

DETAILED PROJECT REPORT

Flood Hazard Mapping & Drainage Analysis of
Kottayam Municipality,
Kottayam, Kerala

FLOOD VULNERABILITY & MITIGATION



K-DISC
Kerala Development and Innovation
Strategic Council



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Insight • Dialogue • Impact



DETAILED PROJECT REPORT:

FLOOD VULNERABILITY & MITIGATION

**Flood Hazard Mapping & Drainage Analysis of
Kottayam Municipality, Kottayam, Kerala**

Submitted by

Technology and Governance Support Forum

Submitted to

Kerala Development and Innovation Strategic Council



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List of Abbreviation

Sl. No	Abbreviation	Expansion
1	OLOI	One Local Body One Idea
2	K-DISC	Kerala Development and Innovation Strategic Council
3	LSGI	Local Self Governing Institution
4	DPR	Detailed Project Report
5	KII	Key Informant Interview
6	MSL	Mean Sea Level
7	GIS	Geographic Information System
8	KSDMA	Kerala State Disaster Management Authority

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Chapter 1: General Background

1.1 Problem Statement

The problem, as stated by the Kottayam Municipality:

“Recurring floods seriously affect human lives and the agricultural sector. Lack of a comprehensive water disposal system is a problem.”



The problem description as submitted by the Municipality:

“Continuous floods are severely affecting the agriculture and health production sectors in the Kottayam Municipality area. The main reason for this is the lack of effective drainage systems. Waterlogging due to continuous rainfall is a major problem in urban areas. A scientific drainage system is essential in the town area. Examples of this are Kurian Uthup Road, Nehru Stadium, Nagampadam Bus Stand and Park which gets waterlogged when it rains.

Till ten years ago, Kottayam had 2340 acres of paddy cultivation in 22 Padasekharam, today only 60% of it is there. 850 acres of paddy was lost due to continuous waterlogging (summer) mostly seen in Kumaranalloor & Nattakom. Along with this, the waterlogging has also affected the production of other agricultural crops such as coconut, banana, castor and rubber.

Water-borne disease, fresh water shortages, floods and waterlogging plague the city. There are still areas in the city where fresh water is scarce. Nattakam and Parampuzha are the western areas where the transport facility is destroyed when it rains. There should be better disaster preparedness urban planning plans for climate change and rainfall events.”

The challenges faced by Kottayam Municipality necessitate an immediate and scientifically driven approach to mitigate the issues of urban flooding and waterlogging. The substantial decline in paddy cultivation, coupled with the loss of other agricultural crops, underscores the critical impact on the local economy and food security. Furthermore, the prevalence of waterborne diseases and disruptions to transportation networks highlight the broader implications of inadequate drainage infrastructure.

This initiative is being implemented under the "One Local Government One Idea" (OLOI) program led by the Kerala Development and Innovation Strategic Council (K-DISC). The program aims to empower Local Self-Government Institutions (LSGIs) in Kerala to address multifaceted developmental challenges through innovative and practical solutions. By fostering partnerships between LSGIs, academic institutions, subject-matter experts, and startups, the OLOI program seeks to enhance governance, service delivery, and sustainable development at the local level.

Within this framework, the project aspires to establish a scalable and sustainable model for urban flood management, incorporating scientific drainage systems, climate-resilient urban planning, and enhanced disaster preparedness. By addressing the root causes of waterlogging and its socio-economic repercussions, this initiative aims to restore agricultural productivity, improve public health, and enhance the overall quality of life for the residents of Kottayam Municipality.

1.2 Scope of the project

The project focuses on developing solutions to address critical local challenges. Key areas include:

- **Knowledge Integration:** Utilizing expertise from academia, government, and industry to address developmental issues.

- **Problem Analysis and Solution Development:** Analyzing problems identified by LSGIs and developing innovative, feasible solutions.
- **Community-Centric Approach:** Ensuring solutions are practical, accepted by the community, and aligned with local needs.
- **Sustainability and Scalability:** Prioritizing long-term sustainability and the potential to scale successful solutions.

1.3 Objectives

Our aim was to develop a preliminary project report with a focus on understanding the context and mapping the existing situation. Our objectives were:

- Identify and categorize wards based on flood hazard areas, and create ward-level flood risk maps delineating flood-affected zones and vulnerable infrastructure.
- Map and analyze the root causes of flooding and challenges within the existing drainage network through primary and secondary data analysis.
- Identify key stakeholders influencing the drainage network as well as those directly affected by flooding, and capture their aspirations, expectations, and concerns to align proposed solutions with local needs.
- To establish a problem framework that identifies ward-specific flood risks and root causes, enabling targeted interventions and fostering local innovations for enhanced resilience.

This Situation Assessment Report has been prepared in alignment with the objectives outlined in Section 1.3 of the project. To achieve these objectives, extensive field studies were conducted in collaboration with technical experts, local residents, stakeholders, and practitioners. Through detailed analysis, the issues and their root causes were thoroughly examined to gain a deeper understanding of the ground realities.

The current flooding situation was analyzed at the ward level to identify the types of flooding and their primary causes within each ward. This ward-level analysis provided critical insights into the prevailing challenges and highlighted the key areas that require targeted interventions.

Chapter 2 : Study Area Profile

2.1 Study Area

The Kottayam Municipality is located in the Kottayam district of Kerala and is the administrative hub of the district. It is bordered by the villages of Nattakom, Velloor, Kottayam, and Perumbaikad. The municipality comprises 52 wards and is surrounded by Vijayapuram Panchayat to the east, Thiruvappu Panchayat to the west, Aymanam and Kumaranalloor Panchayats to the north, and Nattakom Panchayat to the south.

The town serves as an important transit hub, connecting the highlands to the backwater region and is known for its mixed land-use patterns, combining commercial, residential, and agricultural zones. The region's natural setting includes water bodies such as the Kodoor and Meenachil rivers, which influence its hydrology and susceptibility to flooding.

Below is the profile of Kottayam Municipality:

Table 1: *Profile of Kottayam Municipality*

Parameter	Details
Area	15.99 sq. km ¹
Number of Households	14,386 ²
Total Population	55,374 ²
Age Group (0–6 years)	4,571 ²
Literacy Rate	96.4% ²

¹ Kottayam Municipality Master Plan, 2015

² Census of India, 2011

Male Population	27,769 ²
Female Population	27,605 ²
Sex Ratio	994 females per 1,000 males ²
Work Participation Rate	34.2% ²
Major Rivers Influencing Area	Kodoor River, Meenachil River ³
Topography	Mixed terrain with low-lying flood-prone areas ⁴
Climate	Tropical monsoon with heavy rainfall during June–September ⁵

This detailed profile provides a comprehensive understanding of Kottayam Municipality's demographic, geographic, and socio-economic characteristics, highlighting critical factors influencing its flood vulnerability. The municipality spans an area of 15.99 sq. km, with a population density of approximately 3,465 persons per sq. km (calculated from Census 2011 data). The Kodoor and Meenachil Rivers, which flow through the area, are significant contributors to urban flooding during monsoons, particularly affecting low-lying wards such as Nattakom, Kumaranalloor, and Parampuzha (Kerala State Disaster Management Plan, 2020). Nearly 20% of the municipality's area falls within flood-prone zones, and the region receives an annual average rainfall of approximately 3,000 mm, with over 70% concentrated between June and September (Indian Meteorological Department, 2023).

³ Kottayam Municipality Master Plan, 2015

⁴ Kerala State Disaster Management Plan, 2020

⁵ Indian Meteorological Department (IMD), 2023

The carrying capacity of major drains has decreased by 35% due to sedimentation and encroachments (Centre for Water Resources Development and Management, 2021). Agricultural activities have suffered significant setbacks, with paddy cultivation reduced by 40% over the past decade due to waterlogging and land-use changes. Other crops, such as coconut, banana, and rubber, have also experienced productivity losses (Kerala Agricultural Statistics, 2021). The municipality has reported an 18% increase in waterborne diseases such as leptospirosis and dengue during flood seasons over the past five years (Kerala Directorate of Health Services, 2022).

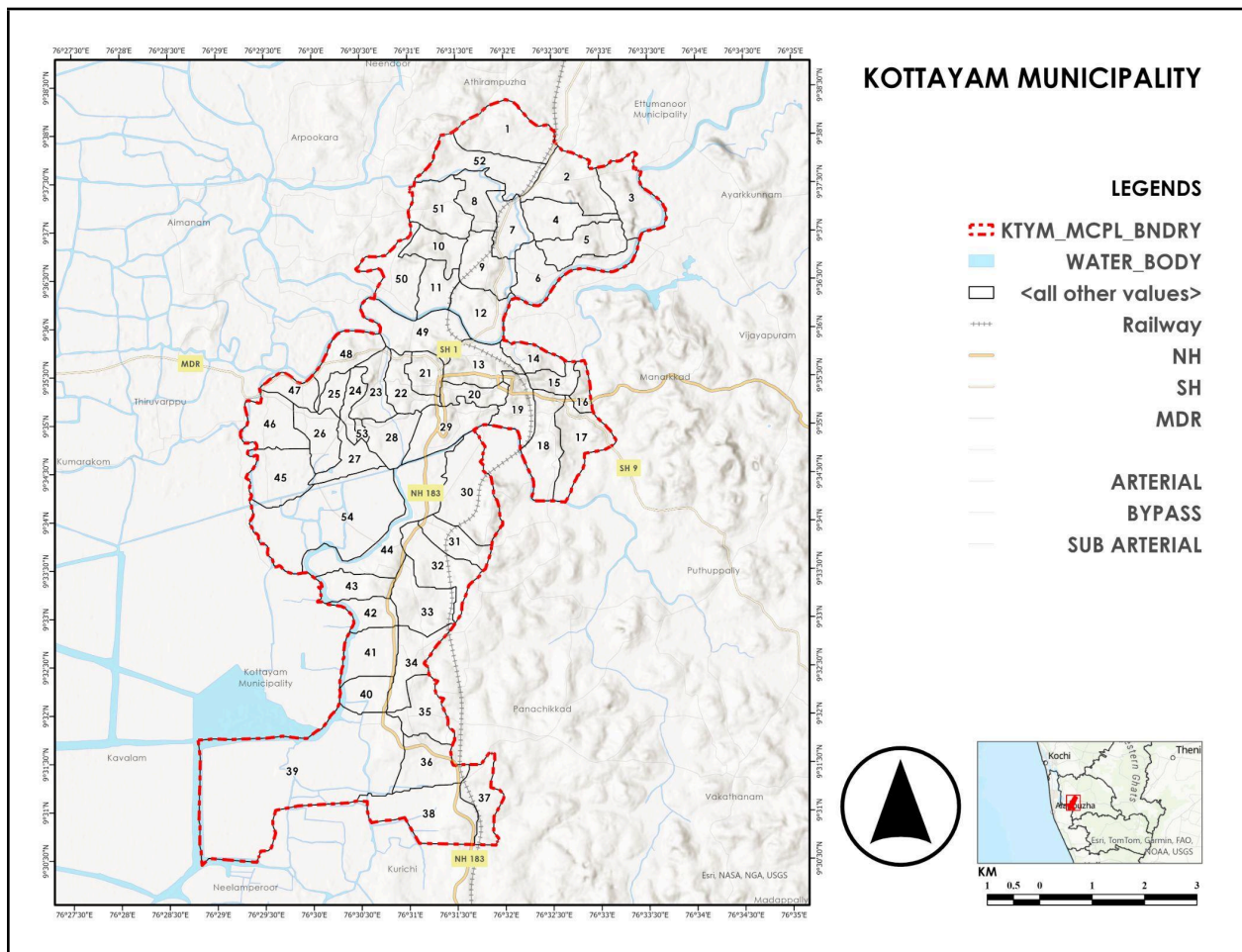


Figure 1(a) : Map of Kottayam Municipality

Infrastructure inadequacies exacerbate the problem, with more than 60% of drainage systems either clogged or undersized, particularly in high-traffic zones like Nagampadam and Nehru Stadium (Kottayam Municipality Engineering Department, 2023). Transportation networks face frequent disruptions, with Parampuzha and Nattakom recording road damage during at least 20 rainfall events annually (Kerala Public Works Department, 2023). A 2019 study by the National Institute of Technology Calicut identified the potential for implementing nature-based solutions, such as urban wetlands and bioswales, to enhance floodwater absorption and reduce runoff. GIS-based flood modeling conducted by the State Land Use Board in 2022 identified five critical hotspots where immediate interventions, such as desilting and bund strengthening, could reduce flood risks by 25%.

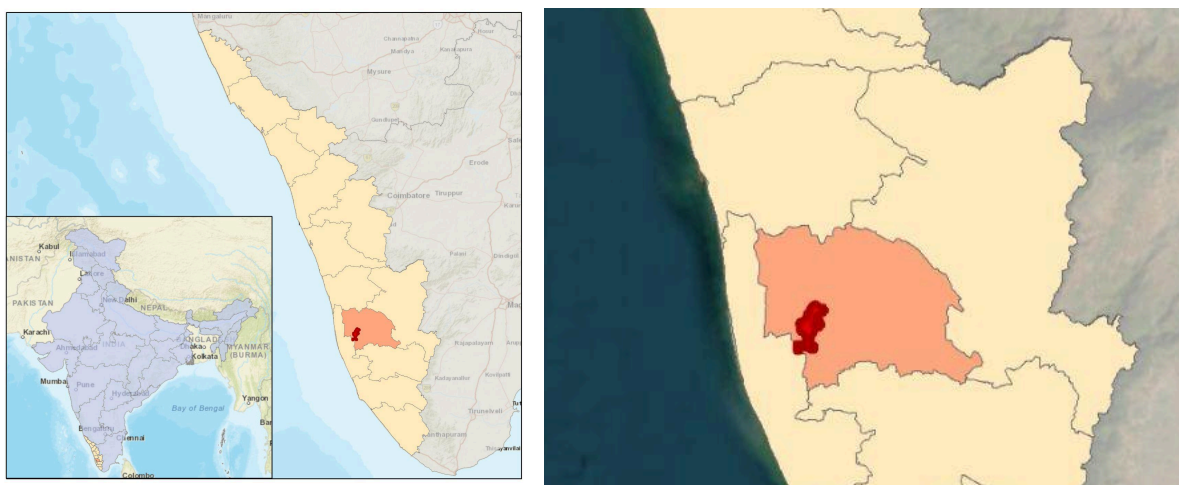


Fig 1(b): Location context of Kottayam Municipality

2.2 Land Use Land Cover

The Kottayam Municipality, characterized by its mixed land use, has undergone significant changes in land use and land cover (LULC) over the past seven years. According to the LULC maps for 2017 and 2023, the built-up area has increased from 69% in 2017 to 70.52% in 2023, while vegetation cover has decreased from 29% in 2017 to 25.50% in 2023⁶. These shifts have resulted in increased surface runoff and reduced soil infiltration, heightening the risk of flooding due to diminished rainfall absorption capacity.

⁶ United States Geological Survey (USGS)

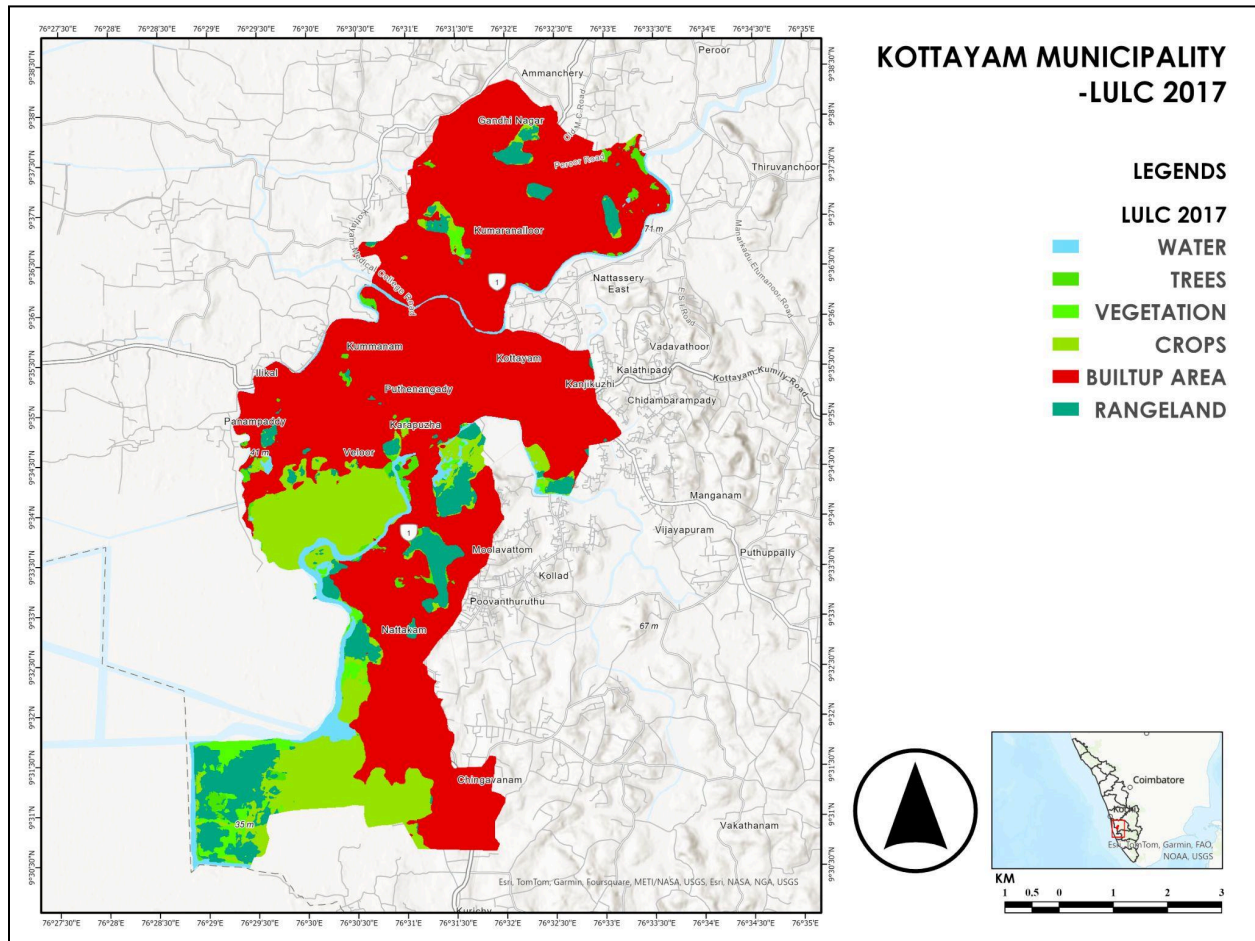


Figure 2: Map Of LULC 2017

These findings align with broader regional trends. Varghese and Latha (2020) observed significant urban expansion in the region, often at the expense of wetlands and agricultural fields. 168% increase⁷ in built-up areas in the Kidangoor watershed between 2000 and 2017, coupled with a decline in other land use categories. Wetlands, essential for flood mitigation, have seen reduced capacity to absorb runoff⁸⁹. The proliferation of impervious surfaces exacerbates this issue by accelerating surface runoff and overwhelming drainage systems .

⁷ Sreejith, S., & Sreejith, S. (2018). *Land use and land cover changes in the Kidangoor watershed, Kerala*

⁸ Ramsar, M., Kumar, S., & Singh, R. (2019). *Wetland loss due to urban expansion: A case study of the Delhi region*

⁹ Sudhakar, S., Ramesh, R., & Kumar, R. (2020). *Impact of impervious surfaces on runoff and drainage systems in urban areas.*

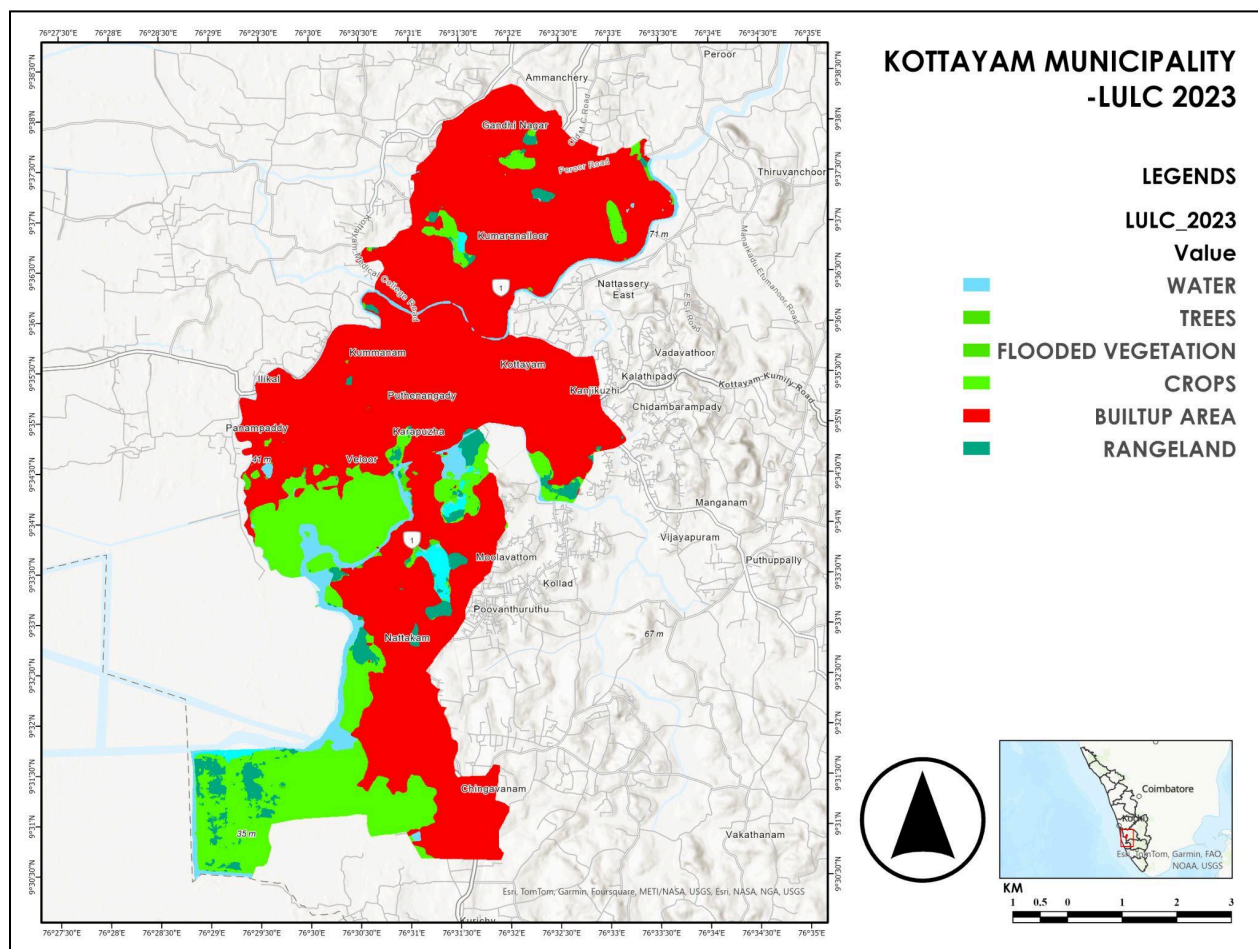


Figure 3: Map Of LULC 2023

The loss of wetlands also impacts biodiversity and water quality. Wetlands provide habitats for various species, and their destruction has led to notable biodiversity loss¹⁰. Furthermore, their role as natural water filters has diminished, impairing water quality.¹¹

2.3 River and other Water Systems

The Kottayam Municipality is nestled between two significant rivers—the Meenachil and Kodoor—both of which play a vital role in the region’s hydrology while contributing to flood risks. These rivers traverse residential areas, posing threats to both human life and agriculture.

¹⁰ Menon, P., Nair, R., & Thomas, S. (2017). *Wetland losses and the status of wetland-dependent species*.

¹¹ Thomas & George, 2021

- **Meenachil River:** The Meenachil River, originating from the Western Ghats near Erattupetta, spans 78 kilometers and drains 1,272 square kilometers before emptying into Vembanad Lake. The basin receives significant rainfall, ranging from 2,420 mm to 4,686 mm annually, with the majority during the monsoon season (ResearchGate, 2023). The average temperature fluctuates between 26.2°C and 29.4°C. Hydrologically, the Meenachil basin has an annual yield of 2,349 million cubic meters, with 1,110 million cubic meters being utilizable. The river has 38 tributaries, contributing to its flow (ResearchGate, 2023). The basin faces challenges such as water pollution, sedimentation, and depletion due to urban waste and sand mining, which have reduced its water retention capacity, leading to water shortages, especially in summer (ResearchGate, 2023). Bacteriological studies of the river reveal seasonal water quality variations, which are critical for public health assessments (ResearchGate, 2023). The region's geological features, including palaeo-deposits, significantly impact the basin's hydrology and water resource management (ResearchGate, 2023). Addressing these environmental issues is crucial for developing sustainable flood mitigation and water resource strategies.
- **Kodoor River:** The Kodoor River originates between the hills bordering Kottayam and Pathanamthitta districts and eventually merges with the Meenachil River. Along with the Puthenthode River, it reaches Vembanad Lake through Pazhukkanilam Kayal. The average annual rainfall in the Kodoor River basin is around 3,093 mm, with an average temperature of 27.3°C. Hydrologically, the Kodoor River basin has an annual yield of 2,349 million cubic meters, with 1,110 million cubic meters being utilizable. The river has 38 tributaries, contributing to its flow. The Kodoor River basin is characterized by a mix of agricultural land and forested areas, with the river playing a vital role in irrigation. However, the river faces challenges such as sedimentation and contamination from agricultural runoff and urban waste, which affect water quality.

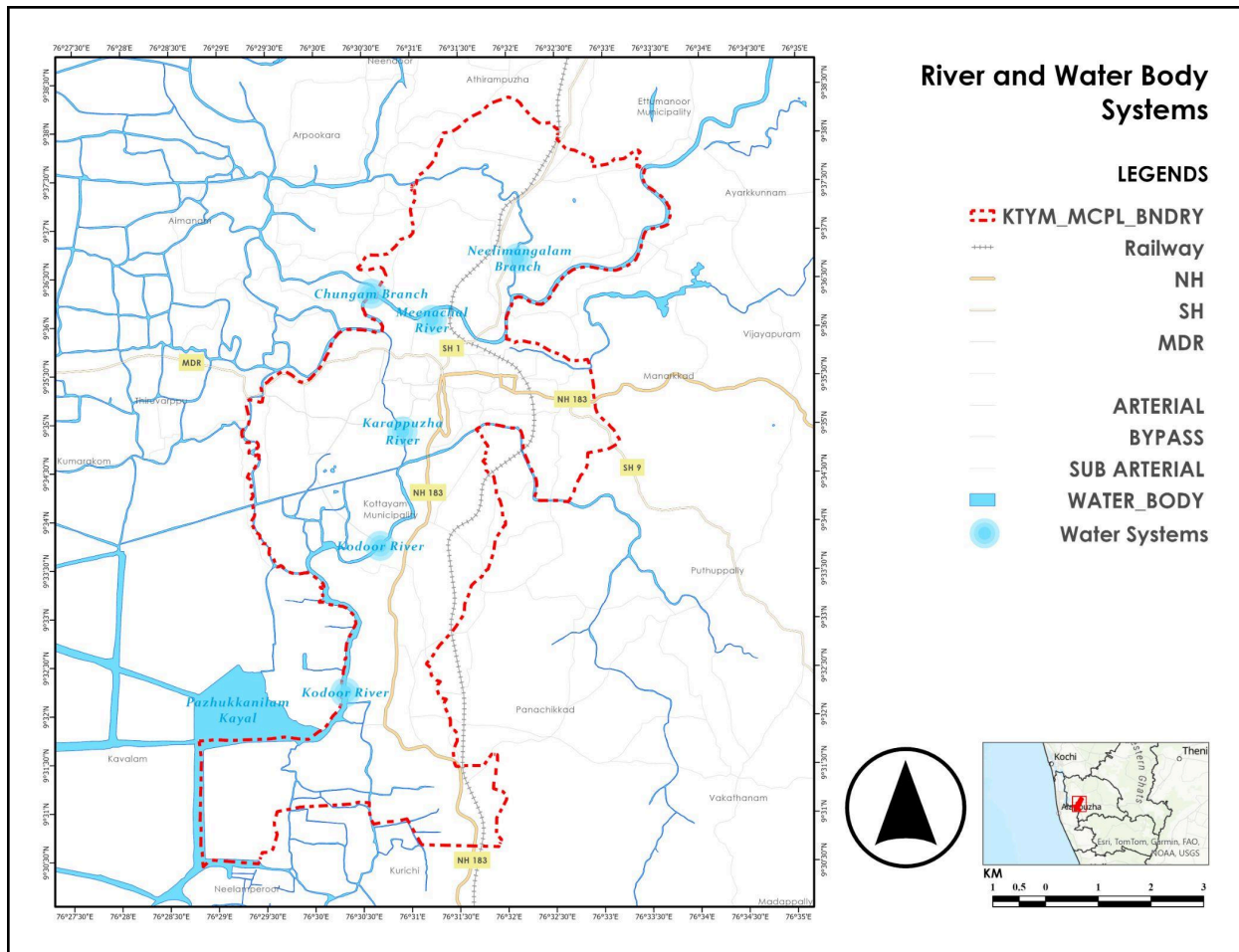


Figure 4: River and Water Body System

2.4 Flood Risks and Hydrological Characteristics

Both rivers significantly contribute to the flooding challenges faced by Kottayam Municipality. Heavy rainfall leads to sediment accumulation, which clogs drainage channels and impedes the flow of water towards Vembanad Lake. The absence of upstream reservoirs and the shrinking capacity of the Vembanad wetland exacerbate the situation.

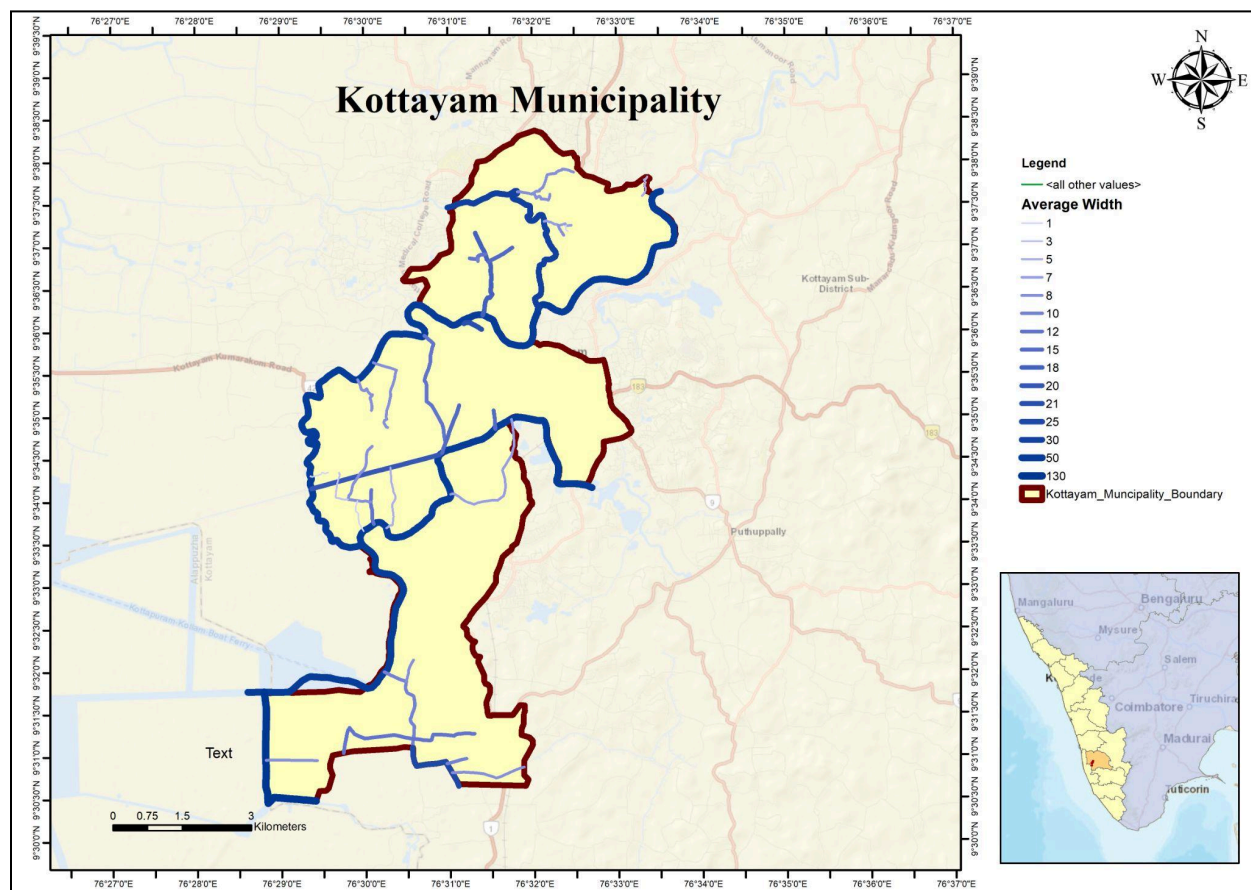


Figure 5: River and Water Body System within Kottayam Municipality in accordance to width

Within the municipality, water bodies exhibit a wide range of widths—from larger stretches of approximately 130 meters, associated with major rivers, to smaller streams as narrow as 1 meter. While the broader rivers influence the region’s overall hydrology, the smaller streams are critical for managing localized drainage and runoff during intense rainfall. These variations underscore the need for diverse and context-specific water management strategies.

2.5 Topography

Kottayam municipality occupies a unique position within Kerala's altitudinal zones. Classified as a midland area, the municipality's landscape encompasses both midland and lowland features. The elevation varies considerably, ranging from -4 meters to 57 meters above mean sea level.

- Lowlands: Villages like Nattakom and Veloor fall within the low-lying areas of the municipality. These areas are seen towards the western ends of the municipality and most of the area in this region are occupied by agricultural or residential areas.
- Midlands: Kottayam and Perumbaikad regions represent the midland zones with higher elevations compared to the lowlands. These are the regions where most of the settlements or the urban areas are lying.

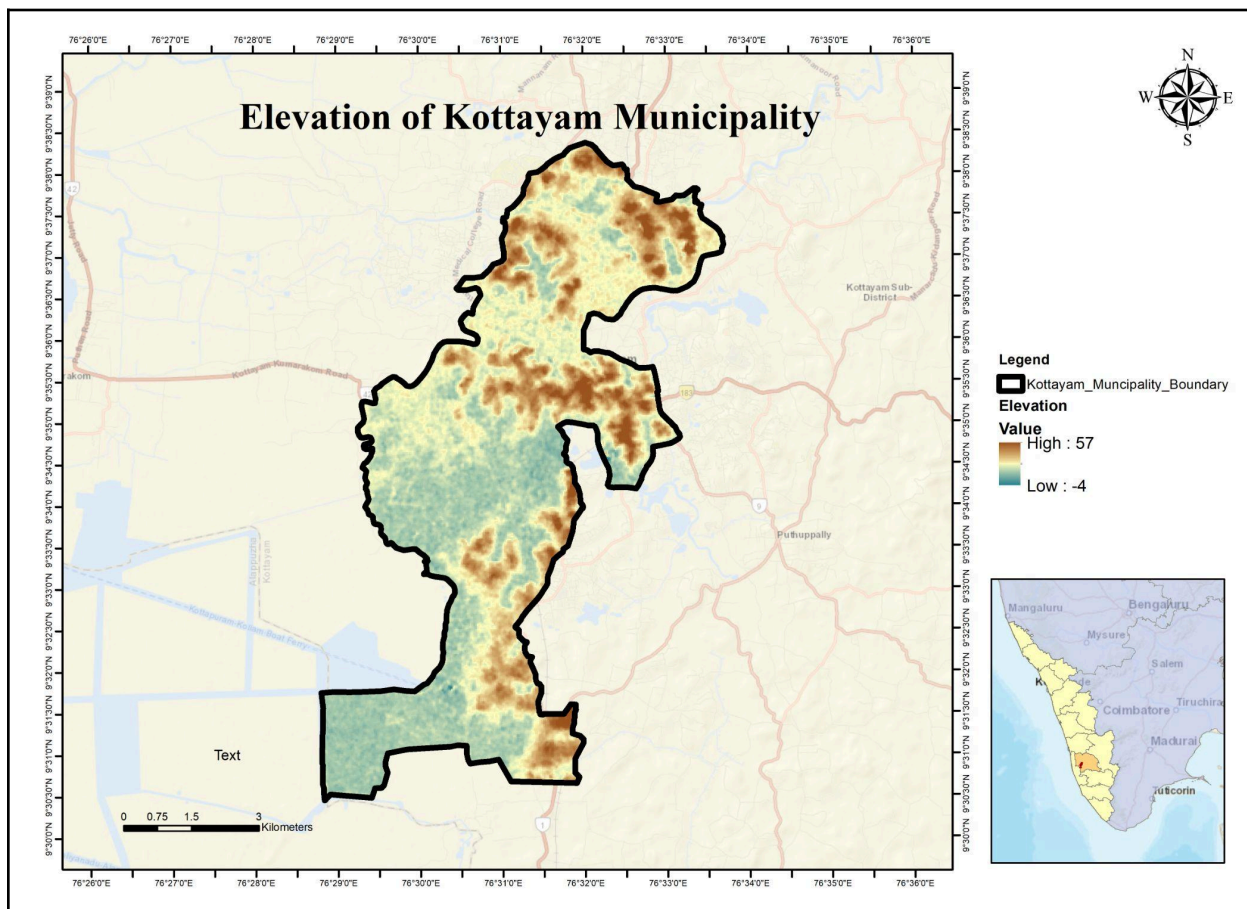


Figure 6: Topography Map

2.6 Flood susceptibility Zones delineated by KSDMA

Methods adopted by KSDMA for hazard mapping to delineate the flood susceptibility Zones:

- Implemented and calibrated on available dataset the distributed hydrological model Continuum on the entire region of Kerala

- Run the hydrological model forced by meteorological reanalysis on an extended period (40 years)
- Create discharge statistic on the entire region for present and future climate
- Provide technical assistance in the development of the flood hazard maps in present and future climate in the Kerala region.
- Note that there maybe variations

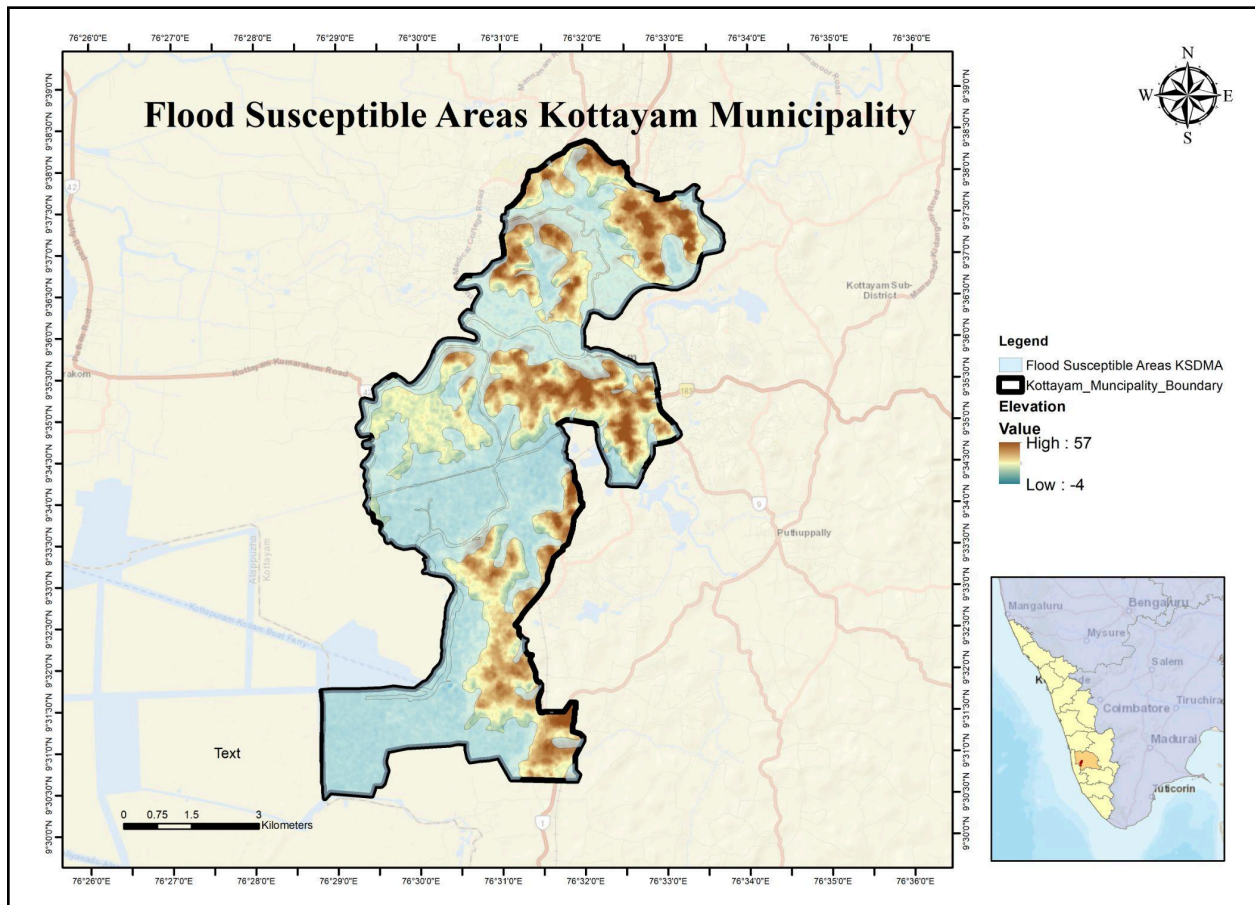


Figure 7: Map of Flood Susceptibility Zones

The given map includes both topography and flood susceptibility zones identified by KSDMA, illustrating that low-lying regions are more prone to flooding compared to highlands. This information highlights the correlation between elevation and flood risk, demonstrating that areas at lower elevations are significantly more vulnerable to flood events. By incorporating these two factors, the map provides a comprehensive understanding of how topographical features influence flood susceptibility, thereby helping in the assessment and management of flood risks

in the region. While map is a representation of the possible areas which could be effected by floods, there might be variation on field as the flow conditions and other variables might vary on filed as due to other influential factors.

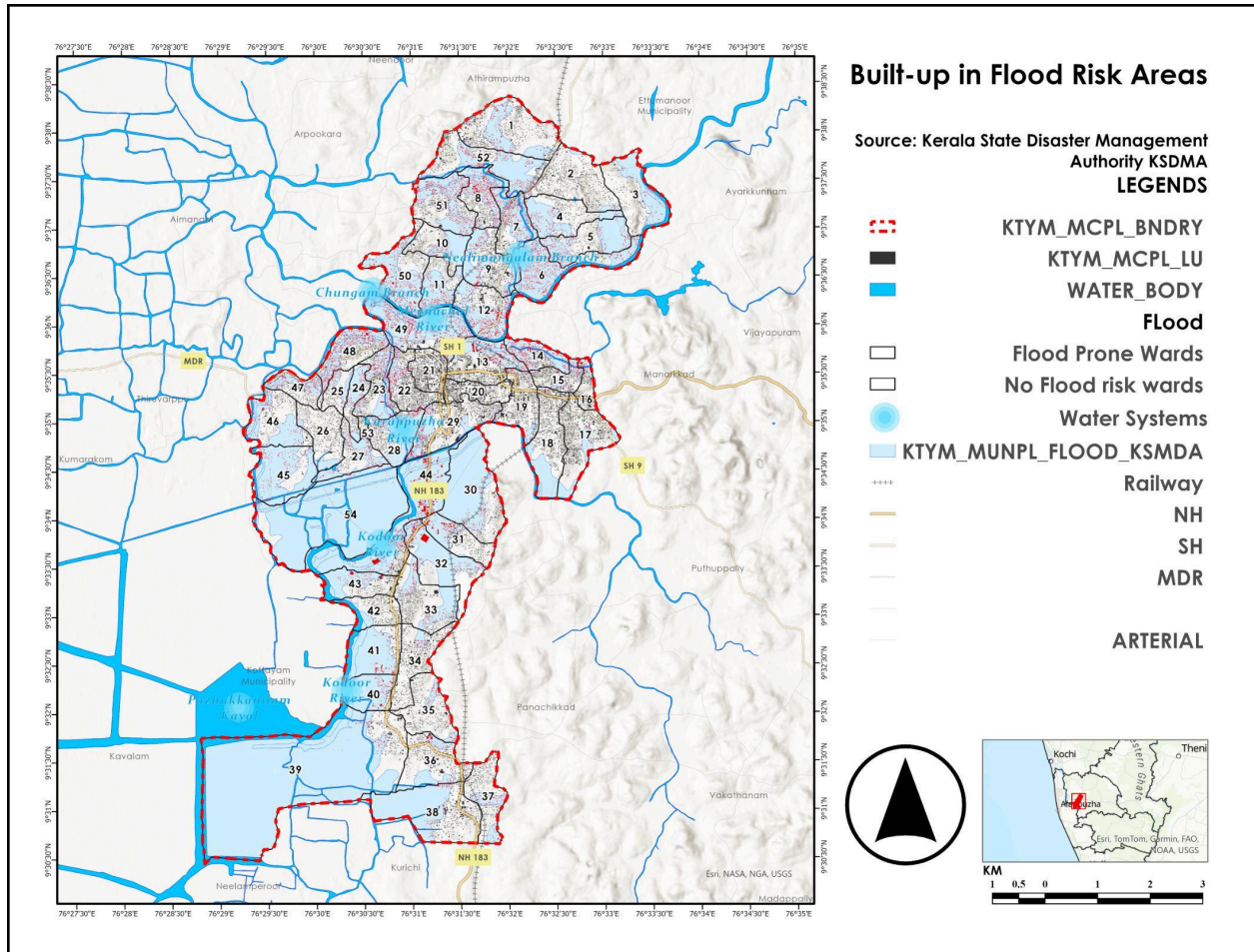


Figure 8: Map of Built-up in Flood Susceptible Zones

The given map incorporates both built-up areas and flood susceptibility zones identified by KSDMA, revealing a significant overlap between the two. This integration allows us to discern that many developed areas are situated within regions marked as high-risk for flooding. By examining the map, it becomes evident that urban development is concentrated in areas prone to flood hazards, highlighting a critical issue for urban planning and disaster management. This spatial analysis underscores the need for targeted flood risk mitigation strategies and better land-use planning to protect built environments from potential flood impacts.

2.7 Roads and Connectivity

Kottayam Municipality is characterized by a well-developed road network that facilitates connectivity both within the municipality and with its neighboring areas. The major roads traversing through the municipality include the **Main Central (MC) Road**, **Kumarakom Road**, **Pala Road**, and several arterial and sub-arterial roads. These roads are critical in linking Kottayam to other parts of Kerala, serving as lifelines for transportation, trade, and communication.¹²

2.7.1 Major Roads within the Municipality:

1. **Main Central (MC) Road:**

- The MC Road is a key state highway that cuts across Kottayam Municipality, providing connectivity to major urban centers such as Thiruvananthapuram and Angamaly.
- As a heavily trafficked corridor, it influences both urban expansion and drainage patterns in the region.

2. **Kumarakom Road:**

- This road connects Kottayam to Kumarakom, a prominent tourist destination.
- Its proximity to water bodies and low-lying areas makes it susceptible to inundation during heavy rainfall and flooding.

3. **Pala Road:**

- This road connects Kottayam with Pala, passing through hilly terrains and urbanized zones.
- Altered drainage patterns due to urban sprawl along this road have compounded flood risks.

4. **Nagampadam-Chirakulam Road and Other Local Roads:**

- These roads facilitate intra-municipal connectivity, linking residential, commercial, and institutional zones.
- Many of these roads are flanked by small drains, which often overflow during intense rainfall events.

¹² Kerala Public Works Department.

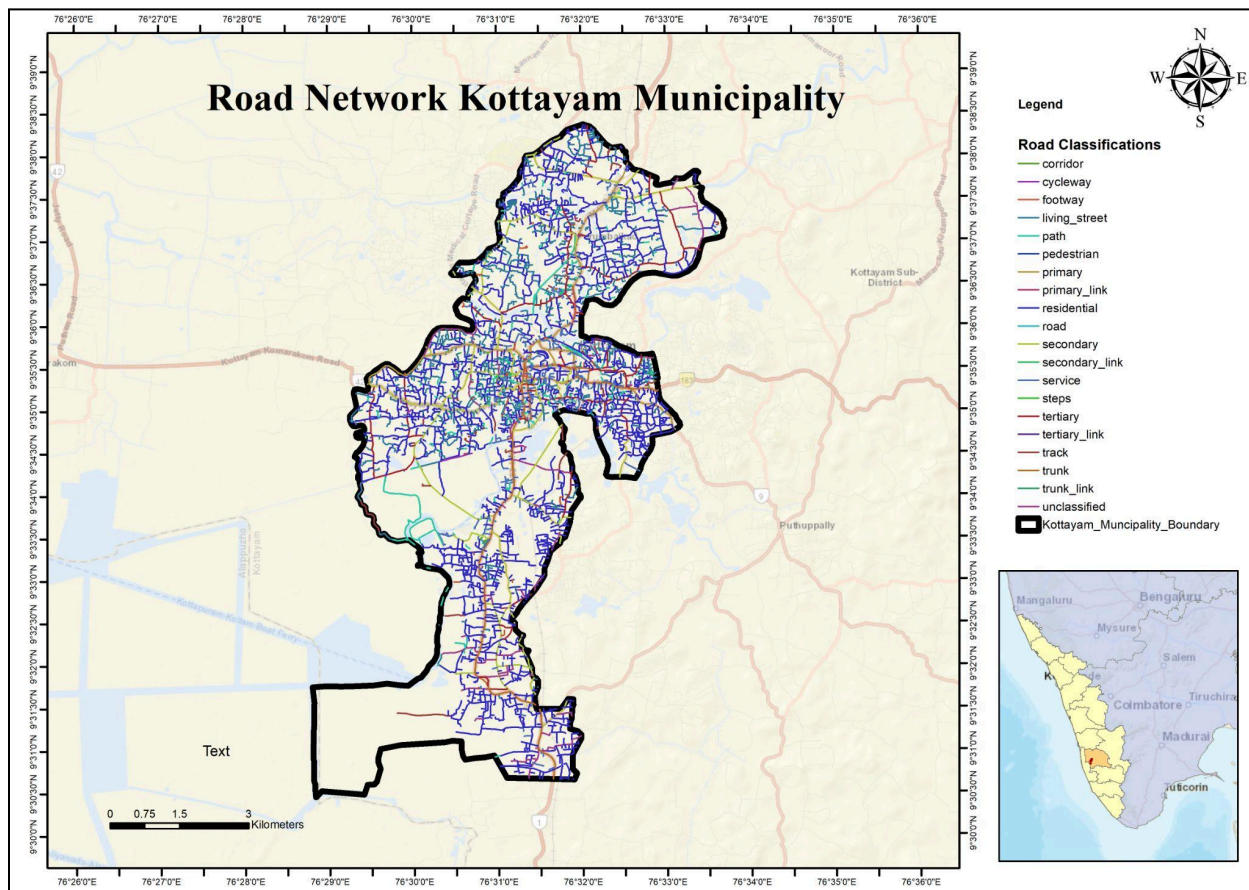


Figure 9: Road Network in Kottayam Municipality

2.7.2 Influence of Roads on Floods:

The extensive road network within Kottayam Municipality significantly influences flood dynamics, often exacerbating the impact of flooding during heavy rainfall events. Major roads such as the Main Central (MC) Road and Kumarakom Road, along with smaller arterial and local roads, frequently alter natural drainage patterns, disrupting water flow and leading to waterlogging in adjacent low-lying areas. The reduction of permeable surfaces due to urbanization along roads increases surface runoff, while inadequate cross-drainage structures, encroachments, and poorly maintained roadside drains further obstruct the movement of water. Roads near flood-prone areas, particularly those adjacent to the Meenachil and Kodoor rivers, are vulnerable to inundation and backflow during intense rains, cutting off essential connectivity.

Additionally, narrow secondary roads with insufficient drainage systems channel stormwater into densely populated areas, compounding the flood risks. In addition, it has been reported that over the years, certain smaller streams and creeks that remained active during the monsoons have been converted into roads, particularly smaller roads. Over time, the height of these roads has also been raised, resulting in water that would normally be contained within these areas flowing instead through the houses situated along the sides of these roads

2.8 Topography and Geology

According to the division of places in Kerala based on altitudes, Kottayam(fig 6)is classified as being a midland area.Kottayam municipality lies in both midland & lowland topography.Kottayam municipality has an elevation of about -4 to 57 from above mean sea level.Nattakom and veloor villages have low elevation.Kottayam & perumbaikkad region has high elevation.

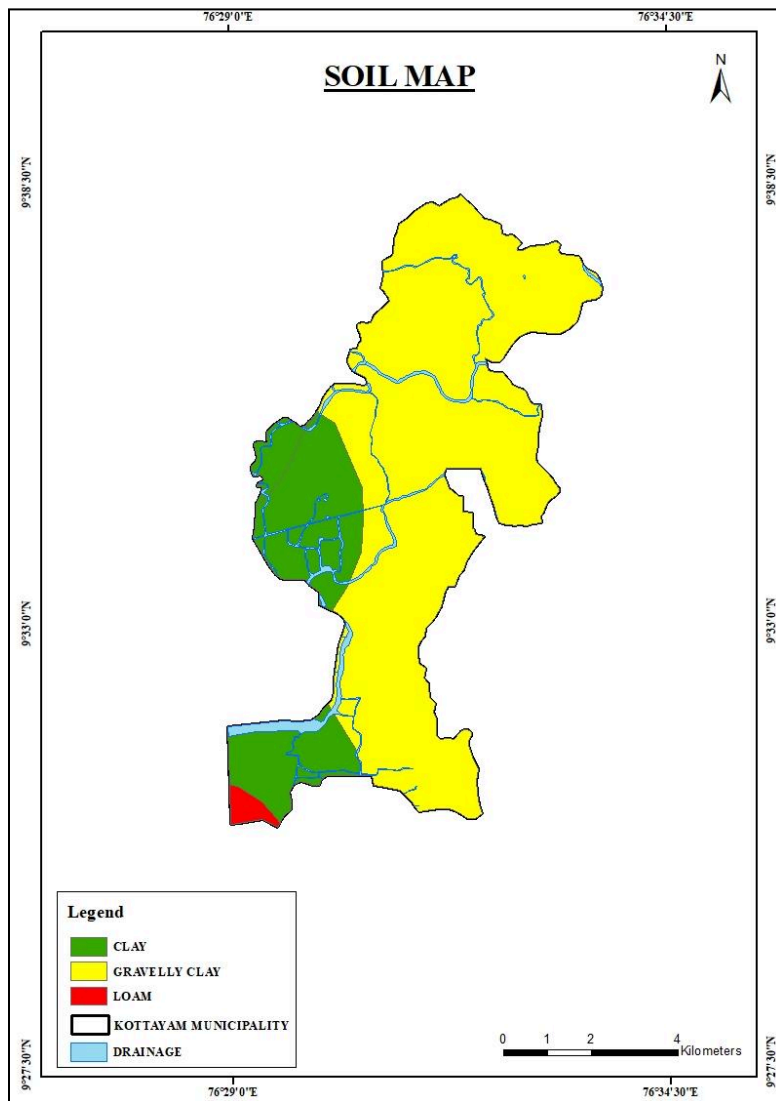


Figure 10 : Soil map

The above figure (10) shows types of soil present in the area. majorly clay, gravelly clay & loamy soil.

Table 2 : Soil Types Found within Kottayam Municipality

Soil	Characteristics
Clay	Very High Water Holding Capacity And The Soil Contains Essential Nutrients For Plant Growth.
Gravelly Clay	They Have The Best Stability Because Of The Relative Firmness When Compared To Dry Sandy Soil Which Will

	Always Shift Or Moist Soil Which Is Prone To Flooding.
Loamy Soil	The Mixture Of Clay, Sand And Silt Soil Which Consists Of Additional Organic Matter And Is Very Fertile Compared To Other Types Of Soil.

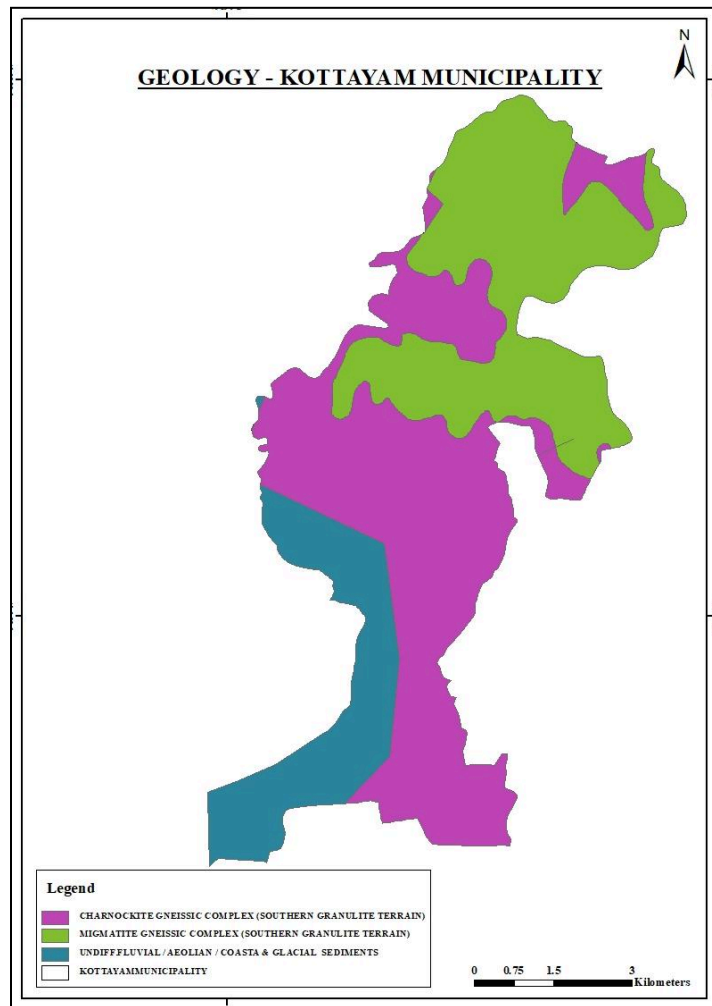


Figure 11: Geology map

Geology Map (fig: 11) describes the major type of soil present in this region. Charnockite, migmatitic & fluvial rocks are seen in this region. Fluvial rocks are formed by the deposition of sediments brought by the river and it is mainly in Nattakom. Charnockite &

Migmatic rock possess metamorphic characteristics. Metamorphic rocks formed under high temperature & pressure.

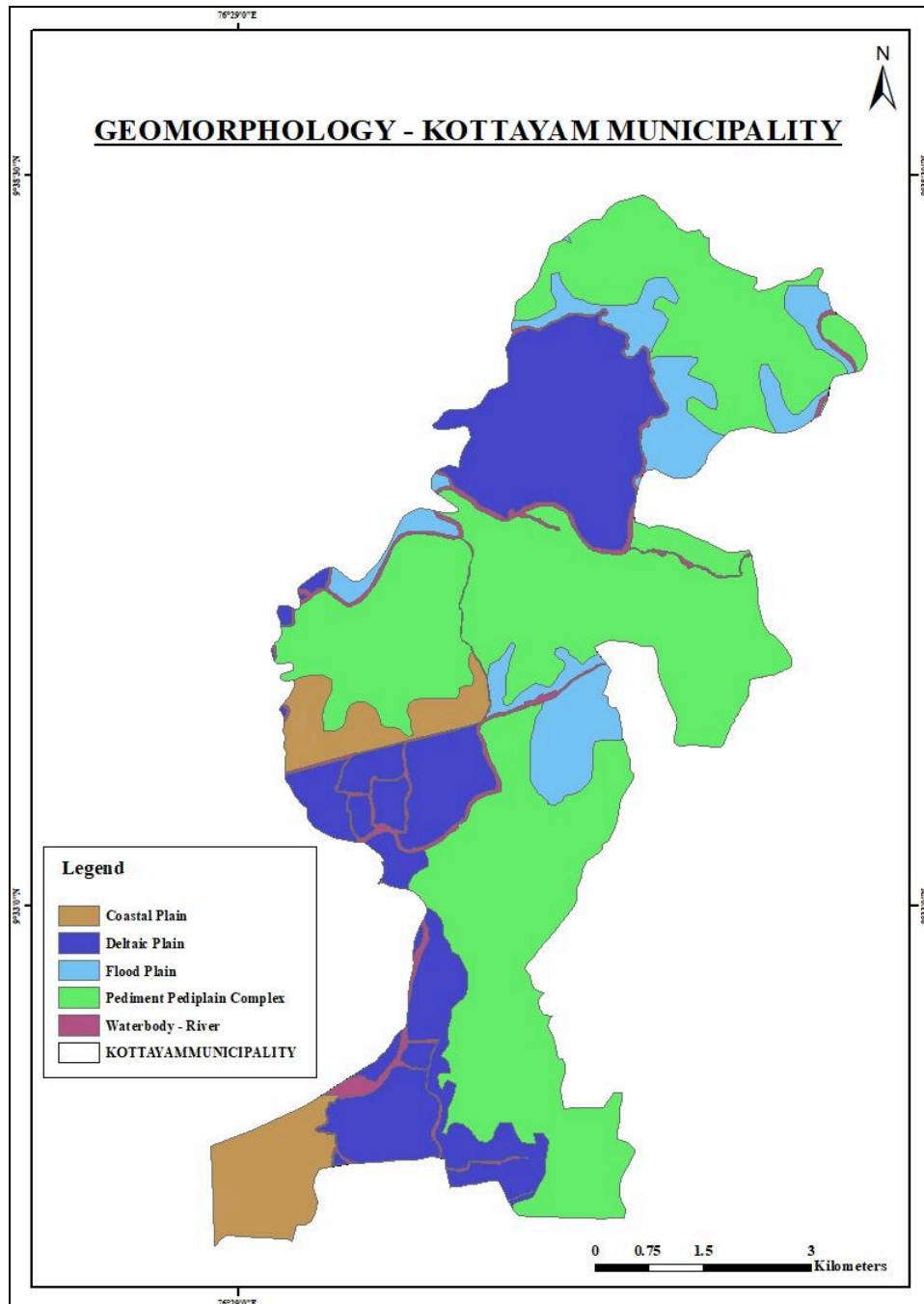


Figure 12 : Geomorphology map

Table 3 : *Geomorphology of Kottayam municipality*

Coastal plain	Coastal plain is a low land adjacent to the sea coast
Deltaic plain	A delta is a relatively flat area at the mouth of a river or a river system in which sediment load is deposited and distributed
Flood plain	It is an area of flat land alongside a river. Flood plains are naturally very fertile due to the river sediment
Pediment -Pediplain complex	A pediplain is a relatively flat rock surface formed by joining several pediments. Pediments are generally found in arid and semi-arid areas and may have a thin veneer of sediments.

A contour line represents a line on a topographic map that connects points of equal elevation, illustrating the elevation or depression of the ground surface (Fig. 13). Within Kottayam Municipality, the areas of Veloor and Nattakom exhibit gentler slopes compared to Kottayam town and Perumbaikad. The elevation in the municipality ranges from approximately -4 meters to 57 meters above mean sea level. While Nattakom lies at a relatively lower elevation, Perumbaikad is situated at a higher elevation. In the broader context of Kottayam district, the municipality is predominantly located within the lowland region. Additionally, it is noteworthy that Kottayam serves as a transition zone between the midland and lowland regions.

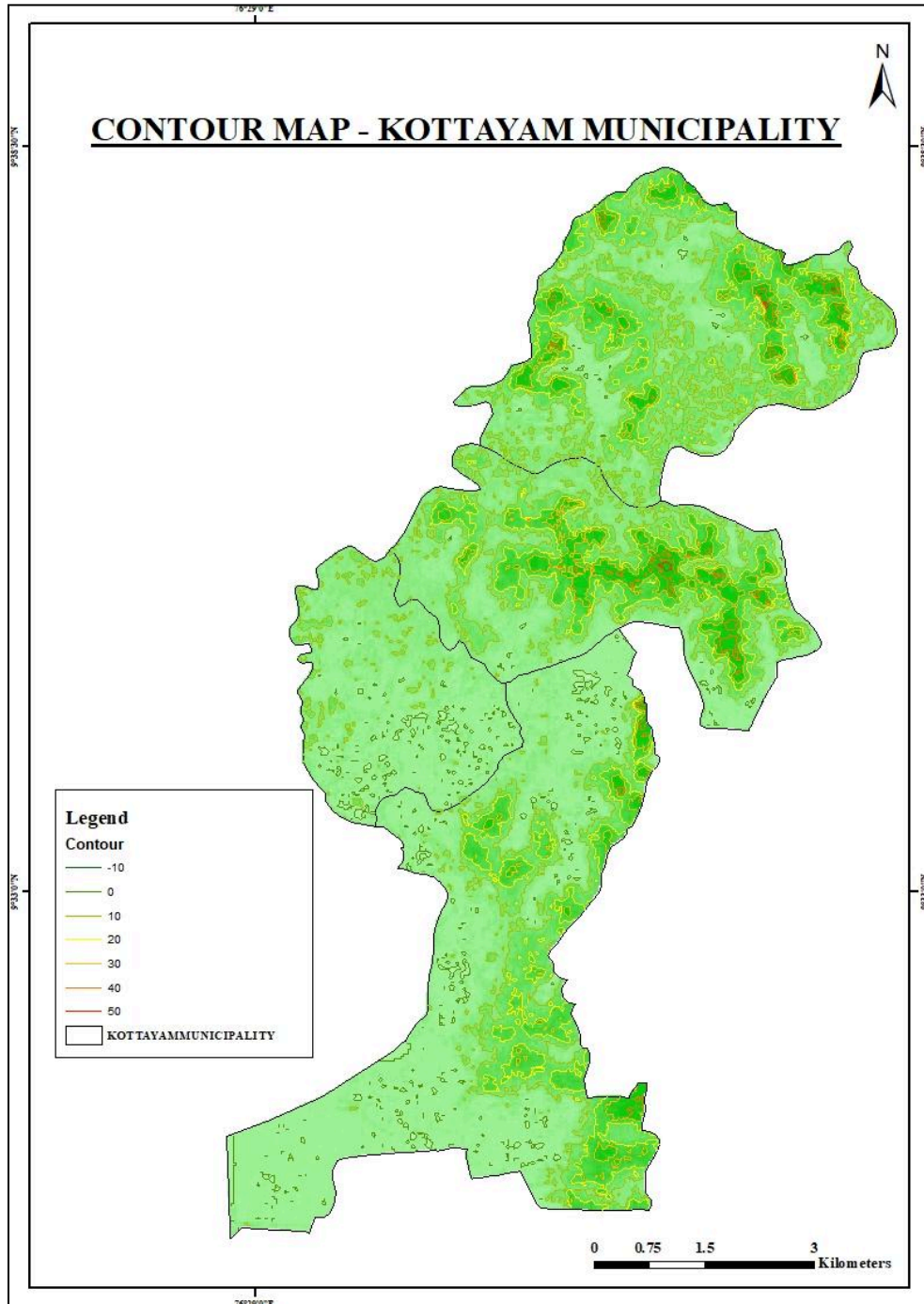


Figure 13: Contour map

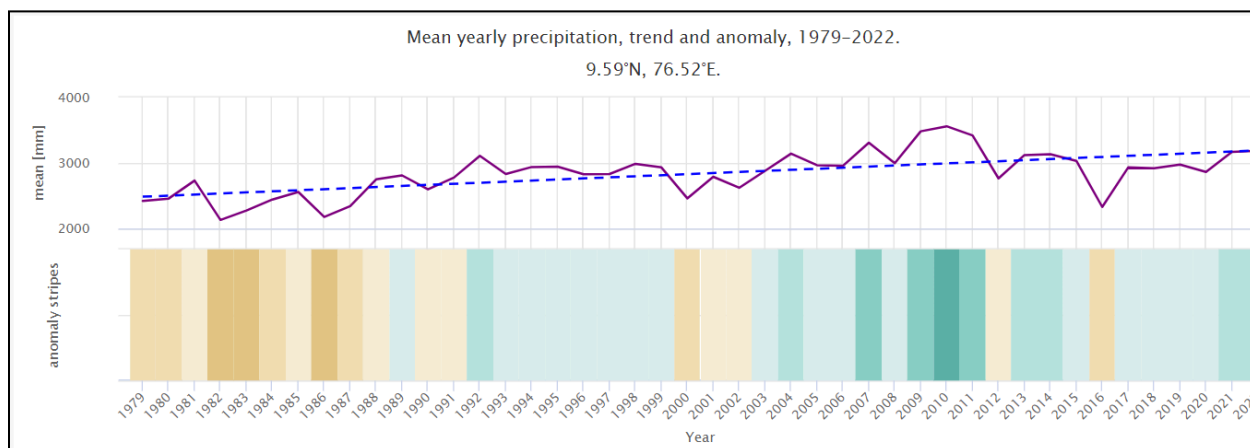


Figure 14 :Rainfall data of 1979-2022

The above figure (14) shows the yearly precipitation of rainfall from 1979-2022. From this, we can understand that the heavy rainfall occurs in the period of 2009-2011. The lowest rainfall happens during the period of 1980s. 2021 & 2022 witness heavy rainfall than 2020.

2.2.1 Occupational details

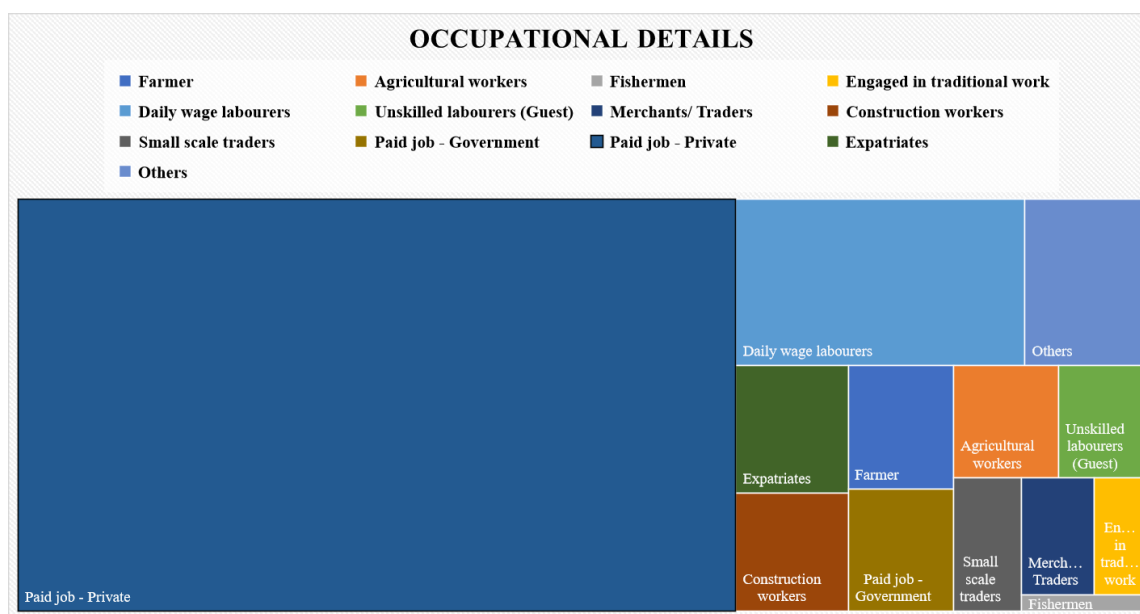


Figure 15: Occupational details

The occupational details of people in Kottayam municipality (fig 15) are under various sectors, which means it includes farmers, agricultural workers, fishermen engaged in traditional work, daily wage labourers, unskilled labourers (guests), merchants and traders, construction workers,

small-scale traders, paid jobs (government), paid jobs (private), expatriates, and others. The majority of people do private, paid jobs. That is, 63.66% of people are doing private-paid jobs.

Table 4 : *Workforce classification*¹³

Main Workers				Marginal Workers		
Total workers	Agricultural labourers	Other workers	Cultivators	Total workers	Other workers	Cultivators
17799	182	17176	80	1940	1812	42

The occupation is classified into main workers and marginal workers (table 4); the main workers are subdivided into agricultural labourers, other workers, and cultivators. 1.02 % of agricultural labour, 96.49 % of other workers, and 0.44 % of cultivators are included as main workers. The marginal workers are subdivided into other workers and cultivators. 93.4% of other workers and 2.16% of cultivators are included as marginal workers.

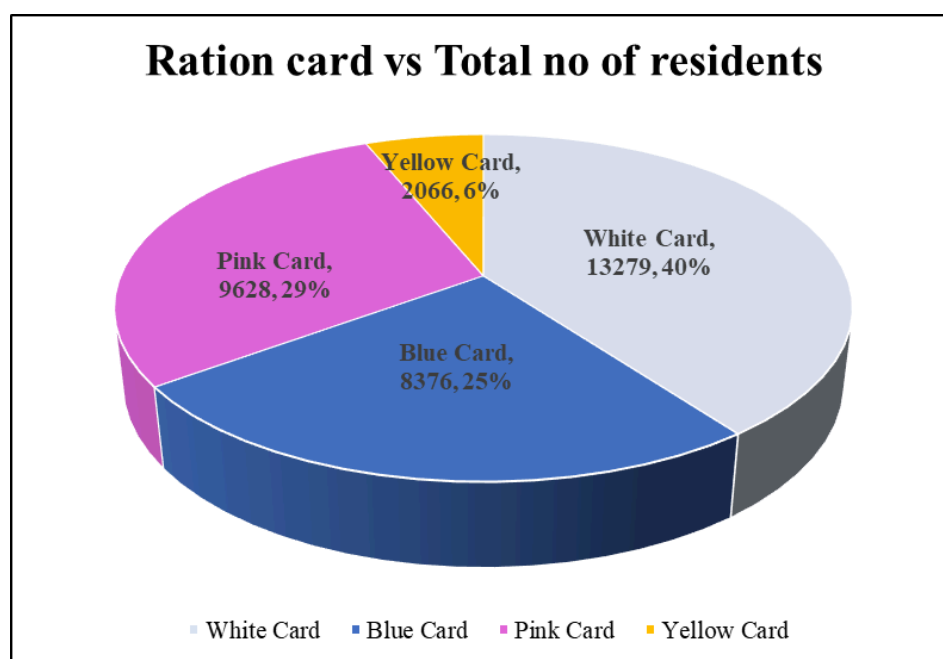


Figure 16: Ration Card Details

¹³ Kerala Agricultural Statistics. (2021).

The ration card beneficiaries (fig 16) include non-priority, non-priority subsidy or above poverty line (APL), priority or below poverty line (BPL), and the most economically backward section of society, Antyodaya Anna Yojana Beneficiaries. The majority of residents, which means 40% of residents in Kottayam municipality, are on the non-priority beneficiary list. and others are 25% of blue card beneficiaries, 29% of pink card beneficiaries, and 6% of yellow card beneficiaries in Kottayam municipality.

In conclusion, Kottayam Municipality, with its diverse topography, evolving land use patterns, and the confluence of the Meenachil and Kodoor rivers, presents a complex and dynamic profile for flood management. The mixed urban and rural characteristics of the 52 wards, coupled with inadequate drainage infrastructure and increased pressure from urbanization, have amplified the municipality's flood risks. A detailed understanding of these unique local factors is crucial for formulating effective and sustainable flood mitigation strategies tailored to the needs of the community.

Chapter 3: Aspiration of Stakeholders

The aspirations of various stakeholders were collected in two stages. One during the FGD conducted at the Panchayat and later on during the key informant interviews. The Kottayam Municipality is united by a collective vision for a thriving and sustainable community. This vision is shared by a diverse group of stakeholders, including government officials, local residents and environmentalists. They all aspire to restore Meenachil & kodoor river to their original splendour, thereby overcoming the existing challenges and issues.

A significant step towards realising this vision was taken during a Key Informant Interview (KII) held at the Panchayat office. There, the Panchayat president, along with ward members, agricultural officers, and representatives from the Padasheskara committee, collectively outlined their shared vision for the panchayat. This collaborative effort underscores the commitment of the community towards the revitalization of rivers. The community's collective goal is to address various aspects of river management. They emphasise the importance of cleaning the rivers to restore their natural flow. Additionally, they express concern about tributaries of the rivers affected by sedimentation, showing a strong desire to tackle this issue. Encroachments have also led to the narrowing of the boundaries of the river, prompting the community to seek viable solutions. The another important problem faced by the entire municipality is the improper drainage facility for the flow of water during the period of consequent floods. The another major concern of the community is towards the flow of water from the Vembanad lake to the Municipality. To scrutinise the water holding capacity of Vembanad lake to identify the reduction of depth of the lake. These shared aspirations demonstrate a comprehensive approach to mitigating flooding and ensuring the sustainability of the river.

Chapter 4: Ward-Level Situation Assessment

During the site visits in Kottayam Municipality, data was primarily collected on flood issue mapping, including the marking of flood point boundaries and recording flood depth and duration. Wards were initially selected for assessment based on available data, with a focus on areas such as Pallipuram, Puthettu, Parambuzha, Mullenkuzhi, and Nattassery. Stakeholder consultations indicated that all wards experience flooding, and three types of flooding were identified within Kottayam Municipality: riverine flooding, urban flooding, and flooding in low-lying terrains.

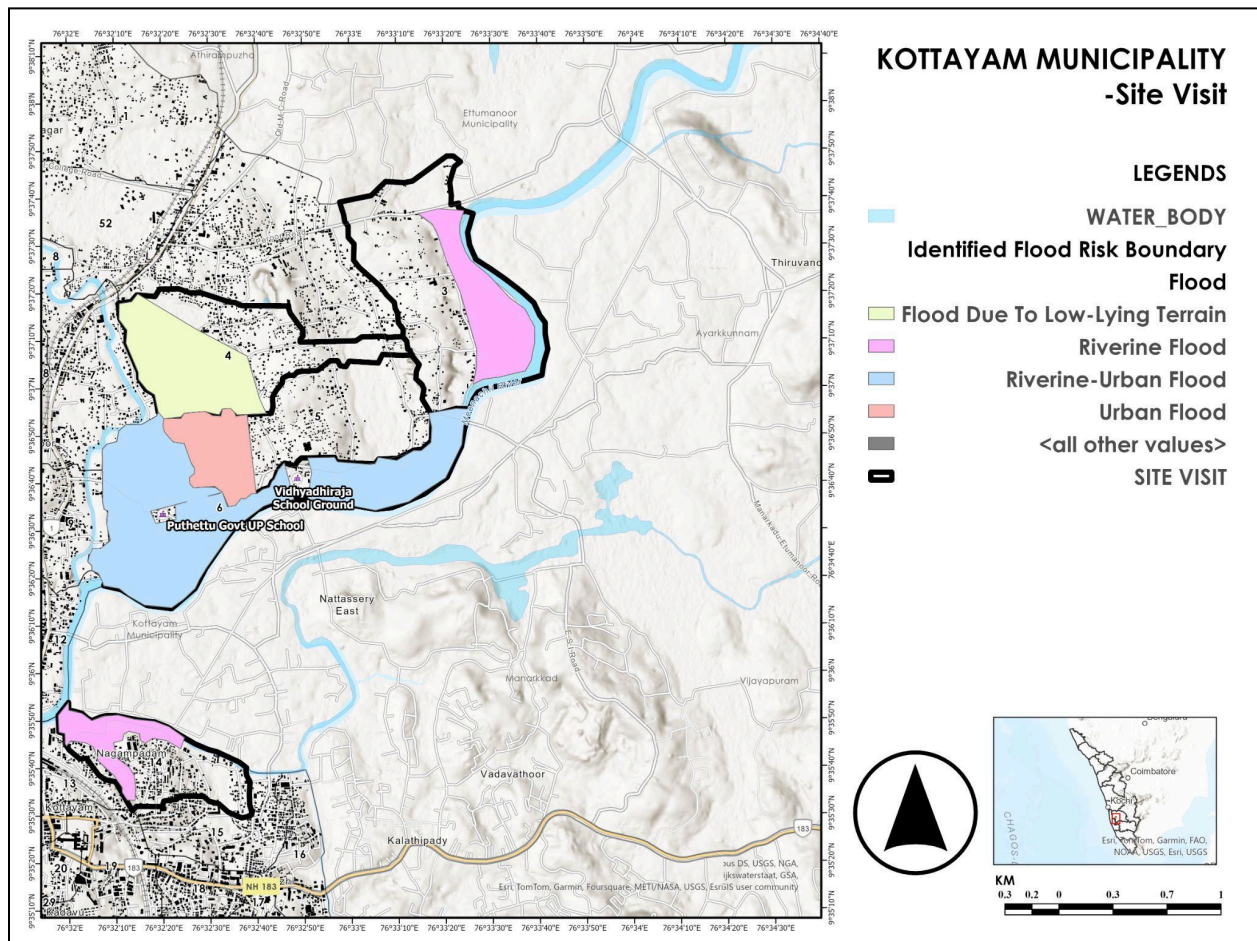


Figure 17: Types of Flooding

4.1 Flooding In Kottayam Municipality

Flooding in Kottayam Municipality is a multifaceted challenge influenced by its unique geographical, hydrological, and urban characteristics. The municipality faces three primary types of flooding: riverine flooding, urban flooding, and flooding due to low-lying terrain. Each type is driven by distinct factors such as the overflow of rivers, inadequate urban drainage systems, and the natural topography of the region. Understanding these flood types and their underlying causes is critical for devising targeted and effective flood mitigation strategies. The following sections, listed below, provide a detailed analysis of these flooding phenomena, highlighting site-specific issues observed during field visits and their implications for flood management.

4.1.1 Riverine Flood

Riverine flooding, a significant issue in Kottayam municipality, is caused by the overflow of nearby rivers, particularly the Meenachil River and Kodoor River, both situated within residential areas. Encroachment has reduced the Meenachil River to less than half its original width due to blocked streams, roads, homes, and converted paddocks. Sediment accumulation in canals has decreased water capacity, causing frequent overflows during heavy rain. Another major concern is the formation of the island Pazhukkanila, which disrupts the flow to Vembanad Lake during floods. Our visits identified Wards 3, 6, and 14 as suffering from riverine flooding, with the Meenachil River flowing through Parambuzha and Puthettu. The Meenantharayar River flows through Mullenkuzhi. Problems identified include river encroachment, stream conversion, sediment accumulation, lack of sidewalls, Presence of mosses\algae, destruction of sidewalls, bund breaches, and impractical river deepening, which contribute to the severity of flooding, potentially due to pooling, as noted by technical members.. These factors contribute to the severity of flooding, thereby increasing the intensity of riverine floods.

4.1.2 Urban Flood

Urban flooding, one type of flooding in Kottayam municipality, is primarily caused by inadequate drainage systems in urban areas. Blocked streams, where natural waterways are obstructed, and the conversion of streams into roads exacerbate this issue. Drainage clogging often leads to flash floods. During site visits, Wards 5 and 6 were identified as suffering from

urban flooding due to the lack of proper drainage systems. The shifting land use pattern has increased runoff, as infiltration rates have decreased due to more built-up areas compared to vegetation, and the use of interlocking pavers outside houses. These factors contribute significantly to urban flooding in these wards.

4.1.3 Flood Due To Low-Lying Terrain

Flooding in Kottayam municipality also occurs due to its low-lying terrain, as the district encompasses both lowland and midland regions with elevations ranging from -16 to 50 meters above mean sea level. The natural topography of the region, characterized by reduced slopes and slower drainage, causes water to accumulate slowly, heightening flood risk. Nattakom and Veloor villages, having low elevations, are particularly affected. During site visits, Ward 4 was identified as being prone to flooding primarily due to its low-lying land. These geographical features significantly contribute to the flooding issues in these areas.

4.4 Methodology

This methodology integrates a combination of GIS software, mobile data collection tools, and cloud storage to create flood boundary maps that are both comprehensive and up-to-date. Extensive field visits were conducted across select wards, including Wards 3, 4, 5, and 6, to gain a deeper understanding of the specific flooding issues faced by Kottayam Municipality. These field visits allowed for direct observation of the flood-prone areas, infrastructure conditions, and the impact of environmental factors such as sediment accumulation, encroachment, and inadequate drainage. During these visits, technical teams assessed critical aspects such as riverbank stability, drainage blockages, and the role of local topography in exacerbating flood risks. Additionally, data on land use patterns, building density, and land elevation were gathered to support a more nuanced understanding of flood vulnerabilities. By combining field data with GIS-based analysis, the approach allows for real-time updates and provides a dynamic, accurate representation of flood risks in the area. This ensures that the flood boundary maps are not only up-to-date but also reflective of the actual conditions on the ground, facilitating more informed decision-making and effective flood mitigation strategies tailored to the specific needs of the municipality.

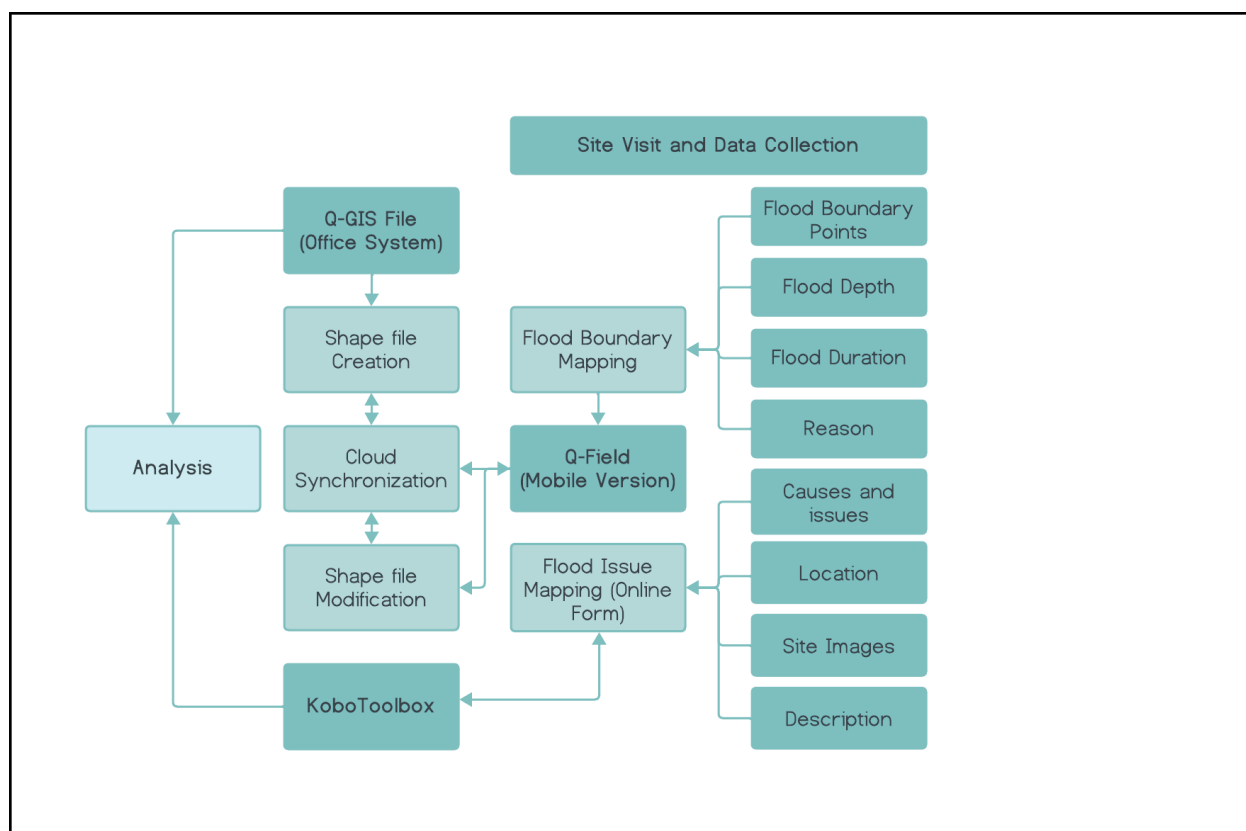


Figure 18 :Methodology for onfield data collection

During the site visit, the following issues were identified as contributing factors to flooding in Kottayam Municipality:

Blocked drainage systems, Absence of culverts and shutters, Encroachment on the river, Encroachment on streams, Siltation of water bodies, Presence of mosses, algae, and waste dumping in water bodies , Inadequate drainage facilities, Breaches and destruction of bunds and sidewalls.

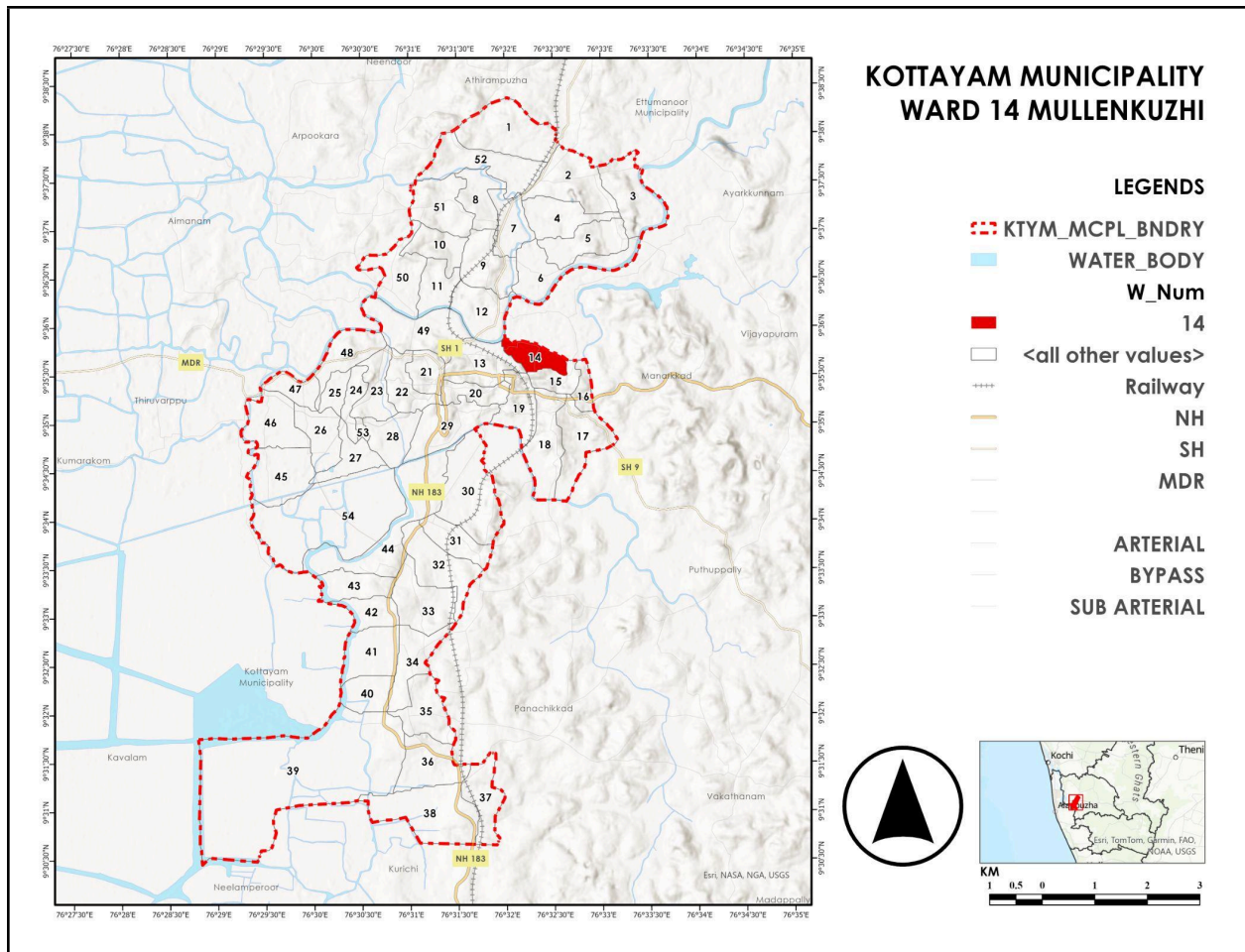
4.5 Detailed Analysis of Flooding Issues by Ward

Following the methodology outlined above, comprehensive site visits were conducted across selected wards to collect firsthand data on the prevailing flooding issues. The collected information was meticulously processed and analyzed to gain a deeper understanding of the factors contributing to flood risks in each ward. This analysis includes observations on

infrastructure conditions, drainage systems, encroachments, land use patterns, and topographical features. The insights gained from these site visits have been crucial in identifying specific vulnerabilities and are presented in detail below.

4.5.1 MULLENKUZHI, WARD 14

Mullenkuzhi, located in the northeastern corner of Kottayam Municipality, shares its border with Vijayapuram Panchayat. The ward, with approximately 850 houses. Residents of the Ward 14 volunteered to map the flood boundaries and issues, contributing valuable data which are helpful in OLOI Project for Flood Mitigation.



(i) Identified Water Systems

Identified River/Backwater systems existing in Ward 14 during site visit

- Meenachil River
- Meenatharayar (tributary branch of Meenachil River)
- A Natural Drainage

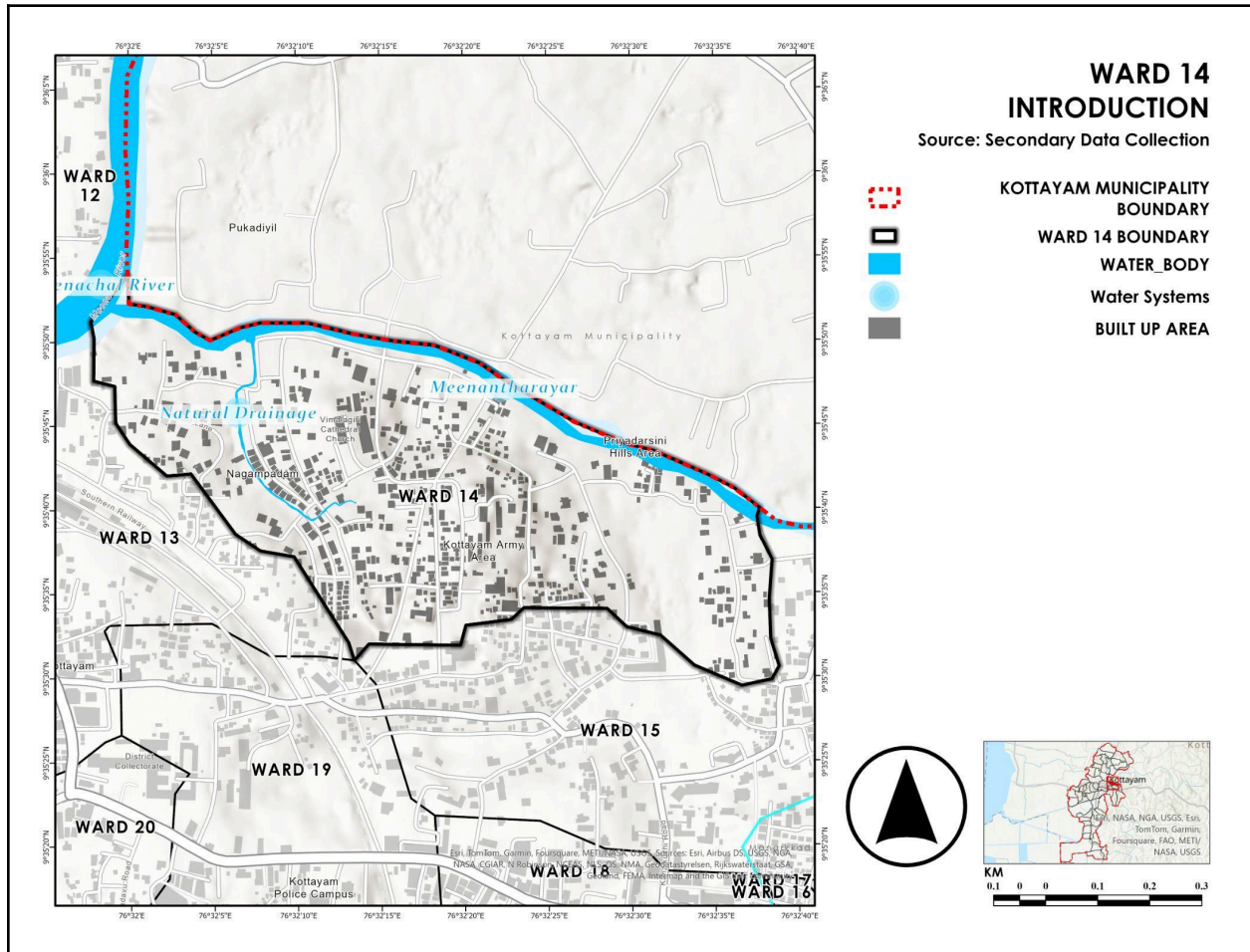


Figure 20 : Map of Mullenkuzhi

The figure depicts the water systems which flow through ward 14. Blue lines represent the water systems, while gray polygons represent existing built-up areas. During the summer months, natural drainage flows northward towards the Meenatharayar river, which originates in the highlands of Mullenkuzhi, located in the center of the ward.

(ii) Topography

The provided figure highlights the varied topography of Ward 14, ranging from highlands to low-lying areas.

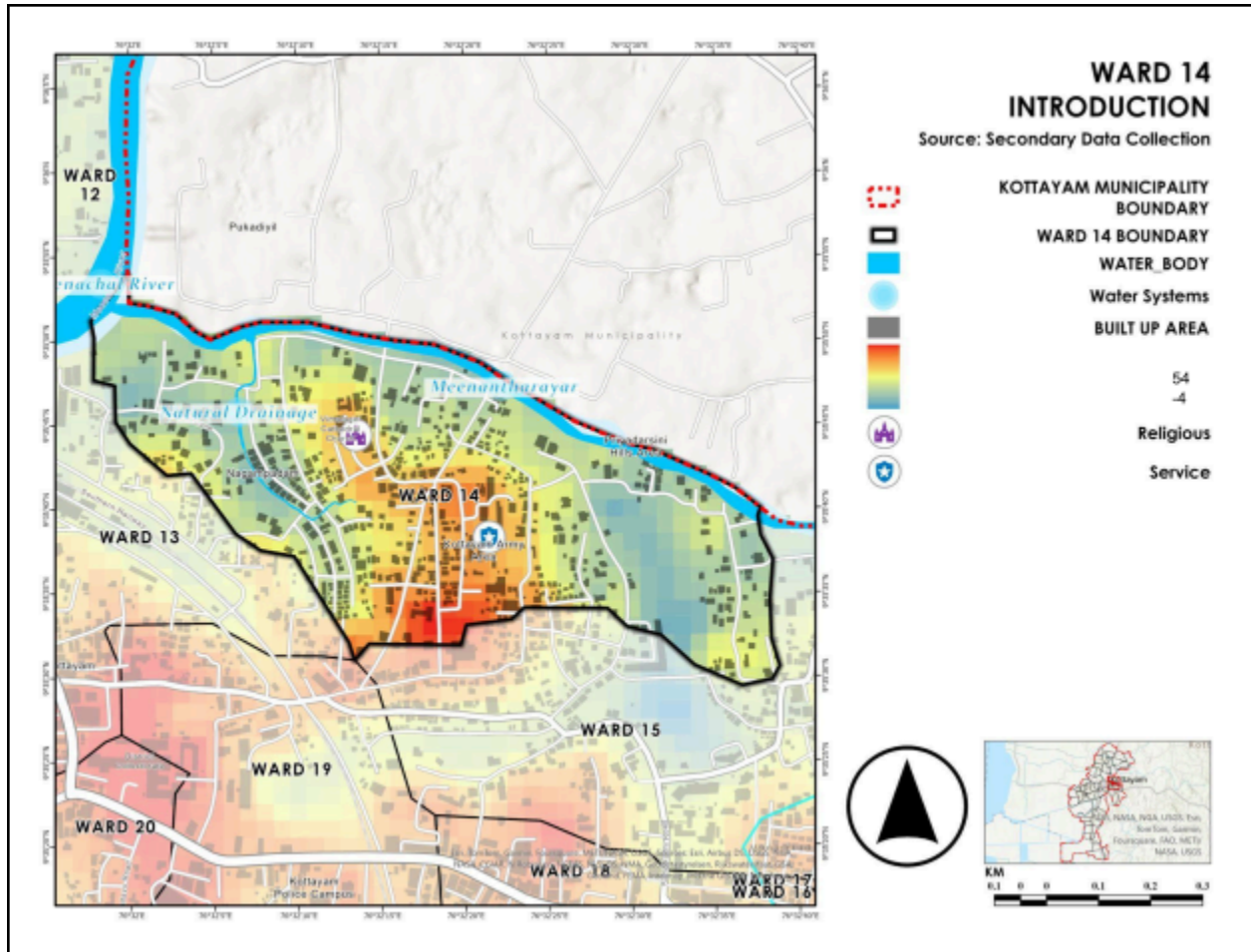


Figure 21 : Topography Map of Mullenkuzhi

The orange-red colored regions represent the highlands, which include prominent landmarks like the Vimalagiri Catholic Cathedral and the Armed Reserve Police Camp. These highlands act as a sub-basin for the natural drainage system that flows northward towards the Meenacharayar river. However, as this natural drainage passes through built-up areas, it accumulates organic and inorganic waste materials. This pollution negatively impacts the flow and quality of the natural drainage system.

(iii) Flood Risk Areas- KSDMA

The Figure overlay a flood susceptibility zone map created by the Kerala State Disaster Management Authority (KSDMA). Areas marked in red within the built-up zones coincide with these identified flood risk zones, indicating flood affected Built-ups

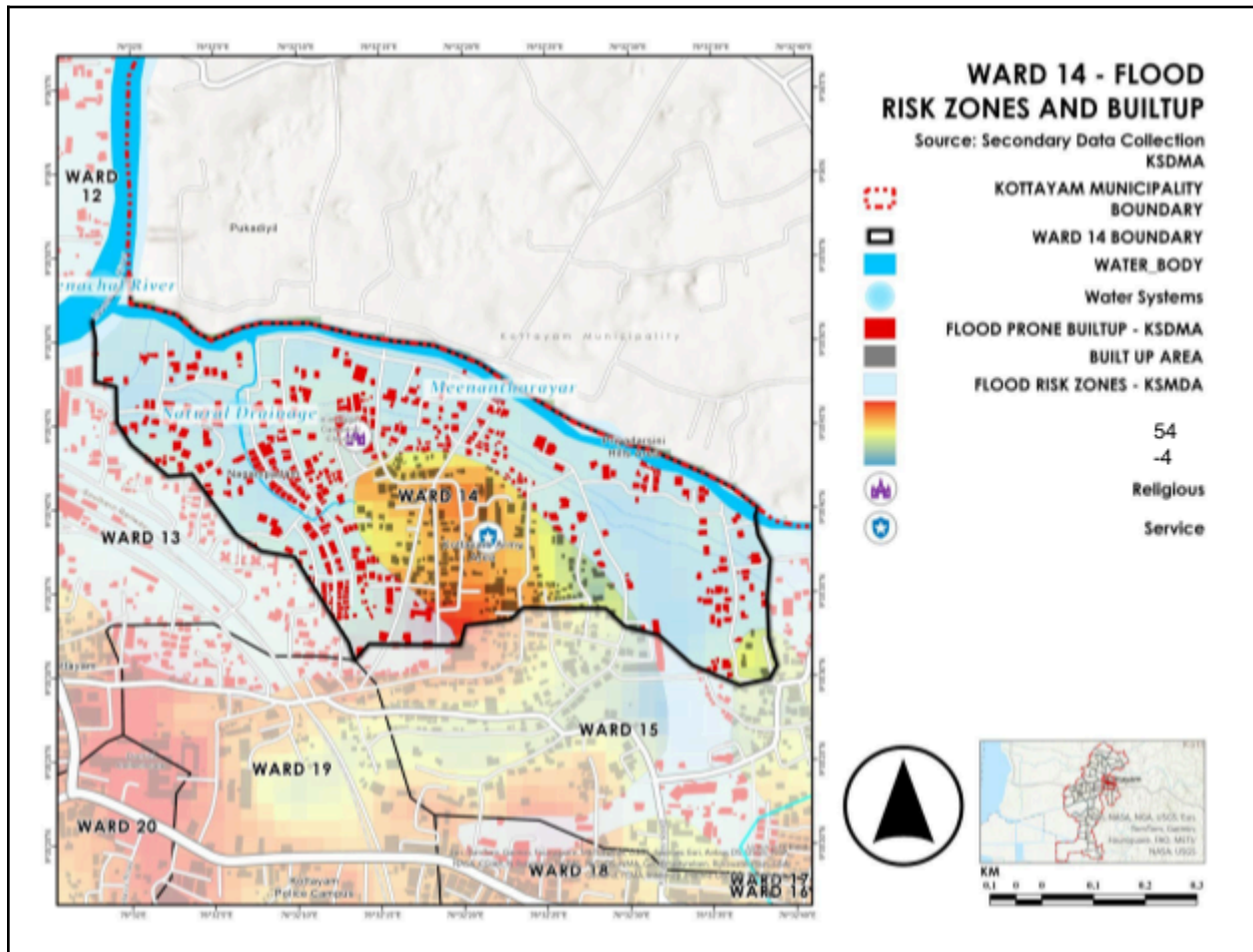
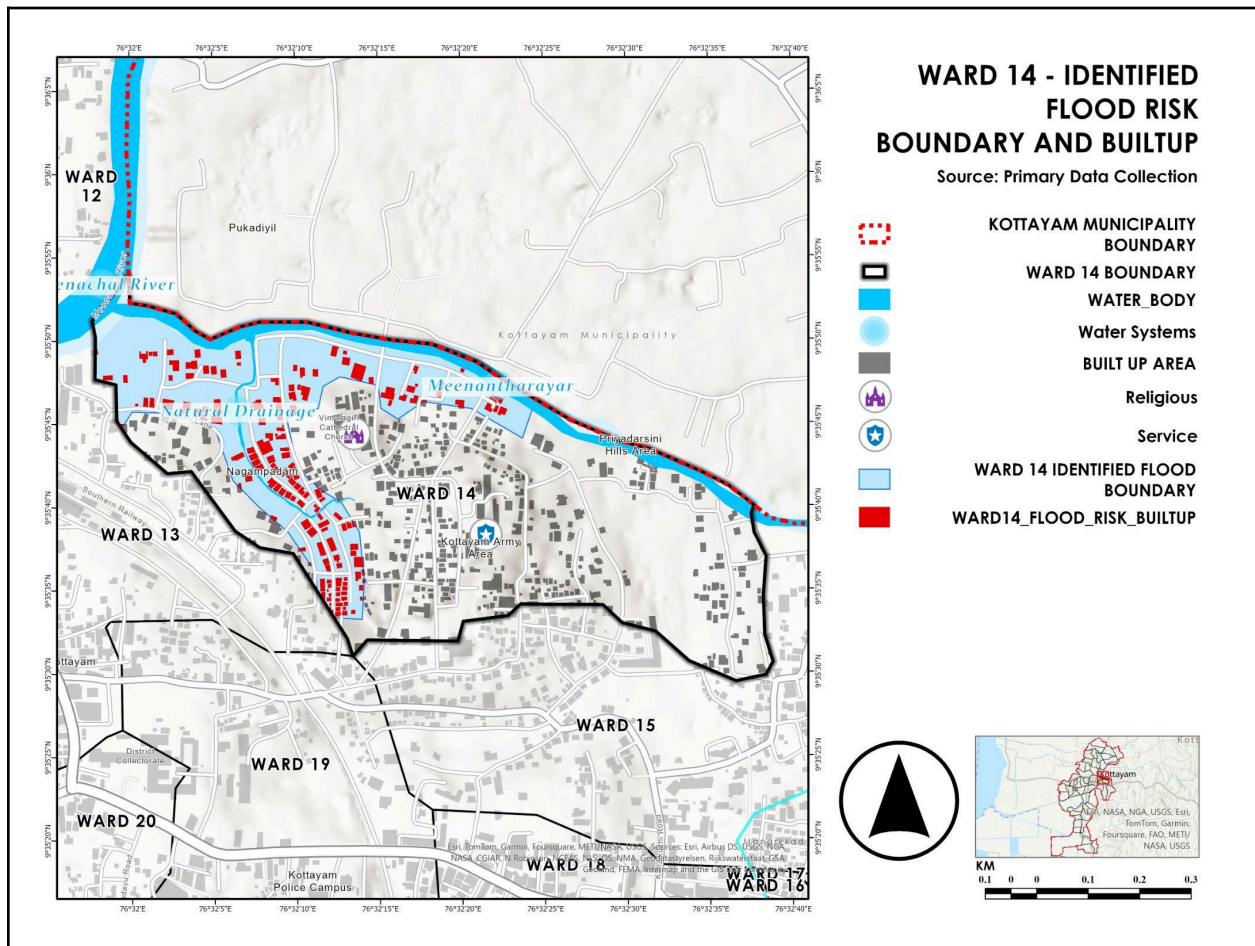


Figure 22: Flood Risk Zones and Built up Ward 14

(iv) Flood Mapping



The provided map offers a clear picture of flood risk in Ward 14, integrating existing built-up areas, other features, and the identified flood risk boundaries. Key takeaways include the delineation of flood risk boundaries, which identify areas most susceptible to flooding. These boundaries are overlaid on the map to provide a clear visual representation of flood-prone zones. Additionally, buildings located within these flood risk areas are highlighted in red, indicating their heightened vulnerability to flooding. An on-site investigation further revealed that, within Ward 14, approximately 850 houses are situated in flood-prone areas, with around 350 of these

homes being directly affected by flooding. This data underscores the critical need for targeted flood mitigation measures in these vulnerable regions.

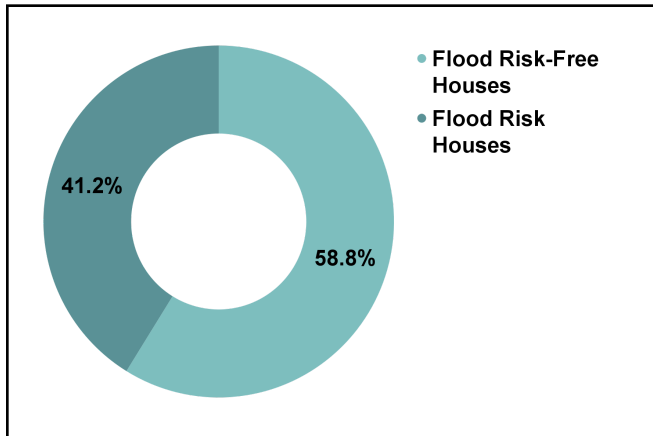


Figure 24: Flood affected Households

- Flood Duration:** Residents reported that floodwaters typically remain for a period of 3-5 days, highlighting the prolonged disruption caused by flooding events.

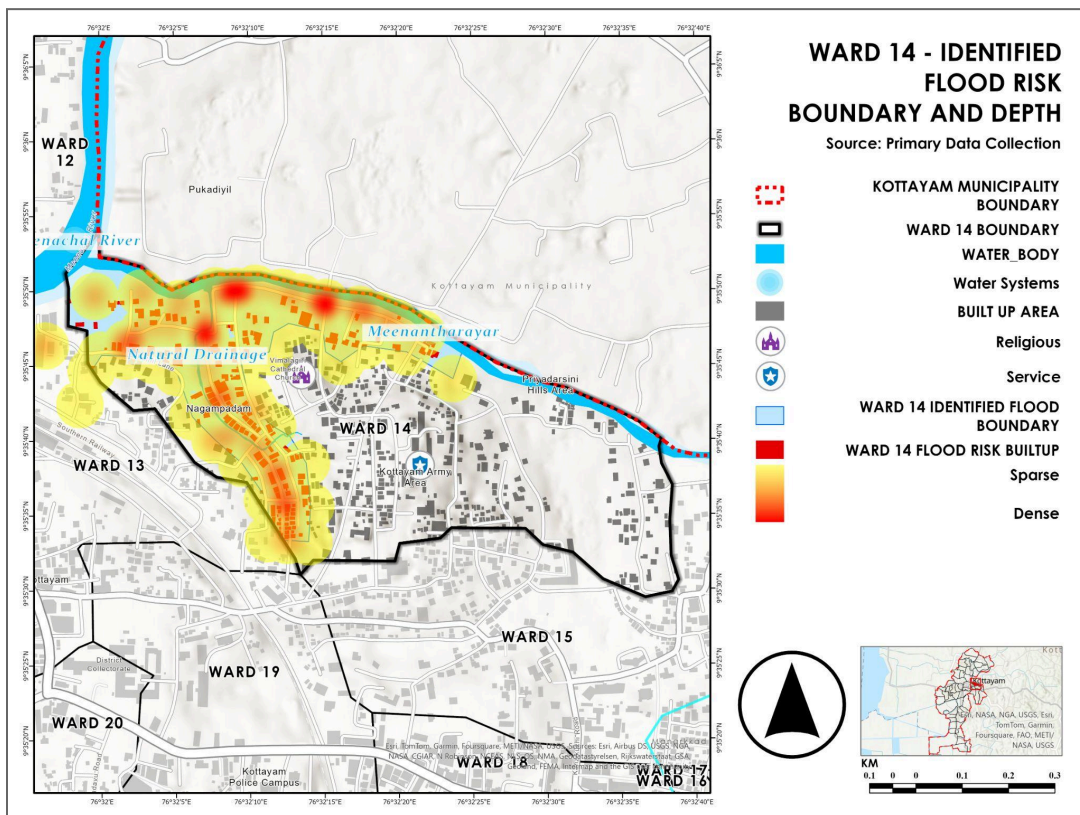


Figure 25 : Flood risk zones and maximum Flood Depth Ward 14

The provided Map shows the varying depths of flooding within Ward 14, along with existing built-up areas and other features. Here's a breakdown of the key points:

- **Flood Depth Overlay:** The map incorporates information on flood depth across the ward.
- **Red Areas:** These areas represent the locations experiencing the most severe flooding, with water levels reaching depths of 5-6 feet from the ground.
- **Yellow Areas:** Areas shaded in yellow indicate locations with moderate flooding, where water levels typically range from 2-4 feet from the ground.

(v) Issue Mapping

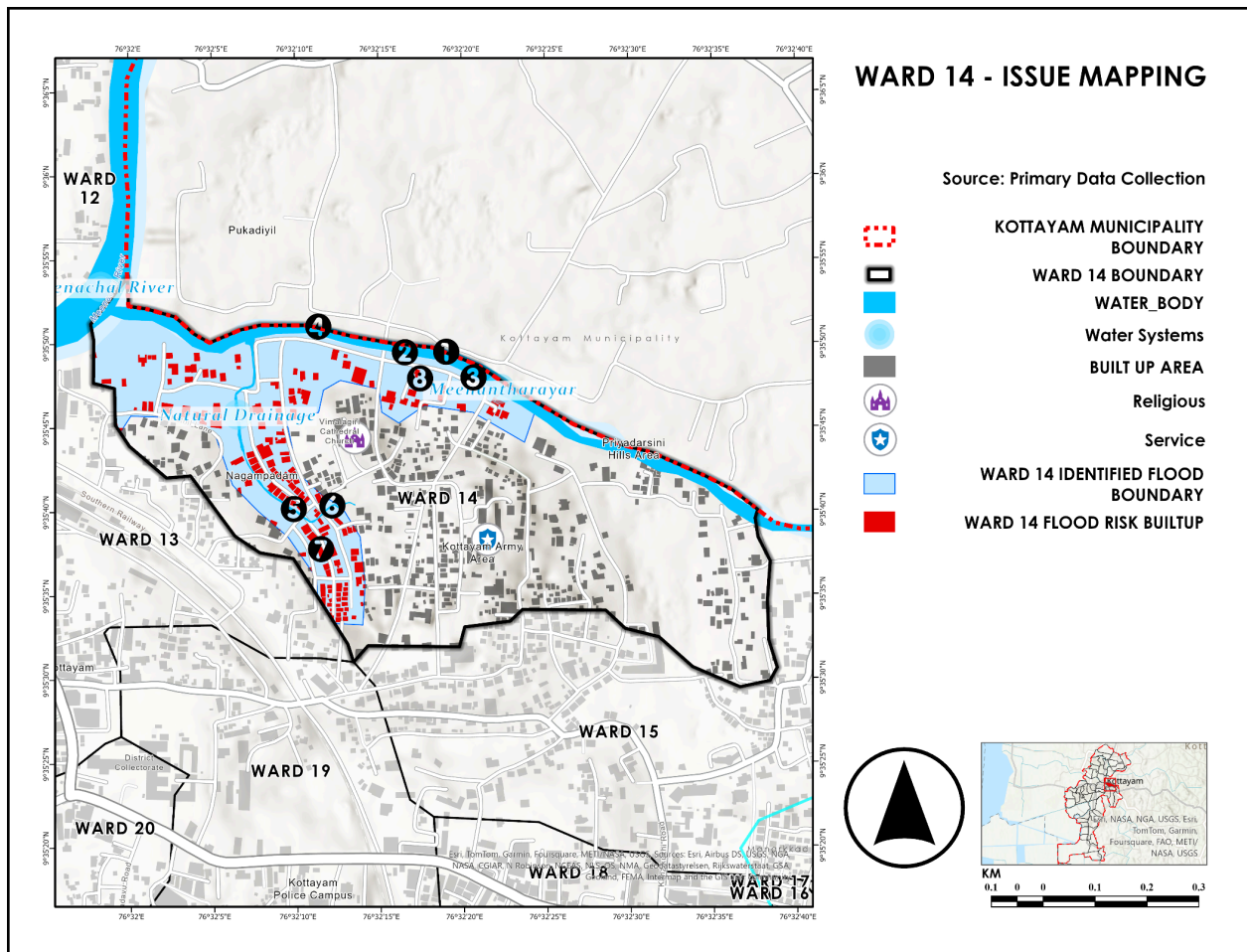


Figure 26 : Issue Mapping of Ward 14.

The issue mapping of Ward 14 is depicted in Figure 21, with each number corresponding to specific problems in their respective locations.



1. Encroachment - Plot Boundary walls are built over Side walls

2. Stilt collected from the Meenantharayar disposed on the Banks itself - Later it deposited back to Canal with rainwater runoff

4. Deepening of Meenantharayar Results-Lowering of Ground water level in Localities Well



3. Decline in the Water carrying capacity (Depth and Width) of Meenantharayar - Due to Stilt Deposit and Encroachment



5. Polluted Natural drain - Due to the Pollutant discharge from the Armed Reserve Camp and other Structures in the highlands of Ward 14

6. Natural Drain - interrupted flow due to placement of grills to collect waste and bottle neck formed due to placement of Culvert



7. Abandoned Houses - due to Frequent Flooding (Lintel Level), Some of the Residents sold their property due to unsafe conditions

8. Flood After Effects - Many of the structures and houses are in risk of structural damage due to the moisture trapped inside the Walls which affects adversely on stability of House.

Fig 27 (a,b,c,de) : Issues Mapping ward 14

4.5.2 PALLIPPURAM, WARD-4

Pallipuram, located in the northeastern corner of Kottayam Municipality, faces significant flood risk. An estimated 90% of the area lies in a flood-prone zone. Specific locations like Mudakkam, Kulikadumambhagam, Adathinakam, Vettikakkuzhy, Thottingal, Neelimangalam, Puthettu Road, and Pallippuram itself experience repeated flooding. The monsoon season (June to September) brings the highest flood risk, with residents facing inundation up to four times a year. Flood durations typically range from 10 to 16 days, with an average depth of 1.5 meters, impacting an estimated 300 out of 530 houses. The yearly flooding forces residents to migrate and devastates agriculture, particularly paddy fields

(i) Flood Mapping

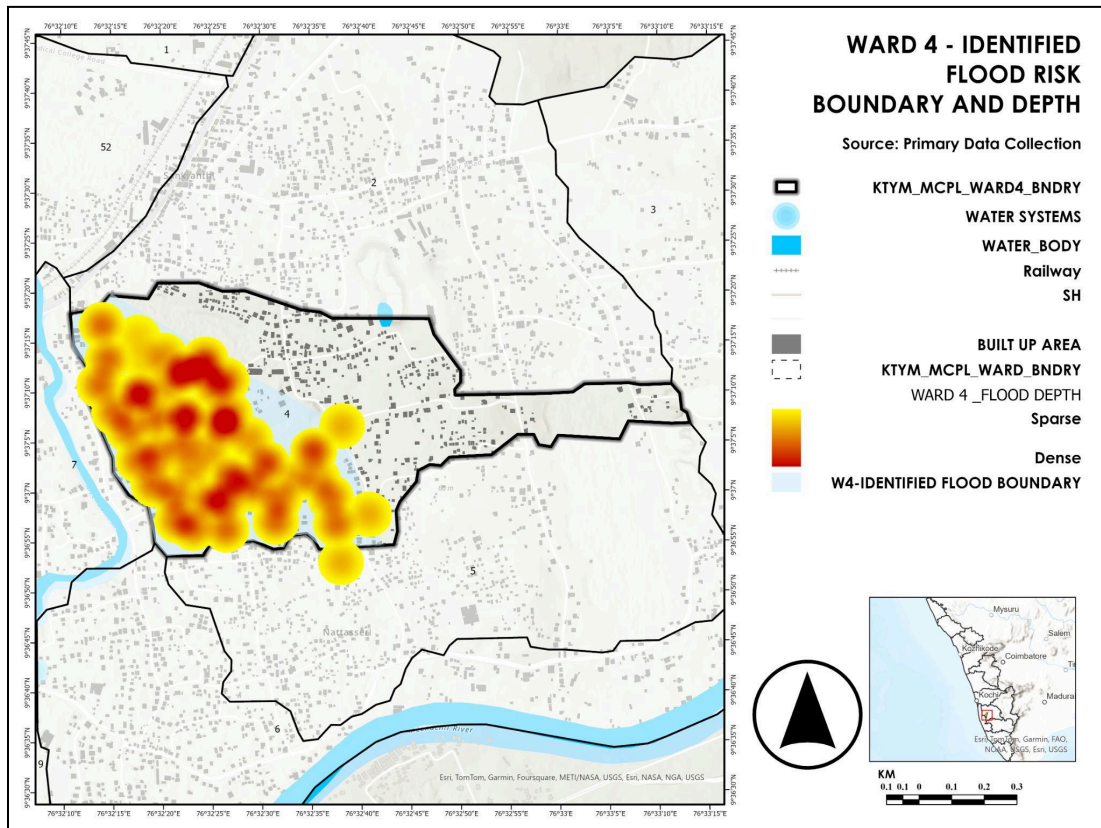


Figure 28 :Map of Identified Flood risk Boundary and depth

The provided Map shows the varying depths of flooding within Ward 4, along with existing built-up areas and other features. Here's a breakdown of the key points:

- **Flood Depth Overlay:** The map incorporates information on flood depth across the ward.
- **Red Areas:** These areas represent the locations experiencing the most severe flooding, with water levels reaching depths of 3-2 m from the ground.
- **Yellow Areas:** Areas shaded in yellow indicate locations with moderate flooding, where water levels typically range from 2-1 m from the ground.

(ii) Issue Mapping

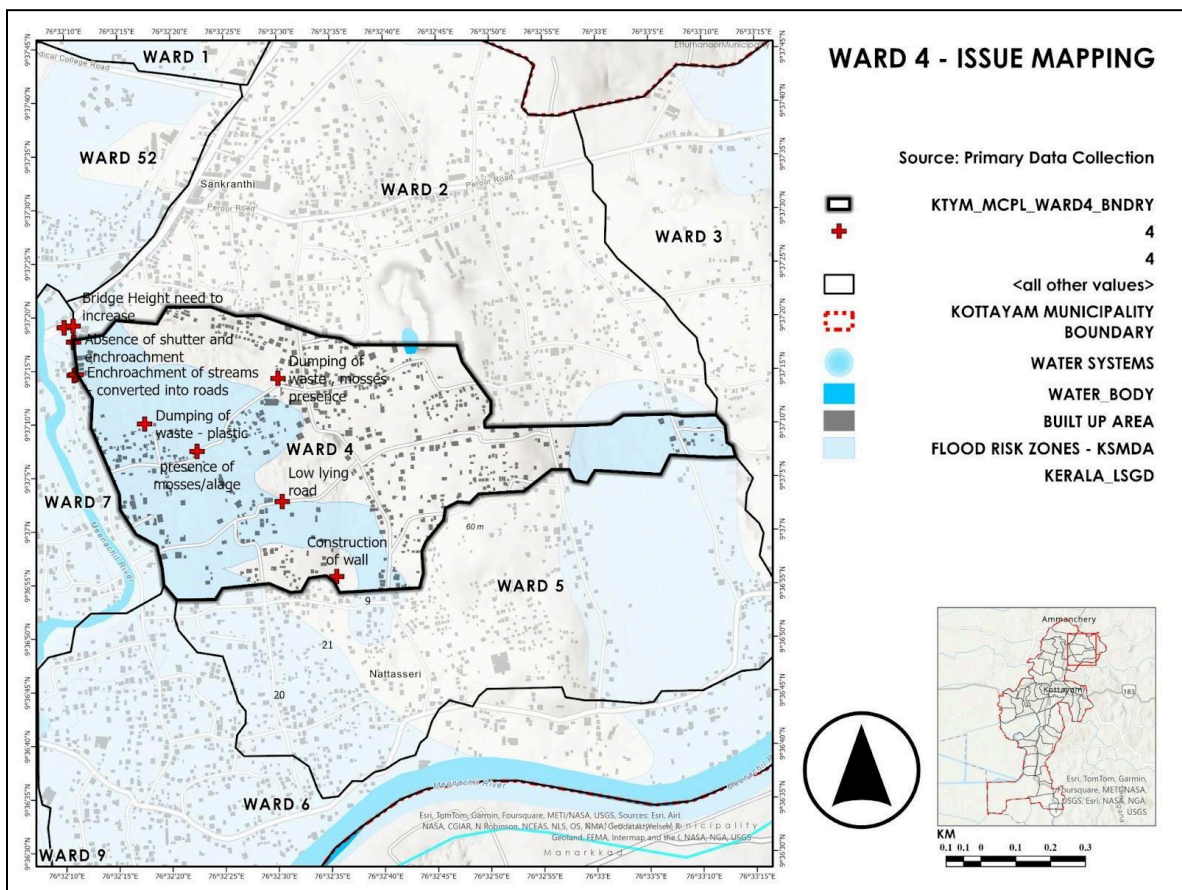


Figure 29: Issue Mapping of Ward 4

Several factors contribute to Pallippuram's flooding woes. Improper management including malfunctioning or absent shutters, disrupts water flow. Encroachment on waterways by buildings and other structures further restricts drainage. Silt deposition narrows canals and streams, reducing their capacity to handle water. Low-lying roads act as barriers, impeding water flow and exacerbating flooding. Additionally, mosses and algae add to the problem by hindering water passage.

(ii) Causes of Flooding

Encroachment

Encroachment is a significant issue in Pallippuram, manifesting in various forms across different parts of the area. A notable example is the encroachment of streams due to urbanisation, where small streams, initially measuring around 0.5 meters, are transformed into roads, disrupting the natural water flow. This can lead to flooding during heavy rains.



Figure 30: Encroachment On Streams

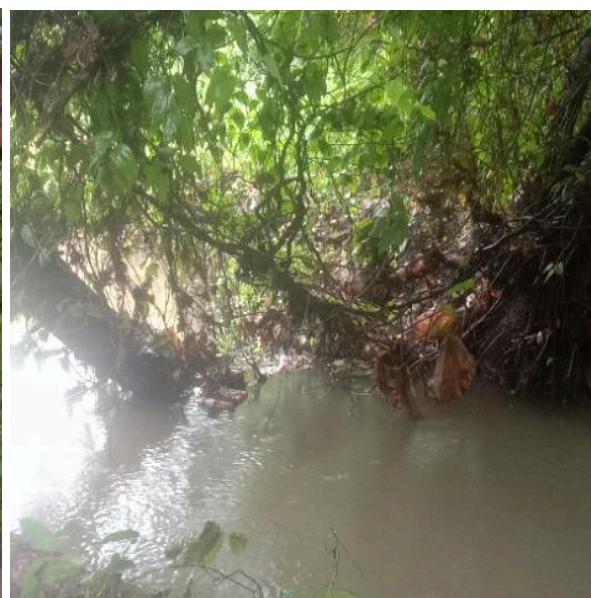


Figure 31: Stream Flow Disruption

Due To Flora

Encroachment of rivers is a major issue, with river width being reduced due to parts of the river being converted into land. Another significant problem is the encroachment of trees along the sides of the riverbanks, as seen in the Cherupayithodu stream, which originates from the

Meenachil River. Additionally, the encroachment of trees disturbs the natural flow of the stream, increasing the risk of flooding in nearby areas and underscoring the urgent need for effective measures to address these encroachments.

Blocked Drainage

Blocked drains are one of the causes of urban flooding in Pallipuram. In Pallipuram, you can see both urban and riverine flooding. Blocked drainage due to compound wall construction significantly restricts the flow of water into the Cherupayithodu stream during heavy rain, disrupting the natural flow and potentially forcing a shift in paddy field cultivation patterns. Furthermore, according to stakeholders, the Neelimangalam Bridge's height aligning with the road may raise concerns about water and debris backup during heavy rain events, potentially causing overflow. These factors collectively contribute to an increased risk of flooding and disruption of agricultural activities, highlighting the critical need for effective drainage and well-planned infrastructure development.



Figure 32: Blocked drain due to compound wall and bridge

Moss/Algae Growth and Waste Dumping

Mosses and algae, along with dumped waste, are observed in the Pallipuram ward of Kottayam municipality. The presence of mosses/algae and the ongoing dumping of waste in

Cherupayithodu pose a significant threat to the surrounding areas. This buildup significantly reduces the watercourse's flow velocity and overall capacity to hold water, thereby increasing the risk of severe flooding. Immediate action, such as cleaning the waterway and implementing proper waste management strategies, is crucial to mitigate these flood risks.

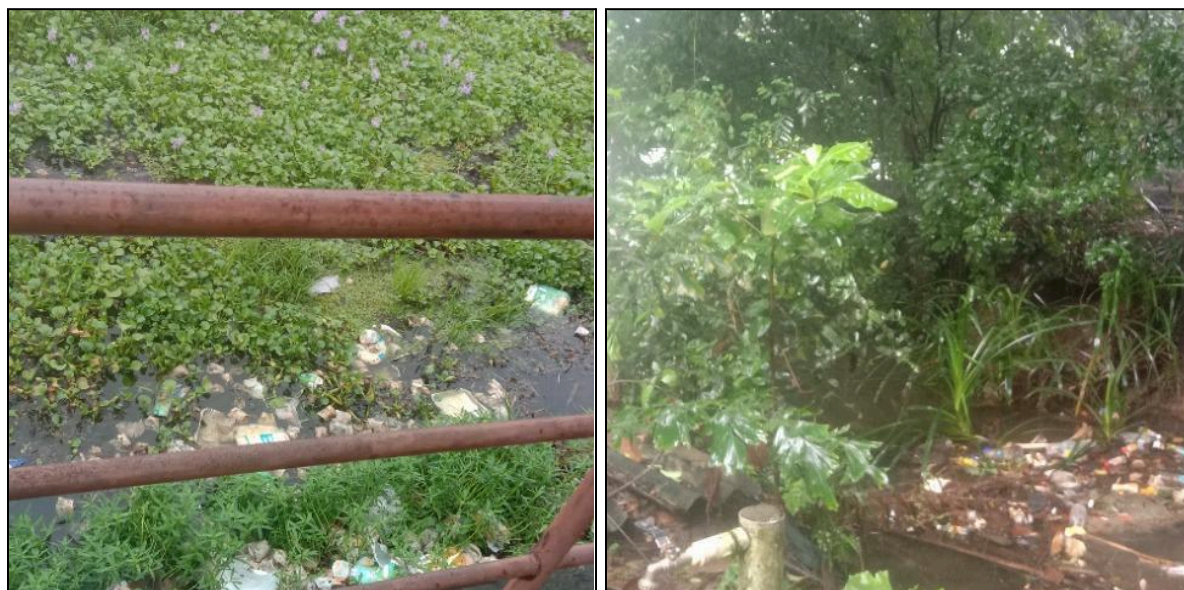


Figure 33 : Mosses\algae presence in the river *Figure 34: Dumping of waste*

The insufficient number of properly functioning shutters along waterways within the Kottayam Municipality, specifically in Pallipuram, is causing a considerable issue. An example of this predicament is evident in Pallipuram, where the river passing through Neelimangalam is facing impediments due to the lack of shutters. The absence of shutters means that there is no effective way to regulate the water flow, which in turn leads to uncontrolled water levels during heavy rainfall or sudden water discharges. Consequently, this unregulated flow can lead to the overflow of rivers, resulting in the inundation of surrounding areas.

Low Lying Terrain

Kottayam, located in both the lowland and midland regions, faces recurring floods, particularly in areas like Pallipuram, where the road lies predominantly in low-lying terrain. According to the map (Figure), blue region indicates low-lying terrain Orange colour indicates high-lying terrain

This low-lying terrain exacerbates flooding issues as it accumulates water slowly due to its reduced slope and slower drainage, significantly heightening the flood risk. In Pallipuram, the Pulikattumadam-Edathinikam road, suffers from particularly low elevations, making them prone to frequent inundations. These roads' low heights and positions in the landscape make them key contributors to the flooding problems in the area, posing persistent challenges

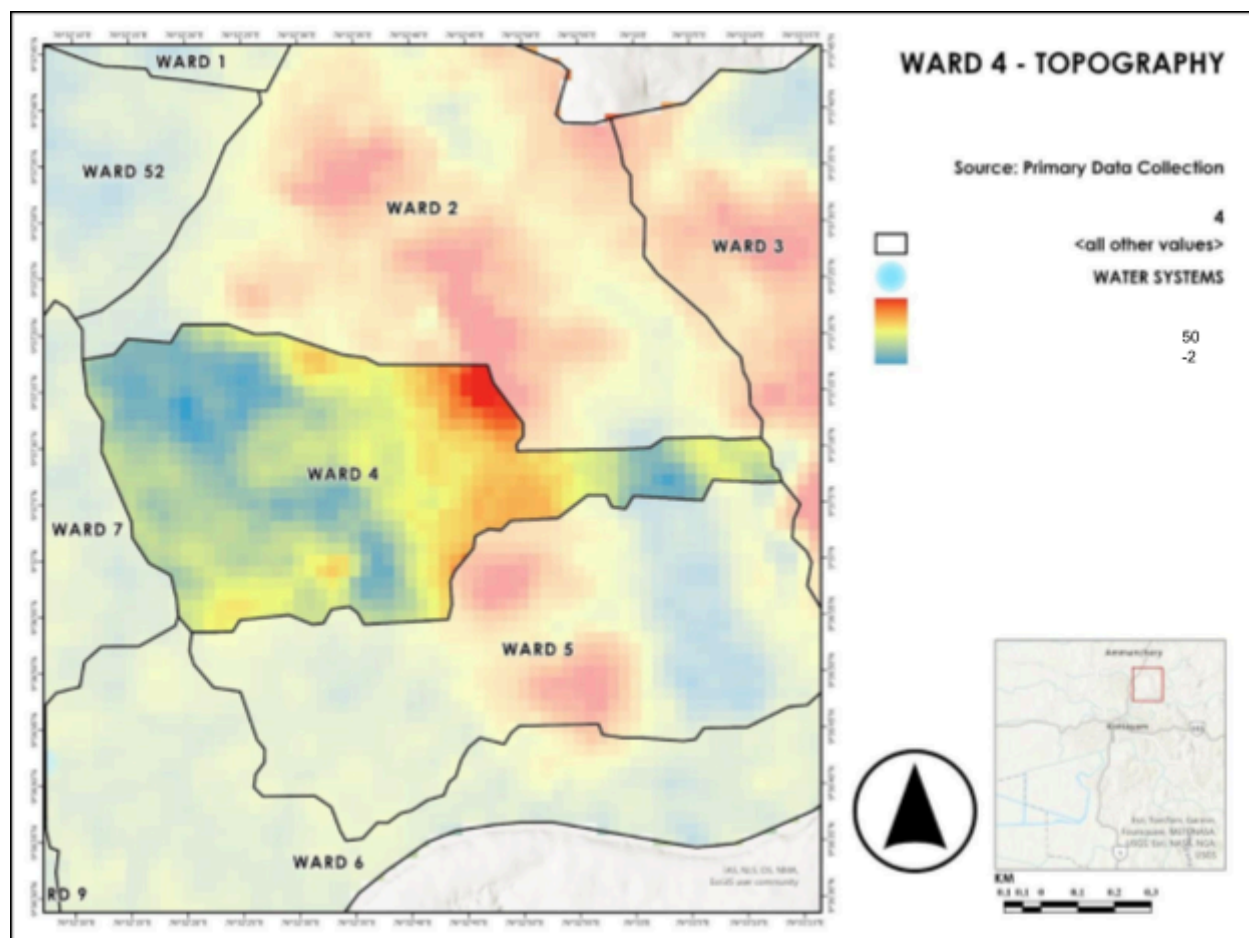


Figure 35: Topography of Ward 4

4.5.3 PUTHETTU, WARD 6

Puthettu, located in the northeastern corner of Kottayam Municipality, is entirely located in a flood-prone area except for the government UPS School Puthettu and Shree Vidhyiraja Seva Mission School. The region experiences a high risk of flooding, particularly in May, June, and September, with floods occurring three times a year. Floods typically last for three days, with an

average depth of 1.5 meters. This recurrent flooding significantly impacts the area, decreasing land demand and prompting migration among the local population.

(i) Topography

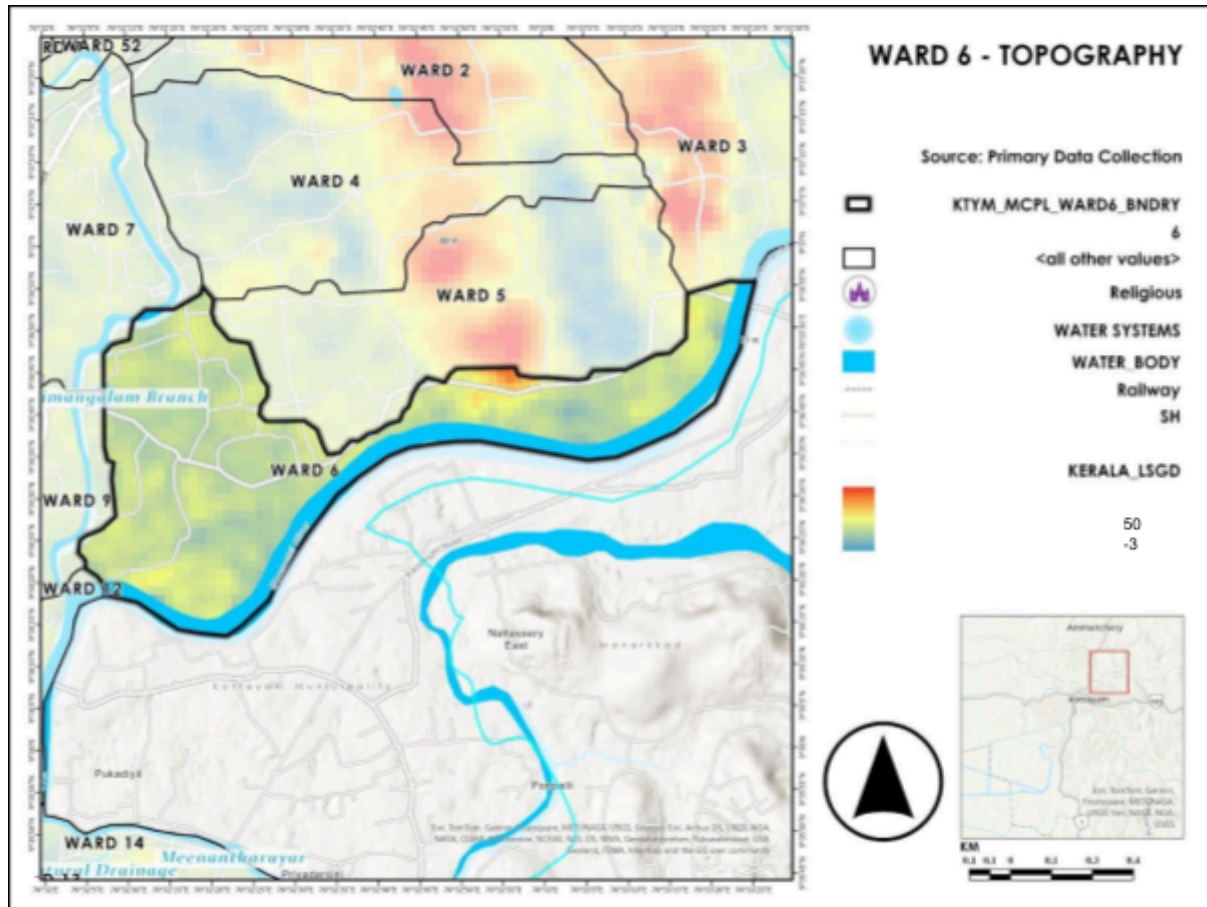


Figure 36: Topography Map of ward 6

The figure illustrates that the map uses colour coding to represent the terrain. Blue regions indicate lowlands, which are areas with relatively low elevation. In contrast, yellow regions represent the midlands, areas with a higher elevation than the lowlands. the location of Puttethu sits at the intersection of these two zones.

(ii) Flood Mapping

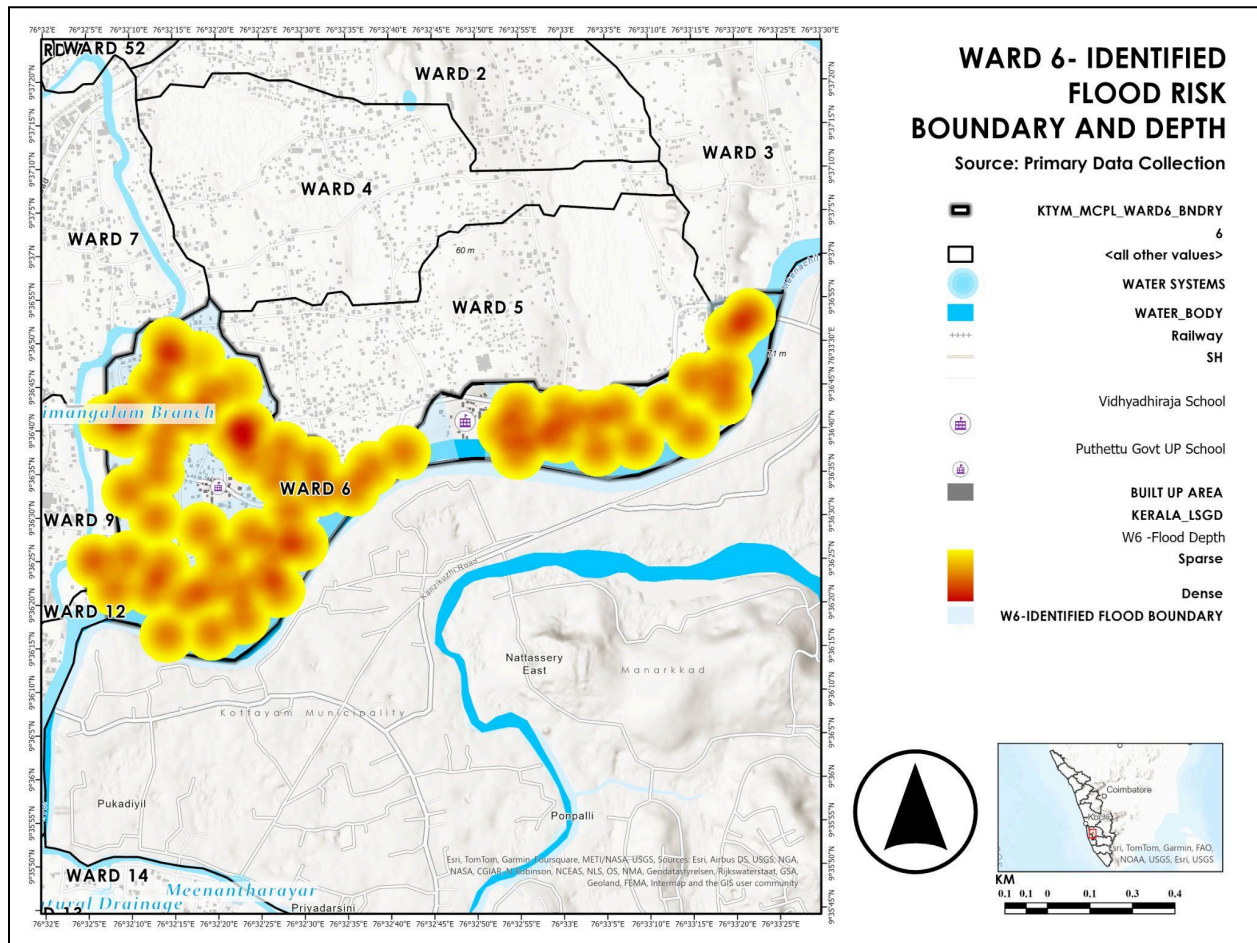


Figure 37 : Flood risk zones and maximum Flood Depth Ward 6

The provided Map shows the varying depths of flooding within Ward 6, along with existing built-up areas and other features. Here's a breakdown of the key points:

- **Flood Depth Overlay:** The map incorporates information on flood depth across the ward.
- **Red Areas:** These areas represent the locations experiencing the most severe flooding, with water levels reaching depths of 2-1.5 m from the ground.
- **Yellow Areas:** Areas shaded in yellow indicate locations with moderate flooding, where water levels typically range from 1.5-0.75 m from the ground.

(iii) Issue Mapping

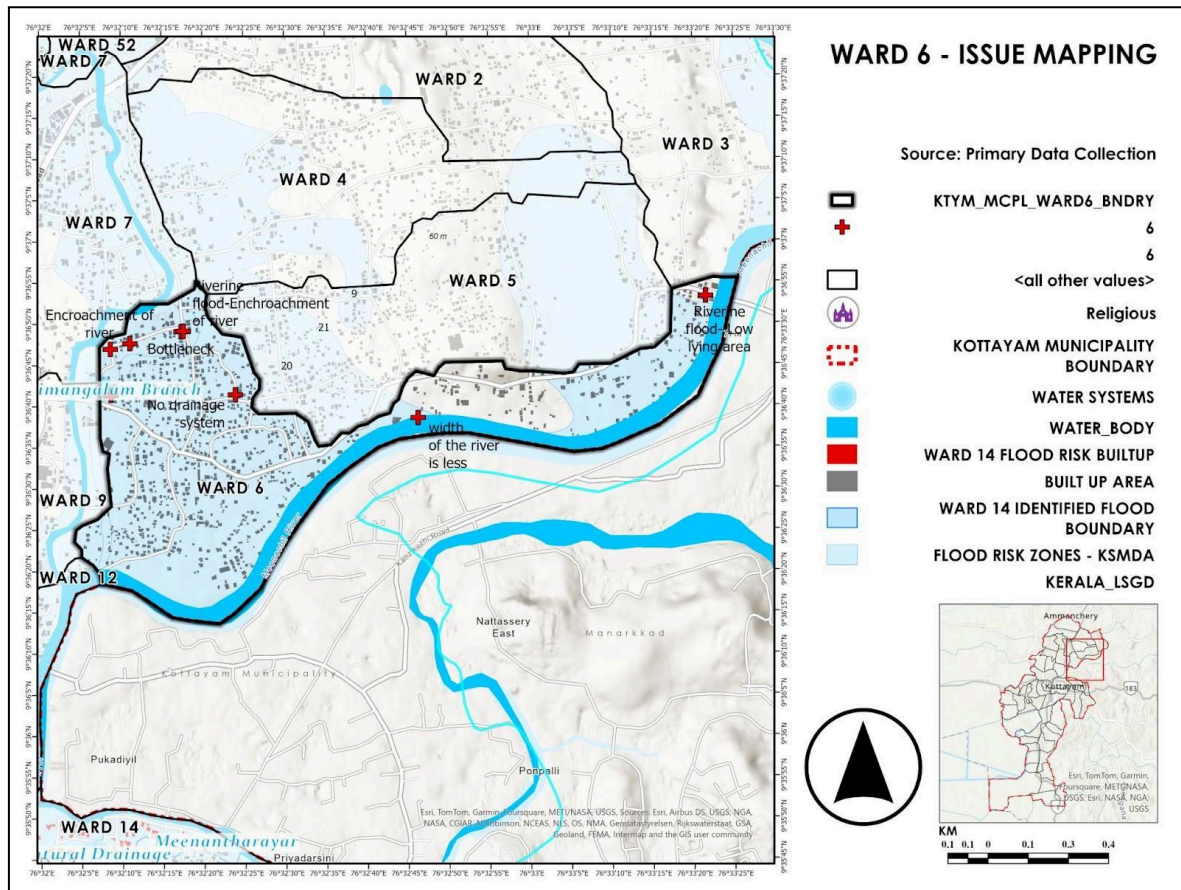


Figure 38: Issue mapping Ward 6

During our site visit, we observed several issues in Puthettu. The primary causes of flooding in Puthettu include encroachment, which disrupts natural water flow and reduces the area available for drainage. Siltation in streams further exacerbates the problem by decreasing their capacity to carry excess water. Additionally, the overflow of the Meenachil River significantly contributes to flooding, as the river's banks cannot contain the increased water volume during heavy rains. The lack of proper drainage facilities further intensifies the situation, preventing efficient water runoff and leading to frequent and severe flooding in the area.

(iv) Causes of Flooding

Lack of Drainage facilities

One of the significant issues in Puthettu is the lack of drainage facilities. In some parts of Puthettu, there is no drainage system available, which contributes to urban flooding in the area. In Attickalpadi Karindelli, the absence of drainage facilities leads to recurring floods, with rainwater only being disposed of through evaporation by sunlight. The disappearance of a canal in Puthettu hinders the natural flow of rainwater, causing severe waterlogging. The canal may get blocked by debris or silt, reducing its capacity to carry water. In response, local people have created temporary channels to manage rainwater flow, but these makeshift solutions are insufficient to address the persistent flooding problem effectively.



Figure 39: Absence of Drainage Facility



Figure 40: Temporary Channel

Encroachment

In Kottayam municipality, encroachment has become a significant issue, particularly evident along the Meenachil River as it flows through Vettikkakuzhy. Encroachment has resulted in portions of the river being converted into land, thereby reducing the width of the river channel. This narrowing, compounded by sediment accumulation along the banks, has created bottlenecks in the river's flow. These bottlenecks not only diminish the river's water-holding capacity but also increase the risk of overflow during heavy rainfall events. Furthermore, changes in the river's

gradient exacerbate these issues, potentially heightening the susceptibility to riverine floods in the region. In Choorakattil, such encroachment has already led to riverine flooding, causing structural damage in nearby areas.



Figure 41: Encroachment Of River



Figure 42: Formation Of Bottleneck

Siltation

One of the significant issues in Puthettu is siltation. Puthettu Ward 6, located where the Meenachil River connects to Cherunaram and flows through Puthumali bridge, is particularly susceptible to flooding due to siltation. As sediment accumulates in the riverbed, the water depth reduces significantly, and its capacity to hold water diminishes. This phenomenon, leading to overflows around the narrowed river channel and causing more frequent and severe flooding events in the surrounding areas.



Figure 43: Encroachment due to Vegetation

Blocked Drainage

In Puthettu, blocked drainage is a significant issue contributing to flooding. The area faces problems with insufficient culvert capacity, where a drainage channel that was originally 6 meters wide has now been reduced to just 1 meter. This drastic reduction in drainage capacity leads to immediate flooding during heavy rainfall, exacerbating the flood situation in Puthettu.



Figure 44: Encroached Stream

4.5.4 NATTASSERY, WARD 5

Nattassery, located in the northeastern corner of Kottayam Municipality, faces significant flood risks. With 50% of its area, including Paruthikuzhy, Vayanasala, Vettikakkuzhi, and Pularipuram, classified as flood-prone, the ward experiences frequent flooding, averaging three flood events per year primarily in May and June. These floods, lasting approximately 3 days with an average depth of 1.5 meters, are attributed to various factors like encroachment on floodplains, blocked drainage, and absence of Culverts ultimately leading to population displacement due to recurring flood occurrences.

(i) Topography

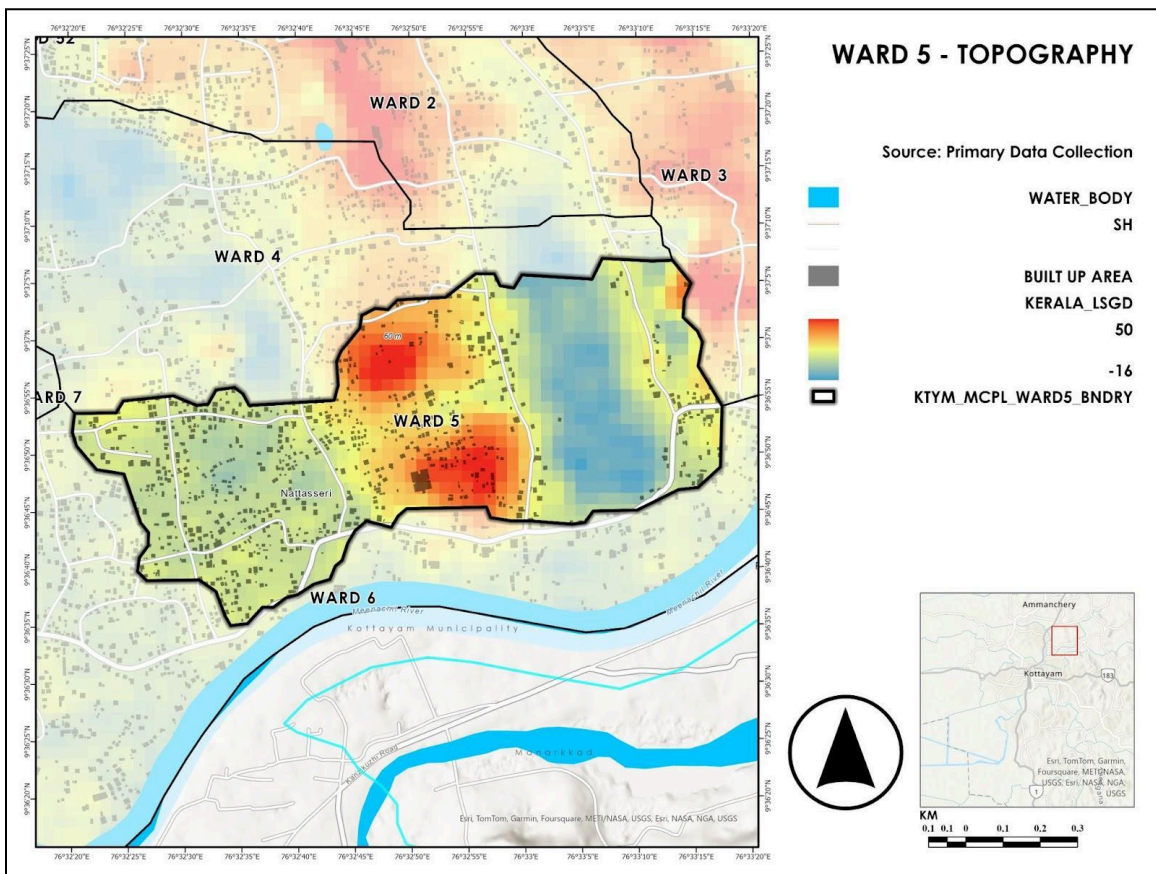


Figure 45: Topography of Ward 5, Nattassery

The figure illustrates that the map uses colour coding to represent the terrain. Blue regions indicate lowlands, which are areas with relatively low elevation. In contrast, Red regions

represent the higher elevation . The location of Nattassery sits at the intersection of these high and low elevation areas.

(ii) Flood Mapping

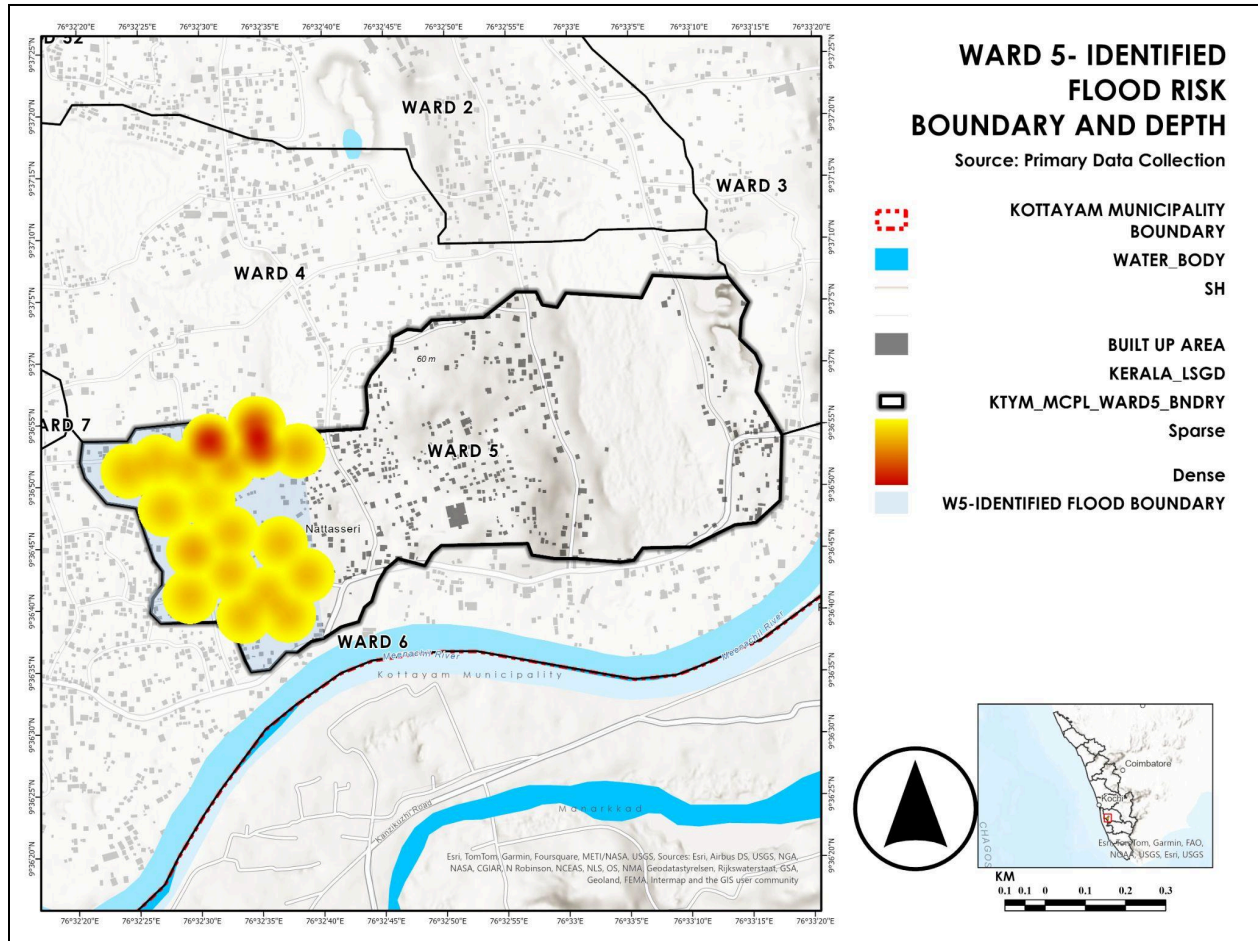


Figure 46: Flood risk zones and maximum Flood Depth Ward 5

The provided Map shows the varying depths of flooding within Ward 5, along with existing built-up areas and other features. Here's a breakdown of the key points:

- **Flood Depth Overlay:** The map incorporates information on flood depth across the ward.
- **Red Areas:** These areas represent the locations experiencing the most severe flooding, with water levels reaching depths of 5-2 m from the ground.

- **Yellow Areas:** Areas shaded in yellow indicate locations with moderate flooding, where water levels typically range from 1.5-1 m from the ground.

(iii) Issue Mapping

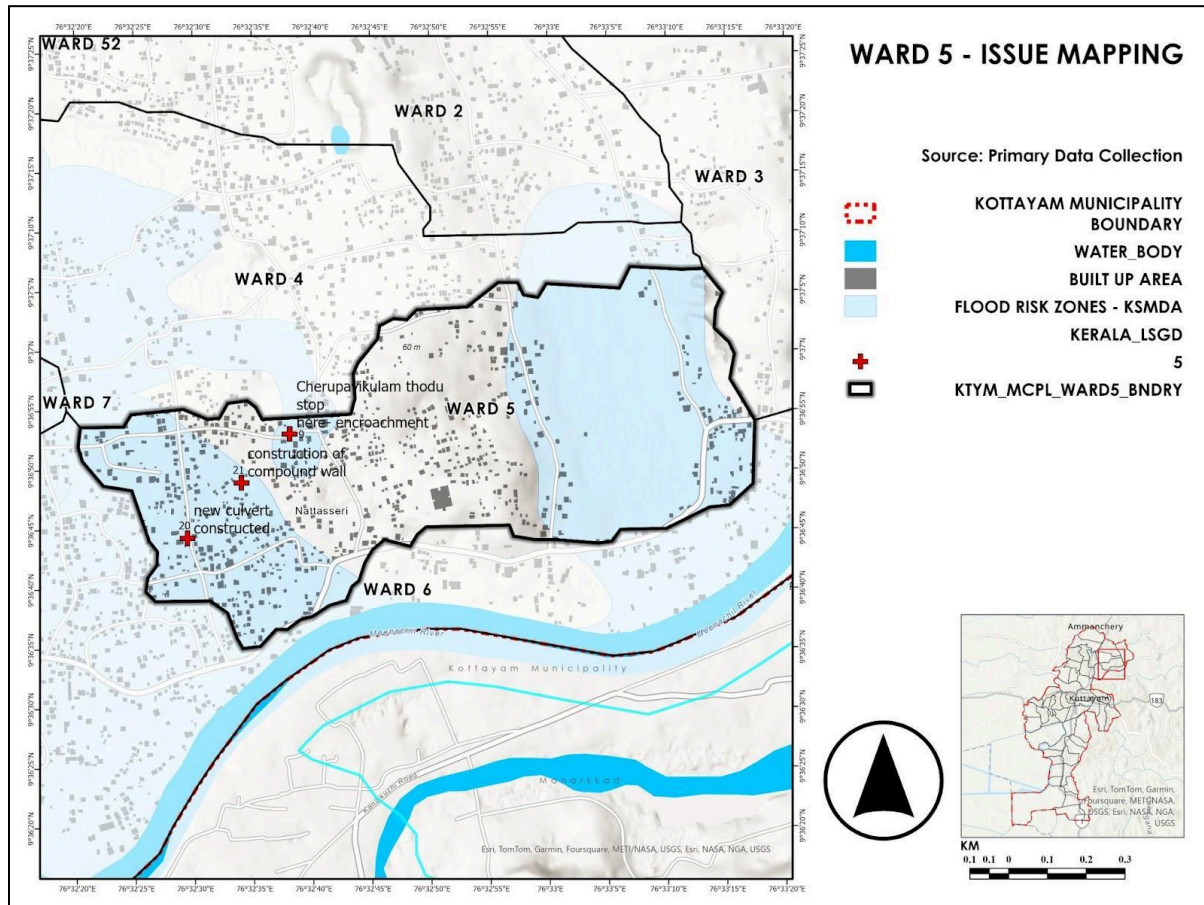


Figure 47 :Issue Mapping for Ward 5

During our site visit to Nattassery, we observed several critical issues, with the primary concern being the blocked drainage system and the absence of culvert. These deficiencies are likely significant contributors to the increasing frequency and severity of flooding in the area.

(iv) Causes of Flooding

Blocked Drainage

Nattassery, another flood-prone area within the municipality with 50% of its land susceptible to flooding, experiences drainage issues that exacerbate the problem. Blocked drainage channels and construction of compound walls in Paruthikuzhy, a particularly flood-prone location within

Nattasserry, restrict the natural flow of rainwater towards Cherupayithodu, leading to waterlogging even after a single day of rainfall and ultimately causing displacement of residents.



Figure 48: Blocked drainage in Paruthikuzhy

Absence of Culvert

The Kottayam municipality requires a sufficient number of culverts, as evidenced by the situation in Nattasserry, where the absence of culverts has led to significant issues. Previously, the Cherupayithodu stream connected to Karadhel Bridge without obstruction, but encroachment has now blocked this flow, transforming the area into a residential zone. Nattasserry, the use of pipes instead of culverts may cause problems such as blockage, debris accumulation, capacity limitations, and reduced flow efficiency, thereby increasing the flood risk in the area.



Figure 49: Absence of Culvert



Figure 50 : The use of pipes instead of culverts.

4.5.5 Parampuzha, Ward -3

Parampuzha, located in the northeastern corner of Kottayam Municipality, experiences significant flooding concerns. Areas particularly prone to flooding include Kuzhiyalippady, Puthenpurakkal, Pichakasserymali, Arthykulam, Chungakarottupadi, and Velloorparambu Mukkudimalil Road. The flood risk is highest during the monsoon season, typically occurring twice a year in May, June, and July. Several factors contribute to these floods, including encroachment on waterways, siltation buildup, drainage issues, low-lying terrain, and occasional river overflow. Flood events in Parampuzha typically last for around seven days, with an average water depth of 1.5 meters

(i) Topography

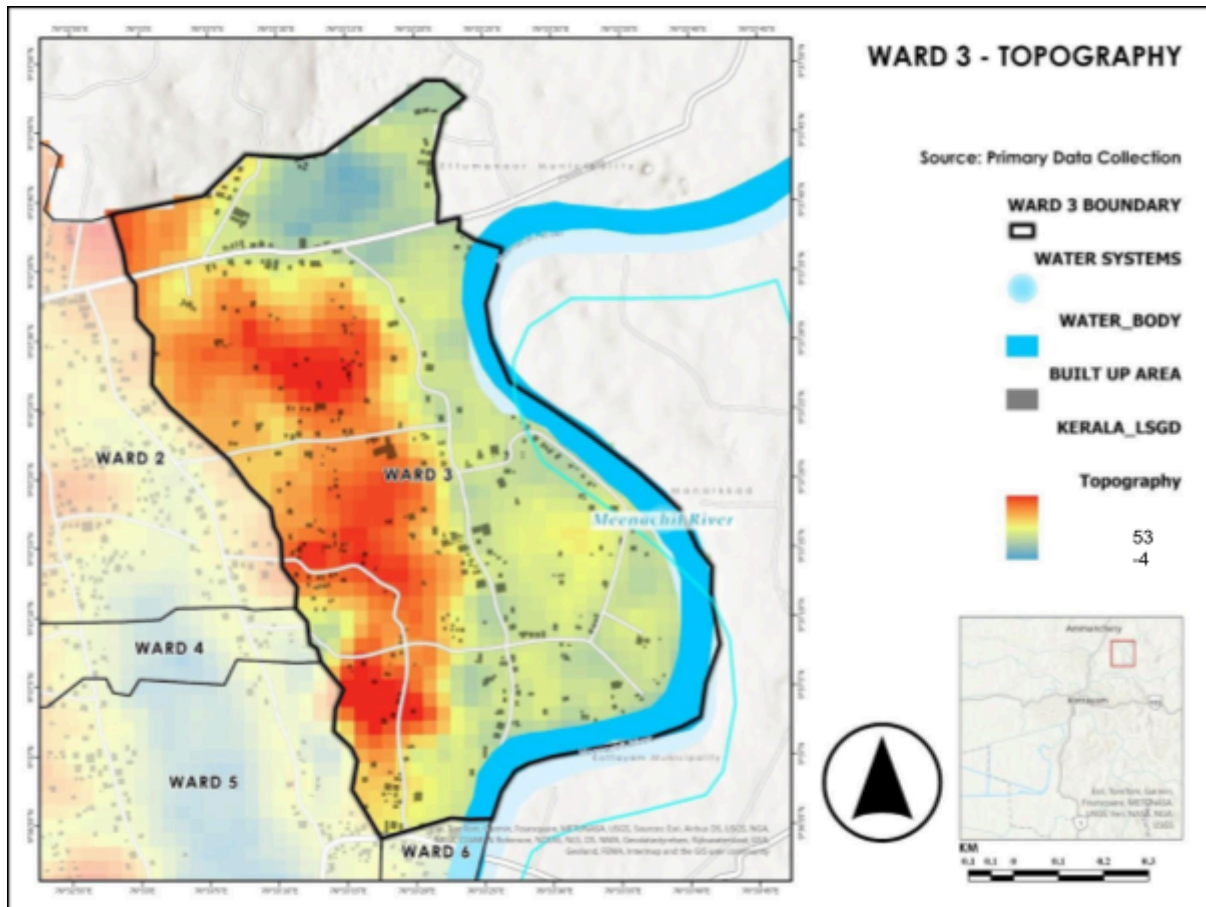


Figure 51 : Topography Map of Ward 3

The figure illustrates that the map uses colour coding to represent the terrain. Blue regions indicate lowlands, which are areas with relatively low elevation. In contrast, orange regions represent the midlands, which are areas with relatively high elevation. the location of Parambuzha sits at the intersection of these two zones.

(iv) Flood Mapping

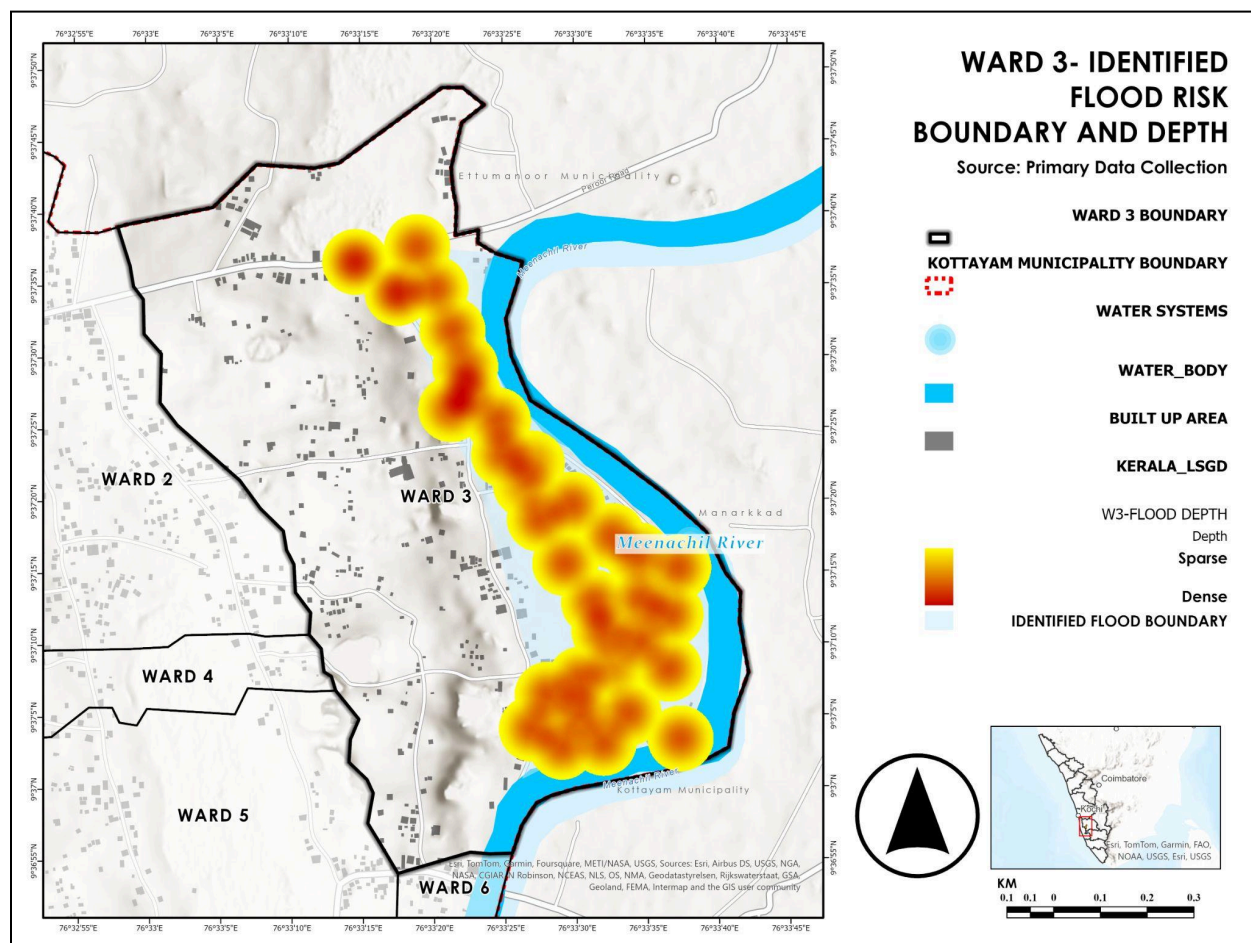


Figure 52 : Flood risk zones and maximum Flood Depth Ward 3

The provided Map shows the varying depths of flooding within Ward 3, along with existing built-up areas and other features. Here's a breakdown of the key points:

- **Flood Depth Overlay:** The map incorporates information on flood depth across the ward.
- **Red Areas:** These areas represent the locations experiencing the most severe flooding, with water levels reaching depths of 2 m from the ground.
- **Yellow Areas:** Areas shaded in yellow indicate locations with moderate flooding, where water levels typically range from 0-1.5 m from the ground.

(iii) Issue Mapping

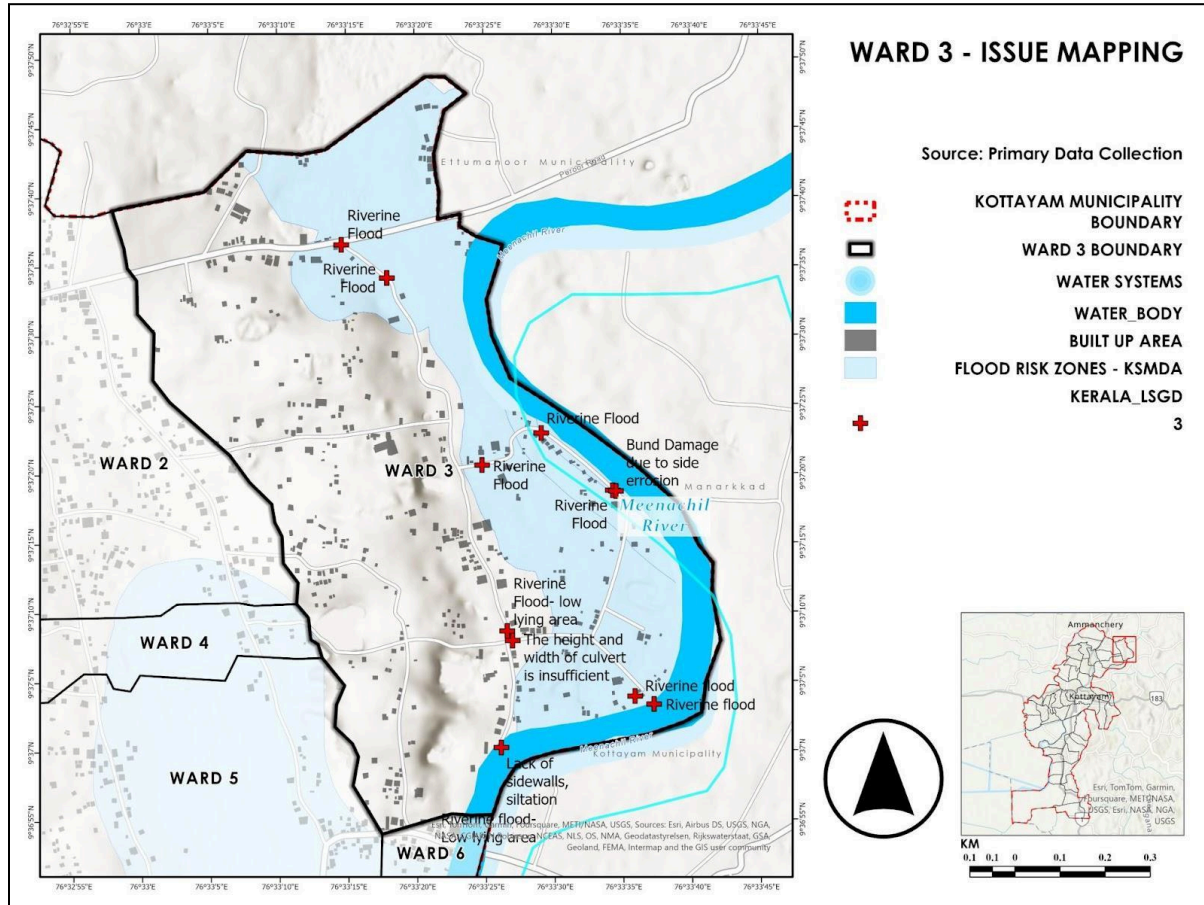


Figure 53 : Issue Mapping for Ward 3

(iv) Causes of flooding

Bund Breach

In Parambuzha, we observed that the bund has been significantly damaged due to erosion from the riverbank, leading to restrictions on bus travel along this road out of concern for potential further damage. The absence of a proper sidewall along this section further increases the flood risk. Without a sufficient barrier, flooding can persist for up to seven days, with floodwaters overflowing more easily onto the road and surrounding areas, potentially causing more widespread inundation and property damage.



Figure 54 : Lack of side wall

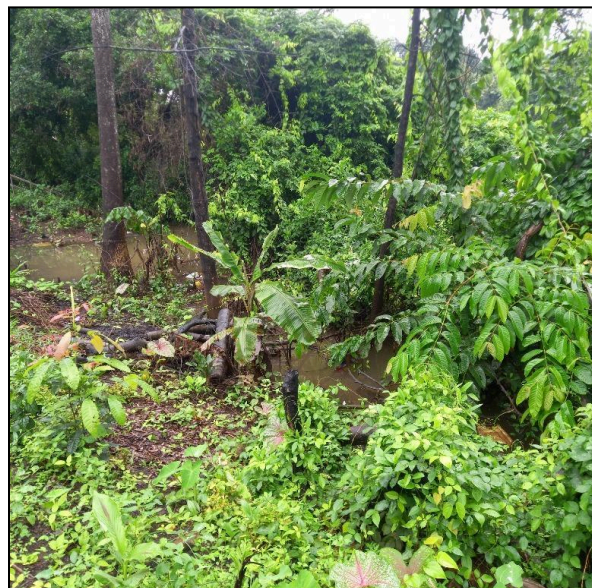


Figure 55 : Bund breach due to Erosion

Inadequate Culvert Capacity

In Parambuzha, the insufficient dimensions of the culvert have caused one-meter-deep flooding for seven days as shown in Figure (). Another example in Parambuzha is the culvert, which was originally designed to handle six meters of drainage, now reduced to just one meter, drastically limiting its capacity to manage water flow as shown in figure (). This reduction in drainage capacity has led to prolonged and severe flooding, highlighting the urgent need for a sufficient number of adequately sized culverts. Without these improvements, the inadequate drainage infrastructure will continue to exacerbate flooding, leading to more frequent and severe inundation of the area.



Figure 56: Insufficient Culvert

Riverine flood

The Parambuzha is more prone to riverine floods. In Parambuzha, the decrease in the depth of the Meenachil River due to siltation has led to a reduction in its water-holding capacity, prompting local efforts to deepen the sides of river river; however, this deepening has inadvertently increased the incidence of riverine floods, likely caused by pooling, which has in turn resulted in severe structural damage. In some areas of Parambuzha, this has resulted in the destruction of the bottom parts of the sidewalls, further exacerbating the flooding.



Figure 57 : Area with pooling effect

4.6 Conclusions

The analysis of flood risk across the various wards highlights several critical issues that contribute to recurring inundation, primarily stemming from inadequate drainage systems, encroachment on natural watercourses, and the gradual degradation of water-holding capacities in key infrastructure.

In multiple wards, the drainage channels are hindered by sedimentation and blockages, significantly reducing the capacity for effective water flow. In Ward 14 and Ward 5 (Nattassery), these limitations are compounded by poorly designed culverts or the complete absence of such infrastructure. The absence of adequately sized culverts restricts water flow, increasing the likelihood of waterlogging during periods of rainfall. This issue is observed to persist for extended durations, sometimes lasting up to a week, as seen in Parambuzha (Ward 3), where insufficient culvert dimensions exacerbate the flooding, preventing timely drainage of water.

Sedimentation buildup, common in areas like Ward 4 and Ward 6, obstructs the cross-sectional flow area of drainage systems, resulting in insufficient conveyance of stormwater. The reduced cross-sectional capacity leads to the overloading of existing stormwater systems, particularly during high-intensity rainfall events, further intensifying flood risks. The rapid urbanization in these areas, marked by an increase in impervious surfaces, exacerbates surface runoff, overwhelming drainage systems that were designed for lower volumes of water.

Encroachments, particularly along floodplains and watercourses, further disrupt the natural flow of water. This issue is most prominent in Nattassery, where the construction of compound walls obstructs the free flow of rainwater into natural drainage channels. Such encroachments not only limit water passage but also lead to localized flooding, as seen in Paruthikuzhy in Nattassery, where blocked drainage has resulted in prolonged waterlogging.

In addition to drainage and encroachment issues, fluvial flooding due to reduced water-holding capacity in rivers, like the Meenachil River in Parambuzha (Ward 3), compounds the flood risk. Siltation within the riverbed has lowered the river's capacity to manage water, while erosion along riverbanks and bunds increases vulnerability to riverine flooding. The lack of effective

flood control structures, such as sidewalls or reinforced bunds, makes the area susceptible to prolonged flooding, even during moderate rain events.

The overarching problem across these wards is the inadequate capacity of the stormwater infrastructure to manage increasing volumes of runoff, largely due to the combined effects of sedimentation, encroachment, and urbanization. Additionally, the absence of proper flood control measures, such as culverts and flood barriers, exacerbates the flood risk, leading to prolonged and damaging flooding events. Addressing these issues requires significant improvements in infrastructure design and maintenance, ensuring that drainage systems are capable of handling peak runoff and that flood-prone areas are adequately protected through reinforced bunds and natural watercourse restoration.

Chapter 5: Watershed Modeling

Kottayam municipality has been experiencing recurring floods, prompting a rainfall runoff modeling study to determine the runoff volume and intensity of flooding. For this analysis, daily rainfall data from August 2018, a period of extreme rainfall in Kerala, was utilized to find the peak flow. The required data included a Digital Elevation Model (DEM), daily rainfall data, land use/land cover maps, and soil maps. Watershed modeling was conducted using the HEC-HMS software, with four main components developed for the model: basin model manager, meteorologic model manager, control specifications manager, and input data.

5.1 Methodology

Rainfall-runoff modeling with HEC-HMS follows a structured approach to simulate the hydrological dynamics within a watershed. The process begins with meticulous data acquisition, including land use/land cover (LULC) maps obtained from Esri, soil maps from the Food and Agriculture Organisation.FAO, and digital elevation models (DEMs) sourced from the USGS Earth Explorer. Rainfall data is collected and processed alongside these inputs to create comprehensive hydrological models. Data preparation, including the calculation of parameters like curve numbers, is carried out using ArcGIS Pro to ensure accurate input values for the HEC-HMS model. These parameters are critical for defining the initial abstraction, loss, and basin characteristics.

Once the input data is prepared, the HEC-HMS model uses these parameters to simulate the transformation of rainfall into runoff. The model applies various methods, such as the Muskingum routing method, to route the runoff through the watershed and predict the discharge at the basin outlet. By integrating these elements, HEC-HMS provides a detailed and dynamic simulation of the hydrological processes, allowing for accurate analysis and runoff behaviors within the watershed.

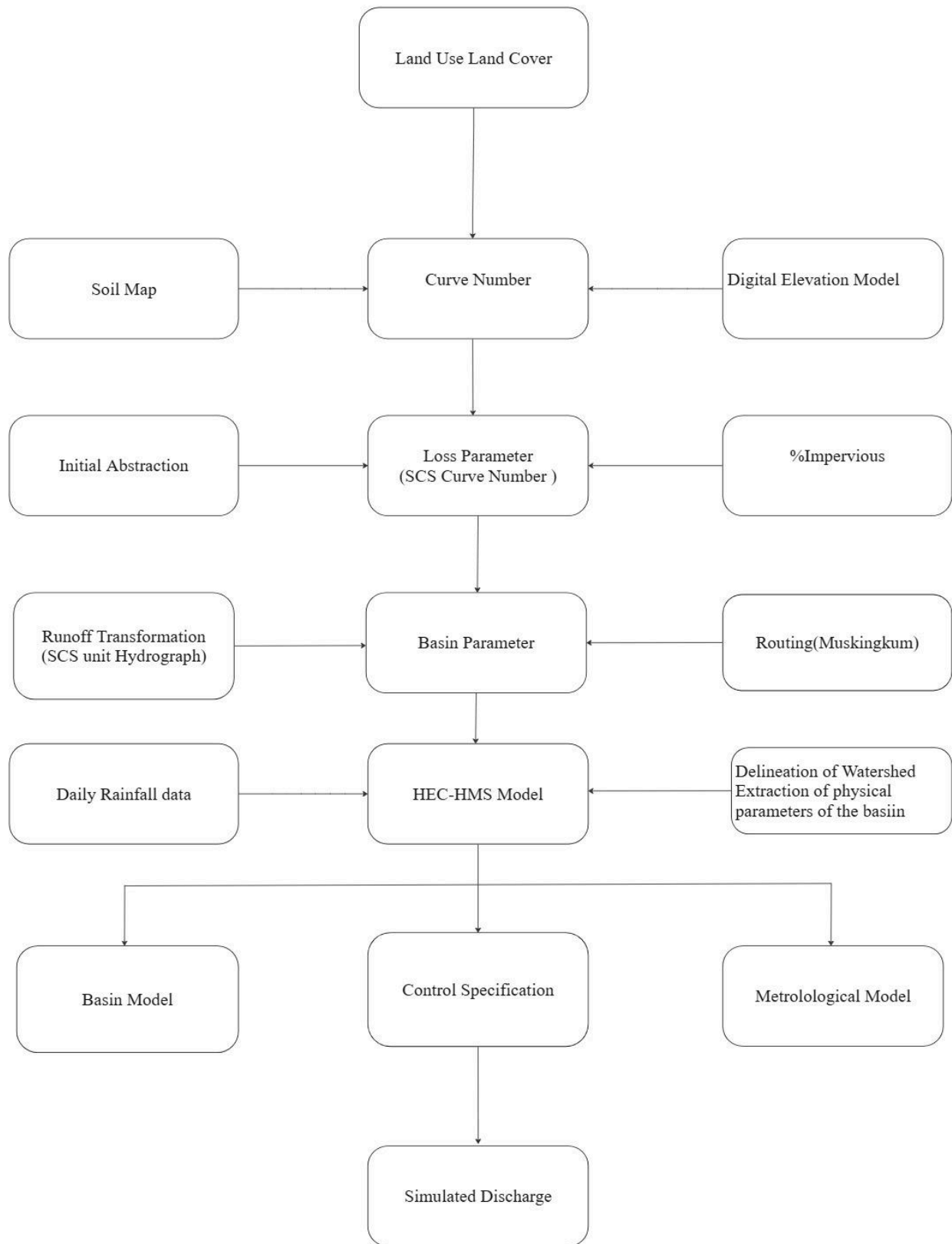


Figure 58: Flowchart for Watershed Modelling Using HEC-HMS

In Kottayam municipality, clay loam and sandy clay soils are classified under Hydrological Group C, which signifies moderate infiltration and high runoff potential. This classification indicates that these soil types tend to have relatively low infiltration rates and are more likely to contribute to surface runoff during heavy rainfall events. As a result, areas with clay loam and sandy clay soils are more susceptible to flooding, as the reduced capacity for water absorption can lead to increased runoff and potential accumulation of water, exacerbating flood risks. The SCS Curve Number method was employed to determine the curve number, using land use/land cover data, antecedent moisture content, and soil information. The Soil Conservation Service (SCS) Curve Number method was used for initial loss estimation, and the SCS unit hydrograph was used for runoff transformation to estimate excess precipitation by deducting total losses from total precipitation. The Muskingum method was adopted for routing. Watershed delineation identified five sub-basins.

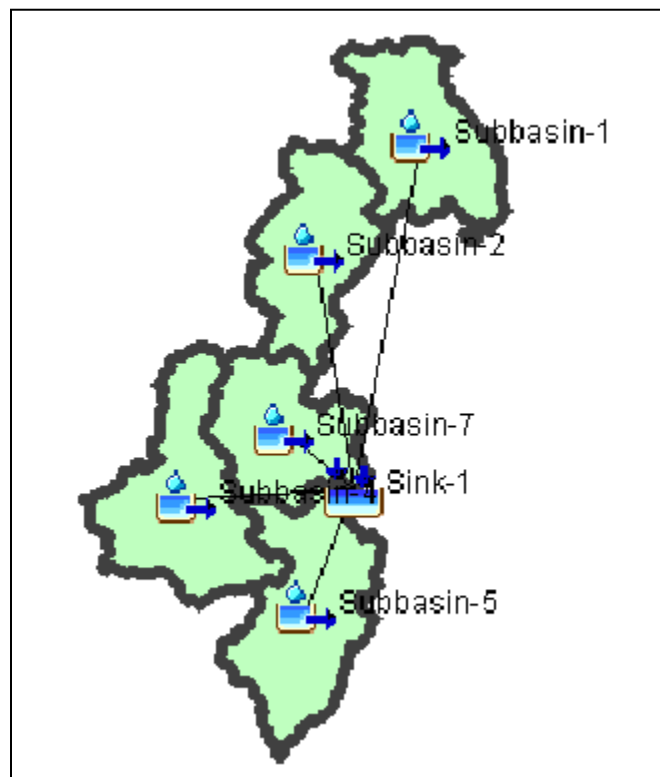


Figure 59: Watershed Map

Lag time, which is the interval between peak rainfall and peak runoff, was calculated for each sub-basin in relation to the time of concentration. A meteorological model was then created,

$$T_c = \frac{l^{0.8}(s+1)^{0.7}}{1140y^{0.5}}$$

specifying a time series of rainfall at a gauge and associating this gauge with each individual sub-basin.

$$\text{Lag Time} = 0.6T_c$$

Where, T_c = Time of Concentration

S = Maximum Potential Retention(in)

Y = Average Watershed Land Slope(%)

Table 5: Lag Time Calculation

Subbasin	Curve Number	Slope y	S	L (ft)	y(%)	Tc	Lag Time(min)
Subbasin-1	92.7148	0.06263	0.78576	10391.3	6.263	0.85964	30.946902
Subbasin-2	93.1605	0.07869	0.73416	12643.5	7.869	0.879	31.64417
Subbasin-4	91.4573	0.03822	0.93407	14719.9	3.822	1.53746	55.3486
Subbasin-5	89.7498	0.0648	1.14208	16528.6	6.48	1.39149	50.09377
Subbasin-7	93.1731	0.06912	0.73271	15771.8	6.912	1.11868	40.27265

Daily rainfall data from the Indian Meteorological Department (IMD) was added to the respective sub-basins, covering the period from August 3, 2018, to August 23, 2018.¹⁴

5.2 Result

The rainfall runoff analysis for Kottayam municipality, conducted using HEC-HMS from 1 August to 23 August 2018, provided critical insights into the flood event during this period. The computed results indicated a peak discharge of 23.5 cubic meters per second (m³/s), which occurred on 18th August 2018. This peak discharge marks the highest flow rate experienced,

¹⁴ Indian Meteorological Department (IMD). (2023). Weather and climate information.

signifying a moment of intense water flow and potential flooding. Additionally, the total runoff volume recorded was 513.83 million cubic meters (mm). The substantial volume of runoff, combined with the high peak discharge, highlights the severity of the flood event, as the municipality's drainage systems were overwhelmed by the excessive water flow. These findings underscore the need for effective flood management strategies to mitigate the impact of such extreme hydrological events in the future, ensuring better preparedness and resilience against potential flooding.

Table 6: Global Summary Result

Hydrologic Element	Drainage Area (KM2)	Peak Discharge (M3/S)	Time of Peak	Volume (MM)
Subbasin-5	5.1406	5.4	18Aug2018, 00:00	507.87
Reach-1	5.1406	5.5	18Aug2018, 00:00	507.77
Subbasin-4	5.0654	5.4	18Aug2018, 00:00	512.67
Subbasin-1	4.2777	4.5	18Aug2018, 00:00	516.15
Subbasin-2	3.9910	4.2	18Aug2018, 00:00	517.37
Subbasin-7	3.6433	3.9	18Aug2018, 00:00	517.40
Sink-1	22.1180	23.5	18Aug2018, 00:00	513.83

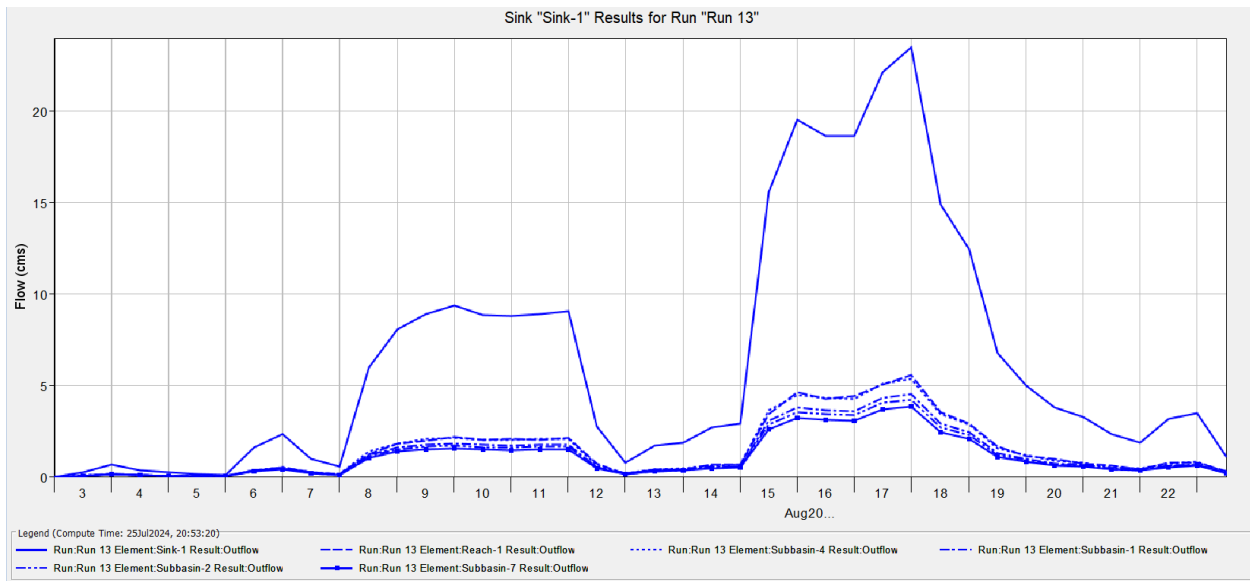


Figure 60: Global Summary Result From HECHMS

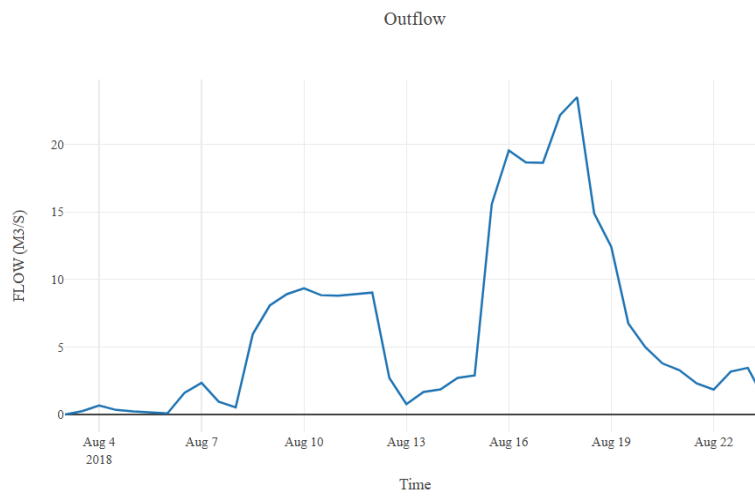


Figure 61 :Graph shows outflow for sink 1

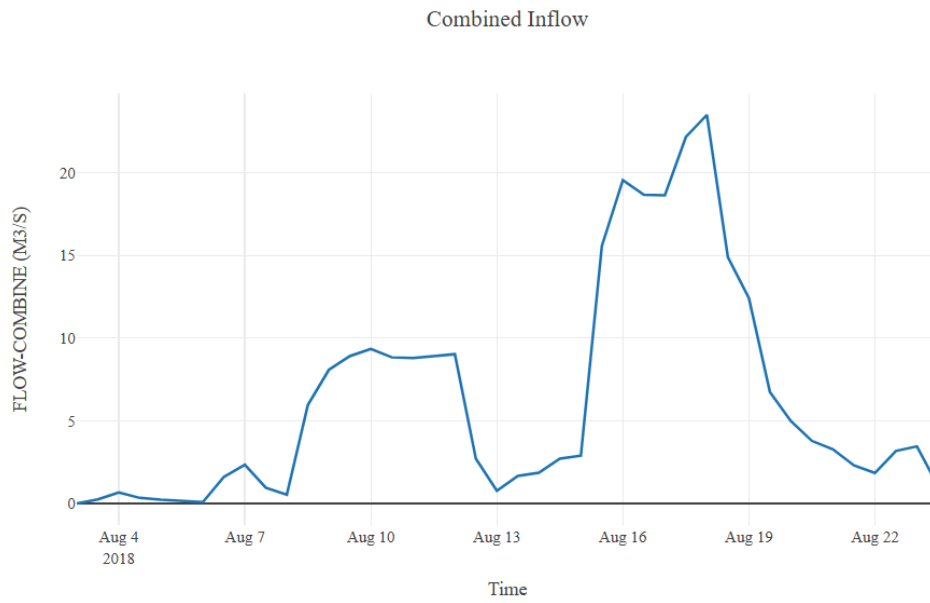


Figure 62: Graph shows Combined inflow of Sink 1

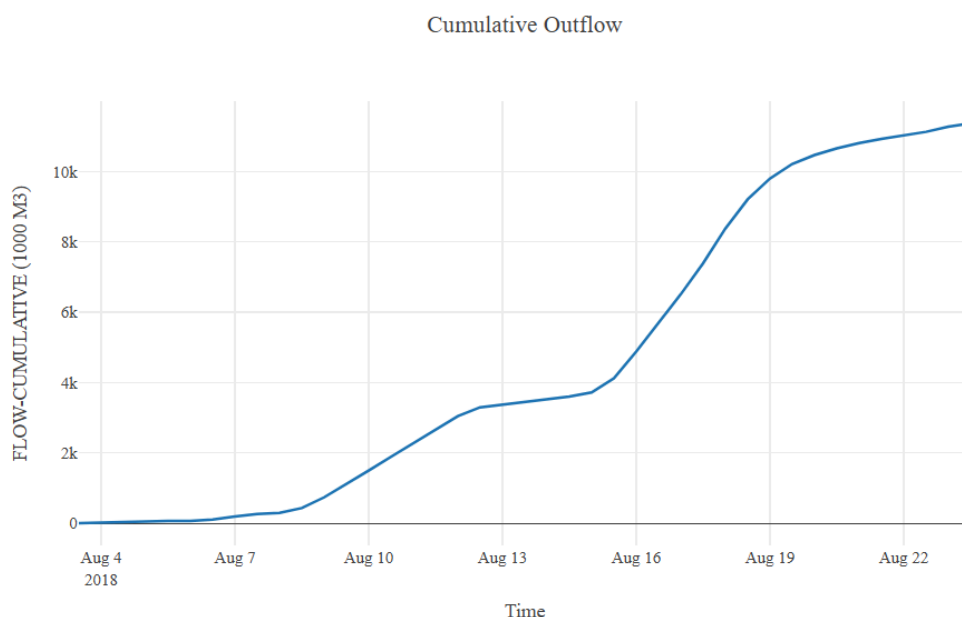


Figure 63 :Graph shows Cumulative Outflow of Sink 1

The rainfall-runoff modeling conducted for Kottayam Municipality provides a comprehensive understanding of the hydrological dynamics during extreme rainfall events. By using HEC-HMS software, critical data such as daily rainfall, land use/land cover maps, digital elevation models, and soil information were integrated to simulate the transformation of rainfall into runoff. This allowed for the detailed modeling of watershed behavior, considering factors such as soil permeability, surface runoff potential, and the basin's drainage characteristics. A notable aspect of the study was the calculation of lag time, which revealed the time delay between peak rainfall and peak runoff for each sub-basin. This parameter is essential for assessing the timing of flood risks and provides valuable input for future flood forecasting.

The results obtained from the study, particularly from the period of August 1 to August 23, 2018, illustrate the severe flood risks faced by the municipality. The model calculated a peak discharge of 23.5 cubic meters per second (m^3/s) on August 18, 2018, highlighting a moment of extreme water flow and the potential for significant flooding. This value represents the highest flow rate encountered during the event, underscoring the severity of the rainfall-induced flood. The total runoff volume during this period was calculated to be 513.83 million cubic meters. This large volume of runoff, in conjunction with the high peak discharge, reflects an

overwhelming flood event, suggesting that the drainage systems within the municipality were insufficient to handle the excessive flow of water. The findings also reinforce the vulnerability of areas with clay loam and sandy clay soils. These soil types, classified under Hydrological Group C, exhibit moderate infiltration rates and high runoff potential, making them particularly prone to flooding during heavy rainfall. The reduced capacity of these soils to absorb water exacerbates the situation, leading to higher surface runoff and prolonged flooding. This insight is crucial for targeted flood risk management, especially in regions with such soil characteristics.

Additionally, the study's use of the Muskingum routing method to simulate the movement of runoff through the watershed proved effective in understanding how water flows through the area, providing a more accurate prediction of discharge at the basin outlets. The integration of the SCS Curve Number method for initial loss estimation and runoff transformation also contributed to a more refined and reliable model. This comprehensive approach, combining multiple hydrological models and accurate input data, offers a detailed simulation of watershed behavior and runoff characteristics during extreme rainfall events. Overall, the study underscores the urgent need for improved flood management strategies to mitigate the impact of future extreme hydrological events. The results highlight the importance of understanding local hydrological conditions, such as soil types, land use patterns, and watershed delineation, in developing effective flood prevention and mitigation measures. The data provided by this modeling study is essential for guiding future infrastructure improvements, better flood forecasting, and resilience planning in Kottayam Municipality.

Chapter 6: Problem Framework

Several factors have been identified as primary contributors to the flooding issues in Kottayam Municipality. These factors are interrelated and compound the challenges posed by flood management, particularly in the face of increasing urbanization, environmental degradation, and climate change. The issues identified, along with their technical implications, are as follows:

6.1 Unplanned Construction:

Rapid and unregulated construction in flood-prone areas has significantly reduced the natural floodplain, impairing the landscape's ability to accommodate and mitigate floodwaters. Encroachments into buffer zones along water bodies, such as riverbanks and floodplains, diminish the volume of water that can be naturally absorbed and stored. These constructions obstruct natural drainage channels, increase runoff, and inhibit water percolation into the ground. Alterations to hydrological flow paths due to such encroachments exacerbate surface runoff and impede efficient water conveyance, thereby intensifying the risk of localized flooding, especially during peak rainfall events. Over time, the expansion of built-up areas has further increased runoff, and encroachments on rivers and streams have amplified these effects. Studies have demonstrated the adverse effects of urbanization on flood risk, with research from the U.S. Geological Survey (2003) showing how urban development accelerates runoff to streams by removing vegetation, grading soil, and constructing drainage networks, ultimately increasing flood risks. In a similar vein, a study published in *Water Resources Management* (2016) discusses how urbanization disrupts natural drainage patterns, leading to increased surface runoff and a higher likelihood of flooding. Additionally, research published in *Sustainability* (2020) emphasizes that land use changes, such as urban development, directly affect hydrological characteristics, such as runoff, further exacerbating urban flooding. This body of research highlights the critical need for land management strategies that consider the impact of construction and encroachment on flood risks.

6.2 Unplanned Deepening Leading to Pooling Effect:

The accumulation of fine sediments (silt) and organic sludge in Kottayam's canals has significantly reduced their water-holding capacity. These materials, originating from agricultural runoff, vegetation, and organic decay, settle at the canal bottoms, leading to shallower waterways. Historically, local communities engaged in sediment extraction from rivers, which was then sold. However, the introduction of legal measures, such as the Kerala Protection of River Banks and Regulation of Removal of Sand Act, 2001, established a framework for sustainable sand mining, introducing local committees to oversee and manage extraction activities. Further restrictions followed in 2013 when a ban was imposed on sand mining in the Muvattupuzha River due to concerns over excessive and unregulated extraction. In 2016, the Kerala government implemented a statewide ban on riverbed sand mining, citing the depletion of sand deposits and associated environmental impacts.

While these legal measures were crucial in protecting river ecosystems, they also restricted the traditional practice of silt extraction by local communities. As a result, sediment accumulation in canals and rivers has increased, leading to reduced water-holding capacity and exacerbating flooding and waterlogging issues. Additionally, regular desiltation efforts face significant delays due to issues related to fund allocation and interdepartmental coordination. Desiltation projects by the irrigation department are typically executed on a first-come, first-served basis, leading to inefficiencies in addressing silt accumulation.

Further compounding the issue, unregulated and haphazard deepening of canals, rivers, and water bodies has led to the formation of depressions or low-lying areas where water accumulates and stagnates, causing a pooling effect. This phenomenon is exacerbated when runoff volume exceeds the designed capacity of these water bodies. Inadequate hydrological modeling during deepening activities often leads to discrepancies between the intended flood storage capacity and actual conditions, restricting effective water discharge. The pooling effect results in prolonged inundation, impeding the natural drainage process and increasing the vulnerability of surrounding areas to sustained flooding, particularly in urbanized zones with limited permeability.

6.3 Untimely Interventions:

The effectiveness of flood management measures is critically dependent on timely and systematic interventions, such as the maintenance of drainage systems, reinforcement of riverbanks, and floodplain management. However, in Kottayam Municipality, these interventions are often delayed or not aligned with the flood risk cycle. Insufficient foresight in implementing pre-monsoon measures, such as desilting of drainage systems and river channels, weakens the flood resilience of the region. The lack of proactive measures also results in poorly maintained flood barriers and levees, reducing their ability to withstand extreme hydrological events. Delays in these interventions significantly increase flood risk during peak rainfall periods. This is consistent with findings from various studies on flood risk management, which highlight the critical role of timely interventions in reducing flood damage (Racker et al., 2020; Kumar and Sreedharan, 2019).

Research also shows that ineffective flood management interventions lead to increased vulnerability, particularly when drainage systems and river channels are not maintained adequately. Studies indicate that a delay in desilting activities exacerbates flooding, especially when areas are already vulnerable due to increased surface runoff caused by land use changes (Patel, 2021). The importance of proactive measures, such as reinforcing flood barriers before the onset of heavy rainfall, has been emphasized in numerous case studies on flood-prone regions (Sharma et al., 2022).

6.4 Lack of Proper Drainage/Culverts:

The absence of an integrated and well-maintained stormwater drainage system is a key contributor to urban flooding in Kottayam. The drainage infrastructure, particularly in high-density areas, is insufficient to manage the increased runoff due to urbanization. Additionally, poorly designed or blocked culverts restrict the flow of stormwater, causing water to accumulate in urban areas. Inadequate sizing of culverts, as well as the absence of suitable stormwater management solutions like retention basins, further exacerbates localized flooding. The lack of effective drainage leads to the rapid build-up of surface water, particularly in areas

with impermeable surfaces such as asphalt roads and concrete structures, which contribute to flash floods and waterlogging.

6.5 Culverts Replaced with Pipes:

The replacement of traditional culverts with pipes of smaller diameters has created hydraulic bottlenecks in the stormwater drainage system. Culverts, designed to convey large volumes of water, are often replaced with undersized pipes that cannot handle high-flow conditions, especially during intense rainfall events. This reduction in conveyance capacity increases the risk of overtopping and localized flooding. Furthermore, inadequate hydraulic analysis and failure to account for extreme stormwater events during design contribute to these inefficiencies. The inability of these pipes to cope with the stormwater runoff results in water backflow, causing prolonged inundation in downstream areas.

6.6 Encroachment of Riverbanks/Flood Plains:

The encroachment of riverbanks and flood plains undermines the natural flood attenuation capacity of these areas. Riverbanks serve as natural buffers during high-flow conditions, and flood plains act as storage zones, absorbing excess water during floods. However, the encroachment of these areas through construction and land reclamation reduces the floodplain's capacity to accommodate water. Additionally, these alterations disrupt the natural flow of rivers, increasing the velocity and volume of floodwaters, which can lead to higher flood depths and more extensive floodplain inundation. Encroachment also compromises the structural integrity of riverbanks and increases the likelihood of riverbank failures during extreme flood events.

6.7 Encroachment and Conversion of Streams into Roads:

The conversion of natural streams and waterways into roads and built-up infrastructure has obstructed the natural hydrological flow. Streams, which originally provided essential pathways for stormwater conveyance, have been replaced with impermeable surfaces, which increase surface runoff and decrease the capacity for water infiltration. The alteration of these watercourses leads to the disruption of the natural drainage system, causing water to back up and

flood adjacent areas. Moreover, the conversion of streams into roads often leads to inadequate culverts or underpasses, further obstructing the flow of water and exacerbating flooding risks in urbanized areas.

6.8 Weakened Bunds:

Bunds, or embankments, are crucial infrastructure for controlling water levels and preventing flooding, particularly along rivers and lakes. In Kottayam, the integrity of these bunds has been compromised due to neglect, insufficient maintenance, and encroachment. Weakened bunds are vulnerable to breaches, particularly during high-flow conditions or storm events. The inability of bunds to withstand pressure from rising water levels increases the risk of flooding in adjacent areas. Additionally, improper design and the failure to account for future changes in hydrological conditions further compromise the ability of bunds to perform their protective role during extreme flood events.

6.9 Construction in Low-Lying Terrain:

The construction of buildings and infrastructure in low-lying, flood-prone areas exacerbates the impact of flooding. Low-lying terrain has a natural predisposition to accumulate water due to reduced elevation and slower drainage. When such areas are developed without adequate flood mitigation measures, they exacerbate the hydrological imbalance by reducing available floodplain and obstructing natural drainage pathways. These developments contribute to higher runoff and impede water infiltration, leading to more frequent and severe flooding in areas where water flow is already restricted due to topography.

6.10 Non-utilization of Rivers for Transportation:

The underutilization of river systems for transportation has resulted in poor management and maintenance of these waterways. Rivers, which can serve as natural conduits for floodwater conveyance, have been obstructed or altered due to sedimentation, infrastructure development, and neglect. As a result, these rivers are no longer capable of accommodating excess stormwater during high-flow conditions, leading to localized flooding. Furthermore, river management

practices, including dredging and desilting, are often inadequate, further reducing the capacity of these rivers to mitigate flood risks.

6.11 Anomalies in Weather – Increased Rainfall Intensity:

The region has witnessed a marked shift in rainfall patterns, with increasing intensity and frequency of heavy rainfall events. These anomalies in weather are largely attributed to climate change and have significant implications for flood management. The sudden and intense rainfall, often exceeding the design capacity of existing drainage systems, leads to flash floods and the overflow of water bodies. Additionally, the increased rainfall intensity results in higher peak runoff rates, which overwhelm stormwater infrastructure and increase the likelihood of widespread flooding. The failure to incorporate these changing rainfall patterns into flood risk models and infrastructure planning exacerbates the flooding risk and highlights the need for more adaptive flood management solutions.

Each of these factors requires a multidisciplinary, integrated approach to flood risk management that combines advanced hydrological modeling, urban planning, structural reinforcement, and climate resilience strategies. Addressing these issues will require coordinated efforts from municipal authorities, engineers, urban planners, and environmental experts to mitigate the adverse impacts of flooding and enhance the region's overall flood resilience.

Chapter 7: Challenges to Opportunities

Flooding in Kottayam Municipality is a complex and persistent problem that affects the urban environment, agriculture, and the well-being of its residents. Despite the municipality's ongoing efforts to manage water flow, several challenges continue to hinder effective flood mitigation. From the lack of appropriate machinery for desilting narrow water bodies to issues of inter-departmental coordination, these problems demand innovative, resource-efficient solutions. To address these challenges, a focused approach is necessary—one that encourages the development of new technologies, methodologies, and cooperative strategies. Below are the key challenges that must be addressed to improve flood management in Kottayam Municipality:

7.1. Lack of Suitable Machinery for Desilting Small Water Bodies

Small canals and water bodies, which are typically around 1 meter wide, play a crucial role in the municipal drainage system, particularly in preventing waterlogging and flooding. However, existing machinery, such as large desilting machines and mechanical dredgers, is unsuitable for narrow water bodies. These machines are designed for larger channels and are inefficient and impractical for small canals.

Problem Details:

- **Size Mismatch:** The current machinery cannot effectively navigate small canals due to their size, leading to inefficiency in desilting and cleaning these critical watercourses. Small-scale desilting tools that can fit into these narrow spaces are either non-existent or not readily available. The one meter wide smaller canals are inaccessible for the currently available machinery
- **Limitations for Workers:** Workers are unable to carry out tasks in small water bodies due to the unhygienic, dangerous, and resource-intensive nature of the work. The difficult and hazardous conditions in small canals make it challenging for them to participate effectively.
- **Accumulation of Sediment:** The inability to effectively desilt these small canals leads to the accumulation of sediment, debris, and aquatic vegetation such as algae and water hyacinth, which obstruct water flow and exacerbate flooding during heavy rains. The

accumulation of these organic materials also contributes to the deterioration of water quality, making it a health concern.

- **Impact on Flooding:** Blockages in small canals reduce the efficiency of the entire drainage system, contributing to widespread waterlogging in low-lying areas and further increasing the frequency and severity of flooding events. These blocked water bodies not only affect floodwaters during rainy seasons but also prevent the natural recharge of groundwater, affecting water availability in dry periods.

This highlights the pressing need for an innovation challenge focused on designing compact, mobile desilting machinery that can be deployed in narrow channels, ensuring regular maintenance and minimizing flooding risks in urban and rural areas.

7.2. Collaborative Flood Mapping and Technology Integration

Mapping flood-prone areas and assessing on-field conditions are crucial for effective flood risk management. However, the current data collection process is time-consuming and resource-intensive, requiring significant human and technical resources. Traditional manual approaches limit the speed and scope of flood assessments.

Problem Overview:

- **KSDMA Data:** While the flood-prone area data provided by KSDMA is valuable, it may not capture all on-the-ground issues observed during field assessments.
- **Manual Data Collection:** Field teams currently visit flood-prone areas in person to conduct surveys, which is labor-intensive and can delay flood mitigation planning and response.
- **Data Quality Variability:** The quality of manually collected data can fluctuate due to various factors such as weather conditions, accessibility, and personnel expertise. Important details like hidden blockages or minor embankment breaches may be missed, affecting data reliability.

- **Impact on Flood Mitigation:** Inconsistent and inefficient flood mapping can delay the identification of critical flood hotspots, potentially exacerbating damage to infrastructure, agriculture, and livelihoods.

Incorporating students into flood mapping efforts offers a scalable, community-driven solution to address these challenges. We have already utilized this approach for flood mapping in a few wards with the help of our interns who happens to be post graduate students in various related fields, and the results have been promising, demonstrating improved accuracy and efficiency in data collection. Through a structured approach, students contribute to data collection and analysis using modern tools such as GIS, mobile applications etc. This engagement not only enhances flood risk assessment but also builds the capacity of students by providing hands-on experience with technology and disaster management, creating a future workforce capable of tackling flood resilience challenges. With proper training, students can efficiently cover larger areas, improving the speed and precision of data collection. Additionally, their involvement fosters local awareness and engagement, as they work directly with community members during mapping activities.

To further enhance flood risk management, integrating innovation challenges into this process can drive technological advancements and practical solutions. These challenges can bring together students, professionals, and tech enthusiasts to explore and develop cutting-edge approaches such as automated mapping solutions that combine remote sensing, drone-based assessments, and GIS tools for faster, more precise mapping. They could also lead to the development of real-time monitoring systems using mobile or IoT-based technologies for continuous data collection and sharing. Furthermore, innovation challenges can support the creation of analytical tools that provide advanced analysis and visualization of flood data, aiding in informed decision-making.

By combining on-ground student involvement with innovation-driven problem-solving, this approach promotes more efficient and reliable flood data collection while empowering communities and fostering long-term flood resilience.

7.3. Fostering Collaborative Ownership in Flood Management

Flood management is a multifaceted issue that requires coordination between several departments and agencies. However, there is often a lack of collaboration between entities such as the **Minor Irrigation Department**, **Major Irrigation Department**, **Municipal Corporation**, and **Urban Planning Authorities**. This results in fragmented flood mitigation efforts and missed opportunities for synergy.

Problem Details:

- **Siloed Departments:** Each department has its own mandates, and often there is little communication or alignment between them regarding flood mitigation strategies. For example, while the irrigation departments may focus on water flow and canal management, urban planning departments are concerned with land use and drainage systems, leading to inconsistent strategies. This lack of coordination creates inefficiencies and redundancy in addressing flood-related issues.
- **Lack of Integrated Solutions:** Flood control measures like drainage systems, water retention structures, and embankments are often planned in isolation, without considering their combined impact on the municipality's overall flood risk. This leads to the implementation of isolated projects that do not address the broader flood management needs of the city.
- **Impact on Flood Mitigation:** The absence of an integrated approach to flood management means that flood mitigation measures are often piecemeal and reactive, rather than proactive and comprehensive. This results in missed opportunities for sustainable, long-term solutions. Furthermore, the fragmented approach leads to delays in response during critical flood events, as agencies struggle to coordinate efforts.

To bridge this gap, there is a pressing need to establish a collaborative platform that brings together all relevant departments, fostering continuous dialogue, joint decision-making, and

shared accountability. This platform would not be limited to a digital tool but would function as an institutional mechanism—through regular interdepartmental meetings, shared action plans, and cross-sectoral task forces—to ensure a more coordinated and proactive approach to flood management. By enabling structured communication, aligning strategies, and pooling resources, this initiative can drive comprehensive, long-term flood mitigation efforts while improving response efficiency during critical flood events.

7.4. Presence of Pipes instead of Culverts in Smaller Streams

In many areas of Kottayam, pipes have been used instead of traditional culverts where roads cross small streams. While pipes are a cost-effective and quicker solution in the short term, they significantly reduce water flow capacity, contributing to issues like flooding and waterlogging, especially during heavy rainfall.

The primary reason for not replacing these pipes with culverts is cost concerns. Installing culverts involves higher upfront investment due to more expensive materials, labor, and planning. Municipalities, working with limited budgets, often prioritize quicker, less expensive fixes like pipes, despite their long-term inefficiencies. Furthermore, installing culverts is more complex and time-consuming, particularly in urban areas with established road networks and land use constraints.

Another issue is the lack of awareness regarding the long-term consequences of relying on pipes. While they are cheaper and quicker to install, pipes often fail to handle peak stormwater flow, especially during monsoon rains. Over time, this leads to increased flooding, damage to infrastructure, and higher long-term costs due to the cumulative effects of inadequate drainage.

To address these issues, a solution-focused approach, could be used to explore cost-effective alternatives to pipes. These could include modular culverts or self-cleaning drainage systems that balance affordability with long-term effectiveness for proper flood management.

Problem Details:

- **Hurdles of replacing existing pipes with culvert:**

Culverts require higher initial costs for materials, labor, and planning, which makes them

less attractive to municipalities with limited budgets. In contrast, pipes are a more immediate, budget-friendly solution despite their long-term inefficiencies.

- **Restricted Water Flow:**

Small-diameter pipes significantly reduce the capacity of watercourses to handle stormwater, especially during heavy rainfall. These pipes can also become clogged with debris, further obstructing water flow and increasing the risk of flooding.

- **Insufficient Drainage Capacity:**

Pipes, often placed under roads, cannot accommodate peak water flow rates, leading to localized flooding. This design flaw becomes more problematic during high rainfall events, especially in the monsoon season.

- **Impact on Flooding:**

The inadequate drainage caused by pipes exacerbates flooding and waterlogging, particularly during the monsoon season. This results in damage to infrastructure, agricultural land, and residential areas, leading to economic losses and increased strain on municipal resources.

Addressing these challenges requires innovative solutions that strike a balance between affordability, efficiency, and ease of implementation. Exploring alternatives such as modular culverts, prefabricated drainage units, or adaptive water flow management systems could provide cost-effective and scalable options. Research and development efforts should focus on designing solutions that municipalities can feasibly adopt within budgetary constraints while ensuring improved drainage performance. Encouraging interdisciplinary collaboration among engineers, planners, and policymakers will be key to driving innovation in urban flood management.

Conclusion

The challenges outlined in this report—lack of suitable machinery for desilting, time and resource-intensive mapping, poor coordination between departments, and inefficient drainage solutions using pipes instead of culverts—are major obstacles to effective flood management in Kottayam Municipality. These issues stem from infrastructural limitations, financial constraints, and fragmented planning approaches, necessitating strategic interventions that are both practical and scalable. Without addressing these gaps, the municipality will continue to struggle with recurring flood events, leading to damage to infrastructure, economic losses, and disruptions to daily life.

A key step toward overcoming these challenges is fostering innovation and collaboration. Engaging students in mapping efforts has already proven effective in selected wards, demonstrating how community-driven data collection can enhance flood risk management. Expanding such initiatives will not only accelerate data collection but also build a culture of local participation and awareness. Similarly, improved coordination among municipal departments, including the irrigation, urban planning, and disaster management authorities, is essential to ensure that flood mitigation strategies are implemented in an integrated and systematic manner.

To further drive progress, there is a pressing need for a structured platform that brings together experts, government departments, and innovators to develop practical solutions. One way to achieve this is through a hackathon—an event that can serve as a catalyst for designing compact desilting machinery suitable for narrow canals, refining GIS-based flood mapping tools, improving mechanisms for interdepartmental coordination, and exploring cost-effective alternatives to inefficient drainage solutions. Such a platform would not only generate innovative technical solutions but also encourage interdisciplinary collaboration, ensuring that ideas are both practical and implementable within the municipality’s resource constraints.

By integrating these efforts, Kottayam Municipality can move beyond reactive flood management toward a proactive, data-driven, and collaborative approach. This shift will enable the municipality to implement more efficient, cost-effective, and long-term flood mitigation

measures. More importantly, it will create a foundation for sustained resilience, ensuring that Kottayam is better equipped to handle future climate uncertainties and extreme weather events. A well-structured approach, combining community participation, technological innovation, and institutional coordination, will lead to a safer and more adaptable urban environment for its residents.

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