by the National Institute of Urban Affairs (NIUA) and supported by the Global EbA Fund.

The overarching goal of the EPIC project was to create an enabling environment for mainstreaming ecosystem-based adaptation (EbA) practices in a city's water management strategy. Bhubaneswar was selected as the pilot city for the project and the focus was on mitigating urban flooding.

As part of the project, a thorough baseline assessment of the city was done vis-à-vis urban flooding to identify hotspots and vulnerable areas. In parallel, the various natural ecosystems in the city were mapped to analyse their potential to mitigate flooding.

Nature-based solutions were then designed to address the flooding threat in twelve hotspot locations.

This strategy document provides an elaborate account of the process followed to arrive at the nature-based solutions for mitigating the urban flooding situation in different locations of the city.

1. INTRODUCTION

India is highly vulnerable to the impacts of climate change due to its geographical diversity, population density, and dependence on the monsoon. Erratic and unpredictable monsoon patterns, marked by prolonged dry spells followed by intense, short-duration rainfall, disrupt water availability and overwhelm drainage systems. Many urban areas are experiencing acute water shortages due to inadequate water infrastructure, declining groundwater levels and inadequate rainwater harvesting. Simultaneously, all metro cities, Mumbai, Chennai, Bengaluru, along with developing cities like Bhubaneswar, are increasingly becoming prone to urban flooding, primarily due to high-intensity rainfall in short duration, encroachment along natural ecosystems like waterbodies/wetlands and natural drains, and poorly maintained or undersized stormwater systems.

Odisha, located on the eastern coast of India, is one of the most climate-vulnerable States in the country. It has a long history of being affected by cyclones, floods, droughts, and rising sea levels, all of which are intensifying due to climate change. The state's geographical position along the Bay of Bengal makes it a frequent target of tropical cyclones. Cyclone Fani (2019), Cyclone Amphan (2020), and Cyclone Yaas (2021) are recent examples of devastating storms that caused widespread destruction in terms of lives, infrastructure, and livelihoods.

Despite its vulnerability, Odisha is widely recognized for its proactive approach to climate adaptation and disaster risk reduction. The state has implemented a range of measures aimed at improving climate resilience, guided primarily by its State Action Plan on Climate Change (SAPCC), which aligns with the National Action Plan on Climate Change (NAPCC). Odisha's SAPCC, updated in 2018, outlines sector-specific strategies in agriculture, water resources, forestry, energy, and urban development to mitigate and adapt to climate change impacts.

2. CITY IN FOCUS: BHUBANESWAR

Bhubaneswar, the capital city of Odisha State, is famously known as the city of temples; some of them date back to the 6th Century. It is also the most populous city of the State, having a population of approximately 9 lakh. The Bhubaneswar Development Planning Area stretches across 422 sq.km. (an addition of 173 revenue villages) in which the municipal corporation limit covers 148.1 sq.km.

The city is one of the first planned cities in India, and its modern outlook was envisioned by German architect Otto Königsberger in 1949. The city planning emphasised the neighbourhood concept, parks and open spaces in addition to ease of connectivity. The city is spread across 67 Census wards and has been experiencing very high growth both in terms of urban built-up area as well as population. There are around 116 authorised and 320 unauthorised slums.

The temple city of Odisha is also amongst the fastest growing cities in the East Zone in the category of cities with a population of more than 10 lakhs.

The unique geo-climatic conditions in the eastern coastal plains of the State make Bhubaneswar more vulnerable to multiple natural hazards like earthquakes, heavy winds, cyclones, floods, etc. For the past three decades, Bhubaneswar has been experiencing unprecedented contrasting extreme weather conditions; from heat waves to cyclones, from droughts to floods and has become one of the hottest Indian cities in recent times.

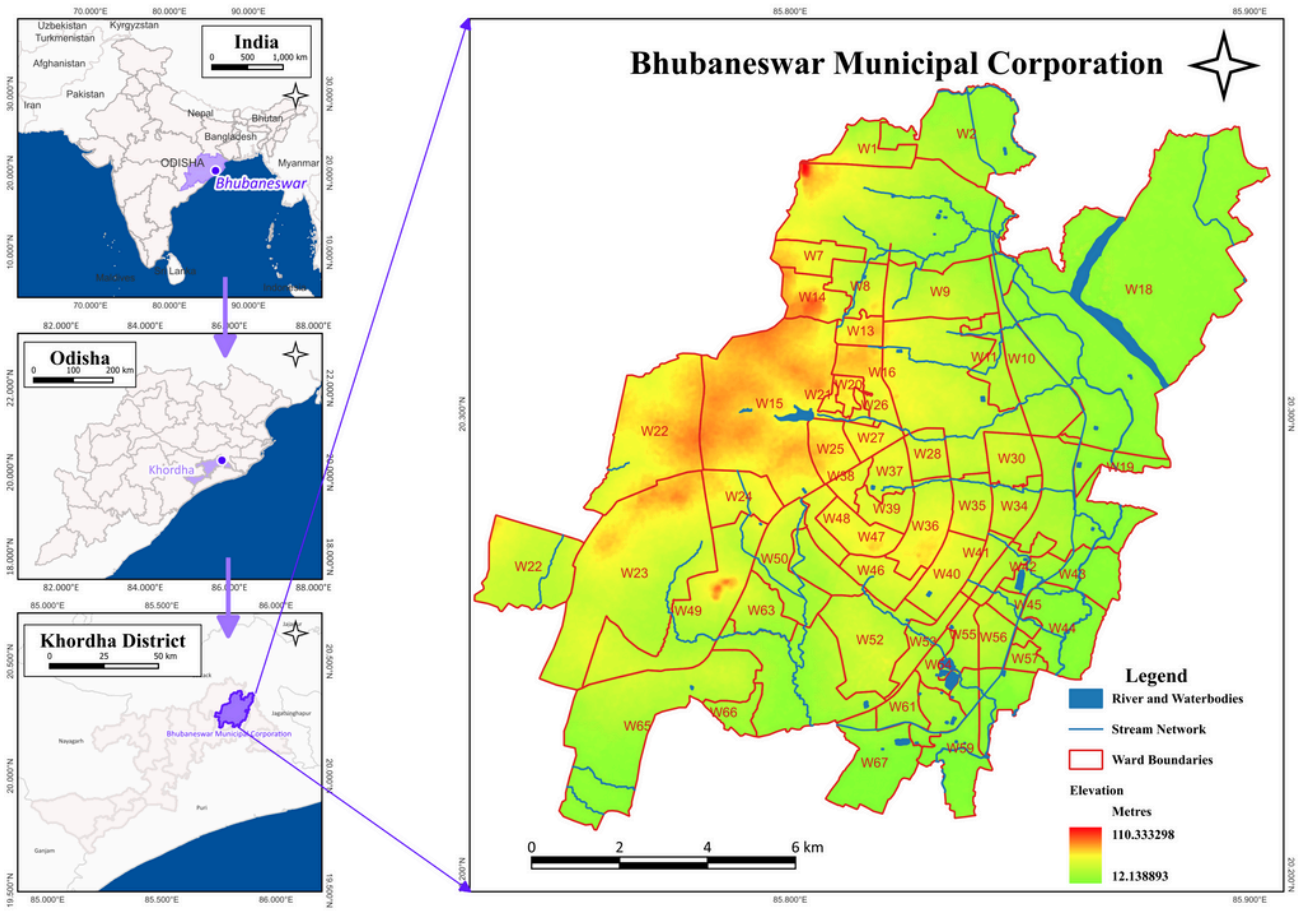
The city has taken several proactive steps for climate change adaptation, in particular in the power, roads, and drainage infrastructure development activities. To support and be part of the State Disaster Risk Reduction (DRR) activities, the city administration is active in developing measures for a climate risk-resilient urban centre. The city is part of the UNISDR's "**The Making Cities Resilient Campaign**" and is a Recipient of "SASAKAWA Recognition 2011". It is also a Role Model for Community Preparedness.

Bhubaneswar's City Development Plan also accounts for the risk zones of the city while considering any new development projects. The city is also working on preparing a comprehensive Heat Stress Action Plan to combat the dangers of heat waves and the urban heat island effect.

The city is located to the south of the Mahanadi River, and its geography is bounded by the Kuakhai River on the east, the Daya River on the south, and Chandaka Wildlife Sanctuary and Nandankanam Zoo on the northern and western parts. Natural drains, wetlands, marshes and riparian buffers are conspicuous ecosystems present in the city.

Bhubaneswar has an undulating topography, with a major slope from northwest to east. A number of natural drainages follow this slope and merge in the lowland marshy areas, and ultimately in the Daya river. The water requirement for Bhubaneswar City is primarily met by River Kuakhai, River Daya and groundwater sources. River Kuakhai and River Daya are the major surface water sources. All the natural drains flowing west to east, crisscrossing the city, contribute to the River Daya and River Kuakhai's flow and thus are critical elements in the city's water supply mechanism. These natural drains also play a vital role in discharging stormwater during the monsoon season to protect the city from urban flooding.

There are 14 such natural drains varying in their lengths and widths, some of which pass through high-density settlements. These drainages form micro catchments within the city boundary and have been modified with rapid urban development. This can potentially impact the overall natural functions of natural drains like flood mitigation, and groundwater recharge jeopardising the overall water security of the city. Like many other cities in India, the natural ecosystems in the city are also facing threats of growing urbanisation.

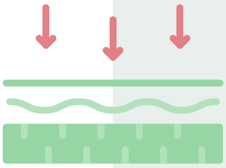


Map 1: Location of Bhubaneswar city

2.1. Status Quo

The city of Bhubaneswar is developed on rugged terrain. The lateritic plateau terrain, which has undergone erosion, has carved out a natural drainage system in the city. The network of drains in the city is approximately 74 kilometres, covering 14 natural drains. The city receives an average of 1487 mm of rainfall annually. The runoff water is discharged from the city through secondary and tertiary drains. The ultimate outfall points of these drains are in the 11 primary natural drains and 3 primary sub-natural drains passing through the city. All these 14 drains finally discharge into the Gangua nala on the Eastern side.

As acknowledged by the city administration, in recent times the city has flooded more frequently due to erratic rainfall concentrated in a short duration. Additionally, as the city has developed, the natural recharge capacity of the city has decreased as per various reports (GIZ,2022; and NIUA,2023). Climate experts also indicates that the city would witness extreme weather conditions in the future which will be further exacerbated with rapid urbanisation. Following are the key factors contributing to the urban flooding situation in the city:

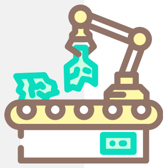


Reduction of permeable areas: Bhubaneswar has witnessed rapid urban growth, which has significantly reduced the city’s green cover and open spaces, which earlier used to absorb excess rainwater and prevent flooding. As per the study conducted by the Bhubaneswar Municipal Corporation (BMC), the city's built-up area has gone up significantly, from 135 sq km in 2010 to over 225 sq km by 2023. Also, as per the inventory of parks and open spaces prepared by the Bhubaneswar Development Authority (BDA), 19 of 67 wards in the BMC area do not even have a single park or garden.

Inadequate infrastructure: Bhubaneswar's existing drainage infrastructure has not kept pace with the city’s expansion. Many parts of the city still rely on old, undersized drainage systems that are incapable of handling the volume of water during heavy rainfall. Blockages caused by solid waste and encroachments further aggravate the situation.

Encroachment in ecosystems: Over the years, there has been significant encroachment in the city's natural ecosystems, like lakes and ponds, which historically acted as reservoirs for excess rainwater. This encroachment has reduced the city’s capacity to manage rainwater, leading to increased flooding.

Inadequate solid waste management: Poor waste management practices have led to the accumulation of garbage in drainage channels, causing blockages. This not only reduces the efficiency of the drainage systems but also increases the risk of flooding during heavy rains.

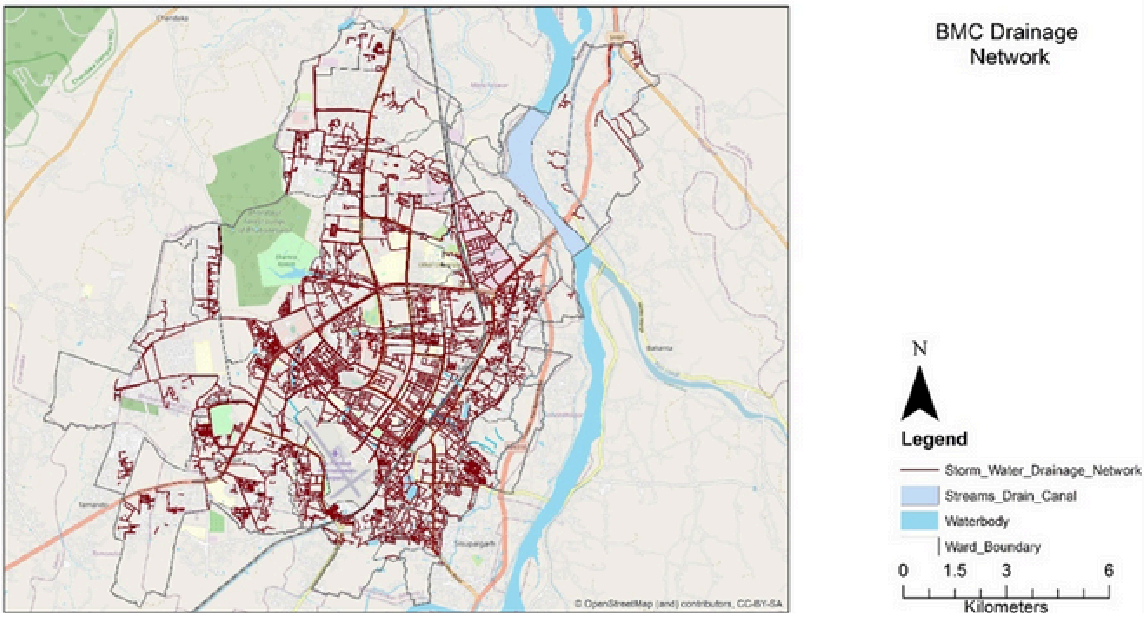


Changing rainfall patterns: In the last three decades, the city has witnessed a shift in its rainfall patterns, with more intense and erratic rainfall events becoming common. Climate change has contributed to this phenomenon, with short periods of heavy rainfall overwhelming the city’s drainage systems. The traditional monsoon patterns are being replaced by unpredictable and extreme weather events, leading to urban flooding. The rainfall intensity per event has varied from 100 mm to 520 mm and the frequency of flash floods across coastal Odisha has increased considerably from 1960 onwards. As per the report from BDA, nearly 60% of urban area is classified under vulnerable to extreme to moderate risk of flooding.

2.2. The City's Efforts to Manage Urban Flooding

The city administration has initiated several measures to mitigate urban flooding. The major emphasis is on grey infrastructure; however, some level of blue infrastructure is also included in the urban flood mitigation strategy. As a long-term solution, the city is strengthening the existing stormwater infrastructure while also maintaining the old systems through activities such as de-silting, widening, and cleaning of the drainage network.

The stormwater drainage network in the city is approximately 1,200 km long, covering about 70% of the total road network. Almost 50% of this network is maintained by the BMC, while the remainder falls under the responsibility of R&B, IDCO, and NHAI



The city is also rejuvenating water bodies within its limits under government schemes such as the MUKTA Mission. Additionally, green spaces are being developed to create sponge areas in the Nayapalli area, to help absorb rainwater.

The BMC has identified 74 water bodies, out of which 21 were shortlisted for renovation or restoration at an estimated cost of approximately ₹33.08 crore, to be carried out in two phases (Drainage Report, 2021). All 21 water bodies were planned to be de-silted and de-weeded, and equipped with proper retaining walls along the waterfront, pathways or parikrama, landscaping, water outlets to discharge excess water, and railings or fencing as per the needs and preferences of local residents. Although several initiatives are being led by the BMC and BDA, significant gaps remain in the effective management of the city's blue and green infrastructure.

3. FLOOD RISK, HAZARD AND VULNERABILITY MAPPING

Despite experiencing frequent urban flooding during every monsoon, the city lacks a comprehensive and systematic assessment of the issue. A thorough and accurate analysis is essential for effective flood management, as it enables strategic planning and proactive response. By identifying vulnerable and high-priority areas, such an assessment can guide targeted interventions and efficient resource allocation.

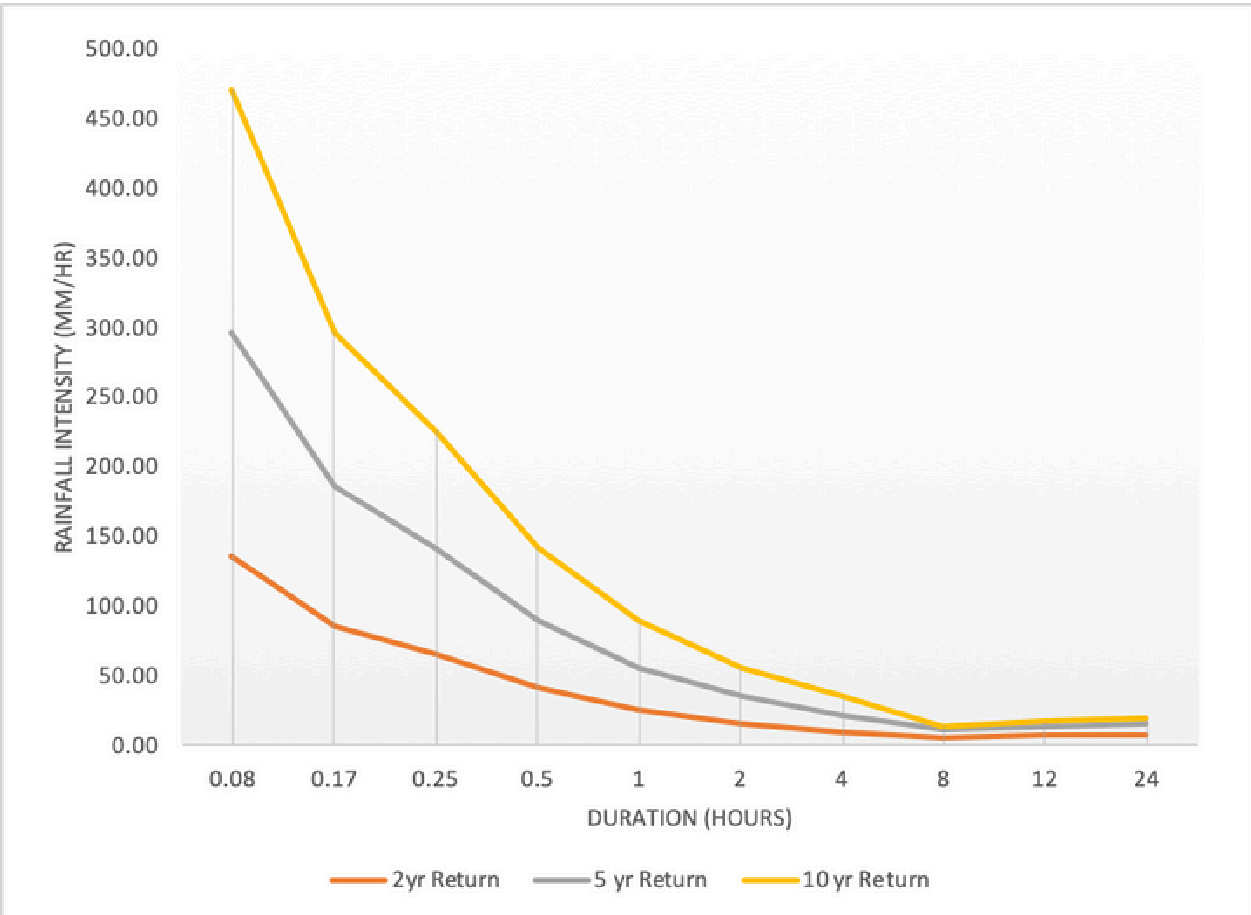
To address this gap and develop a scientifically grounded dataset, a detailed assessment of flood risk, hazard, and vulnerability was conducted as part of the project.

3.1. Intensity-Duration-Frequency Curve For Bhubaneswar

Flood risk refers to the probability of flooding occurring in a given geographic area. The first step in the flood risk assessment involved deriving the Intensity-Duration-Frequency (IDF) curve using long-term rainfall data. For this purpose, 16 years (from 2000 to 2015) of daily rainfall data from the Bhubaneswar station was analyzed.

The annual peak rainfall in the city during this period ranged from 33 mm to 133 mm, indicating significant variability in rainfall patterns. Data from subsequent years (post-2015) may show even greater variations in annual peak rainfall, likely influenced by the impacts of climate change.

IDF Curve of Bhubaneswar City



3.2. Micro-Catchments and Runoff Analysis

The maximum rainfall intensity for 1-hour duration for 2 year and 5 years return period is 20.64 mm/hr and 30.05 mm/hr, respectively. But the present capacity of natural drains can handle rainfall intensities up to 20 mm/hr. So, even an intense rainfall of a 2-year return period causes waterlogging and inundation depths up to 1m are quite common in most of the vulnerable areas every monsoon. (Source- Climate-KYC & Bhubaneswar Smart City)

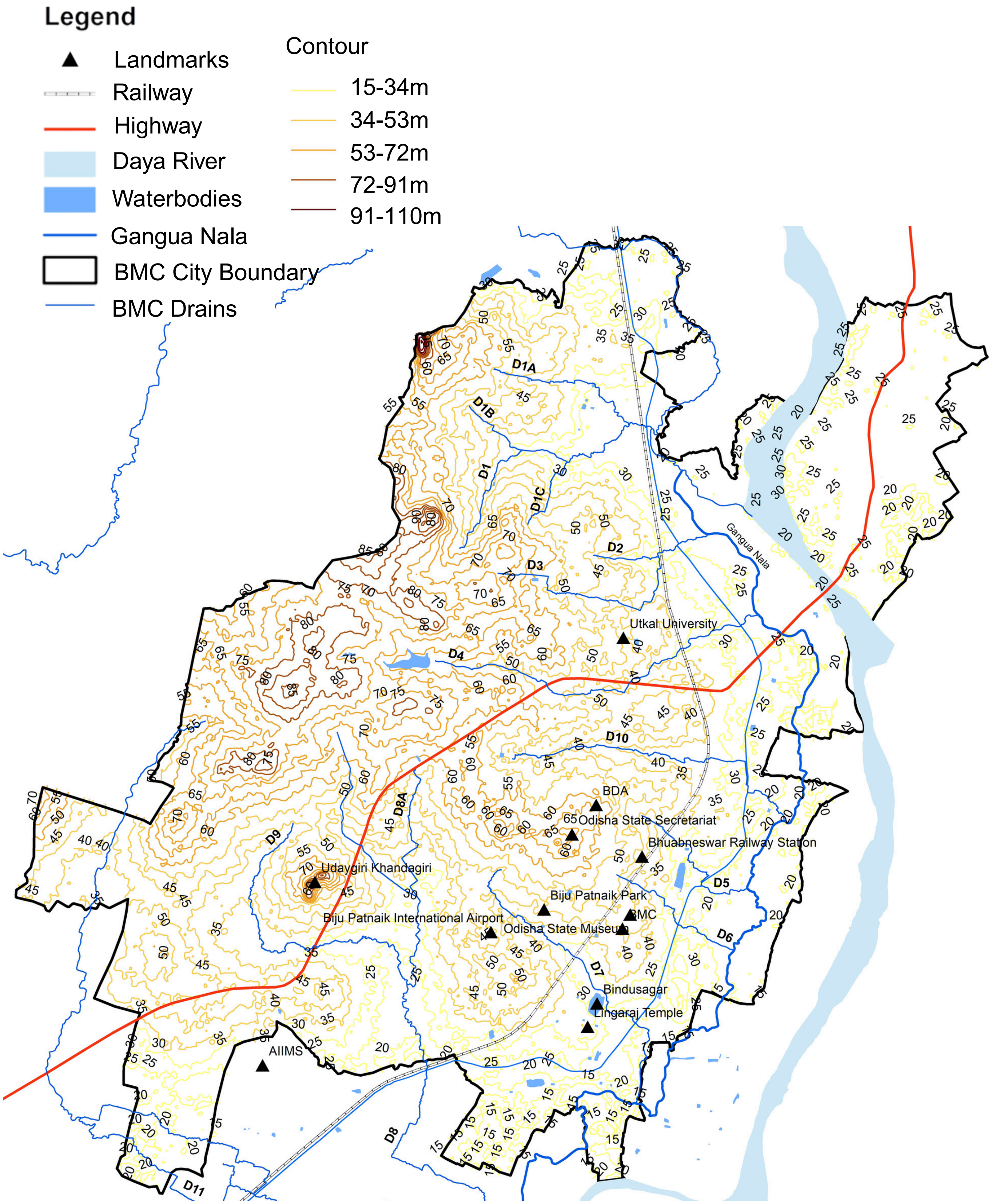
The hydrological assessment of the natural drains in Bhubaneswar city was essential to determine surface runoff and drainage discharge during rainfall events. Currently, direct discharge measurements of the 14 natural drains—such as through the V-notch method—have not been conducted. Therefore, the hydrological properties of these drains were assessed through micro-catchment analysis using GIS tools.

This runoff analysis aimed to identify the hydrological characteristics of the micro-catchments associated with each natural drain and to estimate runoff volumes using the ArcGIS program and a Digital Elevation Model (DEM). As part of this process, a natural drainage map and a contour map were created for Bhubaneswar.

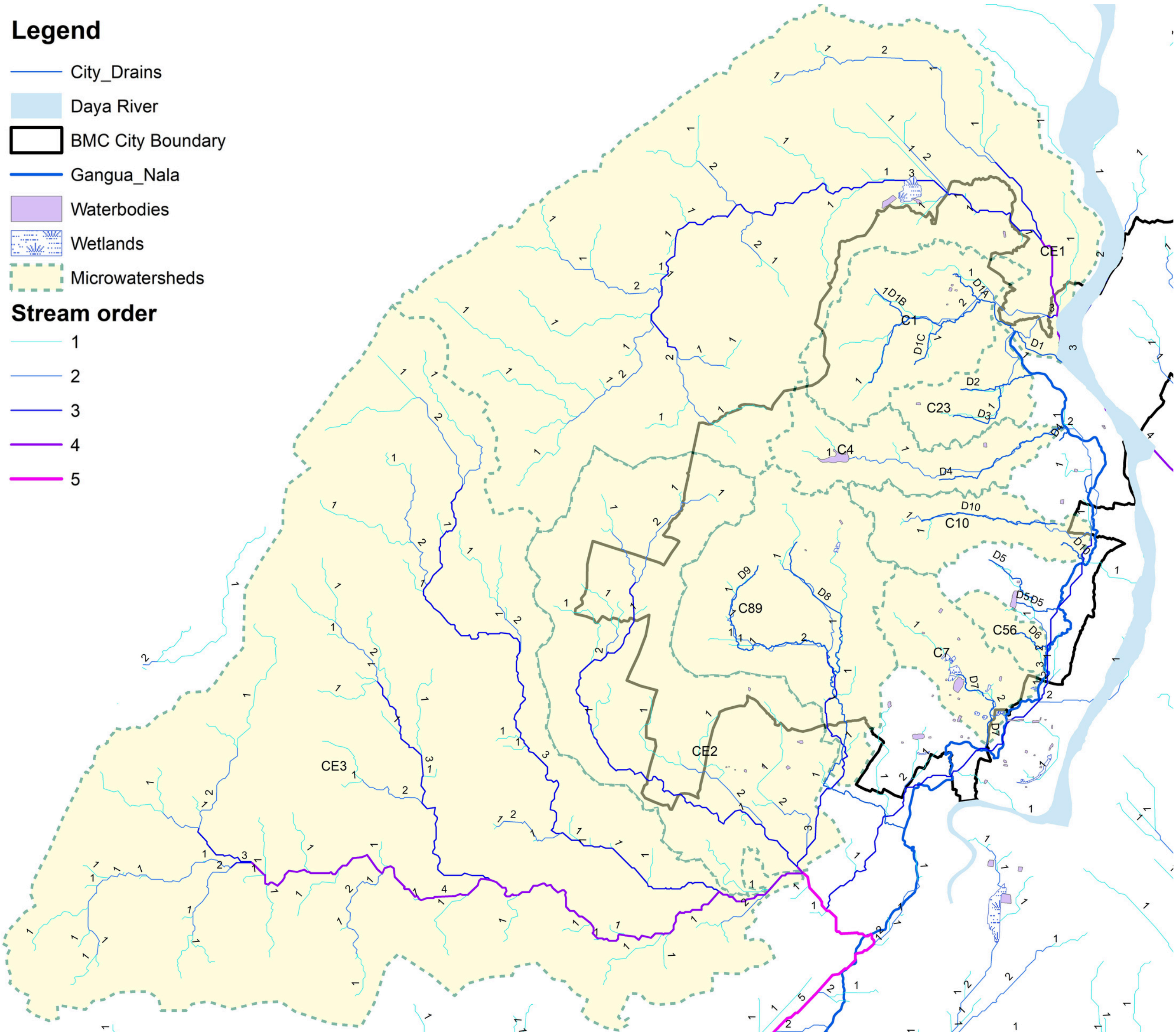
The city's topography—particularly in the western region—is undulating and includes 14 valleys (comprising 11 natural drains and 3 sub-natural drains). Each valley contains a natural drainage channel located at its lowest contour point.

Micro-catchment identification: To understand the characteristics of the catchment area, a micro-catchment map was created for all the natural drains flowing through the city. The 14 natural drains formed 10 different micro-catchments denoted as C1, C23, C4, C56, C7, C89, C10, CE1, CE2, and CE3. The area of each micro-catchment was calculated to help analyse the runoff discharge from each micro-catchment. *(Refer to map 3 on page no. 18)*

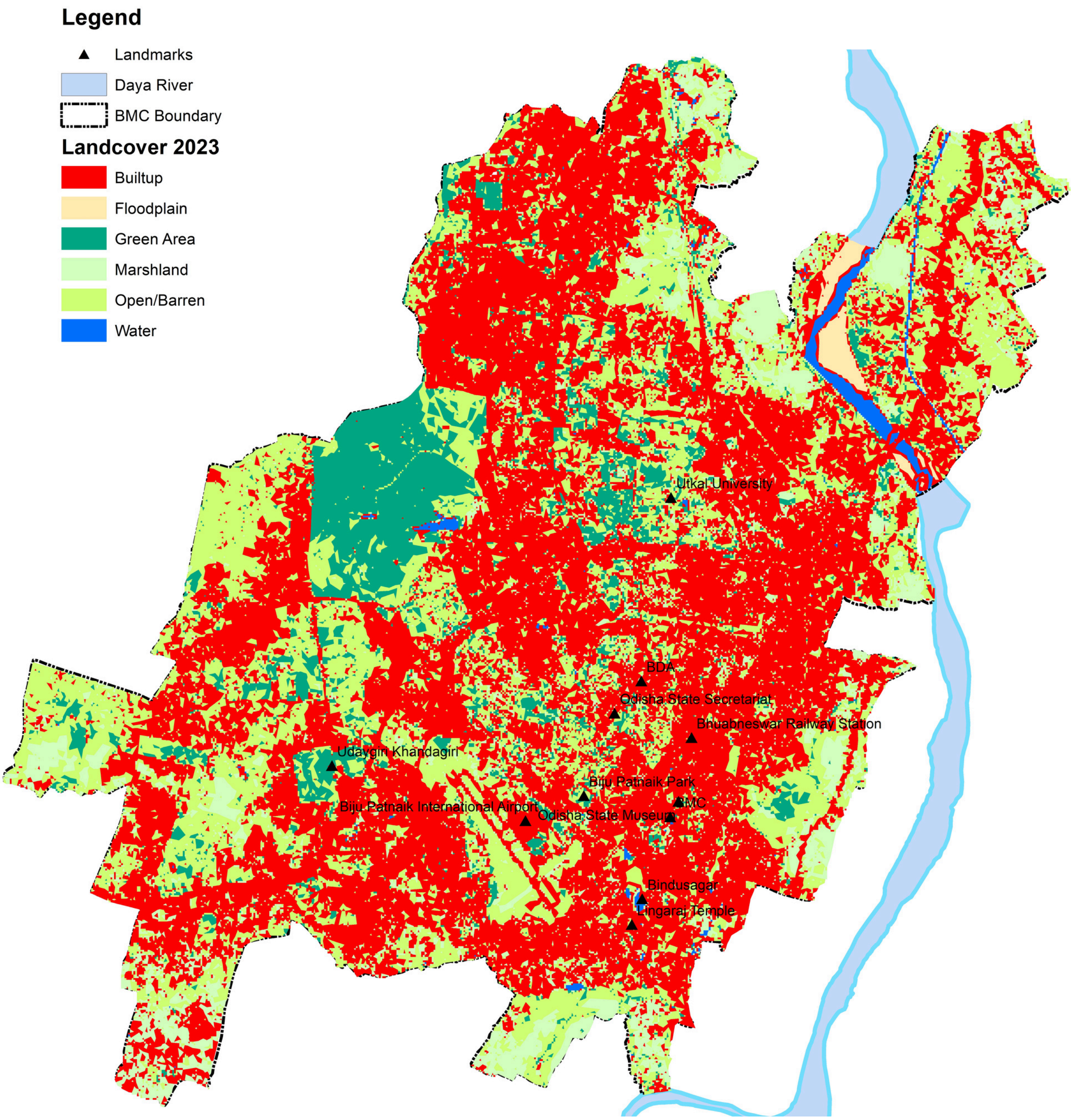
Land Cover: Land cover is one of the significant variables for runoff estimation. The classification was performed to generate different land use/land cover types, namely water body, dense forest, open forest, natural vegetation, existing agricultural land, agricultural fallow, wasteland, home shed land and urban built-up for each micro-catchment. *(Refer to map 4 on page no. 19)*



Map 2: Contour map of Bhubaneswar city



Map 3: Micro-catchment map of Bhubaneswar city



Map 4: Land Cover map of Bhubaneswar

The Rational Method—an empirical formula that is commonly used in urban areas for computing peak rates of runoff for designing drainage structures—was used to understand the city's run-off.

Rational Method - Q=10 CIA (m3/sec), where
Q – Peak rate of runoff
C – Co-efficient
I – Intensity of the rainfall (mm/hr)
A – Area of the catchment

The runoff generated from the seven major catchments is provided in Table 1

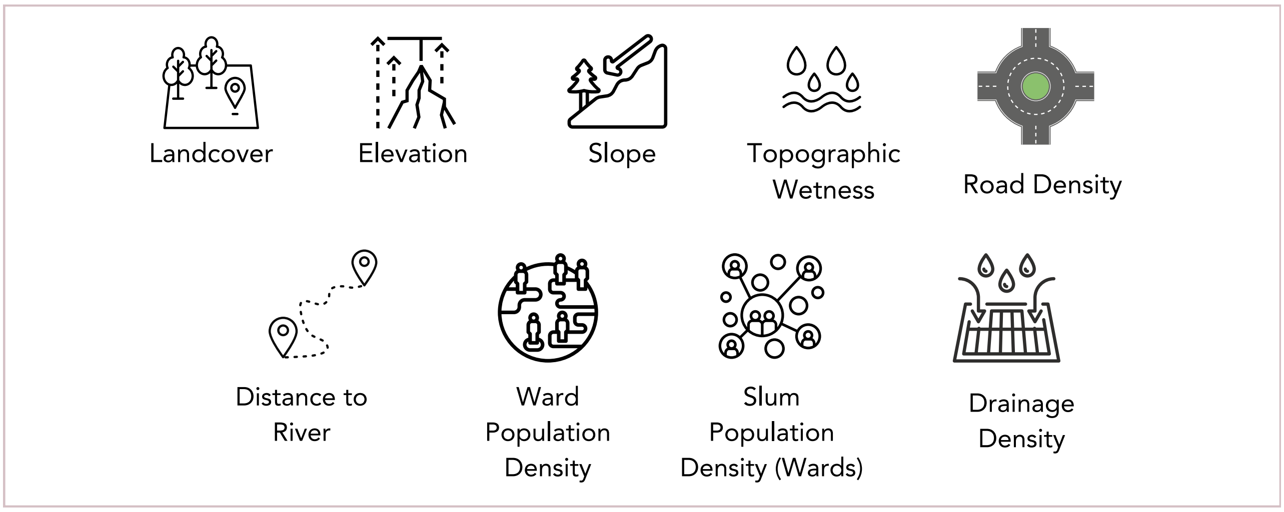
Table 1: Runoff generation from the seven major drain catchments

S.No.	Drain	Drain Length	Catchment area (Hectares)	Constant	Tc (Min)	i	Q (m3/hr)
1	C1	1000	2000	0.7	11.70	92.45	12,94,300
2	C23	800	700	0.75	10.00	100.8	5,29,200
3	C4	1500	1300	0.75	19.92	67.4	6,57,150
4	C56	6000	300	0.8	111.69	9.47	22,728
5	C7	9000	1100	0.8	163.71	9.50	83,600
6	C89	1000	3200	0.5	11.37	94.01	15,04,160
7	C10	1100	1000	0.6	15.74	75.32	4,51,920

The total runoff generated in the city which accumulates within these seven catchments of area around 9,600 Ha is 45,43,058 m3/Hr (44,565 cusec).

3.3. Flood Vulnerable Areas in the City

The following parameters were considered to prepare composite flood vulnerability map of city to identify flooding hotspot areas in the Bhubaneswar city. (The detailed methodology is presented in Annexure 1)



A composite flood risk map was developed by integrating key parameters related to both hazard and vulnerability. Thematic maps for each parameter were prepared using GIS, based on data gathered from secondary research, satellite imagery, field surveys, and inputs from city officials.

A GIS-based Multi-Criteria Decision Analysis (MCDA) approach, along with weighted overlay analysis, was employed to create a composite hazard map on a scale of 1 to 5. The Analytical Hierarchy Process (AHP) was used to assign weights and prioritize factors, resulting in the generation of composite flood hazard and vulnerability maps.

The composite flood risk map was prepared showing categories from 1 to 5, where 1 signifies low risk and 5 signifies high risk. The analysis of flood risk, hazard, and vulnerability was mapped at the ward level, identifying those located in zones ranging from medium to very high flood risk. *(Refer to map 5 & 6 on page no. 22 & 23 respectively)*

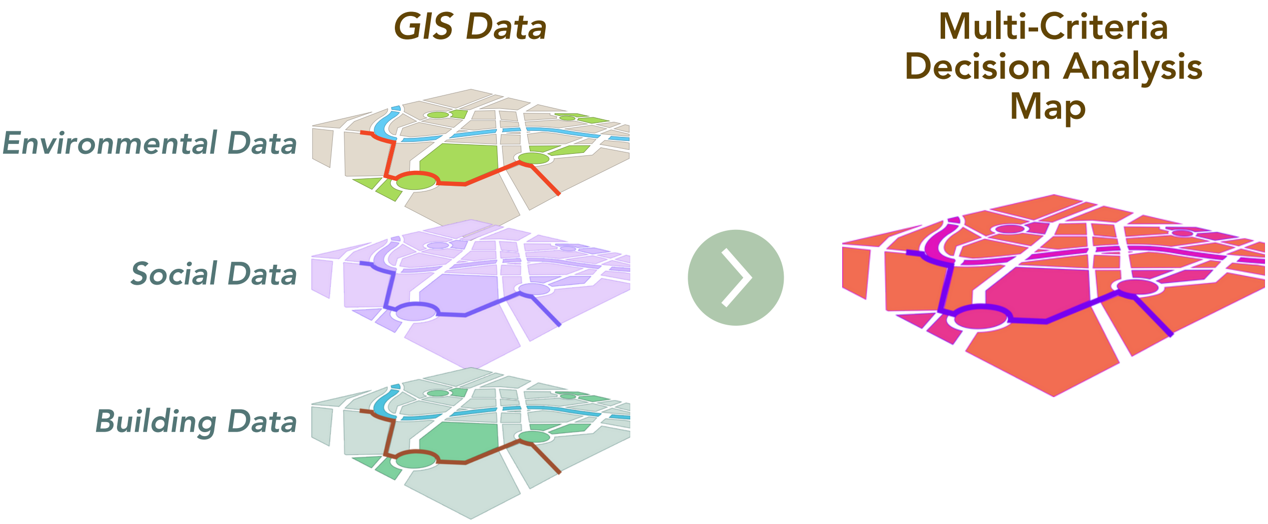
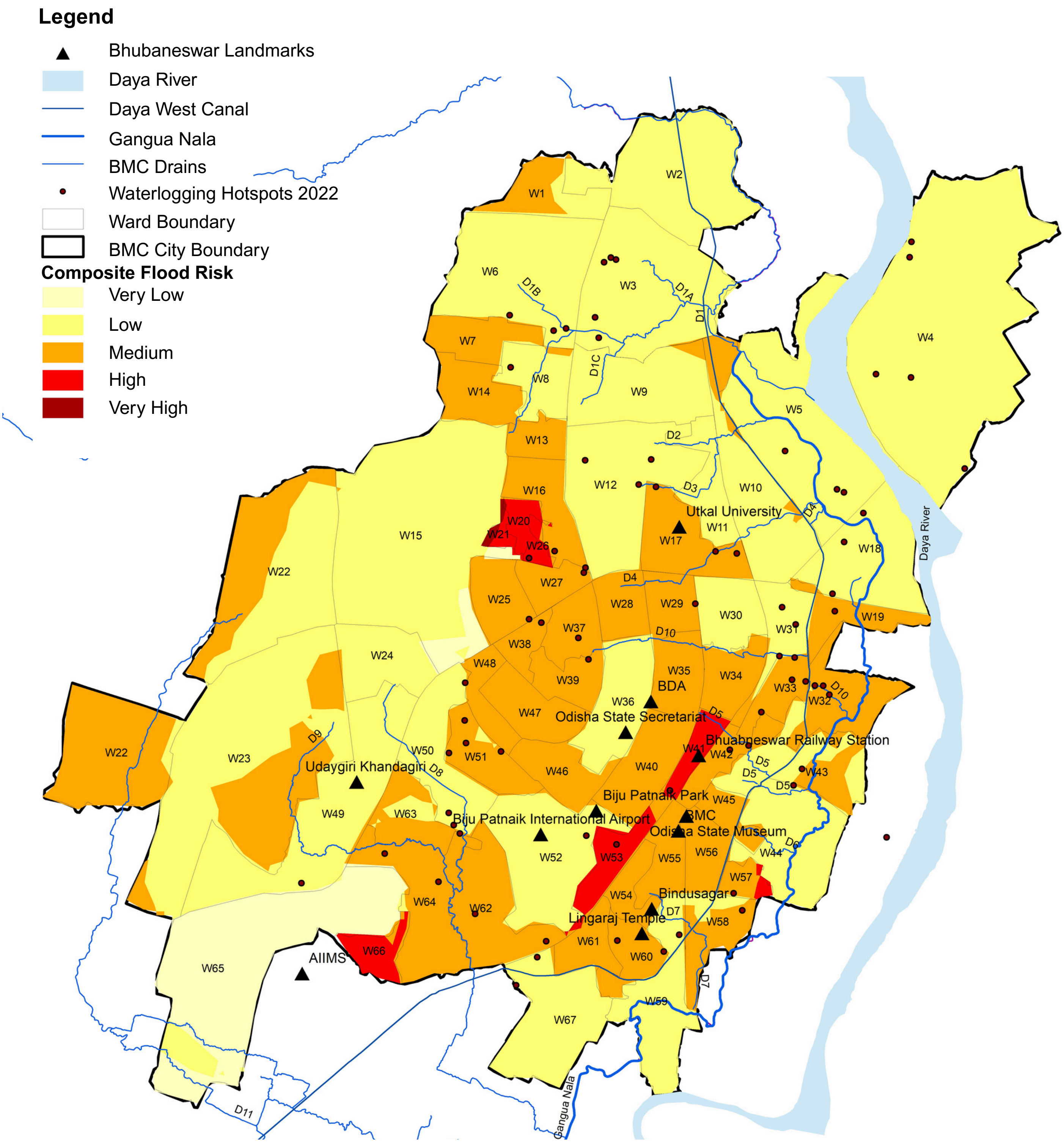
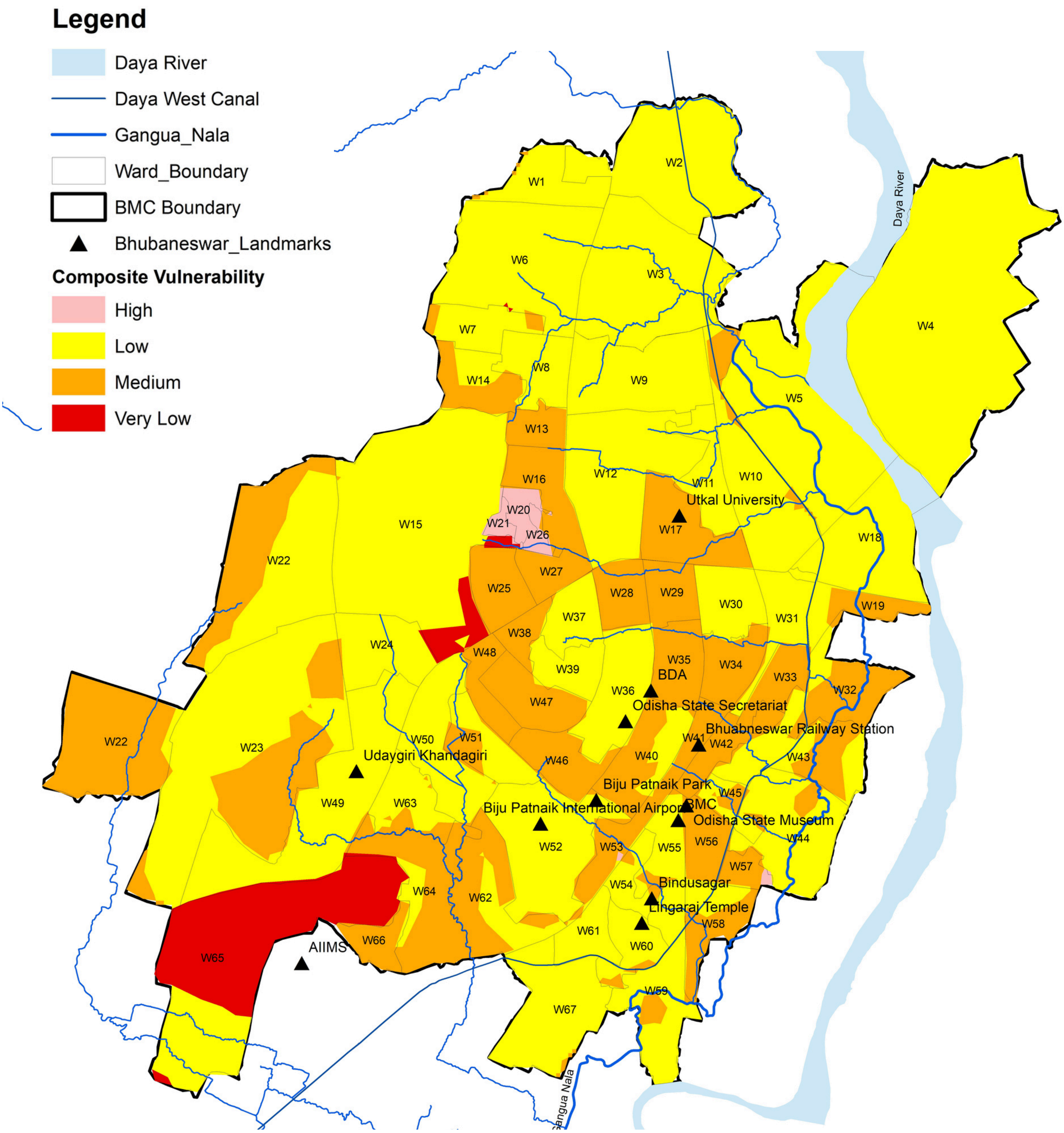


Table 2: Wards at risk of urban flooding

Flood risk	Ward numbers	No. of wards	Estimated area at risk (sq km)	Estimated population at risk
Very High	20, 21	2	0.0955	3,561
High	20, 21, 26, 41, 53, 57, 66	7	3.24	99,623
Medium	1, 7, 9, 10, 13, 14, 16, 17, 19, 22, 23, 25, 27, 28, 29, 31, 32, 33, 34, 37, 38, 39, 42, 43, 45, 46, 47, 48, 51, 54, 55, 56, 57, 58, 60, 61, 62, 63, 64, 66	40	53.76	5,88,737
Total		**54**	**~ 57**	**6,91,921**



Map 5: Composite flood risk map of Bhubaneswar city



Map 6: Composite flood vulnerability map of Bhubaneswar city

3.4. Flood Hotspot Data Analysis and Validation

The flood-vulnerable areas in the city, identified through the GIS-based MCDA approach, were further analyzed and validated through a consultation meeting with the Drainage Department of the Bhubaneswar Municipal Corporation (BMC). During this consultation, the BMC provided a detailed list of locations that experience waterlogging during the monsoon season.

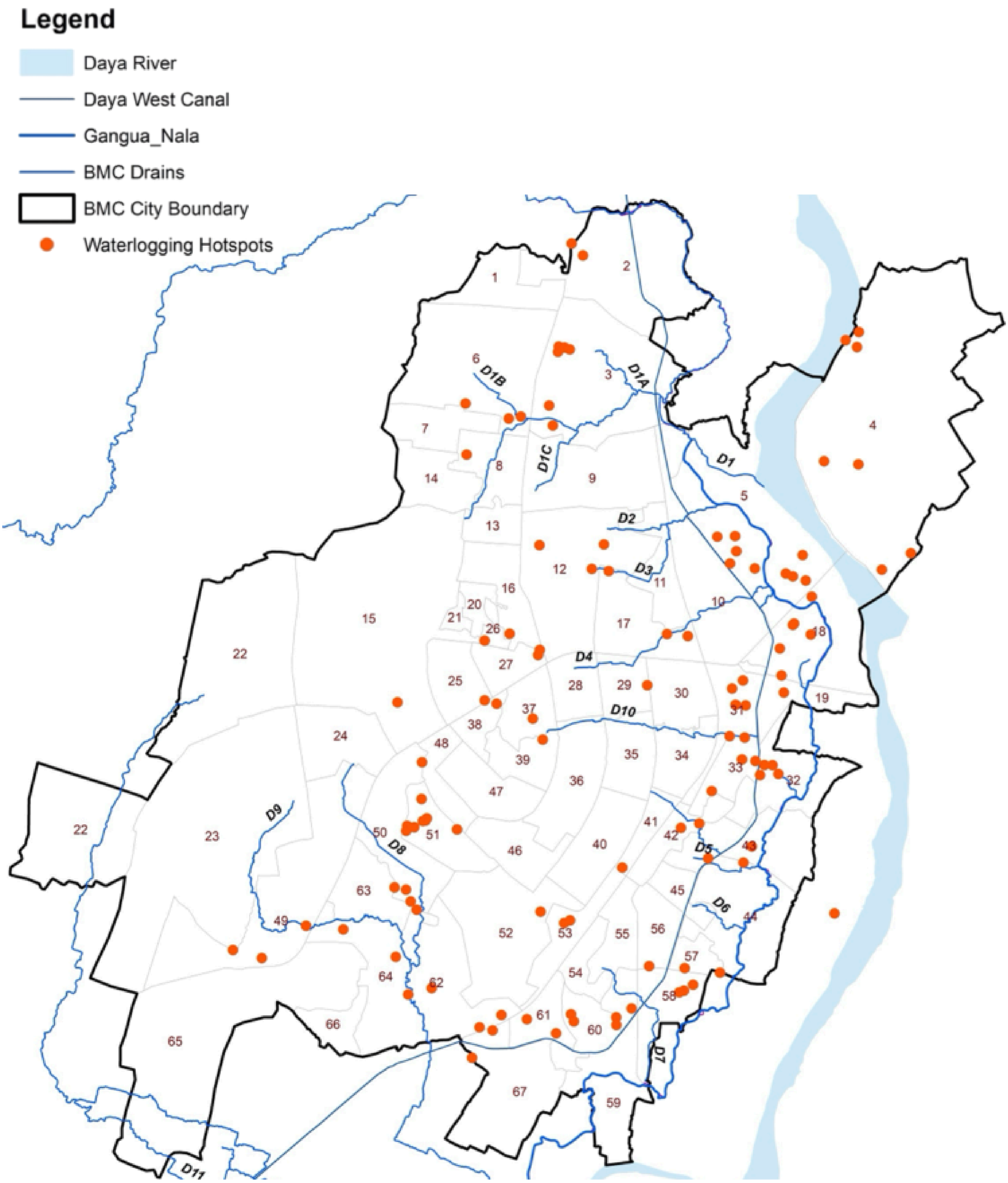
The list includes approximately 90 locations with moderate to high levels of waterlogging. Out of these, 19 locations are identified as low-lying points where dewatering through pumping is the only viable solution, according to BMC officials (based on ~~personal~~ discussions with drainage department engineers; NIUA, 2024).

As a result, the BMC decided to establish pumping stations at these 19 vulnerable locations by installing pump sets with appropriate capacity during the heavy rains of June 2022.

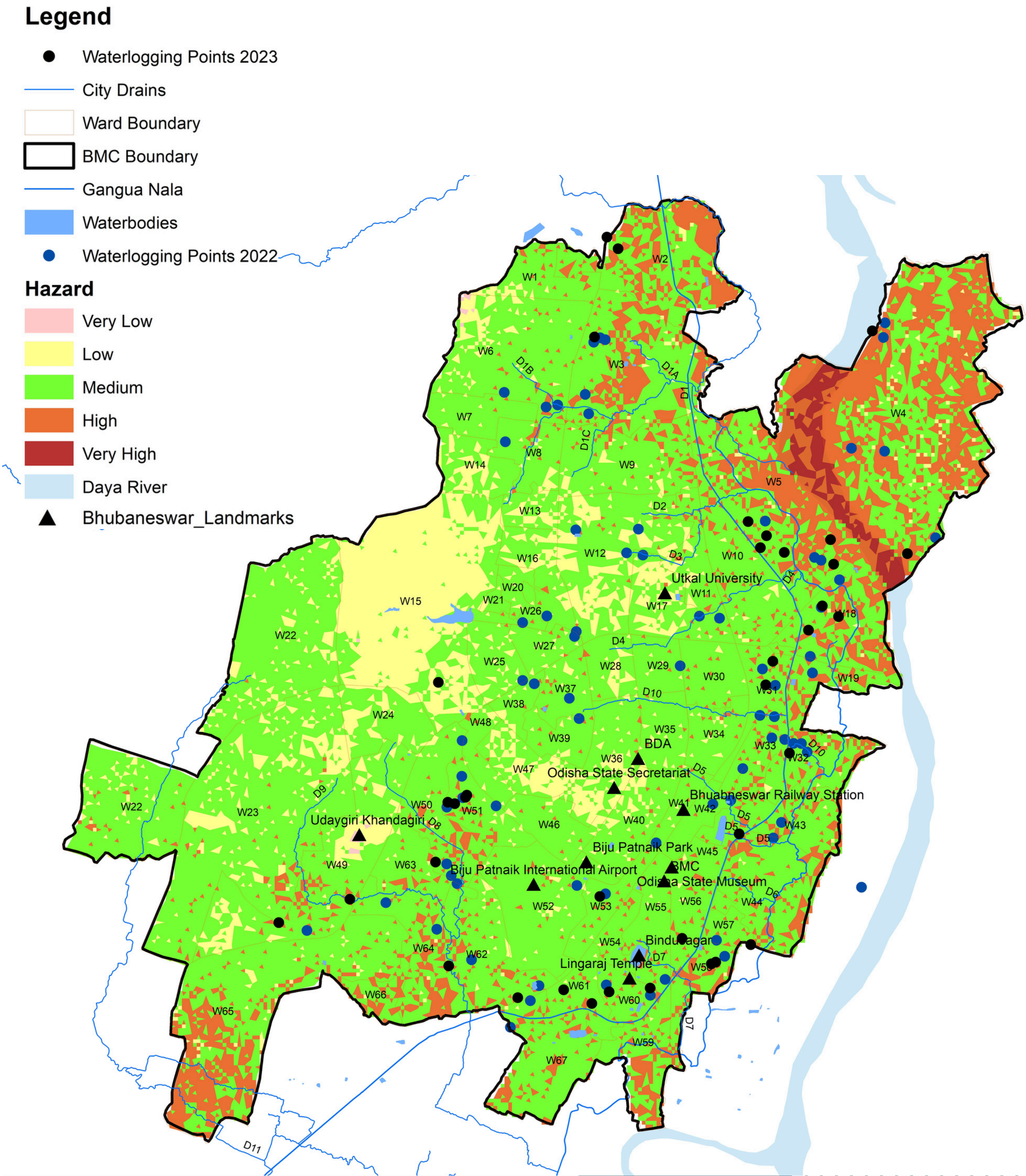
The locations of reported flooding hotspots, as provided by the Bhubaneswar Municipal Corporation (BMC), were overlaid onto the flood hazard map (Map 8) developed through a composite weighted overlay analysis of key contributing factors. This comparison revealed a strong spatial correlation between the reported flood incidents and the flood hazard prone areas identified through the analysis.

Pictures showing flooding in Bhubaneswar city
Source: Times of India article and NIUA

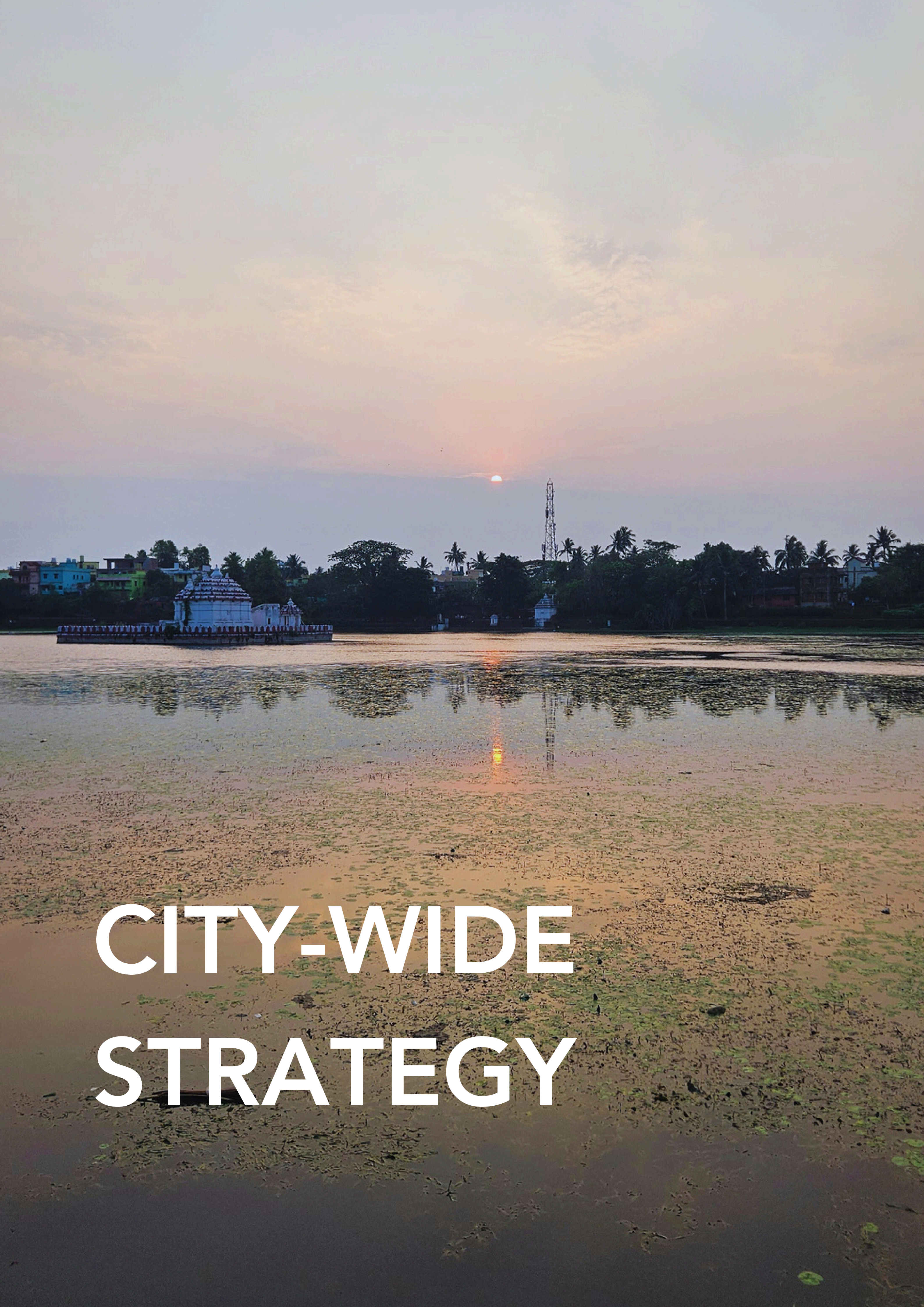
Map 8 illustrates this spatial relationship and supports the validation of the flood risk assessment.



Map 7: Flooding hotspots in the city



Map 8: Flooding hotspots overlaid with composite flood hazard map of urban flooding



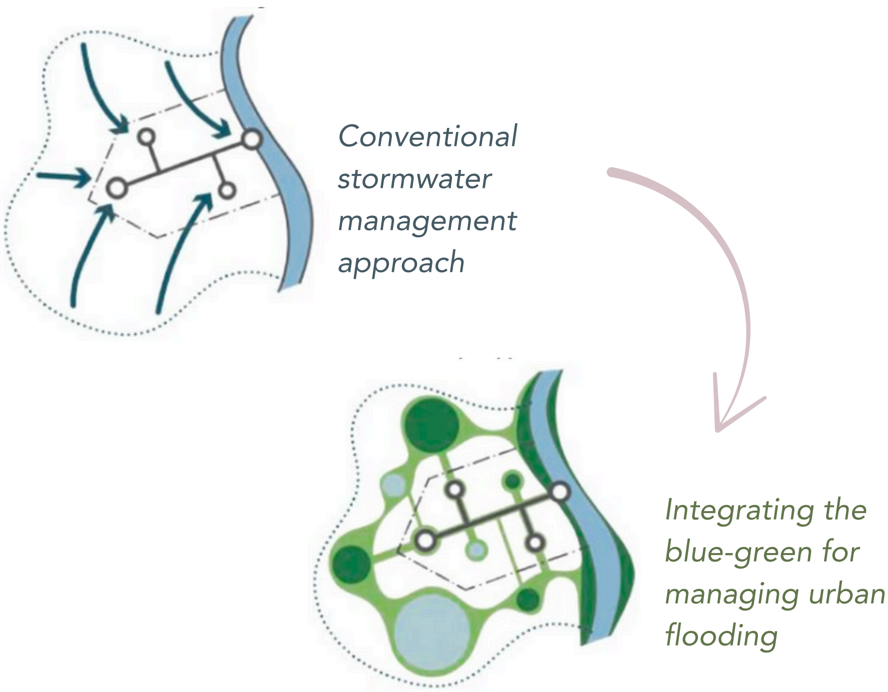
CITY-WIDE STRATEGY

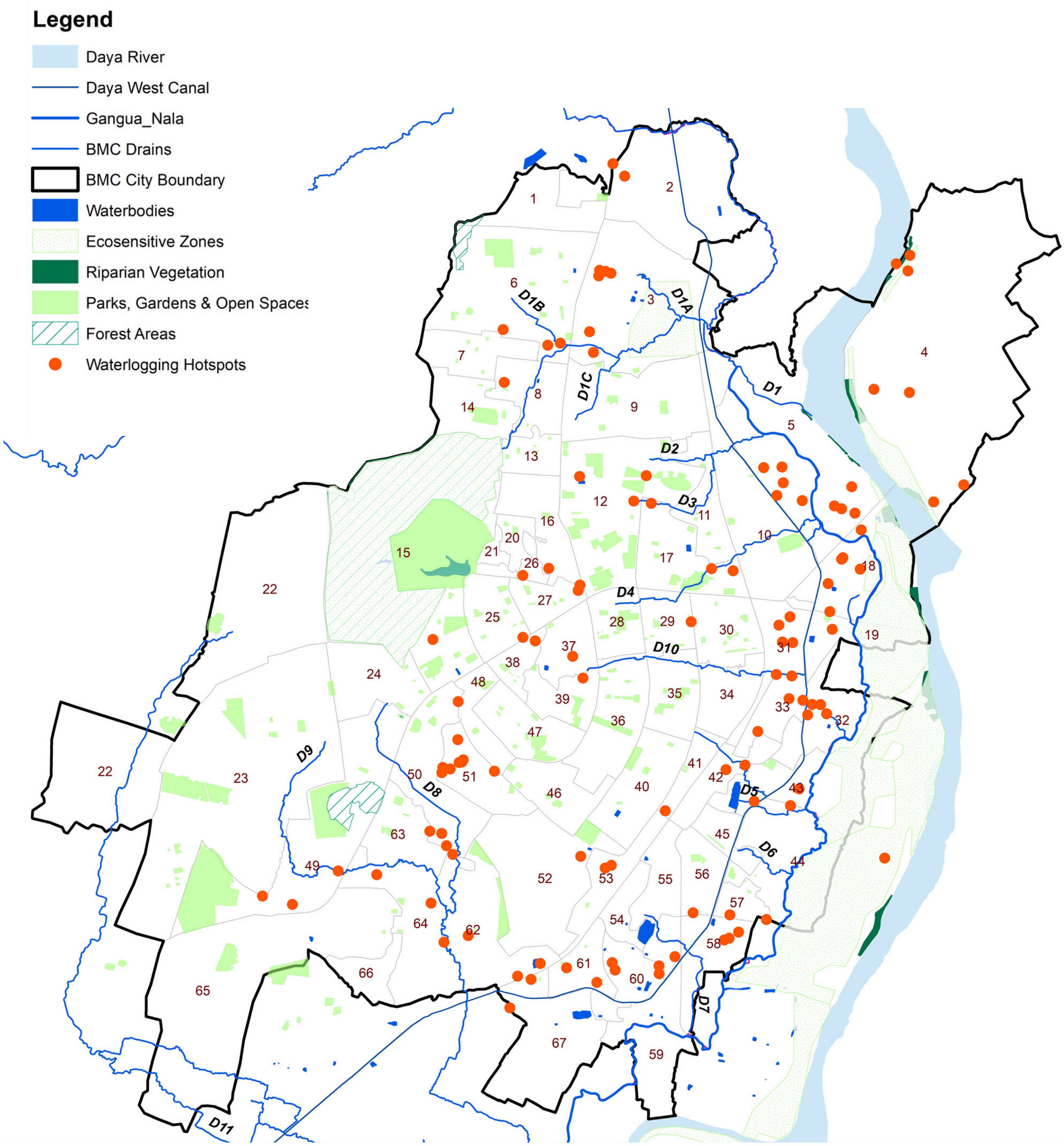
4. CITY-WIDE STRATEGY FOR MANAGING URBAN FLOODING

The detailed assessment of flooding in Bhubaneswar highlighted the critical need to integrate ecosystems into urban flood management strategies. The analysis involved mapping flood-prone hotspots and overlaying them with existing blue-green infrastructure, such as wetlands, water channels, parks, and open spaces. This revealed a strong spatial correlation between flooding zones and these ecological assets. (Refer to map 9 on page no. 29)

This finding underscores the vital role of blue-green infrastructure in regulating stormwater and mitigating flood impacts, emphasising the need to preserve and restore these natural systems. Based on these insights, a comprehensive, city-wide strategy for managing urban flooding in Bhubaneswar has been developed.

The proposed approach includes conserving and restoring natural ecosystems, such as natural drains, lakes, wetlands, and marshlands, alongside implementing sustainable stormwater management practices like bioswales, rain gardens, and permeable pavements. Additionally, flood-resilient planning will be integrated into urban development policies. By combining ecological preservation with engineered solutions, the city can build long-term resilience against the growing threat of urban flooding.





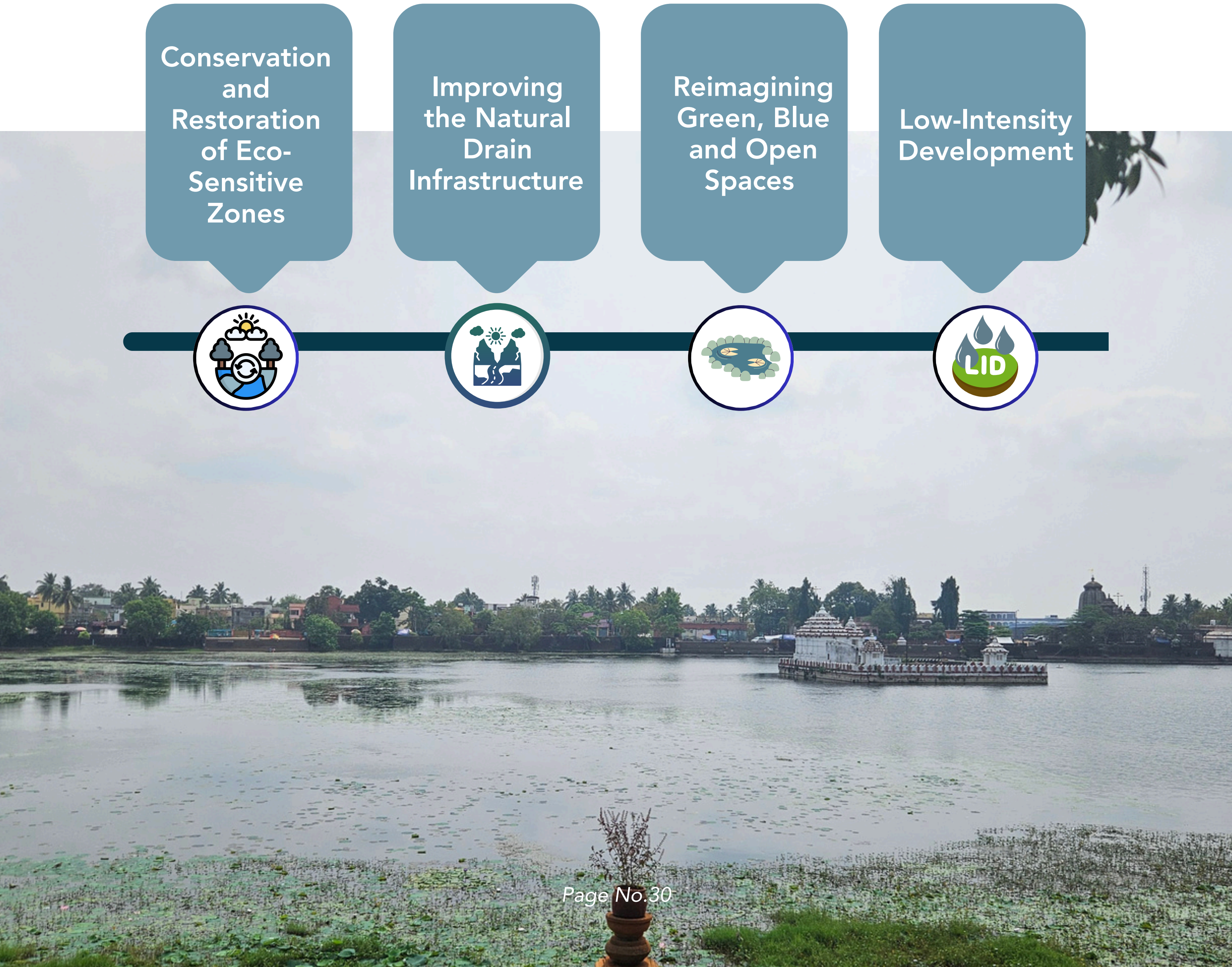
Map 9: Flooding hotspots overlaid with the blue-green infrastructure

The principle of the city strategy is based on the two important aspects of flood management, which are reducing the run-off and creating space for absorption of the runoff generated in the city.

City Strategy for Managing Urban Flooding

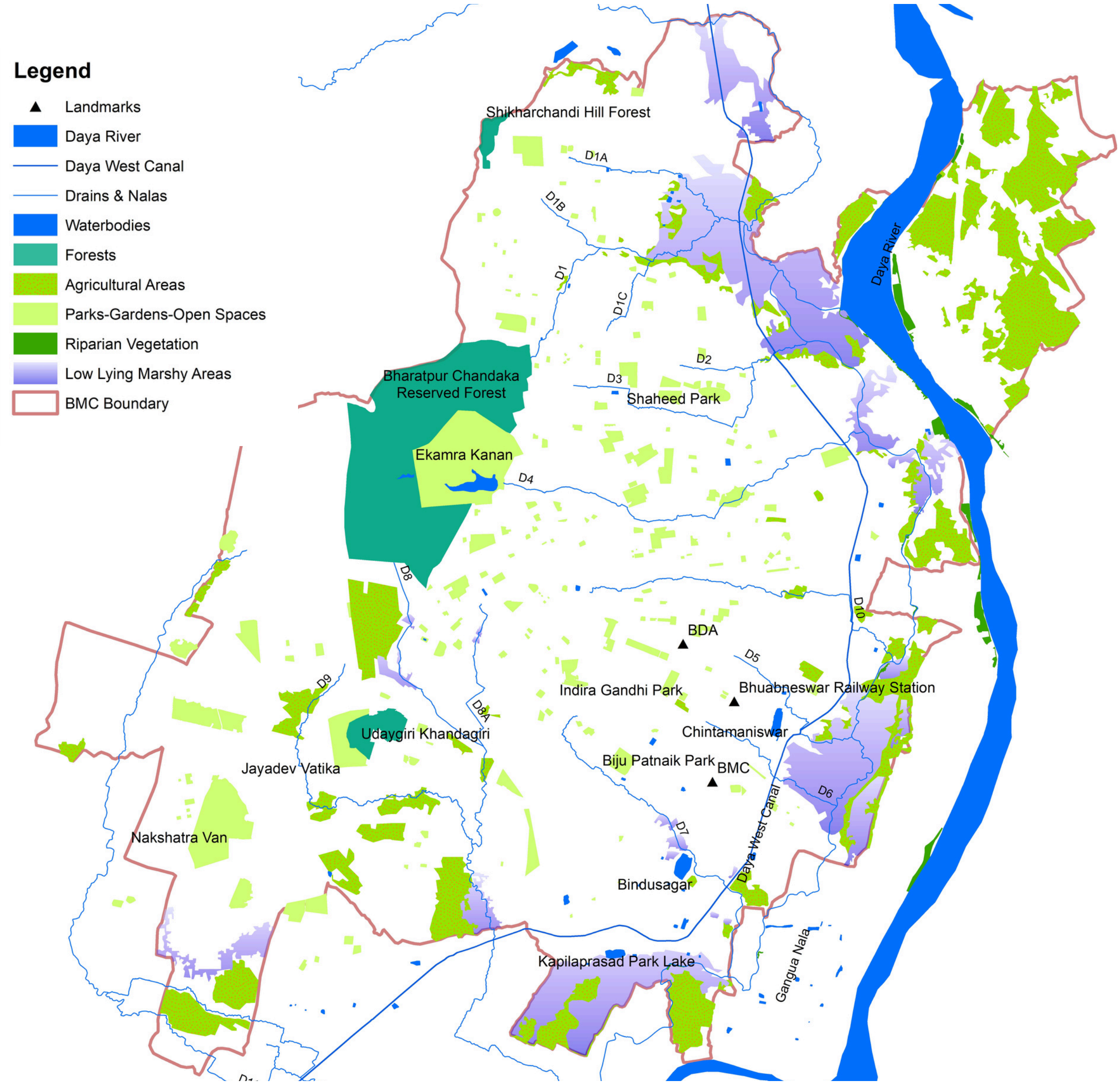
- Creating space for water absorption
- Reducing the surface run-off generation

The city strategy for flood management in the city has been categorised in four major sections, which are; provided in the graphics below. The section below talks about each strategy in details and provides a guidance for the city to implement each of these strategies.

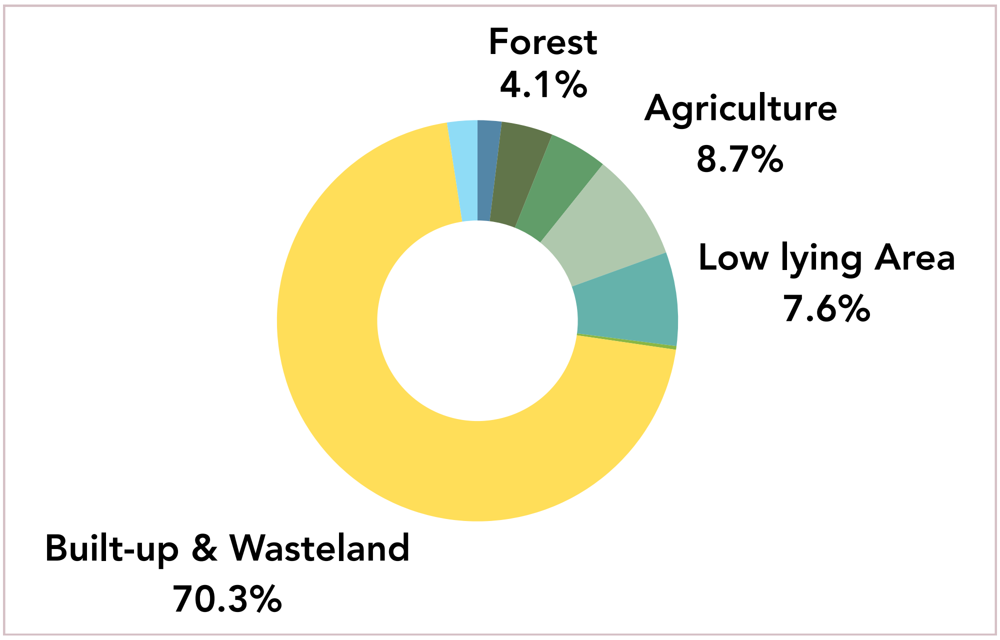


4.1. Conservation and Restoration of Eco-sensitive Zones

The city is dotted with a number of distinct ecosystems— hills (*Shikharchandi & Udaigiri-Khandagir*), natural forest (*Chandaka*), wetlands (*Gautamnagar, Sampriti vihar*), water bodies/pokharis (*Bindusagar, Chintamaneshwar*), natural drains (*14 drains*), marsh/grass-lands, riparian zones (*along Daya river*), and urban greens like forest patches, and parks (Nikko park, Jaydev Vatika).



Map 10: Ecosystems in Bhubaneswar city

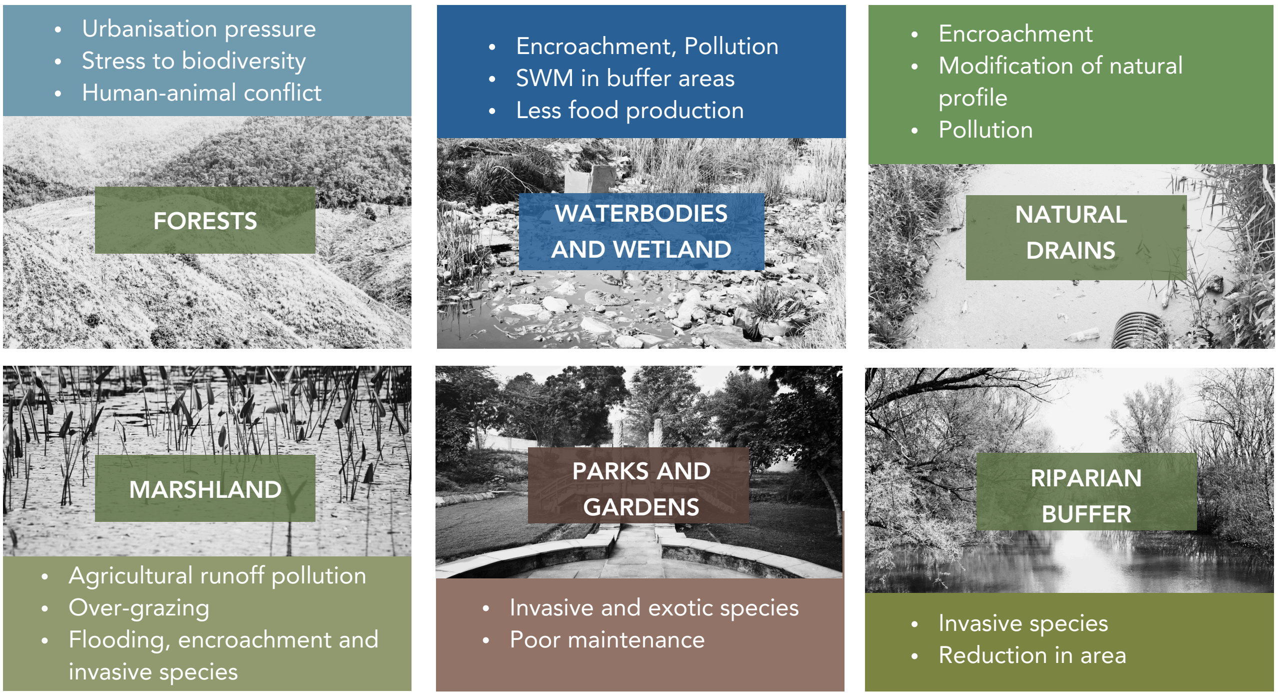


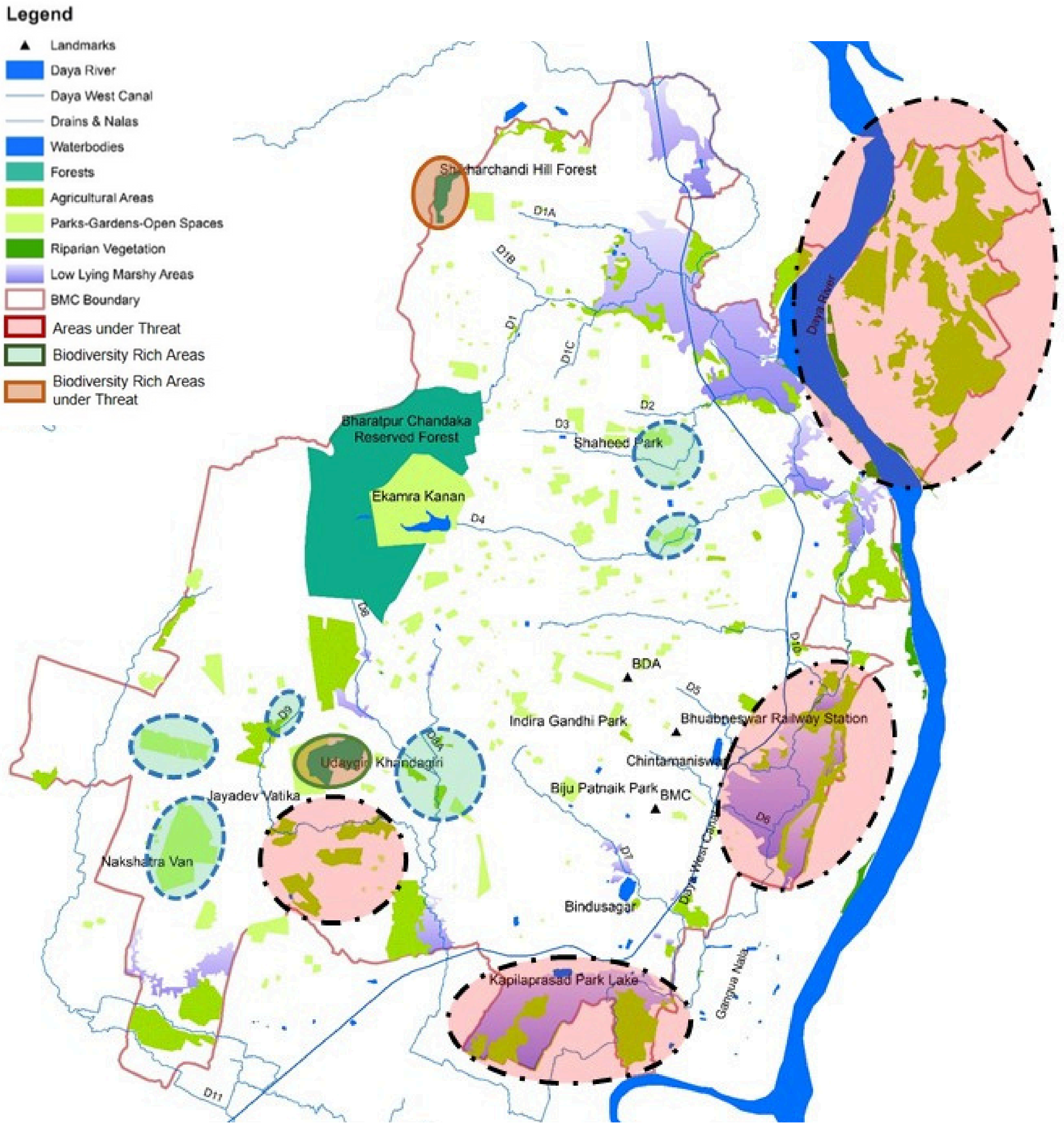
Area covered by different ecosystems in the municipal corporation boundary

With inputs from city officials and sector experts, an ecosystem and biodiversity map was developed for the Bhubaneswar Municipal Corporation (BMC) area. The assessment identified around six small patches within the city that are flourishing in terms of biodiversity, indicating healthy ecosystems. However, the analysis also revealed several larger patches where signs of ecological degradation suggest significant threats to local ecosystems and biodiversity. (Refer to map 10 on page no. 31)

Each of these ecosystems was analyzed in detail to assess the specific threats they face due to increasing urbanization pressures. To ensure a comprehensive understanding of their current condition, inputs from city officials and sector experts were incorporated, offering valuable contextual knowledge and ground-level insights.

The graphic below depicts the major threats identified for each of the ecosystems:





Map 11: Ecosystems and biodiversity status in Bhubaneswar city

The diversity of ecosystems within Bhubaneswar plays a vital role in maintaining the city's environmental health. These ecosystems help regulate the local climate, store carbon, support biodiversity, and provide recreational spaces for residents. Protecting and restoring these natural systems is essential for enhancing the city's resilience to the impacts of climate change.

As highlighted earlier, there is a direct correlation between flooding hotspots and ecosystem degradation in the city. One of the key strategies recommended for cities like Bhubaneswar, facing frequent urban flooding, heat stress, and cyclones, is the restoration and conservation of its diverse ecosystems. Following are the key recommendations that the city can adopt for the protection and restoration of eco-sensitive zones:

1.Conduct a Detailed Analysis of Development Types in Eco-Sensitive Zones

Carry out a comprehensive land-use and land-cover study to understand the nature and extent of existing and proposed developments within eco-sensitive areas. This analysis should identify activities that are harmful to local ecosystems and recommend alternatives or mitigation measures.

2. Demarcate No Development Zones (NDZs) and Regulated Development Zones

Clearly delineate No Development Zones within environmentally sensitive regions to prevent ecological degradation. In Regulated Development Zones, permit only low-impact activities such as:

- Upgrading civic infrastructure (e.g., drainage, sanitation)
- Road widening (with environmental safeguards)
- Establishment of non-polluting industries or services

3. Establish Biodiversity Zones along Riverbanks

Designate and protect dedicated biodiversity zones along river corridors to preserve and enhance the ecological integrity of riparian ecosystems.

4. Declare the Kuakhai River Floodplain as a No-Development Zone

Legally declare the Kuakhai River floodplain as a strict No Development Zone to retain its natural function in flood mitigation and groundwater recharge.

5. Expand Natural Buffers Along Riverbanks and Floodplains

Restore and preserve natural spaces along water bodies to allow safe, seasonal flooding and reduce urban flood risk. These areas should also serve as ecological buffers and green corridors.

6. Promote Native Species in All Plantation Activities

Ensure that all city-wide plantation efforts prioritise native plant species.

- Saplings should be sourced primarily from nurseries managed by the City Forest Department.
- Local nurseries should be incentivised or mandated to cultivate native species to meet city greening goals.

7. Develop a City-Level Plantation Strategy

Formulate and implement a comprehensive urban greening strategy that aligns with ecological priorities, biodiversity conservation, and climate resilience objectives. The strategy should guide species selection, planting locations, and maintenance protocols.

8. Make Biodiversity Assessments Mandatory for Large-scale Development

Require that all major development projects undergo a biodiversity impact assessment as part of the environmental clearance and urban planning approval process.

9. Establish a Green Initiative Facilitation Centre within BMC

Set up a dedicated centre under the Bhubaneswar Municipal Corporation to support citizen-led greening projects, such as:

- Community parks
- Kitchen gardens
- Rain gardens

This centre would provide technical guidance, materials, and coordination support for small-scale eco-initiatives.

4.2. Restoration of Natural Drains

As mentioned earlier, Bhubaneswar has 14 major natural drains that function as stormwater channels during the monsoon season and carry black water during the lean season. The total length of the drain network is approximately 73.30 km, covering all 14 natural drains.

All natural drains within the jurisdiction of the Bhubaneswar Municipal Corporation (BMC) are maintained by the BMC, except for Drain No. 11. Currently, all stormwater flowing through the city's secondary and tertiary drainage systems is ultimately discharged into the Gangua Nala via these natural drains, and then into the Daya River.

Out of the 14 natural drains, Drains No. 1, 3, 4, 5, 6, 7, 9, 10, and 11 discharge directly into the Gangua Nala. The remaining drains first discharge into the aforementioned main drains, which then carry the water to the Gangua Nala.

Table 3: Details of natural drains in Bhubaneswar

S.No.	Drain	Place of Origin	Outfall Point	Length of Drain (km)	Width of Drain as per CDP (m)	Available Width of Drain (m)
1	1	Chandaka Sanctuary	Gangua	5.7	14.3	3.5-9
2	1B	Chandaka Industrial Estate Infocity	Drain No 1	2	4	1.8-4
3	1C	Omfed Square Chandrasekharpur	Drain No 1	2	4	3-4
4	2	Dhirikuti Basti	Drain No 3	0.85	4.9	3-5
5	3	OSAP Battalion, Kalinga Hospital Square	Gangua	4.226	9	2-8
6	4	Ekamra Kanan	Gangua	7.5	9.2	2.5-9
7	5	Gurudwara Janpath Road	Gangua	3.542	5	2.5-5
8	6	Arya Palace Hotel Janpath	Gangua	3.112	6.5	3-4
9	7	Culvert near LIC Staff Quarter Surya Nagar	Gangua	5.454	7.6	3-5
10	8	Damapada Sanctuary	Drain no 9	5.362	9	6-9
11	8A	CRPF Campus	Drain no 8	3	4.5-6	2.5-4.5
12	9	CET College	Gangua	15.5	14.83	4.5-9.5
13	10	Nayapalli Haja	Gangua	7.375	10	4-6
14	11	Sampur	Gangua	7.68		6-8

One of the major causes of flooding in Bhubaneswar is the reduced capacity of natural drains due to encroachments and the accumulation of solid waste. Clearing and restoring the functional pathways of these drains is essential to reduce the impact of flooding in the surrounding areas.

As indicated in the table above, the current widths of many drains differ from the dimensions specified in the City Development Plan (CDP), further affecting their discharge capacity. To effectively leverage these existing drains for stormwater runoff management, the city can adopt the following two strategies:

4.2.1. Drain restoration as per the width recommended in the CDP

There is a critical need for the systematic widening of drainage channels in Bhubaneswar to enhance their carrying capacity and effectively mitigate urban flooding. This involves restoring the existing drains to the dimensions outlined in the City Development Plan (CDP), which is essential for managing the increasing volume of stormwater runoff resulting from more intense and frequent rainfall events.

This issue is particularly critical in rapidly urbanising areas, where encroachments along natural drainage paths (buffer zones) have significantly reduced the carrying capacity of drains. While the city has taken initial steps to widen and channelise certain drains to accommodate higher runoff volumes, a comprehensive city-wide approach is necessary to achieve a meaningful impact.

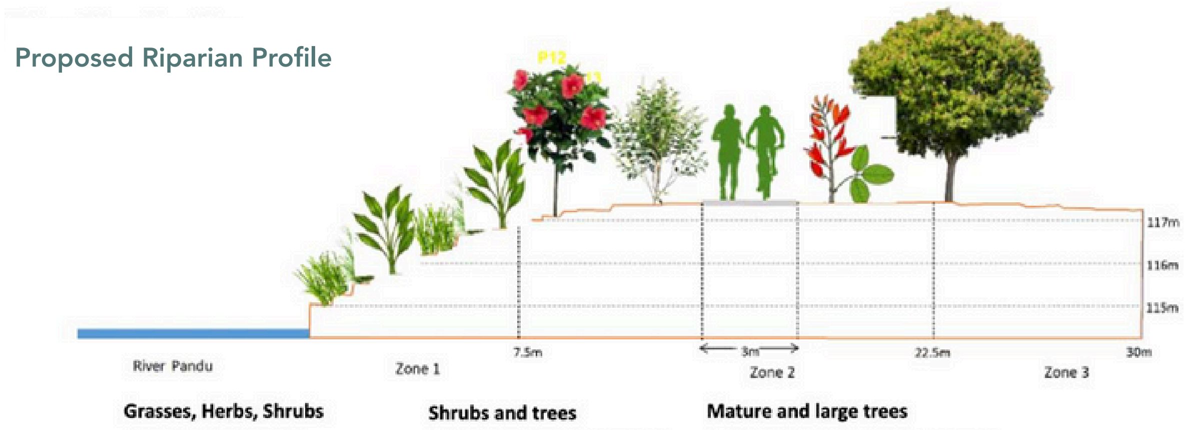
In many locations, drains have been either concretised or encroached upon, severely limiting the potential for further widening. Therefore, it is essential to identify and prioritise stretches that remain relatively natural and free from encroachments. These segments present the greatest opportunity for effective restoration through desilting, deepening, and widening, aligned with the dimensions outlined in CDP.

Drain restoration efforts must focus on reclaiming the natural flow corridors, ensuring unobstructed water movement, and enhancing the overall capacity and resilience of Bhubaneswar’s stormwater drainage network.

4.2.2. Provision of Riparian Edge

Another important aspect of drain restoration is the provision of green edges along the drains wherever feasible. Riparian buffers serve multiple ecological and hydrological functions, including reducing soil erosion, filtering pollutants, improving the microclimate, and slowing the velocity of surface runoff entering the drains.

It is proposed to establish riparian buffers along major natural drains throughout the city, with widths varying based on land availability and the width of the drain. Depending on the specific context and intended function, the buffer width can range from 1 metre to 30 metres. These green edges will not only enhance the environmental quality of the drainage corridors but also contribute to flood mitigation and urban resilience.



Species that are native to the Bhubaneswar region and can be used for creating the riparian buffer are provided below;

- **Mango**: Mangifera indica
- **Neem**: Azadirachta indica
- **Banyan**: Ficus benghalensis
- **Peepal**: Ficus religiosa
- **Gulmohar**: Delonix regia
- **Ashoka**: Saraca asoca
- **Kadamba**: Neolamarckia cadamba
- **Mahua**: Madhuca longifolia
- **Teak**: Tectona grandis
- **Jamun**: Syzygium cumini
- **Other native species include:** Vetiver, Karanja, Chhatiana, and Bahada (Terminalia bellerica).

As per the assessments carried out during site visits and secondary data collection, 14 drains have been prioritised for renaturalisation and redevelopment in priority 1, 2 and 3. The factors contributing to this prioritisation are existing conditions in terms of lining of drains, flooding hotspots, available space, and land use along the drains.

Table 4: List of natural drains prioritised for renaturalisation and redevelopment

Drain	Place of Origin	Length of Drain (km)	Width of Drain as per CDP (m)	Available Width of Drain (m)
1	Chandaka Sanctuary	5.7	14.3	3.5-9
1B	Chandaka Industrial Estate Infocity	2	4	1.8-4
1C	Omfed Square Chandrasekharpur	2	4	3-4
2	Dhirikuti Basti	0.85	4.9	3-5
3	OSAP Battalion, Kalinga Hospital Square	4.226	9	2-8
4	Ekamra Kanan	7.5	9.2	2.5-9
5	Gurudwara Janpath Road	3.542	5	2.5-5
6	Arya Palace Hotel Janpath	3.112	6.5	3-4
7	Culvert near LIC Staff Quarter Surya Nagar	5.454	7.6	3-5
8	Damapada Sanctuary	5.362	9	6-9
8A	CRPF Campus	3	4.5-6	2.5-4.5
9	CET College	15.5	14.83	4.5-9.5
10	Nayapalli Haja	7.375	10	4-6
11	Sampur	7.68		6-8

Priority 1
Priority 2
Priority 3

Case Example

Redevelopment of Drain No. 9

Existing condition of the drain 9

- Length of drain - 15.5 km
- Width of the drain as per CDP – 14.83 m
- Available width - 4.5 to 9.5 m

The restoration of Drain 9 is expected to significantly improve its carrying capacity and help reduce flooding in the surrounding areas. It is recommended that the drain be widened in accordance with the dimensions specified in the City Development Plan (CDP). Additionally, the provision of a riparian buffer along its edges is proposed to enhance ecological and hydrological functions.

The proposed cross-section of the drain—reflecting the widened channel and integrated riparian buffer—is illustrated below:

The width of the drain has been increased from 9 meters to 12 meters, including a 2-meter riparian buffer along the edge to stabilize the banks and prevent future encroachments. The impact of the drain restoration and the provision of the riparian buffer was assessed by analyzing the changes in the flow capacity of the drain, as well as the reduction in flow velocity.

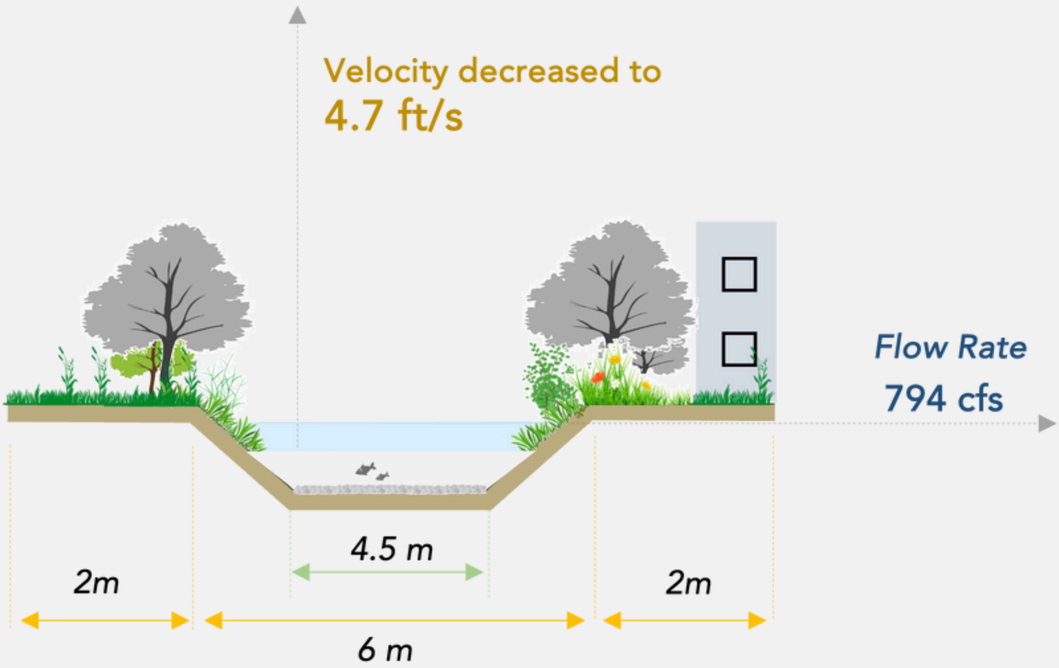
Proposed drain redevelopment

Scenario with limited space along the drain

If the drain width is increased to 10m

Flow rate increases to 794 cfs

Velocity decreases to 4.7 ft/s



Similarly, the restoration and optimization of other drains throughout the city can be leveraged to reduce waterlogging and flooding in the areas through which these drains pass.

4.3. Reimagining Green, Blue and Open Spaces: Groundwater Recharge and Flood Reduction

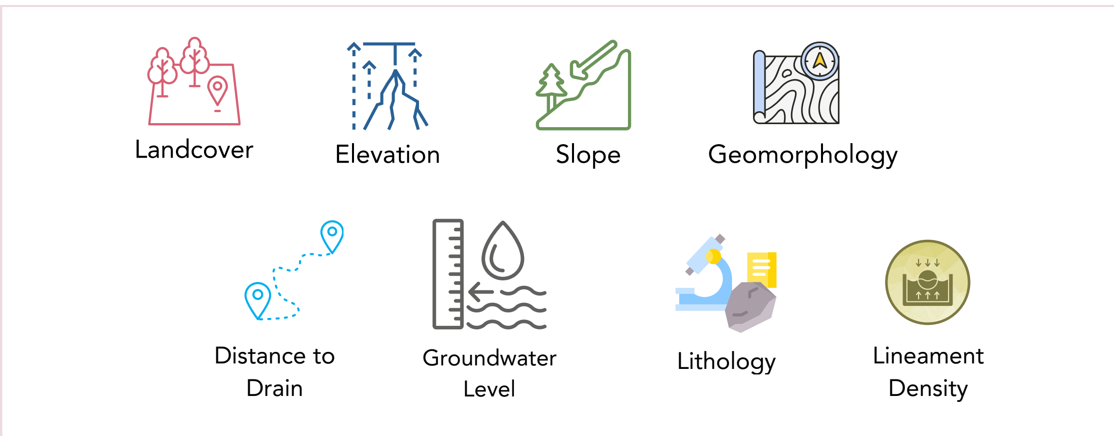
Open spaces serve multiple functions within a city. The concept is to redevelop existing open spaces, both public and private, to fulfil additional roles within neighborhoods. As 'green sponges,' these spaces have the potential to hold rainwater during rainy periods, preventing runoff from streets and other surfaces. By retaining water, these spaces allow it to percolate into the ground, rather than running off and flooding low-lying areas.

When water is retained in these open spaces, activated parks contribute to a range of secondary benefits, including reducing the urban heat island effect, improving local microclimates, enhancing air quality, maintaining green spaces, promoting groundwater recharge, and raising awareness about blue-green infrastructure as a sustainable measure at the neighborhood level.

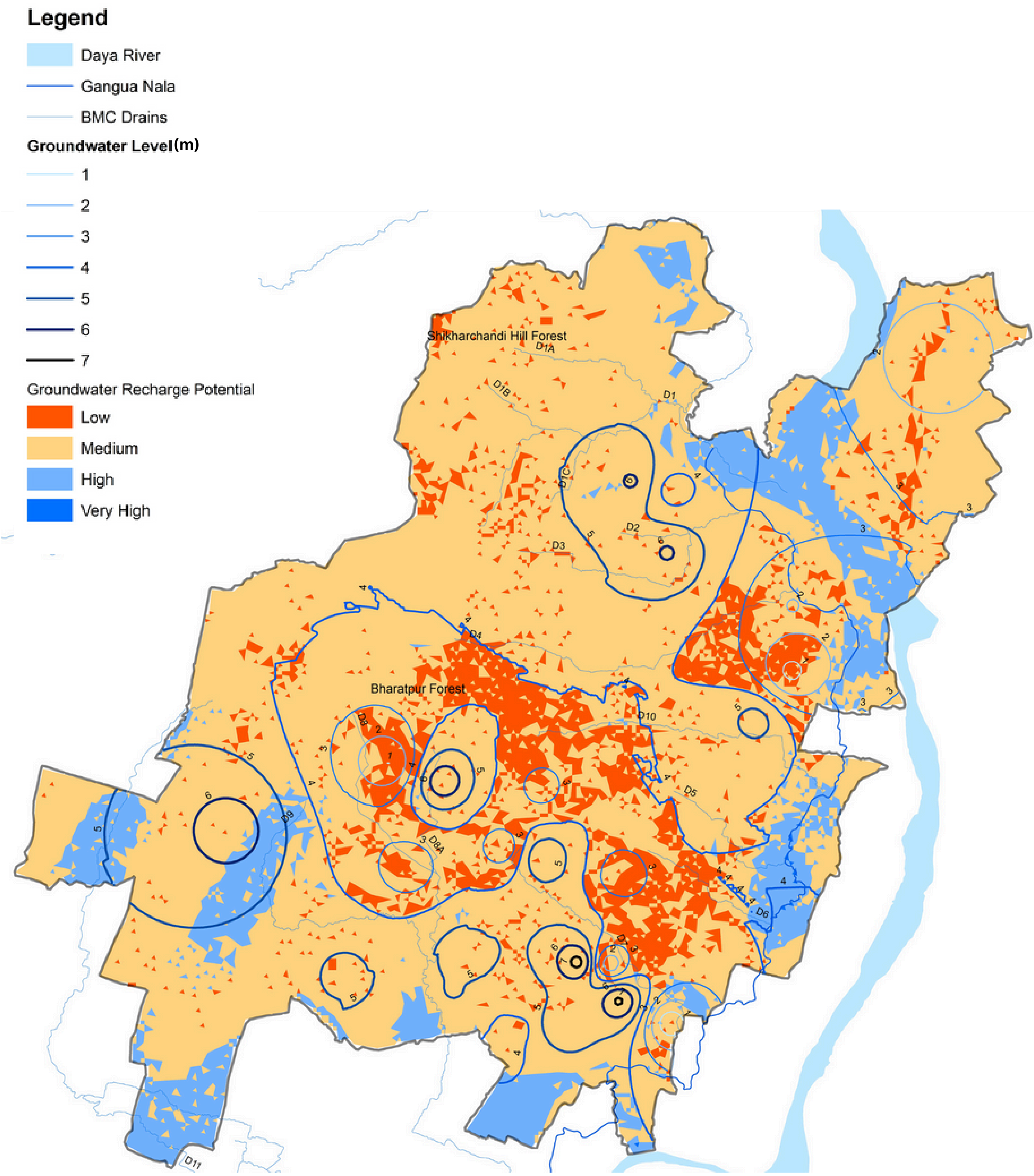
Over the years, built-up areas in Bhubaneswar have increased by 44.77%, while other land categories such as cropland and vegetation have experienced a decline. This shift in land use and land cover has hindered rainwater percolation into the ground, increasing runoff and contributing to urban flooding.

Bhubaneswar, with the highest groundwater utilization rate of 86.60% in the state, has been categorized as "semi-critical" according to the Central Ground Water Board (CGWB) report. Groundwater development in the city is carried out through open/dug wells, shallow and deep bore wells, as well as shallow and filter point tube wells. The Public Health Engineering Department (PHED), Government of Odisha, is the primary agency responsible for groundwater extraction for domestic water supply. In addition, many residential complexes, such as flats and individual homes, also rely on groundwater in areas without access to PHED's piped water supply. 42 MLD water is supplied from Groundwater which is almost 17% of the total daily water supply (Source- Odisha PHED). Unaccounted extraction using borewells, handpumps etc. also adds to the stress.

To assess the ground conditions and identify potential locations for groundwater recharge, a detailed GIS-based Analytical Hierarchy Process (AHP) was employed. The analysis incorporated the following parameters (methodology detailed in Annexure 2).



The map 12 below represents the potential groundwater recharge areas in the city along with the existing groundwater levels.



Map 12: Groundwater potential area vis-a-vis groundwater levels (in m)

Map 12 was overlaid with the existing land cover map to identify open spaces, parks, and gardens that can be leveraged for groundwater recharge *(Refer to map 13 on page no. 44)*. Bhubaneswar's building bye-laws mandate the installation of rainwater harvesting (RWH) systems, particularly for buildings constructed on plots of 300 sq.m. or more. These regulations require appropriate infrastructure for the collection, conveyance, and recharge/storage of rainwater, especially in group housing, institutional, and commercial developments. Despite these provisions, implementation remains inconsistent due to a lack of awareness, enforcement, and technical capacity.

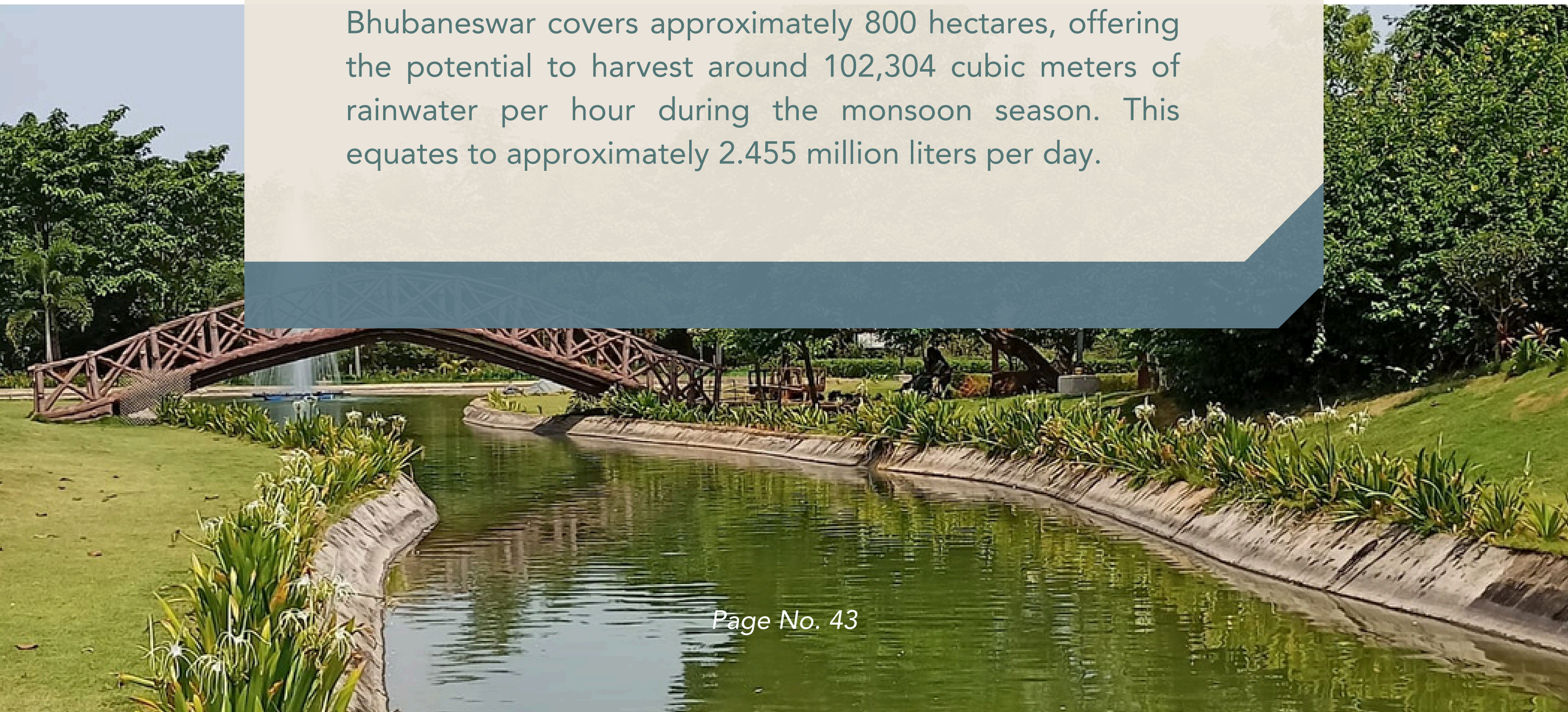
The CHHATA Mission (Community Harnessing and Harvesting Rainwater Artificially from Terrace to Aquifer), launched by the Government of Odisha, provides a significant opportunity to strengthen RWH adoption. The scheme offers up to a 75% subsidy (up to ₹45,000) for rooftop RWH systems in urban households and public institutions, aiming to improve groundwater recharge and water security.

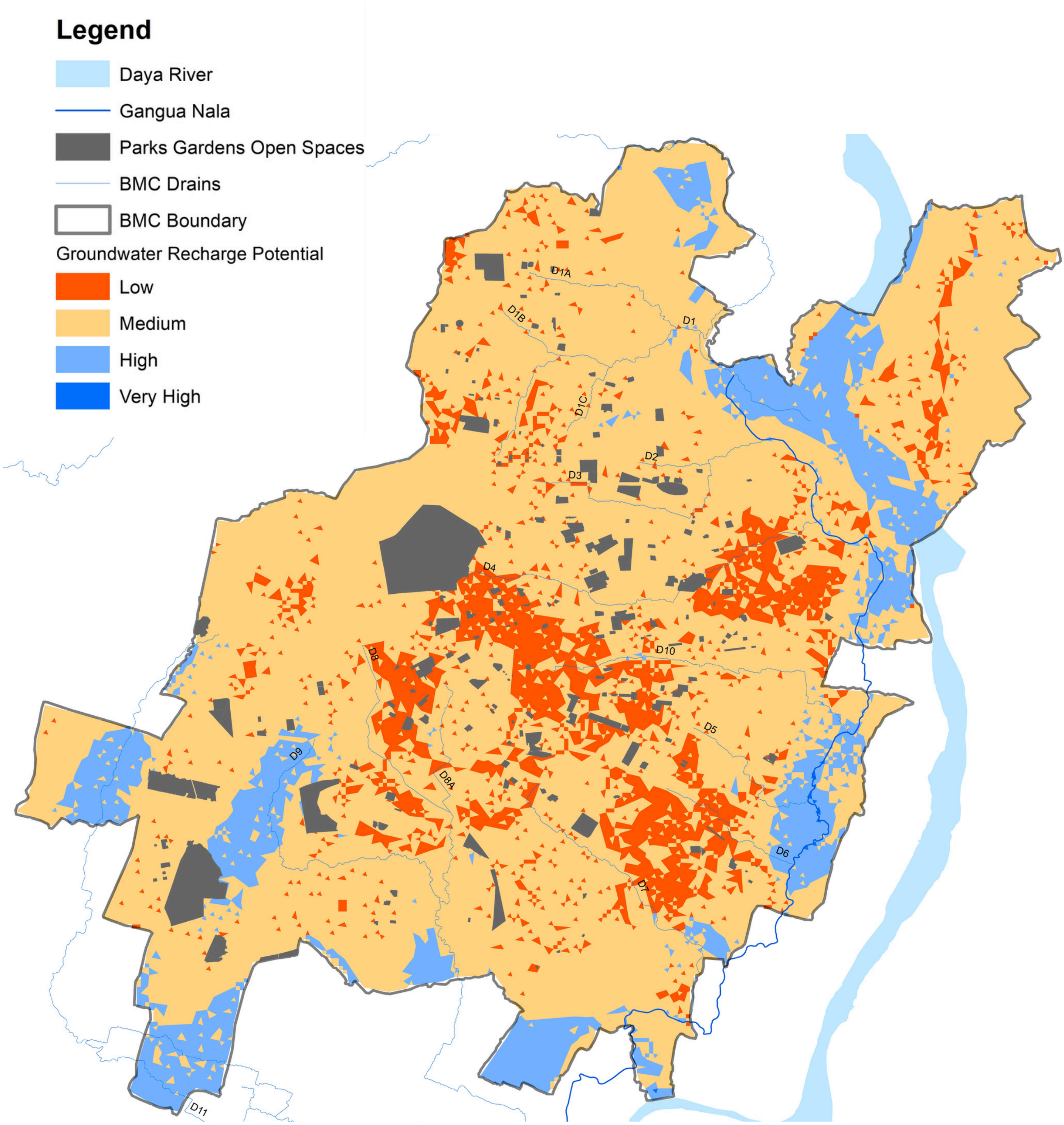
To fully capitalize on the CHHATA scheme, Bhubaneswar can adopt a strategy of retrofitting public buildings with model RWH systems, mapping RWH potential in water-stressed and flood-prone wards, and integrating RWH into the planning of parks and green open spaces.

Groundwater recharge in open spaces, parks, and gardens is a "low-hanging fruit" for BMC, as these spaces already serve multiple functions. Creating neighborhood parks that unlock the potential of small-scale open spaces, as well as activating underutilized green spaces in neighborhoods for various purposes (e.g., parks, sports grounds, community gardens, arboretums), can help reduce runoff at the neighborhood level while contributing to groundwater recharge.

Additionally, the city should promote awareness campaigns in local languages, engage Resident Welfare Associations (RWAs) and Self-Help Groups (SHGs) for decentralized implementation, and introduce monitoring mechanisms, such as property tax-linked audits or an online dashboard.

The total area of parks, gardens, and open spaces in Bhubaneswar covers approximately 800 hectares, offering the potential to harvest around 102,304 cubic meters of rainwater per hour during the monsoon season. This equates to approximately 2.455 million liters per day.





Map 13: Groundwater potential area overlaid with green spaces in Bhubaneswar

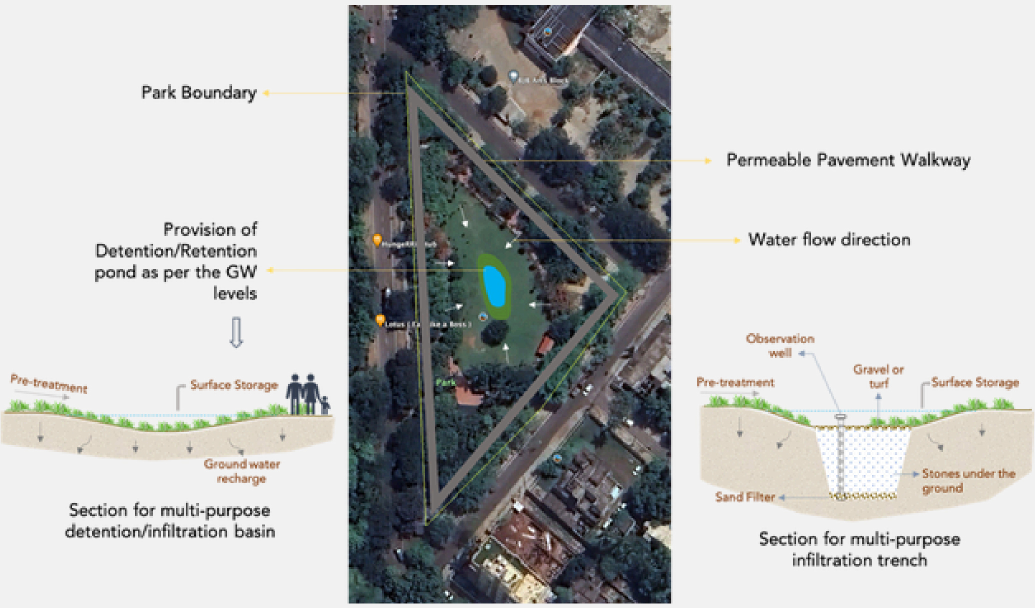
Case Example
Re-imagining the BRJ Park, Bhubaneswar

BRJ Park is centrally located in Bhubaneswar, close to the Bhubaneswar airport. Previously known as the Forest Park, it is a popular spot among locals, particularly in the mornings.

Area of the Park: 52,000 sqm

The park's area presents an opportunity to divert surrounding runoff, which could help reduce the pressure on the existing stormwater drainage system in the area.

The graphic below illustrates how the park can be leveraged as a "sponge" to absorb rainfall within the surrounding catchment area.



4.3.1 Restoration and Rejuvenation of Waterbodies and Wetlands

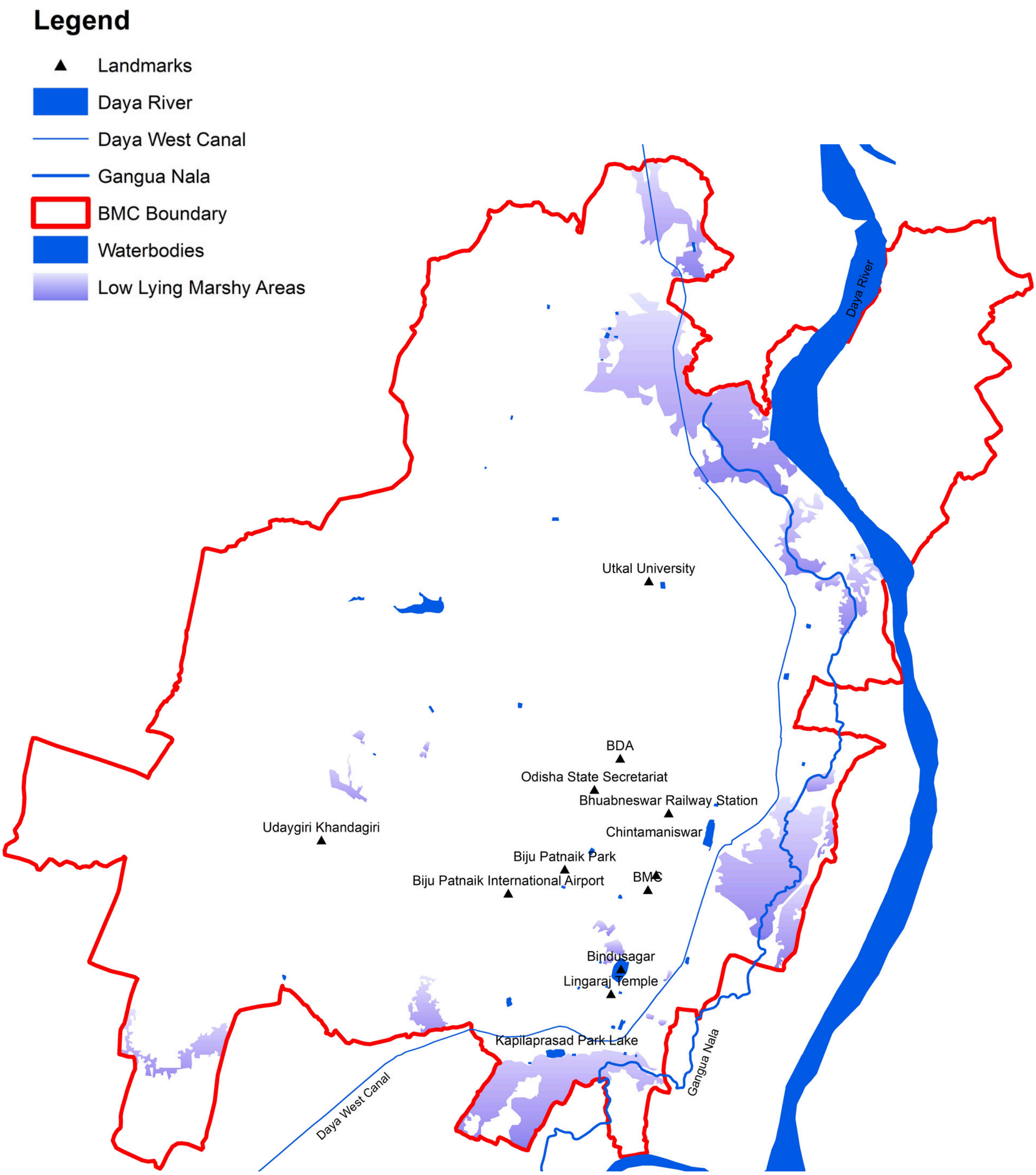
Bhubaneswar is home to numerous waterbodies, wetlands, a canal system, marshes, riparian buffers, and natural drains, many of which are under threat due to rapid urbanization, encroachments, and pollution. Notable waterbodies such as Bindusagar, Gautamnagar Wetland, and Sampriti Vihar Lake have historically functioned as natural sponges, absorbing excess rainfall, recharging groundwater, and regulating stormwater flow. However, unchecked urban growth has significantly reduced the city's permeable surfaces, resulting in increased surface runoff and severe waterlogging.

The restoration and rejuvenation of these ecosystems are essential for flood mitigation. Revitalized waterbodies can slow down stormwater flows, reduce peak discharge, and enhance infiltration, which would alleviate the strain on the city’s already overwhelmed drainage infrastructure. The existing waterbodies within the city limits were mapped using both secondary and primary data. The total area of waterbodies, including lakes and ponds, is approximately 0.605 square kilometres, while the area of marshland is about 170 square kilometres.

A site visit was conducted across several key waterbodies, including marshlands and canals. Most of these waterbodies were heavily polluted, clogged with solid waste, and extensively covered by invasive water hyacinth. The unchecked spread of these aquatic weeds, coupled with high pollution loads from untreated wastewater and runoff, has significantly reduced the holding and percolation capacity of these waterbodies. In many instances, natural inflow and outflow channels were either blocked or altered, further exacerbating the issue. These conditions not only undermine the role of waterbodies in flood mitigation but also present serious environmental and public health risks.

Waterbody covered with water hyacinth due to increased pollution load

Canal filled with sewage and water hyacinth



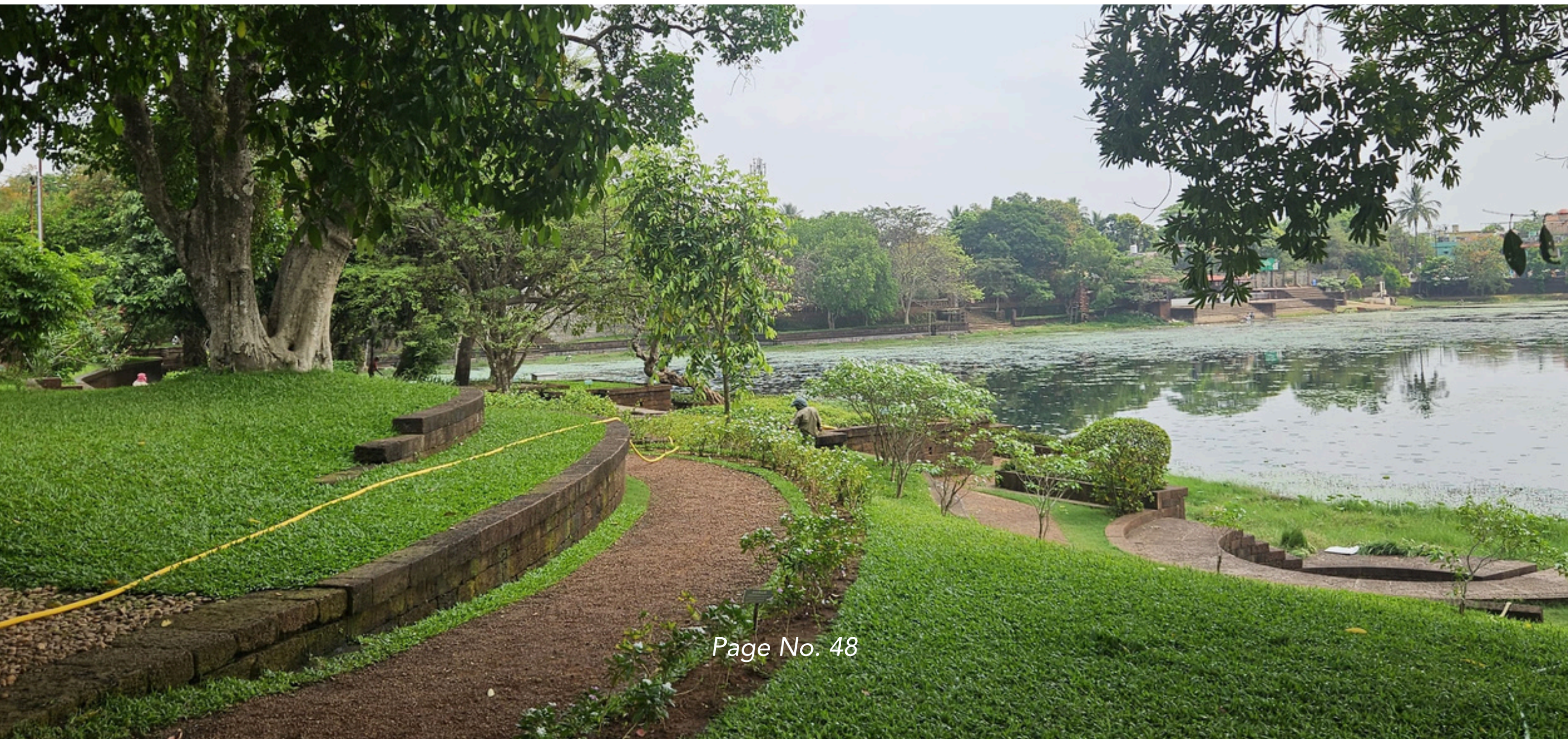
Map 14: Existing waterbodies and marshland in Bhubaneswar

Currently, Bhubaneswar lacks a comprehensive and structured database on its waterbodies, one that captures crucial information such as physical condition, water quality, biodiversity, community engagement, and usage patterns. As an essential first step, the city must establish a robust inventory system focusing on four key dimensions:

- **Physical Dimension:** This assesses the morphological and structural characteristics of each waterbody.
- **Water Quality Dimension**: This evaluates critical parameters such as BOD, COD, DO, and turbidity.
- **Quantity Dimension**: This measures the water-holding and recharge capacity of the waterbody.
- **Management Dimension**: This documents existing governance structures, maintenance practices, and institutional responsibilities related to waterbody upkeep.

This analysis will help the city strategically prioritize waterbodies for restoration based on their condition and importance. Once priority sites are identified, their restoration can be integrated into ongoing initiatives, such as the MUKTA mission. For instance, under the MUKTA mission, a 900-meter stretch of Drain No. 10 was rejuvenated with eco-sensitive landscaping and riparian edges. This not only reduced local flooding but also created recreational and livelihood opportunities.

To effectively rejuvenate waterbodies and reduce urban flooding in Bhubaneswar, a holistic approach addressing multiple factors is essential. First, protecting the catchment area is crucial to prevent encroachments and maintain natural inflow paths. Rejuvenation efforts should include desilting and restoring the original holding capacity of the waterbody to ensure it can absorb and store excess rainwater during heavy rainfall events. Proper management of inlet and outlet structures is also necessary to regulate water flow, prevent blockages, and avoid backflow from drains or sewers. Improving water quality by diverting sewage, using decentralized wastewater treatment, and employing in-situ purification methods such as floating wetlands will enhance the ecological health of the waterbody. Additionally, developing a riparian buffer or green edge using native vegetation helps absorb surface runoff, stabilize banks, and slow down water flow, thereby contributing to flood mitigation.



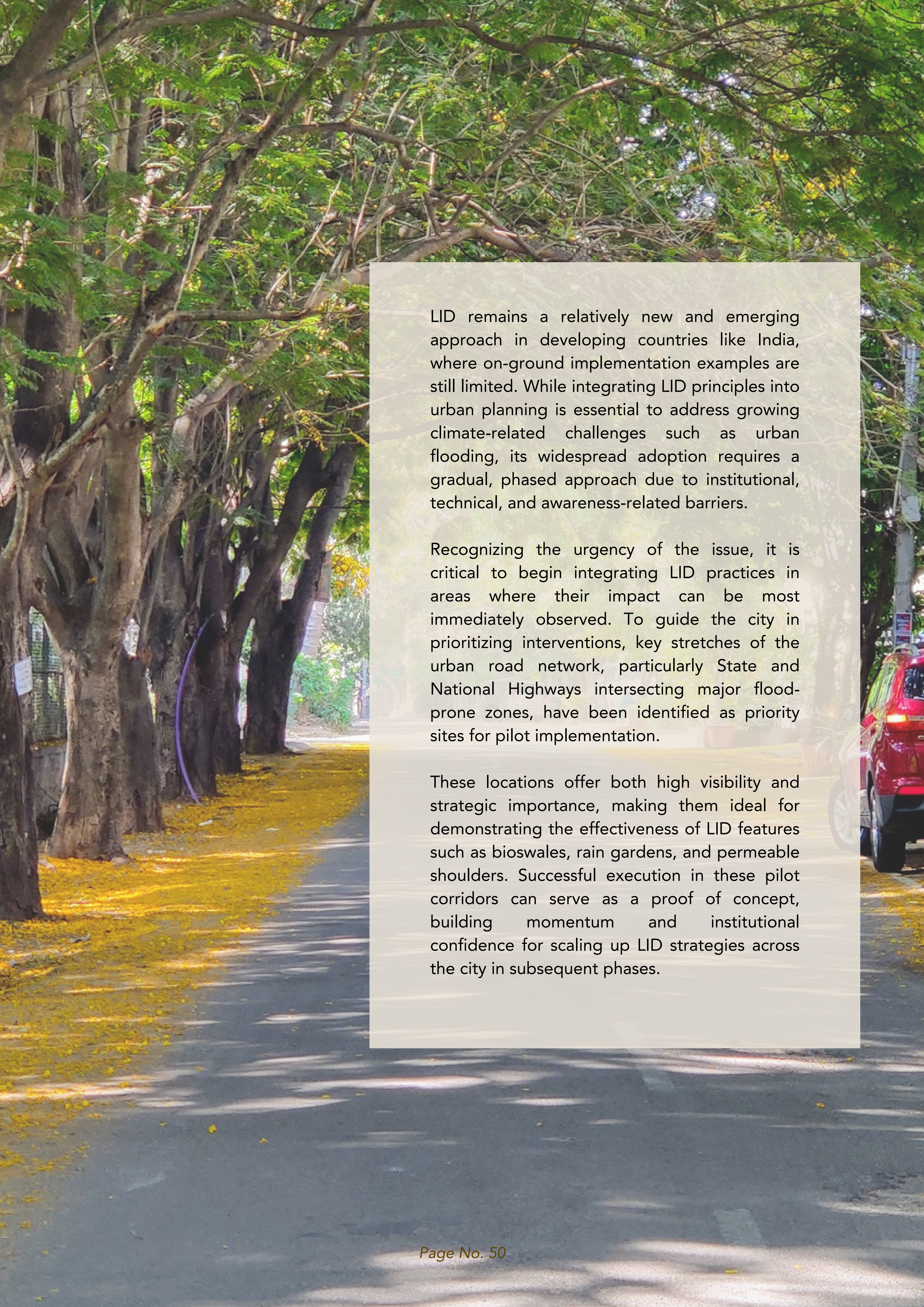
4.4. Towards Low Intensity Development

As urban centers like Bhubaneswar face increasing risks from climate change, particularly erratic and high-intensity rainfall events, Low-Impact Development (LID) emerges as a critical strategy for enhancing urban resilience. LID focuses on limiting impervious surface coverage, regulating development densities, and aligning built forms with the land's natural drainage contours. By dispersing development and minimizing hardscaping, LID reduces the volume and speed of stormwater runoff, easing the burden on city infrastructure and lowering the risk of urban flooding. To effectively adapt to urban flooding, it is essential to integrate LID principles into city zoning and land use regulations, particularly for new developments, peri-urban areas, and redevelopment zones.

A core component of LID involves the integration of nature-based solutions like swales, rain gardens, and permeable pavements, which offer practical ways to manage urban stormwater at its source. For instance:

- **Swales:** These shallow, vegetated channels are designed to slow down runoff along roads and open spaces, allowing water to infiltrate gradually into the ground.
- **Rain Gardens:** Shallow landscaped depressions planted with native vegetation, rain gardens act as micro-catchments, capturing and filtering stormwater from rooftops, sidewalks, and streets, thus reducing the volume and speed of runoff entering the drainage system.
- **Permeable Pavements:** Used in parking areas, pedestrian paths, and low-traffic roads, permeable pavements allow rainwater to seep through their surface, preventing waterlogging and contributing to groundwater recharge.

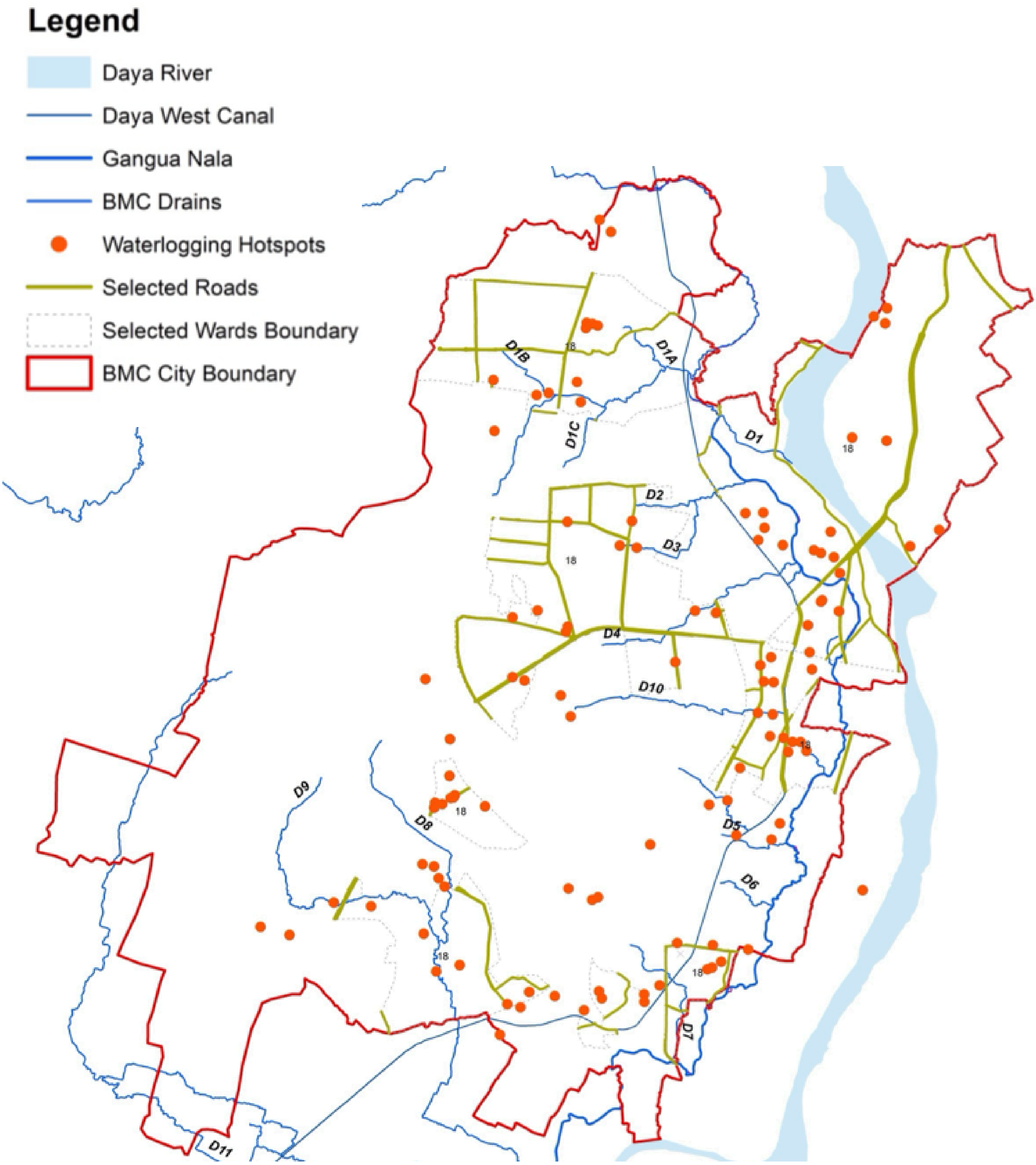
Together, these strategies decentralize stormwater management, reduce pressure on conventional drainage infrastructure, and play a vital role in minimizing urban flood risks. Additionally, they enhance the city's resilience to climate change by improving water management and promoting sustainable development practices.



LID remains a relatively new and emerging approach in developing countries like India, where on-ground implementation examples are still limited. While integrating LID principles into urban planning is essential to address growing climate-related challenges such as urban flooding, its widespread adoption requires a gradual, phased approach due to institutional, technical, and awareness-related barriers.

Recognizing the urgency of the issue, it is critical to begin integrating LID practices in areas where their impact can be most immediately observed. To guide the city in prioritizing interventions, key stretches of the urban road network, particularly State and National Highways intersecting major flood-prone zones, have been identified as priority sites for pilot implementation.

These locations offer both high visibility and strategic importance, making them ideal for demonstrating the effectiveness of LID features such as bioswales, rain gardens, and permeable shoulders. Successful execution in these pilot corridors can serve as a proof of concept, building momentum and institutional confidence for scaling up LID strategies across the city in subsequent phases.



Map 15: Major roads passing through city overlaid with flooding hotspots

Case Example - Rain Garden

- Total Road Network length in City = 2497km
- Prioritised Road length = 250 km (40,19,029 sqft)
- Unit Size – 10ft x 4.9ft (Area – 49sqft)
- Water holding capacity = 21,325.46 cubic meters /rainfall event

Case Example - Swales

- **Taking prioritised road length =** 250 km (Taking a minimum width of 1m and depth of .5 to develop swales)
- **Runoff Volume:** The total runoff volume generated by the catchment is 1,821,575 cubic meters
- **Swale Retention Capacity:** The swale system's total retention capacity is 50,000 cubic meters

The swales designed along the 250 km road with the given dimensions (1 m width and 0.5 m depth) can only retain a small fraction of the total runoff volume. Additional measures, such as increasing swale dimensions, adding infiltration zones, or reducing runoff volume with permeable surfaces, are needed to manage the excess water effectively.

Swales along the road in Delhi

Green roofs are another promising yet underutilized component of LID in India, where their application is still at a nascent stage, primarily limited to isolated demonstration projects. Despite their proven benefits in mitigating urban heat, managing stormwater runoff, and enhancing building energy efficiency, the widespread adoption of green roofs faces challenges related to cost, design awareness, structural feasibility, and policy support. However, with increasing urban densification and climate vulnerabilities such as intense rainfall and heatwaves, green roofs present a timely and necessary solution for sustainable urban growth.

To enable a gradual and scalable transition, it is essential to identify and target strategic zones for pilot implementation. Public and institutional buildings, such as government offices, educational institutions, hospitals, and transit hubs, offer ideal opportunities due to their large roof areas and public visibility.

Case Example - Green Roofs

Green roofs are areas of living vegetation installed on top of buildings for a range of reasons including visual amenity, enhanced building performance and the reduction of surface water runoff. In the summer a green roof can typically retain between 70%-80% of the run-off


Green roof project in Pune

Estimating runoff reduction for provision of green roof on 200 Hac of built-up area (10% of total Built-up area) - 25% reduction in runoff

- 25,640 cubic meter/hr from 1,02,560 cubic meter/hr

Bhubaneswar has made significant strides in promoting non-motorized transport, with the development of a dedicated cycle track network as part of its Smart City Mission. The city's Bhubaneswar Smart Streets initiative introduced over 15 km of integrated cycle tracks, especially along key corridors like Janpath, Sachivalaya Marg, and around major public institutions and markets. These cycle tracks are well-marked, often shaded, and integrated with footpaths, aiming to create a safe and green mobility experience.

Existing cycle track in the city

This expanding network presents a great opportunity to support urban flood mitigation by incorporating pervious pavements. Unlike traditional impervious materials, pervious pavements allow rainwater to seep through and recharge the ground, reducing surface runoff and pressure on stormwater drains. By retrofitting existing cycle tracks or designing new ones with permeable materials such as porous concrete, interlocking grass pavers, or gravel beds, the city can create linear sponge corridors across the city. These corridors would not only support sustainable mobility but also serve as decentralized stormwater management systems, helping absorb rainwater in flood-prone zones and improve groundwater recharge.

5. Way Forward

Urban flooding in Bhubaneswar city occurs every monsoon, especially in the past few years. Increasing the city's paved surface is further aggravating the conditions. The stormwater drainage division has identified around 80 hotspots, which face severe flooding lasting from a few hours to two days. At several locations, which are low-lying areas, dewatering with diesel pumps is the only way to alleviate urban flooding.

The city of Bhubaneswar is blessed with natural assets like rivers, Natural Drainages, Waterbodies & Wetlands, Open Marsh areas, etc. While the city administration is laying the stormwater drainage network, the natural assets can be leveraged to reduce the short-duration chaos due to urban flooding in multiple areas in the city. The nature-based solutions (NbS) can be integrated with the stormwater drainage network wherever possible to complement it and, to an extent, reduce the cost of infrastructure development.

While physical infrastructure and site-specific nature-based solutions offer effective flood reduction methods, city-scale or neighbourhood-level strategies for long-term impacts are also needed.

5.1. Key Take Aways

- Urban flooding in Bhubaneswar city occurs every monsoon, especially in the past few years. Increasing the city's paved surface is further aggravating the conditions. The stormwater Planning and managing the city's intricate drainage network is critical in reducing urban flooding
- Micro-catchments for each drainage provided in this document should be further detailed with land use and land cover change witnessed, surface run-off estimations, and their ground validation with appropriate methods
- The new City Development Plan (CDP) being prepared by the city administration should provide provisions for drainage buffer areas and redefine the drainage width
- The eco-sensitive zones demarcated in the Master Plan should be reassessed and audited for protection with adequate legal provisions
- Natural assets in the city should be leveraged and reimagined as Blue-Green Infrastructure to reduce short-duration urban flooding
- City's open and green areas can potentially store large volume of stormwater
- The road network of the city provides excellent avenues for implementing swales, rain gardens, etc., which are easy to implement and low-impact development provisions

Annexures

Annexure 1

The following parameters were considered to prepare a composite flood risk map of city to identify hotspot areas and further suggest NbS to address it.

1. Land cover
2. Elevation/DEM
3. Slope
4. Topographic wetness index
5. Distance to the river
6. Ward wise population density
7. Ward wise slum population
8. Road density
9. Drainage density

A composite flood risk map was prepared by integrating the aforementioned parameters related to hazard and vulnerability. Various thematic maps were prepared for the respective parameters using GIS (relevant information used for preparing the maps has been collected from secondary research, satellite imageries, field surveys, as well as information collected from the city officials). The following are details of each parameter considered in preparing the flood risk map of Bhubaneswar city -

- **Land Cover:** Land cover of Bhubaneswar city was classified into six categories (Built-up, Open, Green areas, Waterbody, Floodplain and Marshlands) using IRS LISS III satellite data of 2019 available from the BHUVAN portal of ISRO, Govt. of India. Each category of land cover has different potential to generate runoff (due to different runoff coefficients) and accordingly they are prone to flooding. For example, green spaces are least prone to flood hazards compared to built-up spaces.

- **Elevation**: Low-lying areas are more susceptible to flooding and waterlogging in the cities. The Digital Elevation Model prepared using the CARTOSAT data was used in identifying low-lying areas.

- **Slope**: Slope is an important factor in determining the rate and duration of surface runoff. The speed at which water flows will primarily depend on the slope of the area. Water flows slowly on flatter surfaces and remains stagnant for a longer time, making them more vulnerable to flooding compared to steeper surfaces. The slope (percentage) map was created based on CARTOSAT DEM of 30m resolution available from the BHUVAN portal of ISRO. Areas having low slope values are expected to face prolonged waterlogging and, therefore, are more prone to urban flooding in the city.

- **Topographic Wetness Index (TWI):** This is an indicator of the impact of topography on runoff flow direction and accumulation, which can effectively spatially express the differences in watershed moisture. TWI is the function of slope and the upstream contribution area. TWI indicates the tendency of an area to accumulate water. It is a proxy for soil moisture. Areas having higher TWI vales are more prone to flooding.

$$TWI = ln\frac{upslope\ catchment\ area}{slope\ in\ degrees}$$

- **Distance to river (m):** Proximity to the river increases the chance of an area getting flooded. Areas adjacent to the river are more likely to be inundated in the case of a flooding event. Keeping this in mind, different cities have kept provisions of no development buffers or setback distances from rivers in their Master/Development Plans and Building Bye-Laws/Regulations
- **Ward-wise population density:** Wards having higher population density are more vulnerable in case of a flood disaster, as the evacuation of the people will be challenging. Ward wise population density (persons/sq.km.) was estimated using population data provided by the Bhubaneswar Municipal Corporation
- **Ward-wise slum population percentage:** Wards having a greater number of slums and informal settlements are more vulnerable to flooding events because of the limited coping capacity of slum dwellers to withstand flood disasters
- **Road density:** Road density (length of road networks available per unit area in km/sq.km.) was calculated using the road network data downloaded from the OpenStreetMap (OSM). Areas having higher road density are less vulnerable to flooding events due to the ability of people to evacuate quickly
- **Drainage density:** Drainage density (length of drainage/stream network per unit area) was calculated using the storm water drainage network data provided by the Bhubaneswar Municipal Corporation. The higher the drainage density of an area, the more likely it is to be flooded.

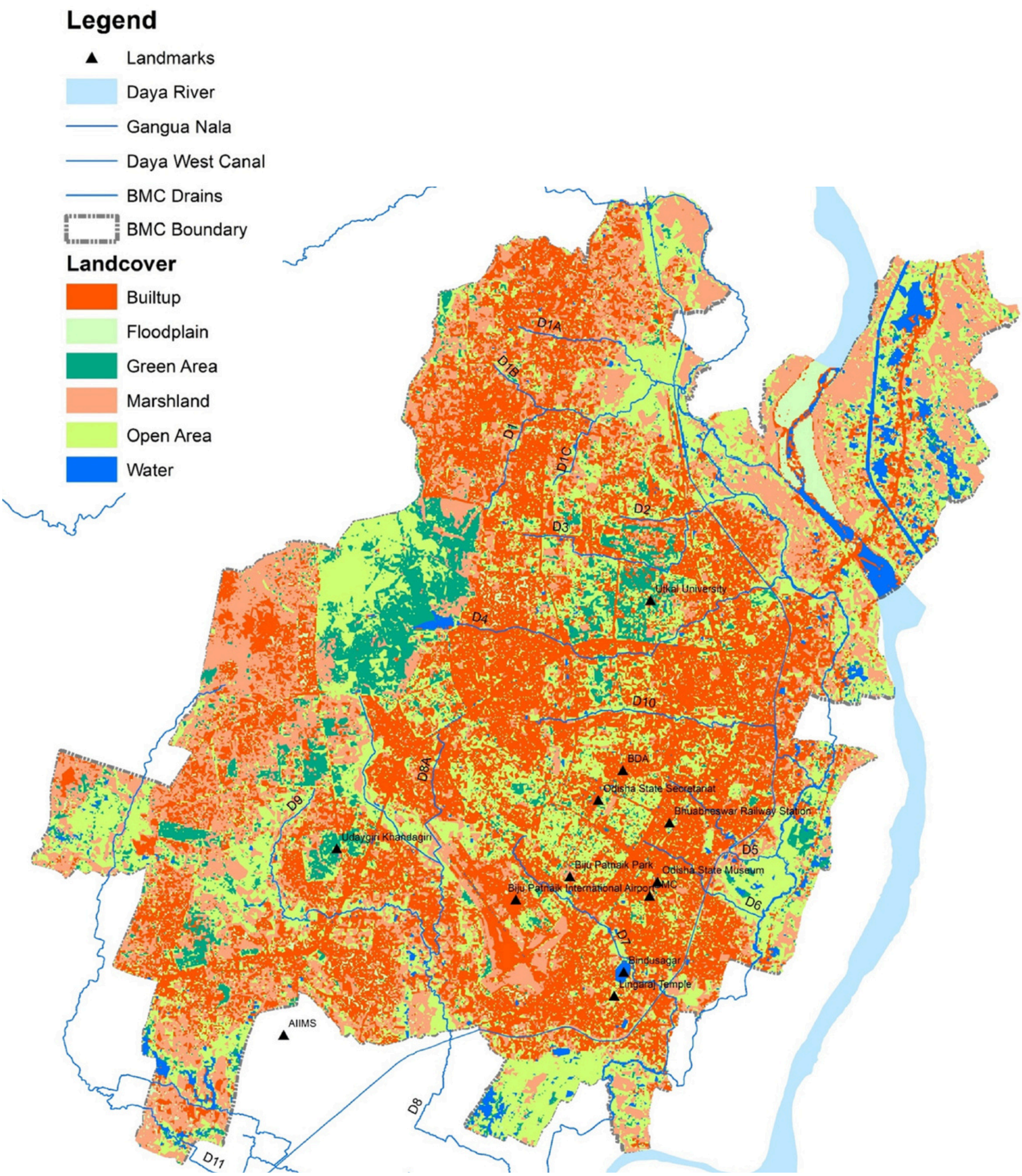
The following are the thematic maps used to prepare a composite flood risk map for Bhubaneswar city. All the parameters were normalized into a scale of 1 to 5 (where 1 signifies low risk and 5 signifies high risk) using raster reclassification in ArcGIS. Composite flood risk was evaluated by incorporating both flood hazard and vulnerability.

GIS based Multi Criteria Decision Analysis (MCDA) and weighted overlay analysis were carried out for preparing composite flood hazard and vulnerability maps (on a scale of 1 to 5). Weightages of different parameters were calculated through the Analytical Hierarchy Process (AHP), and the following formulas were used for calculating composite flood hazard and vulnerability.

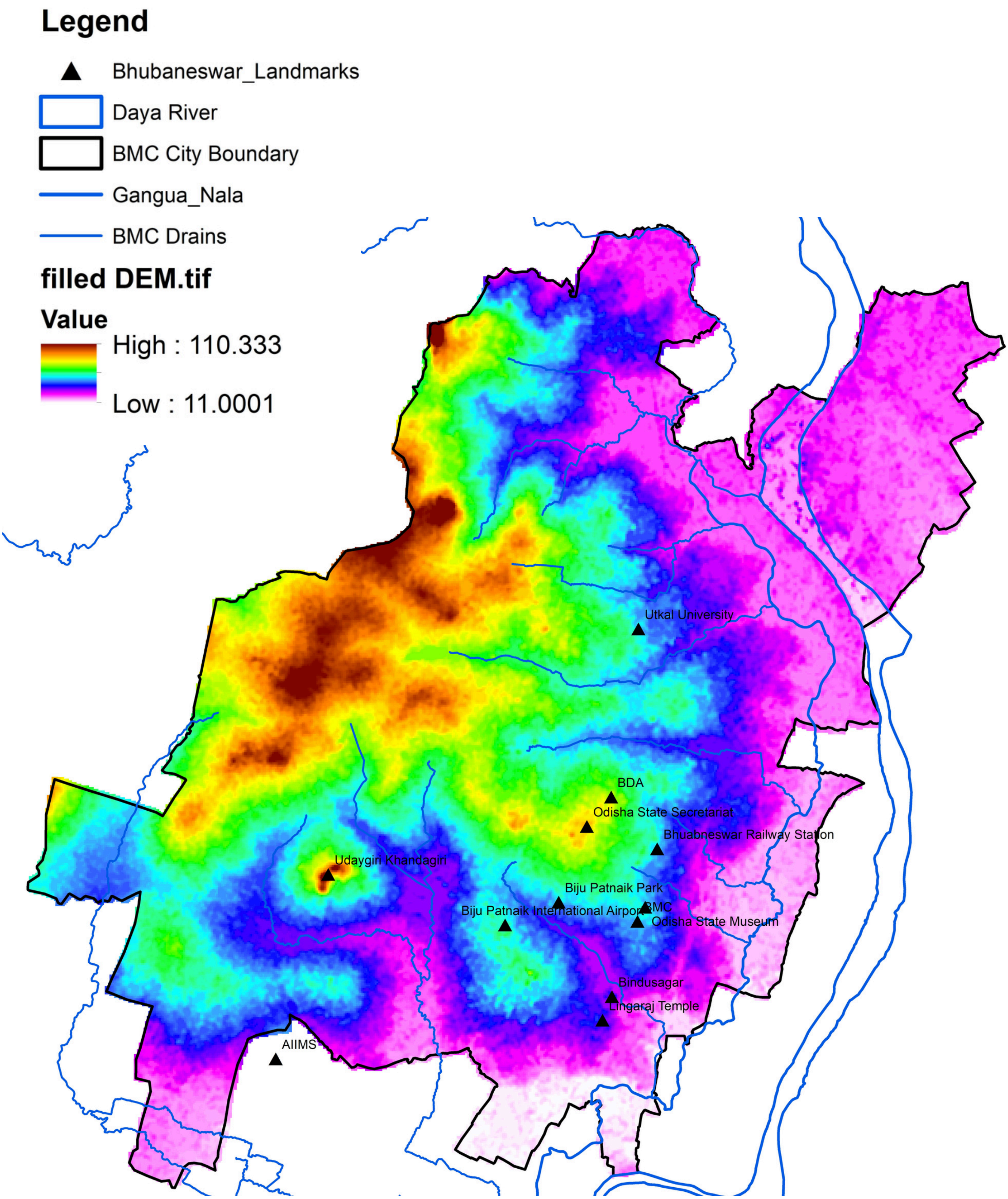
- **Composite Flood Hazard** = (0.35 x Landcover) + (0.27 x Elevation) + (0.14 x Slope) + (0.06 x TWI) + (0.18 x Distance to river)
- **Composite Flood Vulnerability** = (0.52 x Population density) + (0.31 x Slum population) +(0.10 x Road density) + (0.07 x Drainage density)
- **Composite Flood Risk** = Composite Flood Hazard x Composite Flood Vulnerability

Locations of observed flooding hotspots of two consecutive years (2022 and 2023) were collected from the Bhubaneswar Municipal Corporation and were plotted against the flood hazard map generated from the composite weighted overlay analysis, and a good correlation was observed in the observed flood locations and the flood-prone areas highlighted from the analyzed data.

Following maps shows various parameter-based outputs for flood vulnerability analysis.

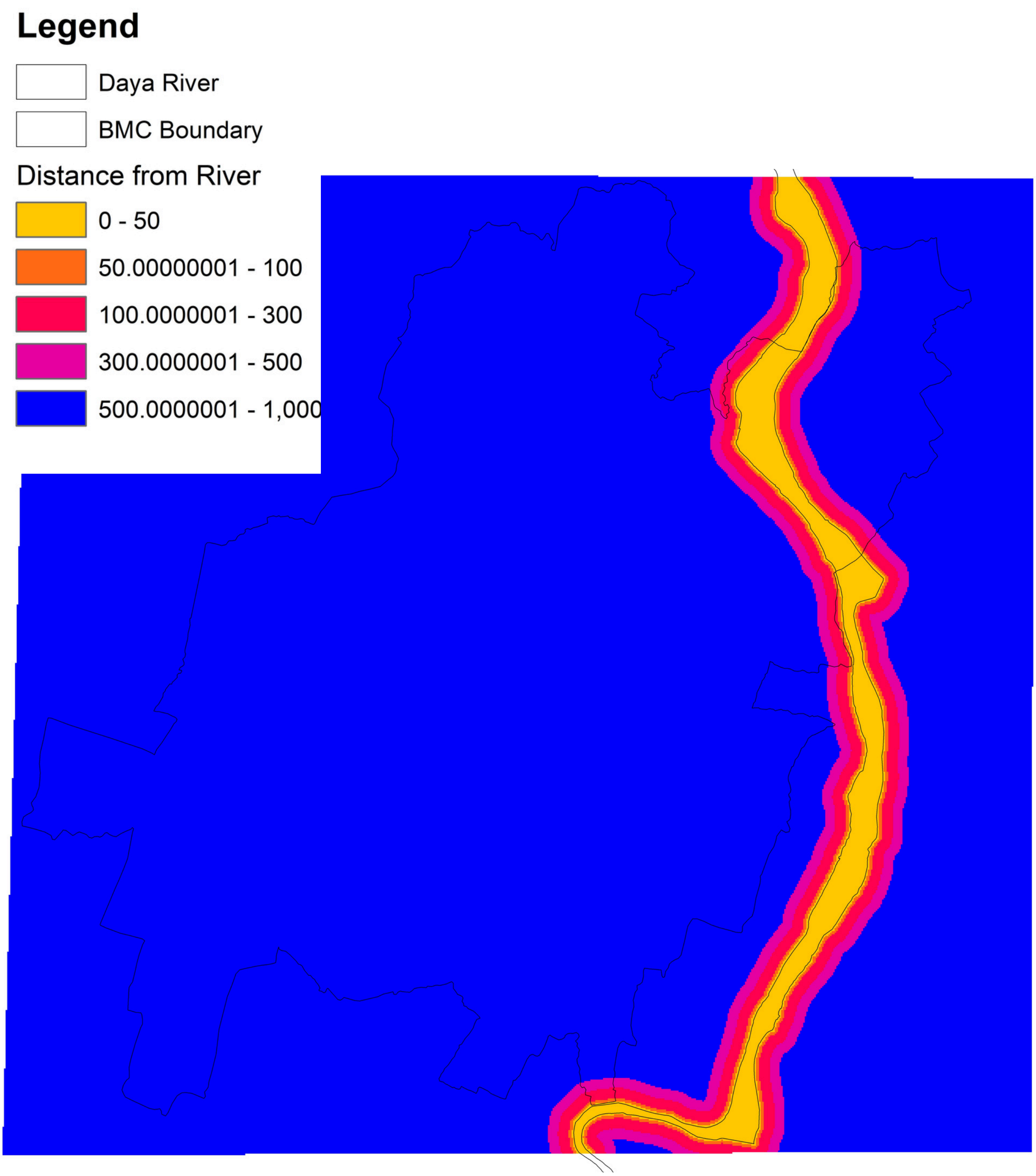


Landcover 2019

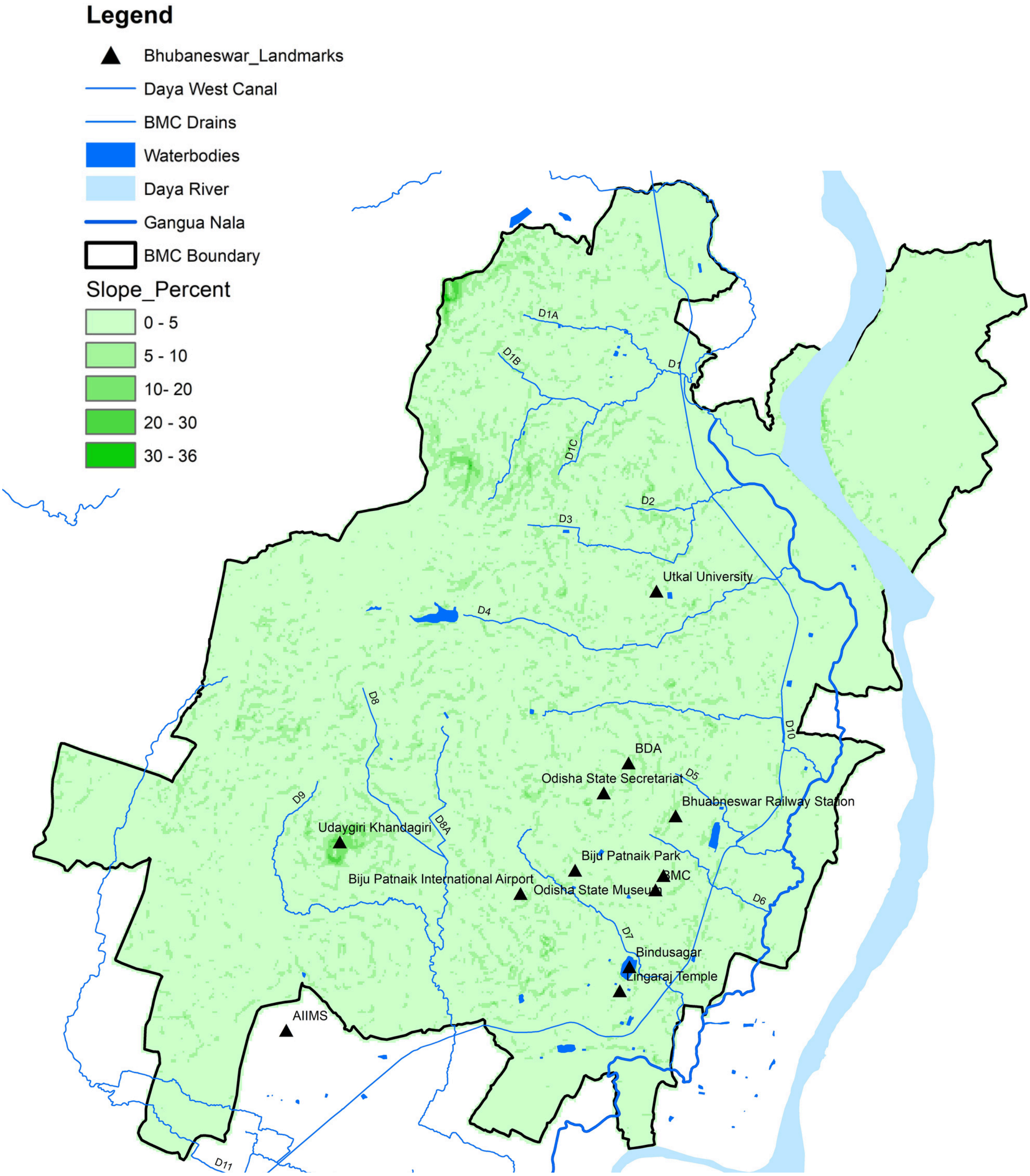


Legend
Bhubaneswar_Landmarks
Daya River
BMC City Boundary
Gangua_Nala
BMC Drains
filled DEM.tif
Value
High : 110.333
Low : 11.0001
Utkal University
BDA
Odisha State Secretariat
Bhuabneswar Railway Station
Udaygiri Khandagiri
Biju Patnaik Park
Biju Patnaik International Airport
BMC
Odisha State Museum
Bindusagar
Lingaraj Temple
AIIMS

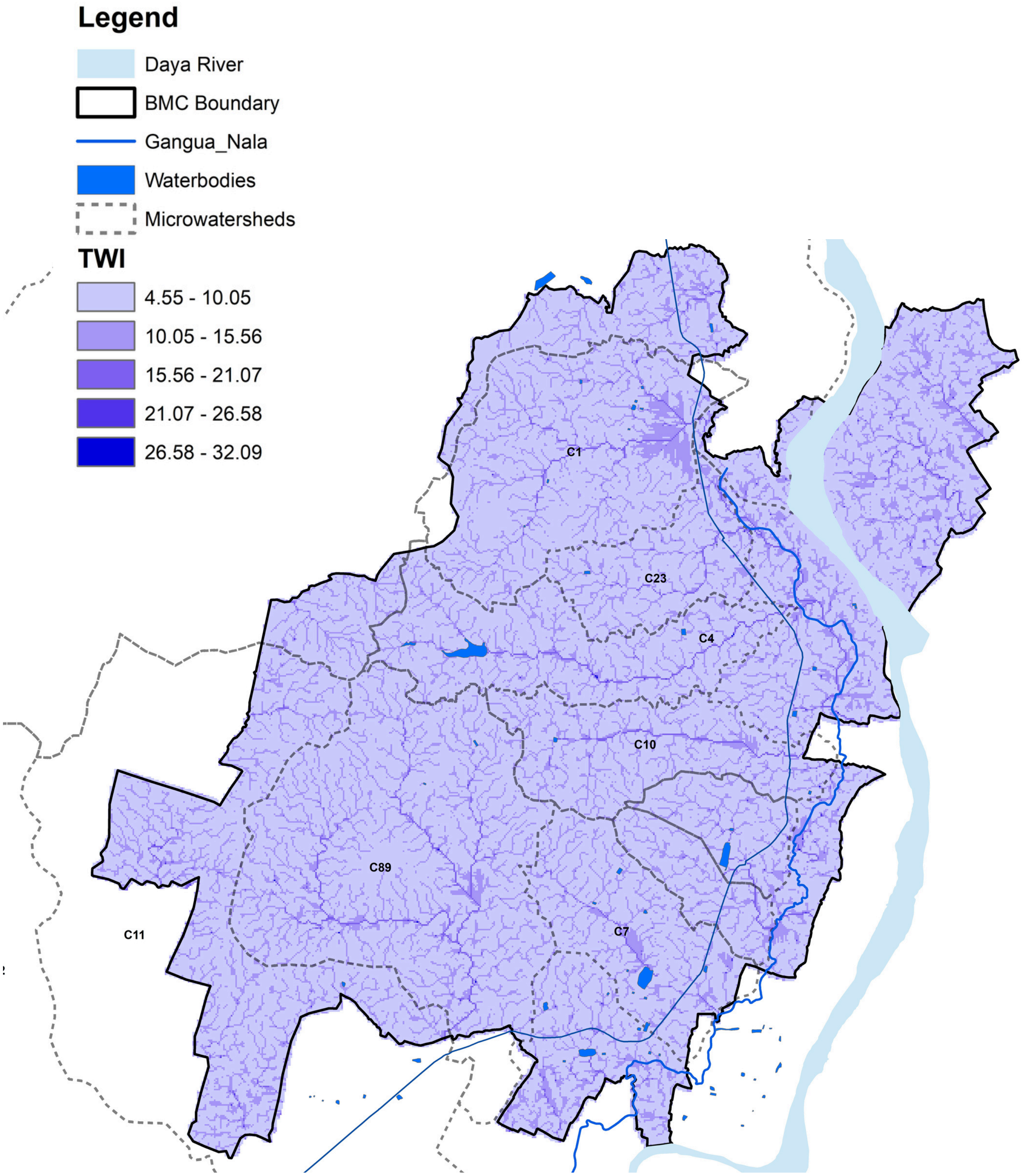
Elevation



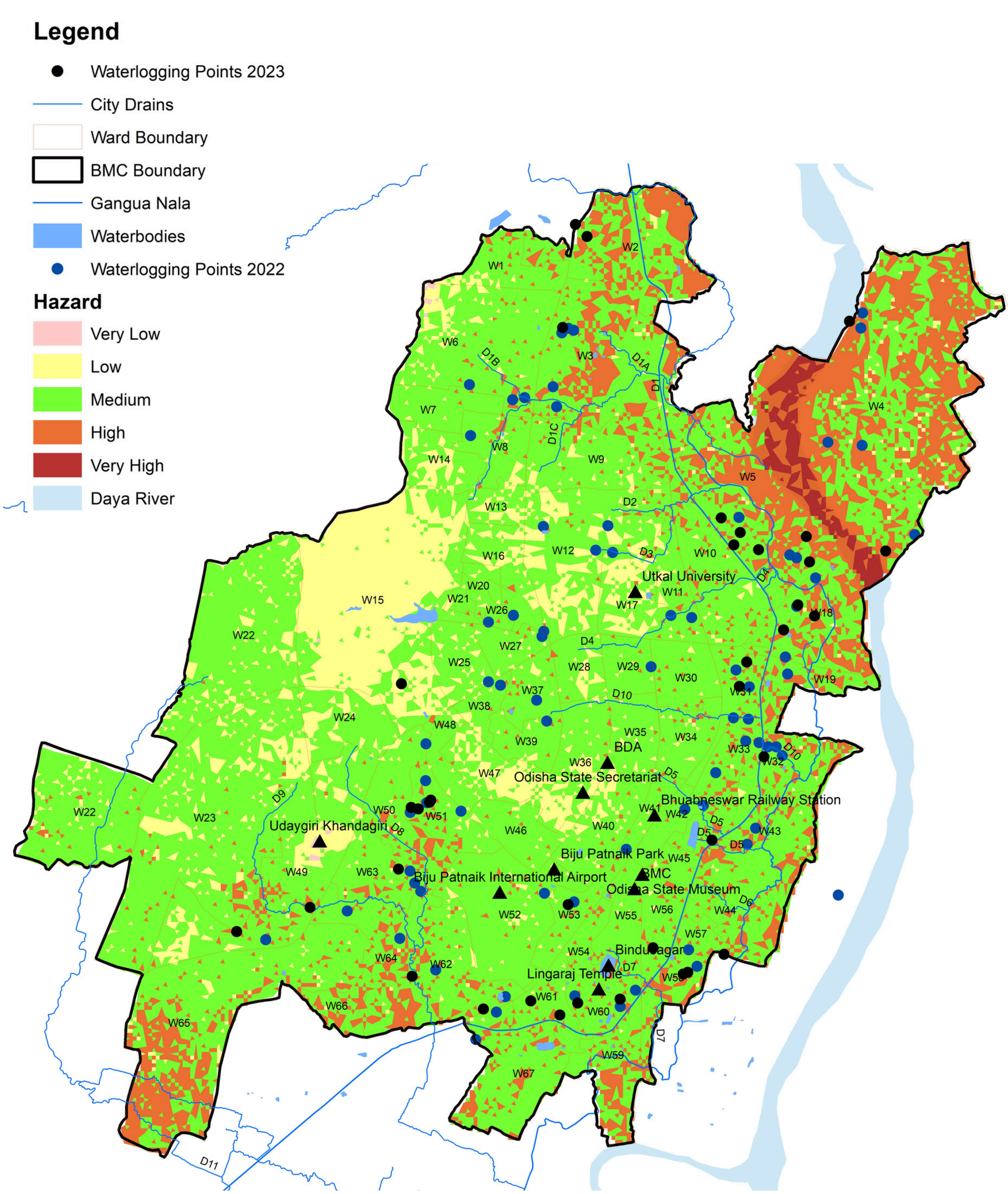
Distance to River


Legend
Bhubaneswar_Landmarks
Daya West Canal
BMC Drains
Waterbodies
Daya River
Gangua Nala
BMC Boundary
Slope_Percent
0 - 5
5 - 10
10- 20
20 - 30
30 - 36
D1A
D1B
D1
D1C
D2
D3
Utkal University
D4
D8
D10
BDA
D5
Odisha State Secretariat
Bhuabneswar Railway Station
D9
Udaygiri Khandagiri
D8A
Biju Patnaik Park
BMC
Biju Patnaik International Airport
Odisha State Museum
D6
D7
Bindusagar
Lingaraj Temple
AIIMS
D11

Slope



Topographic Wetness Index

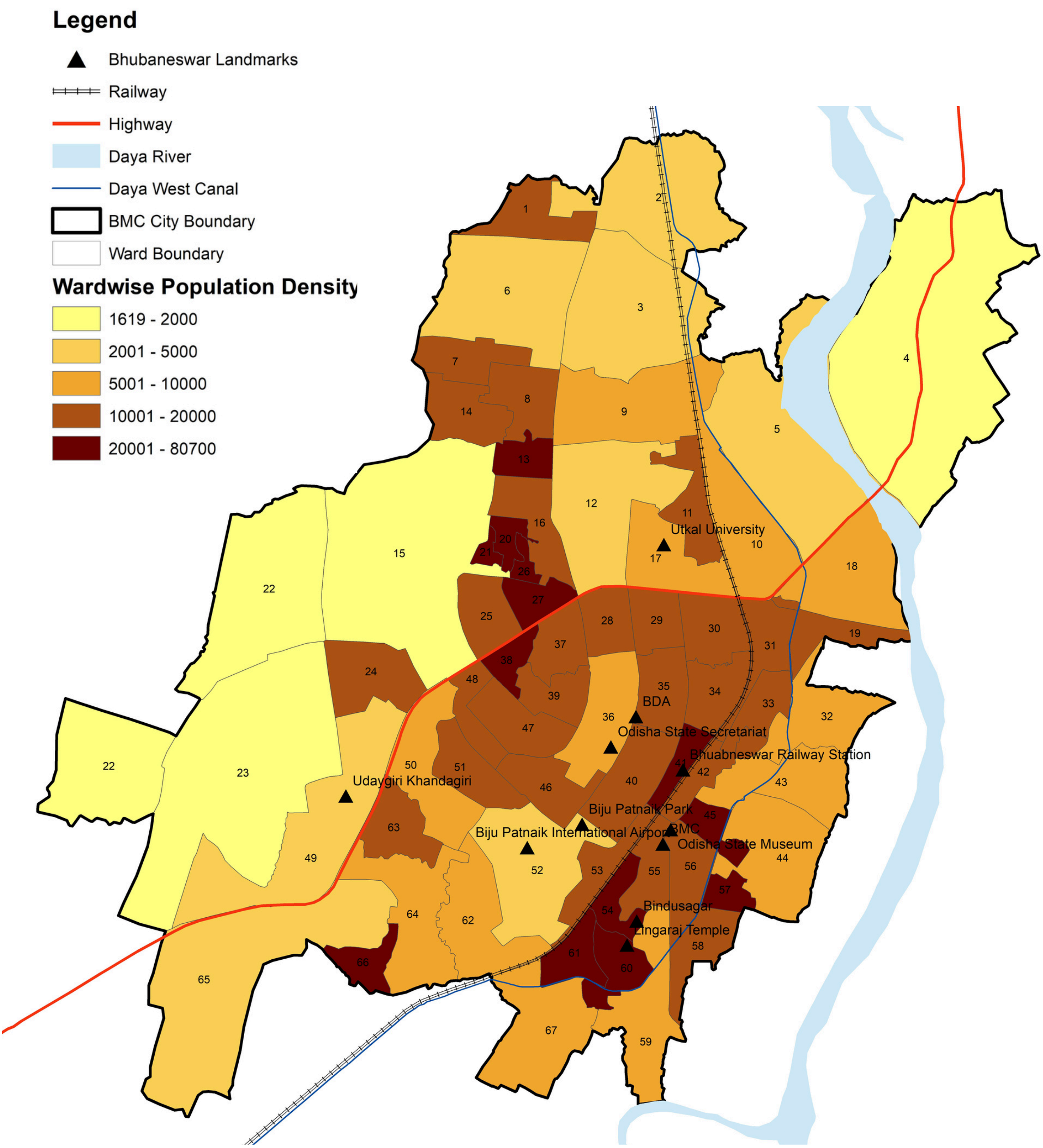


Note-
Composite Flood Hazard has been analysed using following parameters-

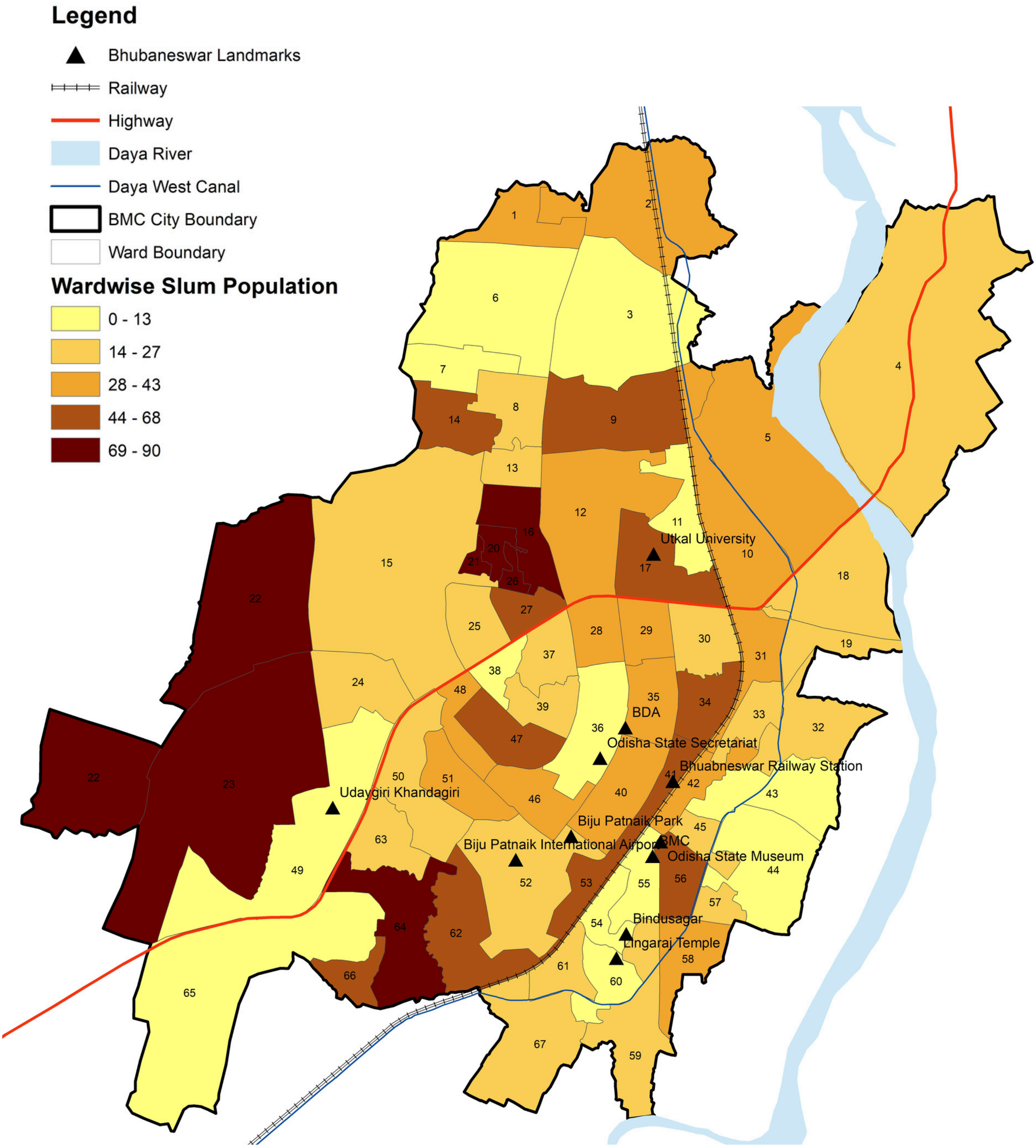
1. *Elevation*
2. *Slope*
3. *Drainage density*
4. *Distance from river*
5. *Landcover*
6. *Topographic Wetness Index*
7. *Groundwater levels*

Waterlogging points are locations where dewatering has been done by BMC

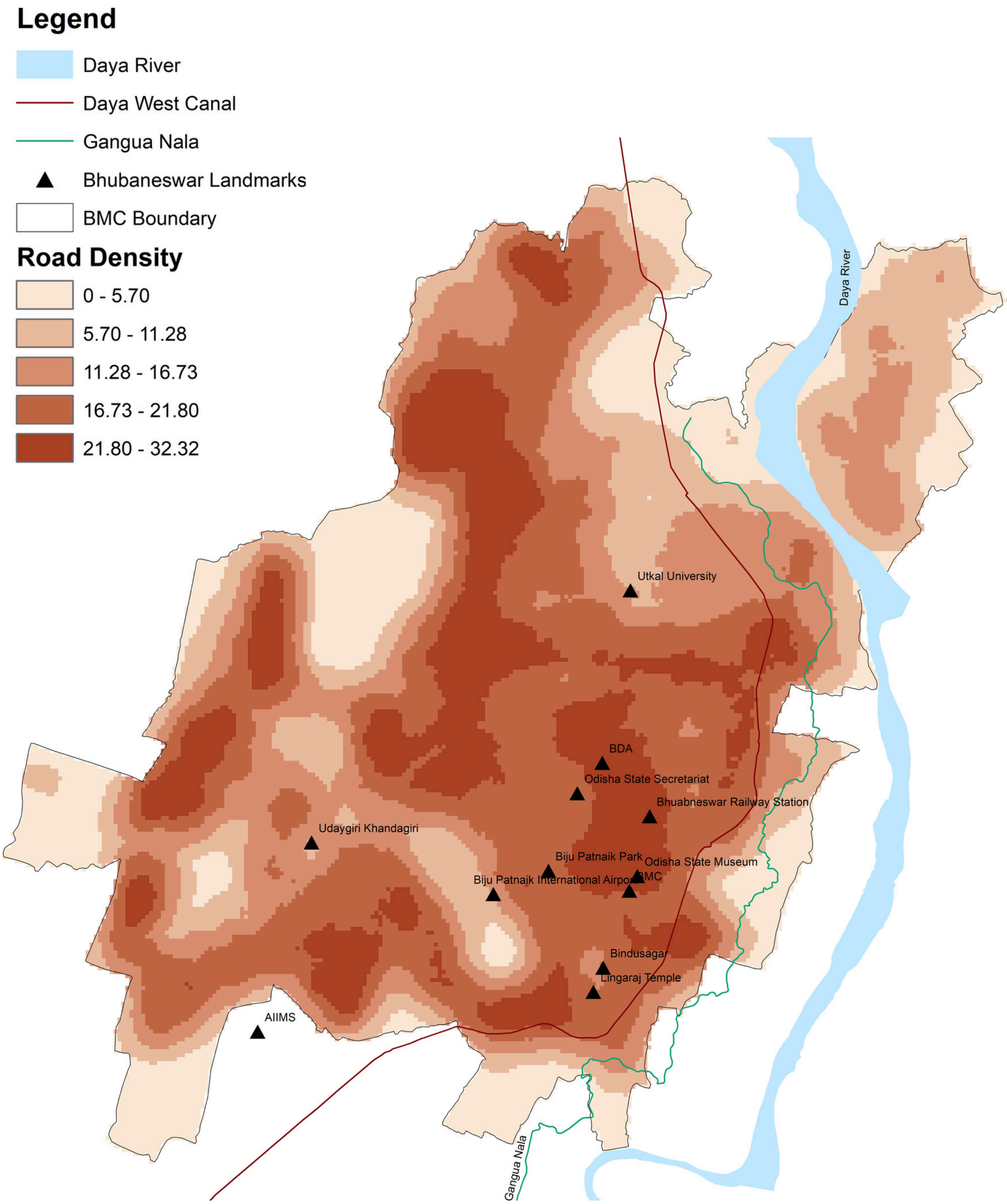
Flood Hazard



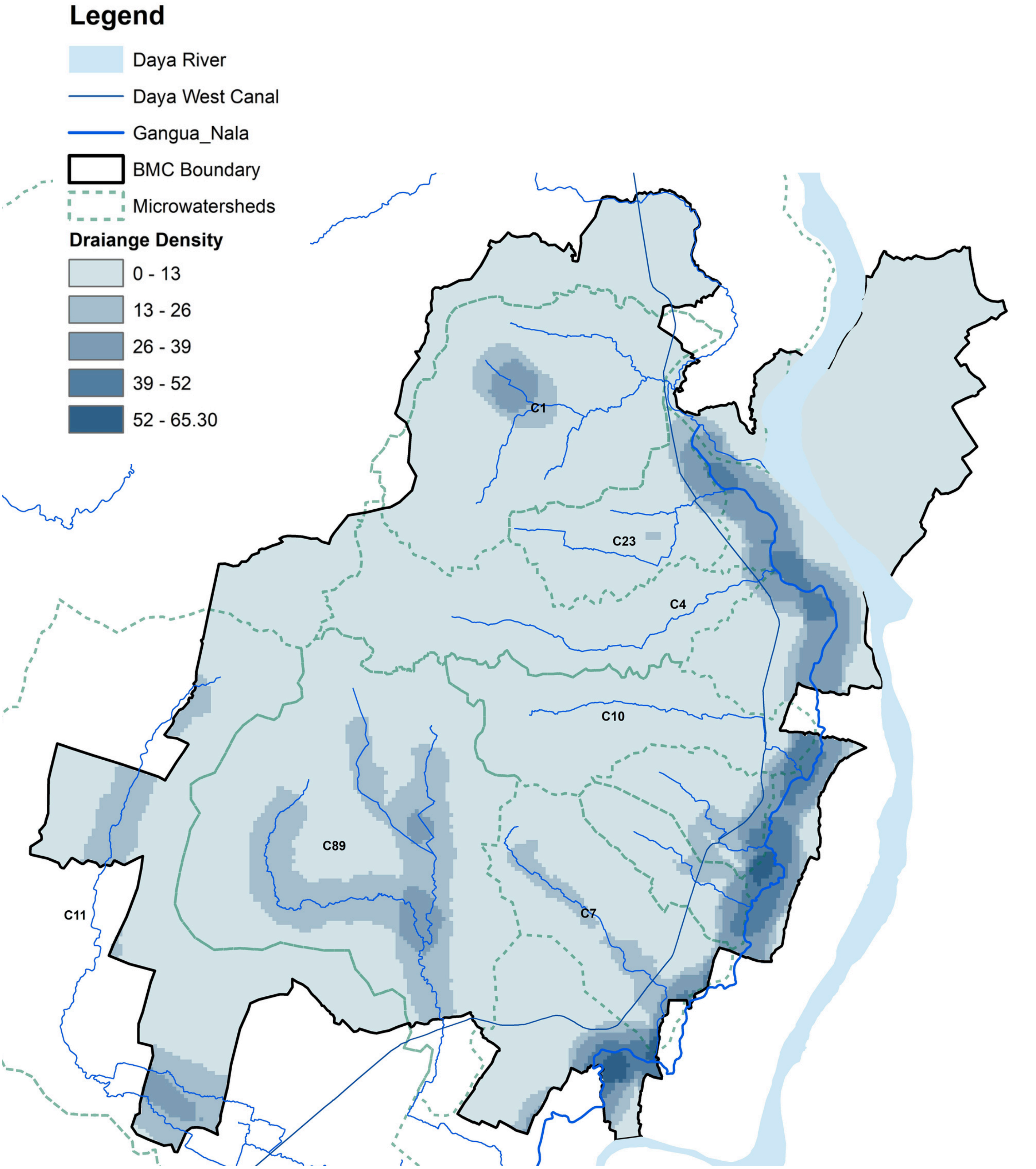
Wardwise Population Density



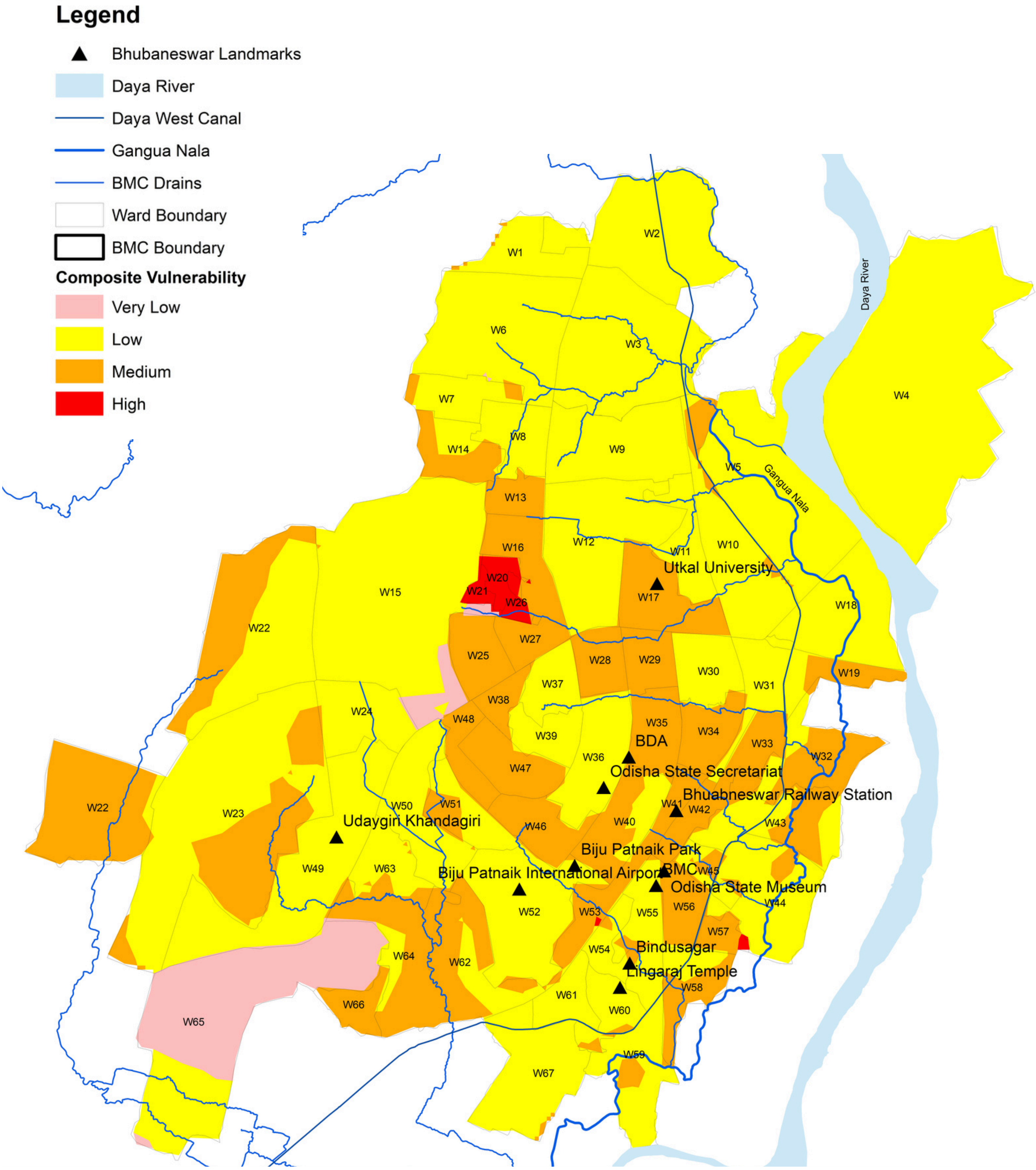
Wardwise Slum Population



Road Density



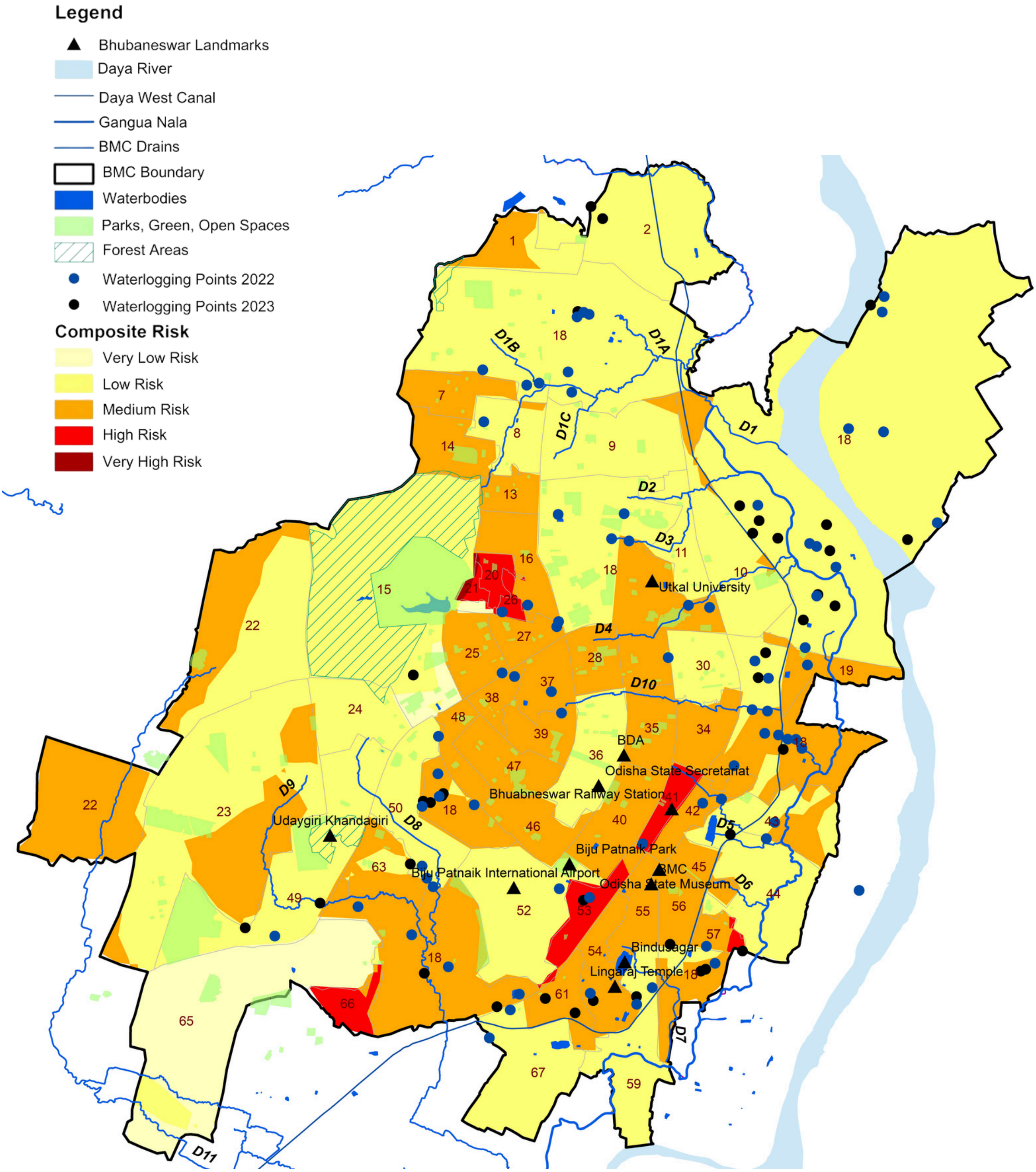
Drainage Density



Composite Flood Vulnerability has been analysed using following parameters-

1. *Wardwise population density*
2. *Wardwise slum population*
3. *Road density*
4. *Drainage density*

Flood Vulnerability



Flood Risk

Composite Flood Risk has been analysed by integrating Composite Flood Hazard and Composite Flood Vulnerability

Scoring Criteria (Flood Hazard)

Score/ Parameter	1	2	3	4	5
Landcover	Vegetation/ green area	Open/ barren area	Builtup area	Low-lying marshalnd	Waterbody/ river/ floodplain
Elevation	56-110m	40-55m	26-39m	21-25m	11-20m
Slope	More than 30%	20-30%	10-20%	5-10%	Upto 5%
Total Wetness Index	4.55-10.05	10.05-15.56	15.56-21.07	21.07-26.58	26.58-32.09
Distance to River	More than 500m	300-500m	100-300m	50-100m	Upto 50m

Scoring Criteria (Flood Vulnerability)

Score/ Parameter	1	2	3	4	5
Wardwise Population Density	Upto 2000 persons//sq km	2000-5000 persons/sq km	5000-10000 persons/sq km	10000-20000 persons/sqkm	More than 20000 persons/sqkm
Drainage Density	0-13 km/sqkm	13-26 km/sqkm	26-39 km/sqkm	39-52 km/sqkm	52-65 km/sqkm
Wardwise Slum Population (%)	Upto 15%	16-30%	31-40%	41-50%	More than 50%
Road Density	21.80-32.32 km/sqkm	16.73-21.80 km/sqkm	11.28-16.73 km/sqkm	5.7-11.28 km/sqkm	0-5.7 km/sqkm

Annexure 2

Potential groundwater recharge areas were identified based on the following parameters.

1. Geomorphology
2. Land cover
3. Lineament density
4. Groundwater level
5. Slope
6. Lithology
7. Elevation
8. Distance to drains

The following are details of each parameter considered in preparing the flood risk map of Bhubaneswar city -

- **Geomorphology:** Geomorphology—the study of landforms and the processes that shape them—is crucial for identifying potential groundwater recharge zones because it helps reveal the natural features and conditions that influence how water infiltrates into the ground. Groundwater movement is primarily controlled by the surface geology and geomorphology of an area. It moves both vertically and laterally based on aquifer configuration, which is determined by weathering thickness and fracture intensity in hard rock formations, and by grain size and sediment thickness in soft rock formations. Alluvial plains and floodplains have the best recharge potential, pediment zones have moderate potential and hills and valleys have the lowest recharge potential.
- **Land Cover:** Land cover significantly influences groundwater recharge potential by controlling surface runoff, evapotranspiration, and infiltration processes. Vegetated land covers, such as forests and grasslands, enhance infiltration and reduce surface runoff through root development and organic matter accumulation, which improve soil permeability. In contrast, impervious surfaces in urban or built-up areas inhibit infiltration and increase runoff, thereby reducing recharge. Agricultural lands present variable recharge potential depending on land management practices, crop type, and irrigation methods. Bare or fallow lands may permit infiltration, but are also susceptible to erosion and compaction, which can limit recharge over time. Thus, land cover type modulates the hydrological balance at the surface and directly affects the spatial distribution and efficiency of groundwater recharge zones.
- **Lineament Density**: Lineaments are linear features such as faults, fractures, and joints that act as conduits for groundwater movement and infiltration. Lineament density, referring to the abundance of linear geological features like faults and fractures, is generally positively correlated with groundwater recharge potential. Areas with higher lineament density often exhibit increased groundwater recharge due to enhanced infiltration pathways, especially in hard rock terrains. Lineaments act as preferential pathways for groundwater recharge by providing channels for water to infiltrate into the subsurface. These features, often representing zones of weakness in rock formations, allow water to move more readily through the ground.
- **Groundwater Level:** Groundwater levels refer to the depth of the water table, the upper boundary of the saturated zone where all the pores and fractures in the soil are filled with water.

Lower groundwater levels usually indicate a greater potential for recharge, because there's more available space (unsaturated zone) in the aquifer to accept infiltrating water, whereas higher groundwater levels suggest that the aquifer is already saturated or near saturation, which reduces recharge potential (less capacity to absorb more water).

In general, areas with low water tables and high-permeability soils are ideal for artificial recharge projects. The relationship is governed by Darcy's Law and principles of unsaturated flow in the vadose zone. When the groundwater level is deep, the unsaturated zone is thick, increasing the storage capacity and potential for vertical percolation. As the water table rises, the unsaturated zone shrinks, reducing the capillary suction gradient and potentially leading to decreased recharge.

- **Slope:** Generally, there is an inverse relationship between slope and groundwater recharge potential. Gentler slopes promote infiltration and percolation into aquifers, while steeper slopes tend to favour surface runoff and soil erosion, reducing recharge.

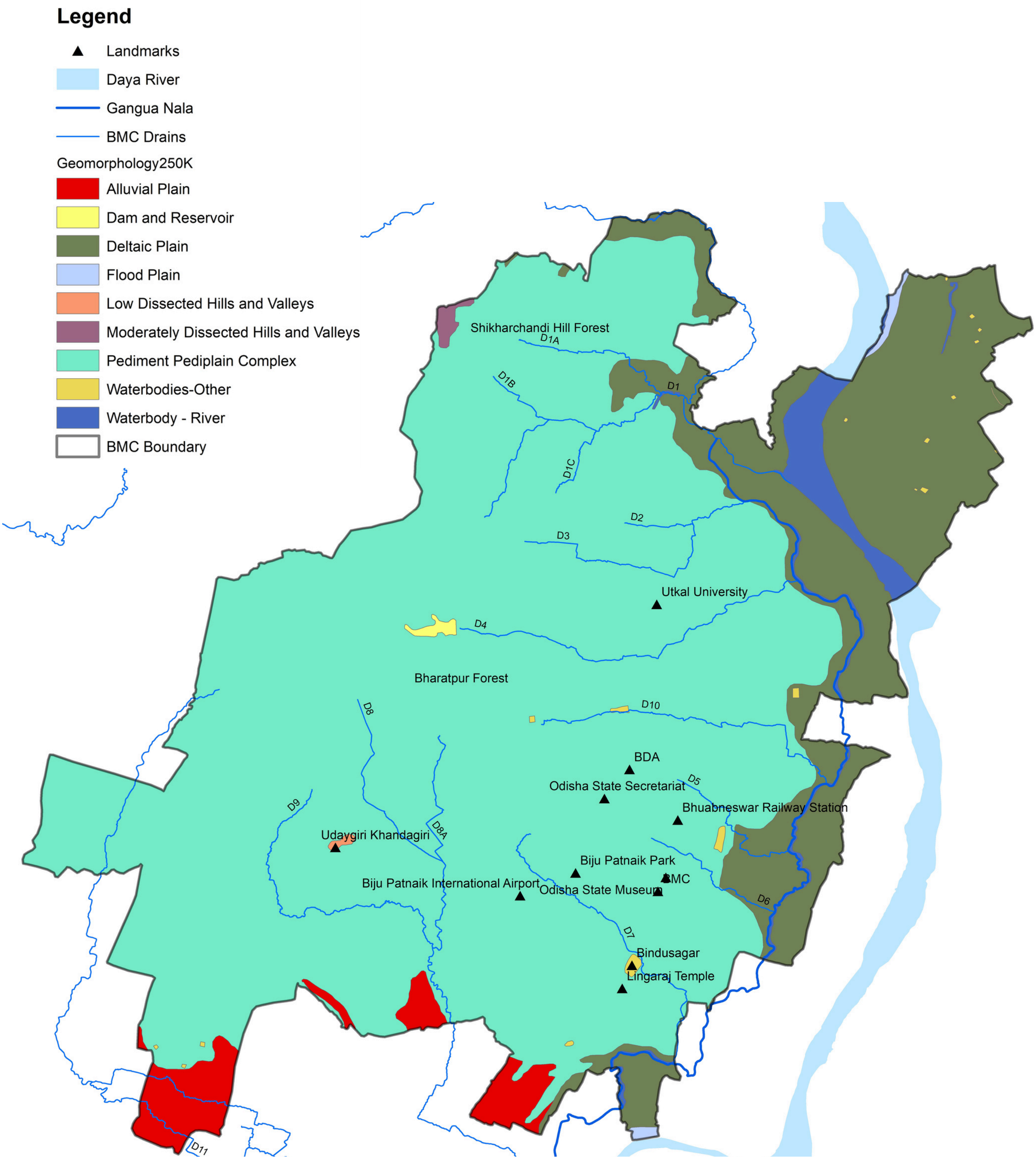
- **Lithology:** Lithology refers to the physical characteristics of rock or sediment, including mineral composition, grain size, sorting, degree of consolidation, porosity, and permeability. These parameters directly control infiltration, percolation, and aquifer storage properties, which together define groundwater recharge potential. Permeable, porous, and fractured rocks support high recharge, whereas impermeable, fine-grained, or unfractured rocks inhibit recharge. Coarse alluvium (sand, gravel), limestone etc have very good recharge potential; sandstone, basalt, silt etc have moderate recharge potential; granite, shale, clay etc have lowest recharge potential.

- **Elevation:** In the groundwater potential zoning, low elevation areas have been assigned a higher weightage, indicating their greater potential, while high elevation areas have been assigned a lower weightage.

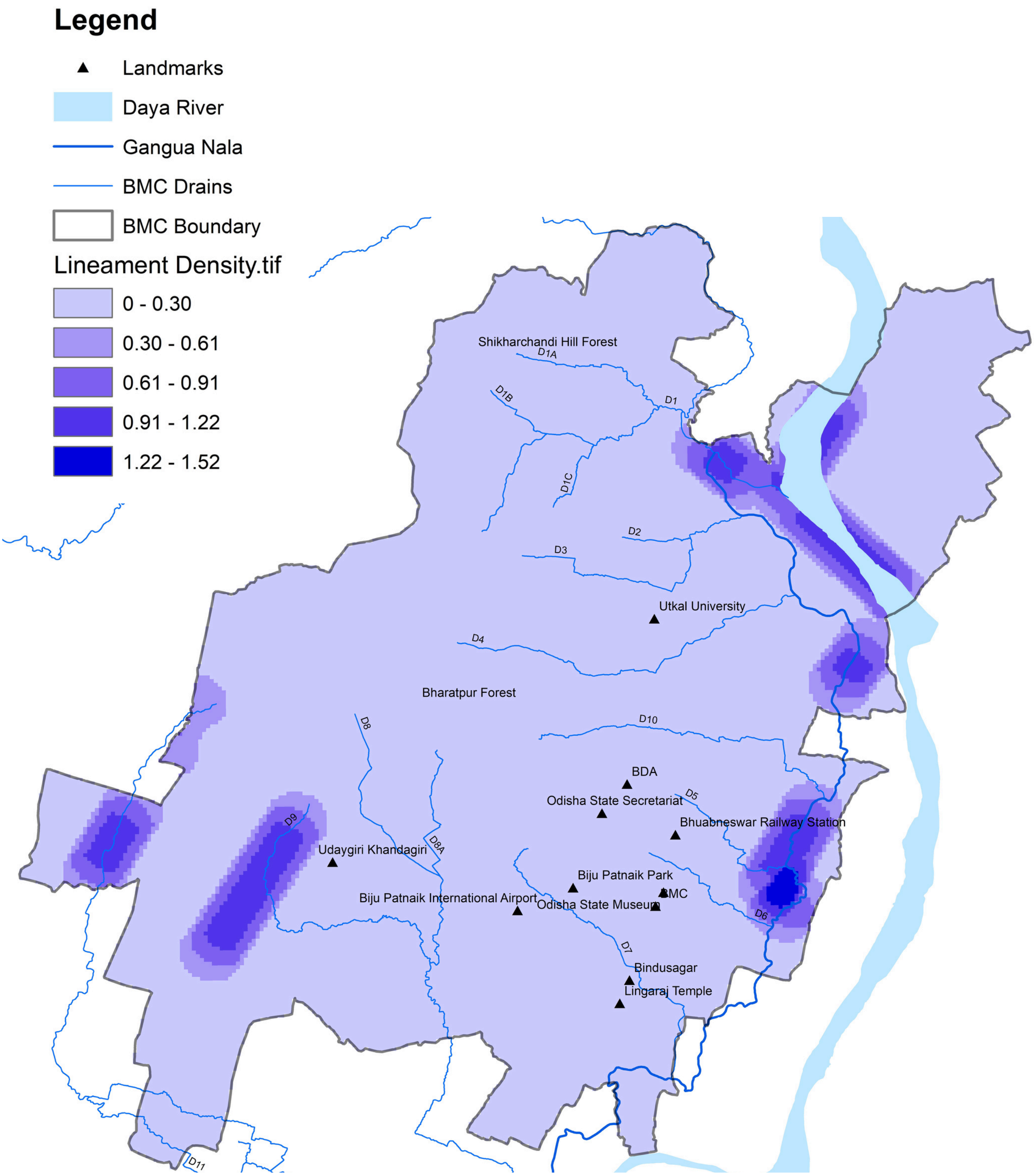
- **Distance to drains:** The city of Bhubaneswar does not have a proper sewerage system and therefore, the natural drains also carry wastewater along with stormwater. Because of this reason, sites which are at close proximity to the drains have been considered less suitable for groundwater recharge, due to possibility of mixing of untreated water with the surface runoff or even groundwater through leaching.

Following are the thematic maps used to identify potential groundwater recharge zones. Groundwater recharge potential has been analysed by using MCDA and AHP techniques and by overlaying the above mentioned layers. Recharge potential has been rated on a scale of 1 to 5, where 5 indicates high recharge potential and indicates low recharge potential.

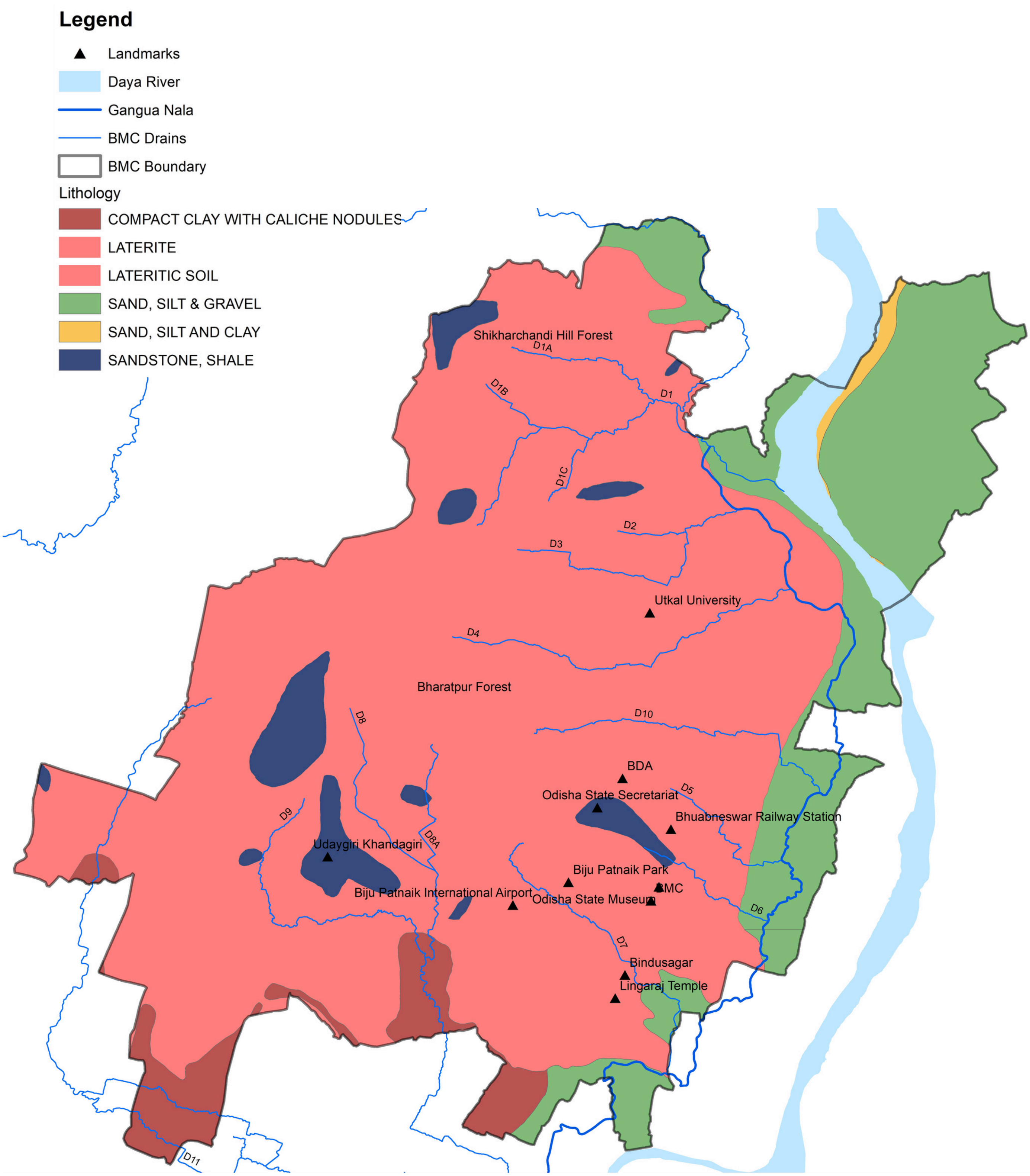
- **Groundwater Recharge Potential** = (0.30 x Geomorphology) + (0.20 x Landcover) + (0.15 x Lineament density) + (0.12 x Depth to groundwater level) + (0.09 x Slope) + (0.07 x Lithology) + (0.05 x Elevation) + (0.02 x Distance to drains)



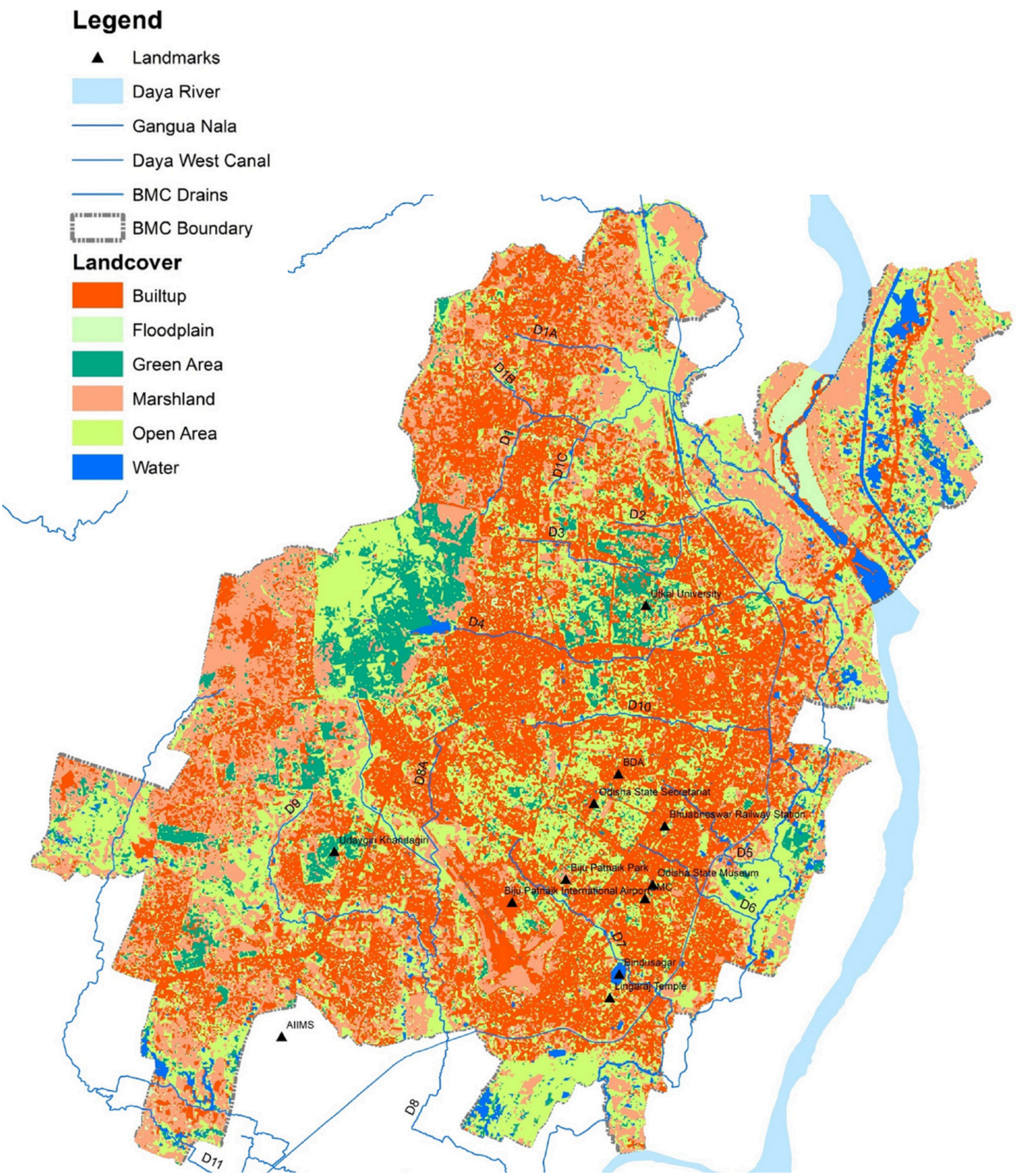
Geomorphology



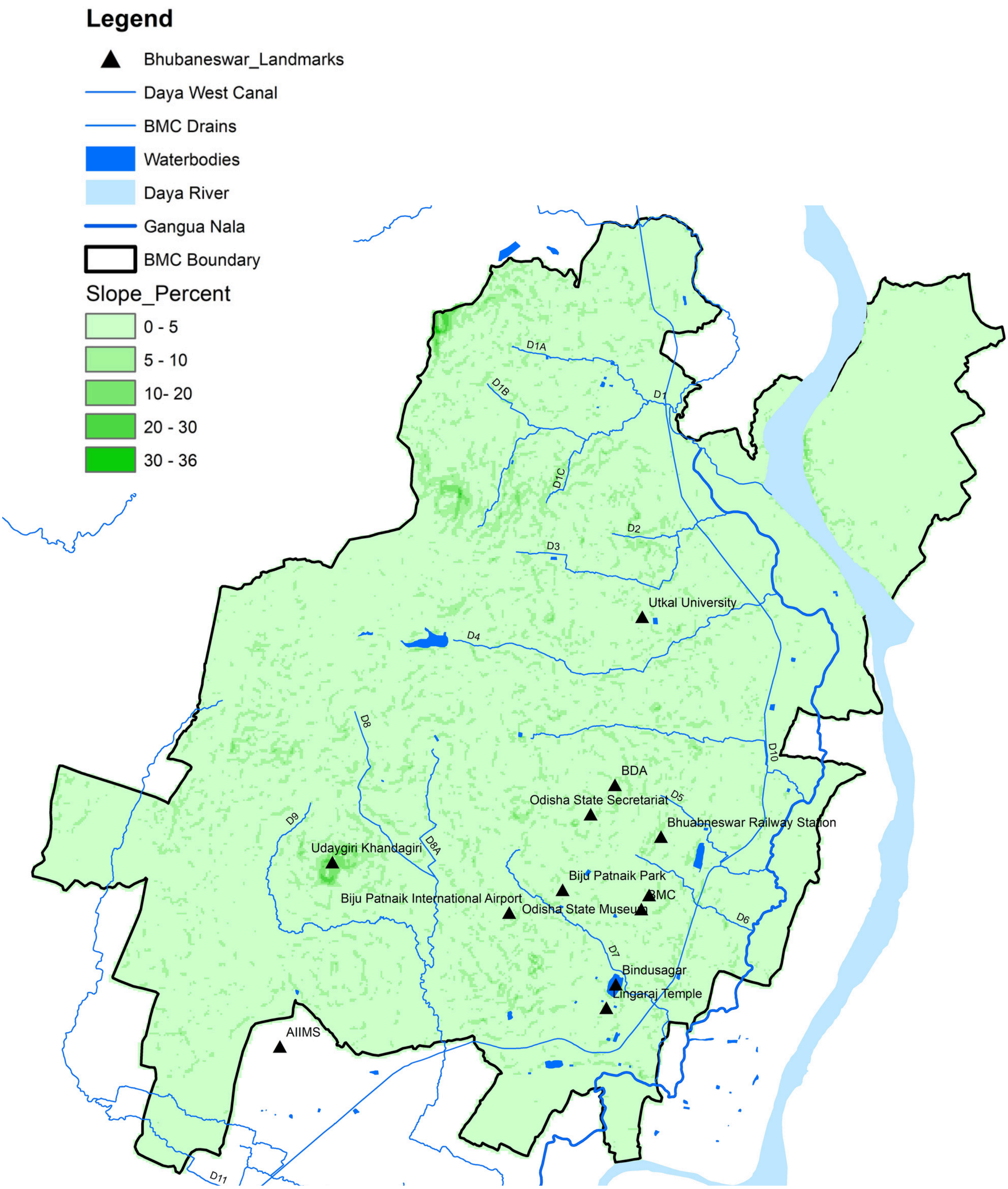
Lineament Density


Legend
Landmarks
Daya River
Gangua Nala
BMC Drains
BMC Boundary
Lithology
COMPACT CLAY WITH CALICHE NODULES
LATERITE
LATERITIC SOIL
SAND, SILT & GRAVEL
SAND, SILT AND CLAY
SANDSTONE, SHALE
Shikharchandi Hill Forest
D1A
D1B
D1
D1C
D2
D3
Utkal University
D4
Bharatpur Forest
D8
D10
BDA
Odisha State Secretariat
D5
Bhuabneswar Railway Station
D9
Udaygiri Khandagiri
D8A
Biju Patnaik Park
BMC
Biju Patnaik International Airport
Odisha State Museum
D6
D7
Bindusagar
Lingaraj Temple
D11

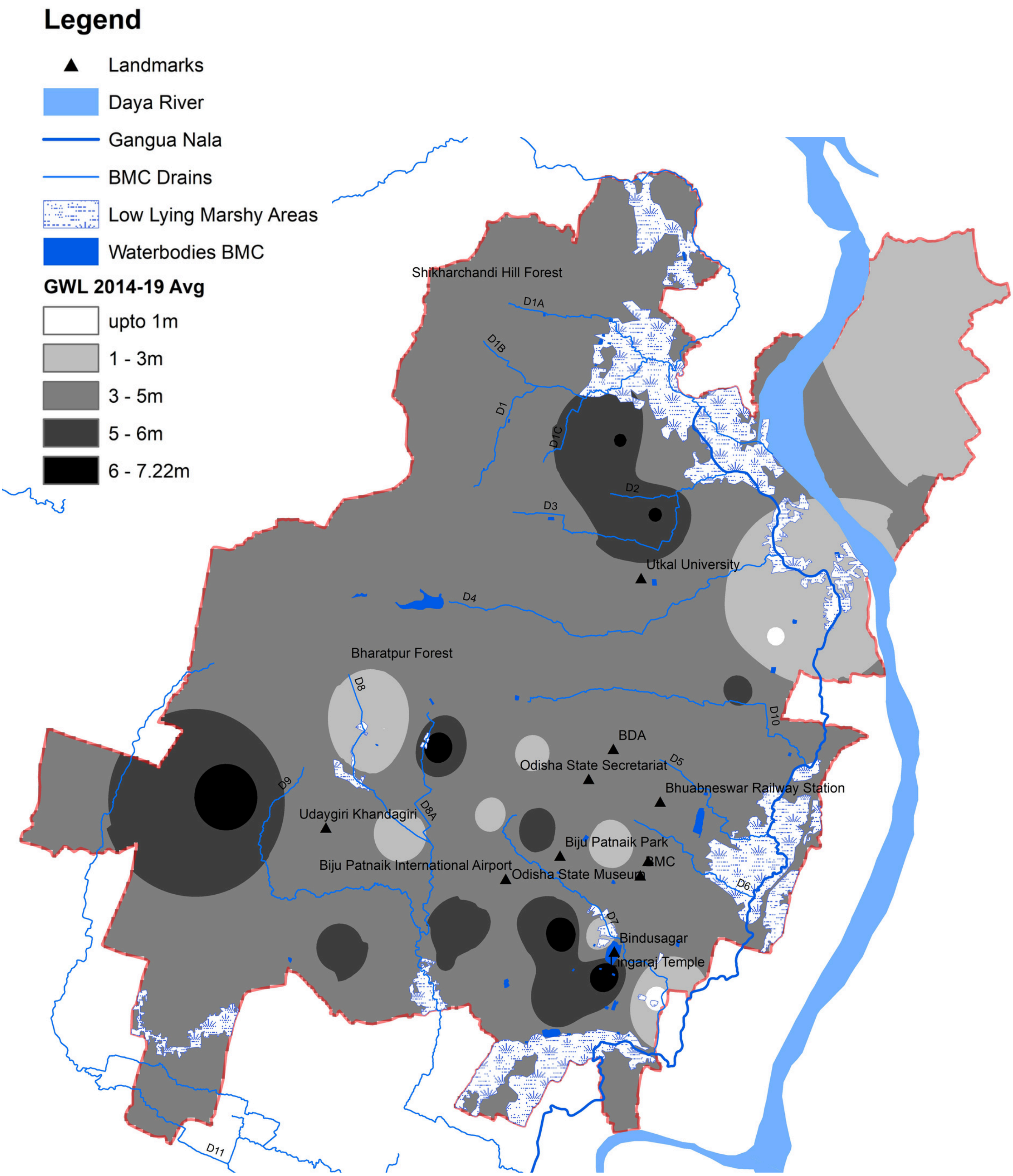
Lithology



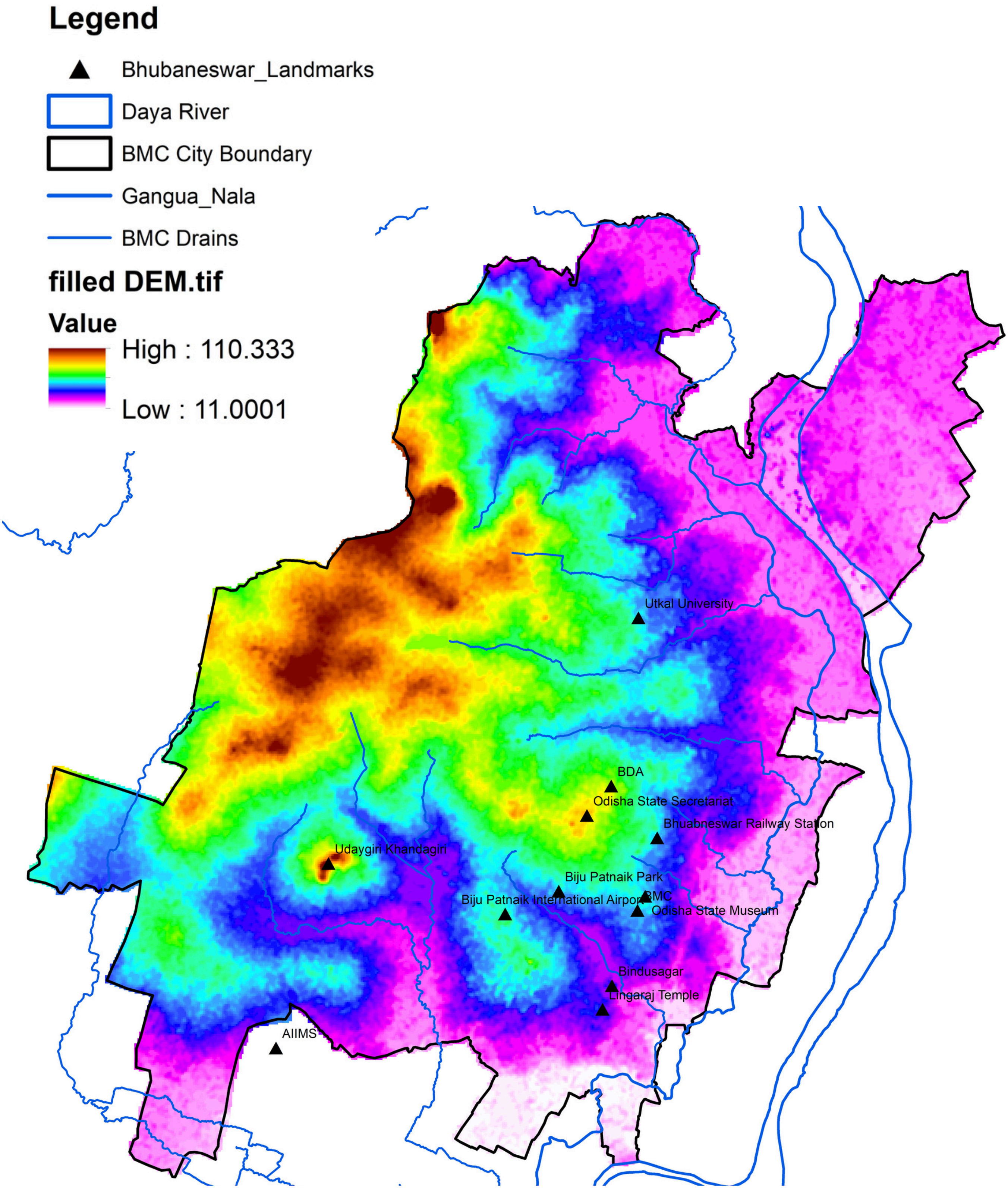
Landcover 2019


Legend
Bhubaneswar_Landmarks
Daya West Canal
BMC Drains
Waterbodies
Daya River
Gangua Nala
BMC Boundary
Slope_Percent
0 - 5
5 - 10
10- 20
20 - 30
30 - 36
D1A
D1B
D1
D1C
D2
D3
D4
D5
D6
D7
D8
D8A
D9
D10
D11
Utkal University
BDA
Odisha State Secretariat
Bhuabneswar Railway Station
Udaygiri Khandagiri
Biju Patnaik Park
BMC
Biju Patnaik International Airport
Odisha State Museum
Bindusagar
Lingaraj Temple
AIIMS

Slope

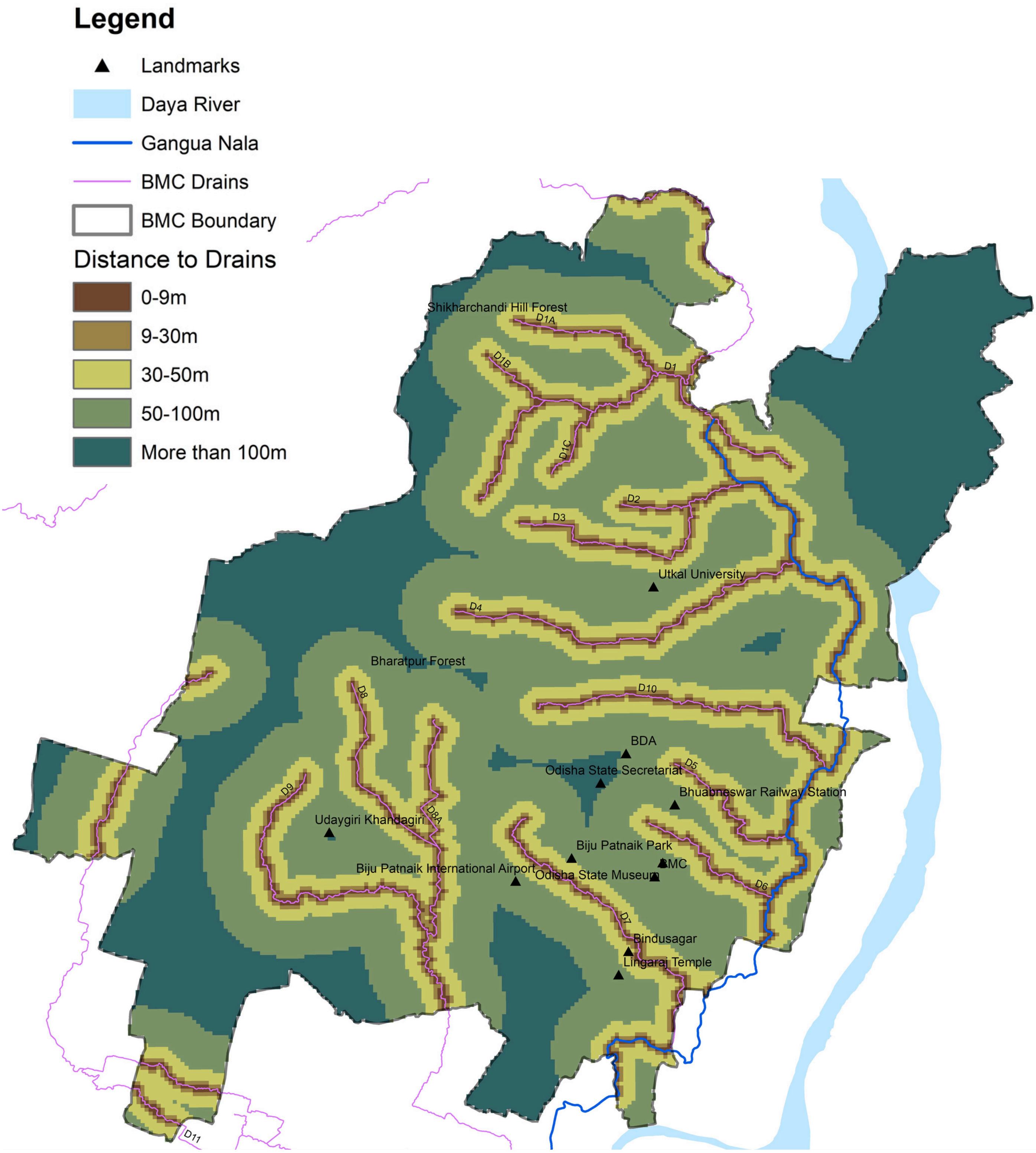


Depth to Groundwater



Legend
Bhubaneswar_Landmarks
Daya River
BMC City Boundary
Gangua_Nala
BMC Drains
filled DEM.tif
Value
High : 110.333
Low : 11.0001
Utkal University
BDA
Odisha State Secretariat
Bhuabneswar Railway Station
Udaygiri Khandagiri
Biju Patnaik Park
Biju Patnaik International Airport
BMC
Odisha State Museum
Bindusagar
Lingaraj Temple
AIIMS

Elevation



Distance to Drains

Scoring Criteria

Score/ Parameter	1	2	3	4	5
Geomorphology	Hills & valleys	Deltaic plain	Pediment	Waterbodies	Alluvial plain & floodplain
Landcover	Builtup	Green area	Water & floodplain	Marshland	Open area
Lineament Density	Upto 0.3 km/sqkm	0.3-0.61 km/sqkm	0.61-0.91 km/sqkm	0.91-1.22 km/sqkm	1.22-1.52 km/sqkm
Lithology	Laterite	Compact clay	Sandstone	Sand, silt & clay	Sand, silt & gravel
Groundwater Level	Upto 0.5m	0.5-1m	1-2.5m	2.5-5m	More than 5m
Slope	More than 30%	20-30%	10-20%	5-10%	Upto 5%
Elevation	80-110m	50-80m	30-50m	20-30m	11-20m
Distance to Drains	Upto 9m	9-30m	30-50m	50-100m	More than 100m

Notes

National Institute of Urban Affairs

National Institute of Urban Affairs
1st Floor, Core 4B,
India Habitat Centre, Lodhi Road,
New Delhi - 110003, India
(+91-11) 24643284/ 24617517 (ext. 214)
urvers@niua.org

Global EbA Fund

BHUBANESWAR MUNICIPAL CORPORATION BMC

National Institute of Urban Affairs