

# **IMPACT OF TAWA DAM RELEASE IN NARMADAPURAM**

*A Thesis Project*  
*submitted in partial fulfillment of the requirements for the*  
*award of the degree of*  
**Bachelor of Planning**

**By**

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## **Declaration**

I **SUPRABH PADELE**, Scholar No **2211002105** hereby declare that the thesis titled Impact of tawa dam release on narmadapuram submitted by me in partial fulfilment for the award of degree of Bachelor of Planning, at Maulana Azad National Institute of Technology, Bhopal, India, is a record of Bonafide work carried out by me. The matter/result embodied in this thesis has not been submitted to any other University or Institute for the award of any degree or diploma.

**Signature of the Student**

**Date:**\_\_\_\_\_



## Certificate

This is to certify that the declaration of **SUPRABH PADELE** is true to the best of my knowledge and that the student has worked under my guidance for one semester in preparing this thesis.

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## LIST OF ABBREVIATIONS

| Abbreviation | Full Form                              |
|--------------|----------------------------------------|
| GIS          | Geographic Information System          |
| QGIS         | Quantum Geographic Information System  |
| NRV          | Non-Return Valve                       |
| NDMA         | National Disaster Management Authority |
| CWC          | Central Water Commission               |
| IMD          | India Meteorological Department        |
| LULC         | Land Use Land Cover                    |
| DEM          | Digital Elevation Model                |
| TOC          | Table of Contents                      |
| BEE          | Bureau of Energy Efficiency            |
| CPM          | Construction Project Management        |
| ULB          | Urban Local Body                       |
| DPR          | Detailed Project Report                |

## सारांश

यह अध्ययन इस बात पर शोध करता है कि तवा बांध (Tawa Dam) से पानी छोड़े जाने का मध्य प्रदेश में नर्मदा नदी के तट पर स्थित नर्मदापुरम शहर की जलविज्ञानी (hydrological) स्थितियों और बाढ़ की संवेदनशीलता पर क्या प्रभाव पड़ता है। पिछले कुछ वर्षों में, शहर में बाढ़ की घटनाएं अधिक बार और तीव्र हुई हैं, विशेष रूप से मानसून के मौसम के दौरान। इस शोध का उद्देश्य यह समझना है कि वर्षा और भू-भाग जैसे प्राकृतिक कारक, शहरी विकास और भूमि उपयोग में परिवर्तन जैसी मानवीय गतिविधियों के साथ मिलकर बाढ़ की इन स्थितियों को कैसे प्रभावित करते हैं।

यह अध्ययन वर्षा के पैटर्न, बांध से पानी छोड़े जाने के डेटा, भूमि उपयोग के वितरण, जल निकासी प्रणाली और स्थल की विशेषताओं के विश्लेषण पर आधारित है। इस क्षेत्र में वर्षा अत्यधिक मौसमी है, जिसमें अधिकांश बारिश कुछ ही महीनों के भीतर होती है, जिससे सतही जल का बहाव (surface runoff) बहुत तेज़ हो जाता है। इसके साथ ही, अत्यधिक वर्षा के दौरान तवा बांध से छोड़ा गया पानी निचले इलाकों में नदी के स्तर को अचानक बढ़ा देता है। ये कारक मिलकर एक ऐसी स्थिति पैदा करते हैं जहाँ नदी प्रणाली बहुत तेज़ी से प्रतिक्रिया करती है, जिससे बाढ़ को प्रबंधित करने या नियंत्रित करने के लिए बहुत कम समय मिल पाता है।

स्थल की भौतिक विशेषताएं भी इसमें महत्वपूर्ण भूमिका निभाती हैं। यहाँ का भू-भाग मुख्य रूप से समतल है, जिससे पानी आसपास के क्षेत्रों में आसानी से फैल जाता है। आदर्श रूप से, एक विस्तृत बाढ़ क्षेत्र (floodplain) की उपस्थिति अतिरिक्त पानी को सोखने में मदद करनी चाहिए, लेकिन इन क्षेत्रों में बढ़ते निर्माण और बस्तियों ने इस प्राकृतिक क्षमता को कम कर दिया है। इसके अतिरिक्त, निर्मित क्षेत्रों (built-up areas) की वृद्धि ने पक्की सतहों को बढ़ा दिया है, जिससे जमीन द्वारा पानी सोखने की प्रक्रिया कम हो गई है और जल-निकासी की मात्रा बढ़ गई है।

यह अध्ययन इस बात पर भी गौर करता है कि मौजूदा बुनियादी ढांचा और बस्तियां इससे कैसे प्रभावित होती हैं। कई सड़कें, उपयोगिताएँ और आवासीय क्षेत्र निचले और बाढ़ संभावित क्षेत्रों में स्थित हैं, जो उन्हें बाढ़ की घटनाओं के दौरान अधिक संवेदनशील बनाते हैं। जल निकासी की खराब स्थिति पानी को बाहर निकालने की प्रक्रिया को धीमा करके स्थिति को और भी खराब कर देती है।

कुल मिलाकर, यह अध्ययन इस बात पर जोर देता है कि नर्मदापुरम में बाढ़ केवल एक प्राकृतिक समस्या नहीं है, बल्कि यह नियोजन के निर्णयों (planning decisions) और विकास के तरीकों से भी गहराई से जुड़ी हुई है। यह भविष्य के जोखिमों को कम करने और शहर की लचीलापन (resilience) को बेहतर बनाने के लिए जलविज्ञानी समझ और शहरी नियोजन के बीच बेहतर समन्वय की आवश्यकता को रेखांकित करता है।

## **ABSTRACT**

This research examines the hydrological impact and vulnerability associated with the discharge of water from the Tawa dam, on Narmadapuram, which is situated on the Narmada river, in Madhya Pradesh. In recent years, the city has experienced increasingly frequent and severe floods, particularly during the monsoon season, and an attempt has been made to study natural phenomena such as rainfall and topography, along with anthropogenetic forces such as urbanization and land use changes that contribute to the same.

The study is based on analysis of rainfall patterns, data of discharge from the dam, land-use patterns of the city, drainage patterns, and site characteristics. In terms of climatic regime, rainfall over the region is highly seasonal, with most rainfall occurring within a few months, leading to high surface runoff. At the same time, during high rainfall events, the dam water is discharged downstream, causing a sudden increase in river flow. The system thus exhibits rapid response with little time for mitigation and control.

The topography of the study site also influences flood patterns. Being fairly flat, water can spread easily over large areas; although the presence of a large flood plain ideally contributes to water absorption, the increased encroachment and settlement in the flood plains reduce the available absorptive capacity. Built-up areas increase infiltration capacity and thereby promote higher runoff over the otherwise contributing pervious areas.

The study takes into account the impacts on infrastructure and settlement. Residential areas, utilities, roads, etc. Are established in the low-lying flood-prone areas. The prevailing poor drainage system increases waterlogging over a longer period of time.

Finally, it may be concluded that the flood situation is not merely a natural phenomenon but rather is closely connected with planning and development practices.

# **1.INTRODUCTION**

## **1.1 Background**

The riverine settlement of Narmadapuram lies along the Narmada River in Madhya Pradesh, and its development has occurred within a symbiotic relation to the physical setting. The role played by the Narmada River in the physical and biotic aspects of the area is also reflected in the human settlement patterns that the Narmada has nurtured throughout history. In recent years, however, Narmadapuram has faced frequent inundations and flooding, particularly during the monsoons.

One of the most influential aspects in this shift to frequent flooding has been the construction of the Tawa dam on a tributary of the Narmada, the Tawa. This dam provides water for irrigation, domestic consumption, and flood management. When the dam's reservoir experiences a high inflow of water (which generally occurs when the Tawa receives significant amount of rainfall), some portion of this water is released at a controlled rate downstream.

This release, particularly when it coincides with intense rainfall within the city boundaries of Narmadapuram at the same time, creates rapidly rising river water levels, causing a flood, an entirely different phenomenon from the slow gradual flooding of the river in pre-dam situations.

## **1.2 Problem Statement**

Flood is a recurring phenomenon at Narmadapuram, despite having a major river system and a regulating dam. However, the issue is not solely restricted to hydrology but also due to the nature of urban development in Narmadapuram.

Expansion into floodplain areas and increase in density, along with the loss of pervious areas have substantially changed the natural character of the area while drainage facilities at large parts of the city are either choked or lack the required capacities and hence lead to stagnant water pools at the event of heavy rainfall.

There is a distinct lack of co-relation between hydrology and planning, thus contributing to its vulnerability which requires being explored from environmental and spatial angles.

## **1.3 Study Area**

It can be seen that flood occurrence in Narmadapuram is becoming frequent and severe. This phenomenon of inundation of the city deserves comprehensive study to identify the causes and consequences of this. Dams are normally built to control water flow and prevent flooding downstream, however, release pattern of dams could be

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responsible for unforeseen events in the downstream when combined with regional and local aspects of precipitation and land use.

We must establish how the dams release flow, interacting with the land features and drainage network, along with urban areas, which influences the behavior of floods. Further, by identifying the flood-prone areas, the most vulnerable zone can be identified for taking up planning initiatives immediately.

It becomes pertinent to understand the nature of flood phenomena in the city with an effective study and also help in planning decisions more logically.



fig 1: Location Map of Narmadapuram

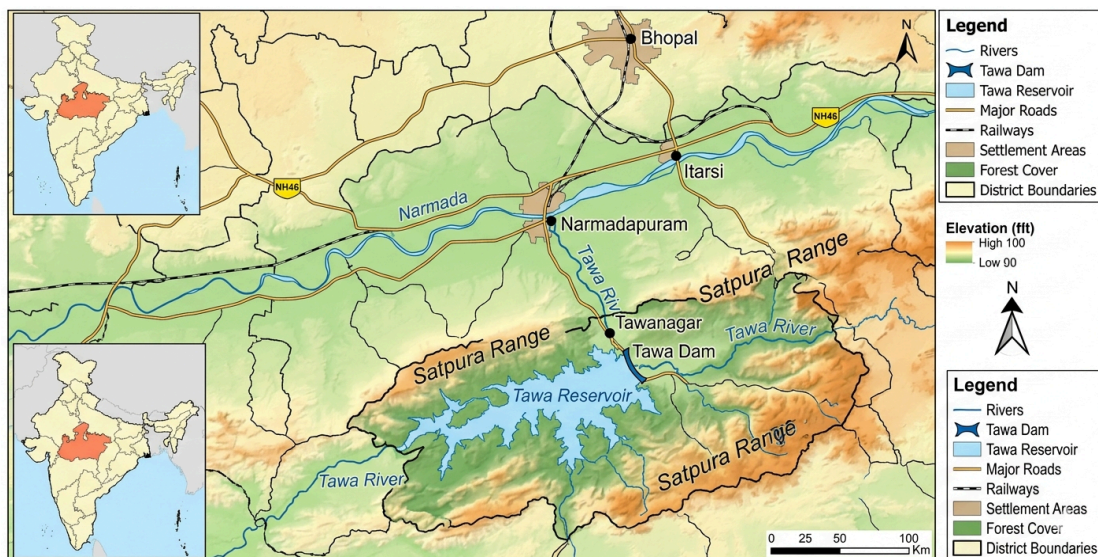


fig 2: Regional Connectivity Map of Narmadapuram

## **1.4 Aim**

To analyze the impact of Tawa Dam release on the hydrological behavior, spatial patterns, and flood vulnerability of Narmadapuram.

## **1.5 Objectives**

- Examine patterns and seasonality of rainfall in the study area.
- Assess patterns of discharge and the impact of dam release.
- Examine the pattern of land use and settlements in the area.
- Identify potential areas of flood hazard using spatial analysis.
- Evaluate exposure of infrastructure and accessibility during flooding.

## **1.6 Scope of Study**

The present study attempts to provide a clear understanding about the behavior of floods in Narmadapuram through application of both hydrological and spatial analysis.

It includes parameters like rainfall, discharge, topography, land use, drainage and infrastructure so as to understand the patterns and relationships governing flood conditions. It also includes analysis of flood extent, flood depth and flood risk mapping, and delineating problem areas and will provide a starting point to generate preliminary planning guidelines for flood damage reduction.

## **1.7 Limitations**

- The study is based primarily on secondary data from available sources
- Limited access to real time and long term dam discharge data
- Accuracy of results depends on the resolution of spatial datasets
- Temporal variations may not be fully captured
- Detailed hydraulic modeling is beyond the scope of this study



## **2. LITERATURE REVIEW**

### **2.1 Introduction**

An investigation into the flood dynamics of a riverine environment within the urban matrix requires considering both the natural hydrological process and anthropogenic influences on flood dynamics.

A review of studies, concepts and ideas regarding dam-controlled rivers, floodplain processes, urban floods, and planning has been carried out in this chapter, in order to provide a theoretical basis for analysis of Narmadapuram and selection of factors affecting the flood hazard.

### **2.2 Hydrological Behavior of River Systems**

Flow is a variable phenomenon and it is mainly dependent upon rainfall, characteristics of catchment and seasonality of season. In natural state of river, stream discharge raises during rain events and again comes down during no rain period showing a stable hydrologic regime.

With implementation of a large intervention as dam the behavior is drastically affected. Some findings report abnormal peak discharge, lag in time and change in discharge regime downstream areas due to regulated river flow underdam impact. This becomes especially evident during intense rain.

The comparison is made using hydrograph where various parameters such as rising limb, peak discharge and recession limb illustrate the speed of river's reaction to rain.

### **2.3 Impact of Dams on Downstream Flow**

Dams are built to control flow for reasons like irrigation, water supply and flood prevention. Despite controlling water flow, dams also produce unforeseen effects downstream. In the event of intense rainfall, water accumulated in the reservoirs need to be regulated and released downstream, resulting in sudden rises in discharge downstream when natural flow is added.

Many research found that such regulated releases would exacerbate the floods if operated without considering the downstream hydrological situation.

### **2.4 Floodplain Dynamics**

Floodplains are flat, relatively low-lying areas that run along rivers and store flood waters during extreme flow events. Their capacity to act as natural buffer zones reduces flood damage and risks in surrounding areas.

During urbanization, it is common for large parts of floodplains to be developed for residential, commercial or industrial use or for the construction of infrastructure, limiting their storage capacity and increasing flooding risks. Floodplain preservation and management strategies are widely advocated in scientific literature as tools to manage flood risks, such as floodplain zoning and buffer zone development.

## **2.5 Urbanization and Surface Runoff**

Hydrological processes are affected by urban development in numerous ways. Urban development such as the construction of roads, buildings and pavements increase the amount of impervious areas and decreases the infiltration capacity of soil. Hence a significant percentage of precipitation is transformed into surface runoff.

It has been established that urban environments yield runoff coefficients and flow velocities much higher than those generated under natural conditions, as well as greatly decrease infiltration rates, which causes water to accumulate faster within a drainage system. Furthermore the often haphazard nature of urban development results in disturbance of existing drainage paths.

## **2.6 Drainage Systems and Flooding**

Effective drainage is also very important in handling of storm water in the urban environment. Natural drainage network should channel the surface run off to rivers or water body. Many urban areas have a problem of having poor or in-adequate and damaged/blocked natural drainage system as a result of construction activities. Literatures reveal that, poor capacity in drainage system would be result of waterlogging, increasing of time persistency of flood and localized flooding of moderate rain fall

## **2.7 Climate Change and Extreme Rainfall**

Recent research indicates that climate change will lead to an increase in the frequency and severity of extreme weather events. Modification of rainfall events (specifically the intensity and short duration nature of storms) are the cause of increase runoff and potential for flooding. Due to the pre-existing problems of planning, urban areas are vulnerable to these alterations. This compounding fact of weather and human influences is what complicates flood management and makes a plan for it challenging.

## **2.8 CASE STUDIES**

### **2.8.1 Kerala Floods, 2018 (India)**

The 2018 Kerala floods, one of the worst such natural disaster in recent India's history were caused by massive excess monsoon rain over an unprecedented span of time. One of the largest causes was the synchronous release of water from reservoirs across the state.

Kerala has a vast network of dams for irrigation and hydel power generation purposes. During periods of heaviest rain, reservoirs across the state were filled close to their maximum capacity and then large quantities of water were released within a short span.

Coupled with the extremely wet ground conditions and the high river flows, these synchronized release caused flooding across several river basins. The flood brought with it considerable land submergence and infrastructure damage as well as massive evacuation and loss of life. One of the lessons learned during this incident was the lack of synchronised reservoir operation, failure in real time decision making on the downstream impact of reservoir releases, and rather reactive than proactive release.

#### **Key Learnings**

- Dam release during peak rainfall can significantly amplify flood intensity
- Lack of coordination between reservoirs increases cumulative downstream impact
- Real-time data and forecasting are essential for flood management
- Floodplain encroachment increases damage potential

#### **Relevance to Study**

This matter is the current relevant case study concerning Narmadapuram and the effect of downstream releasing from Tawa Dam. The relevance of coordinated dam operation and assessment of downstream capacity and local rainfall is essential before release.

### **2.8.2 Room for the River Programme, Netherlands**

Given its low topography the Netherlands has had considerable experience in flood management. Historically flood control was mainly based on structural measures,

such as dikes and embankments. However, due to growing risks, a change of strategy was introduced by means of the "Room for the River" programme.

The idea of the programme was to accommodate the river in flood circumstances rather than controlling it within constraints, which involved moving the dikes further away from the river, lowering flood plains, constructing a secondary channel, removing obstructions limiting the flow and so forth. This would not only lower the flood levels but it would also improve spatial quality and enhance environmental conditions.

### **Key Learnings**

- Flood management can be achieved by working with natural systems
- Increasing floodplain capacity reduces flood height and intensity
- Spatial planning plays a key role in flood mitigation
- Non-structural approaches can be more sustainable than rigid control systems

### **Relevance to Study**

For Narmadapuram, this case highlights the necessity of preservation and rehabilitation of the floodplain. Instead of indiscriminate construction, plans should be prepared such that a space for water is afforded and pressure on the river system is minimized.

### **2.8.3 Sabarmati Riverfront Development, Ahmedabad (India)**

Urban riverfront development with regulated river flow, is the essence of the Sabarmati Riverfront project. River in Ahmedabad is primarily regulated by water release from upstream, thus it is a semi-regulated river.

The project comprises channelizing river, building embankments and developing riverfront spaces. Although the project enhanced visual appeal of the city, its land use efficiency, it drew criticism for changing the natural character of river. The river channelization decreases floodplain area of river, limiting its capacity to handle excessive water during heavy flood. It further increases reliance on engineering solutions for flood protection by depending on upstream controls.

### **Key Learnings**

- Riverfront development can improve urban space but may alter natural systems
- Channelization reduces natural flood buffering capacity
- Dependence on controlled discharge increases system sensitivity
- Balance between development and ecology is essential

### **Relevance to Study**

This case is of significance because Narmadapuram is also a controlled river environment and shows the hazards of heavy manipulation of river bank and the need to maintain the natural ecology of the river during urban design interventions.

## **2.9 OVERALL INFERENCE FROM CASE STUDIES**

This case is relevant as it is a controlled river environment also (like Narmadapuram) and demonstrates the risks of an over-manipulated river bank as well as the necessity of natural river ecology in urban design interventions.

### 3. STUDY AREA

#### 3.1 Location and Regional Context

Narmadapuram, earlier known as Hoshangabad, is centrally located within the State of Madhya Pradesh, just on the southern bank of the Narmada River. The city is located within the Narmada river basin, one of the largest west flowing rivers of India.

Geographically it lies between the large city of Bhopal and the other important urban center of Itarsi, thus providing importance as a regional junction. The presence of the river Narmada also traditionally holds a lot of significance from the perspective of settlement, agriculture, economy, etc.

The important tributary of the Narmada, known as the Tawa River joins the main river upstream of Narmadapuram. The Tawa Dam, constructed across the river Tawa, regulates the flow of the Narmada River and hence indirectly, the conditions in the Narmadapuram city.

#### 3.2 Physiography and Topography

The topography of Narmadapuram is generally flat to gently sloping. The land generally slopes in the direction of river. This topography with low relief has an impact on flood behavior, as the lateral extent of water flow increases with increase in discharge.

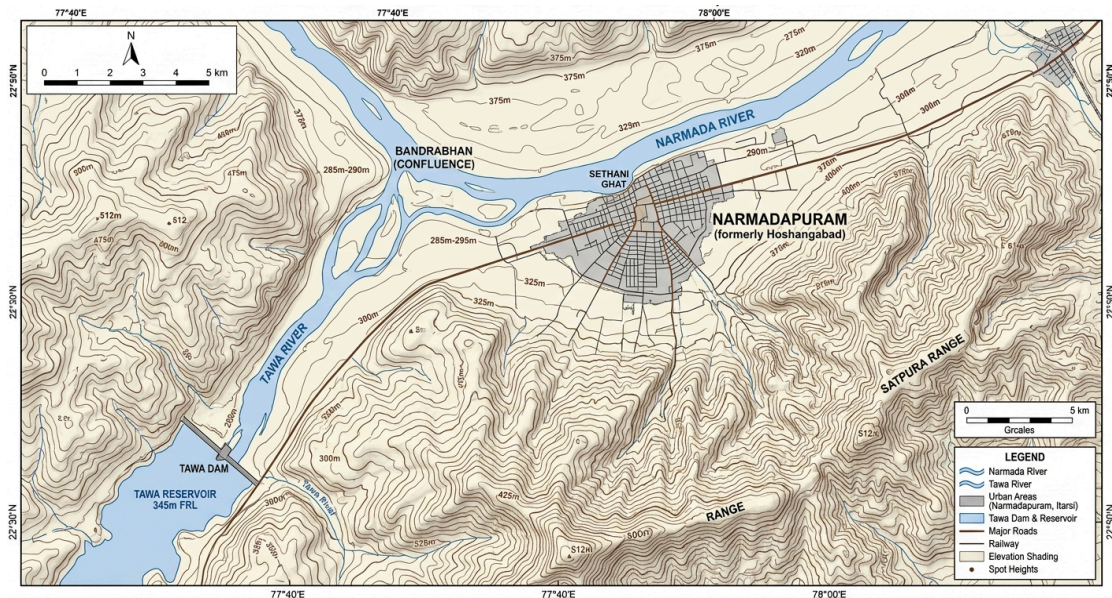


fig 3: Topography and Elevation Map of Narmadapuram

Lack of high slopes decelerates water flow velocity, causing accumulation of water and prolonged flooding in the area. The flat areas in close proximity of the river and drainage lines are most susceptible as they hold water.

This topographical feature together with active floodplain in the area make it flood-prone.

### 3.3 Climate and Rainfall

Narmadapuram experiences a tropical monsoon climate which is characteristic of having three distinct seasons, namely the summer, monsoon, and winter. The monsoon season runs from June to September, providing bulk of the annual rainfall. Rainfall events in this season tend to be concentrated in relatively short time spans of relatively high intensity, which gives rise to surface runoff being fast. Intense rainfall enhances the inflow to the Tawa reservoir as well as within the city drainage network.

The fact that the rainfall occurs seasonably causes a large amount of water having to be managed within a relatively short span of time, which along with dam releases causes risk of floods.

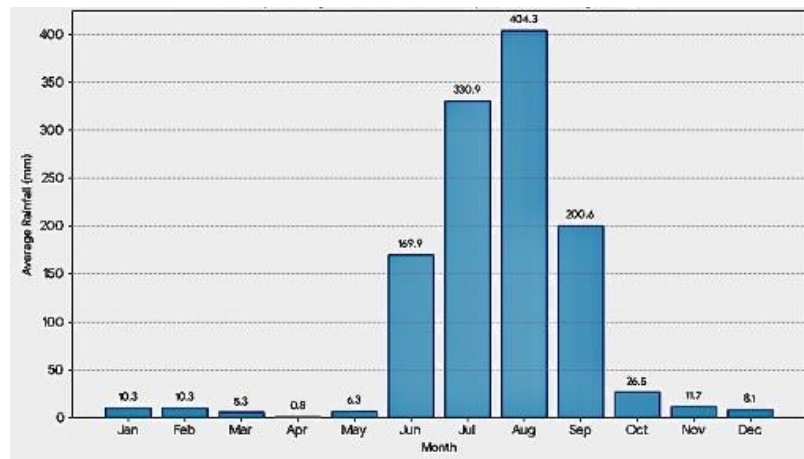


fig 4: Rainfall graph

### 3.4 Hydrological Context

Hydrology of the study area can be controlled by the natural river systems and by intervention at upstream areas. The river Narmada is the main drainage stream and tributaries of this river such as the river Tawa contribute to it. The release from the Tawa Dam affect the river flow at downstream especially during the monsoon. Water levels are governed by the released water from the reservoir. When the releases from the reservoir are at same time as rain at downstream, water level at river Narmada increased very fast.



## IMPACT OF TAWA DAM RELEASE IN NARMADAPURAM

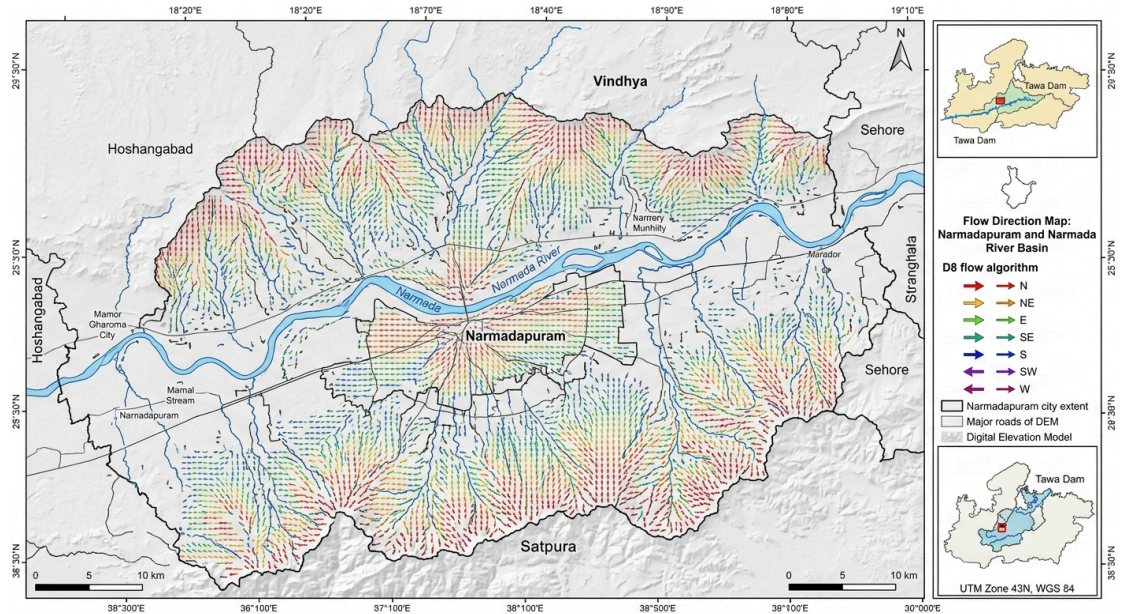


fig 5: Hydrological Network Map Showing River System

### 3.5 Drainage Pattern

The surface runoff is disposed off by a natural drainage system in the region. This system is dendritic and smaller streams and channels flow and merge into larger channels, which further feed into the river. This drainage system discharges the surface runoff into the Narmada River. At times of heavy rainfall, the existing drainage system is unable to discharge the high magnitude of runoff and the stagnant water body persists for a significant time.

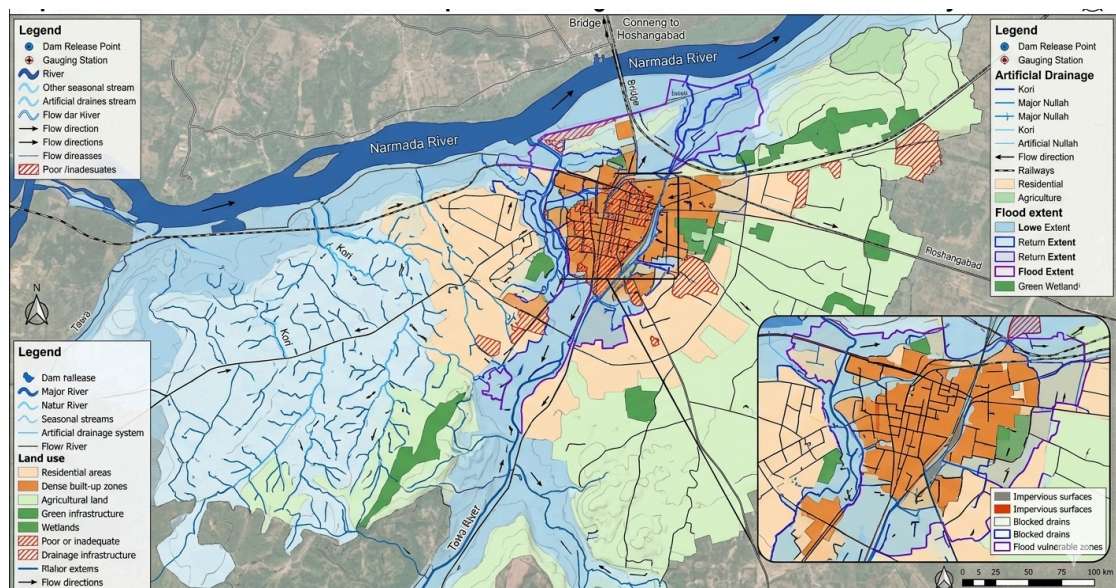


fig 6: Drainage Pattern Map of Narmadapuram



### 3.6 Land Use and Settlement Characteristics

Landuse in Narmadapuram, is a mixture of residential, commercial, agricultural and open spaces. Much of the development is seen near river and along major transportation routes.

With passage of time the development of the city has taken place in low-lying areas and areas on floodplain, consequently bringing the settlements in areas that are exposed to flood. Increased runoff has been a result of increased development of high-density built-up area, owing to presence of impervious surface.

Also, low density and informal and unauthorized settlements occupy vulnerable locations due to their availability and affordability.

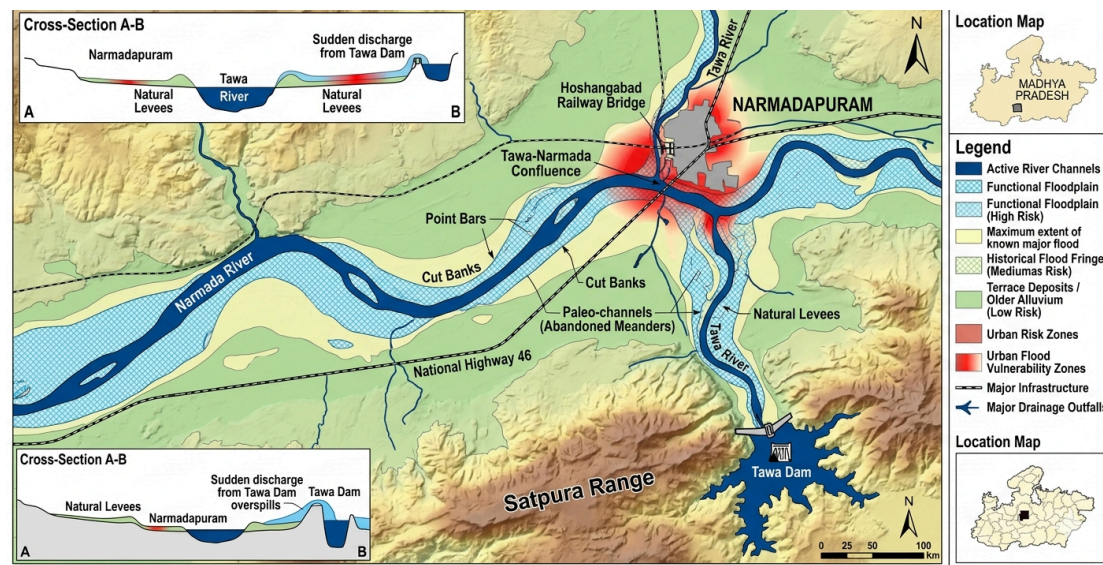


fig 7: Land Use Land Cover (LULC) Map of Study Area

### 3.7 Infrastructure and Connectivity

City contains several road, utilities, public service required for its operation. But the services were developed in several areas that could be easily flooded.

Road close to the river and several low lying areas could not be accessed during the flooding, and there would be issues of water supply and electricity.

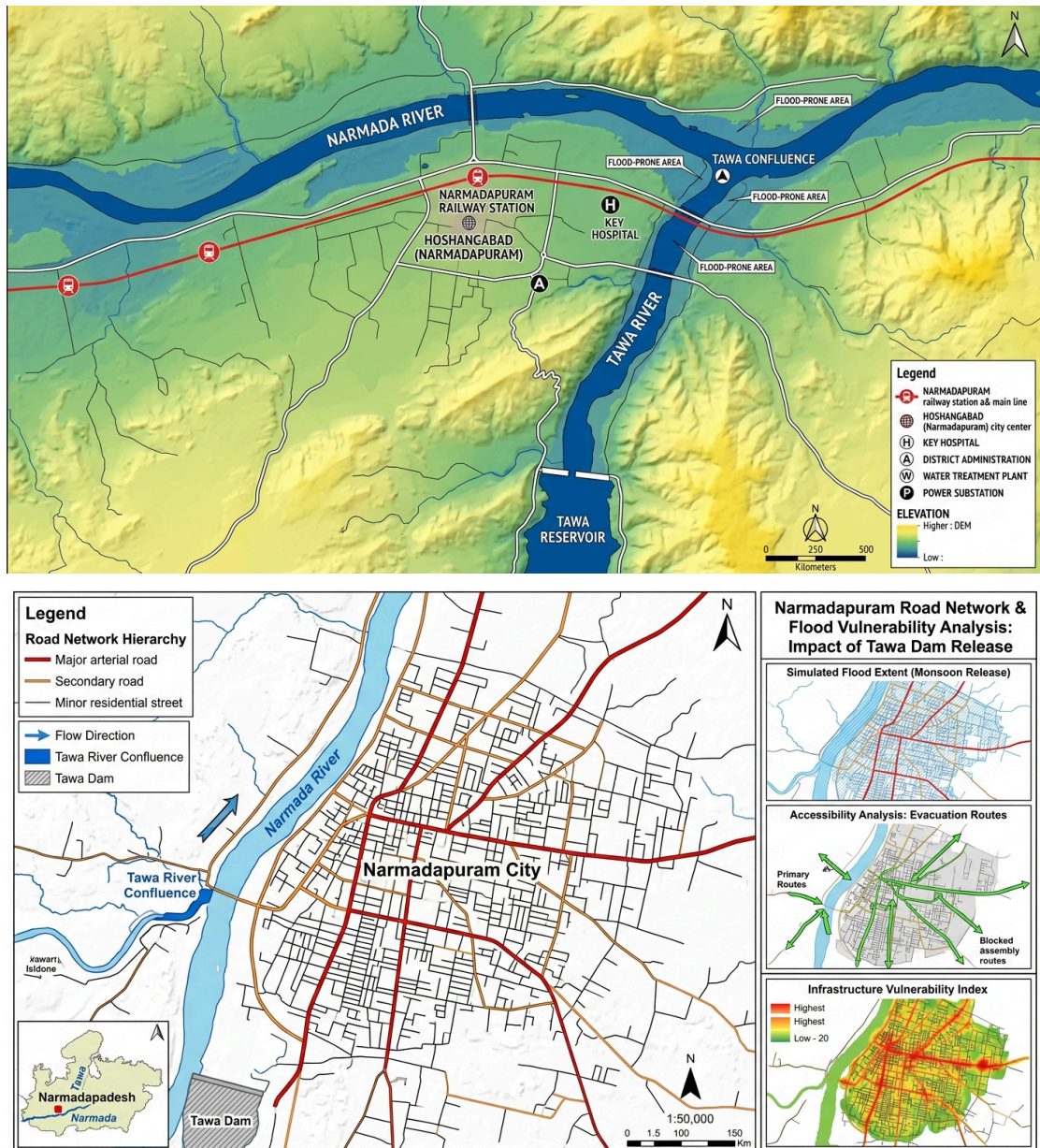


fig 8: Infrastructure and Road Network Map

The location of facilities without flood hazard awareness also implies that more effective planning and hydrological integration is necessary.

## 3.8 Key Inference

There are natural and man-induced factors that influence the susceptibility of flood in the study area. The natural factors include the topography and the monsoonal rainfall and the presence of major river. These natural features are amplified by man-induced factors, including discharge from dam, the urbanization of flood prone areas and poor drainage system.

## **4. METHODOLOGY**

### **4.1 Introduction**

In this chapter the methodology adopted for the study is being discussed which mainly deals with the selection of topic of study and the techniques to collect and analyze data. It presents the flow of operation for arriving at the conclusion for study. This process would reveal a relationship between hydrological activities and spatio-physical development of Narmadapuram.

### **4.2 Rationale for Topic Selection**

The title, 'Influence of Tawa Dam Release on Narmadapuram', was chosen due to a recent and noticeable increase in flood occurrences in Narmadapuram; and how these events have begun to visibly alter settlements, city infrastructure, and livelihood of the citizens.

Narmadapuram serves as an interesting case of both natural and man-made flood causes. The existence of the Narmada River makes Narmadapuram naturally susceptible to floods, whereas the intervention in the natural process by Tawa Dam further exacerbates the problem.

During the monsoon seasons, there have been occurrences of water being suddenly released from the Tawa Dam along with the local rains, thus drastically altering the water levels at Narmadapuram in a very short period. The effect this dam control has on floods and how a city develops in response to these changes in water levels.

The chosen title was also explored as it provides an insight into both Hydrology and City Planning. With the study of such influences on planning, the city of Narmadapuram can be adequately adapted to such a phenomenon, particularly riverine cities with the same predicaments.

### **4.3 Research Approach**

The methodology of this study is a combined one including hydrological analysis and spatial analysis.

The hydrological analysis includes research on rainfall pattern, discharge pattern, generation and behavior of runoff and flow pattern.

The spatial analysis studies include the issues of land use, terrain, drainage system and arrangement of infrastructure. Combining the two methods helps to clarify how the natural environment influences flooding condition under human activities in urban area.

## **4.4 Data Collection**

The study is primarily based on secondary data which is collected from reliable sources, including:

### **4.4.1 Hydrological Data**

- Rainfall data (monthly and seasonal)
- River discharge data
- Dam release information

### **4.4.2 Spatial Data**

- Satellite imagery
- Land use land cover data
- Topographical maps

### **4.4.3 Infrastructure Data**

- Road network
- Public utilities
- Settlement patterns

The collected data forms the base for all further analysis and mapping.

## **4.5 Data Processing and Tools Used**

To analyze and represent the data effectively, various digital tools were used:

- GIS (QGIS): for spatial mapping and analysis
- Google Earth Pro: for satellite imagery and elevation reference.

- Adobe Illustrator / Photoshop: for final sheet preparation

These tools helped in generating thematic maps such as land use, drainage, flood zones, and infrastructure overlays.

## **4.6 Analytical Framework**

The study follows a step-by-step analytical process:

### **Step 1: Rainfall and Hydrological Analysis**

- Study of rainfall patterns and intensity
- Analysis of discharge variation and dam release
- Interpretation of hydrograph
- Identification of runoff characteristics

Purpose: To understand how water enters and moves within the system

### **Step 2: Site Analysis**

- Topography and slope analysis
- River morphology
- Soil characteristics
- Drainage pattern

Purpose: To understand how physical conditions influence water movement

### **Step 3: Land Use and Settlement Analysis**

- Mapping of land use distribution
- Built-up density analysis

- Identification of settlement patterns
- Analysis of green cover

Purpose: To understand how urban development affects runoff and exposure

#### **Step 4: Flood Analysis**

- Mapping of flood extent
- Analysis of flood depth
- Study of flood duration
- Identification of vulnerable zones

Purpose: To understand spatial characteristics of flooding

#### **Step 5: Infrastructure and Risk Analysis**

- Overlay of flood zones with road networks
- Identification of critical infrastructure
- Accessibility analysis during flood events

Purpose: To evaluate functional impact of flooding

#### **Step 6: Issue Identification**

- Identification of planning gaps
- Analysis of cause–effect relationships
- Synthesis of findings

Purpose: To derive key problems for planning intervention.



| Step | Analysis Type           | Components Covered                           | Purpose                                     |
|------|-------------------------|----------------------------------------------|---------------------------------------------|
| 1    | Hydrological Analysis   | Rainfall, discharge, hydrograph, runoff      | Understand water input and flow behavior    |
| 2    | Site Analysis           | Topography, river morphology, soil, drainage | Understand physical influence on water flow |
| 3    | Land Use Analysis       | Built-up, density, settlements, green cover  | Assess impact of urban development          |
| 4    | Flood Analysis          | Flood extent, depth, duration                | Identify spatial flood characteristics      |
| 5    | Infrastructure Analysis | Roads, utilities, accessibility              | Evaluate functional impact                  |
| 6    | Issue Identification    | Planning gaps, cause-effect relationships    | Derive key planning issues                  |

Table No. 4.1: Analytical Framework of the Study

#### 4.7 Flow of Methodology

Data Collection → Hydrological Analysis → Spatial Analysis → Flood Analysis → Infrastructure Analysis → Issue Identification.

#### **4.8 Limitations of Methodology**

- Dependence on secondary data sources
- Limited availability of real-time dam operation data
- Absence of detailed hydraulic simulation
- Accuracy dependent on spatial data resolution

#### **4.9 Outcome of Methodology**

It helps understand more deeply the interaction between dam release, rainfall and urban development which affect flood pattern. It also offers a solid ground for the analysis of planning problems and provides basis for the development of risk mitigation measures.



## **5. ANALYSIS & FINDINGS**

### **5.1 Introduction**

In this chapter, Narmadapuram's hydrological processes, physical parameters, spatial structure and physical features, physical system including physical environment and physical infrastructure system, are investigated for identifying causes of vulnerability to flood events. Each factor is presented as it occurs sequentially, from inputs and response of water, followed by characteristics of relief and land-use and flood impact and risk.

Individual parameter's description is not the intention of this chapter but interactions among various parameters as a system are studied. The findings are interpreted using quantification and spatial analysis, and planning issues identified.

### **5.2 Hydrological Analysis**

#### **5.2.1 Rainfall Characteristics**

Seasonal distribution of rainfall in the area is very much seasonal; most of the rainfall is concentrated in the monsoon period. In the rainfall events, the intensity of rainfall is very high and short in duration, and it greatly effects runoff.

When high intensity rainfall event occurs, the rate of rainfall greatly exceeds the rate of infiltration into the soil and therefore large amount of surface runoff is generated. Increased pressure on the drainage network and river courses is applied.

Fluctuations in intensity of rainfall in different events result in fluctuations in runoff volumes and hence make flood forecasting difficult.

#### **Inference**

High-intensity rainfall events generate rapid runoff, contributing to sudden increases in water levels.

#### **5.2.2 Discharge Dynamics and Dam Influence**

The regime of discharge for Narmada River at Narmadapuram is heavily dependent on the upstream releases from the Tawa dam. If it rains profusely in the upstream regions, then the Tawa reservoir gets a high influx and hence the releases are made out for to reduce the storage of water at a safe level. The discharges from this spill release significantly modify the discharge pattern. In fact, rather than showing a continuous trend of increase in flow, Narmada River displays huge and instant

increases. These spill releases from Tawa Dam combined with local rains and runoff result in rapid increase of water levels at Narmadapuram.

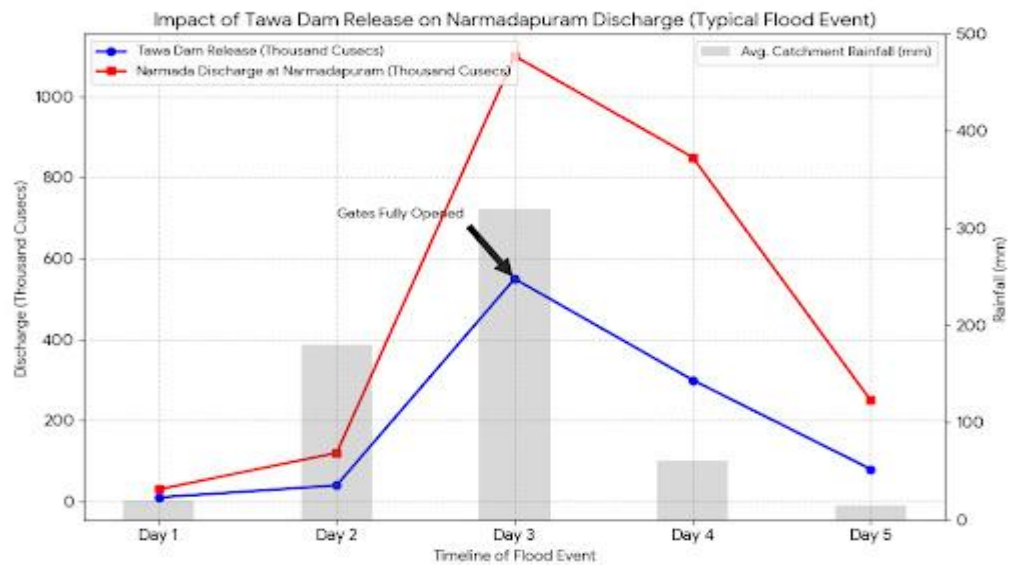


fig 9: Flow Accumulation Map of Narmadapuram

The lack of synchronization between reservoir release and downstream conditions further increases flood risk.

## Inference

Dam release introduces abrupt variations in discharge, intensifying downstream flood conditions when combined with local runoff.

## 5.2.3 Hydrograph Interpretation

It shows from the derived hydrograph for the study region, that there is a sharp rising limb, a high peak discharge and a very short recession limb. This demonstrates a quick hydrological response to rain and dam discharge.

The reduction in lag time between rainfall and peak discharge, shows that water is traveling rapidly through the catchment and that it is only taking a short time to get to the river channel.

## IMPACT OF TAWA DAM RELEASE IN NARMADAPURAM

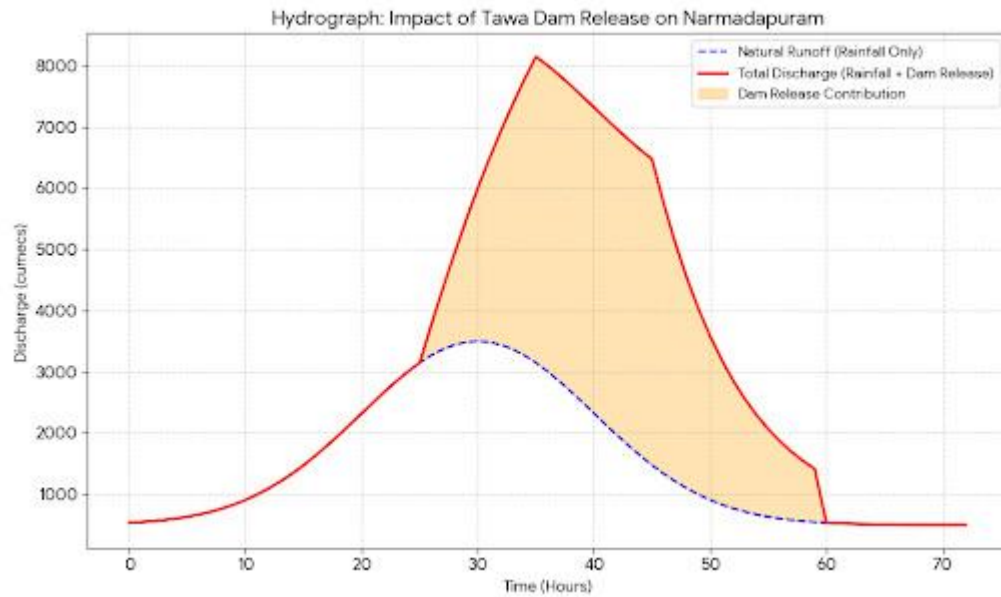


fig 10: Hydrograph

Such hydrograph characteristics are typical of urbanizing catchments with reduced infiltration and increased runoff.

### Inference

The system exhibits a flash response, with high peak discharge and reduced lag time, increasing flood intensity.

### 5.2.4 Runoff Generation and Impervious Surfaces

Land use has greatly affected the runoff generation in study area. Increasing built up areas, increasing impermeable surfaces, like roads, pavements, buildings which cannot seep water into soil surface and runoff coefficients have been increased. The increased surface runoff quickly flows into the drainage system.

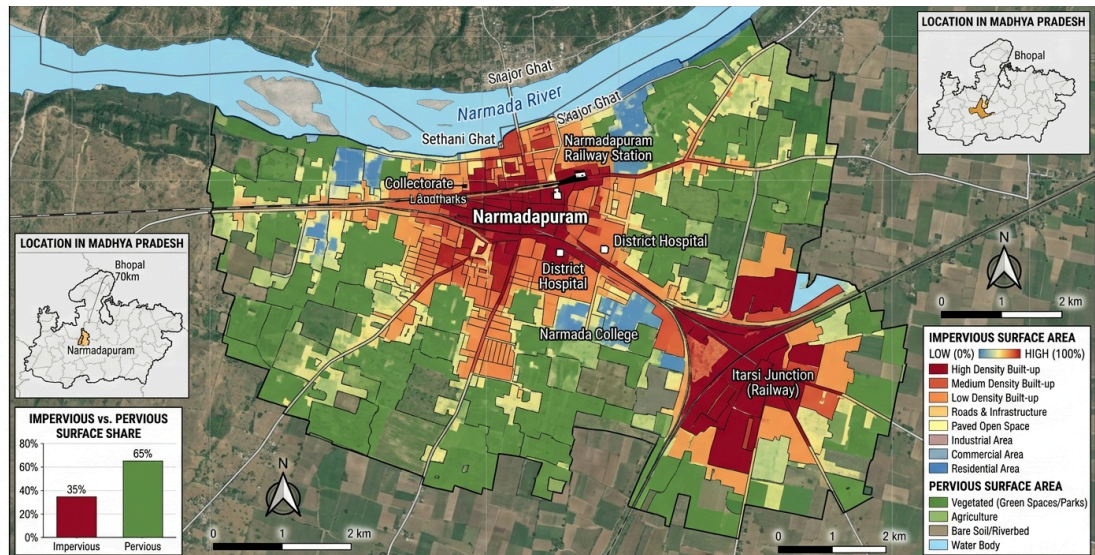


fig 10: Impervious surface map

This not only increases the volume of water but also its velocity, leading to faster accumulation in low-lying areas.

## Inference

Impervious surfaces amplify runoff generation, increasing both the volume and speed of water flow.

### 5.2.5 Flow Accumulation and Drainage Paths

The flow accumulation analysis identifies zones where the surface runoff from various up slope locations converge. The natural drainage paths and low lying areas in the study area are the locations where the flow accumulates. The accumulation of flow at these regions concentrate the surface flow in the areas increasing their probability of being inundated.



## IMPACT OF TAWA DAM RELEASE IN NARMADAPURAM

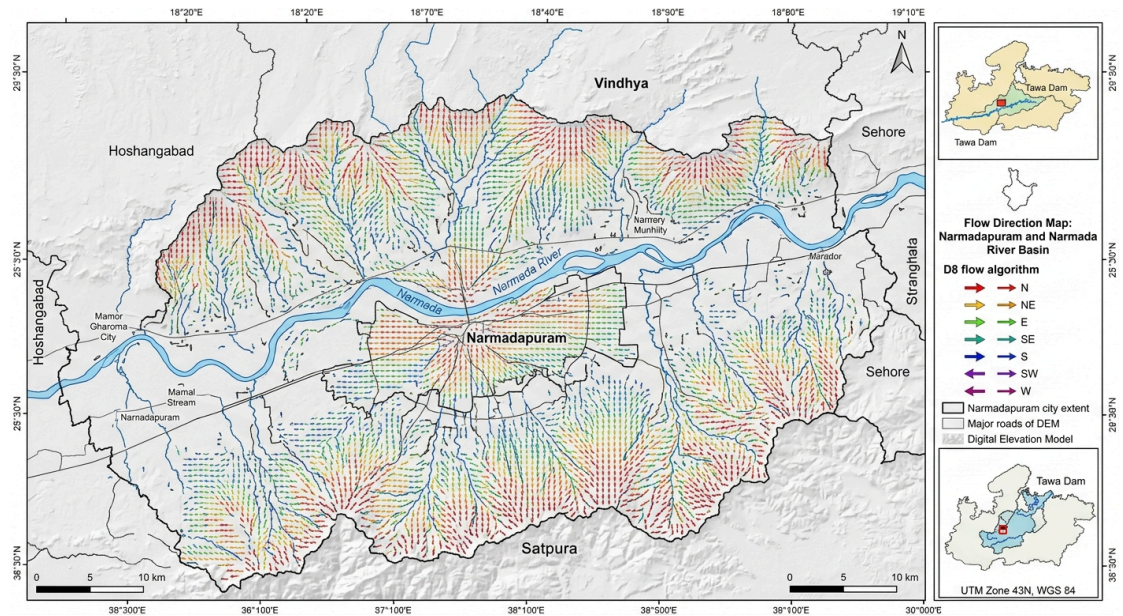


fig 11: Drainage pattern map

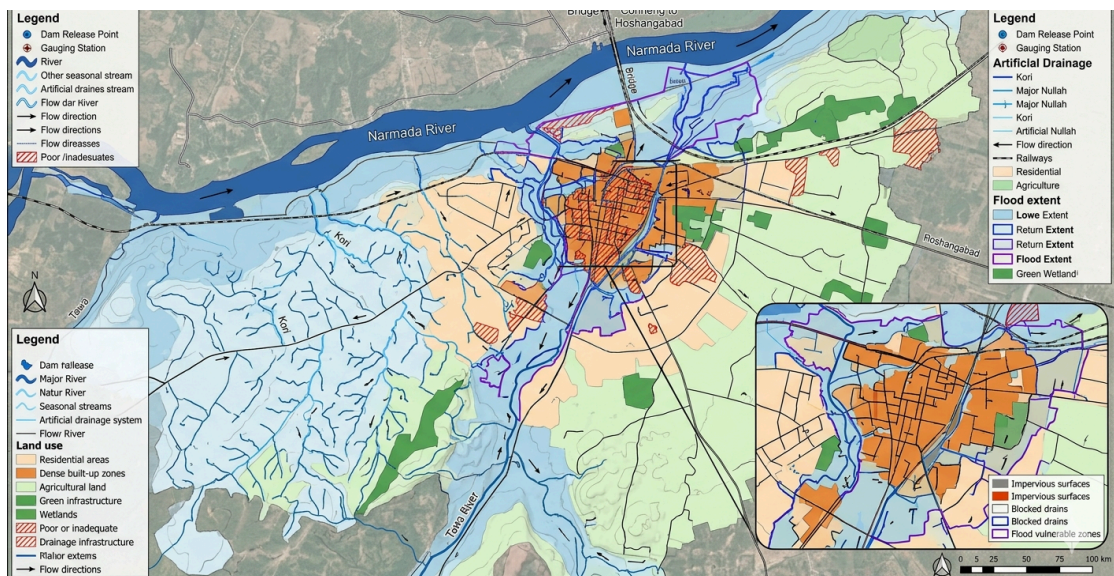


fig 12: Flow accumulation map

Flow direction analysis further confirms that water movement follows the natural slope towards the river, with certain areas acting as collection points.

### Inference

Concentration of flow along drainage paths leads to localized high-intensity flooding.

## 5.2.6 Time of Concentration

The time of concentration appears to be low which signifies that water flows to the river at different parts of the catchment in a short time. This results in rapid build up of discharge, sharp peaks of flow and high flood severity.

This low time of concentration is attributed to urbanization and efficient but overburdened drainage system.

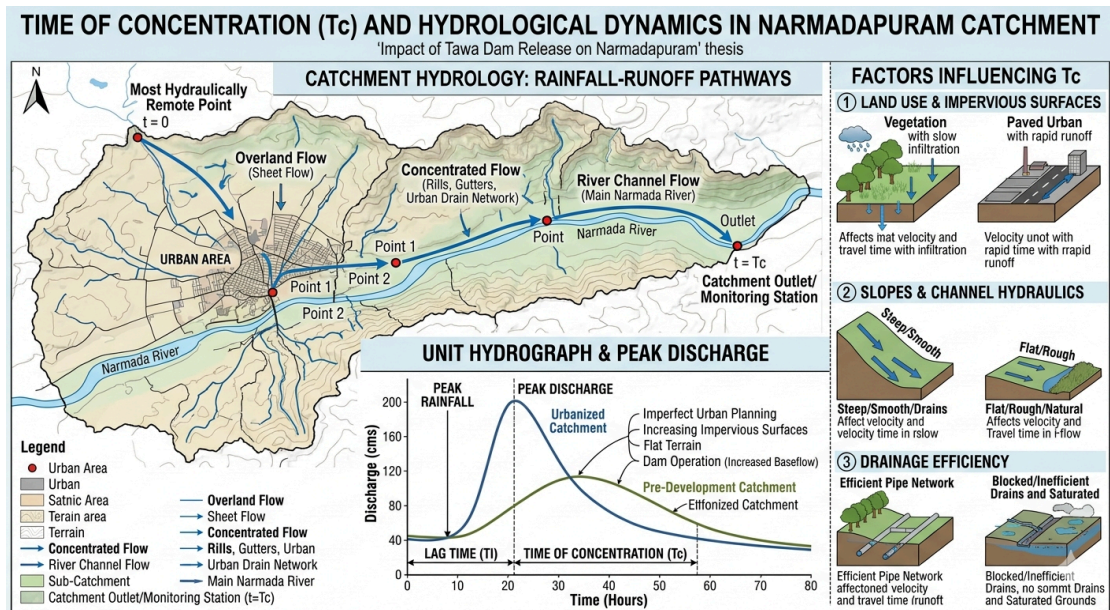


fig 12: Time of concentration

## Inference

Shorter concentration time leads to faster and more intense flood peaks.

| Parameter     | Observation                       | Impact on Flooding         |
|---------------|-----------------------------------|----------------------------|
| Rainfall      | High intensity, seasonal          | Rapid runoff generation    |
| Dam Discharge | Sudden release peaks              | Sharp rise in river levels |
| Hydrograph    | Steep rising limb, short lag time | Flash flood conditions     |



|                       |                                      |                              |
|-----------------------|--------------------------------------|------------------------------|
| Runoff                | Increased due to impervious surfaces | Higher flow volume and speed |
| Time of Concentration | Low                                  | Faster peak discharge        |

Table No. 5.1: Hydrological Characteristics and Impact

## 5.3 Site Analysis

### 5.3.1 Topography and Elevation

The gentle slopes and very little variation in the relief of Narmadapuram causes slow velocity of flowing water and its dispersal over a large area. The flood prone areas are the areas located at low-levels close to river/drainage. This naturally stores water during the flood and results in its larger coverage and time of occurrence.

### Inference

Flat terrain promotes lateral spread and prolongs water stagnation.

### 5.3.2 River Morphology

The Narmada River in the study area exhibits a meandering pattern, which increases its interaction with the floodplain. The curvature of the river influences flow velocity and direction, leading to variations in flood behavior along different sections.

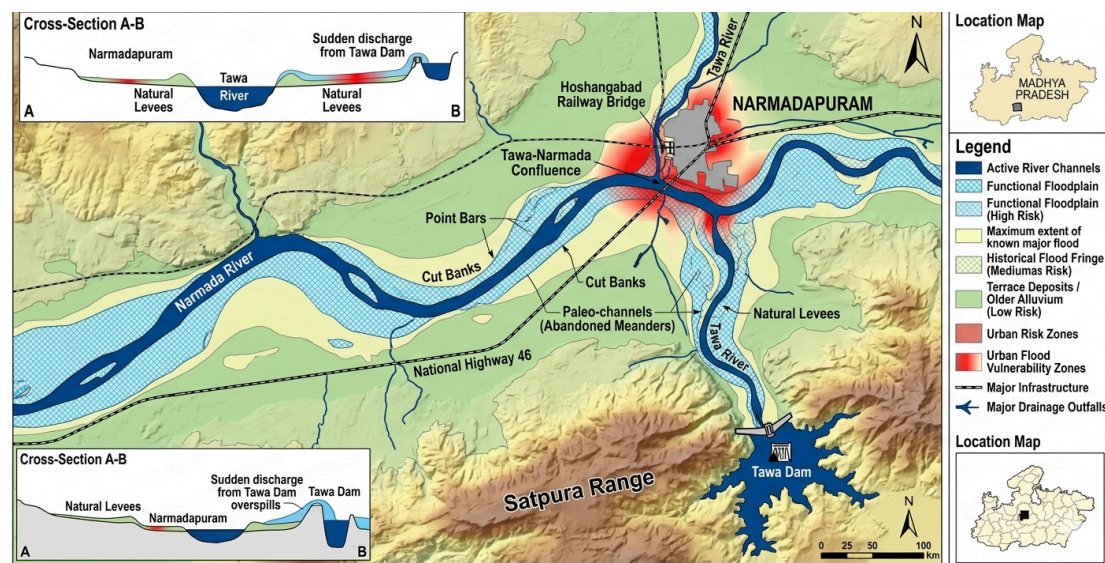


fig 13: River Morphology map

Wider sections of the river allow for greater water spread, while narrower sections increase flow velocity.

### Inference

River morphology influences flow dynamics and flood distribution.

### 5.3.3 Drainage System Efficiency

Blocked most of these pathways. The discharge capacity of drains has been minimized due to construction, encroachment and neglect.

With heavy rainfall, the system is flooded for long duration.

### Inference

Reduced drainage efficiency increases flood duration and severity.

### 5.3.4 Soil and Infiltration

Most of the soil is alluvium and under natural conditions infiltration rate are moderate but, due to constructional development and compaction by man the permeability has been greatly reduced. Due to reduced permeability infiltration is greatly reduced and converted into runoff.

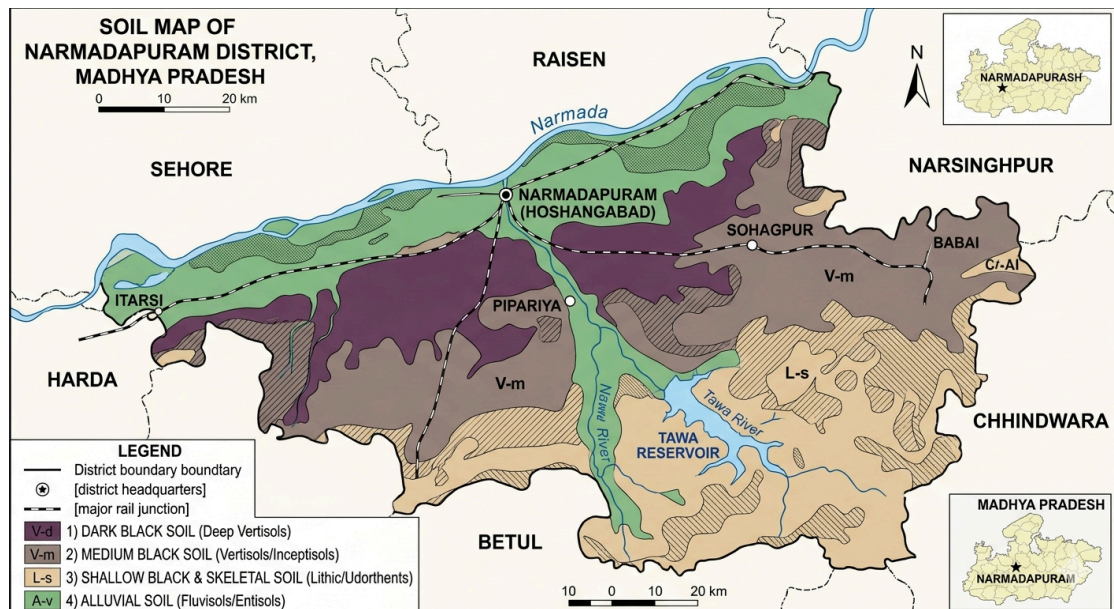


fig 14: soil map



**Inference**

Reduced soil permeability contributes to increased runoff and flood risk.

| Parameter        | Observation                | Impact on Flooding        |
|------------------|----------------------------|---------------------------|
| Topography       | Flat terrain               | Lateral spread of water   |
| River Morphology | Meandering river           | Uneven flood distribution |
| Drainage System  | Inefficient and obstructed | Waterlogging              |
| Soil             | Reduced permeability       | Increased runoff          |

Table No. 5.2: Physical Characteristics and Flood Influence

**5.4 Land Use and Settlement Analysis****5.4.1 Land Use Distribution**

The spatial structure exhibits concentrations of built-up areas for housing and commerce along the river and transportation networks, with rural lands scattered in peripheral zones and being progressively substituted with built-up lands. Increased risk of flood due to the settlement of areas prone to flood.

**Inference**

Spatial distribution of land use increases flood exposure.

### 5.4.2 Built-up Density

High-density areas exhibit increased impervious surfaces, leading to reduced infiltration and increased runoff.

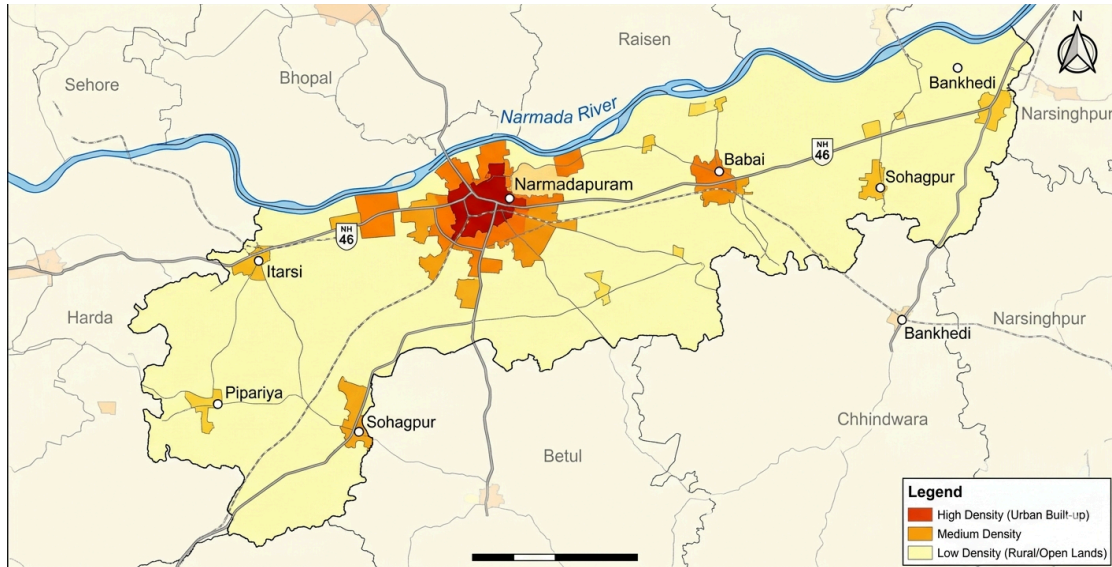


fig 15: Built up density Map

These areas also experience higher stress on drainage systems.

#### Inference

Density directly influences runoff and drainage load.

### 5.4.3 Settlement Patterns

The unplanned and informal settlements are found in low lying and hazard-prone areas as a result of limited availability of land.

The settlements are devoid of any infrastructure.

#### Inference

Settlement location and type increase vulnerability.

### 5.4.4 Green Cover and Open Spaces

The presence of green cover is scarce and in fragments, which also limit the potential of the area to absorb the water naturally.

The runoff rate is less and drainage rate is higher in the vegetated regions.

## Inference

Green spaces play a critical role in reducing flood intensity.

| Parameter        | Observation                | Impact on Flooding   |
|------------------|----------------------------|----------------------|
| Land Use         | Development near river     | Increased exposure   |
| Built-up Density | High density               | Increased runoff     |
| Settlements      | Located in low-lying zones | High vulnerability   |
| Green Cover      | Reduced and fragmented     | Reduced infiltration |

Table No. 5.3: Land Use and Flood Vulnerability

## 5.5 Flood Analysis

### 5.5.1 Flood Extent

Flooding is concentrated along the river and spreads across adjacent floodplain areas.

The extent of flooding is controlled by terrain and discharge levels.

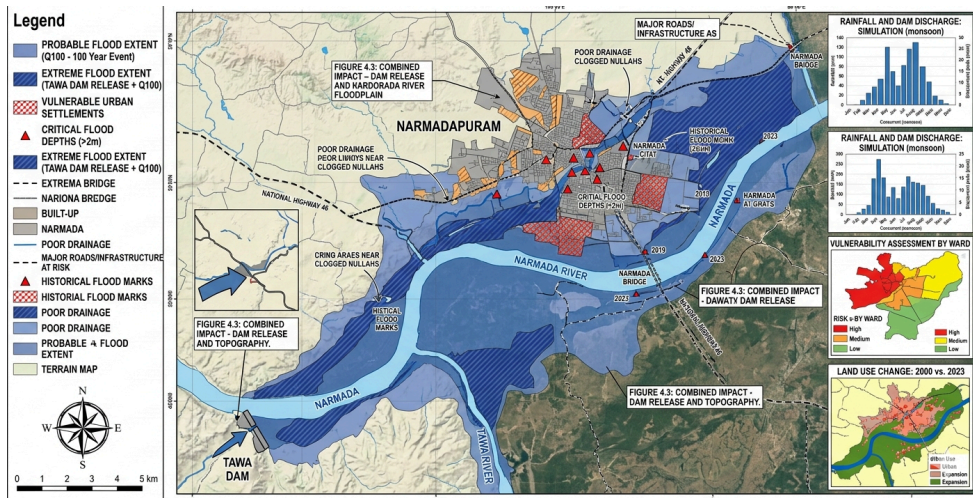


fig 16: Flood extent map

## Inference

Flood extent is governed by topography and river proximity.

### 5.5.2 Flood Depth

Maximum depth occurs at lowest elevation points closest to the river, with depth decreasing as elevation increases. Higher depths will correlate with increased damage potential.

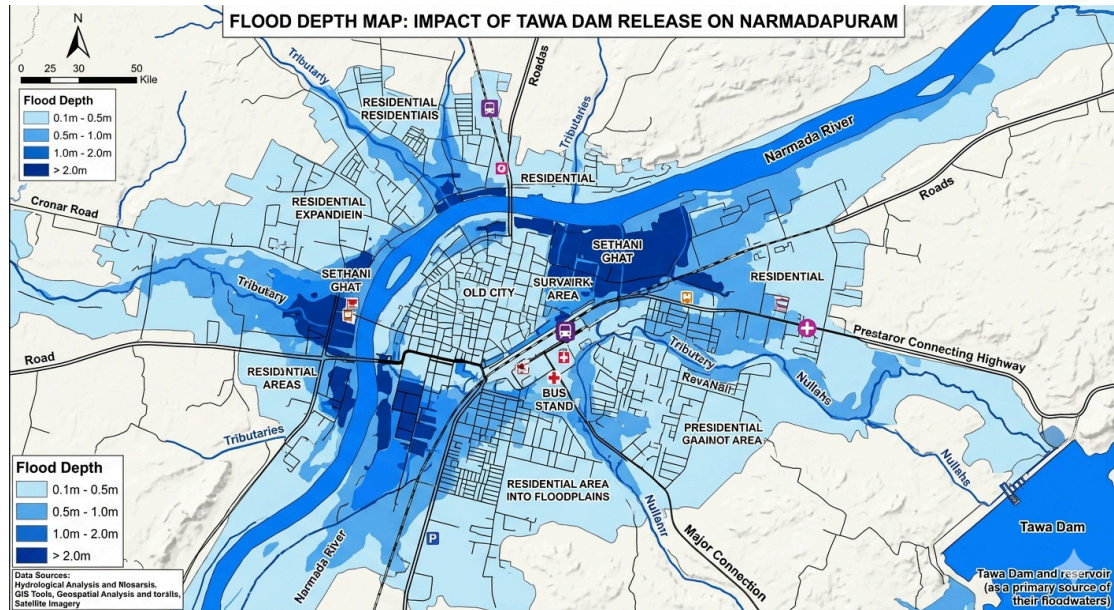


fig 16: Flood depth map

## Inference

Flood depth reflects elevation and flow concentration.

### 5.5.3 Flood Duration

Flood duration in an area with low slope and low drainage would be high,

Stagnation of water due to slow discharge.



## IMPACT OF TAWA DAM RELEASE IN NARMADAPURAM

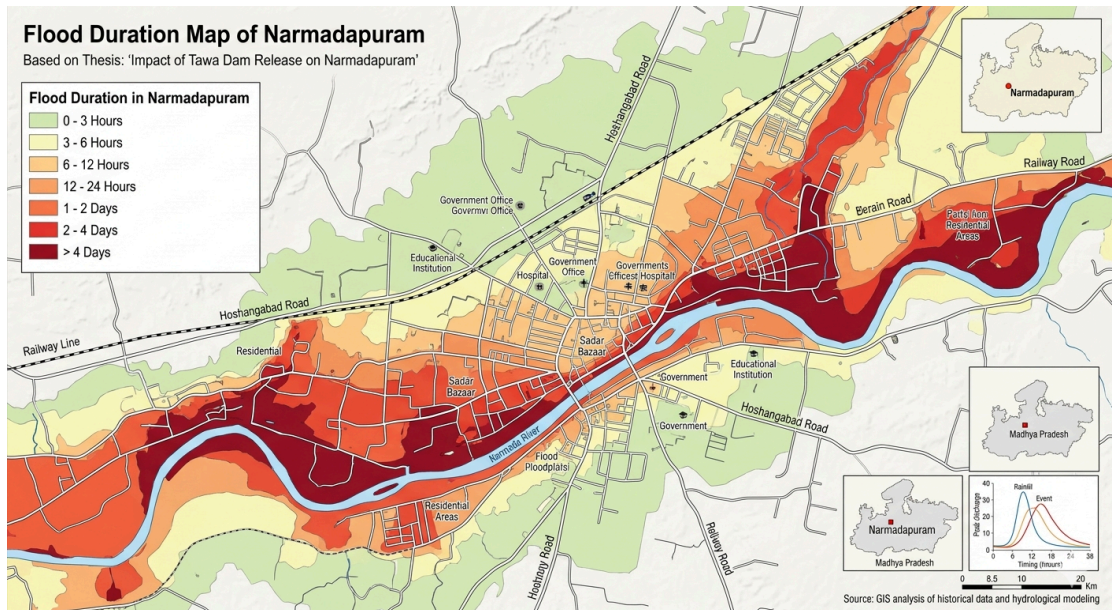


fig 17: Flood Duration map

### Inference

Drainage inefficiency increases flood duration.

### 5.5.4 Flood Vulnerability

High vulnerability is observed in areas where flood-prone zones overlap with dense settlements and infrastructure.

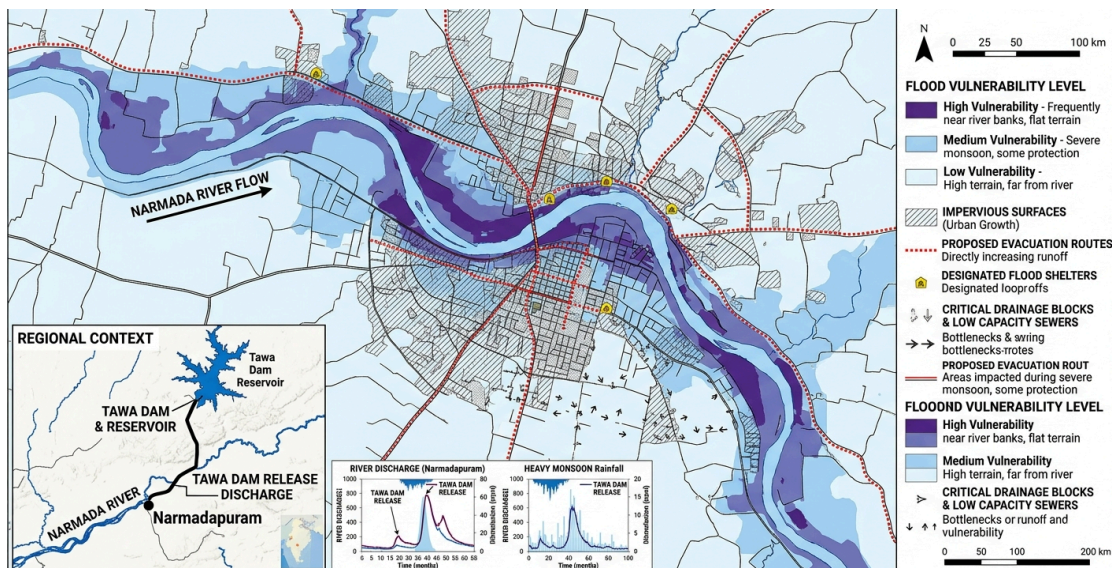


fig 18: Flood vulnerability map

### Inference

Risk increases with overlap of hazard and exposure.

| Parameter      | Observation                      | Impact              |
|----------------|----------------------------------|---------------------|
| Flood Extent   | Along river and floodplain       | Large affected area |
| Flood Depth    | High in low-lying zones          | Severe damage       |
| Flood Duration | Prolonged due to drainage issues | Long recovery time  |
| Vulnerability  | Overlap of hazard + settlements  | Increased risk      |

Table No. 5.4: Flood Characteristics

## 5.6 Infrastructure and Risk Analysis

### 5.6.1 Road Network

Flooding disrupts major and minor roads, affecting connectivity.

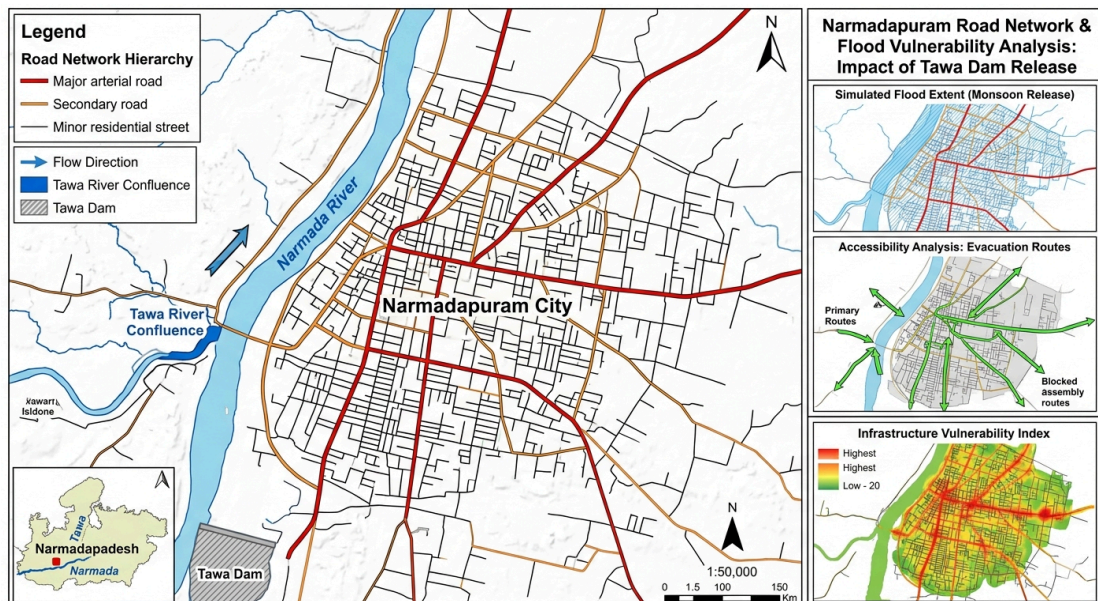


fig 20:Road network map



## Inference

Transport networks are highly vulnerable to flooding.

### 5.6.2 Critical Infrastructure

Hospitals, utilities, and public facilities located in flood zones are at risk.

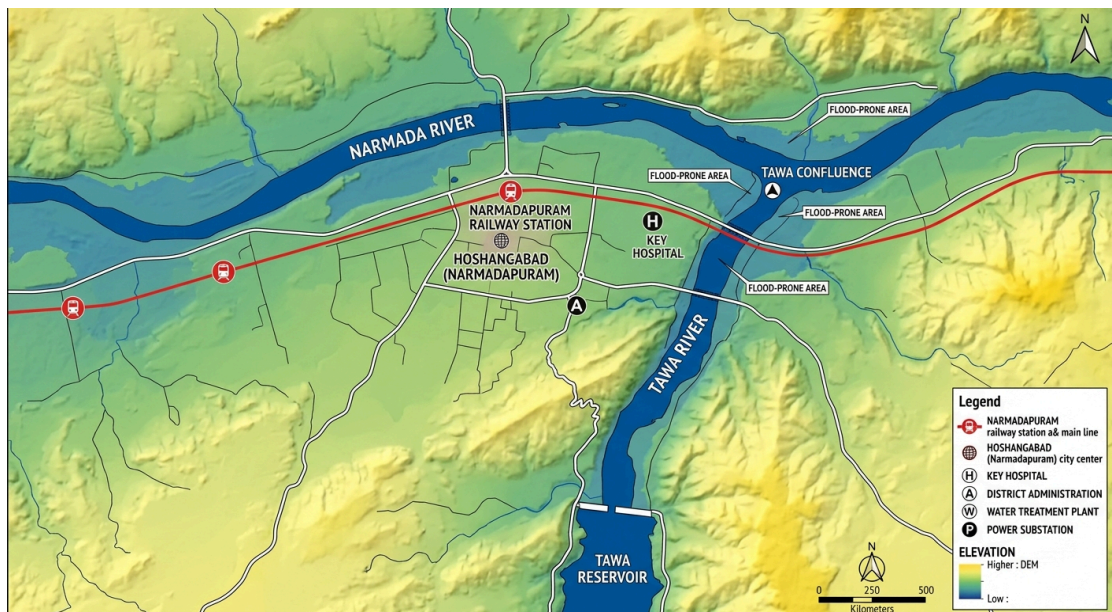


fig 21: Critical infrastructure map

## Inference

Infrastructure placement increases system vulnerability.

### 5.6.3 Accessibility

Flooding creates isolated zones, limiting emergency response.

## Inference

Accessibility is significantly reduced during flood events.

| Component    | Issue Identified | Impact               |
|--------------|------------------|----------------------|
| Road Network | Flood disruption | Reduced connectivity |



|                         |                         |                            |
|-------------------------|-------------------------|----------------------------|
| Critical Infrastructure | Located in flood zones  | Service interruption       |
| Accessibility           | Isolation during floods | Delayed emergency response |

Table No. 5.5: Infrastructure Vulnerability

## 5.7 Integrated Synthesis

- It is evident from the analysis that flood risk in Narmadapuram has been a result not of a single factor, but rather the interacting effects of several factors.
- Hydrodynamic Factors: Rainfall + Dam Release discharge is enhanced
- Physical Factors: Topography + drainage controls water flow
- Spatial factors: Settlement + land use increases exposure
- Infrastructural factors: Vulnerability is increased.

## 5.8 Key Planning Issues

- Floodplain encroachment
- Increased runoff due to urbanization
- Inadequate drainage infrastructure
- Infrastructure located in high-risk zones
- Unplanned settlements
- Reduced green cover

| Issue Category          | Description                               |
|-------------------------|-------------------------------------------|
| Floodplain Encroachment | Development in natural flood zones        |
| Increased Runoff        | Due to urbanization                       |
| Drainage Inefficiency   | Inadequate and blocked systems            |
| Infrastructure Risk     | Poor placement in flood-prone zones       |
| Unplanned Settlements   | Located in vulnerable areas               |
| Reduced Green Cover     | Loss of natural absorption capacity       |
| Lack of Integration     | Disconnect between planning and hydrology |

Table No. 5.6: Summary of Planning Issues

## 6. INTEGRATED PLANNING PROPOSAL FOR FLOOD-RESILIENT NARMADAPURAM

### 6.1 Introduction

On the basis of the hydrological regimes, topographic features, land use distribution, and the planning systems, it is clear that flooding at Narmadapuram is an outcome of natural processes and planning failures.

Intensified monsoonal rain, release of water from Tawa Dam according to management, flat topography, increasing urbanisation resulted in recurring flooding at Narmadapuram at severe extent. Standard Flood management solutions which primarily depends upon engineering structures can no longer cope up with these realities.

Thus an integrated urban planning approach is needed that synergises hydrology and planning. The presented solution is proposed based on this finding and proposes an integrated planning based, ecological and engineering multi- scalar plan to minimise flood risks and increases the resilience of the city.

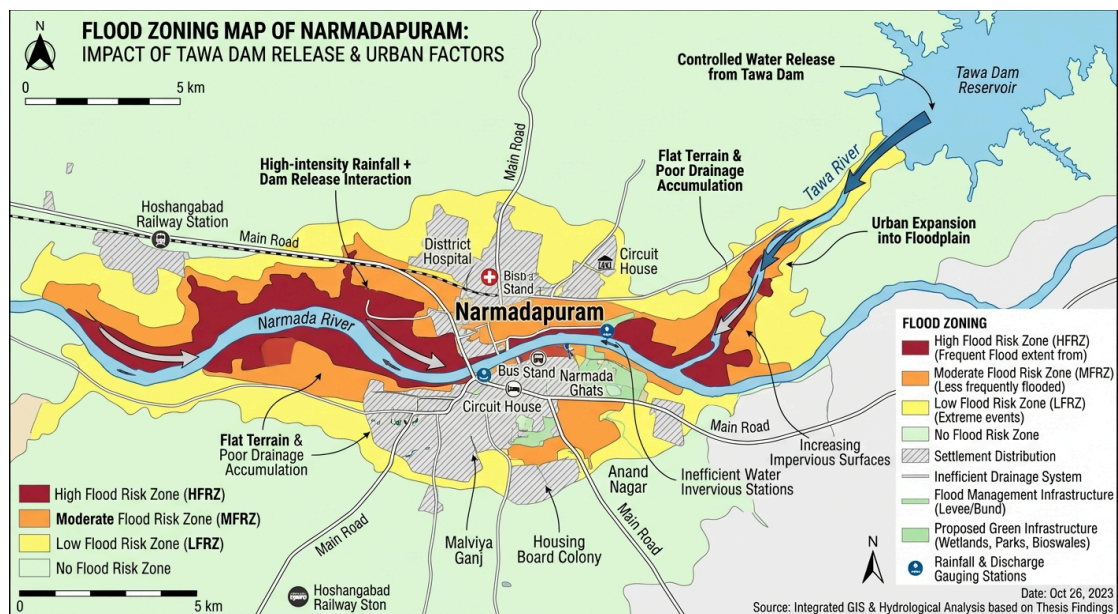


fig 22: Flood zoning map

## 6.2 Concept Framework

### 6.2.1 Living with Water

The concept of "Living with Water" underpins the proposal and is based on the idea that urban systems must be able to accommodate and integrate with natural hydrological processes rather than oppose them. It also seeks to establish floodable areas where the risk of flooding is limited and well-managed without threatening settlements or essential urban infrastructure.

The concept promotes move away from rigid flood defense structures to more adaptive and flexible system capable of handling fluctuation in water flow; it becomes of paramount importance in river systems such as the Narmadapuram where the flow is regulated by the dam.

## 6.3 Floodplain Zoning Strategy

It suggests flood plain zoning to be a prime planning mechanism guiding development according to flood risk and delineating high, moderate and low risk zones. It is formulated to guide land-use according to the natural dynamics of the river system.

The high risk zone is restricted to flood compatible uses, such as open spaces and ecological buffers. Since it is in low-lying areas, the river zone along with the river preserves its natural function as a flood reservoir.

Development in the moderate risk zone is allowed but under regulations like restricted landuse, higher plinth level and lower density.

The low-risk zones allow urban development, diverting development pressures away from risky areas.

The framework is intended to limit risk, promote flood plain functionality and manage urban growth sustainably.

| Zone Type | Characteristics             | Land Use    | Control Measures |
|-----------|-----------------------------|-------------|------------------|
| High-Risk | Floodplain, low-lying areas | Open spaces | No construction  |

|               |                    |                        |                 |
|---------------|--------------------|------------------------|-----------------|
| Moderate-Risk | Transitional zones | Controlled development | Elevated plinth |
| Low-Risk      | Higher elevation   | Urban development      | Standard norms  |

Table No. 6.1: Flood Risk-Based Zoning

## 6.4 Hydrological Strategy: Adaptive River System

### 6.4.1 Room for the River Approach

In an effort to manage flood dynamics at the river scale, the proposal includes a layered riverfront structure that permits the river to expand safely when water levels rise at times of highest flow.

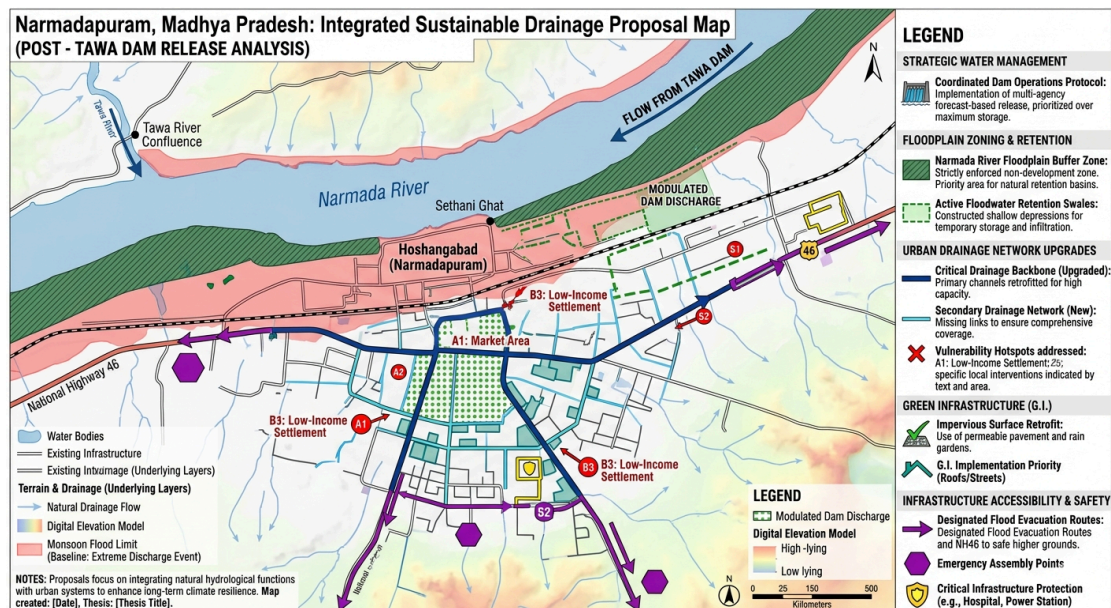


fig 23: Drainage proposal map

The first level or flood plain is a natural transitional space for the storage of temporary water excess from the high flow discharges. The second level or raised public promenade provides an additional functional space usable for medium flood stages. Finally, the third level consisting of urban forest and sponge edges provides a protective canopy for both runoff absorption and a minimized impact to the built-up environment.

| <b>Tier</b> | <b>Component</b> | <b>Function</b>   | <b>Benefit</b>       |
|-------------|------------------|-------------------|----------------------|
| 1           | Flood Meadow     | Water storage     | Reduces peak flood   |
| 2           | Public Corridor  | Buffer + movement | Maintains usability  |
| 3           | Sponge Edge      | Absorption        | Protects built areas |

Table No. 6.2: Tiered Riverfront Strategy

## 6.5 Spatial Strategy: Blue-Green Network

### 6.5.1 Urban Water Retention System

At city scale, the proposal aimed to enhance urban capacity to absorb and manage water by a series of blue-green infrastructure which can alleviate surface runoff and promote infiltration.

Sloping terrain becomes topographic sinks (monsoon period: temporal detention basins, dry period: public spaces).

Use of permeable surfaces everywhere in city, to promote groundwater recharge and reduce surface runoff.

Bioswales and green streets inserted into the road network to infiltrate and filter runoff, while the restoration of natural drainage through blue corridors guarantee smooth flow of water.

| <b>Element</b>     | <b>Function</b> | <b>Outcome</b>       |
|--------------------|-----------------|----------------------|
| Sinks              | Water storage   | Reduced runoff       |
| Permeable Surfaces | Infiltration    | Groundwater recharge |



|                |               |                      |
|----------------|---------------|----------------------|
| Bioswales      | Filter runoff | Improved drainage    |
| Blue Corridors | Water flow    | Reduced waterlogging |

Table No. 6.3: Blue-Green Infrastructure

## 6.6 Engineering Strategy: Non-Return Drainage System

### 6.6.1 Controlled Drainage Mechanism

River water entering the city drainage system due to refluxing at high discharge is one of the causes for flooding in Narmadapuram. To tackle this problem a non-return drainage system is proposed, which facilitates uni-directional flow of the water within the system. Non-return valves will be provided at all outfalls and sluice gates will be operated according to the river stages. Pumping stations are proposed at some locations to facilitate effective draining during such events.

The proposed interventions are backed up by a hybrid drainage system that employs both gravity and pumping.

| Component        | Function          | Benefit                     |
|------------------|-------------------|-----------------------------|
| NRV Valves       | Prevent backflow  | Reduces flooding            |
| Sluice Gates     | Control discharge | Regulates flow              |
| Pumping Stations | Active drainage   | Works in extreme conditions |
| Hybrid System    | Combined system   | Reliable performance        |

Table No. 6.4: Drainage System Components

## **6.7 Integrated System Approach**

The strength of this plan is that it combines the strategies of hydrologic, spatial and engineering to work as one. The strategies contribute to flood mitigation in a separate way but they together contribute to flood risk reduction.

Water is managed by: first being contained in the floodplain, then being absorbed and stored in the urban matrix, then finally being passed off through engineered systems.

## **6.8 Infrastructure and Settlement Strategy**

Infrastructure hardening and support to the most vulnerable settlements are foreseen as interventions to mitigate the consequences of flooding on urban systems. Critical infrastructure is elevated or flood-proofed, so to ensure continuity of services during floods.

In turn, settlements at risk were singled out for relocation to safer locations; in cases of no relocation being possible, the building of adaptive housing structures (e.g., stilted houses, elevated houses) is suggested as an intervention to enhance safety, and improve resilience of settlements and of the city in general.

## **6.9 Policy and Implementation Framework**

Implementation of the recommended strategies will rely on adequate institutional capacity and cooperation. Institutional requirements are: Enforcement of floodplain zoning and planning requirements, and cooperation between municipal government and dam management agencies, and integration of strategies into the legal planning system. A phased implementation approach (i.e., short, medium, and long term) is suggested.

## **6.10 Conclusion**

This integrated planning approach goes beyond the conventional, 'reactive' flood management, to a 'proactive and adaptive' one. Through accommodation (hydrological), absorption (spatial), and control (engineered) systems, the proposal develops a robust mechanism to tackle flood disasters under natural and engineered induced situations. It provides not only a model for Narmadapuram, but can be replicated and scaled to similar riverine towns elsewhere.

IMPACT OF TAWA DAM RELEASE IN NARMADAPURAM

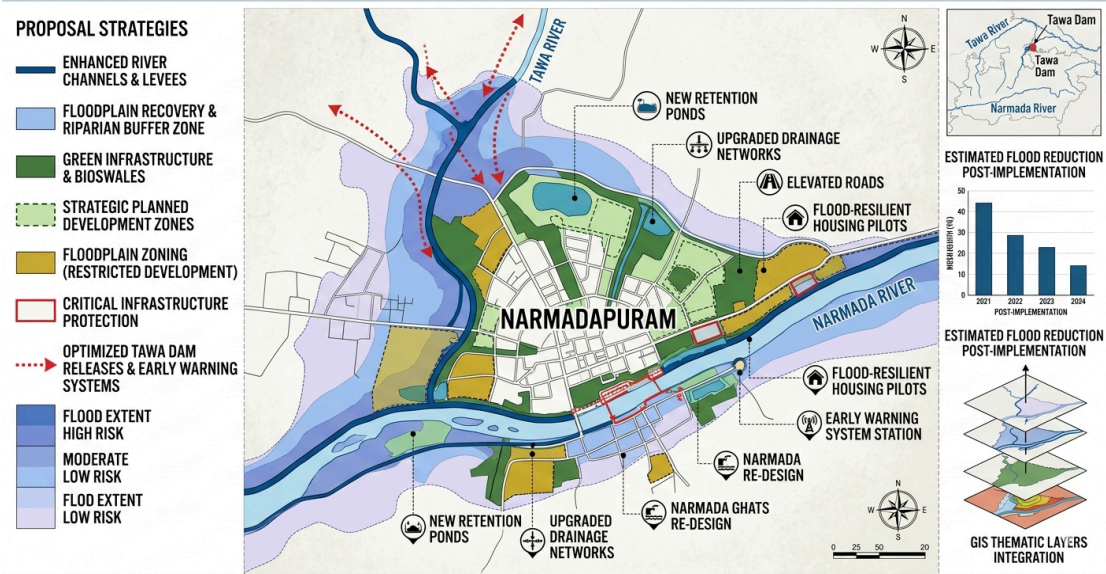


fig 24: planning proposal map

## **7. PHASING, GOVERNANCE AND IMPLEMENTATION FRAMEWORK**

### **7.1 Introduction**

A staged implementation approach supported by an institutional governance framework and institutional arrangements for implementation is presented in this chapter.

Not just the design of the strategies, but the efficient, institutionalized implementation and sustainable long-term governance of them, would decide the success of the proposed flood-resilient planning framework for Narmadapuram. Because the problem is multifaceted-where dynamics are dictated by dam regulation induced releases, urban runoff and climatic changes-it requires an institutionalized approach towards implementation, to translate plan provisions into action.

### **7.2 Phasing Strategy**

The application of these strategies is organized in three phases-short-term, medium-term, long-term based on the priority and practicability of each measure and level of intervention.

#### **7.2.1 Short-Term Phase (1–2 Years)**

In the short-term phase, immediate and high impact actions aimed at mitigating flood risk using existing infrastructure and less substantial interventions can be implemented.

Some of these can include:

- Desilting and desilting of existing drainage channels
- Demolition of vital encroachments along natural water channels and riverbanks
- Identification and demarcation of high-flood risk zones
- Installation of temporary flood barriers and early warning system
- Implementation of policy measures for floodplain management.

#### **7.2.2 Medium-Term Phase (3–5 Years)**

This phase would concentrate on construction and spatial planning actions for enhancing resilience of the city in managing floods.

Primary actions included would be:

- Construction of blue-green infrastructure elements like detention ponds, bioswales and permeable surfaces
- Implementation of floodplain zoning and managed land uses.
- Installation of pumps and check valves at major outfalls
- Upgradation of drainage systems consistent with natural flow directions
- Commencement of relocation programs for the highest-risk populations

Focus would be on enhancing resilience of the city using integrated systems approach with engineering solutions and spatial interventions.

### 7.2.3 Long-Term Phase (5+ Years)

The long term phase focuses on "the entire incorporation of the hydrological and urban systems; establishing adaptive and resilient flood management."

- Complete realization of the layered riverfront system under the "Room for the river" concept.
- Dissemination of the blue-green network to the entire urban area.
- Inclusion of smart flood monitoring systems and alert system.
- Institutionalizing coordinated river dam operation and urban planning mechanism.
- Consistent reassessment and modification of policies.

| Phase       | Duration | Focus Area              | Outcome                |
|-------------|----------|-------------------------|------------------------|
| Short-Term  | 1–2 yrs  | Immediate fixes         | Risk reduction         |
| Medium-Term | 3–5 yrs  | Infrastructure + zoning | System strengthening   |
| Long-Term   | 5+ yrs   | Full integration        | Sustainable resilience |

Table No. 7.1: Implementation Phasing

## **7.3 Governance Framework**

Effective implementation will necessitate a structure of multi-level governance with coordination between different agencies responsible for water resource management, urban planning and development of infrastructure.

### **7.3.1 Institutional Coordination**

Several agencies and stakeholders participate in managing floods in Narmadapuram such as:

- Municipal Corporation,
- Urban Development Authorities,
- Water Resources Department (Dam management authority),
- Disaster management authorities, and many more.

This aspect necessitates the existence of a coherent framework for the sharing of information, timely and coordinated decision-making as well as integrated planning especially at the time of high rainfall and when water has to be released from dams.s.

### **7.3.2 Policy Integration**

The suggested measures must be integrated into the present planning and regulatory structure so as to guarantee their long term efficacy. The relevant policy measures are:

- Compulsory implementation of floodplain zoning legislation
- Flood hazard considerations should be incorporated into master plans.
- Development control regulations should apply to construction in high hazard areas.
- Permeable surfaces and green infrastructure should be required in new constructions.

These measures allow for planning decisions to be consistent with hydrological realities.

### **7.3.3 Community Participation**

Community engagement is an essential component of the successful implementation of flood management schemes.

Awareness campaigns, consultations with stakeholders and community involvement in routine maintenance will contribute towards the successful implementation of various intervention methods.



Community involvement can assist in:

- Promoting preparedness and response
- Facilitating local drainage maintenance
- Assisting in relocation and adaptation initiatives

| Stakeholder         | Role               | Responsibility            |
|---------------------|--------------------|---------------------------|
| Municipal Authority | Urban management   | Drainage & infrastructure |
| Water Dept          | Dam control        | Release management        |
| Planning Authority  | Regulation         | Zoning enforcement        |
| Disaster Authority  | Emergency response | Risk management           |

Table No. 7.2: Governance Structure

## 7.4 Implementation Mechanisms

### 7.4.1 Execution Strategy

Execution of proposed interventions needs a phased operational plan to integrate the proposed interventions to the planned engineering, administrative, operations. It consists of: Prioritization of intervention according to levels of risk allocation of agency responsibilities  
Integration of interventions to existing development programs

### 7.4.2 Monitoring and Evaluation

Regular monitoring will be carried out to determine whether strategies are working as expected and have ongoing effectiveness.

Performance metrics include;

- The performance will be monitored at regular intervals through periodic review of the vulnerable areas
- Monitoring of drainage efficiency

- The use of GIS and other data-driven monitoring techniques
- Evaluation of the performance of all measures.

By measuring performance, this allows for adaptive management, changes will be made to strategy on observed effects.

### **7.4.3 Capacity Building**

Building institutional and technical capacity is required for proper implementation. This includes:

- Municipal staff and planner training.
- Introduction of the state-of-the art techniques for hydrologic and spatial analysis.
- Technical guidelines for flood-resilient planning are needed.

## **7.5 Financial Considerations**

The development of these strategies need to rely on a multi-source funding mechanism to ensure economic viability and sustainability in the long term.

Potential funding sources include:

- Government funding via urban development and water management programs,
- Public Private Partnerships for river front and infrastructural development,
- Investment planned phase-wise corresponding to each stage of implementation.
- A carefully drawn financial planning scheme helps ensure an efficient allocation of resources and a time bound implementation.

## **7.6 Conclusion**

In order to implement the proposed framework to the existing Narmadapuram's flood vulnerability, an effective strategy regarding phase of implementation, governance, and execution must be developed. With such strategic plan and coordinating mechanisms across the institution, the city will be able to transform itself toward a resilient and adaptable flood management system from the short term implementation towards long term. Moreover, this framework will not only guide the execution but will also establish a governance mechanism that promotes continuous adaptation and enhancement toward a sustainable system.

## 8. CONCLUSION AND FUTURE SCOPE

### 8.1 Summary of Research

In this work, effect of release of Tawa Dam on the hydrological condition of Narmadapuram and susceptibility of floodings studies, focusing on its interaction with urbanization. hydrological study, spatial analysis and infrastructural survey to find the factors contributing to the flood condition is used.

It is found that combination of high intensity monsoonal rain, abrupt dam release, flat terrain and low infiltration capacity and unmanaged urban growth into flood prone zones contribute to flood condition in Narmadapuram, due to poor coordination between upstream water management system and downstream planning system.

Considering these observations, an integrated planning framework for Narmadapuram is proposed which consists of floodplain zonation, flexible riverfront development, blue-green infrastructure and engineered drainage system. Here, the water is to be managed not to be controlled but adapted to, integrated with, managed in and around the city

| Objective                 | Method Used         | Outcome                 |
|---------------------------|---------------------|-------------------------|
| Rainfall analysis         | Hydrological study  | Patterns identified     |
| Land use study            | GIS mapping         | Vulnerable zones mapped |
| Flood identification      | Spatial analysis    | Risk zones defined      |
| Infrastructure assessment | Overlay analysis    | Weakness identified     |
| Strategy development      | Integrated approach | Proposal achieved       |

Table No. 8.1: Validation of Objectives

## 8.2 Key Contributions of the Study

The main contributions of this research to the area of urban planning and flood management can be found as the provision of an integrative and multi-disciplinary approach that makes a bridge between hydrology and spatial planning; they are:

- Definition of the connection between dam-regulated discharge and urban flood hazard, and validation of it with other hydrological, hydraulic and social models.
- Showing how patterns of land uses and drainage networks impact on flooding behavior.
- Integration of the hydrological and spatial elements with engineering solutions in a unified design framework.
- Proposing a specific and location-based planning such as the tier riverfront system, blue-green corridors and non-return drainages and their advantages.
- Developing an example which could be extended to other regulated rivers impacting on urban areas.

## 8.3 Validation Against Objectives

The objectives laid out in this study were all fulfilled by a systematic process of analysis and design.

Through an understanding of hydrological components and system responses, an understanding of patterns in rainfall and discharge were obtained.

By studying land use and settlement patterns, areas exposed and vulnerable were identified.

Spatial and flood analyses enabled mapping of areas subject to flood.

Identification of exposed infrastructure and accessibility provided a clear view of the urban system's weaknesses.

Finally, development of planning strategies to combat these vulnerabilities was undertaken in the form of an integrated proposal framework.

This case validates that analysis can be directly translated to an effective proposal.

## 8.4 Limitations of the Study

The study offers good insights on flood processes and planning efforts. But there are some limitation that should be considered.

The study mainly used the secondary data sources. Accuracy can be an issue in some instances.

Insufficient time-based dam operation data for long-term and real-time has hindered further in-depth analysis of dynamics.

No hydraulic modeling and simulation capabilities can limit the ability to accurately predict the response in flood dynamics.

Spatial analyses is limited to the availability and resolutions of data sets and can limit the micro-level interpretation.

Although limited in the ways above, the study offers a good framework for concept and planning.

## **8.5 Recommendations for Future Use**

The framework developed can be applied by planning authorities and policymakers to plan the flood-resilient development of urban Narmadapuram.

Important recommendations derived are:

- Inclusion of floodplain zoning within the legally mandatory plans
- Acceptance of the blue-green infrastructure strategy as an everyday urban development tool
- Operation coordination of dam systems based on real-time data
- Integration of flood risk into infrastructure design and development regulations

## **8.6 Extensions to the Study Area**

The method and techniques designed in this study may be useful in other locations in the Narmada River basin and other river cities suffering from regulated systems induced floods:

- Cities located downstream of a dam
- Cities with rapid, unguided growth
- Cities affected by extreme rain events exacerbated by climate change

With some local adjustments to fit the conditions of a place, this may aid in the general regional planning and emergency response activities.

## **8.7 Future Scope**

The above work can further be extended and developed into the following lines of research.

- Developing real time flood forecasting and monitoring system

- Integrating Hydraulic and Hydrodynamics modeling for improving simulation
- Study smart data driven flood management systems
- Developing detailed design and implementation of proposed solutions
- The work can then enhance the performance of flood resilient plan.

## **8.8 Final Statement**

In this work, it has been confirmed that the flood management in Narmadapuram cannot be dealt with separate, reactive actions, but in an integrated, adaptive and proactive manner of planning. The proposed idea integrates hydrological knowledge with spatial planning and engineering approaches to show how urban systems can be designed to integrate with the natural systems.

The framework provided not only addresses immediate problems associated with flooding, but can help building of a sustainable, climate resilient and climate responsive urban environment which can be applied for context similar to the studied region.



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