National River Conservation Directorate
Ministry of Jal Shakti,
Department of Water Resources,
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Government of India

Infrastructure and Planning in

Periyar River Basin

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Periyar River Basin

National River Conservation Directorate (NRCD)

The National River Conservation Directorate, functioning under the Department of Water Resources, River Development & Ganga Rejuvenation, and Ministry of Jal Shakti providing financial assistance to the State Government for conservation of rivers under the Centrally Sponsored Schemes of 'National River Conservation Plan (NRCP)'. National River Conservation Plan to the State Governments/ local bodies to set up infrastructure for pollution abatement of rivers in identified polluted river stretches based on proposals received from the State Governments/ local bodies.

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Centres for Periyar River Basin Management and Studies (cPeriyar)

The Center for Periyar River Basin Management and Studies (cPeriyar) is a Brain Trust dedicated to River Science and River Basin Management. Established in 2024 by IIT Palakkad and NIT Calicut, under the supervision of cGanga at IIT Kanpur, the center serves as a knowledge wing of the National River Conservation Directorate (NRCD). cPeriyar is committed to restoring and conserving the Periyar River and its resources through the collation of information and knowledge, research and development, planning, monitoring, education, advocacy, and stakeholder engagement.

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cGanga is a think tank formed under the aegis of NMCG, and one of its stated objectives is to make India a world leader in river and water science. The Centre is headquartered at IIT Kanpur and has representation from most leading science and technological institutes of the country. cGanga's mandate is to serve as think-tank in implementation and dynamic evolution of Ganga River Basin Management Plan (GRBMP) prepared by the Consortium of 7 IITs. In addition to this, it is also responsible for introducing new technologies, innovations, and solutions into India.

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Acknowledgment

This report is a comprehensive outcome of the project jointly executed by IIT Palakkad (Lead Institute) and NIT Calicut (Fellow Institute) under the supervision of cGanga at IIT Kanpur. It was submitted to the National River Conservation Directorate (NRCD) in 2024. We gratefully acknowledge the individuals who provided information and photographs for this report.

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Preface

In an age of dynamic economic growth and rapid urbanization, the role of strategic infrastructure planning has become paramount. The ability to design, develop, and sustain infrastructure systems that balance societal needs with environmental stewardship is essential for fostering equitable and resilient communities. This report aims to provide a comprehensive perspective on infrastructure planning, delving into the challenges, innovations, and strategies that shape the future of our built environment.

Across the following chapters, you will find an in-depth exploration of the principles and frameworks that underpin effective infrastructure systems. Drawing on meticulous research, expert insights, and illustrative case studies, the report highlights the interconnections between infrastructure and quality of life, economic development, and environmental sustainability.

The intent of this report goes beyond presenting data and theories; it serves as a practical resource and a call to action. Stakeholders at all levels—policy makers, urban planners, engineers, and community members—are urged to recognize the pivotal role of infrastructure in shaping a sustainable future. By fostering a deeper understanding of planning methodologies, innovative technologies, and inclusive decision-making, we aspire to empower readers to contribute meaningfully to the advancement of infrastructure systems.

This report would not have been possible without the dedication and expertise of the numerous contributors who generously shared their knowledge and experiences. Their invaluable input has transformed this document into a beacon for informed decision-making, offering guidance to address both present and emerging challenges.

As you navigate through this report, we invite you to engage with the opportunities and responsibilities of infrastructure planning. Together, we can chart a path toward resilient and inclusive development, ensuring that our infrastructure systems remain robust and sustainable for generations to come.

Centres for Periyar River Basin

Management and Studies (cPeriyar)

IIT Palakkad & NIT Calicut

Contents

List of Figures

List of Tables

1. Introduction

Periyar River Basin is a key resource for Kerala, supporting agriculture, water supply, energy production, and transportation. With increasing urbanization and development, planning infrastructure in the basin has become essential to meet growing demands while protecting the environment. Proper infrastructure planning focuses on balancing development with conservation, improving disaster resilience, and ensuring sustainable use of resources for the benefit of local communities.

1.1 Overview of urban planning

Urban planning in the Periyar River Basin focuses on balancing rapid urbanization with the region's ecological integrity. As a vital hydrological and ecological area in Kerala, the basin faces challenges such as increased settlements, deforestation, and land degradation. Effective urban planning integrates sustainable development principles, prioritizing flood risk management, biodiversity conservation, and green infrastructure. By zoning urban areas based on environmental vulnerability and implementing sustainable practices, urban planning in the basin aims to mitigate environmental impacts while fostering resilient and inclusive urban growth.

1.2 Infrastructure development plans

Infrastructure development in the Periyar River Basin involves collaborative efforts by city planners, government agencies, and non-governmental organizations (NGOs) to address the region's diverse needs. These plans include projects for improving transportation networks, enhancing water supply and sanitation systems, and supporting urban development in growing areas. Government agencies focus on large-scale projects like dams, irrigation, and flood management, while NGOs contribute through community-based initiatives, such as rainwater harvesting and renewable energy systems. City planners integrate these efforts to ensure sustainable and inclusive development, balancing urban growth with the basin's ecological and social priorities.

2. Developmental plan

The Developmental Plan for the Periyar River Basin emphasizes sustainable growth while addressing the challenges posed by environmental vulnerabilities and urbanization. This section consists of land use zoning based on the Environmental Vulnerability Index (EVI), urban expansion, and smart city initiatives.

2.1 Land Use Zoning for the Periyar River Basin Based on Environmental Vulnerability Index

The Periyar River Basin, located in Kerala, India, is a vital ecological and hydrological resource supporting biodiversity, water supply, and socio-economic activities in the region. Spanning an area of 5216 km^2, the basin comprises diverse landscapes, including dense forests, agricultural lands, urban settlements, and water bodies. The region's ecological health and water resource sustainability are increasingly threatened by anthropogenic pressures such as urbanization, deforestation, and agricultural expansion. This section aims to delineate land use zones in the basin to balance developmental needs with environmental conservation. Land Use and Land Cover classification for 2017 and 2024 was performed using ArcGIS 10.8 software, utilizing Sentinel-2 satellite imagery with a 10-meter spatial resolution. The Maximum Likelihood Classification algorithm was applied to categorize the landscape into six classes: waterbody, settlement, barren, agricultural land (cultivated), agricultural land (uncultivated), and dense vegetation. Land use zoning was conducted using the EVI, which integrated elevation, slope, aspect, Normalized Difference Vegetation Index (NDVI), and Land Use Land Cover (LULC) patterns through Principal Component Analysis (PCA).

2.1.1 Land Use Land Cover Classification

Land Use and Land Cover patterns for the years 2017 and 2024 and statistics shown in Figures 1, 2, and 3, respectively, highlight significant trends in the Periyar River Basin between 2017 and 2024. In 2017, dense vegetation covered 1908.21 km² (36.59%) of the basin, while cultivated agricultural land occupied 1210.54 km² (23.21%). By 2024, dense vegetation reduced to 1799.48 km² (34.49%), and cultivated land declined to 858.83 km² (16.46%), reflecting a shift towards urbanization and land degradation.

During this period, barren land increased from 353.01 km² (6.77%) to 498.55 km² (9.56%), and settlements expanded from 277.64 km² (5.32%) to 303.06 km² (5.81%). These changes

underline the growing anthropogenic pressure on the basin's ecosystems, emphasizing the need for strategic land use planning. Water bodies remained relatively stable, covering approximately 231.00 km² (4.43%) in 2017 and 226.67 km² (4.34%) in 2024. Meanwhile, uncultivated agricultural land increased from 1235.61 km² (23.69%) to 1529.41 km² (29.33%).

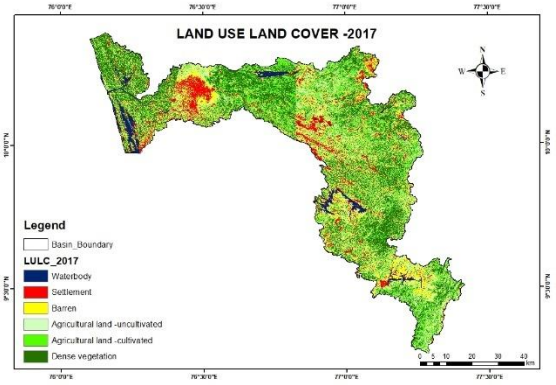

Figure 1 LULC pattern for the year 2017

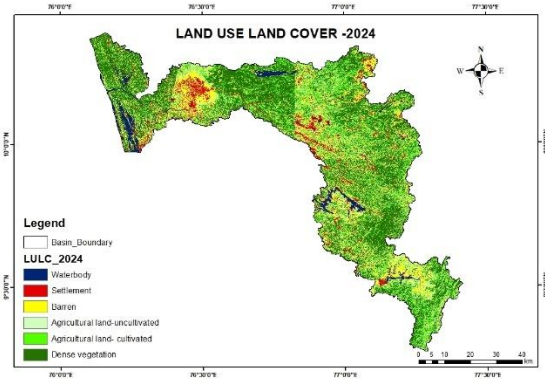

Figure 2 LULC pattern for the year 2024

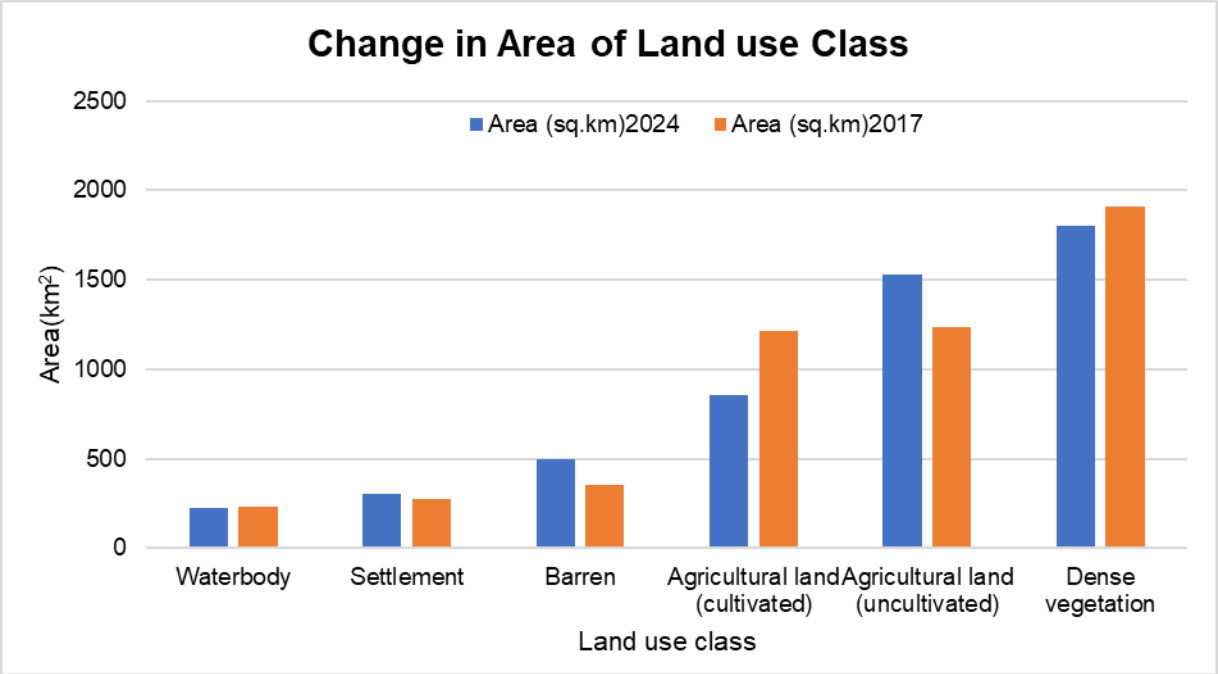

Figure 3 LULC statistics of Periyar River Basin

2.1.2 Land Use Zoning

The land use zoning for the Periyar River Basin was developed based on the EVI, categorizing the basin into four distinct zones as listed in Table 1. The analysis of the EVI for 2017 and 2024 is shown in Figures 4 & 5 respectively. It highlights significant interconnections between land use patterns and environmental vulnerabilities across the basin. The settlement areas, marked in red on the LULC, exhibit a strong correlation with zones of heavy vulnerability on the EVI map, reflecting the environmental pressures caused by urban expansion, impervious surfaces,

and inadequate resource management. These areas are highly susceptible to pollution, water stress, and habitat fragmentation, necessitating urgent interventions such as sustainable urban planning, pollution control measures, and the incorporation of green infrastructure.

Table 1 Evaluation level of EVI (Boori et al., 2014)

Evaluation Level	Number	EVI	Feature Description
Slight vulnerability	I	> 1.5	Relatively stable ecosystem and anti-interference ability, healthy dense vegetation and low altitude
Light vulnerability	II	1.5-2	Relatively unstable ecosystem and poor anti-interference ability, complex vegetation distribution
Medial vulnerability	III	2-2.5	Unstable ecosystem, medial human interference, dominated by alpine shrub grass
Heavy vulnerability	IV	> 2.5	Extremely unstable ecosystem, high socio-economic activities, degraded forest

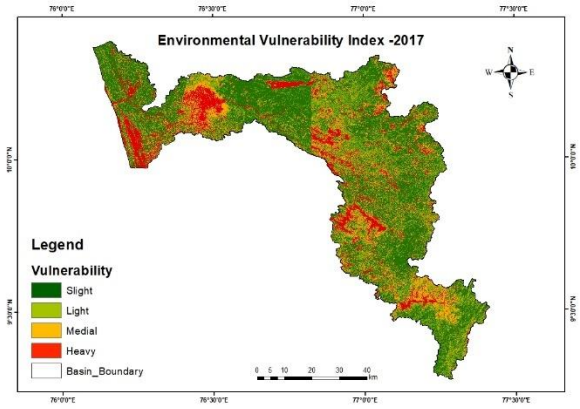

Figure 4 EVI for the year 2017

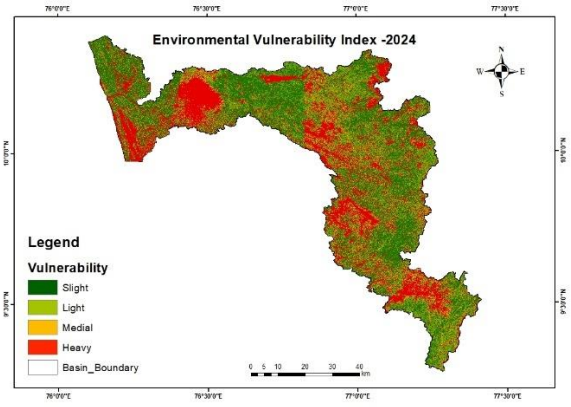

Figure 5 EVI for the year 2024

Cultivated agricultural lands, represented in light green, show moderate vulnerability, aligning with the medial vulnerability zones, likely due to the intensive use of chemicals, over extraction of water, and soil degradation. Sustainable practices, including organic farming, crop rotation, and efficient irrigation systems, are vital to mitigate this vulnerability. Uncultivated agricultural lands, in light green, exhibit vulnerability levels ranging from light to medial, indicating risks of soil erosion and degradation into barren land if left unmanaged. Conservation initiatives such as agroforestry and afforestation can rehabilitate these areas while improving ecosystem services. Dense vegetation, shown in dark green, corresponds with zones of slight vulnerability, underscoring the critical role of forests in buffering environmental stresses, maintaining biodiversity, and regulating hydrological cycles. These regions require robust conservation

measures, including the prevention of deforestation and community-based forest management, to preserve their ecological functions. Waterbodies, represented in blue (in the LULC classification), are subjected to light to heavy vulnerability due to factors like pollution, encroachment, and over extraction, emphasizing the need for strict water management policies, pollution prevention strategies, and the restoration of riparian buffers. Barren lands, marked in yellow, are strongly linked to heavy vulnerability, reflecting environmental degradation caused by erosion and vegetation loss. Immediate restoration efforts, such as soil stabilization, reforestation, and the conversion of these lands into productive areas, are necessary.

2.2 Urban expansion

The urban expansion of the Periyar River Basin and the tourism growth around Vembanad Lake are closely linked, alongside other drivers such as population growth, industrial development, and infrastructure expansion, shaping socio-economic and dynamics. Vembanad Lake, attracting over 1.6 million tourists annually, has driven infrastructure development that extends into the Periyar Basin, particularly in Kochi. This has spurred urban growth, with Kochi's urban population increasing by 185% between 1991 and 2020. Rising demand for residential and commercial spaces has led to a 15–20% decline in agricultural lands and wetlands, while built-up areas expanded from 7% in the early 1990s to over 20% by 2020 (Vishnu et al., 2024). Increased reliance on water resources has escalated pollution, with the Lower Periyar region showing a 45% rise in contaminants over two decades. The expansion of Kochi International Airport, handling 13 million passengers annually, has further fuelled unplanned growth. Environmental impacts include a 48% rise in surface runoff, projected to reach 65% by 2100, and reduced groundwater recharge, heightening flood risks, as seen in the 2018 and 2019 floods that affected over 1 million people and caused damages exceeding ₹30,000 crore (Jacob and Dwarakish, 2015). While tourism in Vembanad Lake does not directly drive Periyar Basin's urbanization, its indirect impacts highlight the need for integrated regional planning. Sustainable land use policies, eco-sensitive infrastructure, and coordinated water resource management are essential to balancing tourism and urbanization, ensuring long-term ecological and economic resilience.

2.3 Smart City Initiatives

The Smart City initiative in the Periyar River Basin, particularly centred around Kochi, represents a transformative urban development program aimed at improving infrastructure, enhancing quality of life, and fostering economic growth through the integration of smart

technologies. Launched as part of the Indian government's nationwide Smart Cities Mission in 2015, Kochi was one of the initial cities selected for this ambitious initiative. The Smart City Kochi project focuses on creating a sustainable urban ecosystem by addressing challenges such as traffic congestion, inefficient waste management, water scarcity, and inadequate housing. With a substantial investment of ₹2,000 crore (approximately $240 million), the program emphasizes a mix of retrofitting, redevelopment, and greenfield projects to ensure holistic urban renewal. Key interventions under the initiative include the development of smart transportation systems, such as the integration of the Kochi Metro with water transport and bus services, aimed at promoting sustainable mobility while reducing traffic-related emissions. The construction of state-of-the-art sewage treatment plants and the deployment of smart water meters are steps towards addressing water resource challenges, including the deterioration of water quality in the Periyar River due to untreated sewage. Another critical focus is enhancing waste management by introducing smart bins and waste-to-energy plants, which help to curb the issue of solid waste entering the river system. Urban flooding, a persistent challenge in the basin, is being tackled through the implementation of real-time flood monitoring systems and improved drainage networks.

Economic development is also a cornerstone of the Smart City initiative, with the creation of IT parks, such as the Infopark in Kakkanad, and the establishment of the Kochi Integrated Tourism Zone. These projects are designed to attract investments, create jobs, and boost tourism. Moreover, the Smart City initiative emphasizes green infrastructure, including the promotion of solar energy, rainwater harvesting systems, and urban greening projects, to enhance climate resilience and reduce the urban heat island effect (Source: https://smartcity-kochi.in/).

3. Water Supply Network Plan

The Water Supply Network Plan for the Periyar River Basin focuses on providing efficient and sustainable water distribution across Idukki, Ernakulam, and Thrissur and key strategies include optimizing the network, increasing storage capacity, and ensuring equitable access to clean water.

3.1 Water Source Management

Originating from the Sivagiri Hills in the Western Ghats at an altitude of about 1,830 m, the river flows westward for approximately 244 km before emptying into the Arabian Sea. Its basin, spanning an area of 5216 km^2, covers significant portions of Idukki, Ernakulam, and Thrissur districts and provides a crucial lifeline to the millions of people residing in these regions. The river's course is marked by diverse ecosystems, including forested catchments, agricultural lands, urban settlements, and wetlands such as the Vembanad Lake, a designated Ramsar site, location features of the Periyar river basin. Periyar River supports a wide range of uses, from providing drinking water to major cities like Kochi to irrigating extensive agricultural fields and supplying water for industrial operations in areas like Eloor and Edayar. The river water is also used for hydroelectric power generation, with the Idukki Hydroelectric Project being one of the largest and significant contributors to Kerala's energy grid. This multi-purpose utilization makes the Periyar an indispensable resource for the state's socio-economic development. This river plays a critical role in addressing Kerala's growing water demands. Large-scale drinking water supply systems, such as the Aluva Water Treatment Plant, draw directly from the Periyar to meet the needs of urban and suburban populations. Rural areas also benefit from community-managed water supply schemes under initiatives like Jalanidhi. In addition to domestic consumption, the river's waters sustain vast agricultural activities through the Periyar Valley Irrigation Project, which serves over 32,000 hectares of farmland. Industrial hubs along the river depend heavily on its waters for manufacturing processes and cooling systems. Despite its significance, the Periyar River faces numerous challenges that threaten its ability to sustain these functions. Pollution from industrial effluents and untreated sewage, coupled with over-extraction of water for agricultural and industrial purposes, has degraded its quality. Seasonal variability, driven by the monsoon-dependent flow, often leads to water shortages during dry months, and the effects of climate change have further exacerbated this problem. Disputes over sharing its waters, such as those involving the Mullaperiyar Dam, highlight the complexities of managing this vital resource.

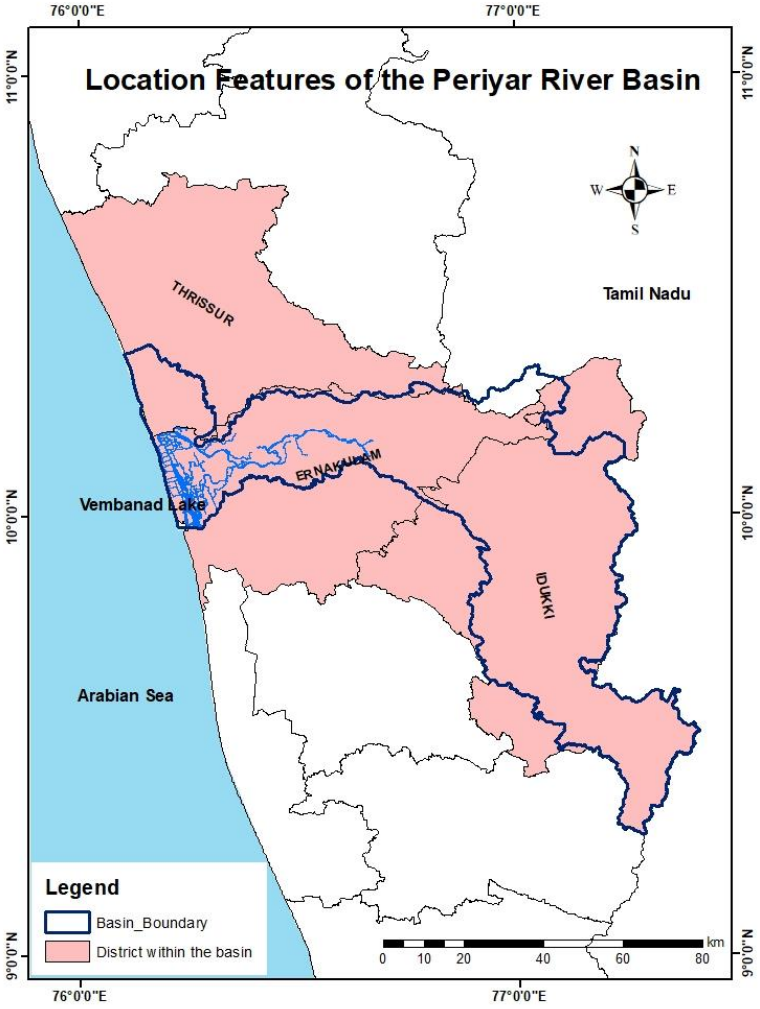

Figure 6 Location features of Periyar river basin

3.1.1 Water Supply Scheme by Jalanidhi in the Periyar River Basin

Jalanidhi water supply scheme in the Periyar River basin is a vital initiative designed to provide safe and reliable drinking water to households in the Vazhakkulam Gram Panchayat in Ernakulam district. Commissioned in January 2012 under the Jal Jeevan Mission, this large-scale gravity-based water supply scheme has been effectively catering to the needs of residents in wards 2 and 6 of the panchayat. Water supply system is sourced from the Periyar River, with the intake located at Marampally. The river serves as an abundant and dependable source, ensuring a steady supply of water without significant quality concerns. The collected water undergoes treatment and is distributed to households through an organized infrastructure that includes a pumping station and an overhead storage reservoir (OHSR) with a capacity of 100,000 L, situated in Cembaraky. The scheme is designed to cover 370 households, distributed

among various social categories: 150 Scheduled Castes (SC), 100 Scheduled Tribes (ST), and 120 general households. This inclusive approach ensures equitable access to clean water across different communities.

Infrastructure and Functionality

- *Pump House and Equipment:* Located at Marampally, the pump house and associated infrastructure, including a 4 HP pump set, are in good working condition. The panel board is well-maintained, ensuring uninterrupted operation.
- *Distribution System:* The water distribution network is functional, enabling efficient supply to the designated wards.
- *Storage Tank:* The overhead storage reservoir (OHSR) plays a crucial role in storing and managing the treated water supply. With a capacity of 100,000 liters, it supports uninterrupted water availability.
- *Disinfection Unit:* The disinfection unit is operational, ensuring that the distributed water is safe for consumption.
- *Water Meters:* Functional water meters aid in monitoring consumption, enhancing the scheme's efficiency and transparency.

The operation and management (O&M) of the scheme are overseen by a committee, with active participation from five individuals. The scheme demonstrates sound financial management, with an average monthly income of ₹15,000 and expenses of ₹10,000, resulting in a surplus of ₹5,000. This financial stability reflects the effective governance of the scheme by the beneficiary group (BG) (Jalanidhi, 2012).

3.1.2 Periyar Valley Irrigation Project

Launched in 1956, Periyar Valley Irrigation Project (PVIP) has evolved into a vital lifeline for agriculture, drinking water supply, and industrial needs in the Ernakulam district. With an extensive network of canals, barrages, and supporting infrastructure, PVIP sustains thousands of farmers, ensuring water distribution and contributing to the region’s economic stability. The project primarily relies on water stored at the PVIP Barrage in Bhoothathankettu, sourced from hydroelectric projects along the Periyar River, the independent catchment area below these projects, and the Idamalayar Hydroelectric Project. Its core objective is to irrigate approximately 32,800 hectares of agricultural land across six taluks—Kothamangalam, Muvattupuzha, Kunnathunadu, Aluva, Paravoor, and Kanayannoor. Additionally, PVIP

provides drinking and industrial water to the Greater Cochin area, mitigates high tides in the Periyar River, and supports lift irrigation schemes. At the heart of the project lies the PVIP Barrage at Bhoothathankettu, a 210.92 m long structure equipped with 15 shutters and a maximum floor level of 34.95 m. This barrage plays a critical role in regulating water flow into the canal system. Recent rehabilitation efforts under the Dam Rehabilitation and Improvement Project (DRIP) have led to the replacement of old shutters, the strengthening of barrage pillars, and the construction of a parallel bridge to reduce traffic congestion. The PVIP's canal network is an intricate system designed to distribute water efficiently across agricultural lands. The Main Canal, spanning 8 km, splits into two branches at Muthamkuzhi—the Low-Level Canal (LLC) extending 20.8 km and the High-Level Canal (HLC) covering 24 km. Primarily composed of earthen materials, the main canal has some concrete-lined sections; however, the absence of lining in certain areas has led to breaches and water loss, particularly affecting tail-end regions like Paravoor and Edappally. The LLC, the oldest and most significant canal in the system, supplies water to several branch canals, including Kottappadi, Kodanad East, Kodanad West, and Aluva. Over time, wear and tear, aging, and damage to its sides have reduced its efficiency, impacting water distribution to the farthest reaches. The HLC, initially lined with concrete, caters to areas such as Mazhuvannoor, Kizhakkambalam, Kolenchery, and Karukappilly. However, much of its structure has deteriorated over time, necessitating ongoing maintenance. In total, the PVIP comprises an extensive network of 685 km of branch and distributary canals, ensuring the irrigation of the designated 32,800 hectares of farmland.

3.1.3 Lift Irrigation Schemes

The **Periyar Valley Irrigation Project (PVIP)**, implemented under the Irrigation Department of Kerala, plays a vital role in supporting agriculture, drinking water supply, industrial use, and flood control in the Periyar River Basin. The project provides irrigation to approximately 32,800 hectares of farmland, contributing to increased agricultural productivity and improved water security across rural and urban areas. Notably, PVIP also includes lift irrigation schemes such as Methala, Eramalloor, and Kallil commissioned in 2011 that draw water from the High-Level Canal (HLC) to irrigate an additional 199 hectares in targeted zones.

Beyond agriculture, the PVIP supplies drinking water to the Greater Cochin region and provides industrial water to major establishments like the Fertilizers and Chemicals Travancore (FACT). The project also regulates high tides in the Periyar River, thereby preventing flooding in low-lying areas.

The infrastructure is maintained through a combination of state budget allocations and external support, such as the Dam Rehabilitation and Improvement Project (DRIP), which has recently funded critical upgrades including the replacement of barrage shutters, strengthening of pillars, and construction of a parallel bridge to reduce congestion. Administratively, the PVIP is managed by two divisions Division No. 1 at Perumbavoor and Division No. 2 at Aluva each overseeing multiple subdivisions and sections. Key operational areas like the barrage, main canal, and HLC fall under the supervision of Section No. 1/1 at Bhoothathankettu.

Despite its wide-ranging benefits, PVIP faces operational challenges such as aging infrastructure, inefficient earthen canals, and declining water flow in the Low-Level Canal (LLC) and HLC particularly affecting tail-end regions like Paravoor and Edappally. Addressing these issues through timely maintenance, modernization, and efficient water management is essential to sustaining the long-term impact of the project (Irrigation Department, Government of Kerala, 2024).

3.1.4 Mullaperiyar Dam

Mullaperiyar Dam is a historic structure located at the confluence of the Mullayar and Periyar rivers in Kerala, within the Periyar Tiger Reserve. Built during the British colonial period, it stands 155 feet high and 1200 feet long, and its construction in 1895 led to the creation of an artificial lake central to the reserve. The dam's primary purpose was to divert the waters of the west-flowing Periyar River eastward to Tamil Nadu, addressing the irrigation and drinking water needs of the rain-shadow districts, including Theni, Madurai, Sivaganga, and Ramanathapuram. This redirection also transformed arid lands in Tamil Nadu into fertile agricultural regions. The dam helped mitigate flooding in the Travancore region of Kerala. Over the years, the dam has played a vital role in water resource management, supporting irrigation across over 2,08,000 hectares and meeting the drinking water needs of several towns in Tamil Nadu (Department of Water Resources, River Development and Ganga Rejuvenation, 2024).

3.2 Pipeline Networks

Available pipeline networks in the Periyar river basin consist of a Drinking water supply system, an Industrial water supply, Water distribution system.

3.2.1 Drinking Water Supply Systems

Kochi Water Supply Scheme, one of Kerala's most critical water supply projects, draws water from the Periyar River at Aluva, which is subsequently treated at the Aluva Water Treatment Plant (AWTP). This plant, the largest of its kind in the state, processes a capacity of over 225 MLD to cater to the water demands of the rapidly growing urban population of Kochi as well as nearby suburban areas. The AWTP uses advanced filtration and chlorination processes to ensure the safe delivery of potable water to over 2 million people. Beyond Kochi, the river supports water supply systems in other towns and cities such as Perumbavoor, Muvattupuzha, and Kothamangalam, where smaller water treatment plants help meet local water demands, with the river continuing to serve as the primary source (KWA, 2022).

Kochi Water Supply Scheme

The Kochi Water Supply Scheme addresses the growing demand for water in Kochi Corporation and its surrounding municipalities and grama panchayats. It includes a modern 190 MLD capacity Water Treatment Plant (WTP) at Aluva, which draws raw water from the Periyar River and is currently operational. The project will modernize existing infrastructure, improve distribution networks, and meet future water requirements effectively. The existing water supply network includes four WTPs operating at KWA's Aluva headworks with a combined capacity of 225 MLD. Figure 7 shows the current operation of the systems, which are overburdened and producing 290 MLD (30% overload). Figure 8 shows the existing distribution system from the headworks at Aluva. Figure 9 shows the distribution system with the proposed 143 MLD Water Treatment Plant at Aluva.To address the challenges of overloaded systems and growing demand, the new 190 MLD WTP will integrate advanced treatment technology.

Components of the WTP:

- *Aerators*: Ensure oxygenation and removal of dissolved gases.
- *Flocculators and Clarifiers:* Facilitate sedimentation and removal of suspended particles.
- *Dual-Media Filters:* Provide enhanced filtration efficiency.
- *Disinfection Units:* Employ chlorination and UV methods for water safety.
- *Reservoirs and Pump Houses:* For effective storage and distribution.

Distribution Network

The enhanced distribution network will cover Kochi Corporation, Aluva, Thrikkakara, Kalamassery, Eloor, and Maradu municipalities, along with surrounding panchayats. The existing and proposed distribution routes are represented in Figure 10.

Key Challenges and Mitigation

The Periyar River faces several challenges in water management, including overloading of existing Water Treatment Plants (WTPs), leakage and inefficiencies in transmission lines, and rising water demand due to rapid urbanization. To address these issues, mitigation measures include constructing new WTPs with modern infrastructure, upgrading old pipelines to reduce water losses, and implementing strategic planning for equitable distribution, ensuring reliable supply to all areas, including tail-end regions.

Figure 7 Existing WTP complex at Aluva and proposed site (Source: KWA, 2022).

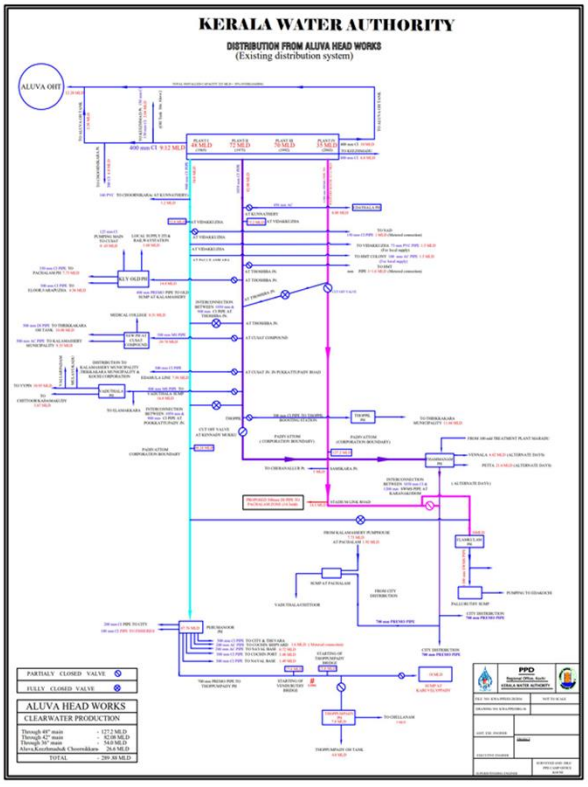

Figure 8 Existing distribution system from headworks at Aluva (Source: KWA, 2022).

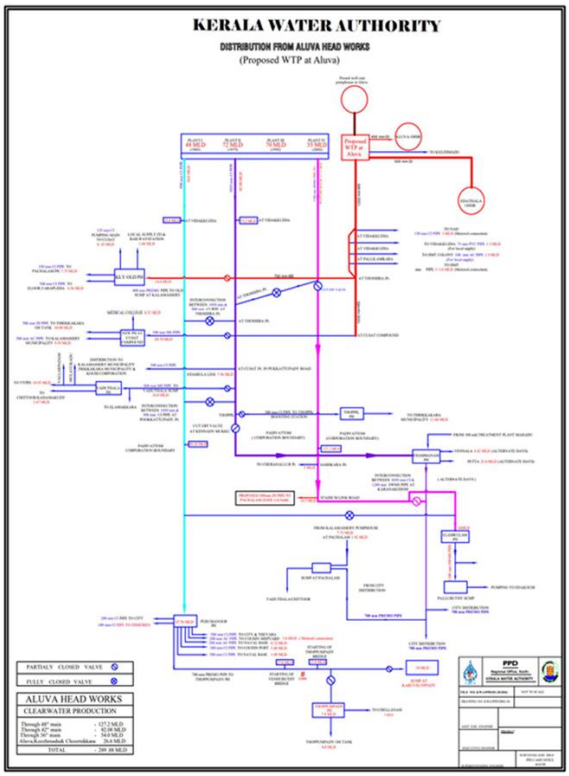

Figure 9 Distribution from Aluva (Source: KWA, 2022).

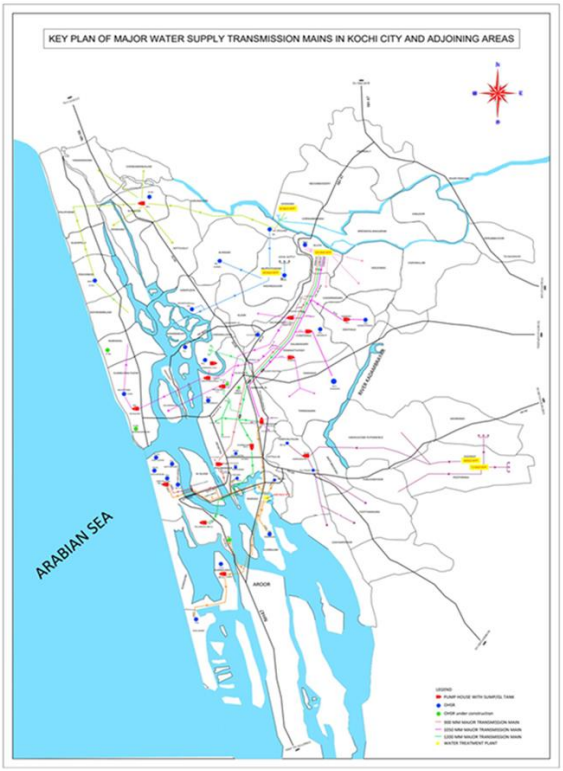

Figure 10 Key plan of major transmission lines in Kochi city (Source: KWA, 2022).

Aluva Region

For the Aluva region, the overhead reservoir within the proposed WTP will serve as a critical component in water distribution. The new pumping line from the WTP will ensure adequate supply to other grama panchayats, with a 1250 mm diameter MS pipeline delivering 96.72 MLD of treated water to Kalamassery, Thrikkakara, and Eloor areas.

Vypin Region

All tappings from the existing 1050 mm pipeline carrying water from the Aluva WTP will be disconnected to repurpose the line for Kochi's water needs, allowing it to supply 82 MLD of water to the Thammanam pump house. From there, 37.62 MLD will be allocated to the Vaduthala pump house to meet the demands of Nayarambalam, Njarakkal, Elamkunnappuzha (Vypin area), and Mulavukad grama panchayats. The 3.86 MLD demand for Kadamakkudi grama panchayat will be met by the Muppathadam WTP, while Cheranelloor grama panchayat and the Kunnumpuram division of Kochi Corporation will receive 12.25 MLD from city.

Ernakulam City Region

In Ernakulam city, nine distribution zones are planned, leveraging both existing and new reservoirs under the AMRUT projects. The load reduction on the 1050 mm CI pipeline, made

possible by the new Aluva WTP, will allow additional water to reach the Thammanam pump house for efficient use. The existing 1200 mm MS line will also function more effectively without reverse pumping operations. Plans include constructing new overhead tanks at Vennala, and Kaloor Quarters compound, along with a master sump at Kaloor, ensuring sufficient storage and distribution capacity.

Western Kochi Region

Currently, the Western Kochi region relies on the Maradu WTP, Perumanoor pump house, and Elamkulam pump house. Future plans focus on primarily serving this area from the Maradu WTP. Ten distribution zones are planned, supported by new overhead reservoirs at Edakochi and Karuvelippady under the AMRUT scheme, as well as effective utilization of existing reservoirs to address water stress in this region.

Maradu Region

The Maradu region's water needs are currently met by the existing 100 MLD WTP at Nettoor, Maradu. Enhancements to the raw water pump house and the incorporation of dual-media filters are expected to increase production by an additional 20 MLD, significantly boosting capacity for the region.

KWA Pipeline Road: Aluva to Kochi

KWA maintains a dedicated pipeline road connecting the Aluva WTP site to Kathrikkadavu Railway line in Kochi, spanning 20 km. Major pipelines of 900 mm, 1050 mm, and 1200 mm diameters supply water along this route. The initial 2.4 km stretch from the Aluva WTP to Nirmala School Junction features two roads (via Zeenath Theatre and Rose Nagar), each accommodating specific pipeline configurations. The remaining stretch accommodates all three pipelines, ensuring consistent and reliable water transmission to the city.

KWA Land at Aluva

A 1.57-hectare plot near the existing WTPs has been allocated for the new plant. This area, previously occupied by 43 staff quarters in poor condition, has been repurposed, with alternative accommodations provided to staff. The plot currently includes a 14-lakh-liter overhead reservoir (OHSR) constructed in 1981, serving Aluva Municipality's high-level zones. The new WTP design incorporates sludge blanket clarifiers with plate settlers and dual-media filters, optimizing space and efficiency. If needed, the old OHSR can be demolished, and a new reservoir installed above the filter house to save space. Proximity to the water body

simplifies sludge disposal, and existing infrastructure ensures cost-effective power connections (KWA, 2022).

3.2.2 Industrial Water Supply

The industrial belt along the Periyar River, particularly in regions like Eloor and Edayar, relies heavily on water drawn from the river for cooling and production processes. These areas are home to various industries, including petrochemicals, chemicals, and manufacturing plants, which require vast amounts of water for their operations. The river's water is used extensively in industrial cooling systems, as well as in the production of raw materials and finished goods. However, the significant water demand from these industries, along with their wastewater discharges, has raised concerns about water quality and availability, further highlighting the need for efficient water management practices and pollution control measures in these regions. Periyar River, which flows through the heart of Kerala, is home to an extensive industrial belt that spans across areas like Eloor and Edayar, regions that have become key industrial hubs in the state and are shown in Figure 11. The proximity of these regions to the Cochin Port, along with established infrastructure, has led to the rapid growth of a variety of industries. Eloor and Edayar are home to some of the most significant industrial facilities in Kerala. Key players in the region include:

- *Fertilisers and Chemicals Travancore Limited (FACT):* A prominent public sector enterprise located in Eloor, FACT produces fertilizers, chemicals, and petrochemicals, and remains one of the largest employers in the region.
- *Petrochemical and Chemical Plants:* A host of petrochemical industries operate in Eloor and Edayar, including companies involved in the production of polymers, rubber, and chemicals, which contribute to both domestic and international markets.
- *Metal and Alloy Processing Units:* Industries in the metal and alloy processing sectors play a vital role in the regional economy, with facilities producing essential materials for various construction and manufacturing industries.
- *Pharmaceuticals and Fertilizer Plants:* These plants, including some high-tech pharmaceutical manufacturing units, are part of the core industrial ecosystem, supplying essential products to both national and global markets.

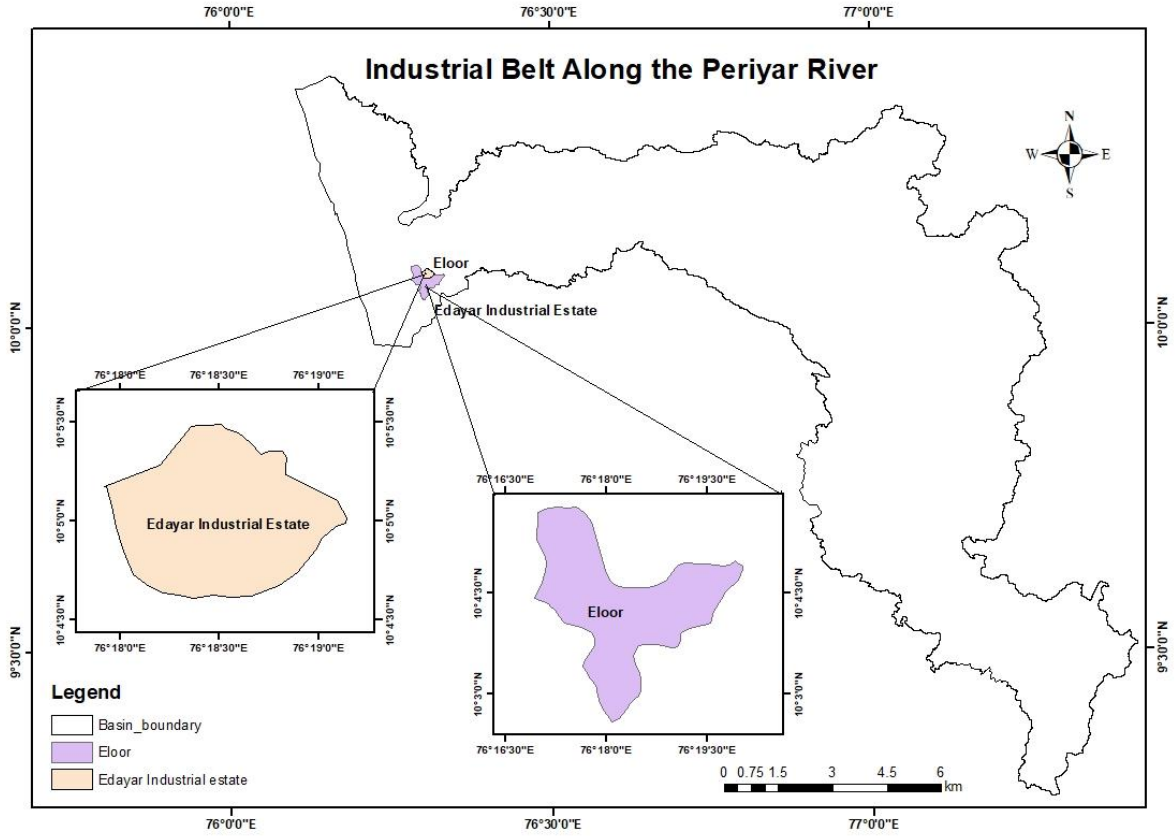

Figure 11 Industrial belt along the Periyar river basin

The industrial belt along the Periyar River has significantly contributed to Kerala's economy but has also led to severe environmental issues. Water pollution from industrial effluents, including heavy metals and toxic chemicals, has degraded the river despite effluent treatment plants (ETPs) being in place. Air pollution from emissions in Eloor and Edayar has led to respiratory diseases, while soil contamination from hazardous waste has impacted agriculture. Additionally, thermal pollution has disrupted aquatic ecosystems, reduced fish populations and threatened local livelihoods. Public health concerns, including respiratory diseases, cancer, and waterborne illnesses, have worsened due to prolonged exposure to industrial pollutants.

The economic expansion has caused displacement, loss of livelihoods for fishing communities, and water scarcity. In response, regulatory measures such as stricter pollution controls, common effluent treatment plants (CETPs), and environmental inspections have been implemented, though enforcement remains a challenge. To ensure sustainable growth, industries must adopt cleaner technologies, integrate renewable energy, and engage communities in environmental management. Restoration efforts, such as wetland rehabilitation and reforestation, are crucial for restoring the ecological balance of the Periyar River basin (Ambily and Menon, 2019; Balakrishnan et al., 2021).

3.2.3 Hydroelectric Projects

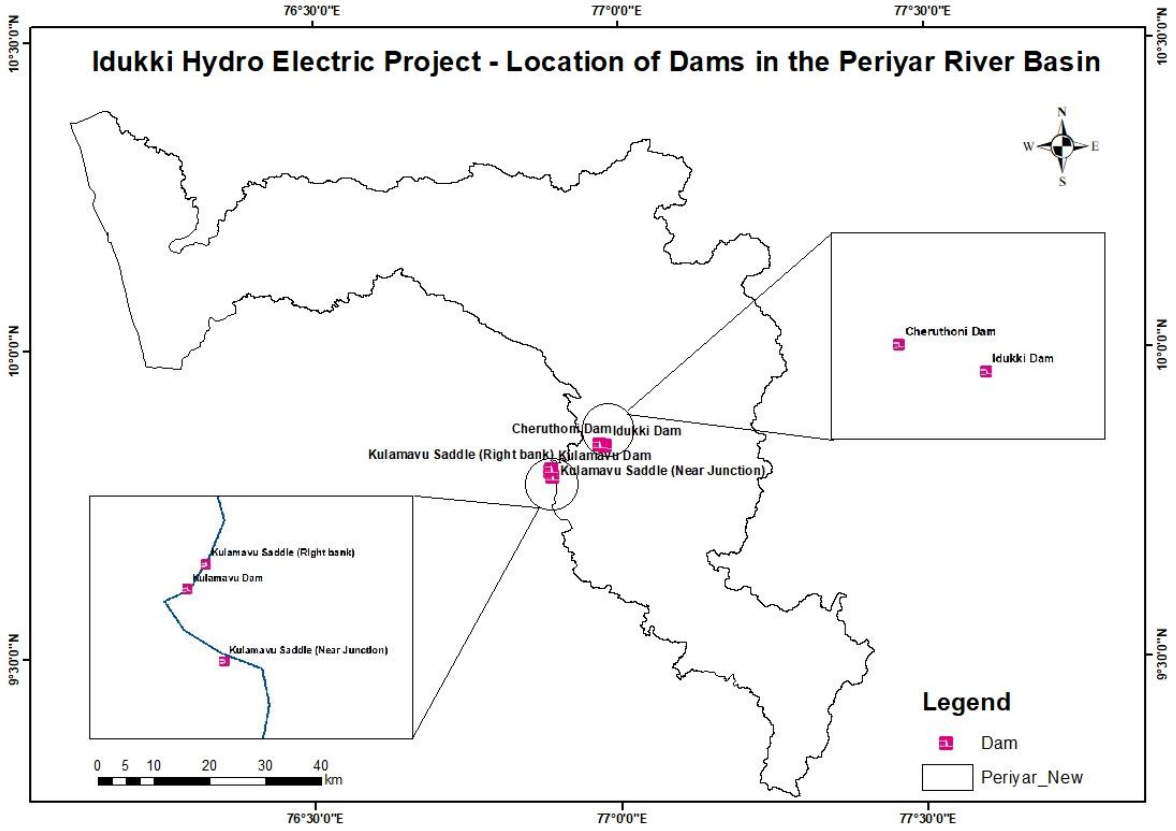

Figure 12 Idukki hydroelectric project -location details of Dam

The Periyar River plays a crucial role in Kerala's power generation through several hydroelectric projects, most notably the Idukki Hydroelectric Project (IHEP), the state's largest. Located in Idukki District, IHEP has an installed capacity of 780 MW and operates by harnessing the regulated flow of the Periyar River, stored in the Idukki Reservoir. The project utilizes three major dams the Idukki Arch Dam, Cheruthoni Dam, and Kulamavu Dam and was commissioned with technical consultancy from M/s Surveyor, Nenniger, and Chenevert and financial aid from the Government of Canada. It was inaugurated by Prime Minister Indira Gandhi on February 12, 1976. IHEP features an underground powerhouse, the largest cavern of its kind in India, measuring 141 m in length, 20 m in width, and 34.5 m in height, accessed via a 599-meter-long tunnel. The powerhouse houses six vertical Pelton turbines, each rated at 130 MW, designed to handle a high head of 660 m, with each unit discharging 25 cubic meters of water per second. These turbines drive salient pole synchronous generators operating at 375 RPM and generating at 11,000 volts. The project has an annual energy potential of 2148 million units (MU), with a catchment area of 640 km^2. The reservoir has a gross storage capacity of 1996.3 million cubic meters (MCM) and an effective storage of 1459.5 MCM at the Full

Reservoir Level (FRL) of 2403.6 feet, while the Minimum Drawdown Level (MDDL) is 2280 feet to ensure operational efficiency.

Electricity generated at IHEP is transmitted through a network of 220 kV and 66 kV feeders, ensuring reliable supply across Kerala. Major 220 kV feeders include Idukki Pallivasal (IDPV), Idukki New Pallom (IDNE), Idukki Kalamassery 1 and 2 (IDKL-1, IDKL-2), Idukki – Kothamangalam (IDKM), and Idukki – Lower Periyar 1 and 2 (IDLP-1, IDLP-2). Local distribution is supported by 66 kV feeders such as Moolamattom – Vazhathope (IDVZ), Moolamattom – Thodupuzha (IDKK), and Moolamattom – Malankara (IDML). The six generating units were commissioned between 1976 and 1986, with the first unit starting operation on February 12, 1976, followed by Units 2 and 3 later that year, and Units 4, 5, and 6 completed by 1986.

3.2.4 Irrigation Projects

The Periyar River is critical to agricultural activities in the region, with the Periyar Valley Irrigation Project (PVIP) being one of the key irrigation schemes in the basin. This project supplies water to approximately 32,000 hectares of agricultural land, primarily in the Idukki and Ernakulam districts. Water is distributed via a network of canals that draw from the river's flow, supporting the cultivation of various crops, including rice, vegetables, and cash crops like rubber and coconut.

3.2.5 Water Distribution System in the Periyar River Basin

Water is sourced primarily from the river and its tributaries, with an extensive network of reservoirs, canals, and treatment plants ensuring efficient distribution to urban and rural regions. Domestic water demand constitutes the largest share, driven by the needs of households for drinking, sanitation, and daily activities. Industrial water consumption, while comparatively smaller, is concentrated in specific zones and supports the region's economic and manufacturing activities. Commercial water use, encompassing businesses, institutions, and service sectors, adds another dimension to the basin's water distribution network. To address these diverse demands, the basin is divided into four primary water distribution divisions P.H Division, Kochi 18, Painavu and Muvattupuzha.

Distribution of Water Demand in the Periyar River Basin under the P.H Division, Aluva

Water demand in the Periyar River Basin under the Public Health (P.H) Division Aluva is distributed across three primary sectors namely domestic, industrial, and commercial. Domestic sector accounts for the highest water demand, measured at 86.473 MLD. This reflects the dependence of residential areas on the Periyar River Basin for essential daily needs, including, sanitation, and other household activities. Commercial sector, with a demand of 11.25 MLD, represents a much smaller share. This usage likely arises from businesses, institutions, and other service-based entities operating within the basin. While modest compared to domestic demand, it highlights the role of commercial activity in contributing to overall water consumption. Industrial sector shows the lowest water demand at 5.592 MLD, indicating limited industrial activity in the region or reliance on alternative water sources for industrial processes. The Periyar River Basin P.H Division, Aluva is divided into five subdivisions Aluva, Angamaly, Vadakkekara, Head Works, and Perumbavoor, and the location details are shown in Figure 13**.** Each subdivision manages the water supply and resources in its area.

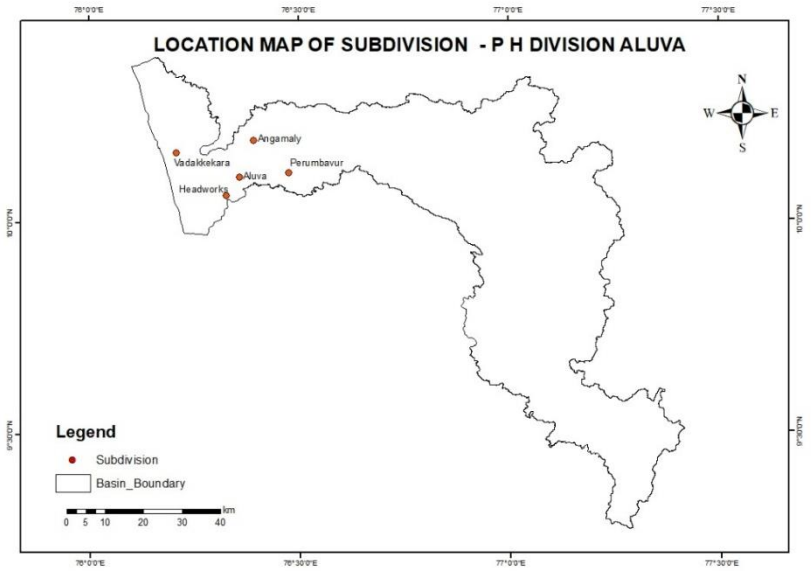

Figure 13 Location map of subdivision- P.H division Aluva

Aluva Subdivision

The water supply system in Aluva Subdivision is supported by a well-structured network of overhead tanks, sumps, pumping stations, and direct connections from the Water Treatment Plant (WTP) in Aluva. This infrastructure ensures water distribution across municipalities and panchayath. Water storage facilities in the Aluva subdivision include multiple overhead tanks (OHT) and sumps with varying capacities, ensuring efficient water distribution across different

administrative areas. The Aluva OHT, with a capacity of 16 L, serves the Aluva Municipality, while the Keezhmadu OHT, with a 22 LL capacity, supplies water to Keezhmadu and Edathala Panchayaths. The Kodikuthumala OHT, also with a 22 LL capacity, caters to Edathala and Choornikkara Panchayaths. Additionally, the Thevakkal OHT, with a 0.3 LL capacity, and the Compara Sump, with a 22 LL capacity, provide water storage for Edathala Panchayath. The Kailas Colony Sump, with a capacity of 1 LL, also serves Edathala Panchayath. In addition to these storage facilities, water is directly supplied from the Aluva Water Treatment Plant (WTP) to Choornikkara Panchayath, ensuring a streamlined and effective distribution network. Despite having a well-established water supply network, the subdivision lacks a sewerage system. There are no household connections, and no information is available on interception or diversions. This gap highlights an area for immediate attention to improve waste management and sanitation. Overall, the water supply system in the Aluva Subdivision demonstrates an organized distribution network, the lack of sewerage infrastructure and quality data on discharges highlights areas for improvement in integrated water resource management. Aluva subdivision houses two key pumping stations Compara Pump House and the Kailas Colony Pump House, both of which are operational and integral to the water supply network. However, the lack of recorded data on domestic and industrial drains, including discharge volumes and quality, highlights a significant gap in wastewater management and environmental monitoring, posing a challenge for effective resource management.

Angamaly Subdivision

The water supply system in Angamaly Subdivision is supported by a comprehensive network of Water Treatment Plants (WTPs), Overhead Storage Reservoirs (OHSRs), Ground-Level Storage Reservoirs (GLSRs), and pumping stations. This infrastructure ensures the distribution of treated water across Angamaly Municipality and several panchayaths. The subdivision has multiple water storage facilities, including OHSRs, GLSRs, and sumps, strategically positioned to serve various administrative areas. These facilities ensure a reliable water supply for residential, commercial, and industrial users. The Angamaly OHSR, with a capacity of 16 LL, caters to Angamaly Municipality, while the Pothiyakkara OHSR, with a capacity of 7.90 LL, serves Thuravoor, Kalady, Malayattoor, and Neeleswaram areas. The Chowara OHSR, with a substantial capacity of 630 LL, supplies water to Paravur Municipality and its adjoining panchayaths, while the Chowara OHSR (H.W Section), with 135 LL capacity, serves Sreemoolanagaram, Kanjoor, Parakkadavu, Chengamana, Kunnukara, and Nedumbassery panchayaths. For Ayyampuzha Panchayath, the Kunthiri GLSR and Thanikkodu GLSR have

storage capacities of 1.5 LL each, while an additional Thanikkodu GLSR holds 0.6 LL. The Ambaalappara GLSR, with a 1 LL capacity, and the Uppukallu Sump, with a 2.5 LL capacity, further support the water distribution in the region. Manjapra Panchayath is served by the Marigiri OHSR with a 5 LL capacity, whereas the Illithodu GLSR, with 6.17 LL capacity, caters to Malayattoor Panchayath. This well-structured infrastructure ensures efficient water distribution, addressing the needs of different communities within the subdivision. Angamaly Subdivision lacks a sewerage system. This subdivision houses several pumping stations located at Angamaly Office Compound, Pothiyakkara WTP Compound, Marigiri, Ambaalapuram, Uppukallu, Thanikkodu, Illithodu, and the H.W Section Chowara WTP. These stations are integral to the smooth functioning of the water supply network.

Vadakkekara Subdivision

The water supply system in Vadakkekara Subdivision is supported by a network of WTPs, OHSRs, and pumping stations that ensure water distribution to multiple panchayaths. The subdivision receives treated water from two key WTPs located at Chowara with capacities of 63 MLD and 13.5 MLD. Vadakkekara Subdivision is equipped with multiple OHSRs strategically placed to serve different administrative areas. This well-structured storage network ensures the efficient supply of treated water to residential and administrative regions. Despite having a robust water supply network, the Vadakkekara Subdivision lacks a sewerage system, with no household connections or available data on interception or diversions. The water storage and distribution infrastructure in this subdivision includes several OHSRs catering to different panchayaths. The Thiruvilamkunnu OHSR, with a capacity of 7 LL, serves Nedumbassery Panchayath, while the Chengamad OHSR, with a capacity of 0.5 LL, supplies water to Chengamadu Panchayath. The Malayikunnu OHSR, with a 3.5 LL capacity, serves Kunnukara Panchayath, and the Puliyanamkunnu OHSR, with a substantial 45 LL capacity, supports Parakadavu Panchayath. Additionally, the Alamthuruth OHSR, with a capacity of 5 LL, supplies water to Vadakkekara and Chittattukara Panchayaths. Despite the well-structured water storage system, the lack of a sewerage network remains a major infrastructure gap in the subdivision. Vadakkekara subdivision has two key pumping stations located at Moozhiyal and North Paravoor, which are operational and integral to the water supply system.

Head Works Subdivision

Head Works subdivision is equipped with a Water Treatment Plant (WTP) at Aluva with a capacity of 225 MLD, which supplies water to Keezhamad and Choornikkara Panchayaths. Aluva WTP serves as the primary facility for water treatment and distribution within the

subdivision. The treated water is distributed to the service areas of Keezhamad and Choornikkara Panchayaths, ensuring a reliable water supply to residential and administrative regions. Head Works Subdivision lacks a sewerage network, with no household connections or information on interception or diversions. This gap represents a critical challenge in wastewater management and sanitation. Head Works Subdivision has its primary pumping station located at Aluva, which is crucial for maintaining the water supply network's efficiency.

Perumbavoor Subdivision

Perumbavoor Subdivision sources its water primarily from the Periyar River and wells that depend on the Periyar Valley Irrigation Project (PVIP) canal, which is PVIP-fed. The subdivision operates multiple WTPs and an extensive network of storage reservoirs and pumping stations, ensuring water distribution to municipalities and panchayaths. Perumbavoor Subdivision's water storage and distribution infrastructure includes (OHSRs), Ground-Level Storage Reservoirs (GLSRs), and tanks connected to various WTPs. This infrastructure ensures efficient water distribution across the subdivision, addressing the needs of both residential and administrative areas. Perumbavoor Subdivision lacks a sewerage system, with no household connections or interception mechanisms in place. Perumbavoor Subdivision operates several pumping stations, including the Panamkuzhi Pump House, which is integral to water distribution. However, there is no recorded data on domestic and industrial drains, their discharge volumes, or quality. This absence of information indicates a critical gap in wastewater and drainage management.

The Perumbavoor Subdivision has a well-developed water storage and distribution infrastructure, supported by multiple water treatment plants (WTPs) and storage facilities catering to various panchayaths and municipalities. The Perumbavoor WTP, with a capacity of 2.50 MLD, supplies water to the Peechanamugal Tank (8 LL), which serves Rayamangalam Panchayath. The Kunnakkatumala WTP, with a 6 MLD capacity, caters to Okkal Panchayath. The Cheranalloor WTP, with a capacity of 7.50 MLD, supplies water to the Mayoorapuram OHSR (14 LL) and Kaiyyuthiyal GLSR (9 LL), which serve Koovappady Panchayath. The Kanjirakkadu WTP, with a capacity of 10 MLD, distributes water to the Chundamala Tank (12.5 LL) for Vengola Panchayath and a 10 LL OHSR at the Perumbavoor Office Compound for Perumbavoor Municipality. The Chembarky WTP, the largest in the subdivision with a 25 MLD capacity, supplies water to the Poyyakunnam OHSR (24 LL) and Chembarky OHSR (14.70 LL), serving Vazhakkulam, Kizhakkambalam, and Kunnathunadu Panchayaths. Additionally, the Panamkuzhi Pump House supplies water from the Vakkuvally Tank (0.45

MLD) to parts of Vengoor and Mudakkuzha Panchayaths, ensuring a comprehensive and efficient water distribution system.

Distribution of Water Demand in the Periyar River Basin under Kochi-18

Water demand in the Water Supply Division, Kochi-18, is divided among three sectors: domestic, commercial, and industrial. The domestic sector accounts for the highest demand at 641.47 MLD, reflecting extensive residential coverage and reliance on centralized water supply for essential daily needs. The commercial sector, with a demand of 29.95 MLD, includes usage by businesses, institutions, and service establishments, highlighting its role in supporting regional economic activities. The industrial sector has the lowest demand at 9.324 MLD, indicating limited industrial presence in the area. The disparity in demand across sectors underscores the dominance of residential consumption in Kochi-18.

Paravoor Subdivision

Paravoor Subdivision consists of mainly three sections Muppathadom Section, Njarakkal Section and Paravoor Section.

a) Muppathadom Section

Muppathadom Section relies on the Periyar River as its primary source of water. The water distribution system in this section is supported by multiple Overhead Tanks (OHTs) and sumps, ensuring a consistent supply to residential and administrative regions. Water storage facilities in the Muppathadom Section include OHTs and sumps located at various points to serve the administrative boundaries of Alangadu, Karumaloor, Kadungalloor, and Varappuzha Panchayaths. Muppathadom Section lacks a sewerage network. No household connections or facilities for wastewater interception and diversion are available. This Section has a well-structured water storage and distribution infrastructure, ensuring efficient water supply across various panchayaths. The Kunnel Overhead Tank (OHT), with a capacity of 18 LL, serves Alangadu and Karumaloor Panchayaths, while the UC OHT, with a capacity of 8 LL, supplies water to Kaumaloor, specifically the Millupady and Thadikkadavu areas. The Kadungalloor OHT, also with an 8 LL capacity, caters to Kadungalloor Panchayath. Additionally, the CWPH Sump, with a 10 LL capacity, supports water distribution in Karumaloor, Alangadu, and Kadungalloor. The GIDA (Goshree Islands Development Authority) Varappuzha – Kadamakudy Sump, with a capacity of 3 LL, ensures water availability for Varappuzha and Kadamakudy Panchayaths, reinforcing a reliable and efficient supply network in the region. The primary pumping station in the Muppathadom Section is located at Section No. 1, Muppathadom

(b) Njarakkal Section

Njarakkal Section is dependent on the Periyar River for its water supply. It features a network of Overhead Service Reservoirs (OHSRs) and Ground Level Storage Reservoirs (GLSRs) to meet the water demand across its administrative boundaries. The Njarakkal Section faces a similar situation to Muppathadom, with no sewerage network or associated infrastructure. The Edavanakkad Aniyil OHSR, with a capacity of 11.15 LL, serves Edavanakkad Panchayath, while the Malippuram OHSR, with a capacity of 13.80 LL, caters to Elamkunnapuzha and Njarakkal Gram Panchayaths. The Murikkumpadam OHSR, with a storage capacity of 11.80 LL, supplies water to Elamkunnapuzha Panchayath. Additionally, the Njarakkal OHSR, with a capacity of 17.90 LL, serves Njarakkal Panchayath, and the Puthuvypu GLSR, the largest in the section with a 50 LL capacity, supports water distribution to both Elamkunnapuzha and Njarakkal Gram Panchayaths, ensuring a reliable and consistent water supply. The Njarakkal Section has three operational pumping stations ensuring efficient water distribution across different gram panchayaths (GP). These include the Puthuvypu Pump House in Elamkunnapuzha GP, the Nayarambalam Pump House in Nayarambalam GP, and the Karithala Pump House in Pallippuram GP. Despite the well-established water supply infrastructure, there is no available data on the discharge or quality of wastewater from domestic or industrial drains, posing significant challenges for effective environmental management and wastewater treatment in the region.

(c) Paravoor Section

The Paravoor Section relies on the Periyar River as its primary water source and is supported by GLSRs and OHSRs to ensure efficient distribution across various municipalities and panchayaths. The storage infrastructure includes a GLSR with a capacity of 28.9 LL, serving Paravoor Municipality along with Ezhikkara, Kottuvally, and Chendamangalam Panchayaths. Another GLSR, with a capacity of 16 LL, supplies water to Paravoor Municipality and its adjoining areas. Additionally, a 14.4 LL OHSR located at the KWA Office Compound in North Paravoor further strengthens the distribution network, ensuring a reliable water supply to the region. Similar to the other sections, the Paravoor Section lacks sewerage infrastructure, with no household connections, interception facilities, or diversions. The main pumping station for this section is located at the KWA Office Compound in North Paravoor. However, as with the other sections, there is no data on wastewater discharge volumes or quality, which limits efforts toward effective environmental management.

Distribution of Water Demand in the Periyar River Basin under P.H Division, Painavu

P. H division Painavu consists of two subdivisions Painavu and Peermade subdivision, location map is shown in Figure 15. Location map of subdivision and section – W.S division Kochi -18 shown in Figure 14.

Painavu Subdivision

Painavu Subdivision primarily relies on the Periyar River as its main water source. The water demand is divided among domestic (4.2 MLD) and commercial needs (0.8 MLD), while industrial water demand is recorded is not available. Painavu Subdivision maintains a robust storage and distribution network comprising WTPs, OHSRs and sumps. These facilities serve various administrative areas. The Painavu Subdivision has a well-established water storage and distribution system, ensuring reliable supply across multiple areas. The WTP Old Tank, with a capacity of 1.8 LL, serves Cheruthonni to Kesamuni and Vellakkayam, while the WTP New Tank, with a larger capacity of 3.2 LL, supplies water from Cheruthonni to Paramavu and Vellakkayam. The Gandhi Nagar Tank, with a capacity of 1 LL, caters to the Gandhinagar to Mariyapuram region. Additionally, the Kurishumala Sump, with a 1.5 LL capacity, supports water distribution from Painavu to Paremavu and Tannikkandam. The Microwave storage facility, with a 2.5 LL capacity, serves Kuyilumala to Painavu, while the Kesamuni Tank (2.23 LL) supplies water from Kesamuni to Vazhathope. The Oxford Tank, with a 2.96 LL capacity, ensures distribution from Oxford Kavala to Karimban. Lastly, the Vallikettikavala Tank, with the highest capacity of 3.9 LL, supports water supply from Bhoomiyamkulam to Maniyarankudi, strengthening the overall distribution network in the region. This subdivision lacks a dedicated sewerage system, with no household connections or available information on wastewater interception or diversions. Pumping stations function as part of the existing storage infrastructure. The absence of data on domestic and industrial drains, including discharge volumes and quality indicates limited attention to wastewater and drainage management.

Peermade Subdivision

Peermade Subdivision primarily relies on the Periyar River as its main water source, supported by multiple pump houses and water treatment facilities. The domestic water demand is 18 MLD, with no recorded demand for industrial or commercial use. The water supply infrastructure includes several pump houses and treatment plants that ensure reliable distribution across the region. Notable facilities include the Haileburiya Pump House/Plant (9.50 MLD), Kumily Source Pump House/Plant (4.75 MLD), and Vandiperiyar Pump House/Plant (1.75 MLD). Additional support is provided by the Marykulam (0.70 MLD),

Upputhara (0.43 MLD), Pasuppara (0.24 MLD), Puliyanmala (0.19 MLD), and Vandanmedu (0.21 MLD) pump houses. These collectively meet the subdivision's domestic water needs. Despite a well-structured water distribution network, Peermade lacks a dedicated sewerage system, household connections, or data on wastewater interception and diversions. Furthermore, there is no available information on domestic and industrial drains, including their discharge volumes and quality, indicating limited attention to wastewater management in the region.

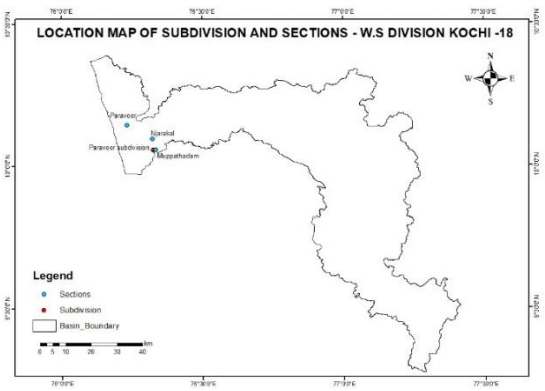

Figure 14 Location map of subdivision and section – W.S division Kochi -18

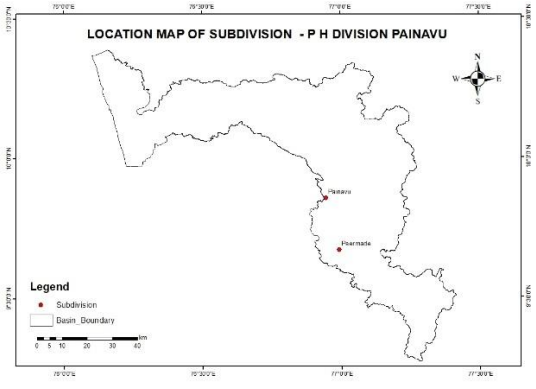

Figure 15 Location map of subdivision -P. H division Painavu

Distribution of Water Demand in the Periyar River Basin under the P.H Division Muvattupuzha

a) ARWSS to Kuttamangalam-Neriyamangalam Section

The Augmented Rural Water Supply Scheme (ARWSS) to Kuttamangalam-Neriyamangalam Section relies on the Periyar River. Its infrastructure includes a Water Treatment Plant (WTP) at Avolichal (325 LL capacity) and multiple Ground Level (GL) tanks: Kottarammay (2.2 LL), Villamchira (4.1 LL), and Neriyamangalam (0.25 LL), ensuring efficient distribution. The system serves 3,536 domestic, 176 non-domestic, and four special connections, with no industrial connections. Wastewater management is limited, mainly covering domestic users. The primary pumping station at Avolichal supports supply efficiency. Expansion is needed to meet future demand and enhance wastewater management.

b) RWSS to Pindimana Section

The Rural Water Supply Scheme (RWSS) for the Pindimana Section is sourced from the Periyar River. The infrastructure includes a 3.5 MLD Water Treatment Plant at Malippara, supported by a sump and a GL tank to ensure efficient distribution. The RWSS to Pindimana Section features a well-structured water storage and distribution system, ensuring efficient supply to the region. The WTP at Malippara, with a capacity of 350 LL, serves the Pindimana Panchayath, while the GL Tank at Malippara, with a storage capacity of 0.5 LL, and the Sump

at Malippara, with a capacity of 8 LL, support water distribution within Malippara Panchayath. The section also has a limited sewerage system, consisting of 3,551 domestic connections and 111 non-domestic connections. There are eight special connections, but no industrial connections, highlighting the need for potential expansion to accommodate future wastewater management requirements. The primary pumping station for this section is located at Malippara.

c) RWSS to Kottappady Section

The RWSS to Kottappady Section sources its water from the Periyar River, utilizing a 2.95 MLD Slow Sand Filter (SSF) Plant at Kannakkada and a 1.72 LL Overhead Tank (OHT) at Kallumala to ensure efficient distribution within Kottappady Panchayath. The section also has a well-established sewerage system, comprising 3,779 domestic connections, 116 non-domestic connections, and 101 industrial connections. Additionally, there are 176 special connections, indicating a broader service coverage. The water supply and wastewater management in this section are further supported by a dedicated pumping station located at Plamudy.

d) RWSS to Keerampara Section

The Keerampara Section relies on the Periyar River as its primary water source, supported by a 1.5 MLD Slow Sand Filter (SSF) Plant at Punnekad and a 1.75 LL Ground-Level (GL) Tank, ensuring efficient water distribution within Keerampara Panchayath. The sewerage system in this section includes 2,073 domestic connections and 101 non-domestic connections, with four special connections. However, there are no industrial connections, indicating a focus on residential and small commercial wastewater management. Water supply and wastewater handling in the region are further supported by the main pumping station located at Thattekad.

3.3 Water Treatment Plants

Water treatment plants purify raw water from sources like rivers and lakes to provide safe, clean water for communities.

3.3.1 Water Treatment Plant at Aluva

The Aluva Water Treatment Plant, managed by the Kerala Water Authority, is the largest of its kind in Kerala with a capacity of 310 MLD, playing a crucial role in supplying safe and clean water to Aluva, Ernakulam, and surrounding areas.

4. Sewerage and Drainage Network Plan

The Sewerage and Drainage Network Plan focuses on managing wastewater and stormwater in the Periyar River Basin, addressing water pollution, urban flooding, and public health.

4.1 Sewerage system mapping

Kerala Water Authority (KWA) has carried out a preliminary investigation to determine the coverage area for the proposed sewerage network in Ernakulam and Idukki districts. The investigation considered several influential parameters to guide the decision-making process for sewerage network planning. These parameters include expected population density, geographical classification based on topographical features, urbanization factor, proximity to water bodies.

Sewerage and STP Network in Ernakulam District (Periyar River Basin)

The existing sewage treatment infrastructure in Ernakulam district consists of a single STP located in Elamkulam, part of the Kochi Sewerage System. This facility has a capacity of 4.5 MLD, supported by a 28 km sewer network with 650 manholes, but serves only 5% of the city area. Furthermore, it is situated outside the Periyar River Basin and does not address the wastewater treatment needs within the basin. In response to these gaps, a comprehensive sewerage and STP network has been planned under the Periyar River Basin to serve an area of 374.6 km² and a population of 12,08,318 across 55 local bodies. The network includes multiple STPs with capacities ranging from 1.6 MLD to 17.9 MLD, strategically located in zones such as Edavanakkad, Vadakkekara, and Alangad. Effluent discharge will be directed into nearby water bodies, including the Periyar River and associated canals like Manjaly Thodu and Perandoor Canal, ensuring effective treatment and ecological balance. The largest STP in Vadakkekara will serve 150,712 people, while smaller plants address the needs of focused areas. The planned network represents a significant improvement over the current system by expanding coverage, increasing treatment capacity, and addressing the specific needs of the Periyar River Basin. It aims to enhance sanitation, support ecological restoration, and provide sustainable wastewater management for Ernakulam district. Plan for LSGIs proposed with STPS and sewage network – Ernakulam.

The sewage treatment infrastructure across various zones in Ernakulam is designed to cater to a population of 1,208,318 through a total treatment capacity of 140.5 MLD (Million Liters per Day). These treatment plants discharge effluents primarily into the Periyar River, along with Manjaly Thodu, Kuzhuppilly Thodu, Appangad Canal, Onjithodu, Thodu, and Perandoor Canal. The largest STP, with a capacity of 17.9 MLD, is located in Vadakkekara, serving a

population of 150,712 across 26.72 km². Other major plants include those in Alangad (16.2 MLD, 147,284 population), Edathala (14.2 MLD, 132,148 population), and Njarakkal (13 MLD, 124,728 population). The smallest STPs are in Kalamassery (1.6 MLD, 9,614 population) and Choornikkara (2.9 MLD, 23,333 population). The Edavanakkad STP (10.3 MLD) serves multiple local bodies, including Kuzhuppilly and Pallippuram, covering 28.17 km² and a population of 98,816. Similarly, the Kanjoor STP (11.9 MLD) supports Kalady, Sreemoolanagaram, and surrounding areas over 46.78 km², covering 109,581 people. The Eloor STP (11.3 MLD) discharges into the Periyar River, treating sewage from Eloor and Cheranalloor, benefiting 86,245 people. Additionally, some locations such as Puthenvelikkara, Neeleeswaram, Kuttampuzha Vadattupara, and Kadamakkudy Kothad lack documented STP capacities but still contribute to sewage treatment efforts. The Edappally STP (11.1 MLD), serving Kochi-Kaloor and Pachalam, discharges into the Perandoor Canal, covering 7.19 km² and 68,760 people.

Planned Sewerage and STP Network in the Periyar River Basin for Idukki District

The sewerage and STP network planned for the Periyar River Basin in Idukki District covers 160.47 km^2, serving a population of 91,413. It is divided into key regions with dedicated STPs for efficient wastewater management. Region 1 (Munnar and Devikulam) spans 80.4 km^2, serving 28,701 people, with an STP at Munnar (1A) discharging effluent into the Muthirapuzha River to reduce pollution in this environmentally sensitive area. Region 3 (Kattappana, Erattayar, and Kamakshi) covers 80.07 km^2, serving 62,712 people, with an STP at Kattappana (3A) discharging into a local Thodu connected to the Periyar River, ensuring proper wastewater treatment for Kattappana Municipality and adjoining panchayats.

STP at Elamkulam

Sewage Treatment Plant (STP) at Elamkulam, Kochi, operates using Moving Bed Biofilm Reactor (MBBR) technology, a proven and efficient method for wastewater treatment. With a design capacity of 5 MLD (Million Litres per Day), the plant currently processes 4 to 4.5 MLD during dry periods, translating to a flow rate of approximately 208.33 cubic meters per hour. This level of utilization highlights the critical role of the facility in managing sewage and ensuring environmental protection in the region. The quality of the treated sewage meets stringent standards, ensuring that the effluent discharged into the receiving water body, the Chettichira Canal, is of high quality and environmentally safe. Key quality parameters for the treated effluent include a Biochemical Oxygen Demand (BOD) of 10 mg/l or lower, Suspended

Solids of up to 30 mg/l, and a Chemical Oxygen Demand (COD) of 100 mg/l. The plant also ensures that E. Coliforms are limited to 1 x 10^3 MPN per 100 ml, reflecting effective disinfection processes. The treated sewage maintains low nutrient levels, with Total Nitrogen (as N) less than 10 mg/l and Total Phosphorus (as P) below 2 mg/l, minimizing the risk of nutrient pollution in the receiving water body. The pH of the effluent is maintained within the range of 6 to 9, ensuring it is neither acidic nor alkaline, further supporting safe discharge. The treated effluent is odourless, free from oil, grease, and any obnoxious matter, making it environmentally non-disruptive. The sludge produced during the treatment process is described as in-offensive in odour and easily drainable, facilitating effective sludge management. However, the plant reports no sludge generation, further simplifying operational management. The Chettichira Canal, the designated receiving water body, benefits significantly from the high-quality treated effluent discharged from the Elamkulam STP. Existing Sewerage Treatment Plant in Idukki shown in Table 2 & Table 3 shows the Plan for LSGIs proposed with STPs/ FSSM (Faecal Sludge and Septage Management) and sewage network in Idukki. Proposed Sewerage System Map of Periyar River Basin shown in Figure 16.

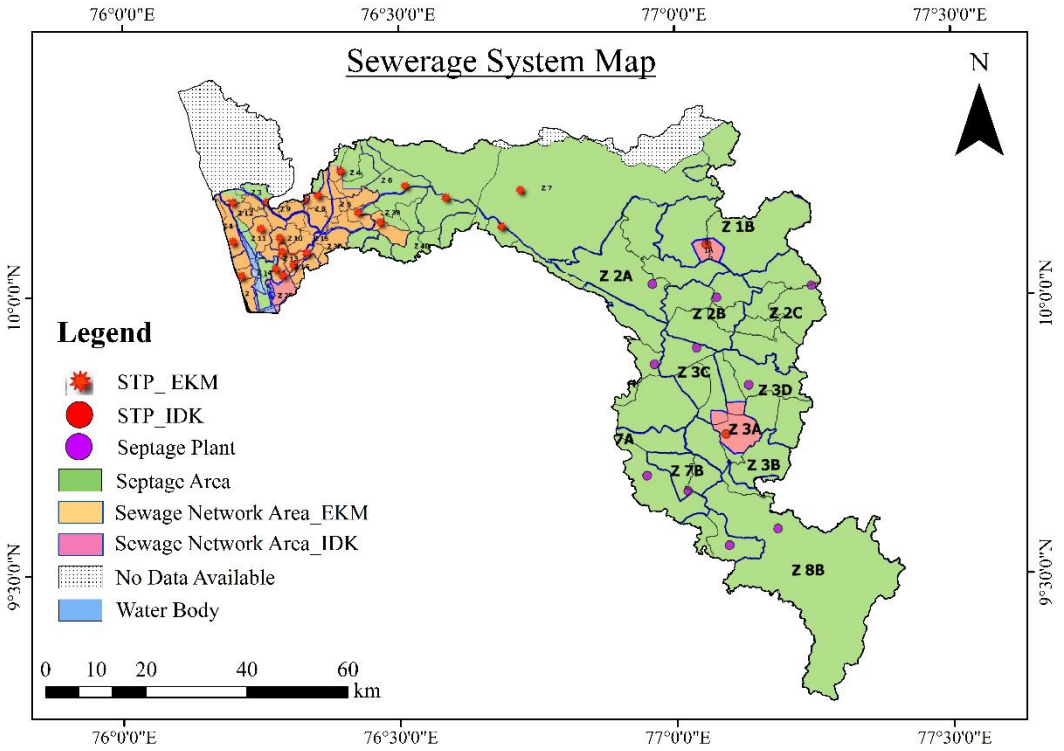

Figure 16 Proposed Sewerage System Map of Periyar River Basin (Source: Comprehensive district sewerage plan for Ernakulam district, Kerala & Comprehensive plan for sewerage/septage management in Idukki district, Kerala,2020 and 2021

Table 2 Existing Sewerage Treatment Plant- Idukki (Source: Suchitwa Mission,2020)

Block	Name of the local body	No. of wards	Total houses	Total Institutions	Number of STPs
Nedumkandam	Karunapuram	17	6845	350	0
	Pampadumpara	16	5155	320	0
	Rajakumari	13	5060	385	0
	Rajakkadu	13	4222	678	0
	Nedumkandam	22	12920	2320	0
	Udumbanchola	14	6483	453	0
	Senapathi	13	3428	190	0
Idukki	Kanjikuzhi	18	6842	326	0
	Vathikudy	18	6750	680	0
	Arakkulam	15	4650	300	0
	Mariyapuram	13	4100	383	0
	Vazhathoppu	14	7326	670	0
	Kamashi	14	5125	240	0
Azhutha	Vandiperiyar	23	10536	920	0
	Elappara	17	5354	874	0
	Peruvanthanam	14	3546	318	0
	Kumali	20	8072	1413	0
	Peermade	17	6229	303	0
	Kokkayar	13	2509	68	0
Kattappana	Erattayar	14	5030	495	0
	Vandanmedu	18	No	803	0
	Chakkupallam	15	6200	638	0
	Kattappana	34	14000	3600	0
	Ayyappankovil	13	4091	350	0
	Kanchiyar	18	7500	650	0

	Upputhara	18	8000	750	0
Adimali	Mariyapuram	21	14429	139	1

Table 3 Plan for LSGIs proposed with STPS and sewage network – Idukki

Region	Name of LSG Covered	Municipality/GP (M/P)	Expected population covered in STP network	% of Population covered	Area in Sq.km for STP Network/FSSM	% of Area covered	STP Identification	STP Location	Effluent discharging waterbody
REGION 1	Munnar	GP	28701	**60**	80.4	20	1A	Munnar	Muthirapuzha
	Devikulam	GP		40		20			
REGION 3	Kattappana	M	62712	90	80.07	90	3A	Kattappana	Thodu
	Erattayar	GP		60		60			
	Kamakshy	GP		40		40			
TOTAL			91,413		160.47				

4.2 Waste Water Treatment Facilities

Wastewater treatment is essential for protecting water resources from industrial and domestic pollution. In the Periyar River Basin, industries use Effluent Treatment Plants (ETPs) and Sewage Treatment Plants (STPs) to manage wastewater, supporting recycling and sustainability. Advanced systems like neutralization tanks and biogas plants exist, but gaps remain where facilities rely on Common Effluent Treatment Plants (CETPs) or lack proper infrastructure. Key discharge points, such as near the Pathalam regulator cum bridge, highlight pollution risks. Stricter regulations, zero-discharge technologies, and treatment upgrades are needed to safeguard the Periyar River's ecological health.

4.2.1 Industrial Waste Management and Treatment Facilities

The industrial sector in and around Ernakulam, as well as other parts of Kerala, encompasses public sector undertakings, private companies, and non-government enterprises spanning chemicals, petrochemicals, rubber, and soft drinks. These industries generate hazardous waste, including heavy metals like mercury, copper, lead, and cadmium, alongside industrial by-products such as slag and effluents. Waste management practices vary, with some industries employing Effluent Treatment Plants (ETPs), biogas plants, and secured landfill facilities (SLFs), while others lack adequate treatment systems. Key industries such as Hindustan Insecticides Ltd., Travancore Cochin Chemicals Ltd., FACT Udyogamandal Division, and Indian Rare Earths Ltd., handle significant hazardous waste, with some discharging wastewater into water bodies despite regulatory structures. Others, like Binani Zinc Ltd., and Cochin Leathers Pvt. Ltd., have advanced treatment facilities with equalization tanks, clarifiers, and filtration systems. However, industries such as National Battery Industries and Sree Sakthi Paper Mills Ltd., still struggle with proper waste management.

Sectors like electrical, metal, and chemical industries generate e-waste, metal sludge, and phosphate waste, using oil traps, settling tanks, and pressure sand filters for treatment. Some food and beverage industries report minimal waste challenges, while rubber and fertilizer industries, such as Rubber O Malabar Products Pvt. Ltd., and Biocon Organics (P) Ltd., implement wastewater reuse and biogas plants. However, certain slaughterhouses and chemical firms lack proper facilities, highlighting compliance gaps. The Periyar River Basin faces wastewater treatment challenges, with industries discharging untreated effluents at critical points like the Pathalam regulator cum bridge, threatening water quality, aquatic life, and

public health. Urgent measures, including stricter monitoring, regulatory enforcement, and treatment system upgrades, are essential for sustainable industrial waste management.

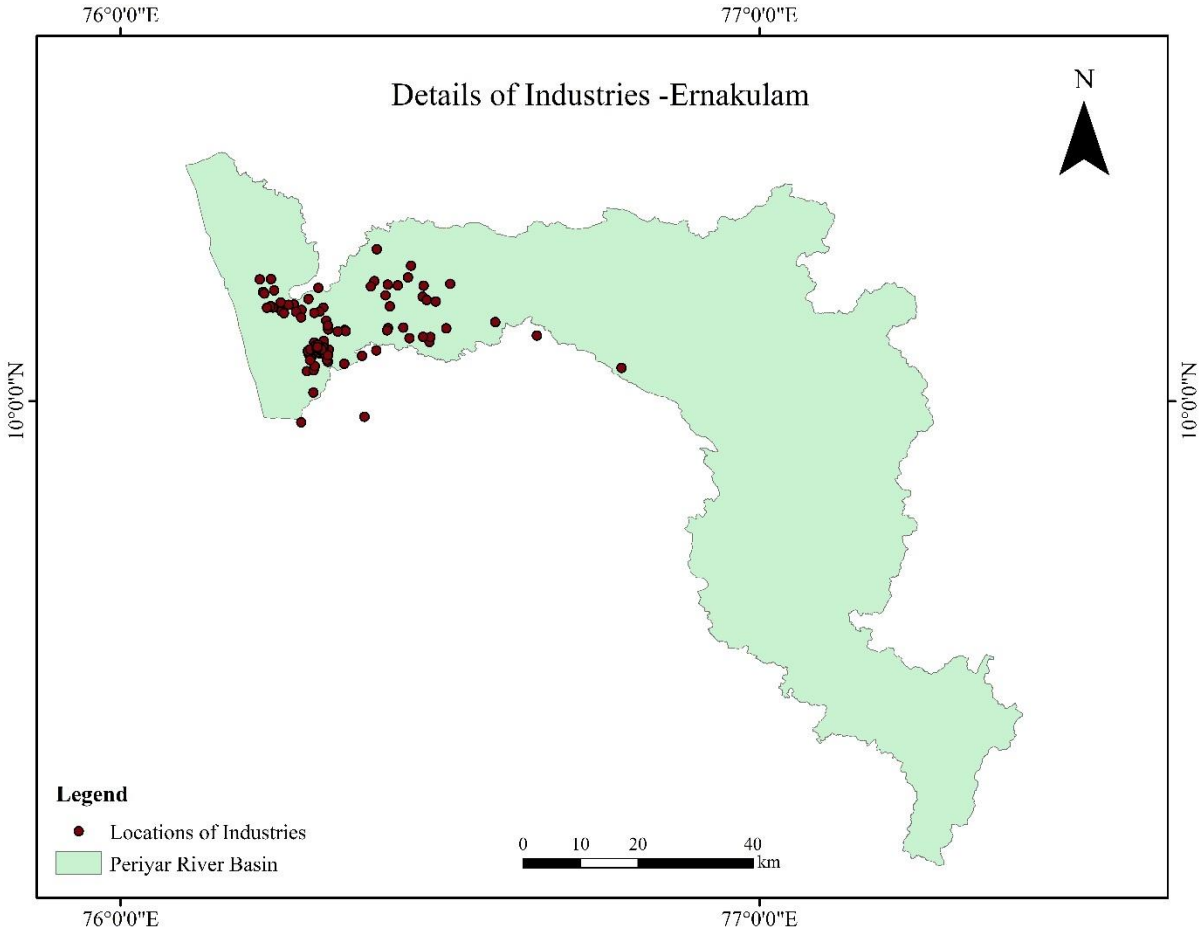

Figure 17 Details of Industries in Ernakulam

5. Sanitation Plan

The Periyar River Basin, a crucial water source for Kerala, faces growing sanitation challenges due to rapid urbanization. Inadequate facilities and poor waste management have led to pollution, posing health risks to local communities. Efficient waste disposal systems, source segregation, recycling, and composting are essential to reduce environmental impact. Community involvement through awareness campaigns ensures sustainability, aligning with national initiatives like the Swachh Bharat Mission.

5.1 Public Toilets

The Periyar River Basin encompasses several Urban Local Bodies (ULBs) that play a crucial role in managing water resources and sanitation infrastructure. Public and community toilets are key components of urban sanitation strategies, reflecting ongoing efforts to improve sanitation and public health. The availability of sanitation facilities across these ULBs varies, with Kochi leading with 157 public toilets (PT) and one urinal. Other notable ULBs include Kalamassery with 19 public toilets and 3 community toilets, Kodungallur with 10 PTs, Irinjalakuda with 4 PTs, and Angamaly with 3 PTs. However, many areas lack dedicated urinals and community toilets, highlighting gaps in the region’s sanitation infrastructure.

Kochi Municipality leads the basin with the most extensive sanitation network, featuring 157 PTs and one urinal. This reflects the city's proactive approach to urban sanitation, addressing the needs of its dense population and busy public spaces. Kalamassery Municipality also provides a balanced infrastructure with 19 public toilets and three community toilets, focusing on both general public usage and the needs of underserved neighbourhoods. Other municipalities like Kodungallur, Irinjalakuda, and Neeleswaram have moderate infrastructure, with 10, 4, and 4 PTs, respectively. While progress is evident, these municipalities require expansion to meet the demands of growing populations. On the other hand, Angamaly, Paravur, and Aluva have limited facilities, with only three public toilets in Angamaly and Paravur, and just one in Aluva.

Community toilets, essential for underprivileged areas, are notably scarce, with Kalamassery being the only ULB to report three community toilets. The lack of such facilities in other municipalities, particularly in dense or informal settlements, emphasizes the need for targeted infrastructure development to ensure all residents have access to sanitation. The absence of urinals in most ULBs, apart from Kochi, is another key issue. Urinals are cost-effective

solutions for managing public sanitation in high-traffic areas, reducing the pressure on public toilets. Their inclusion could improve sanitation efficiency, especially during peak hours.

5.2 Waste Management

The Periyar River Basin, encompassing major parts of Ernakulam, Idukki, and Thrissur districts, is one of the most urbanized and industrialized regions of Kerala, significantly contributing to the state's solid waste generation. Kerala produces approximately 10,505 tonnes of solid waste daily, with Urban Local Bodies generating 3,472 tonnes and Grama Panchayats contributing 7,032 tonnes. Out of this, households account for 49%, institutions 36%, and public spaces 15%. About 77% of the waste is biodegradable (6,410 tonnes), 18% is non-biodegradable, and the remaining 5% is inert. Managing the large volumes of biodegradable and plastic waste, estimated at 592 tonnes per day, is a critical concern in the basin. The waste management system in the region adheres to Kerala's decentralized approach, involving source segregation, door-to-door collection, transfer to Material Collection Facilities (MCFs), processing at Resource Recovery Facilities (RRFs), and final disposal or recycling. Approximately 75% of biodegradable waste is treated at the household and community levels, with initiatives underway to increase this to 85–90 percent through the installation of six lakh composting and bio-methanation units. Non-biodegradable waste is collected from around 46 lakh sources by 1,461 Haritha Karma Sena units, stored in 994 MCFs, and processed in 169 RRFs for recycling or road construction. District-level data reveals regional variation in waste generation and processing efficiency within the basin. Idukki's rural areas generate 162.3 tonnes per day (TPD) of biodegradable and 40.6 TPD of non-biodegradable waste, with processing rates of 80% and 71%, respectively, while urban areas process 73.1% and 66% of their respective waste streams. In Ernakulam, rural regions generate 379 TPD of biodegradable and 162 TPD of non-biodegradable waste, processing 70% and 45%, while urban areas produce 356 TPD and 152 TPD, with processing efficiencies of 60% and 47%, respectively. Thrissur's rural areas show poor performance, with both biodegradable and non-biodegradable waste processing rates at only 6.79%, while its urban areas process 82.27% of biodegradable waste but only 4.37% of non-biodegradable waste. E-waste generated in the basin is collected by the Clean Kerala Company and transported to authorized recycling facilities outside the state. Hazardous waste, particularly from industrial zones in Ernakulam, is managed under statutory provisions, with a 130 TPD treatment facility in operation within the district. Strengthening of the waste management framework in the Periyar Basin is supported by ongoing efforts in

source-level segregation, community composting, decentralized infrastructure, strict regulatory enforcement, research collaboration, and digital monitoring using tools such as the Smart Garbage App.

5.2.1 Solid Waste Management

As per the SWM Rules 2016, "solid waste" includes domestic, sanitary, commercial, institutional, catering, market, street, horticulture, agricultural, and treated bio-medical waste, excluding industrial, untreated bio-medical, e-waste, battery, and radioactive waste. Waste management includes waste reduction, recycling, composting, hazardous waste treatment, collection, transportation, and implementing regulations. Once segregated, waste can be processed through methods tailored to its specific type shown in Figure 18.

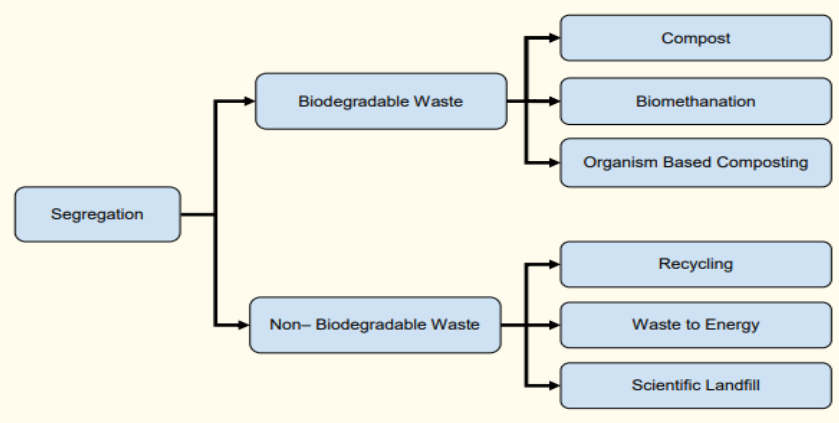

Figure 18 Process flow of Solid Waste Management

Biodegradable Waste Management

Biodegradable waste, such as food scraps and yard waste, is processed using the methods are Composting, Anaerobic Digestion, Organism-Based Composting.

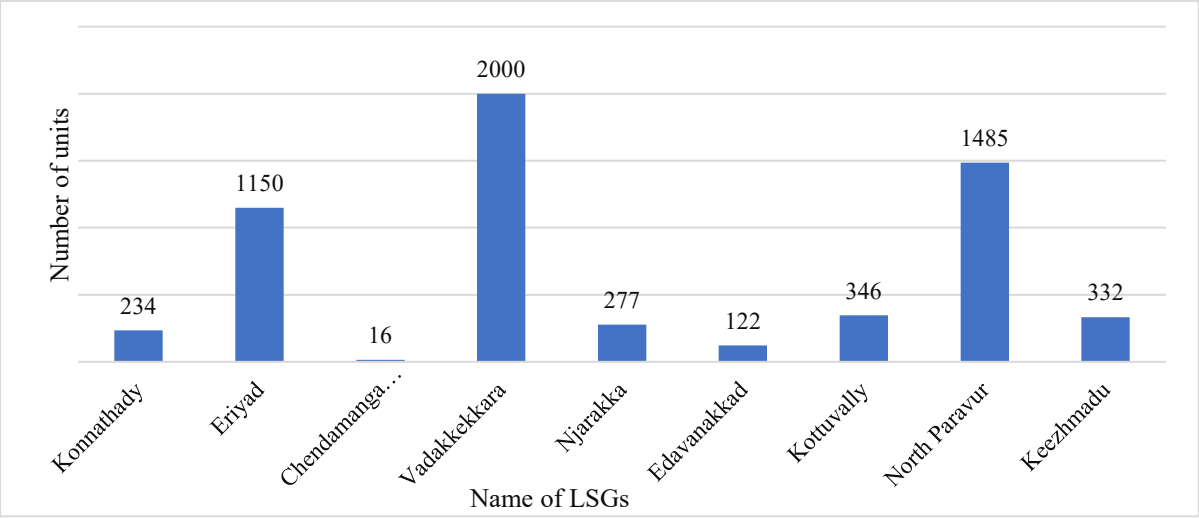

Figure 19 Distribution of Bio Composter Bins Across Local Self-Governments (LSGs)

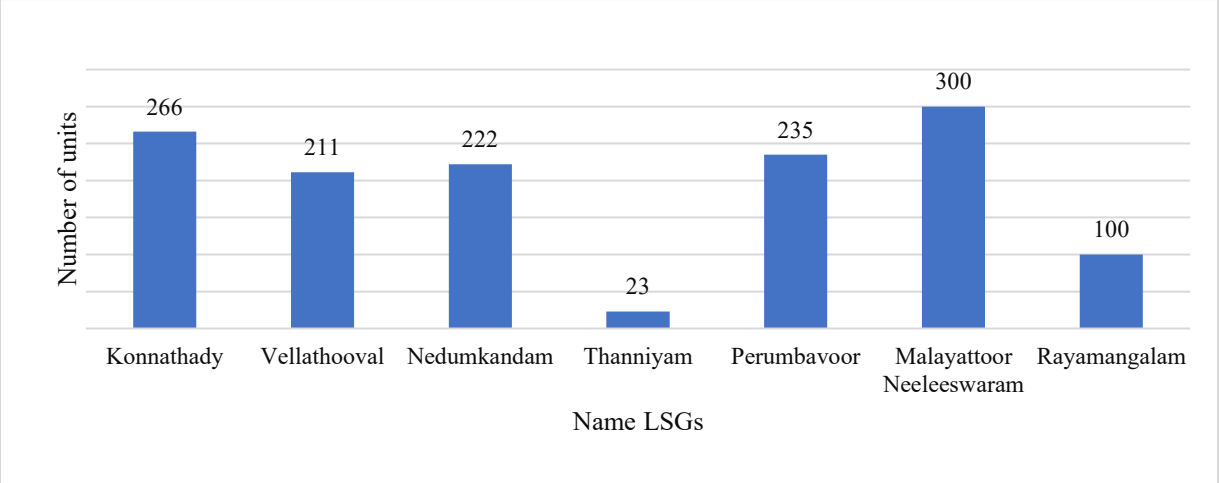

Figure 20 Distribution of Ring Compost Units Across Local Self-Governments (LSGs)

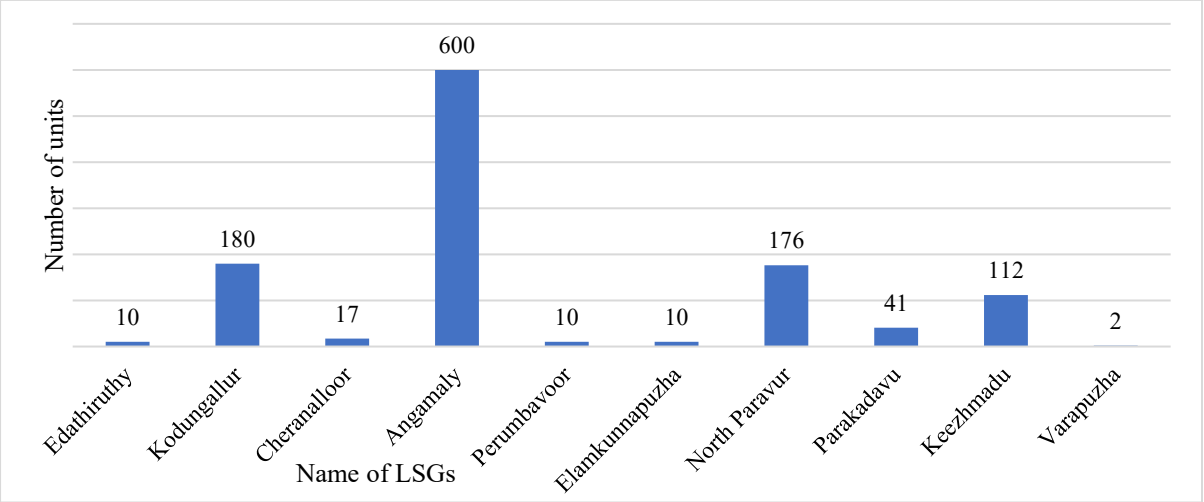

Figure 21 Distribution of Biogas Plants Across Local Self-Governments (LSGs)

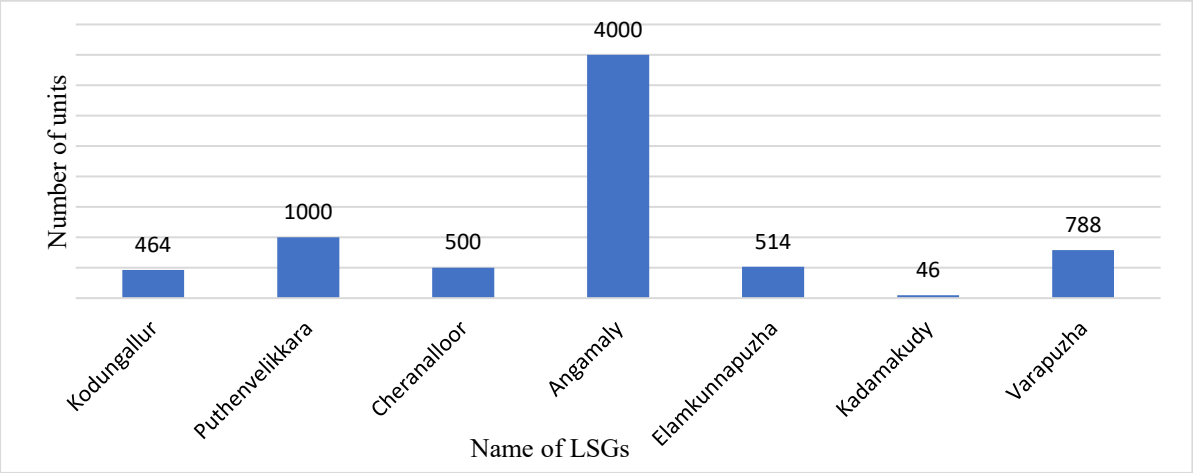

Figure 22 Distribution of Biodigester Pots Across Local Self-Governments (LSGs)

Figures 19 to 22 show the distribution of waste management facilities across LSGs in Idukki, Ernakulam, and Thrissur. Ernakulam leads in Bio Composter Bins, with Vadakkekkara (2,000 units) and North Paravur (1,485 units). Idukki excels in Ring Compost Units, notably in

Konnathady (266 units) and Vellathooval (211 units). Angamaly, Ernakulam, tops Biogas Plant installations (600 units), while Biodigester Pots are prominent in Angamaly (4,000 units) and Kodungallur (464 units). Based on the 2020-21 Suchitwa Mission Annual Report, these trends highlight LSG's efforts in sustainable waste management.

Other Disposal Facilities

In the Ernakulam district of the Periyar River Basin, the Bucket Compost facility is operational in Kuzhuppilly. This facility focuses on managing organic waste through composting, helping in waste reduction and sustainable waste management practices. Similarly, in Chendamangalam, the Kitchen Bin facility is available, which is designed to aid in the segregation and disposal of kitchen waste. Kodungallur Municipality in Thrissur has implemented decentralized waste management with 8,224 biodigester pots**,** 1,752 biogas plants**,** 600 bio-compost bins**,** 4,377 pipe compost units, and 38 Bokashi buckets, promoting efficient household-level organic waste management.

Non-Biodegradable Waste Management

The non-biodegradable waste management process involves a systematic approach to handle waste effectively, ensuring environmental sustainability. It begins with the collection of non-biodegradable waste by the Haritha Karma Sena from households, institutions, and commercial establishments. The collected waste is then transferred to Material Collection Facilities (MCFs) established at the grama panchayat (GP) or municipal ward level, where initial segregation takes place. At these facilities, the waste is sorted into recyclable and non-recyclable categories. The segregated waste is further transferred to Recycling and Resource Facilities (RRFs) at the block or municipal level for advanced processing. Recyclable plastics are shredded and utilized for polymerized road construction, promoting eco-friendly infrastructure development. Other plastics are compressed into bales using baling machines and sold to authorized recyclers. The remaining non-recyclable waste, categorized as rejects, is sent for coprocessing in cement kilns or disposed of safely in sanitary landfills. This structured process not only reduces environmental contamination but also promotes sustainable waste management practices (Plastic and Other Non-Biodegradable Waste Management in Kerala, LSGD 2023).

Material Collection Facility & Resource Recovery Facility

The Material Collection Facility receives the non-biodegradable waste that is gathered through door-to-door collection. A Material Collection Facility is a place where non-biodegradable garbage can be temporarily kept and where various categories, like paper, plastic, bottles, and

packaging paper, are separated out by secondary segregation. After being separated, the MCF output is either sold to recyclers or moved to RRFs. In Kerala, the Haritha Karma Sena (HKS) plays a crucial role in collecting sorted plastic waste from households and institutions. This waste is then transported to MCFs. MCFs, which must adhere to specific criteria like a minimum building size of 500 sq. ft and the presence of essential equipment like bailing machines and weighing balances, serve as temporary storage locations for the collected plastic. As of 27 January 2023, there were 932 functional MCFs in panchayats, 114 in municipalities, and 21 in corporations, forming a vital network for efficient plastic waste management.

Table 4 Existing Waste Management Infrastructure in Ernakulam under Periyar River Basin

Grama Panchayat	Present Population (2024)	Area of Existing MCF (sq. ft)	Area of Existing RRF (sq. ft)	Area of Existing MCF and RRF (sq. ft)	Dry Waste Generated (TPD)
Alengadu	44279	2100	600	2700	2.2
Aluva	24,074	3500		3500	2.1
Angamali	35,921	2500	2500	5000	3.1
Asamannur	20728	900		900	1
Ayyampuzha	15254	1400		1400	0.8
Chendamangalam	31479	400	800	1200	1.6
Chengamanad	30032	1400		1400	1.5
Cheranallur	32840	1100	400	1500	1.6
Chittattukara	33601	900		900	1.7
Choornnikkara	35150	1400		1400	1.8
Edathala	47449	2100		2100	2.4
Edavanakkadu	23386	800		800	1.2
Elamkunnappuzha	54437	1200		1200	2.7
Eloor	39,418	3800		3800	3.4
Ezhikkara	19342	900		900	1
Kadamakkudi	17491	300		300	0.9
Kadungalloor	44897	1100		1100	2.2
Kalady	30355	2600		2600	1.5
Kalamasseri	76,252	2600	800	3400	6.7
Kanjoor	24196	2300		2300	1.2

Karukutty	30182	1300		1300	1.5
Karumaloor	38726	600		600	1.9
Kavalangad	31909	1200		1200	1.6
Keerambara	13444	2900		2900	0.7
Keezhmadu	39251	3200		3200	2
Kizhakkambalam	35812	100		100	1.8
Kochi (MC)	646,238	5300	7400	12700	72.7
Kothamangalam	41,688	4100		4100	3.6
Kottappadi	38901	2700		2700	1.9
Kottuvalli	19217	300		300	1
Kunnukara	35968	1600		1600	1.8
Kuttambuzha	23363	1700		1700	1.2
Kuvappady	26246	3000		3000	1.3
Kuzhuppilli	13028	800		800	0.7
Malayattoor - Neeleswaram	27356	1800		1800	1.4
Manjapra	17186	1700		1700	0.9
Mazhuvannur	36585	1600		1600	1.8
Mookkannur	21069	1400		1400	1.1
Mudakkuzha	18629	500		500	0.9
Mulavukadu	23436	100		100	1.2
Narayambalam	25898	2300		2300	1.3
Nedumbassery	33602	1400	1500	2900	1.7
Nellikkuzhi	44204	2200		2200	2.2
Njarakkal	25504	1300		1300	1.3
Okkal	25961	1200		1200	1.3
Pallippuram	15938	900		900	0.8
Parakadavu	18969	1100		1100	0.9
Paravur	33,815	2500		2500	3
Perumbavoor	30,173	150	1400	1550	2.6
Pindimana	17732	600		600	0.9
Puthenvelikkara	30299	2400		2400	1.5

Rayamangalam	39418	2600	2600	2
Sreemoola Nagaram	27595	2100	2100	1.4
Thuravur	23044	300	300	1.2
Vadakkekkara	35149	1000	1000	1.8
Varappuzha	28714	1800	1800	1.4
Vazhakkulam	44569	1800	1800	2.2
Vengola	54181	900	900	2.7
Vengoor	23547	1000	1000	1.2

Table 4 highlights data from 51 Grama Panchayats in the Periyar River Basin, covering population, MCF and RRF areas, and dry waste generation. Facility sizes vary, with some Panchayats lacking RRFs. Dry waste generation ranges from 0.7 to 2.7 TPD, with higher levels in Vengola and Elamkunnappuzha, emphasizing the need for tailored waste management solutions

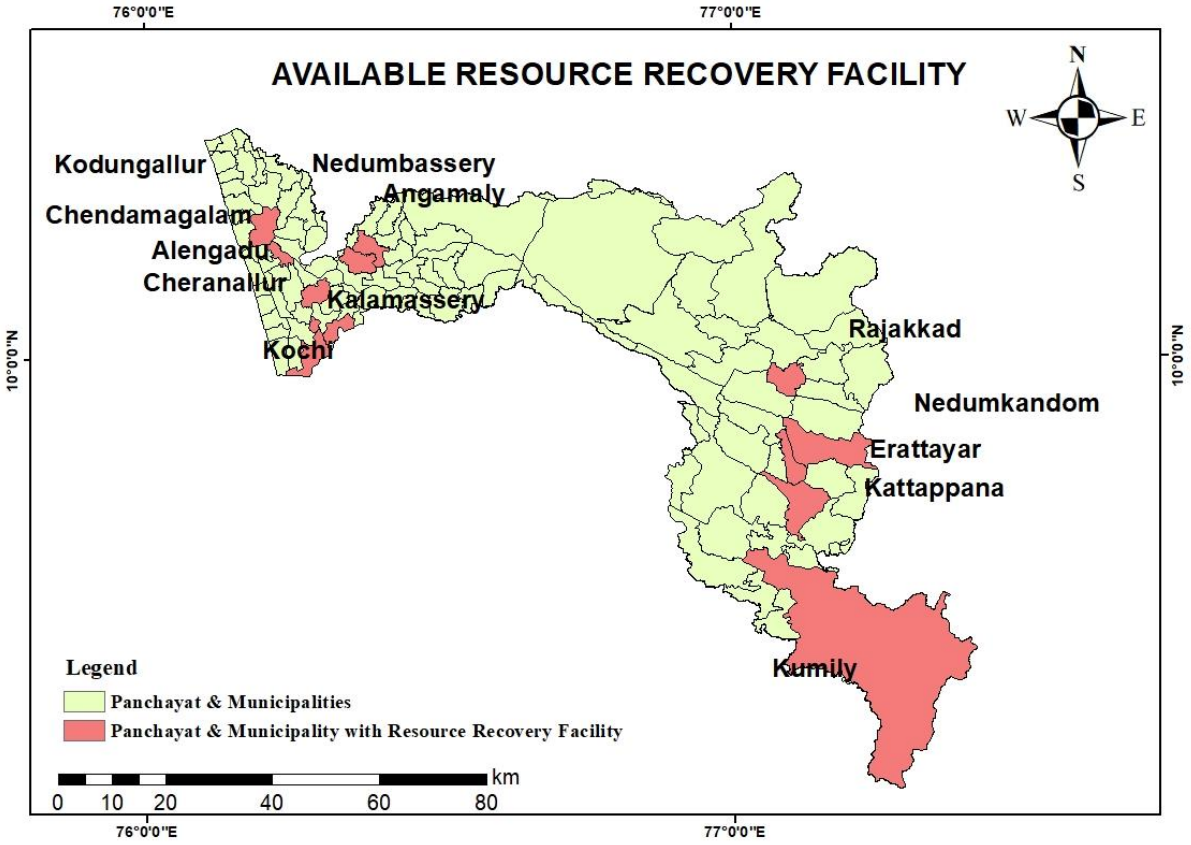

Figure 23 Available Resource Recovery Facilities in Periyar River Basin

Figure 23 highlights the Resource Recovery Facility (RRF) in the Periyar River Basin under Kerala's Suchitwa Mission, promoting sustainable waste management through the 3Rs—

reduce, reuse, and recycle. These facilities process biodegradable waste for composting or biogas production and recycle non-biodegradable waste, while hazardous and e-waste are handled per safety norms. Suchitwa Mission collaborates with LSGs, encourages community participation, integrates technology, and partners with industries to enhance waste utilization, aiming to improve public health, conserve resources, and establish Kerala as a model for sustainable waste management.

Block-wise Overview of Waste Management Facilities

The Suchitwa Mission provides data on waste management infrastructure across Ernakulam, Thrissur, and Idukki districts within the Periyar River Basin. In Ernakulam, facilities are available in blocks like Alangad, Parakkadavu, Vypin, Angamaly, Mulanthuruthy, Edapally, Kothamangalam, Vazhakkulam, Paravur, and Vadavukode. In Thrissur, the focus is on Kodungallur Municipality and Vellangallur Gram Panchayat. Idukki's infrastructure covers Nedunkandam, Azhutha, Idukki, and Kattappana blocks. These efforts reflect a comprehensive approach to improving sanitation and waste management in the basin. The waste management infrastructure in Ernakulam's Alangad, Parakkadavu, and Vypin blocks includes MCFs, Toilet and Bathroom (TAB) units s, and RRFs, ensuring efficient waste handling. In Alangad, MCF units range from 500 to 2500 sq ft across locations like Alangad Market and Varappuzha, with TAB units in Alangad and Karumalloor GPs and an RRF in Panayikkulam. Parakkadavu features MCFs (400 to 2100 sq ft) in Kondotty, Athani Market, and Kunnukara, along with Mini MCFs in Sreemoolanagar and Puthenvelikkara. Bottle Booths are common in Nedumbassery and Puthenvelikkara, while TAB units, some with seating and latrines, are placed at Kaprassery School and Kunnukara Junction. An RRF operates at Athani Market (2100 sq ft). In Vypin, MCFs are located near key sites, including Narakkal (1200 sq ft, Panchayat office), Nayarambalam (1600 sq ft, shopping complex near the bridge), and Edavanakkad (1100 sq ft, near Aniyal Bridge and water tank). These facilities collectively strengthen waste management efforts in the region.

The Alangad Block in Ernakulam has multiple waste management facilities catering to different Panchayats. Alangad Grama Panchayat has a 2500 sq. ft. MCF at Alangad Market, along with three TAB units located at Alangad Market, Karinganthuruth, and within the Panchayat office. Kadungallur has a 750 sq. ft. MCF on Vrindavan Road, while Varappuzha hosts a 1000 sq. ft. MCF at the bus stand and a TAB unit in the Panchayat office. Karumalloor features a 500 sq. ft. MCF at Thattampady and a TAB unit in the Panchayat compound. Additionally, an RRF is situated in Panayikkulam, supporting waste recovery in the region.

The existing waste management infrastructure in Vypin Block, Ernakulam. Narakkal has an MCF with a capacity of 1,200 sq. ft. near the Panchayat office. Nayarambalam hosts a 1,600 sq. ft. MCF at the Panchayat shopping complex near Nayarambalam Bridge, while Edavanakkad has a 1,100 sq. ft. MCF near the Aniyal Bridge, close to the water tank. Angamaly Block has diverse waste management infrastructure, including MCF units (ranging from 250 to 2138 sq ft) in various locations such as near canals, railway stations, and junctions. The block also has several TAB units (Basic and Standard) spread across key locations, alongside Mini MCF units and Bottle Booths. These units serve areas like Ayyampuzha, Kalady, Karukutty, Malayatoor, and Mookkanoor, enhancing waste management coverage in the region. Waste management facilities in the Mulanthuruthy block consist of one MCF with capacity 1450 sq. ft.

Waste Management Infrastructure in Parakkadavu Block in Ernakulam consist of various waste management and public infrastructure facilities across multiple panchayats. In Sreemoolanagar, there is a 2000 sq.ft. MCF (Material Collection Facility) at Kondotty, along with two Mini MCFs in Wards 9 and 6. Chengamanad has a 400 sq.ft. facility in Kaprassery, five Mini MCFs, two seating TAB sites in Parambayam, and a 6-seating plus 2-latrine TAB facility in Kaprassery School. Nedumbassery has a 2100 sq.ft. MCF in Athani Market, 19 Mini MCFs covering all wards, and 36 Bottle Booths distributed across 19 wards. Parakkadavu hosts an 1130 sq.ft. MCF in Mambra, six Mini MCFs in Wards 2, 3, 7, 8, 9, and 13, but no Bottle Booths. Kunnukara has two MCFs, one of 650 sq.ft. and another of 750 sq.ft. in Kunnukara and North Kuthiyathodu, respectively, along with 15 Mini MCFs spanning all wards. Puthenvelikkara has a 2000 sq.ft. MCF, 17 Mini MCFs, and 17 Bottle Booths, all covering respective wards. The RRF (Resource Recovery Facility) in Parakkadavu is located at Athani Market and spans 2100 sq.ft. Additionally, various TAB sites have been proposed in locations like Moozhikulam, Chettikulam, Kunnukara Junction, and Puthenvelikkara Panchayath Compound. The existing waste management infrastructure in Edapally Block, Ernakulam, includes various facilities across different panchayats. Kadamakudy has a 29 sq.ft. MCF at Kothad and a school toilet facility at St. Francis School, Pizhala. Cheranalloor features a 1100 sq.ft. MCF at Vishnupuram and three Thumpoormuzhi composting units at Kuttisahib, ICT Service, and Nattuvetti Kadav. Elankunapuzha has a 1200 sq.ft. MCF at Puthuvyp, Ochanthuruth. These facilities support waste management and sanitation efforts in the region.

The waste management infrastructure in Kothamangalam Block, Ernakulam, includes multiple Material Collection Facilities (MCFs) across different panchayats. Kottapady has an MCF

located in the Panchayat's own building, while Nellikuzhi, Kuttampuzha, and Paingotoor also have MCFs without specified locations. Keerampara features a 2690 sq.ft. MCF in Ward 13, and Pindimana has an MCF near the Pindimana Bus Station. Kavalangad hosts both an MCF and a basic TAB facility at Neryamangalam Bus Stand. These units play a crucial role in managing waste disposal and maintaining environmental sustainability in the region.

The waste management infrastructure in Angamaly Block, Ernakulam, consists of various Material Collection Facilities (MCFs), TAB units, Mini MCFs, and Bottle Booths distributed across multiple panchayats. Ayyampuzha has a 1500 sq.ft. MCF above the canal, while Kalady (1000 sq.ft.), Kanjoor (2138 sq.ft.), and Karukutty (1200 sq.ft.) have their facilities near the canal and railway station. Malayatoor Neeleeshwaram has an 1800 sq.ft. MCF at the center, Manjapra has a 1600 sq.ft. facility at Chathupadam, Mookkanoor has a 1500 sq.ft. unit, and Thuravoor has a smaller 250 sq.ft. MCF at Ward 14 Junction.

TAB facilities are distributed across different locations, including standard units near the Kalady Private Bus Stand and Thuravoor Ward 14 Junction, and basic units in Ayyampuzha, Mookkanoor, Karukutty, and Neeleeshwaram. Mini MCFs are also present, with Ayyampuzha having three near the canal at FHC, Manjapra having 13 at locations like Elavally and Merigiri Junction, and Thuravoor featuring 16 across various spots including Vathappad and Anavattara. Kanjoor has five Mini MCFs, while Karukutty has 14 spreads across different wards. Malayatoor Neeleeshwaram has nine Mini MCFs covering areas such as Ward 11 and SNDP Colony. Additionally, a single Bottle Booth is located in Malayatoor. These facilities play a crucial role in improving waste management and sanitation across the region.

Vazhakkulam Block in Ernakulam hosts MCFs in locations like Mudikkal, Keezhmad, and Ambedkar Gramam, with Mini MCFs widely distributed, particularly in Edathala and Vazhakkulam. TABs are located at Ponjassery and Vengola, while Kizhakkambalam has 38 bottle booths for waste segregation. Vadavukode Block features MCFs in all six panchayats, including a 2000 sq. ft. unit in Aikkaranad. Mini MCFs are common, with Aikkaranad and Vadavukodu Puthankurisu hosting 29 and 39 units, respectively, alongside TABs at key locations like St. Peter's College and Kadamattom Church. Kodungallur Municipality has 44 Mini MCFs (0.5 TPD), a 2 TPD MCF, 5 RRFs, a 5 TPD Windrow Compost, and a 4.1 TPD Thumburmuzhi Aerobic Bin, while Vellangallur GP has 6 Mini MCFs (0.5 TPD) and an 1800 sq. ft. MCF. In Idukki under the Periyar River Basin, waste management facilities vary, with Elappara and Kattappana Municipality featuring MCFs, RRFs, and Bottle Booths, while Udumbanchola and Vandanmed have basic setups with a single MCF each.

Paravur Block in Ernakulam has multiple waste management facilities across various Panchayats. Chittatukara, Vadakkekara, Chendamangal, Ezhikkara, and Kottuvally have MCFs located at sites like SNDP Hall (Neendoor), near Chettikkad Church, and Trikkapuram Hall. TAB units are placed at Kuryappilly Kadavu, St. Sebastian School (Gothuruth), Adikkulam Shopping Complex, and Chathanad Ground. Mini MCFs are distributed widely, with Chittatukara having seven across locations like Puthiyakavu and Muzaris, while Vadakkekara and Kottuvally have 20 each, covering most wards. Chendamangal and Ezhikkara also have 15 and 10 Mini MCFs, respectively, ensuring decentralized waste management in the region.

Idukki's waste management infrastructure under the Periyar River Basin includes MCFs, Mini MCFs, RRFs, and Bottle Booths across multiple Panchayats. Karunapuram, Peruvanthanam, Peerumade, and other areas have MCFs ranging from 600 to 2200 sq. ft, with the highest Mini MCF count in Kattappana Municipality (48). Elappara and Peerumade have 17 and 20 Mini MCFs, while Chakkupallam GP has 35. RRFs are limited, with only Rajakadu having one (1000 sq. ft). Bottle Booths are present in areas like Kamashi (15), Pampadumpara (6), and Peruvanthanam (22), while several Panchayats lack them entirely.

5.2.2 Liquid Waste Management

Liquid waste management (LWM) in Kerala involves decentralized solutions like STPs, Feacal Sludge Treatment Plants (FSTP), and greywater systems, supported by the Suchitwa Mission. Kodungallur Municipality has completed bio-mining (1393 m^3) and operates an FSTP with a 6000 LPD capacity. Vellangallur GP lacks bio-mining but has initiated a 6 KLD liquid waste management project. These initiatives aim to reduce environmental pollution and promote sustainable wastewater disposal. Continuous monitoring and community participation further strengthen the effectiveness of these waste management systems. Liquid waste management in Idukki under the Periyar River Basin primarily involves soak pits, with no Grey Water Systems, STPs, or FSTPs reported. Vandanmed GP has the highest number of soak pits (500), followed by Rajakadu (150), Vathikkudy (150), and Kanjikkuzhi (138). Other Panchayats, including Peruvanthanam (7) and Vandidperiyar (3), have fewer soak pits, while several areas like Pampadumpara and Udumbanchola lack data.

5.3 Community Sanitation Programs

The Community Level Sanitation Plan (CLSP) aims to improve sanitation, waste management, and hygiene through community participation, focusing on solid and liquid waste management, household toilets, and composting systems. It promotes awareness, behaviour change, and

inclusive infrastructure, ensuring access to essential sanitation facilities, especially in underserved areas. In Kerala, key initiatives include the Swachh Bharat Mission (Rural and Urban), Haritha Keralam Mission, Kochi City Sanitation Project, Clean Kerala Company Initiatives, and Panchayat-Level Programs. The Suchitwa Mission, the implementing agency for Haritha Keralam, leads sustainable waste management through four schemes: Suchitwa Keralam (Rural and Urban) and Swachh Bharat Mission (Rural and Urban).

Suchitwa Keralam (Rural & Urban)

The state government prioritizes source-level bio-waste treatment, which accounts for 70-80% of total waste, through composting and bio-methanation systems. Government-supported projects in Grama Panchayats and Urban Councils promote suitable technologies, with 60% of households already equipped with source-level treatment systems. The Suchitwa Mission supports Local Self-Government Institutions (LSGIs) by empanelling service providers for treatment projects. Initiatives like Haritha Karma Sena (HKS) units, MCFs, and RRFs further enhance biodegradable and non-biodegradable waste management. The Suchitwa Keralam (Rural) program focuses on pre-monsoon cleaning, upgraded processing plants, Information, Education, and Communication (IEC) activities, Self-Help Group (SHG) support, mechanized septage handling, and worker welfare. Effective planning, inter-departmental collaboration, and fund convergence ensure efficient waste management across urban and rural areas.

Haritha Keralam Mission

Mission Haritha Keralam promotes hygienic waste management, soil and water conservation, and organic farming through community participation. The mission actively involves NGOs, social activists, students, and environmentally conscious citizens to implement scientific waste management practices. It also supports decentralized waste treatment, promotes household-level composting, and strengthens MCFs, RRFs.

Harithakarmasena

The Haritha Karma Sena (HKS) initiative established through the Kudumbasree Mission, is a notable example of decentralized, community-driven waste management across Kerala's local self-governing institutions (LSGIs). Formed in nearly all LSGIs, HKS groups are trained by the Kerala Institute of Local Administration (KILA) and Kudumbasree, supporting sustainable waste collection and resource recovery efforts. Currently operational in 857 Grama Panchayats, 87 Municipalities, and 5 Corporations, HKS receives Viability Gap Funding to enhance its long-term sustainability. In Idukki, 52 units operate in Grama Panchayats and 2 in municipalities, with no presence in corporations. Ernakulam has 82 units in Grama Panchayats,

13 in municipalities, and 1 in the corporation. Thrissur leads with 85 units in Grama Panchayats, 7 in municipalities, and 1 in the corporation, highlighting its extensive waste management efforts across different administrative levels.

Haritha Sahaya Sthapanam

Due to a lack of dedicated staff for waste management in LSGIs, professional support agencies, called Haritha Sahaya Sthapanam (HSS), have been engaged to assist with HKS activities. These 51 agencies provide technical support to 335 Grama Panchayats, 46 Municipalities, and 2 Corporations by developing sustainable business models, enhancing HKS members' capabilities, and identifying micro-enterprise opportunities. Their efforts have helped over 700 LSGIs achieve the *Suchitwa Padavi* status for exceptional cleanliness and waste management in the Periyar.

The Periyar River Basin has a varying distribution of Resource Recovery Facilities (RRFs) across districts. In Idukki, there are 52 Grama Panchayats (GPs) with 3 functional RRFs, while 8 Block Panchayats (BPs) require 8 RRFs. The district has 2 municipalities, both requiring and having 2 functional RRFs, but no RRFs exist in corporations. Ernakulam, with 82 GPs, has 6 functional RRFs, while 14 BPs require 14. Its single Taluk-level RRF (TRRF) is operational, whereas 13 municipalities require 13 RRFs, with only 7 functional. The district's corporation requires 4 RRFs, but only 2 are operational. Thrissur has 86 GPs with 12 functional RRFs, while 16 BPs require the same number. It has 8 TRRFs, all functional, and 7 municipalities requiring 7 RRFs, with all operational. The district’s corporation requires 4 RRFs, but only 2 are functional. The data highlights disparities in waste recovery infrastructure, emphasizing the need for further development to enhance waste management efficiency.

The status of Suchitwa Padavi standards in Local Self-Governments (LSGs) across the Periyar River Basin varies by district. In Idukki, 33 LSGs were revisited and inspected, with standards improving in 7, remaining unchanged in 26, and not declining in any. Ernakulam had 54 inspections, where 36 LSGs showed improvement, 13 remained unchanged, and 5 experienced a decline. Thrissur saw 52 inspections, with 40 LSGs improving, 4 unchanged, and 13 experiencing a decline. While progress is evident in many LSGs, the decline in some highlights the need for continued efforts in maintaining and enhancing waste management and sanitation standards.

6. Riverfront Development Plan for the Periyar River Basin

The Riverfront Development Plan for the Periyar River Basin restores degraded riverbanks through pollution control, flood management, and biodiversity enhancement. It integrates green infrastructure, recreation, and community involvement, ensuring ecological health, urban renewal, and improved quality of life.

6.1 Initiatives on riverbank protection

Idukki's irrigation plan includes water harvesting, irrigation, and groundwater recharge under *Har Khet Ko Pani*, *Per Drop More Crop*, and *PMKSY*.

Thodupuzha Block

Under the *Har Khet Ko Pani* initiative by MoWR, 152 groundwater structures were developed over 5–7 years, covering 8,000 hectares at ₹5628.4 lakhs, alongside the rejuvenation of a 125-hectare water body for ₹250 lakhs. The *Per Drop More Crop* scheme by MoA &Field Water Development Advisory Committee (FWDAC) implemented two stone bunds across 25 hectares at ₹60 lakhs. Under *PMKSY* Watershed by Department of Land Resources (DoLR), 113 check dams and 117 Nallah bunds were constructed, enhancing irrigation in 1,383 hectares at a cost of ₹3872.6 lakhs.

Elamdesam Block

Under the *Har Khet Ko Pani* initiative by the Ministry of Water Resources (MoWR,) 66 stabilized structures and 93 check dams were built, creating an irrigation potential of 1,645 hectares at ₹4,155.45 lakhs. The *Per Drop More Crop* scheme by MoA & FWDAC developed 3,400 water harvesting structures and 126 stone bunds, benefiting 1,282 hectares at ₹818.83 lakhs. Under *PMKSY* Watershed by DoLR, various water conservation structures, including check dams, farm ponds, and groundwater recharge units, contributed 1,157.71 units to conservation efforts.

Idukki Block

Under *Har Khet Ko Pani*, MoWR implemented 300 canal protections, 30 check dams, 246 ponds, and 344 public wells, benefiting 3,929 hectares at ₹7,807 lakhs. *Per Drop More Crop* by MoA & FWDAC introduced 400 drip irrigation systems, 350 sprinklers, and 1,200 water

harvesting structures at ₹6,748.67 lakhs. *PMKSY* Watershed by DoLR developed farm ponds, additional check dams, and land improvements, enhancing irrigation for 4,825 hectares at ₹7,421.5 lakhs.

Kattappana Block

Under *Har Khet Ko Pani*, MoWR implemented lift irrigation, pond construction, and canal protection, benefiting 5,406 hectares at ₹9,840 lakhs. *Per Drop More Crop* by MoA & FWDAC introduced drip irrigation, sprinklers, and drought-proofing measures, covering 5,470 hectares at ₹5,909.69 lakhs. PMKSY Watershed by DoLR developed 1,152 farm ponds, 91 check dams, and groundwater recharge structures, supporting irrigation for 25,905 hectares at ₹8,030.71 lakhs.

Nedumkandam Block

Under *Har Khet Ko Pani*, MoWR implemented lift irrigation, side protection, and groundwater development, benefiting 1,250 hectares at ₹3,881.95 lakhs. *Per Drop More Crop* by MoA & FWDAC introduced drip irrigation, sprinklers, and 2,220 water harvesting structures, enhancing irrigation for 1,270 hectares at ₹104,127.04 lakhs. *PMKSY* Watershed by DoLR developed farm ponds, check dams, and groundwater recharge structures, supporting irrigation in 9,855 hectares at ₹4,215.4 lakhs.

Devikulam Block

Under *Har Khet Ko Pani*, MoWR implemented 266 canal side protections, 49 check dams, and 40 field canal works, benefiting 7,400 hectares at ₹22,140 lakhs. *Per Drop More Crop* by MoA & FWDAC introduced stone bunds, irrigation pump sets, and water harvesting structures, enhancing conservation across 7,064 hectares at ₹22,188 lakhs. *PMKSY* Watershed by DoLR developed farm ponds, fishery ponds, check dams, and percolation tanks, improving irrigation for 3,769 hectares at ₹1,189.2 lakhs.

Adimali Block

Under *Har Khet Ko Pani*, MoWR implemented 703 side protection works, 158 check dams, and 3,434 ponds, benefiting 1,525 hectares at ₹6,635.2 lakhs. Per Drop More Crop by MoA & FWDAC introduced drip and sprinkler systems along with 2,453 water harvesting structures,

covering 1,850 hectares at ₹9,672.4 lakhs. *PMKSY* Watershed by DoLR developed farm ponds, check dams, and percolation tanks, enhancing irrigation for 7,800 hectares at ₹7,407.15 lakhs.

V. P Thuruth, Kodungallur Municipality

Two major Dry Rubble Masonry (DR Masonry) construction works are being undertaken for the protection of the Periyar River near V.P Thuruth in Kodungallur Municipality. DR Masonry helps prevent erosion while maintaining natural water flow and slope stability.

1. Completed work: 0.36 km long side protection was constructed on the south side of V. P Thuruth, specifically on the western side of Kottapuram bridge.
2. Ongoing RMF work: 0.244 km long river bank protection work is currently ongoing to protect the right bank of the periyar river in the north-west portion of V.P Thuruth.

6.2. Walkways

Several walkways along the Periyar River serve as recreational spaces and contribute to sustainable riverfront development. These walkways play a crucial role in promoting eco-tourism, environmental awareness, and community well-being while enhancing the aesthetic and functional value of the riverfront areas.

6.2.1. Existing Walkways in the Periyar River Basin

The walkways along the Periyar River Basin in Ernakulam and Thrissur districts reflect the region's efforts toward sustainable riverfront development. The location map of the walkways is shown in Figure 24. Walkways in the basin continue to enhance the well-being of local communities, support environmental protection, and boost tourism. The Periyar River Basin features several scenic walkways, primarily concentrated in Ernakulam and Thrissur districts, offering both recreational and sightseeing opportunities. In Ernakulam, the Marine Drive Walkway is a popular location along the backwaters, ideal for walking, boating, and enjoying nature. The Subhash Chandra Bose Park Walkway provides a peaceful environment near the riverfront, well-suited for morning walks and evening relaxation. The Munambam Walkway is known for its coastal views and serene ambiance near the river's mouth. Another notable walkway is the Willington Island Walkway, offering views of the Cochin Port and backwaters, situated on an artificial island created for port activities. The Vypin Walkway, located on Vypin Island, boasts lush greenery and picturesque waterways, while the Mangalavanam Bird Sanctuary Walkway provides a nature-focused trail through a rich mangrove ecosystem

teeming with birdlife. Additionally, the Cochin Port Walkway allows visitors to observe port activities in a scenic setting, making it popular among both tourists and locals.

In Thrissur district, the Kottapuram Fort Walkway highlights the historical significance of Kottapuram Fort, allowing visitors to enjoy scenic river views while walking along this heritage site. In Idukki district, no data is available regarding walkways in the Periyar River Basin. These walkways collectively enhance tourism and recreation in the region, providing opportunities for relaxation, historical exploration, and nature appreciation (Kerala Tourism Infrastructure Limited, KTIL, 2020).

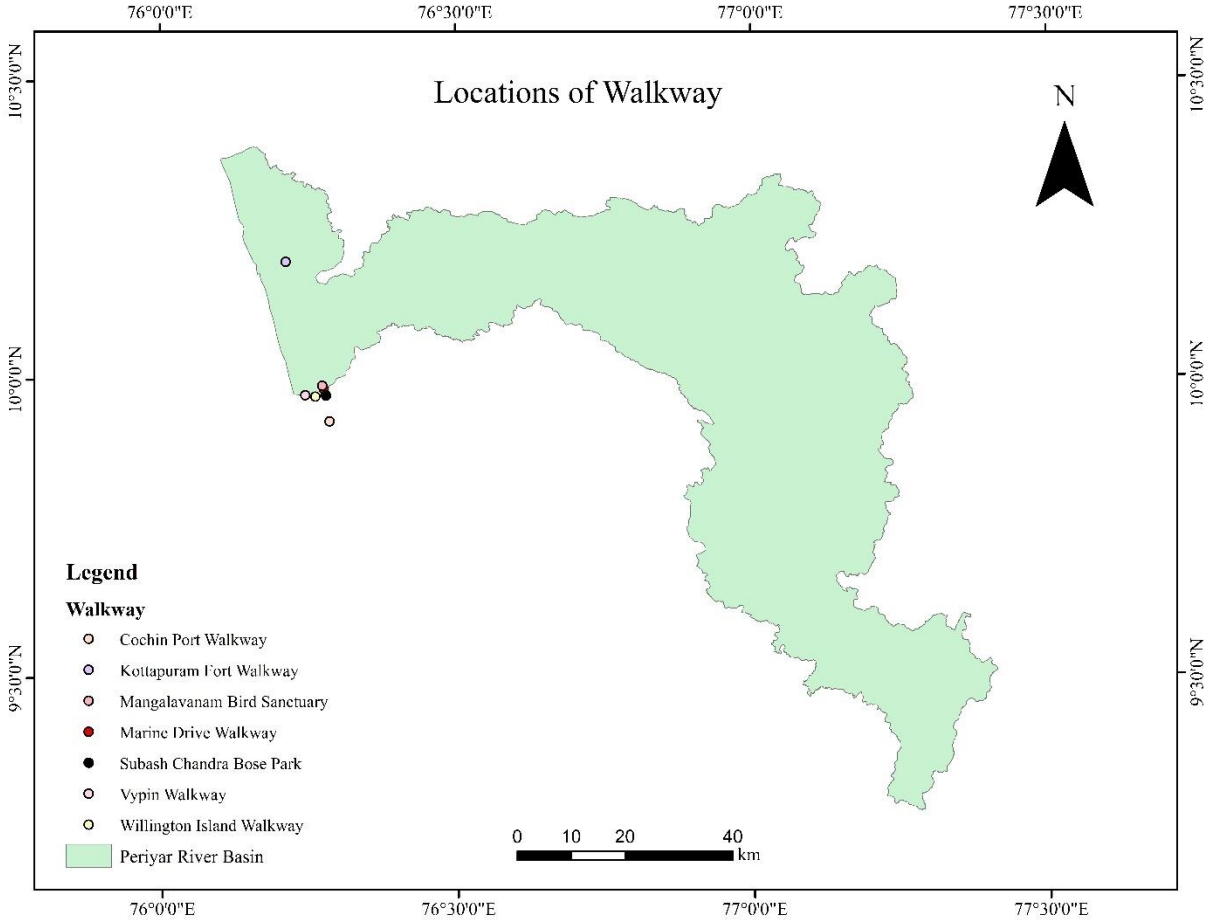

Figure 24 Location of existing walkways

6.3. Ecological Restoration

Ecological restoration seeks to revitalize degraded ecosystems, restoring their natural functions, biodiversity, and overall ecological balance. By addressing land degradation and strengthening biodiversity resilience, it also improves the essential services these ecosystems provide. Success assessments are crucial for justifying its use in natural resource management and refining best practices (Wortley et al., 2013). This process involves applying ecological knowledge to understand ecosystem functions and using that understanding to preserve their structure and function (Martin, 2017). When done sustainably, restoration helps protect biodiversity, boost human well-being, and support climate resilience. Involving communities and experts is essential for repairing ecosystems and fostering a healthier relationship between people and nature. Combined with conservation and sustainable practices, it becomes key to transforming environmental conditions from degradation to positive improvement (Gann et al., 2019).

6.3.1. Importance of Ecological Restoration in the Periyar Basin

The Periyar River Basin is ecologically vital, hosting diverse flora, fauna, and numerous endemic species. It supports 36 fish species, surpassing the Pamba river-stream system in diversity, with sites like Azhutha showing notable richness (Radhakrishnan & Kurup, 2010). The basin's forests, including tropical evergreen, semi-evergreen, and moist deciduous types, are home to unique plants like *Neelakurinji*, rare orchids (*Brachycorythis wightii*), and medicinal species such as *Drosera peltata* (Arun, 1999; Kerala Forest and Wildlife Department). Recent discoveries, such as *Emblicachakrabarti*, further highlight its botanical importance (The Hindu, 2023). Several Western Ghats endemics, including *Baccaurea courtallensis*, *Calophyllumelatum*, and *Vateria indica*, are also found in the basin (Sakthivel & Sreekumar, 2011). Aquatic ecosystems in the river are dominated by *Bacillariophyceae* (phytoperiphyton) and rotifers (zooperiphyton), supporting endangered fish species like *Garramullya* and *Garrasurendranathanii* (John & Kumar, 2021; Ajitkumar et al., 2001). Iconic wildlife, including the Leopard, Sloth Bear, Sambar Deer, and rare birds like the Ceylon frogmouth, underscores the basin's ecological significance (Kerala Forests and Wildlife Department).

6.3.2. Biodiversity Loss: Urgent Conservation Needs

The Periyar River Basin has undergone significant ecological degradation, necessitating urgent restoration efforts. Over the past five decades, 16 fish species, including eels, catfishes, and

gobies, have been lost due to habitat degradation and pollution (Status Report on Periyar River). Despite this, the basin remains a biodiversity hotspot, hosting 56% of Kerala's endemic fish species. Endemic species like *Garraperiyarensis*, restricted to less than 20 km² in the upper reaches of the river, face critical threats from habitat degradation and pollution (Gopi, 2001; Arunkumar & Manimekalan, 2018; Ali & Raghavan, 2015).

Human activities, such as tourist boat operations, sewage dumping, and overfishing, further degrade water quality and threaten native species (Ranjeet et al., 2010). Additionally, invasive species like *Cyprinus carpio* and *Clarias gariepinus* disrupt ecosystems by outcompeting native species, increasing turbidity, and altering habitats (Sandilyan et al., 1998). The Periyar River Basin is a vital ecological region, rich in biodiversity, home to numerous endemic species, and supporting a variety of unique flora and fauna. However, the basin is facing significant ecological challenges, including habitat degradation, pollution, invasive species, and human activities that threaten its delicate ecosystems. The loss of several fish species and the decline in water quality have underscored the urgent need for ecological restoration. Immediate efforts focused on habitat preservation, invasive species control, and pollution reduction are essential to protect and restore the basin's biodiversity.

Initiatives on riverbank protection

Riverbank protection is vital for sustainable water resource management in the Periyar River Basin, addressing soil erosion, land loss, and ecosystem degradation. Initiatives such as sidewall construction and watershed development stabilize banks, mitigate flood impacts, recharge groundwater, and support agriculture. By integrating modern engineering with traditional practices, these measures enhance ecological balance, water security, and rural livelihoods. Protecting the riverbanks ensures sustainable resource management, reduces flood risks, and promotes the long-term resilience of the Periyar River and its dependent communities.

Implementation of Side Protection Works in Idukki District Blocks for Riverbank Stabilization and Water Conservation

Side protection works undertaken in various blocks of the Idukki district under schemes like Har Khet Ko Pani and PMKSY Watershed, highlighting their scope, impact, and investment. These initiatives focus on stabilizing riverbanks, preventing erosion, and enhancing water conservation and irrigation efficiency. The water conservation efforts in the Periyar River Basin include various projects aimed at enhancing irrigation and protecting riverbanks. In the

Elamdesam Block, under the PMKSY Watershed scheme (DoLR - MoRD), sidewall protection works were implemented, with a total investment of ₹207.73 lakhs. The Idukki Block saw two major initiatives: the Har Khet Ko Pani scheme (MoWR) for side protection works of field canals, benefiting 1125 hectares with an investment of ₹1848.01 lakhs, and the PMKSY Watershed scheme (DoLR - MoRD), which focused on sidewall protection with 1500 structures covering 1800 hectares at a cost of ₹4510 lakhs. The Nedumkandom Block also benefited from the Har Khet Ko Pani scheme (MoWR) for side protection works in Thodu/Padasekharam, with 100 structures covering 656.9 hectares at a cost of ₹1022.8 lakhs. Similarly, in Devikulam Block, side protection works were carried out under the same scheme, covering 266 structures across 3000 hectares at a cost of ₹1593.2 lakhs, with implementation spanning 2 to 7 years. Finally, in Adimali Block, 703 structures were built for Thodu/Padasekharam under the Har Khet Ko Pani scheme (MoWR), covering 60 hectares at a total cost of ₹3629.2 lakhs, also with a 2 to 7-year implementation period.

To improve water, use and riverbank protection efficiency, strategies focus on renovating existing infrastructure, protecting critical ecosystems like forests and wetlands for groundwater recharge, and replicating successful water management models. The action plan includes rehabilitating water sources and waterways, repairing distribution systems, and upgrading structures such as irrigation ponds and check dams to stabilize riverbanks. Periodic de-silting of reservoirs and the use of eco-friendly methods to prevent encroachments are essential for long-term sustainability. Community engagement is key to empowering local organizations to monitor and manage water resources. Further, regulating resource extraction and rejuvenating unused tanks and springs will enhance water availability. To create new water conservation and riverbank protection structures, priorities include constructing rainwater harvesting systems, implementing erosion control techniques, and building protective structures like check dams and ponds. Additionally, abandoned quarries can be repurposed for water storage, reducing environmental degradation while enhancing water availability. These integrated efforts aim to promote sustainable water use, stabilize riverbanks, and ensure long-term ecological health. Table 5 Summaries Details of Side Protection Works Undertaken in Various Blocks of the Idukki District.

Table 5 Details of Side Protection Works Undertaken in Various Blocks of the Idukki District (District irrigation plan: Idukki,2017)

Sl No	Name of the block/Sub districts	Concerned ministry Department	Component	Activity	Total Number /Capacity (cum)	Command Area /Irrigation potential(ha)	Period of Implementation	Estimated Cost (Rs.in Lakhs)
1	Elamdesam Block	DoLR - MoRD	PMKSY Watershed	Sidewall protection				207.73
2	Idukki Block	MoWR	Har khet ko pani	Side protection works of field canals	300	1125	5yrs	1848.01
		DoLR - MoRD	PMKSY Watershed	Sidewall protection	1500	1800	5yrs	4510
3	Nedumkandom Block	MoWR	Har khet ko pani	Side protection works-Thodu / Padasekharam	100	656.9	5 years	1022.8
4	Devikulam Block	MoWR	Har khet ko pani	Side protection works-Thodu / Padasekharam	266	3000	2-7 yrs	1593.2
5	Adimali Block	MoWR	Har khet ko pani	Side protection works-Thodu / Padasekharam	703	60	2-7 yrs	3629.2

7. Findings and Future Direction

Periyar River, Kerala's longest river (244 km), flows into the ecologically significant Vembanad Lake—a Ramsar site of international importance—and then into the Arabian Sea. The river holds immense ecological, cultural, and economic significance, supporting agricultural productivity, hydroelectric projects, tourism, and drinking water needs. However, the basin faces mounting challenges from rapid urbanization, deforestation, and land degradation, significantly disrupting its ecosystems. Settlements and barren lands, identified as highly vulnerable areas through the vulnerability index, are under severe environmental stress. Over-extraction of water for agriculture and industry, coupled with the increasing impacts of climate change, has exacerbated these vulnerabilities. Inadequate infrastructure, such as insufficient sewerage and stormwater drainage systems, further contributes to environmental degradation and heightened flood risks in urban areas.

Addressing these challenges requires an integrated and comprehensive approach. Conserving forests and water bodies is critical for maintaining ecological balance and reducing vulnerability. Large-scale ecological restoration efforts, such as reforestation, wetland conservation, and habitat restoration, can safeguard biodiversity and support long-term ecosystem stability. Sustainable land use practices, including organic farming, agroforestry, and afforestation, are essential to mitigate the adverse effects of urbanization and intensive agriculture. Strengthening infrastructure for water supply, sanitation, and stormwater drainage will protect both public health and the environment. Technological integration, such as the use of Geographic Information Systems (GIS), IoT-enabled systems, and automated sensors, can improve resource management and infrastructure efficiency. Improving governance frameworks and institutional coordination between government agencies, NGOs, and local communities is vital for the successful implementation of management plans. Policies regulating land use, urban expansion, and industrial development must prioritize inclusivity and sustainability. Continuous monitoring using advanced technologies such as artificial intelligence and machine learning can enable predictive assessments and dynamic planning, ensuring adaptive solutions to evolving challenges. In this way Infrastructure planning plays an important role in meeting the resource and development needs of the present generation while ensuring ecological conservation and sustainability for future generations.

8. References

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Annexure

1. Figure 7: Existing WTP complex at Aluva and proposed site
   (Source: KWA, 2022)
   Link to Figure
2. Figure 8: Existing distribution system from Headworks at Aluva
   (Source: KWA, 2022)
   Link to Figure
3. Figure 9: Existing distribution system from Headworks at Aluva *(Source: KWA, 2022)*
   Link to Figure
4. Figure 10: Key plan of major transmission lines in Kochi city and adjoining areas.
   (Source: KWA, 2022)
   Link to Figure