

**LANDSCAPE DEVELOPMENT OF THE EDGE OF RIVER
GANGA IN PATNA, BIHAR.**

**MASTER OF ARCHITECTURE
(LANDSCAPE)**

Smita Kumari Saha
2017MLA015



**SCHOOL OF PLANNING AND ARCHITECTURE, BHOPAL
NEELBAD ROAD, BHOURI, BHOPAL – 462030**

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LANDSCAPE DEVELOPMENT OF THE EDGE OF RIVER GANGA IN PATNA, BIHAR.

Submitted

*In partial fulfillment of the requirements for the
award of the degree of*

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(LANDSCAPE)**

By

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Department of Landscape
School of Planning and Architecture, Bhopal



Declaration

I Smita Kumari Saha, Scholar No. 2017MLA015 hereby declare that the thesis entitled Landscape Development of the Edge of River Ganga in Patna, Bihar, submitted by me in partial fulfillment for the award of Master of Architecture (Landscape), in School of Planning and Architecture Bhopal, India, is a record of bonafide work carried out by me. The matter embodied in this thesis has not been submitted to any other University or Institute for the award of any degree or diploma.

20.05.2019

Smita Kumari Saha

Certificate

This is to certify that the declaration of Smita Kumari Saha is true to the best of our knowledge and that the student has worked under the guidance of the following panel.

RECOMMENDED

Miss Richa Raje

ACCEPTED

Prof. Sanjeev Singh
Head, Department of Landscape

Acknowledgement

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Foremost, I want to offer this endeavour to our GOD Almighty for the wisdom he bestowed upon me, the strength, peace of mind and good health in order to finish this thesis.

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1.0. INTRODUCTION

1.1. Defining Waterfront and Waterfront Developments

The heterogeneous nature and characteristics of the waterfront include natural waterfront and constructed waterfront. Human-altered waterfront character and location can be urban or semi-urban in nature. Natural waterfront areas could also be altered in order to preserve and enhance their special features for various purposes such as eco-tourism, habitat conservation, nature research, etc. Therefore, a one-size-fits-all concept might not be applicable for ' Waterfront Development.'

The American Heritage Dictionary defines waterfronts as a land abutting a body of water or the part of a city that abuts water, especially a district of wharves where ships dock.

Collins Essential English Dictionary describes the waterfront as the area of a town or city next to an area of water, such as a harbour or dockyard. The Urban Land Institute refers to an urban waterfront as the water edge in cities and towns of different scales such as a river, lake, ocean, bay, creek or canal whether it is manmade or natural.

The definition of 'Waterfront Development depends on the characteristics of the waterfront site, the planning framework and development approach. Various planning authorities, local communities, investors, and other stake holders including local residents may be involved in any waterfront development process. Depending on the site, waterfront developments could be new waterfront projects to acquire new facilities, investments and operators to the area/region. It could also be development projects to preserve natural habitats along with public amenities or it could also be rejuvenation projects, which aim to improve existing condition and addressing deterioration which can be urbanized or semi-urbanized areas with human settlements and, or specific land uses or land covers at the water.

In this research, the term 'Waterfront' is applied to the area at, the type of water bodies is River in Patna, the study area. The study is restricted to the extent of a water body or flowing waterway within the boundaries of the study area.

1.2. Background

Rivers has always been an integral part of human civilization. The Ganga river is the largest basin of the Indian subcontinent. The river is a system comprising the main course and the tributaries, which carrying a sediment from both natural and anthropogenic sources.

Craig Smith and Fagence (1995) states, “The principal purposes of waterfront redevelopment include the achievement of public access to the waterfront, improvement of the image of derelict waterfront areas, and the achievement of economic regeneration by breathing new life into such areas”.

For Bihar, Ganga is not just a river but also has an extraordinary religious importance. The Ganga is a symbol of faith, hope, culture, and sanity, as well as a source of livelihood for millions of peoples. It is the centre of social and religious tradition in the Indian sub-continent and particularly sacred in Hinduism.

Rapidly growing population, rising living standards, and exponential industrialization and urbanization growth have exposed water resources to various forms of degradation. Today, the rivers have become a little more than city sewers and garbage dumps.

The understanding of the need, association, and sensitivity towards the holy river will help me to find out the issues and address it in the designing process. There is a need for space where people can revive their connection with the water and the association will make them aware of it.

People have lost the importance of the River Ganga and its connection to day to day life and religious rituals of the people of Bihar.

“Ganga is no more the Holy River for its people.”

The following thesis would to research on various aspects that would help to reconnect Ganga to its people. The design interventions would be to use landscape as a tool to rejuvenate Ganga to its glorious past. Patna needs city level open public space which can reconnect the nature to its people and for this the river bank is the best location as the city people are culturally associated with it.

1.3. Aim

The aim of the thesis is to establish the cultural association of Ganga and to revive the lost ecology of the river edge. The goal is to create good quality cultural and recreational space along the riverfront of Ganga in Patna.

The project identifies an edge along the river Ganga in Patna which can be used by people on an everyday basis. Also, such critical edges need resilience in terms of landscape. The site will be delineated on the basis of analysis of different layers and primary site visit.

1.4. Objectives

- To map the network of open spaces in the town to conclude the requirement of more open and recreational space in the town.
- To investigate the cultural and social significance in the context of the designed landscape. To understand the existing relationship between people and the river and map the activities.
- To determine the parameters and principles that influences the setting along the riverfront as a public space.
- To study and map the evolution of settlement of the Patna city with the river. And to understand the negotiation of the town with the river over the period of time. To analyse how the landscape of the river edge has changed.
- To understand the proposed development plans under Master Plan and Smart city mission and to analyse the effects on the city as well as river edge.
- To understand the behaviour of the River Ganga and its effect on the city.

1.5. Need or importance of study

The major downside outlined during this thesis research revolves round the role of waterfront development in urban regeneration because waterfronts are essential to open resources where visitors can carry out diverse social and cultural activities on a regular basis.

The thesis topic was chosen as it a need for the present situation. If we assess the open recreational space in the city; Patna has no such city level recreational space. There is a lack of not only large-scale continuous landscape renovation and old city recovery, but also improvement of urban environmental quality, especially, riverfront ecological systems. The urban lifestyle and health of present days are degraded in terms of quality; there is a very need for us to go back and connect to our roots.

This thesis will enable me to design a cultural space to provide a platform for cultural and religious activities; recreational urban space for the public which will distract them from their busy routine; and ecological rich zone such wetlands for nature to help the earth to sustain. The artificial riverbank has broken the initial nature character of the riverfront and made the river diversity into singleness, which changed the original forms of the eco-system. Meanwhile, the vertical steep artificial masonry and revetment makes the riparian zone into cold space, which lacks interest, thereby isolating people from the water.

1.6. The Site location

The Site is located at the left end of the city Patna, Bihar. Patna is the capital city of Bihar state and one of the oldest continuously inhabited places in the world. The History of Patna spans at least three millennia. Patna is situated on the southern bank of the Ganga river. The city also straddles the other rivers such as Sone, Gandak, and Punpun. The city is approximately 35 kilometres in length and 16 to 18 kilometres wide.

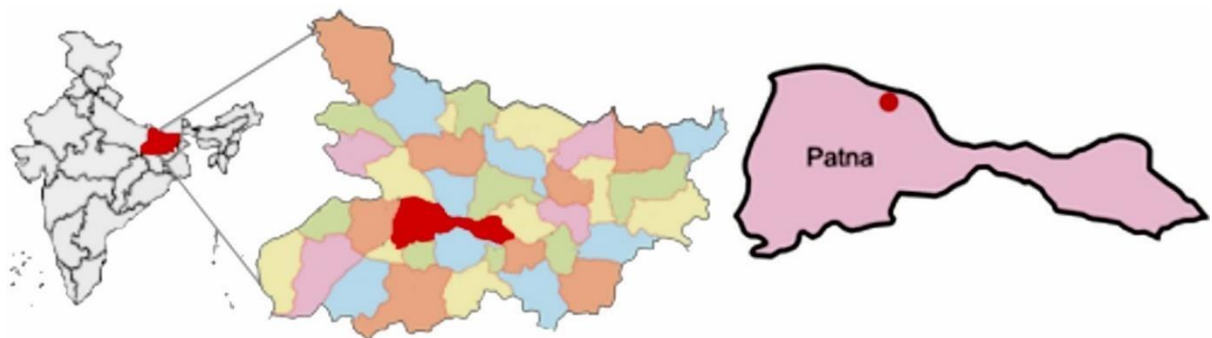


Figure 1. Site Location – Patna, Bihar

Source: Self made

The study examines the developmental potential of Ganga's waterfronts, in Patna along with issues surrounding its natural and urban waters, which may impact any potential waterfront development. It articulates a vision for the future of Ganga's waterfront.

This thesis will cover 2.89 km² study area which is located in Digha, at the west part of Patna and the total design area is 1.08 km². This will cover around 2.55 km stretch of the river front.

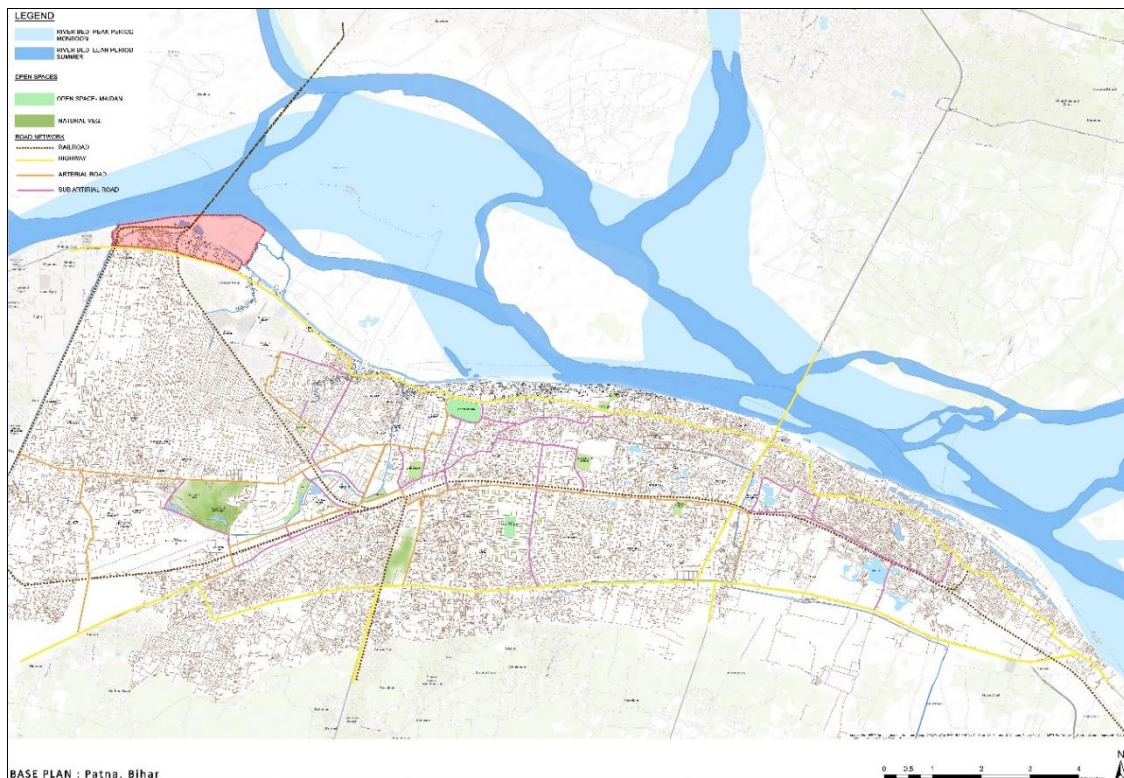


Figure 2. Patna Base Map highlighting study area

Source: Self-generated map in GIS



Figure 3. Google Image of Site and surrounding: Proposed Ghat area. of Patna

Source: Self-generated

1.7. Smart City Proposal in Patna, Bihar

As per smart city project the government of Patna, Bihar has proposed several Ghats, riparian edge and recreational parks etc. Transforming the water bodies in and around Patna into active public spaces and developing recreational activities along the river-front. To create organized public spaces that will improve the liveability quotient and quality of life.

The concept of smart city has a lens through which they see every city and land similarly. The eastern part of Patna has been developed under the Smart City Mission and for west part no proposal has been given.

In my study I as a landscape architect will assess the land on the basis of its landform, hydrology, geomorphology and other parameters which governs the design.

1.8. Study area, Digha Ghat, Patna

The site boundary is determined by the natural boundaries; at the northern edge it has Ganga river creating a boundary, the southern edge is demarcated by the highway which is connecting east and west ends of Patna and the left and right edge is defined by the nallahs which is drained into the river.

The site has features such as river at the northern edge, waterlogs which has potential to be developed as wetland, Highway, Digha bridge & Major roads

providing connectivity to the ghat and transition corridor at different levels and height which will provide a view of the ghat area.

This site is highly active in terms of activities; the primary activities that take place are boating to cross the river, performing rituals and other cultural activities, people come here for the recreational purposes such as bird and dolphin watching, morning walk, photography and photoshoot. The site also has activities such as sand mining, brick manufacture which is affecting the topography of the site.



Figure 4. Base Map of the study area at Digha, Patna

Source: Self-generated map in GIS



Figure 5. Site Image, Digha, Patna

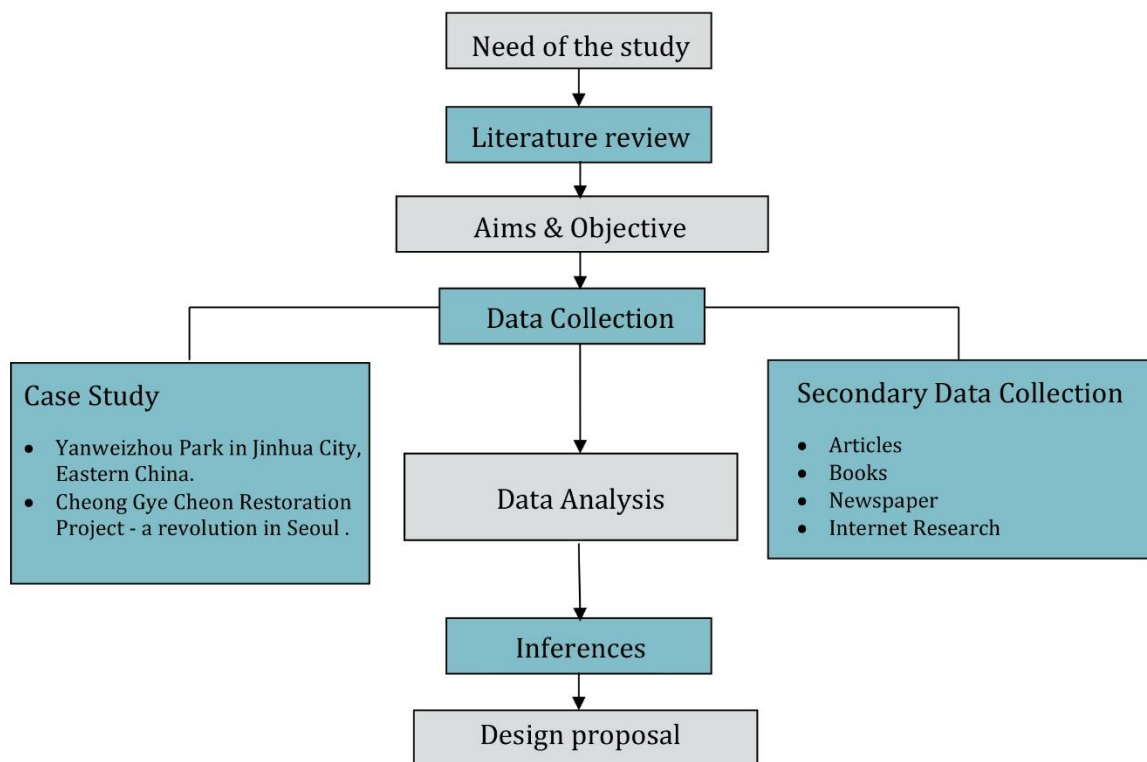
Source: Self-Clicked

1.9. Case study identification

Case Study

- Yanweizhou Park in Jinhua City, Eastern China.
- Cheong Gye Cheon Restoration Project, Seoul

1.10. Methodology



1.11. Nature of study

- River edge protection from soil erosion.
- The revival of the littoral zone by reducing concrete retaining edge.
- The riparian zone will be maintained to attract native fauna.
- Ghat will be developed through which people can access the river for religious or recreational activities.

- Recreational Parks will be developed at the riverfront to create active public space.
- The riverfront will be flood resilient design.
- The design will be for extreme climatic situations.
- Fulfil ecological damages.
- Policies to manage untreated wastewater discharge into the river, illegal brick kiln near the river edge and illegal sand mining.
- The critical or core area will be designed as a prototype and for less critical zone or for regional scale the policies can be made.

2.0. LITERATURE REVIEW

The theory of riverfront rejuvenation and features are examined by means of a literature study. The following databases and sources were assessed to establish the availability of material for this study:

- Academic thesis and Research Papers
- ResearchGate Publications
- Google Scholar
- SPA Bhopal Library
- Newspaper articles and
- Patna district report etc.

The literature review of the thesis includes an overview of waterfronts and the role of the waterfront developments.

- (1). History of Riverfront cities,
- (2). Importance of Riverfront,
- (3). Patna as a Riverine city and,
- (4). River edge growth pattern in Patna.

Subsequently, the literature study will help to lay the foundation for the practical study using the abovementioned resources

2.1. History of Riverfront cities

Cities and water can be said to have a love-hate connection, and this is particularly true of rivers in Indian cities. Many Indian towns owe their places to rivers and these rivers provided trading possibilities and water sources.

In recent years, cities across China are beautifying their waterfronts, and cities as diverse as Singapore and Seoul are redeveloping and converting their rivers into assets. It is an effort to bring nature back to the city. But the Indian cities have their backs turned to their rivers.

Rivers were once trading and transport arteries, nowadays many of them have suffered neglect as roads, and evolving trading patterns have supplanted the rivers' economic and social functions. Their decrease has been followed by economic devastation as their waters have become polluted and function as a strong waste disposal floor. In addition, riverbank settlements developed into legally ambiguous areas as old settlements were separated from land formalization systems and exposed to environmental decay from waterways. Far from being an asset, these waterways have become an eyesore and sometimes also a hazard due to flooding

exacerbated by poor planning and poor knowledge of the place of these water bodies in the broader global eco-system.

2.2. Importance of Riverfront

In perspective of their significant contributions to the environment, the significance of metropolitan waterways has always been acknowledged for water supplies, wildlife preservation, forestry and leisure. In fact, waterways also have certain definite environmental, social, cultural and financial characteristics. They are used by individuals for a broad range of reasons such as drinking water, irrigation industry, power generation, transportation, flood control, fishing, boating swimming and aesthetic pleasure.

Rivers have many functions such as offering a link between landscapes and communities and gathering individuals around the same notion for a creative and sustainable environment. "People from all parts of society should and also private and public stakeholders should be included in the development of a river management plan in order to find effective solutions for the use of natural resources". (Firehock, Doherty, & West., 2006)

Floodplains are prone to flooding hazards in regards to human and natural operations. Loss of lives and assets and damage to animal habitats can be quoted among the waterside hazards created by culture. Past uses of rivers and social tendencies are effective in the present condition of rivers.

Despite the unsatisfactory circumstances of water supplies in many areas, the growing effectiveness of wastewater therapy technologies offers fresh possibilities for residents and morphologically and economically improved waterways. Flood control schemes and water quality in metropolitan regions should be provide with consideration and significance in order to achieve a standard quality of living along river banks. Flood control schemes and water quality in metropolitan regions should be provided with consideration and significance in order to achieve a standard quality of living along river banks. (Gumiero B, 16-19 June 2008).

2.3. Patna as a Riverine city

Ganga is the most sacred river of Hindus. It has been life-source to many communities, and hence, commonly called "Ganga Maa". The mother river has given birth to many cities, its proud progenies, of which Patna has always been prominent in terms of its history, religion, culture and commerce.

The Ganga river, like any other rivers of India, is gradually polluted. The capital city's fast urbanization, Patna, has not integrated natural ecological processes into its growth planning. As a consequence, rivers that used to be frequently worshiped by pilgrims play a less significant part in everyday social activities.

2.4. River edge growth pattern in Patna

Water is the city's lifeblood. For centuries, towns have thrived on large rivers that ensure water availability while addressing problems of production, trade, transportation and defence at the same time.

Bihar is one of the most widely inhabited states in India, with well over 850 people per square mile. The state also had one of the largest demographic development levels in the country in the late 21st millennium. Bihar is mainly rural, with the large bulk of the inhabitants residing in the fertile fields in compact or grouped settlements. The Kosi River harnessing has maintained settlement in its valley, while a heavily advanced irrigation scheme maintains a big population on the South Bihar Plain. The major cities in Bihar are Patna, Gaya, Bhagalpur, Muzaffarpur, Darbhanga, Munger, and Bihar Sharif.

3.0. CASE STUDY

3.1. CHEONG GYE CHEON RIVER RESTORATION PROJECT- Case Study 1

3.1.1. Introduction

Area: 605.6 sq. km

Population: 10.3 m

Catchment area: 61 sq. km

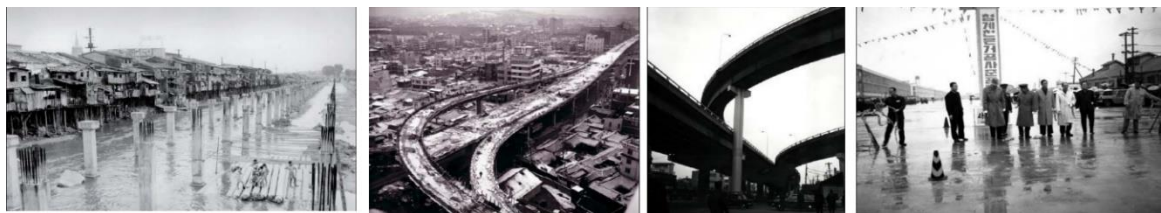
Length: 13.7 km, Width: 20-85 m

3.1.2. Overview

The City of Seoul is Korea's capital for 600 years and is changing from an autonomous, development-oriented urban landscape to one that values its people's quality of life and the importance of functioning ecosystems to a major paradigm shift. The highway was demolished in 2003 and the covered Cheonggye cheon stream has now been restored.

The Cheong gye cheon river restoration project has created ecological and recreational opportunities for the 3.6-mile corridor which is the centre of Seoul. It has helped in blooming the economic growth and development in the area which was languished for several decades in Seoul. The Cheong gye Plaza is a popular venue for culture and arts, and the stream passes under the 22 bridges before merging with the Hangang River. It has many attractions and is a popular spot for local people and tourists along its length.

3.1.3. History



The stream was covered with an elevated highway after the Korean War (1950-1953), as part of the country's post-war economic development. Became Korea's biggest commercial area with over 6,000 buildings, 100,000 small shops and 1,500 street vendors.

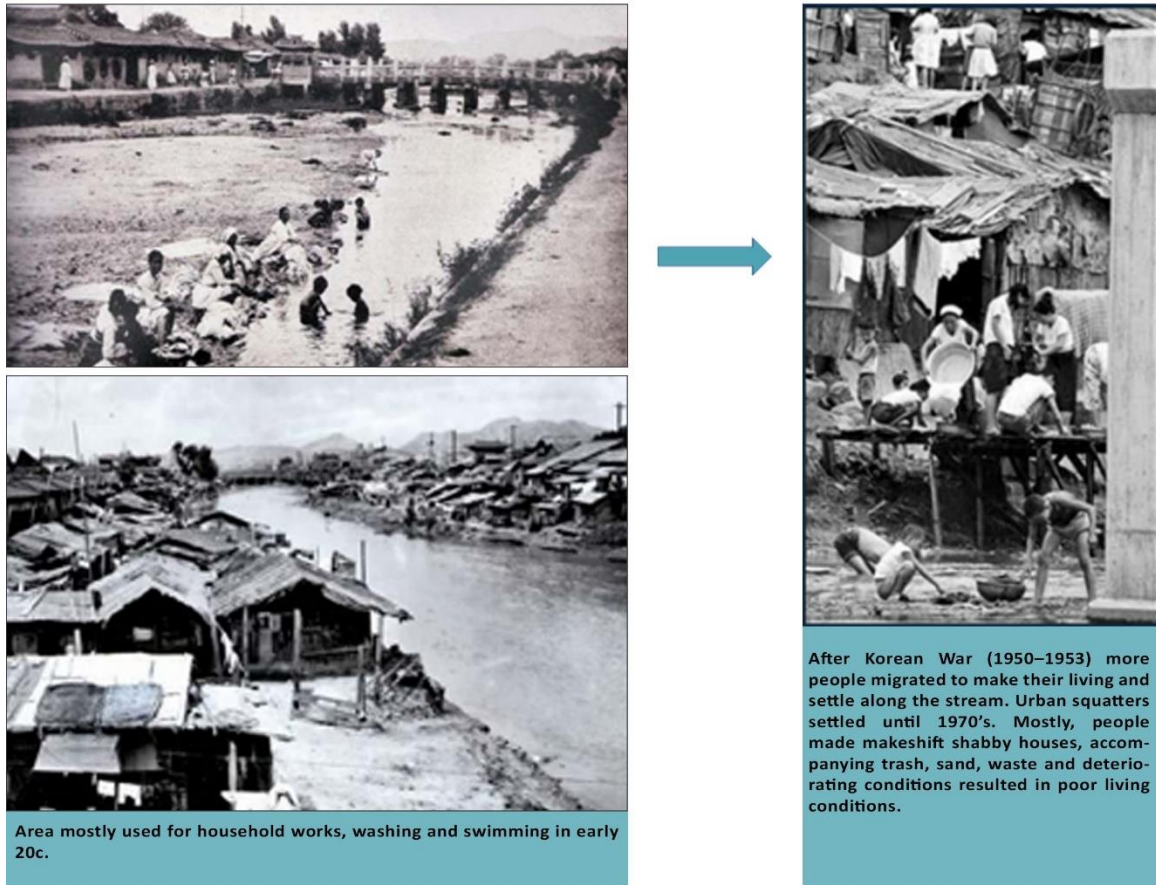


Figure 6. Stream condition before Riverfront development, Korea

3.1.5. DECISION TO RESTORE (2002)

- Urban management shifted to develop high quality living and create environmentally friendly city.
- Historic and cultural restoration.
- Downtown revitalisation, balanced regional development

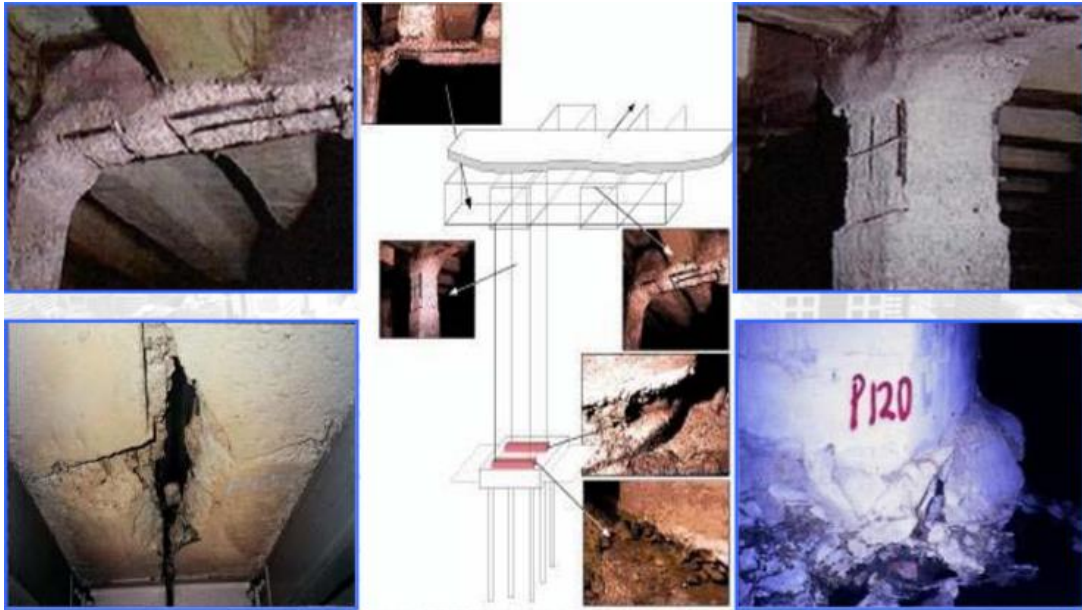


Figure 7. Bridge condition before Riverfront development, Korea

3.1.6. CHALLENGES FACED BY THE PROJECTS

Challenge 1- Transport

- Cheong gye Road & the highway was the major network for approx. 170,000 vehicles/day.
- Project was delayed due to the Cheong gye road and highway.
- Many media and interest groups warned about the major traffic congestion and problems related to the same.

Solutions

- Driving 4-wheelers was discouraged in the city centre by making it mandatory to leave car one out of ten days.
- In Cheong gye cheon area and Metropolitan area, the traffic system was improved by reducing the flow of personal vehicles and encouraging the use public transport; also allowing traffic flow in one-way streets.
- Different modes of public transport system like subway system and bus only lane was introduced.
- Permission to load/offload building materials for stores was given only at night to avoid any disturbance.

Challenge 2- Neighbouring Merchants

- Traffic congestion caused difficulty in doing business, by preventing accessibility to their shops and other business was difficult.
- Noise & dust due to demolition/construction caused decline in business.

Solutions

- Provide parking spaces and reduce parking fee.
- Financial support by providing low-interest loans and grants for the market remodelling and promoting stores.
- The City government purchased products for official use from the stores.
- Provide a business centre in an outer area and arranging special market place of 7,500 sqm. for street vendors.

3.1.7. CONSTRUCTION PROGRESS



Stage 1: Scaffolding construction (July 2003)



Stage 2: Highway demolition (August 2003)Stage



3: Covered rod demolition (January 2004)



Stage 4: Sewer, road and bridge construction (September 2004)

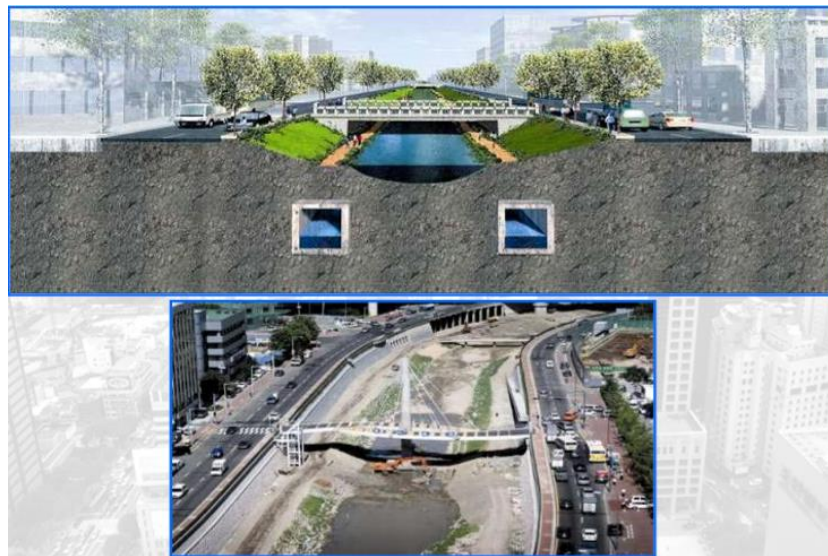


Figure 8. Construction phases of development, Korea

Stage 5: Landscape of the recovered Area (May 2005)

3.1.8. BRIDGE DESIGN

Design in order to minimize flow resistance and created as cultural places with artistic landmark.



Figure 9. Bridge Construction (no.22)

3.1.9. LANDSCAPE DESIGN

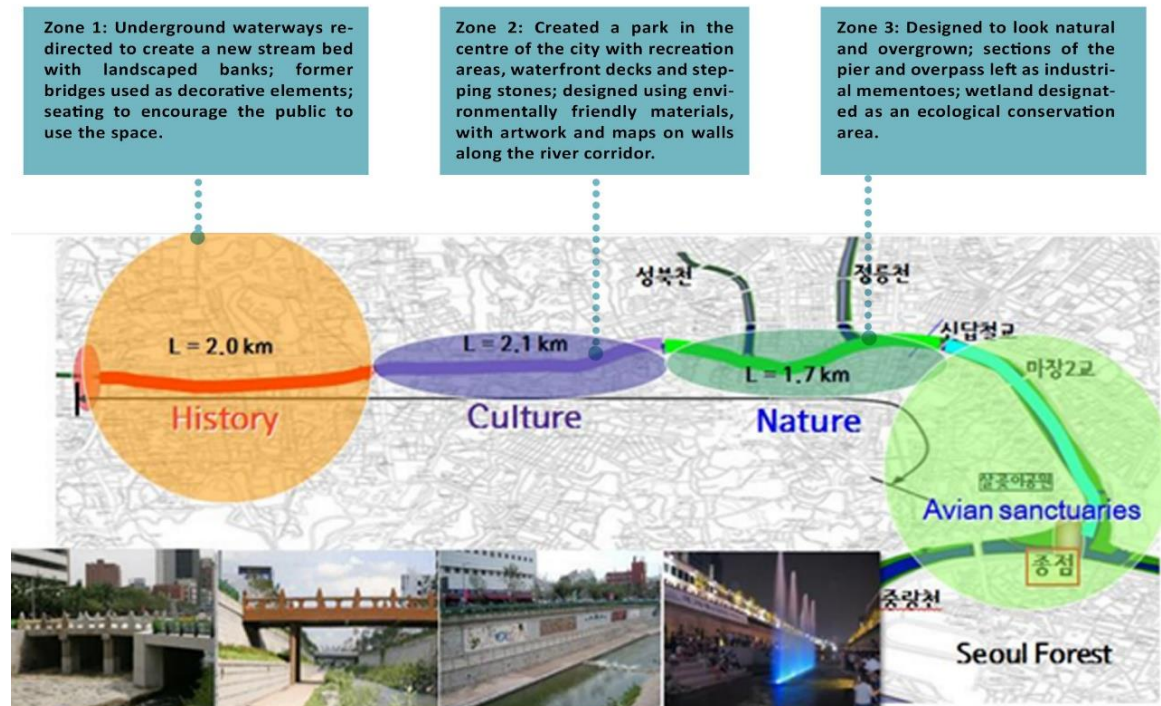


Figure 10. Design Concept

Concepts

- New waterside green belt: west to east.
- Gradual transformation from urban to natural landscape.
- Create ecological bio-top and environment. Scenic Water fountains and waterfalls were created to appeal the people.

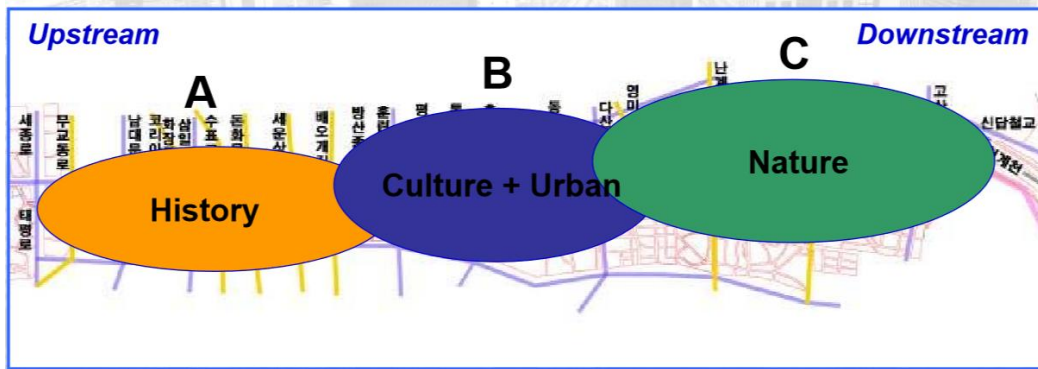


Figure 11. Design Concept

3.2. YATNWEIZHOU PARK, JINHUA CITY, CHINA- Case Study 2

3.2.1. Introduction

Location: Jinhua City, Zhejiang Province, China.

Size: 26 Hectares

Client: Jinhua Municipal Government

Design Firm: Turenscape

Completed: 2014

3.2.2. Site Introduction

The Jinhua city population consisting of at least one million, has 64 acres underdeveloped riparian wetland and Jinhua River which is formed by the convergence of Wuyi and Yiwu River,

The riparian wetlands beyond Yatnweizhou have been disrupted by opera house construction. The 100 meters wide rivers are inaccessible as they are divided into densely populated regions. The cultural facilities adjacent to Yatnweizhou are underutilized and sand mining has destroyed the remaining 20 ha riparian zone. Poplar tree (*Populous Canadensis*) and Chinese wingnut dominate the existing wetland and provide food and shelter for native avifauna.

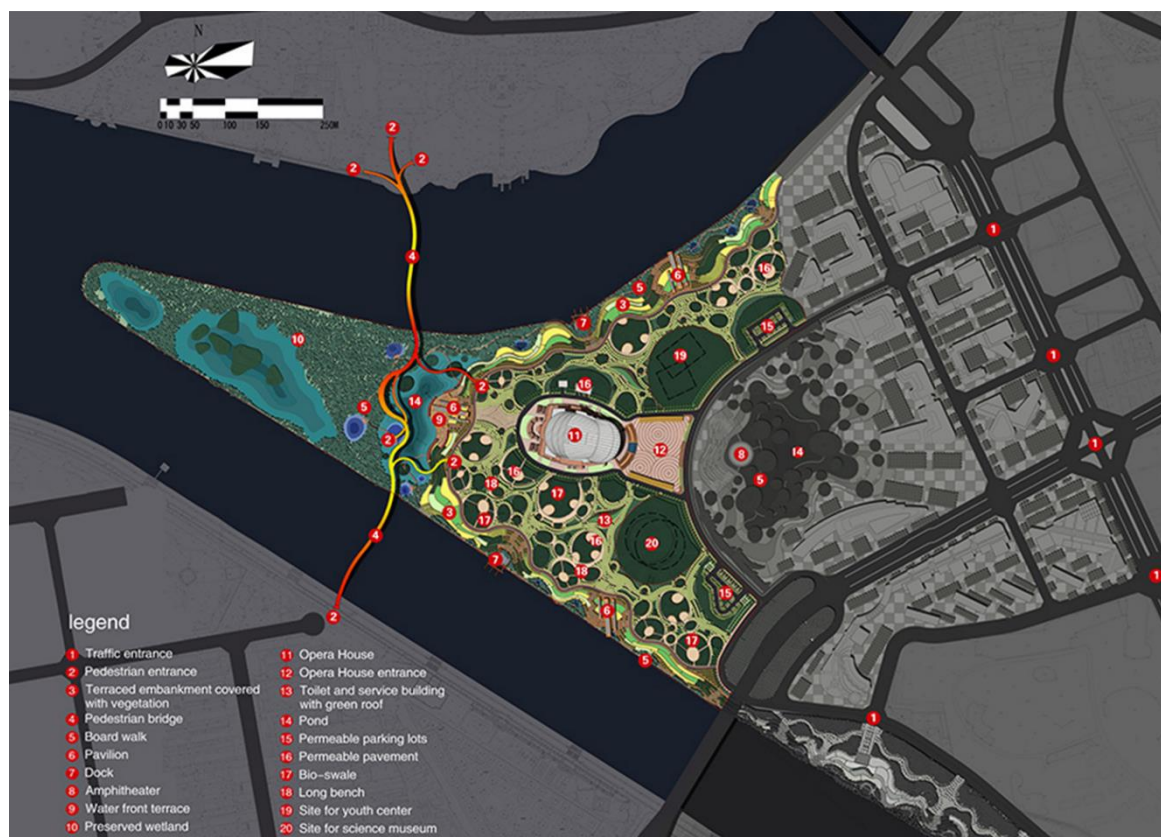


Figure 12. Master Plan of the Yatnweizhou Park

3.2.3. SITE CONDITIONS

The site conditions have four major challenges:

- How to preserve the rest of the riparian wetland habitat and provide the residents of the area with amenities?
- How to control flood in the area and what approach to use to avoid the same whether to provide high, concrete retaining wall or co-operation to allow the park to flood?
- How to design a landscape area by incorporating the existing building into the same to provide a unique experience to the visitors?
- How to connect the urban populated areas back to the natural riparian landscape to unify the communities and maintain the cultural identity of Jinhua City?



Figure 13. *Pre-existing site condition during 2011 and transformation after 2014*

3.2.4. RESILIENT LANDSCAPE DESIGN STRATEGIES

A.) Adaptive Habitat protection and Improvement tactics

Minimum interventions in existing riparian sand quarries

Preserve the micro climate and natural vegetation of the existing riparian zone with minimum intervention to allow the habitat to evolve over time. This is to be done by adding native species to the area to enrich and adapt to increase biodiversity.

Water Resilient Terrain and Planting Design

Annual flooding is serious problem during monsoon. The long-term strategies were to make concrete floodwall along the riverbanks and floodplains and acquire land

for development. By doing so, it severed the ties between the city and natural and ultimately exacerbating the destructive force of the annual floods.

B.) WATER RESILIENT TERRACED RIVER BANK EMBANKMENT

Following this formula, floodwalls would protect the wetland from the 20- 50-year floods creating dry land, but destroy the wetland ecosystem.

The landscape architect came up with a unique solution to harmonize with the flood by using cut-and-fill strategy to balance earthwork and water resilient embankment covered with flood adaptive native vegetation.

The design strategy employed is for only a small section compared the river embankment which is very long, this project showcases a resilient ecological solution to large scale flood management.

C.) WATER RESILIENT INLAND AREA

Another strategy used is to make the area permeable to create water resilient landscape with use of gravel obtained from the site for pedestrian areas. Permeable concrete pavement for vehicular roads and parking, circular bio swales with tree planters and inner pond which improves the water quality by allowing water to pass through gravel layers



Figure 14. Seasonal Variation of the Site

During the dry season, with grasses covering the terraces on the embankment; during the monsoon season with uninterrupted connection of the city through the bridge.



Dry season



Flood season

Figure 15. The flood-adapted boardwalk integrates the path system with the terraces. This path affords visitors an intimate naturalistic experience over the riparian vegetation.

D.) RESILIENT PEDESTRIAN BRIDGE

Connecting cultural identity

A pedestrian bridge snakes across the two rivers, linking the parks along the riverbanks in both the southern and northern districts, connecting the city with the newly constructed Yanweizhou Park within the river.

The bridge design was inspired by the local tradition of dragon dancing during the Spring Festival. For this celebration many families bind their wooden benches together to create a long and colourful dragon that winds through the fields and along narrow dirt paths. The Bench Dragon is flexible in length and form as people join or leave the celebration. The dragon bends and twists according to the force of human flow. Like the bench dragon in the annual celebration the Bench Dragon

Bridge symbolises not only a form of celebration practiced in Jinhua area, but is bond that strengthens a cultural and social identity that is unique to this area.

Flood Resilient Bridge

The new bridge is elevated above the 200-year flood level, while the ramps connecting the riparian wetland park can be submerged during the 20 years and larger floods. Floodwaters cover the park for a very short period of time. The bridge also hovers above the preserved patch of riparian wetland and allows visitors an intimate connection to the nature within the city.

Flexible across for Residents

The many ramps to the bridge create flexible and easy access for residents from various locations of the city in adaptation to the flow of people. The bridge was designed to reinforce the festive, vernacular tradition, but also an art form with a bold and colourful combination of bright red and yellow ones that are strengthened by night lighting. All together 700m long, the bridge is composed of steel structure with fiberglass handrails and bamboo paving. The main bridge is five meters wide, with four meters wide Ramps. This Bridge is officially named Bayong Bridge (Bridge of Eight Chants), after famous poems written in ancient times about landscapes surrounding the site. It is truly a resilient bridge that is adaptive to river currents and the flow of people while binding city and nature, future and past.

E.) RESILIENT SPACE FOR A DYNAMIC EXPERIENCE

The large oval opera house (designed by the Zhejiang Architecture Institute) posed significant challenges for the Landscape Architect. First the building shape tends to repel rather than embrace the user and landscape. Finally, the designers were challenged with the problem of how to integrate the singular flood proof big object into the floodable, riparian waterfront. The design uses curve as the basic languages, including the curvilinear bridge, terraces and planting beds, concentric paving bands of black and white, and meandering paths that defines circular and oval planting areas and activity spaces. The dynamic ground of the pavement and planting patterns define circular bio swales and planting beds, densely planted with native trees and bamboo, bound by long benches made of fiberglass. The circular bio swale and planting patches resemble raindrop ripples on the river. These curves and circles are the unifying pattern language that integrates the building and the environment into a harmonious whole. The reverse curves simultaneously refer to the shape and scale of the building while forming a contrasting shape that is human in scale and enclosed for more intimate gatherings. They also reflect the weaving of the dynamic fluxes of currents, people and material objects that together create a lively pleasant and functional space.

4.0. SITE DOCUMENTATION & ANALYSIS

4.1. Geology

Ganga ghats are component of the Indo-Gangetic alluvium, one of India's three primary physiographical divisions, separating extra-peninsular areas on the west from the continental area on the west. Since the Middle Pleistocene times, the flat plain is considered to result from a granular filling of a huge depression with alluvial deposits.

This forming a part of the flood plains of the Ganga. The landform has a monotonously flat relief with elevation. The western part of the district is sloping due north and north-east, with elevation of the land surface varying from 68 m in the south to 48 m in the north, and from 67 m in the west to 45 m in the east. A notable geomorphic feature is the strong natural levee formation or upland all along the southern bank of the Ganga which acts as a natural barrier thereby causing many of the streams flowing from south to run parallel to the course of Ganga before finally joining it further east of the district boundary.

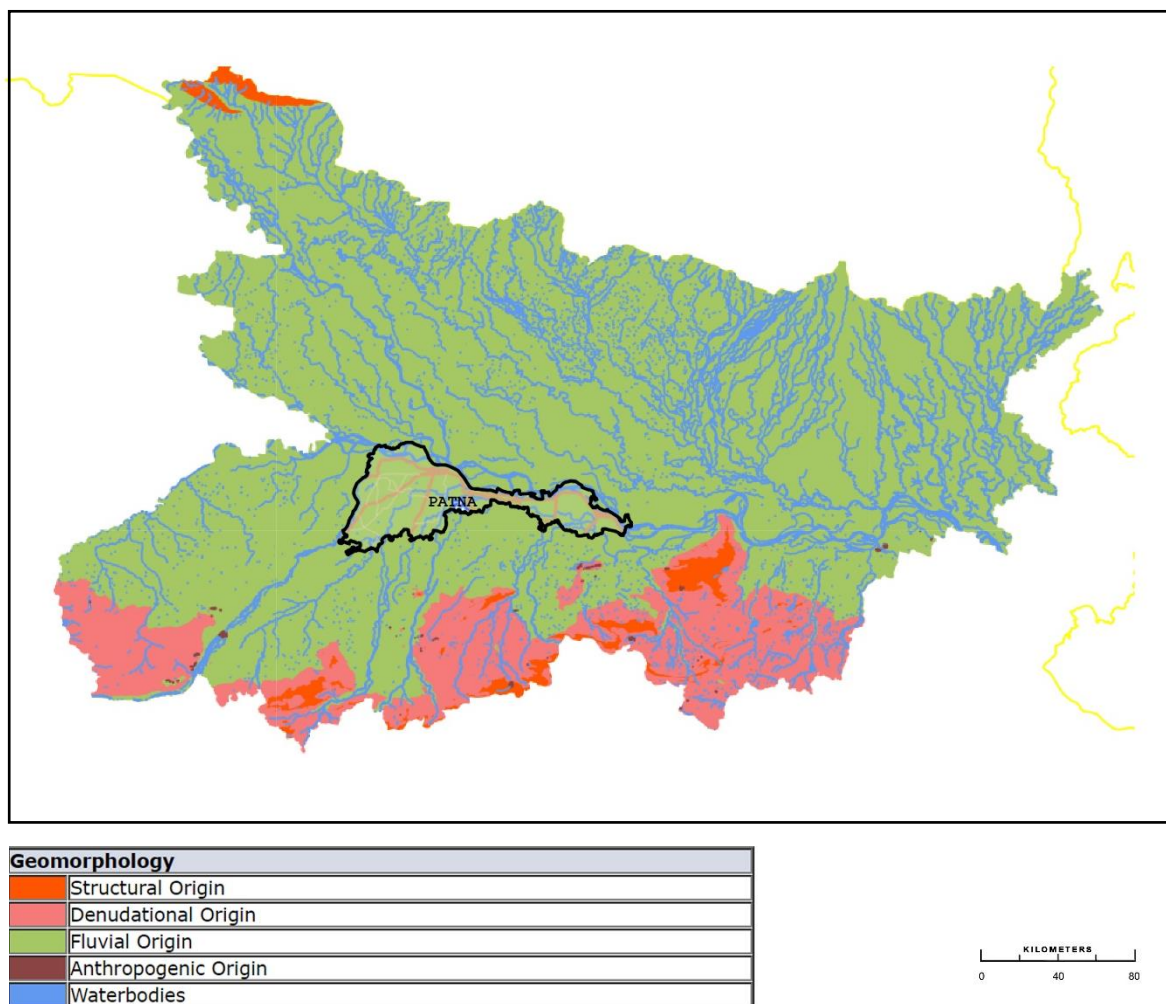


Figure 16. Geomorphological map of Bihar

Source: Bhuvan map

The primary geo-morphology of Patna is fluvial origin mostly (almost 89 percent of the total area), denudational and structural origin is (11 percent of the total area).

Fluvial origin- The landforms created as a result of degradational action (erosion) or aggradation work (deposition) of running water is called fluvial landforms. Fluvial process, the physical interaction of flowing water and the natural channels of rivers and streams. Such processes play an essential and conspicuous role in the denudation of land surfaces and the transport of rock detritus from higher to lower levels.

Denudational origin- Denudation is an erosive process of breaking and removing the rocks from the surface of the earth. It is a wearing away of terrestrial land by weathering, erosion, moving water.

Structural origin- Structural landform, any topographic feature formed by the differential wearing away of rocks and the deposition of the resulting debris under the influence of exogenetic geomorphic forces. Such forces operate at the interface of the planetary atmosphere, lithosphere, cryosphere, and hydrosphere. The processes generating these forces are the major agents of erosion, transport, and deposition of debris. They include fluvial, eolian, glacial, groundwater, and coastal-marine processes, as well as those associated with mass movement.

4.2. Soils

The Soil of this region are predominantly sandy loam with clay loam at places with low to medium nutrient status. It is generally alkaline with pH value ranging from 6.3 to 8.2. Traditionally soils in an area are classified on the basis of mode of deposition. Soils are divided into three groups

- (i) Recent alluvium (ii) Tal and (iii) Older alluvium.

The soils of the region have developed on alluvial deposits transported from relatively younger geological formations where physical weathering is predominant and the soils developed in them are generally coarser in texture.

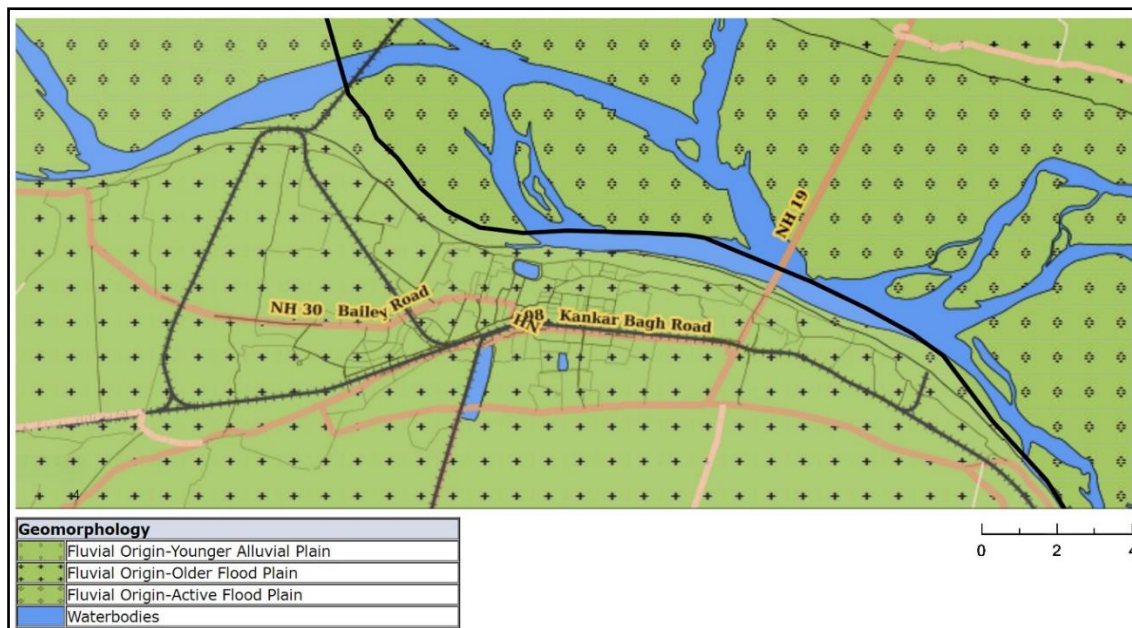


Figure 17. Geomorphological map of Patna
Source: Bhuvan map

4.3. Physiography and Relief

The city of Patna lies virtually in the heart of the South Bihar Plain. It is a part of the alluvial flood plain of the Ganga, and is surrounded by river Punpun in the south and the Sone in the west. The area presents the typical physiographic and relief characteristics of the Indo Gangetic plain of the North India. Structurally, the plain is the foredeep of the Himalayas covered by the alluvial deposits. The foredeep was believed to be created by the rise of the Himalayas and filled in by river alluvium in due course. The superficial alluvial deposits are resting on the continental shelf of the sea, which has been receding ever since the Tertiary period of geological history, leaving behind layers of marine and estuarine sediments. They now lie buried under the thick mantle of alluvial deposits.

Physio graphically, the city of Patna lies within the South Bihar Plain, the part of Ganga basin lying towards south of the river Ganga. The areas of Patna, surrounded by three important rivers the Ganga, the Sone and the Punpun is a part of Magadh Plain, which is incidentally the middle unit of the South Bihar Plain. The whole region of Magadh Plain is almost a synonym of a homogenous level, seemingly featureless plain from one end to the other.

The entire land is characterized by the monotony of relief. Towards southern edges of the city low lying areas exist as a result of gradual decline of the slope. These low-lying areas, commonly known as the 'Jallas' are permanently water logged. Towards the south of the narrow strip of land of the Ganga levee, lies the tree-less vast plain low land, locally known as 'Taal'. The Taal area extends eastward practically from the southern stretch of the Patna urban agglomeration. Taal is rather a peculiar physiographic feature of the Patna district, perhaps marking the old bed of the river Son that used to meet the Ganga on the eastern side of present-day Patna. Singh (1966), in his article on the effect of changing river courses on the development of urban centres, takes the e.g. of ancient Patna and with help of multiple

sketches, have tried to depict the changing nature of the river's vis-a-vis the development of Patna. Studying those sketches as reproduced in Fig. 2.3, will elucidate how the present day Taal area was created, on the old river bed of the Son, which has subsequently shifted westwards, thus giving a saucer like shape to the city of Patna.

Nearly entire plain land of the study area has broad alluvial soil cover. Alluviums are divisible into 'Khadar' and 'Bhangar' thorough out the Indo Gangetic plain. The former, newer in age, covers the flood plains in the vicinity of rivers and also the old beds, and is replenished annually by new deposits. They mostly consist of fine silts, but at times sandy as well. The Bhangar is the older alluvium, which generally covers the upper tracts beyond the annual flood limit in the valley flats. These soils grade from sandy to clayey loam, but are often heavier with higher clay factor in depressions.

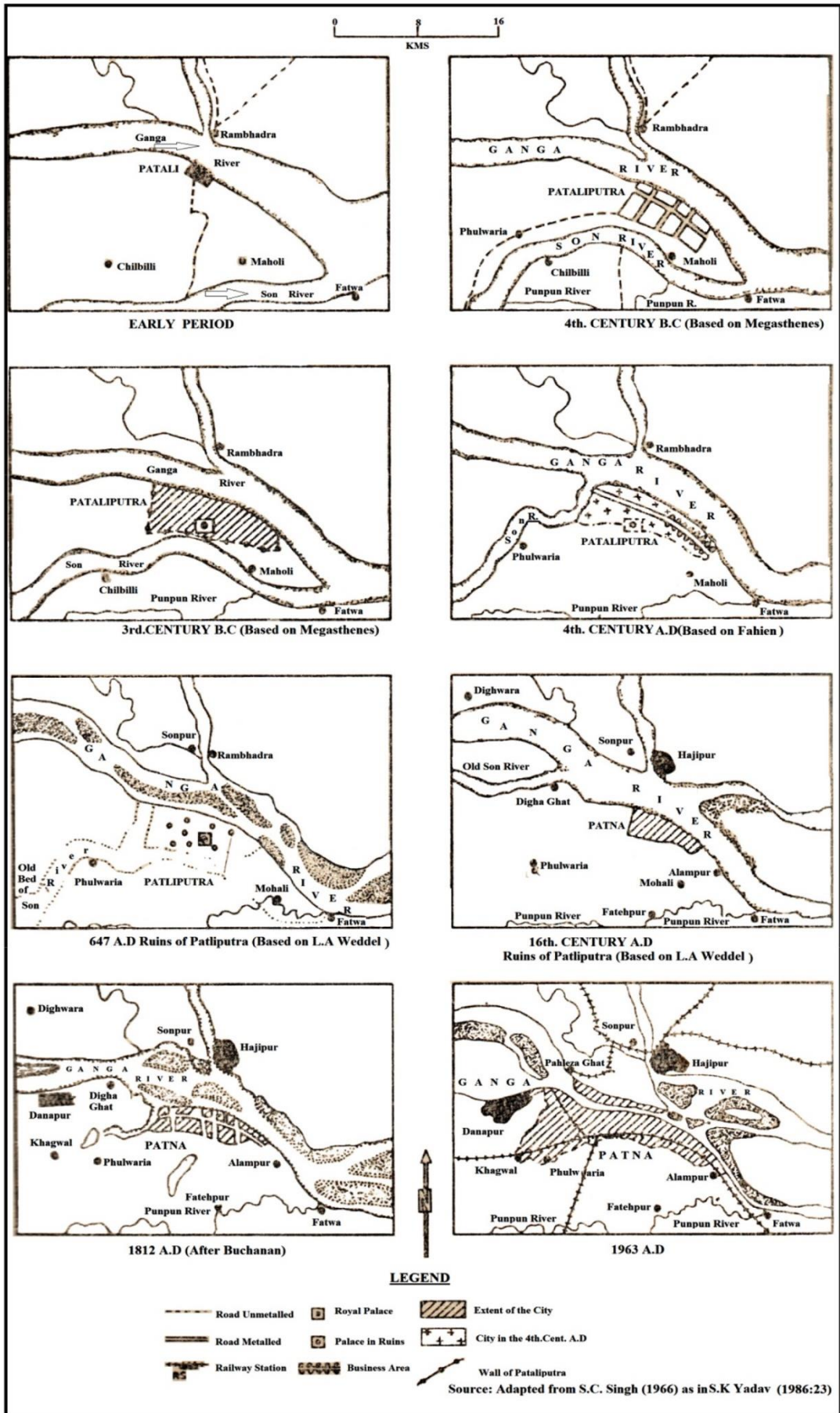


Figure 18. Changing Course of River Son & Its effect On Patna's Topography

4.4. Slope



Figure 19. Slope Analysis map of Study area, Patna

Source: Self-generated in GIS

Patna is located on the southern bank of the river Ganga and in the eastern part of India. The exact cartographic co-ordinates of Patna city are 25.6°N 85.1°E. It has an average elevation of 53 m. A characteristic feature of the geography of Patna is at the confluence of rivers. The topography of Patna is saucer shaped as per Patna City Development Plan prepared in the year 2006.

The city of Patna is situated on the older fluvial deposition at elevation and near the city-edge the land is sloping towards the river.

4.5. Climate

The area under the city of Patna represents the typical climatic conditions of the Gangetic Plains of Bihar. In general, it has a humid sub-tropical climate with hot summers and mild winters; Patna is in Cwa region according to Koppen's climate classification. Although the region has a somewhat continental interior location within the subtropical climatic belt, the monsoon reigns supreme here (Singh, 1992:198). Cwa according to Koppen's classification stands for 'Humid subtropical climates', which is abundant in India along the river Ganga.

Patna falls under the humid subtropical climate; however, it is different from the rest of the northern hemisphere. Winters, over here is typically mild, dry and relatively short. Summers tend to be long and very hot, starting from April and peaking in May and early June. In June temperatures often exceeding 40 °C which is extremely dry, complete with dust storms, and hot winds. During this period, many native trees shed their leaves to save water. This is followed by the cooler monsoons; Patna experiences heavy rains on almost a daily basis. Average high temperatures decrease during the monsoon season but the humidity increases. Which results in hot and humid conditions, similar to summers in other humid subtropical climates.

Average Minimum and Maximum Temperature Over the Year

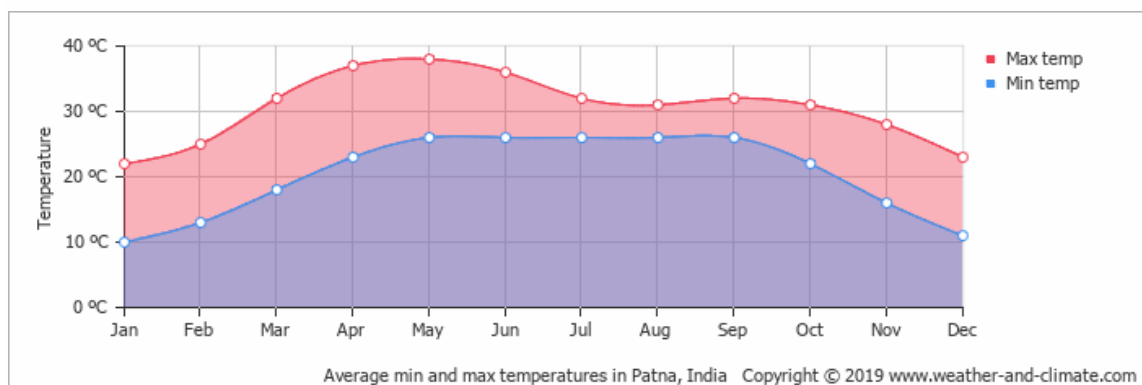


Figure 20. Average minimum and maximum temperature data of Patna

The summer seasons in Patna prevails from mid-March to mid-June, as the temperatures tend to increase by the end of February and practically by March. Summer is the season of continuously rising temperature accompanied by falling humidity and pressure. Peak average maximum temperature ranges between 35° C to 37° C during the month of April-May. Occasionally the temperature rises up to 40° C or so.

Average Wind Speed Over the Year

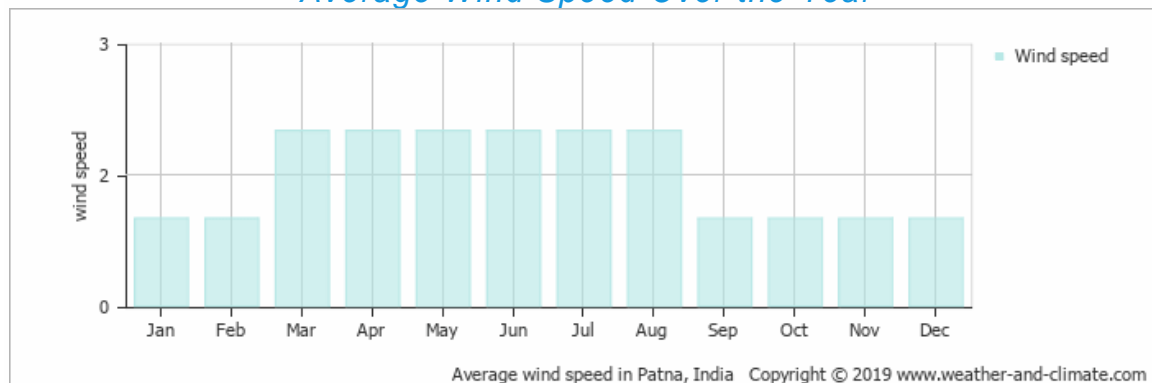


Figure 21. Average Wind Speed data of Patna

Source: Climate Dept.

During this hot season, the weather conditions over Patna remain dry, interrupted by high velocity winds and occasional thunder storms. These dusty thunder storms take place generally in afternoons due to local heating or under the impact of north-westers. These storms are the chief sources of pre monsoon rains over the plain areas, resulting in sudden decrease of temperature giving some respite from the scorching heat. At times they also bring hail storms.

Average Monthly Precipitation Over the Year (Rainfall, Snow)

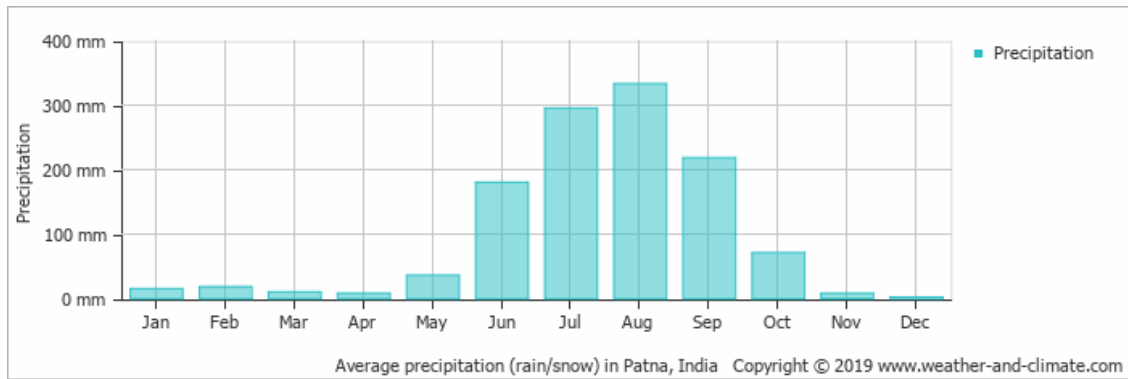


Figure 22. Average Monthly Precipitation Data of Patna

Source: Climate Dept.

The season of general rainfall starts by the mid-June over Patna with the cloud burst of the south-west monsoon. The advent of the monsoon is occasioned by almost a sudden rise of relative humidity to over 70%, a sudden fall in the temperature generally by 5°C to 8°C and sudden change of wind direction from west and north-west to east and south east. The mean June temperature at Patna drops to 29.7°C in July and 29.2°C in August from 32.9°C. The summer monsoon season provides about 85% of the annual rainfall over the South Bihar plain area. The south west monsoon gradually retreats from the region by the end of September and the beginning of October. October however remains a sticky and sultry month with a relatively clear sky, higher level of humidity and moderate temperature.

Average Humidity Over the Year

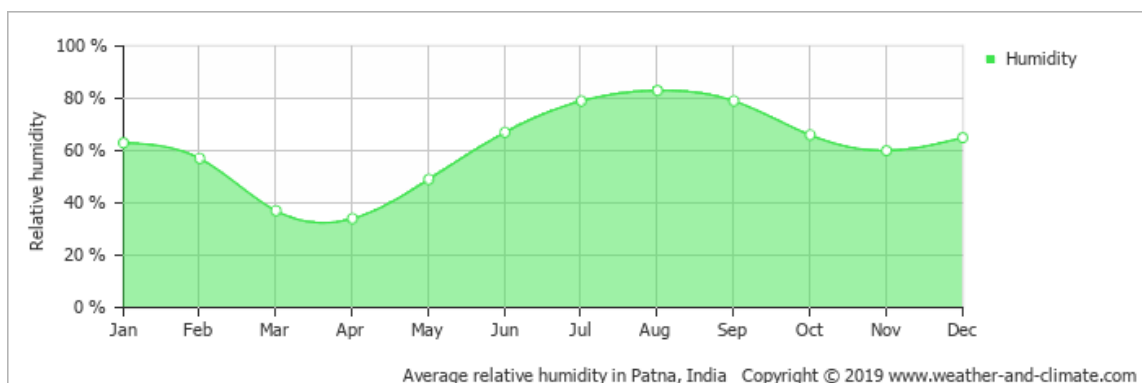


Figure 23. Average Humidity data of Patna

Source: Climate Dept.

By November the cool weather sets in, with a marked fall in both temperature and relative humidity. The humid easterly winds are replaced by the dry north westerly or westerly winds. The weather conditions become colder in the last quarter of December and January is the typical winter month in this part of the South Bihar Plain. Winter comes to its peak in early January, when sometimes the mercury drops down to as low as 4°C in Patna especially under the influence of cold waves. These cold spells often cause cloudiness and light rains due to the shallow but extensive Western Depression.

Though the study area receives the bulk of rainfall during the south west monsoon period, rains however occur in all seasons with variable amounts. The annual rainfall of Patna ranges between 900 to 1200 mm. July happens to be the wettest and November driest month. The following figure 2.4 presents the monthly rainfall and temperature figures of Patna.

4.6. Land Use

Patna has grown as a trade and business centre in the last ten-fifteen years and is experiencing fast migration from the immediate hinterland and various parts of Bihar State. It led in fast urbanization becoming outgrowths of Patna City in neighbouring regions of Patna Municipal Area. In the lack of planning interventions since 1981, fast growth has resulted in haphazard development in the town of Patna. Which resulted into degradation of open space and forest area (only 2.34 sq.m. per capita), uncontrolled and unregulated construction activities and brick Kilns and sand mining along the riverbed of Ganga, formation of slum and unregulated construction within core city.

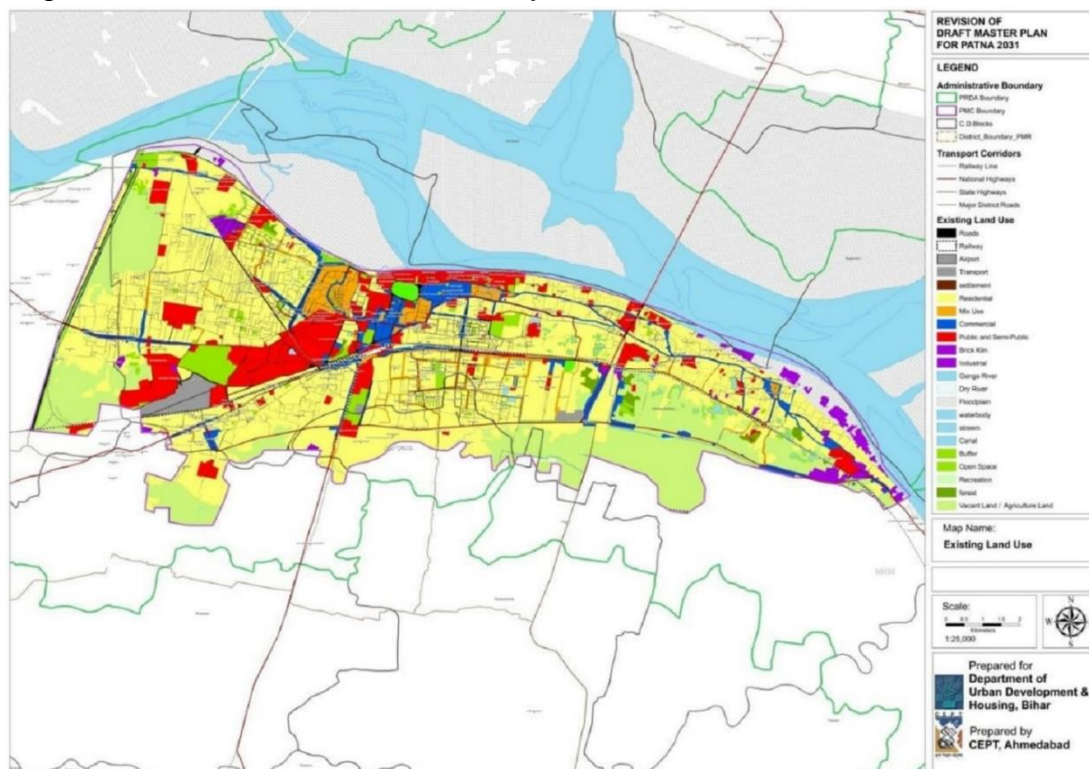


Figure 24. Existing Land-use Map of Patna Municipal Corporation Area

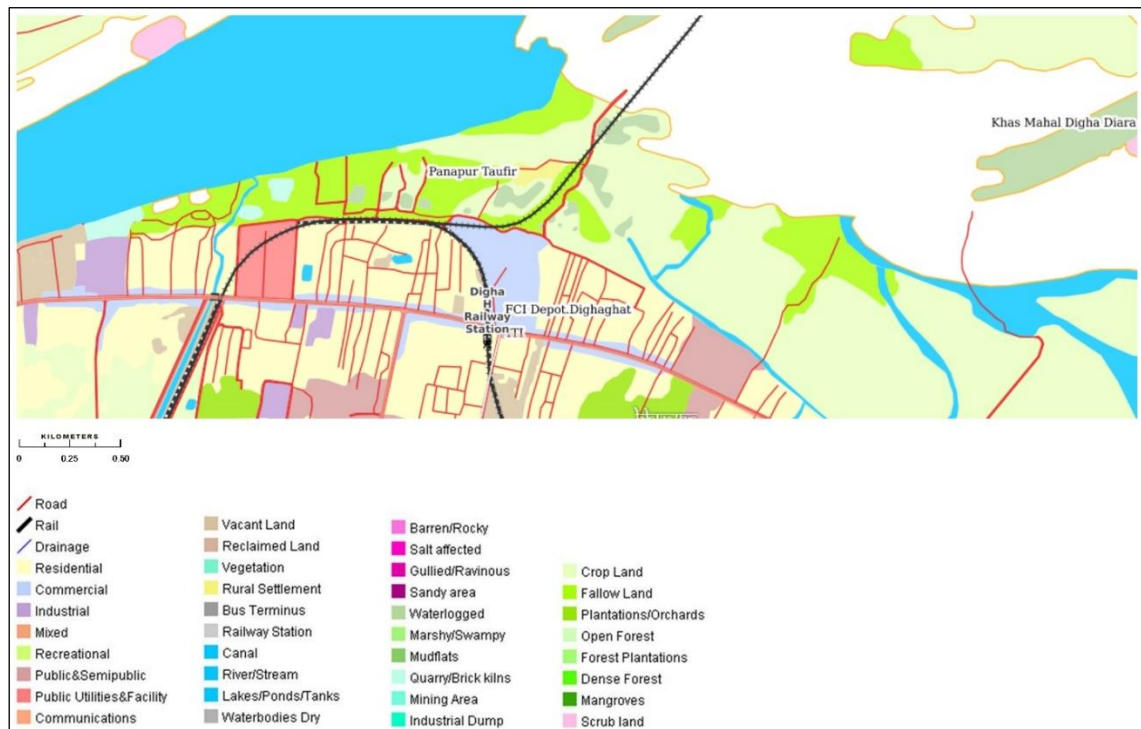


Figure 25. Land-use and Land-cover Map of Study Area, Patna

Source: Bhuvan

The states come under the Ganga basin and this region is widely grown, making up about 40 percent of India's complete region. Approximately 14 percent of the land is not eligible for agriculture and is used for multiple non-agricultural purposes. Although the entire sown region covers 50 per cent of the Ganga basin states area, the total cropped area & cultivable land constitutes 73 per cent & 65 percent of the basin states area, respectively.

4.7. Economy

According to the 2001 survey, Bihar is predominantly an agrarian state with about 90 percent of the inhabitants residing in rural regions. Bihar is a wealthy agrarian region that is traversed by the Ganges River. Bihar can readily be defined as a fertile alluvial plain occupying the Gangetic Valley. The plain stretches from the northern foothills of the Himalayas to a few miles south of the Ganges River as it passes from west to east through the state. Rich agriculture and beautiful groves spread throughout the state.

Bihar grows Kharif and Rabi plants and rice, bajra, corn, jowar, sugarcane, tur, potato and seeds are the main agrarian goods. The primary cash crops of Bihar are sugarcane, potato, tobacco, petroleum seeds, garlic, jute and mesta. Kharif and rabi food grains constitute 64 and 36 percent of the total production of food grains in the State, respectively. The fruits are: mangoes, banana, jack fruit and litchis. This is one of the very few areas outside China which produces litchi in

abundance. Despite its agricultural wealth, Bihar is India's poorest State, with high illiteracy and infant mortality rates.

The rivers of Bihar make the water available for irrigation purpose and also help in generating the hydro-thermal energy for the State. Apart from this they provide a medium for water transport, provide fishes for fishery industry and enrich the natural resources of state in many other ways.

4.8. Demographic Characteristics of Bihar

According to census in 2001, Bihar has a population of 82,878,796 persons with approx. area of 94,163 sq kms. Up until 1991 census was the second most populous state after Uttar Pradesh. But after its bifurcation and creation of Jharkhand, it slipped down to third, after U.P and Maharashtra.

The sex ratio in Bihar is lower than in the rest of India as a whole. As per census in 2001 the no. of literate persons is 31,675,607, with 20978955 are males and 10696652 females among total literate. This data figure show that male literacy rate is almost double than the female literacy rate, with having 2 literate male for every 1 female with males greatly outnumbering females.

With 497 compared with 273 persons per sq km, the population density is much higher in Bihar than compared to other parts of India. Bihar has been going a very slow rate of urbanisation (13%) compared to whole of India.

Demographic Characteristics of Bihar vis-a vis India, 2001.

Characteristics	India	Bihar
Population (2001)- Total	1,027,015,247	82,878,796
Rural	741,660,293	74,199,596
Urban	285,354,954	8,679,200
Percentage Decadal Growth Rate	21.34	28.43
Literacy Rate		
Persons	65.3	47.5
Male	75.8	60.3
Female	54.1	33.5

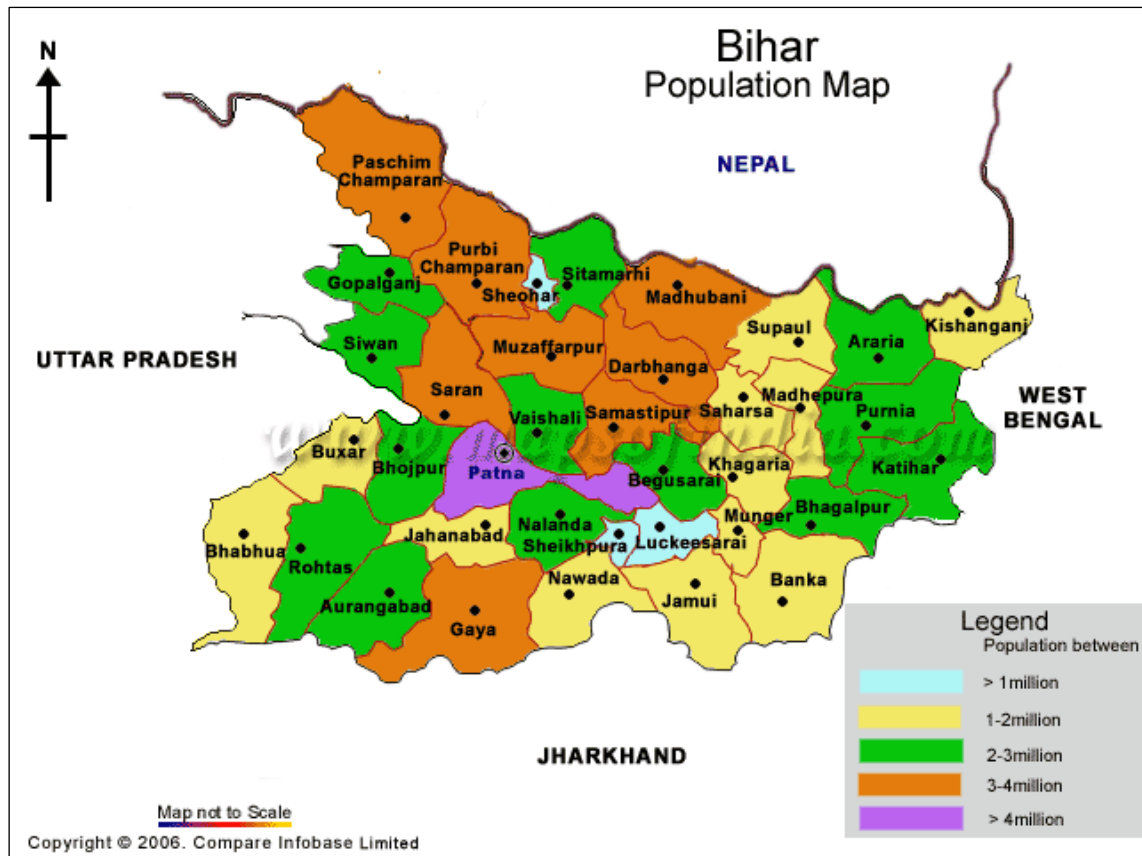
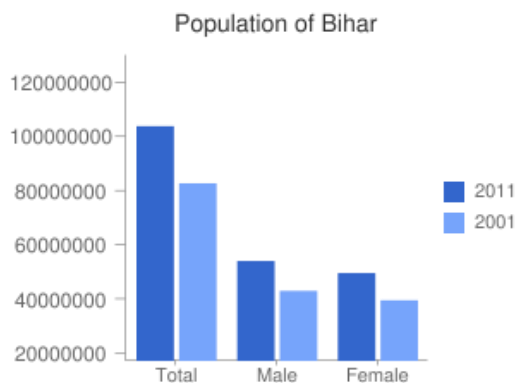


Figure 26. Population Map of Bihar

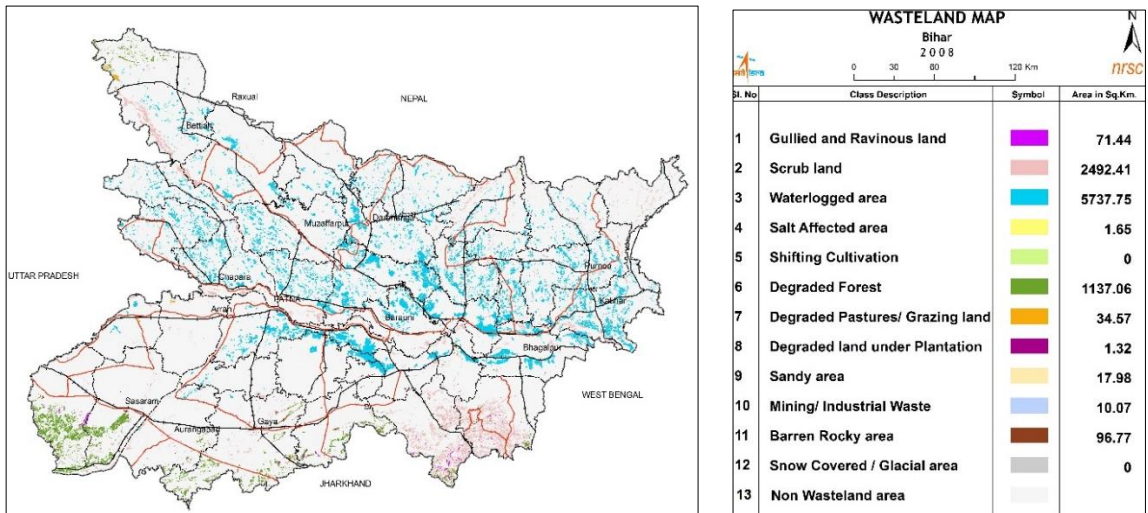
Source: Infobase LTD.



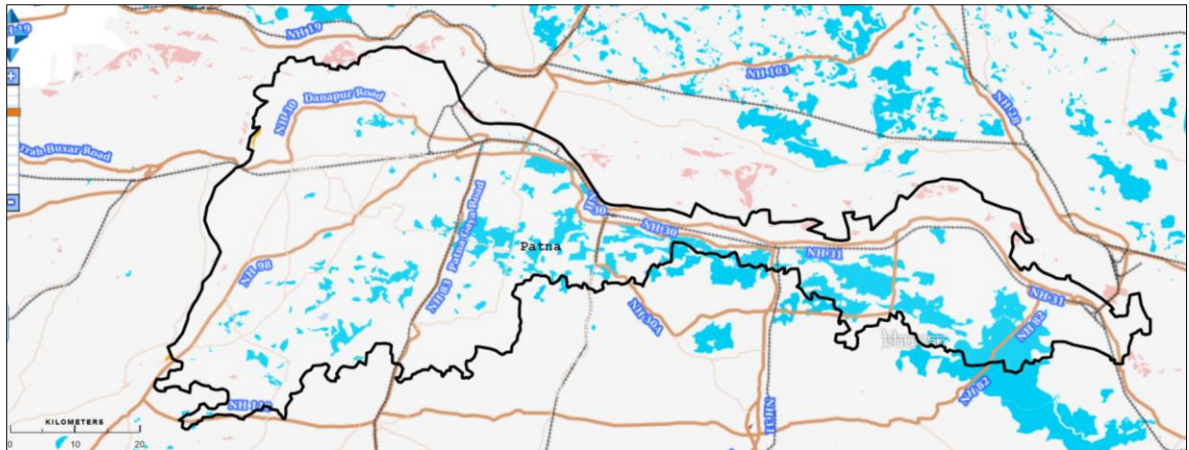
4.9. Wasteland Study

The term wasteland means low-quality land from an agricultural point of view, often referred to as degraded land. According to National Wastelands Development Board, waste land is defined as "degraded land that can be brought under vegetative cover' with reasonable effort and which is currently under-utilized and land which is deteriorating due to lack of appropriate water and soil management or on account of natural causes".

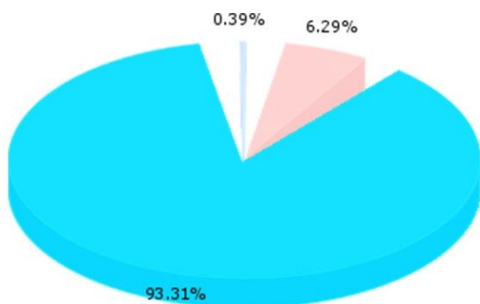
Wasteland Map of Bihar



Wasteland Map of Patna



Wasteland Information (2008-09) for Patna
Total Geographical Area : 453.54 Sq. Km



Wasteland Information (2008-09) for Bihar
Total Geographical Area : 9601.01 Sq. Km

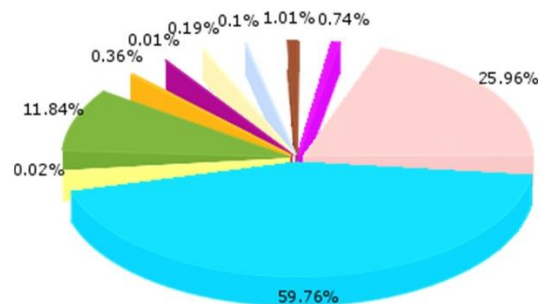


Figure 27. Waste Land data of Patna and Bihar

Source: Bhuvan

Scrub Land

These areas possess shallow and skeletal soils, at times degraded, extremes of slopes, severely eroded and lands subjected to excessive aridity with scrubs dominating the landscape. They have a tendency for intermixing with cropped areas. They appear in light yellow to brown to greenish blue depending on the surface moisture cover and vary in size from small to large having either contiguous or dispersed pattern. The vegetal cover on scrub lands may be dense or sparse.

Waterlogged Area

Waterlogged land is that land where the water is at/or near the surface and water stands for most of the year. These lands are distinctly seen in light to dark blue tone of varying size and shapes on satellite image. By virtue of their location in flood plains, coastal tidal flats, lagoons and river plains, these can be delineated with good accuracy. Subtle variations in tones depending on the presence of aquatic vegetation, irregularity in shape, textural behaviour of the vegetation – smooth or mottled depending on the duration of waterlogging may sometimes share common spectral properties with that of crops. The duration of water logging may be for less than 6 months to more than 6 months in a year.

4.10. Hydrology

The Ganga is a trans-boundary river of Asia which flows through the nations of India and Bangladesh. The 2,525 km (1,569 mi) river rises in the western Himalayas in the Indian state of Uttarakhand, and flows south and east through the Gangetic Plain of North India into Bangladesh, where it empties into the Bay of Bengal. It is the third largest river in the world by discharge.

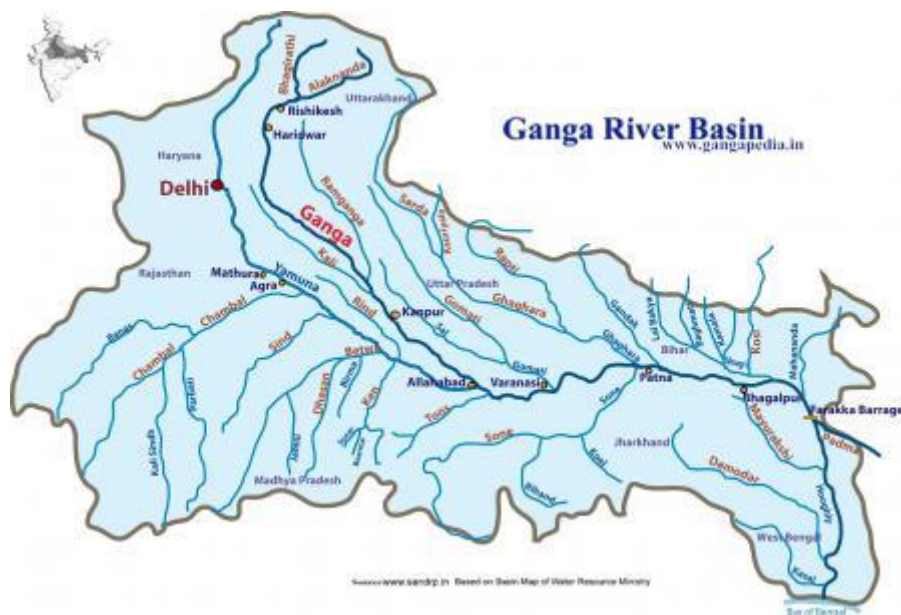


Figure 28. Ganga River Basin Map

Source: Water Dept.

The drainage pattern of Bihar is trellis and dendritic due to physical condition. The Rivers of Bihar flow through alluvial deposits where slope is very small, forming wide flood plains but the catchment area of these rivers is large.

Ganga is the main river of Bihar that enters into the state from Chausa which formed the boundary of Bhojpur and Saran district.

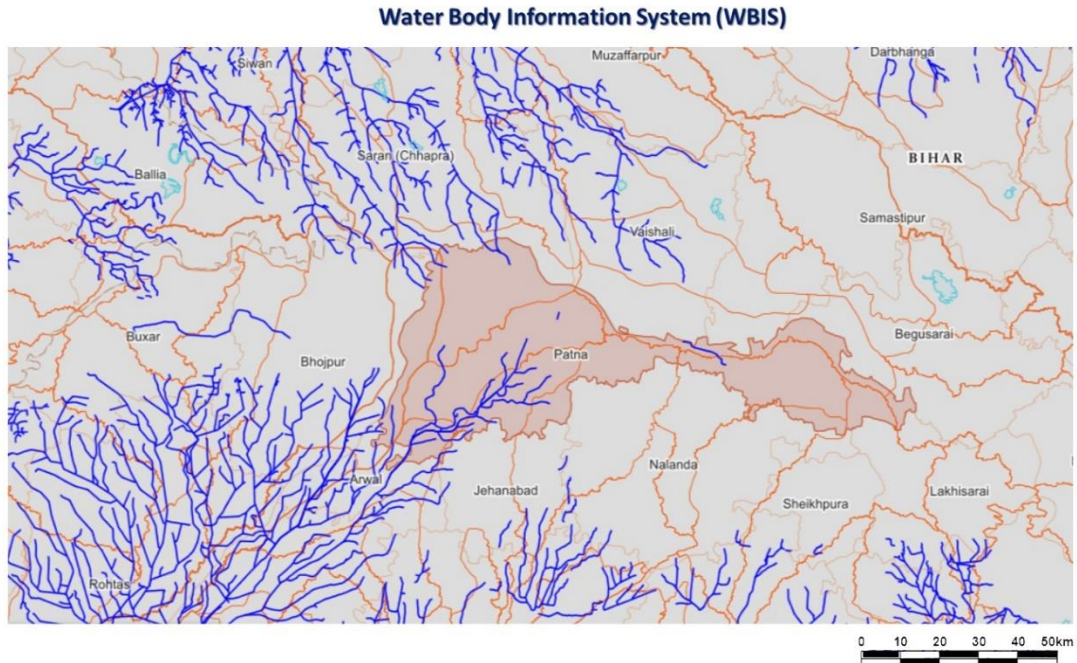


Figure 30. Drainage Map of Study Area, Digha, Patna

Source: Bhuvan

The project area is mostly falling under the river basin of Ganga and sub basins of Punpun, Gandhak and Burhi-Gandak-Bagmati river basins. The Digha ghat or Janardhan ghat is situated at the southern edge of the river ganga. There are two nallahs flowing along the east and west edge of the which drains into the river.



Figure 29. Nallahs within the site area, Digha, Patna

Source: Self-generated map in GIS

4.11. Activity Analysis

On the basis of activities, the site can be classified into different categories:

1. Recreational – Boating, bird watching, photography, morning walk etc.
2. *Cultural/Religious* – Bathing, performing rituals, Murti visarjan etc.
3. *Livelihood/ Economical* – Fishing, sand mining, brick manufacturing, vegetable farming, etc.

1. Recreational Activity

Boating

The primary activity of the site (Digha Ghat) is boating which connects Patna to the other cities across river. Historically, this ghat was used as a major port for transport, export and import. Even now, the port is used very frequently. Approximately 450-600 people commute regularly on a daily basis. The users mostly comprise of students, employees and people who come to Patna for amenities.



Figure 30. People commuting by boat

Source: Self clicked

Even though the J.P. Setu connects Patna to Sonpur, most people still prefer to cross Ganga River by boat. Per boat capacity is approx. 80 people and it takes approx. 1 hour to fill one boat and 10-20 minute to reach to other end (as per the survey).

Digha ghat being a very important port which connects the northern Ganga-edge to southern edge (Patna), needs to be maintained properly. As of now there is distinctive dock for people to wait for boats for commute. The edges are very accident prone as the soil bed becomes wet and clayey; it becomes very inconvenient for people to reach boats. The edge needs to be designed to cater such important activity.

Fishing

Fishing is another economic activity in these areas, as of now very less fishing activity has been observed as it comes under Gangetic Dolphin's zone. Since, looking at the reducing number of fishes was observed on which Dolphins feed; fishing is prohibited at this Digha-ghat. Although illegal fishing is being carried out by some fisherman, but it needs to be restricted through policies in order to save endangered species (Ganga Dolphins)



*Figure 31. Fishing in Ganga river
Source: Self clicked*

Others

Secondary recreational activities include morning walk, evening walk, dolphin watching, bird watching, photography, film shooting, etc. Since this is the largest ghat of Patna and the edges provide the widest view of the river and the city in the skyline. Also, Digha is famous for its scenic view point which is located at an elevated area from where one can get the scenic view.



Figure 32. Recreational Activities along Digha Ghat

Source: Self clicked

The Ganga River is home for many flora and fauna, such as Gangetic dolphins, various species of fishes, spot shelled turtle and various aquatic species. Also, the stretch of river at Digha is part of Dolphin corridor mapped in EIA report of River Front Development, Patna. The need to maintain the water quality of the river is also to ensure the safety of Ganga Dolphins, which are endangered species. Therefore, Dolphin Conservation Plan and policies are required. Also, constructions near these areas should be monitored properly in order to have minimal disturbance to ecology and their habitat. Ganga River is also home for variety of fishes. The species of fishes reported are Rohu, Catla, Hilsa, *Mystus sp.*, *Cirrhinus Sp.*, etc.

The site also has considerable number avifauna species and provide them with food, enriched habitat and breeding space to these avifauna. The commonly reported avifauna in the study area during primary survey, with higher diversity are common crow, Myna, Eagle, Sparrow, Babbler, Pigeon, Cattle Egrets, Red Vented Bulbul, Drongo, Sparrow, Indian Roller, etc.

Also, various types of migratory birds visit the ghat during winter which attracts the visitors for bird watching.

2. Cultural Activity

The Digha ghat, is very famous for Chath puja celebration. Approximately 3 lakh people come to this ghat. During Chath, the ghat is maintained by the Bihar government as its auspicious festival and to avoid the accidents.



Figure 33. Digha Ghat during Chath Puja
Source: Self clicked



Figure 34. Digha Ghat during Chath Puja at Patna

Economical Activities

Sand mining

The issue of illegal sand mining has affected many areas in Bihar especially in terms environmental hazards.

“Sand mining, mostly illegal, is rampant at various places along the banks of Ganga, including Maner, Danapur, Digha, Alamganj and several Ghats in Patna City such as Kali Ghat, Damriyahi Ghat and Mahavir Ghat.”

(Sources: The Telegraph, Published 13.04.15)

Unabated illegal sand mining in river beds is now being cited as the major cause for the flood which need to be restricted through policies and if sand mining is being done, it needs proper environmental clearance and needs to be monitored in order to avoid any harm being done in river bed.

Despite of so many policies and guidelines still in place provided by government, the sand mafias are exploiting the nature.

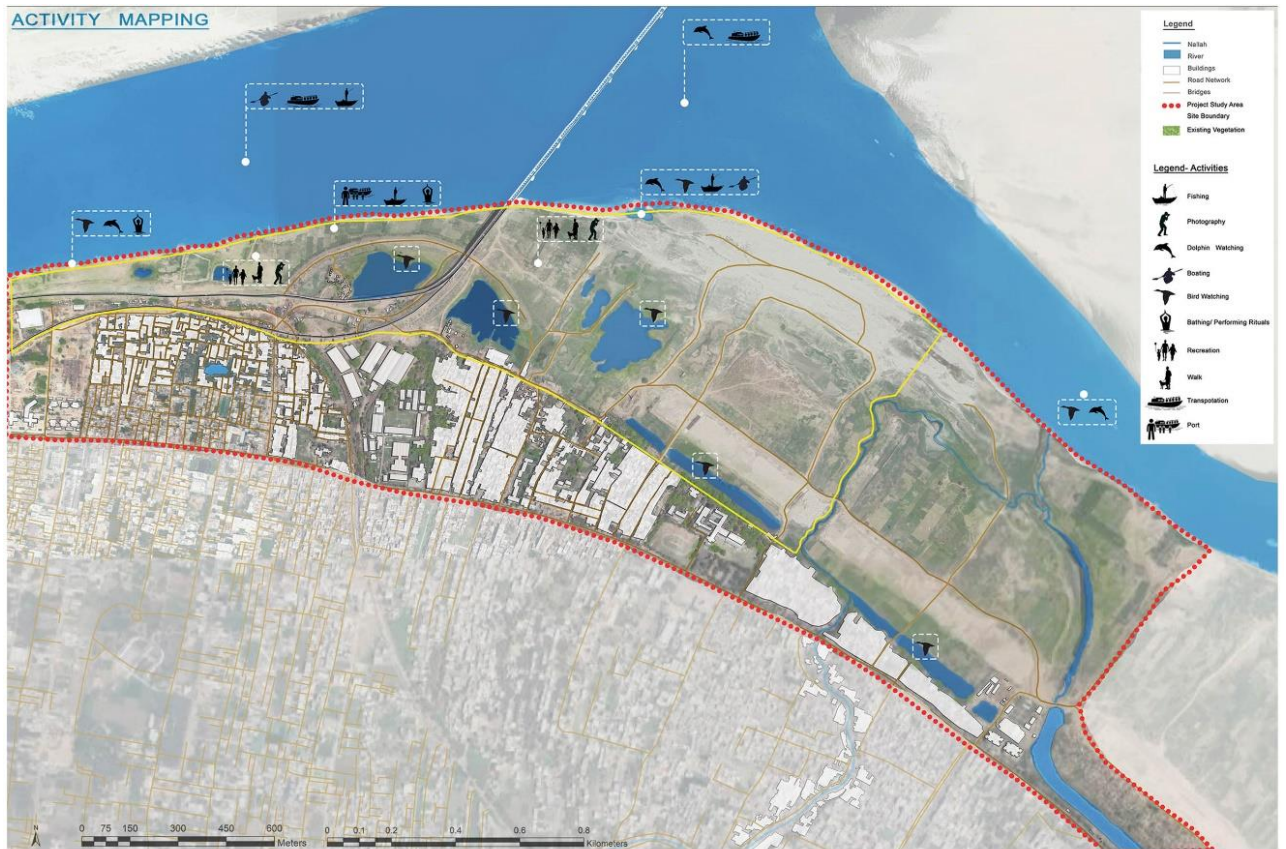
Brick kiln/ Brick manufacturing

Heavy volume of waste material generated by the brick kilns get deposited on the southern banks of the Ganga, pushing the river north from the city.

In order to avoid this kind of damage done by brick kiln industries proper research done by authority and only then the location should be provided for these industries. The State Level Environment Impact Assessment Authority (SEIAA) and Bihar State Pollution Control Board (BSPCB) guideline need to be followed while making policies.

“The Ganga has in fact, shifted its course near Digha due to construction of brick kilns. Apart from erosion of soil, the waste material dumped from these brick kilns have also led to change in the course of the Ganga at Digha.”

(Sources: The Telegraph India's Article by Piyush Kumar Tripathi, Published 11.04.15)



ACTIVITY TABLE

ACTIVITIES		MORNING	AFTER NOON	EVENING	NO. (APPROX)
RECREATIONAL	PHOTOGRAPHY/ PHOTOSHOOT	20	5	20	15-20/100
	DOLPHINE WATCHING	30	2	20	20-30
	BIRD WATCHING	35	10	30	30-35
	WALK	40	15	35	35-40
CULTURAL	PERFORMING RITUALS	25	15	5	15-25/1000
	FISHING	15	5	10	15
LIVELYHOOD	SAND MINNING	10	10	0	10
	AGRICULTURE	30	15	0	30
	BOATING	480	80	400	480
	BATHING	40	15	10	20-30
DAILY RITUALS / MISCELLANEOUS	BATHING	40	15	10	20-30
	DOMESTIC	65	45	15	65-45

ACTIVITY CHART



ACTIVITY GRAPH

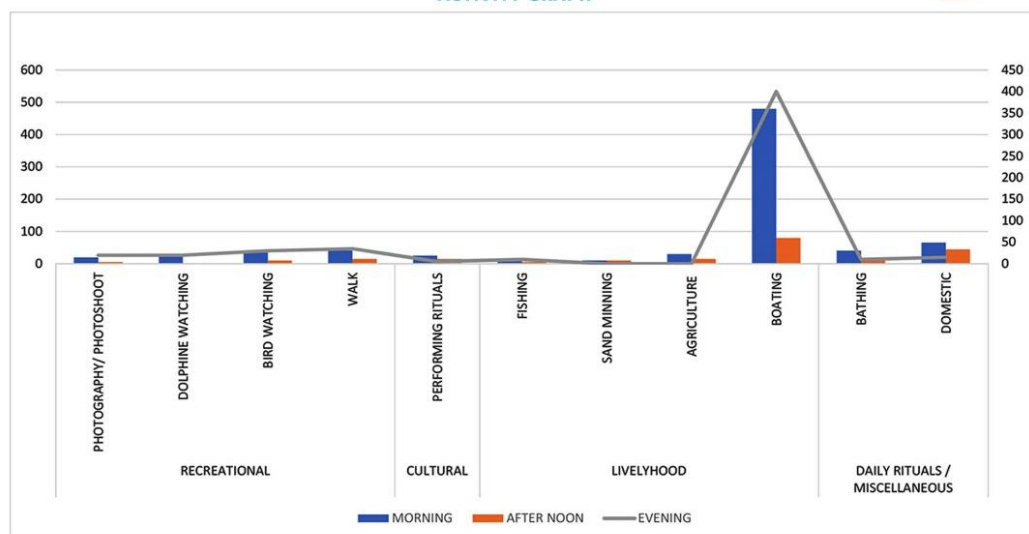


Figure 35. Digha Ghat- Activity Analysis

5.0. CONCEPT AND DESIGN PROPOSAL

The proposal Scheme referenced the rich cultural and religious association of the site with past when this place was used as a mode of transportation. In ancient Patna, the Digha Ghat was used as a port to connect Patna with the cities across the river through waterways using boats.

In this thesis proposal, I am rejuvenating the past glory by designing boating arena. This will include dockyard for boats, accessibility to the boats and waiting area for people etc. Spaces and routes are reformed using existing contours providing variety of recreational activities and framed views across the river depending on the elevation within the site/ ghat.

For design, the site is divided into three parts on the basis of the type of existing activities, land use and the land ownership

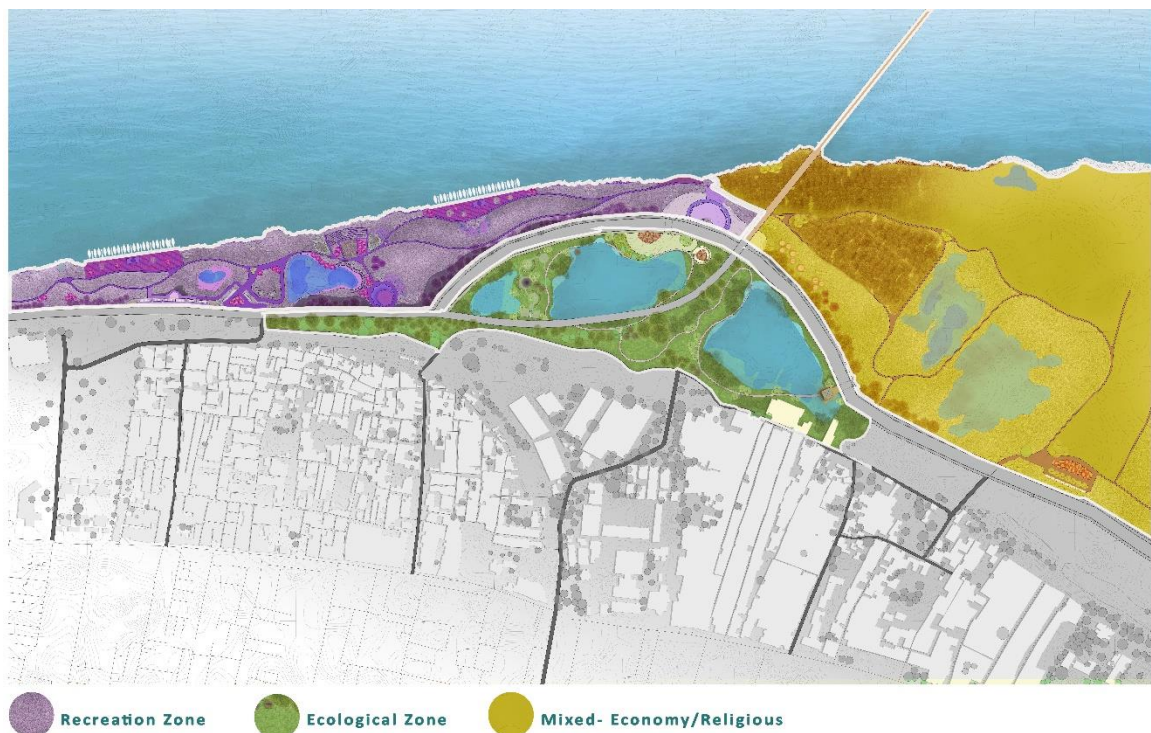


Figure 36. Zoning