MITIGATION PLAN FOR FLUVIAL FLOOD MANAGEMENT IN PARAVUR TALUK

THESIS REPORT

Submitted by

Sreejith T D (TKM20MUP016)

MUP (2020 - 2022) BATCH

To

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Post Graduate Degree of M. Planning in

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DEPARTMENT OF ARCHITECTURE

THANGAL KUNJU MUSALIAR COLLEGE OF ENGINEERING

CERTIFICATE

Certified that the Project entitled **"Mitigation plan for Fluvial flood management in Paravur taluk"** submitted by **Sreejith. T. D. (TKM20MUP016)** of MUP (2020-22) BATCH, in partial fulfillment of the requirements for the award of Post-Graduate Degree in Urban Planning, under the APJ Abdul Kalam Technological University is a Bonafide work carried out by them under our guidance and supervision.

THESIS GUIDE	HEAD OF THE DEPARTMENT
Ar. Rahna Abubaker	**Dr. Annie John**
Assistant Professor	Department of Architecture
Department of Architecture	TKMCE
TKMCE	

INTERNAL EXAMINER **EXTERNAL EXAMINER**

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Sreejith T D

(TKM20MUP016)

MUP (2020 - 2022) Batch

ABSTRACT

Flooding is considered one of the most disastrous global hazards which has been occurring more frequently in recent times. Inundation causes damage to the Environment, Infrastructure, social wellbeing, economic stability, disordered transport and communication facilities, as well as loss of life. Kerala is considerably less prone to Flooding when compared to the other Indian states. The recent flood of 2018 was such a devastating one which resembles the great floods in history dated almost a century back.

The flood events showcased the severity and effects on the socio-economic aspects, psychological aspects, infrastructural aspects, etc. of the region. The change in climatic conditions and Global warming cause the uprise in temperature resulting in a varying climatic shift in precipitation and wind turning the monsoon rainfall into cloudburst events. Flood management is to be considered futuristically, in which river floods are most vicious and are to be appropriately managed. This Thesis is about making a model Mitigation plan for Fluvial flood management in Paravur taluk to focus on and optimize the need to control and adapt the inundations from a regional perspective. The study discusses the way to approach the scenario futuristically for fluvial flood management considering community about controlling the vulnerable changes in the climatic conditions as referred to in IPCC reports.

Keywords: Flash flooding, Inundation, Fluvial flooding, Inter Governmental Panel for Climate Change

DECLARATION

I hereby declare that the project entitled **"Mitigation plan for Fluvial flood management in Paravur taluk"** is a Bonafide record of the study done as part of thesis work of under the supervision of Ar. Rahna Abubaker during the **Fourth Semester M. Plan (2022)** Post Graduate Degree Course in the Department of Architecture, Thangal Kunju Musaliar College Of Engineering, Kollam. I declare that, to the best of my knowledge, the work reported herein does not form part of any other project report or dissertation on the basis of which a degree or award was conferred on an earlier occasion to any other candidate.

Place: Kollam
Date: 07/09/2022

Sreejith T D
(TKM20MUP016)
MUP (2020 - 2022) Batch

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CHAPTER 1 **INTRODUCTION**

1.1 BACKGROUND STUDY

Global climate change has affected rapid global, regional and local environmental changes, resulting in immediate impacts through Natural disasters such as floods, etc.

Flooding, considered one of the most disastrous global hazards, has recently occurred more frequently. Inundation causes damage to the Environment, Infrastructure, social wellbeing, economic stability, disordered transport and communication facilities, and Loss of life.

The state of Kerala is susceptible to several natural and manufactured calamities to varying degrees. The state's catastrophe risk is exacerbated by increased vulnerabilities brought on by several variables, including rapid urbanization, environmental degradation, population growth, and climate change. These flash flood episodes have been linked to increased probability in Kerala due to rapid growth and deforestation. Kuttanadu region, Kole lands of Thrissur district, coastal tracts of Ernakulam and Malappuram districts, and western Kottayam district abutting Vembanad lake are additional significant regions prone to flooding. Alappuzha region is 50% flood-prone. "One-degree rise in temperature could trigger an increase in average rainfall events by 7%, Kerala is more urbanized than many cities in the country" - Ulka Khelkar (Director climate change, World Resource Institute, India)

The Kochi neighbourhood in Ernakulam, formerly referred to as the Queen of the Arabian Sea in Keralan history, is a fantastic illustration of growth and preservation. The heavily populated Ernakulam District symbolizes Kerala State's literacy, manufacturing, trade, and commerce accomplishments. Ernakulam epitomizes the highly modern phase of Kerala society due to its inclusive culture, comparatively high per capita income, and residents' unwavering enthusiasm for being informed about political, economic, social, and cultural events nationally and internationally. (ernakulam, 2022) . The projected sea-level rise for Kochi in 2030 is estimated to be around 0.11 metres. In 2050, it will be 0.23 metres. In 2060, it will be 0.30 metres. According to NASA's new visualization tool on future sea level rise in coastal cities, Kochi will have a sea level rise of 0.15 metres from the current 195-2014 baseline levels by 2040. By 2130, the tool predicts a 1 m increase.

1.2 NEED FOR STUDY

From 2018 onwards, Kerala is aware of the depth of disasters encountered in a century, developing worst scenarios highlighting the importance of disaster management for which flooding is a significant cause. On considering the Global Climate change, which will encounter the impact and need for focus studies on flood management in a futuristic perspective. The unpredictable surge in rainfall caused a varied pattern throughout the years from 2018 onwards, which shows how climate change can affect the spatial structure. Within the District, according to the Flood data from the Kerala state disaster management authority, in a taluk-wise comparison of Flood inundation shows up, Paravur Taluk was the most vulnerable and affected by the 2018 Flood events. Considering the situation, in a futuristic perspective, the events can be more devastating than that of the current situation, rises us the need for a mitigation plan for the area as a model to be adopted to sustain the deluge. Impeding the importance of considering such as a crucial factor while planning for the community's wellbeing.

1.3 RESEARCH QUESTION

- How can the Deluge impacts be minimalized?
- How effective is flood management? And What else can be considered for the betterment of the same?

1.4 AIM

"To Develop a model plan to Mitigate the Fluvial Flooding in Paravur Taluk. "

1.5 OBJECTIVE

- To understand Fluvial Flooding, Flood management, Mitigation plan etc., through literature review.
- To analyze and understand the study area, spatial structure and parameters over the Flood scenario.
- To understand about methods and implementation of Fluvial flood management through case studies and best practices.

- To study over the site and Case studies through overlay analysis to arrive at the findings and observations.
- To develop a model to adapt and mitigate Fluvial Flooding on Paravur Taluk.

1.6 METHODOLOGY

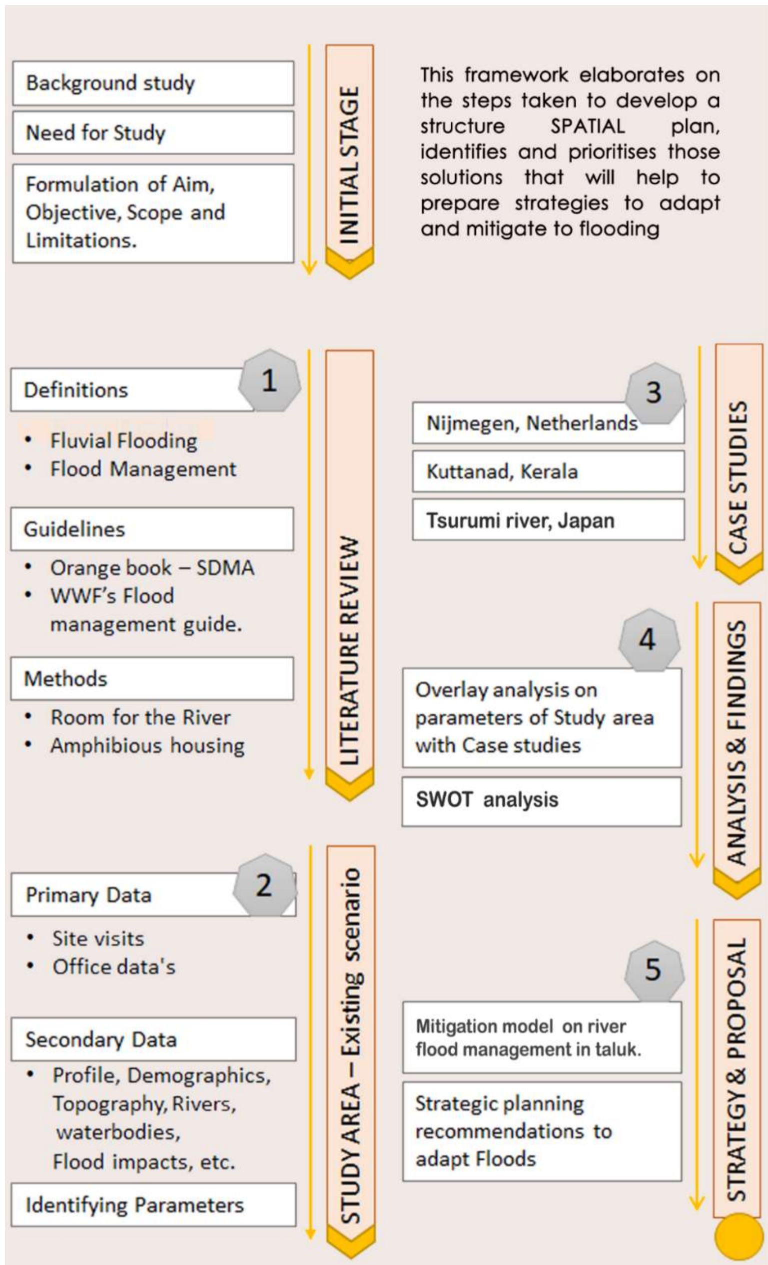


Figure 1 – Methodology

Source: Zurich.com

1.7 SCOPE

- According to the IPCC report, climate change and global warming urge cause a dramatic increase in the persisting climatic conditions resulting in an extreme monsoon period causing a plethora of Flood scenarios surges the necessity of flood management.
- Within the District, Paravur taluk is most prone to fluvial flooding, so studying and analysing various methods from literature helps in identifying the gaps and conflicts within the previous studies.
- The study focuses on the Flood mitigation approach at the taluk level to achieve a model plan to be adopted widely as a futuristic approach in Fluvial flood management.

1.8 LIMITATION

- The study concentrates on the Mitigation process rather than preparedness, recovery and rescue parts in Flood management.
- The study considers the 2018 flooding event as the max Inundation and criteria to be managed.

\

CHAPTER 2 **LITERATURE REVIEW**

2.1 **DEFINITIONS**

2.1.1 FLUVIAL FLOODING –

A fluvial, or river flood, occurs when the water level of a river, lake, or stream rises and overflows onto the surrounding banks, beaches, and adjacent land. A lot of rain or Snowmelt may have caused the water level to rise. A river overflow can result in smaller rivers flowing downstream, destroying dams and dikes and saturating neighboring communities, causing extensive damage. Models consider previous, anticipated, present river levels, soil and topography characteristics, and river flooding probabilities.

The length of time and amount of rain that falls in the river's catchment region affect how severe a flood will be. Other elements include the topography around the river system and soil water saturation brought on by earlier rainfall. Floodwater often rises more slowly and is shallower in flatter locations, where it frequently persists for days. In places with hills or mountains, floods can happen shortly after a downpour, drain exceptionally rapidly, and result in damage from debris flow. Models consider previous precipitation, predicted precipitation, current river levels, soil and topography factors, and more to evaluate the likelihood of river flooding.

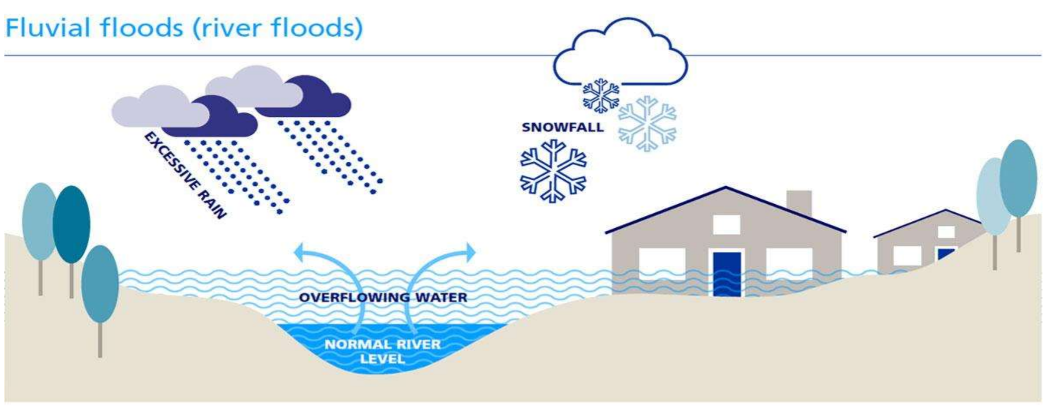


Figure 2 - Fluvial flood picturization

Source: Zurich.com

Types -

- Overbank Flooding - occurs when the water rises and overflows over the edges of a river or stream. This is the most common and can happen in any channel, from small streams to huge rivers.
- Flash flooding - A sudden, mighty torrent of water moving at a high rate of speed that happens in an established river channel. Flash floods are deadly and devastating, not just because of the intensity of the water but also because of the hurtling Debris that is frequently swept up in a rush.

2.1.2 FLOOD MANAGEMENT

FLOOD CONTROL refers to all methods used to reduce or prevent the damaging effects of flood waters. (encyclopedia, 2022).

FLOOD RELIEF methods are used to reduce the effects of flood waters (encyclopedia, 2022).

An emergency flood control strategy is divided into four phases, which are

Mitigation - that Activities designed to mitigate flooding risk are meant to cut it down or even entirely before it happens.

Preparedness – Preparedness activities are intended to achieve a sense of readiness for the flooding emergency.

Response – Providing urgent help, such as search and rescue and emergency relief, is part of the emergency flood management response phase. While the specifics of this phase depend on the nature of the community, the main objective is to provide for people's fundamental necessities up until recovery starts.

Recovery – Standard recovery procedures connect emergency and routine situations. Providing short-term shelter, reconstruction, counselling after an event, and education are a few examples of these efforts.

2.1.3 MITIGATION PLAN –

The mitigation plan defines the planning process for identifying and putting into action steps to reduce or eliminate losses, such as Loss of life, property, functionality, etc., due to any form of hazards. It is the activity to stop the risk from happening in the first place and the first line of defense for high exposure hazards. Additionally, it aids in lowering the likelihood that the detected risk would have an impact, and regardless of its presence or intensity, measures will be prepared for it in advance. (ramakrishnan, 2017)

2.2 GUIDELINES

2.2.1 STATE DISASTER MANAGEMENT

According to the Disaster Management Act of 2005, State Disaster Management Authority is a statutory organization (Central Act 53 of 2005). The Kerala State Disaster Management Authority was established in 2007 and its current membership was recruited in 2013. It is a statutory non-autonomous body that reports to the Chief Minister of Kerala.

Have State and District Emergency Operation Centers for the cumulative operation of actions during disastrous occasions.
Currently, the Central Water Commission does not provide flood forecasting services in the State (CWC). An alternative to flood forecasting is to use rainfall prediction as the trigger, with irrigation and KSEB closely monitoring river levels by hand and updating the District EOC on water levels at various sites.

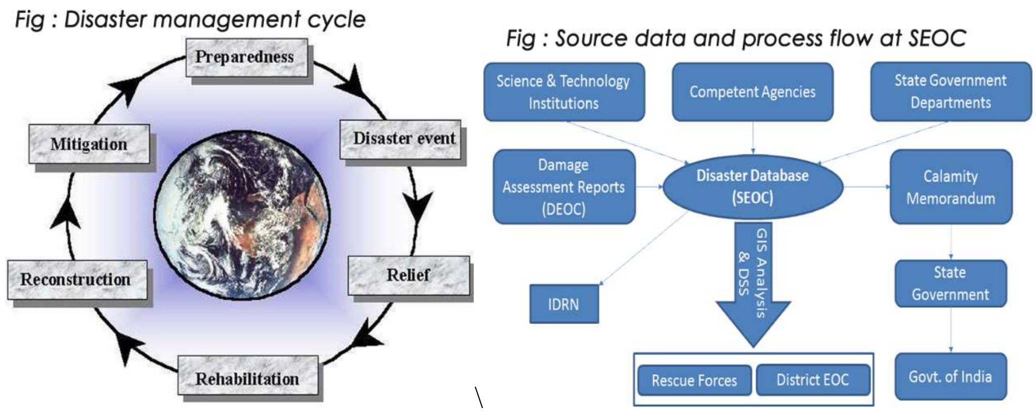


Figure 3- Disaster management cycle and process

Source: Orange book 2019

Average time Functions of SEOC & DOC -

- Mitigation and Preparedness Strategic and spatial planning.
- Create and deliver technical and scientific advisories to the government and KSDMA on topics pertaining to disaster management.
- Conduct and keep the hazard, vulnerability, and risk assessment up to date.
- Creating and maintaining the disaster database, conceptualizing, implementing, and maintaining hazard early warning systems,
- Conducting research on disaster risk reduction-related issues, and creating and maintaining the disaster database.

Warning Systems and Standard Operating Procedures -

Heavy rain (ERW) (more than 244.4 mm) In the places where it is anticipated that the rainfall would have an impact, the most vigilance is required.

Weighty rainfall (VRW) (124.5 to 244.4 mm) - Be prepared - Actions to be taken and sustained till a warning is withdrawn in the districts predicted to be affected by the rainfall Heavy rainfall (HRW) (64.4 to 124.4 mm) - Be updated - Actions to be taken and sustained till a warning is withdrawn in the districts predicted to be affected by the rainfall

2.2.2 NATURE BASED FLOOD MANAGEMENT

Floods occur in a watershed, a region with a range of geological, ecological, and social components that are all integrally linked. The compatibility of flood risk management approaches to the nature of the proposed interventions, the scope of the intervention, and where they are deployed in the watershed determines their success.

Based on the nature of actions, flood risk management objectives can be divided into three categories:

- Reduce, retain and detain flood flows
- Improve conveyance and enhance resistance to damage in waterways
- Adapt to floods

Flooding impacts national/regional, watershed, floodplain, community, and home levels. As a result, methods should be chosen depending on the individual needs at various scales.

STRUCTURAL METHOD

Civilizations have employed structural methods to manage flood danger for thousands of years. Certain portions of the Nile River have ancient flood barriers to roughly 1000 BCE.' To defend themselves from flooding, the early settlers in India's Indus and Ganges plains (2500 BCE) erected ring bunds, which are low walls built along the curves of hills. To manage structural flood risk, engineering interventions (complex engineering) like flood embankments and dams as well as ecological interventions (soft approaches) like soil conservation and wetland restoration were adopted (also known as natural and nature-based methods). Integrated flood management (IFM) takes into account both structural and non-structural techniques.

- Hard engineering methods - Dams and reservoirs, Diversions, Levees, Canal widening and deepening, Floodway's, Pumping, Revetments, and Multi-purpose infrastructure
- Soft methods - Restoring the upper watershed, restoring wetlands, restoring riparian vegetation, and removing barriers

Methods for reducing, retaining and detaining flood flows -

Reducing, storing (retaining), or delaying (delaying) the input (flood flow) of water is the first type of structural flood risk control solution. Traditionally, these approaches are built to handle a flood occurrence of a certain magnitude—typically referred to as a design flood—that is statistically calculated to occur once every x number of years, referred to as the return period.

Dams and reservoirs (complex method) -

A flood control reservoir is a commonly used flood risk management method for temporarily storing floodwater. For other uses, including irrigation or the production of hydroelectric power, water can be stored for a short time (a few days) or longer duration.

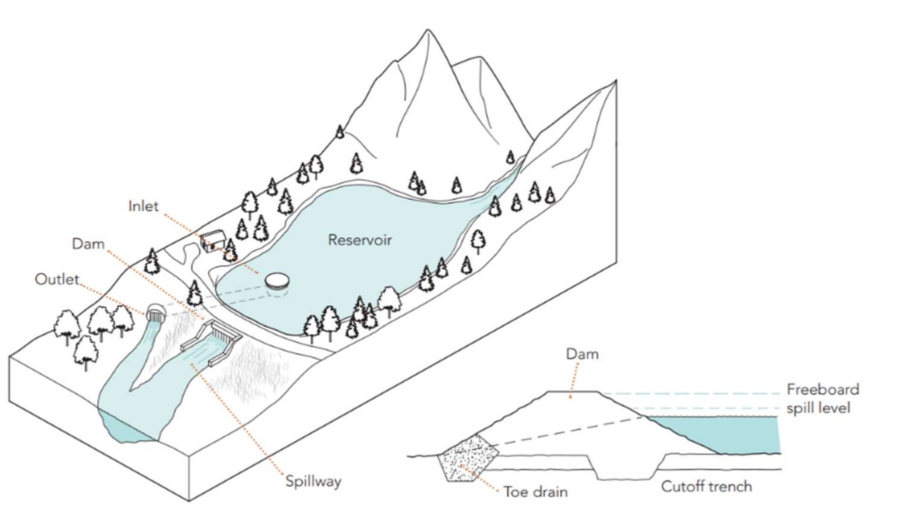


Figure 4 - Dam and reservoir representation

Source: WWF's Flood management guide, Chapter 5

The main objective is to store water. You can lower the flood peak and lengthen the lag period. Dam, inlet, sluice/outlet, spillway, and gates are the major parts (optional). A dam's (or a reservoir's) size is determined by the amount of water it can hold during a storm event (measured in cubic metres or acre-feet). A reservoir's ability to lessen flood peaks and lengthen lag times depends on its storage capacity. This volume of storage is proportional to the height of the dam (spill level).The barrier may fail if water spills or seeps through it considerably. As a result, three design precautions are recommended.

- When determining the dam height, add a height called the freeboard to the spill level.
- Spillways should be precisely sized to ensure proper spillage.
- Preventing considerable water from seeping beneath the dam should be a priority.

Diversions (complex method)

Some floodwaters are diverted away from a floodplain and into an adjacent floodplain or watershed via diversion devices. For example, a weir or barrage placed over a river can redirect part of the water away from its natural route, lessening the risk of flooding downstream.

The main objective is to reduce flood by sending a portion of the inflow onto a floodplain, peaks. The flow that must be redirected from the floodplain is used to build a diversion structure (for flood abatement) (as a portion of the design flood). With components includes Weir, intake/inlet, diversion canal/tunnel, and gates (optional). The size of the intake and the height of the weir can both be modified to alter the diverted flow. A weir reduces water velocity and causes small upstream impoundment, which should be factored into the design. The critical safety issues in design are the foundation strength and the longevity of the materials utilized for the weir/barrage. A breach of a weir/barrage could result in catastrophic consequences for communities.

Upper watershed restoration (soft method)

Evaporation and vegetation intercept a percentage of the water that falls in a watershed, preventing it from reaching the ground. Another considerable amount of water seeps into the earth rather than onto surface rivers as runoff. This infiltrating water is then slowly released as groundwater into streams, lakes, and wetlands (base flow). Managers can lower downstream flood risk by ensuring that optimal interception and infiltration are maintained in the upper section of a watershed and runoff is controlled.

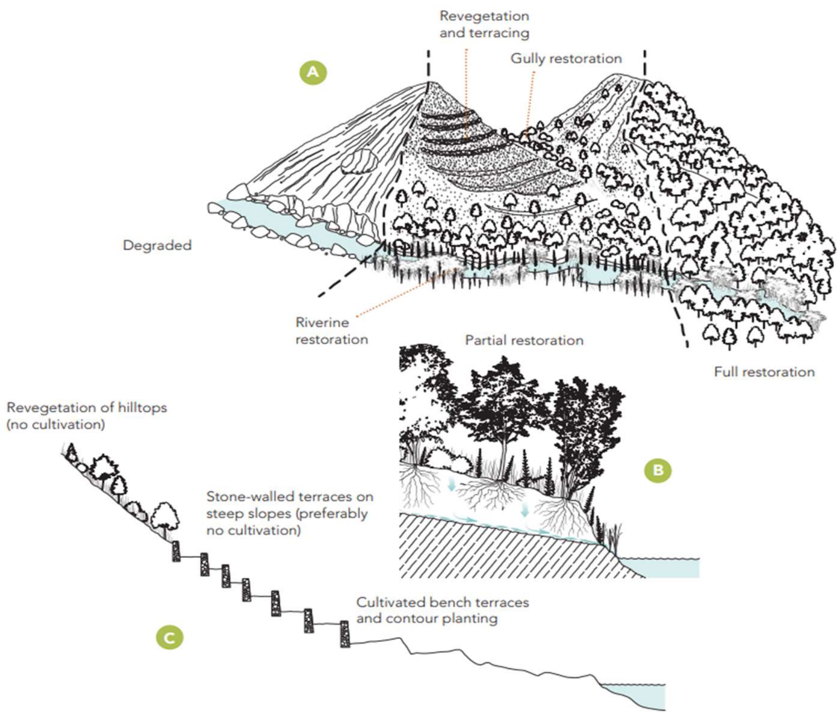


Figure 5 - Upper watershed restoration

Source: WWF's Flood management guide, Chapter 5

The main objective is to reduce the runoff by increasing infiltration and base flow with components like vegetation, erosion control structures, bioengineering features, and drainage.

Infiltration is the proportion of a unit of precipitation that seeps into the ground as opposed to flowing as runoff, and it is the goal of watershed restoration programs (for flood control) to improve infiltration. A measure of a soil's susceptibility to erosion called erosivity is widely used in the design. The spacing, sizing, structural design, and construction material must all be carefully determined when using physical structures to prevent corrosion, such as terraces or soil bioengineering components.

Wetland restoration (soft method)

Wetlands can help to decrease flash floods and storm surges by reducing water velocity and detaining runoff. Wetlands can hold stormwater and reduce localized flooding, especially in paved metropolitan areas with low infiltration and higher-velocity runoff. In a floodplain, natural wetlands can behave as a sponge, storing floodwaters and filtering pollutants. Various natural wetland types can be found in different regions of a watershed. The following are a few of them:

- Marshes: In the lower reaches of rivers, wetlands are characterized by low grassy vegetation and peaty soil that may hold much water.
- Forested wetlands and riverine wetlands: Wooded or shrub-covered areas adjacent to a river can absorb small increases in flow and prevent localized flooding.
- Shallow lakes and ponds: Occur in landscape depressions; operate as a reservoir during storms, gently releasing water to the aquifer or natural waterways; vital in urban and agricultural regions to control overland flooding.

A wetland can once again contribute to flood management by being helped to reestablish its health and function through wetland restoration. A natural wetland can be restored, as well as its extent and biological services, by removing non-wetland components and rebuilding missing wetland regions. In the course of the process, there may be excavation, removal of hydraulic infrastructure, eradication of invasive and non-wetland species, diversion of unclean runoff away from the wetland, and flooding of some areas. Due to the fact that wetlands are multipurpose ecosystems, restoring them can have a positive financial impact on activities like fishing, recreation, and the gathering of reeds, fruits, and fodder.

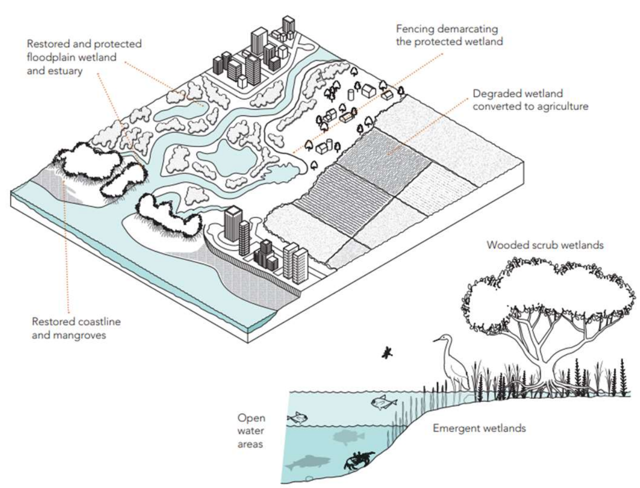


Figure 6 - Water Restoration

Source: WWF's Flood management guide, Chapter 5

A design objective is to Increase the wetland's water-holding capacity and restore its natural services. Components include Restored wetland, fencing, bunds, hydraulic control structures, and paths. It's impossible to assign a simple set of denominators for water-holding capacity in wetland restoration; the overall quality of the habitat is more essential than a quantitative increase in water-holding capacity. Wetland restoration planning is the initial stage in removing the causes of degradation (pollution sources, filled-in areas, invasive species) and allowing the wetland to regenerate naturally. Hydrological patterns, water quality, invasive species, percentage of obligatory wetland species, and soil qualities are among the ecological indicators used to assess progress. Wetland restoration plans should include reestablishing natural vegetation, animal routes, and spawning and nesting areas because plant and animal species linked with wetlands help lessen flood damage. Wetland restoration does not necessitate the use of safety standards.

Methods for conveyance and resistance to damage

Levees (complex method) – When the water level of a waterway (river, stream) rises over the height of the banks and overflows, it is called a riverine flood. Raising the bank height along a particular stretch of the river is one strategy for dealing with such a flood. Levees are structures that are built to elevate river levels. Levees are often constructed along riverbanks from soil (or rock-filled) structures. Levees are created on one side (bank) of the river in certain circumstances to protect a specific area along that bank; in other cases, both banks are raised. Roads, railway tracks, and footpaths are all common uses for levees.

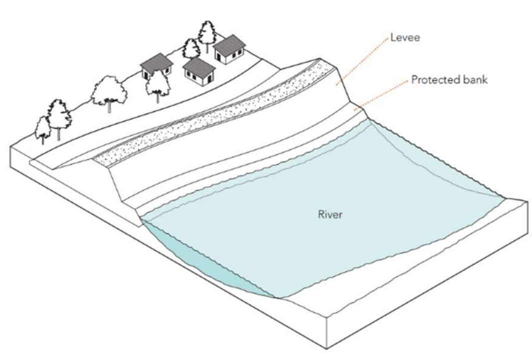


Figure 7 - Levees – representation

Source: WWF's Flood management guide, Chapter 5

Levees are often constructed along riverbanks from soil (or rock-filled) structures. Levees are created on one side (bank) of the river in certain circumstances to protect a specific area along that bank; in other cases, both banks are raised. A design objective is to prevent overbank floods, and increase the carrying capacity of the main river by elevating the bank height using artificial structures. Roads, railway tracks, and footpaths are all common uses for levees. The main components are Levees, bank protection (lining, vegetation, revetments), lock gates, and pumps. The primary safety undertaken is the structure's stability and ability to withstand water pressure, scouring, and erosion without rupturing. The water level corresponding to the flood in the stream is used to design levees. The levee height (bank height) should exceed this water level. The levee's size and structural strength must also be assessed to withstand the water pressure of the planned flood water level. The load stress on the system should be considered if the levee is used for other purposes, such as roadways and rail tracks. A levee breach can result in devastating flash floods.

Furthermore, levee problems include the risk of overtopping if a flood exceeds the design flood, the upstream and downstream implications of altered river features, the risk of a false sense of security encouraging settlement around the structure, and the elimination of potential flood benefits. To avoid unforeseen damages due to overtopping, spillways should be integrated into levee designs. Periodic inspection, maintenance, cleaning, and repair of these structures are also essential.

Canal widening and deepening (complex method)

The breadth, depth, slope, and smoothness of the canal bed determine the volume of water that a natural or artificial waterway may carry. Any of these variables can be improved to raise the waterway's carrying capacity and lessen the risk of floods and overflow. The most common and usually cheapest approach to improve the flow of a river is to widen it by reducing the banks. This is sometimes referred to as channel improvement. Because the terrain usually limits the depth and slope of a canal, it is only used in exceptional circumstances.

A design objective is to change a channel's width, depth, slope, and smoothness to increase its carrying capacity (also known as discharge capacity). Channel improvement initiatives aim to increase the waterway's discharge capacity by altering its width, depth, slope, and bed smoothness. To prevent sedimentation or scouring of the banks, the channel's water velocity is kept at roughly two m/s. The channel banks should be built with correct slopes or lined to prevent erosion. The critical concern in design is the stability of the banks after they have been modified. People

Floodways (complex method)

Another technique to increase a waterway's carrying capacity is to provide an alternate passage for some of the flow. When the flood flow exceeds the waterway's carrying capacity, a floodway is a parallel canal, enclave, or reservoir that receives overflow. In normal conditions, the floodway should be dry and usable for other purposes, such as farming. The design objective is to add an auxiliary passage to a canal to increase its carrying capacity (discharge capacity). With Existing channels, additional channels (floodways), inlets, and outlets, the aggregate discharge capacity of the existing and different channels is planned so that the design flow may be safely accommodated. The discharge capacity of the different path/channel is determined by its breadth, depth, slope, and bed smoothness. Having supplementary channels that can be used for other purposes during dry years is always cost-effective (agriculture, for example). However, this land may impair the channel bed's surface roughness, dramatically slowing water flow. The potential of secondary floods along the auxiliary pathway is floodways' most serious safety problem. The channel's and banks' stability are also crucial for safety.

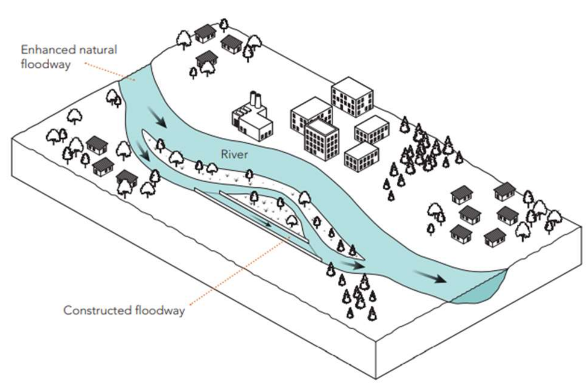


Figure 8 - Floodways representation

Source: WWF's Flood management guide, Chapter 5

Riparian vegetation restoration (soft method) -

Most riparian ecosystems (habitats adjacent to or along streams) are inherently resistant to erosion and scouring caused by high-velocity flows and floods. Riparian ecosystems that have been altered or degraded lose their ability to safeguard streams, resulting in excessive decline. Most riparian plant species have evolved to cope with high water velocities and changing water levels. Plants are stabilized, and root-zone soil is firmly held by formations such as buttresses and adventitious roots. Riparian habitats provide a buffer against rapid water level rises. Riparian ecosystems in upper watershed streams also break the energy in high-velocity flows, reducing the risk of flash flooding or erosion downstream. Fallen trees and organic litter on the banks slow the water flow and give additional soil protection. The restoration of riparian ecosystems will aid in erosion control and bank protection.

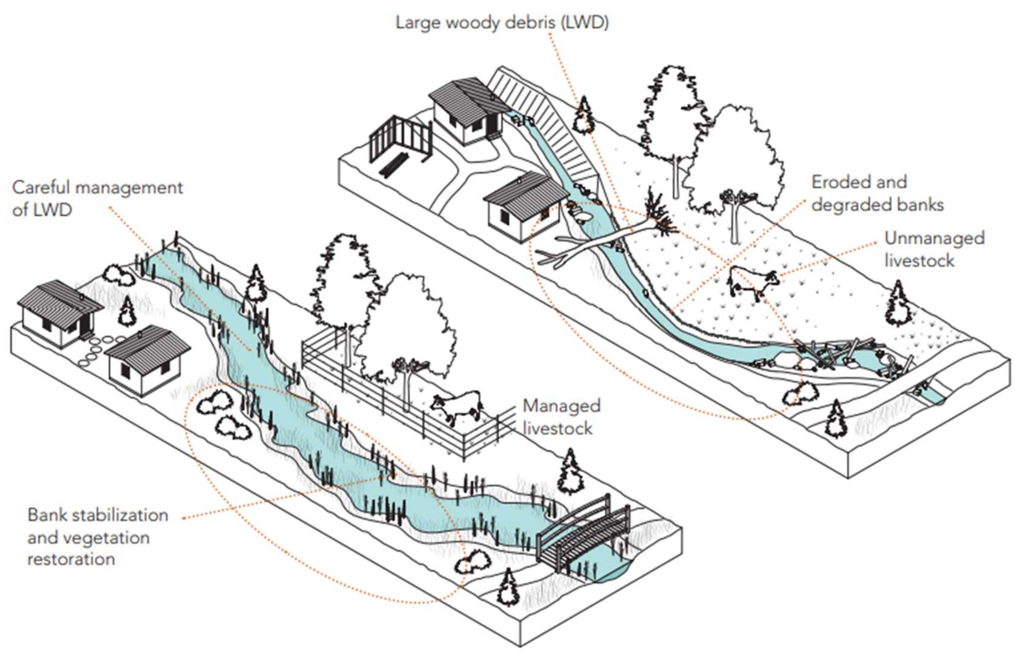


Figure 9 - Riparian vegetation - representation

Source: WWF's Flood management guide, Chapter 5

A design objective is to increase the inherent resistance of streams to sustain high-velocity, high-flow circumstances with main components including restored vegetation, restored habitats, access structures (pathways, pears), and fences. Identifying the locations to restore and selecting the appropriate plant species for revegetation are the most significant design challenges in riparian restoration. Most plants won't grow in wet riparian areas, and introducing the wrong plant species could result in excessive silt trapping and bank filling. Supplementary interventions, such as artificial bank stabilization or revetments, may be required depending on the current level of human alteration and erosion damage. Unless additional procedures such as revetments are used, safety considerations are rarely significant in riparian restoration.

Removal of barriers (soft method)

Removing flow obstacles is another approach to increasing the capacity of waterways (tiny and medium streams). In natural systems, clearing the streambed of rocks, grass, and Debris obstruct flow. Removing weeds from streams can also help to restore flow. Streams in urban and agricultural settings are frequently covered with weeds that block the natural flow, necessitating continuous weeding. Mechanical collectors can remove floating weeds, while volunteer weeding organizations can remove emergent and submerged weeds.

Removing obsolete structures such as ageing bridges and narrow culverts in human-modified systems is also necessary. Culvert opening is carefully dismantling (and replacing with bridges) or enlarging narrow trenches. Removing such obstacles might be very beneficial in places experiencing urbanization, where runoff (overland flow) has risen over time. Many constructions that impede urban streams were constructed without regard for current stream buffer distance rules. Removing these constructions is an excellent technique to boost or restore a waterway's conveyance capacity. On the other hand, specific unlawful structures are ubiquitous in low-income settlements and necessary for daily life. Removing them should be done with considerable caution and with the help of the community

Moving levees away from the waterway's borders can also boost conveyance capacity (also known as levee setback). Setbacks on levees improve water flow and connect the stream to floodplain areas. Widening the waterway's limits reduces downstream bottlenecks and back-flushing by slowing water flow during floods. This method also aids in the restoration of riverine habitats and lowers the expenses of operating and maintaining levees, which degrade more quickly when subjected to high-velocity water pressure.

Eliminating natural features near river mouths, such as sandbars and rocks, to avoid back-flushing during large flows is a more invasive approach to reducing waterways' obstacles. This procedure can disrupt the stream's natural flows and functions, including fish migration, and should be carefully designed by professionals in collaboration with the communities that use the rivers.

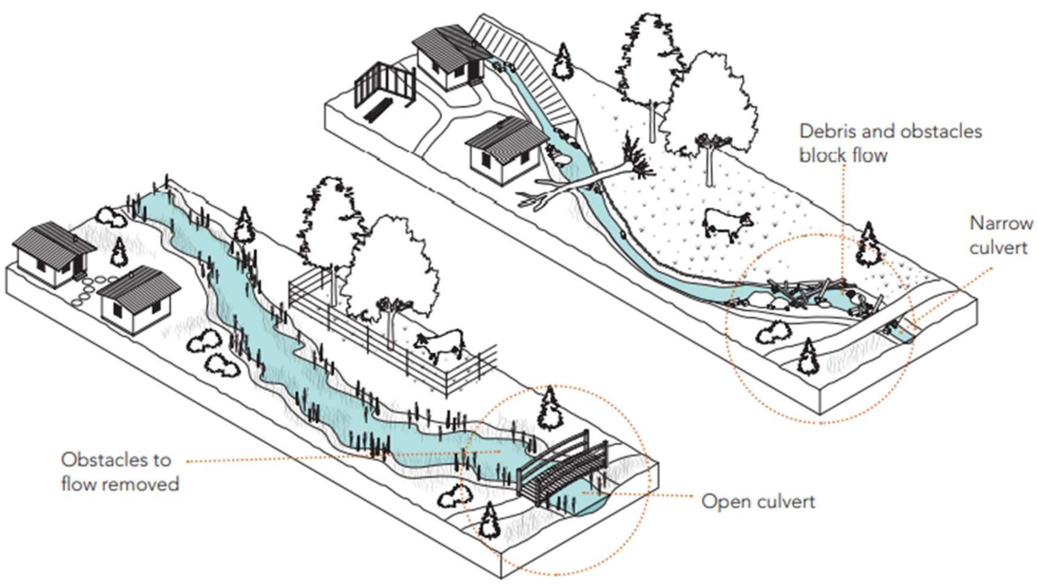


Figure 10 - Debris removal

Source: WWF's Flood management guide, Chapter 5

Design objectives are removing elements that lower the cross-sectional area or increase the roughness of a river to restore or improve it's carrying capacity.

Barrier reduction programs aim to increase waterways' carrying capacity (discharge capacity) while reducing the surface's roughness. In a natural stream, however, correctly calculating the increase in flow when a barrier is removed is extremely difficult.

Regular weeding and debris removal procedures do not prioritize safety. However, dismantling existing designed structures, eliminating unauthorized forms, and removing natural obstacles (e.g., massive rocks) can pose significant risks to people and property and should be prepared by a safety team.

METHODS FOR ADAPTING FLOODS.

Multi-purpose infrastructure (complex method) –

Multi-purpose infrastructure is public infrastructure that can be utilized for flood conveyance or detention during the wet season and other uses during the dry season. Here are some examples:

- Retention basins and multilevel traffic tunnels that serve as drainage tunnels during the wet season
- Parks and recreation spaces are made to withstand brief floods during heavy downpours.
- Tennis court and basketball court were built underground to serve as retention ponds when it rained.

Multi-purpose infrastructure should be physically and functionally adequate for its various objectives while providing the requisite hydraulic conveyance and storage capacity for flood management. Designers should plan such infrastructure based on the specific needs of a location and maximize the advantages to all stakeholders. A multi-purpose park, for example, should be prepared to withstand multiple days of floods without causing damage to its trails, seats, or open areas.

A design objective is Hydraulic functions (storage, conveyance, and infiltration) should be integrated into the shared infrastructure.

When it comes to constructing multi-purpose infrastructure, there are three key considerations:

- It should be built structurally and functionally to fulfil its primary role (car park, tunnel etc.).
- It should be developed hydraulically for secondary flood-related purposes (storage, conveyance, detention).
- The structure must be safe when exposed to water and when extra loads/pressure are applied for secondary flood-related purposes.

All safety considerations about constructing the related hydraulic structure (detention basin/pond, infiltration device, stormwater tunnel). To reduce the risk of flooding to infrastructure users, certain design safeguards must be used. For instance, a multipurpose traffic drainage tunnel should include a safe and dependable closing mechanism to keep traffic out during flooding. A public area should also take into account the risks posed by water contamination, vector breeding, and physical concerns following a flood. The necessary specialists should address any reservations regarding the infrastructure's varied applications (such as a playground or a traffic tunnel) in their specific contexts.

Non-structural methods

Physical interventions for non-structural flood risk management strategies (engineering or ecological) are not required. Depending on the nature of the interventions, non-structural approaches can be divided into two categories:

1. Governance changes include modifying or establishing laws, rules, or organizational processes to encourage (at various levels) actions that will help with flood prevention, mitigation, or adaptation.
2. *Community and home practices change* - Community and household practices refer to approaches that actively engage the community and families to instil behaviours that contribute to flood prevention, mitigation, or adaptation.

Under governance

Land use planning

The origins and consequences of floods can be influenced by land use planning. Land use planning in a country is governed by various laws and procedures, including land-use and urban Development acts, national physical plans, environmental regulations, and long-term development plans, and is carried out at many administrative and policy levels. National planning commissions make decisions, which are then passed down to local council offices. Any initiative aimed at reducing flood risk must include proper land use planning. Zoning is the essential part of flood risk management, even though land use planning is multidisciplinary:

- Zoning establishes the geographical distribution of various land uses and what should be permitted or prohibited in specific areas.
- Careful planning of adequate land cover and Development in various landscape areas can assist a manager in managing hydrological flows and is essential for soil protection.
- In urban settings, zoning can help reduce flood damage (for example, by permitting flood buffer zones along rivers to be free of buildings) and facilitate flood evacuation.

Flood and waterproofing (building regulations).

Better construction designs can reduce flood damage at the household and local scales. The official incorporation of flood-proofing elements into building designs is becoming increasingly popular worldwide. Some cities have made this a requirement. Some of the objectives of such design principles include the following:

- To make the structures more flood-resistant (e.g., use of moisture-tolerant material, Introducing Amphibious housing)
- To enhance the building's ability to function amid floods (e.g., elevated buildings and pathways)
- To increase the compound's drainage, infiltration, and temporary water storage (e.g., domestic rain gardens)

Flood risk mitigation can be aided by designs that blend traditional knowledge with modern technology and recent developments.

Regular maintenance of headworks

Physical infrastructure (headworks) such as dams, canals, drainage systems, and pumping systems are frequently used in flood risk control. Most of these constructions require some level of ongoing care once they are completed. Daily maintenance and regular operating personnel may be required for certain headworks, such as pumping stations or barrages with automatic gates. Others, such as open drainage systems or minor watershed dams, may require periodic maintenance to remove accumulated Debris and silt. Due to a lack of care, capacity may be diminished, or faults will occur, resulting in flooding.

Flood monitoring and warning framework

Flood risk management includes flood monitoring, forecasting, and giving flood alerts. Flood probabilities and damage estimations are possible through the observation of long-term flood trends. Upon making estimates, vulnerable groups should be informed of potential dangers. Regardless of scale, flood monitoring and warning require a range of actions at different levels and must be well-organized and scientific. The effectiveness of an operation can be harmed by a lack of cooperation, and false warnings could unnecessarily agitate the public. The majority of nations have established a national framework for disaster management that includes a flood monitoring and warning system. Through the Global Observing System, the World Meteorological Organization (WMO) supports national meteorological agencies. Individual federal meteorological agencies work with irrigation departments and river basin agencies to collect and forecast weather and hydrological data. Other global and regional networks, including the Asian Disaster Preparedness Centre (ADPC) and the International Flood Network (IF Net), work closely with national authorities to issue flood alerts. As a result, forecasts and warnings for specific flood-prone areas can be issued before a storm or rainy season. Local government and village leaders, local flood committees, and community-based organizations should be involved in effective community communication even while national disaster management authorities can offer notifications.

2.3 METHODS

2.3.1 ROOM FOR RIVER

Dutch flood mitigation initiative that focuses on creating "room for the river" by increasing the depth of rivers, storing water, relocating dikes, creating high water channels, lowering floodplains, lowering groynes (structures built into the river that disrupt water flow) and removing polders (tracts of land surrounded by dikes).

Extremely high-water levels in the Netherlands in the 1990s produced several challenges, prompting the adoption of 'Room for the River' as the new starting point for dealing with high water levels in and around rivers. Increasing the depth of rivers, storing water, shifting dikes, establishing high water channels, lowering floodplains, lowering groynes (structures inserted into rivers that obstruct water flow), and removing polders are all part of a Dutch flood control program (tracts of land surrounded by dikes). Landscapes near rivers can be renovated to act as "natural water sponges" in the case of a flood by making "space for the river."

Measures in and around

1. *Dyke relocation:* The floodplains become larger by moving the dykes further inland. This helps to give the river greater area, allowing it to absorb more high water.
2. *High-water channel:* Discharging excess water through a high-water channel is another alternative. Some of the river's water is diverted to another route when there is high water. By building two more dykes, we may create the track, a river branch.
3. *Building attractive groynes and lowering perpendicular groynes:* We occasionally decrease a groyne (a short stone dam at right angles to the river) or construct attracting groynes (parallel to the river). This aids in the water discharge from the river.
4. *Soldering:* This is the process of moving the dyke further inland. This implies that the river can flow into and out of the area with high water.
5. *Lowering the flood plain:* Floodplains have risen over the millennia due to the deposition of materials such as sand and clay. Reducing flood plains may give the river more space when the water level is high.
6. *Water retention:* They occasionally store too much water, like in the Volkerak-Zoommeer. This is done when the Maeslant storm-surge barrier, the Hartel storm-surge barrier, and the Haringvliet lock complex are closed, and river water cannot be discharged into the sea.
7. *Deepening the summer bed:* We lower the river bed by excavating the ground. This gives the water more excellent room to move about. The riverbed will be exacerbated as a result.
8. *Improvements to dykes:* Where room for widening watercourses is not available, the dike can be strengthened and, if required, raised.

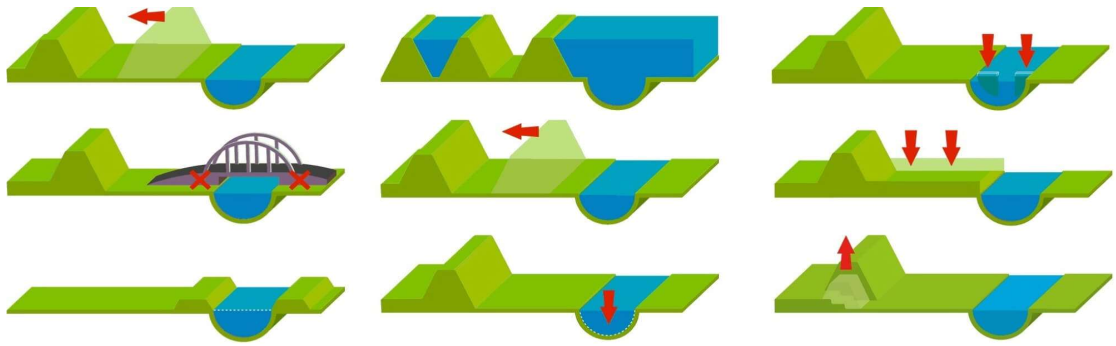


Figure 11 - Room for river methods

Source: climate-adapt.eea.Europa.eu

2.3.2 FLOATING AND AMPHIBIOUS HOUSING

Building in a flood zone is complex; nonetheless, it should be considered in situations of protection, safety, and recovery plans, among other things, so that new initiatives can be implemented. An amphibious house is a structure that sits on the ground but rises to its dock in the event of a flood, where it floats, buoyed by the floodwater. Most amphibious dwellings are moored to flexible mooring posts and rest on concrete foundations. They may travel upwards and float if the water level rises. It was initially launched in the Netherlands and then in the United Kingdom. In the face of increased floods and a housing crisis, the Netherlands is seeing an increase in interest in floating dwellings. From French Polynesia to the Maldives, these floating settlements inspire more ambitious Dutch-led projects in flood-prone countries (Rubin, 2022).

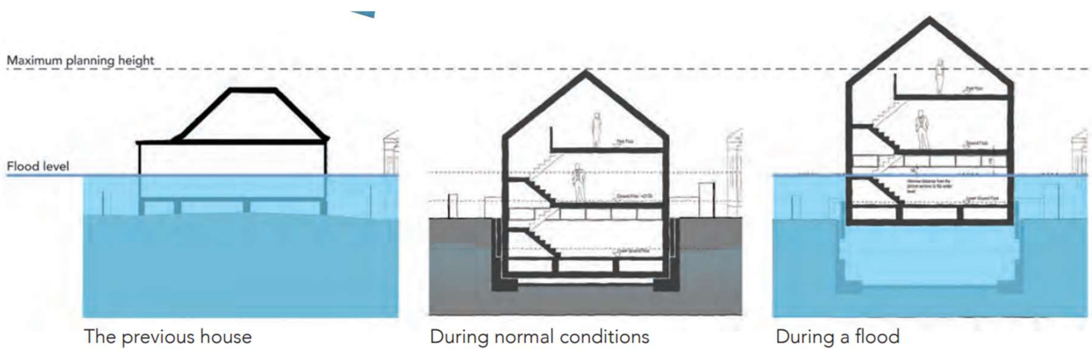


Figure 12- Amphibious house by BACA architects.

Source: Formosa, Amphibious home, BACA Architects, UK.

"During the flood event, the whole house will raise gently like a boat and will keep all of the habitable spaces safe above the flood level, rather than building flood defenses, [The Life Project] considers a different approach, to acknowledge man cannot beat nature and actually to make space for water," says Richard Coutts cofounder of Baca architects (Winston, Dezeen - magazine, 2014)

UK's "first amphibious house" can float on floodwater like a boat - Dezeen. https://www.dezeen.com/2014/10/15/baca-architects-amphibious-house-floating-floodwater/

Figure 13 - Amphibious housing (Maasbommel)

Source: Amphibious homes, Maasbommel, Netherlands.

Figure 14 - Amphibious housing - mooring posts (Maasbommel)

Source: Amphibious homes, Maasbommel, Netherlands.

In a recreation area outside the dikes near Maasbommel in Gelderland Province, 32 amphibious and 14 floating homes have been realized. The amphibious homes are fastened to flexible mooring posts and rest on concrete foundations. If the river level rises, they can move upwards and float. The fastenings to the mooring posts limit the motion caused by the water. The floating homes are lowered when the water level drops and rest on concrete foundations (Groenblaw, n.d.)

CHAPTER 3 **CASE STUDY**

3.1 ROOM FOR RIVER WAAL - Protecting the city of Nijmegen.

IN GENERAL

' The risk of Flooding in the Netherlands is steadily growing. The capacity of flood plains and rivers are decreasing, and water levels rise due to more frequent and heavier rainfall ' (sector, 2019)

The Netherlands suffered severe flooding during the 1990s, which caused severe damage and Loss of lives. Due to such extreme water level rise, they started a flood protection approaches in rivers called the Room for the River Program.

Figure 15 - Nijmegen floods

Source: climate-adapt.eea.europa.eu

In 2007 Government initiated with Development of a room for river program to manage high water levels by lowering flood plains, creating water buffers, relocating levees, increasing the depth of side channels, and constructing floodways and bypasses. The program consisted of 30 projects, with most of them completed by 2018 and expected to be finished by 2022.

NIJMEGEN AND THE WALL

Like other towns situated along rivers, Nijmegen, the oldest city in the Netherlands, has a long-standing love-hate connection with the river Waal, the primary branch of the Rhine. It is situated in the eastern section of the nation, close to the border with Germany. The river Waal quickly curves and narrows east of the city, blocking the river's flow and leaving Nijmegen's lower areas and nearby floodplain lands exposed to high water levels and swirling currents for millennia. Nijmegen has a waterfront with ship landings along the southern side of this constrained portion of the river. The settlement of Lent is shielded from floods on the other side of the river by a dike. The river was the narrowest here. One of the latest severe flooding episodes that threatened the city took place in January 1995, when the Waal swelled due to heavy rainfalls in western Europe and the snow melting and frozen soil in the higher upland. A major river in The Netherlands is the Waal River - a lowland river that begins near the Pannerdens Canal, in which the Rhine splits into the Lower Rhine and the Waal. The river has wide bends and a winter bed of 2 km; the second section, from which Nijmegen originates, is narrower. 350 to 400 metres in width, on average.Netherland was susceptible to climate change and its impact. Thus, Room for the River was considered. To protect the city of Nijmegen and the village of Lent from Flooding.

Figure 16 - Actual condition of river waal

Source: worldlandscapearchitect.com

ROOM FOR RIVER PROGRAMME

GOAL is to reduce the height of flood plains, build water buffers, relocate levees, deepening side channels, and build flood bypasses to control more excellent water flows levels in Dutch rivers. The bottleneck in the river Waal at Nijmegen. In this specific place, "making room for the river" is involved. Relocating the existing dike, situated on the northern shore of the Waal at the village of Lent, 350 meters inland; excavating a new ancillary channel. And the creation of a river island in-between.

Figure 17 - River Waal after implementing room for the river

Source: worldlandscapearchitect.com

- The existing dike was moved 350 m inland to create room for an ancillary river channel,
- Ancillary channel with a width of 150-200 m and a length of 3 km was dug providing more space for flooding
- The channel creates a new island used as an urban river park.
- Existing bridges were extended, and new ones were built.

The project was started in 2012, and by 2016, the dike had been moved, and the auxiliary canal and new had been built. After 2016, the region saw more Development providing room for urban amenities, including entertainment and housing.

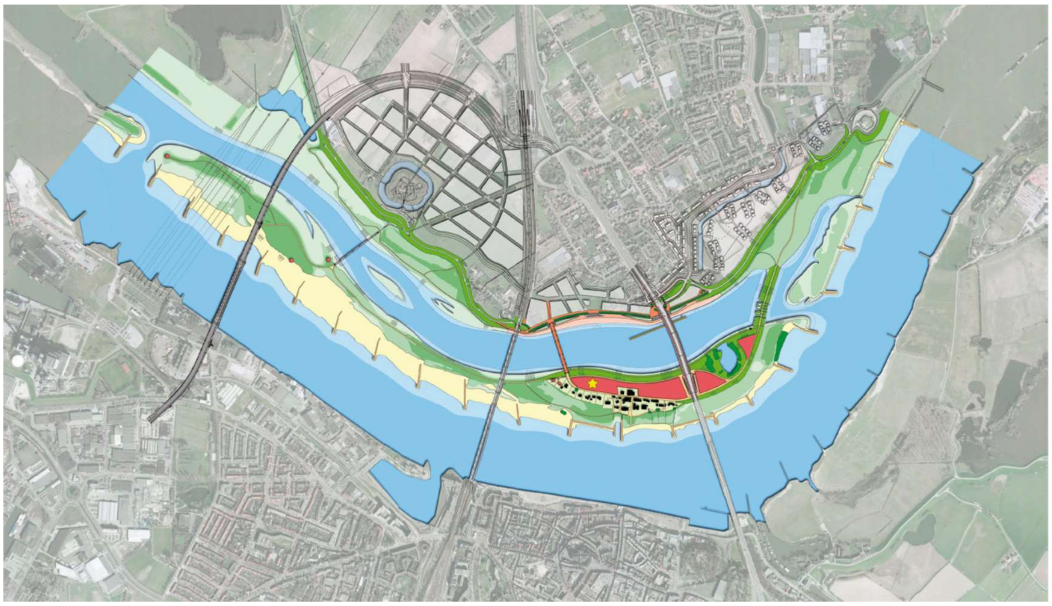


Figure 18 - Floodway for river waal

Source: worldlandscapearchitect.com

3.2 RIVERINE PERSPECTIVE - Protecting KUTTANAD BASIN

IN GENERAL

The region, which includes the districts of Alappuzha, Kottayam, and Pathanamthitta, is widely renowned for its sizable paddy fields and unique natural features. It is one of the few places in the world where farming is done between 1.2 and 3.0 metres (4 to 10 feet) below sea level, and it is also the lowest point in India. The Kuttanad basin extends over 1600 sq km. The region is nestled between the foothills of the Western Ghats in the east and the comparatively elevated plains of coastal Alappuzha in the West. Kuttanad region is categorized as North Kuttanad, Upper Kuttanad and Lower Kuttanad.

RIVER IS AN ISSUE.

Kuttanad's monsoons bring the flooding issue engendered by the region's four major rivers. Rivers are Pampa, Achenkoil, Manimala and Meenachil - drain into the Kuttanad trough, taking a weblike course about 35 km south of Alappuzha town. Heading north throughout Kuttanad empties into the Arabian Sea through the Vembanad lake. The Kuttanad area is a complex system of rivers debouching into a mesh of larger and smaller canals with many permanent and temporary links. This makes it impossible for any engineer to comprehend the flows through the system in the wet season and gain insight into where flow deviations and bottlenecks exist. This results in seemingly erratic and virtually unmanageable flow through the system. (IWRM Report). In 1989, Dutch-funded Kuttanad is conceiving a water balance study resulting in an integrated proposal. The proposal was to split Vembanad lake into two, not taking up the integral implementation.

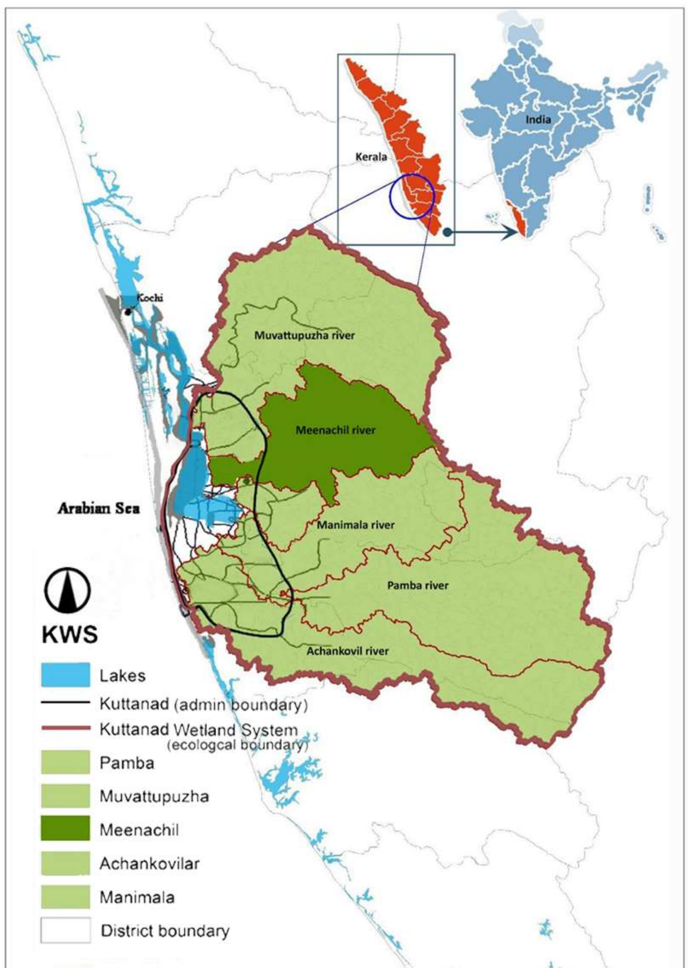


Figure 19 - Kuttanad map

Source: IWRM action plan Kuttanad

FLOODING –

Apart from rainfall, it was mainly flooded from the rivers out of the Pamba, Manimala and Meenachil watersheds, whereas Achenkovil and Muvattupuzha rivers contributed to a lesser extent

Rivers, AC canal, Thotappily head canal and Vembanad lake are Primary water systems, and Interconnected canal system is the secondary water system and minor and bund-like canal compartments in Padam as tertiary water systems

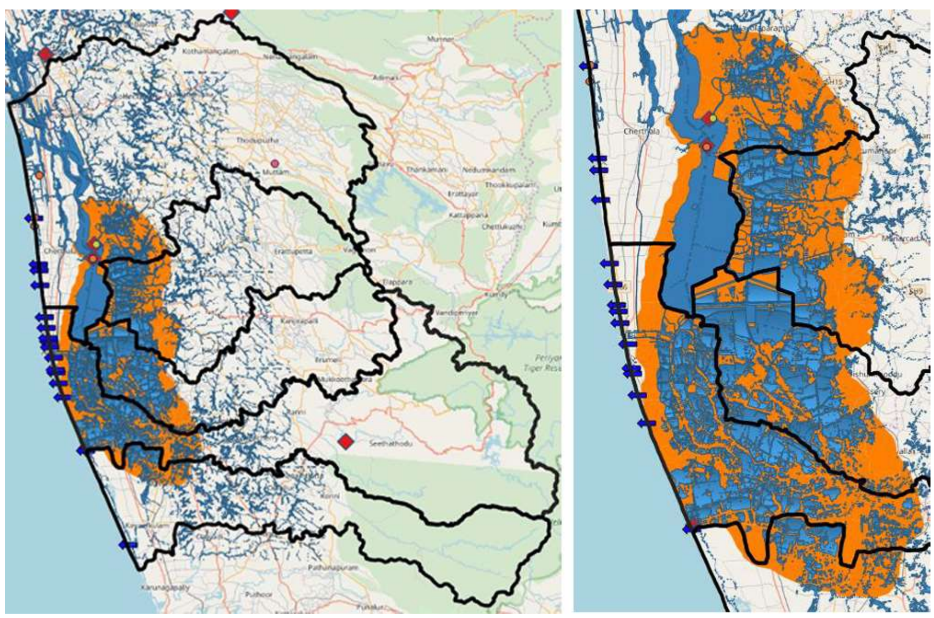


Figure 20 - Flood map - 2018 floods Kuttanad region.

Source: IWRM action plan Kuttanad

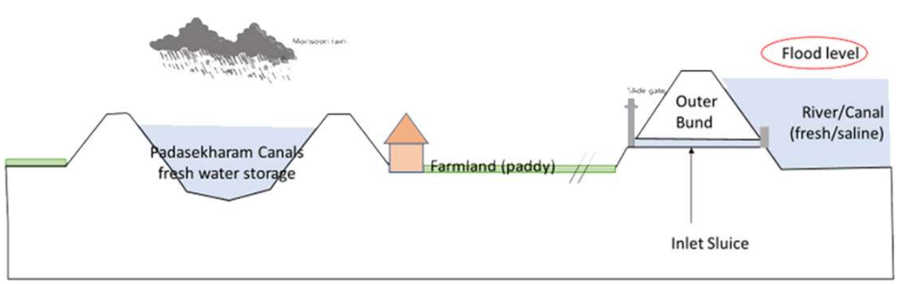


Figure 21 - Flood management Kuttanad

Source: IWRM action plan Kuttanad

INTERVENTIONS -

- Dredging, deepening of spillways and canals.
- Heightening of bunds
- Extend of widening of the AC Canal
- Re-aligning diversion point of Pamba and Thottappally Lead Canal
- Develop bypass canals parallel to the leading channel
- Upgrading the current system of dewatering units
- Reshaping Thottappally outlet canal
- Alternative (controlled) outlets from Vembanad Lake Regulator between Manimala and Pamba river permanent opening Thottappally outlet with sea

3.3 MULTIPURPOSE TSURUMI RIVER RETARDING BASIN – JAPAN

Tsurumi river basin's rapid urbanization has caused a large amount of rainwater to flow into the river once, causing flood damage frequently.
Watershed have an area of 235 sqm with the length of the main channel 42.5 km having a population of 1,960,000 (Jan 2019)

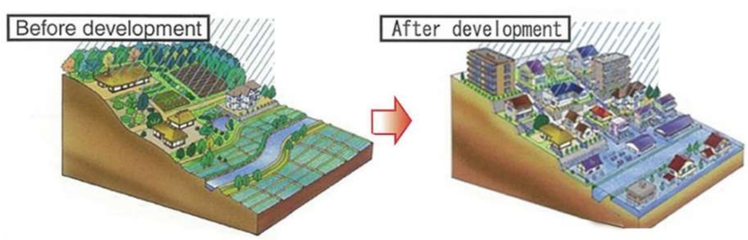


Figure 22 - Water retention capability

Source: Keihin River office report – GoJ

- GOAL 1 - To protect people from disaster.
  Temporarily capturing flood water from the Tsurumi River, this retarding basin protects the surrounding and downstream areas from flood damage

- GOAL 2 - To provide a recreation area for the city.
  The Tsurumi River Retarding Basin was developed jointly by the national government and the Yokohama City government for multiple purposes, including flood control and municipal functions (medical and park facilities)

- GOAL 3 - To provide habitat for organisms
  Parks were developed, and the natural environment was improved by recycling dead water an area like ponds etc.

Figure 23 - Comprehensive Flood control measures.

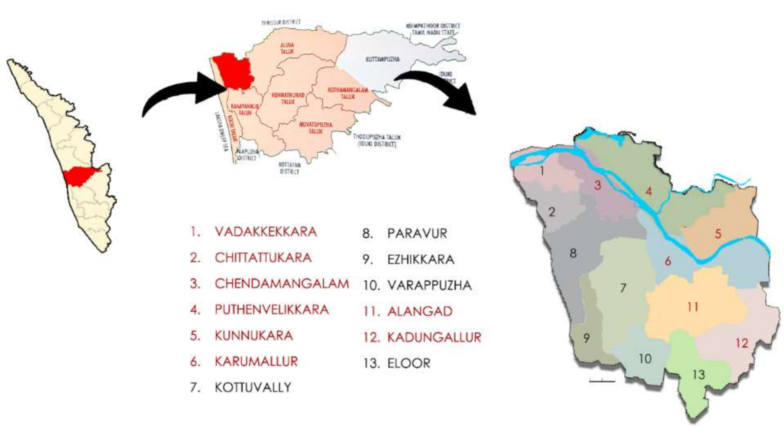
Source – Tsurumi river management report

CHAPTER 4 STUDY AREA

4.1 ABOUT

North-western Ernakulam district, which borders Thrissur district, is where Paravur Taluk is located. The taluks surrounding Kochi are Kodungallur to the West, which includes Vypin Island, Chalakudy to the north, Mala, Aluva to the east, which provides for Angamaly, Nedumbassery, and Aluva, and Kanayanur to the south, which provides for Cochin City. Site have a total area of 195.2 sqkm comprises of 13 LSGs having 2 muncipalities (N.Paravur and Eloor) and 11 gram panchayats, with a total population of 4,10,571 with 200,612 males and 209,959 females out of the total population, 93.4% people live in Urban areas while 6.6% live in Rural areas

Coastal regulations along the river stretch for 100 m is considered as NO DEVELOPMENT ZONE, in which for islands (Thuruthu), it is about 50m from river line, or half the width of the river, of which is shorter. The Periyar River surrounds the taluk in the east and the extensive network of canals and streams make up the Varapuzha Backwaters in the south. The taluk's administrative centre is North Paravur. The urban agglomeration of Kochi includes Paravur. The western regions of the taluk are coastal regions with prawn and pokkali rice cultivations. Fertile areas can be found towards the east. The Udyogmandal section of the taluk is where Kochi's heavy industries are situated. Among the Eleven Gram Panchayats and two municipalities under Paravur taluk most affected were kunnukara, chendamangalam, puthanvelikkara, kadungallur, alangad & karumallur. They are adjacent to river banks and are about 90%+ flood affected. In Kunnukara panchayat was 99% Flood affected with no camp facilities.



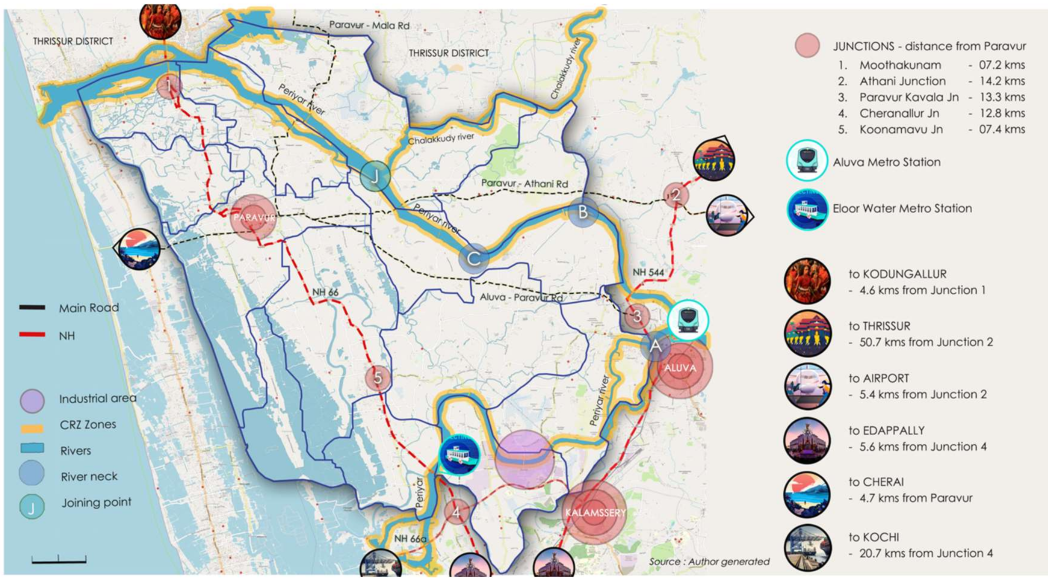


Figure 24 - Paravur Taluk detailed map

Source – Author Generated

4.2 REGIONAL CONNECTIVITY

Paravur Taluk lies on the North Western part of Ernakulam district, which shares a border with Thrissur district in the north. It has Aluva taluk to the East, Kanayanur taluk on the South and Kochi Taluk on its West.

Cochin International Airport, Aluva Railway station, Kochi Metro, National Waterway 3 are in close proximity and taluk boundary have connectivity with Cochin Water metro and National Highway 66.

The hierarchy of settlements has been classified in the Ernakulam District Urbanization report (2011) as Kochi Corporation the First Order and Aluva, Paravur, Kalamassery as Second order settlements

4.3 DEMOGRAPHICS

Paravur taluk have a total Population of 4,10,571 peoples, with Urban population of 3,83,325 and rural population of 27,246. With a Population density 2368 per square kilometre. Comprises of Total 1,02,472 house with 95,706 urban & 6,766 rural houses. Have an average literacy of 87.05% with 88.02 % for male and 86.13 % for Female.

Table 1 - Populaiton comparison

LSG's	POPULATION			Population density (per sqkm)	Annual population change (2001-2011)
	1991	2001	2011		
MUNCIPALITIES					
Paravur	27906	30059	31503	3493 / sqkm	4.58%
Eloor	-	30094	39016	3459 / sqkm	22.8%
PANCHAYATS					
Vadakkekkara	-	20099	32745	3513 / sqkm	38.6%
Chittattukara	-	25320	31303	3308 / sqkm	19.1%
Chendamangalam	26825	28147	29326	2708 / sqkm	4.02%
Puthanvelikkara	-	32213	33372	1308 / sqkm	3.47%
Kunnukara	-	16433	21765	1024 / sqkm	24.4%
Karumallur	-	26858	29805	1568 / sqkm	9.88%
Kottuvally	34457	38037	42922	2044 / sqkm	11.38%
Ezhikkara	-	17201	18019	1180 / sqkm	4.53%
Varappuzha	22514	24524	29397	2672 / sqkm	16.57%
Alangad	-	40596	47329	2044 / sqkm	14.22%
Kadungallur	25433	35463	39666	2498 / sqkm	10.6%

Source – Author Generated

4.4 RIVERINE INFLUENCE

Site comprises of mainly 2 major rivers Periyar and Chalakkudy rivers

PERIYAR RIVER –

Orgins from Sivagiri hills in Tamil Nadu, and is the longest river in kerala with a length of 244kms with an average width of 0.405km. Periyar river basin is about 5398 sqkm with a discharge rate of 295 cum/s at mouth and 223 cum/s in average and discharges into arabian sea and Vembanad lake at Ernakulam districts coastal stretch.

- The river with the most significant potential for discharge and the length.
- A dependable river that supplies drinking water to numerous significant communities
- Uses the Idukki to produce a substantial percentage of Kerala's electrical power.

- A dam and flows run beside an area of commercial and industrial activity.
- Besides sustaining a thriving fishery, it provides water for residential consumption and irrigation throughout its course.
- 25% of Kerala's industries are situated along the banks of the river Periyar, which runs through the floor-edayar region for a distance of 5 kilometres. (Udyogmandal)

The river splits at Aluva into Munambam, which reaches the sea, and Vaduthala reaches Vembanad lake.Paravur Taluk lies between these strectes, of about 17.27kms on Aluva - Vaduthala (Marthandavarma) and 27.47 kms on Aluva - Munambam (Mangalappuzha) Both surpass through the study area, coving a length of 15.94kms on Aluva - Varapuzha stretch 17.5 kms on Aluva - Vadakekkara stretch.

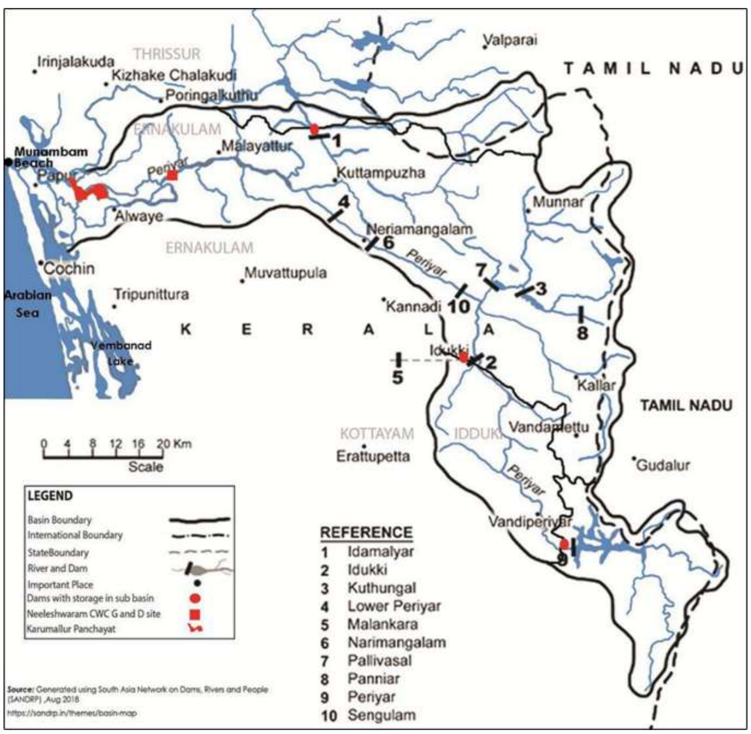


Figure 25 - Periyar river basin

Source: Room for river – Periyar report

MARTHANDAVARMA BRANCH - have a length of 15.94 km and River subdivides into - Edayar and Muttar rivers for a length of 3.90km, forming a delta. After the delta, it flows towards Varapuzha. This stretch is known as Varattar Stretch. Another stretch diverting from the Varattar branch is Edamula -Manjummel-Muttarstretch. It also flows towards

Varappuzha. These two stretches finally join near Varappuzha Bridge.

Major canals -

- Onjithode(Kadungallor and ALANGADU panchayath)
  - Karipuzha Angadikadavu thode, Karukathode
- KakkunniMethanamthode(AlangaduPanchayath)
- Manavalathode(AlangaduPanchayath)
- Periyar to Periyarthode(AlangaduPanchayath)- Plackkatamppilly Chirayam Thode
- Vembalathode(KadungalloorPanchayath)
- Panachithode(Eloor Municipality)
- Kolavelipadamthode(KadungalloorPanchayath)
- Varapuzhathode(VarapuzhaPanchayathThode)
  - Kachappillythode, Punathilthode.

MANGALAPPUZHA BRANCH - have a length 17.5 km, The north trending Mangalapuzha branch joins the Chalakudy river and discharges into the Arabian sea at Munambam, Local bodies covering along the Left are - Karumallur, Chendamangalam,Alangad, Paravoor Municipality, Vadakkekara and along the right are - Kunnukara and Puthanvelikkara.

Tributaries on Left -

- Alangad - Periyar thodu
- Karumallur - Periyar thodu, Karukadamoppu thodu, Anachal thodu, Kallykuzhy thodu, Naduvilathattu thodu
- Vadakkekkara - Pooyampally thodu, kaiparamthodu
- Chendamangalam - Paravur puzha, Korakkara puzha, Paliyam thodu, karinthiri aar, Alunkal thodu - with sub tributaries Puthan thodu, Kuzhuveli thodu, Kayikkara thodu, Kongini thodu, Kundekavu thodu, Kannachira thodu, Pashni thodu, Pashni thodu.
- Paravur Municipality - Paravur puzha, Korakkara puzha and sub branches.

Tributaries on Right –

- Puthanvelikkara - Chalakkudi river, Pandipadam Thodu, Kuttikattupallam Thodu, Payikattupallam Thodu, Thondal thodu, Thuruth thodu.
- Kunnukara - Chalakkudy river, Manjaly thodu, Cheriyathekkanam thodu.

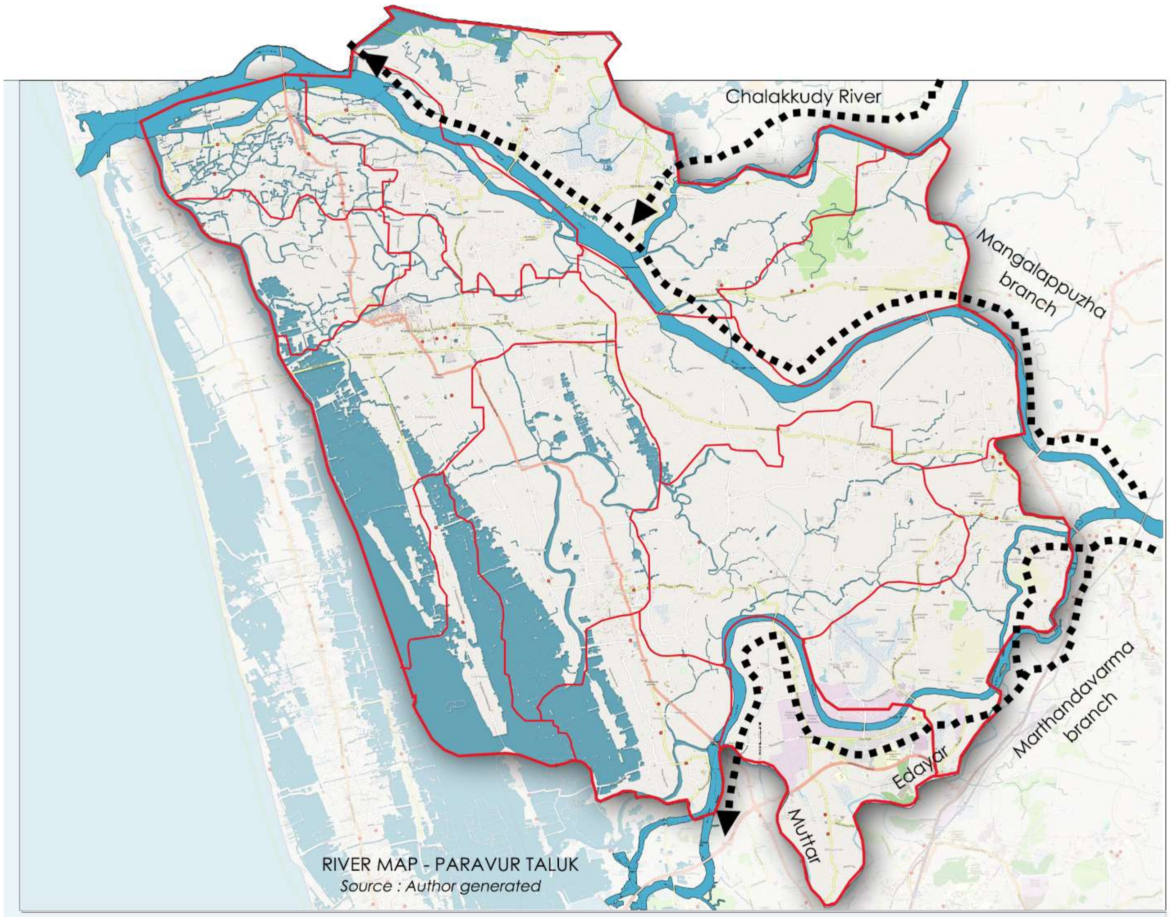


Figure 26 - River map of Paravur taluk

Source: Author generated

CHALAKKUDI RIVER –

Orgins at Anamalai region at Tamil Nādu which passes through Thrissur district in Kerala is a tributary of Periyar river and joins at Paravur taluk, with a total length of145.5 km having 5398 sqkm river basin with an average discharge of 53cum/s.

- The fifth longest river in Kerala passes through 3 districts
- It flows along the banks of Chalakudy Town,

- the largest community along the river's path, and is a tributary of the Periyar river. Due to the few industries and waste disposal sites nearby may be the cleanest and most pure river in the state, if not all of India.

- 2018 Flood - One of the severely affected rivers in the state during the 2018 Flood event. Except for the slightly elevated hilltops, all the towns and villages within 5 kilometres of the river were drowned. The river was already flooding all the nearby streams, low-lying areas, and agricultural fields while straightening up the meandering curves developed throughout millennia. It was classified as a Level 3 Calamity, or "calamity of a severe kind" by the Indian government. The Great Flood of 1924 is the most significant flood to have hit Kerala.major issues identified are Silt accumulation, No maintenance / Cleaning, Waste dumping, Obstructive blockages, Lost the drain connectivity, Encroachments.

4.5 CLIMATIC CONDITIONS

Kerala has a tropical monsoon climate; extreme eastern fringes experience drier tropical wet and dry weather. It has a humid marine environment and receives significant amounts of rain during the summer monsoon season (June to August), but in the east, a drier tropical climate is predominant. During the summer, Kerala is subject to gale-force winds, storm surges, and heavy downpours brought on by cyclones; however, the winters are considerably colder and quieter. On the plains, Kerala's daily average temperature ranges from 82°F to 90°F (28°C to 32°C).

4.6 TOPOGRAPHY

Have a variation in a gradient from 0m to 37m
High altitude areas -Kadungallur (12), Eloor (13), Eastern and Western parts of Karumallur (6) and North of Puthanvelikkara have 25m, 17m, 19m, 33m and 37m, respectively. N. Paravur city core, Low lying areas -Vadakkekkara (1), Chendamangalam (3), Chittatukara (2), Puthanvelikkara (4), Kunnunkara (5), Karumallur have an average of 5m, with which have lowest points of 0m to the highest of 37m. Ezhikkara (9) has the most insufficient land coverage.

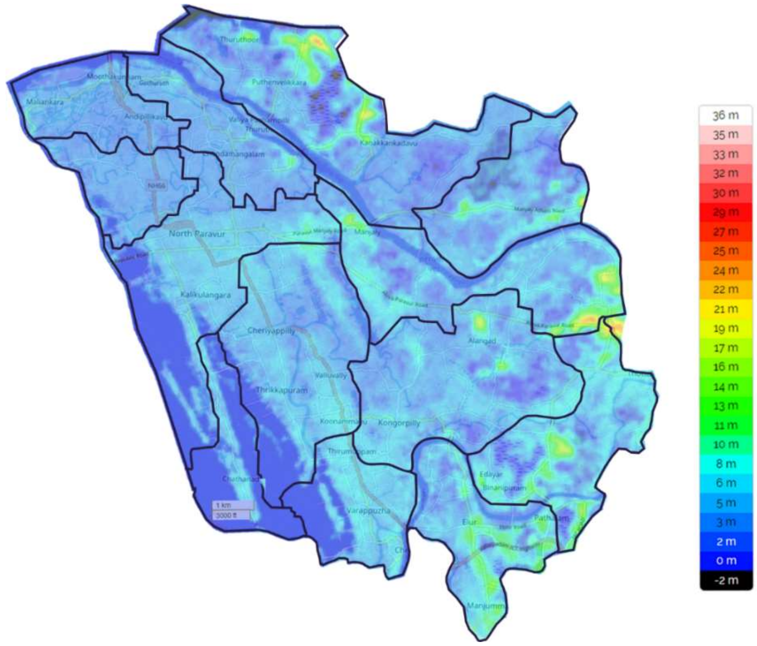


Figure 27 - Topography map Paravur taluk

Source: KSREC, KSDMA, UNEP, UN GRID, CIMA (Italy)

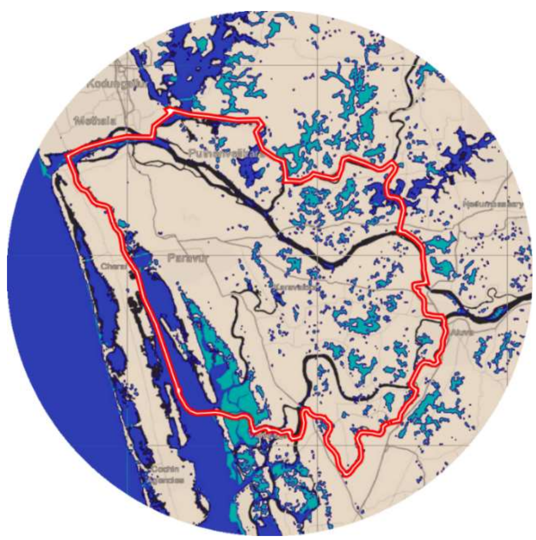


Figure 28 - Map showing 3m contour sea level rise.

Source: Author generated

The Map shows a 3m contour level water inundation, in which the low-lying areas are affected.

Figure 29 - Map showing 5m contour sea level rise.

Source: Author generated

The Map shows a 5m contour level with areas affecting the Kunnukara, Puthanvelikkara, Alangad & Kadungallur

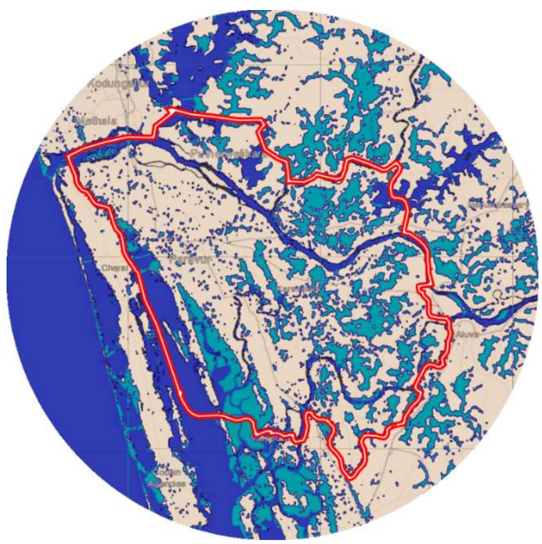


Figure 30 - Map showing 7m contour sea level rise.

Source: Author generated

The Map shows a 7m contour level water inundation, in which the low-lying areas are affected.

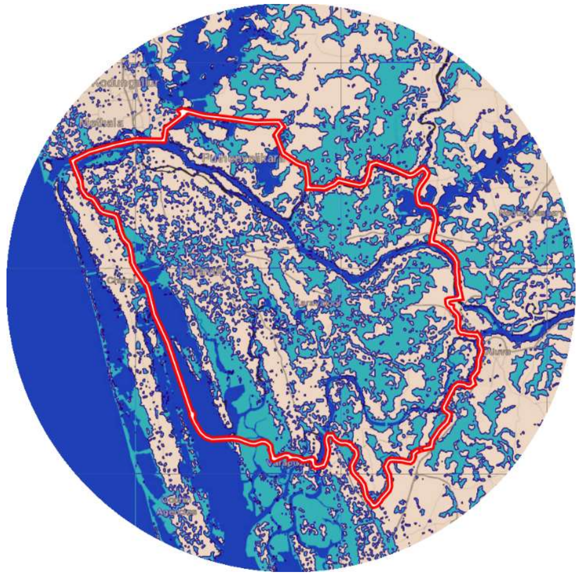


Figure 31 - Map showing 9m contour sea level rise

Source: Author generated.

The Map shows 9m contour level water inundation, covers up the Kunnukara, Karumallur and kadungallur completely

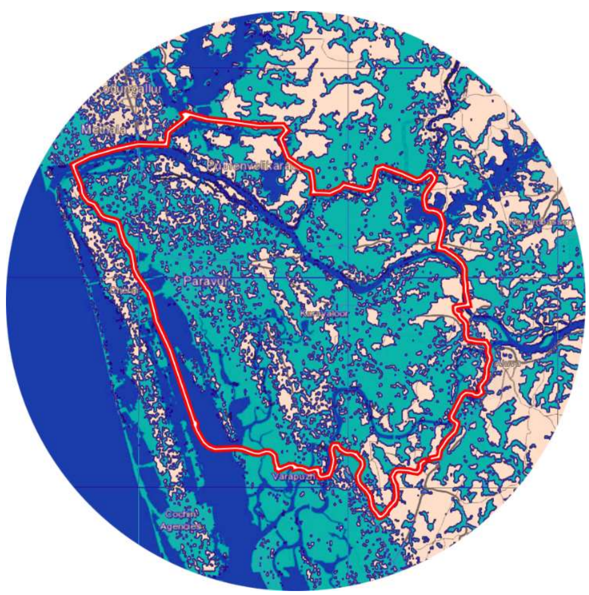


Figure 32 - Map showing 11m contour sea level rise.

Source: Author generated

The Map shows 11m contour level water inundation, covering most of the taluk area under. Which shows the average height of the land is about 11m

4.7 LAND USE

Paravur taluk lies uunder the Kochi Urban agglomeration area. The map shows the distribution of the whole land use and cover split of the Study area.

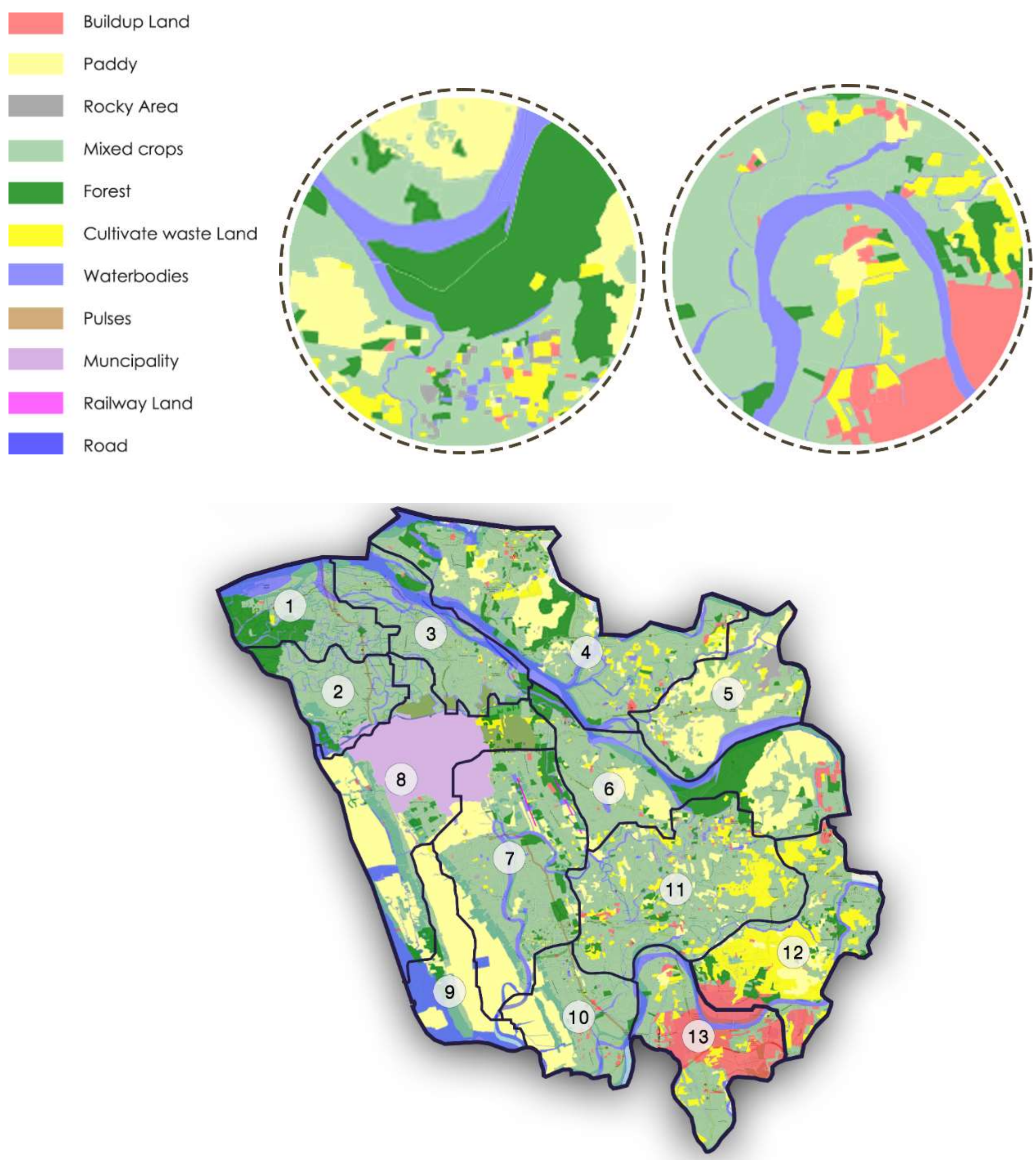


Figure 33 - Landuse map with basic details

Source: Author generated with details from kslulbris.

4.8 FLOODING

2018 flooding was mostly affected in Paravur taluk in comparison to the taluks in Ernakulam district with the flood datas from the District disaster management authority on notified flood affected houses were of Paravur taluk stands highest with 84608 houses, whereas second somes Aluva taluk with 35725 houses, and on the array have Kanayanur taluk, Kochi taluk, Kunnathunadu taluk, Muvattupuzha taluk and Kothamangalam taluk with 22920, 13421, 10350, 8613 and 2075 respectively.

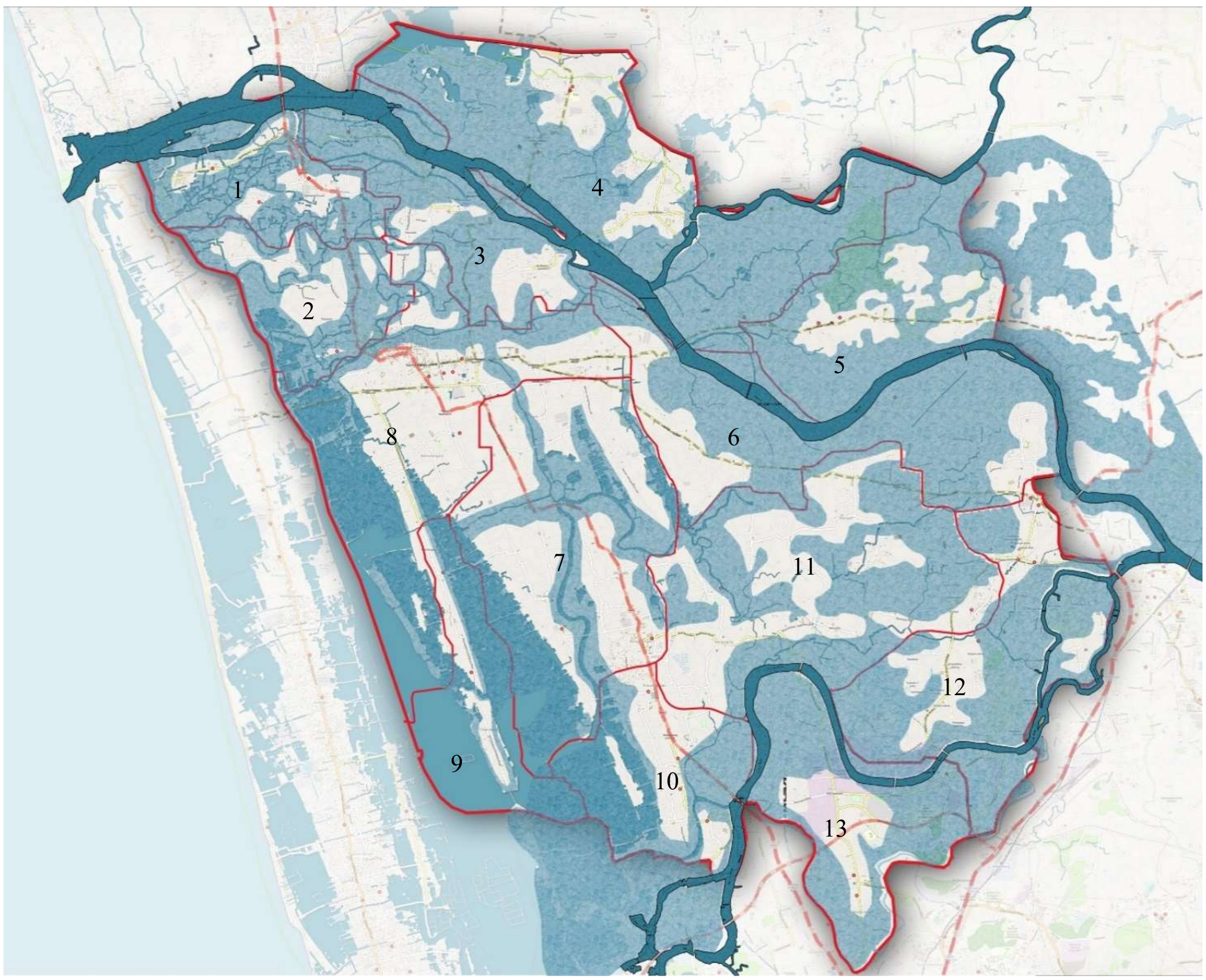


Figure 34 - Flood map of paravur taluk

Source: Author generated concluding data from Flood susceptibility, KSDMA.

Map showing the Flood level in August 2018, the peak flood recorded in the region.

Most the flood are affected over the river banks and the low-lying areas. The highest flood level demarcated is about 9m to 11m in altitude Majorly river Periyar and Chalakkudy river banks are most affected, and the connecting canals and inner drainage canals caused a massive impact on flooding. Both municipal regions were higher in altitude, which caused less damage from flooding.

4.8.1 PARTIALLY FLOOD AFFECTED LSG's

ELOOR MUNICIPALITY (13)

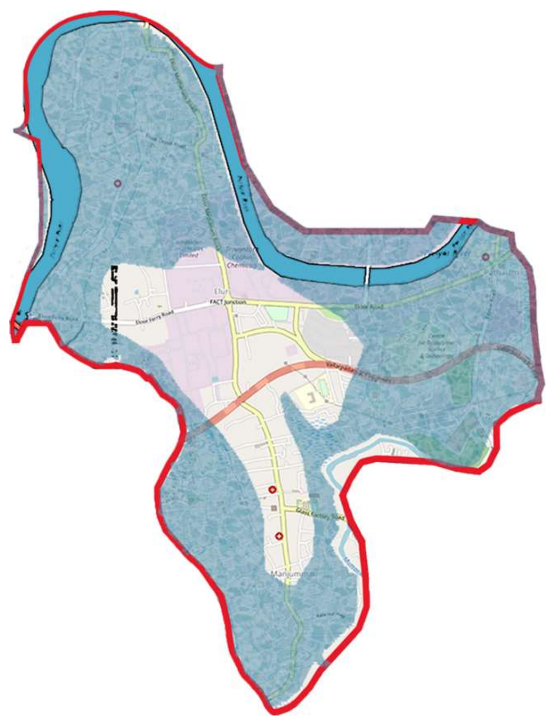


Figure 35 - Eloor municipality

Source: Author generated concluding data from Flood susceptibility, KSDMA

Total Area of 11.28 sqkm with Population of 36637 with Men 18293 and Women 18344 (as per 2011 census) comprises of total 8872 Houses within 31 wards. Thirteen wards were inundated by above 75%, and three communities were unaffected.

As the municipality has loamy sand and some other gravelly soil. There is no shortage of water due to the high inflow of water. Having known for the rural lifestyle Today, the paddy fields adjacent to this area are filling up. About 33 of notified drain canals majority are silted, which causes the Inundation

EZHIKKARA (9)

total Area of 15.27 sqkm with a Population of 18019 with 8784 men and 9235 women as per censes 2011. Comprises of 6156 houses within 14 wards. Most of the wards were flood affected but not severely, the veteran river is the mainstream within. Panchayat is topographically divided into 3, Light admixture of sludge (75%), Low lying farmlands (20%), and wetlands (5%). About 39 houses were completely damaged, and 995 were partially damaged—6 notified canals and three ponds.

Figure 36 - Ezhikkara panchayat

Source: Author generated concluding data from Flood susceptibility, KSDMA

KOTTUVALLY (7)

Total area of 20.82 sqkm with a Population of 42922 having 21034 men and 21888 women as per census 2011. Comprises of 11733 houses within 22 wards. Ten wards were inundated by above 75%. and four neighbourhoods were affected by about 50%.

Cheriyappally river is the mainstream which is a tributary of Periyar. Panchayat consists of swamps and high plains with open fields. The central and northern parts are high and sloping plains. The West consists of swampy areas and coastal plains and other sections are typical sandy areas

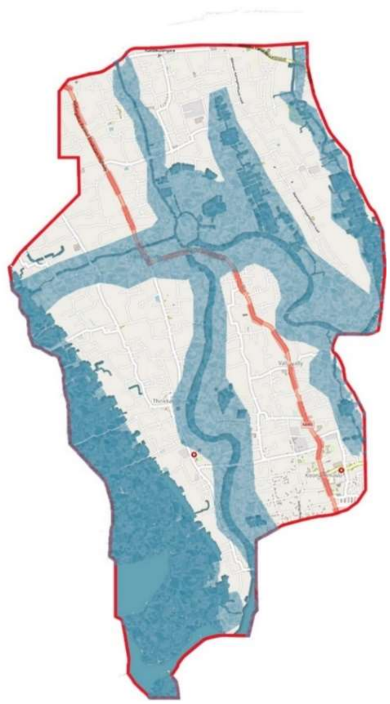


Figure 37 - Kottuvally panchayat

Source: Author generated concluding data from Flood susceptibility, KSDMA

PARAVUR MUNICIPALITY (8)

Total area of 9.02 sqkm with a population of 31503 with 15060 men and 16443 women as per census 2011. Comprises of 8997 Houses within 29 wards. A total of 23 wards were flood affected, of which nine neighbourhoods were above 90% inundated.

As the municipality is a sandy area, the rainwater storage capacity is only about 7 to 9 meters. At greater depths, clay and rock are intermingled. The water that comes from deep because of lying is salty and sour. The largest crop in the area is coconut and other intercrops.

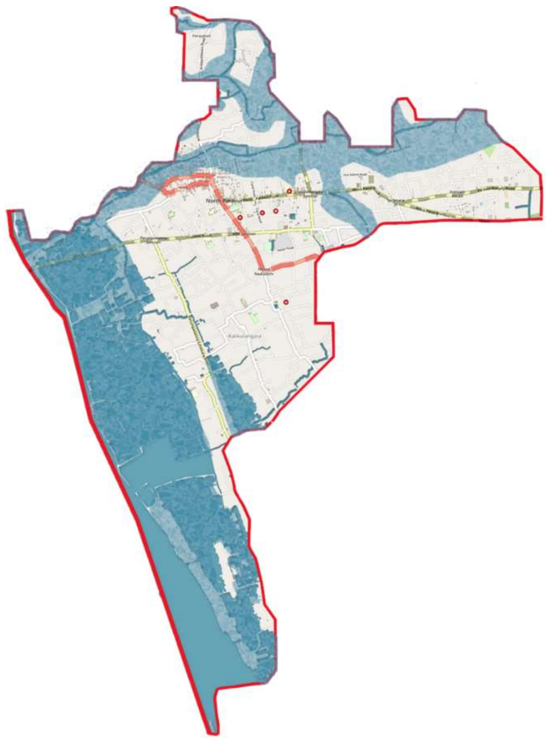


Figure 38 - Paravur muncipality

Source: Author generated concluding data from Flood susceptibility, KSDMA

VARAPPUZHA (10)

Total area of 7.74 sqkm with a population of 29397 with 14529 men and 14868 women as per census 2011. Comprises of 9333 houses within 16 wards. Most of the wards were flood affected but not in a severe manner, Periyar river is the mainstream within. Panchayat is located over the fringe resulting in high population density, which causes a change in land use. Topographically the land is about 10m high from MSL, and the 2018 flood marks 8' inundation levels. Twenty houses entirely and 3200 homes were partially damaged.

Figure 39 - Varappuzha panchayat

Source: Author generated concluding data from Flood susceptibility, KSDMA

4.8.2 MOST FLOOD AFFECTED LSG's

VADAKKEKKARA (1)

Total area of 9.5 sqkm with a population of 32745 with 16484 men and 15897 women as per census 2011. Comprises of 10330 houses within 20 wards. All wards are flood affected, above 90% affected. Periyar has a direct connection. Panchayat has sandy loam range block coloured soil, And the land is known for the historic Muziris centre. After the 2018 floods, soil structure changed. Five hundred eighty-eight houses were entirely, and 6250 homes were partially destroyed in 2018, and 152 homes were decapitated entirely in 2019. ward 3, 8,10 - Normally, floods

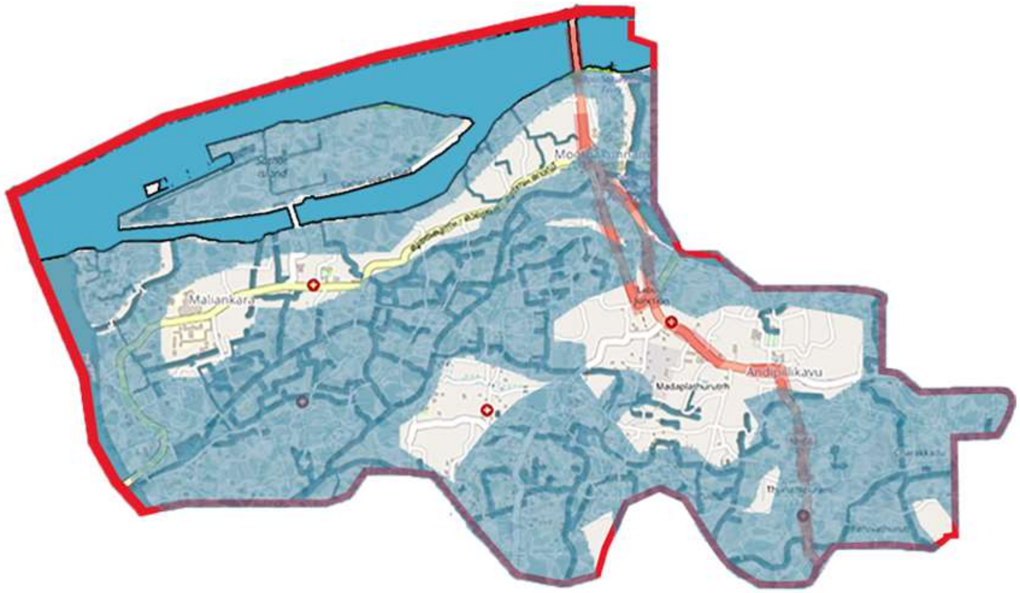


Figure 40 - Vadakkekkara panchayat

Source: Author generated concluding data from Flood susceptibility, KSDMA

CHITTATTUKARA (2)

Total area of 9.46 sqkm with a population of 31303 with 15264 men and 16031 women as per census 2011. Comprises of 10330 houses within 18 wards. All wards are flood affected, above 90% affected. Periyar has a direct connection. Panchayat has sandy loam range block coloured soil. The entire area has low-lying topographic features. After the 2018 floods, soil structure changed.One hundred ninety-two houses and 3420 homes partially destroyed and livelihood loss of 1133 no's in 2018 flooding.

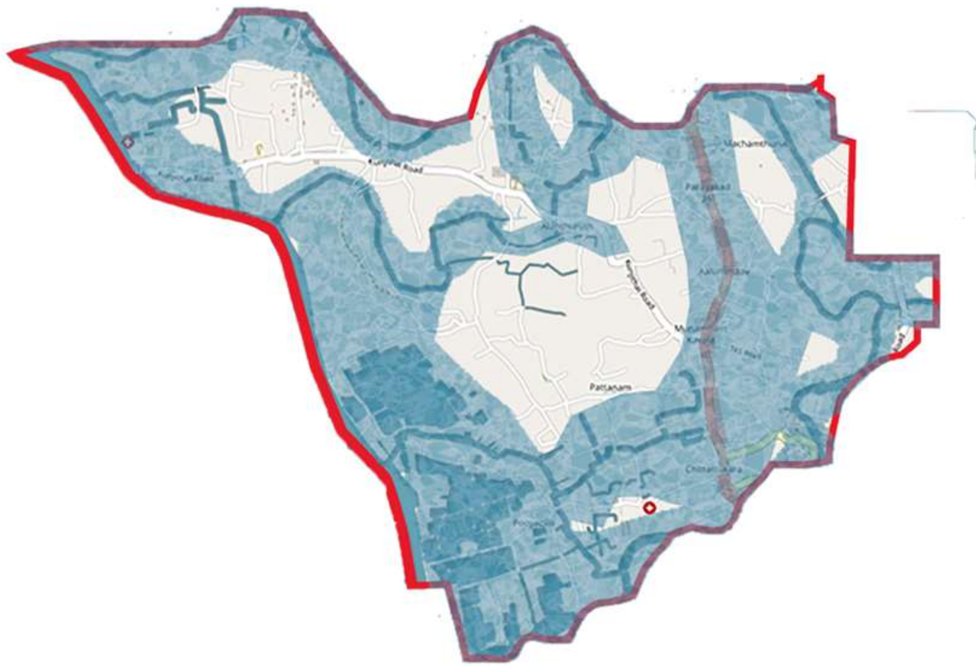


Figure 41 - Chittatukara Panchayat

Source: Author generated concluding data from Flood susceptibility, KSDMA

CHENDAMANGALAM (3)

Total area of 10.72 sqkm with a population of 29326 with 14153 men and 10223women as per census 2011. Comprises of 10223 houses within 18 wards. All wards are flood affected, above 90% affected. Periyar has a direct connection.
Panchayat covers rivers, streams and creeks. The Periyar River and the Chalakkudipuzha join together and flow around. There is fertile loam everywhere except the fort (highland) with red stone. Two hundred ninety-five houses and 5979 homes partially destroyed, 29326 are prone to flooding.

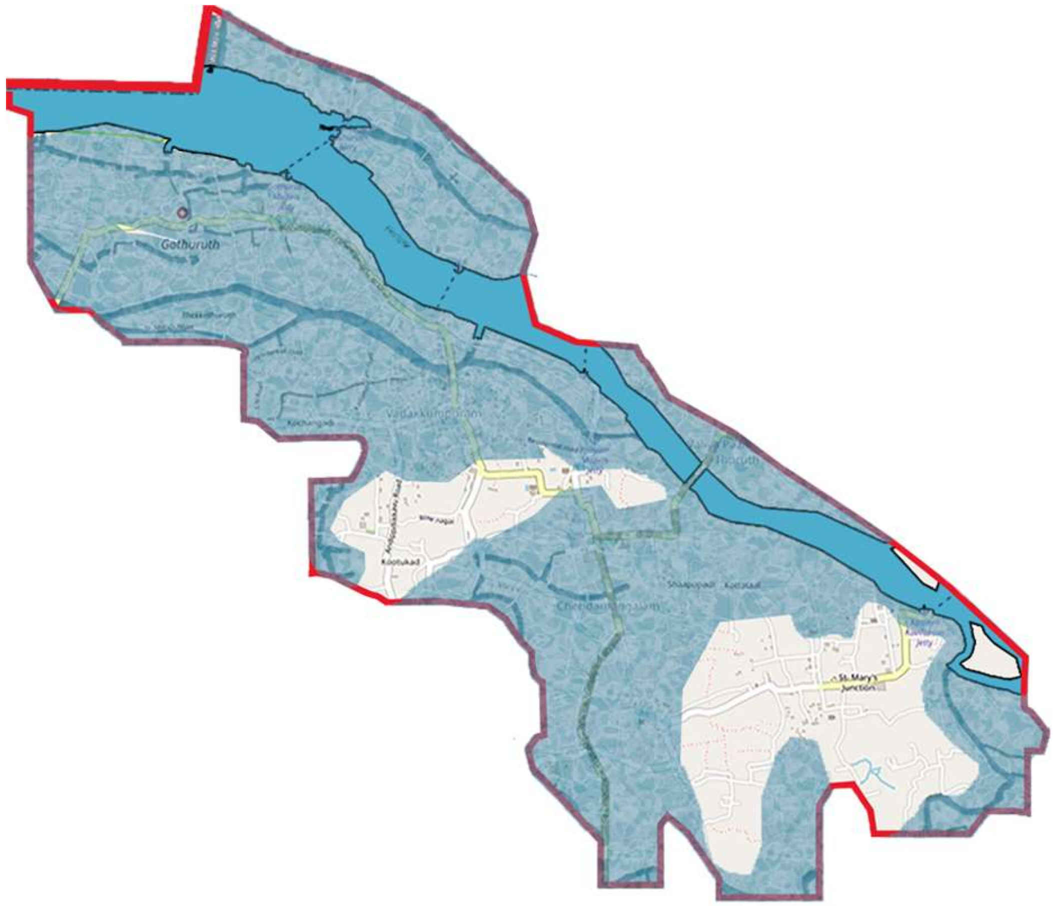


Figure 42 - Chendamangalam Panchayat

Source: Author generated concluding data from Flood susceptibility, KSDMA

PUTHANVELIKKARA (4)

Total area of 19.87 sqkm with a population of 33372 with 16251 men and 17121 women as per census 2011. Comprises of 8302 houses within 17 wards. All wards except highlands of wards 1-6 are flood-affected above 90% affected.

Panchayat is surrounded by water. Small, big, intermittent hills covered with Relatively well-drained loamy soils, gravel and clay mixed with alluvium. Chalakkudi river joins Periyar, and an 8 km stretch covers Periyar in the south. Eighty-nine houses were completely, and 2355 houses were partially destroyed.

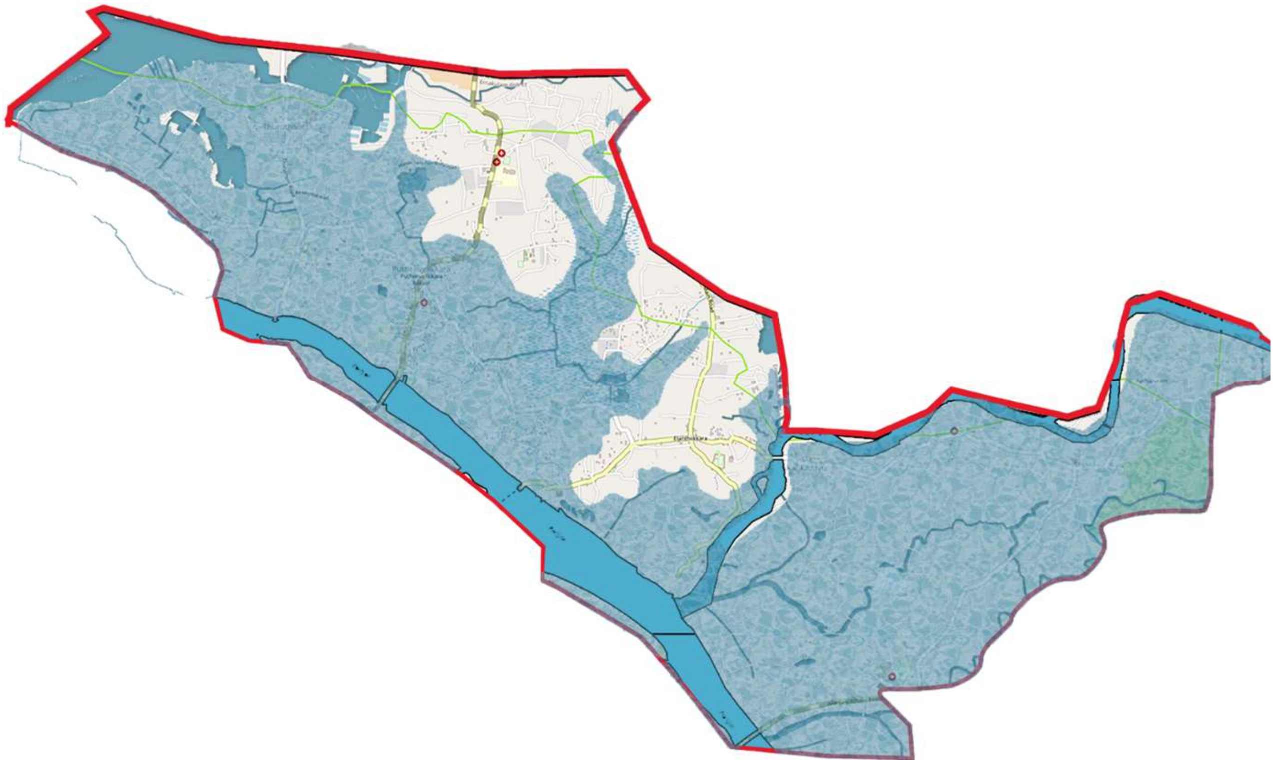


Figure 43 - Puthanvelikkara Panchayat

Source: Author generated concluding data from Flood susceptibility, KSDMA

KUNNUKARA (5)

Total area of 21.25 sqkm with a population of 21765 with 10610 men and 11155 women as per census 2011. Comprises of 8302 houses within 15 wards. All wards are flood affected, above 90% affected. Rivers - Periyar and Chalakkudi river.
Panchayat has a low terrain with flood plains of both Chalakkudi river (N), Periyar (S), and Manjali canal in the center and West, causing Inundation. It is considered the rice grain of Paravur, and the primary industry is Brick construction.

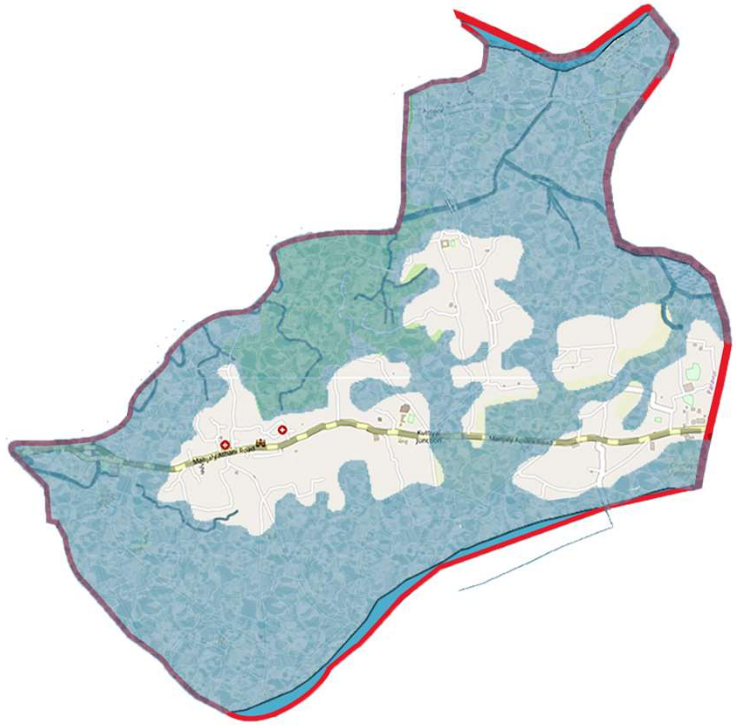


Figure 44 - Kunnukara panchayat

Source: Author generated concluding data from Flood susceptibility, KSDMA

KARUMALLUR (6)

Total area of 21.05 sqkm with a population of 29805 with 14452 men and 15353 women as per census 2011, with a total of 19 wards. Except for highland wards elsewhere, floods affected above 90% affected. Rivers - Periyar.
Panchayats Low-lying areas are below riverbed level and therefore vulnerable to flood. Development is concentrated in the highlands. Roads and buildings are obstructing the natural flow. 11m is the Flood level from the 2018 Floods.

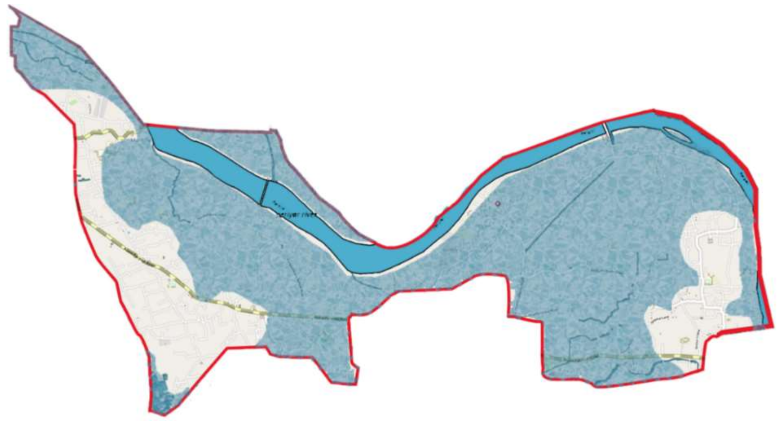


Figure 45 - Karumallur Panchayat

Source: Author generated concluding data from Flood susceptibility, KSDMA

ALANGAD (11)

Total area of 18.35 sqkm with a population of 47329 with 23204 men and 24125 women as per census 2011. Comprises of 10330 houses within 18 wards. All wards are flood affected, above 90% affected. Rivers - Periyar and Neerikod.
Panchayats Low-lying areas are below riverbed level, therefore vulnerable to flood.
One hundred eighteen houses are completely, and 2833 houses are partially destroyed, and 1808 are prone to flooding.

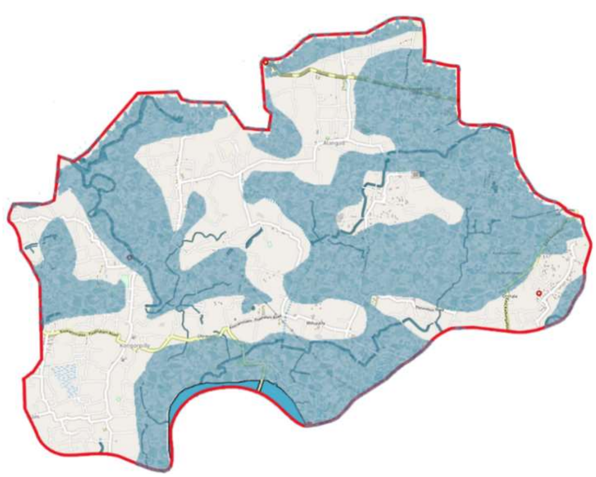


Figure 46 - Alangad Panchayat

Source: Author generated concluding data from Flood susceptibility, KSDMA

KADUNGALLUR (12)

Total area of 18.05 sqkm with a population of 45117 with 22505 men and 12612 women as per census 2011. Comprises of 15456 houses within 21 wards. Except for one ward, all are flood-affected above 90% affected. Rivers - Periyar and Onjithodu.

Panchayats lie at 11m above sea level. 2018 flood caused 8’-12' inundation levels. Have industrial areas under wards 16,17 and 18. Thirty-six houses are completely, and 3201 homes are partially destroyed, and 634 are prone to flooding.

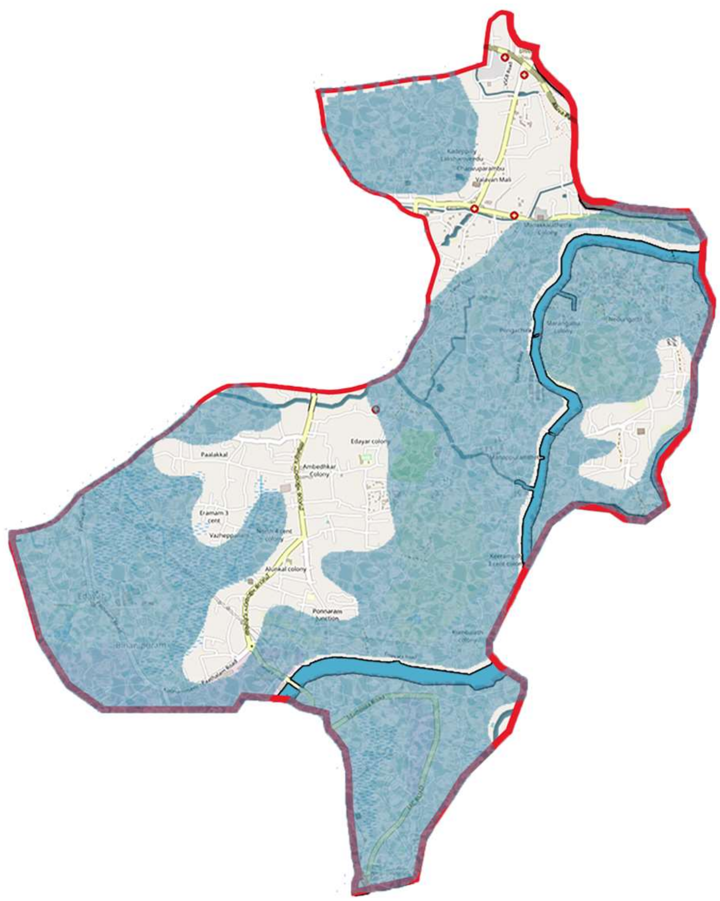


Figure 47 - Kadungallur Panchayat

Source: Author generated concluding data from Flood susceptibility, KSDMA

4.8.3 FLOOD MANAGEMENT – CURRENT SCENARIO

In the aftermath of the consequent flood events from 2018 Government of Kerala has initiated full swing over the managemental methods and attributes for Resilience. Until 2018 the authorities were unaware of the disaster due to its low probability, and history stated the condition with a significant Flood scenario a century ago. KSDMA have the authority of a grassroots level approach on management from state to District, Taluk, LSG's up to each member group. The Disaster management authorities are more focused on the Preparedness, Rescue and Relief parts, which are more of a quick course setting that requires preparation and settling up. Orange book was introduced by the Kerala disaster management authority to rich fudge the workability of LSGs towards disaster management. Each LSDs are organized to build its Disaster management plan with all the necessities in the field of Preparedness, Rescue and Recovery. Safe camp locations, Flood damage reports, and immediate action plans for flood management are coined by respective LSGs through action plans. Community-based mock drills, Grass root level preparedness and a planned approach are organized to act efficiently and on disastrous occasions for the community's wellbeing.

MITIGATION - Designed the inner canals, clearing and deepening, named Operation Vahini.

PREPARDNESS - Proper guidance from District to all LSGs on caring for and educating its community to a well-aware mentality for reducing crisis in administration and within society. IAG - Inter-Agency Group, within panchayat were organized with required resource manual of accessible NGOs, other organizations, Motor vehicle department etc.

RESCUE - IRS - Incident Response System is managed by the district collector as head, adjoining with Police, Fire and Rescue, Health etc. Associated a local rescue team for the instant operation, including NGOs and other self-serving community-based organizations like kudumbashree.

RECOVERY - They are facilitating with proper location of unaffected camps for safe, healthy facilities.They are clearing Debris and providing financial assistance and Flood insurance for the affected. Recovery action plans managed by LSG's

CHAPTER 5 **ANALYSIS**

5.1 **SWOT ANALYSIS**

STRENGTH-

Taluk lies under the Kochi urban agglomeration area, with proximity and connectivity to central urban nodes. Have access to all connectivity within the resulting taluk as the residential hub of Urban agglomeration. Have station and quick access to the rapid transit system of Kochi through Water metro and Metro rail. Have tourism potential with historical remains and Muziris tourism projects with integrated connectivity access through land and water mobility. Edayar Industrial area.

WEAKNESS –

The low-lying topography results in Inundation. The influence of the Chalakkudy river with Periyar causes flood damage along the streamline resulting in a long inundation time.
No maintenance of the canal system.
Urbanization - affects the agrarian lifestyle

OPPORTUNITY –

Taluk has many natural drains and canals (thodu), which can be managed, maintained, and reacquired. On behalf of Tourism have high potential, and inland water canals can be considered. Have direct connection and access to Kochi's Rapid transit system.
Prioritizing and improvising the Agricultural integrity.

THREAT –

Encroachments along the inner canals, natural drains, rivers
River pollution from the Udyogmandal industrial area.
Change in farmlands, wetlands, and marshlands demand low water penetration capacity causing Inundation.

5.2 **OVERLAY ANALYSIS**

FLOOD HISTORY –

Table 2 - Flood history Overlay analysis

NIJMENGEN - Netherlands	Faced flood threats continuously, The city's most recent significant flooding was recorded in 1993 and 1995.
KUTTANAD - Kerala	The Flood of 1924 is the most affected, and it is the most flood-affected area in the state of Kerala due to its low topographic level of about -1 to -3m
TSURUMI RIVER - Japan	Flooded since the middle of the Showa era (1926 - 1989). Severe floods dated on1958 and 1976 September
PARAVUR TALUK	Flood of 1907, 1924 and 2018 are the most severe events The area was prone to flood till February 1976 (Idukki dam commissioned)
INFERENCE - Considering Nijmegen and Tsurumi River Japan, and Kuttanadu, Flood events were continuous, and in the case of Paravur taluk Flood was known for the period before 1976 from there, the 2018 flood was most affected	

CAUSES –

Table 3 - Causes Overlay analysis

NIJMENGEN - Netherlands	Heavy rainfall, Snowmelt, and Frozen soil in highlands

KUTTANAD - Kerala	The low topography and heavy rainfall are significant causes of flooding, Noted topography was 1m to 3m below sea level
TSURUMI RIVER - Japan	Severe rainfall and Snowmelt are the causes of flooding
PARAVUR TALUK	Most of the land is low lying-in nature. Periyar river and the influence of the Chalakudy river are other causes. Intense rainfall and cloudburst events due to Global climate change resulted in the 2018 flood.
INFERENCE - Low-lying geography with extreme rainfall events is the primary cause of flooding.	

PHYSICAL IMPACTS –

Table 4 - Physical impact analysis

NIJZMEGEN – Netherlands	Contaminated flood water pollutes the river and its habitat. Damage caused to infrastructural facilities & services is in a controlled manner.
KUTTANAD – Kerala	Damages to the transport system Contamination of resources Loss in agriculture affects the economy

	Devastated conditions in essential services (water supply etc.)
TSURUMI RIVER - Japan	Contamination of natural resources from the flood water.
PARAVUR TALUK	Severely affected the infrastructure and services, with the destruction of build structures, Transport system, Water supply system, Contamination of resources (well etc.). The whole devastating situation of the land area after the flood event.
INFERENCE - Nijmegen and Japan have a continuous high impact on floods, which are controlled through proper management measures. Kuttanadu is different with factors of low topography and is prone to flooding, whereas Paravur taluk was not organized for a flood event.	

SOCIAL IMPACTS –

Table 5 - Social impact analysis

NIJMENGEN – Netherlands	Causalities were reported in 1955 floods with the huge Loss of lives, crops, livestock, and property damage.
KUTTANAD – Kerala	Causalities were reported during every monsoon period over the area. Loss of lives, crops and property damage is severe.

TSURUMI RIVER - Japan	Loss of lives, crops and property damage is reported.
PARAVUR TALUK	About 84608 houses were reportedly flood-affected, and 50 plus homes were destroyed. Most causalities were reported during the 2018 floods with Loss of lives, crops, livestock, and property damage.
INFERENCE - The community of Nijmegen adapted impact, Japan, and Kuttanad, whereas, in the case of Paravur taluk, the case was different, resulting in more devastating situations.	

FLOOD MANAGEMENT –

Table 6 - Flood management analysis

NIJMENGEN – Netherlands	Nijmegen has introduced the room for river project for flood management. Allocates space for rivers to flood, which protects the inhabitants from flooding
KUTTANAD – Kerala	The government is considering the situation and adapting the Netherland model of flood management Providing levees and sluices for water management with room for river concept.
TSURUMI RIVER – Japan	Initiated an integrated water management program through adapting multi-purpose infrastructural initiatives to manage floods

	in a much more practical and aesthetic manner.
PARAVUR TALUK	Have relevance after the latest flood event (no flood management plans initiated before) which entrusts the initiative for proper drain management, naming as room for river project, and Operation Vahini, which indulges inner canal, drain and tributary management.
INFERENCE - Nijmegen, Netherlands, has the best-known Flood management method, which is internationally accepted. The same is being considered in the case of Kuttanadu and Paravur taluk, where multi-purpose methods are more on an integrated approach to flood management.	

CHAPTER 6 **PROPOSAL**

VISION

To develop a spatial plan model for river flood management focusing on mitigation measures considering the acquired inundation levels as an obligatory reference

MISSION

Riverine reorganization – Integrated approach on flood management to withstand 8m level through structural and non-structural methods and to protect and preserve the Periyar river bed, and connecting streams

Adapting the flood – To have a planned and regulated development for redefining the methods of approach in management for future proofing.

STRATEGY

In regional perspective Proper dam management is the major necessity in flood management which should be properly managed and maintained regularly, sorting the flood impact management scenario in Kerala. Regulations on deforestation and dredging along the river, whereas manage right of way for the river too. A proper flood warning system and no enhancements to be permitted on and strict actions should be taken.

In local level Community awareness programs are conducted to educate on adapting floods, LSG's are to be strictly evaluated for maintenance of man made and natural drainages with timely evaluation. Redraft building rules with regulatory measures for river embankments and flood adaptive construction methods and measures in compulsory. For the utilization of flood plain's multi-purpose infrastructures to be implemented in PPP model by intervening various sections within.

PROPOSALS

1. DESILTING AND DEEPENING OF CANAL

The existing canal system is to be desilted and deepened to manage the water flow. Paravur taluk has a connected drainage system that includes natural and artificial canals. Canals have a width of 1-6m in range, in which all encroachments are to be retrieved.

2. WIDENING OF RIVERS

The existing river tributaries are to be considered and maintained, in which some parts are required. Widening the current river course and deepening provides more water flow. Widening offers more room for the river, which manages the flood flow.

Figure 48 – Conceptual imagery of the Proposed river widening

Source: Google images

3. PROVIDING DIKES

Dikes are to maintain a continuous riverbank level of about 8m, with low land water management. River beds have a depth of average of 3-4 m, whereas the river banks have a topographic variation of about -1m to 15m. 2018 Flood level was 11m, which has a 1 in 10 to 20-year probability.

4. ROOM FOR RIVER

Because rivers divert over time and can cause turns and bends due to natural and human causes, providing space over bends and curves can allocate and manage the flood flow. Clearing the obstacles, lowering the flood plains, and dike relocation are significant procedures.

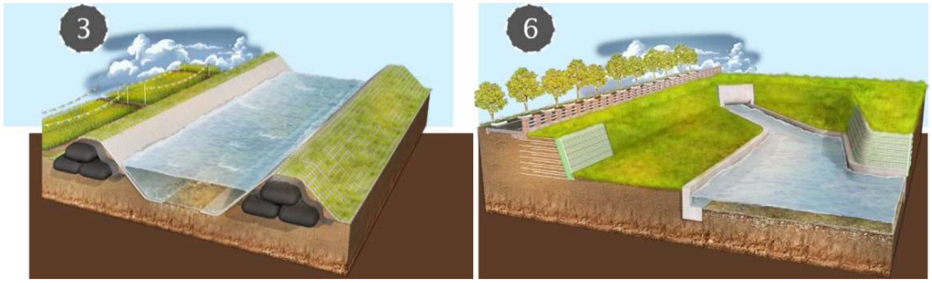


Figure 49 - Conceptual imagery of the Proposed river dikes and retarding basin.

Source: Google images

5. MULTI-PURPOSE INFRASTRUCTURE

Utilization of flood plains and low topographical regions with multi-utilitarian usages. The spaces will be parks, natural beds, and riverfront development areas with rising new tourism aspects.

6. RETARDING BASINS

Retarding basins are low-lying areas of land set aside to temporarily store stormwater during heavy rain. Many basins are grassy areas that provide a recreational space for the community while dry. The low-lying existing regions were converted into retarding basins to catch flood water. Canals have a width of 1-6m in range, in which all encroachments are to be retrieved.

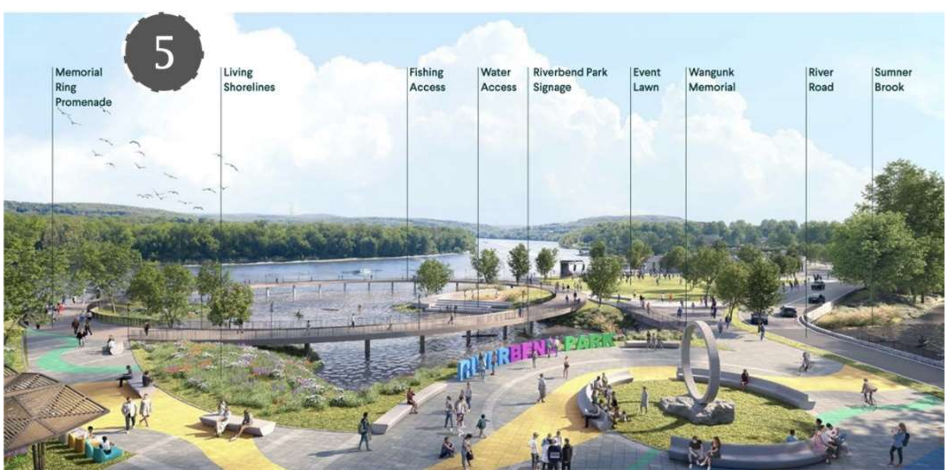


Figure 50 - Conceptual imagery of the Proposed multipurpose infrastructure

Source: Google images

7. FLOOD PLAIN

Land regions close to rivers and streams frequently flood is known as floodplains. The areas were set under no development zones and provided as flood plains. The land can be used for farming purposes under the government policy to develop agriculture.

8. SLUICE GATES

They are designed to seal in one direction. They are commonly used to control water levels and flow rates in rivers and canals, managing the Inundation of Periyar and Chalakkudy rivers. Through sluices, the flood water flow level must be optimized and managed to inner canals and tributaries.

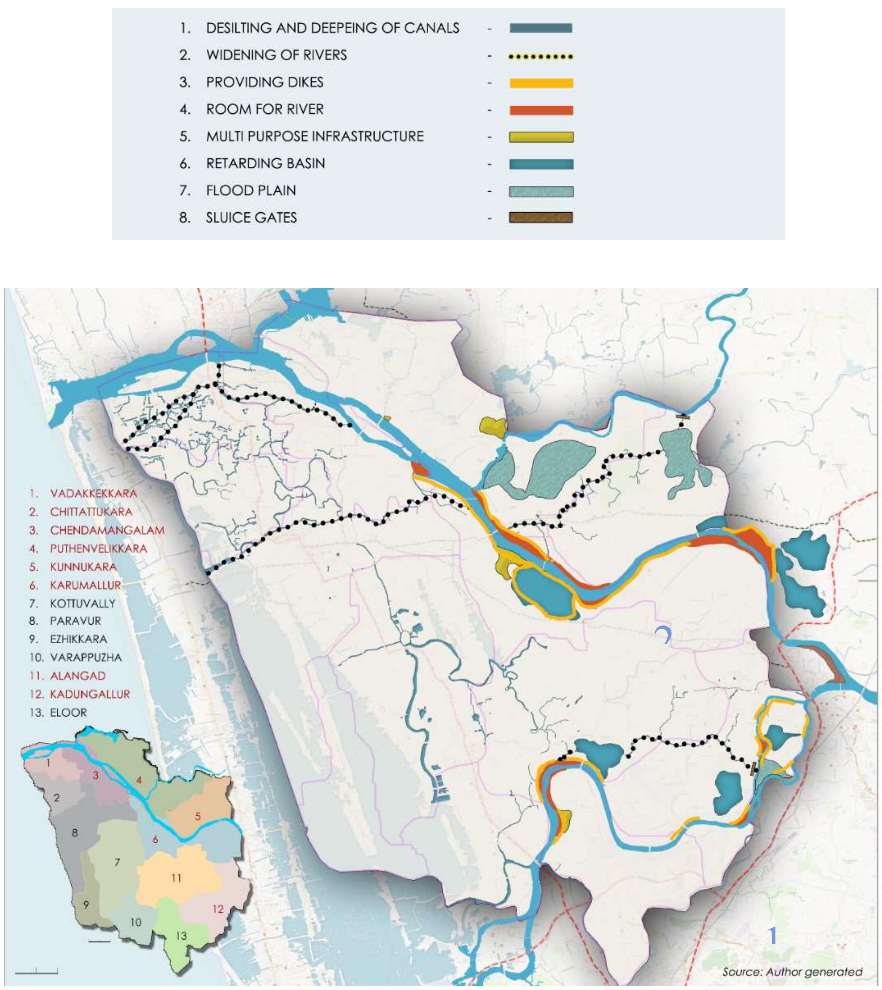


Figure 51 - Proposal

Source: Author generated

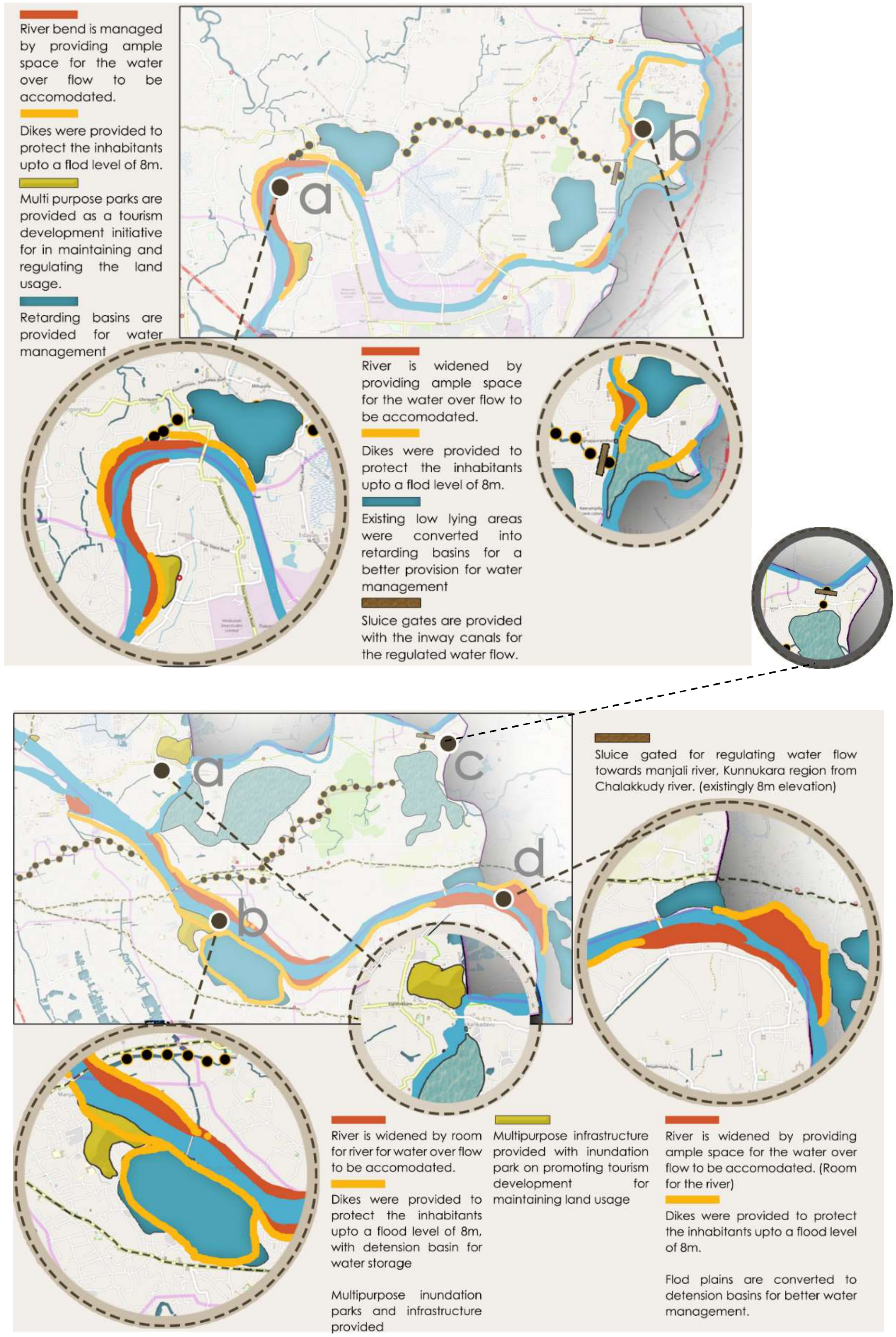


Figure 52 - Proposal detailed

Source: Author generated

CHAPTER 7 **REFERENCES**

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