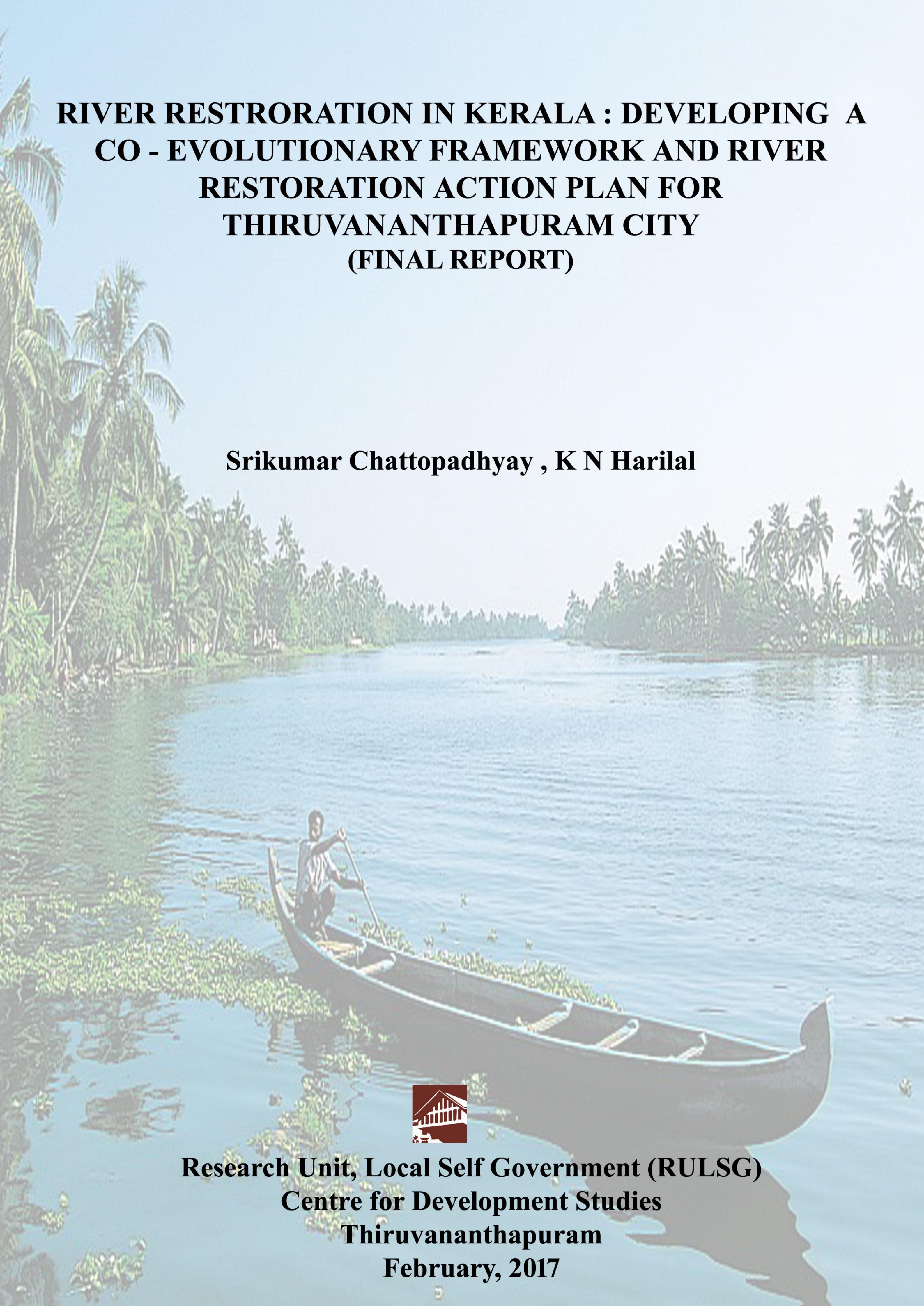

RIVER RESTRORATION IN KERALA : DEVELOPING A CO - EVOLUTIONARY FRAMEWORK AND RIVER RESTORATION ACTION PLAN FOR THIRUVANANTHAPURAM CITY

(FINAL REPORT)

Srikumar Chattopadhyay , K N Harilal

Research Unit, Local Self Government (RULSG)
Centre for Development Studies
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Executive Summary

This project on 'River restoration in Kerala: Developing a co-evolutionary participatory framework and river restoration action plan for Trivandrum city' proposes to develop a frame work of river restoration in the state of Kerala and also work out an action plan for restoration of Trivandrum City rivers. This study tries to follow co-evolutionary approach and link river restoration activities with the concepts of Integrated Water Resource Management (IWRM) and Integrated Urban Water Management (IUWM). Kerala is well endowed with water resources; however there are several challenges ranging from drying up of traditional sources to quality deterioration of surface and subsurface water mostly due to human activities. People's easy access to water is now shrinking. The situation will be further complicated with ensuing climate change.

The State Water Policy (SWP) first formulated in 1992 and revised in 2008 follow national water policy. There is proposal to form National Water Commission at the national level and follow an integrated approach with necessary space for state level activities. Formations of KWA and subsequently Jalanidhi were part of reforms of water governance in the State. However there are found wanting to address the problems holistically. Further change in water governance is necessary. While a centralized governing system will consider allocation and reallocation of resources among water surplus and water deficit regions, the decentralized local self governments should be given responsibility for conservation, maintenance, proper use and equitable distribution of local water resources. These arrangements require multi-level poly centric governance system.

Rivers in Kerala are under stress. There are problem of flood plain occupation, water quality deterioration, and indiscriminate extraction of river bed deposits. River bank mapping and sand auditing was introduced at the behest of Revenue Department since 2011. So far, work has been completed for 16 rivers covering a length of around 750km. It is found that out of 16 rivers only seven rivers have sand deposits above summer water level, part of which can be mined. River bank maps help assessing status of the river banks including nature of human intervention.

The proposed river restoration frame work for Kerala consists of six steps: building environment and setting up restoration team, scoping, preparation of restoration plan, plan

implementation, monitoring and community involvement and people's participation. Most common goals of river restoration are related to ecorestoration and increasing biodiversity, stabilizing channels, improving riparian and in-stream habitat, improving water quality and summer or base flow. Restoration activity may be planned for the whole river and also for segments with proper prioritization. Appropriate institutions may be formed to coordinate river restoration activities. The successful pursuit of river rejuvenation entails forging linkages and sharing of responsibilities among different stake holders including people.

Thiruvananthapuram city falling within the catchment of Karamana river is well drained through 180km long water courses, which are severely degraded. The Karamana River, main source of drinking water supply for the city is facing problem due to over exploitation of river bed deposits and water quality deterioration. Self-sustaining capacities of the rivers are lost due to point and non-point source pollution. Thiruvananthapuram city also faces regular problem for storm water drainage and water logging. Encroachment, deterioration of channels, gradual expansion of surfaced area, decrease in infiltration and increase in surface run off combindly contributed. The 'Operation Anantha' programme initiated to tackle the storm water flood in some parts of CBD area remained unfinished.

Problem of city rivers are multidimensional. There are several challenges like high population pressure, lack of buffer zone between river and settlements, competing land use, private ownership of land and little or no statuary regulation for construction. Stakeholders' participation is necessary and the city requires a Master Plan urgently in the frame of IUWM. The master plan should envisage detailed action plans for all 20 micro water sheds and 100 Wards covering the city. The adjoin panchayats may also be included. The Master plan should stress on priority fixation involving all stake holders including tourism department. Developing stewardship and advocacy for rivers are necessary. The strategy we propose is to win the rivers back to the public sphere and restore the river centric socio-cultural activities. This will have a multiplier effect on river protection and rejuvenation.

The stress is on watershed based site specific approach with active involvement of local people to forge partnership in project formulation and execution, to conduct social auditing, and to create and nurture a healthy river environment for a sustainable future. Appropriate socio-political-technical space is necessary to accomplish these tasks.

RIVER RESTORATION IN KERALA: DEVELOPING A CO-EVOLUTIONARY FRAMEWORK AND RIVER RESTORATION ACTION PLAN FOR TRIVANDRUM CITY

CHAPTER I

Introduction

1.0 Introduction

Rivers, integral parts of human civilization, are heritage resources however our record in managing these essential resources particularly over the past hundred years has been riddled with short-sightedness. Progress of civilization, growing urbanization and apparent decline in direct dependence of human being on river systems has contributed to changing perspective of use of river resources. Rivers are viewed as source of water and sediment, which are minable economic goods. Interfering within river's domain has a long history, perhaps as old as human civilization itself. Today, many of the world's rivers and catchments are degraded due to intensive human impacts including damming, diversions, storages, clearing of vegetation and other habitat removal, introduction of invasive species and pollution. The damaging effects to aquatic ecosystems through these changes have long been known and demonstrated and it is now globally well recognized that the rivers are under stress. The United Nations Water Conference in Mar del Plata, Argentina in March, 1977 epitomised the concern about the fresh water. The thirteenth Stockholm Water Symposium in 2003 focused on drainage basin security. It was pointed out that the drainage basin security would be a key to reach Millennium Development Goals (MDG), most of which are directly or indirectly water-related. Although 2015 was the target year to accomplish the tasks set for MDG, little has been done in the matter of river management, particularly in the developing countries.

Aquatic ecosystems are being impaired by human activities worldwide (Gleick 2003). The human sub-system of Earth System had influenced the fluvial processes or river system through numerous interventions of various magnitudes. These interventions have resulted in serious perturbation and in many places the system is disturbed beyond resilience limit. In case of agricultural settings, river ecosystems are experiencing increased nutrient and sediment loads, altered flows, and habitat degradation, whereas in urban dominated areas, there are municipal drainage, industrial effluents, sewage discharge, waste water flow, increased impervious surfaces and infrastructural constraints on river channels which have led to the injection of chemical pollutants, river flow modification, and system instability. Besides, there are excessive sand mining from river bed and increasing with drawl of water for various purposes. All these activities together caused irreparable damage to the riverine ecosystem. Now the situation has been so alarming that river restoration is considered as an important task to be accomplished urgently with due care.

The river restoration is primarily a series of activity meant to ‘protect and rehabilitate the physical and biotic processes of a river in a way that is conducive to the progression of ecosystems towards their natural state’ (Koehn et al, 1997). This thrust on ecological restoration and river centric approach is sometimes critised. It is argued that on the one hand human benefits are not adequately addressed and on the other hand there is multiplicity of land ownership and all parts of catchment are not under control of a single department which makes restoration activities not just difficult but sometimes impractical. The third issue in case of Kerala is excessive pressure on land due to intense use and high population pressure, besides the pace of global change, which has an all encompassing impact. It is now being stressed that in river restoration the focus should be on recovering, stabilizing and enhancing ecosystem functions and services of the rivers and the restoration activities may be socially driven with involvement of community and integrated with the area plan following the principle of sustainability science, which is trans-disciplinary, community based, interactive and participatory.

1.1 Changing Perspective of River Restoration

Over the years, there had been change in concept and content of river management. The thrust was on quality analysis of river water in 1950s when water was considered merely as a commodity and it was available in abundance. However by 2000 there had been a gradual change in outlook and rivers are considered part of ecosystem and the thrust has been to improve the relationship between rivers and human within the larger frame of human environment relationship (Table 1).

Table 1: Changing Perspective in River Restoration

Year	Activities	Thrust area
1950	Continuous survey of water quality	Improvement of Water Quality
1960	Developing sewerage system and water intake points	Amenities and landscape
1980	Promotion of accessibility between rivers and urban, improvement of urban landscaping and river front amenities	
1990	Regeneration project of river and ecosystem	Nature and ecosystem
2000	Improvement of relationship between river and human, community and nature	Ecosystem and human

Modified after Asian River Restoration Network, 2007

1.2 River Restoration across the Globe: A Brief Review

All major countries have undertaken restoration projects and there had been a perceptible change over the years- from the structural mechanistic approach the emphasis, now, is on integration, improvement of relationship between ecosystem and human, and sustainability. We try to briefly describe initiatives undertaken in some of the major countries in the World.

In USA, the National River Restoration Science Synthesis (NRRSS) reported findings from a database of 37,099 stream and river restoration projects from around the nation (Bernhardt et al. 2005). Most projects were of small scale (<1.5 km in length). A Meta data has been developed and all projects were listed under one of the 13 broad categories: Bank Stabilization, Storm water Management, Water Quality Management, Flow Modification, Channel Reconfiguration, Fish Passage, Riparian Management, In-Stream Species Management, Dam Removal/Retrofit, Floodplain Reconnection, In-Stream Habitat Improvement, Aesthetics/Recreation/Education and Land Acquisition. Nationally, the most common goals were to enhance water quality, manage riparian zones, improve in-stream habitat, fish passage and bank stabilization. Stream restoration activities have increased dramatically in all States of USA. A national framework is in place to undertake restoration projects, being followed by various Government and Non Government agencies.

In UK, following publications of a series of scientific articles and popular books highlighting inadequacy of structural interventions on river regime and ecological degradation of river systems, river restoration projects largely developed in the late 1980s to redress the environmental degradation of rivers and to provide a basis for improved river management in the future (Wharton and Gilvear, 2006). In 1994, River Restoration Centre (RRC) was established to promote, facilitate and support best practices in river, water courses and flood plain management across UK. By 2011, RRC holds information for more than 2000 river projects. It concentrates on knowledge exchange on river restoration and management activities, provides case specific advice and assessment of river projects and ongoing management of rivers and also imparts guidance and mentoring to inform best practice river management and restoration. The RRC also holds river restoration network conference in the month of April in each year since 2000 to share experiences of river restoration work and to broaden the RR network.

The London River Action Plan (Anon., 2009) provided a guideline to help restore rivers for people and nature. The river Thames, which is an iconic symbol of London city, with its tributaries forms a blue ribbon network stretching into every one of London's 33 boroughs. These tributaries provide corridors of green landscape offering habitats for wild life and opportunities for outdoor recreation close to local community. The Thames has been hugely improved, however many of its tributaries leaves much to be desired. The present challenge is to restore and improve London rivers. Five key aspirations of this plan are i) improve flood management using more natural processes, (ii) reduce the likely more negative impact of climate change, (iii) reconnect people to the natural environment through urban regeneration, (iv) gain better access for recreation and improved well being, (v) enhance habitats for wild life. Similar goals are being set for river restoration in various parts of the world (Cha et al., 2011, Wekiva River System Advisory Management Committee, WRSAMC, 2012).

Adopted in the year 2000, the European Union's Water Framework Directive (WFD) is a major driving force influencing water management at the national, regional and local levels in all EU countries. The directive stipulates river basin management, requirements to coordinate water use within river basins and undertake river basin planning, and substantive requirements concerning the “good” ecological and chemical status of European waters. Water Framework Directive (WFD) is often considered the principal driver of recent changes in the scalar organisation of water governance and advocacy in Europe (Commission of the European Community, 2000; 2007).

In Australia, both communities and governments, supported by State and Australian Government funding programs, strive at local, catchment, regional and State levels to rehabilitate natural riverine environments and to sustain agricultural productivity. The Australian’s Prime Minister’s Science, Engineering and Innovation Council has argued that it is 10 to 100 times cheaper to maintain ecosystems than to repair them, yet relatively little is invested in the protection of the remaining, relatively undisturbed, functioning and diverse high-value aquatic ecosystems. In 2004, Council of Australian Government agreed to the National Water Initiative (NWI), which will chart the future responsibilities and progress towards sustainable management of the nation’s rivers and aquifers. Provisions in the associated intergovernmental agreement commit most governments to identify, protect and manage high-conservation-value rivers and aquifers and their dependent ecosystems.

The background paper on “Protecting Australian rivers, Wetlands and Estuaries” (Kingsford et al., 2005) proposed a national framework of river protection focusing on three main elements:

i) Nationally consistent collection of information on rivers, wetlands and estuaries, which will entail agreement on spatial scale and classification and evaluation systems for identification of rivers and dependent ecosystems of high conservation value

ii) Protection schemes that operate at different scales such as:

– a ‘whole-of-river’ approach that could include establishment of an ‘Australian Heritage Rivers’ system
– protection of high-conservation-value rivers, river segments and dependent ecosystems (floodplains, wetlands, estuaries) in a national, State, regional and local context (using current legislative and policy tools; i.e. environmental flows, protected areas, natural resource planning and management, and incentives) and

iii) Operational and institutional arrangements— coordinated programs involving jurisdictions in implementation of a national framework.

Japan is one of the countries practicing river management for a very long time, however river restoration has been booming since the beginning of 1990 when the River Bureau (MLIT) launched the initiative of "Nature-oriented River Works"(Nakamura et al, 2006). The major aim was to conserve and restore river corridors and their rich biodiversity. This initiative was strongly influenced by "Naturnaher Wasserbau" ("near-natural river engineering") in Switzerland and Bavaria, Germany. Between 1990 and 2004, >23,000 "Nature-oriented River Works" projects were realized throughout Japan. Over the years, ecological integrity became the key objective in place of simple flood defence measures. It is a clear shift from projects at the habitat scale to integrated projects of entire river corridors.

The present agenda of Japan stresses on river management by classifying rivers as Class A, Class B, Secondary, and Regular Rivers based on their importance. Activities cover flood control, environmental issues, conservation of aquatic ecosystem, restoration of longitudinal continuity facilitating free movement of fishes and other aquatic life along the rivers and bringing back flood plain dynamics. Booming restoration activities stimulated the formation of new academic societies and encouraged small NGO activities. Since 1998, a unique annual event is the "River Day Workshop" in July. It is a contest and festival of river activities drawing participation from NGOs, school children, and river managers to present and boast their river-related activities in front of judges.

Asian River Restoration Network (ARRN), Japan River Restoration Network (JRRN) and Foundation for Riverfront Improvement and Restoration (FRIR), Japan have documented river restoration works in various Asian countries, particularly in Japan, Malaysia, China, Tiwan, Korea, Combodia, Phillipines and Singapore. All countries emphasised on restoration activities with various measures of success. ARRN attempted to link Integrated Water Resource Management (IWRM) and River Restoration. It has been observed that river restoration is of vital importance to socio-economic sustainable development in parallel with flood and water use management and that it (river restoration) warrants a new methodology compared to flood control and water utilisation.

Considering specific characteristics of monsoon Asia it is urged to establish a river restoration guideline suitable for Asian monsoon region for countries with similar social and natural conditions. The international scenario briefly discussed here indicates that restoration activities across the countries of the World are taken up with specific goals and time targets.

1.3 River Restoration Initiatives in India: A Brief Review

India has a long history of river management for flood control and irrigation development. The Damodar Valley Corporation (DVC) in the pattern of TVA of USA was a coordinated effort both technically and in the matter of governance. There are several multi purpose river valley projects taken up in various parts of India. All the States in India introduced Command Area Development (CAD) programme. Many of these projects brought good results, but there are also instances where desired results could not be achieved.

Government level initiatives for river restoration started with Clean Ganga project taken up during 1980s. National Ganga River Basin Authority (NGRBA) has been established to spearhead the activities. The principal aim is to i) prepare a river basin management plan and ii) Regulation of activities aimed at prevention, control and abatement of pollution in Ganga to maintain its water quality and to take measures relevant to river ecology and management in the Ganga basin States. Restoration of Yamuna river is another programme being initiated involving Central and State Governments. Thames River Restoration Trust (TRRT) of UK is extending help to restore Yamuna river.

Besides, there are several other attempts undertaken by Government Departments and NGOs. The Tarun Bharat Sanga in Rajasthan has rejuvenated seven streams in Rajasthan. This is one of the most demonstrative examples of river rejuvenation by people’s active participation at the grass root level. Restoration of Nagpur rivers was taken up by Nagpur Municipal Corporation in 2013 (Puranik and Kulkarni, 2014) after preparation of a detailed restoration plan at the instance of the Nagpur Municipal Corporation (Anon., 2012). Chennai River Restoration Trust under Government of Tamil Nadu has initiated ecorestoration of Adyar Creek, Adyar creek estuary and Cooum river. Detailed project report (DPR) for restoration of Cooum river is underway (The Hindu, Feb., 14, 2014). The Sabarmati river front project, executed by the Ahmedabad Municipal Corporation in 1997, concentrated on beautification of river front with little care for the restoration of river ecology.

1.4 River Restoration in Kerala

Degradation of river ecosystem and pollution of water is a matter of serious concern in Kerala. In fact there are save river campaigns from time to time. It began with Silent Valley movement in 1977. Since then there were several save river campaigns for rivers like Chaliyar, Bharatapuzha, Periyar, Chalakudy, Pamba, Karamana etc. Voluntary organizations are also formed in case of some rivers. However, systematic river restoration work has not yet been started in Kerala. Government of Kerala, under Pampa River Basin Authority Act, 2009, had set up an authority to restore the Pamba river, one of the most polluted rivers in Kerala due to large scale pilgrim concentration for religious-cultural occasion. However works are yet to begin. The RITES prepared a detailed project proposal for cleaning of Karamana river and Killi ar. One of the components of cleaning Karamana river near Thiruvallam and some peripheral works in Killi ar have been initiated at the instance of KSCSTE and TRIDA. Kerala Biodiversity Board has also started some work for Karamana river restoration. These are all piecemeal approach. A systematic programme on river restoration in Kerala is a felt need and warrants urgent attention.

1.5 Concept of Co-evolutionary Framework

Co evolution is proposed as an alternative framework for understanding change in complex social-ecological systems ((Folke et al, 2005) and a foundational concept in ecological economics (Coastanza et al., 1997). It is argued that coevolutionary approach provides a framework for analysing the mutual causal impacts between systems, which can help to overcome debates about the relative causal efficacy of different natural and social factors, and can elucidate the roles of structure and agency in changing practices (Kallis and Norgaard, 2010, Foxon 2010). It is also contended that a coevolutionary approach tries to link other intellectual streams with the traditional concerns of ecological economics and therefore enables to provide rich and complementary insights. Based on Darwinian principle of evolution the natural and social systems are assumed to coevolve through mutual interaction and casual influence. Variation, inheritance and selection are three Darwinian processes involved in evolution. An evolutionary analysis tries to explain how these three processes function to produce varieties, to retain advantageous properties and pass on to the future and why entities differ in their propagation (Hodgson, 2010). A useful co evolutionary framework is expected to incorporate the co evolution of technologies, institutions, business strategies and social practices within a multi level micro-meso-macro framework (Foxon, 2010). It is all pervasive and in case of development co evolution between society and nature is valued as beneficial by human (Norgaard, 1984).

1.6 Need for Co-evolutionary Framework for River Restoration

Rivers are elements of biophysical system and act as natural corridors. However human interventions are well evident through water abstraction in the upper catchment by impounding of reservoirs arresting normal flow, water diversion through canals, flow of agricultural runoff, discharge of industrial effluents, and sewerage discharge. These actions have modified the natural functional behavior of rivers and in the process the hydrological cycle, sediment cycle and nutrient cycles are altered. The normal fluvial system now operates as social ecological interactive system, a concept that recognizes mutual interdependence of anthropogenic and natural process and calls for integrated approach in identifying the problems, analyzing it considering biophysical set up and human induced actions and finally devising site specific solutions. The dynamics of environmental change can be systematic or cumulative (Turner II et al, 1990). The cumulative change results from increasing human intervention in nature's domain. Conditions of rivers are manifestations of the cumulative actions that tend to modify the natural processes. The frame work for river restoration is considered under socio-ecological coevolution as in this case social system affects biophysical system which in turn impacts societal evolution throwing challenges in river management. Evolutionary process in river management refers to variations of river conditions, retention of characteristics from one generation to next generation, referring to institutional memory and selection of favorable characteristics in relation to the environment.

Interaction between biophysical and human processes varies differently at different spatial scale, leading to changes in prioritizing locations first by considering the entire river network followed by high priority river reaches within the river network and finally concentrating on focal areas within the high priority segments. The common ecological restoration activities are designed mostly on the basis of hydrology, fluvial geomorphology, riparian vegetation, flood plain dynamics or quality of river water or river biota. The primary focus normally was on physical and biological components of the river system, rarely human activities are considered with due importance. This trend is now changing and the proposed approach will be comprehensive covering both technical and non-technical issues.

The rivers in Kerala originating from the Western Ghats flow down to the Sea. The 41 west flowing rivers pass through the area administered by three distinct governing systems: the upper reaches is under forest department, the land surrounding the middle and lower segments of the river are privately owned and governed by Revenue department and the tidal influenced section falling under coastal zone is subject to Coastal Regulation Zone (CRZ) rules. Management activities taking care of major part of river regime might have to address issues related to private property management. The river restoration activity is therefore not just technical intervention rather it has to address governance issue also. The co evolutionary framework proposed here will take note of this set up.

1.7 Factors for Restoration Activities

River restoration requires a spatial framework, for which flood plain provides a common base for documenting physical, biological, demographic and economic characteristics along the river corridor (Gregory and Hulse, undated). Configuration of channel, its position, and land use may change over time. In fact, flood plain occupancy increases over the years and land use and vegetation types have been grossly altered, however, the flood plain-area usually inundated by floods remains relatively constant in human time scale. The factors considered for restoration can be considered under two categories: biophysical and social. Characteristic features under these two categories are discussed here.

Biophysical Factors

Biophysical factors considered for river restoration are geomorphic characteristics of the catchment, channels and flood plain, materials composition, hydrology, and riparian/ flood plain vegetation. The physical processes control sediment and water movement. The role of physical process is well appreciated in ecological approach of river management, which recognizes river continuum concept and flood pulse concept. Restoration activity is a deliberate intervention, potential of triggering a process of change, which may be of cascading effect. Channel features are dynamic and prone to frequent change. The condition varies spatially and linear approach to prescribe similar intervention measures for all stretches does not yield desired results and sometimes appears to be counterproductive. Therefore, it requires proper understanding of the dynamics of river system for devising stabilizing measures. Study of patterns of river channels over various time period offer useful contexts for determining potential responses to restoration in the future.

Diversity and extent of riparian vegetation and floodplain forests are closely linked to channel structure and dynamics of flooding. High diversity of vegetative species is found in the river reaches characterized by high geomorphic complexity. Confluence of tributary streams exhibit complex mosaics of riparian forests, whereas single channel reaches contain simpler patterns of vegetation. The stability of the single channel reaches can support older vegetation as it is not exposed to the effects of floods as frequently as more complex channel reaches. Intensity and frequency of flood and channel complexity play important role in riparian biodiversity. Growing and enhancing vegetation cover for river bank stabilization assume greater significance, however selection of vegetation warrants analysis of physical processes.

Demographic, Economic Factors and Governance

Demographic and economic characteristics are principal social factors that impact river regime, which is manifested through land use pattern. The combination of landuse, demography and economic condition creates a context for considering potential future ecosystem patterns and locations for restoration efforts. Expansion of settlements and other economic activities occupying flood plain have been intensified as part of development process and urbanization. Major urban development in river floodplains is largely irreversible and urban fringe areas are under tremendous pressure for change thereby impervious surface areas are increasing at a faster pace.

Economics influences landowner decisions about the use of lands along the river corridor. Interest of land owners and their participation in restoration work will largely depend on the goods and services that they expect to derive from such acts to protect the river corridor. Regulatory processes and government policies play important role in landowners' decisions. Patterns of land productivity and land value strongly influence the feasibility of restoration and must be evaluated along with patterns of river modification and ecological condition.

Rivers are common property resource and provide important ecological services. As rivers are protected by laws while property rights on the land that influences rivers are privately owned and also protected, the river restoration activity pervades scientific, political, regulatory, and legal process.

1.8 Objectives of this Project

This project on 'River restoration in Kerala: Developing a co-evolutionary participatory framework and river restoration action plan for Trivandrum city' proposes to provide a river restoration framework for the state and to work out an outline for river restoration action plan for Thiruvananthapuram city. Apart from technical issues, the report deliberates on people's participation, role of local self government and institutional issues for river restoration. The main aim of this project is to initiate debate on changing the current fractured and *ad hoc* nature of river restoration activities that are being followed by different departments resulting in competing use, overlap and repetition and to advocate a process that internalizes the variety of technical, societal, economic and political structures and set a new governance system in river management in Kerala, particularly in the urban areas. The overarching goal of this project is to contribute in transiting to sustainability in water resource development and management in the State.

1.9 Organisation of the Report

This report has been organized through seven chapters. The first chapter is introduction. It introduces the problem and deliberates on changing trend of river restoration besides providing a brief review of river restoration work in different countries and in India. The second chapter is on water resources of Kerala- a contextual analysis. The third chapter concentrates on water policy and water governance in Kerala. The fourth chapter discusses on river restoration framework in Kerala. The fifth and sixth chapters deliberate on settings of Trivandrum city and an outline of Trivandrum city river restoration plan. The Seventh chapter provides summary and conclusion.

CHAPTER II

Water Resources of Kerala: A Contextual Analysis

2.0 Introduction

The State of Kerala is well endowed with water resources. Perhaps it is the only State in India where hydro-electric power meets 80% of the electrical energy requirements and surface water provides bulk of its fresh water demand. However, like in all other places, Kerala is facing problems in water sector. There is indiscriminate use and deteriorating water quality, as a result, availability of good quality water is gradually reducing. Rainfall is the only source of fresh water in Kerala and it records wide spatio-temporal variations in its availability. While there is virtually little or no control on incoming rain, once rainwater reaches surface of the earth and start flowing either as surface runoff or infiltrates to recharge ground water the entire process is subject to land and land use management. In other words, running water and infiltration, two of the most important components of hydrological cycle are governed by geoenvironmental setting and human actions. Therefore, the discussion on water resources begins with a brief outline of bio-physical set up of Kerala.

2.1 Bio-physical set up

Kerala located in the south-western part of the Indian Peninsula covers an area of 38,860 km^2 or 1.2% of total geographical of India and accommodates little over 33 million people or 3% of India's population according to the 2011 Census data. Sandwiched between the Lakshadweep Sea in the west and the Western Ghats in the east, the State appears like a narrow strip of land with a maximum width of around 100 km in the Ernakulam-Idukki stretch. This geographical location has provided the State with unique geo-environmental set up that has profound impact on environmental resource base of the state.

Relief and Geology

Relief distribution in terms of area-altitude ratio is asymmetric with as much as 62% of the total geographical area lying below 100 m (Chattopadhyay and Mahamaya, 1995). The coastal plain is wide in the central part around the Vembanad lake coinciding with sedimentary basin and it tapers both towards north and south. From the coastal plain, elevation increases in stepped manner justifying the nomenclature of Ghats. Average rise of land is 27 m for every Kilometre from the coastline towards east and relief amplitude increases with the rise in altitude. Seventy per cent of landmass in Kerala fall in the slope category of >15%. The Western Ghats crest line reaches the maximum altitude of 2695 m at the Anamudi- the highest point in south India. The monolithic Western Ghats is broken by 30 km wide Palghat Gap at the altitudinal level of 100 to 200 m. This Gap connects Kerala plain with the Tamil Nadu plain and has pronounced influence on climate, culture and economy of the State. The Western Ghats and the Eastern Ghats merge at the Nilgiri hills in Tamil Nadu, an extension of which is the Kunda hill ranges in the State. Twenty three per cent of the land lying above 600 m altitude is the provenance of all rivers in the State and is the primary source zone of sediment and water. Abrupt rise of the Western Ghats from 100 m upward with precipitous slope is a characteristic feature of Kerala's topography that controls hydrology, climate, land use, infrastructural development and settlement distribution.

Geologically Kerala is a part of the south Indian shield. The rock types are dominated by crystalline formations. Four major formations found in Kerala are: (i) Crystalline rocks of Precambrian, (ii) Sedimentary rocks of Tertiary (iii) Laterite capping the crystalline and the sedimentary formations and (iv) Recent and sub-recent sediments forming the low lying areas, coastal area and river valleys (Geological Survey of India, 2005). Bulk of the rocks of Kerala, especially the granulites and associated gneisses belong to the Precambrian. The on land sedimentary formations are confined to Neogene period only. They include pebble beds, sandstone, grit, clay with shells, marl and limestones. All the rock types (crystalline and sedimentary rocks) are lateritised to variable depths. Duricrust formations are marked in places. Recent and sub-recent sediments cover the low lying areas, coastal plain and river valleys. Rock types, their composition and degree of weathering influence landform development. Rugged terrains are mostly on hard rocks and radial drainages usually characterize areas affected by granite intrusions. Structural control is well evident in drainage development. Fractured hard rocks are conducive for ground water recharge. Laterites are also good aquifers.

Rainfall

Rainfall is the main source of fresh water in the State. Normal rainfall in Kerala (1950-1990) is around 280cm (Simon and Mohankumar, 2004). However, there are wide variations in year to year rainfall. Kerala received the highest average annual rainfall of 415 cm in the year 1962 and the lowest rainfall (151cm) occurred in 1982 (KSLUB, 1995). Precipitation shows increasing trend from the coast to inland and the maximum is recorded along the foothills around Neriyamangalam (451 cm) in the south and Kuttiyadi (417 cm) in the north. It decreases further east and the lowest rainfall (<100cm) is recorded in the rain shadow region along the leeward eastern slopes of the Anamudi around Chinnar and North Marayur. Although the zone of highest rainfall is located in Idukki-Ernakulam border, in general the Malabar area receives higher rainfall than the Travancore region. The Palghat Gap, lying almost in the central part of the Western Ghats of Kerala, disrupts the rainfall trend due to its sudden reduction in relief, resulting in considerably low rainfall. Kerala receives rainfall almost in every month. This year-round rainfall and high precipitation in the foothills have contributed to the perennial water supply in the rivers. Orographic influence on rainfall is pronounced.

Based on rainfall and clouding characteristics four seasons can be identified in Kerala: South-West monsoon (locally known as *Kalavarsham*) (June to September). North-East monsoon (locally known as *Thulavarsham*) (October and November), Winter (December-February) and Pre-monsoon (March-May). Total rainfall received during S-W monsoon increases steadily from Trivandrum in south to Kasaragod in north along the coast and the contribution of south west monsoon rain to total annual rainfall also increases in the same direction (Sampath and Vinayak, 1989). The contribution of the North-East monsoon is high in the southern part and it is considerably less in the northern part. The northern stations are characterized by single peak during June-July, whereas the southern stations (south of Palghat) record two peaks: June-July and October. The winter months are characterized by minimum clouding and rainfall. It may be noted here that Kerala does not experience winter season like other parts of the country. The average minimum temperature in the winter months does not fall below 20^{o}C in most part of the State. The highly elevated Western Ghat areas covering parts of Idukki and Wayanad districts record low temperatures during winter months.

How dependable is Kerala rainfall? The Maximum Assured Rainfall (MAR) during the South-West monsoon period was expected to be realized during the last week of July while during the North-East monsoon the MAR occurred during the third week of October. General variability of rainfall for the state is between 20 and 40 percent above or below the expected values. Trends of variability change according to season. The northern part, especially the Kasargod-Kannur area records variability around 50% from year to year. It is generally observed that if rainfall is low in the South-West monsoon, it is partly compensated for during the North-East period. Monsoon failure for both the periods is very rare. The state therefore enjoys a certain amount of assured rainfall each year. There was a 50 percent chance for observing a dry week during the months of May and November.

Decrease in Rainfall

Decrease in rainfall is one of the issues debated under climate change programme. Kerala is one of the few States in India where rainfall data are available for more than 100 years. Soman et al, (1988) used the data set from 1901 to 1980 for 75 stations. Comparing the amount of rainfall received during 1901-1940 with that of 1941-1980m the changing trend has been worked out. The maximum decrease of rainfall of >20% is noticed in the foothill region stretching over the boundary between Idukki and Ernakulam districts. The 15% to 20% reduction zone spreads over southern foothill zone. Incidentally it may be noted that the major reservoirs are located in this zone of high rainfall reduction. Reduced rainfall can impact the hydro power and drinking water situation. The entire Western Ghat section recorded reduction in rainfall. However the Malabar part experiences relatively less change. Decrease in annual rainfall is also the minimum all along the coastal tract. Disaggregating the rainfall data for the seasons it is found that rainfall reduction is high during south west monsoon and it is not so appreciable during the north east monsoon period.

Landform

Landform zones running parallel to the coastline in NW-SE direction follow the longitudinal trend of topographic grain of the State. Three well identifiable landform zones with distinct geomorphic processes are: the Western Ghats, the Coastal Plain and the Undulating Lateritic Terrain (ULT) connecting these two units. There are two high level surfaces above the Western Ghats scarps marked in six patches and three low level surfaces marked between the coast and 300 m altitude (Chattopadhyay, 2004). The Western Ghats occupying the eastern part of the State form southern segment of the *Sahyadri* or the Great Indian Escarpment. It represents the edge of an up-raised and disrupted continental block with date of formation during the early Miocene (Radhakrishna, 2001). The Palghat gap at an altitudinal range of 100 to 300 m drained by the Bharathapuzha is a major break within the Western Ghats ranges. Two prominent tectonic blocks of Wayanad and Anamalai are located in the northern and southern segments of Palghat gap respectively. The north-easterly tilted Wayanad plateau drained by Kabini River is well developed at an altitudinal range of 700 to 900 m and characterized by subdued relief and wide valleys. The high altitudinal zone extends further south to Kunda hills, Silent valley and Attapadi valley adjoining Nilgiris, where the Eastern Ghats merges with the Western Ghats to the northeast of the Palghat gap. The part of the Western Ghats extending from south of the Palghat gap to Trivandrum-Nagercoil is considered as Southern Ghat or southern Sahyadri. Width of the Western Ghats narrows down in the Khondalite belt to the south of Achankovil-Kallada shear zone. The Agasthamalai (1809m) is the highest point in this part and the crest line slopes towards north. Western Ghats, as the catchment area of all the rivers of Kerala, plays a very important ecologic, economic and cultural role.

Undulated Laterite Terrain (ULT) connecting the Western Ghats and the Coastal Plain is primarily a subdued terrain evolved through pedimentation, lateritisation and parallel slope retreat, valley formation and expansion of aggradational plain. Laterite has developed as a cap on all types of rocks including recent sediments. Laterite usually forms during the final stage of land surface reduction and provides a cap rock protecting the old surface. Landform in Kerala is linked to laterite profile development. Hard crust formations facilitate parallel slope retreat or pediplanation in tropical areas; however, in the absence of a crust, landform usually develops due to peneplanation. Lateritic mesas at different altitudinal levels below

300 m are conspicuous landform features in Kerala. Narrow alluvial valleys indented into laterite landscapes give rise to undulated landform. The ridges and slopes are lateritic and the lowlands are alluvial.

The steep sloping lands, predominance of lateritisation, narrow width and structural control on drainage pattern and topography all together have imposed certain restrictions in development of fluvial landscape. Valleys and floodplains in most cases are narrow with possible exception of the Bharathapuzha, the Periyar River and the Pamba. The Kuttanad area lies 1 to 2 metre below mean sea level and continues to be a wet land. Alluvial fans have developed to the east of the Vembanad Lake.

Characteristics of sea waves, tidal range and direction of littoral current are the main factors influencing the coastal processes. In addition to these, the rivers directly debouching into the sea have pronounced influence on coastal geomorphology, sediment distribution and beach character. Formation of offshore bar and subsequent development of lagoon due to sea level change is a unique feature of Kerala coast. The coastal zone in Kerala is not uniform; it exhibits distinct spatial differences in material composition, morphology and surface features from north to south. The central part of the coast from Ponnani mouth to north of Asthamudi composed of recent sediments is considered as a permeable coast. Existence of an internal basin covering this area since Tertiary has been reported (Chattopadhyay, 2002). The northern and southern parts are characterized by laterites, sedimentary deposits and crystalline hard rocks. With an area of 205 km^2, the Vembanad is the largest lagoon in the west coast fed by seven major rivers. Bordering the Vembanad Lake there are three sets of beach ridges signifying transgression and regression. The southern part of the coast is characterized by Varkala cliff on sedimentary rocks, Kovalam headland on crystalline and Teri sand deposits further south. Pocket beaches are well developed. Palaeo sand ridges are found in patches in different parts of the coastal plain. Around 250 km of Kerala coast are affected by severe erosion.

Land use

Land in Kerala is intensely utilised. Hardly there is any vacant or unused land in the State. Land use pattern of Kerala is quite different from that of the rest of India. Net sown area constitutes 54.1% of the total geographical area of the State against an all India average of 42.86%. Multi-tier cropping system and dominance of tree crops and plantations are unique features in Kerala. Relation between land use and landform is quite explicit here. Nature of land use varies with altitude. The coastal plain and the adjoining low lands are dominated by coconut and rice. It is densely populated. All major urban centres are located in the coastal plain. The main transport lines, railways and roadways have developed in the coastal plain. The undulated lateritic terrain hosts crops like coconut, varieties of fruit tree crops, rubber, cashew, tapioca, pepper etc. Coconut dominates in the land up to 100 m altitude. Rubber plantation is an important component of land use up to 500 m altitude. It has replaced tapioca, cashew, coconut, tree crops, and degraded forest lands. Settlements are amidst mixed tree crops. Further up there are tea and coffee plantations in the Western Ghats. Cardamom is raised above 1000 m altitude. Forests are found over the rugged scarp slopes and high hills.

Kerala has experienced considerable land use change. Forest cover came down from 44% in 1905 to 17% in 1973 (Chattopadhyay, 1985). Other changes are from multi- tier to mono cropping, diversion of lowlands, and land shaping and occupancy of floodplain. Analysis of crop statistics indicated that, between 1961-62 and 2006-07, area under rice cultivation reduced by 73%. Land use change has serious implications on water quality (Chattopadhyay et. al.; 2005) and over all hydrological conditions.

2.2 Population

Kerala accounted for 2.76% of India's population in 2011. It was 3.1% in 2001. This indicates that the growth of population in Kerala is lower than that of all India average. Kerala's achievement in demographic sector is an example for the rest of India. Although population growth is well controlled, population density is very high. In 2001, Kerala recorded population density of 819 persons/ km^2. This figure rose to 859 persons/ km2 in 2011. Most of Kerala's population is concentrated in coastal plain and adjoining lowlands. There are wide variations in population distribution within the State **(Table 2.1)**.According to 2001 Census data, district wise distribution shows that Malapuram is the most populous district with 3.63 million people living here and Wayanad district housing only 0.78 million people stands at the bottom. Population density varies from 215persons / km2 in Idukki district to 1498 persons/ km2 in Alappuzha district. Alappuzha district maintained its lead in population density in 2011 census year also.

Population distribution is closely related to the physiographic condition of the State**.** The Population density decreases with increase in altitude. The districts like Wayanad and Idukki, which are located within the Western Ghats record low density, the lowest being in Idukki, which has high intra-district internal relief variation compared to Wayanad. Population densities in northern districts like Kasaragod and Kannur are also low. There are extensive hard crust laterite surfaces not very hospitable for usual crop husbandry and livelihood opportunities.

Kerala is well known for migration both inside and outside India. Internal migration which is an important issue in the matter of demographic change and consequent land use change merit attention of all planners and administrators. Unlike other parts of India intrastate migration in Kerala is not restricted to rural – urban movement. People are moving from one place to other within the rural areas itself. It has been reported in a study that 87 percent of rural internal migrants had migrated to other rural areas within the state and about 68 percent of migrants originating from urban areas had also moved to the rural areas while the other 32 percent of urban migrants staying outside Kerala moved from one urban area to another (Chattopadhayay 1988). Due to rural urban continuum and easy accessibility the push-pull factors underpinning population movement are not so effective in Kerala. Kerala has a long history of internal migration from lowlands in the west to the high lands in the east and also from Travancore area in the south to the Malabar area in north Kerala. Modern day migration started with introduction of plantation agriculture in the high altitudes and plateaus. It was followed by the initiatives of "Grow More Food" campaign, when forest lands and wet lands had been reclaimed to accommodate food crops. The nature of migration changed over the years.

Table 2.1: District-wise Distribution of Population Density and Growth

Districts	Total population (in 000) 2011	Density of Population (persons per Sq. Km)				Decade Growth (in per cent)		
		1981	1991	2001	2011	1981-1991	1991-2001	2001-2011
Kasaragod	1307	438	538	604	654	22.8	12.3	8.28
Kannur	2523	651	757	813	852	16.6	7.4	
Wayanad	817	260	315	369	383	21.3	17.1	3.79
Kozhikode	3086	958	1118	1228	1318	16.7	9.8	7.33
Malappuram	4113	677	872	1022	1158	28.9	17.1	13.31
Palakkad	2810	456	532	584	627	16.5	9.8	7.36
Thrissur	3121	805	903	981	1026	12.2	8.6	4.59
Ernakulam	3282	1053	1170	1050	1069	11.1	-10.3	1.81
Idukki	1109	193	215	252	254	11.2	1.72	0.79
Kottayam	1975	771	830	884	896	7.71	6.5	1.36
Alappuzha	2128	1319	1415	1489	1501	7.28	5.2	0.81
Pathanamthitta	1197	426	450	467	453	15.6	3.8	-2.99
Kollam	2635	873	967	1037	1056	10.7	7.2	1.83
Thiruvananthapuram	3301	1184	1344	1476	1509	13.5	9.8	2.24
State total & averages	**33406**	**655**	**749**	**819**	**860**	**14.3**	**9.35**	**4.91**

2.3 Management of Water Resources

Availability of clean and quality water over the seasons and across the entire state is a major component of natural resource endowment in the state. Most of the rivers in Kerala are perennial. This is due to high and year round rainfall in the provenance combined with deep soil and high biomass density in major parts of the source region. Despite high fluctuations between monsoon and non-monsoon months in drainage discharge, all rivers have base flow throughout the year. Quality water has contributed to improved health conditions and high quality of life. On an average Kerala receives little less than 300 cms of rainfall varying from coast to the highlands and also from south to north. As the population density is very high per capita availability of water in Kerala is 12,500 lpcd (litre/capita/day), which is decreasing with growth of population. Besides, some parts of the state already face scarcity of drinking water in certain periods of the year. Secondly, quality deterioration restricts easy availability. If the water resource is deteriorating and quality problem restricts easy availability, the very foundation of the Kerala mode of development will be in jeopardy. Therefore, management of water resources assumes significance for sustaining and strengthening Kerala's development.

2.3.1 Surface Water

Characteristics of Rivers

Rivers in Kerala are small by all India standards. The longest river, the Periyar is only 244 km long. Catchment of the Bharathapuzha is the largest in the State with 6186 km^2. Kerala has 44 rivers, out of which 41 flow westward to the Lakshadweep Sea and the rest three are east-flowing rivers. Some of the west-flowing rivers have a portion of their catchments in the adjoining States of Tamil Nadu and Karnataka. There are only 11 rivers having the length of more than 100 km each. Large or small, all the rivers in Kerala have originated in the Western Ghats and traverse all the three landform zones. Therefore all river basins show similar diversity in geomorphic characteristics and land use pattern. While the topographic grain is longitudinal in a north-south direction, the river basins are elongated in an east-west direction giving rise to alternate ridge and valley topography. Rivers are short and swift flowing with steep gradient from the source to 100 m altitude. Below 100 m altitude rivers are sluggish and all the rivers join sea through lagoons. Some of the river mouths show spit formation. Study of gradients of some selected rivers indicates that the coastal plain extends far more eastward in central Kerala than in the northern and southern parts of Kerala. Some of the rivers like Chalakudy, Periyar and Pamba have gradients of 1/250 or more for $3/4^{th}$ of their courses from their sources indicating hilly nature for major part of their courses.

Fresh Water Structure

Many of the rivers have been dammed in their upstream sections for irrigation and hydroelectric projects. There are 53 reservoirs of all sizes covering an area of 429 sq. km. Total stored surface water in Kerala is estimated at 5,500 million cubic metre (Mm3). Water is diverted through canals for irrigation during the dry season. It also helps recharging wells in certain areas. Many of these reservoirs are used for supplying drinking water. Kerala has several fresh water bodies, of which nine are important and combindly cover 16 km^2 area. Sasthamcotta Lake in Kollam district and Vellayani Lake in Thiruvananthapuram district are used for drinking water supply to Kollam municipality and parts of Trivandrum city respectively. Water budgeting for Sasthamcotta Lake has indicated that the annual yield of this lake is to the tune of 4.7 million cubic meters (CESS, 1998). Ponds and tanks are traditional rainwater harvesting structures, used widely in tropical countries. The ponds in Kerala may be grouped under three types: (a) natural depressions (locally known as chiras in some parts of the State), (b) excavated and man-made ponds or tanks, and (c) valley-head ponds (or Talakkulam). While the first two types are located in the low-lying areas, the third type is located at the valley head. Water is impounded by constructing a barrier or dam across the valley. Valley-head ponds are used mainly for irrigation purposes supplementing rainwater to grow rice or other crops after the monsoon. Many of the valley-head ponds in Kerala are associated with springs. Spring-fed ponds are perennial; however all springs do not yield large quantities of water. According to Kudumbashree Mission (2004) there are 46337 ponds in Kerala whose combined area is 275km^2 (**Table 2.2)**. State has 995 large ponds with the minimum water storage capacity of 1500 cubic meters each (CWRDM, 1989). Of these, 287 ponds are public and 137 belong to temples. They are found throughout the state, but a sizable number are concentrated in Palakkad District, which is drought-prone due to the effect of the Palghat Gap. Rainfall in this area is lower than in other parts of the state. Even the Thiruvananthapuram Urban Corporation area can boast of as many as 80 ponds, some of which are still in use.

Table 2.2: Details of Selected Fresh Water Resource Structures in Kerala

Type of Structure	**Number of items**	**Area covered in ha**
Private ponds	35763	21986
Panchayat ponds	6848	1487
Quarry ponds	879	341
Ponds under religious institutions	2689	480
Village ponds and other structures	185	496
Irrigation ponds	852	2835
Reservoirs	53	42890
Check dams	80	259
Bunds/ Barrier/ Anicut/ Shutter	70	879

Source: Kutumbashree Mission, 2004

2.3.2 Ground Water

Kerala has good groundwater potential with a replenishable groundwater resource of 6841 Mm3 and net availability of 6230 Mm3. The gross groundwater draft for all use as on 2004 was 2920 Mm3 of which 62% were used for irrigation and the rest 38% were domestic and industrial drafts (Central Ground Water Board, 2006). Traditionally people in Kerala depend on open wells for meeting their domestic needs and also for irrigating homestead gardens. There are about 4.5 million open wells in Kerala. The density of open wells is very high (150 to 200 wells / sq.km), perhaps the highest in the country. In coastal tract, the density of wells rises to as high as 400 wells / sq.km. More than 90 percent wells are used for domestic purposes for one activity or another. Gound water recharging potential depends upon biophysical characteristics like geology, structure, topography, slope, infiltration capacity of soil and rainfall. Recharging potential is relatively higher in Palakkad and Trissur districts compared to other districts. However stage of development of groundwater is the highest in Kasaragod district (71%), which is draught prone and the lowest is in Wayanad district (22%) which is a high level plateau. The overall stage of development in the state is 47%.

The groundwater scenario has changed considerably during past 10 to 15 years. In 1989, the gross groundwater draft was only 935 Mm3 and in 1999 it rose to 2693 Mm3 and in 2004 it was 2920 Mm3. Ground water development increased from 9.5% in 1989 to 43% in 1999 and to 47% in 2004 (Central Ground Water Department, 2008). All 152 blocks were safe in 1989, where as in 2004 only 101 blocks are safe and among the rest as many as 30 blocks are semi critical, 15 blocks fall under critical and 5 blocks are over-exploited.

2.4 Water Availability and Demand

Total annual yield of all the rivers in Kerala is estimated to be 78,041 Mm3, in which the west-flowing rivers contribute 64,263 Mm3 and the rest is from three east flowing rivers (Govt. of Kerala, 1974). Kerala’s share is 70,323 Mm3. The total annual yield in Kerala is about 30% less than that of a single river like Godavari. On average, one square kilometer of catchment area yields 1.81 Mm3 of which 60% is usable. A recent estimate indicates that total surface water availability in Kerala after accounting for losses due to evapo-transpiration and interception is about 54,410 Mm3. Of which 41,000 Mm3 flows as surface runoff, 7900

Mm3 infiltrates to recharge ground water and the rest is stored in reservoirs (Planning Commission, 2008). It is not appropriate to plan to use the entire quantity of 41,000 Mm3 of water. Some quantity of fresh water is required as environmental flow to maintain functioning of hydro ecosystem of all water bodies, like rivers, lakes, and back waters. Some amount is required to prevent salt water ingress from the sea and some flow should be maintained to flush out wastes regularly discharged into the rivers from human settlements. Water requirement for flushing wastes is increasing with incremental waste discharge as a consequence of growing consumption. It is generally estimated that 40% of flow should be allowed for these functions and rest 60% can be considered as annual utilizable water. However, this may not be feasible because rivers are rain-fed in nature and hence experience wide variations in flow between lean season and monsoon. Drawing 60% water during non-monsoon months may not be practical as rainfall is the main source of all available water and it is mostly concentrated during monsoon months. There are variations in availability and demand over the seasons. Annual availability indicates surplus of 8,506 Mm3 however summer season experiences deficit of 7,142 Mm3 **(Table 2.3)**. Per capita fresh water availability in Kerala as on 2001 was 9450 lpd of rainwater, 1022lpd of surface water and 590lpd of ground water (ENVIS Centre, 07/10/2014).

Table 2.3: Water Availability and Demand in Kerala (in bcm) in 2001

Items	**Annual**		**Summer season**	
	Availability	**Demand**	**Availability**	**Demand**
Surface water	24.60		3.70	
Ground water	5.10		5.10	
Stored surface water	5.50		5.50	
Domestic demand		1.20		0.80
Birds and Animals		0.40		0.30
Industrial demand		6.40		3.20
Conservation of kari land		5.00		3.50
Irrigation		13.70		13.70
Total	**35.20**	**26.70**	**14.30**	**21.50**
Surplus/ deficit	+8.50		-7.10	

Source: Central Ground Water Board (2012)

2.5 Use of Water Resources

The State has an utilizable yield of 42.67bcm according to PWD estimate. The major uses are for drinking and domestic purposes, irrigation, industry and generation of hydro power. Water recreation is another important emerging sector associated mainly with tourism.

Drinking Water

Traditionally people used to depend on dug wells for meeting their need of drinking and domestic water. In general every house hold in the rural area has at least one well. Some of the urban households still maintain wells in their premises. In Kerala, there are schemes for providing piped water supply to 204 lakh persons who come to around 64 percent of the total population in the State comprising of 59 percent rural and 79 percent urban. Government of Kerala set up an organization Jalanidhi (Kerala Rural Water supply and Sanitation Programme) under the directions of Government of India to initiate rural water reforms programme with financial support from the World Bank.

The first phase launched in the period between 2000 and 2008 covered 1.13 million people building 3663 village level water supply schemes in 112 Gram Panchayats or 11% of all Gram Panchayats. The evaluation report (Independent Evaluation Group, 2013) indicated that according to the independent household survey commissioned by the World Bank (2008) 44% of community schemes reported periodic water shortage and actual water supply was 45 litres against designed supply envisaged to be on an average of 60 litres per capita per day . The water supply fell down to only 29 lpcd during summer season. Some project schemes resorted to three days rotational water supplies in the summer to serve all consumers. In 2012 another survey indicated that majority of the interviewees stated that they draw water from traditional sources to supplement water supply projects (ibid). Although the project was rated 'satisfactory' based on relevance, efficacy and efficiency, it was pointed out that 'its performance towards the end of the project was less than its demonstrated potential' (ibid).

With regard to urban population, the highest coverage is in Kottayam district (97.6 %) and the lowest is in Wayanad district (50%). District wise rural and urban piped water coverage is shown in **Table 2.4**. However it may be noted that not all people brought under the schemes receive piped water in sufficient quantity.

The drinking water and sanitation sectors deserve immediate attention. In coastal area around 70% of dug wells are used for household purposes. The estimates show that 17 per cent of the villages in Kerala do not get any benefit of protected water supply and 69 per cent are partially covered. Therefore, 86 per cent of the village area are either not covered or only partially covered. In partially covered areas, 14 per cent households get only less than 10 liter/day and 55 per cent get less than 20 liter/day.

Table 2.4: District-wise Population Covered by Water Supply Schemes as on July,2003

Sl. No.	District	Rural Population covered	% to Total Rural population	Urban population covered	% to Total Urban population	Total population covered	% to total population
1	Thiruvananthapuram	1477911	68.99	916344	83.86	2394255	74.01
2	Kollam	1075859	50.9	453781	97.41	1529640	59.19
3	Pathanamthitta	592674	53.49	107700	87.15	700374	56.86
4	Alappuzha	1154817	77.65	521854	84.43	1676671	79.64
5	Kottayam	812061	49.12	292663	97.63	1104724	56.57
6	Idukki	504908	47.13	55012	96.11	559920	49.61
7	Ernakulam	1467865	90.5	303990	88.31	2771855	89.46
8	Thrissur	1547278	72.44	696877	83.01	2244155	75.42
9	Palakkad	1151025	50.92	253839	71.21	1404864	53.68
10	Malappuram	1676401	51.21	344860	96.88	2021261	55.68
11	Kozhikode	593495	33.39	747527	67.9	1341022	46.58
12	Wayanad	555354	73.36	14835	50.11	570189	72.49
13	Kannur	578945	48.44	708332	58.2	1287277	53.36
14	Kasaragod	633132	65.3	143298	61.3	776430	64.32
Total		**13821725**	**58.64**	**6560912**	**79.36**	**20382637**	**64.02**

Source: Nair and Chattopadhyay, 2005

Grass root level analyses in some places show even a more dismal picture than this. Some panchayats in Palakkad district reported that 70% households do not have their own source of safe water and 41% of households have to walk more than 50 m to collect water. Efforts of 50 years of public intervention in creating drinking water facilities in this area have succeeded to develop a water infrastructure that is capable of catering hardly 27 per cent of the households in the area (Nair and Chattopadhyay, 2005). In some Panchayats drying up of wells during summer months is a common phenomenon which affects sizable households depending on well water for drinking purposes. The worst sufferers are poor and landless households, small land holders, scheduled castes and scheduled tribes. It is women who bear the brunt of the ordeal of fetching water from far away places. Caste and gender based inequities and economic inequalities are dominant in several panchayats.

Household level data obtained from Census 2011 indicated that out of 7.72 million households only little over 29% households are covered by tap water supply. Treated tap water is available for 23.35 % of households. The rest depend on untreated tap water. Well water is the main source of drinking water for sixty two per cent of households and bulk of these wells (47.4%) are uncovered **(Table 2.5, Fig. 2.1)**. District level variations indicate that more than 50% of the households in Ernakulam district have access to treated tap water. Palkkad and Trivandrum with around 30% of households falling in this category distantly follow Ernakulam. The districts of Kannur, Kasaragod and Malappuram lag far behind with around 10% of households enjoying this facility. It is important to note that majority of the households in all 14 districts except Ernakulam depend upon uncovered well for drinking purposes. A sizable section of households in Idukki and Wayanad use spring water. The Census data also brought out that 77.7% of households have drinking water sources within their premises, 14.1% have near the premises and the rest 8.2% have to travel some distance to fetch water.

Disaggregating these data for rural urban sectors it is found that even in urban areas around 59% households depend on well water against an all India average of 6.2%. Ernakulam, Palakkad and Thiruvananthapuram are only three districts, each of which has more than 50% of urban households catered by tap water supply **(Table 2.6).** Over the years, tap water supply in urban areas could not keep pace with population growth (Table 2.7). It may be noted here there are certain discrepancy in data on water supply. Nevertheless, the State faces problem in the matter of drinking water supply.

Table 2.5: Distribution of Households According to Main Source of Drinking Water in the Districts of Kerala

Districts/ Taluks	Total no. of households	Tap water (%)		Well water (%)		Tube wells bore wells hand pump (%)	Others- rivers/ canals/ springs (%)
		Treated	Untreated	Covered	Uncovered		
Trivandrum	828774	31.92	6.26	12.5	44.4	2.12	2.8
Kollam	663,276	17.62	9.5	18.96	49.96	0.79	3.17
Pathanamthitta	319,968	15.18	3.92	31.01	44.32	1.34	4.23
Alappuzha	528,275	25.72	9.25	11.91	33.90	14.33	4.89
Kottayam	480,453	19.24	3.66	33.03	36.9	1.58	5.59
Idukki	276,976	18.39	11.82	7.82	32.51	4.18	25.28*
Ernakulam	791,737	52.98	4.25	12.88	27.59	0.96	1.34
Thrissur	743,830	22.24	5.25	19.0	44.16	7.82	1.53
Palakkad	628,287	33.34	9.53	7.36	41.0	5.94	2.83
Malappuram	774,595	11.1	3.75	12.84	65.6	3.33	3.38
Kozhikode	683,825	16.48	4.53	14.86	57.94	2.10	4.09
Wayanad	185,403	14.76	7.81	6.95	58.9	3.25	8.33**
Kannur	543,209	8.63	3.09	8.17	73.11	2.53	4.47
Kasaragod	267,762	9.65	4.07	3.63	58.93	21.36	2.36
Kerala	7,716,370	23.35	5.98	14.64	47.4	4.2	4.43

Source: Census, 2011 *15.25% spring water, **4.86% spring water

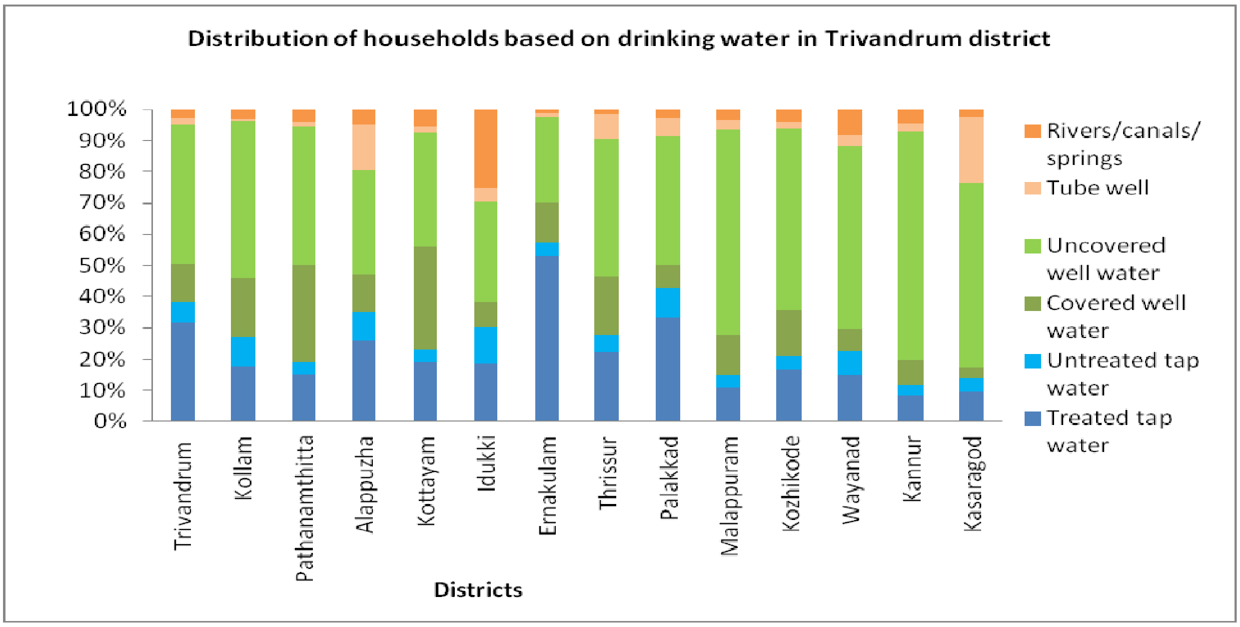

Fig 2.1: District-wise Distribution of Households According to Drinking Water Source (2011)

Table 2.6: **Distribution of Households According to Main source of Drinking Water in the Districts of Kerala (Urban Sector)**

Districts/ Taluks	Total no of households	Tap water (%)		Well water (%)		Tube wells bore wells hand pump (%)	Others-rivers/ springs (%)
		Treated	Untreated	Covered	Uncovered		
Trivandrum	438,167	47.52	4.17	10.97	33.78	1.77	1.79
Kollam	289,599	24.22	8.96	21.39	42.82	0.85	1.76
Pathanamthitta	34,579	30.19	3.63	34.26	28.98	0.72	2.22
Alappuzha	282,426	25.16	9.54	11.01	34.09	17.22	2.98
Kottayam	137,746	26.48	3.17	34.98	32.29	0.84	2.24
Idukki	12,327	46.05	3.42	26.67	21.37	1.66	0.83
Ernakulam	535,427	63.17	3.07	11.65	20.32	1.12	0.67
Thrissur	496,902	21.61	5.08	20.17	43.58	8.36	1.2
Palakkad	151,969	49.46	5.03	7.95	31.86	4.98	0.72
Malappuram	337,084	11.51	2.88	14.86	65.79	2.99	1.97
Kozhikode	451,597	19.08	3.6	17.93	54.69	2.42	2.28
Wayanad	6,717	25.55	4.69	2.99	60.07	2.33	3.74
Kannur	344,363	10.27	1.57	8.73	75.75	2.13	1.55
Kasaragod	101,793	13.81	4.8	3.87	54.13	21.36	2.03
Kerala							

Source: Census, 2011

Table 2.7: Temporal Variations in Coverage-Urban Households

Survey period	1998-99 National Family Health Survey	2000-02 (NSS 58th round)	Census 2011
Tap	37.6	42.6	34.9
i) Private	17.8		
ii) Public	19.8		
Hand pump		2.0	4.6
Well		55.3	58.9
Others	62.4 (includes hand pump and wells also	0.1	1.6

Irrigation Projects

Irrigation was a priority sector of intervention in agricultural development of Kerala since independence like rest of the country. The thrust on irrigation was aimed to stabilise agricultural production, particularly the 2nd crop. Owing to topographic conditions, a major network of canal irrigation was built up in Palakkad district and parts of Trissur districts. Subsequently other districts were also covered. There are 18 dams devoted to irrigation infrastructure of which 13 dams have storage capacity and the rest five are barrages (GOK, 2010). By 2008-09, net irrigated area in the State was 3.99 lakh ha and gross irrigated area was 4.58 lakh ha. Only 19% of net sown area received irrigation water. Canal irrigation accounted for 24% of net area irrigated. With change in land use pattern, particularly diversion of paddy land for other uses, the purpose for which the large irrigation projects were conceived has been questioned.

Industrial and Recreational use of Water

Based on a per capita consumption of 1601pd and projected population of 5.53 crore in the year 2021, the annual domestic and industrial uses have been estimated at 3230 Mm^3 and 4270 Mm^3 or 6.5% and 9% respectively of the total projected demand. The total requirement under these two sectors is thus 7500 Mm3. Besides, there is a need to keep provision for environmental flow and also flow to wash away the pollutants discharged into the rivers from industries, agricultural run offs and domestic effluents.

2.6 Challenges for Water Management in Kerala

The Global Water System (GWS) Project raised three thematic questions: (i) the magnitude of anthropogenic and environmental changes in global water system and the key mechanism by which they were induced, (ii) the main linkages and feed backs within the earth system arising out of changing GWS and (iii) resilience and adaptability of GWS to the change and strategy for sustainable development (Vorosmarty et al., 2004). All these three questions are important for Kerala. In spite of rich endowment of water resources, Kerala faces problem of water availability both in terms of quantity and quality. The challenges for water management are to understand the nature of human activities and the natural forces that generate pressures influencing the water system. Many of these are highly dynamic; they change at a faster pace influencing water management strategies and policies (UNEP, undated-2). The issues that merit attention in water resource management of Kerala are: (i) Sustainability of water source, (ii) Improvement and maintenance of water quality-surface and ground, (iii) Operation and maintenance, (iv) Technical support, (v) Intersectoral coordination, (vi) Governance and (vii) Climate change. Some of these issues are briefly elaborated here.

Sustainability of Water Sources

Demand for water resources is increasing and at the same time water availability is declining due to deteriorated water quality of surface and sub surface sources and also drying up of traditional water sources like ponds and springs. The availability and demand calculations of CGWB **(ref. table 2.3)** indicated that summer season faces shortage of 7.10 bcm. As the water retention capacity of the river catchments is coming down due to change in natural vegetation cover, removal of soil, excavation of hills, and spread of surfaced area the summer water availability is decreasing. In stream interventions, removal of sands and clay from flood plain also contribute to declining water holding capacity of the river and flood plain systems. Springs, catering to the drinking water need of more than one lakh families in the State are facing problems of drying up. Wayanad and Idukki districts reported drying up of springs. Drinking water situation is grim in both these districts, particularly in the rugged hilly areas. One of the major challenges of water management in Kerala in coming years will be sustainability of water sources.

Improve and Maintenance of Water Quality

Deterioration of water quality, both of surface water and ground water is a major issue. The KSCSTE report indicated that waters of almost all of 44 rivers in Kerala are being increasingly polluted by industrial and domestic waste, pesticides and fertilisers used in agriculture. Most of the industries are located in the near the thickly populated coastal plain and along riversides. Dispersed nature of settlement has complicated the situation. One of the estimates indicated that around one million cubic metre of waste is generated daily in the coastal areas of the state, of which a significant amount directly reaches the surface water bodies in the coastal areas. Kerala State Pollution Control Board classified the rivers according to the best use. Hardly there is any stretch of river in the State from where water can be directly used. Water quality of selected rivers is given in the **Table 2.8.**

Table 2.8: Water Quality Parameters (Selected) for Selected Rivers

Rivers	**Water Quality**					**Remarks/ problems**
	pH	**BOD (mg/l)**	**DO (mg/l)**	**TDS (mg/l)**	**CPCB best use ***	
Kabani (sampling year:2006-2007& no. of samples- 21)	6.17–8.20	0.11-11.08	3.46-11.68	13.2–233.6	B (31%), C (46%) D (21%)	Quality problem, untreated domestic and municipal effluents.
Bharathapuzha (2005-2010, 27)	6.67-10.17	0.03-7.0	3.40-14.6	22.9 – 419.2	B (17%), C (63%) D (15%)	High turbidity near sand mining sites. bacteriological contamination
Chalakudy (2009-2010, 23)	5.27-7.89	0.07-7.45	3-10.8	18.8 - 718.7	A (52%), C (39%), D(9%)	Sand and clay mining, excessive water withdrawal and saline water ingression
Periyar (2005 – 2008, 35)	5.65-8.42	0.06-4.73	1.60-11.8	12.5-566.8	B (18%), C (57%), D (8%), E (15%)	Saline ingression, industrial effluents along downstream, heavy metal pollution
Pamba (2007, 21)	6.15-8.60	0.13-11.8	0.26-10.23	17.6-226.2	C (45%), D (40), E (13%)	Quality problem, Cadmium and copper concentration slightly high.
Achankovil (2009, 20)	6.01-8.22	0.07-3.60	4.64–10.43	35.6-127.6	A (5%), B (20%), C (75%)	Require treatment and disinfection for drinking
Karamana (2007-2008, 20)	4.39-7.72	0.06-39.11	2.4-11.53	15.8-6533.2	C (47%), E (37%)	Water quality 75% of water samples are acidic. Carries urban sewage.

*CPCB (Central Pollution Control Board) best use classification: A- Drinking water source without conventional treatment but after disinfection, B - Outdoor bathing (organized), C- Drinking water source with conventional treatment followed by disinfection, D- Propagation of wild life, fisheries and E- Irrigation, industrial cooling, controlled waste disposal. Figures in bracket indicate percentage of total samples in the Class.
Source: Compiled from Environmental Monitoring Programme on Water Quality, 2009, 2010, 2011 & 2012, Kerala State Committee for Science, Technology and Environment and Centre for Water Resources Development and Management.

Kochi is the main industrial belt. Around 300 medium and large-scale and about 200 small-scale industries are discharging effluent directly into saline or freshwater bodies. It is reported that nearly 260 million litres of trade effluents are dumped into the Periyar estuary every day from the industrial belt in Kochi. The industrial effluents include mercury, insecticides such as DDT and BHC, copper, sulphides, ammoniac nitrogen, zinc, lead and phosphates. There is no efficient water treatment system in industries and city municipalities. A recent study on the Pamba river indicated high pollution level due to human intervention (David, et al, 2015). The stretch receiving effluents from Sabarimala pilgrim centre is highly polluted. The agriculture discharge containing fertilizer residues and other nutrients particularly dissolved inorganic nitrogen (DIN) is a matter of major concern for the Vembanad lake into which the river Pamba is debouching.

CGWB (2012) reported that ground water of Kerala show problems of iron concentration of > 1.0mg/litre in parts of all 14 districts and nitrate concentration of >45mg/litre in parts of all 14 districts except Ernakulam, Kannur and Kasaragod. Kerala is one among the top five states in India having presence of iron and nitrate in ground water. Besides, parts of Palakkad district also reported high electrical conductivity (>3000µS/cm) and fluoride concentration (>1.5mg/ litre). Bacteriological contamination of ground water is widely reported. Considering the fact that 62% of households depend on wells for meeting drinking water need deteriorating quality of ground water is a matter of serious concern. Management of deteriorated ground water is more complex than surface water as sub-surface geochemical reaction between contaminants and earth materials are not always well-understood and the subsurface movements of pollutants are slow and difficult to detect. Improving water quality of both surface and ground water is a huge task as it is also linked with solid and liquid waste management. Retention time of pollutants in ground water is much longer than that in surface water.

Operation and Maintenance

Operation and maintenance of drinking water supply structure is another serious challenge. Treatment of drinking water supplies to maintain minimum residual chlorine of 0.5 mg/l is necessary. Experimental studies indicated that the quality of drinking water supplies in the state clearly indicates high level of bacterial contamination. This poses a serious risk to public health which is evident from high incidence of acute diarrheal diseases and other water borne infections among the people especially the poor sections of the community. Continuous disinfection of drinking water and maintenance of the potable quality is a necessary prerequisite. It is also reported that there is high transmission loss of drinking water due to leaking pipe lines. As sewerage lines run underground more or less parallel to the drinking water supply lines there are every possibilities for contamination. Both source and supply lines require proper maintenance and operation.

Challenge of Water Governance

Water management is a multi–institutional activity. Water resource department is the principal custodian however there are other departments involved in management and execution of various water resource projects. The Public Health Engineering Department (PHED) of Government of Kerala was the controlling authority of public water supply in the Urban sectors till 1984. Kerala Water Authority (KWA) was formed in April 1984 as an autonomous body entrusted with the job of planning, implementation and management, revenue collection, and maintenance of the water supply systems. Over the years public water supply was introduced in the rural areas also. The KWA emerged as the largest institution in the field of water supply, and implemented several small, medium and large urban and rural piped water supply schemes. However, as the demand for pipe water supply in the rural areas grew, KWA found wanting to manage the water supply schemes to the satisfaction of users.

The idea of decentralized water governance system cropped up from time to time. This demand was strengthened with emergence of People’s Plan Campaign. Almost at the same time the new policy initiatives of Government of India following globalization tried to promote demand based, community managed decentralised water supply run jointly by the State, civil society and people/ beneficiary. As part of these initiatives rural water supply was separated and a new organization, the Kerala Rural Water Supply and Sanitation Agency (KRWSA) was launched and entrusted with the responsibility to facilitate the implementation of rural water supply systems. The first phase of this project also known as ‘Jalanidhi’ was launched during the period of 2000-2008. During this phase 3663 villages and 1.13 million people were covered. This was well above the target. The Project performance assessment report prepared at the behest of the World Bank (IEG Public Sector Evaluation, 2013) considered the performance satisfactory, however highlighted a couple of points which merit close scrutiny. These are (i) quality of water-70% of beneficiaries boil their drinking water as chlorination is not preferred due to bad taste, (ii) lack of technical and executive hands for maintenance, (iii) dearth of experienced NGOs, (iv) dependence on donor agency for maintenance cost and (v) institutional problems related to repair of major damage to community schemes. The last one was noted as having significant risk to development. The second phase of Jalanidhi started in 2012 to cover 224 villages that face scarcity of drinking water.

Climate change

One of the issues of current importance having long term implication on water resources is climate change. It is already reported that the rainfall during south west monsoon is declining and there is increasing incidence of high intensity rainfall separated by longer dry period. This will affect existing water management infrastructures. In one hand, due to reduction in rainfall there will be less storage and on the other hand, high intensity rainfall will cause increased storm runoff. The problem in the urban areas will be more severe as storm drainage will pose serious water dispersion challenges. Besides, increased temperature will accelerate evapo-transpiration causing loss of soil moisture which will also impinge on water availability of the State. Any future water management activity should internalize the climate change issue.

CHAPTER III

Water Policy and Governance in Kerala: A Critical Evaluation

3.0 Introduction

During the past decade, water governance has globally experienced a major shift, from technology-oriented, centralised approaches towards multi-level, decentralized and user-centred approaches. In both developing and developed countries, inclusion of different levels of governance, decentralisation, public participation, promotion of Integrated Water Resource Management (IWRM) and the emergence of the river basin as an important scale of planning and intervention are significant trends of changing governance (Moss and Newig, 2010; Tropp, 2007). India also has witnessed several paradigmatic shifts in management and governance of water resources. Structural changes are currently underway in India on how water is governed and managed in order to deal more effectively with challenges of increasing water stress. Causal factors include growing demand, mismanagement of water resources, water pollution and issues of inter-state /intra-state rivers. Global transitions in water governance, including promotion of Integrated Water Resources Management (IWRM), river basin approaches and inclusion of participation are also reflected in the India government's policy (UNICEF, 2013). In general terms, there is a clear policy shift from a supply-driven to a demand-driven approach, characterised by decentralisation and user participation. The country's comprehensive National Water Policy (NWP) addresses water as a state subject which is a finite and vulnerable resource and focuses on the importance of a river basin governance approach involving various stakeholders.

3.1 National Water Policy

The concept and history of watershed management in India started way back in 1880 with the Famine Commission and then with the Royal Commission of Agriculture in 1928 (Joshi et.al, 2004). After 1960s there were several policies and programmes initiated by different ministries including Ministry of Water Resources, Ministry of Agriculture, Ministry of Rural Development (MoRD), and Ministry of Environment and Forest (MoEF) at watershed levels. By 1980’s it is realised that water is a precious national asset and planning and governing of water resources need to be steered by national perspectives. Moreover, the severe drought of mid 1980’s forced the Government of India to frame newer policies and to restructure the existing programmes. Thus the First National Water Policy (NWP) was adopted in 1987. Over the years Indian Water Policy has evolved to take cognizance of climatic vagaries and emergence of increasing demand for water as a consequence of development and economic growth. The national water policy has been later revised in 2002 and again in 2012.

The 1987 NWP was a significant milestone in watershed development programmes as it clearly stated "resource planning in the case of water has to be done for a hydrological unit such as a drainage basin as a whole, or for a sub-basin". The policy assigned the responsibility for the design of watershed projects to the state governments. It also emphasised that appropriate organisations should be established for the development and management of a river basin as a whole and that there should be an integrated and multi-disciplinary approach to the planning and implementation of watershed projects, which should include, among others, the creation of master plans for flood control, construction of check dams, soil conservation, and forest preservation and expansion (GoI, 1987). The policy identifies water allocation priorities as drinking water, irrigation, hydro-power, navigation and industrial and other uses.

The revision of the NWP in 2002 further strengthened river basins and sub-basins as units of natural resource management, proposing the creation of river basin organisations (GoI 2002). The document added "With a view to give effect to the planning, development and management of the water resources on a hydrological unit basis, along with a multi-sectoral, multi-disciplinary and participatory approach as well as integrating quality, quantity and the environmental aspects, the existing institutions at various levels under the water resources sector will have to be appropriately reoriented/reorganised and even created, wherever necessary (ibid). The 2002 water policy adopted slight changes in water allocation priorities as; drinking water, irrigation, hydro-power, ecology, agro-industries and non-agricultural industries and navigation and other uses.

In 2012, the Ministry of Water Resources issued a revised NWP. The new policy, among others, raises concerns regarding the effects of land use and land cover changes on water availability and quality. The policy also stated the need for comprehensive legislation for optimum development of inter-State rivers and river valleys to facilitate the inter-State coordination ensuring scientific planning of land and water resources taking basin/sub-basin as unit with unified perspectives of water in all its forms (including precipitation, soil moisture, ground and surface water) and ensuring holistic and balanced development of both the catchment and the command areas (GoI 2012). Though all these policies stressed for integrated approaches at whole river basin level, it could not make any significant changes at ground level, in specific there were no integrated plans executed for the whole river basin in anywhere in the country.

National Water Commission (NWC): Realising importance of inter departmental coordination Government of India constituted a Committee (Mihir Shah Committee) to restructure the Central Water Commission (CWC) and Central Ground Water Board (CGWB). This committee recommended unification of these two organistaions to form National Water Commission (NWC) which will be responsible for water policy, data and governance in the country (Suhag, 2016). The NWC is expected to have eight divisions, namely, (i) Irrigation Reforms Division, (ii) River Rejuvenation Division, (iii), Aquifer Mapping and Participatory Ground Water Managemt Division, (iv) Water Security Division, (v) Urban and Industrial Water Division, (vi) Water Quality Division, (vii) Water Data Management and Transparency Division, and (viii) Knowledgement and Capacity Building Division. Irrigation management transfer, participatory ground water management and rejuvenation of rivers are major recommendations. The main emphasis is to integrate surface and ground water management and to bring ecosystem perspective to the ways water is governed in India (Raina, 2016). However, the report suggests a centralized structure. Besides, it provides little scope for innovation and fails to present a road map to fructify the ideas advanced by it (Nilekani, 2016).

3.2 State Water Policy

The state of Kerala, has occupied an eminent position in the global development debate since the early 1970s (Franke & Chasin, 1992, Ramachandran, 1997, Veron, 2001). In 1990's a "new" Kerala model began to emerge-one that promised to better integrate sustainable development goals into policy making, and to go beyond mere state regulation to include community-based strategies for environmental protection (Veron, 2001). The new policy approach comprises decentralised administration and resource based participatory planning combining productive and environmental objectives. Due to good amount of rainfall and surplus water resources, water resource management and governance was not given adequate attention in the State, although the Centre for Water Resources Development and

Management was established in 1970s to advice State Government in the matters related to water. Since 1990's Kerala began to pay more attention on water governance and watershed based natural resource management, which was, to an extent, influenced by national level policies and developments. Water resources development being a state-governed subject, all the states in India is required to formulate their own state water policies within the ambit of the NWP and subsequently set up a blueprint for water resources development (UNICEF, 2013).

The Government of Kerala has adopted a comprehensive State Water Policy (SWP) in 1992, in line with the National Water Policy, 1987 the first of its kind by any state in the country. The 1992 SWP advocated a river basin/watershed-based planning for integrated development of land and water resources of various regions, pointed to an acute drinking water scarcity experienced for about half the year in various parts of the state and emphasised the need to conserve as much rainwater as possible (GoI, 2008). By 2008, Government of Kerala has revised the water policy. The 2008 SWP addressed water as a common heritage having economic value and the responsibility for its regulated use and conservations vested with every citizen and community. It presents progressive goals to have a State Level River Authority, under which there shall be River basin and Sub basin organisations. It also emphasised on considering the micro watershed as a basic unit and river basin as an integrated unit of micro watersheds to facilitate resource-based approach, user participation and equitable water resource management (GoK, 2008). The 2008 SWP is relevant as it has further consolidated the role of Grama panchayats in water resource management.

3.3 River Basin Governance

Watershed programmes were in operation in Kerala since the early 1970s. Government of Kerala took an important policy decision on advise of State Planning Board during the Ninth Plan (1997-2002) period that the development plans of the Local Self Government (LSGD) institutions should be on watershed basis (GoK, 2010). As part of this decision, there was a state wide campaign of preparing Watershed based Development Master Plan at the Block Panchayat Level, as a tool for institutionalizing decentralized planning based on geohydrological unit. Various committees were constituted at different levels, and the initial works on the preparation of watershed based master plans were also undertaken. Agricultural scientists have divided Kerala's 44 river basin into 151 sub-watersheds (10,000 to 50,000 ha) and 960 milli watersheds of 1,000 to 10,000 hectares. Below this there are several thousand micro watersheds with areas of 100 to 1,000 hectares (Kerala State Landuse Board, 1998, Chattopadhyay & Franke, 2006). Micro watersheds of approximately 500 ha size were delineated and resource inventories had also been prepared at the Block level (GoK, 2010a). On the basis of the decision of the Government of Kerala to continue the watershed based approach during the Tenth Plan period (2002-2007) also, directions were issued to take up further activities for the preparation of the watershed master plans and in the case of agriculture and allied sectors it was made compulsory that the development plans should be watershed based (GoK, 2010b). Since then, there were several initiatives taken place to increase the relevance of watershed approach in planning process and to adopt river basin and micro-watershed as a planning unit at state level.

3.4 Local Self Governments and River Basin Governance

Decentralized planning that followed the 73rd and 74th constitutional amendments and enabling enactments in the State in 1994 started off as the People's Plan Campaign and progressed with institutionalization at different levels, in Kerala. Establishment of panchyati raj became a constitutional obligation and at the same time a step towards local area planning, use of local resources, and decision making at the level of actual resource users. This opened a significant opportunity both for the people and planners to act together at village level. The Kerala People's Campaign for Democratic Decentralisation constitutes a remarkable radical experiment in democracy. Initially called the People's Campaign for the ninth five year plan (1997-2002) it substantially decentralised the functions of the government bureaucracy and also decentralised the planning process (Chattopadhyay & Franke, 2006). Through the People's Campaign, Kerala developed the potential to become the first state of India to have an overall, integrated set of watershed master plans (Isaac & Franke, 2002).

Experience of decentralization in Kerala showed that it is easier to sensitize Local Governments to the subtle links that exist between natural resources within a natural boundary called watershed (GoK, 2010b). Before 1990's most of the watershed projects and programmes were implemented by the Soil Survey Department. After 1990's decentralisation and peoples' participation has aggregated the role of panchayats in watershed projects and programmes in Kerala. All the national level guidelines (GoI, 2002, Hariyali, 2003, Neeranchal, 2006 and revised guidelines in 2008) and water policies (NWP 2002 and 2013) which emphasised on the role of panchayats and inclusion of public participation in water resource management were clearly fitted with Kerala context. Apart from these the state water policies also emphasised the necessity of people's participation in water sector within the framework of decentralised democratic institutions which ensured the role of panchayats.

3.5 Local Level/Micro Level Initiatives

The first successful and complete watershed master plan was prepared by Perambra Block Panchayat in Calicut District, Kerala in association with Kerala Sasthra Sahitya Parishad (KSSP), a People's Science Movement led by local volunteers. According to Chattopadhyay & Franke, (2006), the preparation of watershed plan followed through various steps including preparation of maps for micro watersheds, training of local persons from each micro watershed, forming Watershed Committees at village level, holding a Watershed Mahasabha (major assembly) in each micro watershed, and finalisation of watershed master plans. In 2004, a model watershed master plan for Thirurangadi Block Panchayat in Malappuram District of Kerala has been prepared by the Centre for Earth Science Studies. The master plan marked out the micro-level watersheds in the field and cadastral maps in seven panchayats in Thirurangadi block panchayat to determine the nature of interventions and activities to be carried out for protecting soil and water (CESS, 2004).

A micro watershed atlas of Thiruvananthapuram district released by the Agriculture and Soil Survey Department in 2006, has identified a total of 423 micro watersheds, a physiographic area with a common drainage outlet in the district (The Hindu, 2006). The Kalliassery Block panchayat in Kannur district has prepared a master plan to address acute drinking water shortage. The master plan proposed projects for the protection of 33 watershed systems in the block panchayat (The Hindu, 2013). Government of Kerala also has decided that the Eleventh Plan (2007-2012) proposals of the Local Self Government Department institutions should follow river basin approach. Several similar initiatives have accelerated the significance of water governance and river basin governance in Kerala. Few significant initiatives are briefly explained below.

3.6 Panchayat level Water Policy by Perumanna Grama Panchayat, 2015

It is significant to note that the importance of water governance at local level is getting more attention recently due to resource variability and water quality deterioration. Perumanna grama panchayat in Kozhikode district took the lead being the first panchayat in the State to declare a water policy on the lines of the State government's water policy declared in 2008 (The Hindu, 2015). With the assistance from the Centre for Water Resources Development and Management, Kunnamangalam, Perumanna panchayat drafted the water policy after a detailed study of water resources and usage in the panchayat over the last two years. The water policy includes a 13-point action plan to ensure proper utilisation and conservation of water in its 18 wards.

The policy also emphasised on the need to increase water literacy in the panchayat through extensive awareness programmes. Water conservation committees have been formed at ward level as well as panchayat level, which work in tandem with the committees for agriculture, basic development, education, health and industrial development. It should incorporate in its activities the essence of the water and environment policy of the State government. Need to ensure water quality as well as need to estimate the amount of clean water required for each activities are also outlined in the policy. According to the policy the distribution of water will be arranged taking into consideration the necessity and availability of water in such a way that the water cycle is completed and large scale consumption of water that would have an impact on environment will be discouraged.

3.7 Kochi Municipal Corporation Water Policy and Water Auditing

Cochin Corporation together with SCMS Water Institute, Kochi has taken a very significant step forward by framing a Water Policy in 2015 in realising the roles of Local Self Governments in managing water resources (KMC, 2015). Considering the need for development, Kochi Water Policy (KWP) prioritizes the water allocation as drinking and domestic purposes, commercial and institutional purposes, tourism, industrial, agricultural production, livestock and fisheries, and any other purposes. They also give detailed guidelines for distribution of drinking water in co-operation with Kerala Water Authority. The policy recommends the formation of Kochi Water Information System to serve as a central repository for any water related data about the Corporation.

The policy observes that majority of areas within the Corporation fall in either critical or semi critical groundwater zone. Corporation should therefore consider issuing licence to well drillers and control drilling of new wells in the critical zones. Decentralised water treatment plants and distribution systems have been recommended as solutions to non-receipt of water or low pressure water supply at the tail end of the distribution network. The policy also recommends water audit in every three to five years to be mandatory for large apartment complexes and commercial complexes. Being the policy developed for a LSG it identifies flaws and deficiencies with the existing water management within corporation and provides detailed guidelines on water allocation and drinking water distribution, besides, measures to be taken for critical ground water zones and rooftop rainwater harvesting structures in new buildings.

3.8 Ongoing Programmes

Attempts by Local Governments to integrate natural resource management with micro watersheds began in Kerala during the Ninth Plan with the initiative for Block level Watershed Master Plan preparation (Environmental Assessment Report, 2010). Apart from the Government of Kerala initiatives, few centrally sponsored (Government of India) watershed development programmes also implemented by the State include the Integrated Watershed Development Project (IWDP), Command Area Development Programmes, Hariyali, Western Ghats Development Programme (WGDP), and National Watershed Development Programme for Rain fed Areas (NWDPRA). The Mahatma Gandhi National Rural Employment Guarantee Act (MNREGA) scheme gives top priority for watershed development. It is important to note that Kerala adopts micro watersheds as the implementation unit for all these projects, which are mostly implemented under the responsibility of panchayats. It is relevant to explain few of these attempts here.

3.8.1 The Western Ghats Development Programme

The Western Ghats Development Programme (WGDP) initiated in 1974 recommended 31 Taluks in Kerala which come under the premises of Western Ghats. This programme has been initiated at Taluks and projects under this programme were implemented by Soil Survey Departments. Since ninth plan, the WGDP in Kerala is implemented in participatory mode through Panchayat Raj Institutions and it is fully integrated with the decentralised planning process (GoI, 2008). Though the administrative structure of the programmes is framed on three-tier system like State, District and Panchayat the project implementation is the responsibility of panchayats. The fund required for the projects is distributed though the Grama panchayats. All the projects under this programme are implemented at micro or mini watershed units on the basis of a clear set of "Operational Guidelines' issued by the Government of Kerala based on the Common Approach for Watershed Programmes, and the existing guidelines of other watershed programmes considering the peculiarities of the State. The emphasis was on preparation of integrated development plan for each macro/micro watershed covering all relevant activities, such as, soil-conservation, agriculture, afforestation, fuel and fodder development, minor irrigation, animal husbandry and sericulture (GoI, 2008). It is important to note that few of these activities like fuel and fodder development, animal husbandry and sericulture do not have any apparent direct relation with the watershed boundaries, whereas these activities were also carried out based on watershed boundaries which points towards the increasing influence of watersheds as a unit in planning process.

3.8.2 Mahatma Gandhi National Rural Employment Guarantee Scheme

Another significant step to integrate the activities at micro watersheds within the boundaries of panchayats has been initiated in Kerala when Government of India launched a massive wage employment programme, Mahatma Gandhi National Rural Employment Guarantee Scheme (MGNREGS) in 2006. This scheme aims to enhance the livelihood security of the rural people by guaranteeing hundred days of wage employment in a financial year. The fund under this programme is distributed through the panchayats. Most of the permissible works prescribed in this programme are soil and water conservation activities which are being treated in a fragmented manner. Government of Kerala (GoK) pioneered implementation of these works on watershed basis and issued an order for the preparation of MGNREGS-watershed master plan at panchayat level in April 2009. Since then every panchayat prepares an annual watershed master plan integrating the major activities to be carried out within the watersheds in a panchayat. For this purpose the panchayat demarcates the micro-watersheds within the administrative boundary of the panchayat and select the activities to be carried out within the micro/sub-watershed. Table 3.1 shows a sample of listing of activities for which the fund is allocated within the watershed master plan of selected panchayats in Wayanad District, Kerala (Watershed Master Plan, 2009).

Table 3.1: Sample of Listed Activities in Watershed Master Plans, Kerala

Name of projects	Thariyodu Panchayat		Panamaram Panchayat	
	Parathode Micro watershed	Madathuvayal Micro watershed	Mathothupoil Micro watershed	Manakkavayal Micro watershed
Stone wall construction	×	×	×	×
Mud wall construction	×	×	×	×
Old stone wall maintenance and renovation	×	×	×	×
Fodder crops	×	×	×	×
Bio fencing	×	×	×	×
Planting trees	×	×	×	×
Bio check dams	×	×	×	×
Stone check dams	×	×		
Over flow channel	×	×		
House hold bio compost pit	×	×	×	×
Channel/ stream renovation	×	×		
Check dams	×	×	×	×
Biogas plants	×	×	×	×
pond renovation	×	×	×	×
Deepening of wells	×	×	×	×
vermicide compost	×	×		
rainwater pits	×	×		
fencing line, clearing weeds	×	×	×	×
percolation trench	×	×	×	×
water tank	×	×		
land preparation for cash crop cultivation	×	×		
road construction	×	×		

3.8.3 Integrated Watershed Management Programme

The Integrated Watershed Management Programmes in Kerala are designed with multi-level administrative set up to achieve a river basin based development with scientific priorities. Grama Panchayats are entrusted with preparing watershed master plans by involving people. These master plans are expected to be integrated at the District level and also at the State level (GoK, 2010b). In 2012, Panchayat Development Commissionarate, Kerala issued a circular to set up watershed committees in all the watersheds under Integrated Watershed Management Project (IWMP). The circular emphasised on creating these watershed committees at panchayat level and to work in consonance with the Grama Sabhas. If the watershed spreads over more than one panchayat then there shall be an integrated committee responsible for the whole watershed as well as sub committees for the segments in each panchayat. The Panchayat President will be responsible as head of the watershed committee.

Formation of watershed level committees was originally envisaged in the report of the Hanumantha Rao Committee (1994) which was set up by Government of India to assess the programmes of Draught Prone Area Development Programme (DPAP), and Desert Development Programme (DDP), and suggest improvements. The committee recommended and formulated a single guideline for watershed based development covering DPAP, DDP and IWDP (Integrated Wasteland Development Programme). Government of India's acceptance of this report and gearing up to implement the recommendations through Rural Development Department triggered a major shift in watershed management programme from structural techno-centric mode to participatory ecosystem oriented programme (Nair and Chattopadhyay, 2001). Setting up of watershed level committee was contested by the States where Panchayats were democratically well entrenched, however, the idea was well appreciated by those States, where people showed little faith on Panchayats. Nevertheless Government of India directives emphasised formulation of watershed level committees at different hierarchic levels. The Kerala initiatives can be construed as a step to integrate watershed committees with panchayat, where a separate watershed management unit (watershed committee) will be in place with more power but will be mentored by the Grama panchayat.

3.9 Kerala Rural Water Supply and Environmental Sanitation Agency (Jalanidhi)

This World Bank aided Kerala Rural Water Supply and Sanitation project aims at improving the quality of rural water supply and environmental sanitation services in the State. Government of Kerala launched rural water reforms as per Government of India guidelines by carrying out the World Bank-financed Jalanidhi-I project between 2000 and 2008. Jalanidhi-I covered 112 (11 percent) of the state's Gram Panchayats spanned across 13 districts and implemented 3705 water supply schemes (mostly groundwater based) and 16 large surface water based schemes (Government of Kerala, 2011). The project followed a demand responsive approach encompassing beneficiary participation, capital cost contributions from beneficiaries and the Panchayats, universal household connection provision, full operation and maintenance cost recovery from user fees, and an integrated strategy in water, sanitation, environment and health sectors. On competition of Jalanidhi -I, Government of Kerala has decided to implement Jalanidhi-2, with World Bank support and contribution from Local Self Governments and the beneficiaries since 2012. This phase is continuing, at present.

The main components of Jalanidhi-2 includes community based water supply schemes, rehabilitation of single GP KWA schemes, sanitation, ground water recharge, rain water harvesting and special emphasis on water supply to quality affected habitations. Jalandihi-2 project has three main components including institution building, technical assistance to implementing agencies and infrastructure development. The first component will (i) support capacity building of sector institutions and support organizations, (ii) assist Government of Kerala (GOK) in implementing a state-wide sector development programme, and (iii) support project management costs. The second component will provide technical assistance to implementing agencies such that the infrastructure investments under component three are properly implemented and the resultant services efficiently provided. The third component of the project will fund the implementation of infrastructure investments for: (i) new and rehabilitated intra- Gram Panchayat rural water supply schemes; (ii) pilot rehabilitation and modernization of multi-Gram Panchayat water supply schemes and transfer of internal distribution to Panchayats; and (iii) sanitation schemes, mainly covering community-centric solid and liquid waste management and household sanitation solutions in difficult terrain. The rural water supply schemes are now gradually separated from the urban water supply schemes, which are administered through KWA. While it promotes decentralization and increases efficiency, the questions of source sustainability and long term viability remain.

Over the years there have been several changes in ideas and concepts of water governance in Kerala. Both National and Global level developments have contributed to these changes. Apart from meeting water demands of population, realising importance of ecosystem approaches, need for ecological restoration, maintaining environmental flow and similar broader issues are visible in policy shifts. Most of the policies and guidelines fail at implementation level. Multi-level and poly centric water governance may help to address many of the technical and institutional issues and strike a balance between ‘bottom –up’ and ‘top-down’ approach as all water issues cannot be captured at a single level. It is also necessary to adopt polycentric approaches to adapt with complex set of interacting institutional settings in multi-level water governance. As availability of water varies spatially and there are surplus and deficit regions, centralized governing mechanism is necessary to allocate and reallocate water. However, at the bottom level, the Local Self Government Institution should have a definite role in preserving the water sources, catchment management, augmentation of resources, distribution, use, safe guard and resource base also in conflict resolution. Necessary regulation may be devised to make such arrangements.

Apart from the departments and agencies mentioned here, there are certain other key departments that have a strong bearing on the rivers/water resources such as Revenue, Forests, Local Governments and Irrigation. An Important limitation of the governance mechanism is the inability to coordinate across departments and along scales. Adoption of river basin/ watershed based approach is an important first step to reduce such coordination of actors and integration of their actions. But, the problem of departmentalism does not disappear so first. It requires more concerted effort. Water management is also an area that witnessed introduction of new organizational experiments such as Water Authority and Jalanidhi, which were essentially special purpose vehicles, started with a view to achieve higher levels of efficiency vis-à-vis government departments. But, they do not appear to have served the purpose. They have not been able to improve governance in any notable fashion. But at the same time the SPVs often are not accountable to conventional public scrutiny and social auditing. Another important dimension of water governance in the state is that of property rights. Who holds property rights over land and water resources is important to sustainable management. For instance encroachment of flood plains is a common threat faced by almost all rivers in the state. Apart from encroachment there exists genuine problem of private property rights in many such sensitive areas. Added to this is the absence of collective control over landuse. Kerala is one region in the world where land owners enjoy absolute freedom over choice of land use pattern. Needless to say that it is against the idea of sustainable land and water resources management.

Chapter IV

River Restoration in Kerala: River bank Mapping, Assessment of River bed deposits (Sand Auditing) and River Restoration Framework

4.0 Introduction

The chapter II highlighted the problems of Kerala rivers and argued for undertaking restoration/ rejuvenation measures. Purpose of this chapter is to discuss the framework of river restoration in Kerala. Prior to that, it may be useful to have a brief overview of challenges for river management in Kerala.

4.1 Challenges for River Management

Rivers in Kerala are under stress due to large scale human intervention, which can be broadly categoriesd into two: (i) direct and (ii) indirect interventions (Chattopadhyay and Mahamaya, 2014). Construction of dams and impounding of reservoirs in the upstream sections for drinking water, irrigation and hydroelectric projects are most common human interventions on river systems. Water is diverted through main and branch canals impacting larger areas in the case of irrigation projects. Natural flow of river is interrupted due to construction of dams and impounding of reservoirs. While a new base level is created for the drainage system upstream of the reservoir, the river regime downstream of the dam experiences an altered hydrological system. The river course shows features of late maturity like braided condition, reduced flow and decline in wetted perimeter.

Kerala has 53 dams of different dimensions meant for irrigation, hydro power, drinking water and flood control. Some of the reservoirs are for multipurpose projects. The catchment areas of many of these reservoirs are vulnerable and subject to high degree of erosion and sediment yield during monsoon months. All these reservoirs functioning as silt trap have lost part of their capacity over the years. Available study indicates that some of the reservoirs like Malampuzha experienced an annual average rate of sedimentation of 0.27%. All major rivers in Kerala have been arrested, sometimes in more than one location. Bharathapuzha river has six reservoirs impounded in its tributaries and the Periyar basin has eleven reservoirs. The dams constructed to impound reservoirs also trap nutrients emanating from the catchment and destined to reach coastal waters including lagoons and coastal seas through river system. Once regular flow of water, and sediment and nutrient movements are hindered the biogeochemical cycles operating in the catchment level are interrupted. This has far reaching consequences on coastal processes and coastal productivity. Stagnation of sea-fish catch in the near shore water is partly attributed to this fall of nutrient supply from the up-streams. This is particularly significant in the areas dominated by small catchments as in Kerala. The biogeochemical intervention refers to water quality. Expansion of human settlements and use of chemical inputs for agriculture have enlarged non-point pollution sources. All rivers in Kerala are facing water quality problem and there are reports indicating that river water can hardly be used for domestic purposes. The conditions are alarming for the river stretches passing through urban centres.

Kerala experiences drinking water shortage during summer months over the last several years. Steep slope and undulated topography characterise provenance of all rivers in Kerala. The rivers are swift flowing and residence time of water is short. There is not much scope to construct any more reservoirs. Existing reservoirs are silted up to various measures. Deforestation, diversion of land from agricultural to non agricultural use, shrinkage of wetlands and flood cushioning areas, increased surfaced/ paved area due to expansion of built up area and growing urbanization all in combination contributing to stronger surface run off and lower infiltration and thereby constraining ground water recharge. Depths of rivers have increased due to indiscriminate sand mining from the river bed.

Kerala does not have sufficient reserves of construction grade sand. River-beds are continuously mined for sand. It has been reported that annual sand mining from the seven rivers debouching into the Vembanad lake was 6.63 million m^3 against natural replenishment of 0.086 million m^3 in the storage zone (Padmalal et. al., 2004). Excessive mining has several direct and indirect impacts like erosion of river bank, slumping, lowering of channel, change in thalweg configuration, increase in turbidity, aggravated salt water ingression in the lower reaches, and fall in water table. The river water level controls the water table in the adjoining dug wells, which are the main sources of domestic water both in the rural and urban areas **(refer tables 2.5 and 2.6)**. Along with fluctuation of water level in the rivers, the level of the ground water table also fluctuates. Maintenance of the base flow in the rivers during the non-monsoon months is therefore very significant for water security. Rainfall is the major recharge source of ground water, and the rise in water level in the phreatic aquifer is directly related to precipitation. A falling trend in the post-monsoon months indicates that the rainfall is not sufficient to recharge the aquifer to required level. The climate change can complicate this issue further. Another important matter to consider is deteriorating water quality and pollution of water sources. Incoming water is more or less constant therefore quality degradation will reduce availability and impose further pressure on already constrained resource base. Increasing population pressure and higher consumption will complicate the problem. River passes through three distinct zones: forest area in the upper reaches, agricultural area in the midlands and low lands and tide dominated coastal areas. Each of these segments is governed by a department and there is little interaction among these departments. The major challenges for river restoration are technical as well as governance.

4.2 River Bank Mapping and Sand Auditing

Vested with the responsibility of managing river systems in the State, the Revenue Department, Government of Kerala constituted a High Level Committee composed of Technical and non technical members to evaluate and sanction various projects proposed by the District authorities, Development Blocks and Panchayats intended to protect the rivers under River Management Fund (RMF) in control of District Collectors. It was observed that most of these projects are related to construction of side walls or retaining walls, check dams, pathways, bathing ghats, foot bridges and similar other construction works. Project reports submitted for consideration are supported by site plans and photographs. Hardly these plans are spatially contextualized and after execution there is little follow up action or monitoring of the projects. Revenue department is also empowered to accord sanction for sand mining from the river beds. In fact, the revenue generated from sand mining forms the RMF at the district level. Sand mining has turned to be a very contentious issue and there are court directions to this effect. Government of Kerala also issued orders to regulate sand mining and assess the minable quantity of sand in each river. Non availability of data, deterioration of rivers due to excessive sand mining to meet increasing demand of sand in the construction sector and piecemeal approach in proposing river protection measures all together triggered the idea of initiating measures that can help the state to address these issues in the long term perspective. The programme of river bank mapping and sand mining emerged in this process (River Management Cell, 2015). The programme started in 2011. The University Departments, Engineering colleges and NGOs with professional accomplishments are involved to conduct mapping and assessing river bed deposits using services of students and volunteers. A particular agency has been identified for each river to conduct the survey and assimilate data at the panchayat level. CESS scientists developed the methodology and continue to provide technical support wherever necessary. River bank mapping and sand assessment have been completed for 16 rivers in two phases and it is progressing in some other rivers. There is also discussion to start the third phase of this work to cover the other streams and also tributary streams. Name of the rivers and associated local self governments are given in the **Appendices 1 &2.**

4.2.1 Cadastral Based Information

The river bank mapping is being conducted in cadastral scale to document detailed information under three broad categories: (i) physical features, (ii) land use and (iii) man-made features following a structured data format. River bank, and in-stream geomorphology particularly channel gradient and thalweg determine channel character. Therefore, any project concerning channel maintenance has to address issues related to these three items. A first level analysis of rivers in Kerala indicate that many of the rivers across the State are affected due to excessive sand mining, loss of riparian vegetation and lowering of thalweg. River bank erosion or slumping of river banks, although part of fluvial process, are found to be accelerating due to river bed mining as the toe level equilibrium of the river bank is lost in the process of excavation. All these information are now readily available in cadastral scale maps. Apart from mapping, a detailed data base in structured format has also been developed at a regular interval. Besides, for each survey plot along the river, there are information on physical characteristics, land use and man–made features **(Figs 4.1)**. These data provides base level information for generating river restoration plan.

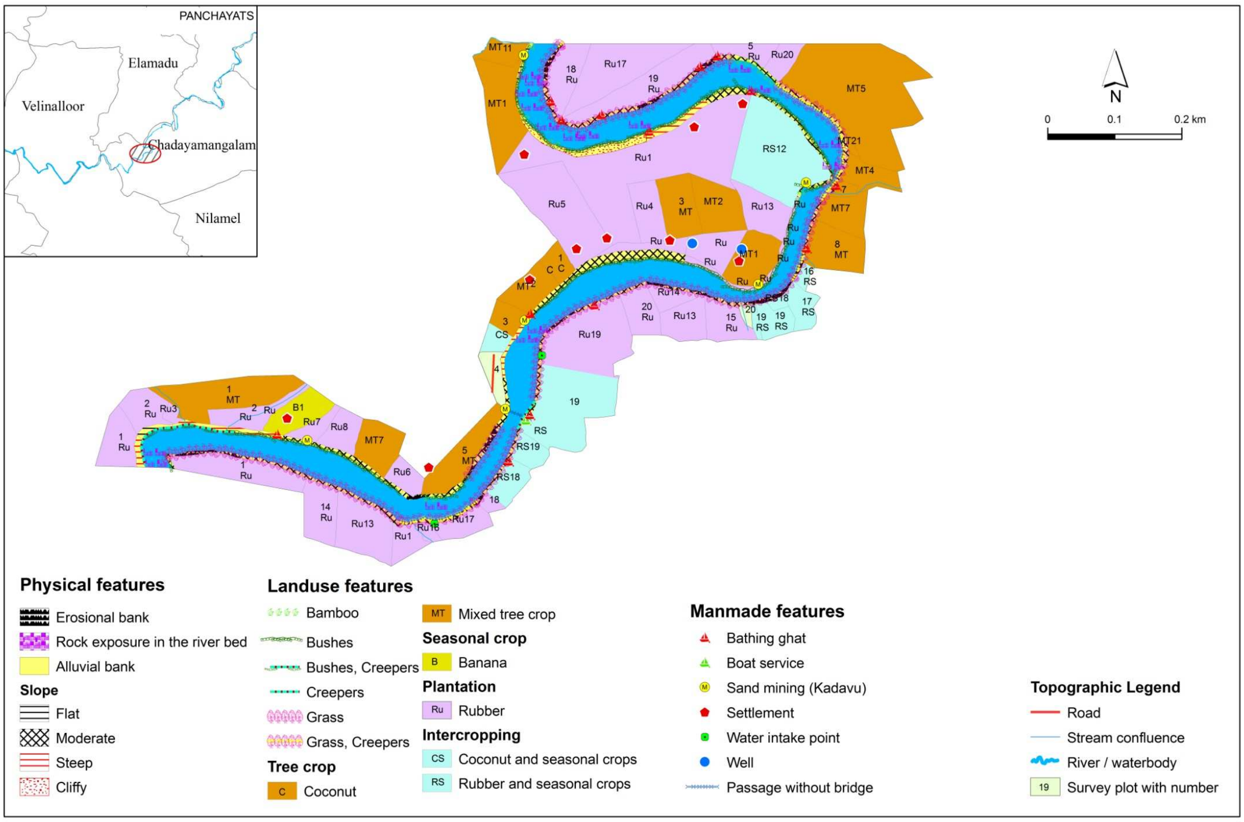

Fig 4.1: A sample River Bank Map Showing Physical, Land Use and Man-Made Features

The cadastral level data are also aggregated at the panchayat level to indicate condition of the bank flowing through the panchayat. Thus each panchayat now has base line information on the condition of the river corridor.

Rivers are more than just flowing water. Each river from its headwaters to its mouth is an integrated system and must be treated as such. They receive water, sediment, organic matter and nutrients from the catchment area. The changes in the catchment area can bring alterations in the channel form and its condition. Hence, along with river bank mapping it is necessary to consider the total basin. It will help integrate upstream downstream issues, understand the interrelatedness of competing uses and users, integrate other natural resources and human interventions. Now only the main trunk of river is mapped and in the next level banks of all major and minor tributaries should be mapped to understand their present status with a view of catchment management. This will provide the base material for preparing river restoration plan for each river as a whole.

4.2.2 Assessment of Riverbed Deposits (Sand Auditing)

The Government of Kerala Act, 2001 envisaged assessment of sand deposits once in every three year. This is in response to the excessive sand mining and resultant deteriorated condition of rivers. The present programme envisaged assessment of bed deposits at 500m interval, on an average, based on cross profiles and also to establish the datum, which can be used in subsequent survey. The Act also suggested certain prohibited stretches on various grounds including biological hot spots & sensitive areas, river reaches with placers and other economic minerals, river segments critically affected by bank sliding/slumping/bank erosion. The available sand deposits above summer water level may be mined according to latest Court order. The survey has been completed for 16 rivers. It has been brought out that out of 16 rivers, only seven rivers have sand deposits above summer water level **(Table 4. 1)**. There are two rivers, namely Neyyar and Karuvannur, without any sand deposits up to 2 metre below summer water level. Both the rivers have lost their bed deposits. Profile level data generated under this programme can also be aggregated for each panchayat, so that panchayat level action plan may be evolved.

Table 4.1: Volume of Sand Available for Mining in 16 Major Rivers in Kerala

Sl. No.	Name of River	Length (Km) Covered	Volume of sand available up to 2m of SWL (m^3) after necessary reductions	Available sand (m^3) above Summer Water Level (Mineable sand)
1	Karamana	32	182657.02	Nil
2	Neyyar	40	Nil	Nil
3	Vamanapuram	43	184573.00	Nil
4	Ithikkara	43	122726.30	41336.64
5	Kallada	45	535613.24	Nil
6	Pamba	60	979280.00	128571.04
7	Meenachil	39	97960.8	Nil
8	Muvattupuzha	52	2431786.31	64555.91
9	Periyar	59	1212389.00	185836.00
10	Karuvannur	34	Nil	Nil
11	Chaliyar	53	487097.08	369502.73
12	Kadalundi	88	1610874.00	273460.00
13	Kuttiyadi	23	46146.00	Nil
14	Kabani	56	40623.8	Nil
15	Anjarakandy	43	6421.35	266.17
16	Chandragiri	39	225518.82	Nil
Total			**8163666.72**	**1063528.49**

Source: River management Cell, Department of Revenue, Government of Kerala, 2016

4.3 River restoration Framework

River bank mapping and sand mining provide the baseline data about the physical attributes of river corridor. Water quality survey conducted by CWRDM sponsored by KSCSTE and the river pollution survey undertaken by KCPCB can all be assimilated in a single frame to assess condition of the river and also river segments. Restoration activity may be planned for the whole river and also for segments although it is always advisable to contextualize the segment wise restoration activity within the whole basin. The intervention for restoration is actually to help the fluvial system to recuperate fast. Deep factual understanding of the system and learning the governing principles are important. The items to be covered under a river restoration and management proposal are given in the **Table 4.2.**

Table 4.2: Items (indicative) to be covered under River Restoration and Management Proposal

(i)	A brief account of the problem in the context of the river segment/ watershed
(ii)	Clear identification of the activity-bank protection, afforestation, regeneration of riparian vegetation, checking of soil erosion, check dam or combination
(iii)	Who proposed the work
(iv)	Statement of benefits and how it will help river restoration
(v)	Environmental impact statement including how do the activities will affect other river segment/ other areas of the watershed
(vi)	Executing agency- Panchayat, Self Help Group, Kudumbashree, Educational Institutions etc
(vii)	Monitoring mechanism- for the immediate work and also in the context of the overall river restoration work

4.3.1 Steps in River Restoration

The proposed river restoration frame work consists of the following steps:

i) Building environment and setting up restoration team

ii) Scoping to set the boundary conditions

iii) Preparation of restoration plan through systematic collection of data, analysis, setting goals and plan finalisation

iv) Plan implementation and execution of restoration measures

v) Monitoring to review timely progress, effectiveness of the projects and maintenance

vi) Community involvement and people's participation

Brief elaboration of each of these steps will highlight the issues involved in the process of preparing restoration plan.

i) Building environment and setting up restoration team

The first step towards river restoration is to create the necessary environment and build a restoration team to take responsibility for the river. Such a team should comprise of representatives of local community, technical experts, government officials and NGOs. In case of a whole river, which flows through more than one districts representative from all the concerned districts may be included. In case of segments the representatives from all the Panchayats through which the river is flowing may be included. In all situations, there should be a core group to steer the entire process of restoration. This core group may be comprised of project manager, technical expert, government representative and representative of local community/ district panchayat/ block panchayat/ gram panchayat as the case may be. The experts involved in the restoration team may be according to the skill required for the restoration job and this may change over the time.

Technical agencies have already been identified for each river to conduct river bank mapping and sand auditing. These agencies can be entrusted with the job to take initiative to form the restoration team. This is necessary as monitoring of sand deposits will be a continuous activity once in every three years. The technical agency, which has established the bench mark may be better equipped to repeat the work to generate the technical data. However the final authority to form the team must be rest with the Local Self Government Institutions (LSGI).

ii) Scoping to set the boundary condition

Scoping is an important step in any environmental programme. It sets the boundaries of the project-what are the questions to be addressed, to what extent and the potentials? The activities involve collation of all available data, identification of knowledge gaps, constraints and drivers of degradation, future possibilities and a clear statement about the possible achievements. The problems and future requirements are also spelt out.

iii) Preparation of restoration plan

This is perhaps the most important activity in river restoration. A good plan is necessary before embarking on any programme. Most of the activities concerning river management in the State are ad hoc arrangements. This has to change and activities should start with a definite plan. There are five components in preparation of restoration plan (Kohen et al, 2001). These are: (i) characterization and system assessment, (ii) problem definition, (iii) objectives and prioritization, (iv) assessing various options and activities and (v) plan finalization.

There is a need to formulate plan based on adequate scientific knowledge of the system. Data generated under river bank mapping, sand auditing and water quality study form the base. There may be additional data requirement to develop a proper plan. The provision may be there to generate such data. Following the pressure, state, impact and response (PSIR) format the problems could be analysed, which should include all biophysical, socio-ecological and economic data, contextualization of the problem, comparison of the situation to the natural/ undisturbed river and follow a broad holistic method.

Defining problem and identifying origin of the problem is essential to ensure that restoration activities can address the root cause of the problem so that solutions are long lasting, and sustainable otherwise the same problem may crop up after some time. A clear understanding of the problem helps devise appropriate intervention. As river functions with specific laws, it is necessary to understand the nature's law controlling variability in fluvial character. For example, erosion and deposition are part of the natural fluvial process. Naturally eroded bank can be stabilized only through thorough understanding of this process.

The objectives of restoration projects must be clearly spelt out identifying the tasks and goals. It should be measurable with tangible benefits and form the key component for evaluation of success. Kohen et al (2001) described objective to be SMART (simple, measurable, achievable, realistic and time bound). It should address both spatial and temporal scales. Considering scientific and social issues priority should be set to achieve the most important objective with reasonable cost and time.

The next component is development of the restoration plan. A plan should have more than one options/ alternatives. Devising the alternatives require considering biophysical, socio-political and economic knowledge including management options. There are several methods developed for catchment management, bank stabilization and other river corridor related actions. Alternative programmes may be picked up from a shelf of available practices. The emphasis is always on green practices, practical and capable of producing greatest benefit. It is important to examine consequences of each of these alternatives before introducing any measures. Sometimes more details are necessary to finalise a particular plan. Flexibility and looking for alternatives are important components of plan preparation.

The last item in this step is finalization of plan. It is to consider all available support, and integration. The river restoration plan should be part of the local and regional plans linked with total catchment. The plan must be discussed among the stakeholders. Ownership of the plan, management and communication are important aspects of plan finalization.

iv) Plan execution and initiation of restoration activities

Implementation of restoration measures warrants due considerations of nature of work, responsibility to execute the work and the time frame to complete the work. Listing of activities and work schedule are important. It may require looking into stream stabilization and habitat reinstatement techniques besides, contract negotiation for execution of work.

v) Monitoring and maintenance

Monitoring is an essential component for successful execution of any project. Similarly maintenance is important to have long lasting effect. Continuous monitoring helps to reach the target, mid course correction and also to learn from failures. Monitoring should be done considering objectives, benchmark situation and using specific indicators. Restoration projects once completed should not be left alone. There should be documentation so that lessons are available for other areas/ groups.

vi) Community involvement and people's participation

One of the most important aspects of river restoration is to forge links between various technical steps of restoration activity and people- community, individual, scientific and technical persons, government agencies, local self government, and non government organizations. These links will help sharing information, field support, coordination, assessment of needs, allocation of resources, ownership and continuity. This will also facilitate adherence to government policies and protocols. The restoration must evolve from the bottom. As rivers cross a number of local bodies and areas administered by separate departments it will be necessary to set up coordination mechanism to facilitate execution of restoration activities.

4.3.2 Restoration Activities

Review of several restoration projects across the world indicated that the most common goals of river restoration are related to ecorestoration and increasing biodiversity, stabilizing channels, improving riparian and in-stream habitat, improving water quality and summer or base flow. Impact of climate change is also an issue considered under river restoration plan as in the case of London. Review of restoration projects in USA indicated that the commonly used method of restoration covers in-stream hydromorphic interventions followed by channel hydromorphic intervention, riparian restoration, and watershed action (Palmer, et al., 2014).

In case of Kerala, the river restoration activities, at the operational level, will mostly cover the following activities:

i) maintenance of catchment,
ii) restoration of water quality and quantity including maintenance and enhancement of summer month flow ,
iii) retrieval of flood plain and stabilization of river banks,
iv) flood control,
v) wild life and habitat restoration,
vi) ecological restoration,
vii) coping with climate change
viii) enhancement of tourism and recreational potentials,
ix) promotion of historical and cultural values and
x) creation of multipurpose space for local residents and promotion of river oriented community development and

Each of these items is a specialized area and requires multidisciplinary approach to address the challenges and achieving goals that are normally being set for river restoration activity. The interventions will be both at the watershed level and also along river corridors. Some selected restorative activities are given in the **Tables 4.3 and Appendix 3.**

Table 4.3: Some Suggested Activities in Different Stretches of River

River stretch	Suggested intervention/activities
Mountainous stretch mostly in the upper reaches of the river	Minimum disturbance and natural regeneration of vegetation
Eroding river stretch with structures like railway/ road way bridges, buildings, infrastructures etc	Bank protective engineering structures with supporting vegetation cover
Eroding river stretch without any installations	Develop riparian vegetation
Normal river stretch with marginal or no erosion	Develop riparian vegetation

4.3.3 Whole River Approach and Segment Wise Intervention

The restoration activities can be broadly divided into two categories: (i) catchment level intervention through watershed approach or whole river approach and (ii) segment wise interventions at river channel or corridor level. Catchment level intervention will address the issues of sediment yield, water yield, lean season flow, water quality, nature of human intervention, land use change and scope of improving the catchment characteristics. Channel level intervention is through in-stream hydromorphy, river bank stabilization, restoration of riparian habitat, moderation of human interventions and in-situ land use. Brief descriptions of these two approaches are provided here.

I. Whole River Approach

The whole river approach follows catchment scale intervention and macro planning. Australia is implementing a scheme to identify heritage river based on high conservation value (Kingsford et. al., 2005). The criteria that can be used for assessing rivers for high conservation values are: (i) largely unaffected by direct intervention for land and water resource development, (ii) good representative example (iii) houses rare or threatened species or communities, (iv) exhibit rare or threatened geomorphic or geologic features, (v) demonstrates unusual diversity, abundance of features, habitats, communities or species, (vi) provide evidence of the course or pattern of the evolution of landscape or biota, and (vii) performs important function within the landscape. As the Missouri River Ecosystem Restoration Plan, USA (undated), stressed it is necessary to consider the whole river for the ecosystem restoration plan. It may begin with identifying criteria and opportunities for future restoration projects, and traverse through the process that envisage participation in prioritising restoration efforts, encourage partnership to develop and implement restoration activities, align restoration and recovery projects, programmes and policies across government and local agencies, actively engage in the design of a basin wide plan for restoration and develop sustainable and system-wide approaches to restoration.

The river catchment can be divided into watersheds and each watershed is characterized based on biophysical, ecological, economic and social variables. Considering sediment and water yield and land use each of the watersheds can be given value to compute priority. It may not be possible to undertake restoration work in all the rivers at a time and therefore there is a need for prioritization and plan for intervention according to priority and fund availability. A data matrix may be developed and rank values can be given for priority identification and treatment.

Demarcation of palaeo channels, mapping of flood plain occupancy and land ownership are part of the inventory to create data base and devise alternatives. There are palaeo channels marked in the lower reaches of several rivers in Kerala. Identification of these channels will help water harvesting and scope of sand availability. Similarly mapping of flood plain occupancy will help understanding status of flood plain. Most of the rivers lost their flood plain, as a result, flood cushioning areas are drastically reduced, which in turn has aggravated flood problem. Flood plain inventory will bring out the nature of floodplain diversion, drivers triggering these diversions and land ownership.

II. Segment Wise Approach

Segment wise approach refers to local level activity and in-situ intervention. It is site specific and includes bank protection, regeneration of riparian vegetation, small check dams to regulate sediment and water movement, creation of a buffer vegetation belt along the water course and such other activities. To develop plan to cater to these requirements it is necessary to zone the river based on river bank and thalweg information. There are evidences of zoning river and developing restoration plans in all the countries engaged in river restoration programme. For example, in USA river segments are classified for Outstanding Remarkable Values (ORV) and protection measures are devised (WRSAMC, 2012). There are segments like wild river segment, scenic river segment, recreational river segment and historic and cultural river segments and atlases are prepared showing the details. These segments are separated for protection and the vulnerable segments are considered for restoration. One such attempt was made earlier in the case of Chalakudy river (Nair and Chattopadhyay, 2005). However, data set used for that exercise was limited. With river bank mapping, profile configuration and sand auditing data the exercise on river zonation can be attempted more elaborately. Data on river water quality can also be integrated in the zoning exercise. Some additional data may be required to complete the exercise. Once a river corridor is zoned or classified, detailed restoration proposals can be evolved spelling out appropriate intervention measures and implementing mechanism.

4.3.4 Development of Kerala River Information System (KRIS)

All these exercises will generate huge amount of data. Developing KRIS is important as river is a very sensitive issue and the data should be made available at the public domain. KRIS is proposed as a tool for both professionals and public to obtain information about status of rivers in the state. It will provide data access and baseline support for projects designed to address river bank erosion, pollution, status of riparian vegetation, landuse in the adjacent plots, settlements within 5m, 10m and 15m from the river banks and other manmade structures present in the river banks at the panchayat level for effective river management. Maps, data and other related research products should also be available through KRIS. Most of the available information is georeferenced for mapping. These can be easily brought under a structured format and may be designed for interactive GIS. The KRIS will have many potential uses and users, from the State High Level Committee on River Management Fund to take decisions about the proposals for river protection and utilization works, to those who want to study the environment of rivers in the state. Every Panchayat and common people should have access to this information.

4.3.5 Governance and Involvement of Community

In Kerala, river management activities fall under the purview of more than one department. The Irrigation department constructs large water harnessing structures like dams and reservoirs for irrigation purposes and also drinking water. The Kerala Water Authority manages intake structures for drinking water supply. The LSGs looks after sand mining and kadavu related activities, whereas the Revenue department collects revenue from sale of sand and also manage land survey works. The CRZ Authority is regulatory body for violation of coastal regulations. The Kerala State Pollution Control Board is entrusted to regulate water pollution. The Police department is for enforcement of rules. There are overlaps, confusion over jurisdictions, clash of interest and indecision in taking up the projects. Effective river management cannot be achieved until there is uniform procedure for managing common property resource like rivers. Establishment of a River Management Authority (RMA) with the integration of different stakeholders and strengthening of existing River Management Cell (RM Cell) will results in the effective management of rivers in Kerala. RMA should be entrusted with the task of formulation of procedures towards achieving this objective. The problem of intervention activities in the private plots along the river banks and their apprehension towards river management programmes can be addressed through a participatory approach at the ground level. The management tiers and functions are given in the **table 4.4**

Table 4.4: Management Committees and their Functions

A. High level committee

*To approve the river basin management plan prepared by the district expert committee

*To settle dispute, if any, arising at the district or further lower level

*To advise state government in the matter of river restoration and management.

B. District river management committee

*Preparation of status report and total basin management plan and action plan for each river

*gradation of the rivers according to problems of sand mining, state of riparian vegetation, catchment condition and pollution

*Zonation at the basin, sub-basin and watershed level

* Listing of all the activity in each zone and priority fixation

*Coordinating the activity among various departments and panchayats

*Approval of activities (Kadavu level intervention, river bank protection of segments, regeneration of riparian vegetation, check dam etc) within the district

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4.3.6 Sharing Responsibility

The successful pursuit of river management entails sharing of responsibilities between the government departments, NGO's, the local communities and water users. River bank mapping and sand auditing in Kerala has been carried out by different institutions with the participation of local communities and LSGs. The implementation of river management activities with the support of these institutions will ensure the involvement of different institutions rather than depending on one or two governmental agencies working in the field.

4.3.7 Linking with People and Panchayats

One of the most important aspects of river restoration is to forge the links among various stakeholders, particularly among people, primarily: individuals, scientific disciplines, community groups, panchayats, government agencies, and non-government organisations, at the local and State level and in some cases national level also. These links will provide for:

• Sharing information;
• Coordination and technical support;
• Assessment of needs; and allocation of resources.

These links will also ensure that the project adheres to the policies and protocols of governments. Involvement of people in successful execution of this programme can be ensured through empowerment, which may be described as a sense of personal control, influence and concern with actual rights to social and political power. The necessary socio-technical space may be created for community empowerment through proper communication, real involvement and influence, and participation. Empowerment involves ownership, which is the key to effective long-term river restoration.

With the execution of river bank mapping and sand auditing programme in all 44 rivers of the state, the panchayats through which rivers flow will have sufficient data to work out management plans of their own to protect that part of the river flowing through the Panchayat. These plans will be within the framework of total river management plan with the specificities appropriate for the respective panchayat. The panchayats may be equipped with necessary technical support to work out panchayat river management plan in a cadastral base. They can form a river management group/ cell drawing technical and nontechnical persons available within the panchayat, and nearby locality. Schools within the panchayat and nearby colleges may be involved for such an exercise. The responsibility for execution of this plan should be vested with the panchayat. The process has to be evolved in such a way that the local people and the panchayat consider management of the river and its upkeep are part of their responsibility.

Chapter V

Trivandrum City: Back ground Information, Biophysical set up and Issue of water and City River Management

5.0 Introduction

This chapter deals with growth and development of Trivandurm city, its biophysical set up and highlights the stress in the water sector and city rivers as a prelude to develop an outline for city river restoration action plan. Water plays a very important role in formation, growth and development of urban centres. In fact, distribution of urban centres is largely determined by water availability. Water is considered as part of the complex web of relations between society and environment, and also it is the medium of social relations. In the densely populated and urbansied coastal cities water has played and continues to play an important role in determining urban expansion, transformation and sustaining the functions (Ridolfi, 2014). Thiruvananthapuram city considered to be a coastal town spreads over adjoing lowland and midlands. There are rivers, streams, lakes and lagoons comprising waterscape of the city. Prior to deliberate on the outline of the plan in the next chapter, it is proposed to discuss about environmental settings, growth of city, settlement pattern and demography, land use change and pressure on water like drinking water and waste disposal to provide an idea about the prevailing situation. It may also be noted that these issues are mutually related and are linked with river management.

5.1 Thiruvananthapuram City: Selected Background Information

Thiruvananthapuram, the capital city, is one of the three important cities in Kerala State. Prior to reorganization of the States in India on linguistic basis in 1956 this city was the citadel of power of Travancore native state. The name of this city, Thiruvananthapuram or Thiru Anantha Puram literally means the town (puram) of Thiru (Sri) Anantha (poly headed holy serpent). Lord Vishnu, the deity of the Padmanabha Swamy temple, is in a reclining position on the coils of poly headed serpent (Anantha). Thus the city has a religious antiquity. Initial settlements sprung up around the Padmanabha Swamy temple centuries back. In the 2nd half of 18th century king Dharma Raja (1758-1798) shifted his capital from

Padmanabhapuram near Nagercoil in Kanyakumari district of Tamil Nadu to Thiruvananthapuram and therefore the king and his eminent Diwan Raja Kesavadasa could be considered as the founders of the present city of Thiruvananthapuram (Poulose, 1979). Trivandrum, a commonly used name even today, is the anglicized version of Thiruvananthapuram. It is only recently that the original name is restored in official records. Initially, a religious settlement developed around a temple acquired administrative functions over the years, and people started congregating around this area. Consequently, character of the town changed both in its settlement pattern and economy. Service sector followed administration and gradually this town started catering to the surrounding rural areas and now it is emerging as an IT hub and a centre providing health services to national and international community. Trivandrum accounts for 45% of total state income from IT sector.

5.1.1 Biophysical set up of Thiruvananthapuram City

Thiruvananthapuram City Region (TCR) extends over flat coastal plain and low lateritic undulated terrain. Lateritic ridges appear to be radiating from the flat coastal plain. The altitude varies from mean sea level to little over 80m. Flood plains and wetlands are mostly confined to below 20m. The coastline in Kovalam Vizhinjam sector is rock and relatively elevated. Three geomorphic units, namely Strand plain, Valley and flood plain and Lateritic undulated terrain characterize the landscape. Average slope is less than 5^o, although there are areas under sloping and moderately steep category. Average annual rainfall in Trivandrum city is around 1700mm. Both the monsoons are active in the city **(Fig 5.1)**. South west monsoon contributes around 49% of total rainfall whereas north east monsoon’s share is 28%. Trivandrum receives rainfall in every month. There are seven types of surface materials: coastal sand, teri sand, sandy clay loam, clay, laterite soil, sand dune and exposed hard rock. The laterite soil covers maximum area followed by coastal sand. Sandy clay loam soil is associated with valleys and flood plains. Karamana is the main river draining the city. Other important river is Killi Ar, a tributary of Karamana. There is one fresh water lake at Vellayani and one coastal brackish water body at Veli-Akkulam. Ground water availability is good in general. But in the Kovalam-Vizhinjam area it is overdrawn and in the panchayats along the eastern border the status is semi-critical (Rani et al., 2011). Depth to water level ranges from 0 to 5m bgl for the wells tapping water in recent sediments, whereas under laterite formation the depth to water level goes more than 10m bgl. Seasonal fluctuation indicated that there is rise of water level up to 5m in major parts of Trivandrum Urban area. Biophysical set up has pronounced impact on growth and development of Trivandrum city.

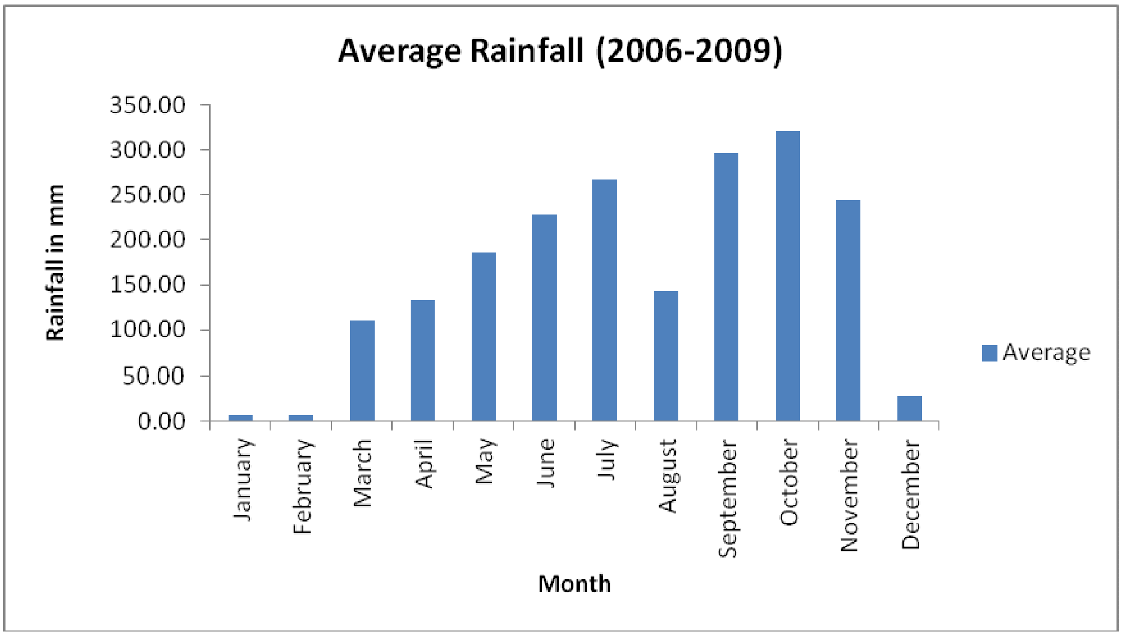


Fig 5.1: Monthly Average Rainfall in Trivandrum City

5.1.2 Growth of Trivandrum City

By the turn of the century (1901) Thiruvananthapuram emerged as a class II town (<100,000 people). With a population of 1, 28,480 it became a class-I town in 1941 and also got the status of Corporation in the same year. When the State of Kerala was formed in 1956 it was decided to house the Legislative Assembly of Kerala in this city and the High Court in Kochi city. In 1981 Census Thiruvananthapuram corporation along with one out growth at Thumba (location of Vikram Sarabhai Space Centre of Indian Space Research Organisation) constituted the Thiruvananthapuram Urban Agglomeration (TUA). By 2001 TUA consisting of Thiruvananthapuram municipal corporation, and five out growths (OG), namely, Kazhakuttam, Sreekaryam, Kudappanakunnu, Vattiyoorkavu and Kovalam, had a population of 889,191 persons .

The Trivandrum urban agglomeration recorded little over one million people in 2011 **(Table 5.1).** Thiruvananthapuram corporation constitutes the core urban area and accounts for 73% of total population of Trivandrum urban agglomeration. The number of Wards in Thiruvananthapuram corporation increased from 24 in 1942 to 100 in 2012. Six census towns were included in the TUA by 2011. TUA recorded high growth rate compared to Trivandrum corporation and the out growth. Population density of Thiruvananthapuram MC was 4392 persons/ km^2 in 2011 whereas the Trivandrum Urban Agglomeration had population density of 3739 persons/ km^2.

Table 5.1: Population and Decadal Growth, Thiruvananthapuram Urban Agglomeration (TUA)

Places	1991	2001	2011	Growth (%) 2001-11	Density (no/ sq.km)
Thiruvananthapuram Municipal Corporation	703859	744739	788271	5.85	4392
Kazhakuttam O.G)	12515	14407	Merged to MC	-	-
Sreekaryam O. G	17245	21423	23528	9.83	2653
Kudappanakunnu O.G	33534	38173	41583	8.93	5407
Vattiyoorkavu O.G	33653	41713	47187	13.12	3944
Kovalam O.G	25419	28736	Merged to MC	-	4247
Venganoor CT	Panchayat	Panchayat	35963	-	2560
Kalliyoor CT	Panchayat	Panchayat	40816	-	2484
Uliyazhathura CT	Panchayat	Panchayat	28230	-	1900
Irooppara CT	Panchayat	Panchayat	23113	-	1873
Pallippuram CT	Panchayat	Panchayat	22512	-	2418
Veilor CT	Panchayat	Panchayat	22816	-	1744
Thiruvananthapuram U A	**826225**	**889191**	**1074019**	**20.78**	**3739**

In the back drop of low growth of population both in the rural and urban areas of the district this variation can be interpreted that people are settling down in the outskirt of the city and the city core is nearing to saturation level given the present mode of settlement pattern. In this context it is necessary to briefly discuss about the settlement pattern of Kerala in general and Thiruvananthapuram in particular, as the census boundary plays an important role in determining rural urban demarcations.

5.1.3 Settlement Pattern

Biophysical environment exerts profound control on settlement system of Kerala (Chattopadhyay, 1994). The basic structure is linear and dispersed. Initial settlements developed along the coastal plain started expanding along the ridges following the road network. The NH 47 connects this city with Kollam to the north west and Nagercoil-Kanyakumari in Tamil Nadu to the south east. The railway line passes along the coastal plain. The NH 47 and Railways run almost parallel to each other. There are two State High Ways and other district roads connecting the surrounding rural areas with the State capital. Linear settlements follow all these routes and the intervening gap areas earlier given for paddy cultivation are subsequently reclaimed to accommodate settlements. Due to linear and dispersed nature of settlement pattern it was practically difficult to demarcate the boundary of the urban areas from the rural areas. The scenario is of historical origin and there are several observations about this trend. The boundary fixed to work out rural urban distribution is an issue to assess the level of urbanization and therefore settlement pattern plays important role, more so in the context of provisioning urban services like water supply and drainage.

5.1.4 Land use/ Land Cover Change in the City Region

The city area has increased from 75km^2 in 1966 to 216 km^2 by 2011, almost three times increase in a span of 45 years. Due to physiographic set up the city grew along certain corridors as already indicated. Spatial growth and incorporation of rural areas in the city is well reflected in land use change statistics. Proportion of residential area relatively came down. If only the core area is considered it will be seen that between 1966 and 1991 low lying paddy fields diminished at a very faster rate. Around 35% of open space reduced in a span of 25 years. The reduction rate is 1.4% per year. Field visit indicates that this rate has increased further and hardly there is any paddy field left. The area under settlement with mixed tree crops had not changed in this period. This is due to the fact that this category gained from the category of paddy but lost equal amount of area to the category of agglomerated settlements. Area under the category of agglomerated settlement had increased by 155% in this 25 years' period. The category of agglomerated settlement represents area with minimum intra settlement space. Map analysis indicated that the growth of agglomerated settlements is taking place mainly in the core area or municipal corporation area of the TUA.

Considering the 2012 data it emerges that proportion of residential area has relatively came down **(Table 5.2)**. However in terms of absolute area it is found that residential area has increased by 137% in a span of 45 years since 1966. The core area covering the municipal corporation area till 1966 was densely settled and getting more and more populated losing all green belts. Satellite data indicated that built up area in Trivandrum city has increased from 15% in 1986 to 46% in 2015 (Jayalekshmi, 2016, personal communication). The rural urban mixed landscape which was earlier seen within the city is now pushed along the periphery of the city. Landuse/land cover change in the city and periphery is quite significant. The city is now growing vertical and also horizontal. Horizontal growth is relatively higher. Traditionally attitude of people in Kerala preferring to live in single house surrounded by open space/ coconut garden is slowly changing due to various reasons. Homestead biodiversity is declining, so is the case with inter settlement space. Landuse change is taking place both at the homestead level and also at the level of use category.

Table 5.2: Land use in Trivandrum City

Category	**1966**	**1990**	**2012**
Total area (in km^2)	74.86	141.74	215.86
Residential	65%	59%	54%
Agriculture (paddy) and fallow paddy land	11%	10%	23%
Public, semi public, parks and open space	6%	9%	13%
Vacant land/ parks and open space	6%	8%	1%
Roads/ streets/ railways	5%	7%	3%
Water bodies	1%	2%	3%
Others	6%	5%	3%

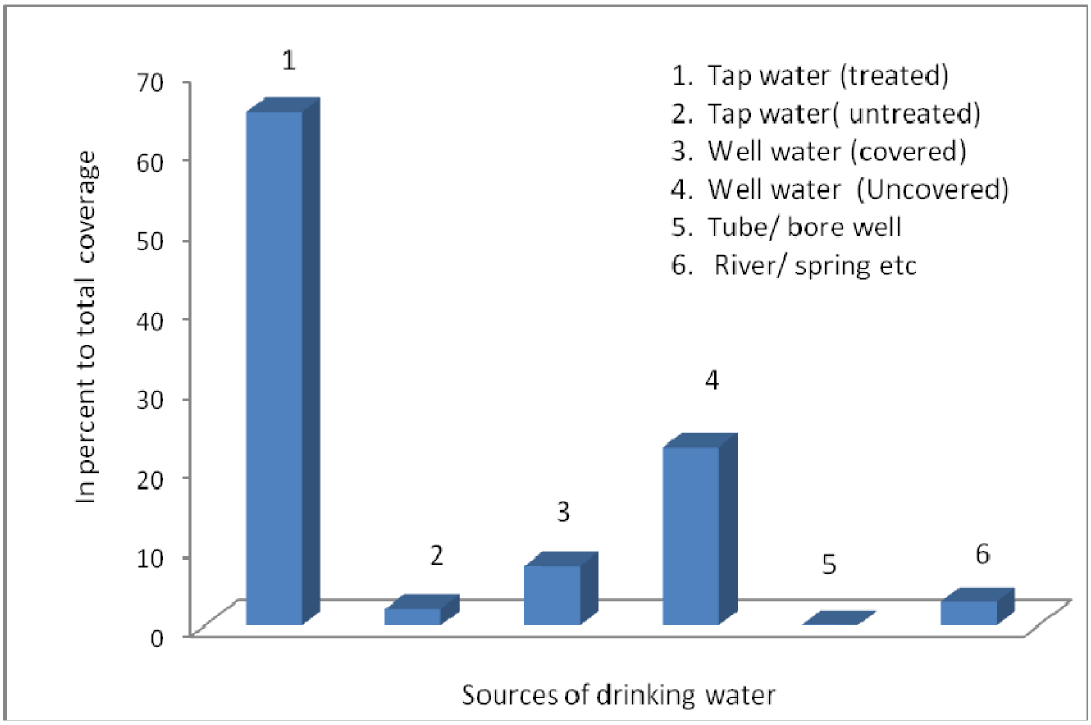
Source: Trivandrum Master Plan, (draft), 2012

5.2 Pressure on Water: Drinking Water and Sanitation

Drinking water and sanitation are linked together. One of the major drivers contributing to water pollution is improper sanitation facilities. It is therefore important to briefly discuss drinking water and sanitation issue here as part of back ground materials for city river management.

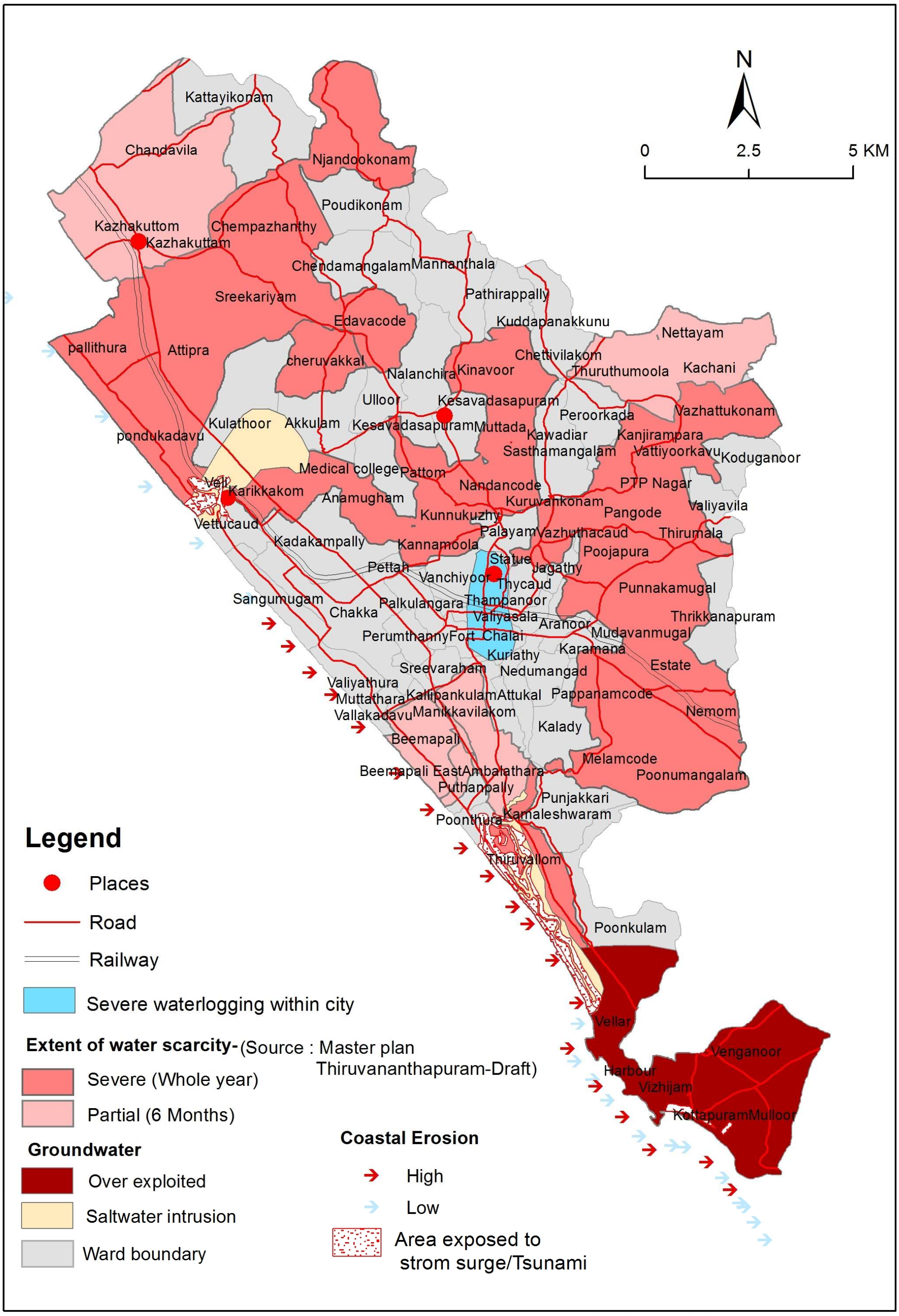
5.2.1 Drinking Water Supply

Drinking water supply in Thiruvananthapuram city is augmented through Aruvikara and Peppara reservoirs, both located on the Karamana river. Kerala Water Authority manages drinking water supply in the city. Around 81% households receive pipe water supply at their premises under KWA. Among the rest 19%, wells cater to the need of drinking water supply for 10% households followed by 4% depending on public tap water, 3% households receive water from tankers and rest 2% manage from various sources. The census data indicated that well water is used by a significant number of households within the Trivandrum urban area **(Fig 5.1)**. The supply is not adequate as is evident from frequent shortage reported by the people particularly during summer months. At present the Trivandrum Water Supply Scheme has the capacity of 273 MLD to cater to the need of 9.57 lakh people. The gap between production and supply is estimated at 137 MLD, whereas the leakage has been estimated to be 43%. Failure of monsoon in consecutive years can have very adverse impact on drinking water supply of the city as water supply mainly depends on surface water, This will also affect health condition. Cutting across physiographic barriers the problem areas are distributed in various parts of the city like Valiyathura and adjoining locality, Manikkavilakam, Asan nagar, Bangaladesh colony, Pulthottam, Vettucaud, Veli, Mannanthala, Nalanchira, Kudappanakkunnu, Pothujanam Lane, Chettikuinnu, Avittam road, Ayurveda college, Kunnumpuram, Press club area, and Medical college area. The elevated areas in the eastern part suffer from occasional shortages **(Fig 5.2).** The ground water, alternative source for drinking water is under stress. While certain pockets are over exploited, the quality of water is an issue warranting serious consideration. There is a gap between ground reality and estimation of ground water resource availability (Soman, 2016)**.** Given the fall in quality of surface water and fluctuation of resource availability due to vagaries in climate there will be increasing dependence on ground water. For meeting future demand and arrive at water security there is a need to develop conjunctive use of surface and ground water. Sustainability of water sources, reduction of leakage and decentralization of resource management can provide the necessary foundation for safe drinking water supply.



Data source: Census data, 2011

Fig 5.2 : Sources of Drinking Water in Trivandrum Urban Area



Sources : CESS,2009,CGWB
Thiruvananthapuram master plan (Draft)

Fig. 5.3 Spatial Distribution of Water Related Problems in Thiruvananthapuram

5.2.2 Waste Management

Waste management is a subject of major concern, particularly in urban areas. With increasing consumerism pervading all walks of life waste disposal has become an important issue. Thiruvananthapuram is a consumer oriented society. It is estimated that total solid waste generation in the city is in the order of 450 tonnes per day, of which 72% reaches the municipal stream of disposal, 19% gets disposed at source and 9% is being collected by Rag pickers (Dileep Kumar, 2017). Households/ domestic sectors contribute the bulk (55.4%) of the municipal solid waste. This was followed by street sweepings (19%), commercial establishments (8.1%) and markets (6.1%). House hold wastes include vegetable and fruit wastes, coconut shells, left over foods, fish and meat waste, paper, plastics, metals and glass. Compostable organic materials contribute 81% of solid wastes in Trivandrum. Source wise physical composition of solid wastes is given in **Table 5.2**. The analysis of chemical characteristics indicated that the density of solid waste is 205 kg/m3 with moisture content of 74%, calorific value of 1698 K.cal/kg, 25.74% Carbon and 0.98% Nitrogen.

Table 5.3: Physical Composition of Municipal Solid Waste from Different Sources in Trivandrum Municipal Corporation (Figures in per cent)

Type of waste	Source		
	Households	Business establishments and Institutions	Hospitals
Organic materials	51.5	41.3	39.4
Paper	10	11.2	16.4
Glass	1.63	3.4	14.1
Textiles	2.68	2.2	10.0
Plastic	5.56	10.7	9.1
Wood	1.38	0.7	0.1
Metal	1.75	2.8	1.3
Ash	4.57	2.6	1.0
Sand	12.84	7.9	3.0
Miscellaneous	8.02	9.0	5.5
Total	100	100	100

Source: Dileep Kumar, 2017

The waste disposal at Vilappilsala has been discontinued due to public protest. The present thrust is on decentralization emphasizing on treatment of solid wastes at source level. Trivandrum Municipal Corporation established 127 aerobic Compost Units in different parts of the city to treat municipal solid waste. Pipe composting units and biogas plants at household level are being encouraged.

5.2.3 Sewage Disposal

Sewage disposal is a big challenge although State records 98.3% households in urban sector to possess toilets. Trivandurm city corporation has only 30% geographical area covered under sewage network system, which is available in 5 blocks out of 18 sewerage blocks in the city (Dileep Kumar, 2016). Works are going on in some parts under ADB programme. On completion it is expected to cater to 45 % of city area. A Sewage treatment plant of 107 MLD capacity is functioning at Muttathara from November, 2013 onwards, however, only 30 to 40 MLD of sewage is reaching the plant every day through the sewerage network catering to 30% of city area. Remaining 70% area depends on septic Tanks and Leach pits. As the leach pits are not sealed, there is leakage affecting ground water. The present practice is to collect the septage using vacuum suction into tankers which are then emptied into open spaces and even into water bodies, one of the most dangerous practices. With the existing system of sewage disposal both surface and ground water are liable to be polluted. The river management in Trivandrum city needs necessarily to consider sewerage management also.

5.3 City Rivers, their Status and Associated problems

Trivandrum city is well drained through the Karamana river and its tributary Killi Ar. Besides, there are another nine small streams or thodus, six flood water drains and several other minor channels that drain various parts of the city. Ulloor thodu, its tributary Pattom thodu and Attipra thodu are significant among the small streams or thodus. While Karamana debouches in the Lakshadweep sea through a back water system, both Ulloor thodu and Attipra thodu join Veli-Akkulam lake. Total length of all these rivers and thodus (streams) in Trivandrum Municipal Corporation is around 65 km and if all the streamlets are considered the total length of natural water courses will be around 180km for the entire corporation area of 215 km^2. Each of the 100 Wards in Trivandrum Municipal Corporation is drained by a natural water course, although in many places these water courses have been lined, realigned and converted as narrow storm drainage and in some areas the drainage line has been converted as road. All the water courses in the city are affected due to wide spread human intervention. Here, we shall discuss the state of Karamana river and Killi ar, two most important water courses in Trivandrum city.

5.3.1 Karamana River

The main river Karamana originates from Chemunji *mottai*, a 1717 m high peak in the Western Ghats and flows for a length of 68 km before joining the Lakshadweep sea near Thiruvallam. Annual discharge of Karamana river was recorded as 936 million cubic metre. The sixth order Karamana basin is fed by three fifth order streams, 14 fourth order streams, 55 third order streams, 282 second order streams and 1141 first order streams. Karamana basin experience land use change both in the upper catchments and also in the lower catchment. Introduction of tea plantation in the early years of 20th century altered the provenance character. Subsequently, introduction of rubber plantation, construction of reservoirs and spread of settlements across the basin have impacted water flow regime and also water quality. The lower part of the river is under intense pressure from urban growth around Trivandrum city.

Impounding of Reservoirs in Karamana River

Karamana river has two reservoirs impounded at Aruvikkara and Peppara to cater to the drinking water need of Trivandrum city. The first stage of construction of Aruvikkara reservoir started in 1928 and completed by 1933 and the second stage was completed in the year 1972. The water spread area at the time of impounding was 48 hectares and the maximum storage capacity was 2 million cubic metre (Mm^3). Water in this reservoir is confined to the main river channel of Karamana and the adjoining tributary valleys. Aruvikkara reservoir is highly silted. KERI conducted sedimentation survey of Aruvikkara in May 2009. According to this survey water holding capacity of the reservoir has come down from 2Mm^3 at the time of final commissioning of the reservoir in 1972 to 1.137 Mm^3 in May, 2009. At Full Reservoir Level (46.63m) water spread area is only 29 ha. There is a reduction of 19ha in water spread area and the storage loss of 0.863Mm^3 during 37 years. The rate of loss of reservoir capacity is to the tune of 1.16% per year. The Peppara reservoir with a water spread area of 5.82km^2 and storage capacity of 70mm^3 was commissioned in 1982 to augment water supply capacity of Trivandrum city at the level of 24/7. However this reservoir is facing problem of siltation (The Hindu, September 9th, 2003) and reduced lean season flow due to various interventions in its catchments.

Sand Mining in Karamana River

Sand mining is reported from all rivers in Kerala. In fact, sand is mined well above the annual yield resulting in deepening of the river bed and alteration of the plan form of river thalweg. Assessment of sediment deposit conducted under the aegis of Revenue Department, Government of Kerala indicated that in a 32 km stretch of Karamana river there are sediment deposits of 0.18 million cubic meter within a depth of 2m below summer water level. The segment of Karamana river flowing through Trivandrum Corporation has deposit of around 21 thousand cubic metre of sediments 2m below summer water level **(Table 5.3)**. However, there is no minable quantity of sediments available in the river as the stipulated guideline envisage sand mining to be restricted only above summer water level. All sediments above summer water level have been removed and there are reports of continuous unauthorized mining even below 2m depth. The river bed level helps maintain the pizhometric level of water and control water levels in the surrounding wells. Removal of sands from river bed causes not only lowering of river bed level but also reduces water holding capacity. This is an important issue in the matter of source sustainability and warrants proper attention of the authorities involved in city river management.

Table 5.4: Volume of Sand in the City Segment of Karamana

Sl. No.	Profile No.	Area of Cross Section (m^2)	Zone of Influence (m)	Volume of Sand (m^3) up to 2m SWL	Prohibited Quantity (m^2)	Volume of available Sand (m^3)	Volume of available sand (m^2) above SWL (Mineable Sand)
1	71	7.35	264.30	1942.61	Nil	1942.61	Nil
2	72	8.57	264.00	2262.48	Nil	2262.48	Nil
3	73	7.85	158.00	1240.30	Nil	1240.30	Nil
4	74	3.80	150.35	571.33	Nil	571.33	Nil
5	75	4.80	212.55	1020.24	Nil	1020.24	Nil
6	76	6.00	229.70	1378.20	Nil	1378.20	Nil
7	77	6.00	159.90	959.40	Nil	959.40	Nil
8	78	12.00	186.70	2240.40	Nil	2240.40	Nil
9	79	9.00	250.50	2254.50	Nil	2254.50	Nil
10	80	8.97	281.30	2523.26	Nil	2523.26	Nil
11	81	5.20	265.00	1378.00	Nil	1378.00	Nil
12	82	8.33	256.30	2134.98	Nil	2134.98	Nil
13	83	10.00	322.50	3225.00	3225.00	0.00	Nil
14	84	3.00	331.50	994.50	994.50	0.00	Nil
15	85	2.62	314.25	823.34	Nil	823.34	Nil
Total				**24948.53**	**4219.50**	**20729.03**	**Nil**

Water Quality of Karamana River

Analysis of selected parameters indicated that water quality of Karamana is in general not good and it deteriorates as river enters Trivandrum corporation area (Harikumar, 2017). The maximum deteriorated condition is noted in the coastal stretch represented by samples collected from Killi Ar confluence, Thiruvallam, Parvathy Puthanar, Pachalloor and Kovalam, all these stations are in the downstream side of the Trivandrum Corporation leading up to sea coast. During monsoon, the value of pH ranged from 6.0 to 6.88 with an average value of 6.2. Out of 20 samples, 15 samples were found to have pH below the lower limit of 6.5 prescribed by BIS. Electrical Conductivity of downstream stations was found to be very high. This is mainly due to tidal incursion. High colour noted in various river segments is related to increased surface run off, sewage discharge, urban effluents and waste dump. During summer months, when river discharge comes down substantially, but other waste input continue to be at the same level, the colour of river water records high value. Weed infestation in many stretches of the river also adds colour to the river water. In post-monsoon season, nitrate-N varied from non detected values to 4.8 mg/l. The Maximum value was observed for the samples collected from Aryanad which is attributable to domestic use and agricultural runoff. In pre-monsoon season, concentration of nitrate-N varied from 0.88 to 6.5 mg/l and the highest value of nitrate-N was observed for the sample collected from the confluence of Parvathi Puthanar, which carries sewage and domestic waste. In monsoon season, the highest concentration of nitrate-N was observed for the samples collected from Pachalloor in the coastal stretch. The river carried high organic load, which is evident from the fact that out of 20 samples as many as 11 samples reported BOD value > 3 mg/l. Bacteriological analysis of the samples clearly indicated microbial contamination in the river. Almost all the stations showed higher index for total coliforms and fecal coliform. E.coli was present in all samples in all three seasons. Karamana river is receiving domestic sewage and its water is polluted mainly due to human actions. Water in none of the stretches, monitored under this programme, is found potable at any time point of the year. It cannot be used without treatment.

5.3.2 Killi Ar

The Killi Ar has substantial presence in Trivandrum city. This fifth order tributary of the Karamana river originates from north of Panavur in Nedumangad Taluk of Thiruvananthapuram District at an elevation of 120 metres above sea level. It drains an area of 95 km^2 spreading over Panavur, Anad, Karakulam, Kudappanakkunnu and Vattiyoorkavu panchayats, Nedumangad Municipality and the City Corporation of Thiruvananthapuram. Killi Ar flows in a broad north-south direction for a distance of over 30 km, before it joins the Karamana River 500 metre south east of Melepuram. Killi Ar is fed by two fourth order, nine third order, 35 second order and 127 first order sub basins. The catchment area is densely populated. Landuse in the catchment experience considerable change over the years. Area under agglomerated settlement has increased by 74% in a span of 25 years since 1989. Part of Killi ar basin falling within the Trivandurm corporation has indicated increase in area under agglomerated settlement by 64% and reduction in area under open space and settlement with mixed tree crops during this period. Whether rural or urban, the basin is experiencing increase in settlement area. Encroachments along flood plains even within river bed, indiscriminate dumping of waste and sewage, and construction of buildings and houses right up to the river front without leaving any spill area for the river have negatively impacted fluvial function.

Water quality study conducted earlier (CESS, 1995) indicated biotic life in the river was largely lost. The river stretch flowing through the corporation area is highly polluted due to sewage disposal, both domestic and municipal, from Karakulam downstream and due to the toxic effluents of tanneries near Vallikod. The report highlighted that the decrease in the value of ammonia nitrogen and increase in the value of nitrate shows that nitrification is taking place in the lower reaches of Killi Ar. The high Nitrate and Ammonia content in the upper reaches of Killi Ar might be due to intense use of chemical fertilizers in agricultural activities in the floodplain areas. These components get concentrated in the summer months, and show some dilution during monsoon months. The recent studies indicate that even in rainy season the dilution is not effective.

5.3.3 Call for Action

Impact of urbanization on river quality is well evident. The Karamana river and its tributary Killi Ar have lost their self sustaining capacity as waste discharge crossed river's natural assimilating capacity even in the monsoon months. The lower courses of Karamana river and its tributary Killi Ar flowing through Trivandrum city corporation are heavily polluted. It receives large quantities of raw sewage discharged from the city and adjoining areas, domestic waste discharge and untreated waste water even from the Milma dairy plant at Ambalathara. Water in the lower stretches of the Karamana river is unfit for human use. It is now affecting human health. Local people demands government intervention in controlling pollution in the river, however even with funds made available at the disposal of the State government the river restoration work could not be kick started (The Hindu, March, 13, 2008). The situation has not changes much as the same problems were reported in subsequent years (The Hindu, 2nd August, 2010, April, 20, 2013). RITES prepared a proposal of Rs. 500 crore for pollution control. KSCSTE along with TRIDA has initiated a project to clean Thiruvallam part of Karamana river during 2013.

Water Quality Management and Cleaning of the River

Water quality of the Karamana river and other streams within the Trivandrum city are polluted and requires a closer look at opportunities to remove bottlenecks related to spatial planning in combination with wastewater management. Water pollutions are caused by both point and non-point sources. Point sources are defined locations that include sewage treatment plants, combined sewer overflows, sanitary sewer overflows as well as illegal dumping and illegal sewage connections. Centralised sewage treatment in Trivandrum cover only 30%. The risk of surface water pollution through sewage is considerably high in Trivandurm city. Along with improvement of treatment technology for point source pollution it is necessary to check non-point source pollution which contributes to deterioration of water quality in the rivers, streams and lakes. The most important urban sources of nonpoint pollution are surfaced lands where dust and other fine grained material accumulate during dry periods and bare soil exposed to erosion and wash out. Storm water carries pollutants and contributes to the degradation of river water body. Wastewater treatment and sewage treatment may be given priority. Decentralised techniques such as minimising combined sewer overflows (CSO) by network separation or regulating runoff from urban surfaces have been of particular interest. A long-term view is necessary. As the rivers are flowing into the city crossing rural area, the agricultural runoff contributes to water pollution, which also warrants due attention for improving water quality. The surrounding panchayats in the upstream may be involved in the venture of reducing non point source pollution. The proposed actions to improve river water quality may be listed as: i) Biological treatment plant, ii) Sewage separation and treatment, iii) improvement of storm runoff, iv) erosion control and (v) regulation of excessive use of fertilizer and pesticides.

Sewage Management

There are already sufficient indications that centralized system of sewage disposal will not be successful. Perhaps the only alternative is to promote decentralised approach in sewage treatment, for which the biggest challenge is availability of land. Local people may be taken into confidence in installing such decentralsied system. For which they may be made aware of the danger of continuing with leach pits and potential problems of surface and ground water pollution. The earlier concept of sewage management to dispose the material is giving place to use sewage materials for various purposes. Water recycled from sewage are used for agriculture and environmental management in many countries. This may be seriously considered. Sewage material is also used as fertilizer. Such practice has been reported from Bangalore. To manage sewage properly, some of the developed countries have imposed household level fees for sewage treatment. Fees are calculated based on water consumption, which is metered. Good services in the urban areas cannot be ensured free for a long time. In view of deteriorated surface and ground water quality sewage management is an important issue for source sustainability.

5.3.4 Elas/ Micro Watersheds

Trivandurm city has developed on lateritic undulating terrain. The low lying valleys between lateritic ridges gradually merge with coastal plain. The original corporation area or core of the city is characterized by 33 well defined micro watersheds or *Elas,* as they are locally known (Chattopadhyay and Jayaprasad, 1990). List of *Elas* with area open space and watershed area are given in the A**ppendix 4.** These *Elas* finally merge with river flood plains and therefore form a complete interconnected drainage basin net. Traditionally central parts of these *Elas* or valley bottoms were given for agriculture and allied activities and the surrounding slopes and ridges were occupied by settlements. Till early 1990s there were paddy fields within the city corporation limit. These paddy fields were earmarked as green belts and reclamation prohibited. The scenario changed during last two decades. Low lying areas were filled up and new settlements sprung up. As a result the ridges and upper slopes are occupied by old houses and the lower slope and valley bottoms exhibit new constructions. Linear settlement pattern changed to agglomeration and there is gradual reduction in inter settlement space. All these have resulted in steady expansion of surfaced area within the city and consequent decrease in infiltration and increase in surface run off resulting in aggravation of water logging and flood problem in the city.

5.3.5 Floods and Water Logging

City suffers from flood/ water logging in every year during monsoon months in more than one occasion, although, due to undulating topography and relatively elevated position water drains out quickly in most of the areas. In southern part of the city some areas experience water logging for 3 to 4 days. It is a problem affecting lives of the citizens of Trivandrum city regularly. Thiruvananthapuram Municipal Corporation (TMC) extends over flat coastal plain and adjoining lateritic undulated terrain with the maximum altitude reaching 76m. The majority of the corporation area falls within the altitudinal range of 10-40m. The river Karamana, and its tributary Killi Ar drain major part of the city. There are another nine small streams or thodu, six flood water drains and several other minor channels that drain various parts of the city. Flood affected areas are distributed mostly adjoining these water courses. Apart from those there are low lying valleys and natural depressions where water accumulation during monsoon is a regular phenomenon. The places often reporting water logging are distributed in Thampanoor (central railway station and bus terminus), East Fort - Chalai (city bus stand, Sri Padmanabha Swamy temple and main market), Vanchiyur, Pettah, Inchakal and slum areas of Chengalchoola, around Vazuthacaud and Thycaud **(Fig. 5.3)**. Other flood affected areas are marked in Pappanamkode, Karamana, Amblathara, Thiruvallam along the river Karamana; Jagathy, Pangode, Poojappura, Maruthankuzhy and downstream along Killi Ar and Ullor and Kannammoola along Ulloor thodu and Pattom thodu respectively (Shravankumar, 2000). A study under Kerala Urban Development Project (KUDP, 1992) identified 112 problem areas in the city and adjoining panchayats which were proposed to be considered for Drainage Planning. Water logging takes place 5 to 6 times in each year. Depth of water reaches up to 1.2m in some cases.

Based on location and severity of problems 59 high priority areas were identified within the Thiruvananthapuram Municipal Corporation area and another 53 sites were located in the adjoining panchayat areas (KUDA, 1992).

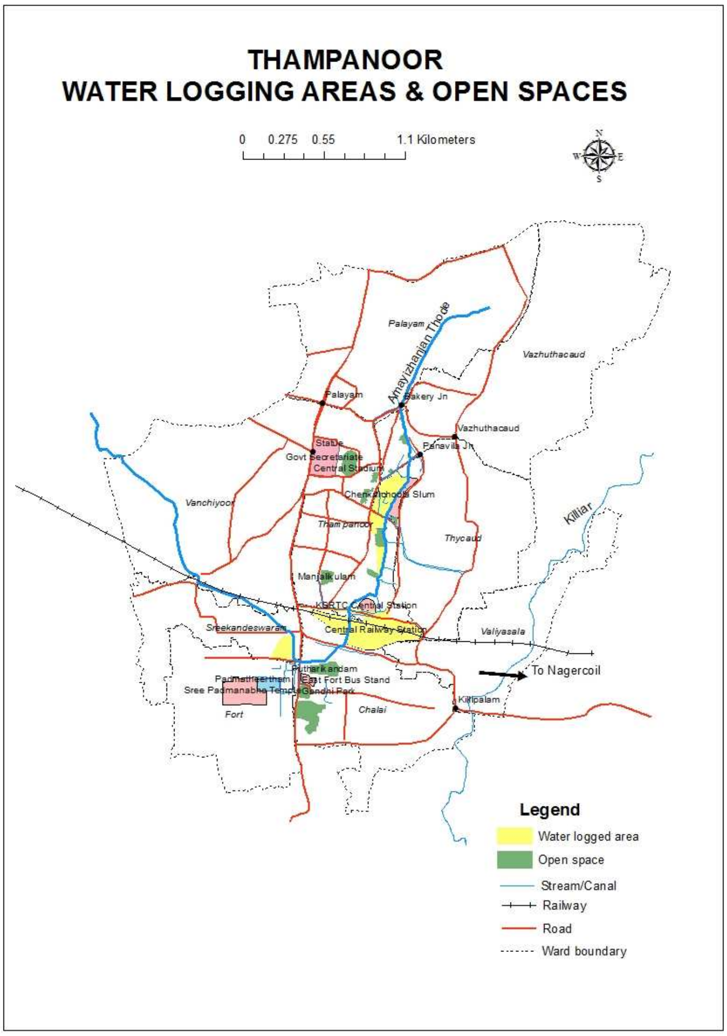


Fig. 5.4 Frequent Waterlogged Area Within the CBD

Operation Anantha

April 21st, 2015 afternoon witnessed heavy rain (161mm) and consequent water logging in many parts of Trivandrum city. Places like Chengalchoola, Thampanur, East Fort, Pettah, Karikakam and Edapazhinji were severely affected. So intense was the rain and water accumulation that trains were delayed for 40-45 minutes. In view of such heavy rains taking place occasionally and consequent water logging creating disruption to normal lives, the Government of Kerala took a cabinet decision on 30th April and the 'Operation Anantha' was launched on 1st May 2015, invoking National Disaster Management Act, 2005. Both short term and long term measures were proposed to remedy the situation (Shaji & Raveendran, 2017). Short term measures comprised of three main activities: (i) Cleaning and desilting of drains, (ii) Shifting of KWA pressure pipes across canals and (iii) Completion of box culvert at Thampanoor. All these three measures were to facilitate quick discharge of water through the canals. The underlying assumption is that water logging occurs as incoming rain water does not get drained out immediately. As long term measures the proposed activities were: (i) Restoration of water bodies for storing water, (ii) Widening of railway culvert at Thampanoor to increase flashing out capacity of the culvert and (iii) Strengthening of solid waste management activities through Suchitwa mission. It is found that dumping of solid waste in the open drains and water bodies hinder free movement of water during heavy down pour. There are several constructions raised along the banks of water courses which mostly encroach on canal/ thodu causing reduction of their width and consequent fall in discharging capacities of these canals. May 31st, 2015 was set as the dateline to remove all encroachments. All concerned departments including KSUDP, Irrigation Dept, PWD, National Highways, KRDF, City Corporation and District Administration were involved in this operation. Several actions have been contemplated. Once completed, they will bring some relief with faster draining out of water; however, it is unlikely that they will solve the problem of water logging altogether. There are much larger issues warranting detailed deliberation. We note here some of them.

Genesis of the Problem

To understand the problem of water logging in Thampanur railway station and surrounding areas it is necessary to investigate the landscape ecology of the area. The Amayizhanjan Thodu, whose head water can be traced from the IMD hill flows down south through Chengalchoola and after crossing railway line it turns westward near Putharikandam and flows through Patoor to reach Kannammoola. Course of this thodu has two distinct parts **(ref. Fig. 5.3)**. The north south upper segment is distinctly bound by the water divides along MG road in the west and Vazhuthacaud-Thampanoor road in the east. This area is the source zone for water. The west flowing lower course (Putharikandam to Patoor) flows more or less along the boundary of lateritic terrain in the north and sandy plain in the south. The micro-watershed boundary along the southern limit is not so distinct. The East Fort- Chalai bazar area is a sandy plain and forms part of the back swamps, remnants of which was traceable behind the market even a couple of years before.

The Amayizhanjan Thodu commands a watershed area of 3.94 km^2. The highest elevation reaches to 62 m above msl and the lowest elevation is 5 above msl. The DEM **(Fig 5.4)** indicates the relief character of this micro watershed. The entire area is densely settled with very small area left as open space. Settlement density is more than 30 per hectare. It is found that more than 78% of 3.94 km^2 micro watershed area is under built up category or paved. As a result, during rain there is direct surface runoff without any scope of infiltration. All the rainwater precipitating in this watershed flows down and accumulates in the low lying area along Amayizhanjan thodu. Normal rainfall in Trivandrum city for the month of June is 325 mm, however in the year 2015 the rainfall received in this month was 288mm, well below the normal rainfall. On 28th June, 2015 daily rainfall was 120mm resulting in severe water logging. In the event of climate change there will be an increase of incidence of high intensity rainfall with intervening prolonged dry period. Probability for water logging will increase. Existing drainage facilities cannot cater to this high rainfall incidence. Even if all the measures proposed under Operation Anantha are executed there is little chance to ameliorate the situation in the case of high intensity rainfall.

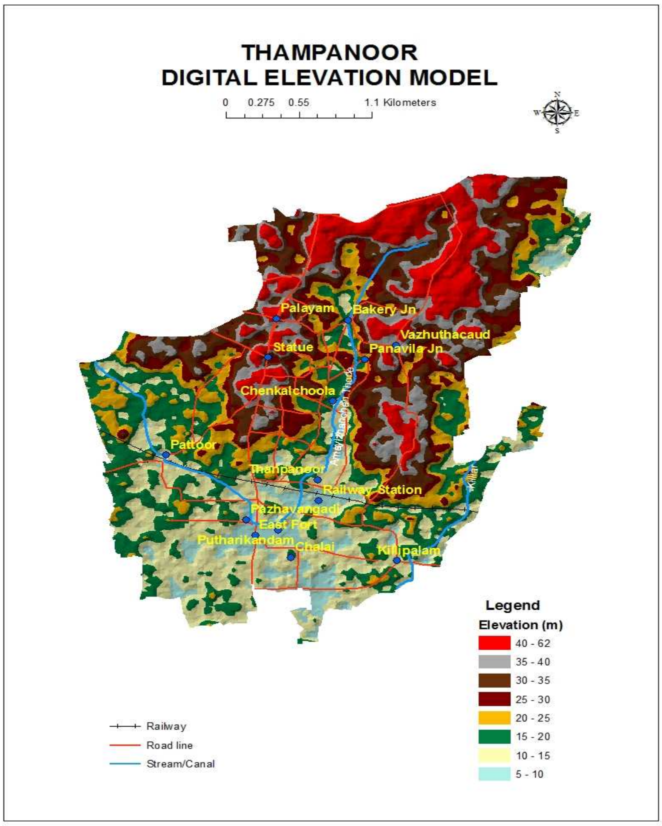


Fig 5.5: DEM of parts of CBD area, Trivandrum city

Management of Storm Water

Analyses of the rainfall incidence, topography and drainage infrastructure indicated that the probable causes underlying flooding are expansion of settlements, growth of surfaced area, reduction of flood cushioning areas due to occupancy of flood plains, encroachment along drainage channels and obstructions, inadequate and or absence of drains, low level of plinth of houses vis a vis road/ drain level, lack of clear cut outlet to primary / secondary drains, inadequate cross drainage, overtopping of banks, inadequate inlets, poor maintenance level and tides/ sea surge in the coastal areas. Majority of the causes are of anthropogenic origin. In the event of climate change there will be an increase in high intensity rainfall with intervening prolonged dry periods. Probability for water logging will increase. Existing drainage facilities cannot cater to this high rainfall incidence. Even if all the measures proposed under Operation Anantha are executed there is little chance to ameliorate the situation in the case of high intensity rainfall. The first phase of Operation Anantha has been completed and the 2nd phase is expected to begin in a couple of month (The Hindu, 20th February, 2016). There are already questions raised about division of responsibilities in urban flood mitigation, involvement of individual plot owners and institutions in containing surface run off from their properties are raised.

The storm water management is another challenge of urban water governance throughout the World and this is related to unbridled urban growth. Even in the city like Phnom Penh, Combodia which has successfully managed the drinking water problem is facing the vagaries of flood water management. The flood problem has been attributed to the faster growth of urbanization in a deltaic landscape without total plan for water regime and this may prove costly for all the gains by PPWSA. A major flood could undo much of the progress achieved during the last twenty years (Doyle, 2012).

Much of the problem of water logging in Trivandurm city is due to unplanned growth of urbanization. The city has limited facility for storm water management and that too in the form of conveyance, e.g. to drain out the water at a faster rate. This trend prevails for traditional storm water management almost in all urban centres. However, there are changes suggested in many cases and the current storm water management proposes hybrid infrastructure which combines structural measures that facilitate conveyance with distributed measures that promote infiltration (Porse, 2013). For long term solution and sustainability there must be a balance between infrastructure development, its performance and environmental goals. It is unlikely that cities can build distributed storm water management infrastructure to cope with the eventuality like the rainfall of 161 mm that occurred on 21st April, 2015. The current storm water management systems are not particularly effective at public engagement, at the same time people's interest in storm water management may be difficult to sustain. Water logging takes place in the zone of convergence however the excess flow starts along the line of divergence. The problem must be addressed at the source. Trivandurm corporation has 180 km long streamlets and each of 100 Wards is bestowed with one or more natural water courses / streamlets, which are mostly converted into rainwater drains. Water accumulates in these drains from individual plots as overland flow. The quantity of water and travel time of flow can be moderated through plot level actions by individual, business houses and institutions at the Ward level by increasing in-situ infiltration and also by increasing capacity of the existing ponds to store water. While there is regulation to construct covered area (house) within a plot, there is no restriction to surface the court yard, which curtails infiltration and contributes to enhanced surface run off. All these water in aggregation contributes to storm water and water logging. Effective storm water management will depend on involvement of all stake holders, system design of distributed infrastructures and decentralized governance.

Harvesting City's own Rain Water

Drawing water from outside the city limit is the common trend of urban water management. This was working well when the urban areas were small. But now urban areas are expanding and water demand is increasing. Perhaps it is time to consider how to capture the rain water falling within the city limit and use it properly. So far very little attention has been paid to use this water or channelize this water in the mainstream of water supply. A simple calculation will highlight the amount of water resources that are not being used systematically. Considering the core city area of 75 km^2 and average rainfall of 1700mm it may be calculated that the city receives 7.5 billion litre of rainwater annually or on an average 350million litre per day (MLD). The Trivandrum city water supply scheme has the capacity to produce 273 MLD which is well below the daily average rainwater received by the city. Discounting for run off co-efficient and other losses even if it can be arranged to harvest only 25% of incoming rain water of 350 MLD the city will have 87.50 MLD of water well above the water proposed to be drawn from the Neyyar reservoir in case of shortage. How to harvest the water precipitating within the city is the real socio-technical issue to be addressed as part of urban water governance. This option needs serious consideration.

5.4 Ground Water

River restoration cannot be accomplished fully without due consideration to ground water. Therefore, a brief discussion on ground water is provided here. Ground water occurs in all geological formations either in unconfined or semi-confined/ confined conditions. Phreatic conditions mainly exist in coastal alluvium and in weathered crystalline formation. Water is tapped mostly by dug wells for domestic or irrigation purposes. In crystalline terrain, ground water occur in semi confined/ confined condition in the deep fractures and can be developed by deep bore wells (CGWB, 1999). Regular monitoring of wells indicated presence of 2/3 water bearing strata (aquifer groups) within the depth range of 200 m (CGWB, 2006). Water Yield varies under different lithologic conditions. Tertiary formations and recent sediments are found to be most productive. Trivandrum city area experience high fluctuation of water table (Rani et al, 2011). During pre-monsoon depth to water level varies from 1.9 to 19.8 m bgl and in the post –monsoon period it is between 1.56 and 19.8 m bgl. The shallowest water level is noted during the month of October/November coinciding with North-East monsoon. This may be due to the prolonged infiltration during monsoon months and reinforced recharge during north east monsoon. Variation in depth to water table depends on hydrogeological formations. Wells in Recent alluviums record depth to water level ranging from 0 to 5 m bgl and those in the laterite terrain show the average depth to water level > 10 m bgl.

CGWB (2013) estimated the net groundwater availability of the Thiruvananthapuram block is 23.74 MCM and the current stage of development is 81%. Spatial variation indicates that there are areas in the peripheral parts of the city where it can be further developed, however, there are also some parts around the city showing over exploitation with more than 100% development. In these areas ground water extraction is more than recharge resulting in fall in ground water level. Comparison of pre and post-monsoon water level shows mixed scenario indicating complexity in ground water occurrence in Trivandrum City Corporation and surrounding areas. It is reported that major portion of Trivandrum city area is experiencing rise in water level up to 5 m, however there are areas like Vizhinjam where water table is falling down indicating over exploitation.

Quality of ground water is also an emerging problem. The coastal aquifers reported high salinity. Electrical conductivity of well water in Vizhinjam area is greater than 1000 µS/ cm. Over exploitation will cause saline intrusion. It is reported that for most of the water quality parameters the ground water in major part of Trivandrum city area is still within the limit. However, bacteriologically contamination is an issue for all the seasons (Harikumar, 2017). Tapping of ground water has increased significantly with increase in population and water use. Number of private tube wells and bore wells has increased significantly. Majority of the households in the panchayat area and even in some parts of the urban area have their own dug wells or bore wells. The ground water, alternative source for drinking water is under stress. While certain pockets are over exploited, the quality of water is an issue warranting serious consideration. There is a gap between ground reality and estimation of resource availability (Soman, 2016)**.** Given the fall in quality of surface water and fluctuation of resource availability due to vagaries in climate there will be increasing dependence on ground water. However, over exploitation and pollution are two main problems for ground water management in Trivandrum city. It is important to note that resident time of ground water is much longer. Once it is polluted, it may take years to get rid of the problem. This matter warrants serious attention as it impacts source sustainability.

Trivandrum city is facing problems both for blue water and grey water. Source sustainability is an emerging issue. Water sources are getting polluted due to waste water and inadequate sewage disposal facilities. There is disconnect between urban people and the river. A comprehensive management plan is necessary to redeem the situation and also bring back the relationship between citizen and the rivers. Future water security will largely depend how best the surface waters are managed. Rejuvenation of rivers assumes great significance in this context.

Chapter VI

Trivandrum City River Restoration Action Plan: An Outline

6.0 Introduction

River restoration within the cities/ urban areas is emerging as an important activity. It is being linked with urban renewal/ rejuvenation programme. The London river management activities are well known. There are several such initiatives for urban river restoration across the globe. In all cases the stress is to restore the river ecology and create a healthy environment for human wellbeing and sustainable livelihood. The earlier thrust on river management following a commodity approach and emphasizing on water supply and quality of water is gradually giving place to ecosystem approach and the traditional linkage between river and people is being restored. This change is evident since 2000. The work on restoration of river segments falling within the city limit has started in cities like Delhi, Nagpur, Ahmedabad Chennai, Bangalore, etc, however the conceptual framework and scope of involving local people are yet to be worked out. River restoration is no more a simple technical intervention. It requires people's participation and an integration of social, economic and ecologic variables.

An important feature of the Trivandrum city River Restoration Action Plan we propose is the strategy to bring back the water bodies to the centre of the public sphere. Water bodies in the city now lack visibility. They are relegated to the backyards of urban life. They are dumping yards of all filth and hence 'decent' people rarely so anywhere near. They are away from public gaze and hence have been transformed into sites of unlawful activities and abodes of criminal gangs. Karamana river for instance is virtually taken over by the sand mining mafia who views ordinary visitors as 'strangers' or unwelcome intruders into their exclusive territories. Even the police dare not normally visit the territories of the sand mining mafia, lest they will be transferred or in the extreme cases physically attacked. Concentration of goonda gangs cannot but lead to concentration of all kinds of shady activities such as illicit brewing, drug business etc. People of every locality should know their water as well as other common resources. They should also be made aware that health condition and environmental securities of the local people depended on the upkeep of land and water resources.

6.1 Integrated Urban Water Management and City River Restoration

The IUWM, an emerging concept to address all water related issue in an urban centre stress on spatial and sectoral integration of water management (Chattopadhyay and Harilal, 2017). It is a departure from pure technical management of water issue, hitherto followed to an alternative approach of creating socio-technical and political space for decentralized solutions. The emphasis is on the need to manage water in its wider ecological and social context and it stresses on tailoring the approach to the specific hydrologic, climatic, political, economic and cultural contexts (Hirsch et al., undated). Restoration of city rivers forms part of integrated urban water management, which is an emerging challenge globally. Several countries have initiated urban river restoration projects. The European Commission under the fifth Framework programme Key Action 4 “City of Tomorrow and Cultural Heritage” initiated research projects on Urban River Basin Enhancement Method (URBEM) for comprehensive understanding of urban river rehabilitation and design (Schanze et al, 2004). Apart from investigating the current state of urban river enhancement the URBEN project stresses on development of new tools, innovative techniques and improved procedures to enhance quality of water courses in urban areas. These tools should provide planning assistance for the differing, multi-functional uses of urban water courses and their adjacent communities. It is expected that these tools will assist decision makers in sustainable management of urban rivers. We are yet to take up programmes like URBEN in Trivandrum or for that matter in India. However, there is a need to initiate the process of deliberating on comprehensive urban river management programme. With this study on Trivandrum city we plan to initiate such a broad based debate.

6.2 Existing Initiatives

There was a government level initiative to develop projects for river restoration. RITES prepared a project proposal worth of Rs. 500 crore to clean Karamana and Killi ar. It is a comprehensive proposal for pollution abatement and includes public awareness programme, parks and afforestation, solid waste management plant, sewage treatment plant, sewer line/ water line rearrangement, storm water drains, and a host of other intervention measures. Non availability of funds and lack of land are two constraints to implement RITES proposal as reported at some official parlance. Recently, one of the components is being executed by KSCSTE and TRIDA to clean Thiruvallam part of Karamana river. Similarly, there are some initiatives in the case of Killi Ar also. Operation Anantha is another recent initiative for flood mitigation undertaken by the Government of Kerala. However, all these measures are mostly structural interventions, fragmented and follow departmental approach with little scope to understand the problem in a larger frame of watershed involving local people and local self government institutions. High population pressure, lack of buffer zone between river and settlements, competing land use, private ownership of land and little or no statuary regulation on construction are various constraints to initiate restoration programmes freely. It is therefore necessary to take the local people into confidence for initiating any intervention measures along the rivers. We propose here a management plan for larger deliberation. It is intended to initiate the dialogue and consider city river management in a holistic frame.

6.3 The Proposed Approach

The proposed approach tries to improve the ecological functions of waters while maintaining the anthropogenic use of them. It warrants compatibility between society and ecology. The first step is to reverse adverse ecological impacts such as changes of channel morphology and water quality. This will have substantial effects on aquatic habitat availability and biodiversity. Besides ecological issues in urban areas there is also a socio-cultural/ society framework for river rehabilitation which calls for social, economic and aesthetic considerations. Balancing of all these dimensions is important to trade the path of sustainability. The rivers in Trivandrum city are in different stages of degradation. A gradation or zoning of the rivers is necessary to fix priority. Similarly catchment conservation will play significant role in ensuring water quality, enhancement of summer water flow and moderation of flood flow. Identification of micro catchments and prioritisation is necessary for designing intervention measures. Therefore Trivandrum city river management plan should be developed considering watershed as well as site specific intervention to achieve the desired goal.

Trivandrum city is drained by Karamana river, its tributary Killi Ar and small streams like Pattom Thodu, and Ulloor thodu. The river Karamana is the main source of drinking supply in the city. The reservoirs are well outside the city limit. Water quality might have to be addressed in the catchment areas also. Similarly upper catchment of Killi Ar is outside the city limit. Establishing relationship among Trivandrum corporation and surrounding panchayats are necessary to initiate meaningful restoration programmes. The water bodies, issues and the key departments and local self governments are given in the **Table 6.1.**

Table 6.1: Water Bodies, Issues, Key Departments and Local Bodies

Rivers/ water bodies	**Issues**	**Departments/Local bodies**
Karamana	Two reservoirs, Reservoir sedimentation, Drinking water source, Water quality, Sand mining, River bank erosion, Flood plain encroachment, Channelization in stretches, Flood	Water Resource Department, KWA, Revenue Department, Tourism department, Trivandrum District administration, District panchayats, Gram Panchayats, Trivandrum corporation
Killi ar	Water quality, Flood plain encroachment, Channelisation in stretches, River bank erosion, flood	Revenue department, KWA, District administration, Gram Panchayats and Trivandurm corporation
Parvati putnar	Water quality	District administration, Trivandrum corporation,
Ulloor thodu/ Pattom thodu	Water quality, Bank encroachment, Channelisation in stretches, Flood	Revenue Department, District administration, Gram Panchayats and Trivandrum Corporation
Ela/ micro watersheds	Channelisation, reclamation, Cross pipes, Culverts, Storm run off	Revenue Department, District administration, Trivandrum corporation
Vizinjum thodu	Water quality, Bank encroachment, Channelisation in stretches	Revenue Department, District administration, Gram Panchayats and Trivandrum corporation
Attipra thodu	Water quality, Bank encroachment, Channelisation in stretches	Revenue Department, District administration, Gram panchayat, Trivandrum corporation
Vellayani lake	Fresh water body, Drinking water source, Sedimentation, Water quality	Revenue department, District administration, KWA, Trivandrum corporation
Akkulam lake	Brackish water body, Lake bed encroachment, Sedimentation, Water quality	Revenue department, Tourism department, District administration, Trivandrum corporation

There are 20 micro watersheds covering Trivandrum city and surroundings. Each of City's 100 Ward is bestowed with a natural water course/ stream/ streamlet **(Fig 6.1).** Many of these streamlets have been converted into narrow rain water outlets to which waste water drains from many of the surrounding households are connected. Water is polluted from the headwater itself. Action plan is required for each of these 20 micro watersheds and the Ward level water courses. This should be planned under the leadership of elected representatives and the involvement of all 901 Resident Associations active in the City. Ward level interventions may be worked out ensuring active participation of local people as part of this action plan both for planning and execution. For relatively larger streams like Killi Ar, Ulloor thodu, Pattom thodu etc, a common passage along both sides of the river can be developed. Small submersible check dams may be constructed in these rivers to enhance flow velocity and mixing of air in the water. There may be provision to fix wire mesh at the mouth of streamlets to prevent non biodegradable material to move into the main water course. Resident Associations and Ward level committees may ensure that only water flows from one Ward to other Ward and not the waste. There is a need to develop a master plan addressing all these technical and non technical issues together.

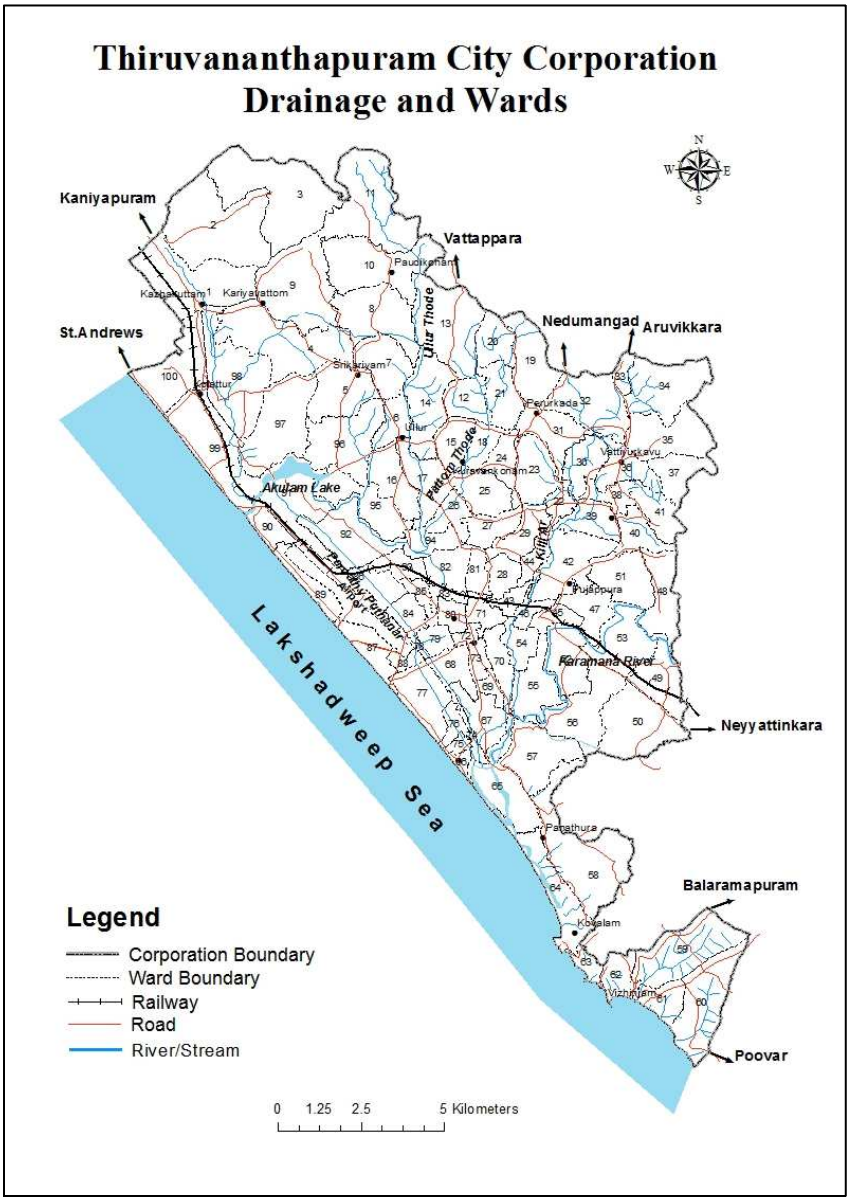


Fig 6.1: Ward Level Distribution of Water Courses in Trivandrum City

6.4 Master Plan for River Restoration

The objectives of river restoration project consist of: (i) Cleaning of river and improvement of river water quality, (ii) Management of flood risk and dispersal of instantaneous flow, (iii) enhancement of summer flow, (iv) Restoration of river ecology, (v) Coping with climate change, (vi) Visual improvement, (vii) Recreational use, (viii) Education (ix) People's participation, (x) Community involvement and (xi) Linking river/ water bodies to people. To fulfill all these objectives it is necessary to develop a master plan spelling out the details and modalities for initiating river restoration activity, which is a multidisciplinary programme and warrants involvement of all stake holders including common public and experts. We discuss here an outline of the master plan and indicate the issues that may form the basis for a comprehensive exercise to develop city river rejuvenation master plan.

6.5 Components of Master Plan

The master plan should begin with a vision and long term goals **(Appendix 5)**. It will stress on priority fixation, facilitate restoration on long term perspective and present restoration activity as a multi stake holder exercise with definite scope for public participation. It may be prepared in such a way that there will be continuity and it will ensure cumulative/ aggregation of individual projects within a holistic frame. Each activity forms part of the total programme.

Fixing priority is one of the components of master plan. However, present data base is not sufficient to accomplish this task. It is necessary to monitor stress/ pressure to which the Trivandurm rivers are subjugated to. The common problems are degraded water quality, loss of biodiversity, bank erosion, flood plain encroachment, construction along the water line / channelisation, sand mining, waste dumping and sewage disposal. The streamlets draining micro watersheds within the city are variously affected. Open space/ paddy fields serving as flood cushioning areas during monsoon months have disappeared. Even the wetlands in the peripheral part of the city are diverted to accommodate non agricultural land use thereby contributing to enhancement of impermeable surfaces.

6.6 Data Base for Master Plan

Pressures on urban waters result from anthropogenic activities. The existing data on river bank mapping, sand auditing and water quality are not adequate. There is a need to complete survey of all 20 micro watersheds, water courses traversing the Wards and *elas* within the city. This can be attempted by monitoring a host of indicators categorized under hydrological, morphological, physico-chemical and biological characteristics. Specific observations of the indicators under each of these four item **(Appendix 6)** will create the required data base. Besides, there should be socio-economic investigation particularly related to ownership of land. All these dada may be collated for devising definite plan to initiate river restoration work.

6.7 Preparation of Rehabilitation Projects

Once the master plan is prepared the rehabilitation project may be initiated with selection of sites and the target areas of rehabilitation, which are related to hydrology and hydrodynamics, morphology and connectivity, water quality, biodiversity, and public health and safety. Execution of project also needs to address the issues like legislation, financing, organisation, time frame, site management and maintenance. There should be necessary provision to assess whether the goals are achieved and to measure success of rehabilitation projects. A list of indicators for these two items is given in the **Tables 6.2 and 6.3.**

Table 6.2: Goals of Urban River Restoration and Indicators

Goals	Indicators
Reduce pollutant loads	Total suspended solids Sewage over flow/ discharge Faecal coliform concentration/ bacterial contamination Dissolved Oxygen Waste dumping
Restore ecological integrity	Macro invertebrate community health Health of river fish community
Wetland area	Extent of wetland area Created/ restored non-tidal wetlands Created/ restored tidal wetlands
Riparian forest/ vegetation	Length of riparian vegetation Biodiversity of riparian vegetation
Public/ private participation	Number of residence association involved Number of Kudumbashree units involved Number of schools involved Number of NGOs involved

Modified after URBEN, European Commission

Table 6.3: Indicators of Success

Ecological Indicators	Social indicators	Economic indicators
Water quality	Use of water	Activities to create income
River depth and width variation	Public transportation stop	Property value
Acidification status	Water contact zone	
Inundability	Anchorage point	
Stream length with riparian vegetation		
Buffer zone	River crossings	
Connection to ground water bodies	Public utility of river sites	
River continuity	Land mark/ view points	
Fish population	Temples/ worship places	
Aquatic vegetation	Recreational facilities	
Hydrogeomorphological conditions	Recreational paths	
Status of pollution from discharged water	Cultural heritage/ Cultural events	

Source: Saraiva (2008)

6.8 Governance

The governance mechanism will have to be designed to incorporate appropriate incentives/disincentives to promote desirable practices and to discourage uncertain behavior. Here we suggest a mechanism of Waste Auditing to be done on their own by large economic units of the city. They may have to be encouraged to submit their ‘waste returns’ to the authorities for making database and facilitating interventions. Each major actor will have to give statements regarding the waste they generate and the means of disposal of the waste. The ‘waste returns’ can be evaluated using tested norms regarding generation of waste associated with different types of economic activity. The city corporation can, as a follow up, think of introducing a tax ‘waste generation’ to finance expenses of disposal and treatment. The state government may have to take the initiative to allow LGS to introduce such charges. It may be noted here that Indonesia had introduced a programme known as PROPER (Programme for Pollution Evaluation and Performance Rating) which is a voluntary disclosure scheme meant for the Corporate Houses listed in stock exchange dealing with foreign product and have significant impact on environment (Wheeler and Afsah, 2005). It is being executed jointly by the provincial regional governments and the regency/municipality regional governments. The programme drew attention of the World Bank as an important step to control pollution.

6.9 People's Participation

Public involvement emerged as a key factor for success of urban river restoration project across the world. European Commission (2003) has brought out a document "Guidance on public participation in relation to the Water Framework Directive – active involvement, consultation and public access to information" spelling out the modalities. It is acknowledged that people's participation increases the acceptance of projects and helps to achieve social sustainability. In Kerala, people's participation in planning process has been successfully demonstrated. The discussion here will highlight the modalities to involve all stake holders in river restoration activities for Trivandrum city rivers.

The city river restoration plan and successful execution of interventions warrant close cooperation and coherent action of urban and surrounding local bodies, information dissemination, consultation and involvement of the local people including all users and concerned groups. Efforts should be there to involve citizens, NGO's, commercial associations, businessmen, institutions and politicians. The elected representatives, citizens, resident associations, private property owners and nature conservation groups concerned with river restoration may be encouraged to contribute in site selection, providing ideas as well as in the planning and implementation of schemes. Tourism sectors can also be involved in the process as this sector is going to be the income generating sector once the water bodies are cleaned and access ensured. The Universities, Colleges, Schools, R & D centres, Employees' associations and Trade Unions are also stakeholders. Politicians have a very definite role in restoration activity as it involves people and legislation and there is also a need to integrate river restoration programme with existing Government programmes like MGNREGS.

Identification of proper stake holders is an important step in river restoration project. Stakeholder's involvement is context specific. The people living in the area, affected group, local opinion makers, and potential contributors for long term programmes may be identified. In this context local residents should be playing a key role. Informing stakeholders about the conditions of a river or a specific river rehabilitation project is very important. It helps confidence building and to win stakeholder's support for the project, promotes stewardship, advocacy and initiates participation. Continuous dialogue and consultation are necessary. The information must be user-oriented and should refer to their specific problems. This will increase citizens' participation in the consultation processes. Local seminars and discussions at the level of Resident Association and small groups will help. Guided tour, river walk, lectures, presentations, exhibition and press release from time to time will encourage local people and students. By involving them in site selection for rehabilitation schemes, voluntary clean up, and ensuring their participation through competition, survey, workshop, and public meetings will help gathering information and ideas from the locality. It will facilitate the process of documenting local knowledge, recounting local history, creating time line and arrange for focus group discussion,

People should have command by way of participation in the conceptualization, preparation, implementation and maintenance of the project. The tasks may be preparing signs at rivers, plantings, reintroduction of fish species, installation of birdhouses, raising and maintaining river side small gardens as well as monitoring of chemical and biological indicators of the water quality. Implementation of pilot schemes, maintenance and monitoring can be taken over by universities or colleges or research institutes or resident associations. Business houses/ industries/ public sector undertakings may also be involved. Annual or bi-annual voluntary clean up can be taken up by schools and colleges.

An important element of the participatory strategy as mentioned earlier will be to bring back water bodies from the backyard to the centre-stage of urban life. The idea is to encourage healthy competition among local communities, elected representatives, schools etc belonging to different wards/regions in the upkeep of water bodies. Model practices and interventions will have to be given awards of encouragement. The media will also be encouraged to make periodic visits so that positive/ negative developments are reported and discussed. Educational especially research institutions will be encouraged to undertake frequent studies on various aspects of the state of affairs of the water bodies.

It is important to develop stewardship and advocacy for rivers, primarily to generate active support for river enhancement, including acts of pleading or promoting river enhancement activities and projects. This requires that citizens and responsible agencies know and understand the problems of urban rivers in order to be able to recognise sources of constraints and possible ways of improvement. Advocacy and stewardship can be promoted through information and the involvement of stakeholders in projects. It has to continue after project completion, so as to establish a continuous awareness and to improve attitudes towards streams and their problems. Finally people may be taken into confidence for forging partnership, social auditing of the project and create and nurture a healthy river environment.

Chapter VII

Summary and Conclusion

This project on ‘River restoration in Kerala: Developing a co-evolutionary participatory framework and river restoration action plan for Trivandrum city’ proposes to deliberate on the complex task of river restoration in Kerala internalizing the recent initiatives of river bank mapping and sand auditing and draw an outline of an action plan for restoration of Trivandrum City rivers. The main aim of this project is to initiate debate on changing the current fractured and *ad hoc* nature of river restoration activities that are being followed by different departments resulting in competing use, overlap and repetition and to advocate a process that internalizes the technical as well as governance issues in water management in Kerala. The overarching goal is to transit to sustainability in water resource management in the State. The study is presented through seven chapters including summary and conclusion.

Rivers are under stress globally and human activities are principal contributors. Brief review provided in the introductory chapter brings out that all most all countries across the world initiated river restoration/ renovation programmes. Several such initiatives have been effective and brought out important lessons. During last couple of decades there were global meets and deliberations to develop theory and practice for water management, river management and water governance. In the process, the ideas of Integrated Water Resource Management (IWRM) and Integrated Urban Water Management (IUWM) have evolved. The common agreement is that the sectoral approach and departmental hegemony to manage different sectors of water within the river basin and also within the urban administrative set up hitherto followed have not yielded desired results. This has now been acknowledged at the Government of India level with constitution of Mihir Shah Committee, which suggested a National Water Commission (NWC) by integrating departments dealing with surface water and ground water.

The normal fluvial system now operates as social ecological interactive system, a concept that recognizes mutual interdependence of anthropogenic and natural process and calls for integrated approach in identifying the problems, analyzing it considering biophysical set up and human induced actions and finally devising site specific solutions. The thrust is on integration of the sectors and harmonization of ecology and society as most of the changes is human induced and majority of the environmental problems are of societal origin.

Co-evolutionary approach is proposed as an alternative framework for understanding change in complex social-ecological systems and to provide a new perspective to address river restoration problem, which is mostly a result of human's indiscriminate use of river system. This framework is expected to address the issues across the scales from micro to macro and to value long term human benefit as the cardinal principle. The traditional trend of ecological restoration designed on the basis of hydrological, geomorphological and other physical attributes and intervention mostly linear in the shape of structural/ engineering measures is being replaced by watershed based site specific approach with active involvement of local people. The emerging governance is multilevel and polycentric.

The contextual analysis of water resources in Kerala highlighted that the State is well endowed with water resources; however there are several challenges in managing water resources sustainably. Demand for water resources is increasing and at the same time water availability is declining due to quality deterioration of surface and sub surface water and also drying up of traditional water sources like ponds and springs. Kerala experiences drinking water shortage during summer months over the last several years. Deforestation, diversion of land from agricultural to non agricultural use, shrinkage of wetlands and flood cushioning areas, increased surfaced/ paved area due to expansion of build up area and growing urbanization all in combination contributing to stronger surface run off and lower infiltration and thereby constraining ground water recharge. Deterioration of water quality, both of surface water and ground water is a major concern. Hardly there is any stretch of river in the State from where water can be used directly. People in Kerala enjoying easy access to water now face hardship due to quality deterioration. Increasing population pressure and higher consumption will complicate the problem further, if ameliorating measures are not introduced immediately. Climate change is another emerging issue that can result in serious water resource management problem due to change in rainfall pattern and also increased evapo-transpiration on account of temperature rise. As a whole, water governance is emerging as a major challenge.

State water policy followed national policy, although the First National Water Policy (NWP) adopted in 1987 addressed water as a state subject. Over the years Indian Water Policy has evolved to take cognisance of emerging water pressures. National Water Policy was revised in 2002 and again in 2012. Drinking water supply is given the top priority in the national policy. The new policy, among others, also raises concerns regarding the effects of land use and land cover changes on water availability and quality. It stressed on the need for comprehensive legislation for optimum development of inter-State rivers and river valleys to facilitate the inter-State coordination ensuring scientific planning of land and water resources taking basin/sub-basin as unit with unified perspectives of water in all its forms and ensuring holistic and balanced development of both the catchment and the command areas. The State Water Policy (SWP) first formulated in 1992 and revised in 2008 envisaged formulation of State Level River Authority, involvement of all citizens in conservation of water, undertake an integrated micro watershed based approach to facilitate resource-based planning, user participation and equitable water resource management. It has also concretised the role of Grama panchayats in water resource management. Formations of KWA and subsequently Jalanidhi were part of reforms of water governance in the State. The KWA, the largest institution in the field of water supply in Kerala, is found wanting in managing the water supply schemes to the satisfaction of users. Performance of Jalanidhi, the Kerala Rural Water Supply and Sanitation Agency instituted to administer rural water supply schemes is also being questioned on various grounds, like source sustainability, quality assurance, technical sustainability and future management. Water management is a multilevel, multi–institutional activity and therefore a balance between ‘bottom–up’ and ‘top-down’ approach is necessary as all water issues cannot be captured at a single level.

Rivers in Kerala are under stress. Catchment as well as river corridors are affected. There are problem of water quality and extraction of river bed deposits. Indiscriminate sand mining reported from all the rivers have seriously jeopardized river ecology. At the instance of Revenue Department, Kerala initiated a programme of river bank mapping and sand auditing in 2011 in order to create a data base for all the rivers and controlling sand extraction from river beds. Science and technology Institutes, University Departments, Engineering Colleges and NGOS are involved in this programme. So far, work has been completed for 16 rivers covering a length of around 750km. Sand auditing exercise, also completed for all these 16 rivers has been brought out. It is found that out of 16 rivers only seven rivers have sand deposits above summer water level. Total sand deposits above summer water level in all these seven rivers, together, are 1.06 million m^3. Part of which can be mined. Most of the rivers have lost their sediment reserves. There is a need for total restriction on sand mining from the river beds.

The proposed river restoration frame work for Kerala consists of six steps: building environment and setting up restoration team, scoping, preparation of restoration plan, plan implementation, monitoring and community involvement and people's participation. Most common goals of river restoration are related to ecorestoration and increasing biodiversity, stabilizing channels, improving riparian and in-stream habitat, improving water quality and summer or base flow. Impact of climate change is also an issue considered under river restoration plan. The commonly used method of restoration covers in-stream hydromorphic interventions followed by channel hydromorphic intervention, riparian restoration, and watershed action. Restoration activity may be planned for the whole river and also for segments with proper prioritization. Data generated through these exercises can be systematized under Kerala River Information System which may be made available at the public domain. Establishment of a River Management Authority or River Research Institute and strengthening of existing River Management Cell will be the first step. The successful pursuit of river rejuvenation entails forging linkages and sharing of responsibilities among different stake holders including people. For which necessary socio-technical-political space may be created. The process has to be evolved in such a way that the local people and the panchayat consider that management of the river and its upkeep is part of their responsibility.
Cities act as one of the main drivers of river degradation. River restoration in the urban areas is a challenging task. We discussed the case of Thiruvananthapuram city in chapters of V and VI. Thiruvananthapuram corporation, the capital city of Kerala, grew from a small city of religious antiquity to a million city by 2011. Its area has increased from 75km^2 in 1966 to 216 km^2 by 2012. The city extends over flat coastal plain and low lateritic undulated terrain. With population growth and horizontal expansion the landscape of the city has changed. More and more rural areas were amalgamated into the urban fold. Growth of urbanization enhances pressure on water service system. Drinking water supply is a major issue. The problem of sewage disposal, waste water and solid waste are other related aspects impacting water bodies.

Trivandrum is endowed with rivers, streams, and fresh water and brackish water lakes. Total length of the rivers, streams and streamlets is around 180km. Each of the 100 Wards in Trivandrum Municipal Corporation is drained by a natural water course. All the water courses in the city are affected due to wide spread human intervention. Karamana River with two reservoirs having combined storage capacity of $72Mm^3$ is the main drinking water supply source. However, the river is facing problem due to over exploitation of river bed deposits and water quality deterioration. Karamana river and its tributary Killi Ar have lost their self sustaining capacity due to point and non-point source pollution including agricultural runoff from rural hinterlands and large quantities of raw sewage discharged from the city and adjoining areas, domestic waste discharge and untreated waste water.

Trivandrum city faces regular problem for storm water drainage. All the 33 low lying areas or *Elas* which used to accommodate excess rain water were filled up and given for settlements or institutional buildings. Linear settlement pattern changed to agglomeration and there is reduction in inter settlement space. All these have resulted in gradual expansion of surfaced area within the city and consequent decrease in infiltration and increase in surface run off resulting in aggravation of water logging and flood problem in the city. Government has initiated the 'Operation Anantha' programme to tackle the storm water flood in some parts of CBD area. Although started with a lot of enthusiasm 'Operation Anantha' did not make much progress and remains as a set of ambitious tasks opened, but left unfinished. Ground water is another sector which faces the problem of over exploitation and pollution.

Problem of city rivers are multidimensional. Therefore the approach suggested for river restoration falls within the broad realm of Integrated Urban Water Management, which stresses on the need to manage water in its wider ecological and social perspectives and tailor the approach to the specific hydrologic, climatic, political, economic and cultural contexts. The constraints to initiate river restoration mostly referring to high population pressure, lack of buffer zone between river and settlements, competing land use, private ownership of land and little or no statuary regulation of construction may be turned into opportunity to take the local people into confidence for executing rejuvenation interventions. For all these, city requires a Master Plan urgently.

The strategy we propose is to win the rivers back to the public sphere. Water bodies should be converted into places where people would like to get together, as it used to be in the past. Water bodies served as common bathing places for the people of all ages irrespective of their class and creed. It was a regular congregation. Bathing ghats along the rivers, now mostly in deteriorated conditions, testify existence of these practices. River banks were also sites of small and big gathering of people for various socio-religious-cultural activities of life. Many such activities have gone redundant and disappeared. It is one of the reasons why the river banks came to acquire such a deserted look. It is in this backdrop that we underline the need to bring the water bodies back to the centre stage of life and culture. The river banks should be places when people gather for various purposes such as exercise, get together of friends, evening/ morning walk, study tours of local students etc. They should be developed into spaces that the local people love to visit and proudly take their guests. It is perhaps the only way the local population would develop a sense of belonging to the river system.

There are 20 micro watersheds identifiable in Trivandrum city and surroundings. Largely they are part of the Karamana river basin. The city river management plan should be contextualized within the Karamana river basin. Provenance of some of the water courses draining the city spread over beyond the urban boundary. Therefore the action plan proposed to be prepared for each of these 20 micro watersheds should have the provision to involve surrounding panchayats, wherever necessary. Action plans for Ward level water courses should also be developed. There is a need for developing data base for each of the water courses. The existing data on river bank mapping, sand auditing and water quality are not sufficient for drawing up detailed plan. The Master plan should begin with a vision and long term goals for restoration activity. It should stress on priority fixation involving all stake holders including tourism department in this process. People must also be involved in site selection and implementation and maintenance of the project. Developing stewardship and advocacy for rivers are necessary. The people’s participation should continue after project completion to forge partnership, conduct social auditing, and create and nurture a healthy river environment for a sustainable future.

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APPENDICES

Appendix 1: List of Local Bodies Involved in River Bank Mapping Programme in Kerala

Sl No	Name of River	Length (km) Covered	Panchayats involved	Corporations / Municipalities involved
1	Karamana	43	Aryananad, Uzhamalakkal, Vallanad, Aruvikkara, Vilappil, Vattiyoorkavu and Vilavoorkal	Thiruvananthapuram Corporation
2	Neyyar	40	Kallikkad,Ottasekharamangalam, Kulathummel, Maranalloor, Keezharoor, Perumkadavila, Chenkal and Kulathoor	Neyyattinkara Municipality
3	Vamanapuram	43	Panavoor, Pullampara, Nellanadu, Vamanapuram, Mudakkal, Kizhuvallam, Kadakkavoor, Chirayinkeezhu, Kallara, Pullimathu, Nagaroor, Karavaram and Vakkom	Attingal Municipality
4	Ithikara	43	Anchal, Ittiva, Edamulackal, Chadayamangalam, Elamadu, Velinallor, Pallickal, Kalluvathukkal, Pooyampally, Adichanalloor, Chathannoor	-
5	Kallada	65	Eroor, Vilakkudy, Thalavoor, Pattazhi, Mylom, Kulakkada, Pavithreswaram, East Kallada, Kadambanand, Kunnathur, Sasthamkotta, Thenmala, Piravanthoor, Pathanapuram, Pattazhi Vadakkekkara and Ezhamkulam	Punalur Muncipality
6	Pamba	60	Cherukolpuzha, Ranni, Vadaserikkara, Kozhenchery, Mallapuzhassery, Aranmula, Ayirur, Angadi, Pazhayangadi, Thottapuzhassery, Naranamuzhi, Ranni Perunad, Vadakkekkara, Thiruvandannoor, Pandanadur, Kadapra, Mannar, Viyyapuram,and Niranam	-

7	Periyar	59	Kavalangadu, Adimaly, Kuttampuzha, Keerampara, Pindimana, Venganoor, Ayyampuzha, Malayattoor, Neeleswaram, Koovappady, Okkal, Kalady, Kanjoor, Vazhakkulam, Sreemoolamangalam and Keezhmadu	Aluva Municipality, Perumbavoor Municipality
8	Chalakudy	35	Ayyampuzha, Manjapra, Karukutty, Melur, Pariyaram, Kadukutty, Mala, Annanada, Kuzhur, Prakkadavu and Puthenvelikkara	Chalakkudy Municipality
9	Chaliyar	69	Areekode, Chaliyar, Chathamangalam, Chikkode, Chungathara, Edavanna, Kavannur, Keezhparamba, Kodiyathur, Mambad, Mavoor, Nilamboor, Pothukallu, Urangathiri and Vazhakad	-
10	Kadalundi	103	A. R. Nagar, Anakkayam, Edarikode, Keezhattur, Kodur, Koottilangadi, Kuruva, Mooniyur, Oorakam, Edappatta, Melattur, Pandikkad, Othukungal, Parappur, Vengara, Alanallur, Ponmala, Thennala, Tirurangadi, Parappanangadi and Vallikkunnu.	Manjeri Municipality and Malappuram Munici Pality
11	Kuttiyadi	29	Marudonkara, Kuttiyadi, Velom, Thiruvallur, Maniyur, Changaroth, Perambra and Cheruvannoor.	-
12	Kabani	74	Pulpally, Thirunelli, Mananthavadi, Panamaram, Edavaka and Thavinjal	-
13	Anjarakandy	46	Chittariparamba, Kolayade, Malur, Mangattidom, Vengad, Keezhallur, Anjarakandy and Perlassery	Mattannur Municipality
14	Chandragiri	39	Chengala, Chemmanad, Muliyar, Karadukka, Bedadukka and Delampady	-
Total			**166**	**10**

Appendix 2: List of Local Bodies involved in Sand Auditing Programme in Kerala

Sl No	Name of River	Length (Km) Covered	Panchayats involved	Corporations/Municipalities involved
1	Karamana	32	Aruvikkara, Vilappil and Vilavoorkal	Thiruvananthapuram Corporation
2	Neyyar	40	Kallikkad, Ottasekharamangalam, Kulathummel, Maranalloor, Keezharoor, Perumkadavila, Chenkal and Kulathoor	Neyyattinkara Municipality
3	Vamanapuram	43	Panavoor, Pullampara, Nellanadu, Vamanapuram, Mudakkal, Kizhuvallam, Kadakkavoor, Chirayinkeezhu, Kallara, Pullimathu, Nagaroor, Karavaram and Vakkom	Attingal Municipality
4	Ithikkara	43	Anchal, Ittiva, Edamulackal, Chadayamangalam, Elamadu, Velinallor, Pallickal, Kalluvathukkal, Pooyampally, Adichanalloor, Chathannoor	-
5	Kallada	45	Pathanapuram, North Pattazhi, Thalavoor, Piravanthoor, Pattazhi, Kunnathoor, Pavithreswaram, Kadambanad, Mylam, Ezhamkulam, Kulakkada, East Kallada, Sasthamkotta and West Kallada	
6	Pamba	60	Cherukolpuzha, Ranni, Vadaserikkara, Kozhenchery, Mallapuzhassery, Aranmula, Ayirur, Angadi, Pazhayangadi, Thottapuzhassery, Naranamuzhi, Ranni Perunad, Vadakkekkara, Thiruvandannoor, Pandanadur, Kadapra, Mannar, Viyyapuram,and Niranam	-
7	Meenachil	39	Meenachil, Mutholy, Kidangoor, Ayarkunnam, Vijayapuram, Bharanamganam, Eattumannor, Aymanam and Thiruvarppe	Pala Municipality and Kottayam Municipality
8	Muvattupuzha	52	Ayavana, Payipra, Avoly, Valakom, Marady,	Muvattupuzha Municipality

9			Ramamangalam, Ikkaranadu, Poothrikka, Maneed, Piravom, Mulakkulam, Thalayolaparampu and Velloor	
9	Periyar	59	Kavalangadu, Adimaly, Kuttampuzha, Keerampara, Pindimana, Venganoor, Ayyampuzha, Malayattoor, Neeleswaram, Koovappady, Okkal, Kalady, Kanjoor, Vazhakkulam, Sreemoolamangalam and Keezhmadu	Aluva Municipality, Perumbavoor Municipality
10	Karuvannur	34	Vallachira, Cherppu, Nenmanikkara, Pothussery, Vllachira, Chazhoor, Karalam, Katur	-
11	Chaliyar	53	Areekode, Chaliyar, Chathamangalam, Chikkode, Chungathara, Edavanna, Kavannur, Keezhparamba, Kodiyathur, Mambad, Mavoor, Nilamboor, Pothukallu, Urangathiri and Vazhakad	-
12	Kadalundi	88	A R Nagar, Anakkayam, Edarikode, Keezhattur, Kodur, Koottilangadi, Kuruva, Mooniyoor, Oorakam, Othukkungal, Pandikkad, Parappanangadi, Parappur, Ponmala, Thennala, Tirurangadi, Vallikkunnu, Vengara	Manjeri Municipality and Malappuram Municipality
13	Kuttiyadi	23	Marudonkara, Kuttiyadi, Velom, Thiruvallur, Maniyur, Changaroth, Perambra and Cheruvannoor.	-
14	Kabani	56	Pulpally, Thirunelli, Mananthavadi, Panamaram, Edavaka and Thavinjal	-
15	Anjarakandy	43	Chittariparamba, Malur, Mangattidom, Vengad, Keezhallur, Anjarakandy and Perlassery	Mattannur Municipality
16	Chandragiri	39	Chengala, Chemmanad, Muliyar, Karadukka, Bedadukka and Delampady	-
Total			**170**	**11**

Appendix 3: Some Selected Restorative Practices

Problems	Alternative solutions	Associated watershed management objectives
1. River bank failure/ erosion	a. Bank protection structure b. Riparian vegetation	a. Maintain life of structures by vegetation support and management b. Protect vegetation cover until sites recover; use reseeding/ replanting to prevent loss
2. Catchment erosion /sedimentation	a. Erosion control measures b. Contour terracing c. Promote vegetation cover	a. Same as 1a b. Revegetate, stabilize slope, terraces and follow land use guidelines c. Protection, re-vegetation, fertilization
3. Water shortage	a. Water harvesting b. Vegetative manipulation	a. Check dam, developing localized collection and storage facilities b. Maintenance of vegetative cover, convert from deep rooted to shallow rooted species to reduce evapora-transpiration loss.
4.Poor water quality	a. Develop alternative supplies from wells, springs b. Treat water supplies	a. Protect and maintain ground water quality b. Protect catchment
5. Flooding	a. Storage reservoir b. Construct levees, channel improvement etc c. Flood plain management d. Reduce overland flow	a. Minimize sediment delivery to the reservoir, watershed protection from erosion b. Minimize sedimentation of down stream c. Zoning of lands for activities d. Afforestation, encourage natural regeneration

Appendix 4: *Ela* (Micro Watersheds) Within Trivandrum City

Name of the ela/ micro watersheds	Catchment area (in Hectares)	Approximate open Area (in Hectares) as on 1992
Nilamel	50.72	25.76
Elanthengu	49.08	22.24
Iranimuttom	57.20	25.56
Karamana Kunathal	65.16	25.00
Kizharannur	26.12	17.00
Melarannur	77.12	14.68
Chadiyara	110.00	20.00
Cheruthala Bhagom	32.00	8.00
Edapazhinji – I	74.00	2.68
Edapazhinji – II	70.00	9.32
Maruthankuzhi – I	116.00	17.00
Maruthankuzhi – II	67.00	17.00
Kokotta ela & Madathuvilakom	209.00	24.00
Edakulam ela	108.00	14.00
Kavaloor ela	91.00	16.00
Nellikonam	165.00	50.00
Arayalloor	108.00	36.00
Peroor Konath & Kallikonathu	64.20	6.00
Konkalathu	22.65	1.36
Koorachal	24.80	6.48
Thelibhagom	34.00	6.00
Alappuram	67.00	21.00
Chengalloor	59.96	13.00
Pradikari	32.00	4.56
Thamalam	69.36	14.00
Cherukode	53.04	7.80
Parambukonam	43.00	8.00
Parayat	28.00	12.00
Muttada	59.00	9.16
Melneloor	117.00	5.00
Thekkumoodu	226.00	27.00
Madathuvilakom Ulloorthody ela	161.00	96.00
Cheruvikkal (Portion)	55.20	5.20

Appendix 5: Master Plan Process

1. Back ground
2. Project vision and guiding principles
3. Existing conditions

    The regional setting

    Landuse, zoning and recreational uses

    Ecological conditions: hydrology, soil and sediment conditions, channel and riparian conditions, Upland, wetland and riparian vegetation conditions, Bird and other communities, fish and aquatic communities, threatened and endangered species,

4. Potential ecological threats

    Water and sediment contamination

    Urban development

    Invasive species

5. Remeadiation and stabilization measures
6. Ecological reference sites
7. Ecological restoration plan

    The vision: restoration goals, objectives/ actions

    Reducing threats to ecological integrity

    Phasing of restoration activities

    Approval process for individual projects

    Institutional strategy for long term protection nd management

    Funding individual projects

    Bench marks

    Adaptive management committee

    Monitoring and documentation

Appendix 6: List of Indicators for Monitoring Stress

I. Hydrological component

i) Increased runoff from sealed or impervious urban surfaces
ii) Increased flow velocities in the water courses
iii) Increased risk of erosion
iv) Decreased dry weather base flow feeding streams

II Morphological component

i) Embankment along the river bank
ii) Alteration of river bed
iii) Culverted sections under infrastructure, building and portions of towns and cities
iv) Installation of urban infrastructure along or underneath the water course (sewer pipes, power supply lines, gas and water pipelines, roads etc.)
v) Unbalanced sediment regime
vi) General loss of sediment transfer causing management problems

III. Physico-chemical component (water quality)

i) Nutrients, heavy metals, salt, organic compounds from sewer overflows or direct waste water discharges and urban surfaces drainage
ii) Disturbed conditions of temperature and radiation because of absence of riparian vegetation

IV. Biological component (river habitat and biodiversity)

i) Reduced natural habitats (water body, river bank, river bed, flood plain, plants)
ii) Reduced habitat accessibility due to discontinuation of riparian vegetation and disturbed ecologic continuum
iii) Qualitative habitat degradation due to unnatural flow and change in sediment character
iv) Degraded riparian areas due to their functional separation from water course and extensive use within the urbanised area
v) Loss of biodiversity (fauna and flora)

Modified after Schanze et al, 2004