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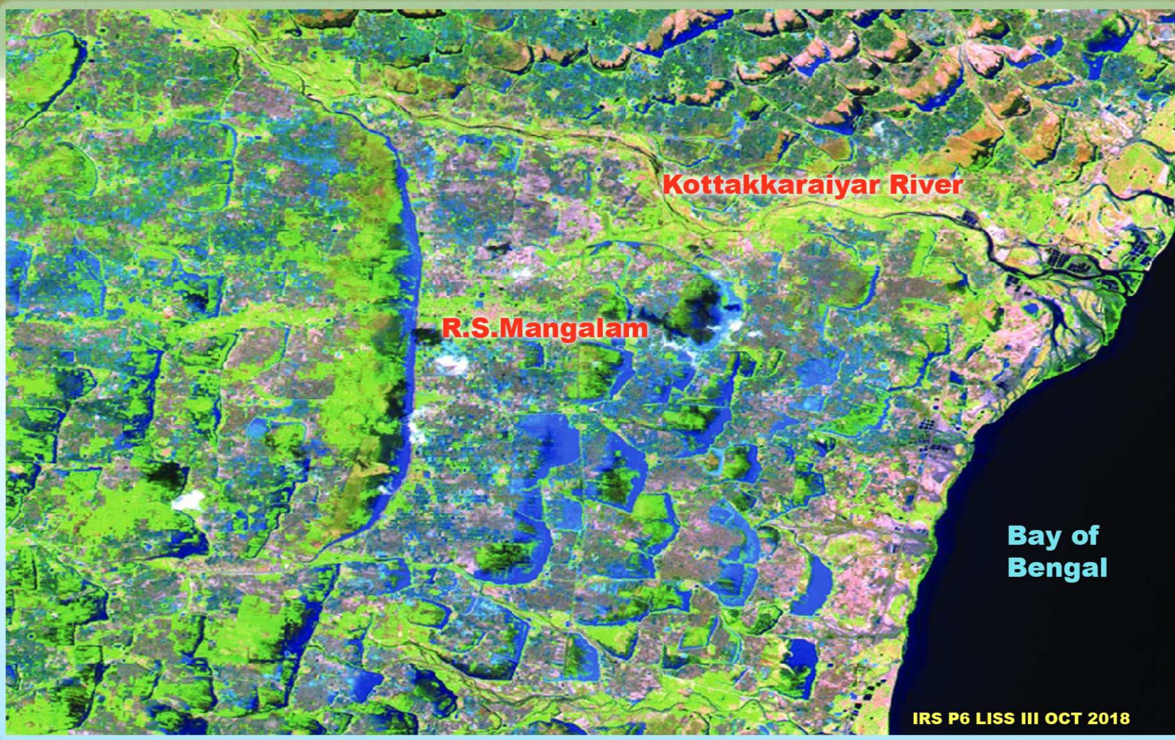
GOVERNMENT OF TAMIL NADU
PUBLIC WORKS DEPARTMENT
WATER RESOURCES DEPARTMENT

MICRO LEVEL REAPPRAISAL STUDY

PAMBAR KOTTAKKARAIYAR RIVER BASIN

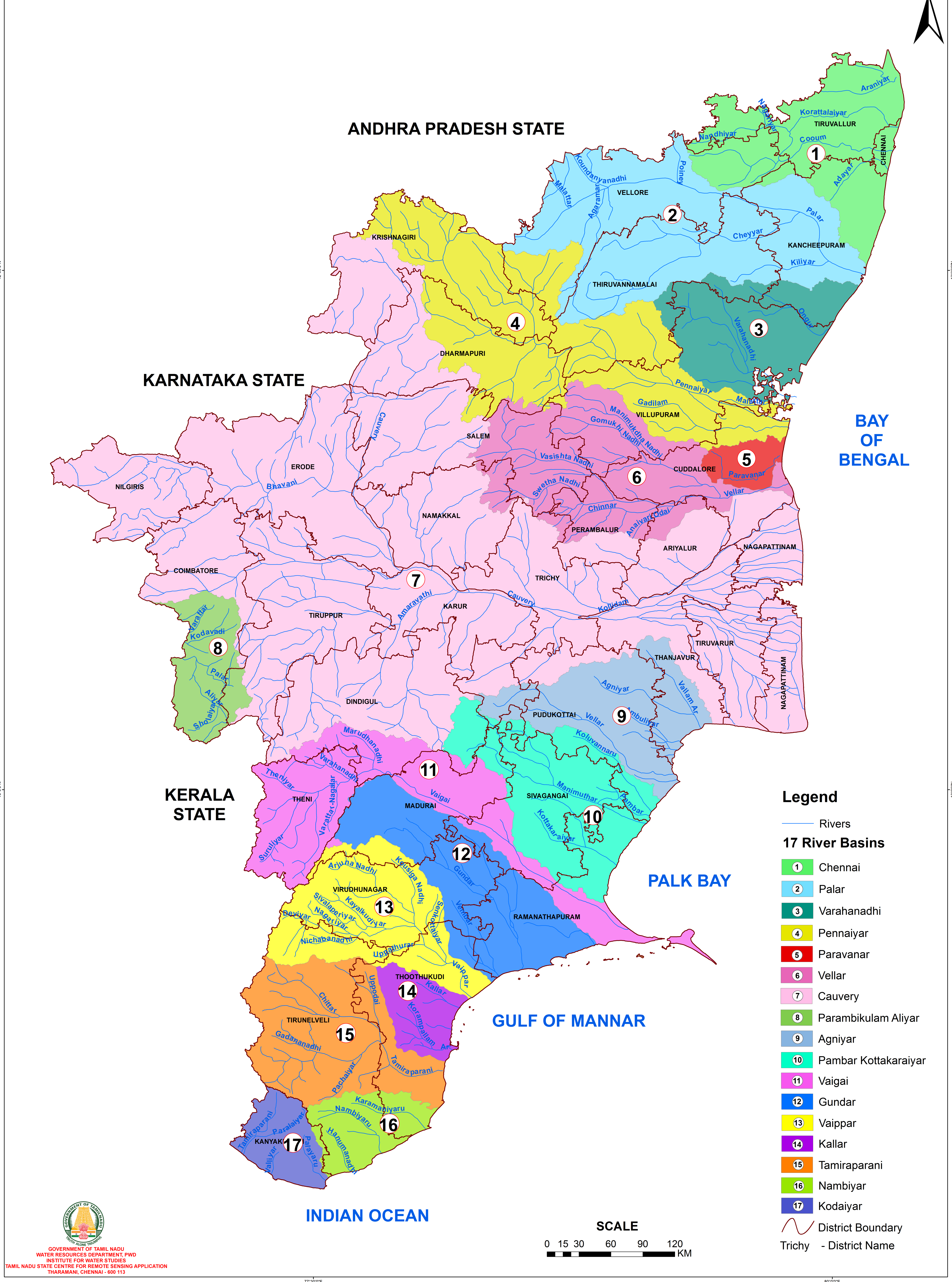
VOLUME I



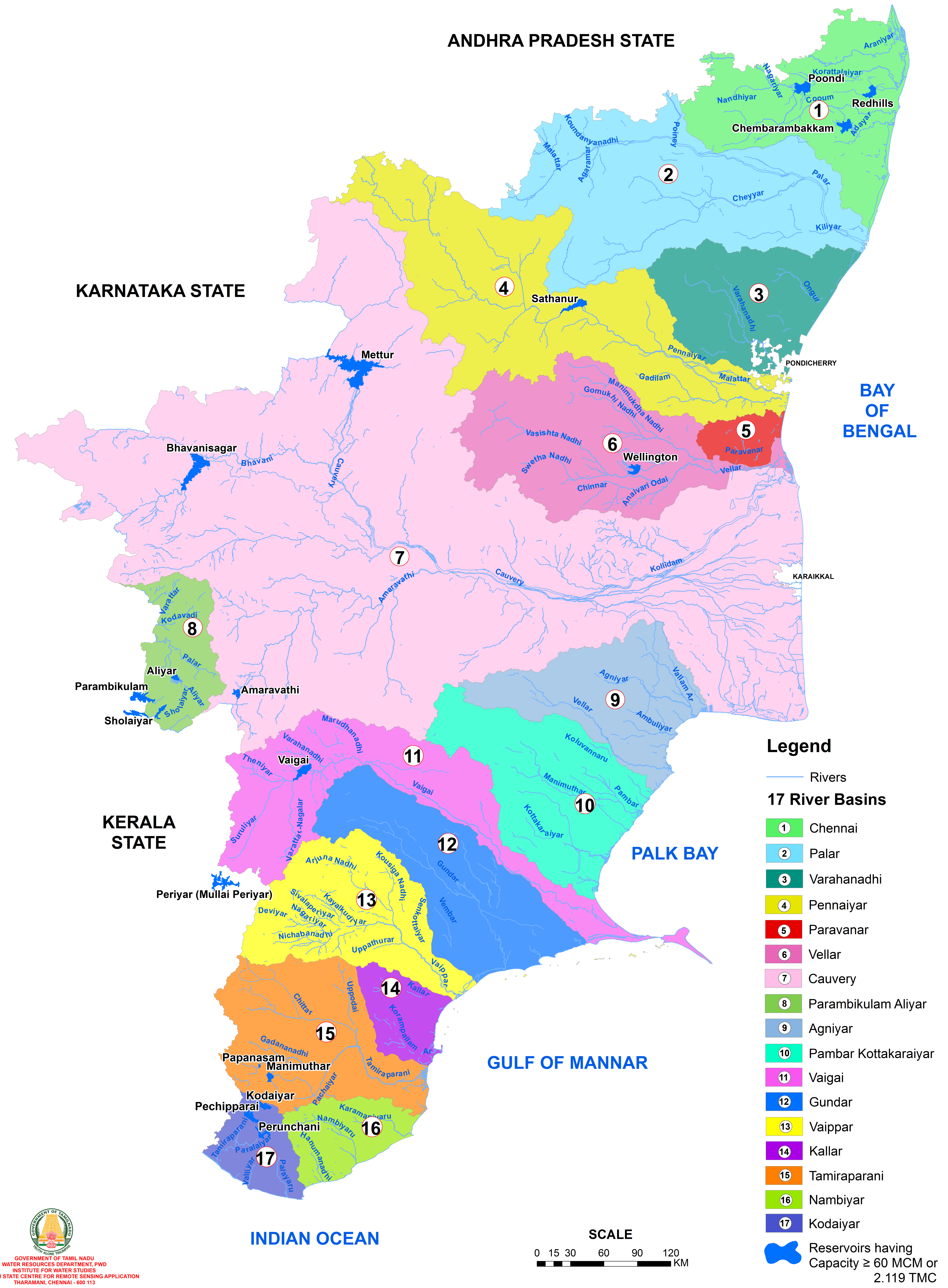
INSTITUTE FOR WATER STUDIES,
HYDROLOGY & QUALITY CONTROL
TARAMANI, CHENNAI-600113.

MARCH 2020

RIVER BASINS OF TAMIL NADU



RESERVOIRS (Under WRD Control) OF TAMIL NADU
(CAPACITY ≥ 60 MCM or 2.119 TMC)



GOVERNMENT OF TAMIL NADU
WATER RESOURCES DEPARTMENT, PWD
INSTITUTE FOR WATER STUDIES
TAMIL NADU STATE CENTRE FOR REMOTE SENSING APPLICATION
THARAMANI, CHENNAI - 600 113

PREFACE

The Institute for Water Studies was established with an objective to assess, plan, and manage the Water Resources in Tamil Nadu in a scientific manner. This Institute carries out Multi-Disciplinary research activities in all the River Basins of Tamil Nadu for effective Water Resources Management. The Government ordered in G.O.(Ms) No.149 Public Works (F1) Department dated 08-06-2019 to change nomenclature of this Institute as Institute for Water Studies, Hydrology & Quality Control in June 2018 in addition to the regular research and water study activities and assigned the quality control work of Water Resources Department and Public Works Department to ensure effective quality control and monitoring of the works and to maintain uniformity in quality.

As a holistic river basin management guide, Micro level Study reports were prepared and completed for 16 River Basins except for Cauvery River basin. The Micro level Study reports were disseminated to the concerned offices of Water Resources Department and all other line departments connected with water resources for wider knowledge sharing and for better understanding of river basin.

As the time moves on, changes are inevitable and according to the requirement, preparation of Micro Level Study report had to be updated by incorporating changes taken place thereafter with regard to land use and water demand of various sectors. The River Basin boundaries were delineated recently in bigger scale, 1:50,000. The updated version of Micro level Reappraisal Study Report was prepared using latest analytical method and latest available software. The reappraisal studies for Kodaiyar, Vaippar, Vaigai, Vellar, Palar, Tamiraparani, Pennaiyar, Paravanar River and Varahanadhi Basins have been completed. The Micro level Reappraisal study of Pambar Kottakkaraiyar River Basin has been taken up for the year 2017 - 2018.

The first river basin report on Pambar Kottakkaraiayr was prepared during the year 1984-1990 under the UNDP project. Subsequently, to update the basin management planning, based on available thematic maps, analytical tools and software the Micro Level Appraisal report of Pambar Kottakkaraiyar River Basin was prepared in the year 2007.

To assess the present water potential, demand and balance as per latest data availability upto the year 2018, the Micro level Reappraisal study of Pambar Kottakkaraiyar River Basin has been taken up in 2018-2019. With the advent of latest satellite imagery and remote sensing techniques various thematic maps of the Pambar Kottakkaraiyar River Basin are prepared. The hydro-meteorological data, groundwater & surface water potential, all sectoral demand (domestic, agriculture, industrial and livestock) are analysed with latest technique using latest version software to calculate the present water balance.

Eventually, some suggestions and strategic action plans are proposed in the Micro Level Reappraisal report for implementation for further better water management of water resources to benefit the basin society and Tamilnadu state.

Chief Engineer & Director, PWD,
Institute for Water Studies,
Hydrology & Quality Control.WRD.

ACKNOWLEDGEMENT

The officials of the Institute for Water Studies, Hydrology & Quality Control express their sincere thanks to the Principal Secretary to Government, Public Works Department for continuous advice and support in preparing the Micro level reappraisal study report of Pambar Kottakkaraiyar River Basin.

The officials of this Institute sincerely thank the Engineer-in-Chief, WRD , PWD for timely contribution during course of preparation of Micro level reappraisal study report of Pambar Kottakkaraiyar River Basin.

The officials of this Institute whole heartily record our gratitude to Er.R.Subramanian, Chairman, Cauvery Technical Cell cum Inter State Waters Wing, Chennai for suggesting to prepare the report on Micro level reappraisal study of Pambar Kottakkaraiyar River Basin and our immense thanks to the Chairman for his valuable technical support and guidance bestowed in preparing this study report.

The officials of this Institute thank the Chief Engineer, WRD, Madurai Region, Chief Engineer, WRD, Trichy Region and the Chief Engineer, WRD, State Ground & Surface Water Resources Data Center, Chennai for sharing surface water data and hydrological & meteorological data respectively which are fundamental in carrying out the Micro level reappraisal study of Pambar Kottakkaraiyar River Basin.

The officials of this Institute also thank the Superintending Engineer, WRD, Lower Vaigai Basin Circle, Sivaganga, the Superintending Engineer, WRD, Periyar Vaigai Basin Circle, Madurai, the Superintending Engineer, WRD, Middle Cauvery Basin Circle, Tiruchy, the Executive Engineer, WRD, Sarguniar Basin Division, Sivaganga, the Executive Engineer, WRD, Manimuthar Basin Division, Devakottai, the Executive Engineer, WRD, Lower Vaigai Basin Division, Paramakudi, the Executive Engineer, WRD , Ex-Zamin Tank Diviaion, Karaikuadi, the Executive Engineer, WRD, South Vellar Basin Division, Pudukottai, the Executive Engineer, WRD, Periyar Main Canal Division, Melur and the Executive Engineer, WRD, Manjalar Basin Division, Periyakulam for their assistance and contributions for the preparation of this study report.

The officials of this Institute acknowledge and thank the Department of Agriculture, , Directorate of Census Operation, Tamil Nadu Water Supply and Drainage Board, Directorate of Public Health Preventive Medicine, Tamil Nadu Pollution Control Board, Directorate of Industries & Commerce, Department of Animal Husbandry & Veterinary Science, Department of Fisheries, Department of Statistics and Economics, Central Water Commission, Central

Ground Water Board and Tamil Nadu Generation and Distribution Corporation for sharing and contributing the requisite data to carry out the Micro level reappraisal study of Pambar Kottakkaraiyar River Basin.

With earnest belief, I assure that the methodology and suggestions put forth in this report for Water Resources planning in Pambar Kottakkaraiyar River Basin will be effective and supportive to Water Resources Department and other line departments in taking necessary actions to improve the management of Water Resources in Pambar Kottakkaraiyar River Basin.

Chief Engineer & Director, PWD,
Institute for Water Studies,
Hydrology & Quality Control.WRD.

MICRO LEVEL REAPPRAISAL STUDY
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VOLUME-I
INDEX

ABBREVIATIONS

ADD	Acute Diarrhoea Disease
AED	Agricultural Engineering Department
ARS	Artificial Recharge Structures
BCM	Billion Cubic Meter
BCR	Benefit Cost Ratio
CCA	Culturable Command Area
CGWB	Central Ground Water Board
CPHEEO	Central Public Health and Environmental Engineering Organisation
CROPWAT	Crop Water Requirement
CWC	Central Water Commission
DIC	District Industries Centre
DO	Dissolved Oxygen
DRIP	Dam Rehabilitation and Improvement Project
EFR	Environmental flow Requirement
ENE-WSW	East North East –West South West
ESP	Exchangeable Sodium Percentage
ETc	Evapo Transpiration of a crop
ETo	Evapo transpiration
EW	East West
FAO	Food and Agriculture Organisation
FCC	False Colour Composite
FRP	Fibre Reinforced Plastic
GIS	Geographic Information System
GOI	Government of India
GoTN	Government of Tamil Nadu
GPS	Global Positioning System
GSDP	Gross State Domestic Product
IAMWARM	Irrigated Agriculture Modernization and Water bodies Restoration and Management
IMD	Indian Meteorological Department
IMR	Infant Mortality Rate
IUD	Intra –Uterine Device
IRS	Indian Remote Sensing Satellite
Kc	Crop Coefficient
LISS	Low Imaging Sensing Satellite
Mcum	Million Cubic Meters
MGD	Million gallons per day
MGNREGA	Mahatma Gandhi National Rural Employment Guarantee Act
MMR	Maternal Mortality Rate
MRS	Monthly Run off Simulation
MSL	Mean sea level
MSME	Micro Small and Medium Enterprise
MSW	Municipal Solid Waste
MSWM	Municipal Solid Waste Management

MT	Metric Tonnes
NADP	National Agricultural Development Program
NBSS	National Bureau of Soil Survey
NE-SE	North East –South East
NE-SW	North East –South West
NGO	Non Government Organization
NNE	North North East
NNE-NE	North North East- North East
NNE-SSW	North North East- South South West
NNW-SSE	North North West- South South East
NPK	Nitrogen, Phosphorous, Potassium
NWDA	National Water Development Agency
NW-SE	North West- South East
NWSW	North West South West
O & M	Operation and Maintenance
PET	Potential Evapo Transpiration
PWD	Public Works Department
RRR	Repair Renovation Restoration
RWH	Rain Water Harvesting
SG &SWRDC	State Ground &Surface Water Resources Data Centre
SIPCOT	State Industries Promotion Corporation of Tamil Nadu
SPIC	Southern Petro Chemical Industries Corporation
SRI	System of Rice Intensification
SSI	Sustainable Sugarcane Initiative
SSW-SW	South South West-South West
SWP	State Water Plan
TACID	Tamil Nadu Corporation for Industrial Infrastructure Development
TANGEDCO	Tamil Nadu Generation and Distribution Corporation Limited.
TBL	Top Bund Level
TDS	Total Dissolved Solids
TH	Total hardness
TIDCO	Tamil Nadu Industrial Development Corporation
TIIC	Tamil Nadu Industrial Investment Corporation
TMC	Thousand Million Cubic feet
TNAU	Tamil Nadu Agricultural University
TNPCB	Tamil Nadu Pollution Control Board
TWADB	Tamil Nadu Water Supply and Drainage Board
UNDP	United Nations Development Programme
VES	Vertical Electrical Soundings
WNW-ESW	West North West – East South West
WRD	Water Resources Department
WRMS	Water Resources Management Studies
WUA	Water User Association
WAPCOS	Water and Power Consultancy Services

VOLUME – I

MICROLEVEL REAPPRAISAL STUDY OF PAMBAR KOTTAKKARAIYAR RIVER BASIN

List of Figures

MICRO LEVEL REAPPRAISAL STUDY
PAMBAR KOTTAKKARAIYAR RIVER BASIN
VOLUME – I

LIST OF TABLES

MICRO LEVEL REAPPRAISAL STUDY
PAMBAR KOTTAKKARAIYAR RIVER BASIN
VOLUME - I
LIST OF PLATES

CHAPTER – 1

INTRODUCTION AND METHODOLOGY

CHAPTER - 1
INTRODUCTION AND METHODOLOGY

1.1 Brief

There are 34 river basins in Tamil Nadu consisting of major, medium and minor basins and they are grouped into 17 major river basins (Plate PK-1A) for the purpose of hydrological studies and water resources planning activities. These river basins are subdivided into 127 sub basins vide Table 1.1. Considering the developments in the river basins, basin studies are to be updated periodically and adopting new methodology and software. Micro level reappraisal studies for Kodaiyar, Vaigai, Vaippar, Vellar, Tamiraparani, Palar, Pennaiyar, Paravanar and Varahanadhi river basins were completed. Now, the micro level reappraisal study of Pambar Kottakkaraiyar basin has been carried out, for which, earlier study was carried out in March 2007. Pambar Kottakkaraiyar basin consists of three sub basins, viz. Manimuttar, Pambar and Kottakkaraiyar (Plate PK-1B).

1.2. River Basin Concept

River basins refer to the hydrological area draining through a system of streams and rivers to the same outlet. Basins are often recognized as the practical unit of water resources management, because this allows the upstream-downstream hydrological interactions to be considered for suggesting solutions in a holistic manner.

The first National Water Policy summarizes the idea of River Basin Planning and Management as, "Water resources development and management will have to be planned for a hydrological unit such as drainage basin as a whole or for a sub-basin, multi-sectorally, taking into account surface and ground water for sustainable use, incorporating quantity and quality aspects as well as environmental considerations".

All India Soil Survey and Land Use Organization, Nagpur, have done the classification of all the drainage basins into watersheds for study, evaluation and management for adaptation in the States. Further breakup can be made into mini watersheds and micro watersheds for detailed evaluation, planning and management for all the resources including groundwater.

The water demand for domestic, irrigation, industries, livestock, power generation and other uses is governed by socio-economic and agricultural factors, including the present and future population size, income level, urbanization, market facilities, remunerative prices, cropping patterns, etc. The rationale of choosing a river basin as the unit for the planning is to optimize the use of water resources in that basin, matching with supply and demand. An analysis of the water balance, water utilisation and allocation plan for different competing water users form the core of a river basin plan.

1.3 River Basin Planning

River basin planning is the process of identifying the way in which a river and its limited natural resources may be used to meet the competing demands, while maintaining the river health. It includes the allocation of scarce water resources between different users and purposes, choosing between environmental objectives and computing human needs, and choosing between competing flood risk and drought management requirements. With increasing development and population, the complexity in river basin planning has increased.

Basin planning has been prompted by the need to manage the challenges associated with one or more of the following fundamental issues:

- Water allocation, reconciliation and utilization planning has tended to be the focus in more arid or seasonally variable basins where population and development has driven water demands.
- Water quality planning has been the focus in highly developed urban, industrial or mining dominated basins, as well as those with intensive irrigation.
- Flood risk management has tended to be the focus in higher rainfall basins, particularly where there is significant downstream development.

1.4. New Approaches in Basin Plan

For effective river basin planning, the approach should be developed according to the specific basin challenges, priorities and conditions. Basin planning exercises need to engage with a complex set of developmental, social, economic and environmental priorities across a range of issues. The social and economic 'footprint' of the basin also becomes an important consideration in a basin planning process, particularly, where there are strong linkages between the basin and regional economic activities located outside of the basin.

The uncertainty and variability around climate change has emerged as a challenge to conventional river basin planning, leading to calls for adaptive management and scenario planning. In the context of global climate change, the following four major systems are important for river basins:

- an improved water management and operation system
- an urban and rural water resources rational deployment and efficient utilization system
- a comprehensive flood control and drought mitigation system
- a water environment protection and river ecology security system

While the practice of basin planning has been under a process of continuous development, two major phases of basin planning have been identified; viz.,

i . Water resources development planning,

ii. More strategic approaches in basin planning.

The latter is an attempt to move beyond managing of infrastructure to a much broader set of objectives associated with the environmental, social and economic development of the basin. The schematic diagram of water planning is given in figure 1.1.

1.5 Strategic Plan

Basin planning processes need to shift from identifying means of how to use more water, to a focus on the judicious management of the existing systems. Strategic plan refers to planning that seeks alignment between the basin plan and the broader social, environmental and economic planning context. Strategic basin planning, is a coherent multi disciplinary approach to manage basin water resources and their users, in order to identify and satisfy social, economic and environmental priorities. The followings are more strategic approach to basin plan;

- Understanding basin interactions
- High level objective - setting at different time frames
- Multidisciplinary teams
- Robust scenario-based analysis
- Reconciling and coordination of activities across all water sectors
- Prioritization
- Sophisticated environmental requirements
- Trade-offs between alternative economic, social and environmental objectives

1.5.1. Ten golden rules of basin planning

The following are the ten golden rules derived from the international lessons and experiences with basin planning over the past century.

1. Develop a comprehensive understanding of the entire basin system
2. Plan and act, even with part knowledge
3. Prioritize issues for current attention, and adopt a phased and iterative approach to the achievement of long-term goals
4. Recognize that basin planning is iterative and often chaotic
5. Enable adaptation to changing circumstances
6. Develop relevant and consistent thematic plans
7. Address issues at the appropriate scale by nesting local plans under the basin plan
8. Engage stakeholders with a view to strengthening institutional relationships
9. Focus on implementation of the basin plan
10. Select the planning approach and methods to suit the basin needs

1.6 Objective of the Study

In Tamil Nadu there are 34 rivers including one west flowing river. The water potential of these rivers is strongly associated with the conditions of monsoons. A poor monsoon rainfall leads to drought conditions and the situation is further aggravated if monsoon fails for consecutive years. Changes in the quantum of rainfall, rainfall pattern and intensity would affect stream flow and in turn, the demand for water. Flood and drought management by scientific approach are required to mitigate the severity of floods and droughts, by incorporating the possible effects of climate change in the design and management of water resources system.

Groundwater has, in the last few decades, emerged as the major source of water supply to domestic, irrigation and industrial sectors in Tamil Nadu on account of the near-total utilization of surface water resources. The need to satisfy the requirements of an ever-increasing population has been exerting a severe stress on the limited groundwater resources in the State.

The sustainable development of water resource requires precise quantitative assessment based on reasonably valid scientific principle. For a controlled development, proper management of water resource and its conservation are very essential. Quantification of water resources is often critical and no single comprehensive technique is yet to be identified which is capable of estimating accurate water resources assessment.

The complexities of the processes governing the occurrence, the capacity of the formation to receive the water and movement of groundwater makes the assessment difficult, since enormous data has to be collected, and a multi-disciplinary scientific approach is to be adopted for location of water in space and time, quantity and quality.

It is necessary that suitable water management strategies be formulated and implemented in Tamil Nadu for optimal and sustainable management of its limited water resources. This study is an endeavor in this direction.

The main objective of this study is an integrated approach to assess the surface water potential, groundwater potential and water balance and to recommend judicious management of water resources of the basin by updating the data used earlier and adopting latest / updated methodology and software versions in computations.

1.6.1 Methodology and Analysis Adopted

The general methodology adopted for this reappraisal study includes the data collection, sorting and validation of those data used for the study.

Using Remote Sensing and the advanced concepts of GIS, Geo databases were generated on the Geo-systems of the basin and there from the Geo-dynamics of the basin were assessed which involves the following:

- Generation of geo-database on geology, geomorphology, lineament, land use and sub-surface lithology.
- Geo-databases on rainfall distribution and evaluation of rainfall dynamics.
- Geo-databases on water level distribution for evaluation of ground water level dynamics.
- Geo-databases on water quality variation for evaluation of water quality dynamics.
- Geo-databases on land use for 2 periods (2006 and 2017) and evaluation of land use changes and reasoning out to suggest remedial measures.
- Estimation of surface water by rainfall runoff method.
- Evolving the groundwater scenario of the basin based on the Groundwater Resources Estimation, done by SG&SWRDC adopting GWREC Norms -1997.
- Assessing the environmental scenario of the basin.
- Estimating the sectoral water demand.
- Arriving water balance based on available surface and groundwater potential and demand.

Finally, the terrain of Pambar Kottakkaraiyar Basin was evaluated on water resources scenario. Rainfall analysis was done by generating contours using GIS software to study the rainfall pattern and influence in the study area. Water level data for Pre and Post monsoon periods were analyzed to show the spatial distribution of groundwater table of the basin. Water quality data for Pre and Post monsoon periods from the observation wells were analyzed by adopting **W**ater **Q**uality **I**ndex (WQI) method and spatial representation of selected parameters to study the quality of water in the entire basin were generated. Geophysical Resistivity data were interpreted by using Wenner Configuration Method to study the thickness of weathered formation, Depth to bedrock and the aquifers of this basin using the dedicated Geophysical software

MRS (Monthly Runoff Simulation) model and NWDA (National Water Development Agency) method are used for estimating the sub basin wise surface water potential.

By assessing and analyzing the above parameters, various recommendations have been made for sustainable water resources management in the basin.

1.7. Basin – Specific data

For River basin wise water resource planning, data connected with water either by way of direct or by indirect means, in the form of spatial and non spatial format are required. Data such as Geology, Soil, Geomorphology, Landuse, Lineament, Hydrogeology, Climate, Water level, Water quality, Environment, Socio-economic, Health, Agricultural, Population, Livestock, Industries, etc. are to be collected. For maintaining consistency, different types of data need to be treated in the same way. Socio-economic, agricultural and livestock statistics etc. are available on the basis of administrative units, which generally, do not coincide with river basin boundaries. To evolve basin-specific data, one has to re-group and fit the data available on administrative units into river basins judiciously. Regrouping of data according to river basins is to be done consistently and systematically in order to strike consistency between basin and the administrative units of entire basin. With regard to administrative units, which are situated in two or more river basins, the value of the variables will have to be split between those basins in proportion to the area contained in the respective river basins.

1.7.1 Data Collection

The spatial and non spatial data pertaining to the Pambar Kottakkaraiyar river basin have been collected from various organizations such as Agricultural Department, Forest Department, Statistical Department, respective District Collectorate, Central Ground Water Board, Survey of India, Central Survey and Settlement, TWAD Board, TNPCB, Industries and various wings of WRD etc. for interpretation and carrying out analysis.

1.7.2 Satellite Data Used

The following Satellite imageries were interpreted for this study

1. IRS ID LISS III and PAN merged data of 2006
2. IRS P6, LISS III data of 2008
3. IRS Resource sat 1 and 2A, LISS IV Mx of 2017

Apart from the above, Aerial Photographs pertaining to Pambar Kottakkaraiyar basin were interpreted.

1.7.3 Interpretation Techniques

1.7.3.1 Visual Interpretation

Through visual interpretation, objects and their classification were interpreted using the hard copies of Aerial Photos and Satellite imageries based on their characteristics such as, shape, size, tone, texture, pattern, location, association, etc.

The IRS P6 LISS III and PAN merged data of 2006 data were used to classify geomorphic features. The digital satellite data was geo-rectified with ground control points (GCPs) obtained from rectified Topo sheets. Radiometric corrections such as filtering, edge enhancement, histogram and Principle Component Analysis (PCA) were done to obtain better visual ability of the digital image.

1.7.3.2 Digital Interpretation

The IRS R2 & 2A LISS IV MX of 2017 were digitally interpreted to derive the Land use / Land Cover pattern of this basin by using digital image processing software. Also various digital enhancement techniques were employed to elicit more and correct information from the digital images pertains to this basin.

1.7.4 Geo database Creation

Geodatabase on various theme maps like Administrative details, Physiography, Geology, Soil, Geomorphology, Land use / Land cover and lineaments, rainfall, water level, water quality were prepared and stored as digital layers in the computer. Also the non-spatial data in the form of statistics, tables and list, graphs etc. were appended with this Geo-database.

1.7.5 Coordinate System

The coordinate system for database needs to be in appropriate units that represent the geographic features in their true shapes and size. The Survey of India 1:50,000 scale graticule has been adopted for database. Transverse Mercator projection and WGS 1984 UTM projected coordinate system are adopted for database, which represents the actual ground distance in meters.

1.8. Updates and Revisions

The planning process is considered as a continuous effort. The assessment and planning process adopted in previous report is based on the scenario of 2006. According to the variations in results for the future-planning horizon based on the current scenario, the recommended "Action Plan" will have to be revised and updated. In the advent of continuous updation of the models and methodology, the database used need to be revised accordingly for an adjustable scientific assessment of water resources and of sectoral water demands of present and future, under different socio-economic development scenarios.

The process of the present planning study, which is proposed for its updating, is presented in Figure 1.2.

1.8.1 Previous and Present Report

The first report on Pambar Kottakkraiyar river basin was prepared in this Institute as a Water Resources Assessment of Pambar Kottakkaraiyar River Basin under UNDP (1988)**.** The second report was brought out by Dr. S. Subramaniyan and Dr. R. Kadirvelu on "Crop water requirement and Irrigation Scheduling - A Guide for Tamil Nadu". The third report on "Assessment of Water Resources of Tamil Nadu " was published by the Sub Committee of State Planning Commission during the year 1987.

The environmental status of Pambar Kottakkaraiyar river basin was discussed in the workshop on " Environmental Status of River Basin Groups - South of Cauvery Basin". In the "State Frame Work Water Resources Plan" (1999), published by this Institute, the water resources scenario of Pambar Kottakaraiyar was discussed. "Environmental Impact Assessment Report of Pambar Kottakkaraiyar" was prepared jointly by the Executive Engineer, Plan Formulation, PWD and, PWD, Karaikkudi Division.

The present report is the state-of-art for the year 2018 and the planning process as demonstrated in this report is based on updated data and tools available as on date. Remote Sensing and GIS technologies with latest tools were employed and simulation models of new type were used. Land use change detection, by studying the decadal scenario of land use pattern of the basin, rainfall pattern, water level dynamics and water balance are focused in the present study which will reflect the exact current scenario. Accordingly recommendation for the future planning with action plan were presented for adoption.

FIG. 1.1. SCHEMATIC DIAGRAM OF WATER PLANNING – STATE AND RIVER BASIN PLANS

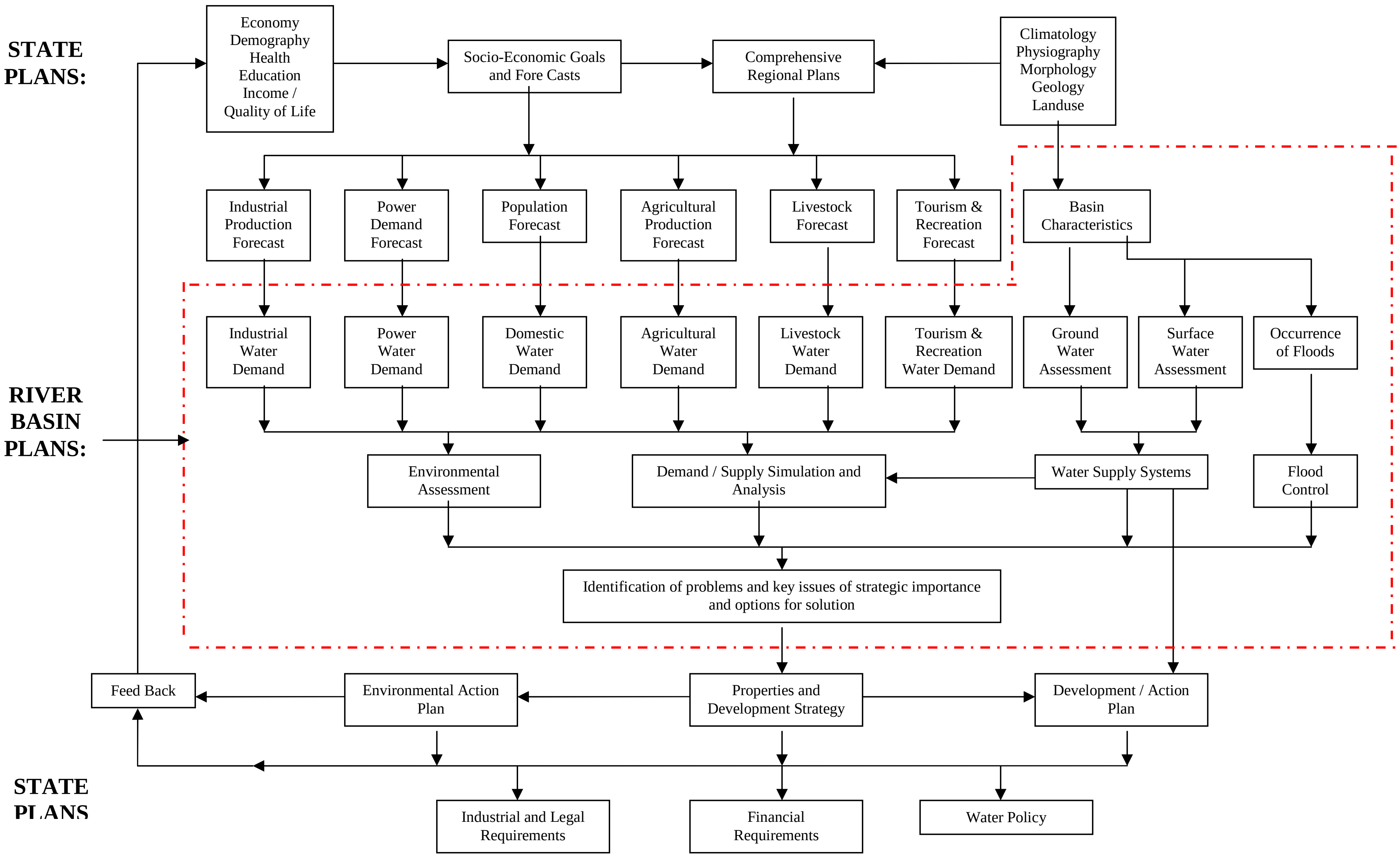


Fig.1.2. FLOW CHART OF RIVER BASIN PLANNING

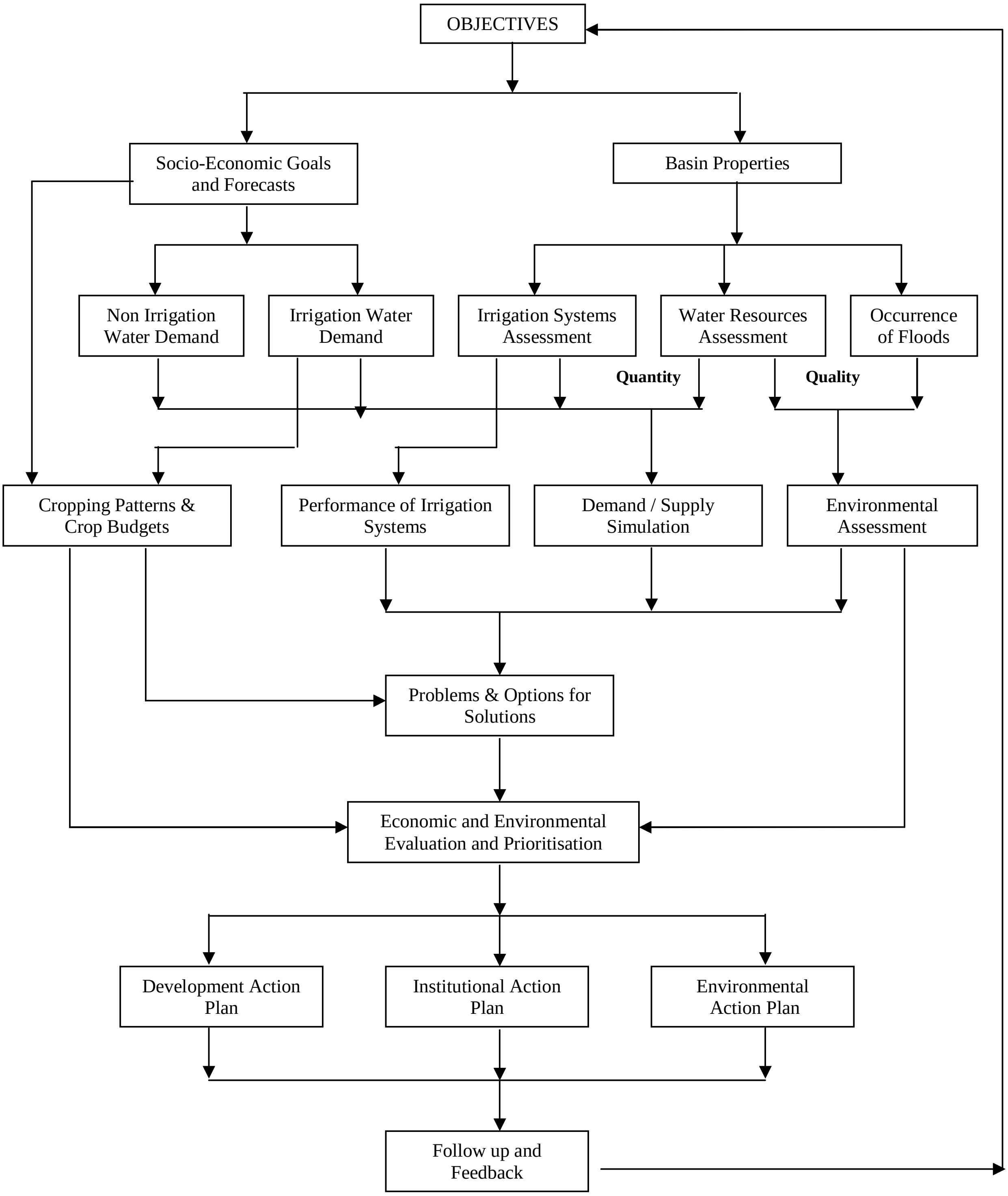


Table 1.1 Details of Basins and Sub Basins

Basin Name	Sub Basin.No.	Sub Basin Name
1. CHENNAI BASIN		
	1	Gummidipoondi
	2	Araniar
	3	Nagariyar
	4	Nandhiyar
	5	Kosasthaliyar
	6	cooum
	7	Adyar
	8	Kovalam
2. PALAR RIVER BASIN		
	9	Upper Palar
	10	Malattar
	11	Agramar
	12	Kavundinyanadhi
	13	Poiney
	14	Vegavathi
	15	Cheyyar
	16	Kiliyar
	17	Lower Palar
3. VARAHANADHI RIVER BASIN		
	18	Varahanadhi
	19	Nallavur
	20	Ongur
4. PENNAIYAR RIVER BASIN		
	21	1A Chinnar
	22	1 B Chinnar
	23	Markandanadhi
	24	Kambainallur
	25	Pambar
	26	Vanniar
	27	Mattuar
	28	Kottapattikallar(Kovilar)
	29	Valayar Odai
	30	Ramakal Odai
	31	Pambanar & Varattar

Basin Name	Sub Basin.No.	Sub Basin Name
	32	Aliyar
	33	Musukundanadhi
	34	Thurinjalar
	35	Gadilam
	36	Upto Krishnagri Reservoir
	37	Krishnagri to Pambar
	38	Lower Ponnaiyar
	39	Pambar to Thirukovilur
5. PARAVANAR RIVER BASIN		
	40	Paravanar
	41	Uppanar
6. VELLAR RIVER BASIN		
	42	Upper Vellar
	43	Sweta Nadi
	44	Chinnar
	45	Anaivari Odai
	46	Gomukhi
	47	Maniukdha Nadi
	48	Lower Vellar
7. CAUVERY RIVER BASIN		
	49	Chinnar
	50	Dodda Halla
	51	Mettur Reservoir to Noyel Confluence
	52	Palar Tatta Halla
	53	Moyar
	54	Upper Bhavani
	55	Lower Bhavani
	56	Noyel
	57	Tirumanimuktar
	58	Amaravathi
	59	Karaipottanar
	60	Pungar (Upper Coleroon)
	61	Ayiaar
	62	Ponnaniyar
	63	Nandiyar-Kulaiyar
	64	Marudaiyar
	65	Lower Coleroon
	66	Cauvery Delta

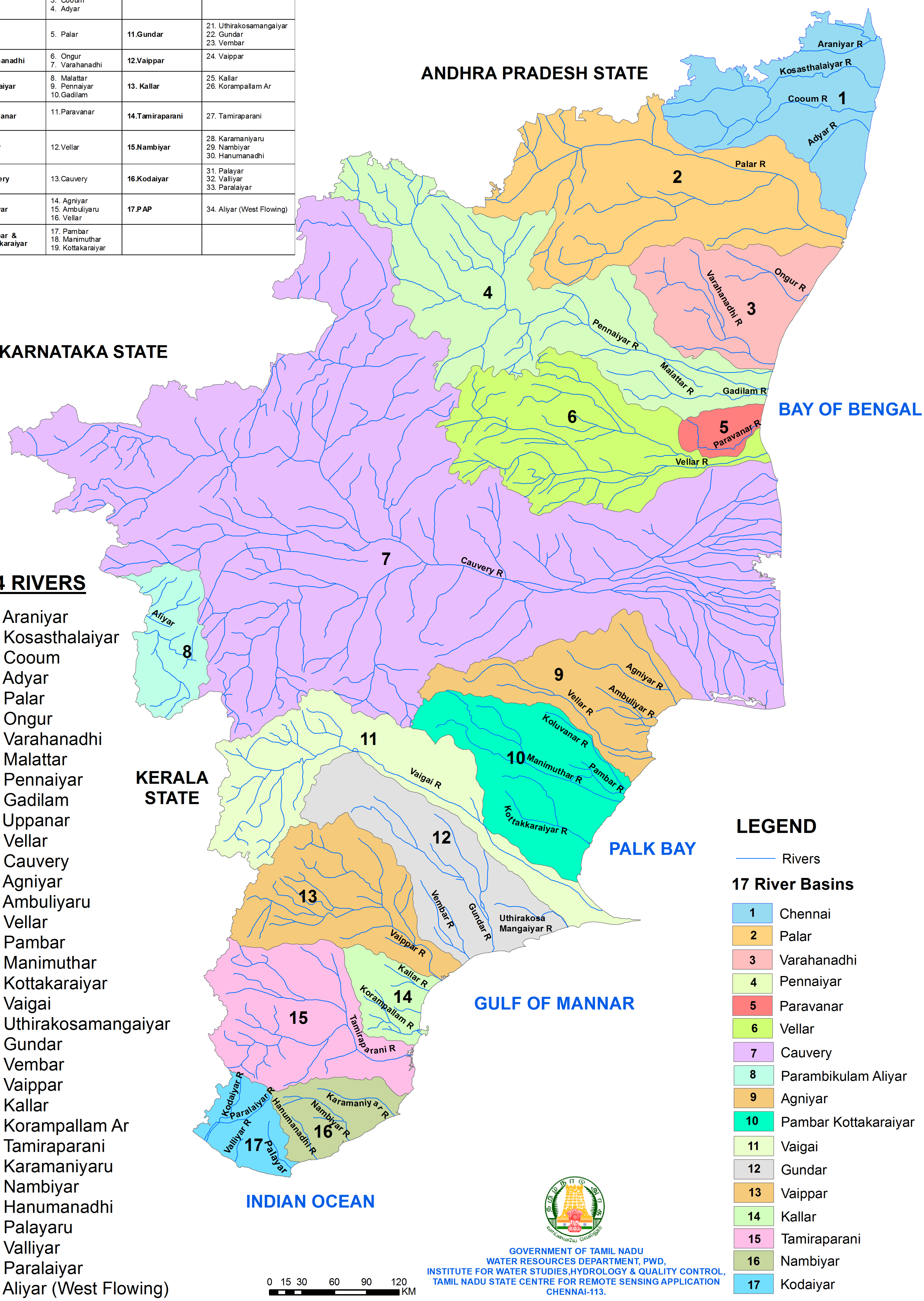
Basin Name	Sub Basin.No.	Sub Basin Name
8. PARAMBIKULAM ALIYAR BASIN		
	67	Walayar
	68	Palar
	69	Aliyar
	70	Sholayar
9. AGNIYAR RIVER BASIN		
	71	Agniyar
	72	Ambuliar
	73	South Vellar
10. PAMABR KOTTAKARAIYAR RIVER BASIN		
	74	Manimuttar
	75	Pambar
	76	Kottakariyar
11. VAIGAI RIVER BASIN		
	77	Upper Vaigai
	78	Suruliyar
	79	Theniyar
	80	Varattar-Nagalar
	81	Varahanadhi
	82	Manjalar
	83	Sirumalaiyar
	84	Sathaiyar
	85	Uppar
	86	LowerVaigai
12. GUNDAR RIVER BASIN		
	87	Upper Gundar
	88	Therkar
	89	Kanal Odai
	90	Gridhamal
	91	Paralaiyar
	92	Lower Gundar
	93	Uthirakosamangaiyar
	94	Palar
	95	Vembar

Basin Name	Sub Basin.No.	Sub Basin Name
13. VAIPPAR RIVER BASIN		
	96	Nichabhanadhi
	97	Kalingalar
	98	Deviyar
	99	Nagariar
	100	Sevalaperiyar
	101	Kayalkudiar
	102	Vellampatti Odai
	103	Arjunanadhi
	104	Kousiganadhi
	105	Sindapalli Uppodai
	106	Uppathurar
	107	Sinkottaiyar
	108	Vaippar
14. KALLAR RIVER BASIN		
	109	Kallar
	110	Chalikulam
	111	Korampallam
15. TAMIRAPARANI RIVER BASIN		
	112	Upper Tamiraparani
	113	Manimuthar
	114	Gadana Nadhi
	115	Pachaiyar
	116	Chittar
	117	Uppodai
	118	Lower Tamiraparani
16. NAMBIYAR RIVER BASIN		
	119	Karamaniyar
	120	Nambiyar
	121	Hanumanadhi
17. KODAIYAR RIVER BASIN		
	122	Pechiparai
	123	Chittar(Kodayar)
	124	Perunchani
	125	Kuzhithurai
	126	Valliyar
	127	Pazhayar

34 RIVERS & 17 RIVER BASINS OF TAMIL NADU

PLATE: PK -01A

Major River Basin / Basin group	Rivers in the group	Major River Basin / Basin group	Rivers in the group
1.Chennai Basin	1. Araniyar 2. Korattalaiyar 3. Cooum 4. Adyar	**10.Vaigai**	20. Vaigai
2.Palar	5. Palar	**11.Gundar**	21. Uthirakosamangaiyar 22. Gundar 23. Vembar
3.Varahanadhi	6. Ongur 7. Varahanadhi	**12.Vaippar**	24. Vaippar
4.Pennaiyar	8. Malattar 9. Pennaiyar 10. Gadilam	**13. Kallar**	25. Kallar 26. Korampallam Ar
5.Paravanar	11.Paravanar	**14.Tamiraparani**	27. Tamiraparani
6.Vellar	12.Vellar	**15.Nambiyar**	28. Karamaniyaru 29. Nambiyar 30. Hanumanadhi
7.Cauvery	13.Cauvery	**16.Kodaiyar**	31. Palayar 32. Valliyar 33. Paralaiyar
8.Agniyar	14. Agniyar 15. Ambuliyaru 16. Vellar	**17.P AP**	34. Aliyar (West Flowing)
9.Pambar & Kottakaraiyar	17. Pambar 18. Manimuthar 19. Kottakaraiyar		



34 RIVERS

1. Araniyar
2. Kosasthalaiyar
3. Cooum
4. Adyar
5. Palar
6. Ongur
7. Varahanadhi
8. Malattar
9. Pennaiyar
10. Gadilam
11. Uppanar
12. Vellar
13. Cauvery
14. Agniyar
15. Ambuliyaru
16. Vellar
17. Pambar
18. Manimuthar
19. Kottakaraiyar
20. Vaigai
21. Uthirakosamangaiyar
22. Gundar
23. Vembar
24. Vaippar
25. Kallar
26. Korampallam Ar
27. Tamiraparani
28. Karamaniyaru
29. Nambiyar
30. Hanumanadhi
31. Palayaru
32. Valliyar
33. Paralaiyar
34. Aliyar (West Flowing)

LEGEND

Rivers

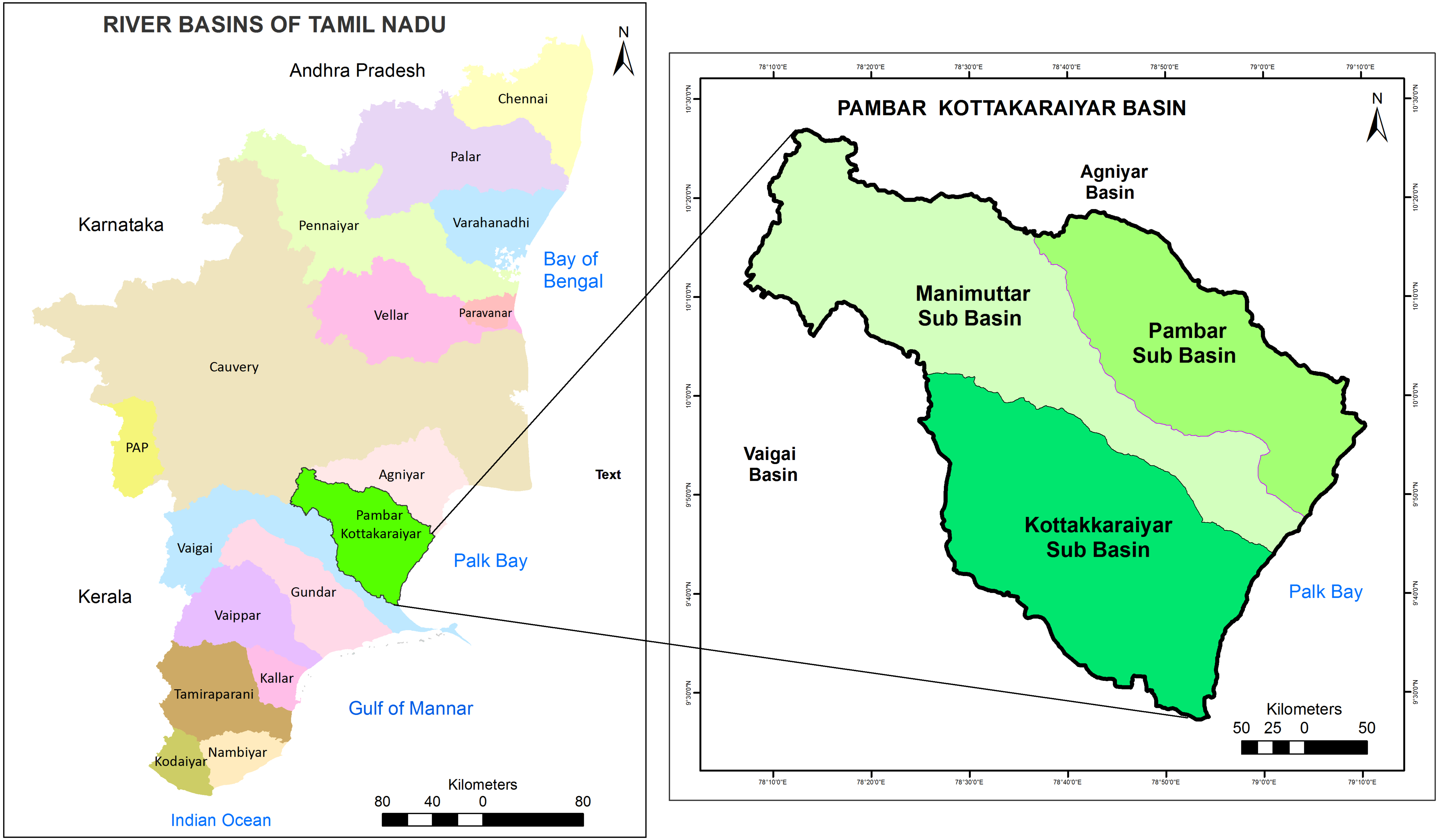
17 River Basins

1	Chennai
2	Palar
3	Varahanadhi
4	Pennaiyar
5	Paravanar
6	Vellar
7	Cauvery
8	Parambikulam Aliyar
9	Agniyar
10	Pambar Kottakaraiyar
11	Vaigai
12	Gundar
13	Vaippar
14	Kallar
15	Tamiraparani
16	Nambiyar
17	Kodaiyar

GOVERNMENT OF TAMIL NADU
WATER RESOURCES DEPARTMENT, PWD,
INSTITUTE FOR WATER STUDIES,HYDROLOGY & QUALITY CONTROL,
TAMIL NADU STATE CENTRE FOR REMOTE SENSING APPLICATION
CHENNAI-113.

Plate: PK - 01B

INDEX MAP OF PAMBAR KOTTAKKARAIYAR RIVER BASIN



Government of Tamilnadu,
Water Resources Department
Institute for Water Studies ,Hydrology and Quality Control,
Tamil Nadu State Centre for Remote Sensing Applications
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CHAPTER – 2

DESCRIPTION OF THE BASIN

CHAPTER -2
DESCRIPTION OF THE BASIN

2.1 Brief

Among the 17 river basins, the Pambar Kottakkaraiyar river basin is the seventh basin from the Chennai basin based on the geographical location. The basin is delineated into three sub basins viz., Manimuttar, Pambar and Kottakkaraiyar. The total area of the basin is 5926.10 sq.km and the basin is located in between N. Latitude 10° 28’ 30” - 09° 27’ 15” and E. Longitude 78° 05’ 30” - 79° 10’ 30”. The basin is falling in Survey of India Topographic Sheets 58 J3, J4, J7, J8, J11, J12, J15, J16, 58 K5, K6, K9, K10, K13, K14, K15, 58 N4 and 58 O1&2 on 1:50000 scale. Pambar Kottakkaraiyar river basin is bounded by the Bay of Bengal in the east, Agniyar basin in the north, Cauvery and Vaigai basins in the west and Vaigai basin in the south **(Plate PK-01B).** The Pambar Kottakkaraiyar basin spreads over parts of Dindigul, Madurai, Sivaganga, Pudukottai and Ramanathapuram districts and Sivaganga district covers major part of the basin. The important towns located in the basin are Tirumayam, Devakottai, Karaikkudi, Tiruppattur, Tiruvadanai, Devipattinam, Ilayangudi, Kalayarkovil, Sivaganga, Tiruppalakkudi and Tondi.

There are 23 taluks including 28 blocks cover this basin of which, only 8 blocks are fully covered and the remaining blocks are partly covered **(Plate PK-02)**. Totally 72 firkas are partially/fully covered in the basin **(Plate PK-03)** andthe details of districts, taluks and blocks falling in the basin are furnished in **Table 2.1** and the sub basin wise extent of area of the administrative units are given in **Table 2.2**. The Pambar Kottakkaraiyar basin has 882 revenue villages, out of which 52 villages are in Dindigul district, 44 villages in Madurai district, 192 villages in Pudukkottai district, 130 villages in Ramanathapuram district, 453 villages in Sivaganga district and 11 villages in Tiruchirappalli district.

The basin area is well connected with roads and railway lines **(Plate PK-04).** All the towns and villages are connected with village roads, district roads, State highways and National highways. The National Highway-NH 45B is passing through Kottampatti to southern districts of Tamil Nadu. National Highways from Pudukkottai to Manamadurai (NH 226), from Pudukkottai to Ramanathapuram (NH 210) and from Madurai to Tiruvadanai (NH 230) are passing through this basin and inter connected with State highways from Dindigul to Devakkottai (SH 35), from Sivaganga to Illayangudi (SH34), from Peravuruni to Illayangudi (SH 28), from Tiruppattur to Melur (SH 191) and from Nattam to Melur (NH 72) which are connected with village roads. Peravuruni to Manamadurai broad gauge railway line passes through this basin.

Table 2.1 Districts, Taluks and Blocks

Sl.No.	District	Taluk	Block
1	Dindigul	Dindigul	Sanarpatti
		Nattam	Nattam
		Vedasandur	Vadamadurai
2	Madurai	Melur	Kottampatti
			Melur
		Vadipatti	Vadipatti
3	Pudukottai	Aranthangi	Aranthangi
		Avudayarkovil	Avudayarkovil
		Manamelkudi	Manamelkudi
		Ponnamaravati	Ponnamaravati
		Tirumayam	Arimalam
			Tirumayam
4	Ramanathapuram	Paramakudi	Naiyinarkovil
		Ramanathapuram	Ramanathapuram
		Tiruvadanai	Rajasingamangalam
			Tiruvadanai
5	Sivaganga	Devakottai	Devakottai
			Kannakudi
		Ilayangudi	Ilayangudi
		Karaikudi	Kallal
			Sakkottai
		Manamadurai	Manamadurai
		Sivaganga	Kalaiyarkovil
			Sivaganga
		Tiruppattur	Semmampattipudur
			Singampunari
			Tiruppattur
6	Tiruchirappalli	Manapparai	Marungapuri

Table 2.2 Sub Basin-wise Administrative Details

Sl. No.	Sub Basin Name	Sub Basin Area (sq.km.)	District Name	District Area (sq.km.)	Taluk Name	Taluk Area (sq.km.)	Block Name	Block Area (sq.km.)
1	Manimuttar	2279.60	Dindigul	531.36	Dindigul	35.08	Sanarpatti	35.08
					Nattam	485.12	Nattam	485.12
					Vedasandur	11.16	Vadamadurai	11.16
			Madurai	278.85	Melur	277.80	Kottampatti	236.48
							Melur	41.33
					Vadipatti	1.05	Vadipatti	1.05
			Pudukottai	98.67	Ponnamaravati	97.39	Ponnamaravati	97.39
					Tirumayam	1.27	Tirumayam	1.27
			Ramanatha-puram	268.59	Tiruvadanai	268.59	Tiruvadanai	268.59
			Sivaganga	1068.07	Devakottai	151.43	Devakottai	137.24
							Kannakudi	14.19
					Karaikudi	225.86	Kallal	221.74
							Sakkottai	4.11
					Sivaganga	34.48	Kalaiyarkovil	29.77
							Sivaganga	4.71
					Tiruppattur	656.30	Semmampatti-pudur	96.00
							Singampunari	221.04
							Tiruppattur	339.26
			Tiruchira-ppalli	34.07	Manapparai	34.07	Marungapuri	34.07
	Total			**2279.60**		**2279.60**		**2279.60**
2	Pambar	1441.58	Pudukottai	746.62	Aranthangi	15.95	Aranthangi	15.95
					Avudaiyarkovil	334.87	Avudaiyarkovil	334.87
					Manalmelkudi	49.24	Manalmelkudi	49.24
					Ponnamaravati	1.18	Ponnamaravati	1.18
					Tirumayam	345.37	Arimalam	135.65
							Tirumayam	209.72
			Ramanatha-puram	77.28	Tiruvadanai	77.28	Tiruvadanai	77.28
			Sivaganga	617.68	Devakottai	200.69	Devakottai	38.23
							Kannakudi	162.46
					Karaikudi	400.27	Kallal	53.20
							Sakkottai	347.07
					Tiruppattur	16.73	Tiruppattur	16.73
	Total			**1441.58**		**1441.58**		**1441.58**
3	Kottak-karaiyar	2204.91	Madurai	21.55	Melur	21.55	Melur	21.55
			Ramanatha-puram	687.54	Paramakudi	134.27	Naiyinarkovil	134.27
					Ramanathapuram	68.21	Ramanatha-puram	68.21
					Tiruvadanai	485.06	Rajasinga-mangalam	373.03
							Tiruvadanai	112.03
			Sivaganga	1495.82	Devakottai	234.50	Devakottai	234.50
					Ilayangudi	296.61	Ilayangudi	296.61
					Karaikudi	115.25	Kallal	115.25
					Manamadurai	39.36	Manamadurai	39.36
					Sivaganga	804.64	Kalaiyarkovil	584.73
							Sivaganga	219.90
					Tiruppattur	5.46	Singampunary	5.46
	Total			**2204.91**		**2204.91**		**2204.91**
	Grand Total							**5926.10**

2.2 Physiography and Relief

Physiography (**Plate PK-05)** deals with the terrain morphology of the basin such as elevation, contour, spot height and forest cover. The physiographic features are derived from Survey of India Topo sheets and Shuttle Radar Topography Mission (SRTM) DEM **(Plate PK-06).** The elevation ranges in between +916 m MSL and 1.5 m MSL. The highest elevation place is observed at Jandamedu in Karandamalai reserved forest. The lowest elevation (+1.5 m) place is observed at south east of Tirupunavasal.

There are several hills with their peak above +400 m MSL in the north, northeast, west, southeast and southwest parts of the basin and most of the hills are covered by reserved forests, viz., Ayyalur reserved forest ▲826 m, Mudumalai reserved forest ▲910 m and Kodangikutta reserved forest ▲673 m in the northern part of the basin. Vella malai reserved forest ▲697 m, Viramalai reserved forest ▲227 m, Punnamalai reserved forest ▲240 m, Tottumalai reserved forest ▲143 m and Singirai reserved forests are in the northeastern part of the basin.

Hills in the reserved forest in the western part of the basin are Karanda malai ▲916 m, Perumalai ▲896 m, Madukamalai ▲651 m, Erakala malai ▲580 m and Nedunkuttu malai ▲498 m, Vellimalai ▲432 m, Karumalai ▲473 m and Valaichcherippatti ▲382 m.

Mamalai reserved forest ▲456 m, Mattur malai ▲444 m, and Piran malai reserved forest ▲708 m are covered in the north east part of the basin. In the southwest portion of the basin reserved forests such as Vellaimalai (▲561 m), Chembuli malai ▲532 m, Mota malai ▲401 m, Kudakudi malai ▲715 m, Pulamalai ▲574 m, Alagar malai ▲659 m and Vellimalai ▲161 m. Nellanendal reserved forest is located in the south east of the basin and Isanikadu reserved forest is noticed in the south west of the basin.

Other than north and north west area, the entire area is a plain terrain and the elevation ranges from 2 m to 100 m above MSL. The general slope of the basin is towards east and southeast directions.

2.2.1 Gradient

Gradients for PambarKottakkaraiyar basin were calculated using US Geological Survey's Digital Elevation Model " Shuttle Radar Topographic Mapping (SRTM) " of 90 m resolution, which was used to generate the drainage network and analysed in GIS software.

Accordingly, in Manimuttar sub basin, the gradient ranges between 1 m / km (i.e 1/1000) and 5 m/km (1/200). The sub basin has been divided in to three parts and in the western part, the gradient ranges between 2.5 to 3.25 m / km, and in the central part the gradient ranges between 3.25 to 4 m / km gradient. In the eastern lowermost part the gradient ranges between 4.2 to 5 m / km.

Whereas in Pambar subbasin, the gradient varies between 1 and 4 m/km. The gradient range of 1 to 2.33 m/km is noticed in 45.81 km in the Koluvanar stretch and 18.05 km in Papan Ar. A length of 58.30 km in Papan Ar has the gradient range 2 to 3.33 m/km and 46.29 km length in Koluvanar river has also the same range. The Papan Ar has the gradient range of 3.33 to 4 m/km in a length of 1.66 km.

In Kottakkaraiyar sub basin, the gradient varies from 1 to 5 m / km. The sub bsain has been divided in to five stretches along Kottakkaraiyar river. Along the Kottakkaraiyar river, 2.28 km length has the gradient rangesfrom 1 to 1.67 m/km, 9.89 km length has the range of 1.67 to 2.6 m/km and 72.65 km length has 2.33 to 3.4 m/km. A length of 20.44 km has the gradient range 3.4-4.2 m/km and 8.80 km length as the gradient of 4.2 to 5.0 m/km. In general, the Pambar Kottakkaraiyar basin has the surface gradient ranges from 1 to 5 m/km.

2.3 Drainage

There are fifteen rivers/streams namely , Palar, TiruManimuttar, Manimuttar, Virisalar, Varshalel Ar, Pambanar, Ten Ar, Kottagudi Ar / Pambar, Koluvanar, Papan Ar, Sarguniyar / Kottakkaraiyar, Nattar and Uppar which drain in this basin. Koluvanar, Papanar, Pambar, Varshalel Ar, Kottakkaraiyar and Uppar rivers confluence with Bay of Bengal. All these rivers are seasonal.

Rivers Palar, Tirumanimuttar, Manimuttar and Virisalar, are the tributaries of Manimuttar river. Perumal Odai and Kannimarattu Odai are the tributary of Tirumanimuttar river. Ten Ar is the tributary of Pambar river. Pambanar, Koluvanar Papan Ar, Nattar, and Upanar rivers drain its own catchment area and flow independently.

The Periyar Main Canal from Vaigai basin enters into this basin near Saruguvalapatti and flows in Silandangudi tank. The total length of the Periyar Main Canal in this basin is 16.02 km. Another Periyar Main Canal enters at Uranganpatti and feeds water to Kurichchippatti tank. The total length of this canal is 1.5 km. Anjukottai Channel having a total length of 14.57 km used to draw water from Manimuttar river to feed water into Irumati Kil Kudi tank. A canal from Vaigai river is feeding water to the Rajasingamangalam tank. The total length of this canal in this basin is 5.82 km.

There is no major/medium or small reservoir or dam in this basin. But there are 9000 small to medium water bodies such as tanks, ponds and Oorunis exist in this basin. Large, medium and small drainages drain water into tanks and rivers in this basin. The tanks are interconnected so as to feed the lower tank from surplus water of the upper tank. Most of the tanks are rainfed or non system tanks.

Based on the physiographic and catchment areas of the major rivers, the Pambar Kottakkaraiyar basin is divided into three sub basins namely Pambar, Manimuttar and

Kottakkaraiyar using Geomatic application on 1:50000 scale **(Plate PK-07).** A drainage map showing the rivers, drainages, canals/Channel and tankshas been prepared from Survey of India topo sheets on 1:50000 scale and shown in **Plate PK-08.**

2.3.1 Manimuttar Sub Basin

Manimuttar sub basin is the largest among the three sub basins having the geographical area of 2279.61 sq.km. The upper part, north and north western part of the sub basin are covered by hills located in reserved forest. Ayyalur, Mudumalai, Kodangikkuttu and Karandamalai hills in reserved forest are in the north western part of the sub basin. Erakala malai, Perumal malai, Vellai malai, Kalingu malai, Chembuli malai and Alagar malai in the reserved forest spread over the south west portion of the sub basin. Pola malai, Moda malai, Budakudi, Karu malai, Valachcheripatti Piranmalai, Vadakaduchedi and Tettivayalchedi reserved forests are located in the north eastern part of the sub basin. Reserved forests, namely, Kallel, Tipanjankadu, Kodungudi, Pungudi, Virai are in the south eastern part of the sub basin. Sethuranganathapattinam reserved forest is in the south western part of the sub basin. The total reserved forest in Manimuttar sub basin is 266.34 sq.km. The surface elevation ranges between +916 m MSL and +3 m MSL. The slope is towards south east.

The river Manimuttar originates in the name of Tirumanimuttar at an altitude of +440 m MSL near Malaipatti village in the west of Erakalamalai reserved forest **(Plate PK-8A).** It gained a name Tirumani Ar after Pungappatti village. Perumal Odai, the left arm of the Manimuttarriver originates at an altitude of +720 m MSL at Perumalai and joins with Tirumani Ar near Chattiram after traveling 8.45 km. The right arm Kannimarattu Odai originates at Jandu Medu at an altitude of + 913 m MSL in Karandamalai reserved forest and join with Tirumani Ar near Nattam. The total length of Kannimarattu Odai is 13.06 km. The Odamanturai Odai having alength of 11.87 kmoriginates at Jandu Medu at an elevation of +840 m MSL and feeds Ottadipatti tank. Sambaiyar river, another tributary of Manimuttar originates at an altitude of +680 m in Alagar hills reserved forest and joins with Manimuttar river near Uralipatti village. Total length of this river is 14.17 km. A distributory from Manimuttar river drains through Vengapatti village and joins Palar river near Singampuneri.

After traversing 34.18 km, the river Manimuttar feeds Kadampatti, Karungattukudi and Nellikundupatti tanks. After Ondanpatti the river is called as Uppar Odai. From the village Kalungapatti, the river is wide and gain the name Manimuttar. Sunnambu Irrupu Ar starts from Sunnambu Iruppu, passes through Pillaiyarpatti, Pudur and Pattamangalam villages and joins with Manimuttar river near north of Kallupatti village. TheManimuttar river passes through Kallel and Devakottai. After Devakottai, the river is called as Devakottai Ar. The same river after Uddiyarkudiyiruppu, is called as Varshalei Ar and finally it joins with Pambar river near

Mekkavayal village. The total length of the Manimuttar river is 127 km. The surplus course of Anattidal tank having a length about 13.07 km joins with Manimuttar river near south of Udaiyachchi village.

Palar river, another tributary of Manimuttar river originates at an altitude of +910 m MSL in Mudi malai reserved forest. This river passes through Singampuneri, Kalappur and Ottaippatti villages. The river width is narrow upto Ottaippatti and then the width increases from Muraiyur village upto Mangudi village and it feeds the Tiruppatur tank and then joins with Virisalar river near Manamelpatti as surplus course of Tiruppattur tank.

Another Manimuttar river originates as a drainage at an altitude of +380 m MSL in Mammalai reserved forest and feeds Kattukudippattu tank. The surplus course of this tank feeds Neduvayal tank and its surplus flows as a river which is called Manimuttar and finally it drains into Vadagaiendal tank. The total length of this Manimuttar river is 19.09 km.

The surplus courses of Vadagaiendal, Ovalippatti, Vanjinnipatti tanks flow as a river, called Virisalar, having the total length of 30.42 km, traverses through Tiruppattur and Kandiramanikkam and confluences with Manimuttar river to the west of Kil Avandippattu. Varshalel Ar originates near Sirunallur tank and confluences with the Bay of Bengal near south east of Narendal. Total length of this river is 8.7 km.More than 3800 small to medium water bodies such as tanks, ponds and Oorunis exist. There is no reservoirs/ dams in this sub basin.

2.3.2 Pambar Sub Basin

Pambar sub basin is the smallest sub basin among thethree sub basins having an area of 1441.58 sq.km bounded by Agniyar river basin in the north, Bay of Bengal in the east and Manimuttar sub basin in the south and west. Sengirai reserved forest is located in the northern part of sub basin. Reserved forest Sethu Ranganathapattinam covering scrubs is located near Amaravati and Pudur villages in the south eastern part of the sub basin. The total forest area covered in this sub basin is 3.58 sq.km. The terrain elevation is ranging in between +1.5 m and +208 m MSL. The terrain slope noticed in the sub basin is towards south east.

There are five rivers, namely, Pambanar, Koluvanar, Papan Ar, Kottagudi Ar or Pambar and Ten Ar which drains into Pambar sub basin **(Plate PK-8B).** Pambanar river originates from the surplus course of Tirumayam tank. The river is narrow up to a distance of 19.72 sq.km and it is wide after Pakkiritakkal village and again it gets narrow shape after Narikkudi village and then confluences with Palantamarai tank. The total length of the river is 41.17 km.

The surplus courses of Elunuttimangalam tank and Valanur tank forms the left and right arm for the Koluvanar river. The river travel through Koluvanur and hence it gains the name Koluvanar river ,and it confluences with the Bay of Bengal near Pudupattinam after traveling a distance of 15.13 km.

Papan Ar originates from the surplus course of Indanur tank. The width of the river is narrow up to Maramangalam village, after that the width increases and confluences with the Bay of Bengal near Sirukadavakkottai. The total length of this river is 22.44 km,and runs parallel to Kuluvanar river.

The right arm of Kottagudi Ar originates from the surplus course of Sakkaivayal tank and its left arm originates from the surplus course of Urivayal tank. The length of this arm is 5.04 km. This river passes through Periya Kottagudi and Chinna Kottagudi villages and so the river has a name Kottagudi Ar. Another right arm originates from the catchment area of Sengattangudi tank and joins with Kottagudi Ar near north east of Kilkudi village. The length of this arm is 7.20 km. The surplus course of Vayarangudi tank flows as a river and joins with Kottagudi Ar to the west of Kurundur village. The length of this river is 5.67 km. After the confluence of all the above arms, the river, named as Pambar,flows through Tiruppunavasal and finally confluences with the Bay of Bengal near Puttukkidapatam. The total length of the river is 26.23 km.

Ten Ar, a tributary of Pambar river originates in the dense scrub jungle area, west of Sankarapuram , and a surplus course from Senjainattar tank joins with Pambar river west of Tirukkalyanapuram. The total length of the river is 34.78 km. There is no reservoir/ dam in this sub basin. More than 2400 small to large size water bodies, such as, tanks, ponds and Oorunis are available in this sub basin.

2.3.3 Kottakkaraiyar Sub Basin

Vaigai basin in the east, Cauvery basin in the west and Bay of Bengal in the east. Total area of the sub basin is 2204.91 sq.km. A total of 18.75 sq.km reserved forest area lies in this sub basin. Vellimalai, Vellakkal, Isanikadu, Melakadu, and Katturani reserved forests are observed in the south western part of the sub basin. The ground elevation ranges in between 4 m and 224 m MSL and the slope of the basin is towards southeast.

Three rivers are flowing in this sub basin ,namely, Sarugani Ar, also called as Kottakkaraiyar, Nattar and Uppar **(Plate PK-8C).** Sarugani Ar originates from the surplus course of Perungudi tank. As the river flows through Sarugani village, it is called as Sarugani river and traverses through Tiruvengampattu, Kokkurani, Chettikottai. After crossing Chettikottai, the river is named as Kottakkaraiyar and confluences with the Bay of Bengal near Karankadu and Ugandangudi. Total length of the river is 84.55 km. This river is the longest river in Pambar Kottakkaraiyar basin. Nattar river originates from the surplus course of Kalakulam tank. The river is narrow upto Vallalkulam, then it is wide and empties into Karaikkulam tank. The total length of the river is 22.94 km.

Uppar river originates from the surplus course of Marudur tank. The left arm originates from a open scrub area, west of Vagaivayal ,and joins with the river near Sirukudi village. The length of this arm is 12.68 km. The right arm of the river originates from the Solandur tank surplus and joins with the river in the north of Sinangudi. The length of this right arm is 10.41 km. Total length of Uppar river is 30.06 km and the river confluences with the Bay of Bengal north east of Pathanendal. Nattarkal Ar originates from a small tank located in the east of Nattarasankottai. Upto Udavayal, the river is narrow and afterwards it is wide and then empties into Kanjiram tank. The total length of the river is 28.14 km.In this sub basin also, there is no reservoir/ dam. More than 2870 small to large water bodies such as tanks, ponds and Oorunis are available in this sub basin.

Periyar Main Canal off taking from Vaigai river enters near Ariyurpattinam in the northern part of the sub basin to feed Silandangudi tank in Manimuttar sub basin. The length of the Periyar Main Canal is 16.02 km. Anjukottai channel having a length of 12.17 km flows through Parambakudi to feed water to Irumati Kil Kudi tank located in the western part of this sub basin. Periyar Main Canalhaving a length of 1.55 km also enters near Uranganpatti to feed water to Alampatti tank. A canal from Vaigai river to feed water to Salaigramam big tank enters this sub basin near Siruvalai village. The length of the canal in this sub basin is 7.5 km. Another canal off taking from Vaigai river, east of Paramakudi, enters this sub basin south west of Saliyavaganapuram village, to feed water to Rajasingamangalam tank.This is one of the oldest intra-basin transfer. Before the canal reaching R.S.Mangalam tank, enroute it feeds 7 other tanks. Total length of the canal in this sub basin is 10.09 km.

2.4 Drainage Morphometry

Identification and outlining of various ground features such as geological structures, geomorphic features and their hydraulic characteristics may serve as direct or indirect indicators of the presence of ground and surface water. The geomorphic conditions are essential pre-requests in understanding water bearing characteristics of hard rocks. The role of rock types and geological structures in the development of stream networks can be better understood by studying the nature and type of drainage pattern and by a quantitative morphometric analysis. The morphometric parameters of a basin are reflective of its hydrological response to a considerable extent and can be helpful in synthesizing its hydrological behaviour. A quantitative morphometric characterization of a drainage basin is considered to be the most satisfactory method for the proper planning of basin management because it enables us to understand the relationship among different aspects of the drainage pattern of the basin, and also to make a comparative evaluation of different drainage basins developed in various geologic and climatic regimes.

Remote Sensing and GIS techniques are the efficient tools in morphometric analysis. In morphometric analysis, remote sensing data can be used in conjunction with conventional data for delineation of ridgelines, characterization, priority evaluation, problem identification, assessment of potentials and management needs, identification of erosion prone areas, evolving water conservation strategies, selection of sites for artificial recharge.

For detailed morphometric analysis of Pambar Kottakkaraiyar basin, sub basin wise drainage layers have been converted to digital format through on-screen digitization from available Survey of India topograpic maps using Arc GIS 10.4 GIS software in the scale of 1:50000 and the attributes were assigned to create digital data base.For computing all morphometric parameters stream order was calculated using method proposed by Stahler (1964). To find out the drainage characteristics so as to explain the overall evaluation of the basin, analysis was done in following heads.

Linear Aspects : One dimension
Aerial Aspects : Two dimension
Relief Aspects : Three dimension

The morphometric parameters for each sub basin were directly computed from the vector data extracted from the topographic maps. The data in the first category includes maximum order of the streams, number of streams in each order, length, area, perimeter and relief for each of the sub basins. Those of the second category are the bifurcation ratios, elongation factor, circularity index, shape factor, drainage density, stream frequency, texture ratio, relief ratio, length of overland flow, constant channel maintenance and infiltration number.

Linear, aerial and relief aspects of each sub basin were computed in GIS environment **(Table 2.3)** followed by simple linear regression analysis to check the mutual dependency of some variables viz.,

1. Stream order Vs Stream number
2. Stream order Vs Stream length
3. Stream order Vs Mean stream length

Table 2.3 Morphometric parameters

Aspect	Sl. No.	Parameter	Unit	Manimuttar	Pambar	Kottakka-raiyar
				Value	**Value**	**Value**
	1	Area(Sq.km)	A	2279.61	1441.58	2204.91
	2	Perimeter(km)	P	344.51	205.38	229.84
	3	Basin Length (km)	L_b(km)	119.42	72.82	82.72
Linear	4	Stream Order	(u)	1,2,3,4,5	1,2,3	1,2,3
	5	Stream Length of all order	L_u	2495.2	689.29	1128.12
	6	Total number of stream segments in all order	N_u	3954	532	1329
	8	Mean stream length (Km)	$Lsm=L_u/N_u$	0.63	1.29	0.84
	9	Bifurcation Ratio	$R_b=N_u/N_u+1$	0.99	10.29	12.12

Relief	10	Basin relief	B_h	913	1338	220
	11	Relief Ratio	R_h	7.65	18.37	2.66
	12	Ruggedness Number	Rn	995.17	642.24	112.2
Aerial	7	Total number of first order	N1	2485	429	1110
	13	Drainage density(km/km2)	$D_d=L_u/A$	1.09	0.48	0.51
	14	Stream frequency	$F_s=N_u/A$	1.73	0.37	0.6
	15	Drainage texture	$R_t=N_u/P$	11.48	2.59	5.78
	16	Circularity ratio	$Rc=4\Pi A/P^2$	0.24	0.43	0.52
	17	Form factor ratio	$Rf=A/L_b^2$	0.16	0.27	0.32
	18	Constant channel maintenance	$C=1/D_d$	0.92	2.08	1.96
	19	Elongation ratio	$R_e=2((\sqrt{(A/\Pi)})/L_b$	0.45	0.59	0.64
	20	Texture ratio	T=N1/P	7.21	2.09	4.83
	21	Infiltration Number	If	1.89	0.18	0.31
	22	Length of overland flow	Lg	0.55	0.24	0.26

2.4.1 Linear Aspects of the Stream System

The drainage network transport water and the sediments of a basin through a single outlet, which is marked as the maximum order of the basin and conventionally the highest order stream available in the basin considered as the order of the basin. The size of rivers and basins varies greatly with the order of the basin. Ordering of streams is the first stage of basin analysis. The results of the linear aspects of drainage network such as, stream order (Nu), bifurcation ratio (Rb), stream length (Lu) and mean stream length for three sub basinsare presented in **Table 2.4**.

Table 2.4 Summary of drainage parameters

Sub Basin	**Stream Order**	**Stream Number**	**Bifurcation Ratio**	**Mean Bifurcation Ratio**	**Stream Length (Km)**	**Mean Stream Length (Km)**	**Area (Sq.Km.)**	**Drainage Density (Km^{-1})**	**Drainage Frequency (Km^{-2})**
Manimuttar	1	2485		4.31	1545.97	0.62	2279.61	0.94	1.38
	2	1065	2.333		519.32	0.49			
	3	324	3.287		187.91	0.58			
	4	70	4.628		65.09	0.93			
	5	10	7.000		176.91	17.69			
Pambar	1	429		10.29	467.20	1.09	1441.58	0.48	0.37
	2	97	4.420		177.99	1.83			
	3	6	16.160		44.10	7.35			
Kottakkaraiyar	1	1110		12.12	837.99	0.75	2204.91	0.51	0.6
	2	208	5.336		159.40	0.77			
	3	11	18.909		130.73	11.88			

2.4.1.1 Stream Order (Nu)

There are four different system of ordering streams viz., Gravelius (1914), Horton (1945), Strahler (1952 and Schideggar (1970). Strahler's stream ordering system, which is a slightly modified Hortons system, has been followed because of its simplicity. Where the smallest, unbranched fingertip streams are designated as 1st order, the confluence of two 1st order channels give a channel segments of 2nd order, two 2nd order stream join to form a segment of 3rd order and so on. When two channel of different order join then the higher order is maintained. The trunk stream is the stream segment of highest order.

The total drainages and major river systems are derived from the Survey of India Topography maps. It is found that Manimuttar sub basin is a 5th order stream, Pambar and Kottakkaraiyar are 3rd order sub basins (**Plate PK-8D, PK-8E& PK-8F**).

The Manimuttar sub basin area is a 5th order drainage basin **(Plate PK-8D).**A total number of 3954 streams were identified of which 2485 are 1st order streams, 1065 are 2nd order, 324 are 3rd order, 70 are in 4th order and 10 are in 5th order stream. Drainage pattern of stream network of the basin have been observed as mainly, dendritic type which indicates the homogeneity in texture. **A** dendritic drainage pattern is the most common form and looks like the branching pattern of tree roots **(Fig.2.1).**Generally, it develops in regions underlain by homogeneous material. That is, the subsurface geology has a similar resistance to weathering so there is no apparent control over the direction of flow of the tributaries. Tributaries formed after joining of larger streams at acute angle (less than 90 degrees). Dendritic drainage pattern is noticed in Kodagipatti, Mallanayakanpatti, Karasanampatti and Kuttupatti.

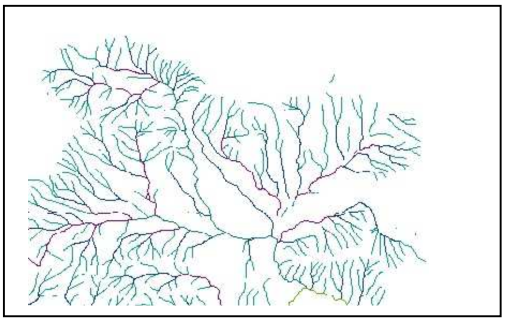


Fig. 2.1 Dendritic drainage pattern in Manimuttar sub basin

In some parts of the Manimuttar sub basin, parallel pattern **(Fig. 2.2)**representedin and aroundOndanpatti, Kila Valavu and Nellikundupatti.Parallel drainage patterns form where there is a pronounced slope to the surface. A parallel pattern also develops in regions of parallel, elongated landforms like outcropping resistant rock bands. Tributary tend to stretch out in a parallel-like fashion following the slope of the surface. A parallel pattern sometimes indicates the presence of a major fault that cuts across an area of steeply folded bedrock. All forms of transitions can occur between parallel, dendritic, and trellis patterns.

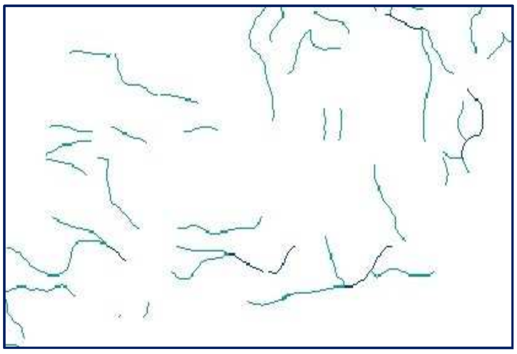


Fig. 2.2 Parallel Drainage pattern in Manimuttar sub basin

Radial pattern types **(Fig. 2.3)** noticed in and around Erakkapatti and Karumbapatti indicate that the topographical features are dipping, folded and highly jointed. A radial drainage pattern forms when water flows downward or outward from a hill or elevated area (Jensen 2006).

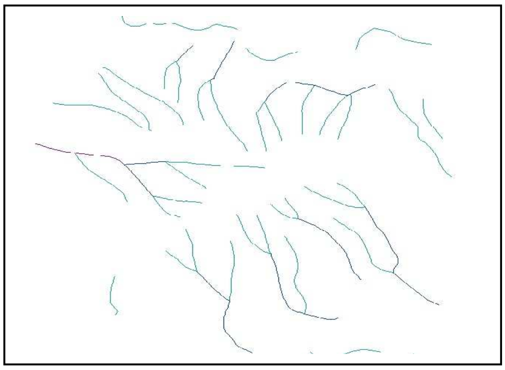


Fig. 2.3 Radialdrainage pattern in Manimuttar sub basin

In Pambar sub basin radial and parallel drainage patterns are noticed**(Plate PK-8E)**. The radial pattern **(Fig. 2.4)** is noticed in and around Avadapoigai and Lakshmipuram. Parallel drainage patterns **(Fig. 2.5)** are noticed in Illuppaikudi and Puduvayal.

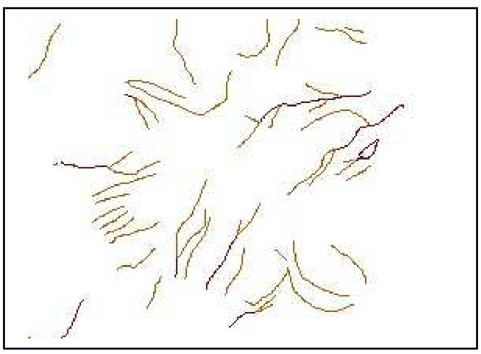


Fig. 2.4 Radial drainage pattern in Pambar sub basin

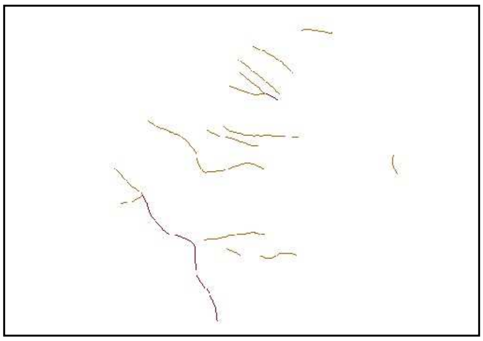


Fig. 2.5 Parallel drainage pattern in Pambar sub basin

Drainages in Kottakkaraiyar sub basin exhibit centripetal and parallel patterns in the entire area. The centripetal drainage pattern is just the opposite of the radial since streams flow towards a central depression. During wetter periods of the year, these streams feed ephemeral lakes, which evaporate during dry periods. Centripetal pattern is noticed in Sengulippatti, Madaguppatti and Mattur area (**Fig.2.6**).

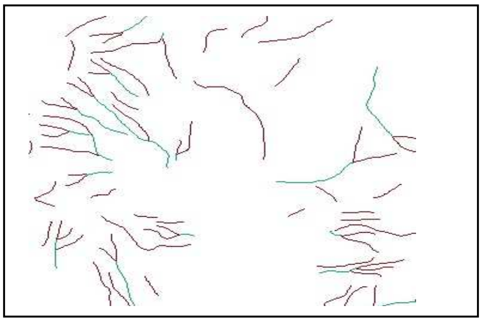


Fig. 2.6 Centripetal drainage pattern in Kottakkaraiyar sub basin

The parallel pattern **(Fig.2.7)** in Kottakkaraiyar sub basin is noticed in and around Karumandakkudi, Paychchattakudi and Periya Kiluvachchi areas **(Plate PK-8F)**.

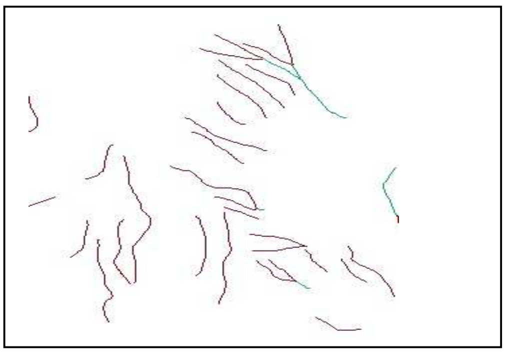


Fig. 2.7 Parallel drainage pattern in Kottakkaraiyar sub basin

The total number of stream segments present in each order is the stream number (Nu). Nu is number of streams of order u. Horton's (1945) laws of stream numbers state that the number of stream segments of each order forms an inverse geometric sequence which when plotted against order, shows a linear relationship with small deviation from a straight line, for most of the drainage systems. The plot of logarithm of number of streams against stream order follows a straight line as proposed by Horton (**Fig. 2.8**). This means that the number of streams usually decreases in geometric progression as the stream order increases in all the sub basins.

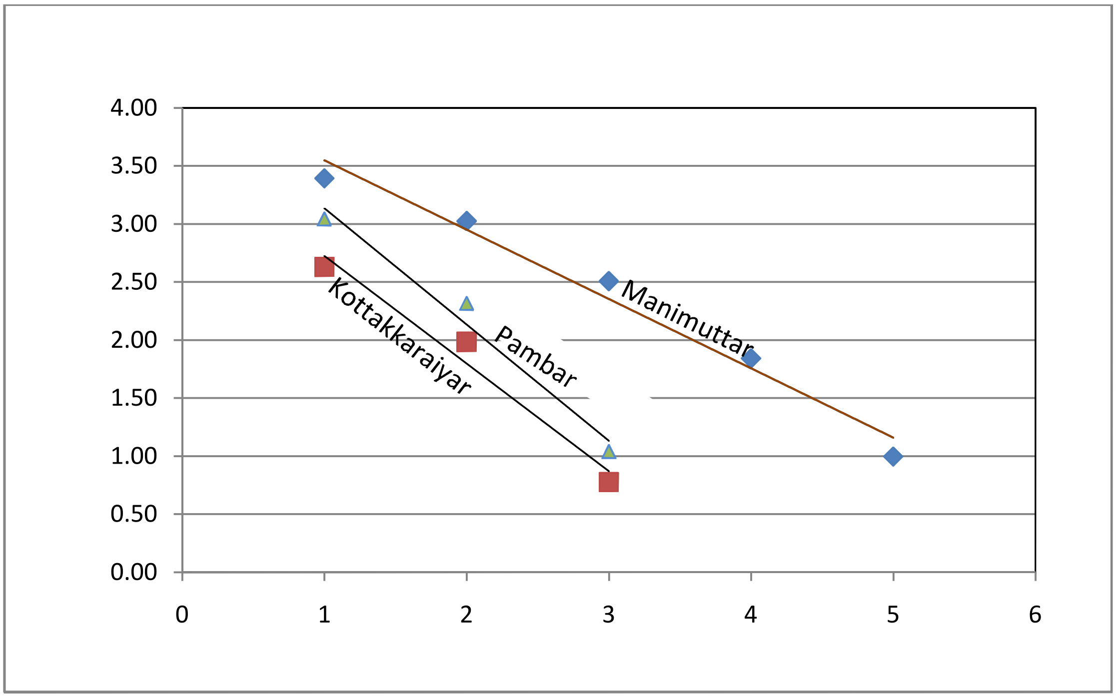


Fig. 2.8 Number of streams Vs stream order

2.4.1.2 Stream Length (Lu)

The total length of individual stream segments of each order is the stream length of that order. Stream length measures the average length of a stream in each order, and is calculated by dividing the total length of all streams in a particular order by the number of streams in that order. The stream length in each order increases exponentially with increasing stream order. The number of streams of various orders in the sub basins is counted and their length from mouth to drainage are measured with the help of GIS software. Plot of the logarithm of stream length versus stream order **(Fig. 2.8)** shows the linear pattern which indicates the homogenous rock material subjected to weathering and erosion characteristics of the basin.

The drainage study shows that the frequency of the drainage development is less in the sedimentary part in Pambar basin (0.37 km^{-2}) and high in Manimuttar sub basin (1.38 km^{-2}) and hence it clearly reflects that the drainage development in the upper part of the Basin is high and the area is highly dissected.

2.4.1.3 Bifurcation Ratio (Rb)

The bifurcation ratio is of fundamental importance in drainage analysis as it is the foremost parameter that links the hydrological regime of a watershed under topological and climatic conditions (Raj et. al., 1999). It helps to have an idea about the shape of the basin as well as in deciphering the run off behaviour. The bifurcation ratio will not be exactly same from one order to the next order because of possibility of the changes in the watershed geometry and lithology but will tend to be consistent throughout the series.

The term bifurcation ratio (Rb) is used to express the ratio of the number of streams of any given order to the number of streams in next higher order (Schumn 1956). Bifurcation ratio characteristically ranges between 3.0 and 5.0 for basins in which the geologic structures do not distort the drainage pattern (Strahler 1964). Strahler (1957) demonstrated that bifurcation ratio shows a small range of variation for different regions or for different environmental conditions. In Manimuttar sub basin, the bifurcation ratio is in the range of 2.3 to 7. It is seen that the bifurcation ratio is increasing with stream order. The mean bifurcation ratio is higher (**Table 2.4**) in Kottakkaraiyar sub basin (12.12) followed by Pambar sub basin (10.29). The higher bifurcation ratio indicates that there may be some structural distortion in the sub basin areas.The average mean bifurcation ratio value is 8.9 for the Pambar Kottakkaraiyar basin which suggests that the basin area is tectonically active (Som et.al).

2.4.1.4 Basin Length

Basin length is the longest dimension of a basin to its principal drainage channel. Among the three sub basins, Manimuttar sub basin has the longest length of 119.42 km. The basin length of Pambar sub basin is 72.82 km and that of Kattakkaraiyar sub basin is 82.72 km.

2.4.2 Aerial Aspects of Drainage Basin

The aerial aspect is the two dimensional properties of a basin. It is possible to delineate the area of the basin which contributes water and acts as stream segment. The watershed can be delineated from where the stream has its confluence with the higher order stream along hillcrests to pass higher slope of the source and return to the junction. This line separates slopes which drain water towards the streams.

Area(A) and perimeter (P) are the important parameters in quantitative morphology. Perimeter is the length of the boundary of the basin which can be drawn from topographical maps. Basin area is hydrologically important because it directly affects the size of the storm hydrograph and the magnitudes of peak and mean runoff. It is interesting that the maximum flood discharge per unit area is inversely related to size of the basin (More 1967). The aerial aspects of the drainage basin such as drainage density (D), stream frequency (Fs), texture ratio (T), elongation ratio (Re), circularity ratio (Rc) and form factor ratio (Rf) were calculated and results are given in **Table 2.3**.

2.4.2.1 Drainage Density (Dd)

Drainage density has long been recognised as a topographic characteristic of fundamental significance. This arise from the fact that drainage density is sensitive parameter which in many ways provides the link between the attributes of the basin and the processes operating long stream course (Gregory and Welling, 1973). It reflects the landuse that affects infiltration and the basin response time between precipitation and discharge. It is also of geomorphological interest particularly for the development of slopes. Basin with high drainage density indicates realisation of a large proportion of the precipitationas run off. On the other hand, a low drainage density indicates that most rainfall infiltrate into the ground and few channels are required to carry the runoff (Roger, 1971). Drainage density is considered to be an important index and it is expresses as the ratio of the total sum of all channel segments within a basin to the basin area i.e., the length of stream per unit of drainage density. It is a dimension, inverse of length (Horton, 1932).

Drainage density is a measure of the texture of the network, and indicates the balance between the erosive power of overland flow and the resistance of surface soils and rocks. The factors affecting drainage density include geology and density of vegetation. The vegetation density influences drainage density by binding the surface layer and slows down the rate of overland flow, and stores some of the water for short periods of time. The effect of lithology on drainage density is remarkable. Permeable rocks with a high infiltration rate reduce overland flow, and consequently drainage density is low.

The drainage density (Dd) of Manimuttar, Pambar and Kottakkaraiyar sub basins is 1.09 km^{-1}, 0.48 km^{-1} and 0.51 km^{-1} respectively. Pambar sub basin indicates low drainage density and Manimuttar sub basin has high density (**Plate PK-8G).**

Manimuttar sub basin is covered by maximum of charnockite and quartzite. Geomorphologically this sub basin is underlained by Shallow and moderate pediments and dissected zones and hence drainage density is higher in this sub basin. The Pambar sub basin shows the lowest drainage density becausethe upper reach of the sub basin underlained by granitic and gneiss and the lower part is under lined by sedimentary formation. It is suggested that the low drainage density indicates that the basin has highly permeable subsoil and thick vegetative cover (Nag 1998). Kottakkaraiyar sub basin lithologically is covered by conglomerate sand stone, shaly sand stone, sand and silt. The geomorphic features found in this sub basin are alluvial and coastal plains. Hence the drainage density of this sub basin is low.

2.4.2.2 Stream Frequency (Fs)

Drainage frequency is directly related to the lithological characteristics. The number of stream segments per unit area is termed as Stream Frequency or Channel Frequency of Drainage Frequency (Horton 1945). The stream frequency value of the Manimuttar, Pambar and

Kottakkaraiyar sub basins is 1.38, 0.37 and 0.60 respectively. Manimuttar sub basin covered by structural hills have higher stream frequency, drainage density while the sub basin Pambar of alluvial formation has minimum. The value of stream frequency (Fs) for the basin exhibits positive correlation with the drainage density value of the area indicating the increase in stream population with respect to increase in drainage density.

2.4.2.3 Texture Ratio (T)

Horton (1945) has defined drainage texture as the total number of stream segments of all order in a basin per perimeter of the basin. It is important in geomorphology which defines the relative spacing of drainage lines. Drainage texture is based on the underlying lithology, infiltration capacity and relief aspect of the terrain. Smith (1950) has classified drainage texture into 5 different textures i.e., very coarse (<2), coarse (2 to 4), moderate (4 to 6), fine (6 to 8) and very fine (>8). If the value of texture is more, then dissection will be more which in turn leads to more erosion.Manimuttar sub basin shows fine texture (7.21) with higher infiltration number (1.89) and it reflects high drainage development. Pambar has the coarse texture as the sub basin has the texture ratio of 2.09. Kottakkaraiyar sub basin has the texture ratio of 4.83 which comes under moderate texture category.

2.4.2.4 Basin Shape

The shape of the basin mainly governs the rate at which the water is supplied to the main channel. The main indices used to analyse basin shape and relief are the elongation and relief ratios. The elongation ratio is calculated by dividing the diameter of a circle of the same area as drainage basin by maximum length of the basin, measured from its outlet to its boundary. Three parameters viz. Elongation Ratio (Re), Circulatory Ratio (Rc) and Form Factor (Rf) are used for characterizing drainage basin shape, which is an important parameter from hydrological point of view.

2.4.2.5 Elongation Ratio (Re)

Schumm (1956) used an elongation ratio (Re) defined as the ratio of diameter of a circle of the same area as the basin to the maximum basin length. The value varies from 0 (in highly elongated shape) to unity i.e. 1 (in the circular shape). Thus higher the value of elongation ratio more will be the circular shape of the basin and vice-versa. Values near to 1.0 are typical of regions of very low relief, whereas that of 0.6 to 0.8 are usually associated with high relief and steep ground slope (Strahler 1964). These values can be grouped as,

Elongation ratio	Shape of basin:
<0.7	Elongated
0.8-0.7	Less elongated
0.9-0.8	Oval
>0.9	Circular

The Re values of the Manimuttar, Pambar and Kottakkaraiyar subbasinsare0.45, 0.59 and 0.64 respectively and these values indicate the low relief of the terrain that is elongated in shape.

2.4.2.6 Circularity Ratio (Rc)

Miller (1953) defined a dimensionless circularity ratio (Rc) as the ratio of basin area to the area of circle having the same perimeter as the basin. The value of circularity ratio varies from 0 (in line) to 1 (in a circle). He described that the basin with the circularity ratio ranging from 0.4 to 0.5 indicates strongly elongated and highly permeable homogenous rocks.

The Pambar and Kottakkaraiyar sub basins having the circularity ratio values of 0.43 and 0.52 corroboratethe Miller's ranges indicate that thesesub basinsare elongated in shape, low discharge of runoff and high permeability of the subsoil and also there is strong structural control on the drainage development. The circularity ratio of Manimuttar sub basin shows somewhat lower value (0.24) and that indicatesthe strong structural control on the drainage development. Therefore, the structural control of drainage is probably responsible for the low values of circularity ratio.

2.4.2.7 Form Factor Ratio (Rf)

Quantitative expression of drainage basin outline form was made by Horton (1932) through a form factor ratio (Rf), which is the dimensionless ratio of basin area to the square of basin length. Basin shape may be indexed by simple dimensionless ratios of the basic measurements of area, perimeter and length (Singh 1997). The range of form factor value is in between 0.1 and 0.8. Smaller the value of form factor, more elongated will be the basin. The basin with high form factors 0.8 has high peak flows of short duration, whereas elongated basin with low from factors has lower peak flows of long duration.

The form factor values of the sub basins Manimuttar, Pambar and Kottakkaraiyar are 0.16, 0.27 and 0.32 which indicate lower value of form factor and thus, represents elongated shape. The elongated basin with low form factor indicates that all the sub basins will have a flatter peak of flow for longer duration. Flood flows of such elongated basins are easier to manage than that of circular basin.

2.4.2.8Infiltration Number (If)

The infiltration Number is defined as the product of Drainage Density (Dd) and drainage Frequency (Fs). The Manimuttar sub basin shows higher infiltration number of 1.89. The higher the infiltration number the lower will be the infiltration and consequently, higher will be the run off. This leads to the development of higher drainage density. It gives an idea about the infiltration characteristics of the basin which reveals impermeable lithology and lower relief. The Pambar and Kottakkaraiyar sub basins show low infiltration numbers of 0.18 and 0.31 as most parts of the sub basins are underlained by alluvial plains.

2.4.2.9Length of overland flow (Lg)

The term length of overland is used to describe the length of water over the ground before it becomes concentrated in definite stream channels. Horton (1945) expressed it as equal to half of the reciprocal of drainage density. It is one of the most important independent variables, which greatly affect the quantity of water required to exceed a certain threshold of erosion. This factor is related inversely to the average slope of the channel and is quiet synonymous with the length of sheet flow to a large degree. Smaller the value of overland flow the quicker surface runoff will enter the streams represents well developed drainage network with higher slope. In a relatively homogeneous area, therefore less rainfall is required to contribute a significant volume of surface runoff to stream discharge when the value of overland flow is smaller than when it is large**.**

The Lg value of Manimuttar sub basin is 0.55, which represents long time flow in the basin. The length of overland flow bears an effective relationship with the drainage density and constant channel maintenance. More the value represents long time of flow in the basin. Pambar and Kottakkaraiyar sub basins show moderate Lg values of 0.24 and 0.26. The alluvial plain parts of the sub basins have a high length of course.

2.4.2.10Constant of Channel Maintenance (C)

This parameter indicates the requirement of units of watershed surface to bear one unit of channel length. Schumn (1956) has used the inverse of the drainage density having the dimension of length as a property termed constant of channel maintenance. If the drainage basin has higher values of this parameter, there will be lower value of drainage density. This constant, in units of square feet per foot, has the dimension of length and therefore, increases in magnitude as the scale of the land-form unit increases. Especially, the constant C provides information on the number of square feet of watershed surface required to sustain one linear foot of stream.

Manimuttar sub basin has lowest constant of channel maintenance 0.92 km^{-2} with highest value of drainage density (1.09). It means that on an average of 0.92 sq.ft surface is needed in the sub basin for creation of one linear foot of the stream channel. Pambar and Kottakkaraiyar sub basins show higher values of 2.08 and 1.96 having lower drainage density value of 0.48 and 0.51. Higher value of constant channel Maintenance reveals strong control of lithology with a surface of high permeability. Sub basins covered with maximum of alluvium of plain and buried pediment deep zones show highest values of C, as the permeability in these zone is high.

2.4.3 Relief Aspects

2.4.3.1 Basin Relief (Bh)

Basin relief is the elevation difference of the highest and lowest point of the valley floor. Manimuttar sub basin relief ranges from 3 to 916 m. The relief range of Pambar basin is 1.5 to 134 m and that of Kottakkaraiyar sub basin is 4 to 224 m.

2.4.3.2 Relief Ratio (Rh)

Relief ratio is defined as the ratio between the total relief of a basin i.e. elevation difference of lowest and highest points of a basin, and the longest dimension of the basin parallel to the principal drainage line (Schumn 1956). This is a dimensionless height-length ratio and allows comparison of the relative relief of any basin regardless of difference in scale or topography. Relief ratio normally increases with decreasing drainage area and size of a given basin (Gottschalk, 1964).The relief ratios of sub basins Manimuttar, Pambar and Kottakkaraiyar are 7.65, 18.37 and 2.66. The high value of relief ratio in Pambar sub basin indicates the presence of highly resistant rocks granitic and gneiss. The high value indicates steep slope and high relief and vice-versa. Relief controls the rate of conversion of potential to kinetic energy of water draining through the basin.

2.4.3.3 Ruggedness Number (Rn)

Strahler (1968) describes ruggedness number is the product of maximum basin relief (H) and drainage density (Dd) and it usually combines steepness with its length.Extremely high values of ruggedness number occur when slopes of the basin are not only steeper but long, as well. The value of ruggedness number in Manimuttar, Pambar and Kottakkaraiyar sub basins is 995.17, 642.24 and 112.2 respectively.

2.4.3.4 Inference from Drainage Morphometric Analysis

The sub basin wise drainage morphometric analysis of Pambar Kottakkaraiyar basin reveals that

1. Dendritic, parallel, centripetal and radial drainage patterns are noticed in the basin.
2. The number of streams are decreasing while the drainage order is increasing
3. Drainage patterns are controlled by lithological formations
4. The basin has low drainage density since the drainages are controlled by hard rock formation in the upper part of the basin.
5. The texture ratio of the basin is 4.71 and categorized as moderate in nature which indicate that the basin has moderate infiltration capacity with low relief and has good potential zones.

6. Based on the shape of the basin, Pambar Kottakkaraiyar is elongated, indicating low discharge of runoff and high permeability of the subsoil and will have a flatter peak of flow for longer duration. Flood flows of such less elongated basins are easier to manage.

2.5 Geology

The study of geology of the Pambar Kottakkaraiyar basin is primarily based on the maps published by the Geological Survey of India, interpretation of satellite data and the inferences derived from the lithology of investigation boreholes and water level observation wells of SG&SWRDC.A geology map on 1:50,000 scale (Plate PK-09)was prepared, showing the surface geology of the basin and also the vertical cross section of borehole lithology for better understanding. An attempt has been made to understand the hydrogeology of the basin.The tentative stratigraphy of the study area is given hereunder.

Period	Epoch	Lithology
Quaternary	Recent to sub recent	Alluvium laterite
Tertiary	Cuddalore formation	Sandstone and shale
Mesozoic	Upper cretaceous	Calcareous sandstones, Arenaceous Limestone with Black clay
	Lower cretaceous	Sandstone with shale
Palaeozoic	Sivaganga Beds (Upper Gondwana)	Shale and Sandstone Basel Boulder bed
Archaean	Dharwar	Pegmatite & Quartz intrusions, Pink Granites, Charnockite, Complex Gneiss (Hb.Gn & Fissile Hb G n). Quartzite, calc gneiss & Limestone Amphibolites, pyroxene Granulite.

The Pambar Kottakkaraiyar basin can be divided into two regions as hard and soft rocks by a contact zone traversing in the middle of the basin. Hard rock formations occur in the upper reaches of the basin.Hard rock comprised of Archaean complex suit. In Archaean crystalline rocks, main types are Quartzite,Charnockite,Gneiss, Migmatite, Granitic and acidic rocks. Gneiss is the predominant rock type among them which covers most of the hard rock region. Hornblende biotite gneisses widely occur in this area. Garnetiferous sillimanite gneisses occur north east of Palakkurichi within the granite gneisses. Large bands of Quartzites are found in the western part near Nattam. Also isolated band is found north of Sivaganga. Migmatite is found in the northern portion of the basin in a small region. Charnockite is found mainly in the western portion and as a small patch in the eastern side.Also isolated occurrence of Charnockite is found along with quartzite in the hills located in the north of Nattam. Granitic rocks are found in both western and eastern side of the hard rock region. Large massive pink granites, parallel to the foliation of gneissic rock occur south east of Nattam. Amphibolites and pyroxene granulites are found as xenoliths and occur as thin hands within gneisses, charnockites and granites. Prominent occurrences are found in Perumamalai and Manikampatti. Calc. gneisses and granulites occur sporadically in the Perumamalai hilly area along with Quartzites, isolated occurrence of crystalline limestone is found to occur 5km east of Natham. Numerous veins of Pegmatites and quartz are intruding the gneisses and Charnockite. They are found to occur at Ayittapatti and Kodukkonanpatti, south of Nattam. Quartz veins in Perumamalai and around Sendurai grades into rose quartz type. Highly weathered spheroidal gneissic rocks are found near a quarry in Nemathampatty**(Fig 2.9).**

Fig 2.9 Highly weathered spheroidal gneiss found near a quarry in Nemathampatty

In the lower reach of the basin, towards east and south to contact zone, soft rock types makes the prominent lithology. Soft rock is comprised of Upper Gondwana sediments known as Sivagangai formation, Cuddalore formation and recent to sub recent sediments. Upper Gondwana formation known as 'Sivaganga beds' of upper Jurassic age overlies Archaean crystalline, which crop out east of Sivaganga Town.Lower and upper Cretaceous formations do not crop out on the surface anywhere in the basin but encounted in the boreholes drilled at Pudur, Sathanikottai, Andavurani, Tiruvadanai and Neyvayal, etc. Cuddalore sandstone formation crops out at Devakottai overlained by laterite and alluvium. This formation consists of coarse grained sandstones, grits with clays and shales.

In soft rock region, three prominent litho units comprising shaly sandstone, sand and silt and altered sequence of sand,silt and clay makes successive layers from the contact zone towards south. In this region, sand and silt makes the predominant type. A lithounit comprising sandstone and conglomerate makes direct contact with Archaean gneissic terrain near Nattarasankottai. Recent to sub recent formations are represented by sands, alluvium, and laterite of coastal, aeolian and fluvial origin. Laterite occurs in parts of Sivaganga, Thirupathur, Karaikudi and Devakottai areas.

Out of the total area of the basin, hard rock occupies 2100.56 sq.km and soft rock occupies is 3825.53 sq.km **(Fig.2.10).** The minimum area of one particular litho unit is Migmatite with an area of 3.15 sq.km and maximum area of 1728.5 sq.km by sand and silt unit **(Fig.2.11 and 2.12).**The percentage of area in the basin comprised by hard rock is 35.44and soft rock is 64.55.

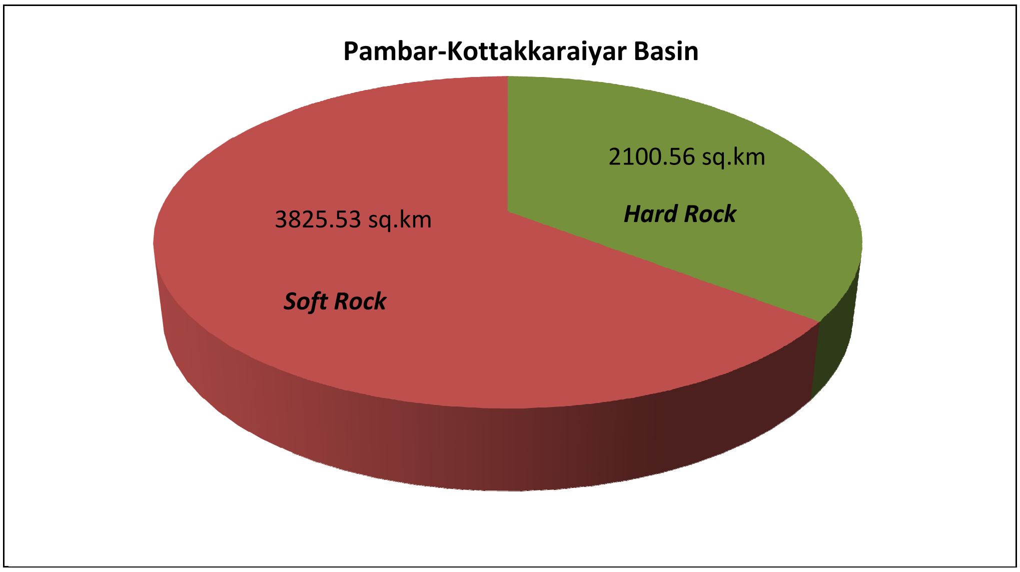


Fig.2.10 Area occupying by hard and soft rocks in the basin

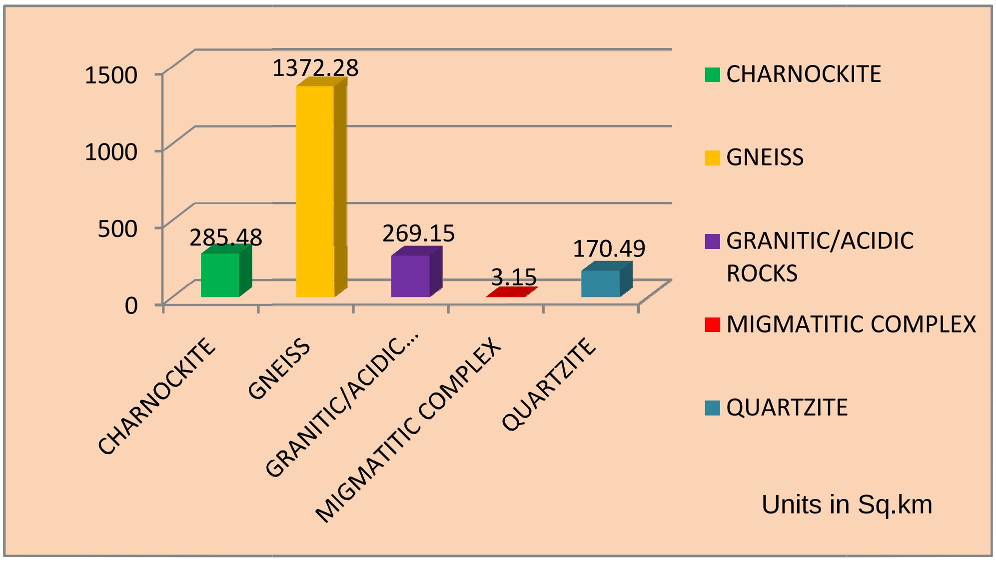


Fig.2.11 Area occupying by hard in the basin

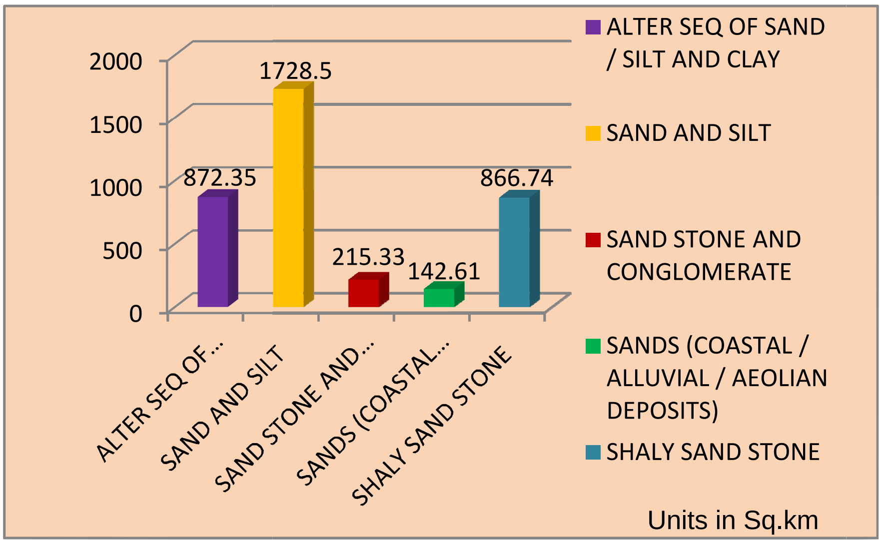


Fig.2.12Area occupying by Sedimentary rock.

Selected borehole vertical cross sections have been prepared to know the lithology of the basin **(Fig. 2.13).**

2.5.1 Hydrogeology

In PambarKottakkaraiyar river basin, 171 boreholes were taken for hydro geological studies (Location of boreholes - **Plate PK-09 and Table 2.5**). Out of these,116 were drilled in sedimentary formations and 55 bore wells located in hard crystalline formation. In hard crystalline formation, the depths of boreholes ranging from 20.2 to 82.5 m below ground level (bgl). From these available data, it is inferred that the maximum depth of weathered zone is 82.5m bgl. In sedimentary formation, the depth of exploratory boreholes ranges from 20.43m to 430 m bgl. In crystalline formation, most of the boreholes are shallow in depth and sedimentary formations have both shallow and deeper boreholes because of the existence of deeper aquifer.

The important aquifer systems of the basin area are

1. Porous formations, viz, alluvium, sandstone etc
2. Weathered and fractured crystalline formations consisting of gneiss, charnockite, granite etc.

The aquifers of porous formations may be grouped as

i. Gondwana aquifers
ii. Lower cretaceous aquifers
iii. Upper cretaceous aquifers
iv. Tertiary aquifers (Cuddalore sandstone)
v. Quaternary aquifers (alluvium)

In hard rock formation, maximum aquifer depth ranges between 48 -78 m and the maximum depth is found in the borehole of Manappacheri which is located in weathered gneissic formation. Another borehole in Mathikaraipatti has aquifer depth of 1.5m - 69.2 m which is in weathered and fractured biotitic gneiss formation.

In sedimentary formation, maximum aquifer depth of 417.12 to 420.22 m is found in the borehole of Tiruvadanai which is in sandstone formation. Also in borehole of Nerkundram, aquifer depth of 283.7 to 320.2 m is found in sandyclay formation.It is to be noted that TWAD Board has drilled a borehole of 1200 ft depth at Sundarapandianpattinam (S.P.Pattinam) in which aquifer is found at a depth between 900 to 1000 ft and it is of good quality (up to 900 ft,the pipes without slot have been erected so as to seal the saline water yield).

Ground water potential of hard rock formations is low as thickness of aquifer is less when compared to soft rock region. In soft rock region, aquifers occur at shallow depth as unconfined (water table)aquifers and also in confined conditions as deeper aquifers.In case of crystalline formations, groundwater occurs under water table condition in weathered and shallow fractured region and under semi confined to confined conditions in deeper fractured region.

The Gondwana aquifers, comprising shale, sandstone and boulder bed, occur at shallow depth as water table aquifers and also in some places it is under confined conditions as deep aquifers.Cretaceous formations which comprises calcareous sandstone and sandstone intercalated with shale. Groundwater is present in semi confined to confined conditions.

Tertiary aquifers comprising sandstone,clays,shale, sand and Cuddalore sandstone aquifer is one of the potential aquifer in the basin. The aquifers occur as water table aquifer (at shallow depth) and as confined aquifer at greater depth.Alluvium is developed along the river courses and the thickness ranges between 6m and 40m and the aquifer is mainly unconfined.

Aquifer parameter values have been determined by aquifer performance test.The general yield of boreholes in crystalline formation is 2-5 lps to 250 lps.The minimum transmissivity value in hard rock region is less than 1 m^2/day and maximum is 65 m^2/day. The minimumstorativity in hard rock region is 2.16X 10^{-5} to 4.9$10^{-5}$ and maximum is 1.32 X 10^{-3}.The general specific yield is less than 2 %.

In soft rock formation, the general yield of boreholes ranges from 75 lps to500 lps.The minimum transmissivity value in soft rock region is 1-10 m^2/day and maximum is 500 m^2/day.The minimum storativity in sedimentary rock is 2.5X$10^{-5}$and maximum is 3.59 X 10^{-4}.The general specific yield is around 12 %. Artesian aquifers are noted in the past and one such borehole under artesian condition is shown hereunder in R.Velangudi village, west of Puduvayal in Karaikudi toTrichy road. These aquifer's artesian condition ceased due to the development of agriculture and domestic bore wells. However, in a aqua culture farm located in East Coast Road, Thirupalaikudi, artesian well is seen**(Fig 2.14).**

Artesian well in Manachai. (ceased 8 years ago)

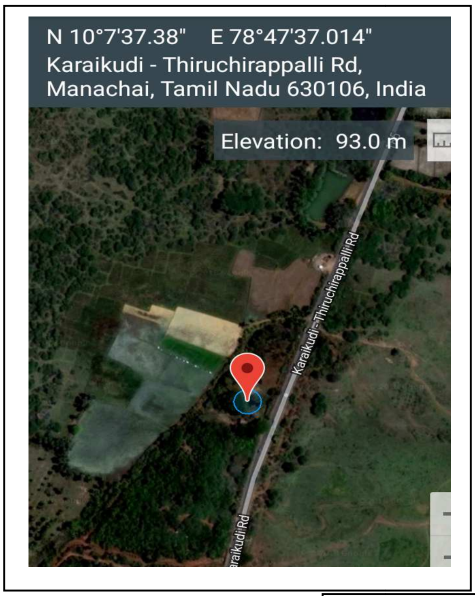


Fig. 2.14Existing artesian well in Thirupalaikudi

Regarding water quality, ground water in phreatic aquifers of the basin, in general, is colourless, odourless and slightly alkaline in nature. The electrical conductivity of groundwater in phreatic zone of hard rock region is in the range of 260 to 6650 µS/cm and that of soft rock region is 220 to11980 µS/cm.Out of 101 samples collected from the borewells in this basin area, 78 is showing good quality, having EC values less than 1500 µS/cm.Remaining 23 samples are showing higher EC values and the quality is moderate to poor.

2.6 Geomorphology

2.6.1 Brief

The study of the landforms constitutes geomorphology. It deals with the morphological characteristics of the earth's surface and its genesis. The study is necessary in many disciplines such as hydrology, groundwater, environmental studies, natural hazards/ disasters, land use / land cover and flood mitigation etc. Geomorphologic maps are extremely useful to planners, scientists and economists.

Tamil Nadu State is a relatively stable land mass characterised by Western Ghats of Archaean Complex with different types of metamorphosed gneisses and Charnokites in the west, with a central plain, eastern Ghats and coastal plain. Based on the genesis, landforms are attributed as Structural, Denudational, Fluvial , Coastal and Aeolian.

The genesis of geomorphic units reveals about the primary porosity - permeability of the landforms which gets modified significantly due to weathering, erosion and dissection, resulting in creation of additional secondary porosity-permeability. Further, morphology of the lithological unit can indicate its influence in recharge. Depending on the morphology, a landform may act as a runoff ,recharge or discharge zone. These landforms can be classified as shallow, moderate and deep, based on their depth of weathering and thickness of deposited materials.

2.6.2 Geomorphological Features

The geomorphological study was carried out in the Pambar Kottakkariyar basin by interpreting the image by its characteristics such as tone, texture, shape, pattern and associated features etc. Four scenes of Indian Remote Sensing Satellite, LISS III sensor of Resource Sat II, with date of pass, 22.2.18 and 23.3.18 were interpreted to identify the geomorphic units. Qualitative assessment was made to identify the geomorphic units which play vital role in selecting the area suitable for groundwater exploration and area suitable for augmenting groundwater recharge. The following four major landforms were identified in the basin, based on its genesis**(Plate PK-10).**

I Landforms of Structural Origin

II Landforms of Denudation Origin

III Landforms of Fluvial Origin

IV Landforms of Coastal Origin

2.6.3 Landforms of Structural Origin

The structural landforms in Pambar Kottakkaraiyar basin includes structural hills and linear and curvilinear ridges.The structural landforms are noticed in the western part of the basin where the geology is of hard rock origin. The structural hills are hills/mountain which exhibit geological structures such as folding, faulting, foliations trends etc., with varying hard rock lithology. The relevence to groundwater prospects is moderate along its valleys,subject to weathering. The linear / curvilinear ridges may be strike controlled with varying hardrock lithology.They are linear in shape, narrow,low lying relief and barren.The groundwater prospects is poor. The structural hills are found in the western part of the basin and the linear / curvilinear ridges are sporadically found in the western part of the basin and around Komanampatti, south of Mungilipatti, northwest of Mayanakkodu, south of Payyampatti, west of Ammapatti, north of

Tondilingapuram, east of Sivandampatti, Vellaicharalai, and east of Vairavanpatti, Pannudaipatti etc.

2.6.4 Landforms of Denudation Origin

The Denudation landforms are occurred in western and middle part of the basin and divided into various geomorphic units such as denudational hills, residual hills, pediment-inselberg complex, pediment, buried pediplain, shallow and moderate, weathered pediplain - shallow and moderate and laterite plain. The denudation process is active in these landforms.The description and its significance to grounwater resources are explained below.

The denudation hills are formed, due to differential erosion and weathering,so that, a more resistant formation or intrution stand as mountains / hills with varying hard rock lithology.They too exihibit geological structures such as joints,fractures,lineaments, etc. Denudation hills are located south of Kayarayapatti in Vellamalai R.F, north of Pudukkottai, in Chembulimalai RF, northwest of Samudrapatti, north of Budakkudi, north of Velayudhampatti in Valaichcherippatti RF, north of Manjamayakkampatti in Nedunkkuttu R.F.

Residual hills are located in and around Nattam and Kottampatti and west of Singampunari and Ponnamaravathi sporadically in the western part of the basin. It is an isolated, low relief formed due to differential erosion so that, a more resistant formation stand as residue, like small hills with varying hardrock lithology. The prospects for groundwater is poor to nil.

Intermontane valley are broad depression between mountains, normally filled with colluvial deposits of varying lithology. In some places, the intermontene valley is controlled by fractures.Depending upon the thickness of fill, the groundwater prospects will be good to moderate. Intermontane valley is located in the south of Sendurai village in the northern top most boundary of the basin.

Inselbergsare located in isolated area in the west of Kallal, Singampunariand Ponnamaravathi. They arealso residual, isolated hill, stand above the ground level with surrounding vast pediplain.They are normally barren and rocky with varying hard rock lithology. The groundwater prospects in inselberg is poor.

Pediment is gently sloping smooth surface of erosional bed rock between hill and plain with thin veneer of detritus.The lithology isof various hardrock formations. Sometimes they exihibit joints, fracture / lineaments. The significance to groundwater ismoderate to poor; varies with underlying lithology and depends on fracture / lineaments.

Buried pediplain – shallow, is a flat and smooth surface, with shallow overburden, ie 0-5 m thickness.It may be cris crossed by lineaments/ fractures with weathered materialof varying hard rock lithology. The groundwater prospects in these landforms are moderate to poor.

Buried pediplain – moderate is also a flat and smooth with moderately thick over burden, ie 5 – 20 m. The lithology will be same as buried pediplain – shallow. This geomorphic units are rated as good to moderate with regard to groundwater occurrence.The weathered pediplain / shallow - moderate are similar to above with shallow to moderate overburden of weathered materials respectively.

Buried pediplain – shallow and Buried pediplain – Moderate are located in the central part of the basin. Buried pediplain – shallow is located in and around Kalaiyarkoil and Kallal, Nattarasankottai, Panangudi, Settanendal, Vettiyur, Mel and Kil Mangalam and Periakarai villages and Buried pediplain – Moderate is seen in Pillatti, Mel Pidayur, Sembanur, Viramangalam, Sundankukkurichi, Udaivayal and Sengulippatti, etc.

Lateritic Plain, located in and around Sivaganagai, west of Kalaiyarlovil,south of Kallal, north west of Devakkottai, west of Sakkotttai and south of Tirumayam. Some of the locations are Serinippatti, Pandani, Pallivasal, Vengalur, Tambupuram, Aramanaipatti,Siruvayal, Kottamangalam, Pallattur, etc. This unit is a higher / elevated flat land with lateritic cappings.There will be no geologic structures over the terrain.The lithology is mainly laterites as capping over granite or meta sediments. Groundwater prospects will be poor since the capping is compact and immpermeable.

2.6.5 Landforms of Fluvial origin

The characteristics of each geomorphic unit of fluvial origin, its lithology, texture and groundwater prospects are described below.

Valley fill is an unconsolidated sediments, deposited by streams /rivers normally in a narrow fluvial valley.The lithology constitutes boulders,cobbles, pebbles, gravel sand and silt.The valley where the deposits occur are mostly fracture controlled.Depending upon the thickness of fill, the occurence of groundwater will vary.Generally, these units are very good for groundwater exploration. A narrow stretch of valley fill deposit is seen in the Alagar hill reservedforest, south west of Kasampatti village in the south western boundary of the basin.

The alluvial plain, is located in south and south eastern part towards the coastal region of the basin and located in and around Illayangudi, R.S.Mangalam, Thiruvadanai, Kannankudi and Sakkottai. Alluvial plain is formed by extensive deposition of alluvium by major river systems.This unit is normally flat/gently undulating surface.These units constitute gravels,sand, silt and clay of varying lithology of sedimentary origin. Silt will be the dominating lithology. The groundwater prospects will be excellent due to its porosity and proximity to water sources.

The flood plain in Pambar Kottakkaraiyar basin exists along the lower reaches of rivers, such as Pambar, Kottakaiyar, Nattar-Kallar, Manimuttar and Kottagudi Ar, in the south eastern part of the basin. It is a flat surface adjacent to a stream / river composed of unconsolidated fluvial sediments, normally subject to periodic flooding by parent stream / river.The lithology will primarily comprise of unconsolidated materials like gravel,sand and silt. Sand will be thedominaing lithology in flood plain.

Deltaic plain with backwater is a gently sloping plain of large extent of area with thick sediments in fan shape,normally formed atthe end of river ccourse.These units consist of material from river borne sediments mostly alluvium.The groundwater potential in these units are very good to good. Deltaic plain is seen in the eastern part of the basin.

2.6.6 Coastal Landform

The coastal plain is a regional land of low relief bounded seaward by the shore and landward by highlands, mainly formed due to coastal action.The lithology in Coastal Plain are sand,silt and clay. Groundwater prospects is promising. However in some places, salinity is a problem.

Mud flat is a muddy flat area, along a shore oraround an island , covered during high tide, uncovered during low tide and devoid of vegetation.The lithology is fine silt and clay. The groundwater is saline.

Beach is a narrow strip of land along sea shore, generally consisting of sand or un consolidated material.Sometimes it can be formed of boulders or shingles.The quality of ground water will be saline except the groundwater occuringas perched water table.

Salt flat is a flat land, bordering the seaestuaries with thin veneer of salt.Fine grained material like clay dominates in this area.The quality of water is saline.

Paleo beach ridges are the geomorphic unit formed due to the action of waves in the sea, which are sub parallel ridges of sand ,shell or pebble varying in amplitude from a few inches to several feet, normally parallel to the coast line.These landforms are stabiised in due course of time and forms paleo beach ridges.The groundwater prospects will be moderate.

Tidal flat is a widened flat surface parallel to coast, primarily comprises of unconsolidatedmaterials like gravels , sands and silt with fine texture.Thequality of water will be poor / saline.

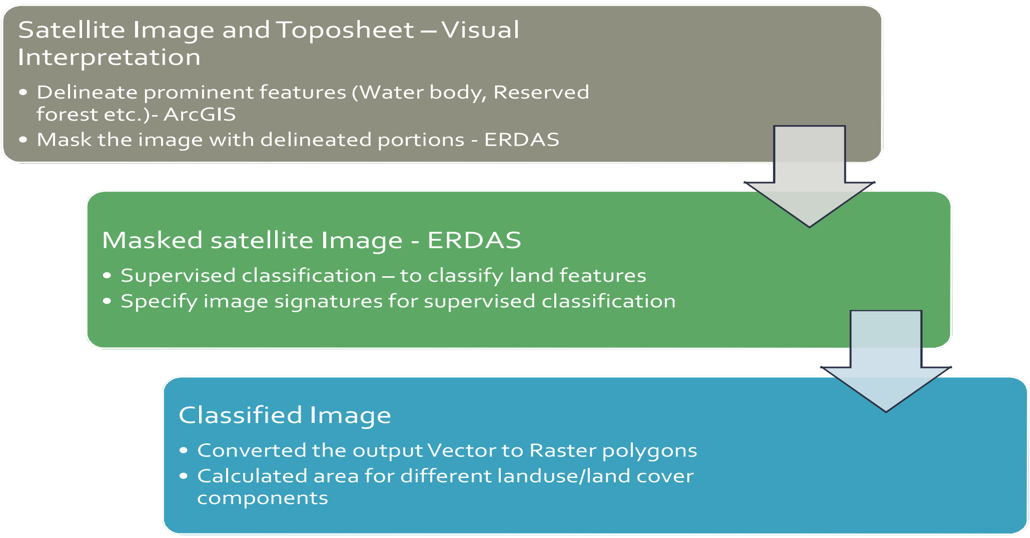
Swale is a geomorphic unit of coastal origin .It is a shallow depression,sometimes swampy, in the midst of generally level land in an undulating ground. It is a long,narrow shallow trough like depression between two beach ridges and alinged roughly parallel to the coastline.

Interpreting the Satellite imagery, the geomorphic units were identified and the groundwater condition is qualitatively assessed for each geomorphic unit, falling in the basin. This study provides firsthand information on the geomorphic units which are relevant to groundwater. To assess the groundwater potential quantitatively, the present extraction, specific yield, and other parameters like bore well / dug well pump test results have to be taken into account. Also the geomorphic units which are indicated as favourable for groundwater exploration, are suitable for constructing artificial recharge structures.

2.7 Land use

Land use and land cover study is necessary for planning, development and land management activities of agricultural sector. Comparison of land use and land cover patterns of the same area in two different periods helps in understanding the variation in utilization and degradation of lands.Remote sensing technique helps in analyzing the current land use pattern. Processing and interpreting the satellite imageries of the study area is one of the best and ideal way to carry out land use study.This report on land use study is based on the interpretation of satellite imagery only and serve as an indicator on basin's land use scenario.

For Pambar Kottakkaraiyar basin land use study, satellite imagery of IRS Resource Sat II, LISS III data acquired on February and March 2018 (**Plate PK-11**) have been interpreted. Land use maps were prepared sub basin wise and shown in **Plate PK-12A, Plate PK-12B and Plate PK-12C**. Visual interpretation and software aided digital interpretation using " unsupervised classification techniques ", have been applied to derive the land use information of the basin. In order to prepare a complete the land use / land cover mapping, Image processing coupled with GIS tools have been employed. The steps involved in the image interpretation for land use classification are shown as below :



Different land use categories with their extent of area, derived from satellite data by adopting level III classification for Pambar Kottakkaraiyar basin have been tabulated sub basin-wise and shown in **Table 2.6, 2.7 and 2.8**. The land use patternof the sub basins are discussed below.

2.7.1. Manimuttar Sub Basin

In Manimuttar sub basin,the extent of agricultural land is 1400.90 sq.km, which is 61.45% of the sub basin area**(Table 2.6).** Harvested land covers much of the agricultural land,followed by dry crops and groves.No major plantation is found in Manimuttar sub basin**(Plate PK-12A).**Barren land occupies an area of 560.52Sq.Km which is 24.59 % of the area.

Table 2.6. Land use pattern in Manimuttar sub basin for the year 2018

Sl. No.	**Land use Category**			**Area in 2018**	**Percentage Area in 2018**
	I Level	II Level	III Level	Sq.km	
1	Built up Land	Settlement and others	Urban	22.23	
			Rural	59.40	
				81.64	3.58
2	Agriculture	Wet Crop / Irrigated Land	Paddy, Sugarcane, Banana and harvested Land	622.46	
		Dry crop/Rainfed land	Cholam, Kambu and Groundnut	496.59	
		Plantation	Cashew plantation		
		Groves	Groves - Coconut, Mango	281.85	
				1400.90	61.45
3	Barren/Waste Land	Barren land	Barren land	17.95	
			Rocky outcrop	218.78	
		Bushes	Shrubs	2.04	
			Scrub	314.40	
		Salt affected / Sandy area	Alkaline	7.34	
				560.52	24.59
4	Others	Saltpan	Saltpan	0.55	
				0.55	0.024
5	Water body/ Wet Land	Water body	Tank	220.58	
			River	15.41	
				235.98	10.35
Total Area				2279.6	100%

Water bodies include rivers and tanks and they occupy235.98 sq.km,which is 10.35% of the total sub basin area. Built up land comprises of rural and urban settlementswhich covers 3.58 % of the sub basin area. Important urban settlements in this sub basin are Singampunari,Nattam, Ponnamaravathi and Tiruppathur.Quarry land occupies 3.83sq.km, which is 0.17 % of the sub basin area. Salt pans are existing in a small patch in the coastal area. Land use classes observed in the sub basin are shown in **figures 2.15 to 2.18.**

Fig. 2.15Groveat Kila Nilakotai

Fig. 2.16Wet crop - Paddy at Nerkuppai

Fig. 2.17 Quarry at Nemathampatty

Fig.2.18Salt pan at Tondi

2.7.2Pambar Sub Basin

In Pambar sub basin, majority of the area is covered by agricultural land**(Plate PK-12B)**. The total area of the agricultural land is 840.48 sq.km, which is 58.3% in the sub basin area**(Table 2.7).** Wet crops and harvested land, covers much of the agricultural land, followed by dry crops, plantations and groves. Cashew is the major plantation in this sub basin. This plantation covers up to 49.064 sq km in the sub basin. Cashew is being cultivated in Sakkottai, Arimalam and Kallal blocks. The area covered by the water bodies such as rivers, tanks is about 277.67 sq.km, representing 19.27 % of the total area. Barren land category occupies an area of 231.56 sq.km which is 16.06 % in the sub basin. Mangroves and salt pans are existing in the estuary of Pambar river in the coast. The land use categories observed in this sub basin are shown in **figures 2.19 to 2.22.**

Fig. 2.19 Wet crop - Sugarcane at Puduvayal

Fig. 2.20 Wet crop Paddy at Kandadevi

Fig. 2.21 Dry crop - Groundnut at Pallattur   Fig. 2.22 Eucalyptus Plantation at Ediyur

Built up land comprising of rural and urban settlements and industries makes up 5.98 % of the sub basin area.Important urban settlements include, Karaikudi,Puduvayal,Pallattur and Kilsevalpatti. Quarry covers 1.49 sq.km, which is 0.1 % of the sub basin area.

Table 2.7. Land use pattern in Pambar sub basin for the year 2018

Sl. No.	**Land use Category**			**Area in 2018**	**Percentage Area in 2018**
	I Level	II Level	III Level	Sq.km	
1	Built up land	Settlement and others	Urban	41.78	
			Rural	43.99	
			Industry	0.409	
				86.17	5.97
2	Agriculture	Wet Crop / Irrigated Land	Paddy, Sugarcane, Banana and harvested Land	572.47	
		Dry crop/Rainfed land	Cholam, Kambu and Groundnut	130.8	
		Plantation	Cashew plantation	49.06	
		Groves	Groves - Coconut, Mango	88.14	
				840.47	58.3
3	Barren / Waste Land	Barren land	Barren land	116.35	
			Rocky outcrop	1.62	
		Bushes	Scrub	102.38	
		Salt affected / Sandy area	Alkaline	9.61	
			Sandy area	0.61	
				230.57	

					15.99
4	Others	Saltpan	Saltpan	5.54	
		Aqua culture	Aqua culture	0.18	0.39
				5.72	
5	Water body/ Wet land	Water body	Tank	259.66	
			River	18.0	
		Wetland	Mangroves	0.98	
				278.64	19.32
Total Area				**1441.58**	**100%**

2.7.3.Kottakkaraiyar Sub Basin

In Kottakkaraiyar sub basin, harvested or current fallow which falls under agricultural land covers by 1293.82 sq.km**(Table 2.8)**.The agricultural land includes dry crops and groves**(Plate PK-12C)**. Water bodies cover about 337.10 sq.km, which is 15.29 % of the sub basin area. Barren land occupies an area of 297.15 sq.km which is 13.48 % of the sub basin area. The major urban settlements viz. Kalayarkovil, Sivaganga, Devipattinam and Nattarasankottai included in the built up land category occupies 134.76 sq.km whichis6.11 % of sub basin area. Aquaculture activities are observed in some places near Devipattinam in the coastal region. Mangroves are existing in the estuary of Kottakkaraiyar river in the coast. Some of the land use features are shown in **figures 2.23 to 2.28.**

Table 2.8. Land use patterns in Kottakkaraiyar sub basin for the year2018

Sl. No.	**Land use Category**			**Kottakkaraiyar Sub basin Area in 2018**	**Percentage Area in 2018**
	I Level	II Level	III Level	Sq.km	
1	Built up land	Settlement and others	Urban	26.1	
			Rural	108.66	
				134.76	6.11
2	Agriculture	Wet Crop / Irrigated Land	Paddy, Sugarcane, Banana and harvested Land	1293.82	
		Dry crop/Rainfed land	Cholam, Kambu and Groundnut	101.69	
		Groves	Groves - Coconut, Mango	32.14	
				1427.65	64.75
3	Barren/Waste Land	Barren land	Barren land Rocky outcrop	173.98	
		Bushes	Shrubs	0.82	

			Scrub	110.64	13.45
		Salt affected / Sandy area	Alkaline	0.36	
			Sandy area	10.86	
				296.66	
4	Others	Saltpan	Saltpan	7.46	
		Aqua culture	Aqua culture	0.78	
				8.25	0.37
5	Water body/ Wet Land	Water body	Tank	319.35	
			River	17.47	
		Wetland	Water logged area	0.27	
			Mangroves	0.49	
				337.58	15.31
Total Area				2204.91	100%

Fig. 2.23 Current fallow at Kalaiyarkoil

Fig. 2.24 Grove-Coconut at Nattarasankottai

Fig. 2.25Mangrove at Devipattnam

Fig. 2.26Aqauculture at Thirupalakudi

Fig. 2.27Alkalinity/Salinity- Kila Nilakottai

Fig. 2.28Alkalinity/Salinity- Kasangugi

2.7.4 Inferences

The land use study of Pambar Kottakkaraiyar basin reveals that the built up land comprises of rural and urban settlements, industries, etc. appears in the imagery as definite shape and pattern, medium to coarse texture and lighter tone. This category is covers 302.58 sq.km and are under intense use. Out of which, 90.11 sq.km area comes under urban and 212.05 sq.km area comes under rural and 0.409 sq.km area covered by industries.

Agricultural practices are observed in major parts of the basin. Surface water and groundwater are conjunctively used in this basin for irrigation. Wet crops and dry crops are being cultivated. Paddy, banana and sugarcane are the main wet crops and dry crops such as sesame, groundnut, cholam, ragi, etc. are being cultivated. As per the satellite data based land use classification for the year 2018, wet crops cultivation is2488.75 sq.km (248875 ha) and dry crop is 729.09 sq.km area (72909 ha). The total area of agricultural land is 3669.05 sq.km (366905 ha) which includes, wet crop, dry crop, groves and cashew plantation.The graphical representation of cultivated land is given in **figure 2.29.**

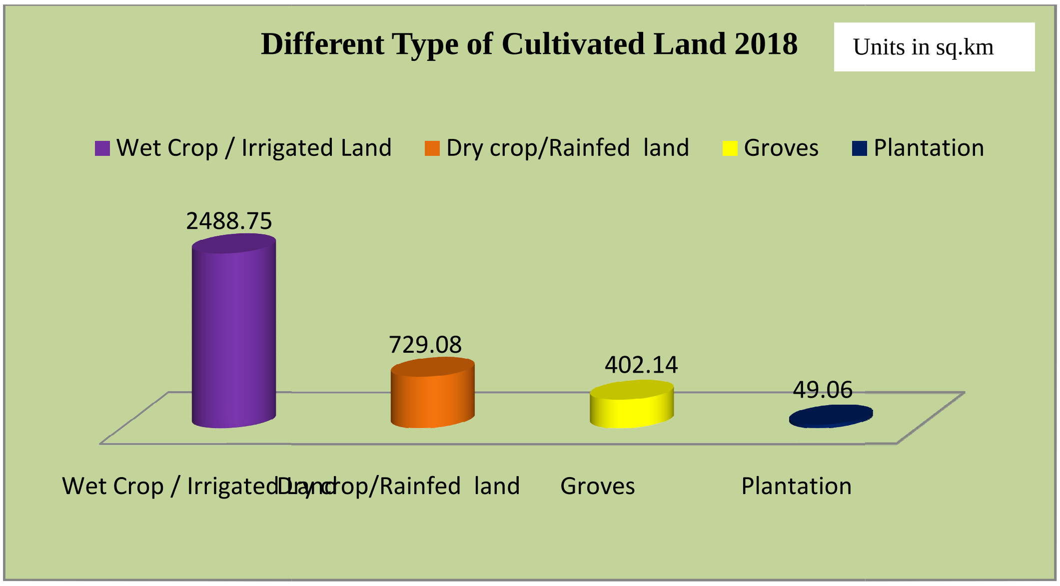
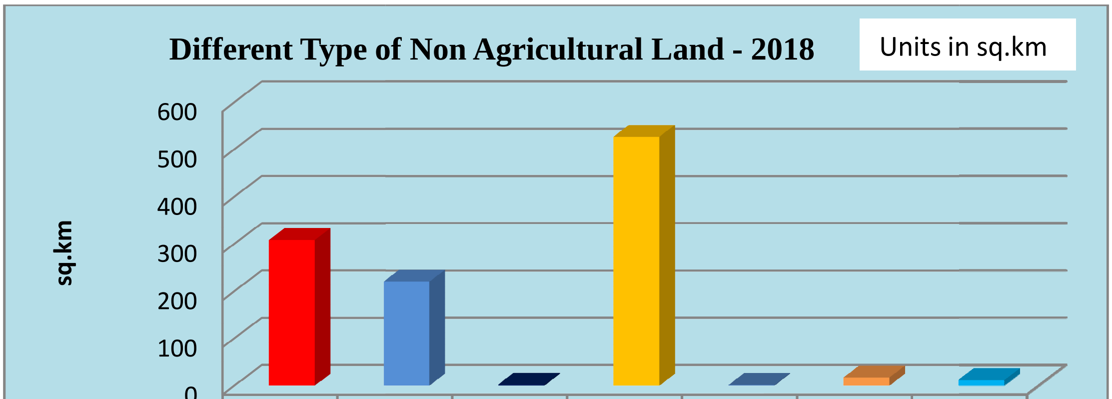


Fig. 2.29 Different type of Cultivated land in 2018

The area of cashew plantation is 49.06 sq.km.Groves in the basin comprises of mango, eucalyptus and coconut. Groves occupies 402.143 sq.km.

Some of the lands are not suitable for either cultivation or for any other practice. Such lands are unproductive because of the nature of the soil i.e alkaline. Such type of soil landforms are sparsely spread over the basin.

The area of non agricultural land is 1089.21 sq.km. The alkaline / salinity areais 17.3 sq km, and the graphical representation of all types of non agricultural land is given in **figure 2.30.**



	Barren land	Rocky outcrop	Shrubs	Scrub	Mangrove	Alkaline	Sandy area
2018 Area	308.28	220.4	2.86	527.42	1.47	17.31	11.47

Fig. 2.30 Different type of non agricultural land in 2018

Water bodies like tanks, ponds, oorunis and rivers, water logged areas such as wetlands/swamps are noticed in the basin which covers 850.76 sq km area.The water bodies for the year 2018 are delineated using February 2018 satellite data in which, all water bodies have full of water with larger extent of water spread area. These area may vary since the information is as on the date on which the satellite passes over the basin area.

The forest lands include reserved forest, open forest with forest blanks are observed in the basin area.

2.8 Lineament

The geological structures, which could be faults,folds, deep fractures, contact zones of rock types were studied and discussed.The lineaments are controlling the flow pattern of major river courses of this basin. Some of them are probable fault, fractured zones and contact zone of geological formations.

The surface lineaments were interpreted visually using IRS P2 LISS III satellite data.Further,the Shuttle Radar Topography Mapping(SRTM) data of United States Geological Survey (USGS), which provides topographic elevation of the earth surface with 90 m spatial resolution was studied using Image Processing and Geographic Information System software.The shaded relief image was generated by giving imaginary light source which gave different shades to the topography, according to the relief of the earth surface.Such relief variation and related shades aided in the precise mapping of the surface lineaments which were expressed as long and linear, well defined depressions. Also the aerial photographs on 1:50,000 scale were studied visually and the lineaments were deduced. The lineaments,deciphered from the satellite image, the SRTM and aerial photographs were integrated and a GIS layer on surface lineaments was prepared (**Plate PK-13**).

Lineament and lineament intersection are the key parameters in the evaluation of landforms.The occurrence of groundwater in the hard rock area are in heterogeneous environment. Greater influence is effected when the lineament with open fractures are overlained by semi consolidated sandstone, porous loose unconsolidated fluvial landforms and various pediments. Lineaments are weak planes and provides effective secondary porosity to the under lying charnockite and hornblende biotite gneisses.The lineaments mapped were cut across byseveral geomorphic units with varying litho units, and act as major conduits for sub surface movement of groundwater in multi direction and also form linear aquifers for enhancing the storage of groundwater in Pambar Kottakkaraiyar basin .

The bore well, which is located in the lineament intersection zone and along lineament zone yields good amount of groundwater. In Pambar Kottakkaraiyar basin, there are six sets of lineaments, which are furnished as below :

1. N-S trending lineament
2. E-W trending lineament
3. NNW-SSE trending lineament
4. ENE-WSW trending lineament
5. WNW- ESE trending lineament
6. NNE-SSW trending lineament
7. NE-SE trending lineament

2.8.1 WNW-ESE Trending Lineament

Lineament is having regional control from Nattam to Tiruppattur which extends upto the coast.

2.8.2 NNE-SSW Trending Lineament

Fractured lineaments, run from east of Chadurvedamangalam to Nerkuppai, another from Kunnakudi to Ponnamaravathi and the next one in the west from Sirumalai reservedforest through Sirugudi Village.

2.8.3 N – S Trending Lineament

A prominent North – South trending lineament is passing through Palaeodeltaic plain (Alluvium) west of Hanumantakudi and along Devakottai, Pallathur, Aravayal and Puduvayal further north in the alluvial contact zone/ sandstone area.Inferences from the lineaments, hydro-geomorphological and subsurface lithological study reveals the following.

The weathered and fractured zone thickness is ranging between 41 and 70 m,below the ground level in the hard rock area where lineament intersection points are dominant; whereas the weathered and fractured zones thickness is ranging between 70 and 160m in the hard rock sedimentary contact zone

In hard rock, sedimentary contact lineament zone,weathered and fractured zone - thicknessis ranging between 70 and 160 m.In the area where sediments overlain the hard rock, the weathered and fractured zones and thickness range varies from 70 to 750 m.

Intensity of lineament frequency is very well exhibited and brought out clearly from the satellite imagery of Pambar Kottakkaraiyar river basin. The lineament intensity and its frequency is showing strong signature at thewest of Karungalakkudi and Kottampatti area, Singampunari and Ponnamaravathi areawhere Palar river is coursing in thenorthwest andsoutheast direction.

Pediplains are widespread in Sendurai, Nattam, Ponnamaravathi, Kilvalau, Sivaganga, Tirumayam, Kunnakudi and Tiruppattur area, where NNE-SSE, NW-SE, NNW-SSE, N-S, ENE-WSW trending lineaments are common. The lineament frequency is moderate in eastern pediplain area with intensively fractured and jointed zones. In Ayyalur reserved forest, Karandamalai reserved forest and Sirumalai reserved forest area the ENE-WSW,NNW-SSE and WNW-ESE trending lineaments are dominant. The width and depth of lineament zone varies laterally and vertically in different litho unit.

Intersections of lineaments are found to be potential groundwater zones. A detailed investigation can be formulated to undertake detailed hydrofracture study in these zones, which are falling under the drought prone districts of Ramanathapuram, Pudukkottai and Sivagangai.

After the identification of lineament in the field, Electro Magnetic (EM 34-3) survey is recommended to identify the width and depth of the fractured zones. Further, it could be confirmed by geophysical resistivity survey for drilling the boreholes.

Almost the entire shallow aquifer zone is tapped for agriculture development in hard rock areas. Hence, to meet the future demand for groundwater, a detailed investigation is warranted in the fractured aquifers. The fractured aquifer can be used for artificial recharge and for storing groundwater in the underground reservoir.

The identification of fractures/jointed zones and contact zone of geological formation in the field will be very useful for constructing the recharge structure across the fractured zone, which will facilitate to raise the groundwater level.

2.9 Geophysics

Electrical Resistivity methods are widely used to delineate the subsurface formations including aquifer. This method involves measurement of resistances of different layers of sub surface by sending current into earth through metal electrodes using different methods of electrode configurations. This measurement of electrical resistivity of different layers of sub surface is called Vertical Electrical Sounding (VES). The results of Vertical Electrical Soundings (VES) conducted in this basin area are analysed and used in order to have better interpolation. The VES together with borehole lithology forms the data base in determination of depth, thickness and spatial distribution of Top Soil, Weathered rock, Fractured and Jointed rocks.

2.9.1 Methodology

Geologically, Pambar Kottakkaraiyar basin can be divided into hard and sedimentary rocks by a contact zone traversing in the middle of the basin. Hard rock formations occur in the upper reaches of the basin. Hard rock comprises of Archaean Quartzite, Charnockite, Gneiss, Migmatite, Granitic and acidic rocks. In the north and north eastern part of the basin these hard crystalline rocks makes predominant lithology. In the lower reach of the basin, towards east and south to contact zone, sedimentary rock types makes the prominent lithology.Sedimentary rock is comprised of Upper Gondwana sediments Cuddalore formation and Recent to sub recent sediments. According to these geological information, the available data of borehole lithology and VES are verified and correlated. The top soil and unconsolidated top layers are identified and demarcated by low resistivity zones. Similarly the thickness of weathered and fractured/ jointed formations are demarcated by moderate and high resistivity values respectively. The details of 73 numbers of Vertical Electrical soundings are appropriately used with 171 numbers of bore well lithological data andare simulated using GIS software for obtaining sub surface geometry of the basin. However, the information about subsurface lithology is restricted to depth of bore wells and depth of penetration of electrical resistivity measurements. The information thus obtained are used in the GIS environment for creation of thematic maps of top soil/unconsolidated formation, weathered rock and fractured / jointed rock layers of the basin (**Plate PK-14, Plate PK-15 and Plate PK-16).**

2.9.2 Topsoil/ Unconsolidated Formation

Plate PK-14 represents spatial distribution, and depth of occurrence of topsoil in m below ground level. Based on the depth of occurrence, these formations are classified further into six sub divisions namely 1. Layers from 0-5 m below ground level, 2. Layers from 5-10 m bgl,3.Layers from 10-15 m bgl,4.Layers from 15-20 m bgl, 5. Layers from 20-30 m bgl and 6. Layers from 30-40 m bgl .The shallow layer of 0-5 m bgl covers majority of the basin area in the central, northern and north eastern part of the basin where, hard rock makes the major lithology and extends up to the upper reaches of sedimentary region. Another shallow layer of 5-10 m bgl occurs as a layer parallel to the coast in sedimentary formation area. The moderately deeper layers of 10-15 m bgl and 15-20 m bgl are observed in sedimentary formations as parallel layers. The deep layer of unconsolidated formations of 20-30 m bgl is mainly observed in the southern portion of the basin parallel to the coast. The deepest layer of unconsolidated formations of 30-40 m is mainly observed in very limited area of sedimentary formations in southern side of the basin.

2.9.3 Weathered Formation

Spatial distribution and depth of occurrence of weathered formation is represented on **Plate PK-15**.This formation may form shallow aquifers on the basis of the depth of the formation. This layer is further subdivided into 5 sub layers based on depth of occurrence and thickness of layers in the basin. The shallow depth of weathered rock ,which is 5-10 m bgl exists in only limited portion in northern region. Formation with 10-15 m bgl covers the entire northern region of the basin. The formations having moderate depth and thickness of weathering 15- 25 m bgl exists mainly in the lower reaches of the hard rock region. The deep weathered formation of 25-35 m bgl occurs only in limited parts as small patches in the southern part of hard rock region. The deepest weathered depth of 35-45 m bgl is found in the lower part of the hard rock region and is found in contact with the sedimentary rock formations.

2.9.4 Fractured / Jointed Formations

Plate PK-16 represents spatial distribution and depth of occurrence of fractured/jointed formation. This zone underlies weathered formation and overlies the basement rocks forming the part of aquifer system. Based on depth of occurrence below ground level, this formation is further sub divided in to 5 sub layers.The layer from 10-20 m bgl is found in small portion of theupper reaches of hard rock region of the basin. The zone of fractured formation which is 20-30 m bgl covers major part of the hard rock region. Most of the area of lower portion of hard rock region is covered by the 30-40 m bgl of the fracturedformation. The deep layer of 40-50 m bgl occurs in small region in the lower area of hard rock region and the deepest layer of 50-63m bgl is found in contact with sedimentary formations about the middle of the basin.

2.9.5 Depth to Bed Rock

Generally bed rocks are observed below weathered or fractured formation in hard rock area. Hence, bottom of these formations are considered as depth of occurrence of bed rock. As per the classification of sub surface layers, it is observed that the bottom layer of fractured rock is mainly30 - 50m bgl which is considered as depth to bed rock in major part of hard rock area of the basin.

The shallow layer of top soil at 0-5 m bgl covers more than 70% of the basin area and shallowdepth of 5-10 m bgl makes about 5 % of the basin area. Moderate depth of 10-15 m bgl and 15-20 m bgl makes about more than 10% of basin area. Remaining deeper layers of unconsolidated formation makes 10-15% of the area of the basin.

The weathered formation of 10-15 m bgl and 15-25 m bgl are observed about 80% of the hard rock area of the basin.The fractured and jointed formations of 20-30 m bgl and 30-40 m bgl occur in 50-60% of the basin area in hard rock region.The deeper layer of top soil or unconsolidated formation occurs in the sedimentary region parallel to the coast. The deeper zone of weathered and fractured layers occurs in hard crystalline rock and sedimentary rock contact zone.

For groundwater recharging purpose, the zones of deeper top soil /unconsolidated formations and deeper thickness of weathered formations are most suitable.

2.10 Soils

Introduction:

Soil is a mixture of organic matter, minerals, gases, liquids, and organisms that together support life. Earth's body of soil, called the pedosphere, has four important functions:

- as a medium for plant growth
- as a means of water storage, supply and purification
- as a modifier of Earth's atmosphere
- as a habitat for organisms

All of these functions, in their turn, modify the soil. The pedosphere interfaces with the lithosphere, the hydrosphere, the atmosphere, and the biosphere. There are different layers in soil that serve different purposes. Humus is the top layer of soil which is very nutrient and mineral rich and ideal for plant growth. The subsoil which is less nutrient but contains lots of minerals and some solid rock pieces.pH of the soil affects plant's growth. Very acidic or alkaline soils make it difficult for certain plant species to become established. Micro organisms in the soil convert toxic compounds within the soil into useful nutrients for plants. For example, ammonia is converted into nitrogen in the nitrogen cycle. These micro organisms also decompose organic matter.

The soil pertaining to the Pambar Kottakkaraiyar river basin has been shown in Plate No. Plate PK - 17 and Plate PK - 18. The predominant soil types found in this river basin is Inceptisols, Alfisols, Entisols and Vertisols.

Soil Classification maps were prepared in 1996 by National Bureau of Soil Survey and Land use Planning, Bangalore (NBSS) in co-operation with the Department of Agriculture, Tamilnadu. The nature of soils with corresponding mapping units in the Pambar and Kottakkaraiyar basin is shown in the following table. (Table 2.10.1)

Table 2.9.1 Soils prevailing in Pambar Kottakkaraiyar basin and its properties.

Sl No	Name of soil type	Soil unit number
1	Alfisols	27,96,169,176,177,187 & 191
2	Inceptisols	66,81,103,210,212,234,246,248,250, 257,259,263 & 264
3	Entisols	195
4	Vertisols	242

Alfisols:

This order consists of deep to very deep, matured soils with alluvial concentration of clay in the sub horizon. The surface horizon is massive and hard. Cultivation is extensive on these soils. They have moderate to high base saturation. Nine sub groups belonging to this category are described below.

a) Typic Haplustalfs:

This consists of reddish to brownish, deep to very deep, moderately drained to well drained, medium to heavy textured, moderately rapid to rapid permeability. Calcareousness in the form of calcic horizon or powdery lime is present, at moderate depth.

b) Udic Haplustalfs:

These soils are similar to Typic Haplustalfs except that they do not have calcic origin.

c) Ultic Haplustalfs:

These resemble Typic Haplustalfs, except that they have base saturation less than 75 % in the textural horizon.

d) Vertic Haplustalfs:

These are also like Typic Haplustalfs but are heavy textured and develop cracks.

e) Typic Rhodustalfs:

These are comparatively dark red soils than Typic Halplustalfs and have secondary carbonates at moderate depth.

f) Udic Rhodustalfs:

These are like Typic Rhodustalfs but do not have secondary lime in the sub horizon and are non-calcareous.

g) Udic Paleustalfs:

The B horizon has a colour hue of 5 YR or Yellower in some part or has a value of 4 or more. They do not have secondary carbonates in the sub surface.

h) Vertic Natrudalfs:

This consists of dark greyish brown, very deep, medium textured, calcareous and imperfectly drained soils. They are alkaline in nature and have sodium accumulation in the diagnostic horizon with Exchangeable Sodium Percentage of 15 %.

i) Plinthustalfs:

Soils of this group are reddish, deep to very deep and well drained but have plinthite, humus, poor mixture of clay within 1.25 m of the soil surface.

Inceptisols:

This comprises of immature soils having profile features more weakly expressed. All the pedogenic processes are active to some extent but none predominates in these soils. They are poorly drained to well drained with moderate to rapid permeability. Most of them are cultivated under irrigated or rain fed conditions.

Entisols*:*

These soils show little or no evidence of development of pedogenic (diagnostic) horizons. Horizons have not been formed in these soils due to shortness of time for pedogenesis. Surface material is removed from the site as fast as the diagnostic horizons are formed. They are found distributed on steep, actively eroding slopes and on flood plains which receive new deposits of alluvium. Erosion is active in these soils. Resistant nature of the parent material like quartzite, bed rock etc, prolongs the period of undistinguished horizonation.

The following are the 4-sub groups identified under Entisols**.**

a) Typic Ustorthentic:

These are reddish brown to red, light to medium textured and mostly non-calcareous soils. They are well drained externally and the permeability is moderate to rapid. Soil erosion is the major concern in this soil. Dry cultivation with millets, pulses and groundnut is quite common.

b) Lithic Ustorthents:

These soils resemble Typic Ustorthents but their depth is within 50 cm followed by bedrock.

c) Typic Ustifluvents:

These soils are dark brown to dark grey soils of fluvial (alluvial) origin with rapid permeability and are well drained. Stratification of layers on account of fluvial deposition with irregular decrease in organic matter along depth is common. These are confined to river systems. Intensive agriculture is being followed on these soils both in irrigated and rain fed.

d) Typic Ustipsamments:

These soils are very deep, freely drained sands and have low water holding capacity.

Vertisols:

This order includes dark brownish grey, very deep, calcareous, heavy clayey and self-churning soils that have deep wide cracks. The surface shows a complex micro topography of mounds and depressions. Slickenside feature is common in the sub surface and the mineralogy is dominantly montmorillonitic, which is a expanding clay. They are moderately well drained with low permeability except in the cracks.

The following two sub groups are identified under Vertisols**.**

a) Typic Chromusterts:

These have a Chroma, moist of 1.50 percent or more and colour value, of less than 3.50 percent and a value of dryness less than 5.50 percent throughout the 30 cm of the pedon and surface soils are grey in colour. The cracks remain open for more than 150 cumulative days in most years.

b) Udorthentic Chromusterts:

The cracks of these soils remain open from 90 to 150 cumulative days in most of the years with higher colour values.

Mapping Unit	**DESCRIPTION AND PROPERTIES OF SOILS.**
27	Deep, well-drained, gravelly clay soils on gently sloping lands, moderately eroded, associated with; deep, well drained, clayey soils.
66	Shallow, somewhat excessively drained, gravelly loam soils on moderately sloping, low hills, severely eroded; associated with moderately shallow, well-drained gravelly clay soils.
81	Moderately deep, well-drained, gravelly clay soils on gently sloping lands, severely eroded; associated with; moderately shallow, well drained, clay soils.
96	Moderately deep, well drained, gravelly clay soils on undulating lands, moderately eroded; associated with; moderately shallow, well-drained, clayey soils.
103	Moderately shallow, well-drained, calcareous clayey soils of gently sloping, inter hill basins, slightly eroded, associated with; very deep, well drained, loamy soils.
169	Moderately deep, well drained, clayey soils on undulating lands, moderately eroded; Associated with rock outcrops.
176	Moderately deep, well-drained, gravelly clay soils on very gently sloping lands; moderately eroded; associated with deep, well drained, gravelly soils.

177	Deep ,well drained; gravelly clay soils on very gently sloping lands, severely eroded; associated with; shallow, somewhat excessively drained, loamy soils.
187	Moderately shallow somewhat excessively drained, gravelly loam soils on undulating lands moderately eroded; associated with; moderately shallow, well drained; gravelly clay soils with slight erosion.
191	Deep well-drained, loamy soils on gently sloping lands, moderately eroded; associated with; deep well drained; loamy soils.
210	Deep, somewhat excessively drained, loamy soils on very gently sloping lands moderately eroded; associated with; moderately shallow, somewhat excessively drained, loamy soils.
212	Deep, moderately well drained, calcareous, loamy soils on nearly level, tank irrigated lands, slightly eroded; associated with; deep moderately well drained, clayey soils.
234	Very deep, poorly drained, calcareous, clayey soils of nearly level lands slightly eroded; associated with; moderately shallow, well drained, calcareous, clayey soils on undulating land with moderate erosion.
236	Deep, moderately well drained, clayey soils on nearly level valleys, slightly eroded; associated with; deep, imperfectly, clayey soils of gently sloping valleys.
242	Very deep, moderately well drained, calcareous clayey soils of nearly level lands, moderately eroded, associated with very deep imperfectly drained, calcareous, cracking clay soils.
246	Moderately shallow, well drained, gravelly loam soils on very gently sloping lands, moderately eroded, associated with deep well drained, loamy soils.
248	Moderately deep, somewhat excessively drained, gravelly clay soils on very gently sloping lands, moderately eroded; associated with deep well drained, gravelly clay soils on nearly level lands with slight erosion.
250	Moderately shallow, somewhat excessively drained, gravelly clay soils on very gently sloping laterite land. Severely eroded, associated with; shallow well-drained, gravelly clay soils.
257	Very deep, imperfectly drained, calcareous cracking clay soils on nearly level, tank irrigated lands, slightly eroded; associated with very deep, imperfectly drained, clayey soils.
259	Very deep moderately well drained calcareous clayey soils on nearly level low lands, slightly eroded, associated with very deep, moderately well drained, calcareous clayey soils.

263	Very deep, moderately well drained, calcareous cracking clay soils on nearly level, tank irrigated lands. Slightly eroded, associated with; very deep, moderately well drained, calcareous clayey soils on gently sloping lands.
264	Very Deep, moderately well drained, calcareous, clayey soils on nearly level lands, slightly eroded, associated with; very deep, moderately well drained, calcareous, cracking clay soils.
279	Periodically flooded lands, salt affected.
282	Periodically flooded lands, salt affected.

Based on the accompanying NBSS Report on land use (Soil Resources of Tamil Nadu for Land-use Planning Executive Summary Report, NBSS Publication No.46,1997) and the corresponding soil classification map, the irrigable soils of the Pambar and Kottakkaraiyar river basin were identified. The irrigable soils main properties are summarized in Table 2.10.3 and their interpretative classifications for land capability for crop production, irrigability and suitability for rice, sugarcane, groundnuts and cotton are given in Table 2.10.2.

Table: 2.9.2.
Soil Major Properties

Type	Unit(*)	Drainage	Surface texture	Depth (cm)	Slope (%)
I	66	S.W. Exc	Ls	100-150	1-3
	187	S.W.Exc	ls	100-150	
	190	Well	cl	50-150	
	191	Well	ls	100-150	
	195	Excess	s	100-150	
	210	S.W.Exc	ls	50-150	
	246	Well	ls	50-150	
II	27	Well	c	100-150	1-3
	81	Well	c	100-150	
	96	Well	c	100-150	
	169	Well	c	100-150	
	176	Well	c	100-150	
	177	Well	c	100-150	
	235	Mod.well	c	50-150	
	248	S.W.Exc	c	100-150	
	250	S.W.Exc	c	100-150	
	103	Well	Cal cl	100-150	
	212	Mod.Well	Cal lo	>150	

Type	Unit(*)	Drainage	Surface texture	Depth (cm)	Slope (%)
III	215 222 234 242 254 257 259 263 264	well Mod well Poor Mod. well Impr Impr Mod Well Mod Well Mod Well	Cal lo Cal cl Cal cl Cal cl Cal cl Cal cl Cal cl Cal cl Cal cl	>150 >150 >150 100-150 >150 >150 >150 >150 >150	1-3
IV	279 282	Well Well	Rocky Rocky	>150 >150	1-3

Drainage
Mod. = Moderately
S.w.exc = somewhat excessive
Impr = Imperfect
c=clayey

Texture
s = sandy
cal cl = calcareous clay.
ls = loamy-sand

(*) Soil association according to NBSS Publication No.46 1997
(**) Per 1 m of soil depth or the entire column if the soil is shallow.

Soil Texture:

Percentage of soil texture in Pambar Kottakkaraiyar basin (Map plate PK - 18)

Sl.No.	Soil Texture	Percentage (%)
1	Clay	15.14
2	Clay loam	4.36
3	Loam	0.01
4	Loamy sand	6.93
5	Sand	5.31
6	Sandy clay	13.19
7	Sandy clay loam	15.77
8	Sandy loam	23.29
9	Miscellaneous, Water body and Habitation	16%

Table 2.9.3 Status of Macro Nutrients in the Districts of Pambar Kottakkaraiyar River Basin

Sl.No	District	Soil deficiency in terms of nutrients in			
		N	OC	P	K
1	Dindigul	80.08%	76.10%	37.44%	2.39%
2	Madurai	98.56%	53.43%	19.16%	13.24%
3	Pudukkottai	98.99%	95.90%	25.62%	55.91%
4	Ramanathapuram	99.65%	84.97%	33.73%	6.64%
5	Sivaganga	99.93%	96.81%	16.53%	12.72%
6	Tiruchirappalli	99.91%	97.54%	52.62%	2.65%

N - Nitrogen , OC - Organic Carbon , P - Phosphorous , K - Potassium.

Table 2.9.4 Status of Micro Nutrients in the Districts of Pambar Kottakkaraiyar River Basin

Sl.No.	District	Zn %		Fe %		Cu %	
		S	D	S	D	S	D
1	Dindigul	76.59%	23.41%	52.89%	47.11%	92.68%	7.32%
2	Madurai	67.75%	32.25%	70.59%	29.41%	97.93%	2.07%
3	Pudukkottai	61.46%	38.54%	57.94%	42.06%	96.47%	3.53%
4	Ramanathapuram	28.03%	71.97%	77.33%	22.67%	95.03%	4.97%
5	Sivaganga	33.48%	66.52%	70.87%	29.13%	67.51%	32.49%
6	Tiruchirappalli	94.06%	5.94%	71.39%	28.61%	99.82%	0.18%

Sl.No.	District	Mn %		B %		S %	
		S	D	S	D	S	D
1	Dindigul	75.20%	24.80%	22.74%	77.26%	55.73%	44.27%
2	Madurai	80.90%	19.10%	20.55%	79.45%	77.21%	22.79%
3	Pudukkottai	96.96%	3.04%	67.06%	32.94%	63.34%	36.66%
4	Ramanathapuram	90.71%	9.29%	14.55%	85.45%	88.97%	11.03%
5	Sivaganga	90.85%	9.15%	36.83%	63.17%	52.47%	47.53%
6	Tiruchirappalli	92.64%	7.36%	0.86%	99.14%	99.94%	0.06%

Source: Soil Health Card

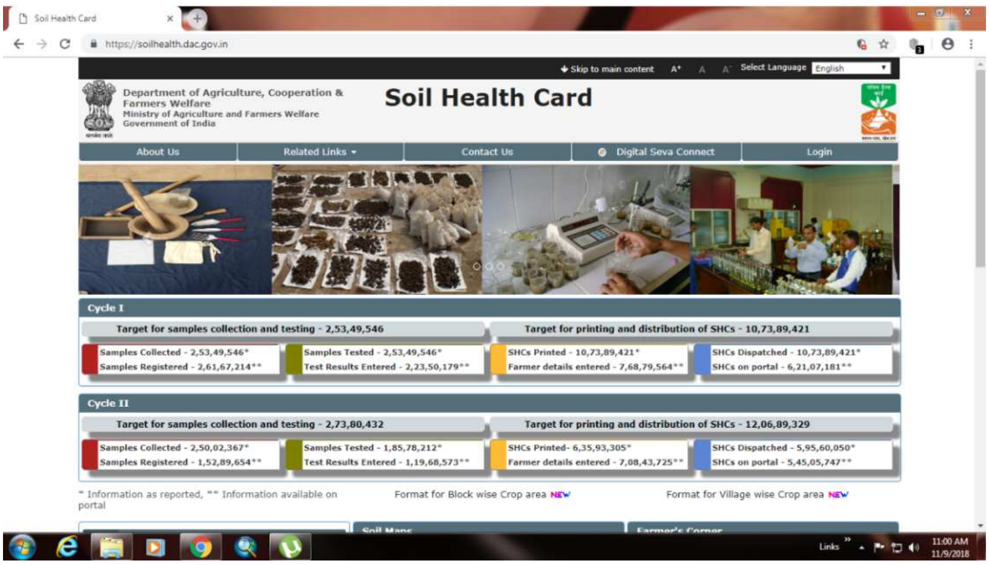
Nutrient Management

Role of organic matter in soil fertility includes the physical and structural condition of the soil maintained by the organic matter. Organic matter improves the soil to dissolve many insoluble soil minerals which are necessary for the plant growth.

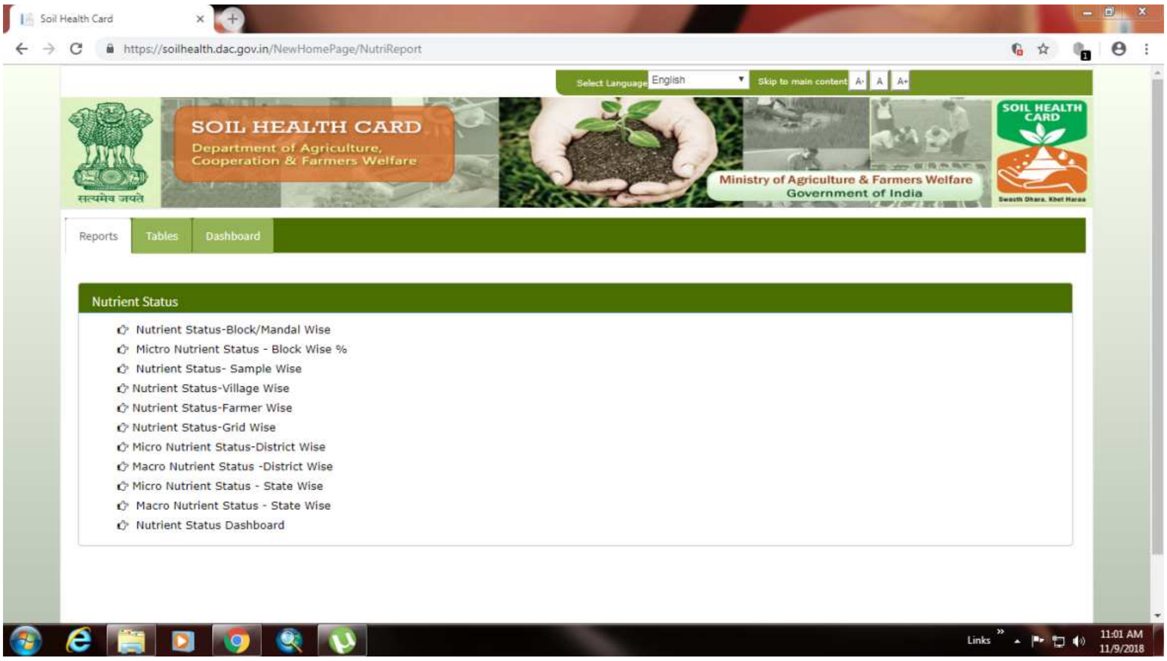
Resource Management

From the soil system, a considerable amount of nutrients are being removed through cultivation of crops, however, being replaced in the form of manure. Perhaps, leaching, erosion, volatilization etc., removes some nutrients from the soil. Soil fertility may be retained by soil testing and adding required organic matter so that the yield could be improved.

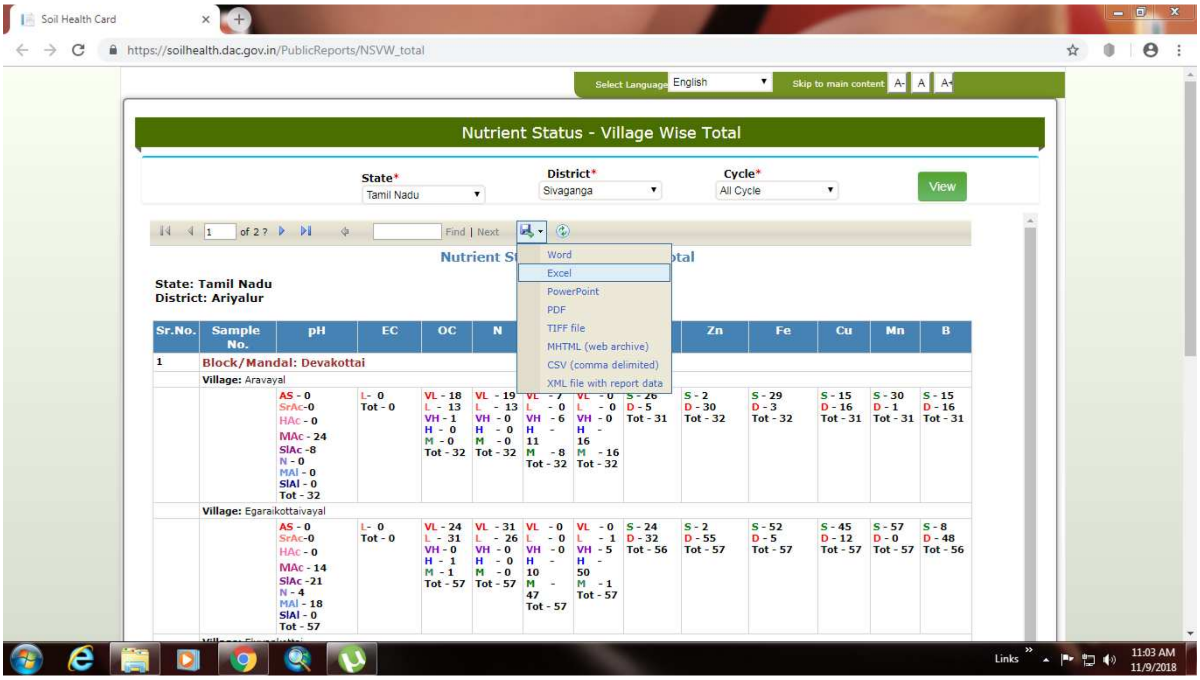
Guide to know the Soil Health - Village wise :



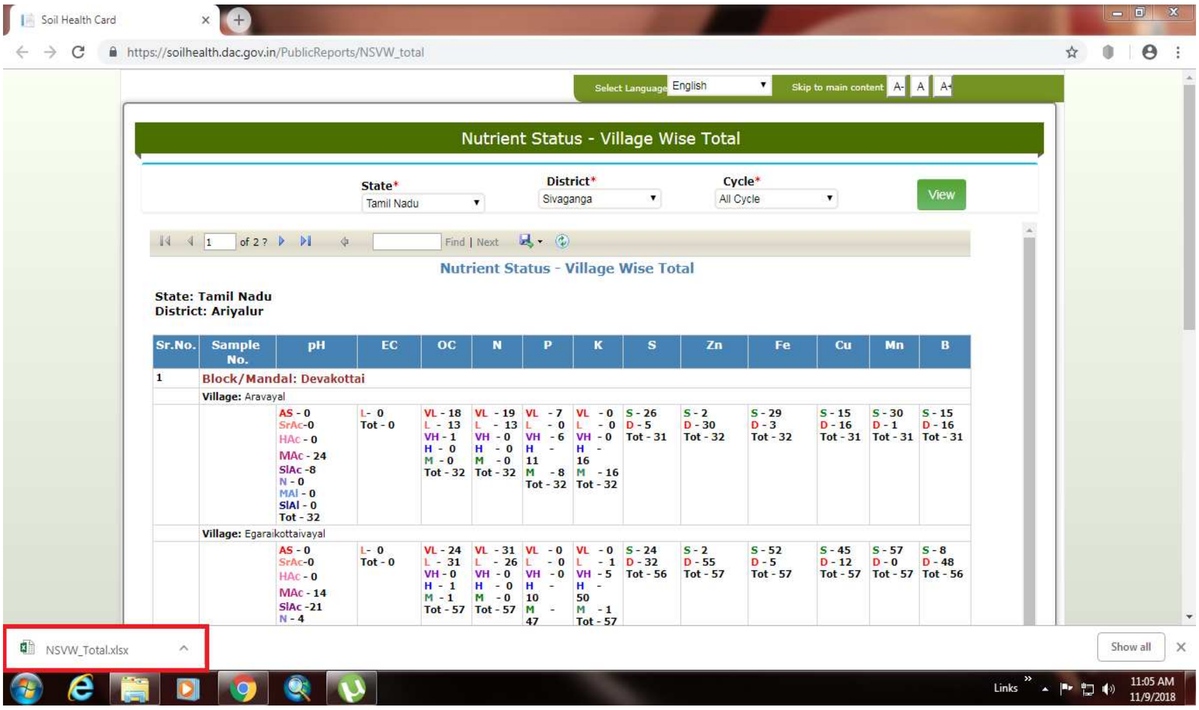
Step 1: Go to https://soilhealth.dac.gov.in
Step 2: Click the Soil health dashboard (A new tab appears)



Step 3: Click the Reports tab
Step 4: Click the Nutrient status/ Micro Nutrient status as per your need
Step 5: Fill the State ,District, Cycle in the given boxes and Click view button (Now it will show the report in an excel file)



Step 6: To down load the report, click the Export drop down menu and select EXCEL.



2.11 Social and Demographic Characteristics

The development of a particular city, town or a region depends upon natural, physical and socio-economic factors. Among these factors the population assumes significance in determining the future pattern of progress and development.

Population trend and population dynamics are important indicators of the present and future water requirement in the River Basin. Also, the social characteristics of the population such as literacy level, level of housing, electrification, in house facilities, urbanization trend, have indirect bearing on water planning.

The Pambar &Kottakkaraiyar River Basin covers part of Pudukottai, Trichy, Dindugal, Sivaganga,Madurai and Ramanathapuram districts. An analysis of social and demographic characteristics in the above six districts gives an idea of such characteristics in the Pambar &Kottakkaraiyar River Basin.

2.11.1 Population in Pambar KottakkaraiyarRiver Basin

The PambarKottaraiyar basin comprises of 18% of total area of Pudukottai District (845.29 sq.km out of 4652.99 sq.km), 1% of total area of Trichy District (34.07 sq.km out of 4467.20 sq.km), 9% of total area of Dindugal(531.36 sq.km out of 6066.73 sq.km) ,78% of total area of Sivaganga District (3181.57 sq.km out of 4104.29 sq.km),8%of total area of Madurai District (300.41 sq.km out of 3701.77 sq.km),and 24% of total area of Ramanathapuram

District (1033.41 sq.km out of 4226.41 sq.km).The population of part of the districts which lie in Pambar &Kottakkaraiyar River Basin as per census 2011 is given below in Table 2.10.1

Table 2.10.1. District wise population details of Pambar&kottakkaraiyar River Basin

Sl.No.	Name of the District	Population in 2011			Population during 2018		
		Rural	Urban	Total	Rural	Urban	Total
1	Dindugul	0.329	0.039	0.368	0.378	0.045	0.422
2	Madurai	0.152	0.040	0.192	0.175	0.046	0.221
3	Pudhukkottai	0.264	0.255	0.521	0.305	0.293	0.599
4	Ramanathapuram	0.203	0.071	0.274	0.233	0.082	0.315
5	Trichy	0.018	0.000	0.018	0.021	0.000	0.021
6	Sivaganga	0.660	0.282	0.942	0.758	0.324	1.082
Total		**1.627**	**0.688**	**2.315**	**1.870**	**0.790**	**2.660**

There are 3(three) sub Basins in Pambar &KottakkaraiyarRiver Basin. The villages and towns falling under each sub basin are sorted out using GIS and its corresponding population is extracted from Census 2011. The village wise population details of each sub basin in Pambar& Kottakkaraiyar River Basin are given in **Appendix 2.9 to 2.11.**The Sub Basin wise Population of Pambar &Kottakkaraiyar River Basin is given in the **Table 2.10.2**. as per census 2011 and projected to year 2018.The population of Pambar&KottakkaraiyarRiver Basin is further projected for the targeted years 2020, 2030 , 2040 & 2050 which is detailed in Chapter 7.

Table 210.2 Sub Basin wise Population in PambarKottakkaraiyar River Basin

S. No	Name of Sub basin	As per census 2011 (in million)			As projected to 2018 (in million)			
		Rural	Urban	Total	Rural	Urban	Total	
1	Manimuthar	0.803	0.366	1.169	0.922	0.420	1.343	
2	Pambar	0.351	0.125	0.476	0.403	0.144	0.547	
3	Kottakkaraiyar	0.449	0.221	0.670	0.516	0.254	0.770	
	Total	**1.603**	**0.712**	**2.315**	**1.841**	**0.818**	**2.660**	

Source: Census 2011

2.11.2 Population Growth

Population growth is influenced by many factors that fall into the broad realms of demographic characteristics, socioeconomic conditions, transportation infrastructure, natural amenities, and land use and development across space and time.

In the micro level reappraisal study of the Pambar&Kottakkaraiyar River Basin, water demand from various sectors is arrived. The domestic water demand of the River Basin is

ascertained by calculating the population within the River Basin. Since, the population data as per census 2011 only available, the present population, population expected in the targeted year shall be accomplished by projecting the population. The population of the Pambar&KottakkaraiyarRiver Basin based on census 2011 is projected to the present year 2018 . The average annual exponential growth rate is used to find the growth of urban and rural population and projecting the population.

The exponential formula used for projecting the population is given below,

$$\mathbf{P_t = P_o (1+X)^t}$$

Where Pt = Population after‘t’ years

Po = Population in the beginning years

X = Average Annual exponential growth rate and is calculated by

$$X = \{e^{(\ln(Yt/Yo)/t)} - 1\} \times 100$$

Where ,X = Annual growth rate

Yo = Population in base year

Yt = Population in t^{th} year

t = Number of years (Current year – Base year)

t = Period in which year population is to be forecasted.

Development and population change are complex that they have exhibited spatial variations in different time periods driven by different factors. The average annual exponential growth rate of Rural population and urban population between and Census 2001-2011 is determined are tabulated as below,

S.No	Census Period	Average Annual Exponential growth rate	
	2001-2011	**Rural**	**Urban**
		2.14%	2.19%

Projections may be made with reference to the recent observed trend in growth. Hence, for this present forecast the growth rate may be adopted as 2.14% for Rural population and 2.19% for Urban Population. The projected population in Pambar&Kottakkaraiyar River Basin for 2018 is given below in **Table 2.10.3**

Table 2.10.3 Projected population in PambarKottakkaraiyarRiver Basin for 2018

Sl. No	Name of Sub basin	Area in Sq.km	Total Rural Population in million		Total Urban Population in million		Total	
			2011	2018	2011	2018	2011	2018
1	**Manimuthar**	2279.60	0.803	0.922	0.366	0.420	1.169	1.343
2	**Pambar**	1441.58	0.351	0.403	0.125	0.144	0.476	0.547
3	**Kottakkaraiyar**	2204.91	0.449	0.516	0.221	0.254	0.670	0.770
	Total	**5926.10**	**1.603**	**1.841**	**0.712**	**0.818**	**2.315**	**2.660**

Source: Census 2011

2.11.3 Population Density

Population density is a measurement of population per unit area. The Sub Basin wise population density of Pambar&KottakkaraiyarRiver Basin is given in Table **2.10.4.** The population density is higher in Manimuthar sub Basin (513 persons per sq.km) and lower in Kottakkaraiyar sub Basin(304 Persons per sq.km).

Table 2.10.4 Sub basin wise Population density in PambarKottakkaraiyarRiver Basin

Sl.No	Name of the sub Basin	Area (Sq.km)	Total population 2011	Density (Person/Sq.km)
1	Manimuthar	2279.60	1168839	513
2	Pambar	1441.58	476167	330
3	Kottakkaraiyar	2204.91	670251	304
Total		5926.099	2315257	1147
Average population Density				391

2.11.4 Population by Sex

The sex wise distribution of population in Pambar&KottakkaraiyarRiver Basin as per census 2011 is given in **Table 2.10.5**

Table 2.10.5 District wise Population by sex in Pambar KottakkaraiyarRiver Basin

Sl.No	Name of the District	Area of the district in the Basin in Sq.km	Total Population 2011 (million)	Population of Male (million)	% Male	Population of Female (million)	% Female
1	Dindigul	531.36	379696	191305	50%	188390	50%
2	Madurai	300.41	204358	102646	50%	101711	50%
3	Pudukottai	845.29	531791	265829	50%	265961	50%
4	Ramanathapuram	1033.41	215009	107307	50%	107701	50%
5	Sivaganga	3182	30250	15113	50%	15136	50%
6	Trichy	34	954153	474857	50%	479301	50%
	Total	**5926.10**	**2315257**	**1157057**	50%	**1158200**	50%

2.11.5 Sex Ratio

Sex ratio is the demographic concept that measures the proportion of males to females in a given population. Changes in gender composition largely reflect the underlying social, economic and cultural patterns of the society in different ways.

Sex Ratio is expressed as number of females for every 1000 males. The Pambar Sub Basin &Kottakkaraiyar Sub Basin has aequal sex ratio of 1000females to every 1000 males. The sex wise distribution of population in all the sub basins of Pambar&Kottakkaraiyar RiverBasin is given below in **Table 2.10.6**

Table 2.10.6 sex wise Population distribution in PambarKottakkaraiyarRiver Basin as per census 2011

Sl. No	Name of the Sub Basin	Population			Male %	Female %	Total %	Sex Ratio
		Male	Female	Total				
1	Manimuthar	0.586	0.583	1.169	50.13%	49.87%	100%	995 females for 1000 males
2	Pambar	0.239	0.237	0.476	50.22%	49.78%	100%	991 females for 1000 males
3	Kottakkaraiyar	0.333	0.337	0.670	49.71%	50.29%	100%	1012 females for 1000 males
	Total	**1.158**	**1.157**	**2.315**	**50.02%**	**49.98%**	**100%**	999 females for 1000 males

2.11.6 Literacy Level

The literacy level of the population is also a vital social indicator of the standard of living and social status. The literacy rate of thePambar&KottakkaraiyarRiverBasin is worked out sub basin wise and is given in **Table 2.10.7.** The overall literacy rate in Pambar&KottakkaraiyarRiver Basin is found to be 56.32 %.

Table2.10.7Details of Literacy level in PambarKottakkaraiyarRiver Basin

(Population in Million)

Sl.No.	Name of the Sub Basin	Literacy Population			Total Population			% Literacy of Population		
		Male	Female	Total	Male	Female	Total	Male	Female	Total
1	Manimuthar	0.446	0.360	0.806	0.586	0.583	1.169	76.06%	61.74%	68.89%
2	Pambar	0.185	0.152	0.337	0.239	0.237	0.476	77.40%	64.13%	70.79%
3	Kottakkaraiyar	0.263	0.220	0.483	0.333	0.337	1.670	78.97%	65.28%	28.92%
	Total	**0.894**	**0.732**	**1.626**	**1.158**	**1.157**	**2.315**	**77.47%**	**63.71%**	**56.20%**

Source: Census 2011

2.11.7 Population Dynamics

Population growth would be reflected on analyzing crucial parameters such as birth rate, death rate, Infant Mortality Rate (IMR), Maternal Mortality Rate (MMR) and life expectancy trends of the population. The details of registered births and deaths in Districts falling under Pambar&KottakkaraiyarRiver Basin as per the Statistical Handbook of Tamil Nadu 2016 is given in **Table 2.10.8**

Table 2.10.8Details of Births and Deaths Registered in Districts covered in Pambar Kottakkaraiyar River Basin

Sl.No	Name of the District	Mid-Year Estimated Populaion for 2018	As on Year 2016				
			Births	Deaths	Infant Deaths	Still Births	Maternal Deaths
1	Dindigul	2359138	30093	17667	88	114	4
2	Madurai	3444061	50873	29082	1308	430	40
3	Pudukottai	1749003	27430	11708	52	77	1
4	Ramanathapuram	1462242	25195	10074	72	80	1
5	Sivaganga	1500565	23047	10473	50	4	1
6	Trichy	2958656	46019	23863	455	335	25

2.11.8 Family Welfare & Impact of Family Planning

Tamil Nadu is pioneer in the implementation of Family Welfare Programme. It is being implemented in Tamil Nadu since 1956 purely on voluntary basis. It is viewed and implemented as a people's programme involving the active co-operation of many sectors and participation of the community at large. The aim of the programme at the early stage was to reduce births by fixing contraceptive targets only. But, now it has been changed to bring down fertility through improving maternal and child health care. The "Target oriented approach" has been shifted to "Community Needs Assessment Approach" in which the needs of the community have to be assessed based on the requirements of the people in the implementation of family welfare and maternity child health programmes.

The overall emphasis and priority given by the Government of India and Government of Tamil Nadu for family welfare and family planning has led to the establishment of institutions to promote family planning knowledge, at rural and urban areas. The Deputy Director of Medical and Rural Health Services and Family Welfare is the implementing authority of family welfare schemes. The adoption of family planning practices reveal that sterilization has been the most favorable method, followed by the use of IUD (Intra – Uterine Device).

Family welfareProgramme details for the districts covered by the Pambar&KottakkaraiyarRiver Basin for the period of 2017-18 is given in **Table 2.10.9**

Table 2.10.9 Details of Family Welfare Programme in Districts of Pambar Kottakkaraiyar River Basin

Name of the District	2017-18			
	Sterilisation	IUCD	OralPill Users	Conventional Contraceptives Users
Dindigul	9018	9996	1631	3785
Madurai	10162	13692	1134	2332
Pudukottai	4486	6212	1060	2415
Ramanathapuram	5768	9827	1656	2893
Sivaganga	5522	9793	2074	2474
Trichy	8770	10767	1736	2980

Source: Director of family welfare, Chennai – 6

2.11.9 Level of Housing

The level of housing is an indicator of water requirement and of urbanization trend. Households that have electricity, water and toilet available within the premises would be using more water in comparison with those that do not have these facilities within the premises. The details of households inPambar&KottakkaraiyarRiver Basin is given in **Table 2.10.10.**

Table No:2.10.10Number of Households in PambarKottakkaraiyar River Basin(2011)

Sl.No	Name of the SubBasin	Total Population (in millon)	Number of House Holds
1	Manimuthar	1.169	288555
2	Pambar	0.476	180820
3	Kottakkaraiyar	0.670	169656
	Total	**2.315**	**639031**

Source: Census of India 2011

2.11.12 Economic Profile and Employment Opportunitiesof the Districts covered in Pambar&Kottakkaraiyar River Basin

There are 596 small scale industries, 33large& medium scale industries in Pambar&Kottakkaraiyar River Basin. The water requirement for the industrial purpose for large & medium and small scale industries are estimated as1.361Mcum and1.101Mcum respectively. The projected future water demand for large & medium scale industries for the targeted year 2020, 2030,2040& 2050 are estimated as 1.688Mcum, 3.037Mcum, 5.467Mcum&9.842Mcum respectively. The projected future water demand for small scale industries for the targeted year 2020, 2030,2040& 2050 are estimated as1.366Mcum, 2.458Mcum, 4.423Mcum&7.962Mcum respectively.

Dindugul District

This is an agrarian district and main activity for lively hood of the people is paddy cultivation. Other crops cultivated are Cumbu, Ragi, Redgram, Black gram, Green gram, Groundnut, Gingelly, Cotton and Sugarcane. The district is an important wholesale market for Onion and Groundnut. Oddanchathram is noted market centre for vegetables. It is also famous for the export of butter manufacture in the near by villages using cream seperators. Batlagundu is an important market centre for Tomato. Nilakottaitaluk is famous for the growing and marketing of flowers and grapes. Kodaikanal is famous for potato cultivation.

Tanneries are thickly situated in the district. The finished and semi finished leather and other leather products have a good export market .A large number of chamber brick units functions in this districts. Dindugul locks and iron safes are specially known for its quality. Handloom , Rice milling, Groundnut and Vermicilli are the other types of food based industries functioning in this district. This district is also known for the flourishing handloom industry at Chinnalapatti. Art - silk sarees and Sungudisarees produced in the above place are in great demand through out India.

Madurai District

The economy is primarily agrarian, supplemented by gradually growing industrial and service sectors. Of late, conscious initiative has been taken to launch rural-oriented projects, as the district offers scope in the field of readymade garments, dairying, floriculture, toy – making, brick kiln, coir and bakery units.

The districthas a very few reputed organisatons in the private sector like T.V.Sundaram Iyengar& sons, Madura coats, Fenner(I) Ltd ,George oaks Ltd etc.,which are engaged in the production of variety of goods like Tyres and Tubes, Machineries ,Textile, Conveyor belts etc., and also provided employment opportunities. There is also very good scope for food processing and agro basis industries. It generates revenue of approximately 2500 crores per annum in the rubber sector.

Pudukottai District

Pudhukottai district, being small and backward district, Agriculture is the main occupation of the people. The important food crops grown are Paddy, Millets like Cholam, Cambu, Ragi and Varagu, Groundnut and Sugarcane. Cashew is the important tree crop grown in the district. The important subsidiary activities carried on by the cultivators and Agricultural labourers are Dairying ,Sheep rearing and poultry.

The main Industries in which they are engaged are wood based industries, Tinkering, Fabricating of metal products, Printing and Binding, manufacture of Agricultural implements and cement tiles, Automobiles servicing & repair and safety matches. There are major fishing villages situated along the coast line Arantangitaluk of the district.

Trichy District

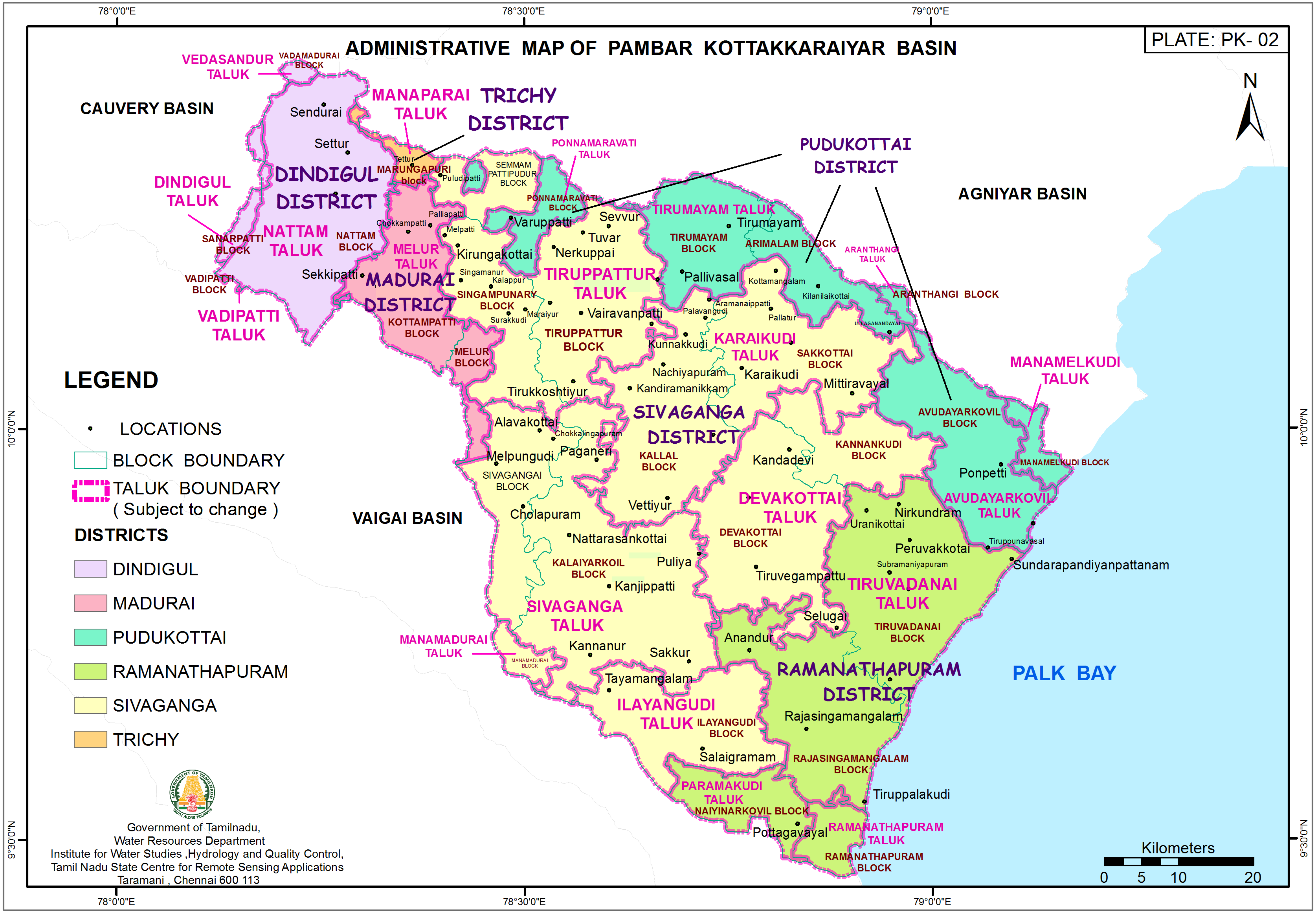
Agriculture sector provides the major source of income to the population of the district and the major crops in this district are Paddy, Cholam, Cotton, Groundnut, Maize etc., In addition the other allied sectors like Diary , Sheep/Goat, Sericulture and Inland fishing are the major sectors contributing to the district economy as well as act as a major source of providing livelihood for improving the income and standard of living of the people. Sugar factory, Distillery, Tannery, Engineering units , Cement industries and Automobile service units are the predominant industries in the district.

Sixty five percentage of India's power plant equipments are made at Trichy only. Bharat Heavy Electricals Limited (BHEL) which is in Trichy is ranking among the leading power plant manufacturers in the world.Cethar vessels Ltd, Ponmali Railway Workshop,Trichirapalli Distilleries and Chemicals Ltd, Trichirapalli steel rolling mills,DalmiaCements,EID parry sugar factory are some of the factories in Trichy adding boost to the district Trichy district economy.

Woraiyur continues to be an important Handloom Textile manufacturing centre.The wholesale market namely Gandhi market located in the heart of city is known for Jaggery trade.

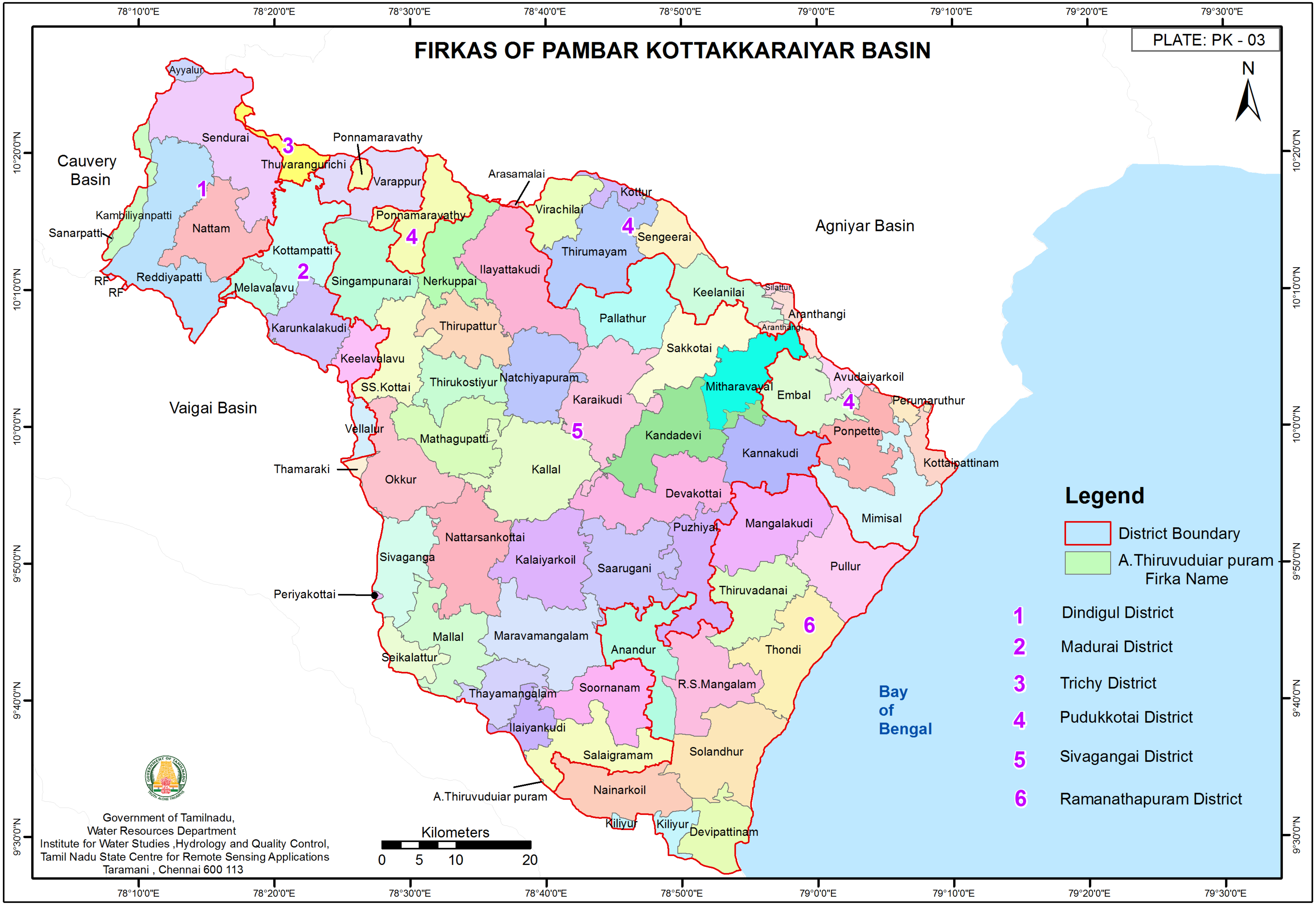
Sivaganga District

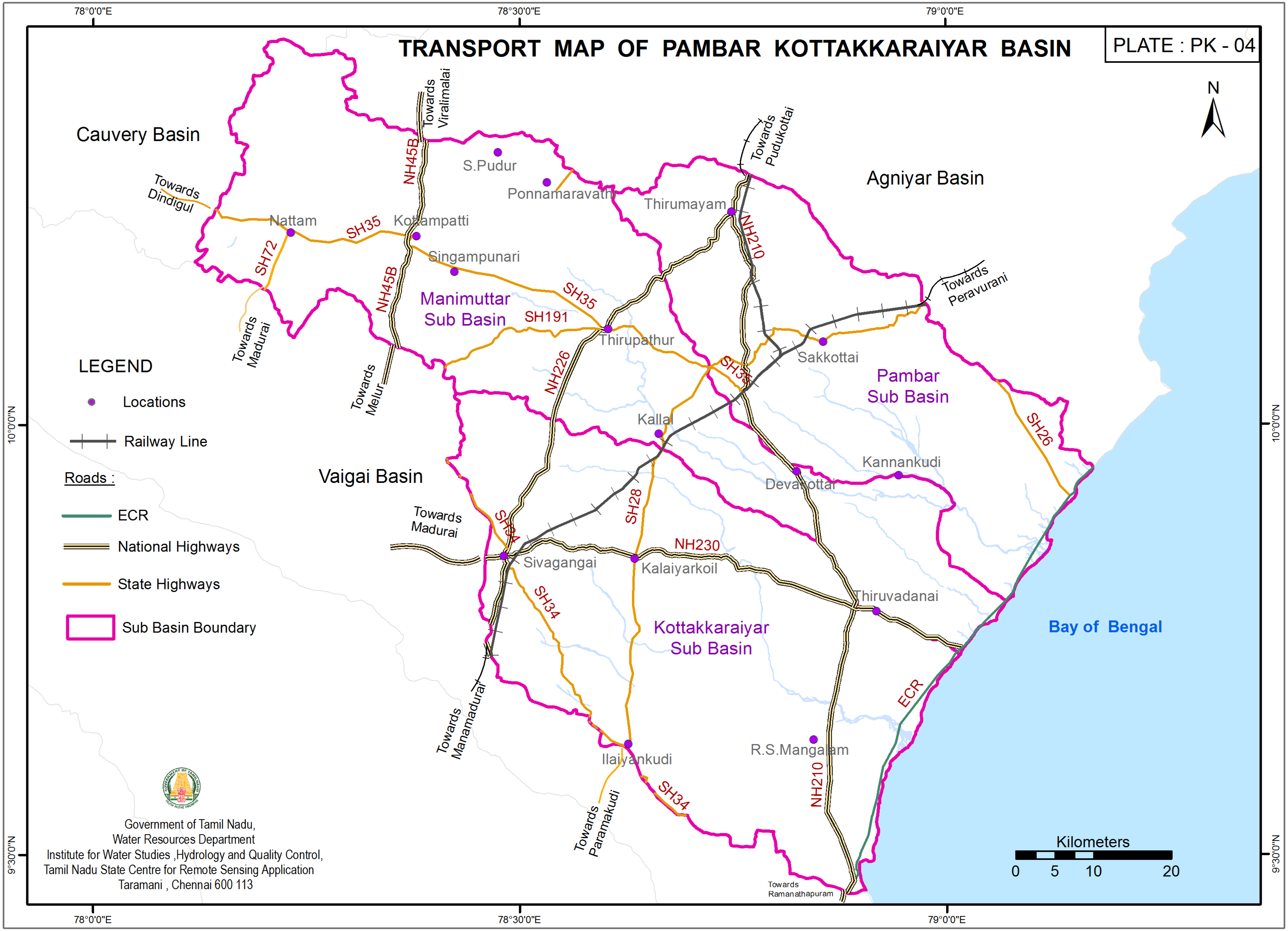
The vast majority of the workforce is dependent on Agriculture. Infact, the principal crop of sivaganga district is Paddy, Rice. The other crops grown are Sugarcane, Pulses, Groundnuts, Millet and Cereals. Sakthi sugar Factory is located in the Padamathur, Sivaganga.It has the capacity to produce more than 5000 tonnes of sugar/day.It provides employment to more than 1000 labourers directly& indirectly.


ADMINISTRATIVE MAP OF PAMBAR KOTTAKKARAIYAR BASIN
PLATE: PK- 02
78°0'0"E
78°30'0"E
79°0'0"E
10°0'0"N
9°30'0"N
N
CAUVERY BASIN
AGNIYAR BASIN
VAIGAI BASIN
PALK BAY
VEDASANDUR TALUK
VADAMADURAI BLOCK
MANAPARAI TALUK
TRICHY DISTRICT
DINDIGUL DISTRICT
DINDIGUL TALUK
SANARPATTI BLOCK
NATTAM TALUK
NATTAM BLOCK
VADIPATTI BLOCK
VADIPATTI TALUK
MARUNGAPURI block
SEMMAM PATTIPUDUR BLOCK
PONNAMARAVATI TALUK
PONNAMARAVATI BLOCK
PUDUKOTTAI DISTRICT
TIRUMAYAM TALUK
TIRUMAYAM BLOCK
ARIMALAM BLOCK
ARANTHANGI TALUK
ARANTHANGI BLOCK
MELUR TALUK
MADURAI DISTRICT
SINGAMPUNARY BLOCK
KOTTAMPATTI BLOCK
MELUR BLOCK
TIRUPPATTUR TALUK
TIRUPPATTUR BLOCK
KARAIKUDI TALUK
SAKKOTTAI BLOCK
ULLAGANANDAYAL
MANAMELKUDI TALUK
AVUDAYARKOVIL BLOCK
MANAMELKUDI BLOCK
AVUDAYARKOVIL TALUK
SIVAGANGA DISTRICT
KALLAL BLOCK
KANNANKUDI BLOCK
SIVAGANGAI BLOCK
DEVAKOTTAI TALUK
DEVAKOTTAI BLOCK
KALAIYARKOIL BLOCK
SIVAGANGA TALUK
MANAMADURAI TALUK
MANAMADURAI BLOCK
TIRUVADANAI TALUK
TIRUVADANAI BLOCK
RAMANATHAPURAM DISTRICT
ILAYANGUDI TALUK
ILAYANGUDI BLOCK
RAJASINGAMANGALAM BLOCK
PARAMAKUDI TALUK
NAIYINARKOVIL BLOCK
RAMANATHAPURAM TALUK
RAMANATHAPURAM BLOCK
Sendurai
Settur
Tettur
Puludipatti
Palliapatti
Chokkampatti
Melpatti
Varuppatti
Sevvur
Tuvar
Nerkuppai
Kirungakottai
Tirumayam
Pallivasal
Kottamangalam
Kilanilaikottai
Aramanaippatti
Palavangudi
Pallatur
Sekkipatti
Singamanur
Kalappur
Maraiyur
Surakkudi
Vairavanpatti
Kunnakkudi
Nachiyapuram
Karaikudi
Kandiramanikkam
Mittiravayal
Tirukkoshtiyur
Alavakottai
Chokkalingapuram
Melpungudi
Paganeri
Kandadevi
Ponpetti
Vettiyur
Cholapuram
Nirkundram
Uranikottai
Nattarasankottai
Peruvakkotai
Tiruppunavasal
Sundarapandiyanpattanam
Subramaniyapuram
Puliya
Tiruvegampattu
Kanjippatti
Selugai
Anandur
Kannanur
Sakkur
Tayamangalam
Rajasingamangalam
Salaigramam
Tiruppalakudi
Pottagavayal
LEGEND
LOCATIONS
BLOCK BOUNDARY
TALUK BOUNDARY
(Subject to change)
DISTRICTS
DINDIGUL
MADURAI
PUDUKOTTAI
RAMANATHAPURAM
SIVAGANGA
TRICHY
Government of Tamilnadu,
Water Resources Department
Institute for Water Studies ,Hydrology and Quality Control,
Tamil Nadu State Centre for Remote Sensing Applications
Taramani , Chennai 600 113
Kilometers
0
5
10
20

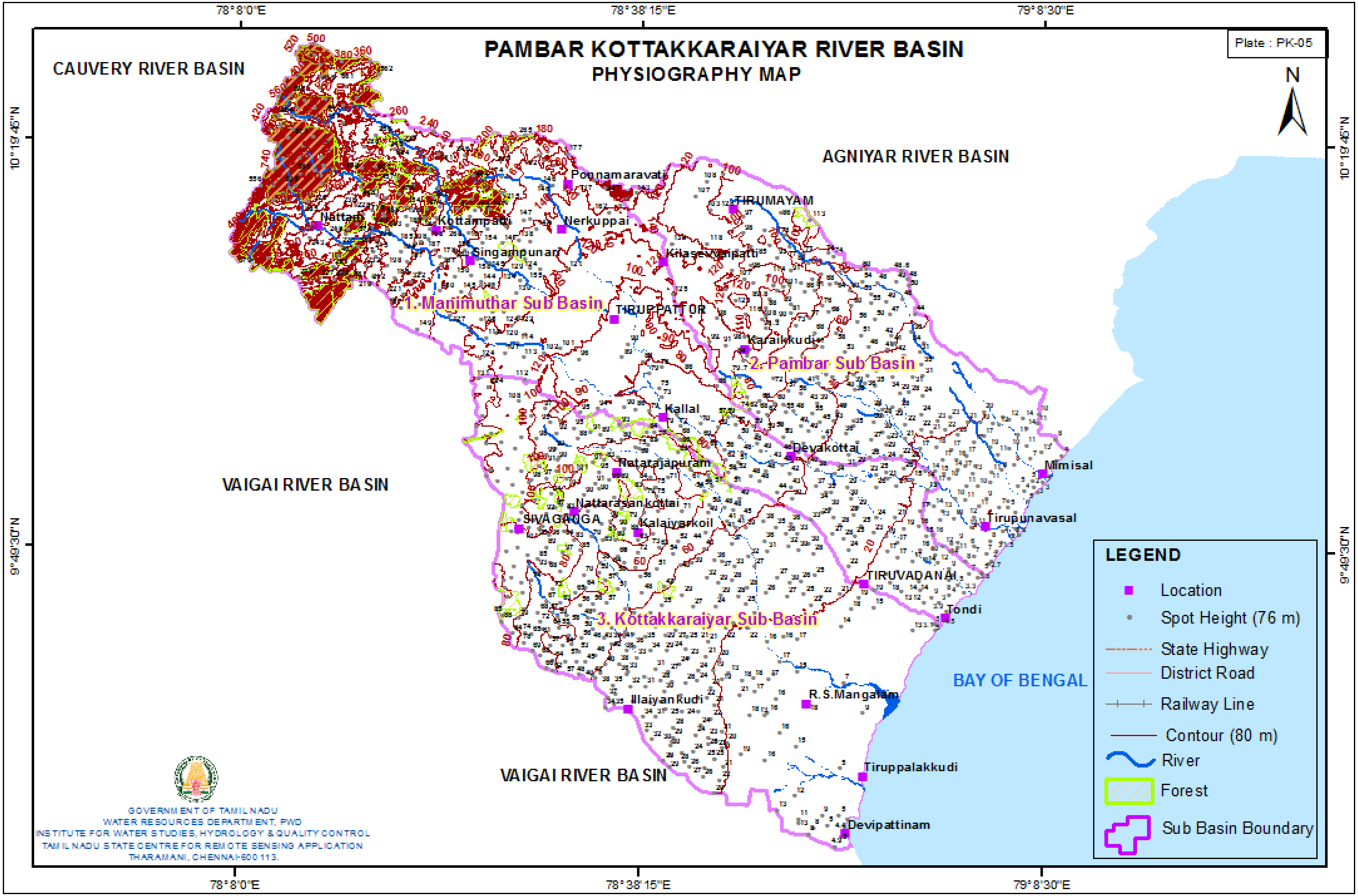
FIRKAS OF PAMBAR KOTTAKKARAIYAR BASIN

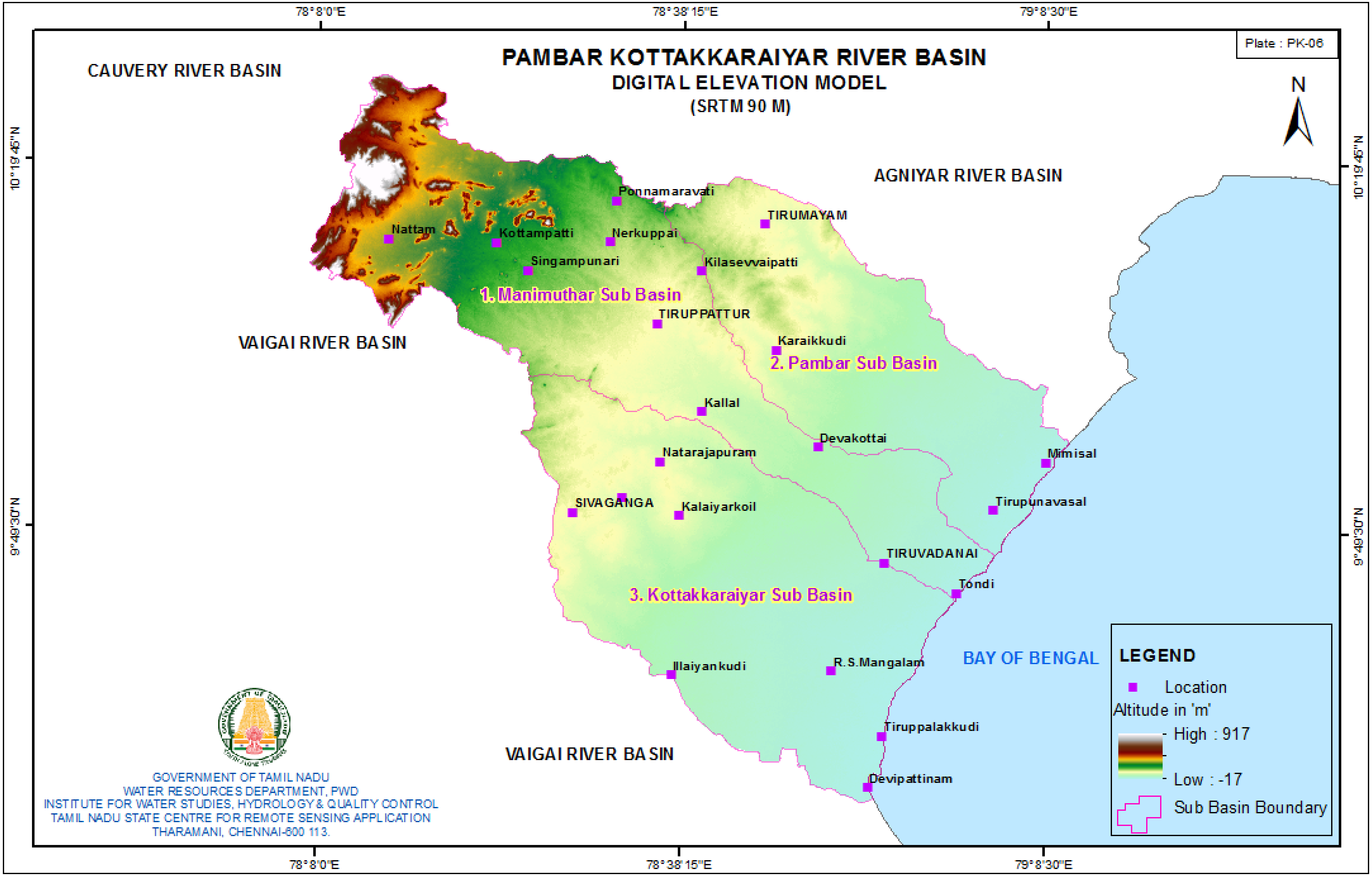
PLATE: PK - 03

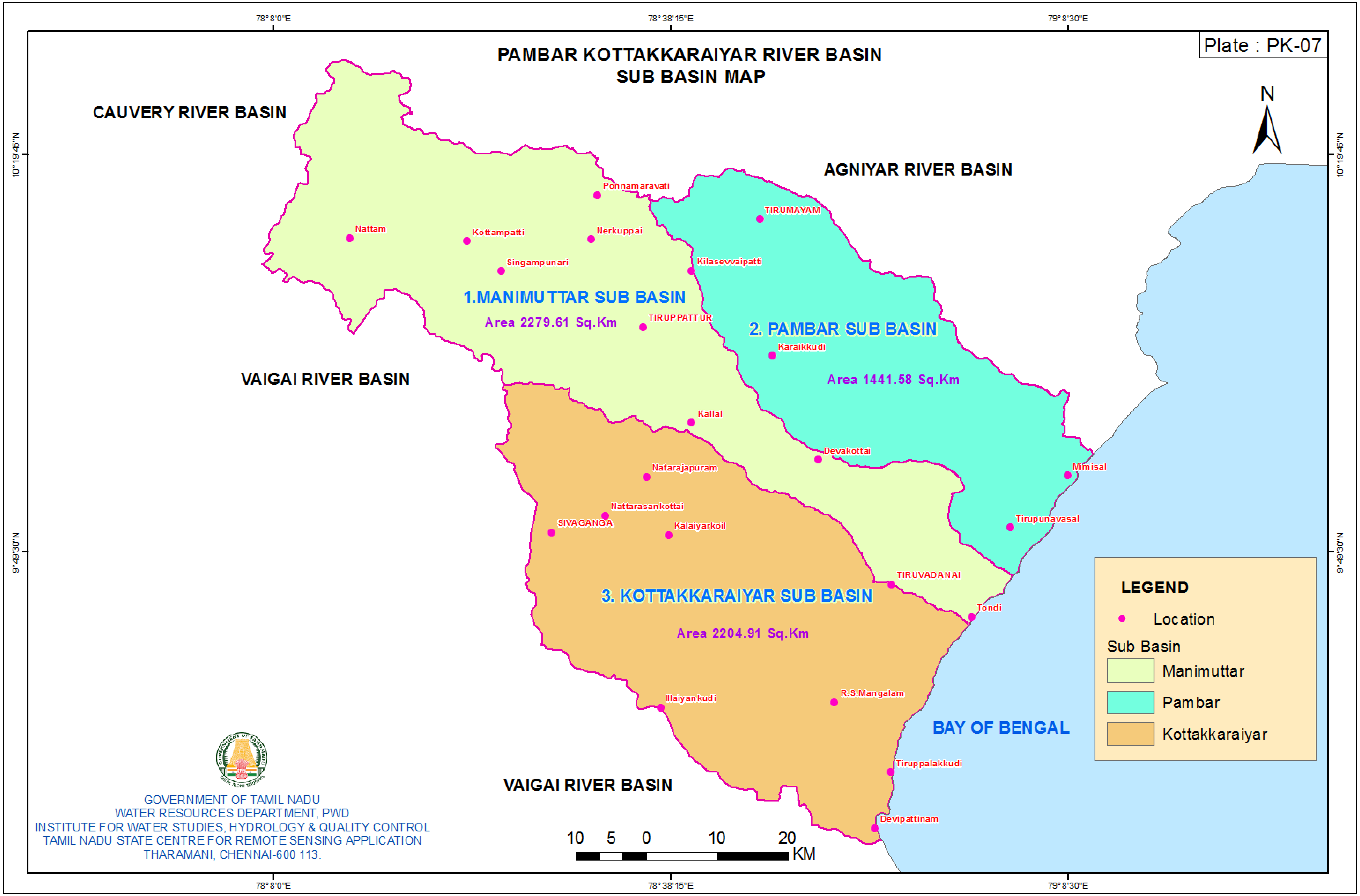


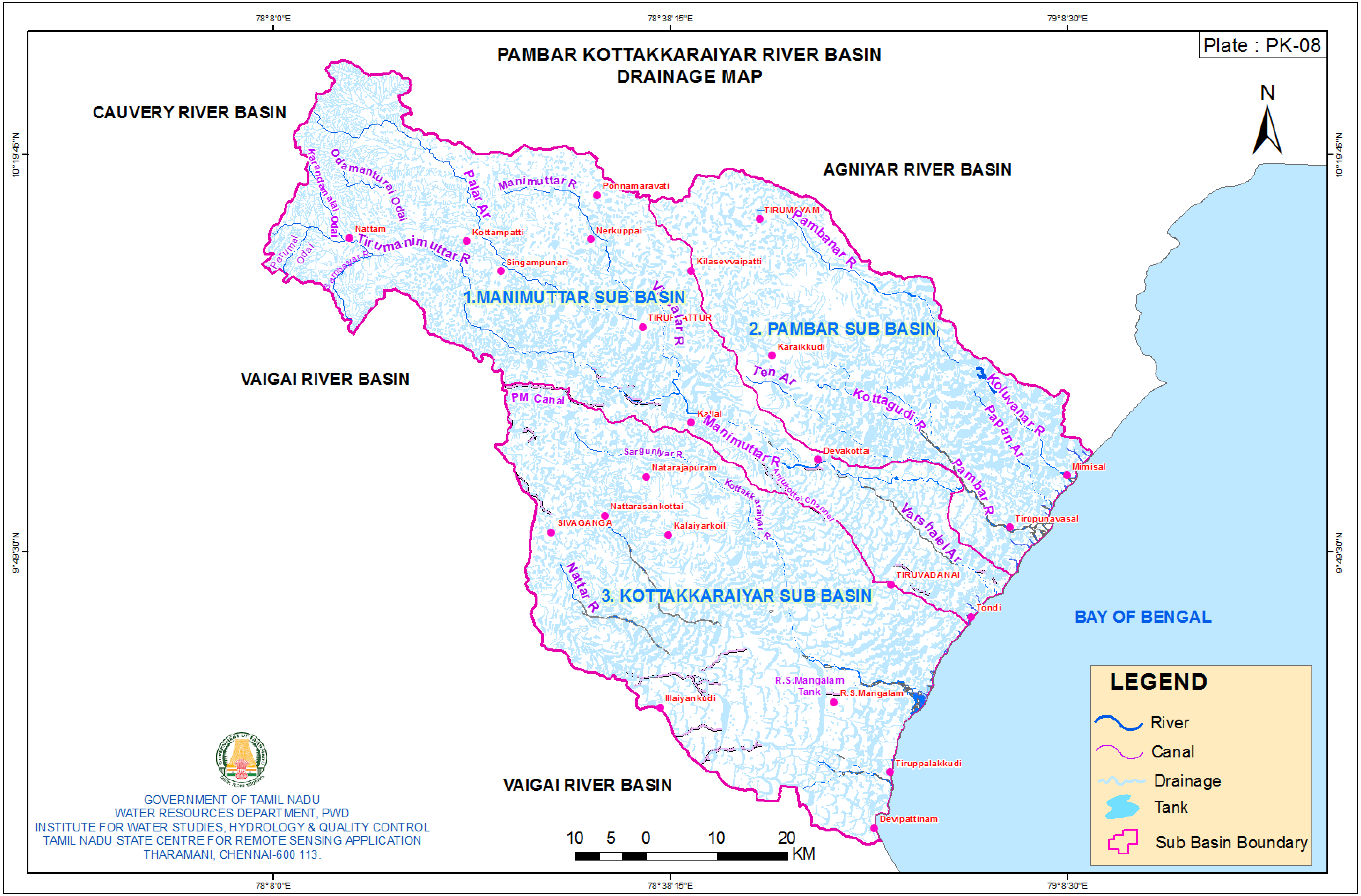


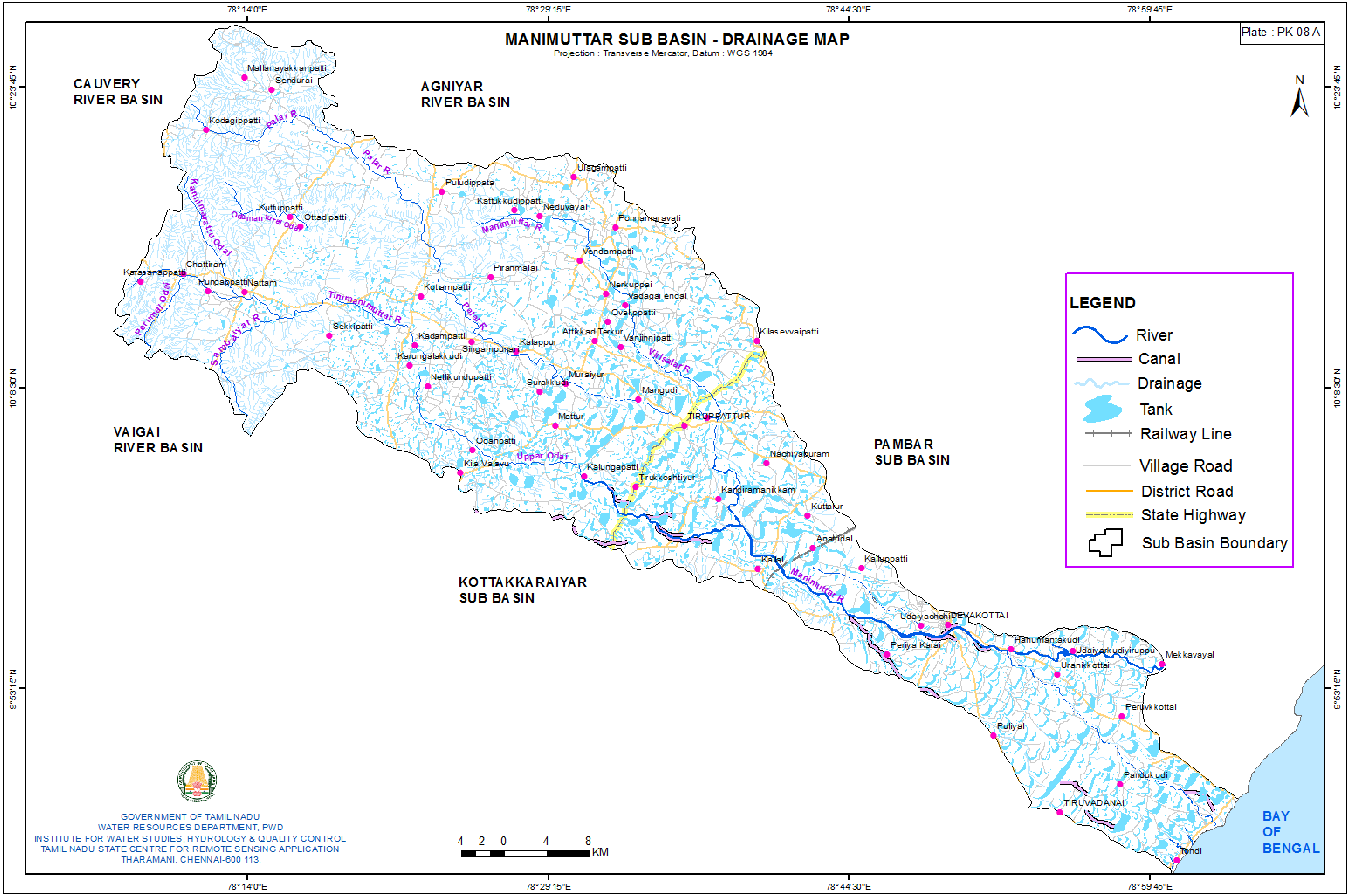
78°0'0"E
78°30'0"E
79°0'0"E
TRANSPORT MAP OF PAMBAR KOTTAKKARAIYAR BASIN
PLATE : PK - 04
N
Cauvery Basin
Agniyar Basin
Vaigai Basin
Bay of Bengal
Towards Viralimalai
Towards Pudukottai
Towards Dindigul
Towards Madurai
Towards Melur
Towards Peravurani
Towards Manamadurai
Towards Paramakudi
Towards Ramanathapuram
S.Pudur
Ponnamaravathi
Thirumayam
Nattam
Kottampatti
Singampunari
Thirupathur
Sakkottai
Kallal
Devakottai
Kannankudi
Sivagangai
Kalaiyarkoil
Thiruvadanai
Ilaiyankudi
R.S.Mangalam
Manimuttar Sub Basin
Pambar Sub Basin
Kottakkaraiyar Sub Basin
NH45B
NH210
NH226
NH230
SH35
SH72
SH191
SH28
SH34
SH26
ECR
LEGEND
Locations
Railway Line
Roads :
ECR
National Highways
State Highways
Sub Basin Boundary
10°0'0"N
9°30'0"N
Kilometers
0 5 10 20
Government of Tamil Nadu,
Water Resources Department
Institute for Water Studies ,Hydrology and Quality Control,
Tamil Nadu State Centre for Remote Sensing Application
Taramani , Chennai 600 113

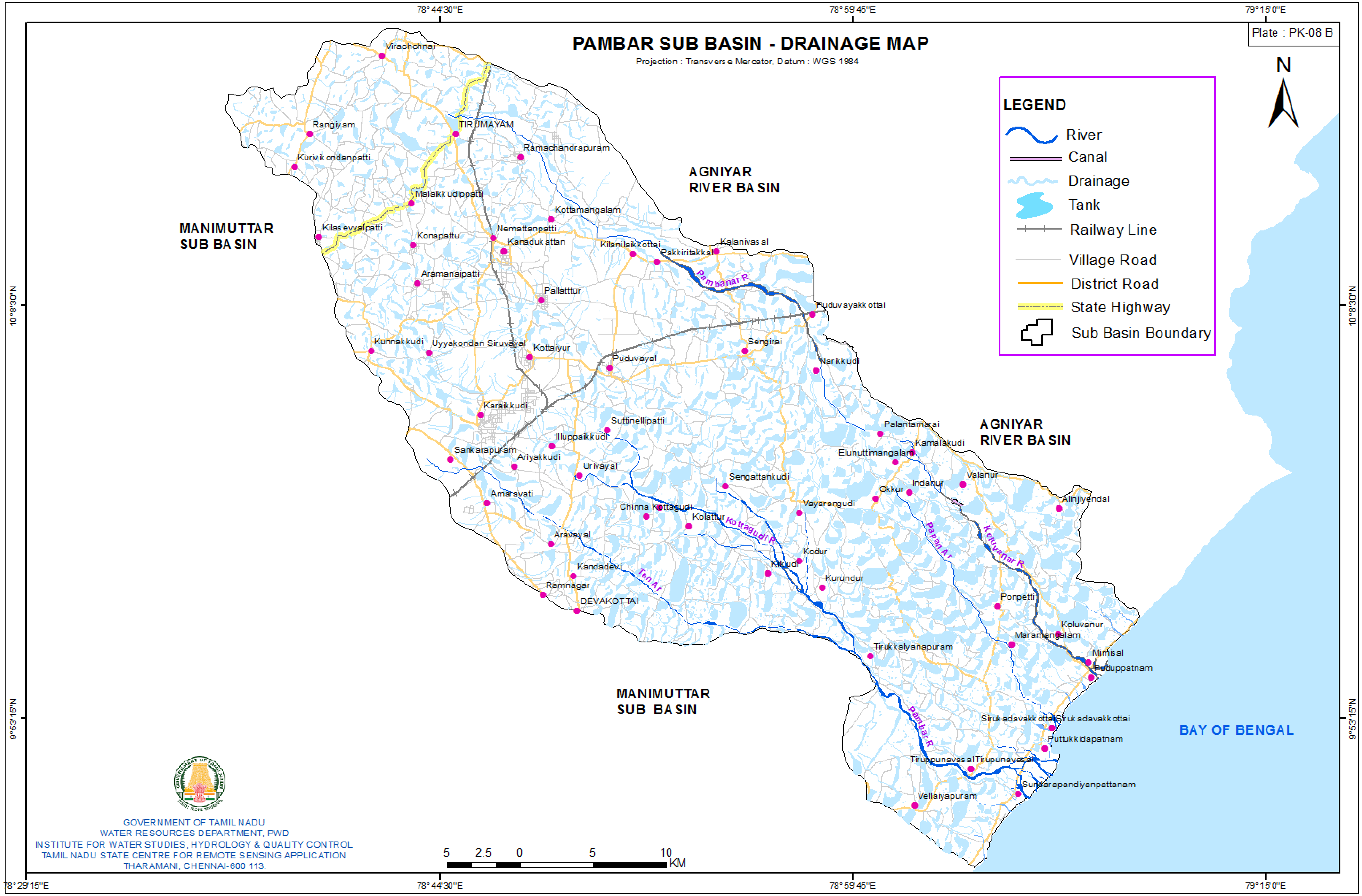

PAMBAR KOTTAKKARAIYAR RIVER BASIN
PHYSIOGRAPHY MAP
Plate : PK-05
N
CAUVERY RIVER BASIN
AGNIYAR RIVER BASIN
VAIGAI RIVER BASIN
VAIGAI RIVER BASIN
BAY OF BENGAL
1.Manimuthar Sub Basin
2.Pambar Sub Basin
3. Kottakkaraiyar Sub Basin
Ponnamaravathi
TIRUMAYAM
Nattam
Kottampatti
Nerkuppai
Singampunari
Kilasevalpatti
TIRUPPATTUR
Karaikkudi
Kallal
Devakottai
Natarajapuram
Nattarasankottai
SIVAGANGA
Kalaiyarkoil
Mimisal
Tirupunavasal
TIRUVADANAI
Tondi
R.S.Mangalam
Illaiyankudi
Tiruppalakkudi
Devipattinam
78°8'0"E
78°38'15"E
79°8'30"E
10°19'45"N
9°49'30"N
LEGEND
Location
Spot Height (76 m)
State Highway
District Road
Railway Line
Contour (80 m)
River
Forest
Sub Basin Boundary
GOVERNMENT OF TAMIL NADU
WATER RESOURCES DEPARTMENT, PWD
INSTITUTE FOR WATER STUDIES, HYDROLOGY & QUALITY CONTROL
TAMIL NADU STATE CENTRE FOR REMOTE SENSING APPLICATION
THARAMANI, CHENNAI-600 113.

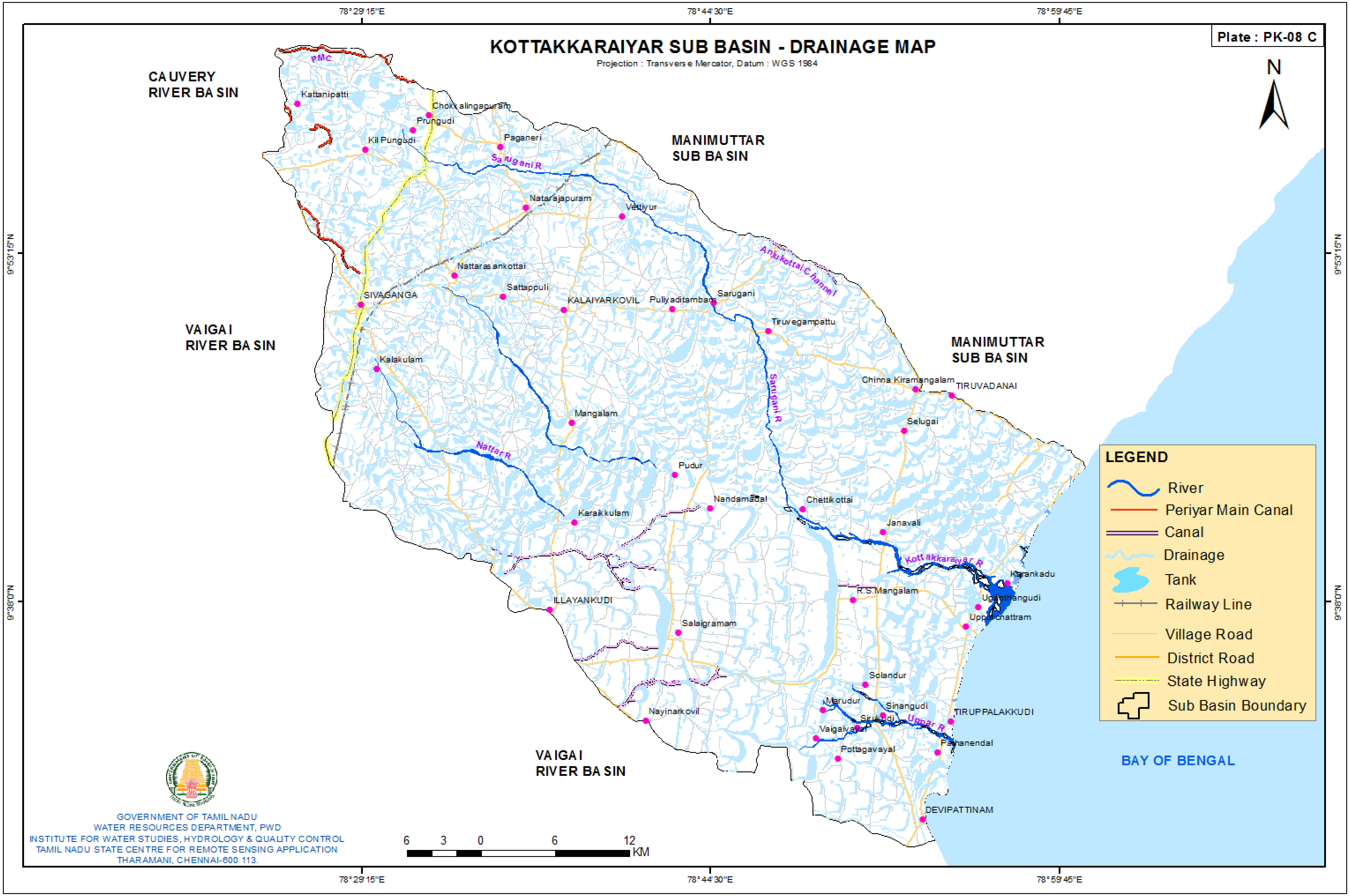

PAMBAR KOTTAKKARAIYAR RIVER BASIN
DIGITAL ELEVATION MODEL
(SRTM 90 M)
Plate : PK-06
N
78°8'0"E
78°38'15"E
79°8'30"E
10°19'45"N
9°49'30"N
CAUVERY RIVER BASIN
AGNIYAR RIVER BASIN
VAIGAI RIVER BASIN
VAIGAI RIVER BASIN
BAY OF BENGAL
1. Manimuthar Sub Basin
2. Pambar Sub Basin
3. Kottakkaraiyar Sub Basin
Ponnamaravati
TIRUMAYAM
Nattam
Kottampatti
Nerkuppai
Singampunari
Kilasevvaipatti
TIRUPPATTUR
Karaikkudi
Kallal
Devakottai
Natarajapuram
Mimisal
SIVAGANGA
Kalaiyarkoil
Tirupunavasal
TIRUVADANAI
Tondi
Illaiyankudi
R.S.Mangalam
Tiruppalakkudi
Devipattinam
LEGEND
Location
Altitude in 'm'
High : 917
Low : -17
Sub Basin Boundary
GOVERNMENT OF TAMIL NADU
WATER RESOURCES DEPARTMENT, PWD
INSTITUTE FOR WATER STUDIES, HYDROLOGY & QUALITY CONTROL
TAMIL NADU STATE CENTRE FOR REMOTE SENSING APPLICATION
THARAMANI, CHENNAI-600 113.

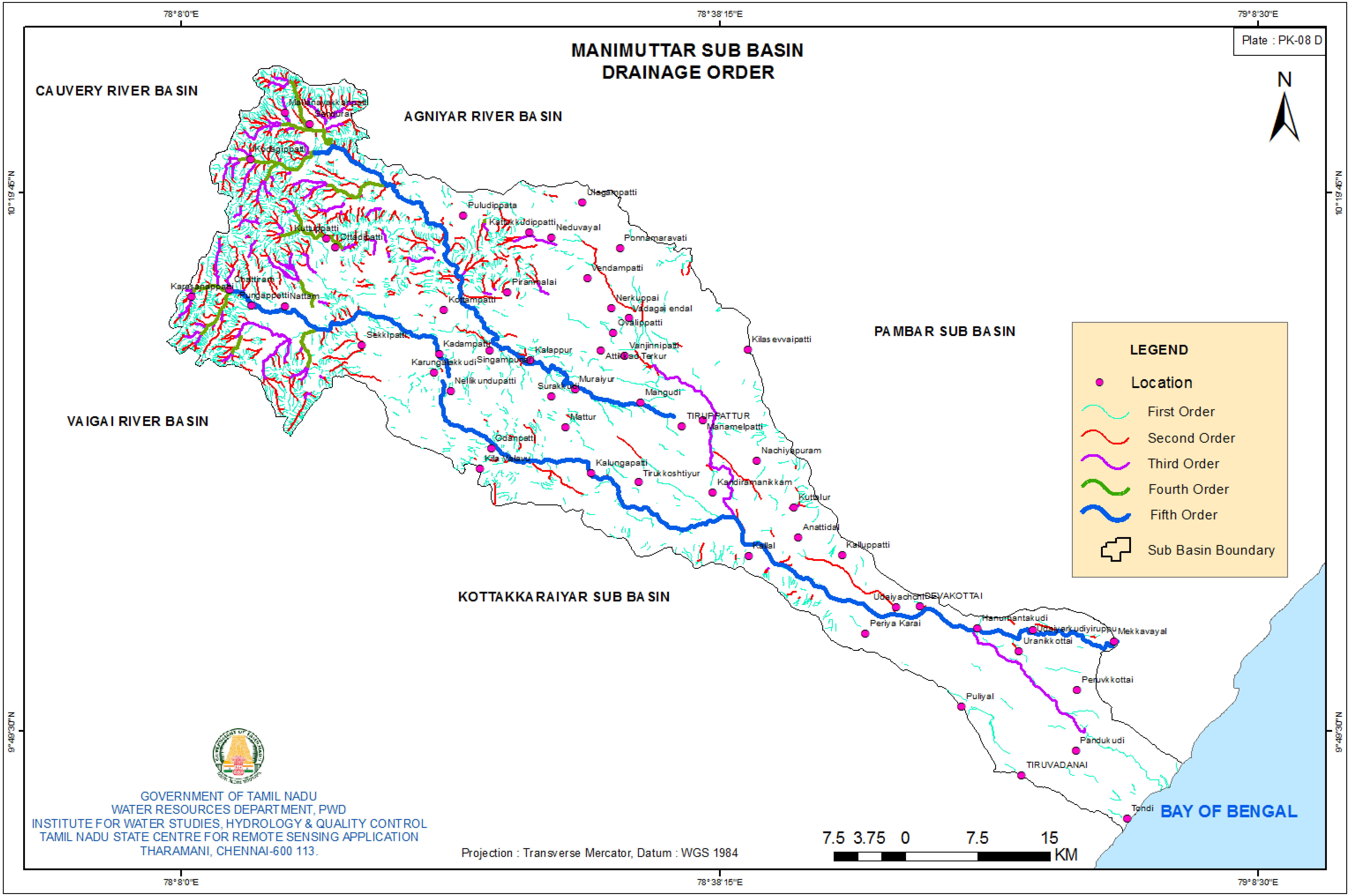

PAMBAR KOTTAKKARAIYAR RIVER BASIN
SUB BASIN MAP
Plate : PK-07
78°8'0"E
78°38'15"E
79°8'30"E
10°19'45"N
9°49'30"N
N
CAUVERY RIVER BASIN
AGNIYAR RIVER BASIN
VAIGAI RIVER BASIN
VAIGAI RIVER BASIN
BAY OF BENGAL
1.MANIMUTTAR SUB BASIN
Area 2279.61 Sq.Km
2. PAMBAR SUB BASIN
Area 1441.58 Sq.Km
3. KOTTAKKARAIYAR SUB BASIN
Area 2204.91 Sq.Km
Ponnamaravati
TIRUMAYAM
Nattam
Kottampatti
Nerkuppai
Singampunari
Kilasevvaipatti
TIRUPPATTUR
Karaikkudi
Kallal
Devakottai
Mimisal
Natarajapuram
Nattarasankottai
SIVAGANGA
Kalaiyarkoil
Tirupunavasal
TIRUVADANAI
Tondi
Ilaiyankudi
R.S.Mangalam
Tiruppalakkudi
Devipattinam
LEGEND
Location
Sub Basin
Manimuttar
Pambar
Kottakkaraiyar
10 5 0 10 20
KM
GOVERNMENT OF TAMIL NADU
WATER RESOURCES DEPARTMENT, PWD
INSTITUTE FOR WATER STUDIES, HYDROLOGY & QUALITY CONTROL
TAMIL NADU STATE CENTRE FOR REMOTE SENSING APPLICATION
THARAMANI, CHENNAI-600 113.


PAMBAR KOTTAKKARAIYAR RIVER BASIN
DRAINAGE MAP
Plate : PK-08
78°8'0"E
78°38'15"E
79°8'30"E
10°19'45"N
9°49'30"N
N
CAUVERY RIVER BASIN
AGNIYAR RIVER BASIN
VAIGAI RIVER BASIN
VAIGAI RIVER BASIN
BAY OF BENGAL
1.MANIMUTTAR SUB BASIN
2. PAMBAR SUB BASIN
3. KOTTAKKARAIYAR SUB BASIN
Karandamalai Odai
Odamanturai Odai
Palar Ar
Manimuttar R
Tirumanimuttar R
Perumal Odai
Virisalar R
Pambanar R
Ten Ar
Kottagudi R
Koluvanar R
Papan Ar
Pambar R
PM Canal
Manimuttar R
Sarguniyar R
Kottakkaraiyar R
Varshalei Ar
Nattar R
Ponnamaravati
Nattam
Kottampatti
Nerkuppai
Singampunari
TIRUMAYAM
Kilasevvaipatti
Karaikkudi
Kallal
Devakottai
Mimisal
Natarajapuram
Nattarasankottai
SIVAGANGA
Kalaiyarkoil
Tirupunavasal
TIRUVADANAI
Tondi
R.S.Mangalam Tank
R.S.Mangalam
Illaiyankudi
Tiruppalakkudi
Devipattinam
10 5 0 10 20
KM
LEGEND
River
Canal
Drainage
Tank
Sub Basin Boundary
GOVERNMENT OF TAMIL NADU
WATER RESOURCES DEPARTMENT, PWD
INSTITUTE FOR WATER STUDIES, HYDROLOGY & QUALITY CONTROL
TAMIL NADU STATE CENTRE FOR REMOTE SENSING APPLICATION
THARAMANI, CHENNAI-600 113.


MANIMUTTAR SUB BASIN - DRAINAGE MAP
Projection : Transverse Mercator, Datum : WGS 1984
Plate : PK-08 A
78°14'0"E
78°29'15"E
78°44'30"E
78°59'45"E
10°23'45"N
10°8'30"N
9°53'15"N
N
CAUVERY RIVER BASIN
AGNIYAR RIVER BASIN
VAIGAI RIVER BASIN
PAMBAR SUB BASIN
KOTTAKKARAIYAR SUB BASIN
BAY OF BENGAL
LEGEND
River
Canal
Drainage
Tank
Railway Line
Village Road
District Road
State Highway
Sub Basin Boundary
Mallanayakkanpatti
Sendurai
Kodagippatti
Palar R
Ulagampatti
Puludippata
Kattukkudipatti
Neduvayal
Manimuttar R
Ponnamaravati
Kuttuppatti
Ottadipatti
Odaman turai Odai
Kannimarattu Odai
Vendampatti
Piranmalai
Chattiram
Karasanappatti
Rungappatti
Nattam
Perumal Odai
Sambaiyar R
Tirumanimuttar R
Kottampatti
Nerkuppai
Vadagai endal
Ovalippatti
Sekkipatti
Kadampatti
Singampunari
Kalappur
Attikkad Terkur
Vanjinnipatti
Kilasevvaipatti
Virisalar R
Karungalakkudi
Nellikundupatti
Surakkudi
Muraiyur
Mangudi
Mattur
TIRUPPATTUR
Odanpatti
Kila Valavu
Uppar Odai
Kalungapatti
Tirukkoshtiyur
Nachiyapuram
Kandiramanikkam
Kuttalur
Anattidal
Kallal
Kalluppatti
Manimuttar R
Udaiyachchi
DEVAKOTTAI
Periya Karai
Hanumantakudi
Udaiyarkudiyiruppu
Mekkavayal
Uranikkottai
Peruvkkottai
Puliyal
Pandukudi
TIRUVADANAI
Tondi
4 2 0 4 8
KM
GOVERNMENT OF TAMIL NADU
WATER RESOURCES DEPARTMENT, PWD
INSTITUTE FOR WATER STUDIES, HYDROLOGY & QUALITY CONTROL
TAMIL NADU STATE CENTRE FOR REMOTE SENSING APPLICATION
THARAMANI, CHENNAI-600 113.


PAMBAR SUB BASIN - DRAINAGE MAP
Projection : Transverse Mercator, Datum : WGS 1984
Plate : PK-08 B
N
LEGEND
River
Canal
Drainage
Tank
Railway Line
Village Road
District Road
State Highway
Sub Basin Boundary
78°44'30"E
78°59'45"E
79°15'0"E
78°29'15"E
10°8'30"N
9°53'15"N
AGNIYAR RIVER BASIN
MANIMUTTAR SUB BASIN
AGNIYAR RIVER BASIN
MANIMUTTAR SUB BASIN
BAY OF BENGAL
Virachchnai
Rangiyam
TIRUMAYAM
Kurivikondanpatti
Ramachandrapuram
Malaikkudippatti
Kilasevvalpatti
Konapattu
Nemattanpatti
Kanadukattan
Kottamangalam
Kilanilaikkottai
Pakkiritakkal
Kalanivasal
Pambanar R
Aramanaipatti
Pallatttur
Puduvayakkottai
Kunnakkudi
Uyyakondan Siruvayal
Kottaiyur
Puduvayal
Sengirai
Narikkudi
Karaikkudi
Suttinellipatti
Illuppaikkudi
Sankarapuram
Ariyakkudi
Urivayal
Palantamarai
Kamalakudi
Elunuttimangalam
Valanur
Indanur
Okkur
Sengattankudi
Alinjiyendal
Amaravati
Chinna Kottagudi
Kolattur
Vayarangudi
Kottagudi R
Papan Ar
Kottiyanar R
Aravayal
Kodur
Kilkudi
Kandadevi
Ten Ar
Kurundur
Ramnagar
DEVAKOTTAI
Ponpetti
Koluvanur
Maramangalam
Mimisal
Puduppatnam
Tirukkalyanapuram
Pambar R
Sirukadavakkottai
Sirukadavakkottai
Puttukkidapatnam
Tiruppunavasal
Tirupunavasal
Sundarapandiyanpattanam
Vellaiyapuram
5 2.5 0 5 10
KM
GOVERNMENT OF TAMIL NADU
WATER RESOURCES DEPARTMENT, PWD
INSTITUTE FOR WATER STUDIES, HYDROLOGY & QUALITY CONTROL
TAMIL NADU STATE CENTRE FOR REMOTE SENSING APPLICATION
THARAMANI, CHENNAI-600 113.


KOTTAKKARAIYAR SUB BASIN - DRAINAGE MAP
Projection : Transverse Mercator, Datum : WGS 1984
Plate : PK-08 C
N
78°29'15"E
78°44'30"E
78°59'45"E
9°53'15"N
9°38'0"N
CAUVERY RIVER BASIN
MANIMUTTAR SUB BASIN
VAIGAI RIVER BASIN
MANIMUTTAR SUB BASIN
VAIGAI RIVER BASIN
BAY OF BENGAL
PMC
Kattanipatti
Chokkalingapuram
Prungudi
Kil Pungudi
Paganeri
Sarugani R
Natarajapuram
Vettiyur
Anjukottai Channel
Nattarasankottai
Sattappuli
SIVAGANGA
KALAIYARKOVIL
Puliyaditambam
Sarugani
Tiruvegampattu
Kalakulam
Sarugani R
Chinna Kiramangalam
TIRUVADANAI
Mangalam
Selugai
Natrar R
Pudur
Nandamadal
Chettikottai
Karaikkulam
Janavali
Kottakkaraiyar R
Karankadu
R.S.Mangalam
Ugenthangudi
ILLAYANKUDI
Uppurchattram
Salaigramam
Solandur
Marudur
Sinangudi
Nayinarkovil
Sirukudi
TIRUPPALAKKUDI
Uppar R
Vaigaivayal
Pattanendal
Pottagavayal
DEVIPATTINAM
LEGEND
River
Periyar Main Canal
Canal
Drainage
Tank
Railway Line
Village Road
District Road
State Highway
Sub Basin Boundary
6 3 0 6 12
KM
GOVERNMENT OF TAMIL NADU
WATER RESOURCES DEPARTMENT, PWD
INSTITUTE FOR WATER STUDIES, HYDROLOGY & QUALITY CONTROL
TAMIL NADU STATE CENTRE FOR REMOTE SENSING APPLICATION
THARAMANI, CHENNAI-600 113.


MANIMUTTAR SUB BASIN
DRAINAGE ORDER
Plate : PK-08 D
N
CAUVERY RIVER BASIN
AGNIYAR RIVER BASIN
PAMBAR SUB BASIN
VAIGAI RIVER BASIN
KOTTAKKARAIYAR SUB BASIN
BAY OF BENGAL
LEGEND
Location
First Order
Second Order
Third Order
Fourth Order
Fifth Order
Sub Basin Boundary
78°8'0"E
78°38'15"E
79°8'30"E
10°19'45"N
9°49'30"N
Puludippata
Ulagampatti
Neduvayal
Ponnamaravati
Vendampatti
Piranmalai
Kottampatti
Nerkuppai
Ovalipatti
Kilasevvaipatti
Sekkipatti
Kadampatti
Kalappur
Vanjinnipatti
Nellikundupatti
Muraiyur
Mangudi
TIRUPPATTUR
Mattur
Odanpatti
Kalungapatti
Tirukkoshtiyur
Nachiyapuram
Kuttalur
Anattidal
Kalluppatti
Kallal
DEVAKOTTAI
Periya Karai
Hanumantakudi
Uranikkottai
Mekkavayal
Peruvkkottai
Puliyal
Pandukudi
TIRUVADANAI
Tondi
Nattam
Chattram
GOVERNMENT OF TAMIL NADU
WATER RESOURCES DEPARTMENT, PWD
INSTITUTE FOR WATER STUDIES, HYDROLOGY & QUALITY CONTROL
TAMIL NADU STATE CENTRE FOR REMOTE SENSING APPLICATION
THARAMANI, CHENNAI-600 113.
Projection : Transverse Mercator, Datum : WGS 1984
7.5 3.75 0 7.5 15
KM

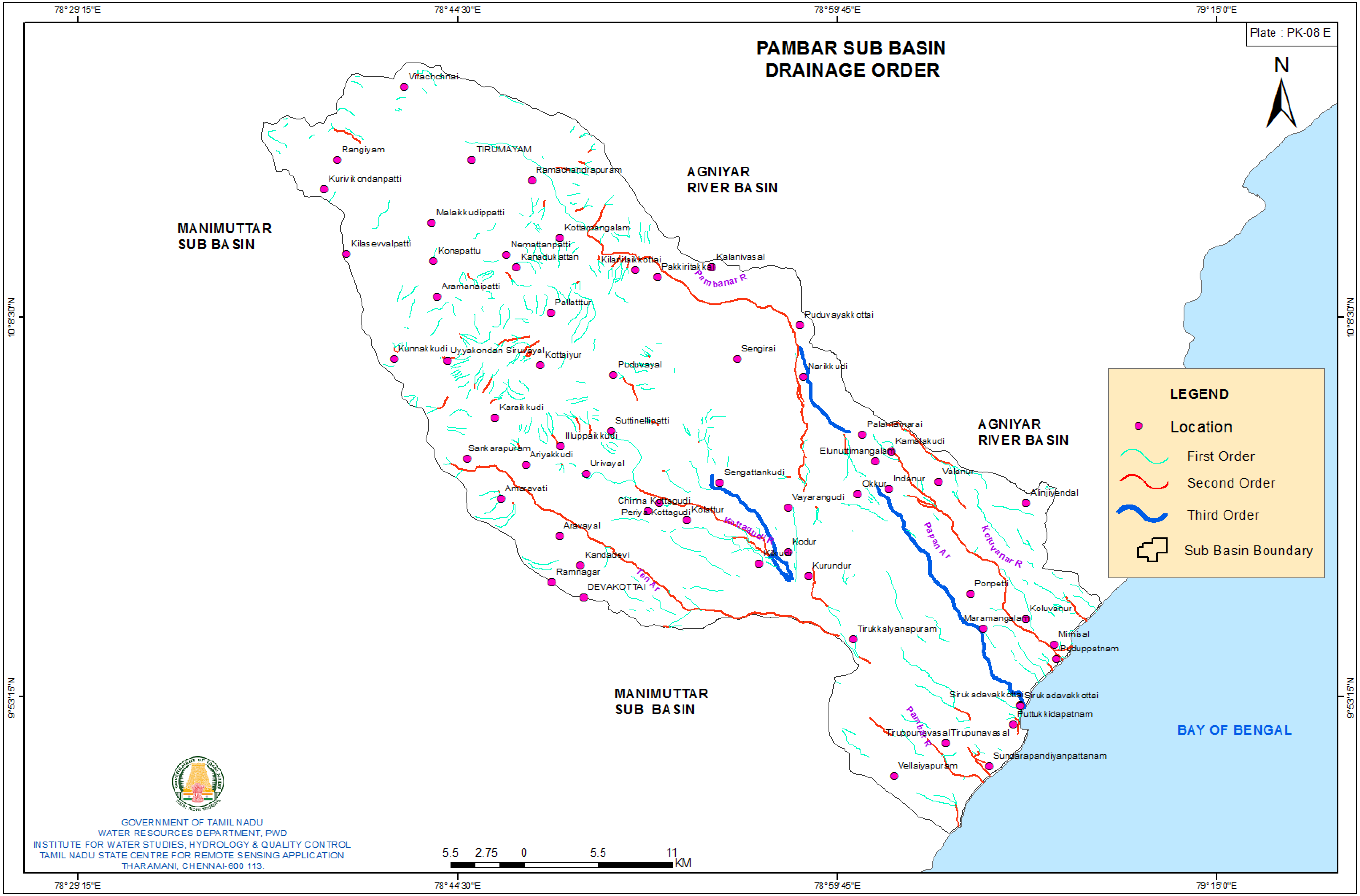
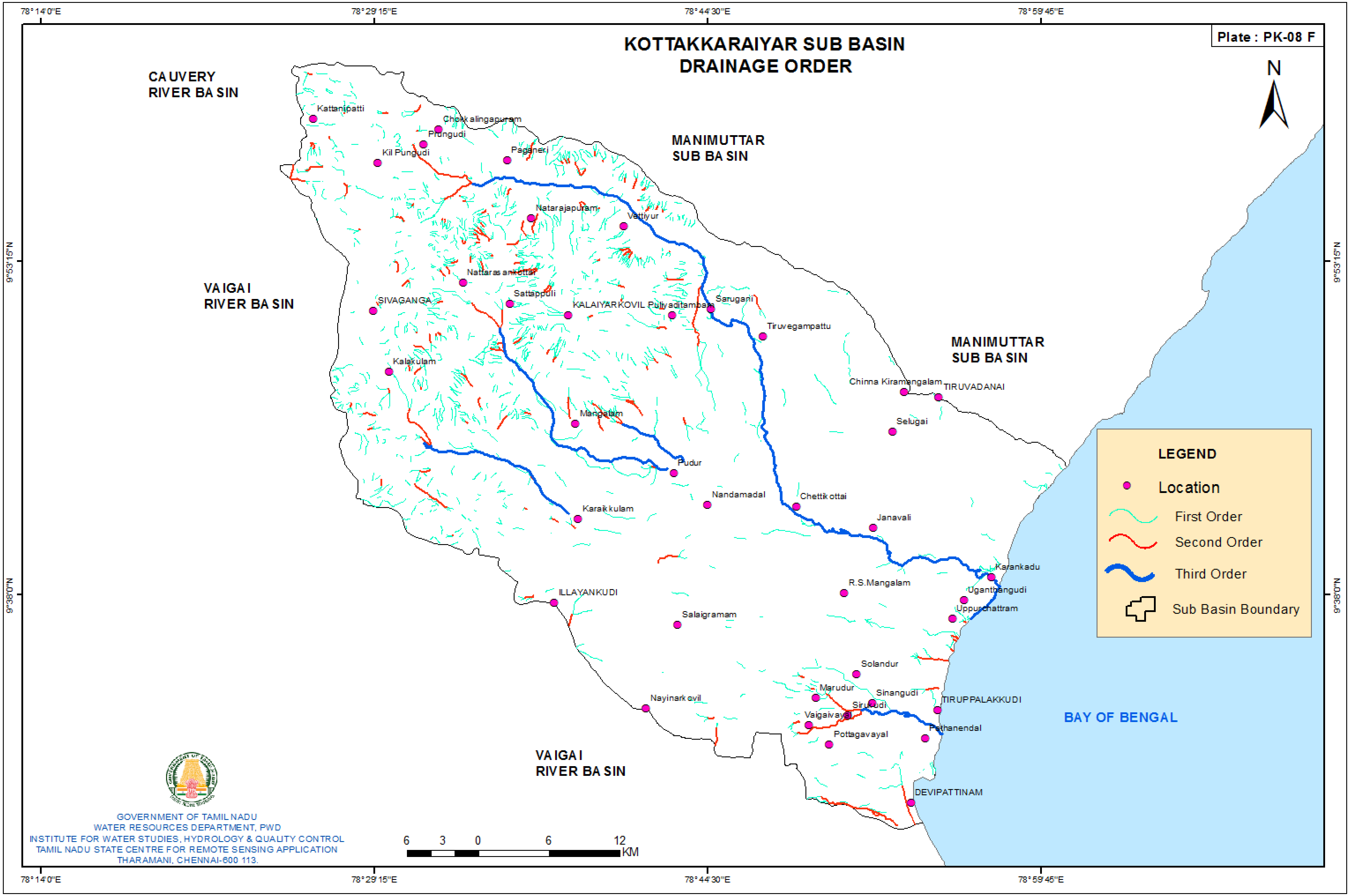
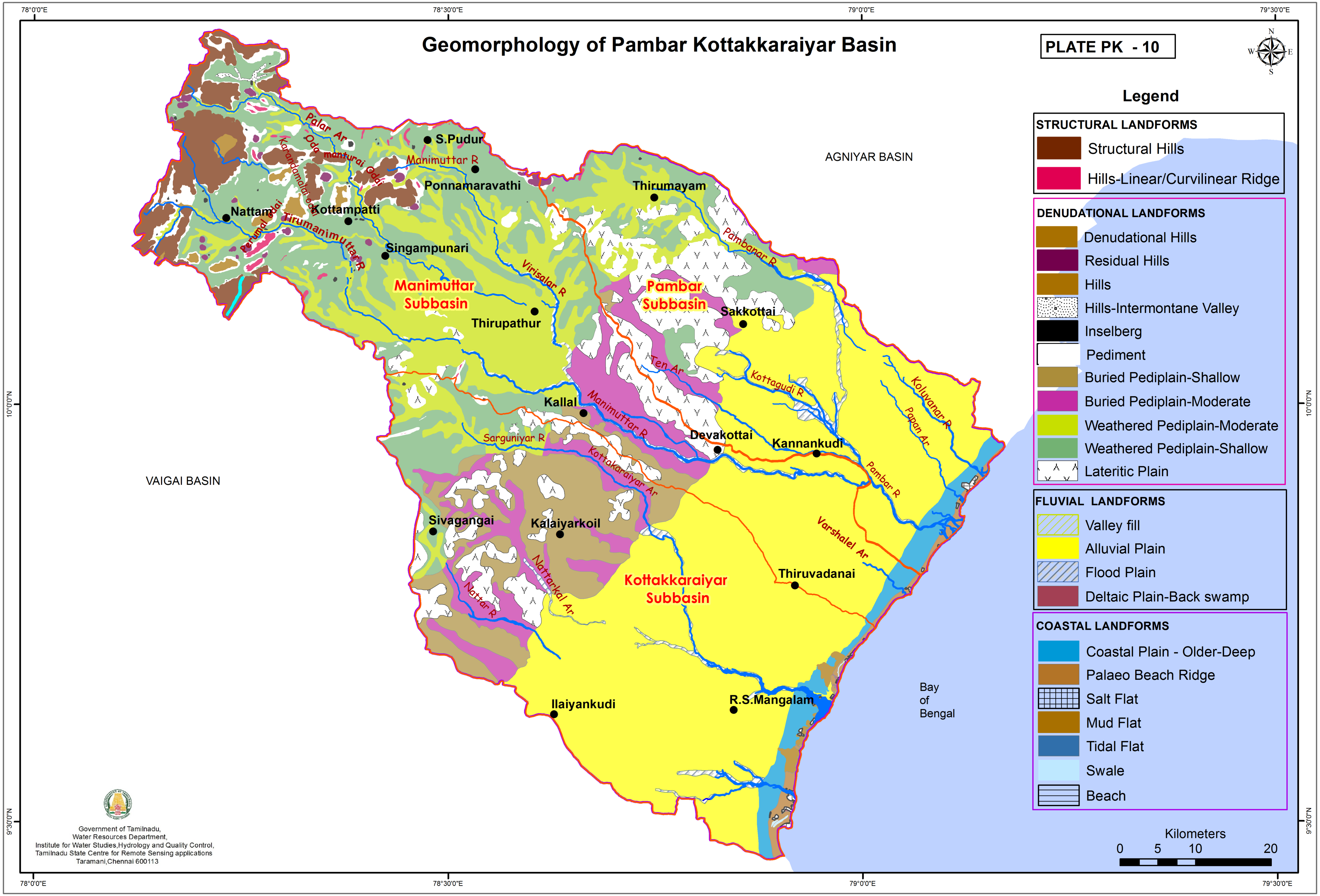


Plate : PK-08 E
PAMBAR SUB BASIN
DRAINAGE ORDER
N
78°29'15"E
78°44'30"E
78°59'45"E
79°15'0"E
10°8'30"N
9°53'15"N
MANIMUTTAR
SUB BASIN
AGNIYAR
RIVER BASIN
AGNIYAR
RIVER BASIN
MANIMUTTAR
SUB BASIN
BAY OF BENGAL
Virachchilai
Rangiyam
TIRUMAYAM
Ramachandrapuram
Kurivikondanpatti
Malaikkudippatti
Kottamangalam
Kilasevvalpatti
Konapattu
Nemattanpatti
Kanadukattan
Kilanilaikkottai
Pakkiritakkal
Kalanivasal
Pambanar R
Aramanaipatti
Pallattur
Puduvayakkottai
Kunnakkudi
Uyyakondan Siruvayal
Kottaiyur
Puduvayal
Sengirai
Narikkudi
Karaikkudi
Suttinellipatti
Illuppaikkudi
Palankarai
Kamalakudi
Sankarapuram
Ariyakkudi
Urivayal
Elunuttimangalam
Sengattankudi
Valanur
Indanur
Okkur
Alinjiyendal
Amaravati
Chinna Kottagudi
Periya Kottagudi
Kolattur
Vayarangudi
Kottagudi R
Papan Ar
Kottiyanar R
Aravayal
Kodur
Kilkudi
Kandadevi
Kurundur
Ramnagar
Ten Ar
DEVAKOTTAI
Ponpetti
Koluvanur
Maramangalam
Tirukkalyanapuram
Mimisal
Buduppatnam
Sirukadavakkottai
Sirukadavakkottai
Puttukkidapatnam
Pambar R
Tiruppunavasal Tirupunavasal
Sundarapandiyanpattanam
Vellaiyapuram
LEGEND
Location
First Order
Second Order
Third Order
Sub Basin Boundary
5.5 2.75 0 5.5 11
KM
GOVERNMENT OF TAMIL NADU
WATER RESOURCES DEPARTMENT, PWD
INSTITUTE FOR WATER STUDIES, HYDROLOGY & QUALITY CONTROL
TAMIL NADU STATE CENTRE FOR REMOTE SENSING APPLICATION
THARAMANI, CHENNAI-600 113.



KOTTAKKARAIYAR SUB BASIN
DRAINAGE ORDER
Plate : PK-08 F
N
78°14'0"E
78°29'15"E
78°44'30"E
78°59'45"E
9°53'15"N
9°38'0"N
CAUVERY RIVER BASIN
MANIMUTTAR SUB BASIN
VAIGAI RIVER BASIN
BAY OF BENGAL
Kattanipatti
Chokkalingapuram
Pirungudi
Kil Pungudi
Paganeri
Natarajapuram
Vettiyur
Nattarasankottai
Sattappuli
SIVAGANGA
KALAIYARKOVIL
Puliyaditambam
Sarugani
Tiruvegampattu
Kalakulam
Chinna Kiramangalam
TIRUVADANAI
Selugai
Mangalam
Pudur
Nandamadal
Chettikottai
Karaikkulam
Janavali
Karankadu
R.S.Mangalam
Uganthangudi
Uppurchattram
ILLAYANKUDI
Salaigramam
Solandur
Marudur
Sinangudi
Nayinarkovil
Sirugudi
TIRUPPALAKKUDI
Vaigaivayal
Pottagavayal
Pathanendal
DEVIPATTINAM
LEGEND
Location
First Order
Second Order
Third Order
Sub Basin Boundary
6 3 0 6 12
KM
GOVERNMENT OF TAMIL NADU
WATER RESOURCES DEPARTMENT, PWD
INSTITUTE FOR WATER STUDIES, HYDROLOGY & QUALITY CONTROL
TAMIL NADU STATE CENTRE FOR REMOTE SENSING APPLICATION
THARAMANI, CHENNAI-600 113.

GEOLOGY OF PAMBAR KOTTAKKARAIYAR BASIN
PLATE PK- 09
78°0'0"E
78°30'0"E
79°0'0"E
10°0'0"N
9°30'0"N
Manimuttar Sub Basin
Pambar Sub Basin
Kottakkaraiyar Sub Basin
Amaravathi
South Vellar
Agniyar
Ambuliyar
Sirumalaiyar
Sathaiyar
Uppar
Gridhamal
Kanal odai
Paralaiyar
Lower Vaigai
Bay of Bengal
Legend
Borehole locations
CONTACT
ALTERED SEQUENCE OF SAND ,SILT AND CLAY
CHARNOCKITE
GNEISS
GRANITIC / ACIDIC ROCKS
MIGMATITIC COMPLEX
QUARTZITE
SAND AND SILT
SAND STONE AND CONGLOMERATE
SANDS (COASTAL / ALLUVIAL / AEOLIAN DEPOSITS)
SHALY SAND STONE
Kilometers
0 5 10 20
Government of Tamilnadu,
Water Resources Department,
Institute for Water Studies,Hydrology and Quality Control,
Tamilnadu State Centre for Remote Sensing applications
Taramani,Chennai 600113


Geomorphology of Pambar Kottakkaraiyar Basin
PLATE PK - 10
N
S
E
W
78°0'0"E
78°30'0"E
79°0'0"E
79°30'0"E
10°0'0"N
9°30'0"N
Legend
STRUCTURAL LANDFORMS
Structural Hills
Hills-Linear/Curvilinear Ridge
DENUDATIONAL LANDFORMS
Denudational Hills
Residual Hills
Hills
Hills-Intermontane Valley
Inselberg
Pediment
Buried Pediplain-Shallow
Buried Pediplain-Moderate
Weathered Pediplain-Moderate
Weathered Pediplain-Shallow
Lateritic Plain
FLUVIAL LANDFORMS
Valley fill
Alluvial Plain
Flood Plain
Deltaic Plain-Back swamp
COASTAL LANDFORMS
Coastal Plain - Older-Deep
Palaeo Beach Ridge
Salt Flat
Mud Flat
Tidal Flat
Swale
Beach
Kilometers
0 5 10 20
AGNIYAR BASIN
VAIGAI BASIN
Bay of Bengal
Manimuttar Subbasin
Pambar Subbasin
Kottakkaraiyar Subbasin
S.Pudur
Ponnamaravathi
Nattam
Kottampatti
Singampunari
Thirupathur
Thirumayam
Sakkottai
Kallal
Devakottai
Kannankudi
Sivagangai
Kalaiyarkoil
Thiruvadanai
Ilaiyankudi
R.S.Mangalam
Palar Ar
Manimuttar R
Virisalar R
Pambanar R
Ten Ar
Kottagudi R
Koluvanar R
Papan Ar
Pambar R
Sarguniyar R
Manimuttar R
Kottakaraiyar Ar
Varshalei Ar
Nattarkal Ar
Nattar R
Government of Tamilnadu,
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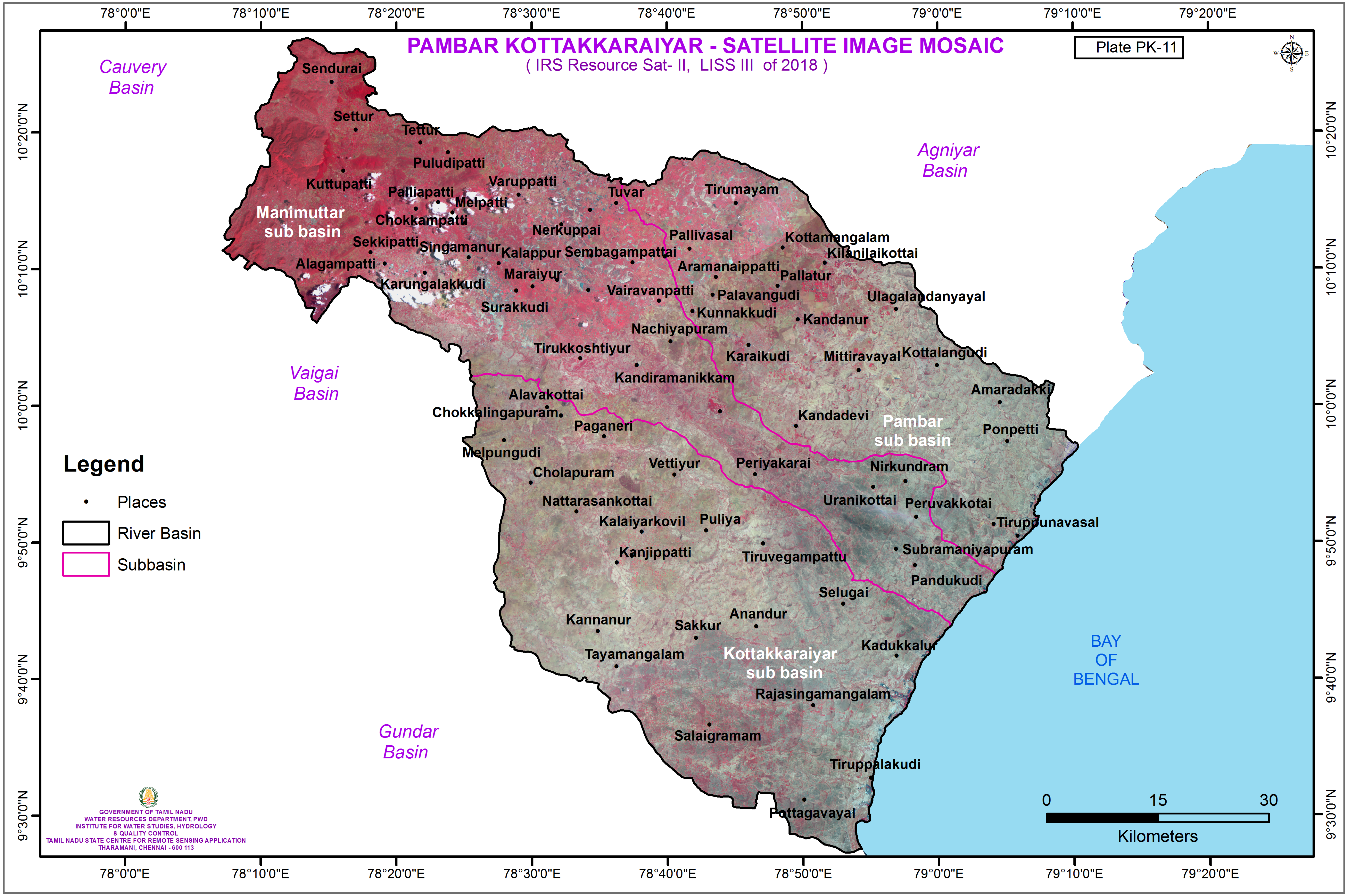
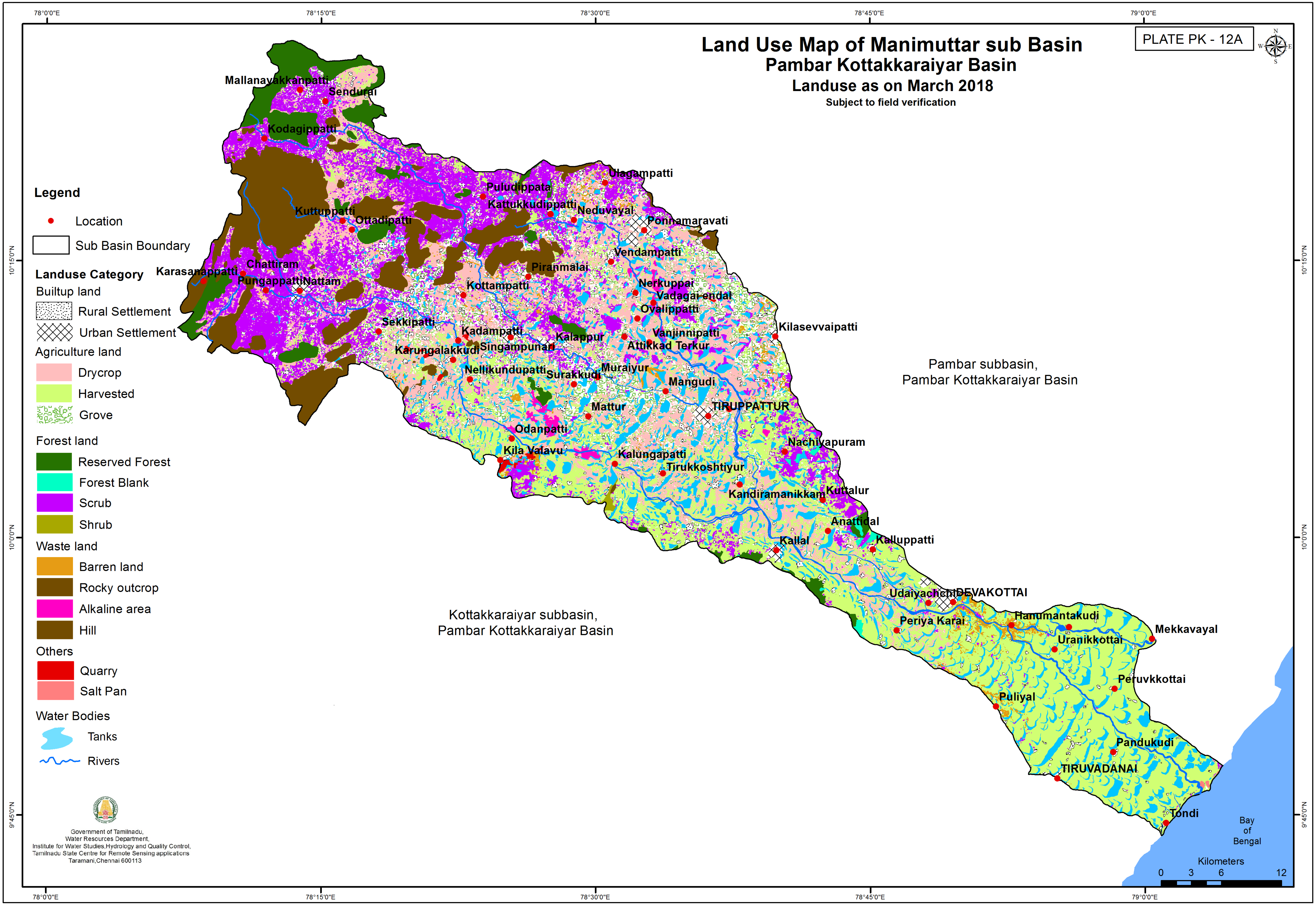
Tamilnadu State Centre for Remote Sensing applications
Taramani,Chennai 600113

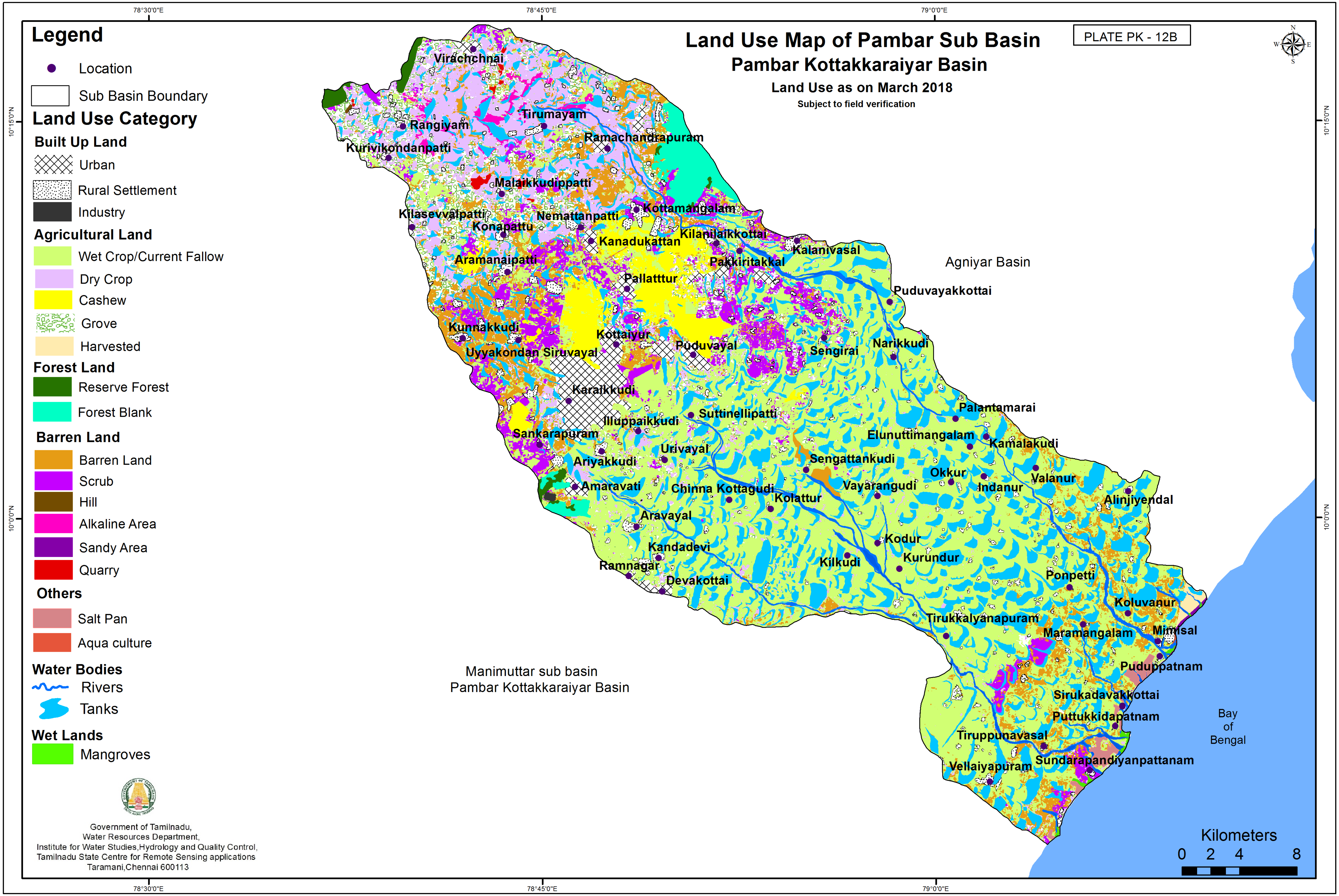


PAMBAR KOTTAKKARAIYAR - SATELLITE IMAGE MOSAIC
(IRS Resource Sat- II, LISS III of 2018)
Plate PK-11
78°0'0"E
78°10'0"E
78°20'0"E
78°30'0"E
78°40'0"E
78°50'0"E
79°0'0"E
79°10'0"E
79°20'0"E
10°20'0"N
10°10'0"N
10°0'0"N
9°50'0"N
9°40'0"N
9°30'0"N
Cauvery Basin
Agniyar Basin
Vaigai Basin
Gundar Basin
BAY OF BENGAL
Manimuttar sub basin
Pambar sub basin
Kottakkaraiyar sub basin
Sendurai
Settur
Tettur
Puludipatti
Kuttupatti
Palliapatti
Varuppatti
Melpatti
Tuvar
Tirumayam
Chokkampatti
Nerkuppai
Pallivasal
Kottamangalam
Kilanilaikottai
Sekkipatti
Singamanur
Kalappur
Sembagampattai
Aramanaippatti
Pallatur
Alagampatti
Maraiyur
Karungalakkudi
Vairavanpatti
Palavangudi
Ulagalandanyayal
Surakkudi
Kunnakkudi
Kandanur
Nachiyapuram
Tirukkoshtiyur
Karaikudi
Mittiravayal
Kottalangudi
Kandiramanikkam
Amaradakki
Alavakottai
Chokkalingapuram
Paganeri
Kandadevi
Ponpetti
Melpungudi
Cholapuram
Vettiyur
Periyakarai
Nirkundram
Nattarasankottai
Uranikottai
Peruvakkotai
Kalaiyarkovil
Puliya
Tiruppunavasal
Kanjippatti
Tiruvegampattu
Subramaniyapuram
Pandukudi
Selugai
Kannanur
Sakkur
Anandur
Kadukkalur
Tayamangalam
Rajasingamangalam
Salaigramam
Tiruppalakudi
Pottagavayal
Legend
Places
River Basin
Subbasin
0
15
30
Kilometers
N
S
E
W
GOVERNMENT OF TAMIL NADU
WATER RESOURCES DEPARTMENT, PWD
INSTITUTE FOR WATER STUDIES, HYDROLOGY
& QUALITY CONTROL
TAMIL NADU STATE CENTRE FOR REMOTE SENSING APPLICATION
THARAMANI, CHENNAI - 600 113

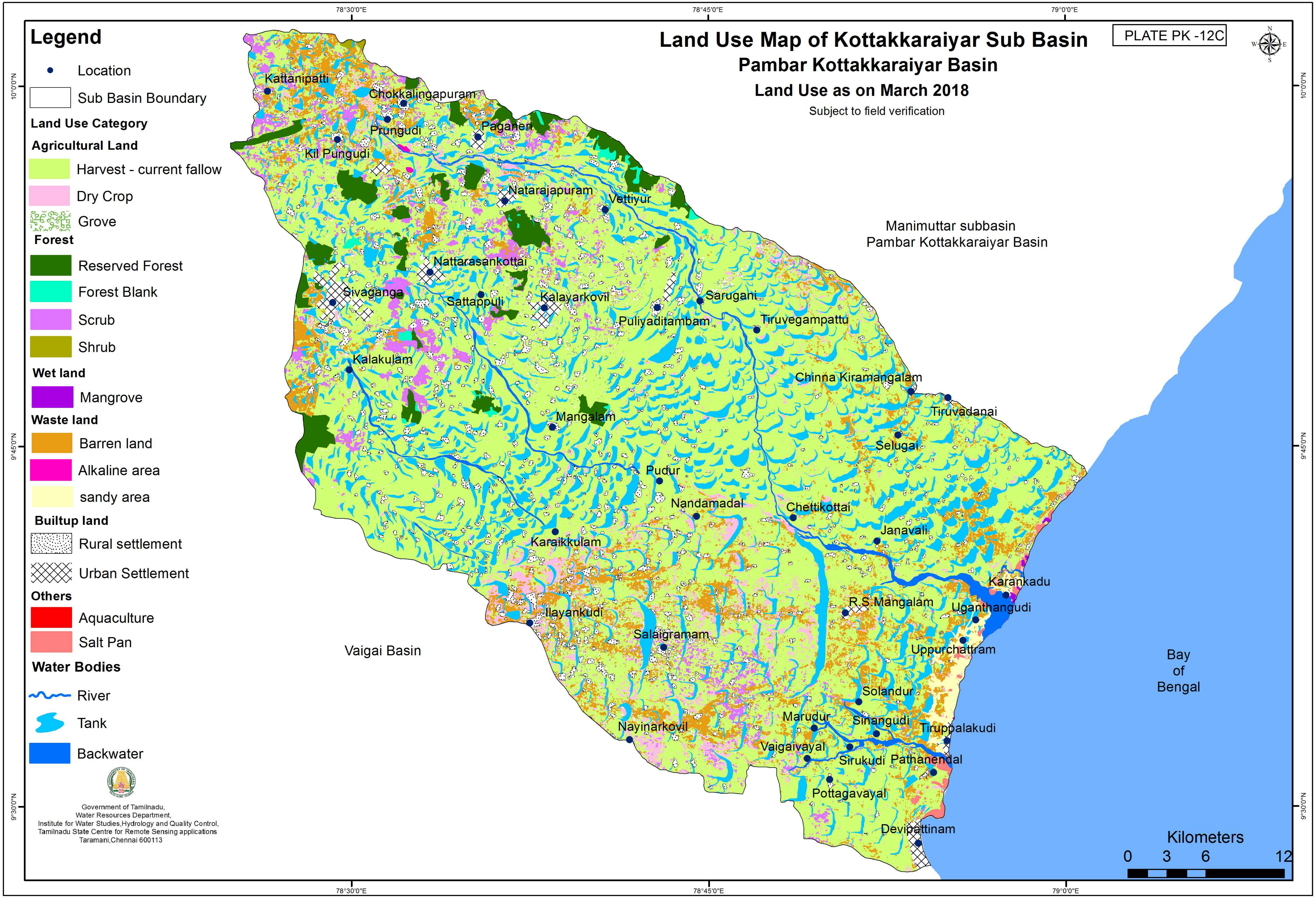
Land Use Map of Manimuttar sub Basin
Pambar Kottakkaraiyar Basin
Landuse as on March 2018
Subject to field verification

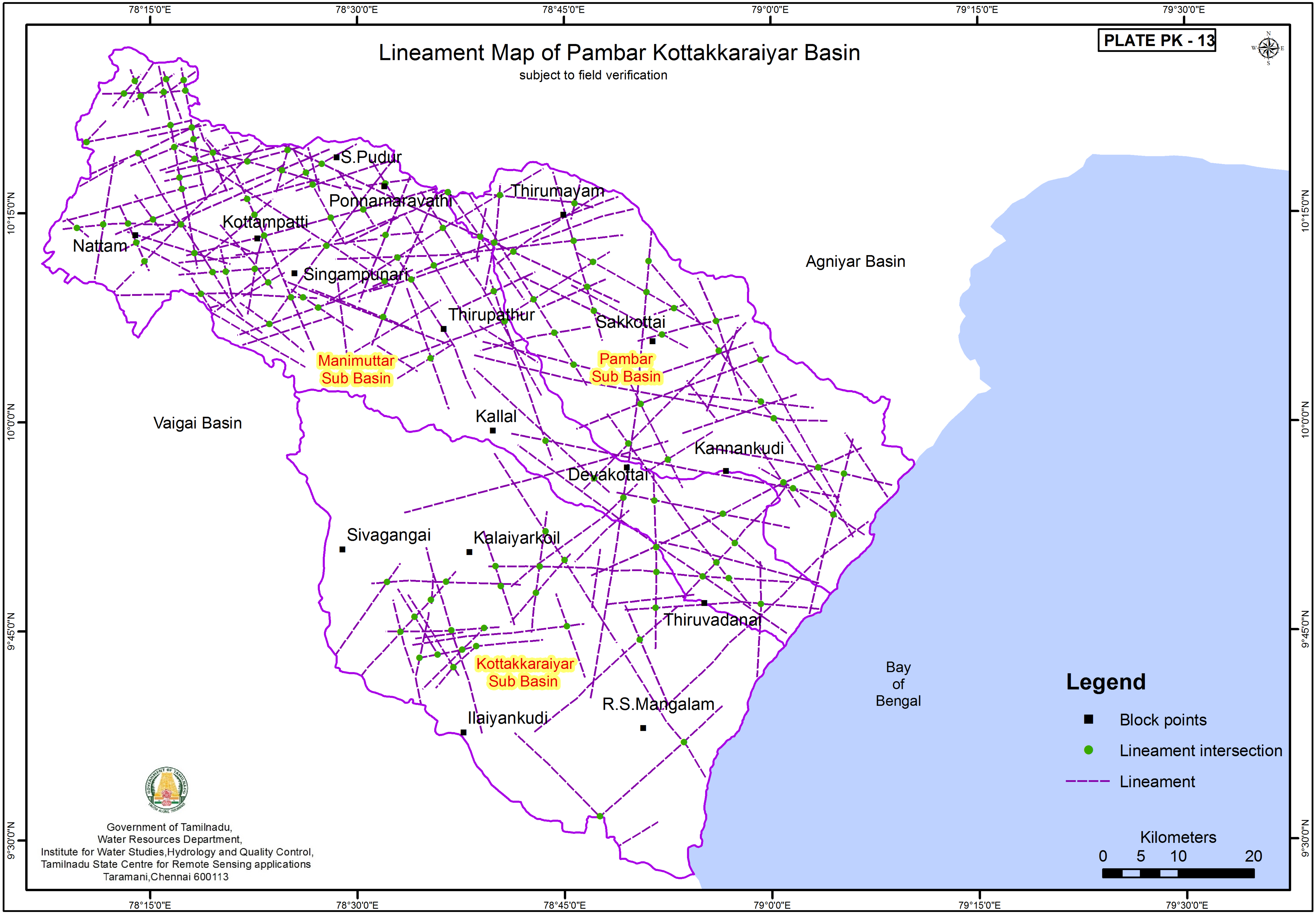
PLATE PK - 12A

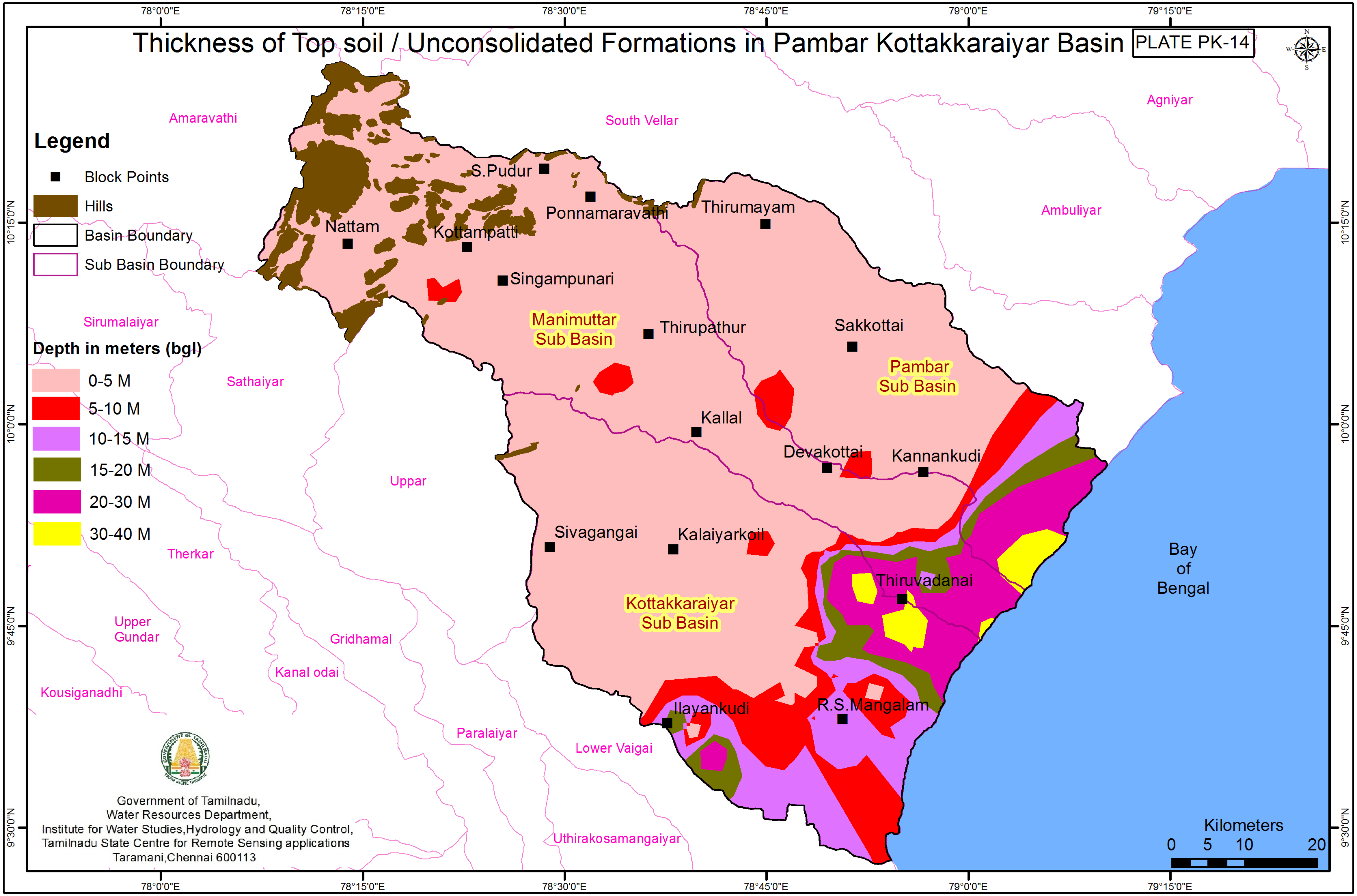


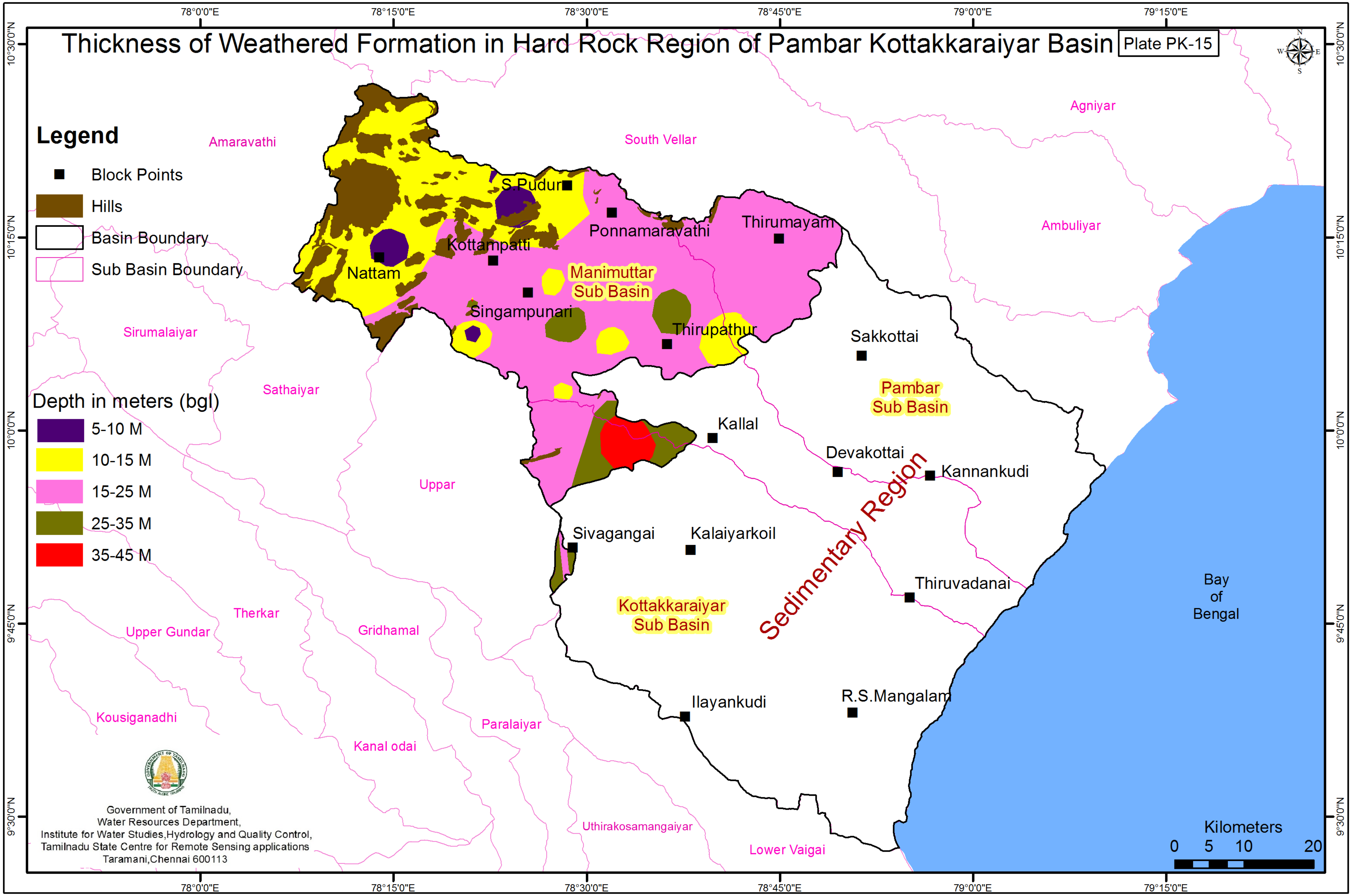


Land Use Map of Pambar Sub Basin
Pambar Kottakkaraiyar Basin
Land Use as on March 2018
Subject to field verification
PLATE PK - 12B
Legend
Location
Sub Basin Boundary
Land Use Category
Built Up Land
Urban
Rural Settlement
Industry
Agricultural Land
Wet Crop/Current Fallow
Dry Crop
Cashew
Grove
Harvested
Forest Land
Reserve Forest
Forest Blank
Barren Land
Barren Land
Scrub
Hill
Alkaline Area
Sandy Area
Quarry
Others
Salt Pan
Aqua culture
Water Bodies
Rivers
Tanks
Wet Lands
Mangroves
Government of Tamilnadu,
Water Resources Department,
Institute for Water Studies,Hydrology and Quality Control,
Tamilnadu State Centre for Remote Sensing applications
Taramani,Chennai 600113
78°30'0"E
78°45'0"E
79°0'0"E
10°15'0"N
10°0'0"N
Agniyar Basin
Manimuttar sub basin
Pambar Kottakkaraiyar Basin
Bay of Bengal
Virachchnai
Tirumayam
Rangiyam
Kurivikondanpatti
Ramachandrapuram
Malaikkudippatti
Kottamangalam
Kilasevvalpatti
Nemattanpatti
Konapattu
Kanadukattan
Kilanilaikkottai
Kalanivasal
Aramanaipatti
Pakkiritakkal
Pallatttur
Puduvayakkottai
Kunnakkudi
Kottaiyur
Puduvayal
Sengirai
Narikkudi
Uyyakondan Siruvayal
Karaikkudi
Palantamarai
Suttinellipatti
Illuppaikkudi
Elunuttimangalam
Sankarapuram
Kamalakudi
Urivayal
Sengattankudi
Ariyakkudi
Okkur
Valanur
Amaravati
Chinna Kottagudi
Vayarangudi
Indanur
Kolattur
Alinjiyendal
Aravayal
Kodur
Kandadevi
Kurundur
Kilkudi
Ramnagar
Devakottai
Ponpetti
Koluvanur
Tirukkalyanapuram
Maramangalam
Mimisal
Puduppatnam
Sirukadavakkottai
Puttukkidapatnam
Tiruppunavasal
Sundarapandiyanpattanam
Vellaiyapuram
Kilometers
0 2 4 8

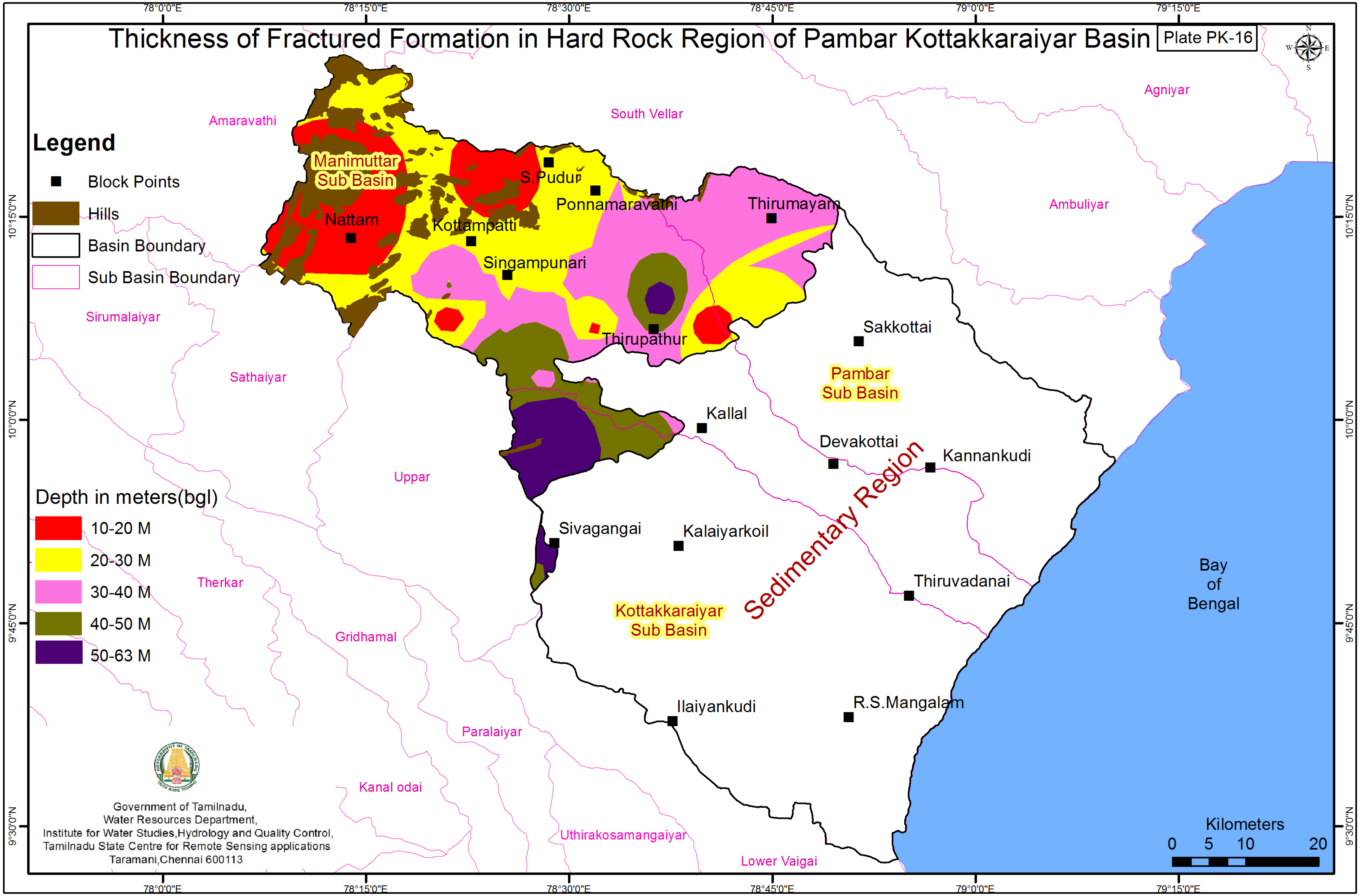

Land Use Map of Kottakkaraiyar Sub Basin
Pambar Kottakkaraiyar Basin
Land Use as on March 2018
Subject to field verification
PLATE PK -12C
Legend
Location
Sub Basin Boundary
Land Use Category
Agricultural Land
Harvest - current fallow
Dry Crop
Grove
Forest
Reserved Forest
Forest Blank
Scrub
Shrub
Wet land
Mangrove
Waste land
Barren land
Alkaline area
sandy area
Builtup land
Rural settlement
Urban Settlement
Others
Aquaculture
Salt Pan
Water Bodies
River
Tank
Backwater
Government of Tamilnadu,
Water Resources Department,
Institute for Water Studies,Hydrology and Quality Control,
Tamilnadu State Centre for Remote Sensing applications
Taramani,Chennai 600113
78°30'0"E
78°45'0"E
79°0'0"E
10°0'0"N
9°45'0"N
9°30'0"N
Kattanipatti
Chokkalingapuram
Prungudi
Paganeri
Kil Pungudi
Natarajapuram
Vettiyur
Manimuttar subbasin
Pambar Kottakkaraiyar Basin
Nattarasankottai
Sivaganga
Sattappuli
Kalayarkovil
Sarugani
Puliyaditambam
Tiruvegampattu
Kalakulam
Chinna Kiramangalam
Tiruvadanai
Mangalam
Selugai
Pudur
Nandamadal
Chettikottai
Janavali
Karaikkulam
Karankadu
R.S.Mangalam
Uganthangudi
Ilayankudi
Salaigramam
Uppurchattram
Vaigai Basin
Bay
of
Bengal
Solandur
Marudur
Sinangudi
Tiruppalakudi
Nayinarkovil
Vaigaivayal
Sirukudi
Pathanendal
Pottagavayal
Devipattinam
Kilometers
0
3
6
12


Lineament Map of Pambar Kottakkaraiyar Basin
subject to field verification
PLATE PK - 13
78°15'0"E
78°30'0"E
78°45'0"E
79°0'0"E
79°15'0"E
79°30'0"E
10°15'0"N
10°0'0"N
9°45'0"N
9°30'0"N
S.Pudur
Thirumayam
Ponnamaravathi
Kottampatti
Nattam
Singampunari
Agniyar Basin
Thirupathur
Sakkottai
Manimuttar
Sub Basin
Pambar
Sub Basin
Vaigai Basin
Kallal
Kannankudi
Devakottai
Sivagangai
Kalaiyarkoil
Thiruvadanai
Kottakkaraiyar
Sub Basin
Bay
of
Bengal
R.S.Mangalam
Ilaiyankudi
Legend
Block points
Lineament intersection
Lineament
Kilometers
0 5 10 20
Government of Tamilnadu,
Water Resources Department,
Institute for Water Studies,Hydrology and Quality Control,
Tamilnadu State Centre for Remote Sensing applications
Taramani,Chennai 600113

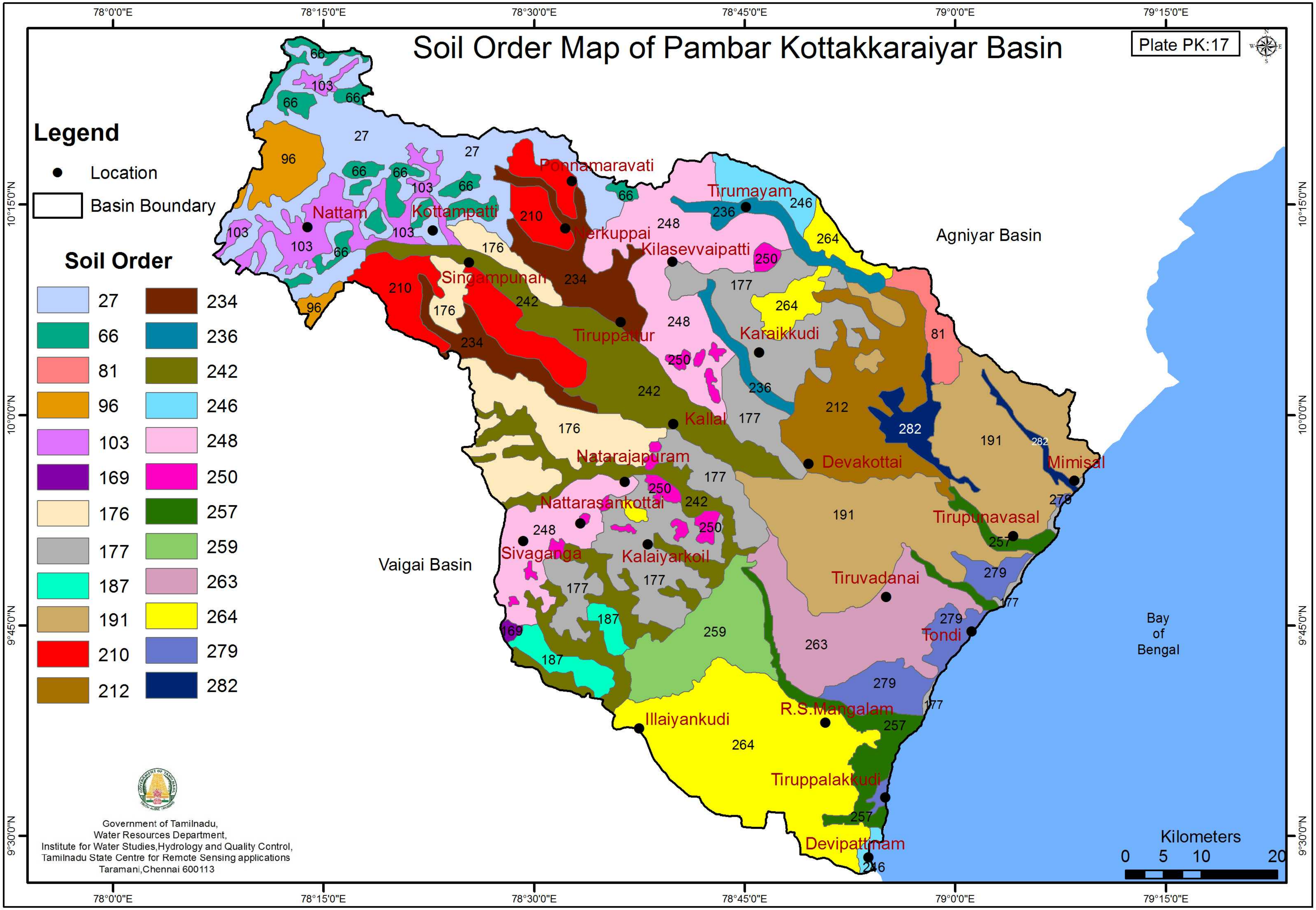

Thickness of Top soil / Unconsolidated Formations in Pambar Kottakkaraiyar Basin
PLATE PK-14
Legend
Block Points
Hills
Basin Boundary
Sub Basin Boundary
Depth in meters (bgl)
0-5 M
5-10 M
10-15 M
15-20 M
20-30 M
30-40 M
Amaravathi
South Vellar
Agniyar
Ambuliyar
Sirumalaiyar
Sathaiyar
Uppar
Therkar
Upper Gundar
Gridhamal
Kanal odai
Kousiganadhi
Paralaiyar
Lower Vaigai
Uthirakosamangaiyar
S.Pudur
Ponnamaravathi
Thirumayam
Nattam
Kottampatti
Singampunari
Manimuttar Sub Basin
Thirupathur
Sakkottai
Pambar Sub Basin
Kallal
Devakottai
Kannankudi
Sivagangai
Kalaiyarkoil
Thiruvadanai
Kottakkaraiyar Sub Basin
Ilayankudi
R.S.Mangalam
Bay of Bengal
Kilometers
0 5 10 20
78°0'0"E
78°15'0"E
78°30'0"E
78°45'0"E
79°0'0"E
79°15'0"E
10°15'0"N
10°0'0"N
9°45'0"N
9°30'0"N
Government of Tamilnadu,
Water Resources Department,
Institute for Water Studies,Hydrology and Quality Control,
Tamilnadu State Centre for Remote Sensing applications
Taramani,Chennai 600113

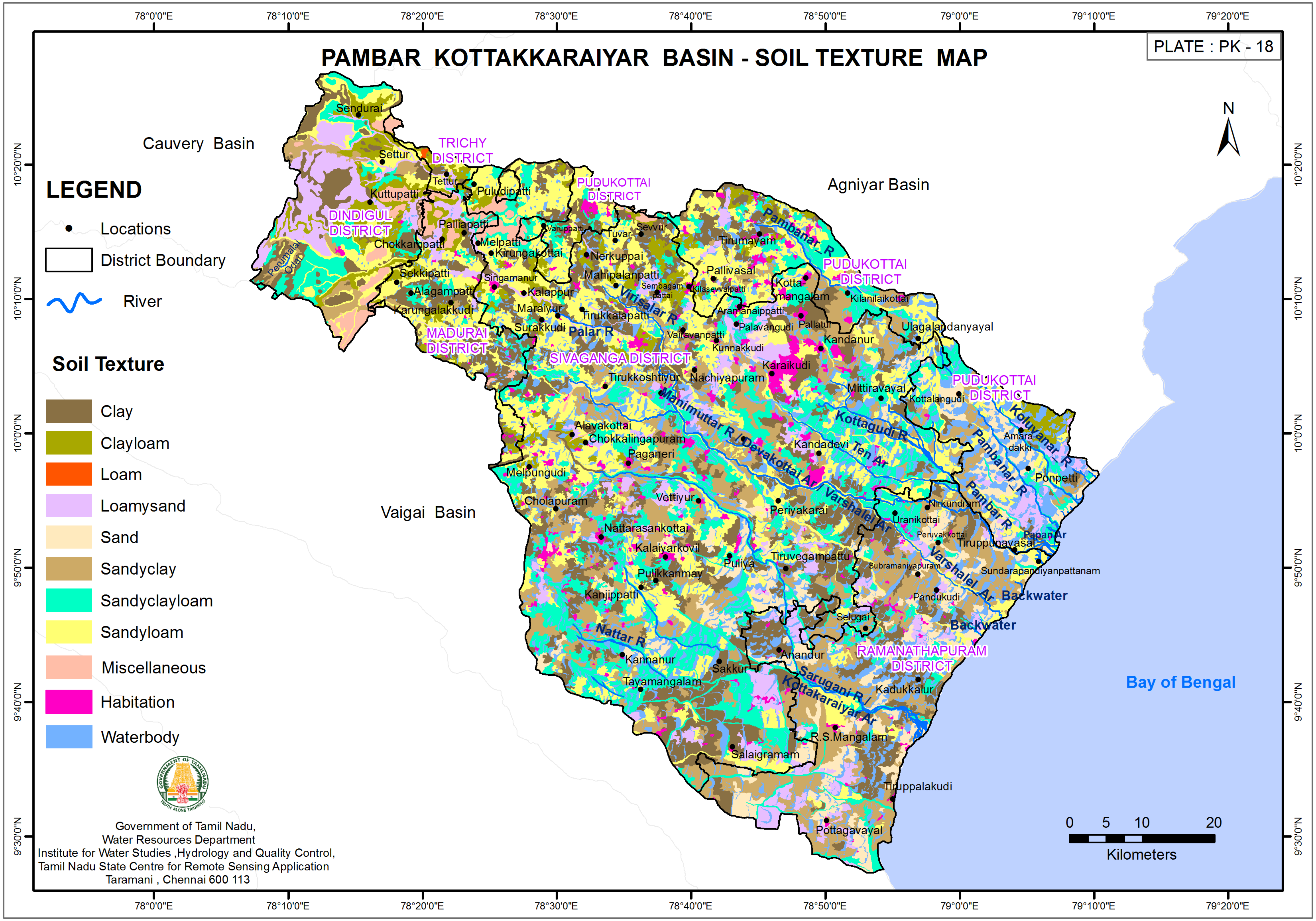


Thickness of Weathered Formation in Hard Rock Region of Pambar Kottakkaraiyar Basin
Plate PK-15
Legend
Block Points
Hills
Basin Boundary
Sub Basin Boundary
Depth in meters (bgl)
5-10 M
10-15 M
15-25 M
25-35 M
35-45 M
78°0'0"E
78°15'0"E
78°30'0"E
78°45'0"E
79°0'0"E
79°15'0"E
10°30'0"N
10°15'0"N
10°0'0"N
9°45'0"N
9°30'0"N
Amaravathi
South Vellar
Agniyar
Ambuliyar
Sirumalaiyar
Sathaiyar
Uppar
Therkar
Upper Gundar
Gridhamal
Kousiganadhi
Paralaiyar
Kanal odai
Uthirakosamangaiyar
Lower Vaigai
S.Pudur
Ponnamaravathi
Thirumayam
Kottampatti
Nattam
Manimuttar
Sub Basin
Singampunari
Thirupathur
Sakkottai
Pambar
Sub Basin
Kallal
Devakottai
Kannankudi
Sedimentary Region
Sivagangai
Kalaiyarkoil
Thiruvadanai
Kottakkaraiyar
Sub Basin
Ilayankudi
R.S.Mangalam
Bay
of
Bengal
Kilometers
0 5 10 20
Government of Tamilnadu,
Water Resources Department,
Institute for Water Studies,Hydrology and Quality Control,
Tamilnadu State Centre for Remote Sensing applications
Taramani,Chennai 600113



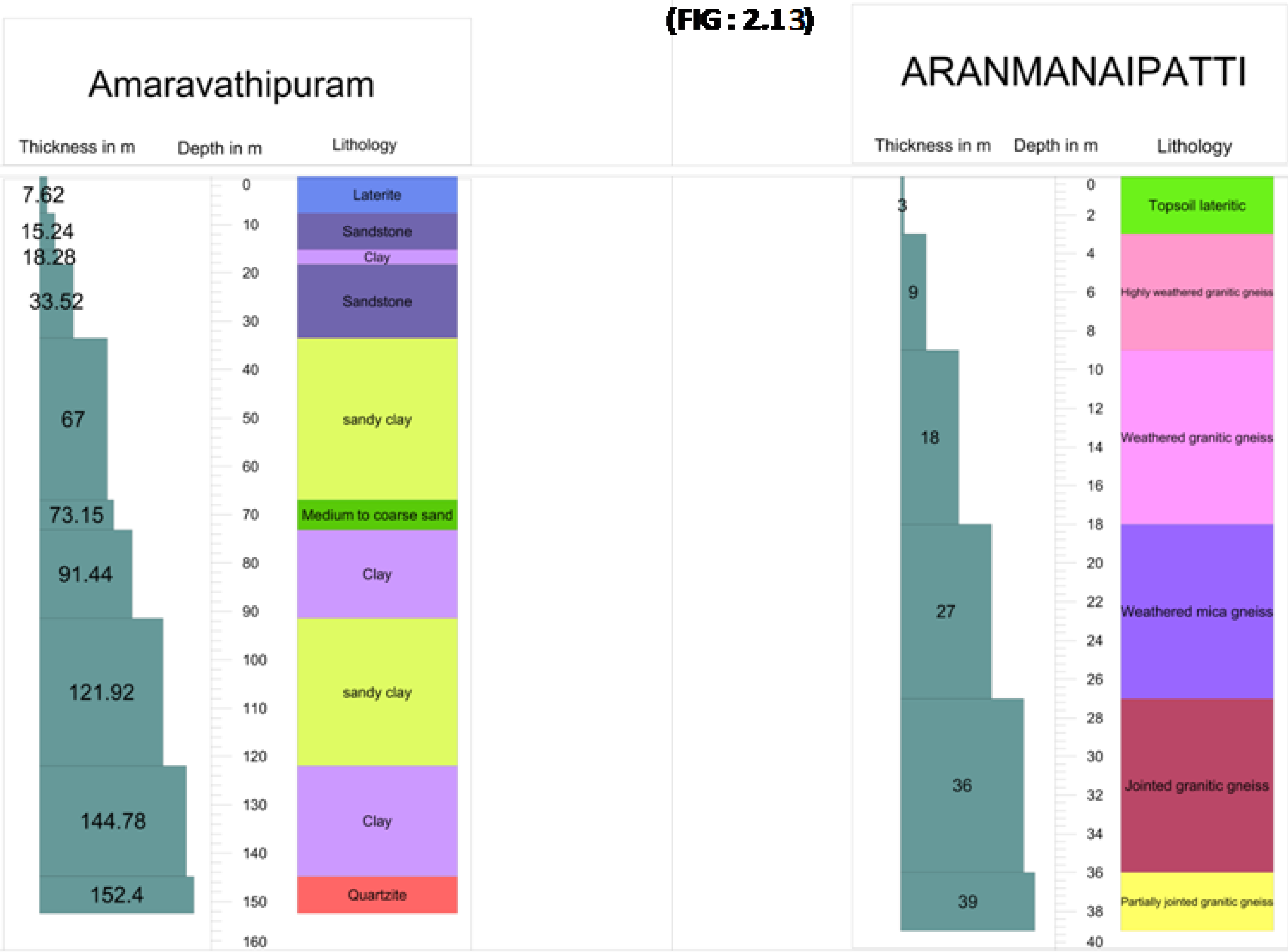
Thickness of Fractured Formation in Hard Rock Region of Pambar Kottakkaraiyar Basin
Plate PK-16
Legend
Block Points
Hills
Basin Boundary
Sub Basin Boundary
Depth in meters(bgl)
10-20 M
20-30 M
30-40 M
40-50 M
50-63 M
Manimuttar Sub Basin
Pambar Sub Basin
Kottakkaraiyar Sub Basin
Sedimentary Region
Bay of Bengal
Amaravathi
South Vellar
Agniyar
Ambuliyar
Sirumalaiyar
Sathaiyar
Uppar
Therkar
Gridhamal
Paralaiyar
Kanal odai
Uthirakosamangaiyar
Lower Vaigai
S.Pudur
Ponnamaravathi
Thirumayam
Nattam
Kottampatti
Singampunari
Thirupathur
Sakkottai
Kallal
Devakottai
Kannankudi
Sivagangai
Kalaiyarkoil
Thiruvadanai
Ilaiyankudi
R.S.Mangalam
78°0'0"E
78°15'0"E
78°30'0"E
78°45'0"E
79°0'0"E
79°15'0"E
10°15'0"N
10°0'0"N
9°45'0"N
9°30'0"N
Kilometers
0 5 10 20
Government of Tamilnadu,
Water Resources Department,
Institute for Water Studies,Hydrology and Quality Control,
Tamilnadu State Centre for Remote Sensing applications
Taramani,Chennai 600113

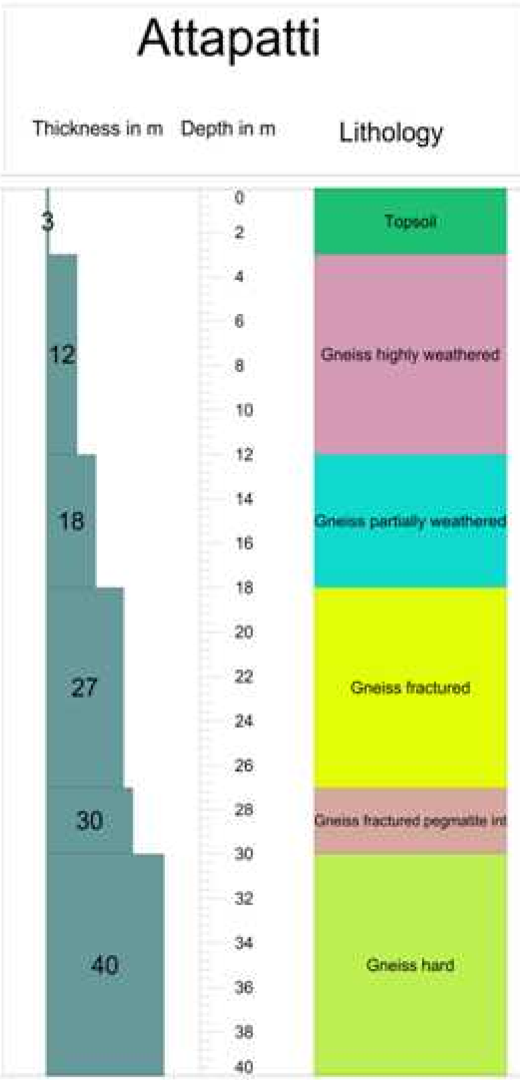

Soil Order Map of Pambar Kottakkaraiyar Basin
Plate PK:17
Legend
Location
Basin Boundary
Soil Order
27
66
81
96
103
169
176
177
187
191
210
212
234
236
242
246
248
250
257
259
263
264
279
282
Ponnamaravati
Tirumayam
Nattam
Kottampatti
Nerkuppai
Kilasevvaipatti
Singampunari
Tiruppattur
Karaikkudi
Kallal
Devakottai
Natarajapuram
Nattarasankottai
Sivaganga
Kalaiyarkoil
Mimisal
Tirupunavasal
Tiruvadanai
Tondi
R.S.Mangalam
Illaiyankudi
Tiruppalakkudi
Devipattinam
Agniyar Basin
Vaigai Basin
Bay of Bengal
Kilometers
0 5 10 20
78°0'0"E
78°15'0"E
78°30'0"E
78°45'0"E
79°0'0"E
79°15'0"E
10°15'0"N
10°0'0"N
9°45'0"N
9°30'0"N
Government of Tamilnadu,
Water Resources Department,
Institute for Water Studies,Hydrology and Quality Control,
Tamilnadu State Centre for Remote Sensing applications
Taramani,Chennai 600113

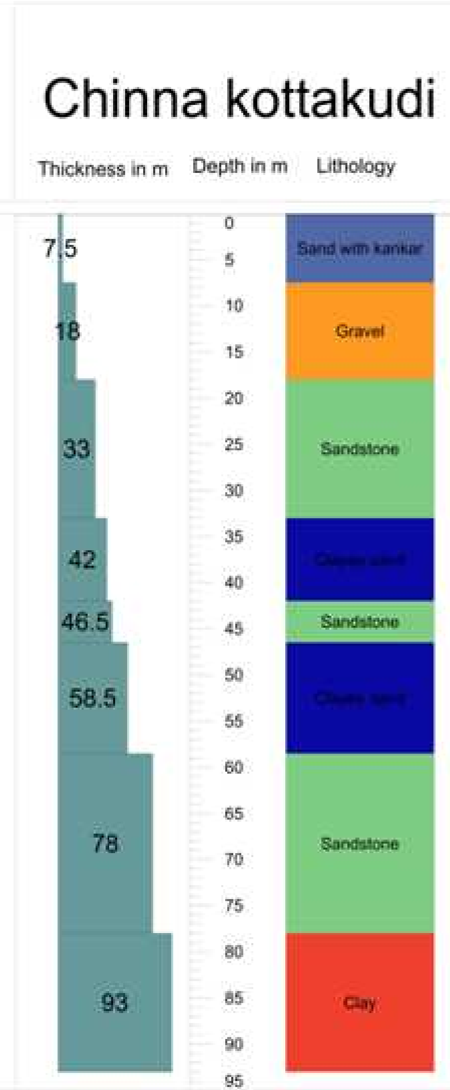

PAMBAR KOTTAKKARAIYAR BASIN - SOIL TEXTURE MAP
PLATE : PK - 18
LEGEND
Locations
District Boundary
River
Soil Texture
Clay
Clayloam
Loam
Loamysand
Sand
Sandyclay
Sandyclayloam
Sandyloam
Miscellaneous
Habitation
Waterbody
Cauvery Basin
Agniyar Basin
Vaigai Basin
Bay of Bengal
TRICHY DISTRICT
PUDUKOTTAI DISTRICT
DINDIGUL DISTRICT
MADURAI DISTRICT
SIVAGANGA DISTRICT
RAMANATHAPURAM DISTRICT
Sendurai
Settur
Tettur
Kuttupatti
Puludipatti
Palliapatti
Chokkampatti
Melpatti
Kirungakottai
Sekkipatti
Alagampatti
Karungalakkudi
Singamanur
Kalappur
Maraiyur
Surakkudi
Tuvar
Sevvur
Nerkuppai
Mahipalanpatti
Tirukkalapatti
Tirumayam
Pallivasal
Kotta-mangalam
Kilanilaikottai
Aranmanaippatti
Palavangudi
Pallatur
Vairavanpatti
Kunnakkudi
Kandanur
Ulagalandanyayal
Karaikudi
Tirukkoshtiyur
Nachiyapuram
Mittiravayal
Kottalangudi
Alavakottai
Chokkalingapuram
Paganeri
Melpungudi
Kandadevi
Amara-dakki
Ponpetti
Cholapuram
Vettiyur
Periyakarai
Nirkundram
Uranikottai
Peruvakkottai
Tiruppunavasal
Nattarasankottai
Kalaiyarkovil
Puliya
Tiruvegampattu
Subramaniyapuram
Sundarapandiyanpattanam
Pulikkanmay
Kanjippatti
Pandukudi
Selugai
Kannanur
Sakkur
Anandur
Tayamangalam
Kadukkalur
R.S.Mangalam
Salaigramam
Tiruppalakudi
Pottagavayal
Pambanar R
Virisalar R
Palar R
Manimuttar R / Devakottai Ar / Varshalei Ar
Kottagudi R
Ten Ar
Pambanar R
Koluvanar R
Pambar R
Papan Ar
Varshalei Ar
Nattar R
Sarugani R / Kottakaraiyar Ar
Backwater
N
0 5 10 20
Kilometers
78°0'0"E
78°10'0"E
78°20'0"E
78°30'0"E
78°40'0"E
78°50'0"E
79°0'0"E
79°10'0"E
79°20'0"E
10°20'0"N
10°10'0"N
10°0'0"N
9°50'0"N
9°40'0"N
9°30'0"N
Government of Tamil Nadu,
Water Resources Department
Institute for Water Studies ,Hydrology and Quality Control,
Tamil Nadu State Centre for Remote Sensing Application
Taramani , Chennai 600 113

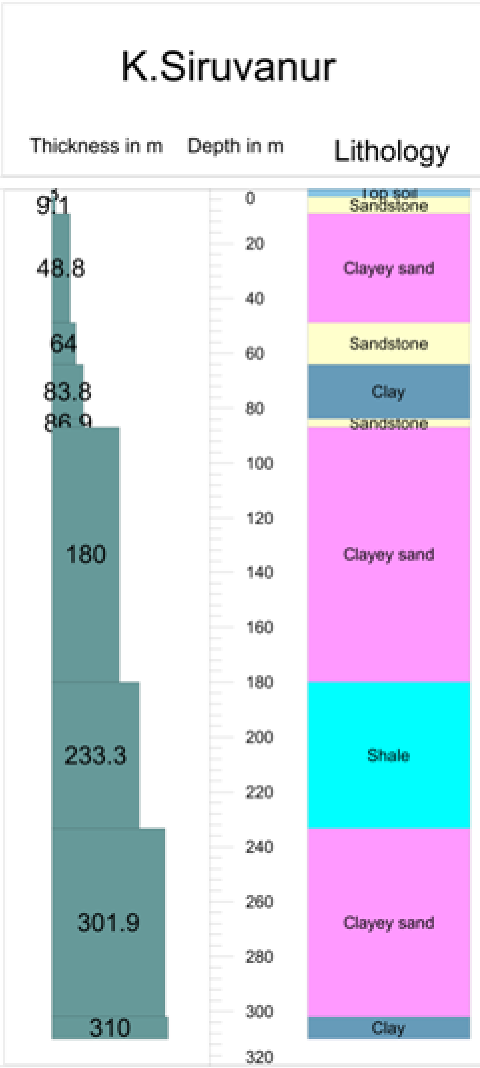
VERTICAL CROSS SECTION OF BOREHOLE

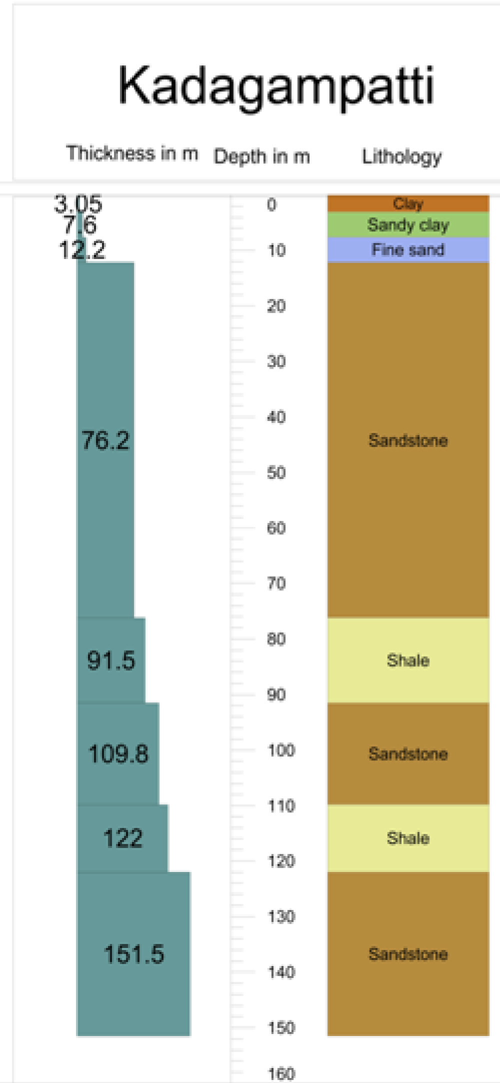
(FIG : 2.13)

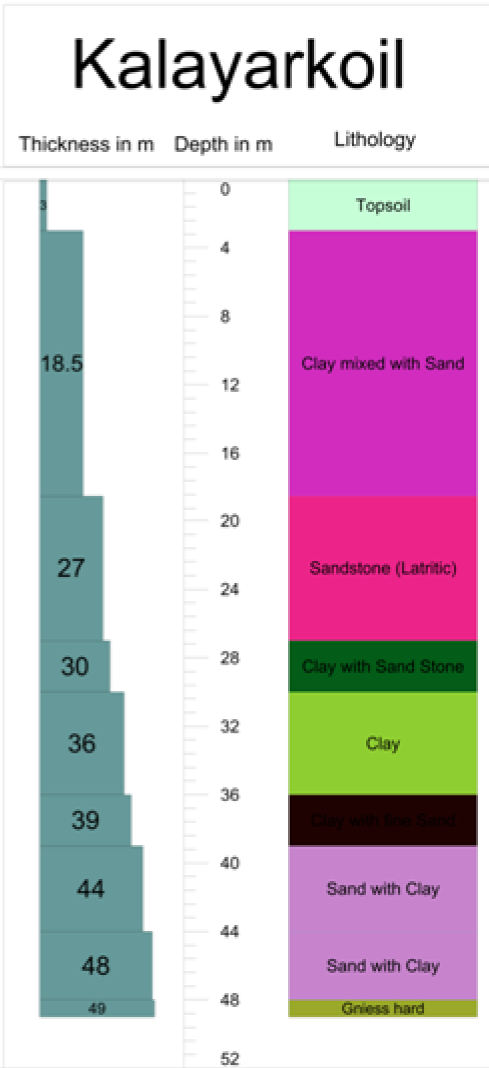


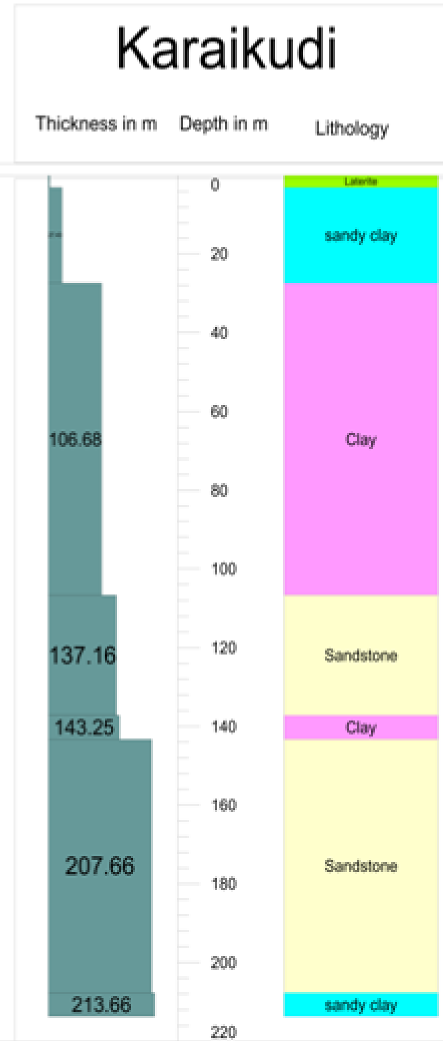

Attapatti
Thickness in m
Depth in m
Lithology
3
12
18
27
30
40
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
32
34
36
38
40
Topsoil
Gneiss highly weathered
Gneiss partially weathered
Gneiss fractured
Gneiss fractured pegmatite int
Gneiss hard

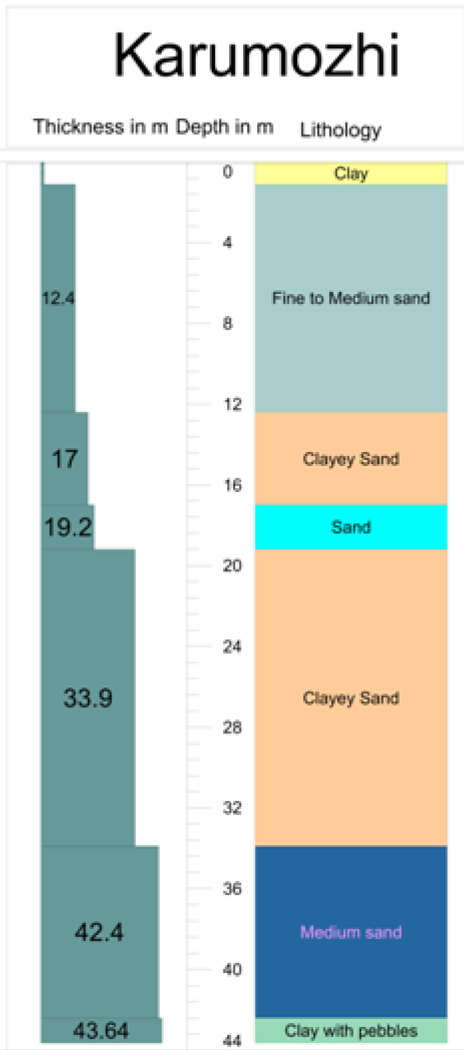

Chinna kottakudi
Thickness in m
Depth in m
Lithology
7.5
18
33
42
46.5
58.5
78
93
0
5
10
15
20
25
30
35
40
45
50
55
60
65
70
75
80
85
90
95
Sand with kankar
Gravel
Sandstone
Sandstone
Sandstone
Clay

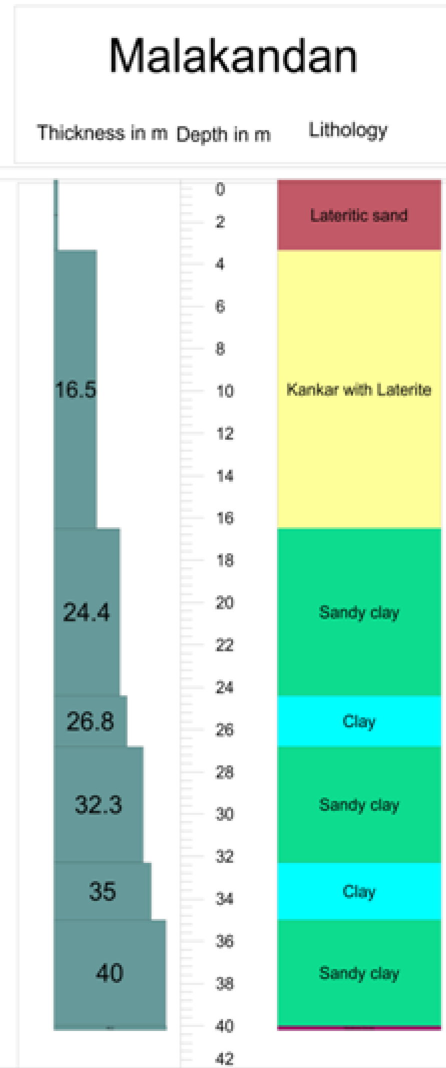

K.Siruvanur
Thickness in m
Depth in m
Lithology
9.1
48.8
64
83.8
180
233.3
301.9
310
0
20
40
60
80
100
120
140
160
180
200
220
240
260
280
300
320
Top soil
Sandstone
Clayey sand
Sandstone
Clay
Sandstone
Clayey sand
Shale
Clayey sand
Clay


Kadagampatti
Thickness in m
Depth in m
Lithology
3.05
7.6
12.2
76.2
91.5
109.8
122
151.5
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
Clay
Sandy clay
Fine sand
Sandstone
Shale
Sandstone
Shale
Sandstone

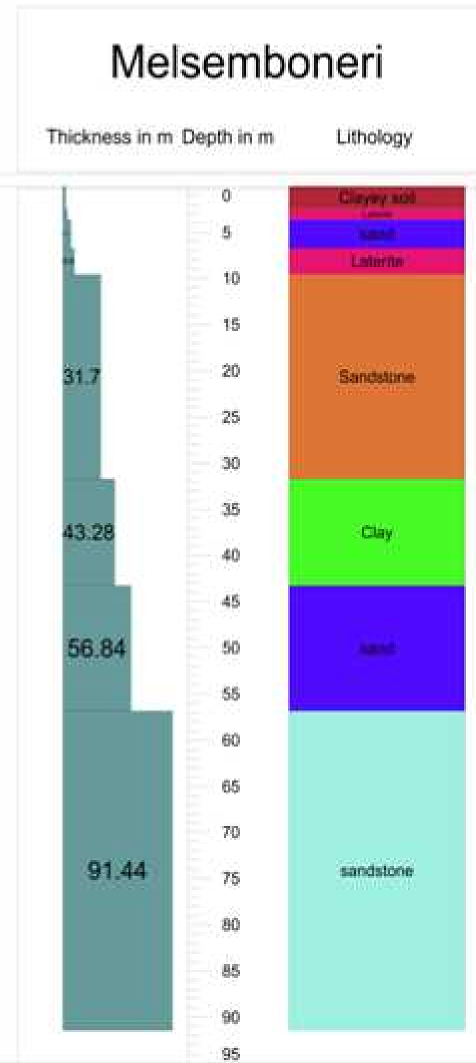

Kalayarkoil
Thickness in m
Depth in m
Lithology
0
4
8
12
16
20
24
28
32
36
40
44
48
52
3
18.5
27
30
36
39
44
48
49
Topsoil
Clay mixed with Sand
Sandstone (Latritic)
Clay with Sand Stone
Clay
Clay with fine Sand
Sand with Clay
Sand with Clay
Gniess hard

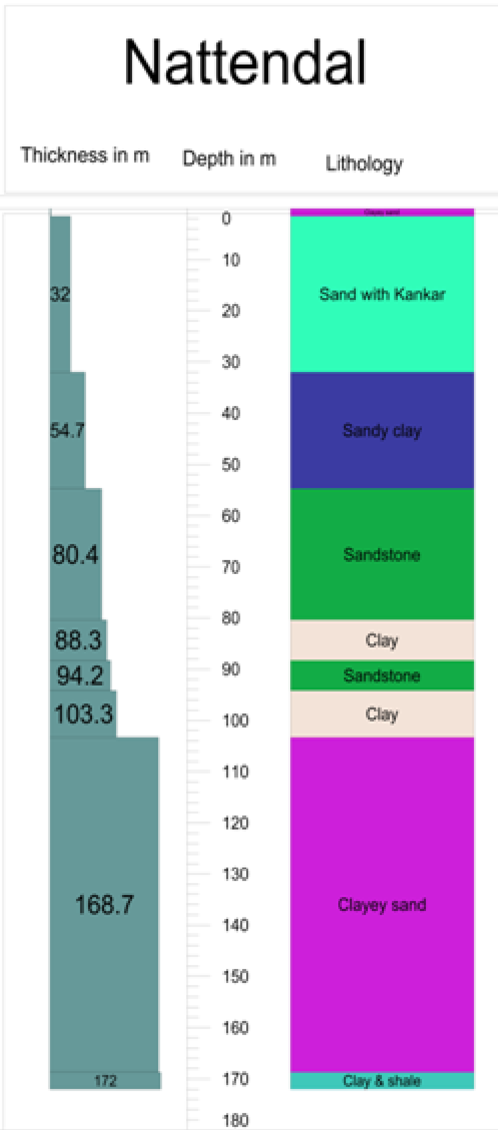

Karaikudi
Thickness in m
Depth in m
Lithology
0
20
40
60
80
100
120
140
160
180
200
220
106.68
137.16
143.25
207.66
213.66
Laterite
sandy clay
Clay
Sandstone
Clay
Sandstone
sandy clay

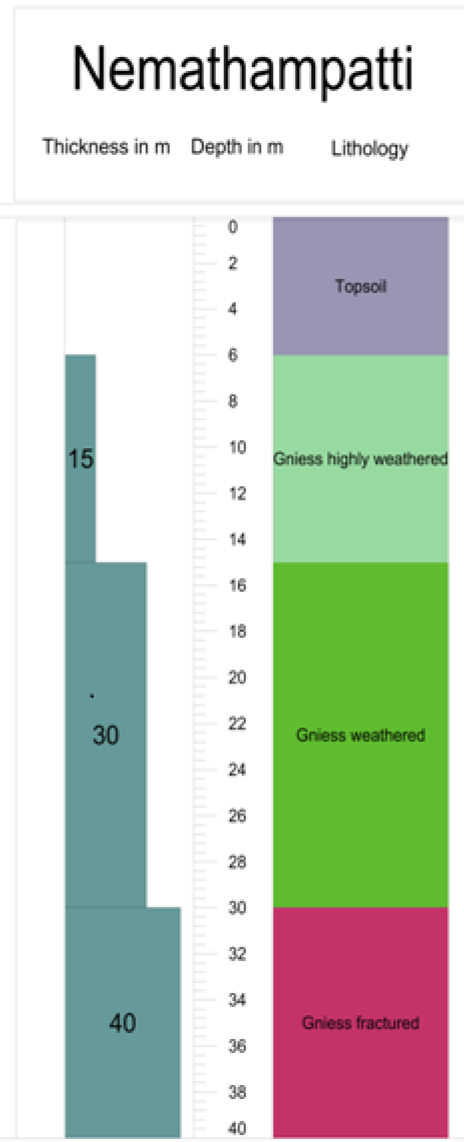

Karumozhi
Thickness in m
Depth in m
Lithology
12.4
17
19.2
33.9
42.4
43.64
0
4
8
12
16
20
24
28
32
36
40
44
Clay
Fine to Medium sand
Clayey Sand
Sand
Clayey Sand
Medium sand
Clay with pebbles

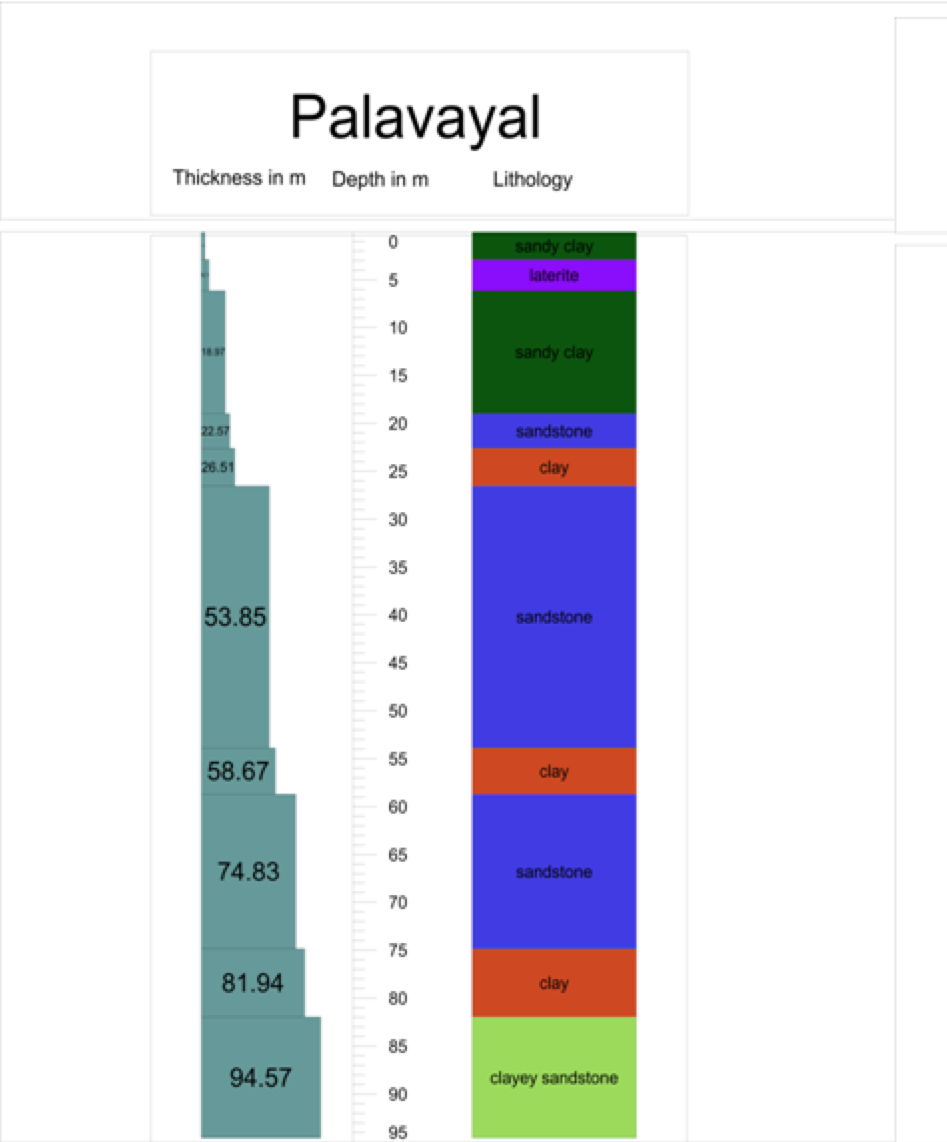

Malakandan
Thickness in m
Depth in m
Lithology
16.5
24.4
26.8
32.3
35
40
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
32
34
36
38
40
42
Lateritic sand
Kankar with Laterite
Sandy clay
Clay
Sandy clay
Clay
Sandy clay


Manappacheri
Thickness in m
Depth in m
Lithology
0
4
8
12
16
20
24
28
32
36
40
44
48
52
56
60
64
68
72
76
80
84
25
82.5
Clay and Kankar
Weathered Gneiss

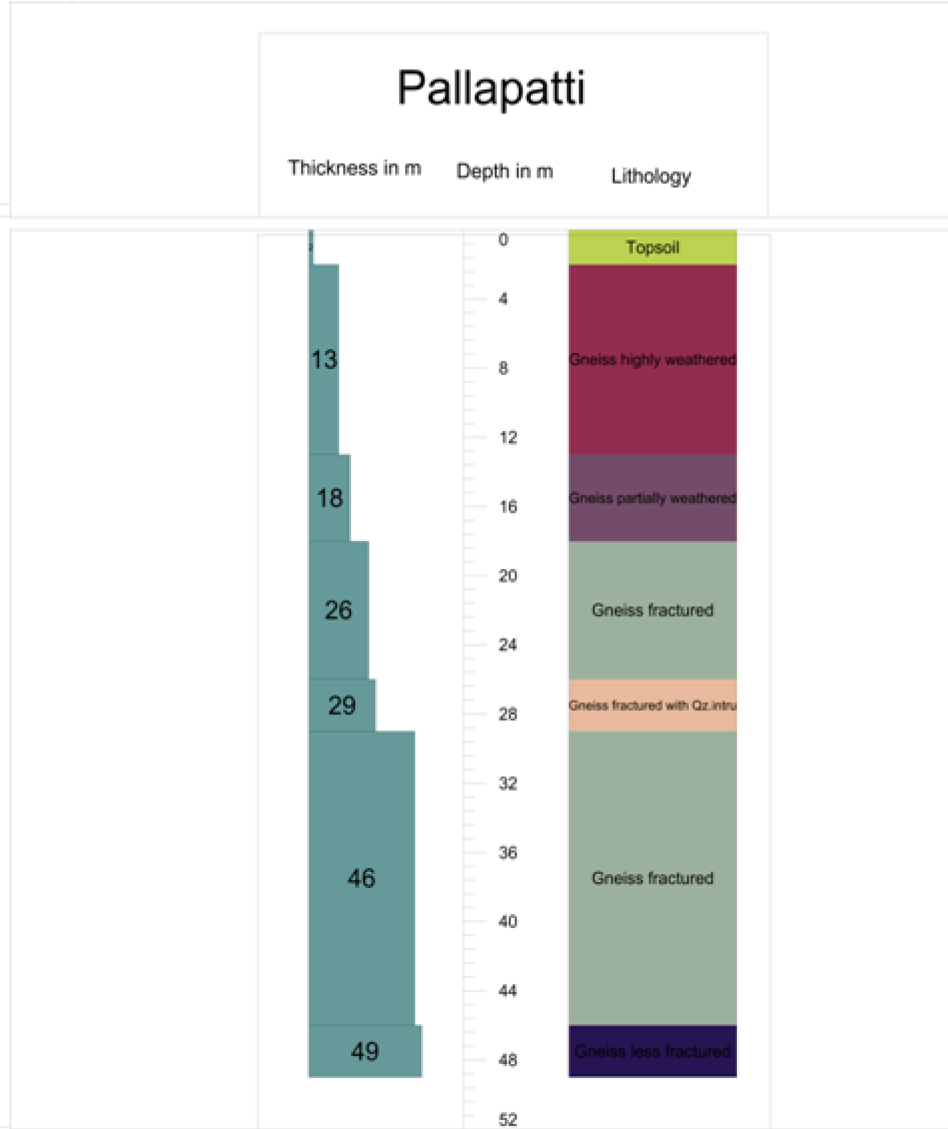

Melsemboneri
Thickness in m
Depth in m
Lithology
0
5
10
15
20
25
30
35
40
45
50
55
60
65
70
75
80
85
90
95
31.7
43.28
56.84
91.44
Clayey soil
sand
Laterite
Sandstone
Clay
sand
sandstone


Nattendal
Thickness in m
Depth in m
Lithology
32
54.7
80.4
88.3
94.2
103.3
168.7
172
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
170
180
Sand with Kankar
Sandy clay
Sandstone
Clay
Sandstone
Clay
Clayey sand
Clay & shale

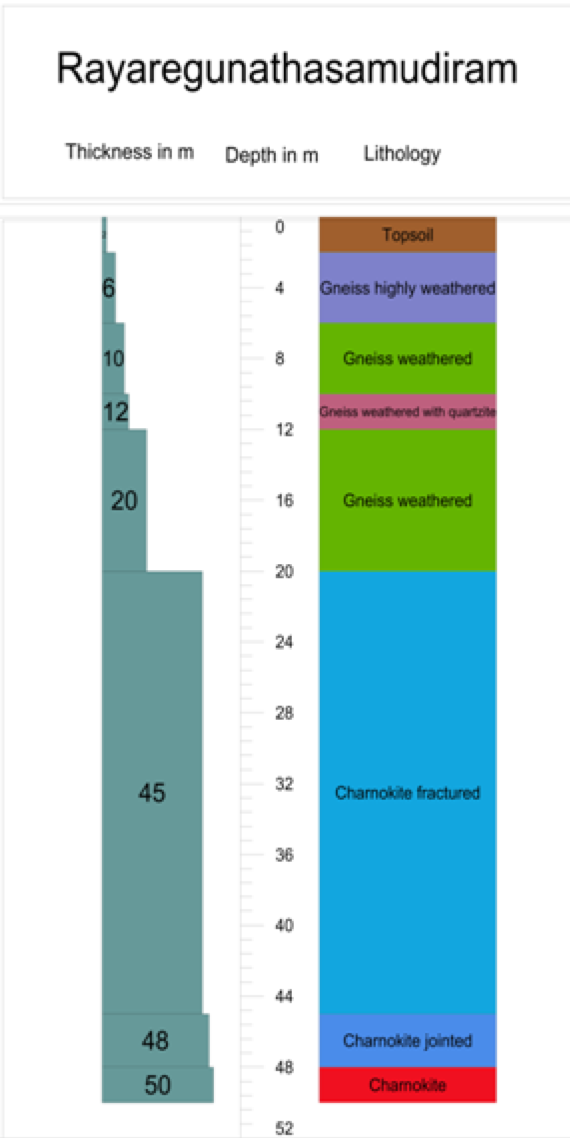

Nemathampatti
Thickness in m
Depth in m
Lithology
15
30
40
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
32
34
36
38
40
Topsoil
Gniess highly weathered
Gniess weathered
Gniess fractured

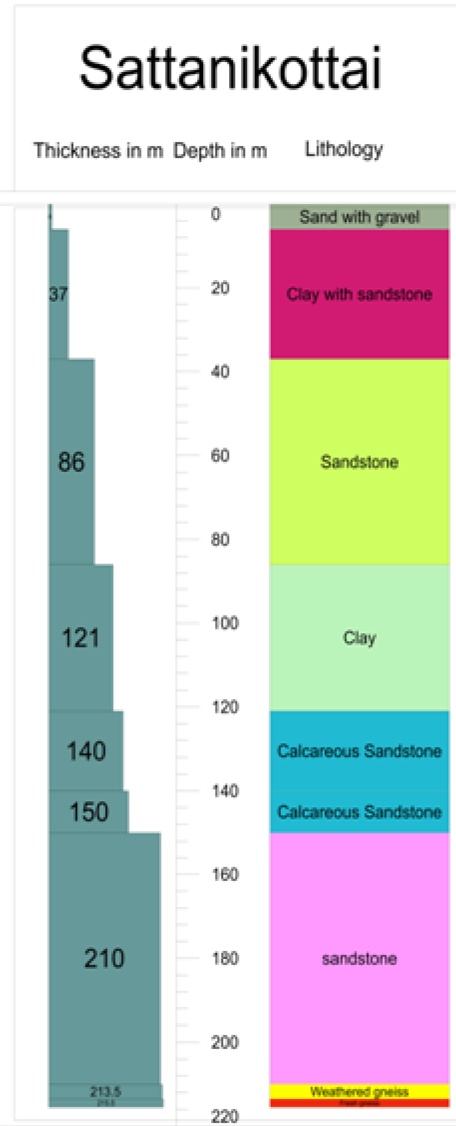


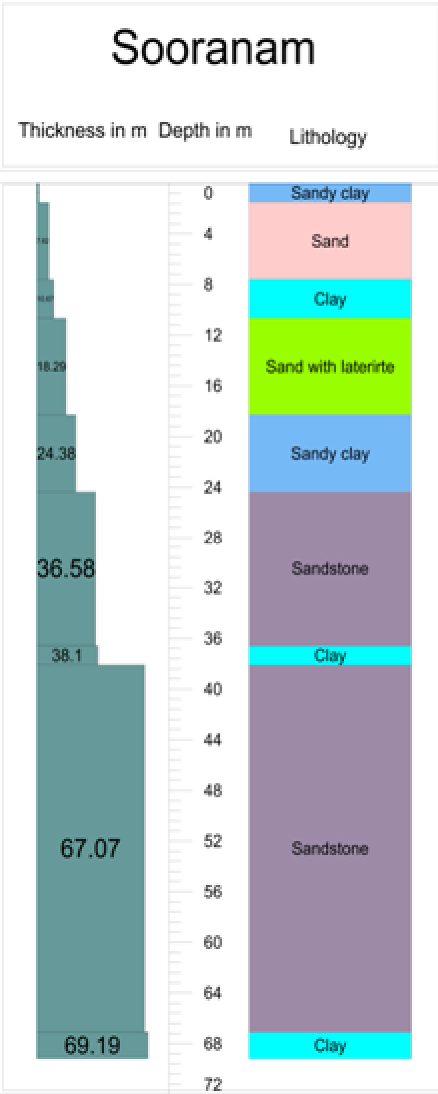
Palavayal
Thickness in m
Depth in m
Lithology
18.97
22.57
26.51
53.85
58.67
74.83
81.94
94.57
0
5
10
15
20
25
30
35
40
45
50
55
60
65
70
75
80
85
90
95
sandy clay
laterite
sandy clay
sandstone
clay
sandstone
clay
sandstone
clay
clayey sandstone

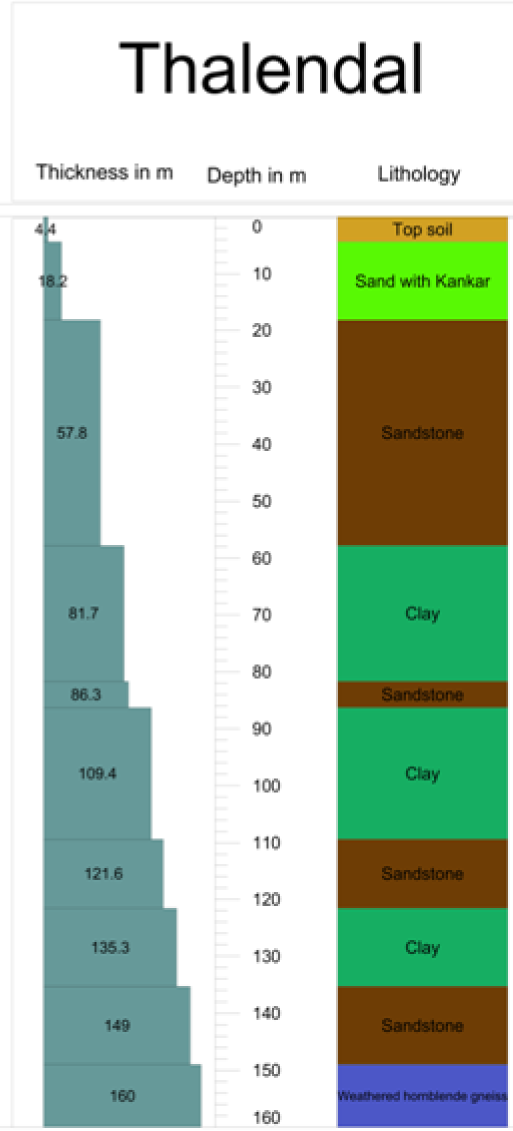


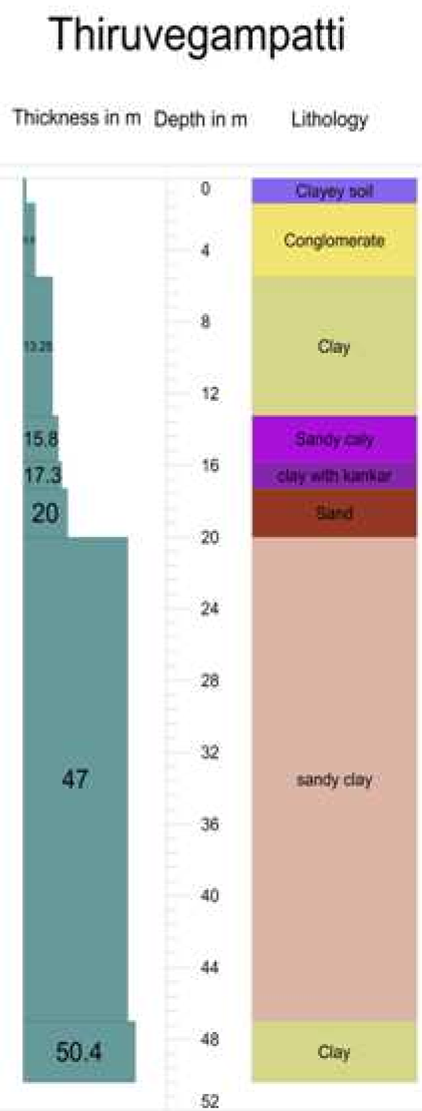
Pallapatti
Thickness in m
Depth in m
Lithology
13
18
26
29
46
49
0
4
8
12
16
20
24
28
32
36
40
44
48
52
Topsoil
Gneiss highly weathered
Gneiss partially weathered
Gneiss fractured
Gneiss fractured with Qz.intru
Gneiss fractured
Gneiss less fractured

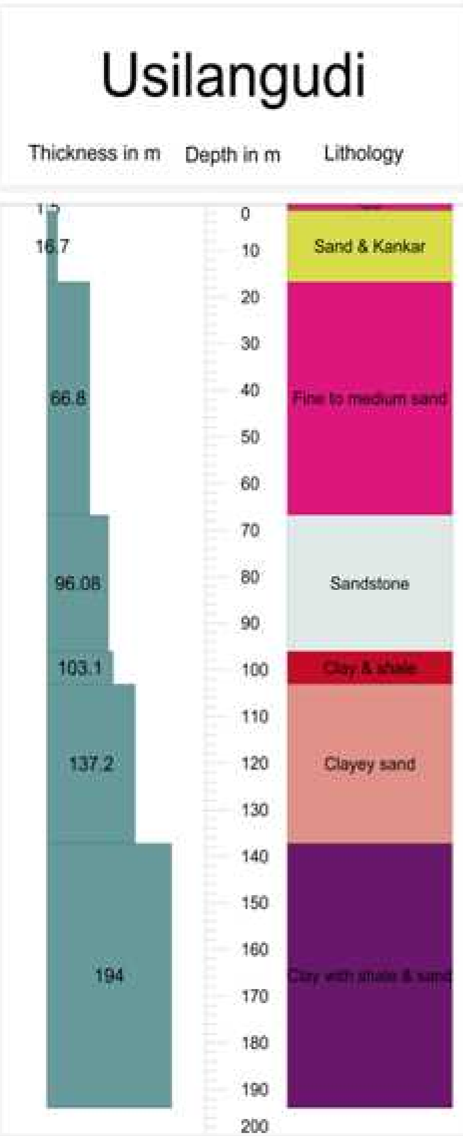

Rayaregunathasamudiram
Thickness in m
Depth in m
Lithology
6
10
12
20
45
48
50
0
4
8
12
16
20
24
28
32
36
40
44
48
52
Topsoil
Gneiss highly weathered
Gneiss weathered
Gneiss weathered with quartzite
Gneiss weathered
Charnokite fractured
Charnokite jointed
Charnokite


Sattanikottai
Thickness in m
Depth in m
Lithology
37
86
121
140
150
210
213.5
0
20
40
60
80
100
120
140
160
180
200
220
Sand with gravel
Clay with sandstone
Sandstone
Clay
Calcareous Sandstone
Calcareous Sandstone
sandstone
Weathered gneiss


Sooranam
Thickness in m
Depth in m
Lithology
Sandy clay
Sand
Clay
Sand with laterirte
Sandy clay
Sandstone
Clay
Sandstone
Clay
18.29
24.38
36.58
38.1
67.07
69.19
0
4
8
12
16
20
24
28
32
36
40
44
48
52
56
60
64
68
72


Thalendal
Thickness in m
Depth in m
Lithology
Top soil
Sand with Kankar
Sandstone
Clay
Sandstone
Clay
Sandstone
Clay
Sandstone
Weathered hornblende gneiss
4.4
18.2
57.8
81.7
86.3
109.4
121.6
135.3
149
160
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160


Thiruvegampatti
Thickness in m
Depth in m
Lithology
15.8
17.3
20
47
50.4
0
4
8
12
16
20
24
28
32
36
40
44
48
52
Clayey soil
Conglomerate
Clay
Sandy caly
clay with kankar
Sand
sandy clay
Clay


Usilangudi
Thickness in m
Depth in m
Lithology
16.7
66.8
96.08
103.1
137.2
194
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
170
180
190
200
Sand & Kankar
Fine to medium sand
Sandstone
Clay & shale
Clayey sand
Clay with shale & sand

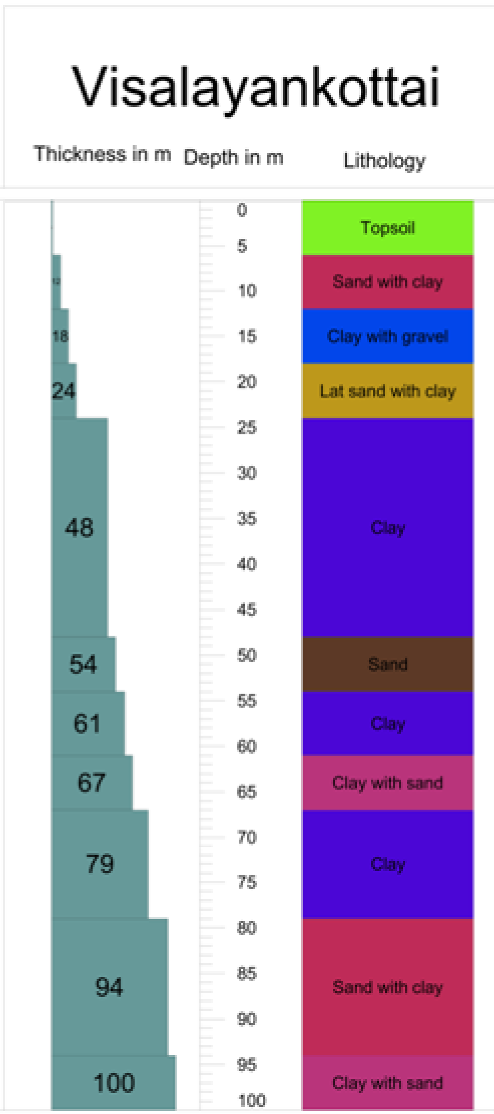

Visalayankottai
Thickness in m
Depth in m
Lithology
0
5
10
15
20
25
30
35
40
45
50
55
60
65
70
75
80
85
90
95
100
18
24
48
54
61
67
79
94
100
Topsoil
Sand with clay
Clay with gravel
Lat sand with clay
Clay
Sand
Clay
Clay with sand
Clay
Sand with clay
Clay with sand

Table 2.5 Borehole Location and Lithology

SI. No	VILLAGE	LATITUDE	LONGITUDE	LITHOLOGY			Aquifer Depth	
1	Alagiamanagiri	10°0'15"	78°28'20"	0	2	Top soil	3.5	35
				2	26	Weathered Gneiss		
				26	35	Fractured Gneiss		
2	Alavakottai	9°59'30"	78°32'30"	0	3	Topsoil		
				3	18.5	Gniess weathered		
				18.5	40	Gniess fractured		
3	Aranmanaippatti	10°11'30"	78°45'40"	0	3	Topsoil lateritic		
				3	9	Highly weathered granitic gneiss		
				9	12	Weathered granitic gneiss		
				12	18	Weathered granitic gneiss		
				18	27	Weathered mica gneiss		
				27	36	Jointed granitic gneiss		
				36	39	Partially jointed granitic gneiss		
4	Attapatti	10°4'57"	78°23'15"	0	3	Topsoil		
				3	12	Gneiss highly weathered		
				12	18	Gneiss partially weathered		
				18	27	Gneiss fractured		
				27	30	Gneiss fractured pegmatite int		
				30	40	Gneiss hard		
5	Ganapathiyapatti	10°16'60"	78°24'26"	0	1.5	Top soil	14	25
				1.5	13.73	weathered charnockite		
				13.73	24.4	Fractured Charnokite		
				24.4	30.5	Fresh Charnokite		
6	Idiamelur	9°54'40"	78°27'30"	0	6	Top soil	4.5	31
				6	31	weathered biotite gneiss		
				31	38.3	Fresh biotite gneiss		
7	Kacharayanpatti	10°7'35"	78°21'10"	0	2	Top soil	5	25
				2	7	Kankar with clay		
				7	16	Sandy clay		

Sl. No	VILLAGE	LATITUDE	LONGITUDE	LITHOLOGY			Aquifer Depth	
				16	25	Weathered & Fractured Gneiss		
				25	26	Fresh Gneiss		
8	Kakkaikalaripatti	10°5'45"	78°32'50"	0	6	Top soil	8	44
				6	8	Kankar with Quartzite		
				8	44	Weathered Gneiss		
9	Kannamangalapatti	10°9'42"	78°25'40"	0	1.82	Lateritic soil	4.88	59.49
				1.82	4.88	Clay		
				4.88	59.49	weathered biotite gneiss		
				59.49	61	Fresh Gneiss		
10	Karaiyoor	10°8'25"	78°33'60"	0	1.22	Laterite soil	4.7	34
				1.22	9.15	Pebbles		
				9.15	34	Weathered Gneiss		
11	Karungalakudi	10°9'30"	78°21'51"	0	3	Topsoil		
				3	6	Gneiss weathered		
				6	13	Gneiss partially weathered		
				13	25	Gneiss weathered		
				25	30	Gneiss fractured		
				30	38	Gneiss less fractured		
				38	48	Gneiss hard		
12	Karuppur	10°6'40"	78°31'52"	0	2	Top soil	3	61.5
				2	6	Fine to Medium sand with Kankar		
				6	61.5	weathered biotite gneiss		
13	Keelakottai	10°5'45"	78°36'45"	0	3	Red soil	3	34.5
				3	28	Weathered Granite Gneiss		
				28	30.4	Fresh Granite Gneiss		
14	Keelsevalpatti	10°11'12"	78°39'52"	0	2	Topsoil		
				2	6	Gniess weathered/fractured		
				6	13.5	Gniess weathered/fractured		
				13.5	18	Gniess fractured		
				18	22	Gneiss		

SI. No	VILLAGE	LATITUDE	LONGITUDE	LITHOLOGY			Aquifer Depth	
				22	24	Gniess fractured		
				24	35	Gneiss		
15	Kottaipatti	10°5'50"	78°30'5"	0	1.83	Red soil	4.27	44.2
				1.83	4.27	Sandy clay with kankar		
				4.27	10.98	Sand with Pebbles		
				10.98	12.8	kankar with weathered Gneiss		
				12.8	44.2	Weathered Gneiss		
16	Kottaivengampatti	10°8'14"	78°24'39"	0	6	Topsoil		
				6	9	Gniess highly weathered		
				9	15	Gniess weathered		
				15	40	Gniess fractured		
17	Kumarathipatti	10°11'15"	78°27'15"	0	1.5	Top soil	5	58
				1.5	3	Sandy clay		
				3	57.9	weathered biotite gneiss		
				57.9	59.45	Fresh biotite gneiss		
18	Kunnakudi	10°6'35"	78°42'30"	0	2	Laterite with clay	2	45
				2	4	Kankar with Quartz		
				4	45	weathered biotite gneiss		
				45	58	Fresh biotite gneiss		
19	Kuratti	10°5'25"	78°41'35"	0	6	Top soil	6	45
				6	48	Weathered Gneiss		
				48	50.4	Fresh Gneiss		
20	Manappacheri	10°10'3"	78°21'8"	0	1	Clayey Soil	25	35
				1	25	Clay and Kankar	48	78
				25	82.5	Weathered Gneiss		
21	Manjinippatti	10°9'20"	78°41'0"	0	4	Red soil		
				4	10	clay		
				10	20	Highly weathd. bio .gr.gneiss		
				20	30	Weathd.bio.gneiss		
				30	35	Weathd.bio.gneiss		

Sl. No	VILLAGE	LATITUDE	LONGITUDE	LITHOLOGY			Aquifer Depth	
				35	45	Jointed bio.gr.gneiss		
22	Mathikaraipatti	10°10'38"	78°25'16"	0	1.52	Top soil	1.5	69.2
				1.52	6.1	Sandy clay		
				6.1	58.83	weathered biotite gneiss		
				58.83	69.2	fractured biotite gneiss		
				69.2	77.72	Fresh biotite gneiss		
23	Nagamangalam	10°16'60"	78°23'0"	0	3	Red soil	4	23.5
				3	4	Clayey soil		
				4	23.5	weathered biotite gneiss		
24	Natham PWD office	10°13'30"	78°13'50"	0	2	Top soil	2	35
				2	17	weathered charnockite		
				17	35	Fractured Charnokite		
25	Nedumaram	10°8'30"	78°37'60"	0	1.5	Topsoil		
				1.5	4.5	Clay with Kankar		
				4.5	9	Gniess highly weathered		
				9	15	Gniess weathered		
				15	24	Gniess weathered		
				24	40	Charnokite fractured		
26	Nemathampatti	10°13'30"	78°45'50"	0	6	Topsoil		
				6	10	Gniess highly weathered		
				10	15	Gniess highly weathered		
				15	30	Gniess weathered		
				30	40	Gniess fractured		
27	Nerkuppai	10°13'0"	78°32'30"	0	1.5	Topsoil		
				1.5	9	Gniess weathered		
				9	18	Gniess fractured		
				18	24	Gniess fractured		
				24	30	Gniess fractured		
28	Paiyur	10°9'30"	78°35'15"	0	4	Clayey soil	6	20
				4	8	Clay with sand & gravel		

SI. No	VILLAGE	LATITUDE	LONGITUDE	LITHOLOGY			Aquifer Depth	
				8	20.2	weathered biotite gneiss		
29	Pallapatti	10°14'58"	78°23'10"	0	2	Topsoil	3	14
				2	13	Gneiss highly weathered		
				13	18	Gneiss partially weathered		
				18	26	Gneiss fractured		
				26	29	Gneiss fractured with Qz.intru		
				29	46	Gneiss fractured		
				46	49	Gneiss less fractured		
30	Paruthiyendalapatti	10°5'50"	78°31'15"	0	10	Top soil	10	44
				10	44	Weathered Gneiss		
31	Pillayarpatti	10°7'5"	78°40'15"	0	1	Top soil	1	38.5
				1	38.5	weathered biotite gneiss		
32	Poolankurichi	10°16'8"	78°35'30"	0	1.5	Topsoil		
				1.5	9	Gniess weathered		
				9	18	Gniess fractured		
				18	28	Gniess weathered fractured		
				28	35	Gniess fractured		
				35	38	Gniess weathered fractured		
				38	45	Gniess fractured		
33	Pudupatti	10°9'0"	78°27'15"	0	8	Top soil	8	28
				8	28	Weathered Gneiss		
				28	30	Fresh Gneiss		
34	Rangaiyam	10°13'40"	78°39'5"	0	2	topsoil		
				2	4	clay		
				4	7	Highly wea.bio.gneiss		
				7	10	Wea.bio.grn.gneiss		
				10	16	Par.wea.bio.grn.gneiss		
				16	25	Jtd. bio.granitic gneiss		
				25	27	Par.wea.bio.granitic gneiss		
				27	30.3	Jtd.bio.granitic gneiss		

Sl. No	VILLAGE	LATITUDE	LONGITUDE	LITHOLOGY			Aquifer Depth	
35	Rayaregunathasamudiram	10°15'25"	78°45'55"	0	2	Topsoil		
				2	6	Gneiss highly weathered		
				6	10	Gneiss weathered		
				10	12	Gneiss weathered with quartzite		
				12	20	Gneiss weathered		
				20	45	Charnokite fractured		
				45	48	Charnokite jointed		
				48	50	Charnokite		
36	S S Kottai	10°0'30"	78°39'40"	0	6	Clay	5.5	69
				6	69	weathered biotite gneiss		
37	Saloor	9°50'45"	78°27'40"	0	1	Top soil	6	41
				1	20	weathered biotite gneiss		
				20	41	Fractured biotite gneiss		
38	Samiarpatti	9°49'25"	78°28'35"	0	2	Top soil	6	21
				2	6	Clay		
				6	21	Weathered Gneiss		
				21	26	Weathered Quartzite		
39	Sembanur	10°4'50"	78°38'0"	0	6.5	Laterite	5	50
				6.5	34	Weathered Gneiss		
				34	56.8	weatherd & Fractured Gneiss		
40	Silambakkonpatti	10°15'52"	78°25'20"	0	3	Top soil	13	33
				3	8	kankar with weathered Gneiss		
				8	30	Weathered Gneiss		
				30	33	Fractured Gneiss		
41	Silandankudi	10°0'45"	78°33'45"	0	9	Weateherd Quartize	5	45
				9	45	weathered biotite gneiss		
				45	70	Fresh biotite gneiss		
42	Sillampatti	10°8'50"	78°36'45"	0	6	Sandy clay	9	28.5
				6	9	Sandy clay with kankar		
				9	28.5	Weathered Gneiss		

SI. No	VILLAGE	LATITUDE	LONGITUDE	LITHOLOGY			Aquifer Depth	
43	Solarampatti	10°5'20"	78°32'10"	0	3.04	clay	4.5	26.8
				3.04	4.5	Laterite with sand		
				4.5	12.1	Sandstone with kankar		
				12.1	26.8	weathered biotite gneiss		
44	Sunnambiruppu	10°5'20"	78°32'10"	0	6.1	sandy clay	9.1	25.9
				6.1	9.1	Clay		
				9.1	10.7	sandy clay		
				10.7	25.9	weathered biotite gneiss		
45	Surakkudi	10°8'22"	78°28'45"	0	1.52	Red clay	8.94	14.94
				1.52	3.05	Sandy clay		
				3.05	20.74	Fine to Medium sand with Kankar		
				20.74	22.26	Weathered Gneiss		
46	Surapatti	10°19'5"	78°23'10"	0	1	Top soil	1	21
				1	9.6	Weathered Gneiss		
				9.6	21	Fractured Gneiss		
				21	22.5	Fresh Gneiss		
47	Thuthur	10°18'48"	78°32'35"	0	2.5	Topsoil		
				2.5	9	Highly weathered gr.gneiss		
				9	17	Weathered gr.gneiss		
				17	32	Jointed gr.gneiss		
				32	35	Fresh granitic gneiss		
48	Tiruppathur	10°6'24"	78°36'10"	0	1	Clayey Sand	5	54.9
				1	6	Sandy clay with gravel		
				6	6.65	Pebbles & Gravel		
				6.5	54.9	Weathered Gneiss		
49	Udinippatti	10°12'13"	78°23'50"	0	4	Red clayey Soil	4	31.5
				4	7	Kankar		
				7	9	Clay with kankar		
				9	13	Kankar		
				13	31.5	Weathered Gneiss		

Sl. No	VILLAGE	LATITUDE	LONGITUDE	LITHOLOGY			Aquifer Depth	
50	Uranganpatti	9°59'34"	78°25'52"	0	4	Topsoil Clayey		
				4	17	Gneiss highly weathered		
				17	26	Gneiss fractured		
				26	34	Gneiss fractured pegmatitic		
				34	40.5	Gneiss less fractured		
51	Vanjinipatti	10°9'45"	78°32'60"	0	4	Sandy Clay	4	37
				4	37	weathered biotite gneiss		
				37	41.5	Fresh biotite gneiss		
52	Vengaipatti	10°13'0"	78°27'0"	0	2	Top soil	2	30
				2	30	Weathered Gneiss		
				30	32.7	Fresh Gneiss		
53	S. koilpatti	10°8'19"	78°28'51"	0	3.5	Topsoil		
				3.5	12	Gniess highly weathered		
				12	18	Gniess weathered		
				18	24	Gniess weathered/fractured		
				24	40	Gniess fractured		
54	Pudukudi	10°0'20"	78°38'20"	0	4.5	Topsoil		
				4.5	10.5	Gniess highly weathered &Kanka		
				10.5	15	Gniess highly weathered		
				15	21.5	Gniess weathered		
				21.5	40	Gniess weathered		
55	Thirunarayanapuram	9°55'30"	78°29'30"	0	1	Top soil	4.5	38.5
				1	11	Kankar		
				11	38.5	Weathered Granite Gneiss		
56	Karumozhi	9°50'0"	78°52'53"	0	1.1	Clay	17	42.4
				1.1	12.4	Fine to Medium sand		
				12.4	17	Clayey Sand		
				17	19.2	Sand		
				19.2	33.9	Clayey Sand		
				33.9	42.4	Medium sand		

SI. No	VILLAGE	LATITUDE	LONGITUDE	LITHOLOGY			Aquifer Depth	
				42.4	43.64	Clay with pebbles		
57	Janaveli	9°41'37"	78°53'45"	0	2.35	Clay	0	0
				2.35	4	Gravel		
				4	10.6	Clayey Sand		
				10.6	12.8	Sandstone		
				12.8	48	Sandy clay		
				48	53.95	shell limestone		
58	Subramaniapuram	10°5'4"	78°47'24"	0	6.75	Laterite soil	7.01	19.3
				6.75	35.22	Sandstone		
				35.22	75.33	Clay		
59	Palavayal	10°5'4"	78°47'2"	0	2.85	sandy clay	48	54
				2.85	6.1	laterite	59	71
				6.1	18.97	sandy clay		
				18.97	22.57	sandstone		
				22.57	26.51	clay		
				26.51	53.85	sandstone		
				53.85	58.67	clay		
				58.67	74.83	sandstone		
				74.83	81.94	clay		
				81.94	94.57	clayey sandstone		
60	Sivagangai	9°50'0"	78°30'0"	0	2	Laterite	0	0
				2	9.2	clayey sand		
				9.2	23	clay		
				23	27	clayey sand		
				27	28.76	clay		
61	Thiruvegampatti	9°50'0"	78°47'35"	0	1.38	Clayey soil	25	36
				1.38	5.5	Conglomerate		
				5.5	13.25	Clay		
				13.25	15.8	Sandy caly		
				15.8	17.3	clay with kankar		

Sl. No	VILLAGE	LATITUDE	LONGITUDE	LITHOLOGY			Aquifer Depth	
				17.3	20	Sand		
				20	47	sandy clay		
				47	50.4	Clay		
62	Anandur	9°43'35"	78°46'47"	0	2	Top soil	18	25
				2	8	Medium sand		
				8	18	Sand with kankar		
				18	24	sandy clay		
				24	29	Fine to coarse sand with gravel		
				29	43	Clay		
				43	64	Sand with kankar		
				64	74.6	Clay		
63	Alagappa college karaikudi	10°3'60"	78°45'60"	0	3	Gravel	34.1	37.8
				3	7	Laterite	51.8	59.2
				7	36.9	sandstone		
				36.9	51.2	Clay		
				51.2	60.3	sandstone		
				60.3	69.15	Clay		
64	Pallathur	10°7'50"	78°48'60"	0	5.49	Laterite	19.28	35.05
				5.49	15.85	Clay		
				15.85	30.05	coarse sand		
				30.05	71	Clay		
65	Melsembonmari	9°58'60"	78°48'60"	0	2.44	Clayey soil	24.38	36.58
				2.44	3.6	Laterite	41.15	53.34
				3.6	6.71	sand	56.39	65.53
				6.71	9.6	Laterite		
				9.6	31.7	Sandstone		
				31.7	43.28	Clay		
				43.28	56.84	sand		
				56.84	91.44	sandstone		
66	Alagappa Arts college hostel Karaikudi	10°4'30"	78°47'10"	0	4.27	Laterite	18.28	31.4

Sl. No	VILLAGE	LATITUDE	LONGITUDE	LITHOLOGY			Aquifer Depth	
				4.27	7	sandy clay	39.62	48.76
				7	9.76	Laterite		
				9.76	31.4	sandstone		
				31.4	44.21	Clay		
				44.21	69.82	sandstone		
				69.82	76.22	Clay		
				76.22	85.06	sandstone		
67	Udayachi	9°56'45"	78°48'24"	0	1.22	Top soil	50.32	54.9
				1.22	3.66	Laterite	67.1	75.2
				3.66	73.15	sandstone	79.3	96.07
				73.15	83.82	Clay		
				83.82	99.06	sandstone		
				99.06	101.96	Red ochre		
68	Andavoorani	9°52'30"	78°59'18"	0	4.5	Clay	32.02	89.97
				4.5	32.02	Clayey sand with kankar		
				32.02	67.1	Sandy clay with gravel		
				67.1	89.97	fine to Coarse sand		
				89.97	97	clay with gravel		
				97	152.5	clayey sand		
69	Amaravathipuram	10°1'0"	78°45'60"	0	7.62	Laterite	22.2	31.4
				7.62	15.24	Sandstone	68	74.1
				15.24	18.28	Clay		
				18.28	33.52	Sandstone		
				33.52	67	sandy clay		
				67	73.15	Medium to coarse sand		
				73.15	91.44	Clay		
				91.44	121.92	sandy clay		
				121.92	144.78	Clay		
				144.78	152.4	Quartzite		

Sl. No	VILLAGE	LATITUDE	LONGITUDE	LITHOLOGY			Aquifer Depth	
70	Radhanur	9°45'37"	78°45'47"	0	1.5	Clay	40	49
				1.5	9.15	sandy clay	70	97
				9.15	33.55	Sandstone	111	120
				33.55	50.55	sandy clay		
				50.55	65.57	Clay		
				65.57	112.85	sandy clay		
				112.85	115.9	Fine to coarse sand		
				115.9	118.51	Clay		
				118.51	152.5	sandy clay		
71	Iluppakudi	10°3'30"	78°48'60"	0	3.04	Fine to coarse sand	15.24	39.62
				3.04	9.1	Laterite	45.72	54.86
				9.1	33.52	clayey sand		
				33.52	100.58	Sandstone		
				100.58	108.2	Clay		
				108.2	152.4	Sandstone		
72	Sankarai (kalathur)	10°6'18"	78°54'30"	0	12.19	clayey sand	20.96	42.52
				12.19	50.29	Sandstone	60.66	70.18
				50.29	71.63	sandy clay		
				71.63	88.39	Shale		
				88.39	94.49	sandy clay		
				94.49	160.62	Calcareous Sandstone		
				160.62	252.07	Clay		
73	Sarugani	9°50'60"	78°44'40"	0	1.52	Top soil	22	60
				1.52	9.14	Laterite		
				9.14	22.86	clayey sand		
				22.86	60.96	Weathered Gneiss		
				60.96	64	Fresh Gneiss		
74	Devakottai	9°56'60"	78°47'60"	0	6.69	Lateritic soil	19.82	21.95
				6.69	22.86	sandy clay	35.66	52.43
				22.86	32	Clay		

Sl. No	VILLAGE	LATITUDE	LONGITUDE	LITHOLOGY			Aquifer Depth	
				32	106.68	sandy clay		
				106.68	112.78	Clay		
				112.78	115.82	Weathered Gneiss		
75	Maravamangalam	9°45'53"	78°38'50"	0	13.72	Laterite	18.3	28.97
				13.72	18.3	Sandstone		
				18.3	43	Weathered hornblende gneiss		
76	Karaikudi	10°3'37"	78°45'52"	0	3.04	Laterite	115.8	131.1
				3.04	27.43	sandy clay	137.1	155.1
				27.43	106.68	Clay	167.3	173.6
				106.68	137.16	Sandstone	185.8	198.1
				137.16	143.25	Clay		
				143.25	207.66	Sandstone		
				207.66	213.66	sandy clay		
77	Kallal	9°59'10"	78°39'40"	0	3.45	Lateritic soil with gravel	10.9	29.28
				3.45	12.19	sandy clay with gravel		
				12.19	18.28	sand with gravel		
				18.28	76.2	weathered biotite gneiss		
78	Puliyal	9°50'60"	78°51'60"	0	1.45	clayey sand	18	49
				1.45	5	sandy clay		
				5	91.8	Sandstone		
79	Mullangadu	10°6'30"	78°52'45"	0	1.52	Fine sand	25	29
				1.52	13.72	medium sand with laterirte	40	50
				13.72	56.42	Sandstone		
80	Ponnalikottai	9°49'45"	78°45'50"	0	1.52	Clay	33.82	55
				1.52	4.57	Sand with laterirte		
				4.57	58.68	Sand & Kankar with gravel		
				58.68	84.18	Medium to caorse sand		
81	Peerkalaikadu	10°6'50"	78°55'0"	0	3.05	sandy clay	16	21
				3.05	51.85	Fine to medium sand with gravel	33.55	64.05
				51.85	64.05	Fine sand		

Sl. No	VILLAGE	LATITUDE	LONGITUDE	LITHOLOGY			Aquifer Depth	
				64.05	69.84	Sandy clay		
82	Mathur	10°3'52"	78°49'37"	0	11.44	Laterite with Sandy clay	27.75	36.6
				11.44	38.12	Medium to coarse sand with clay		
				38.12	51.85	Medium to coarse sand		
				51.85	81.43	Sandy clay		
83	Veeppankulam	9°57'30"	78°43'30"	0	1.5	Sandy clay	22.07	30.02
				1.5	21	Lateritic Sand		
				21	54	Sandstone		
				54	56.4	Weathered Gneiss		
84	Koothalur	10°2'10"	78°42'20"	0	3.5	Sandy clay	14.28	19.25
				3.5	16.16	Lateritic Sand		
				16.16	20.43	Weathered Gneiss		
85	Savarakottai	10°0'50"	78°39'50"	0	1.52	Clay	15.25	19.82
				1.52	10.67	Fine to coarse sand		
				10.67	22.87	Weathered Gneiss		
86	Sithalur	9°45'55"	78°46'40"	3.5	22	Sandy clay with kankar	45.75	54.9
				22	25	Clay	64.05	73.2
				25	55	Sand with kankar		
				55	65	Clayey sand		
				65	82.6	Sandstone		
87	Kalathur	9°48'60"	78°46'30"	0	3.05	Clayey soil	22.6	25.85
				3.05	7.62	Kankar with Sand	28.85	46.05
				7.62	83.82	Sandstone		
88	Nattarasankotai	9°52'0"	78°32'60"	0	1.52	Clay	14.64	21.35
				1.52	12.19	Sandstone	25.87	28.97
				12.19	13.71	Clay		
				13.71	21.33	Sandstone		
				21.33	25.9	Clay		
				25.9	28.95	Sandstone		
				28.95	33.55	Clay		

Sl. No	VILLAGE	LATITUDE	LONGITUDE	LITHOLOGY			Aquifer Depth	
89	Palkulam	9°46'15"	78°39'45"	0	1.5	Clay	16.77	25.92
				1.5	12	Laterite	28.98	37.21
				12	32	Fine to medium sand		
				32	36	Sandstone		
				36	40	Weathered Gneiss		
90	Thatchanendal	9°41'60"	78°33'45"	0	3.05	Laterite	15.25	42.7
				3.05	13.72	Coarse sand with laterite		
				13.72	44.2	Sandstone		
				44.2	47.85	weathered biotite gneiss		
91	Pillukottai	9°43'30"	78°38'45"	0	3.05	Sandy clay	21.33	27.43
				3.05	15.24	Clayey soil with Laterite	30.48	39.65
				15.24	61.57	Sandstone	42.7	51.76
92	Elandakarai	9°43'0"	78°40'45"	0	6.65	Clay	20	40
				6.65	41.7	Sandstone	45	58
				41.7	45	sandy clay with gravel		
				45	61.65	Sandstone		
93	Velarendal	9°48'15"	78°37'45"	0	5	Clayey soil	20	24.57
				5	35	Sandstone	36.67	52.22
				35	39.35	Sandy clay	56.84	61.41
				39.35	69	Sandstone		
94	Ammapattinam	9°49'30"	78°42'0"	0	1.52	Laterite	19.82	25.92
				1.52	10.67	Laterite with Kankar	30.5	44.1
				10.67	36.58	Sandstone with clay		
				36.58	47.24	Sandstone		
95	Periyakannanur	9°43'60"	78°34'60"	0	3.05	Laterite	18.24	30.48
				3.05	13.72	Sandstone	31	38.1
				13.72	22.86	Shale	44.2	51.81
				22.86	38.1	Sandstone		
				38.1	42.67	Clay		
				42.67	53.34	Sandstone		

Sl. No	VILLAGE	LATITUDE	LONGITUDE	LITHOLOGY			Aquifer Depth	
				53.34	53.95	Weathered Gneiss		
96	Seithur	9°41'30"	78°41'30"	0	1.52	Clay	35.2	39.2
				1.52	6	Sandy clay	42.7	48.7
				6	41.15	Sandstone	53.3	58.5
				41.15	53.35	Sandy clay		
				53.35	59.44	Sandstone		
97	Therkusamudram	9°37'0"	78°44'15"	0	3.05	Sandy clay	12.19	15.24
				3.05	56.69	Sandstone	39.62	56.39
98	Ariyandipuram	9°37'15"	78°39'30"	0	1.52	Sandy clay	16.8	25.95
				1.52	25.91	Sandstone	36.6	44.25
				25.91	32	Sandy clay with kankar		
				32	60.96	Sandstone		
				60.96	63.44	Sandy clay		
99	Kallurani	9°37'45"	78°38'30"	0	3.05	Sandy clay	24.4	30.5
				3.05	6.1	Sand	31.1	44.2
				6.1	45.72	Sandstone with clay		
100	Nagamugandagudi	9°39'45"	78°35'15"	0	4.51	Clay with Laterite	18	37.5
				4.51	44.2	Sandstone		
				44.2	56.39	Clay		
				56.39	62.48	Clayey sand		
				62.48	64.9	Weathered Gneiss		
101	Odaikulam	9°41'60"	78°34'15"	0	6.09	Laterite	10.67	43.28
				6.09	39.62	Sandstone		
				39.62	43.28	Weathered Gneiss		
102	Nedungulam	9°51'20"	78°40'40"	0	3.04	Laterite	19.81	30.48
				3.04	9.14	Laterite with clay	31.08	42.67
				9.14	39.62	Sandstone		
				39.62	45.72	Sandstone with clay		
				45.72	48.76	Weathered Gneiss		
103	Sooranam	9°41'30"	78°43'30"	0	1.52	Sandy clay	17	20

SI. No	VILLAGE	LATITUDE	LONGITUDE	LITHOLOGY			Aquifer Depth	
				1.52	7.62	Sand	23	37
				7.62	10.67	Clay	59	67
				10.67	18.29	Sand with laterirte		
				18.29	24.38	Sandy clay		
				24.38	36.58	Sandstone		
				36.58	38.1	Clay		
				38.1	67.07	Sandstone		
				67.07	69.19	Clay		
104	Periyakiluvachi	9°49'5"	78°35'50"	0	4.57	Laterite with clay	16	32
				4.57	9.14	Clayey soil with kankar		
				9.14	18.29	Laterite with fine sand		
				18.29	27.43	Medium to Coarse sand		
				27.43	32	Weathered Gneiss		
105	Somanathapuram	10°0'45"	78°45'0"	0	4.57	Laterite	43.74	50.2
				4.57	10.67	Laterite with clay	62.15	65.35
				10.67	16.76	Sandstone	74.24	84.26
				16.76	43.74	Clay		
				43.74	50.2	Sandstone		
				50.2	73.15	Clay		
				73.15	82.3	Sandstone		
				82.3	88.4	Clay		
106	Tiruvadanai	9°46'60"	78°55'5"	0	27.45	Clayey soil with kankar	349	358.2
				27.45	122	Clayey sand	365.3	378.1
				122	294	Sandstone	470.1	420.2
				294	332	Clayey sand		
				332	360	Sandstone		
				360	430	Clayey sand		
107	Alagappa arts college	10°5'4"	78°47'24"	0	1.52	Lateritic soil	22.9	35.3
				1.52	6.1	Laterite	44.32	49.6
				6.1	15.25	Sandy clay		

Sl. No	VILLAGE	LATITUDE	LONGITUDE	LITHOLOGY			Aquifer Depth	
				15.25	35.07	Sandstone		
				35.07	44.22	Clayey sand		
				44.22	50.32	Sandstone		
				50.32	67.1	Sand		
				67.1	74.73	Clay		
108	Solapuram	9°54'20"	78°30'5"	0	1	Top soil	11	63
				1	63	Weathered hornblende gneiss		
109	Nerkundram	9°54'28"	78°57'30"	0	3.05	Clayey soil	242.7	277.6
				3.05	38	Sandy clay	283.7	320.2
				38	85	Sandstone		
				85	240	Clay		
				240	288	Sandstone		
				288	320	Medium sand		
				320	332	Clay		
110	Sakkottai	10°5'40"	78°51'20"	0	13.72	Laterite	50.29	79.48
				13.72	115.9	Sandstone	87.33	102.6
				115.9	126.57	Clay		
				126.57	144.87	Clayey sand		
				144.87	155.55	Clay		
				155.55	230.27	Sandstone		
				230.27	237.3	Clay		
111	Padarakudi	10°5'30"	78°45'30"	0	2	Top soil	2	63
				2	14	sand with gravel		
				14	63	Weathered Granite Gneiss		
112	Thalaiyur	9°57'18"	78°50'22"	0	1.52	Sandy clay	42	58
				1.52	42	Sandstone	65	75
				42	65.57	Clayey sand	92	115
				65.57	83.87	Sandstone		
				83.87	122	Clayey sand		
				122	124.5	Fresh biotite gneiss		

SI. No	VILLAGE	LATITUDE	LONGITUDE	LITHOLOGY			Aquifer Depth	
113	Karkathakudi	9°44'14"	78°52'30"	0	132.58	clayey soil with sandstone	204.7	220.3
				132.58	216.4	Sandstone	225.3	251
				216.4	270.3	Clayey soil with kankar	281.3	305.7
				270.3	277.4	Sandstone		
				277.4	341.4	Clayey soil with kankar		
				341.4	373.4	Sandstone		
				373.4	409.4	Sandy clay with kankar		
				409.4	422.6	Clay		
114	Soorakulam	9°43'17"	78°43'18"	0	3.04	Top soil	9.72	19.72
				3.04	15.24	Sandstone	24.72	33.41
				15.24	21.33	Sandy clay	39.67	49.65
				21.33	35.04	Fine sand		
				35.04	51.15	weathered biotite gneiss		
115	Kilpidavur	9°40'35"	78°33'35"	0	9.7	Lateritic soil	22	32
				9.7	30.4	Sandstone	44	56
				30.4	35.2	Clay with Laterite		
				35.2	44.7	Sandstone		
				44.7	57	weathered biotite gneiss		
116	Pulavanpatti	9°56'45"	78°37'30"	0	3	Sandy clay	19	40
				3	4	Sandstone		
				4	6	Clay with kankar		
				6	41.08	Medium sand with kankar		
				41.08	42.1	Weathered Gneiss		
117	Kilpuduvetti	9°55'40"	78°41'0"	0	4.5	Laterite	4.5	27
				4.5	27	Weathered Gneiss		
				27	32	Fresh biotite gneiss		
118	Kurunthampatti	9°58'45"	78°41'30"	0	6	Laterite	33.4	42
				6	10	Clay with sand		
				10	18.2	Clay		
				18.2	31.6	Clayey sand		

Sl. No	VILLAGE	LATITUDE	LONGITUDE	LITHOLOGY			Aquifer Depth	
				31.6	33.4	Shale		
				33.4	42.5	Sandstone		
				42.5	57.8	Clay		
				57.8	82.1	weathered biotite gneiss		
119	Satharampatti	9°54'45"	78°38'20"	0	6.1	Lateritic sand	0	0
				6.1	18.3	Laterite with shale		
				18.3	44.1	Clay		
				44.1	48.2	Sandy clay		
				48.2	51.7	Clay		
				51.7	82.2	Clay & Silt		
120	Kandira manickam	10°3'0"	78°38'0"	0	3.3	Sandy clay	15.2	19.8
				3.3	6.4	Fine sand		
				6.4	19.2	Sandy clay with kankar		
				19.2	35.2	Weathered Gneiss		
121	Sullangudi	10°3'15"	78°33'30"	0	1.5	Clayey sand	12.1	28.9
				1.5	12.5	Quartzite		
				12.5	28.9	weathered biotite gneiss		
				28.9	30.4	Fresh biotite gneiss		
122	Kallal	9°59'24"	78°39'50"	0	1.5	Lateritic sand	9	21.9
				1.5	9.1	Medium to coarse sand with kankar		
				9.1	21.9	weathered biotite gneiss		
123	Malakandan	9°55'40"	78°40'10"	0	3.35	Lateritic sand	20	29
				3.35	16.5	Kankar with Laterite		
				16.5	24.4	Sandy clay		
				24.4	26.8	Clay		
				26.8	32.3	Sandy clay		
				32.3	35	Clay		
				35	40	Sandy clay		
				40	40.2	Weathered Gneiss		
124	Panangudi	9°55'45"	78°36'15"	0	4	Laterite	30	50

Sl. No	VILLAGE	LATITUDE	LONGITUDE	LITHOLOGY			Aquifer Depth	
				4	63.8	Sandstone		
				63.8	64.25	Fresh hornblende gneiss		
125	Natarajapuram	9°55'30"	78°36'20"	0	9.7	Clayey sand	14.6	22.2
				9.7	14.6	Clay		
				14.6	22.2	Fine sand		
				22.2	38.11	Clay		
				38.11	59.3	Weathered Gneiss		
126	Arukuranji	9°57'38"	78°42'15"	0	6.1	Laterite	20	28
				6.1	25.6	Fine to Medium Sand		
				25.6	29	Clay		
127	Kalkulam	9°56'55"	78°43'40"	0	3	Top soil	7	33.5
				3	7.6	Fine sand with kankar		
				7.6	33.5	Sandstone		
				33.5	43.6	Shale		
128	Kallangudi	9°54'45"	78°45'45"	0	12.1	Laterite with clay	19.32	27.94
				12.1	33.5	Sandstone		
				33.5	41	Weathered hornblende gneiss		
129	K.siruvanur	9°57'38"	78°59'22"	0	3	Top soil	250	300.7
				3	9.1	Sandstone		
				9.1	48.8	Clayey sand		
				48.8	64	Sandstone		
				64	83.8	Clay		
				83.8	86.9	Sandstone		
				86.9	180	Clayey sand		
				180	233.3	Shale		
				233.3	301.9	Clayey sand		
				301.9	310	Clay		
130	Pethanendal	10°3'60"	78°53'40"	0	4	Clayey sand	34.87	59.56
				4	14.3	Laterite		
				14.3	37.4	Sandstone		

SI. No	VILLAGE	LATITUDE	LONGITUDE	LITHOLOGY			Aquifer Depth	
				37.4	86.5	Fine sand with clay		
131	Nattendal	9°54'5"	78°50'10"	0	1.5	Clayey sand	40.45	55
				1.5	32	Sand with Kankar	60	68
				32	54.7	Sandy clay	85	95
				54.7	80.4	Sandstone	110	160
				80.4	88.3	Clay		
				88.3	94.2	Sandstone		
				94.2	103.3	Clay		
				103.3	168.7	Clayey sand		
				168.7	172	Clay & shale		
132	Usilangudi	10°5'55"	78°57'10"	0	1.5	Top soil	135	170
				1.5	16.7	Sand & Kankar		
				16.7	66.8	Fine to medium sand		
				66.8	96.08	Sandstone		
				96.08	103.1	Clay & shale		
				103.1	137.2	Clayey sand		
				137.2	194	Clay with shale & sand		
133	Vadugani	9°54'60"	78°51'15"	0	12.1	Clay with Kankar	60	100
				12.1	15.2	Sand		
				15.2	18.2	Clay with Kankar		
				18.2	103.3	Sandstone		
				103.3	106.3	Clay		
				106.3	122	Sandstone		
134	Thalendal	9°53'55"	78°48'25"	0	4.4	Top soil	34	39
				4.4	18.2	Sand with Kankar	50	71
				18.2	57.8	Sandstone	100	114
				57.8	81.7	Clay		
				81.7	86.3	Sandstone		
				86.3	109.4	Clay		

Sl. No	VILLAGE	LATITUDE	LONGITUDE	LITHOLOGY			Aquifer Depth	
				109.4	121.6	Sandstone		
				121.6	135.3	Clay		
				135.3	149	Sandstone		
				149	160	Weathered hornblende gneiss		
135	Thalakkavayal	9°55'20"	78°49'60"	0	3	Top soil	106	155
				3	10.6	Lateritic sand		
				10.6	18.2	Clayey sand		
				18.2	103.3	Sandstone		
				103.3	106.4	Clay		
				106.4	161.6	Sandstone		
136	Chittanur	9°56'40"	78°51'20"	0	13.7	Sandy clay with kankar	49	59
				13.7	18.3	Laterite	74	83.5
				18.3	60.8	Sandstone		
				60.8	64	Clayey sand		
				64	82.3	Sandstone		
				82.3	91.2	Clay		
				91.2	106.4	Sand		
				106.4	116	Weathered Gneiss		
137	Sakkivayal	10°4'15"	78°51'10"	0	9.4	Lateritic sand	36.85	45.61
				9.4	23.7	Sandstone	54.9	63.85
				23.7	36.4	Clay	71.93	78
				36.4	39.8	Sandstone		
				39.8	43	Clay		
				43	80	Sandstone		
				80	94.2	Clay		
138	Melmanakudi	10°4'30"	78°51'20"	0	3.2	Top soil	50.5	68.43
				3.2	6.4	Fine sand	74.68	80.75
				6.4	51.2	Sand with laterirte		
				51.2	72.5	Sandstone		
				72.5	79.3	Sandy clay		

Sl. No	VILLAGE	LATITUDE	LONGITUDE	LITHOLOGY			Aquifer Depth	
				79.3	83.2	Sandstone		
139	Kosavan thani vayal	10°2'10"	78°49'5"	0	3	Lateritic sand	40	75
				3	9.14	Clayey sand	125	145
				9.14	94.5	Sandstone		
				94.5	125	Shale		
				125	149.39	Sandstone		
				149.39	160	Shale		
140	Periyakottai	10°7'30"	78°53'45"	0	3	Top soil	47.04	69.5
				3	28.5	Fine to Medium sand		
				28.5	37.8	Sandstone		
				37.8	41	Clay		
				41	60	Sandstone		
				60	61.5	Shale		
				61.5	77	Sandstone		
141	Sengathangudi	10°1'50"	78°55'15"	0	3.05	Top soil	114.6	159.7
				3.05	16.7	Fine sand		
				16.7	86.9	Sandstone		
				86.9	111.3	Clay		
				111.3	245	Sandstone		
				245	250	Clay		
142	Nattucheri	10°5'10"	78°56'40"	0	6.1	Clayey sand	41	44
				6.1	7.6	clay	50	56
				7.6	13.7	Sandstone	62	68
				13.7	15.2	Fine to medium sand	71	77
				15.2	92	Sandstone		
143	Thatchavayal	9°50'40"	78°49'15"	0	6.1	Sandy clay	91.92	110.9
				6.1	10.6	Clayey sand with kankar	125	115
				10.6	109.8	Sandstone		
				109.8	125	Clayeysand		
				125	152.5	Medium to coarse sand		

Sl. No	VILLAGE	LATITUDE	LONGITUDE	LITHOLOGY			Aquifer Depth	
				152.5	160	Clay		
144	Pirambuvayal	10°2'15"	78°52'15"	0	7.6	Sand	57	75
				7.6	16.7	Lateritic sand	84	96
				16.7	54.9	Clayey sand	120	126
				54.9	73.2	Sandy clay		
				73.2	80.8	Clay		
				80.8	129	Sandstone		
145	Alamangalam	10°2'20"	78°55'10"	0	3.05	Sandy clay	45	51
				3.05	15.2	Laterite with sand	65	80
				15.2	50.3	Fine to Coarse sand		
				50.3	68.6	Clay		
				68.6	77.7	Coarse sand		
				77.7	93	clay		
146	Anjanvayal	10°5'45"	78°57'30"	0	9	Sand	41	47
				9	12	Clayey sand	56	62
				12	76	Sandstone	68	74
147	Kadagampatti	9°54'30"	78°50'60"	0	3.05	Clay	113	140
				3.05	7.6	Sandy clay		
				7.6	12.2	Fine sand		
				12.2	76.2	Sandstone		
				76.2	91.5	Shale		
				91.5	109.8	Sandstone		
				109.8	122	Shale		
				122	151.5	Sandstone		
148	Tattani	9°56'20"	78°53'52"	0	1.5	Clay	74	92
				1.5	6	Sandy clay	120	132
				6	21.4	Sand with kankar	169	194
				21.4	39.7	Sandy clay		
				39.7	137.6	Sandstone		
				137.6	144	Clayey sand		

Sl. No	VILLAGE	LATITUDE	LONGITUDE	LITHOLOGY			Aquifer Depth	
				144	200	Sandstone		
149	Siruvanur	9°58'30"	78°58'50"	0	3	Sandy clay	210	270
				3	7.5	Fine sand		
				7.5	16.5	Clayey sand		
				16.5	105	Sandstone		
				105	127.5	Shale		
				127.5	197	Sandstone		
				197	218	Shale		
				218	308	Sandstone		
150	Chinna kottakudi	10°0'32"	78°52'16"	0	7.5	Sand with kankar	54	78
				7.5	18	Gravel	84	90
				18	33	Sandstone		
				33	42	Clayey sand		
				42	46.5	Sandstone		
				46.5	58.5	Clayey sand		
				58.5	78	Sandstone		
				78	93	Clay		
151	Manachi	10°7'40"	78°47'10"	0	3.3	Red soil	62.32	68.32
				3.3	19.7	Clayey sand	80.87	92.46
				19.7	44	Sandstone		
				44	54.9	Clay		
				54.9	65	Sandstone		
				65	77	Clay		
				77	94	Sandstone		
152	Kilpillakarai	9°47'10"	78°44'25"	0	3	Topsoil	54	70
				3	11	Kankar with sandstone		
				11	36.5	Sandstone		
				36.5	41	Clay		
				41	70	Sandstone		
				70	72	Clay		

Sl. No	VILLAGE	LATITUDE	LONGITUDE	LITHOLOGY			Aquifer Depth	
153	Alanvayal	9°46'60"	78°46'5"	0	9	Fine to medium sand	46.62	63
				9	18	Laterite with sand		
				18	42	Sandy clay		
				42	60	Sandstone		
				60	61.5	Clay		
				61.5	63	Sandstone		
				63	69	Shale		
154	Siruvathi	9°51'55"	78°47'60"	0	3.3	Clay	77.84	90.14
				3.3	15	Sand with kankar	94.14	100.4
				15	123.5	Sandstone	114.4	121.5
155	Kakkakottai	10°5'15"	78°58'55"	0	3	Topsoil	45.6	57.28
				3	15	Fine to coarse sand	83.28	89.46
				15	102	Sandstone		
156	Maviduthikottai	9°54'30"	78°50'20"	0	3.05	Topsoil	50.1	66.04
				3.05	21.35	Sand	69.04	72.04
				21.35	59	Sandstone	106	110
				59	61	Clay	139.3	152.3
				61	122	Sandstone	155.3	169.4
				122	139	Clay with sand		
				139	171	Sandstone		
				171	173	Weathered gneiss		
157	Kavathakudi	9°48'15"	78°48'5"	4.5	54	Sandstone	111.7	127
				54	72	Shale		
				72	127.5	Sandstone		
				127.5	156.5	Clay with shale & sand		
158	Sattanikottai	9°56'30"	78°55'15"	0	6	Sand with gravel	40	44
				6	37	Clay with sandstone	46.98	50.96
				37	86	Sandstone	59.98	70.28
				86	121	Clay		
				121	140	Calcareous Sandstone		

Sl. No	VILLAGE	LATITUDE	LONGITUDE	LITHOLOGY			Aquifer Depth	
				140	150	Calcareous Sandstone		
				150	210	sandstone		
				210	213.5	Weathered gneiss		
				213.5	215.5	Fresh gneiss		
159	Kappalur	9°56'60"	78°56'0"	0	15.4	Sand	59	69
				15.4	34	Clay with sandstone	73	77
				34	88.9	Sandstone	145	173
				88.9	143.3	Clay	188	198
				143.3	156	Calcareous Sandstone	202	206
				156	177.35	Calcareous Sandstone		
				177.35	244.3	Sandstone		
				244.3	249.1	Weathered gneiss		
160	Devandathavu	9°55'30"	78°57'30"	0	5.8	Sand	192	195
				5.8	24.8	Sandstone	202	207
				24.8	33.95	Laterite	210	213
				33.95	43.1	Clay	225	232
				43.1	110.2	Sandstone	242	249
				110.2	177.3	Clay		
				177.3	195.6	Sandstone		
				195.6	198.65	Calcareous Sandstone		
				198.65	216.95	Limestone		
				216.95	294.7	Sandstone		
				294.7	296.25	Weathered biotite gneiss		
161	Neyvayal	9°52'0"	78°53'20"	0	3	Sandy clay	221	238
				3	12.28	Sand	253	268
				12.28	95	Sandstone	270	277
				95	102	Clay	279	288
				102	124	Sandstone	299	308
				124	127	Clay		
				127	145	Sandstone		

SI. No	VILLAGE	LATITUDE	LONGITUDE	LITHOLOGY			Aquifer Depth	
				145	179	Clay		
				179	209	Calcareous Sandstone(Limestone)		
				209	316	Sandstone		
162	Thiyathur	9°54'10"	79°4'45"	0	2	Sand		
				2	6	Sandy Clay		
				6	8	Sandy clay with gravel		
				8	10	Sand		
				10	28	Clay		
				28	30	Clay Sand		
				30	38	Sand		
				38	40	Sand		
				40	42	Sand		
				42	52	Sand		
				52	56	Sand		
				56	64	Sandy Clay		
				64	70	Sand		
				70	90	Sand		
				90	102	Sand		
				102	105	Clay Sand		
163	Madagam	10°3'15"	78°57'15"	0	2	Topsoil		
				2	6	Sandy Clay		
				6	8	Clay Sand		
				8	12	Sandy Clay		
				12	22	Sandstone		
				22	24	Sandy Clay		
				24	38	Sandstone		
				38	40	Sandy Clay		
				40	48	Sandstone		
				48	50	Clay Sand		
				50	54	Clay		

Sl. No	VILLAGE	LATITUDE	LONGITUDE	LITHOLOGY			Aquifer Depth	
				54	64	Sandstone		
				64	74	Clay Sand		
				74	88	Sandstone		
				88	100	Clay Sand		
164	Karaikudi	10°5'0"	78°45'60"	0	3	Topsoil		
				3	9.1	Sandstone		
				9.1	18.3	Sand		
				18.3	36.6	Clay		
				36.6	88.4	Sand		
				88.4	100	Clay soft		
165	Vettriyur	9°54'30"	78°40'50"	0	3	Topsoil		
				3	6.5	Clay		
				6.5	36.5	Sand		
				36.5	39	Clay		
				39	46	Sand		
				46	48	Clay		
				48	49	Gniess hard		
166	Kalayarkoil	9°51'0"	78°32'60"	0	3	Topsoil	8.5	27.9
				3	18.5	Clay mixed with Sand		
				18.5	27	Sandstone (Latritic)		
				27	30	Clay with Sand Stone		
				30	36	Clay		
				36	39	Clay with fine Sand		
				39	44	Sand with Clay		
				44	48	Sand with Clay		
				48	49	Gniess hard		
167	Salaigramam	9°35'35"	78°43'0"	0	3	Top clayey soil		
				3	6	Coarse sandstone with Kankar		
				6	10	Medium to coarse sandstone with kankar		
				10	20	Coarse to very coarse sandstone with kankar		

Sl. No	VILLAGE	LATITUDE	LONGITUDE	LITHOLOGY			Aquifer Depth	
				20	36	Medium sanstone		
				36	50	Medium to coarse sandstone		
168	Visalayankottai	9°58'30"	78°44'10"	0	6	Topsoil		
				6	12	Sand with clay		
				12	18	Clay with gravel		
				18	24	Lat sand with clay		
				24	48	Clay		
				48	54	Sand		
				54	61	Clay		
				61	67	Clay with sand		
				67	79	Clay		
				79	94	Sand with clay		
				94	100	Clay with sand		
169	Sengarai	10°6'50"	78°55'45"	0	3	Top lat soil		
				3	6	Sand		
				6	16	Sand with kankar		
				16	27	Sand		
				27	36	Clay with sand		
				36	42	Sand with clay		
				42	70	Sand with kanakar		
				70	74	Clay		
				74	82	Sandstone with clay		
				82	97	Sandstone		
				97	100	Sandstone with traces of clay		
170	Kulamangalam	9°46'40"	78°44'30"	0	6	Topsoil with kankar		
				6	12	Clay with kankar		
				12	48	Clay		
				48	78	Fine sand with clay		
				78	96	Sand		
				96	99	Sand with mica		

SI. No	VILLAGE	LATITUDE	LONGITUDE	LITHOLOGY			Aquifer Depth	
171	Jeyamkondon	10°4'35"	78°55'5"	0	9	Top lat soil		
				9	12	Sand with clay		
				12	24	Sandy clay		
				24	73	Sand with clay		
				73	94.5	Sand with clay		
				94.5	100	Clay		
172	Mithravayal	10°2'30"	78°54'30"	0	6	Topsoil	38.13	44.86
				6	18	Sand	65.69	73.34
				18	30	Clay mix with kankar		
				30	67	Sand		
				67	76	Sand with clay		
				76	85	Sandstone with stiff clay		

CHAPTER - 3

HYDROMETEOROLOGICAL

CHARACTERISTICS

CHAPTER - 3

HYDROMETEOROLOGICAL CHARACTERISTICS

3.1 General

Hydrometeorology is an interdisciplinary field of science that combines knowledge from the atmospheric sciences and hydrology to study the transfer and exchange of water and energy between land and the lower atmosphere. This field is the interface of two well-developed disciplines, meteorology and hydrology.

The scope of hydrometeorology includes analysis of the space-time properties of climatological parameters such as precipitation, minimum and maximum temperaturesand sunshine and their influence on river systems and water bodies. In this regard, this field research is concerned with a broad understanding of the complex interactions between weather and the water resources of the earth.

Rainfall is a key factor determining the sustainability and conservation of living Species on the earth. In dry farming areas, where rainfall is the only source of water for crops, changes in both quantity and distribution of rainfall during the year could affect the economy of an area.

In this section,PambarKottakkaraiyarRiver Basin'sclimatological parameters are studied.The study made on the hydro-meteorological characteristics, includes analysis of rainfall, temperature, humidity, wind speed, sunshine and evaporation. Study has also been made on rainfall Pattern of the basin, which includes the spatial distribution and variability during different seasons, precipitation ratio and its dependability.

The PambarKottakkaraiyar River Basin lies in the districts of Pudukkotai, Trichy, Madurai, Dindigul,Sivagangai, Ramanathapuram of Tamil Nadu State.A detailed study report on the hydro meteorological parameters for PambarKottakkaraiyar River Basin is furnished below.

3.2 Rainfall

3.2.1 Rain gauge Stations

There are 34 raingaugestations in and around the Basin. Considering the distribution of rain gauge stations and the stations having long term records, out of 34 rain gauge stations , only 14 rain gauge stations were selected for detailed analysis.The details of influencing and non-influencing rain gauge stations in PambarKottakkaraiyar River basin are given in the **Table 3.1 (a) and (b)**.

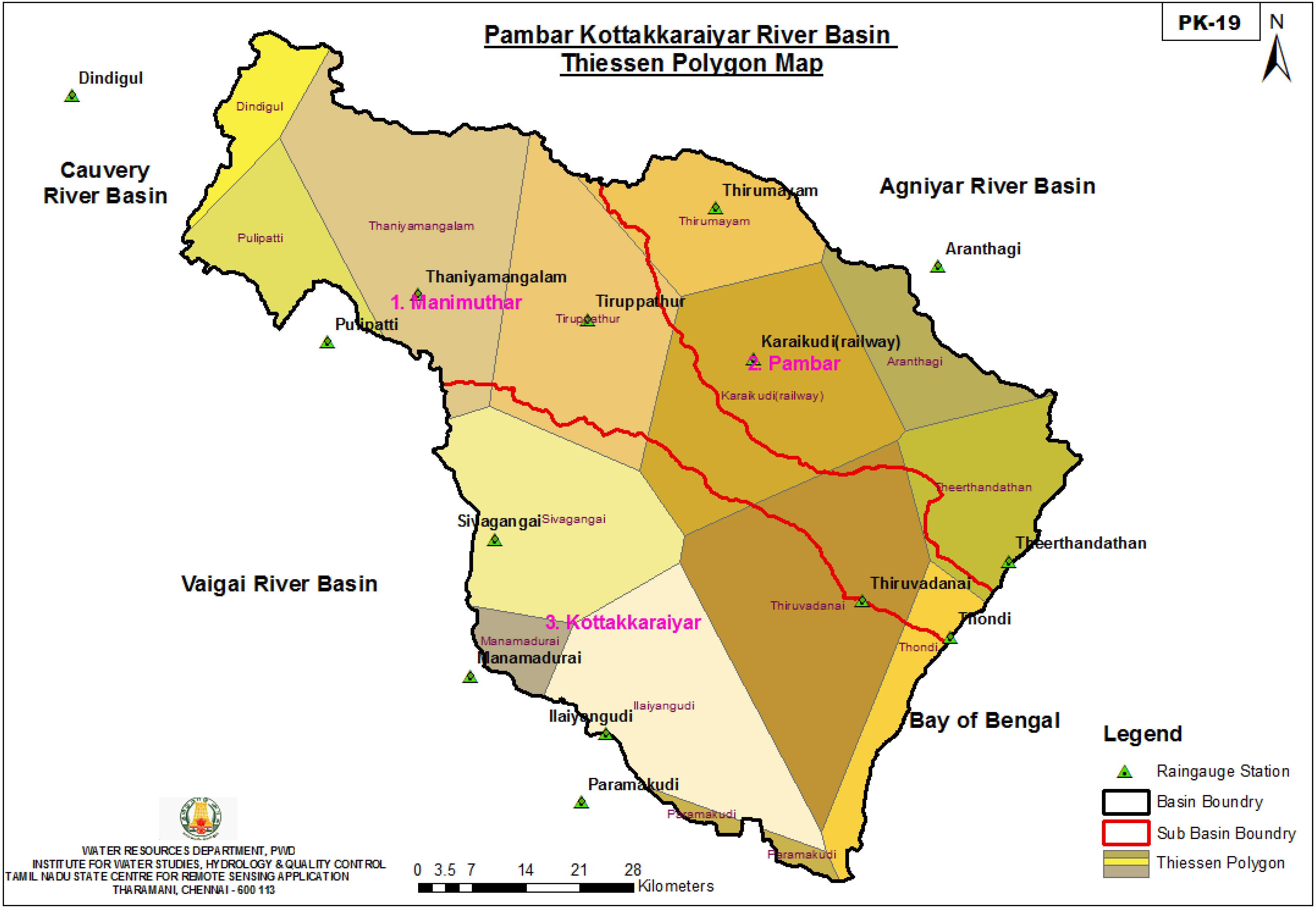
Daily rainfall data for the period of 46years from 1971 to 2017has beencollected from State Ground & Surface Water Resources Data Centre,Chennai.This data is used for Yearly, Monthly and Seasonal Rainfall Probability analysis.For the purpose of rainfall analysis, month is taken as a time step.

3.2.2 Monsoon and Non-monsoon Periods

Geometrically, Tamil Nadu touches the acute southern tip of the Indian Peninsula. The climate of Tamilnadu is generally wet subtropical climate and features fairly hot temperature over the year except during the monsoon season. The State has three distinct monsoon periods of rainfall. The south west monsoon spreads over the period from June to September with strong southwest winds. The north east monsoon spansfrom October to December with dominant northeast winds. Finally, dry season starts from January and ends at May.The monsoon period is hydrological significant for water resource analysis.Though the Monsoon is erratic and uneven, Tamil Nadu receives maximum Rainfall during North east monsoon Annual average rainfall of the State is 971.80mm,(Source: Statistical Hand Book TamilNadu-2017) Its distribution is, however, not uniform.There exists wide variation in rainfall from one part of the districts to the other.

The monthly and season-wise rainfall for 14 rain gauge stations are given in the **Appendix 3.1**. The Rainfall of the basin is determined byThiessen Polygon method. Thiessen Polygon of the basin with raingauge station is prepared and furnished in the Plate**No: PK–19.**Dependable rainfallat 25%, 50%, 75% &90% dependability andseasonwiseaverageand annual rainfall for each of the sub basins have been analysed and tabulated in **Table 3.2 to 3.4**. The season wise Isohyets maps (**Plate No: PK –20 to 24)** are also presented.

Monsoon season **Non Monsoon Season**


Pambar Kottakkaraiyar River Basin
Thiessen Polygon Map
PK-19
N
Dindigul
Cauvery River Basin
Dindigul
Pulipatti
Thaniyamangalam
Thaniyamangalam
1. Manimuthar
Pulipatti
Tiruppathur
Tiruppathur
Thirumayam
Thirumayam
Agniyar River Basin
Aranthagi
Karaikudi(railway)
2. Pambar
Aranthagi
Karaikudi(railway)
Theerthandathan
Theerthandathan
Sivagangai
Sivagangai
Vaigai River Basin
Thiruvadanai
Thiruvadanai
3. Kottakkaraiyar
Thondi
Thondi
Manamadurai
Manamadurai
Ilaiyangudi
Ilaiyangudi
Bay of Bengal
Paramakudi
Paramakudi
Paramakudi
Legend
Raingauge Station
Basin Boundry
Sub Basin Boundry
Thiessen Polygon
WATER RESOURCES DEPARTMENT, PWD
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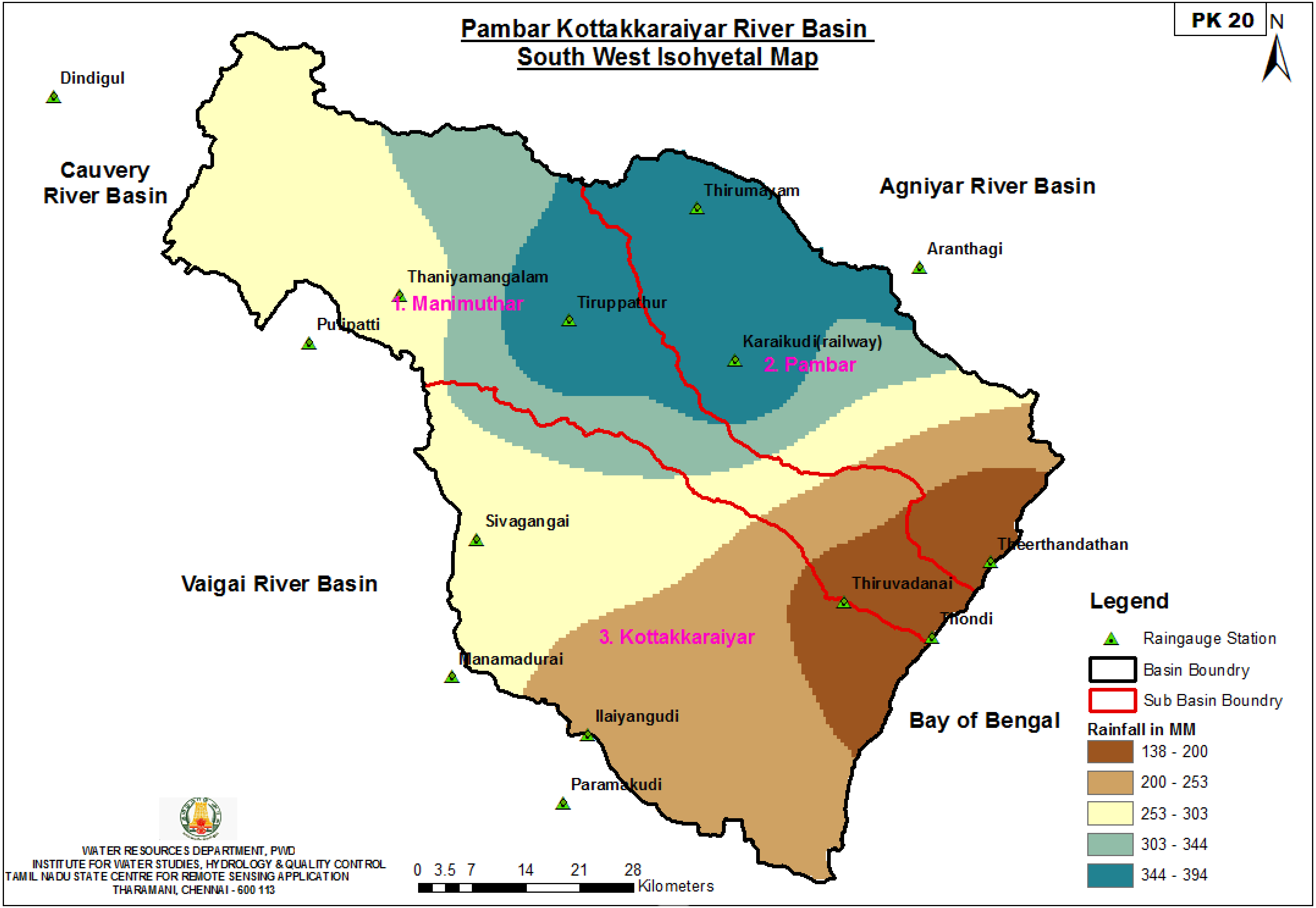
TAMIL NADU STATE CENTRE FOR REMOTE SENSING APPLICATION
THARAMANI, CHENNAI - 600 113
0 3.5 7 14 21 28
Kilometers



Pambar Kottakkaraiyar River Basin
South West Isohyetal Map
PK 20
N
Dindigul
Cauvery River Basin
Agniyar River Basin
Thirumayam
Aranthagi
Thaniyamangalam
1. Manimuthar
Tiruppathur
Pulipatti
Karaikudi(railway)
2. Pambar
Sivagangai
Theerthandathan
Vaigai River Basin
Thiruvadanai
Thondi
3. Kottakkaraiyar
Manamadurai
Ilaiyangudi
Bay of Bengal
Paramakudi
Legend
Raingauge Station
Basin Boundry
Sub Basin Boundry
Rainfall in MM
138 - 200
200 - 253
253 - 303
303 - 344
344 - 394
0 3.5 7 14 21 28
Kilometers
WATER RESOURCES DEPARTMENT, PWD
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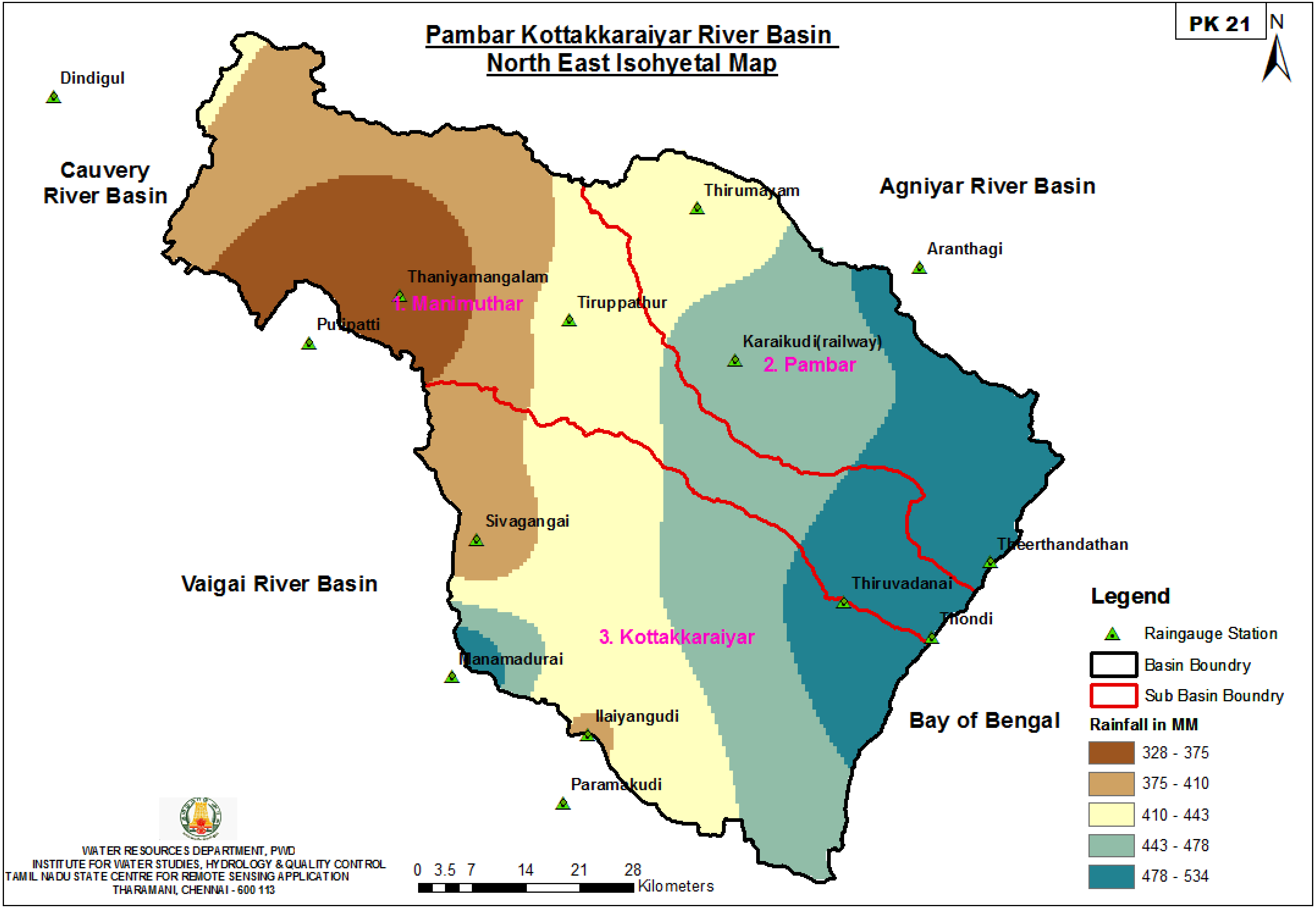
PK 21
N
Pambar Kottakkaraiyar River Basin
North East Isohyetal Map
Dindigul
Cauvery River Basin
Agniyar River Basin
Thirumayam
Aranthagi
Thaniyamangalam
1. Manimuthar
Tiruppathur
Pudipatti
Karaikudi(railway)
2. Pambar
Sivagangai
Vaigai River Basin
Theerthandathan
Thiruvadanai
Thondi
3. Kottakkaraiyar
Manamadurai
Ilaiyangudi
Paramakudi
Bay of Bengal
Legend
Raingauge Station
Basin Boundry
Sub Basin Boundry
Rainfall in MM
328 - 375
375 - 410
410 - 443
443 - 478
478 - 534
0 3.5 7 14 21 28
Kilometers
WATER RESOURCES DEPARTMENT, PWD
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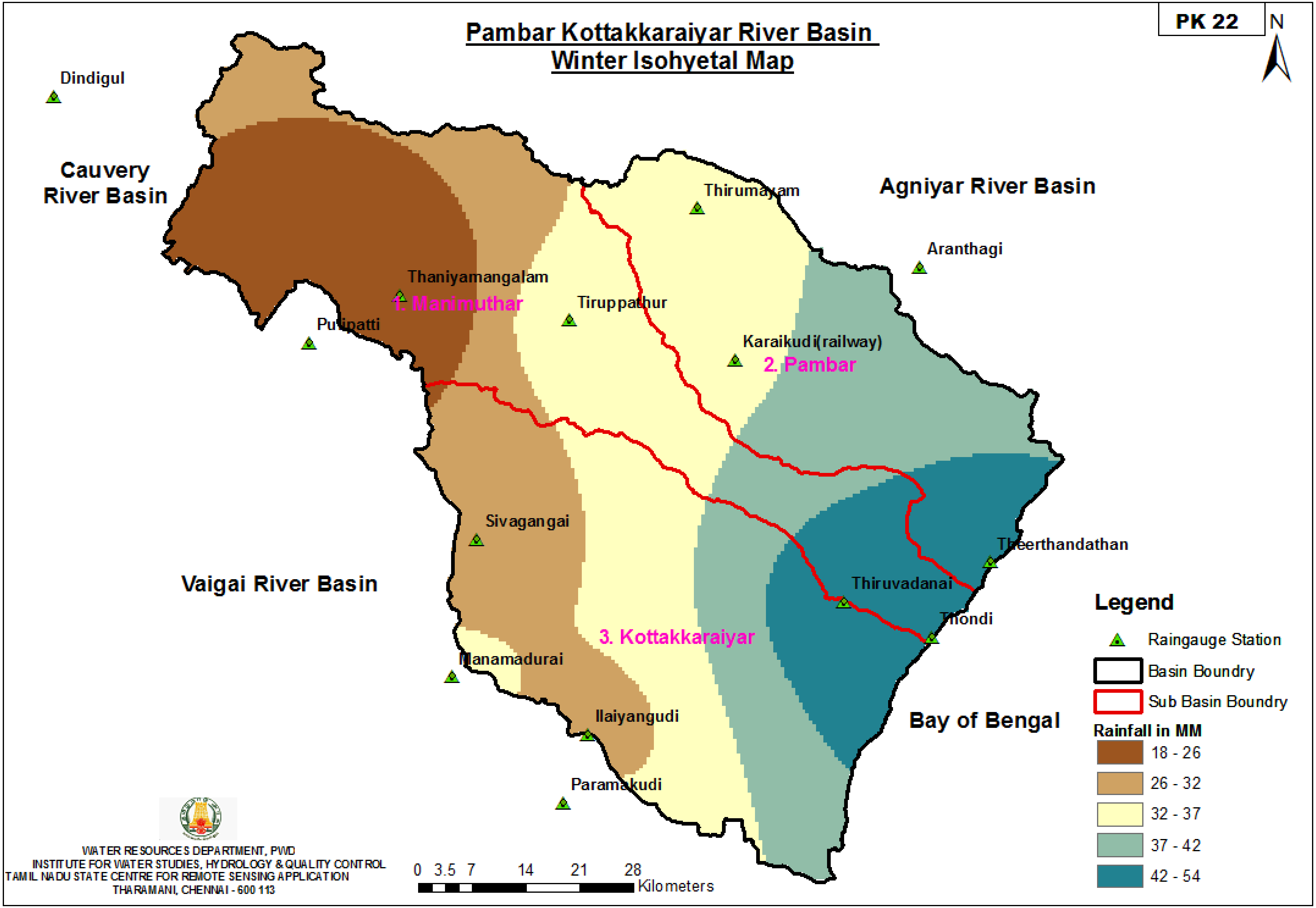
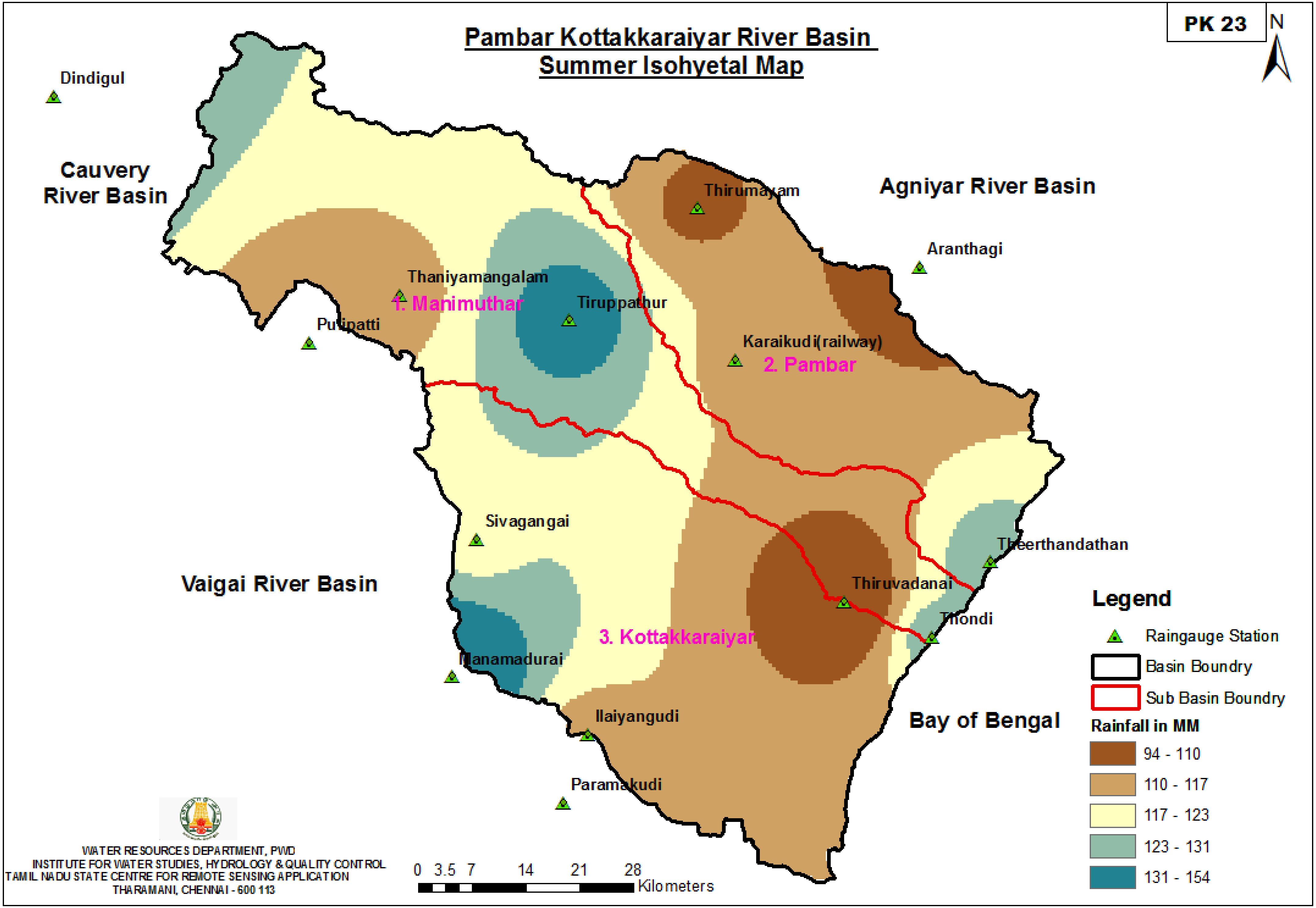

PK 22
N
Pambar Kottakkaraiyar River Basin
Winter Isohyetal Map
Dindigul
Cauvery River Basin
Agniyar River Basin
Vaigai River Basin
Bay of Bengal
Thirumayam
Aranthagi
Thaniyamangalam
1. Manimuthar
Tiruppathur
Pulipatti
Karaikudi(railway)
2. Pambar
Sivagangai
Theerthandathan
Thiruvadanai
Thondi
3. Kottakkaraiyar
Manamadurai
Ilaiyangudi
Paramakudi
Legend
Raingauge Station
Basin Boundry
Sub Basin Boundry
Rainfall in MM
18 - 26
26 - 32
32 - 37
37 - 42
42 - 54
0 3.5 7 14 21 28 Kilometers
WATER RESOURCES DEPARTMENT, PWD
INSTITUTE FOR WATER STUDIES, HYDROLOGY & QUALITY CONTROL
TAMIL NADU STATE CENTRE FOR REMOTE SENSING APPLICATION
THARAMANI, CHENNAI - 600 113


PK 23
N
Pambar Kottakkaraiyar River Basin
Summer Isohyetal Map
Dindigul
Cauvery River Basin
Agniyar River Basin
Vaigai River Basin
Bay of Bengal
Thirumayam
Aranthagi
Thaniyamangalam
1. Manimuthar
Tiruppathur
Pulipatti
Karaikudi(railway)
2. Pambar
Sivagangai
Theerthandathan
Thiruvadanai
Thondi
3. Kottakkaraiyar
Manamadurai
Ilaiyangudi
Paramakudi
Legend
Raingauge Station
Basin Boundry
Sub Basin Boundry
Rainfall in MM
94 - 110
110 - 117
117 - 123
123 - 131
131 - 154
WATER RESOURCES DEPARTMENT, PWD
INSTITUTE FOR WATER STUDIES, HYDROLOGY & QUALITY CONTROL
TAMIL NADU STATE CENTRE FOR REMOTE SENSING APPLICATION
THARAMANI, CHENNAI - 600 113
0 3.5 7 14 21 28
Kilometers

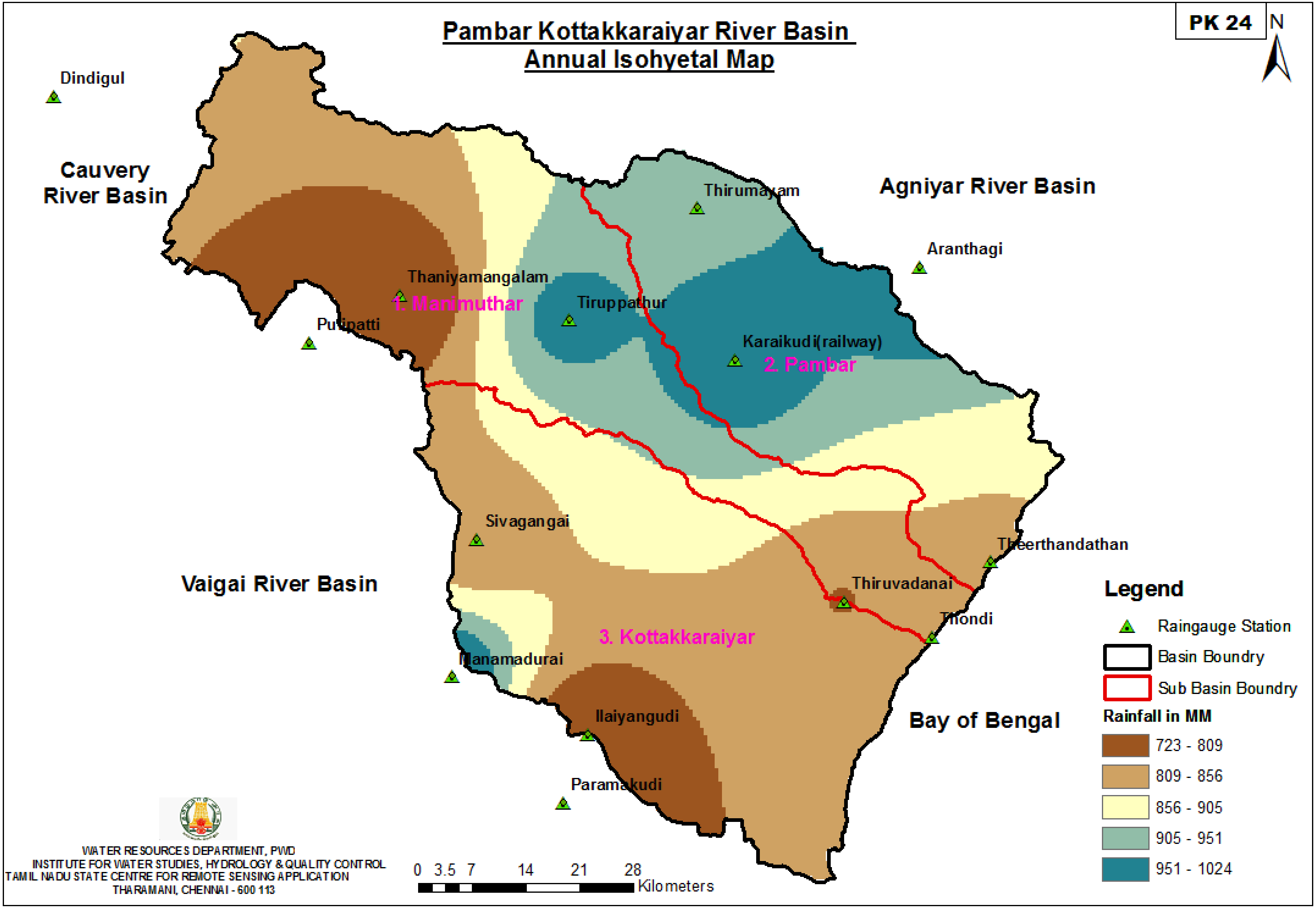

Pambar Kottakkaraiyar River Basin
Annual Isohyetal Map
PK 24
N
Dindigul
Cauvery River Basin
Agniyar River Basin
Vaigai River Basin
Bay of Bengal
Thirumayam
Aranthagi
Thaniyamangalam
1. Manimuthar
Tiruppathur
Puliipatti
Karaikudi(railway)
2. Pambar
Sivagangai
Theerthandathan
Thiruvadanai
Thondi
3. Kottakkaraiyar
Manamadurai
Ilaiyangudi
Paramakudi
Legend
Raingauge Station
Basin Boundry
Sub Basin Boundry
Rainfall in MM
723 - 809
809 - 856
856 - 905
905 - 951
951 - 1024
0 3.5 7 14 21 28
Kilometers
WATER RESOURCES DEPARTMENT, PWD
INSTITUTE FOR WATER STUDIES, HYDROLOGY & QUALITY CONTROL
TAMIL NADU STATE CENTRE FOR REMOTE SENSING APPLICATION
THARAMANI, CHENNAI - 600 113

Table 3.1 (a)

Influencing Raingauge Stations of PambarKottakkaraiyar River Basin

Sl.no	Station Code	Taluk	District	Source	Latitude	Longitude	Data Availability Period
1	Aranthagi	Aranthagi	Pudukkottai	PWD	10°10'28"	79°00'23"	1971-2017
2	Dindigul	Dindigul	Dindigul	PWD	10°21'12"	78°08'01"	1971-2017
3	Ilaiyangudi	Ilaiyangudi	Sivagangai	PWD	09°37'39"	78°37'05"	1971-2017
4	Karaikudi(Railway)	Karaikudi	Sivagangai	PWD	10°04'33"	78°46'43"	1971-2017
5	Manamadurai	Sivagangai	Sivagangai	PWD	09°41'44"	78°27'30"	1971-2017
6	Paramakudi	Natham	Dindigul	PWD	10°06'40"	78°07'14"	1971-2017
7	Pulipatti	Melur	Madurai	PWD	10°05'10"	78°17'30"	1971-2017
8	Sivagangai	Sivagangai	Sivagangai	PWD	09°51'21"	78°29'14"	1971-2017
9	Thaniyamangalam	Melur	Madurai	PWD	10°08'30"	78°23'53"	1971-2017
10	Theerthandathan	Thiruvadanai	Ramanathapuram	PWD	09°49'47"	79°05'18"	1971-2017
11	Thirumayam	Thirumayam	Pudukkottai	PWD	10°14'37"	78°44'46"	1971-2017
12	Thiruvadanai	Thiruvadanai	Ramanathapuram	PWD	09°47'00"	78°55'00"	1971-2017
13	Thondi	Ramanathapuram	Ramanathapuram	PWD	09°44'30"	79°01'14"	1971-2017
14	Tiruppathur	Tiruppathur	Sivagangai	PWD	10°06'45"	78°35'46"	1971-2017

Table 3.1 (b) Non-Influencing Raingauge Stations of PambarKottakkaraiyar River Basin

S.No	Name of Raingauge Station	Taluk	District	Source	Latitude	Longitude	Data avilability Period
1	Arimalam	Thirumayam	Pudukkottai	PWD	10°15'38"	78°53'22"	1977-2017
2	Karaiyur	Thirumayam	Pudukkottai	PWD	10°22'06"	78°36'03"	1971-1974,1986-1989,1993-2002,2004-2017
3	Kundrakudi	Kundrakudi	Sivagangai	PWD	10°07'18"	78°31'06"	1999-2017
4	Idayapatti	Madurai North	Madurai	PWD	09°46'30"	78°16'15"	1976-2017
5	AvudaiyarKovil	AvudaiyarKovil	Pudukkottai	PWD	10°04'52"	79°02'26"	1980-2017
6	Vattanam	Ramanathapuram	Ramanathapuram	PWD	09°46'43"	79°03'28"	1998-2017
7	Marungapuri	Manappaarai	Thiruchirapalli	PWD	10°26'00"	78°24'50"	1975-1999,2012-2017
8	Adalur	Dindigul	Dindigul	PWD	10°21'12"	78°08'01"	1999-2017
9	Vadamadurai	Vedasandur	Dindigul	PWD	10°21'12"	78°44'13"	2002-2017
10	Mimisal	Aranthangi	Pudukkottai	PWD	09°55'17"	79°08'27"	1990-2017
11	NathamTaluk Office	Natham	Dindigul	PWD	10°06'40"	78°07'14"	1976-2017

Table 3.2 - Manimuthar Sub Basin - Season wise- Dependable Rainfall (in mm)

Season	Dependability				Average
	25%	50%	75%	90%	
SW	346.60	278.35	239.82	188.67	295.65
NE	490.72	356.04	267.31	203.41	388.17
Winter	36.34	8.96	2.81	0.00	28.72
Summer	136.94	107.33	61.54	46.66	118.98
Annual	960.98	787.28	656.32	558.03	831.52

Table 3.3–PambarSub Basin - Season wise - Dependable Rainfall(in mm)

Season	Dependability				Average
	25%	50%	75%	90%	
SW	394.42	292.86	247.92	196.29	327.88
NE	555.12	469.27	336.25	255.30	472.17
Winter	38.26	13.17	1.96	0.00	37.76
Summer	143.39	98.17	64.62	45.20	112.82
Annual	1145.69	967.02	766.63	637.94	950.64

Table 3.4–KottakkaraiyarSub Basin - Season wise - Dependable Rainfall(in mm)

Season	Dependability				Average
	25%	50%	75%	90%	
SW	270.93	223.62	170.34	126.60	229.97
NE	522.66	415.86	324.75	223.94	431.83
Winter	43.97	11.76	2.24	0.00	34.97
Summer	127.73	104.44	63.15	44.54	112.95
Annual	920.05	782.47	665.40	576.88	809.72

Table 3.5 –PambarKottakkaraiyarRiver Basin- Dependable Rainfall (in mm)

Season	Dependability			
	25%	50%	75%	90%
SW	337.30	264.90	219.40	170.50
NE	522.80	413.70	309.40	227.50
Annual	1008.90	845.60	696.10	590.90

3.2.3 Dependable Rainfall

The 25%, 50%, 75% and 90% dependable rainfall for PambarKottakkaraiyar River Basinare tabulated above in **Table 3.5**

3.2.4 Frequency Analysis

Frequency Analysis is used to predict how frequent certain parameter will occur and to assess the reliability of prediction. It is a tool for determining design rainfalls and design discharges for hydrology structures, in order to calculate the required hydraulic capacity. Frequency analysis is based on the past records over a long term. Rainfall data is random over the period and when arranged in a chronological order, it constitutes the time series data. From this time series data for each range of annual precipitation frequency in years have been determined and furnished in **Table 3.6** for each of the raingauge stations. From the table it is noticed that rainfall exceeding 1000mm is maximum (54% of the study period (1971-2017)) in Aranthangi and minimum (11% of study period) in ParamakudiandIlaiyangudi. Frequency of Rainfall in the range of 900-1000mm occurred nearly 20% of the study period in Aranthangi, Sivagangai, Thondi. Frequency of Rainfall in the range of 800-900mm occurred in nearly 22% of the study period inPulipatti. Frequency of Rainfall in the range 600 to 800mm rainfall occurred 20% to 39 % of the study period in all stations of the Basin. Frequency of Rainfall in the range400 to 600mm rainfall occurred nearly 33% of the study period inParamakudi. Frequency of Rainfall in the range 200 to 400mm rainfall occurred nearly 7% of the study period in Karaikudi(Railway), Theerthandan, Thondi.Less than 200 mm rainfall has not occurred in any of the stations considered.

Table 3.6 - Annual Rainfall Frequency Distribution

Sl.No.	Name of Stations	Study Period in Years	Exceeded 1000 mm	900 to 1000 mm	800 to 900 mm	600 to 800 mm	400 to 600 mm	200 to 400 mm	Less than 200 mm
1.	Aranthangi	46	25	9	3	6	3	0	0
2.	Dindigul	46	12	8	7	11	8	0	0
3.	Ilaiyangudi	46	5	7	6	18	9	1	0
4.	Karaikudi(Railway)	46	20	5	7	10	1	3	0
5.	Manamadurai	46	16	9	9	9	3	0	0
6.	Paramakudi	46	5	5	7	13	15	1	0
7.	Pulipatti	46	6	4	10	12	13	1	0
8.	Sivagangai	46	10	9	5	11	9	2	0

Sl.No.	Name of Stations	Study Period in Years	Exceeded 1000 mm	900 to 1000 mm	800 to 900 mm	600 to 800 mm	400 to 600 mm	200 to 400 mm	Less than 200 mm
9.	Thaniyamangalam	46	6	6	6	16	11	1	0
10.	Theerthandathan	46	14	3	5	15	6	3	0
11.	Thirumayam	46	18	7	8	8	5	0	0
12.	Thiruvadanai	46	10	8	7	10	9	2	0
13.	Thondi	46	12	9	5	12	5	3	0
14.	Tiruppathur	46	19	7	8	9	3	0	0

3.2.5 Maximum, Minimum and Average rainfall

The maximum, minimum and average annual rainfall for all 14 rain gauge stations in the three sub basins have been tabulated in **Appendix-3.1.1 to 3.1.14**

- Maximum annual average Rainfall of this basin is 945.50 mm i.e. in Pambar Sub basin.
- Minimum annual average Rainfall of this basin is 815.40 mm in KottakkaraiyarSub basin
- Annual average rainfall of the PambarKottakkaraiyar River Basin is 869.17 mm.

Sub basin wise rainfall details are tabulated below **in Table 3.7**

Table 3.7 - Rainfall Details of the Pambar Kottakkaraiyar Basin

Sl. No.	Name of the Sub-basin	No. of influencing RaingauageStaions	Rainfall range in mm(1971 - 2017)					Annual Average Rainfall in mm
			Annual	NE	SW	Winter	Summer	
1	Manimuthar	9	1313.09 To 475.26	508.09 To 163.57	809.27 To 109.94	154.63 To 0.0	335.38 To 27.69	846.70
2	Pambar	6	1371.30 To 439.95	605.16 To 178.99	891.63 To 107.98	237.83 To 0.0	304.02 To 27.34	945.45
3	Kottakkaraiyar	9	1249.20 To 459.15	468.69 To 111.99	798.62 To 120.79	196.09 To 0.0	321.03 To 28.00	815.37

3.2.6 Moving Average

The 5 years moving average graph for the annual rainfall has been drawn for the three sub basins. A linear fit has also been shown along with moving average curve. The details are given in **Appendix 3.2** and**Appendix 3.3.1 to 3.3.3** respectively.

- **The Manimuthar&Kottakkaraiyarsub basin is showing the decreasing trend line.**
- **The Pambar sub basin is showing the increasing trend line.**

3.2.7 Statistical Analysis

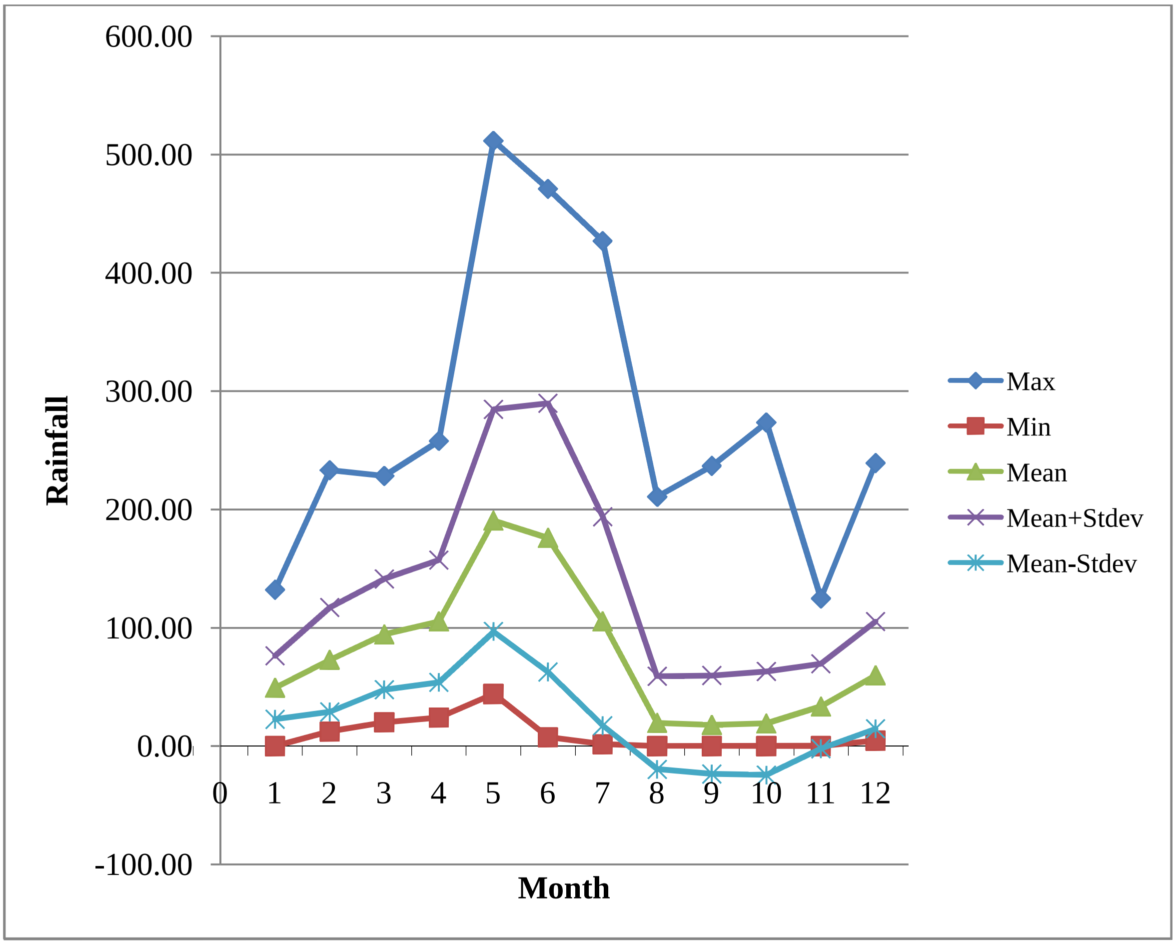
The statistical analysis for the rainfall data has been done for all the sub basins for various seasons namely southwest, northeast, winter, summer and annual. The statistical results namely, Standard Deviation, Coefficient of variation, Skewness and Kurtosis have been analysed and tabulated in**Appendix3.3**

The average value of the PambarSub Basinstatistical Parameters are

- Standard Deviation - 233.10
- Coefficient of variation - 0.25
- Skewness - -0.04
- Kurtosis - -0.90

The Statistical Parameters represents the rainfall distribution pattern with respect to the arithmetic mean of the rainfall data. Based on the Statistical data a model graph representing the rainfall details for Pambar Sub-basin is given below in **Fig 3.1**

Fig.3.1 Statistical Parameters of PambarSub-basin (1971-72 to 2016-17)



3.2.8 Deviation in Rainfall from Mean

The variability of rainfall may be defined as the deviation from the mean.The deficient or excess rainfall years are defined when rainfall of that year departs from the mean rainfall. The rainfall pattern over the basin for 46 years is found to be of alternating sequences of wet (+ve-Deviation) and dry (-ve - Deviation) periods are given in **Table3.8** as depicted from the **fig.3.2**.

Fig.3.2 Deviation from mean South West monsoon Rainfall

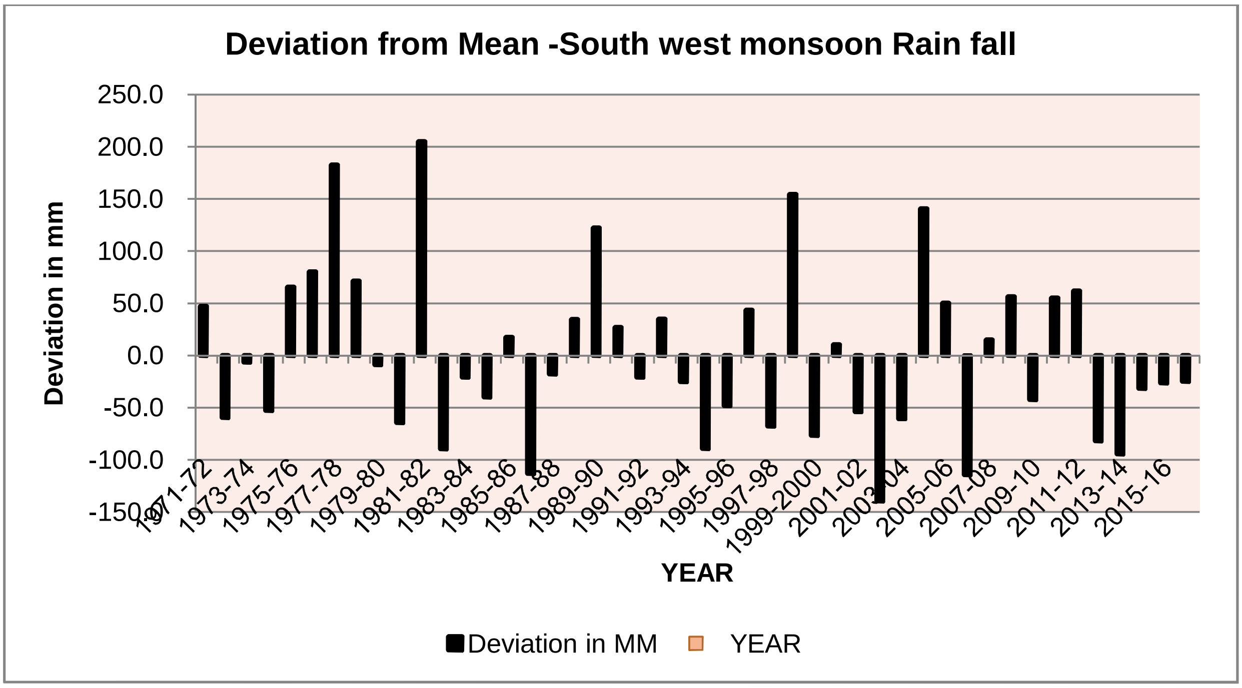


Table 3.8 – Details of deviation in South West monsoon Rainfall

Monsoon	Period of Years	No. of years	Deviation in mm	Deviation
South West Monsoon	1971-1994	12	6 to 113	Negative (-)
		11	17 to 205	Positive (+)
	1995-2017	14	24 to 139	Negative (-)
		9	10 to 154	Positive (+)

Table 3.9 – Details of deviation in North east monsoon Rainfall

Monsoon	Period of Years	No. of years	Deviation in mm	Deviation
North East Monsoon	1971-1994	13	23 to 285	Negative (-)
		10	6 to 357	Positive (+)
	1995-2017	9	38 to 239	Negative (-)
		14	4 to 414	Positive (+)

The North East monsoon and Annual Rainfall deviation from mean details are given in Table 3.9 & 3.10 as depicted from the fig.3.3&3.4 respectively.

Fig.3.3 Deviation from mean North East monsoon Rainfall

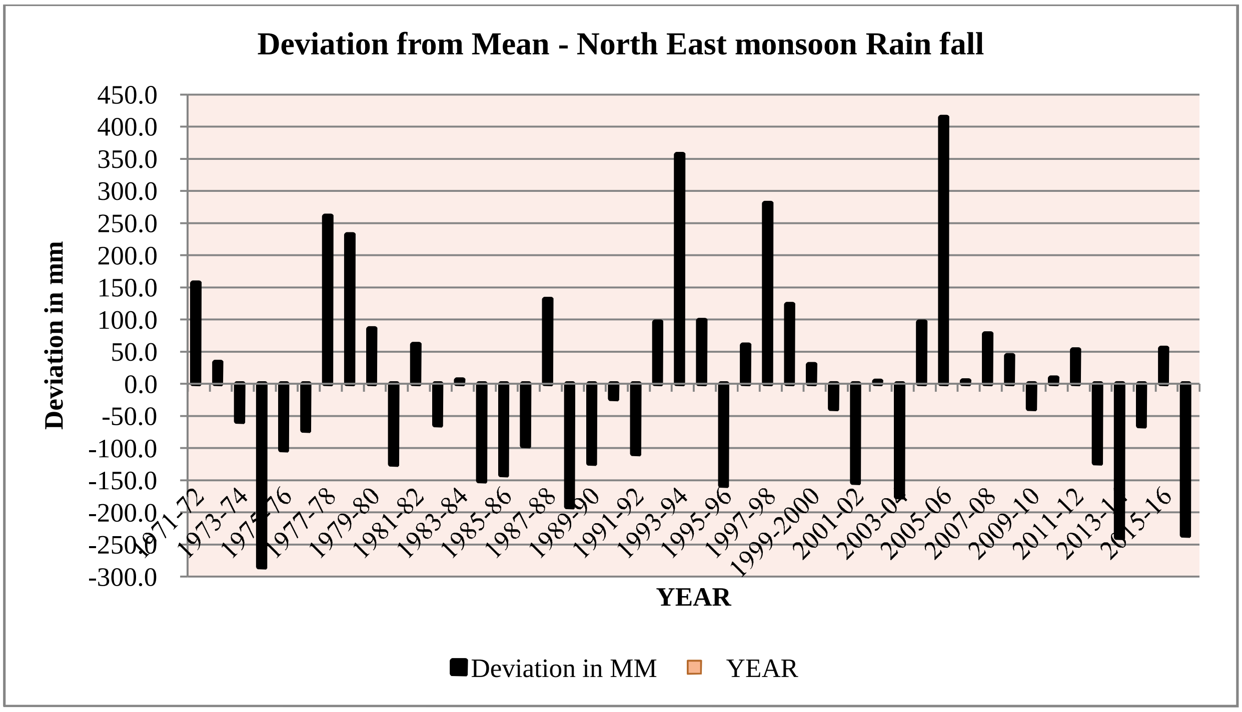


Fig.3.4 Deviation from mean - Annual rainfall

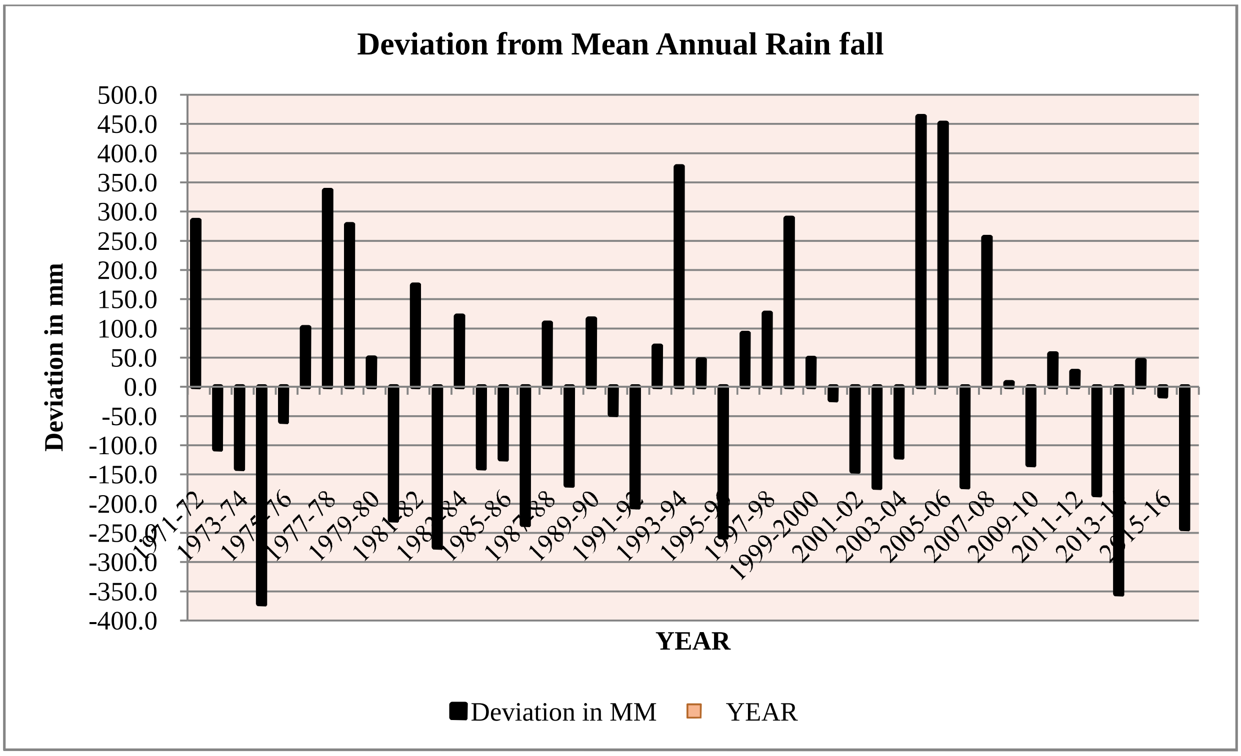


Table 3.10 – Details of deviation in Annual Rainfall

Monsoon	Period of Years	No. of years	Deviation in mm	Deviation
Annual Rainfall	1971-1994	12	47 to 371	Negative (-)
		11	49 to 376	Positive (+)
	1995-2017	12	16 to 355	Negative (-)
		11	7 to 462	Positive (+)

The above observations revealed the fact that the rainfall trend of south west monsoon is decreasing compare to that of north east monsoon over this basin. This trend influences on Annual rainfall pattern over this basin.

3.2.9 Coefficient of Variation Deduced from variability of rainfall

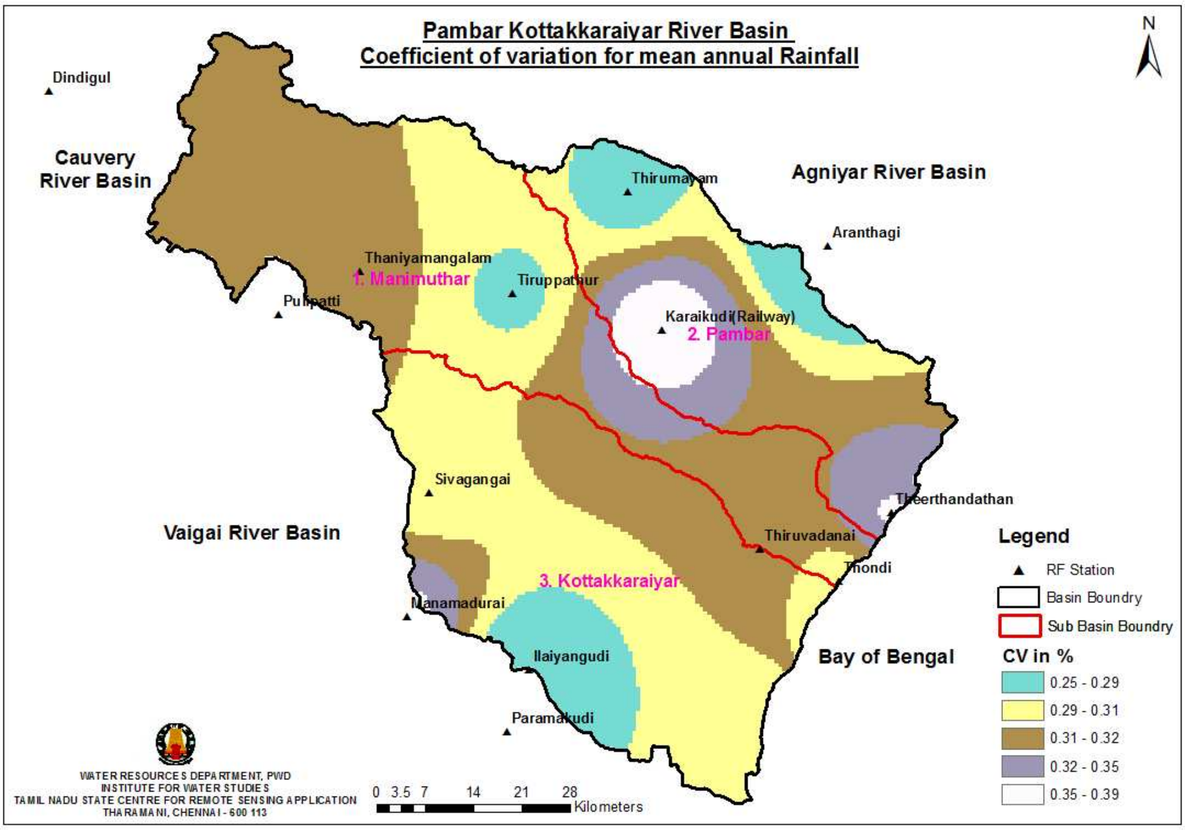


Fig.3.5 Coefficient of variation for mean annual Rainfall

An understanding of Spatial Variation in rainfall is an important requirement for the planning and management of Water Resources. **The Co-efficient of Variation (C_V)** is a measure of relative Variability. It is the ratio of the standard deviation to the mean (average) rainfall. It is generally expressed as a percentage. The higher value of Co-efficient of variation indicates greater level of deviation from the mean. The lower value of Co-efficient of variation,indicates the level of deviation is close to the mean.

Based on the Variability data of 46 years from Raingauge location points, using an inverse distance weighted technique, the Co-efficient of variation for PambarKottakkaraiyar basin for annual rainfall is determined. It ranges from 0.25 to 0.39 (723mm to 1024mm) whereas the mean annual rainfall of the basin is 869.17mm. The annual Co-efficient of Variation in the western part of the basin ranges from 0.31 to 0.32. While in Eastern part of basin it ranges varies from 0.29 to 0.31. Cv value of the basin indicates that variation of Annual rainfall is close tothe mean.

3.3 Climate

Mathematically climate is the statistics of weather over long periods of time. It is measured by assessing the patterns of variation in temperature, humidity, atmospheric pressure, wind, precipitation, atmospheric particle count and other meteorological variables in a given region over long periods of time. Climate differs from weather, that weather only describes the short-term conditions of these variables in a given region.

Kunrakudi weather station is situated inside PambarKottakkaraiyar River Basin and Kamatchipuram weather station lies adjacent to the Basin.Kamatchipuramweather station data is taken for analysis, since it is the station having long term data records.The Location details of weather station considered for analysis are furnished in **Table 3.11** and itsclimatological values are listed in **Table 3.12.**

Table-3.11-Weather Stations

Sl.No	Name of the weather station	Taluk	Sub-basin	Maintained by
1	Kamatchipuram	Dindigul	Amaravathi	PWD

Table-3.12-Climatological Parameters (1991-2017)

Sl. No	Climatological Parameter (Annual Average)	Kamatchipuram
1	Average monthly temperature Maximum in ^{0} Celsius (1991-2017)	33.67
2	Average monthly temperature Minimum in ^{0} Celsius (1991-2017)	24.19
3	Average mean temperature in ^{0} Celsius (1991-2017)	28.93
4	Average relative humidity in % (1991-2017)	60.46
5	Average wind velocity in km/hour (1991-2017)	6.26
6	Average Sunshine hours / day (1991-2017)	7.05
7	Average Pan Evaporation in mm/month (1991-2017)	168.85

3.3.1 Temperature

The Climatological features of the basin have been studied from the data collected from weather station.Temperature is one of the basic factors under climatological features and it is one of the main parameterrequired to calculate the crop water requirement (i.e. reference crop evapo-transpiration). The maximum and minimum temperatures are observed in the weather station.The monthly average Maximum and Minimum Temperature of the

Kamatchipuramstation varies from 39.50^0 Celsius(April-2016) to 26.95^0 Celsius(Dec-1992). The monthly average Minimum temperature varies from 28.10^0Celsius(April-2010),17.95^0 Celsius(Jan-1993).

The average mean, average minimum and average maximum temperature for the Kamatchipuramstation have been computed and tabulated in **Appendix3.4.1 & 3.4.2.**

3.3.2 Relative Humidity

Relative humidity is the ratio of the amount of atmospheric moisture present relative to the amount that would be present if the air was saturated. It is generally expressed in percentage. The relative humidity of air depends on temperature and the pressure of the system. The monthly average relative humidity of the Kamatchipuram station varies from 83.87%(Nov-2010) to 41.53 %(March-1992) **Appendix-3.4.3**

3.3.3Wind speed

Wind velocity is an important climatological parameter which has considerable influence on evaporation and evapotranspiration phenomena. Wind has direct impact on climate and vegetation and is linked with the circulation pattern of the monsoon. The monthly average wind velocity of the Kamatchipuram station varies from 18.48 Kmph (July-1993) to 0.51Kmph (Jan-2015)**Appendix 3.4.4**

3.3.4. Sunshine

The monthly average sunshine hours of the Kamatchipuram station varies from 10.54hrs/day (Mar-1998) to 3.37hrs/day (Nov-2015) **Appendix3.4.5.**

3.3.5 Evaporation

Evaporation is an essential part of the water cycle. The sun (solar energy) drives evaporation of water from oceans, lakes, moisture in the soil, and other sources of water.The estimation of evaporation in water body and transpiration from crop are important parameters to find out the crop water requirement of the crops in that area. The monthly average Pan Evaporation in mm for the Weatherstationis tabulated and given in Appendix **3.4.6.**

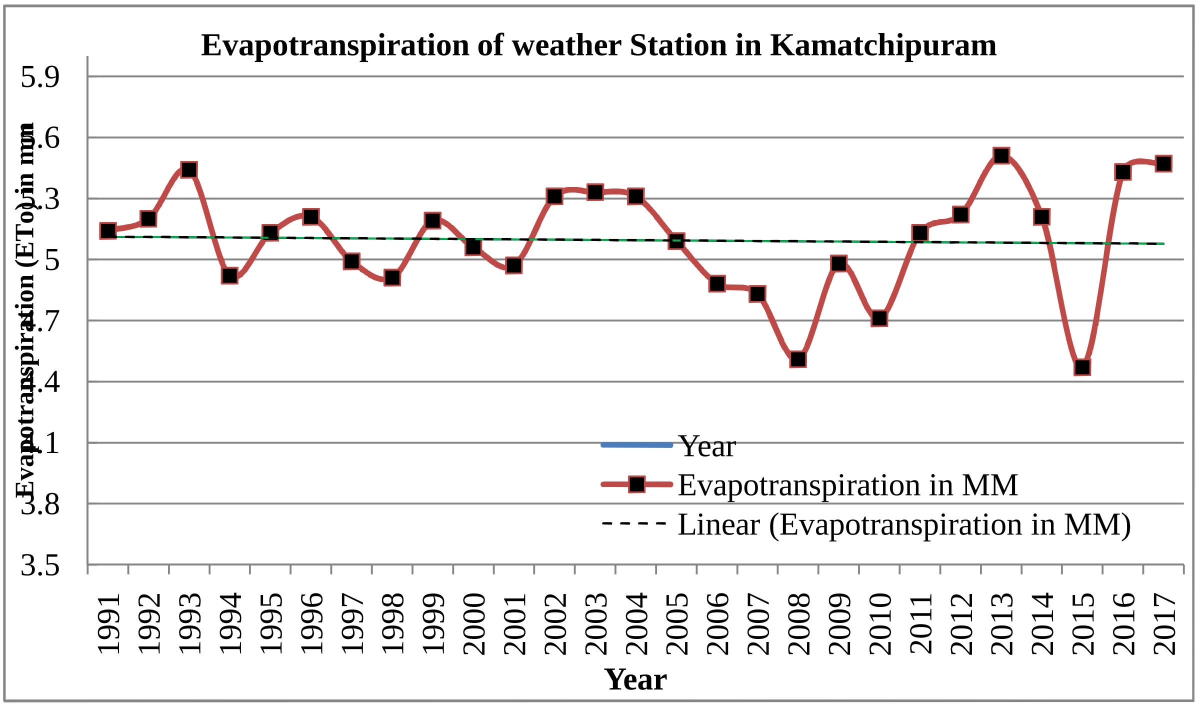
Potential Evapotranspiration

In hydrology, evaporation and transpiration (which involves evaporation within plant stomata) are collectively termed as evapotranspiration.Potential Evapotranspiration is a measure of the ability of the atmosphere to remove water from the surface through the processes of evaporation and transpiration of greenery.

The monthly average Evapotranspiration in mm for the Kamatchipuram weather station is estimated using Modified Penman Montieth Method. The estimated values for this basin are given in **Appendix 3.4.7**. The Annual PET for Kamatchipuram weather station is arrived as 1857.58 mm. The PET for 25 years (1991 to 2017) of daily average for each for

Kamatchipuram weather station is shown in Fig 3.6 The trend line for 25 years data ofPotential Evapotranspiration is Constant.

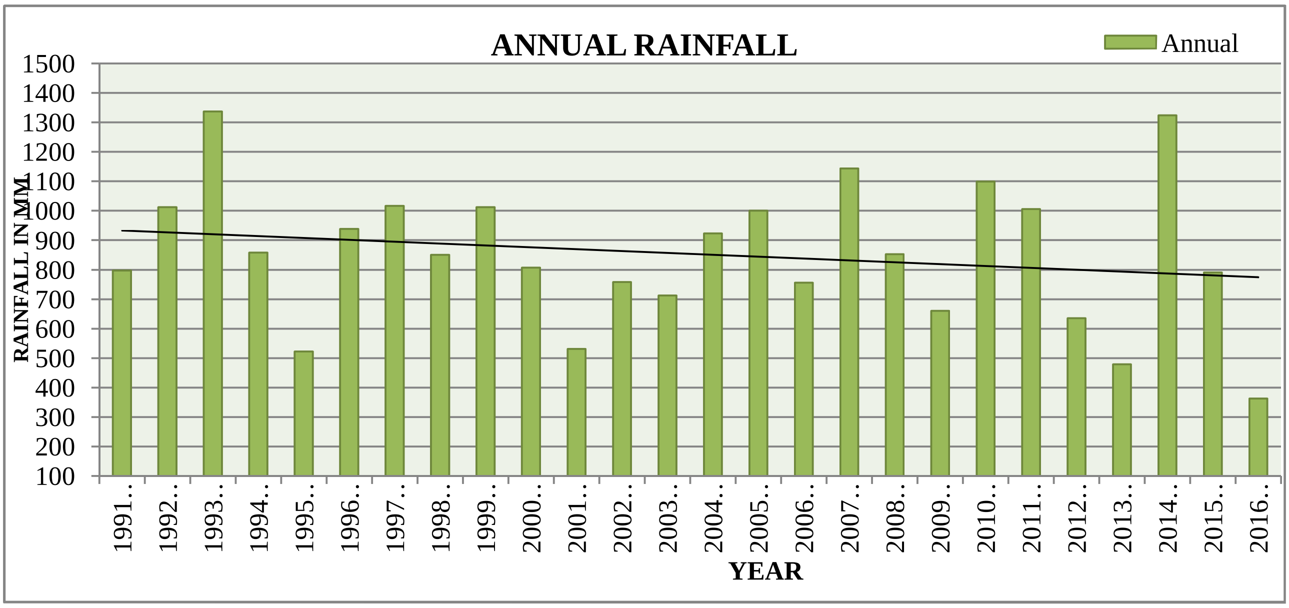
Fig.3.6 Evapotranspiration of weather Station in Kamatchipuram

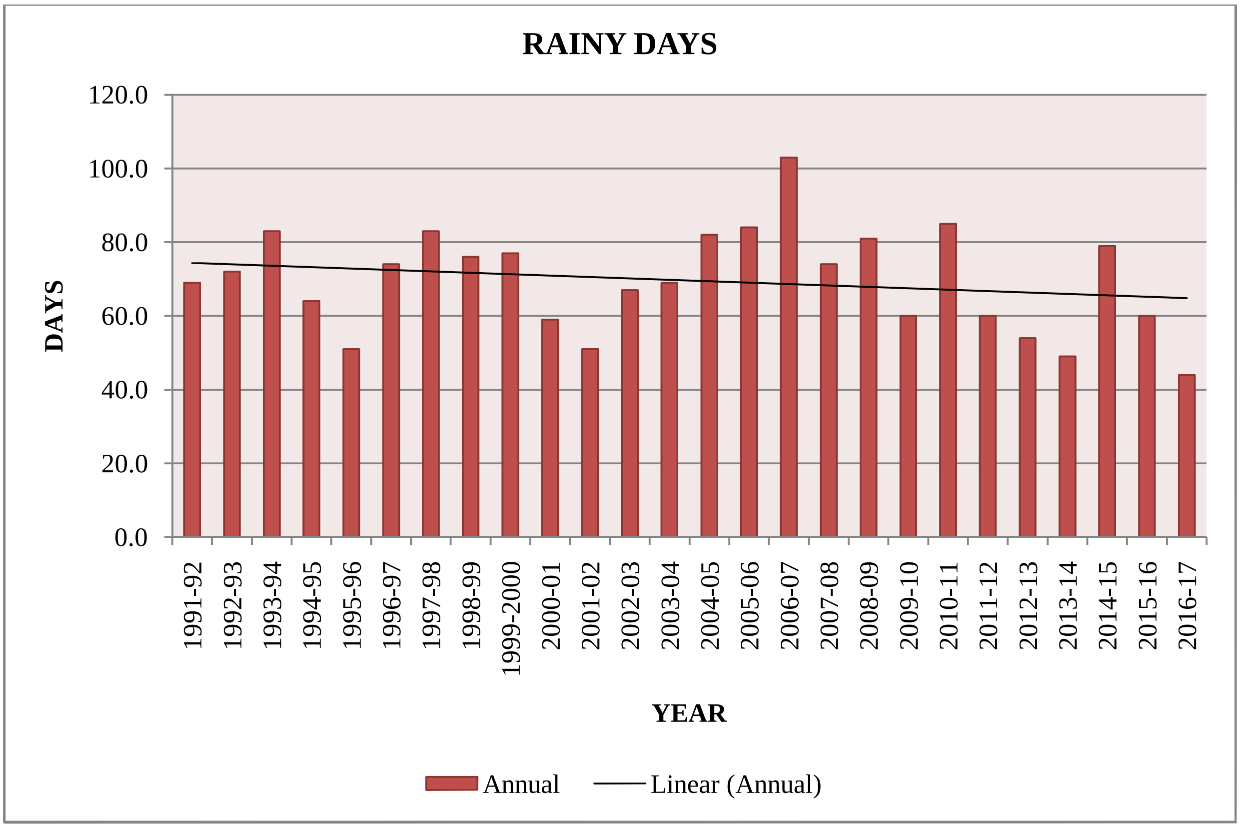


The climatic change inPambarKottakkaraiyar river Basin,over 25years (1991-2017) based on the weather station in Kamatchipuram is summarised below:

- The trend of annual rainfall decreases
- The trend of number of rainy days also decreases
- There is a marginal increase of maximum temperature in summer and winter.
- The minimum temperature also shows increase in pattern in summer and winter.

Fig 3.7 Results of climatic data – Kamatchipuram (1991-2017**)**




RAINY DAYS
120.0
100.0
80.0
60.0
40.0
20.0
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DAYS
1991-92
1992-93
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1994-95
1995-96
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1999-2000
2000-01
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2003-04
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2007-08
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2015-16
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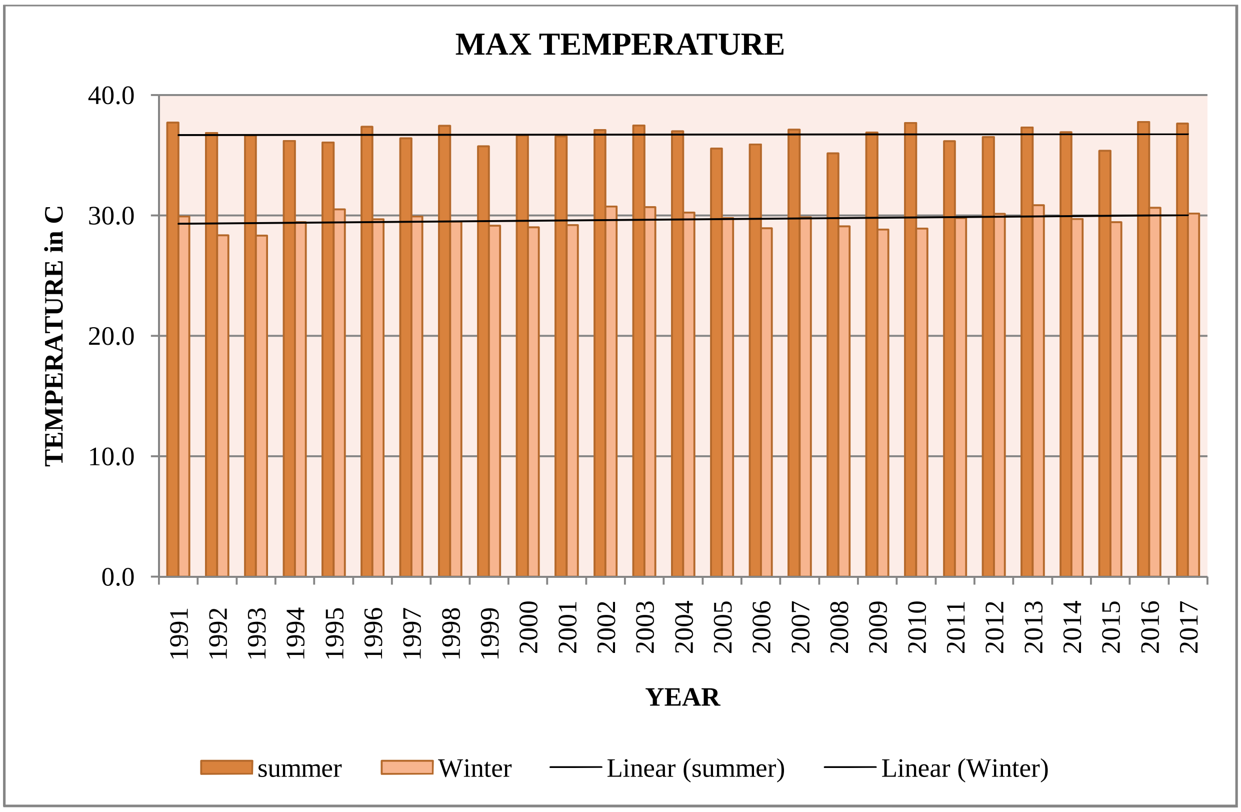
YEAR
Annual
Linear (Annual)


MAX TEMPERATURE
40.0
30.0
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0.0
TEMPERATURE in C
1991
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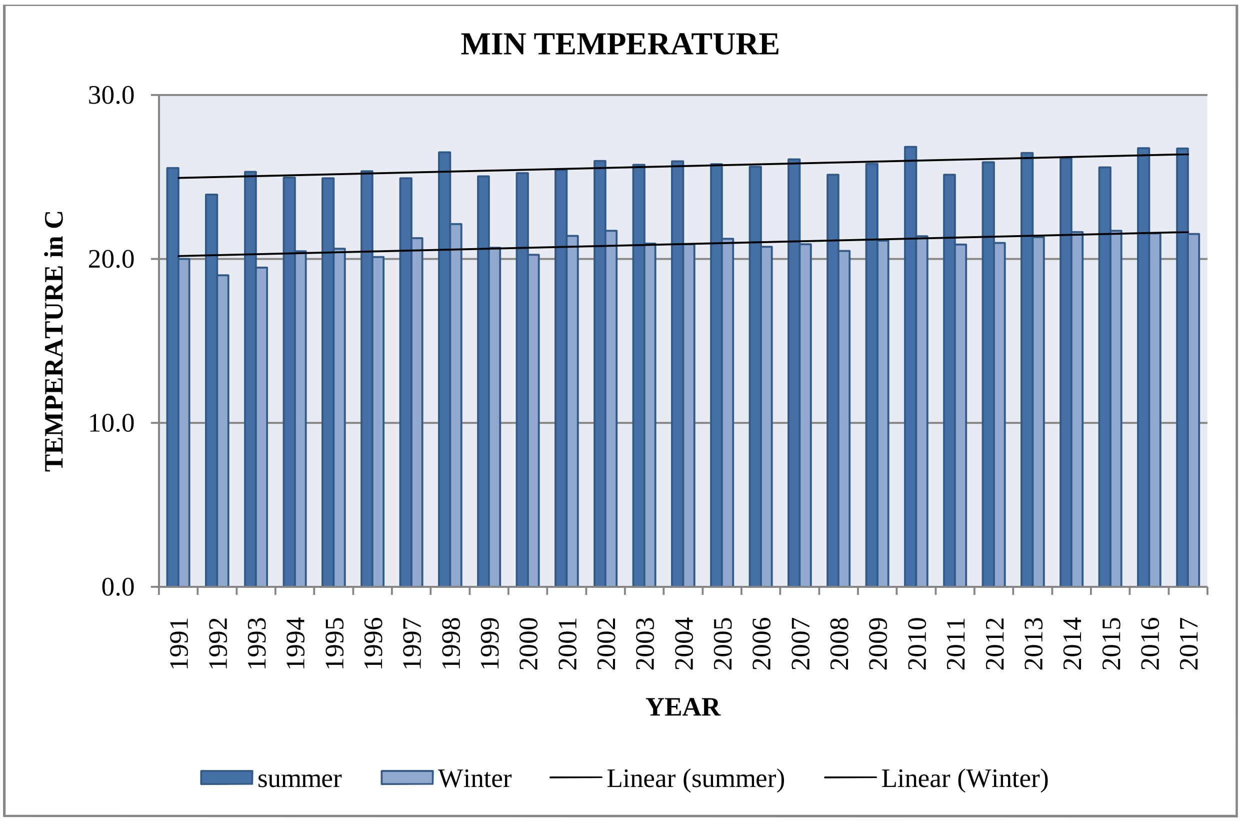
Winter
Linear (summer)
Linear (Winter)



3.3.6 Climatic Classification based on Moisture Index

Climate is the average atmospheric condition of a particular place or region, ranging frommonths to millions of years, 30 years being the classical period defined by the WorldMeteorological Organization (WMO). It represents different weather conditions prevailingat a site or region, considering the analysis of a large amount of data.Climatic classifications are broadly differentiated as either empiric orgenetic methods. Empirical methods make use of actual observed environmental data, such as temperature,humidity, and precipitation, or simple quantities derived from them (such as evaporation) over a long period. In contrast,genetic methods classify climate on the basis of its relating elements, the activity and characteristics ofall factors (circulation systems, fronts, jet streams, solar radiation, topography etc.) that give rise to thespatial and temporal patterns of climatic data.

In this Report, study has been made on the moisture factor existing in the basin area using climatic moisture index which was extensively used by C.W.Thornthwaite and others. Generally Moisture Index varies from -100% to +100%. The annual water surplus or the annual water deficit is the difference between the annual average rainfall and the potential evapotranspiration. The potential evapotranspiration is derived from Modified Penman Monteith method through CROPWAT model.

According to Thornthwaite’s classification scheme,

Humidity Index $= I_h = \frac{100*s}{n}$, and Aridity Index $= I_a = \frac{100*d}{n}$, Where

s = Monthly water surplus calculated as the sum of the monthly difference of precipitation and potential evapotranspiration when precipitation is greater than evapotranspiration (in mm)

d = Monthly water deficit calculated as sum of monthly difference of precipitation and potential evapotranspiration when precipitation is less than evapotranspiration (in mm)

n = Water need (in mm)

Thus Moisture Index is given by

$$\text{Moisture Index} = \frac{\text{Annual Water Surplus / Annual Water Deficit}}{\text{Annual Water need (i.e.) PET}} \text{x100}$$

(Source: Atmospheric Processes/ Climatic Classification By Dr. M.K.Nanda)

The classification climate according to Moisture Index is given in**Table 3.13**

Table 3.13 Moisture Index for Climatic Classification

Moisture Index(%)	**Type of Climate**
+100	Per humid
+100 to +20	Humid
+20 to 0	Moist sub-humid
0 to -33	Dry sub-humid
-33 to -66	Semi-arid
-66 to -80	Arid
-80 to -100	Extremely arid

The annual evapotranspiration (i.e. PET)ofKamatchipuram (1857.58mm/year) weather station is adopted for calculating moisture Index. The Moisture index (Im) for each of the 14 rain gauge stations and for each of the sub basins have been worked out and presented in **Table 3.14 and 3.15**

Table 3.14 - Moisture Index (Im) & Climatic Classification for rainfall station

Sl. No	Station Name	Annual Ave. Precipitation P mm	PET mm	Difference between P&PET mm	Humidity Index (Ih in %)	Aridity Index (Ia in %)	Moisture Index (Im=Ih-Ia) (%)	Classification
1	Aranthagi	1014.7	1858	842.9	0	45.4	-45.4	Semi-arid
2	Dindigul	889.6	1858	967.9	0	52.1	-52.1	Semi-arid
3	Ilaiyangudi	756.5	1858	1101.0	0	59.3	-59.3	Semi-arid
4	Karaikudi(Railway)	1007.9	1858	849.7	0	45.7	-45.7	Semi-arid
5	Manamadurai	1024.2	1858	833.4	0	44.9	-44.9	Semi-arid
6	Paramakudi	723.5	1858	1134.0	0	61.0	-61.0	Semi-arid
7	Pulipatti	732.7	1858	1124.9	0	60.6	-60.6	Semi-arid
8	Sivagangai	814.3	1858	1043.3	0	56.2	-56.2	Semi-arid
9	Thaniyamangalam	751.4	1858	1106.1	0	59.5	-59.5	Semi-arid
10	Theerthandathan	841.9	1858	1015.7	0	54.7	-54.7	Semi-arid
11	Thirumayam	945.7	1858	911.8	0	49.1	-49.1	Semi-arid
12	Thiruvadanai	807.2	1858	1050.4	0	56.5	-56.5	Semi-arid
13	Thondi	855.9	1858	1001.7	0	53.9	-53.9	Semi-arid
14	Tiruppathur	978.2	1858	879.4	0	47.3	-47.3	Semi-arid

Table 3.15 - Moisture Index (Im) & Climatic Classification for Sub Basin

Sl.No	Basin Name	Annual Ave. Precipitation P mm	PET in mm	Difference between P&PET in mm	Humidity Index (Ih in %)	Aridity Index (Ia in %)	Moisture Index (Im=Ih-Ia) (%)	Classification
1	Manimuthar	846.7	1858	1010.9	0	54.4	-54.4	Semi-arid
2	Pambar	945.5	1858	912.1	0	49.1	-49.1	Semi-arid
3	Kottakkaraiyar	815.4	1858	1042.2	0	56.1	-56.1	Semi-arid

3.3.7 Meteorological Drought Assessment

Time series rainfall data analysis of a region helps in better understanding of its drought climatology. Identification of frequently drought affected regions plays an important role in drought management. Further, past performances provide indications on the future scenarios. Information on spatial and temporal dimensions of drought occurrence and its spread enables designing of more focused management tasks. Therefore, systematic understanding of drought climatology is indispensable for evolving efficient drought management strategies particularly in tropical regions like Tamil Nadu.

Long term rainfall data analysis is used for assessment of drought vulnerability. Study of droughts is also important for planning short-term operations, especially in connection with Irrigation scheduling.

Indian Meteorological Department method for drought assessment is simple and widely used. In this method, drought is assessed on the basis of percentage of deviation of rainfall from the long-term annual mean rainfall. The percentage deviation (Di) is given by

$$\mathbf{Di} = \frac{\mathbf{Pi - \bar{P}}}{\bar{P}}$$

Where Pi is the annual rainfall in the year i and $\bar{P}$ is the long-term annual mean rainfall. The percentage deviation of rainfall Di and the category of drought assessment as per IMD are given below in **Table 3.16.**

Table-3.16 Drought Assessment

Sl. No	Range of Di	Classification of drought	Category
1.	> 0	M0	No drought
2.	0 to - 25	M1	Mild drought
3.	-25 to -50	M2	Moderate drought
4.	< - 50	M3	Severe drought

Drought assessment has been carried out for last 17 years forthe area represented by the rain gauge stations in this basin. The classificationof drought such as no, mild, moderate and severe drought for each of the fourteen stations for every year presented in the **Table 3.17** and no.of years in each categoryis given in the **Table 3.18**. It is observed from the **Table 3.17& 3.18** that for maximum No.of years the area represented bythe most of these stations have been classified as Mo (No drought) a few area have greater years in M1 Classification.This basin is not frequently drought prone. Severe drought conditions was felt only in a few Stations like Dindigul(2013-14,2016-

17),Thiruvadanai(2003-04,2013-14),Manamadurai(2012-13), Pulipatti(2006-7), Sivagangai(2013-14), Theerthandathan(2016-17), Thondi(2016-17), Thiruppathur(2002-03)

Drought frequency analysis for 17-year period (2000-01 to 2016-17) indicates that

- Mild drought occurred out of 17 years-9 years in Karaikudi(Railway),8 years in Paramakudi, Manamadurai,Thiruppathur,7years in Dindigul, 6 years in Aranthangi, Thirumayam,, 5 years in Pulipatti, ThanyamangalamRaingauge stations.
- Moderate droughtoccurred out of 17 years -7 years in Manamadurai, Pulipatti, 4 Years in Ilayankudi, Karaikudi(Railway), ThiruvadanaiRaingauge stations.
- **Severe drought occurred for** 2years in Dindigul, Thiruvadanai, 1 year in Manamadurai, Pulipatti, Sivagangai, Theerthandathan, Thondi, Thiruppathurout of 17 years.
- In general, the area represented by all rainfall stations in this basinlies between no drought to mild drought for most of the years.

3.4 Summary

Among the climatic elements the rainfall is the first index to agriculture ever thought by farmers and climatic analyzers as it is the most important factor which determines the cropping pattern of an area in general and the type of crop to be cultivated and its success or failure in particular.Therefore, the above study deals with the rainfall characteristics of the PambarKottakkaraiyarRiver Basin such as the spatial distribution and variability through different seasons, precipitation ratio and frequency occurrences.

The rainfall measurements are used as the major input in water balance studies, such as assessment of water potential. In regional water resources management,rainfall studies provide the simplest guide for distribution of water over anarea. However, the records need careful analysis, linked with an understanding of theeffect of topography and aspect on rainfall distribution.

PambarKottakkaraiyar River Basin consists of three Sub Basins. The sub basin wise influencing rain gauge stations, area of influence of each rain gauge station, area of the sub basin and percentage of weighted area of the influenced rain gauge station, the annual average rainfall and the annual average weighted rainfall for each sub basin are given in **Table 3.19.** The 46 years annual average rainfall of the basin is 869.17 mm.

The previous water plan study of PambarKottakkaraiyar River Basin was carried out in the year 2007 by IWS and the average annual rainfall of the basin was reported as 898 mm.

In general, PambarKottakkaraiyar basin receives more rainfall in North East monsoon than South West monsoon. The rainfall in the basin increases from west to east, and higher rainfall is experienced near the sea coast. The highest rainfall of 945.45mm was recorded in Pambar sub basin. Similarly lowest rainfall of 815.37mm was recorded in Kottakkaraiyarsub basin. On viewing the climatic pattern, it is observed that there is decrease in number of rainy days, further, trend line of rainfall shows declination. In summer and winter, maximum and minimum temperature shows a mildly increasing trend.

Table - 3.17 Meteorological Drought in Pambar Kottakkaraiyar River Basin using IMD Method Drought (Mo - No Drought-M1 - Mild Drought, M2 - Moderate Drought, M3 - Severe Drought)(2001-02 to 2015-16)

Sl.No.	Station Code	2000-01	2001-02	2002-03	2003-04	2004-05	2005-06	2006-07	2007-08	2008-09	2009-10	2010-11	2011-12	2012-13	2013-14	2014-15	2015-16	2016-17
1	Aranthagi	M0	M0	M1	M0	M0	M0	M1	M0	M0	M1	M0	M1	M0	M1	M1	M0	M2
2	Dindigul	M1	M1	M1	M1	M0	M0	M2	M0	M1	M2	M0	M0	M1	M3	M0	M1	M3
3	Ilaiyangudi	M2	M0	M2	M1	M0	M0	M1	M0	M0	M0	M0	M2	M1	M1	M0	M0	M2
4	Karaikudi(Railway)	M0	M1	M1	M1	M0	M2	M0	M1	M1	M1	M0	M2	M2	M1	M1	M2	M1
5	Manamadurai	M2	M0	M1	M2	M1	M1	M2	M1	M2	M1	M1	M2	M3	M2	M1	M1	M2
6	Paramakudi	M0	M0	M1	M2	M0	M0	M1	M0	M1	M1	M0	M1	M2	M1	M0	M1	M1
7	Pulipatti	M1	M2	M2	M1	M0	M0	M3	M1	M2	M2	M2	M1	M2	M2	M0	M0	M1
8	Sivagangai	M2	M0	M1	M0	M0	M0	M1	M0	M0	M2	M0	M0	M2	M3	M0	M0	M1
9	Thaniyamangalam	M0	M2	M0	M1	M0	M0	M0	M0	M0	M1	M0	M0	M1	M2	M1	M1	M2
10	Theerthandathan	M0	M0	M1	M1	M0	M0	M2	M0	M0	M0	M0	M1	M0	M1	M0	M0	M3
11	Thirumayam	M1	M0	M1	M1	M0	M0	M0	M0	M0	M1	M0	M0	M1	M2	M0	M0	M1
12	Thiruvadanai	M0	M1	M1	M3	M0	M0	M2	M0	M0	M1	M0	M2	M2	M3	M0	M0	M2
13	Thondi	M0	M0	M1	M2	M0	M0	M0	M0	M0	M0	M0	M0	M1	M1	M0	M0	M3
14	Tiruppathur	M1	M1	M3	M1	M0	M0	M1	M0	M0	M1	M1	M0	M1	M2	M0	M0	M1

Table 3.18 - Abstract of Drought Assessment (From 2000-01 to 2016-17)

Sl.No.	Station Code	M0	M1	M2	M3
1	Aranthangi	10	6	1	0
2	Dindigul	6	7	2	2
3	Ilaiyangudi	9	4	4	0
4	Karaikudi(Railway)	4	9	4	0
5	Manamadurai	1	8	7	1
6	Paramakudi	7	8	2	0
7	Pulipatti	4	5	7	1
8	Sivagangai	10	3	3	1
9	Thaniyamangalam	9	5	3	0
10	Theerthandathan	11	4	1	1
11	Thirumayam	10	6	1	0
12	Thiruvadanai	8	3	4	2
13	Thondi	12	3	1	1
14	Tiruppathur	7	8	1	1

Table 3.19 - Influencing Raingauge Stations of Each sub-basin

Sl.No	Sub Basin		Rain gauge Station	RG Station Influencing Area in Sq.km	Sub basin Area in Sq.km	Weight in %	Annual average weighted rainfall for the Stations in mm	Annual average weighted rainfall for the sub-basin in mm
1	**Manimuthar**	1	Thiruvadanai	248.79	**2279.60**	0.109	807.15	846.70
		2	Thirumayam	13.77		0.006	945.73	
		3	Thaniyamangalam	746.60		0.328	751.44	
		4	Pulipatti	261.91		0.115	732.71	
		5	Thondi	56.15		0.025	853.42	
		6	Theerthandathan	33.00		0.014	841.87	
		7	Karaikudi(railway)	193.57		0.085	1007.85	
		8	Tiruppathur	575.78		0.253	978.17	
		9	Dindigul	150.04		0.066	889.63	
2	**Pambar**	1	Thiruvadanai	18.63	**1441.60**	0.013	807.15	945.45
		2	Thirumayam	333.94		0.232	945.73	
		3	Theerthandathan	336.87		0.234	841.87	
		4	Karaikudi(railway)	490.19		0.340	1007.85	
		5	Tiruppathur	13.75		0.010	978.17	
		6	Aranthangi	248.20		0.172	1014.67	
3	**Kottakkaraiyar**	1	Sivagangai	569.57	**2204.90**	0.258	814.27	815.37
		2	Thiruvadanai	590.60		0.268	807.15	
		3	Thaniyamangalam	22.64		0.010	751.44	
		4	Manamadurai	93.73		0.043	1024.22	
		5	Paramakudi	47.92		0.022	723.54	
		6	Thondi	136.67		0.062	853.42	
		7	Karaikudi(railway)	73.06		0.033	1007.85	
		8	Ilaiyangudi	611.16		0.277	756.54	
		9	Tiruppathur	59.55		0.027	978.17	
			Basin Total Area	**5926.10**	**5926.10**			**869.17**

CHAPTER 4

IRRIGATION AND AGRICULTURE

CHAPTER – 4

IRRIGATION AND AGRICULTURE

4.1 Introduction

Tamil Nadu covers 4 percent of the geographical area (13.01 Million ha) and caters to 5.96 percent of the population of the country. More than 95 percent of the surface water potential and 80 percent of groundwater potential have been put into use. The total water potential of the State including ground water is 47,125 Mcum and the total surface water potential of the State is 24,160 Mcum including the contribution (7,391 Mcum) from the neighbouring States, viz., Kerala, Karnataka and Andhra Pradesh. The annual per capita water availability in India is about 2200 M^3whereas it is about 750 M^3 in Tamil Nadu.There are 85 dams and 4 reservoirs in the State with a combined storage capacity of 6761 m3(238.58 TMCft).The State's irrigation potential in per capita terms is 0.08 ha when compared to the all-India average of 0.15 ha. There are about 41,127 tanks, 2,239 irrigation main canals and 18.26 lakh irrigation wells in the state. (Source: State Planning Commission Report, 12th five year plan (2012-17).

Irrigation is the artificial application of water to the land in order to fulfil the water requirements of the crops throughout the crop period for the full nourishment of crops.The State has a net irrigated area of 29.12 lakh Ha. About 58.78% of the net area sown is benefitted by irrigation.The total Gross Irrigated area of PambarKottakkaraiyar Basin is 99,845 Ha as per 2016-17year crop area. The main crops cultivated are Paddy,Sugarcane, Groundnut and ChilliesCoconut in addition to Fruits and Vegetables.

Soils

Soil is the most important aspect in successful agriculture and is the original source of the nutrients.As per Technical Report Series of District Ground Water Brochure issued by Government of India, Ministry of Water Resources, the major types of the soilsfound in the Districts covering PambarKottakkaraiyar Basin are as follows:

The soil types found in the Sivaganga District are Red soil, Lateritic Soil, Alluvial Soil and Black Cotton soil. Red soils are prevalent in Devakottai, Tiruppathur and Sivagangaitaluks, while Lateritic soil in Devakottaitaluk. Alluvial soil is found along the river courses and Black Soil in Illayangudi, Manamadurai and TiruppathurTaluks.

The soils found in Pudukottai district can be classified into black, red, ferruginous, lateritic, alluvial and beach soils. Black soils are found in the western part of the district. Red ferruginous lateritic soils are found on the high grounds, south of Annavasal, West of Illupur, north of Malaipatti and east ofAlangudi.

The soils of Ramanathapuramdistrict can be differentiated into viz., clay, coastal alluvium, sandy loam, alluvium, sandy and red soil clay, and black cotton soil.Coastal alluvium occurs in R.S.Mangalam, Ramanathapuram and Thiruvadanai blocks. There are vast stretches of saline and alkaline soils found in the coastal blocks. The fertility status of soil showed that nitrogen content and phosphorus contents of soil are low.The potash content of soil is high in all the blocks. The mineral resources of the soil include gypsum, limestone and magnesium.

The major soil types in the Dindiguldistrict are Red soil, Red sandy soil and Black Cotton soil. Red sandy soils are prevalent in Dindigul and Vedasandur. Black soils are found in all taluks except Kodaikanal.

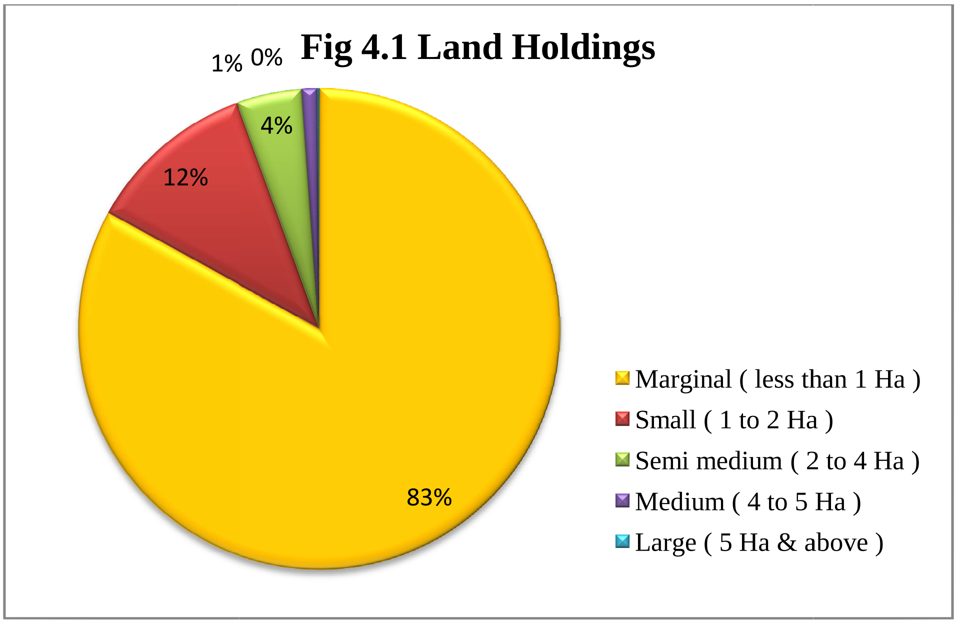
4.2 Land Holdings

A combination of factors such as increasing industrialization, urbanization, housing activities and infrastructure development triggered the conversion of agricultural land into non agricultural uses. This has resulted in a declination of area under cultivation. The scope for the expansion of area available for cultivation is also very limited. Average size of holding in the state was 0.80 Ha. In Tamil Nadu, the per capita availability of land is only 0.19 Ha and the per capita net sown area is only 0.10 Ha. (Ref: Season and crop Report: 2015-16).

As per the latest Agricultural Census 2015-16, the State had 79.37 lakh holdings with an operating area of 59.70 lakh Ha. The category of agriculturists/farmers in PambarKottakkaraiyar Basin on the land holding size is given in **Table 4.1.**Marginal farmers accounts for 81.01%, Small farmers -12.53%, Semi medium farmers-4.90%, Medium farmers-1.26% and Large Farmers- 0.14% in PambarKottakkaraiyarBasin. (Source: Agriculture census 2010-11, Blockwise Number of Operational Holding and Area in Ha).**Fig 4.1** explains the different category of farmers in PambarKottakkaraiyar Basin.

Table -4.1 Sub Basinwise Number of Operational Holding

Social Group	Manimuthar	Pambar	Kottakkaraiyar	Total	Total %
Marginal (less than 1 Ha)	238081	106737	184756	529574	83.02
Small (1 to 2 Ha)	30633	16484	25828	72945	11.44
Semi medium (2 to 4 Ha)	11529	6192	10243	27965	4.38
Medium (4 to 10 Ha)	2862	1538	2185	6585	1.03
Larger (10 Ha & above)	327	270	218	815	0.13
Total	**283433**	**131220**	**223230**	**637884**	**100.00**



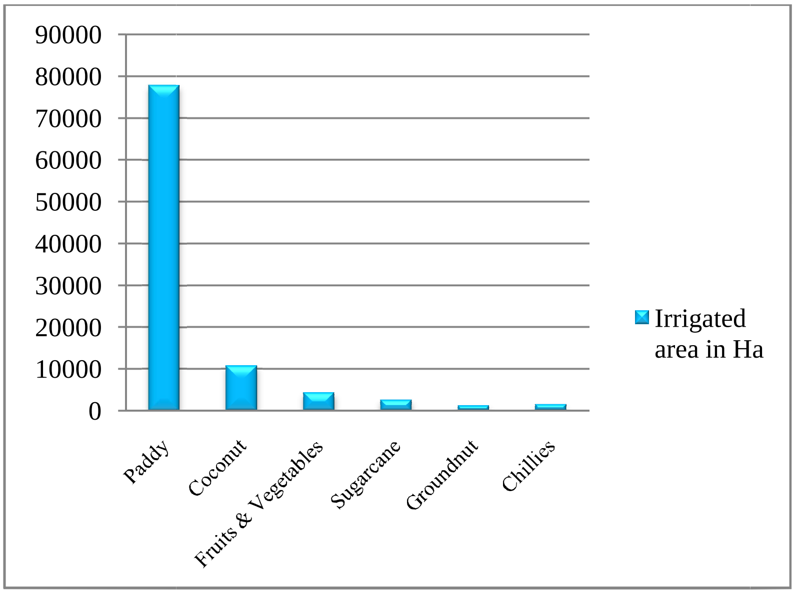
4.3 Irrigation Water Demand Calculation

Major crops and Irrigated area

Irrigated area details for various crops were collected from the Economics and Statistics Department. Irrigated area data for the year 2016-17 was taken for computing Irrigation water demand. The block wise crop area cultivated during 2016-17 was transformed into sub basin area by its block area proportion. Present Sub basin wiseirrigated area of crops in PambarKottakkaraiyar basin is shown in **Table 4.2**. For the irrigation demand calculation, a simplification of crop data was considered by uniform crop plant date and duration of crop growth period in different sub-basins.

For the year 2016-17, gross irrigated area in the basin under different crop is 99,985 Ha. Under irrigated conditions, Paddy (77,868 Ha) is the main crop in this basin, followed by Coconut (10,813Ha), Fruits and Vegetables (4,349Ha), Sugarcane (2604Ha), Groundnut (1265Ha), and Chillies (1538Ha). Irrigated area of major crops is given in **Fig 4.2.**

Figure 4.2 Irrigated area of Major crops (Ha) in Pambar Kottakkaraiyar Basin



The total irrigated area in Manimuthar Sub Basin is 28,100 Ha which accounts for 28% of basin area,Pambar is 27,893 Ha which occupies 28% and Kottakkaraiyar is 43,992 Ha which occupies 44% of the total Basin area.

Fig 4.3 Sub basin wise Irrigated area of crops in Pambar Kottakkaraiyar Basin

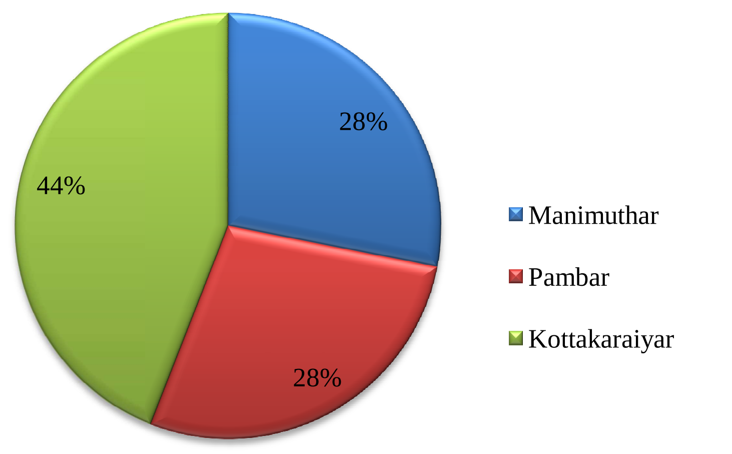
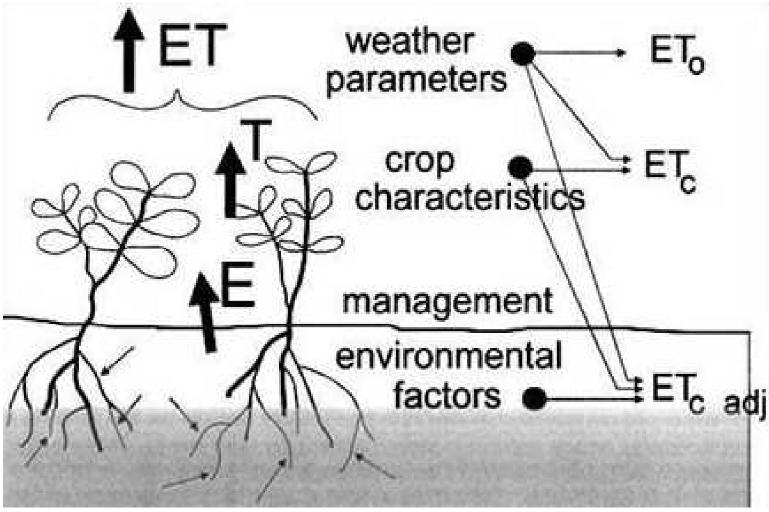


Table 4.2
Sub Basinwise Irrigated Area (Ha) of different crops in Pambar Kottakkaraiyar Basin

Crop	Manimuthar	Pambar	Kottakkaraiyar	Total
Coconut – Per - Jan	8956	834	1022	**10813**
Paddy I - June	4942	8562	12453	**25956**
Paddy II - Oct	9883	17124	24905	**51912**
Cholam - Aug	34	31	12	**77**
Cumbu - Mar	13	0	3	**16**
Ragi - July	7	5	9	**21**
Maize - May	11	67	3	**81**
Red Gram - June	6	2	5	**12**
Black Gram - June	172	77	58	**307**
Green Gram - June	3	1	2	**6**
Other Cereals - July	10	0	2	**13**
Chillies - Feb	132	12	1394	**1538**
Onion-Apr	0	0	0	**0**
Fodder - Mar	33	0	2	**35**
Condiments -Sep	0	0	0	**0**
Sugarcane - Jan	589	567	1448	**2604**
Banana - Apr	0	0	0	**0**
Groundnut - Nov	543	112	609	**1265**
Cotton - Jan	18	1	158	**176**
Gingelly - Feb	2	31	19	**53**
Fruits & Vegetables - July	2472	361	1515	**4349**
Flowers - Per - June	269	100	373	**742**
Turmeric - Sep	5	6	1	**12**
Total	**28100**	**27893**	**43992**	**99985**

4.4 Crop Water Requirement

Crop water requirement *(*CWR*)* is defined as the depth of water [mm] needed to meet the water consumedthrough evapotranspiration ET_c, by a disease-free crop for the complete crop period, growing in large fields under non-restricting soil conditions including soil water and fertility, and achieving full production potential under the given growing environment. The crop water need mainly depends on climate, crop type and growth stage of the crop.



Computational procedure for irrigated crop water under consideration involves simulation of monthly water balance within the effective root zone of the crop. A simplified balance equation presents the basic concept as follows:

STt=STt-1+ERt+TIRt+RIRt-ETAt, where:

t - month.

ST - Root zone storage level between the soil field capacity and wilting point over the effective root depth, mm.

ER - Effective rainfall (total rainfall less surface runoff if exists).

TIR - Technical irrigation, such as pre sowing, germination, or leaching irrigation, net, mm.

RIR - Regular irrigation, replenishing the net crop requirements, mm.

ETA- Actual crop evapotranspiration, a product of ETo and Kc, mm.

Kc - Crop coefficient, a function of crop type and its stage of development, ratio.

ETo - Reference crop evapotranspiration.

Simulation starts with an initial condition describing the state of the root zone soil water just before sowing, i.e. available moisture from previous period.

Basic water need is termed as Technical irrigation. Regular irrigation is applied within the "t" period whenever the root zone moisture level falls below a specified allowable depletion threshold. The allowable depletion is the fraction of the soil storage, which can be depleted from the root zone before moisture stress occurs. The allowable depletion is a characteristic of the crop, and is given as a percentage of the root zone to full soil storage.

The depth of regular irrigation, when applied, is determined so as to replenish the full deficit between the current storage level and the field capacity. In the last month of the irrigation period, if regular irrigation is applied, replenishment occurs only up to the allowable depletion level.

The simulation model distinguishes between two layers within the root zone storage. The upper layer consists of the current root depth and the lower one is thedifference between the current root depth and the full root depth. The current root depth in each "t" period is linearly interpolated between zero at the start of the simulation and the full depth attained at a specified date. After that date, the upper layer remains at full depth level till the end of the simulation and the lower one is zero.

The irrigation balance is simulated in the upper layer. Excess moisture in the upper layer as a result of rainfall or technical irrigation, spills to the lower layer and then percolates below the root zone .Similarly, excess moisture from the lower layer, percolates below the root zone.

The net irrigation requirements include technical irrigation (TIR), regular irrigation (RIR) and leaching irrigation requirement (LIR) as described above.

The gross irrigation requirements (GIR) is obtained by applying efficiency factor EF, as follows: GIR=(TIR+RIR+LIR)/EF.

Hence, it is important to indicate that field percolation losses as a result of excess rainfall, technical irrigation and infiltration from the paddy fields are taken into account by the simulation model. On-farm and off-farm conveyance, runoff, deep percolation other than direct field percolation and operational losses are taken into consideration.

Factors influencing crop water requirements for irrigation

The following features which mainly influence the crop water requirement are:

1) Crop factors - a) Variety b) Growth stages c) Duration d) Plant population e) Crop growing season
2) Soil factors - a) Structure b) Texture c) Depth d) Topography e) Soil chemical composition
3) Climatic factors - a) Temperature b) Sunshine hours c) Relative humidity d) Wind velocity e) Rainfall

4) Agronomic management factors - a) Irrigation methods used b) Frequency of irrigation and its efficiency c) Tillage and other culturaloperations like weeding, mulching etc / intercropping.

Input Data and Parameters

The required inputs for the crop irrigation requirement model include the following data and parameter sets:

Rainfall

Monthly rainfall distributions for four rainfall dependability ie 25%, 50%, 75% and 90% for the weighted rainfall in accordance with the discussion in section 3.2 were used.

Reference Crop Evapotranspiration (ETo)

ETo values calculated for the Kamatchipuram station as discussed is section 3.3of Chapter 3 were used in all the cases.

Crop Parameters

The crop parameters used in the model are presented in Table-4.3.The Kc stages and coefficients were adopted from FAO irrigation Paper No. 56 (Ref: Evapotranspiration - Guidelines for computing crop water requirements). The Kc stages and coefficients for the permanent crops were adjusted to approximate the Kc variation of these crops for the entire year. The growth stage of a crop as in **Fig. 4.4** profoundly influences Kcvalues. The crop growing period can be divided into four distinct growth stages:

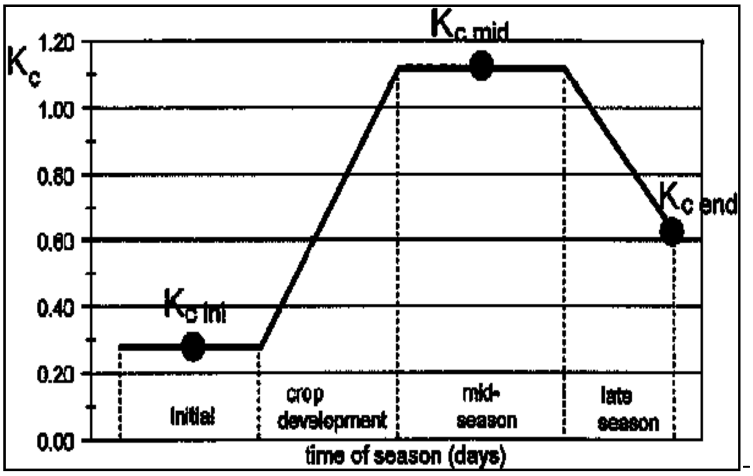
(i) the initial stage (from sowing to about 10% ground cover),

(ii) crop development stage (from 10% to about 70% ground cover),

(iii) mid-season stage (including flowering and grain setting and yield formation stage),

(iv) late season stage (including ripening and harvest).

Figure 4.4 Growth Stage of a Crop



In general, out of the four growth stages, the mid-season stage is the most sensitive to water shortages, as it is the period of the highest crop water need. Water shortage during the mid-season will reduce crop yields substantially.

Soil Parameters

The field capacity and the wilting point of the soil were taken as 30% and 15% respectively for all cases. These values give soil water capacity of 150 mm/m, which could be considered as representative for the majority of the situations in all soils of the basin. Initial water storage condition was taken as dry root zone for all the crops except the coconut, and the fruit crops. For them dry soil layer of 15 cm was taken as initial condition.

Technical Irrigation Data

A planting (pre-sowing) application of 50 mm depth (net), named as technical irrigation was prescribed for all the crops except the coconut and paddy crops. For the paddy,technical irrigation depth isworked out from following data:

Nursery – ETA requirements and infiltration of 2 mm / day during the nursery period for the 8% of the area.

Land preparation - 200 mm

Paddy initial filling - 50 mm

Infiltration of 2 mm /day during the irrigation period.

The crop parameters and technical irrigation for crops for PambarKottakkaraiyar Basin is given in **Table 4.3 & Table 4.4.**

4.5 Basin Net Irrigation Water Demand – Present situation

The monthly crop irrigation requirements as discussed above were applied to the crop areas of the 3 sub basins for the four state of dependablerainfall.The irrigation demand calculated is the balance of the rainfall, the crop actual evapotranspiration, crop change of storage and the technical irrigation requirements and also include direct field deep percolation resulting from excessive technical irrigation and paddy infiltration.

Fig.4.5 explains about the methodology adopted in the calculation of Irrigation Demand. The net Irrigation Water Requirement at 75% DependableRainfall in Manimuthar sub basin in PambarKottakkaraiyar Basin is given in **Table 4.5.**On the same line, Irrigation water demand for 25%, 50%, 75%, 90% dependable rainfall of the three sub basins were calculated and given in **Tables 4.6, 4.7, 4.8 and 4.9** respectively.

Figure 4.5 Methodology for calculating Irrigation Demand – PambarKottakkaraiyar River Basin

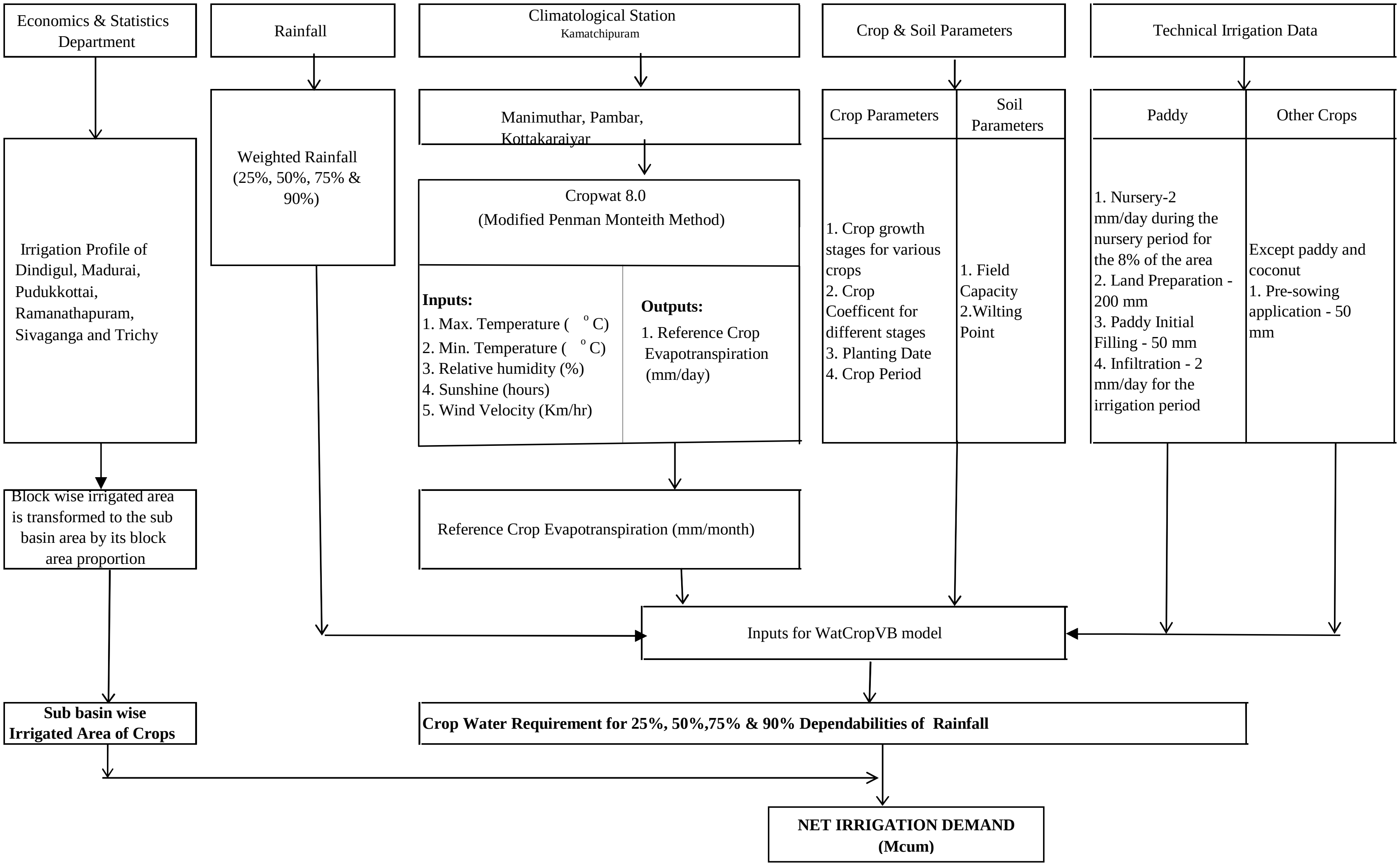


Table 4.3 Crop Parameters in Pambar Kottakkaraiyar River Basin														
Crop No.	**Crop Name**	**Planting Date**		**Crop period**	**Stage-1**	**Kc Stages Stage-2**	**Stage-3**	**Stage-4**	**Data for Kc calculations Wetting Interval**	**Kcmid season Period(3)**	**Kc at harvest**	**Effective root Full depth**	**Time to Full Depth**	**Allow-able deplet-ion**
		Month	Day	(days)	(days)	(days)	(days)	(days)	(days)			(cm)		(%)
1	Coconut- Per-Jan	1	1	365	25	100	100	140	10	1.00	1.00	150	150	40
2	Paddy-First crop-June	6	5	115	30	40	30	15	5	1.10	0.90	15	20	33
3	Paddy-Second crop-	10	20	90	25	35	15	15	5	1.10	0.90	15	20	33
4	Cholam-Mar	3	25	90	20	25	25	20	8	1.00	0.35	125	40	50
5	Cumbu - July	7	15	80	15	25	25	15	8	1.00	0.35	125	35	50
6	Ragi-Feb	2	1	90	20	25	25	20	8	1.06	0.55	125	40	55
7	Maize-Feb	2	25	85	15	25	30	15	10	1.00	0.35	125	40	55
8	Red gram - June	6	10	130	20	40	40	30	10	1.00	0.35	80	30	50
9	Blackgram-June	6	15	70	20	15	20	15	10	1.00	0.35	80	30	50
10	Other Cereals-July	7	15	85	15	25	30	15	10	1.00	0.35	80	30	33
11	Chillies-Sep	9	1	180	30	55	65	30	7	1.05	0.90	75	70	70
12	Onion-Feb	2	1	80	15	25	25	15	5	1.05	0.90	50	35	30
13	Fodder-Mar	3	20	90	20	25	25	20	5	1.00	0.35	125	35	40
14	Condiments-Sep	9	25	100	25	35	20	20	5	1.00	0.35	80	30	50
15	Sugarcane-Jan	1	10	320	30	90	150	50	8	1.25	0.75	150	100	65
16	Greengram - June	6	10	70	20	15	20	15	10	1.00	0.35	80	30	50
17	Banana- Jan	1	1	365	30	100	185	50	7	1.10	1.00	75	100	35
18	Groundnut-Jan	1	5	105	25	35	25	20	10	1.15	0.60	70	45	40
19	Cotton - Feb	2	1	140	30	30	50	30	10	1.15	0.60	140	45	65
20	Gingelly-Dec	12	15	80	15	25	25	15	7	1.15	0.60	125	60	40
21	Fruits & Veg-Per July	7	10	365	25	100	100	140	5	1.05	0.90	100	35	30
22	Flowers-Per-Sep	9	20	365	20	125	125	95	4	0.95	0.85	100	50	20

Table 4.4 Technical Irrigation (Basic Water Need)for Crops in Pambar Kottakkaraiyar River Basin

Crop No.	Crop Name	Field application efficiency	Technical Irrigation											
			Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
		(%)	(mm)	(mm)	(mm)	(mm)	(mm)	(mm)	(mm)	(mm)	(mm)	(mm)	(mm)	(mm)
1	Coconut- Per-Jan	60												
2	Paddy-First crop-June	60						319.2	112	162	54			
3	Paddy-Second crop-Oct	60	34									290	110	162
4	Cholam-Mar	60			50									
5	Cumbu– July	60							50					
6	Ragi-Feb	60		50										
7	Maize-Feb	60		50										
8	Red gram – June	60						50						
9	Blackgram-June	60						50						
10	Other Cereals-July	60							50					
11	Chillies-Sep	60									50			
12	Onion-Feb	60		50										
13	Fodder-Mar	60			50									
14	Condiments-Sep	60									50			
15	Sugarcane-Jan	60	50											
16	Greengram– June	60						50						
17	Banana- Jan	60	50											
18	Groundnut-Jan	60	50											
19	Cotton – Feb	60		50										
20	Gingelly-Dec	60												50
21	Fruits & Veg-Per July	60							50					
22	Flowers-Per-Sep	60									50			

Table 4.5 Net Irrigation Water Requirement at 75% Dependable Rainfall Manimuthar Sub Basin in Pambar Kottakkaraiyar River Basin

S.No.	Crop Name	Crop Area	Crop Water Requirement in MCM												Total	
		(Ha.)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Mcm	Mcft
1	Coconut-Per-Jan	8956.00	5.484	5.559	5.224	5.096	12.468	11.744	10.764	8.417	0.000	7.968	0.000	9.328	82.053	2897.69
2	Paddy-First crop-June	4942.00	0.000	0.000	0.000	0.000	0.000	21.560	8.438	13.246	5.670	0.000	0.000	0.000	48.914	1727.40
3	Paddy-Second crop-Oct	9883.00	9.372	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	28.662	10.871	24.481	73.386	2591.61
4	Cholam-Mar	34.00	0.000	0.000	0.017	0.000	0.062	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.079	2.79
5	Cumbu - July	13.00	0.000	0.000	0.000	0.000	0.000	0.000	0.007	0.000	0.013	0.000	0.000	0.000	0.020	0.69
6	Ragi-Feb	7.00	0.000	0.008	0.008	0.008	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.024	0.84
7	Maize-Feb	11.00	0.000	0.006	0.010	0.020	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.035	1.23
8	Red gram - June	6.00	0.000	0.000	0.000	0.000	0.000	0.003	0.004	0.005	0.004	0.000	0.000	0.000	0.016	0.57
9	Blackgram-June	172.00	0.000	0.000	0.000	0.000	0.000	0.086	0.159	0.000	0.000	0.000	0.000	0.000	0.245	8.64
10	Other Cereals-July	10.00	0.000	0.000	0.000	0.000	0.000	0.000	0.005	0.005	0.006	0.000	0.000	0.000	0.016	0.56
11	Chillies-Sep	132.00	0.155	0.158	0.000	0.000	0.000	0.000	0.000	0.000	0.066	0.000	0.000	0.139	0.518	18.30
12	Onion-Feb	0.00	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.00
13	Fodder-Mar	33.00	0.000	0.000	0.017	0.044	0.058	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.119	4.20
14	Condiments-Sep	0.00	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.00
15	Sugarcane-Jan	589.00	0.295	0.517	0.593	0.683	1.025	1.037	1.007	0.848	0.000	0.889	0.000	0.000	6.893	243.43
16	Greengram - June	3.00	0.000	0.000	0.000	0.000	0.000	0.002	0.004	0.000	0.000	0.000	0.000	0.000	0.005	0.19
17	Banana- Jan	0.00	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.00
18	Groundnut-Jan	543.00	0.338	0.779	0.832	0.233	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	2.183	77.09
19	Cotton - Feb	18.00	0.000	0.018	0.033	0.028	0.032	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.110	3.89
20	Gingelly-Dec	2.00	0.002	0.003	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.006	0.22
21	Fruits & Veg-Per July	2472.00	2.908	3.324	3.150	3.068	3.801	3.245	1.236	0.000	1.020	0.000	0.000	2.600	24.350	859.92
22	Flowers-Per-Sep	269.00	0.240	0.301	0.309	0.310	0.388	0.327	0.279	0.200	0.135	0.000	0.000	0.181	2.668	94.24
	Total	**28095.00**	**18.794**	**10.671**	**10.192**	**9.490**	**17.833**	**38.003**	**21.903**	**22.721**	**6.913**	**37.519**	**10.871**	**36.729**	**241.639**	**8533.49**

Table 4.6

Net Irrigation Water Demand at 25 % Dependable Rainfall in Pambar Kottakkaraiyar River Basin

Sl.No	Sub Basin	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total (Mcm)
1	Manimuthar	3.93	10.25	13.72	13.40	12.09	30.33	16.03	34.73	2.87	28.66	10.87	32.68	209.56
2	Pambar	15.54	1.83	2.81	2.08	2.55	30.46	21.34	18.06	4.68	49.66	19.02	27.76	195.80
3	Kottakkaraiyar	36.80	7.01	6.95	1.27	3.28	69.08	34.15	44.24	13.55	72.23	27.40	40.36	356.31
TOTAL		**56.27**	**19.09**	**23.48**	**16.75**	**17.92**	**129.87**	**71.52**	**97.03**	**21.10**	**150.55**	**57.29**	**100.79**	**761.66**

Table 4.7

Net Irrigation Water Demand at 50% Dependable Rainfall in Pambar Kottakkaraiyar River Basin

Sl.No	Sub Basin	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total (Mcm)
1	Manimuthar	22.46	10.69	16.09	16.04	9.08	39.56	25.74	26.00	15.82	28.66	10.87	16.01	237.02
2	Pambar	16.23	1.84	2.73	0.62	3.99	39.59	18.61	13.87	17.80	49.66	18.84	37.34	221.14
3	Kottakkaraiyar	29.60	7.11	7.67	5.26	5.42	57.35	37.21	39.64	22.39	72.23	28.26	40.36	352.51
TOTAL		**68.29**	**19.64**	**26.49**	**21.92**	**18.50**	**136.51**	**81.57**	**79.51**	**56.02**	**150.55**	**57.97**	**93.71**	**810.67**

Table 4.8

Net Irrigation Water Demand at 75 % Dependable Rainfall in Pambar Kottakkaraiyar River Basin

Sl.No	Sub Basin	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total (Mcm)
1	Manimuthar	18.79	10.67	10.19	9.49	17.83	38.00	21.90	22.72	6.91	37.52	10.87	36.73	241.64
2	Pambar	23.39	1.89	2.82	3.01	2.70	40.47	15.31	33.66	12.51	49.66	18.84	27.76	232.01
3	Kottakkaraiyar	27.62	7.07	7.87	7.37	2.61	63.68	33.95	48.87	7.61	72.23	27.40	63.95	370.22
TOTAL		**69.80**	**19.63**	**20.89**	**19.87**	**23.14**	**142.16**	**71.16**	**105.25**	**27.03**	**159.41**	**57.10**	**128.43**	**843.87**

Table 4.9

Net Irrigation Water Demand at 90 % Dependable Rainfall in Pambar Kottakkaraiyar River Basin

Sl.No	Sub Basin	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total (Mcm)
1	Manimuthar	18.56	10.64	15.96	2.83	23.78	39.17	25.02	21.62	24.42	28.66	10.87	37.75	259.28
2	Pambar	17.20	1.87	2.27	2.35	2.90	39.19	15.53	24.63	12.16	49.84	18.84	46.39	233.16
3	Kottakkaraiyar	12.67	6.48	5.56	7.33	6.53	62.56	28.70	38.43	20.27	79.04	52.24	52.86	372.67
TOTAL		**48.43**	**18.98**	**23.80**	**12.51**	**33.22**	**140.92**	**69.25**	**84.67**	**56.85**	**157.54**	**81.95**	**137.00**	**865.12**

4.6 Future Net Irrigation Water Demand – Lower Limit Scenario

This scenario is based on the identification of changes in the present cropping or cultivation pattern, which would result in, some reasonable lower limit for the future demand of irrigation water in the basin.

Paddy, which is the staple food crop of Tamilnadu is extensively cultivated in all Districts in a normal area of 17.65 Lakh Ha. Paddy accounts for about 50% of the total irrigated area of the state. Nearly 94% of the Paddy area is raised only under irrigated condition. Considering this facts, the lower limit for the future irrigation demand is determined taking into consideration the cultivation of paddy using SRI (System of Rice Intensification) method than the conventional method. If the objective of better yield for a drop of water is to be achieved, then comparatively less water consuming practices of cultivation are to be considered for future planning purposes. Lower Limit Scenario of sub basin wise irrigated area of crops in PambarKottakkaraiyar River Basin are tabulated in **Table 4.10** and net irrigation Water Demand at 25%, 50%, 75%, 90% dependable Rainfall of Lower Limit Scenario are tabulated in **Tables 4.11 to 4.14**. Savings in demand in implementing lower limit scenario pattern of crops in PambarKottakkaraiyar River Basin Basin is listed in **Table 4.15.**

Table 4.10

Sub Basin wise Irrigated Area of Crops (Ha.) in Pambar Kottakkaraiyar Basin Lower Limit Scenario

Crop	Manimuthar	Pambar	Kottakkaraiyar	Total
Coconut - Per - Jan	8956	834	1022	**10813**
Paddy - First Crop - June	1482	2569	3736	**7787**
SRI Paddy I - June	3459	5993	8717	**18169**
Paddy II - Oct	2965	5137	7472	**15574**
SRI Paddy II - Oct	6918	11987	17434	**36338**
Cholam - Feb	34	31	12	**77**
Cumbu - Mar	13	0	3	**16**
Ragi– Jan	7	5	9	**21**
Maize - Jul	11	67	3	**81**
Red Gram - June	6	2	5	**12**
Black Gram - Jan	172	77	58	**307**
Green Gram - Jan	3	1	2	**6**
Other Cereals - July	10	0	2	**13**
Chillies - Jan	132	12	1394	**1538**
Onion-June	0	0	0	**0**
Fodder - Mar	33	0	2	**35**
Condiments -Sep	0	0	0	**0**
Sugarcane - Dec	589	567	1448	**2604**
Banana - Dec	0	0	0	**0**
Groundnut - Dec	543	112	609	**1265**
Cotton - Feb	18	1	158	**176**
Gingelly - Feb	2	31	19	**53**
Fruits & Vegetables - June	2472	361	1515	**4349**
Flowers - Per - June	269	100	373	**742**
Turmeric - June	5	6	1	**12**
TOTAL	28100	27893	43992	**99985**

Table 4.11
Lower Limit Scenerio

Net Irrigation Water Demand at 25% Dependable Rainfall in Pambar Kottakkaraiyar River Basin

Sl.No	Sub Basin	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total (Mcm)
1	Manimuthar	2.99	10.25	13.72	13.40	12.09	24.91	14.48	29.80	2.12	20.64	7.83	26.06	178.28
2	Pambar	11.54	1.83	2.81	2.08	2.55	22.00	16.42	13.00	3.38	35.76	13.75	19.99	145.13
3	Kottakkaraiyar	28.28	7.01	6.95	1.27	3.28	52.22	26.39	33.41	10.00	52.00	19.72	29.06	269.59
TOTAL		**42.80**	**19.09**	**23.48**	**16.75**	**17.92**	**99.13**	**57.30**	**76.21**	**15.51**	**108.40**	**41.30**	**75.11**	**593.00**

Table 4.12

Net Irrigation Water Demand at 50% Dependable Rainfall in Pambar Kottakkaraiyar River Basin

Sl.No	Sub Basin	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total (Mcm)
1	Manimuthar	19.09	10.69	16.09	16.04	9.08	33.45	23.02	21.98	14.12	20.64	7.83	11.53	203.56
2	Pambar	12.05	1.84	2.73	0.62	3.99	29.25	14.13	9.99	13.57	35.76	13.56	26.96	164.45
3	Kottakkaraiyar	22.89	7.11	7.67	5.26	5.42	42.83	28.84	29.62	17.56	52.00	20.59	29.06	268.88
TOTAL		**54.04**	**19.64**	**26.49**	**21.92**	**18.50**	**105.53**	**66.00**	**61.59**	**45.25**	**108.40**	**41.98**	**67.54**	**636.89**

Table 4.13

Net Irrigation Water Demand at 75% Dependable Rainfall in Pambar Kottakkaraiyar RiverBasin

Sl.No	Sub Basin	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total (Mcm)
1	Manimuthar	16.17	10.67	10.19	9.49	17.83	31.96	19.54	19.01	5.32	29.49	7.83	29.87	207.39
2	Pambar	17.28	1.89	2.82	3.01	2.70	29.92	11.60	25.18	9.46	35.76	13.56	19.99	173.18
3	Kottakkaraiyar	21.35	7.07	7.87	7.37	2.61	48.18	26.23	37.08	5.73	52.00	19.72	47.00	282.21
TOTAL		**54.80**	**19.63**	**20.89**	**19.87**	**23.14**	**110.07**	**57.37**	**81.27**	**20.51**	**117.25**	**41.11**	**96.86**	**662.78**

Table 4.14

Net Irrigation Water Demand at 90% Dependable Rainfall in Pambar KottakkaraiyarRiver Basin

Sl.No	Sub Basin	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total (Mcm)
1	Manimuthar	15.96	10.64	15.96	2.83	23.78	33.04	22.37	18.01	21.97	20.64	7.83	30.46	223.48
2	Pambar	12.77	1.87	2.27	2.35	2.90	28.93	11.77	18.20	9.20	35.93	13.56	33.82	173.58
3	Kottakkaraiyar	10.30	6.48	5.56	7.33	6.53	46.96	22.17	28.69	15.86	57.59	38.74	38.55	284.76
TOTAL		**39.03**	**18.98**	**23.80**	**12.51**	**33.22**	**108.93**	**56.31**	**64.90**	**47.03**	**114.15**	**60.13**	**102.83**	**681.83**

Table - 4.15

Net Irrigation Water Demand at 75 % Dependable Rainfall in Pambar Kottakkaraiyar River Basin

Sl. No.	Sub Basin	Present Irrigation Demand (Mcm)	Lower Limit Irrigation Demand (Mcm)	% of Savings in Demand
1	Manimuthar	241.64	207.39	14.17
2	Pambar	232.01	173.18	25.36
3	Kottakkaraiyar	370.22	282.21	23.77
	Total	**843.87**	**662.78**	**21.46**

4.7 Cropping Pattern

From time immemorial due to the good soil health and plentiful water availability, farmers have a set of cropping pattern in command areas of tanks and rivers, which predominantly paddy, banana, sugarcane, coconut and other hydrophilic crops. Due to the changing rainfall pattern over the years, ground water depletion, lack of flows in the rivers, uncontrolled extraction of ground water, scarcity of labour and hike in wages, the existing cropping pattern has ceased to be economically viable. Hence, it is the time to design a new alternate-cropping pattern based on the agro-climatic zone. This must be demonstrated in the farmer’s holdings by a massive research cum extension programmes in order to effectively utilize the natural resources and also to stabilize productivity and profitability. Irrigated area of four major crops for past 6 yearsis shown in **Fig 4.6.**Irrigated area (in Ha) of four major crops grown in the Pambar&Kottakkariyar basin and its crop water requirement is presented in the above table **Table 4.16**

Fig 4.6 Irrigated area of four major crops for past 6 years

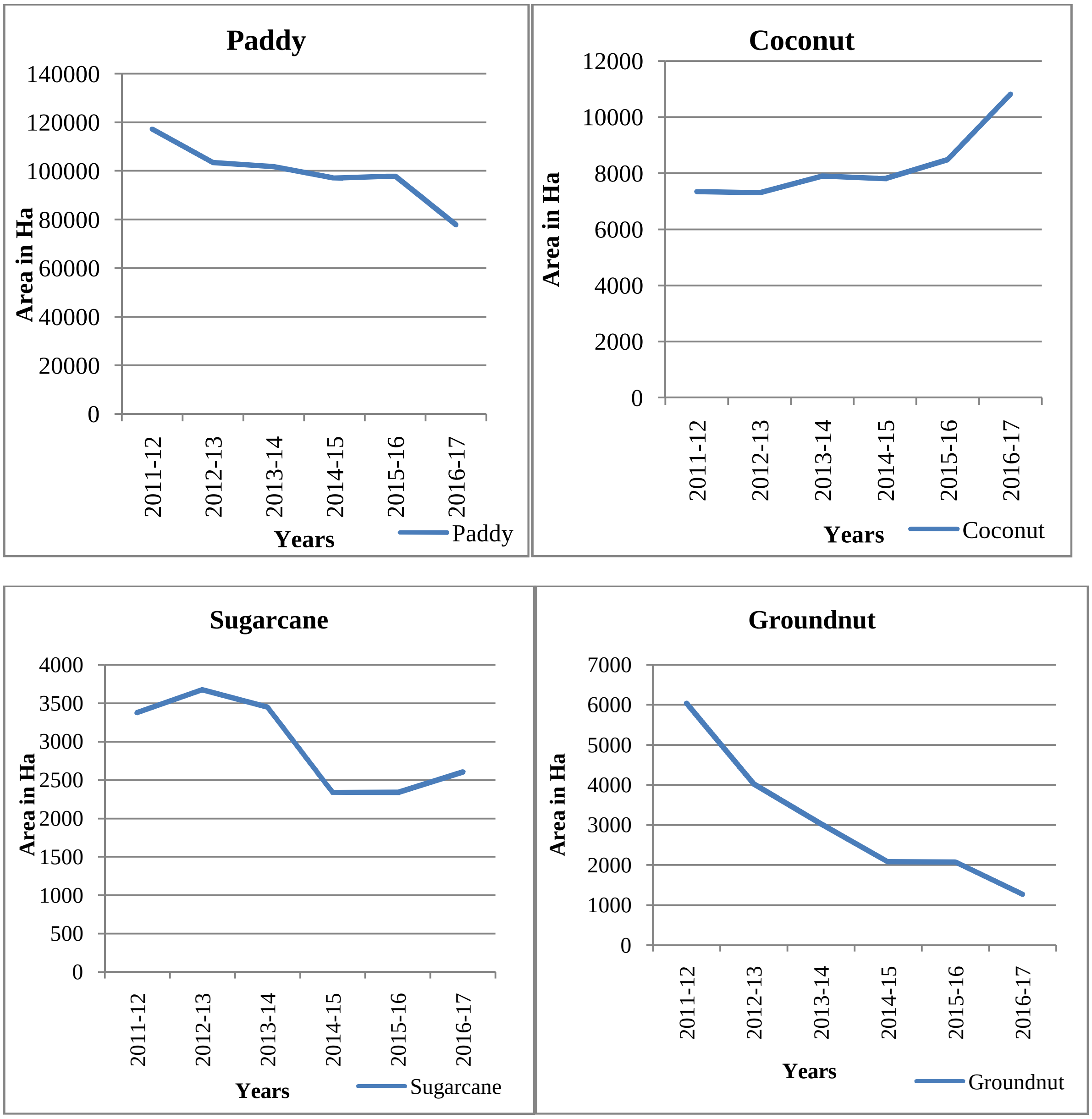


Table 4.16 Irrigated area (in Ha) of four major crops grown in the Pambar &Kottakkariyar basin and its crop water requirement

Paddy				
Year	Crop area in Ha	Crop water reqd. in MCM	Yield rate Kg/Ha	Production in thous. Qtl
2011-12	117224	870.97	3918	4593
2012-13	103468	768.77	2712	2806
2013-14	101720	755.78	4123	4194
2014-15	97093	721.40	4429	4300
2015-16	97865	727.14	3687	3608
2016-17	77868	578.56	2463	1918

Coconut				
Year	Crop area in Ha	Crop water reqd. in MCM	Yield rate Nuts/Ha	Production in thous. Qtl
2011-12	7348	67.31	14799	11
2012-13	7302	66.89	11967	9
2013-14	7892	72.29	9634	8
2014-15	7803	71.48	11655	9
2015-16	8486	77.73	13711	12
2016-17	10813	99.05	10813	12

Sugarcane				
Year	Crop area in Ha	Crop water reqd. in MCM	Yield rate Ton/ Ha	Production in thous. Qtl
2011-12	3375	39.49	113	3814
2012-13	3674	42.99	98	3601
2013-14	3449	40.35	104	3587
2014-15	2336	27.33	107	2500
2015-16	2336	27.33	101	2359
2016-17	2604	30.47	87	2265

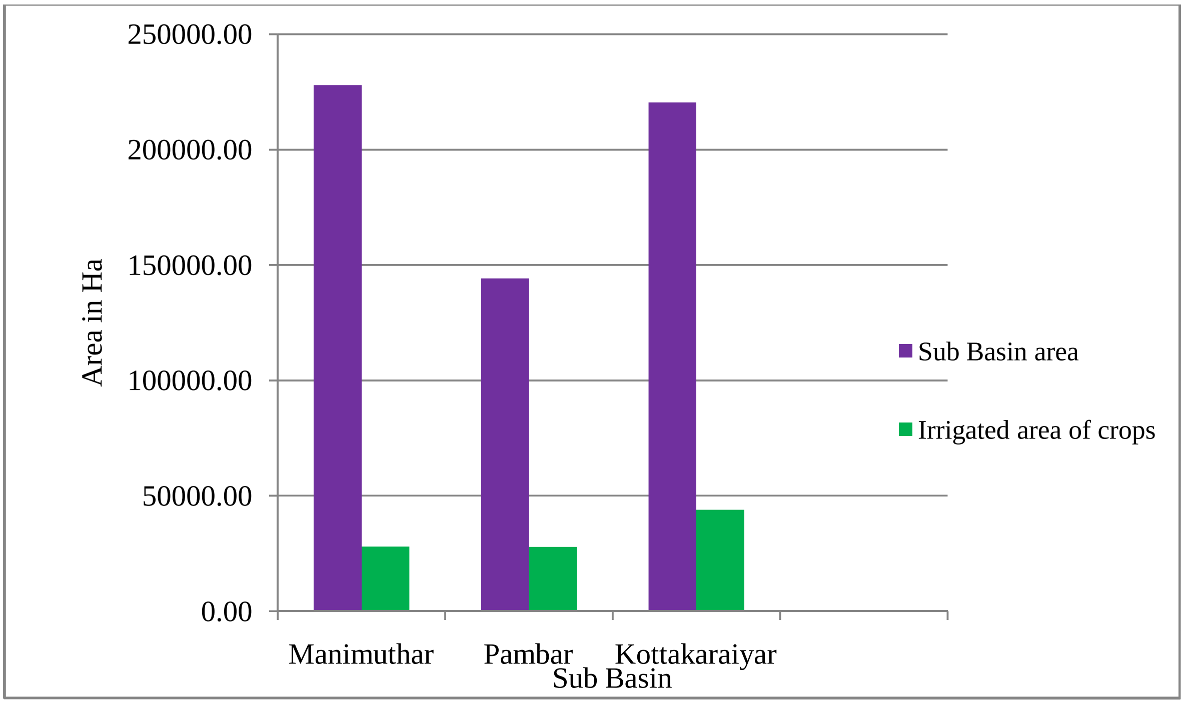
Groundnut				
Year	Crop area in Ha	Crop water reqd. in MCM	Yield rate Kg/Ha	Production in thous. Qtl
2011-12	6042	24.29	2751	166
2012-13	4023	16.17	2314	93
2013-14	3023	12.15	2721	82
2014-15	2076	8.35	2753	57
2015-16	2076	8.35	2574	53
2016-17	1265	5.09	2085	26

It is observed from the table, that crop water requirement varies directly proportion to the crop area. Yield rate is taken from season and crop report of Tamilnadu for the year 2011-12,2012-13,2013-14,2014-15,2015-16,2016-17. Yield rate for the crops may vary with the type of agriculture practices adopted by the farmers.

Existing & Suggested Cropping Pattern in Pambar Kottakkaraiyar River Basin

The major crops cultivated in Pamabar Kottakkaraiyar Basin are Paddy, Coconut, Fruits and Vegetables, Sugarcane, Ground nut and Chillies. The irrigated area for the year 2016-17 in Pamabar KottakkaraiyarBasin under different crops is 99,985Ha. Paddy is cultivated in 77,868Ha, in the balance area, other crops are cultivated. A bar chart showing the irrigated area (Ha) and the total Sub basin area (Ha) for all three sub basins of Pambar Kottakkaraiyar Sub basin is presented in **Fig 4.7.**

Figure 4.7 Sub basin area vs Irrigated area of crops in Pambar Kottakkaraiyar River Basin



The distribution of rain also plays a vital role in crop productivity. Existing cropping pattern during normal rain year (+19% to -19% of normal rainfall) and suggested cropping pattern for Poor rain year (-19% to -59% of normal rainfall) for the Districts covered in this basin are given in the **Table 4.17**.

Table 4.17 Cropping Pattern in the Districts covered in Pambar Kottakkaraiyar River Basin

Sl.No.	District	Block	Existing cropping pattern during normal rainfall year	Suggested cropping pattern during poor rainfall year
1	Dindigul	Sanarpatty	Pulses-Cholam-Groundnut	Cholam-Pulses
			Paddy-Pulses-Groundnut	
		Natham	Paddy-Blackgram	-
			Cowpea-Groundnut	Cowpea-Horsegram
			Groundnut-Horsegram	Cholam-Horsegram
		Vadamadurai	Millets+Pulses	Millets
2	Ramanathapuram	Ramanathapuram	Paddy-Pulses/Gingelly,	SD Paddy/Kudhiravali/Ragi
		Nainarkovil	Paddy,Pulses	Paddy,Millets
		R.S.Mangalam	Paddy-Pulses/Gingelly,	SD Paddy/Kudhiravali/Ragi/Gingelly
		Thiruvadanai	Paddy	SD Paddy / Blackgram / Gingelly
3	Madurai	Melur	Paddy,Pulses,Groundnut Pulses	Groundnut/ pulses
		Kottampatti	Groundnut-Groundnut, Groundnut-Pulses,Paddy-Pulses	Groundnut- Groundnut

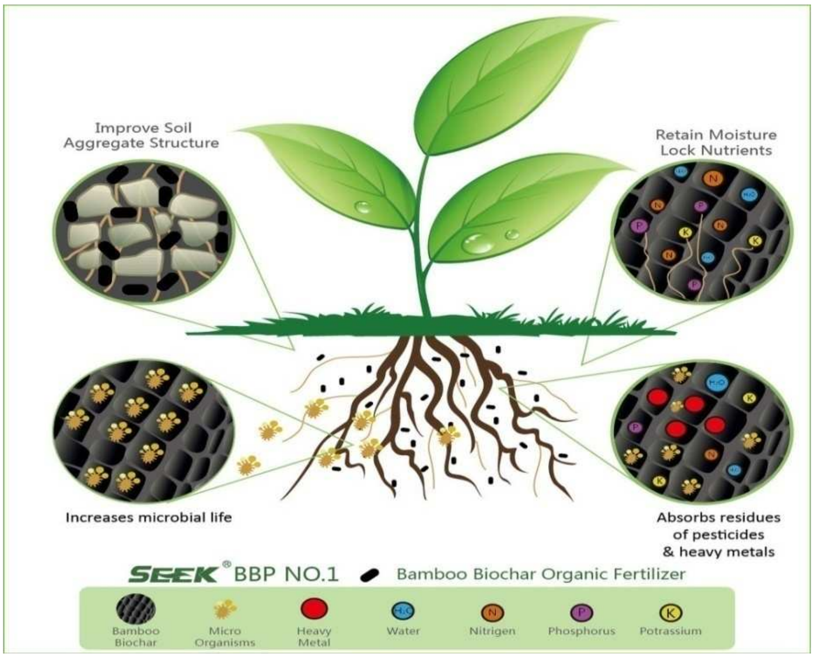
Sl.No.	District	Block	Existing cropping pattern during normal rainfall year	Suggested cropping pattern during poor rainfall year
		T.Vadipatti	Paddy	Maize and pulses
4	Sivaganga	Sivaganga	Paddy /Sugarcane - Pulses/Groundnut	Millets - Pulses/Groundnut
		Kalayarkovil	Paddy - Pulses/Groundnut	Millets - Pulses/Groundnut
		Manamadurai	Paddy/Sugarcane - Pulses/Groundnut	Millets - Pulses/Groundnut
		Thiruppuvanam	Paddy - Pulses/Groundnut	Millets - Pulses/Groundnut
		Ilayankudi	Paddy - Pulses/Groundnut	Millets - Pulses/Groundnut
		Devakottai	Paddy - Pulses/Groundnut	Millets - Pulses/Groundnut
		Kannangudi	Paddy - Pulses/Groundnut	Millets - Pulses/Groundnut
		Sakkottai	Paddy - Pulses/Groundnut	Millets - Pulses/Groundnut
		Kallal	Paddy - Pulses/Groundnut	Millets - Pulses/Groundnut
		Thiruppattur	Pulses/Groundnut-Paddy-Pulses/Groundnut	Pulses/Groundnut-Millets-Pulses/Groundnut
		Singampunari	Pulses/Groundnut-Paddy-Pulses/Groundnut	Pulses/Groundnut-Millets-Pulses/Groundnut
		S.Pudur	Pulses/Groundnut-Paddy-Pulses/Groundnut	Pulses/Groundnut-Millets-Pulses/Groundnut

4.8 Biofertilizers

Biofertilizers are defined as preparations containing living cells or latent cells of efficient strains of micro-organisms that help cropsto uptake nutrients by their interactions in the rhizosphere when applied through seed or soil. They accelerate certain microbial processes in the soil which augment the extent of availability of nutrients in a form easily assimilated by plants.

Biofertilizers are carrier based preparations containing efficient strains of nitrogen fixing or phosphate solubilizing microorganisms. Biofertilizers are formulated usually as carrier based inoculants. The organic carrier materials are more effective for the preparation of bacterial inoculants. The solid inoculants carry more number of bacterial cells and support the survival of cells for longer periods of time. The mass production of carrier based bacterial biofertilizers involves three stages.

- Culturing of microorganisms
- Processing of carrier material
- Mixing the carrier and the broth culture and packing



(Source :www.agritech.tnau.ac.in: Organice Farming: Biofertilizer Technology)

Use of biofertilizers:

- Biofertilizers are known to play a number of vital roles in soil fertility, crop productivity and production in agriculture as they are eco friendly.

- They increase the crop yield by 20% to 30% and replaces chemical nitrogen and phosphorus by 25%.
- They stimulateplant growth.
- Theyactivate the soil biologically and restores natural soil fertility.
- They provide protection against drought and some soil borne diseases.

The quantity of biofertilizers distribution target, quantity distributed and area utilizingit in Hafor the year 2013-15 for the blocks in Pambar Kottakkaraiyar River Basin have been tabulated in **Table 4.18.**

Table 4.18 Bio fertilizer Production and Distribution Details

Block	No of Production Units	Quantity produced in Tonnes	Distribution target in Tonnes	Quantity distributed in Tonnes	Area utilizing in Ha
Sanarpatty		Liquid	0.254	0.254	508
		Carrier	0.007	0.007	700
Natham				6.24	1300
Vadamadurai			1.3	1.3	1610
Ramanathapuram	1		6	6	3000
Nainarkovil	1	0	9	9	3600
Thiruvadanai	0	0	62.84	62.84	24169
Sivaganga			6.2	6.2	1240
Kalayarkovil			9	9	1800
Manamadurai			7.4	7.4	1480
Thiruppuvanam			5.2	5.2	1040
Ilayankudi			8.8	8.8	1760
Devakottai			9	9	1800
Kannangudi			8	8	1600
Sakkottai			6	6	1200
Kallal			5.5	5.5	1100
Thiruppattur			5	5	1000
Singampunari			4.8	4	800
S.Pudur			3.4	3.4	680
Marungapuri		Liquid	0.18	0.180	180
		Carrier	5.5	5.5	110

(Source: Bio fertilizers details collected from Agriculture Department**)**

4.9 Vermicompost

Vermicomposting is a method of using worms to transform organic waste into a nutrient-rich fertilizer. It is a healthy and clean way to eliminate wastes going into our landfills, which improves the environment. Vermicomposting is inexpensive, and only takes two to three months to produce results.

Function

Vermicompost improves the root structure, plant growth, new shoots and blooms ofplants. An increase in crop production/growth is also noticeable. Vermicompost also has ingredients that repel insects, and it can be used as an insect repellent.

Advantages of Vermicompost

- Vermicompost is rich in all essential plant nutrients.
- Provides excellent effect on overall plant growth, encourages the growth of new shoots / leaves and improves the quality and shelf life of the produce.
- Free flowing, easy to apply, handle and store and does not have a bad odour.
- Improves soil structure, texture, aeration, and waterholding capacity and prevents soil erosion.
- Rich in beneficial micro flora such as a fixers, P- solubilizers, cellulose decomposing micro-flora etc in addition to improving the soil environment.
- Contains earthworm cocoons and increases the population and activity of earthworm in the soil.
- Prevents nutrient losses and increases the use efficiency of chemical fertilizers.
- Free from pathogens, toxic elements, weed seeds etc.
- Minimizes the incidence of pest and diseases.
- Enhances the decomposition of organic matter in soil.
- Contains valuable vitamins, enzymes and hormones like auxins, gibberellins etc.

The farmers are encouraged to produce the required organic manure in their own lands by providing subsidy for establishment of 1400 Vermicompost units at a cost Rs.2.17 crore under National Mission for Sustainable Agriculture (NMSA) – Rainfed Area Development.The details such as subsidy given for Vermicompost production units and area covered under Vermicompostusage in the blocks covered inPambarKottakkaraiyarRiver Basin are tabulated in **Table 4.20**.

Table 4.19 - Details of blocks where vermicompost utilized in Pambar Kottakkaraiyar River Basin

Sl.No.	Block	Vermi compost	
		No. of units for which subsidy given	Vermi compost utilized – Area in Ha
1	Sanarpatty	3	3 ha
2	Natham	5	50 ha
3	Vadamadurai	4	12 ha
4	Ramanathapuram	20	150 ha
5	Nainarkovil	20	2 ha
6	R.S.Mangalam	40	890 ha
7	Thiruvadanai	20	150 ha
8	Melur		
9	Kottampatti	5	35 ha
10	Sivaganga	10	100
11	Kalayarkovil	5	50
12	Manamadurai	10	100
13	Thiruppuvanam	10	100
14	Ilayankudi	10	100
15	Devakottai	10	100
16	Kannangudi	10	100
17	Sakkottai	10	100
18	Kallal	10	100
19	Thiruppattur	10	100
20	Singampunari	10	100
21	S.Pudur	10	100
22	Thirumayam	6	310
23	Ponnamaravathy	7	15
	Total	115	1150

(Source: Agriculture Department)

4.10 Major Schemes covered in Pambar Kottakkaraiyar Basin by Agricultural Engineering Department

Mission on Sustainable Dry Land Agriculture

The Director of Agriculture has sent a proposal for development of dryland in cluster mode. In that proposal, it is stated that Dryland Agriculture **refers to cultivation of crops which are entirely dependent on rainfall**. Since, large number of farmers depend on dryland agriculture for their livelihood, sustainability in dryland farming assumes more importance for the upliftment of the farming community. In Tamil Nadu, most of the **Millet crops**, **Pulses crops and Oil seeds** are raised under rainfed condition. In rainfed areas, the input usage and yield obtained are always less compared to irrigated areas.

In order to bring maximum dryland area under cultivation in a phased manner, the Department of Agriculture has suggested a mission mode approach viz. Mission on sustainable dryland agriculture (MSDA) wherein **Cluster based activities** will be adopted. Therefore proposals have been sent tothe Government by the Agricultural Department seeking orders for implementation of a new scheme namely **"Mission on Sustainable Dry Land Agriculture"** for the development of 1,000 dryland Clusters in Tamil Nadu at a total cost of Rs.802.90 crore during the period from 2016-17 to 2019-20.

The Department of Agriculture has proposed to form 1,000 dryland clusters at the State level over a period of 4 years. In the first year, 200 clusters will be formed and in the next two years, 400 Clusters will be formed in each year. Activities will be spread in these 1,000 Clusters over 4 years of period.

The mission mode implementation would be under the following Headings:

- Dryland Cluster of 1000 Ha each
- Formation of Cluster Development Team (CDT)
- A Block level team consisting of ADA as Block Coordinator
- Baseline Survey by each Cluster Development Team (CDT)
- Farmer's Clubs
- Capacity Building
- Entry Point Activities
- Comprehensive Land Development Activities / Establishment of Water Harvesting Structures
- Agronomic Interventions - Promotion of dry land crops through appropriate Cropping system
- Institutional Strengthening – Support for Value Addition for Clusters
- Crop Insurance
- Animal Husbandry

Some of the Agricultural Schemes

Sl. No	Schemes	Eligibility and conditions for availing the benefits
1.	**Assistance to the farmers for quality seed production**	
	Seed Multiplication Scheme of Paddy	
	In order to encourage the farmers and to offset the special efforts taken by them incentive is provided for all the seeds produced by the farmers.	All farmers who produce and supply the seeds to the Department of Agriculture on Contract basis are eligible to enrol and register their seed farms under this programme.
	Paddy Premium for the production of Certified class seeds Rs.2/- per Kg of seed	Preference will be given to form women groups, Farmers Interest Groups.
		The required source seed will be supplied by the Department of Agriculture through the Agricultural Extension Centres on payment.
		The farmers should follow the guidelines given by the field level functionaries / Seed Certification officers to maintain the Quality.
2.	**Assistance to farmers for increasing the crop productivity Macro Management Mode Schemes**	
	Cereals development Programme - Paddy	
	a. Quality seed Distribution through seed village concept: A subsidy of Rs.5 per kg of paddy seeds will be allowed in the sale price at the time of purchase at the Agricultural Extension Centers or 50% cost whichever is less	All farmers are eligible to avail the subsidy under this scheme. Preference will be given to Small/Marginal women farmers and 30% flow will be assured to SC/ST
	b. Demonstrations on System of Rice Intensification: Assistance for improved seed, Conoweeder, Marker, Bio fertilizers and Micro Nutrient Mixture - Subsidy of Rs 3000 per demonstration of 0.4 Ha each.	This Scheme is in operation in all the districts of the State except Chennai, Nilgiris and NFSM rice implementing districts of Sivagangai, Ramanathapuramand Pudukkottai.
	c. Integrated Pest Management Demonstration cum Training @30 farmers per training (Farmers Field School) **-** A lumpsum provision ofRs.17,000 includes Honororium, Training material and conduct of field days	
3.	**Tamil Nadu Agricultural Modernization and Water bodies Restoration Management (IAMWARM)**	
	Demonstrations Paddy SRI (1 ha) 100% subsidy (or) Rs.6,000/-	All farmers through Water Users' Association in the respective phase I (2007-08), Phase II (2008-09), Phase III (2009-10) are benefited under this scheme.

4.	**Seed Village Scheme**	
	a.Distribution of Foundation / Certifiedseeds of Paddy at 50% cost for the production of quality seeds by farmers	All the farmers in the State who are willing to produce quality seeds from their lands for their own use and for distribution to other farmers.
	b.Three Days Training on seed production technology in three important phases of the crops to farmers who receive seeds from the department @ 50% cost for production of quality Seeds. 50 farmers per training totally 8000 training per year.	
	c. Supply of Storage Binto the farmers. Rs.3000/- for 20 qtl bin and Rs.1500/- for 10 qtl. bin (or) 33% cost of bin	
	Rs.2000/- for 20 qtl bin and Rs.1000/- for 10 qtl. bin (or) 25% cost of bin	
5.	**National food security mission rice operated in Nagapattinam,Pudukkottai, Ramnad, Sivaganga and TiruvarurDistricts**	
	Inputs for the Demonstration on improved package of practice @ Rs.2500/- Demo of 0.4 ha or 50% cost whichever is less Inputs for the Demonstration on SRI @ Rs.3000/- Demo of 0.4 ha or 50% cost whichever is less Inputs for the Demonstration on Hybrid rice technology @ Rs.3000/- demo of 0.4 ha or 50% cost whichever is less Production incentive Hybrid rice seeds @ Rs.1000/-qtl Distribution subsidy of Hybrid rice seeds @ Rs.2000/-qtl or 50% cost whichever is less Incentives for Micro Nutrients @ Rs.500/-ha or 50% cost whichever is less Incentives for Conoweeder and otherFarm Implements @ Rs.3000/- implement per farmer or 50% cost whichever is less Plant Protection Chemicals and Bio-Pesticides @ of 50% subsidy or Rs.500/- ha whichever is less. Distribution of Transplanter at Rs.70,000/-(or) 50% cost whichever is less.	All farmers in the National Food Security Mission Rice districts. 33% of the allocation to SF / MF / Women farmers. 16% of the total allocation to SC farmers and 8% to ST farmers. Assistance limited to five hectare per farmer.

(Source: Agriculture Department Website)

4.11 Water Saving Techniques in Crop Production

For some of the major crops grown in PambarKottakkaraiyar river Basin, the following specific strategies can be adopted as suggested by the Water Technology Centre, TNAU, Coimbatore.

(i)Paddy:

The **System of Rice Intensification**, known as SRI is a methodology for increasing the productivity of rice by effectively handling the crop during its growth and effectively utilizing soil, water and nutrients. This methodology is based on **four main principles** that interact with each other:

- Early, quick and healthy plant establishment
- Reduced plant density
- Improved soil conditions through enrichment with organic matter
- Reduced and controlled water application

The advantages are less seed requirement (5 kg / Ha),water saving upto 40%, using conoweeder to plough back the weeds, getting higher tillering which enhances yield and hence high income.The methodology involved are mat nursery method, young seedling transplantation (14 days old seedlings), single seedling in square planting method.

To encourage the farmers to go for SRI cultivation, the Government is providing an incentive of Rs.7500 per hectare under NFSM (Rice) which includes purchase of certain gadgets such as Conoweeder. Farmers are also provided training on this method by the Agriculture Department as well as by KrishiVigyan Kendra., Vridhachalam.

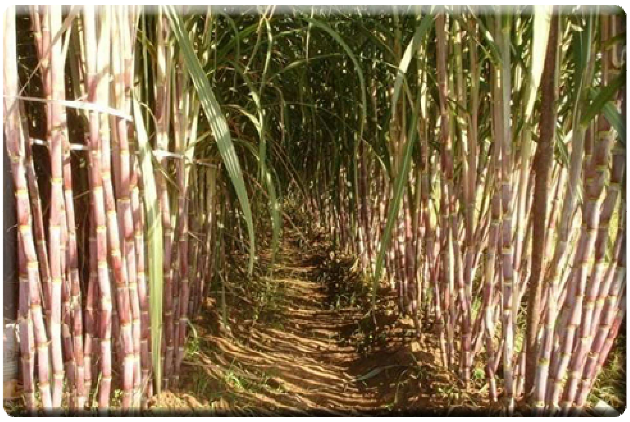
System of Rice Intensification (SRI) Method of Paddy Cultivation

(ii) Sugarcane:

Sustainable Sugarcane Initiative (SSI) is a method thataims at providing practical options to the farmers in improving the productivity of land,and at the same time with less consumption of water and labour. SSI is also expected to reduce the overall pressure on water resources and contribute to recovery of ecosystems. Sustainable Sugarcane Initiative is an innovative method of sugarcane production using less seeds, less water and optimum utilization of fertilizers and land to achieve more yields. The major principles that govern SSI can be stated as below:

- Raising nursery using single budded chips, transplanting young seedlings (25-35 days old)
- Maintaining wide spacing (5 x 2 feet) in the main field
- Providing sufficient moisture through water saving efficient irrigation technologies viz., skip furrow, alternate furrow and sub surface drip irrigation.
- Practicing intercropping with effective utilization of land.

Sustainable Sugarcane Initiative (SSI) method promotes mechanization in cultivation. To promote Drip Irrigation, Government provides 100% subsidy for small & medium farmers and 75% for large farmers.When compared to the conventional furrows, irrigation water saving of 50% and 34.2% is achieved using Skip furrow method and Alternate furrow method respectively.



Sustainable Sugarcane Initiative (SSI)

(iii) Coconut:

Planting ofthe coconut husks at about 30 cm depth around the coconut trees at a radius of one meter and covering it up with earth, will conserve soil moisture.

Use of coir waste as soil mulch around the tree to a thickness of about 3 cm is advantageous to conserve soil moisture especially under scarcity condition. In the first year, irrigation shall be on alternate days and from the second year till the time of maturity, irrigation shall be given twice a week after which once in 10 days. During summer months and also whenever there is no rain, irrigation is a must depending upon soil moisture. Drip Irrigation is the best method of irrigation for coconut. By this, water saving of 63 percent, yield increase by 7 percent and labour saving of 40 percent could be achieved.

(iv) Vegetables:

Drip irrigation at 75 percent of cumulative pan evaporation has registered increased yield up to 59 percent with water saving up to 29 percent.

(v) Groundnut:

The infiltration rate of water is considerably improved by the application of coir waste. By this method, yield of ground nut is also increased. However, more number of irrigation in pre flowering and maturing phase does not show any substantial increase in the yield.

Percentage of saving in water when water saving techniques are adopted on cultivation for the present cultivable area of different crops in PambarKottakkaraiyar River Basin is given below.

Sl. No.	Crop	Cultivated area in Ha	Water requirement-conventional method (MCM)	% of saving by adopting saving technique	Saving (MCM)
1	SRI-Paddy*	77868	646.71	40	258.69
2	SSI-Sugarcane	2604	31.21	40	12.48
3	Coconut	10813	99.83	63	62.89
4	Groundnut	1265	5.70	49.4	2.81
5	Vegetables	4349	44.07	29	12.78
				Total	**349.66**

***This technique is considered for future net irrigation Demand calculation in Lowerlimit scenario.

4.12 Economic benefits derived from water supply for irrigation – One hectare crop budget.

The crop budget for unit hectare involving inputs like fertilizers and other related expenditures, labour costs and net income have been worked out for irrigated wet crops and irrigated dry crops for PambarKottakkaraiyarRiver Basin. The cost of cultivation of crops in Tamilnadu is also appended in **Appendix 4.1 to 4.9 of Volume-II.**

4.13 Summary

4.13.1 Conclusion

- The Gross irrigated area of crops in PambarKottakkaraiyarBasin is reported to be 99,985 Ha.
- Irrigated area in Manimutharsub basin is 28,100 Ha and in Pambar sub basin is 27,893 Ha and Kottakkaraiyar sub basin is 43,992 Ha.
- Out of the total area irrigated, about 77% is under paddy cultivation and 10% is under Coconut cultivation, 4% under Fruits and Vegetables, the remaining inSugarcane, Groundnut, Pulses and millets cultivation.
- Net Irrigation demand of this basin at 75% dependable rainfall is 843.87 MCM.
- Net Irrigation demand of this basin at 50% dependable rainfall is 810.67 MCM.
- Kottakkaraiyarsub basin has the maximum irrigated area of 43,992 Ha which accounts for about 44% of the total irrigated area.
- Pambar sub basin has the minimum irrigated area of 27,893 Ha which accounts for about 27.9% of the total irrigated area.
- Kottakkaraiyar sub basin has the maximum irrigation demand of about 370.22 MCM (about 44%) and Pambar sub basin has the minimum irrigation demand of about 232.01 MCM (about 27.2%).
- 62% of Surface water and 38% of Ground water is being used for irrigation. (Source: Irrigation profile of Ramanathapuram, Pudukottai and Sivagangai Districts).
- Organic farming practice is to be extended in greater manner in this Basin.
- As per 2007, Microlevel Study Report of PambarKottakkaraiyar River Basin, Net Irrigation demand was calculated as 1098.02 MCM at 75% dependable rainfall for an irrigated crop area of 1,26,953 Ha in which Irrigated area of Paddy is 85.6%, Coconut is 3.17% and sugarcane is 2.04% and Groundnut is 1.65%.
- Presently irrigated area is adopted as 99,985 Ha based on good rainfall year 2016-17.On comparing the cultivated area of the present study, it is found that the total irrigated area has decreased from 1,26,953 Ha to 99,985 Ha. Irrigated area of Coconut is increased from 4030 Ha to 10,813 Ha and Paddy is decreased from 1,08,721 Ha to 77,868 Ha. Irrigated area of Chillies, sugarcane remains the same.

4.13.2 Recommendation

- By adopting water saving techniques in agriculture, approximately 33% of irrigation water can be saved. In general,
    1. Crop production can be increased when unirrigated area of this basin is brought under irrigation.
    2. Extraction of ground water can be minimized.
    3. Frequency / Intensity of Irrigation can be improved from prevailing intensity of 1.
- Savings in Irrigation demand of about 258.69 MCM can be achieved if 40% of the area under Paddy cultivation practice is changed to SRI method.
- Using drip irrigation, for the cultivation of sugarcane, 40% of irrigation water (12.48 MCM)could be saved.
- Using coir pith as soil mulch for coconut trees, 63% of irrigation water could be saved (62.89MCM).
- During poor rainfall years, suitable cropping pattern may be adopted with crops that require lesser irrigation like Cotton, Maize, Sorghum, Pulses, etc.

References:

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CHAPTER – 5

SURFACE WATER RESOURCES

AND

IRRIGATION SYSTEM

CHAPTER – 5

SURFACE WATER RESOURCES AND IRRIGATION SYSTEM

5.1 Location

The Pambar and Kottakkaraiyar basin geographically lies in between latitudes $10^{0}28'30''$N and $09^{0}27'15''$ N and longitudes $78^{0}05'30''$ E and 79^{0} $10'30''$ E covering an area of about 5926.10 Sq.Km. This river basin is spread across the following districts of Dindigul, Madurai, Sivagangai, Pudukottai and Ramanathapuram. Pambar and Kottakkaraiyar basin is bounded by Agniyar basin in the north, Cauvery basin in the North west, Vaigai basin in the south and Bay of Bengal in the east.

5.2 Details of Tributaries

The basinis drained by three major rivers namely, Manimuttar, Pambar and Kottakkaraiyar and accordingly divided into three sub basins. The drainage pattern of the rivers and tributaries are already discussed in chapter 2.The details are tabulated in Table 5.1.

Table 5.1 Details of flow of major rivers and tributaries

Manimuttar Sub Basin	
Thirumanimuttar River	
PerumalOdai	It originates at Perumalai in Perumalai reserved forest. It joins with Thirumanimuttar near Chattiram village.
KannimarathuOdai	It originates at JanduMedu in Karandamalai reserved forest and joins with Thirumanimuttar near Nattam village.
Sambaiyar	It originates at Alagar hills and joins the main river at Uralipatti village.
Thirumanimuttar River	It originates near Malaipatti village. It feeds Kadampatti, Karungattukudi and Nellikundupatti tanks. The branch of this river takes off from Uppar near south of Marandippatti village. After connecting series of tanks itjoins Palar,a tributary of Virusuliar near Singampunari village at the downstream of Rajakkal Anicut.
Uppar	Thirumanimuttar river after Odanpatti is named as Uppar.
Manimuttar River	From the village Kalangapatti, the river is called Manimuttar.

Virusuliar River	
Manimuttar River	This is another river with the same name Manimuttar which originates at Mammalai reserved forest and feeds Kattukudipattu tank. The surplus of this take course feeds Neduvayal tank. It finally drains into Vadaganendal tank till which it retains its name as Manimuttar.
Virusuliar	The surplus of Vaduganendal tank is called Virusuliar. The river already referred as tributaries of Tirumanimuttar river. It joins with Manimuttar in the west of KilAvandipatti village , upstream of Poyyalur Anicut and flows further in the name Manimuttar.
Palar	It is a tributary of Virusuliar. It originates in MudiMalai reserved forest of NattamTaluk and infalls into Tiruppatur big tank. The surplus of this tank joins Virusuliar.
Manimuttar River	
Manimuttar River	Sunnambu Iruppar, Virusuliar and Kooraiyar are the tributaries of Manimuttar. The surplus from Eriyur tank also joins Manimuttar. From Hanumanthakudi, the river divides into two arms. The left arm joins with the river Pambar, upstream side of Thirupunnaivasal anicut. The right arm called VarshaleiAr, confluences with Bay of Bengal at Narendal village.
SunnambuIruparu	It is a surplus course of SunnambuIruppu tank and joins with Manimuttar near north KallupattiVillage,i.e.,upstream of confluence with Virusuliar.
Kooraiyar	It is a surplus course from SethuRaghunathaPattinamKanmoi. It joins with the Manimuttar near south of Udayachchi village (near Devakottai town),i.e., at the downstream of Eluvankottai Anicut.
Pambar Sub Basin	
Pambar River	
Pambar	Kottakudiyar, Ten Ar and Manimuttar are the three tributaries of Pambar river. It originates at the surplus of Thamaraikonmai tank.
Kottakudiyar	The surplus course from Sakkaivayal tank forms the origin of Kottakudiyar. It joins as the tributary of Pambar at the upstream of Kalabam Anicut.
Ten Ar	It is the surplus course of SenjaiNattarKanmoi and it joins the river Pambar after a series of anicut the last being Thinaikathanvayal Anicut to west of Tirukkalyanapuram village.

Pambanar	It originates as the surplus course of Tirumayam tank. The river passes through Irumbanadu dividing dam and then passes through Palanthamarai tank, Elanootimangalam tank and becomes Koluvan ar after passing through Elanootimangalam tank.
KoluvanAr	The surplus of Elanootimangalam tank is finally known as Koluvanar.
PapanAr	It is an individual river. It originates near Alattivayal village and is the surplus course of Indanur tank. It confluences with Bay of Bengal near Sirukasavakkotai village.
Kottakkaraiyar Sub Basin	
SaruganiAr / Kottakkaraiyar	Saruganiar originates from the surplus course of Perungudi tank. After crossing the village Chettikottai, the river gets the name Kottakkaraiyar and confluences with Bay of Bengal near Karankadu and Ugandangudi. The surplus from R.S.Mangalam tank confluences with Kottakkaraiyar.
Nattarkal	It originates near Nattarasankottai village and finally finds its way to join with Suriyankottaiyar.
Nattar river	It originates from the surplus course of Kalakulam tank and finally finds its way to Karaikulam tank and then joins with Suriyankottaiyar.
Suriyankottaiyar	It originates from the surplus course of Kottamangalam tank near Multupattanam Village and finally confluences with Raja SingaMagalam big tank.
Lower Vaigai feeder Canal	It originates near Ariyurpattinam village, east of Paramakudi and finally feeds Raja SingaMagalam big tank.
Uppar River	The surplus of the Raja Singa Magalam big tank feeds the Solandur tank. The surplus from Solandur tank is known as Uppar odai and it finally confluences with Bay of Bengal.

The flow diagram for the each of the sub basins are given in figures 5.1 to 5.7.

5.3 Gauging Sites in the Basin

There is no gauge site in this basin.It is further recommended to install gauging sites at Mimisal, Tirupuvanavasal in Pambar Sub basin and at Janavali in Kottakaraiyar sub basin. The location may be confirmed based on the field investigation. The proposed gauging site location mapis shown in Plate PK-**25.**

5.4 Assessment of Surface Water Potential

Surface runoff is the response of a catchment to precipitation reflecting the integrated effects of a wide range of parameters like orientation and shape of the catchment, climate and intensity of precipitation, duration, the direction of storm, slope, soil, land use, etc.

The following influential rainfall stations having long term records are considered for analysis and tabulated in Table 5.2.

Table 5.2 Details of the influencing Raingauge stations

S. No.	Name of subbasins	Sub basin area (sq.km.)	Raingauge stations	No. of Raingauge Stations
1	Manimuttar	2279.60	Pulipatti, Thaniyamangalam, Thondi, Thiruppathur	4
2	Pambar	1441.58	Aranthagi, Karaikudi(Railway), Theerthandathan, Thirumayam	4
3	Kottakkaraiyar	2204.91	Dindigul, Ilaiyangudi, Manamadurai, Paramakudi, Sivagangai, Thiruvadanai	6
	Total	**5926.09**		

Sub basin wise average annual rainfall adopted in the analysis is given vide Appendix 5.2 Surface Water Potential is assessed by the following three methods:

- Rainfall –Runoff Co-efficient Method
- Monthly Runoff Simulation Model (MRS Model)
- National Water Development Agency Approach (NWDA Approach)

5.4.1 Rainfall – Runoff Co-efficient Method

An empirical relationship between rainfall and runoff in terms of yield of the catchment is adopted by assuming a suitable Run-off Co-efficient.

PambarKottakkaraiyar River Basin has a drainage area of 5926.09Sq.Km. Accordingly the sub basin area is divided into hilly, forest and plain area and the yield of each sub basin is arrived.

Yield = C x A x P is used, where,

Y- Yield in Mcum

A - area of catchment in Sq.Km

P - weighted rainfall arrived from Theisson Polygon

C - Run-off Co-efficient

In general, a runoff coefficient of 0.15 for the plains, 0.20 for hilly region and 0.12 for forest area is adopted. The yield from all the sub basins are cumulatively added to arrive at the basin yield. This gives the Surface water potential of the basin.

Adopting 75 % and 50 % dependable rainfall, the potential of the basin is calculated and tabulated in Tables 5.3 & 5.4 respectively. The surface water potential thus calculated for using this method at 75 % and 50 % dependability is 631.29 Mcum& 755.20 Mcum respectively.

Table 5.3 Surface Water Potential by Run off- co efficient method @ 75% dependability

Sl. No.	Name of the Sub Basin	Total Area in Sq.Km	Hilly Area in Sq.Km	Forest Area in Sq.Km	Plain Area in Sq.Km	75% dependable Rainfall in mm	Surface Water Potential in Mcum			Total Potential in Mcum
							in hilly Area	in Forest area	in Plain Area	
1	Manimuttar	2279.60	205.34	61.00	2013.26	678.13	27.85	4.96	204.79	237.60
2	Pambar	1441.58	0.00	9.75	1431.83	766.63	0.00	0.90	164.65	165.55
3	Kottakkaraiyar	2204.91	1.45	80.92	2122.54	694.74	0.20	6.75	221.19	228.14
Total		**5926.10**	**206.79**	**151.67**	**5567.64**	**2139.49**	**28.05**	**12.61**	**590.63**	**631.29**

Table 5.4 Surface Water Potential by Run off- co efficient method @ 50% dependability

Sl. No	Name of the Sub Basin	Total Area in Sq.Km	Hilly Area in Sq.Km	Forest Area in Sq.Km	Plain Area in Sq.Km	50% dependable Rainfall in mm	Surface Water Potential in Mcum			Total Potential in Mcum
							in hilly Area	in Forest area	in Plain Area	
1	Manimuttar	2279.60	205.34	61.00	2013.26	830.66	34.11	6.08	250.85	291.04
2	Pambar	1441.58	0.00	9.75	1431.83	946.81	0.00	1.11	203.35	204.46
3	Kottakkaraiyar	2204.91	1.45	80.92	2122.54	790.83	0.23	7.68	251.79	259.70
Total		**4536.51**	**46.86**	**179.91**	**4309.74**	**2568.30**	**34.34**	**14.87**	**705.99**	**755.20**

5.4.2 Surface Water Potential by MRS Model:

(i) Development of MRS Model

There are different watershed models whose common base is the conservation of mass principle as applied to a watershed, requiring a balance between all the watershed water components, namely, rainfall, evaporation, surface runoff and groundwater replenishment. The models in existence differ in the inter-relationships between these components, and their computational time-steps. Generally speaking, the shorter the time-step, the larger are the number of watershed parameters operated by the model, and the more accurate is the model's output, subject to the availability of data.

Perhaps, the most reliable water shed model is that developed by Stanford University, U.S.A., in the nineteen-sixties, to which the author of the present MRS model being used, had the honour to contribute. The model operates at hourly time-steps, requiring hourly rainfall as input. The Sacramento model adopted by the U.S. National Weather Services operates at daily time-steps. Having applied these types of models in many parts of the world, it became apparent that for water resources projects in regions where the number of rainy days in a rainy month is fairly large, the model may replace the hourly and even the daily time-steps. Conversely, where the density of rain gauges is low the monthly model may even produce better results than the daily or hourly ones. These facts led to the development of the present monthly model, requiring easily accessible monthly rainfall as input. The Monthly Runoff Simulation (MRS) model and the related computer program were developed and prepared by Dr. Moshe Negev of TAHAL Consulting Engineers Ltd., Tel-Aviv, Israel ("TAHAL"). The Monthly Runoff Simulation (MRS) model belongs to the above class of water shed models. The model has since been successfully used and its applicability verified in many parts of the world having diverse climatic and geological conditions.

(ii) The MRS Model - Methodology

The MRS model is a conceptual, distributed, deterministic model in which hydrological water balance computations are carried out. The inputs to the model are monthly rainfall associated with catchment area, mean monthly potential evapotranspiration and several empirical parameters such as runoff coefficient and soil moisture retention capacity. The outputs of the model are the total flow in the river, its surface and base flow components, and the recharge to groundwater (see Schematic Flowchart of the MRS model in Diagram A and Diagram B in VOL–II). The MRS model incorporates several applications such as Reservoir Operation and Probability Analysis. Detailed MRS Model descriptions are given in Appendix 5.1of Volume II.

(iii) Model Calibration

Simulation by the MRS Model normally begins with evaluating the model parameters by way of reconstructing the model, the observed flows at a given location in the river. This process is called "model calibration". Its application requires the input of rainfall data, usually in accordance with the Thiessen polygon method and the input of mean monthly potential evapotranspiration determined by the Penman method or by an evaporation pan adjusted by an appropriate coefficient and observed flows.

The calibration process is the "trial and error", guided by following "best fit" criteria with respect to simulated and observed (sim/obs) flows and by visual comparisons of monthly sim/obs hydrographs.

The following are model parameters requiring evaluation, and their range as encountered in previous calibrations:

V	(evapotranspiration adjustment factor)	0.60 – 1.0
Z	(coefficient of runoff)	0.01 – 0.4
P	(fraction of impervious area)	0.00 – 1.0
M	SMAX (upper limit of SM)	20.00 – 300
C	(base flow recession rate)	0.50 – 0.98
G	GWMAX (upper limit of GW)	0.00 – 1000
B	(fraction of recharge becoming base flow)	0.00 – 1.0

It is a good practice to start calibration by force-closing the water balance, adjust PET by way of V. If V fall out of range, the calibration should be stopped and the input data reconsidered.

In the Pambar Kottakkaraiyar Basin there are no reservoirs found. R.S. Mangalam tank is the biggest tank in this basin but are not having any observed data. Hence with the rainfall data the model parameters were adjusted within its range so that the surface water potential (the output of the model) was approximately in accordance with the output of the other two models discussed in section 5.4.1 & 5.4.3.

Now, the following model parameters are adopted in the model for Pambar sub basin.

V	(evapo transpiration adjustment factor)	0.85
Z	(coefficient of runoff)	0.15
P	(fraction of impervious area)	0.07
M	SMAX (upper limit of SM)	30
C	(base flow recession rate)	0
G	GWMAX (upper limit of GW)	300
B	(fraction of recharge becoming base flow)	0.05

The details of the calculation are also furnished in Appendix 5.2 of Volume II.

Accordingly the 75 % and 50 % dependable surface water potential for the three sub basins for the monsoon and non monsoon periods are individually determined and corresponding annual value is calculated and tabulated in Tables 5.5 and 5.6 respectively.

Table 5.5 75% Dependable Surface Water Potential – MRS Model inMcum

Sl.No.	Name of the Sub Basin	SW	NE	NM	Annual
1.	Manimuttar	60.76	132.50	18.70	211.97
2.	Pambar	38.20	116.00	15.60	169.80
3.	Kottakkaraiyar	32.96	171.*68*	12.95	217.59
Total		131.92	420.18	47.25	599.36
South West Monsoon Potential		**131.92**			
North East Monsoon Potential		**420.18**			
Non Monsoon Potential		**47.25**			
Annual Potential		**599.36**			

Table 5.6 50% Dependable Surface Water Potential – MRS Model inMcum

Sl.No.	Name of the Sub Basin	SW	NE	NM	Annual
1.	Manimuttar	77.83	217.07	13.90	308.80
2.	Pambar	56.47	88.36	63.76	208.59
3.	Kottakkaraiyar	20.92	259.08	7.01	287.00
Total		155.22	564.51	84.67	804.39
South West Monsoon Potential		**155.22**			
North East Monsoon Potential		**564.51**			
Non Monsoon Potential		**84.67**			
Annual Potential		**804.39**			

The Annual Surface Water Potential of PambarKottakkaraiyar Basin at 75% dependability is 599.36 Mcum.

5.4.3 Surface Water Potential by NWDA Approach

Methodology adopted for working out Surface water potential:

(i) Monsoon rainfall data is available for the period from 1971-72 to 2016-17. Weighted rainfall for each of the sub basin is computed by Thiessen polygon method using Arc GIS software.

(ii) The quantity of water utilized for irrigation in the each of the sub basin during monsoon period has been estimated adopting the data on yearly irrigated area and furnishedin section 4.5is adopted in the model.

(iii) There is no observed flow data available for the period from 1971-1972 to 2016-17. Hence this value is taken as 0.By adding this value with the utilization for irrigation each year, Gross monsoon yield in Mcum is obtained. This yield, divided by the Sub Basin area gives the Runoff in mm per unit area.

(iv) Using the Runoff during monsoon and the corresponding figures of weighted average monsoon rainfall for each year for the period from 1971-72 to 2016-17, rainfall-runoff relationships are worked out based on regression analysis for each sub basin. The equation obtained for Pambar sub basin is y = 0.147x+35.803mm.Similar equations for Manimuttar and Kottakkaraiyar sub basin are obtained as 0.104 x + 29.021 and 0.188 x + 35.739 respectively.

(v) With the above equation, the runoff is recalculated for each year using the same monsoon rainfall. The gross monsoon yield of the sub basin for the period from 1971-72 to 2016-17 has been generated. From the yearly yield data, the 75% and 50 % dependable gross monsoon yield value for each sub basin is obtained and tabulated in Table 5.7 and 5.8 respectively.

(vi) **The details of calculation are given inAppendix 5.3.1 to 5.3.24of Vol II**. **75% dependable Monsoon yield (June to December)**

For the whole PambarKottakkaraiyar river basin using NWDA approach, the yield works out to 682.09 Mcum

Table 5.7 75% Surface Water Potential

S. No.	Name of Sub basins	Surface Water Potential in Mcum
1	Manimuttar	193.86
2	Pambar	185.80
3	Kottakkaraiyar	302.43
	Total	**682.09**

Table 5.8 50% Surface Water Potential

S. No.	Name of Sub basins	Surface Water Potential in Mcum
1	Manimuttar	364.66
2	Pambar	220.42
3	Kottakkaraiyar	324.37
	Total	**909.45**

The comparison of surface water potential of all the three methods at 75% and 50 % dependability are tabulated in Table 5.9 and 5.10 respectively.

Table 5.9 75 % dependable Surface Water Potential by three methods

S. No.	Name of Sub basin	Rainfall Runoff Co efficient method	MRS Model	NWDA Approach
1	Manimuttar	237.60	211.97	193.86
2	Pambar	165.55	169.80	185.80
3	Kottakkaraiyar	228.14	217.59	302.43
Total		**631.29**	**599.36**	**682.09**

Table 5.10 50 % dependable Surface Water Potential by three methods

S. No.	Name of Sub basin	Rainfall Runoff Co efficient method	MRS Model	NWDA Approach
1	Manimuttar	291.04	308.80	364.66
2	Pambar	204.46	208.59	220.42
3	Kottakkaraiyar	259.70	287.00	324.37
Total		**755.20**	**804.39**	**909.45**

5.5 The Existing Surface Water Supply Systems

The basin is generally dominated by tanks. There are few independent rivers. There is no reservoir in this basin. The surface water is drawn from tanks. Most of the channels are surplus courses of tanks (or) supply channels. This basin has about 1922 tanks. The non-system tanks use surface water of the direct run off from their own catchment. Whereas the system tanks are filled from the canal flow diverted by the anicuts across the rivers apart from the direct run off of their own catchment.

5.5.1Anicuts

There are totally 83anicuts in the basin and is listed below Sub basin wise. The details of these are furnished in the **Annexure 5.5 of Volume II**.

Manimuttar Sub basin	
1	Unnamandal Anicut
2	Rajakkal Anicut (Palaru)
3	Pudukanmoi Anicut(Palaru)
4	Matti Anicut(Palaru)
5	Kalappur Anicut(Palaru)
6	Boothani Anicut (Palaru)
7	Muraiyur Anicut (Palaru)
8	Muzhuveeran Anicut(Uppar I)
9	VanniMukundhan Anicut(Uppar I)
10	Bhiramanappatti Anicut(Uppar II)
11	Kotti Anicut
12	Pappanpatty Anicut
13	Keelakanmoi Anicut
14	Mahibalanpatty Anicut
15	Chinnakavini Anicut
16	Kandavarayan-patty Anicut
17	Parani Anicut
18	Manayakanmoi Anicut
19	Kilamadam Anicut
20	Naduvikottai Anicut
21	Athani Bed Dam
22	Sunnambirubbu Anicut
23	Pannaithiruthi Anicut
24	Vadamavali Anicut
25	Anjukal Anicut
26	Poyyalur Anicut

27	Kallankudi Anicut
28	Eluvankottai Anicut
29	Kaikudi Anicut
30	Hanumanthakudi Anicut
31	Sirukambiyur Anicut
32	Kattuperiyakulam Anicut
33	Peekulam Anicut
34	Chinnapallankulam Anicut
35	Kallanai Anicut
36	Rejaneri Anicut
37	Karuthakone Anicut
38	Palllathukkal Anicut
39	Anakulam Anicut
40	Kootathukkal Anicut
41	Anjalakarankulam Anicut
42	Rettaikulam Anicut
43	Pallapatti Anicut
43	Kottankulam Anicut
PambarSub basin	
1	Uravayal Anicut
2	Nemmeni Anicut
3	Unjanai Anicut
4	Kandadevi Anicut
5	Kappalur Anicut
6	Thinaikathanvayal Anicut
7	Elanjavur Anicut
8	Valayankanmoi Anicut
9	Chettipatti Anicut
10	Kailasapuram Anicut

11	Nedungudi Anicut
12	Valaramanickam Anicut
13	Edayar Anicut
14	Puduvakottai Anicut
15	Kalabam Anicut
16	Thiruppunavasal Anicut
Kottaikkaraiyar Sub basin	
1	Seenakanmoi Anicut
2	Malaikandan Anicut
3	Kodungulam Anicut
4	Vetrialangulam Anicut
5	Veelaneri Anicut
6	Chettikadambankudi Anicut
7	Kannankundu Anicut
8	Maravamangalam Anicut
9	Kottakkaraiyar Anicut
10	Vallakulam Anicut
11	MarudhanKudi Anicut
12	Kadambankudi Anicut
13	PeriyaKannanur
14	Thirani Anicut
15	Uruvatti Anicut
16	Ponnalikottai Anicut
17	Sirunallur Anicut
18	Suriyankottai Anicut
19	Govindamangalam Anicut
20	Vellarandal Anicut

21	Sarugani Anicut
22	Thiruppalaikudi Anicut
23	Nayar Anicut
24	Madhavanur Anicut

5.5.2 Tanks

The Raja SingaMangalam tank of this basin is one of the biggest tanks in Tamil Nadu. Its bund is 20.8 Km long and has two large masonry weirs on either flanks to surplus the flood flows. The surplus of the left flank weir confluences with Kottakkaraiyar and that of the right flank weir infalls into Solandur tank and the surplus of Solandur tankconfluences withUpparOdai.

Out of the 1922 tanks in the basin above, 775 are system tanks with a registered ayacut of 18067.54 ha and 1147 are non-system tanks with a registered ayacut of 57112.79 ha. The total ayacut benefited by the tanks in the basin comes out to 75180.33 ha. The total capacity of all tanks is 563.41Mcum.The Tanks with capacity >0.92 Mcum is shown in **Plate PK-26.**

Table 5.11 Details of Tanks

Sl.No.	Name of the Sub Basin	System Tanks			Non System tanks		
		Number	Capacity in Mcum	Ayacut in Ha	Number	Capacity in Mcum	Ayacut in Ha
1	Manimuttar	486	28.01	8223.4	478	151.84	18620.51
2	Pambar	-	-	-	452	183.47	24551.99
3	Kottakkaraiyar	289	93.02	9844.14	217	107.08	13940.29
Total		**775**	**121.03**	**18067.54**	**1147**	**442.39**	**57112.79**

Sl.No.	Name of the Sub Basin	Total Number of Tanks	Total Capacity in Mcum	Total Ayacut in Ha
1	Manimuttar	964	179.85	26843.91
2	Pambar	452	183.47	24551.99
3	Kottakkaraiyar	506	200.09	23784.43
Total		**1922**	**563.41**	**75180.33**

5.6 Surface Water Quality

Water is a critical input in agriculture in all its aspects having a determining effect on the eventual yield. Good seeds and fertilizers fail to achieve their full potential, if plants are not optimally watered with required quality.Deteriorating of quality of existing water resources because of pollution has many negative impacts on the environment. Overuse can cause not only water shortage, but harms the environment in several ways including increased salinity and nutrient pollution etc.

In Pambar Kottakkariayar river basin, surface water quality monitoring network is sparse. The SG&SWRDC of WRD is monitoring the surface water quality in Rajasingamangalam and Thiruvadanai only and the CWC surface water quality monitoring location is not falling in the basin. Hence the surface water samples were collected from various tanks by traversing across the basin. (Sampling locations shown in Plate PK-**27**).

They are,

1. Vadamavalli tank
2. R.S.Mangalam tank
3. Periyakulam tank
4. Alathur kanmoi
5. Eriyur big tank
6. Aralikottai kanmoi
7. Solaganpettai tank
8. Nambuthalai tank
9. Kannakudi tank

The water samples were analyzed in the Geochemical Laboratory of SG&SWRDC, located at Madurai

5.6.1 Surface water quality for drinking / Domestic purposes.

The surface water samples collected from nine sampling locations were analysed which shows, the TDS value ranges from 104 mg / l to 289 mg / l. Since the TDS value is well within the limit, all the water quality parameters are also consequently within the permissible limit. Hence the water can be used for drinking and other domestic purposes. However, increased no of sampling locations only throw the local water quality issues.

5.6.2 Surface water quality for Agriculture / Irrigation

The water quality used for irrigation is essential for the yield and quantity of crops, maintenance of soil productivity and protection of the environment. Water used for irrigation always contains measurable quantities of dissolved substances, which are generally called as the salts. The salts should contain small amounts of dissolved solids originating from dissolution or weathering of the rocks. EC and Na play a vital role in the suitability of water for irrigation. The various salts present in the irrigation water not only affect the plant growth directly but also affect the soil structure, permeability and aeration which indirectly affect the plant growth. The total concentrations of soluble salts in irrigation water can be classified into excellent, good, permissible and unsuitable high salinity zones and the values are shown in **Table 5.4.2**. Higher EC in water creates saline soil. The important parameters for judging the degree of suitability of water for irrigation are Electrical Conductivity (EC), Sodium Adsorption Ratio (SAR) and Residual Sodium Carbonate (RSC).

5.6.2.1 Electrical Conductivity (EC)

Electrical Conductivity (EC) is a measure of the degree of the mineralization of the water which is dependent on the residence time of water in the rock formation and the rock - water interaction. As groundwater moves and stays for a longer time along its flow path, the increase in total dissolved concentration and major ions normally occurs. Groundwater in the recharge area is characterized by a relatively low EC than the groundwater in the discharge area which is higher.

Table: 5.12.1 Suitability of EC values for irrigation

Sl.No	EC in µmhos / cm	Salinity Class
1	< 250	Excellent
2	250 – 750	Good
3	750 – 2250	Permissible
4	2250 – 5000	Unsuitable

As far as Pambar Kottakkaraiyar basin is concerned, the EC value is within the permissible limit and the water is used for irrigation throughout the year.the Electrical

Conductivity value ranges from 160 μmhos / cm (Eriyur big tank) to 470 μmhos / cm (Alathur tank) in the basin.

5.6.2.2 Sodium Adsorption Ration (SAR)

Sodium adsorption ratio is used to estimate the sodicity hazard of the water. The Sodium adsorption ratio is used to predict the danger of sodium accumulation in soil. Excess sodium in water produces the undesirable effects of changing soil properties and reducing soil permeability and soil structure. Hence the assessment of sodium concentration is necessary while considering the suitability for irrigation.

While high salt content (EC) in water leads to the development of saline soil, high sodium content (SAR) leads to the development of an alkaline soil. SAR can indicate the degree to which irrigation water tends to enter cation exchange reaction in soil. Sodium replacing adsorbed calcium and magnesium is a hazard as it causes damage to the soil structure and becomes compact and develops permeability problems. This will support little or no plant growth. SAR is an important parameter for the determination of the suitability of irrigation water because it is responsible for the sodium hazard. The suitability of water based on the values of SAR is listed in **Table 5.12.2**

Table: 5.12.2 Suitability of SAR values for irrigation

Sl.No.	SAR	Suitability for irrigation
1	< 10	Excellent
2	10 – 18	Good
3	18 – 26	Permissible
4	>26	Unsuitable

The SAR value is within the range in all the tanks where water samples are collected. The SAR values in the basin ranges from 0.38 to 2.14 meq / l. Hence the water can be used for irrigation for all types of crops as far as the SAR is concerned..

5.6.2.3 Residual Sodium Carbonate (RSC)

Residual Sodium Carbonate index of irrigation water is used to indicate the alkalinity hazard for soil. The RSC index is used to find the suitability of the water for irrigation in clay soils which have a high cation exchange capacity. When dissolved sodium in comparison with dissolved calcium and magnesium is high in water, clay soil wells or undergoes dispersion which drastically reduces its infiltration capacity.

The value of RSC suitable for irrigation is listed in **Table 5.12.3**

Table 5.12.3 Suitability of RSC values for irrigation

Sl.No	RSC (meq / l)	Suitability for irrigation
1	<1.25	Safe
2	1.25 – 2.5	Moderate
3	>2.5	Unsuitable.

The RSC value of the samples collected are very less and ranges from 0 to 0.7 meq / l. Hence the water is safe for irrigation, as far as RSC values are concerned.

Even though the samples collected for surface water quality analysis do not show any sign of surface water quality issues, alkaline soil area are observed in the basin, which is due to the high sodium content in the soil which in turn affect the water quality. Saline quality exists in the eastern coastal part of the basin. Due to the inadequate surface water quality monitoring stations which represent the basin fully, the above issues did not observed from the samples considered for the study. Hence, strengthening of the surface water monitoring stations representing the whole of basin is absolute necessary.

5.7 Interlinking of Rivers

National Water Development Agency in the interlinking of rivers programme has proposed interlinking of Godavari-Krishna-Pennar-Cauvery-Vaigai-Gundar rivers. The Cauvery Gundar link passes through Pambar Kottakkaraiyar basin. By this proposal, the basin will get benefitted. For this, the reach fromCauvery (Kattalai) to South Vellar through Agniyar basin is consideredin Phase-I. The reach from South Vellar to Gundar through Manimuttar sub basin of Pambar Kottakkaraiyar and Vaigai basins will be considered in Phase- II.

5.8 Transfer of Water

In this basin, there is an inter basin transfer of water from Vaigai basin by two main canals:

(i) Periyar main canal and its extensions

(ii) Vaigai main canal

Periyar Main Canal (PMC) takes off from Peranai regulator in Vaigai river. At LS 58010 of Periyar Main Canal the XII branch canal (XII BC) off takes from the Periyar Main Canal and runs along the basin boundaries. Distributaries from this branch canal enters the Pambar Kottakkariayar basin at various location and feeds some tanks. Beyond LS 58010, the Periyar Main Canal is extended as Periyar Extension Main Canal and feeds the Manimuttar sub basin by various branch canals.

The total quantum of water contribution from the branch canals and the extension of Periyar Main Canal into this basin is 168.27 Mcum. The details of the various branch canals and distributaries contributing to the flow in basin are discussed below :

Canal Name	Entry and infall points of canal in the basin
Periyar Extension Main Canal	
PEMC	It enters the basin at Muttukaruppanpatti village and infalls into Karuppanendal tank at Erumaipatti village. There are a number of branch canals from PEMC within the Manimuttar sub basin feeding number of tanks.
MLV	From the PEMC the MLV offlats and finally infalls into Oyyaveerankulam tank at Katchirayanpatti village.
XII Branch Canal	
XII BC	The main branch canal enters the Kottakkaraiyar sub basin at Uranganpatti village and finally infalls Kurichi Kanmoi near Kurichipatti village. Another off take canal from 48 sluice runs completely in the basin and infalls into Karuthan tank at Namanoor village.
MEMC	This is an off taking canal from XII BC which is at the upstream of all distribution channels. It enters the Manimuttar sub basin in the north east of Melvalavu village and after feeding a number of tanks it finally infalls into Kongumankulam tank at Katchirayanpatti village.
1 DC	It enters the basin at Tumbappatti village and finally infalls into Arikanmoi tank at Boothamangalam village.
8DC	It enters the basin at Kilvalavu village and finally infalls into Siruvanai tank at E.Malampatti village.
10DC	It infalls into an Union tank at Kulichcheralpatti village.
11DC	It enters the basin at North of Ariyurpattinam and infalls into the Chinnapanaiyan tank at Keelavalavu village.
SK	Infalls into the tank Pookuli at Saloor village.
11DC	
KAT	It takes off from 11 DC and one arm of it infalls into the Silandangudi tank at north of Ariyurpattinam village. Another arm infalls into Cheppallam tank at Kattanipatti village.
9 DC	
LEMC	It takes off from 9 DC and enters the basin at north of Usilampatti village, and infalls into Pudukulam tank at Kanjirankal village.

The various branches of Periyar Main Canal and its extensions contributing to this basin are shown in figure 5.8.

Two canals branch out from Vaigai Main canal and feeds into the tank of this basin

(i) Lower Main Canal
(ii) Lower Nattarkal Canal

The Lower main canal from Vaigai riverenters in the Kottakkaraiyar sub basin near Siruvalai village, feeds group of tanks around Ilayankudi village.

The Lower Nattarkal canal offtakes from Vaigai river at about 2 Km east of Paramakudi and enters the basin in the south west of Saliyavaganapuram village to feed Raja Singa Mangalam tank. Before the canal reaches R.S.Mangalam tank, it feeds 8 other tanks.

A quantum of 5.13 Mcum per annum is received from Vaigai Main Canal through the above two canals in Pambar Kottakkaraiyar basin.

Canal	Details of infall
Lower Nattarkal Canal	Thalaiyadikottai tank near south west part of Pudur village.
	Andakudi tank near Andakudi village.
	Keelakavanu tank near Keelakavanu village.
	Radapuli tank near Radapuli village.
	Varavani tank near Varavani village.
	Kadarnthakudi tank near Kadarnthakudi village.
	Arambakottai tank near Arambakottai village.
	Panithavayal tank near Panithavayal village.
	Rajasingamangalam tank near Rajasingamangalam village.
Lower Main canal	Ilayankudi tank near Ilamamu village.

The various branches of Vaigai Main Canal contributing to this basin are shown in figure 5.8.

5.9 Out Flow to Sea

The last anicut across Pambar is Thiruppunavasal Anicut. The flow details of the anicut are available only from the year 1992. The details of flow available from 1992 are as follows:

Surplus flow details of Thiruppunavasal Anicut

Date	Discharge in Cumec	Quantity in Mcum
22-11-92	48.31 (av)	4.17
14-11-94	17.08 (av)	1.48
8-11-97	48.31 (av)	4.17
11-11-98 & 12-11-98	48.31 (av) for 2 days	8.34
2-02-02 & 3-02-02	17.08 (av) for 2 days	2.96

In the Kottakkaraiyar sub basin, the last major tank is Raja Singa Mangalam tank. This has two surpluses, one joining Uppar Odai after feeding a small tank named Solandur and finally confluences with the sea. The second surplus joins Kottakkaraiyar, which finally confluences with the sea.

Surplus flow details of Kottakkaraiyar from R.S. Mangalam tank

Date	Discharge in Cumec	Quantity in Mcum
12-11-92 & 13-11-92	28.32 (av) for 2 days	4.90
15-12-97 & 16-12-97	3.68 (av) for 2 days	0.64
9-12-98 & 10-12-98	2.27 (av) for 2 days	0.40
25-11-05 to 12-01-06	133.33 (av) for 49 days	564.46
Dec-2010	-	42.08

From the above records, it is known that this sub basin has been highly affected by flood in the year 2005.After 2010, there is no outflow to sea.

5.10 Issues in the Management of Surface Water Resources

Problems in Tank Irrigation

Tank irrigation, which is one of the most ancient systems in India, has a glorious history of extremely well organised governance and execution of all critical functions of water management such as maintenance, water sharing and arbitrating the conflicts that arise among users from time to time. This basin is predominantly irrigated by tanks throughout the year.

At present the efficiency of tank irrigation system is quiet low. There has been some reduction in storage capacity of tanks due to siltation and encroachment. Available water is further reduced due to losses in the distribution system.

Inadequate supplies to the command area produces soil moisture stress condition and reduces the yield, which in turn forces the farmers to go in for supplemental irrigation by using ground water through bore wells. Recharge of these wells depend upon the hydraulic head of anicut and tanks in the vicinity and aquifer tapped by these wells. Conjunctive use of tank and well water help in increasing the crop production and also improve performance of the system.

Most of the canals in this basin are unlined. This causes losses in conveyance of water. The losses may be evaluated by the field Engineers in future and it is hence recommended to line atleast the channels where the losses are appreciable and the canals leading to the ayacut.

Approach to the structural components of the tanks is difficult due to extensive weeding. The approach is difficult for frequent visits to inspect and maintain the structural components. This may cause deterioration and damage to them in due course of time.

5.11 Suggestions for meeting future needs

For agriculture, the Surface Water Potential of this basin is being utilized in addition to the supplemental irrigation by ground water. Since the maximum quantity of surface water is consumed for irrigation, the following short term measures are suggested for effective consumption of water in irrigation sector:

1. Improving the performance of the existing irrigation system by suitable structural measures.
2. Lining of canals to improve the efficiency by reducing conveyance loss of water.
3. Renovating old tanks and ponds, desilting of tanks and supply channels and constructing recharge structures to improve irrigation potential.
4. Equitable distribution of irrigation water by better water management.
5. Conjunctive use of surface and ground water wherever possible.
6. Introducing modern irrigation techniques like, drip and sprinkler irrigation.
7. There is no Gauging site installed in this basin. Hence automatic flow measuring devices may be installed in anicuts, so as to quantify the flow.

5.12 Conclusion

The Water Potential of a basin comprises of both Surface Water Potential and Ground Water Potential.

Sub Basin wise Surface Water Potential for the basin is assessed by the following three methods:

1. **Rainfall – Run-off Co-efficient Method**
2. **MRS Model**
3. **NWDA Approach.**

The annual Surface Water Potential of Pambar Kottakkaraiyar river basin calculated using Rainfall – Run-off Co-efficient Method is **631.29Mcum** at 75% dependability and that by using MRS Model is **599.36 Mcum**. Also the 75% dependable Monsoon yield (June to December) for the whole Pambar Kottakkaraiyar river basin using NWDA approach works out to**682.09Mcum**.

The total quantum of water contribution from the branch canals and the extension of Periyar Main Canal into this basin is 168.27 Mcum. A quantum of 5.13 Mcum per annum is also received from Vaigai Main Canal in Pambar Kottakkaraiyar basin.

The Surface Water Potential has decreased from 648 Mcum during 2004-05 to 599.36 Mcum during 2016-17. This is due to more rainfall has been recorded in 2004-05 than 2016-17.

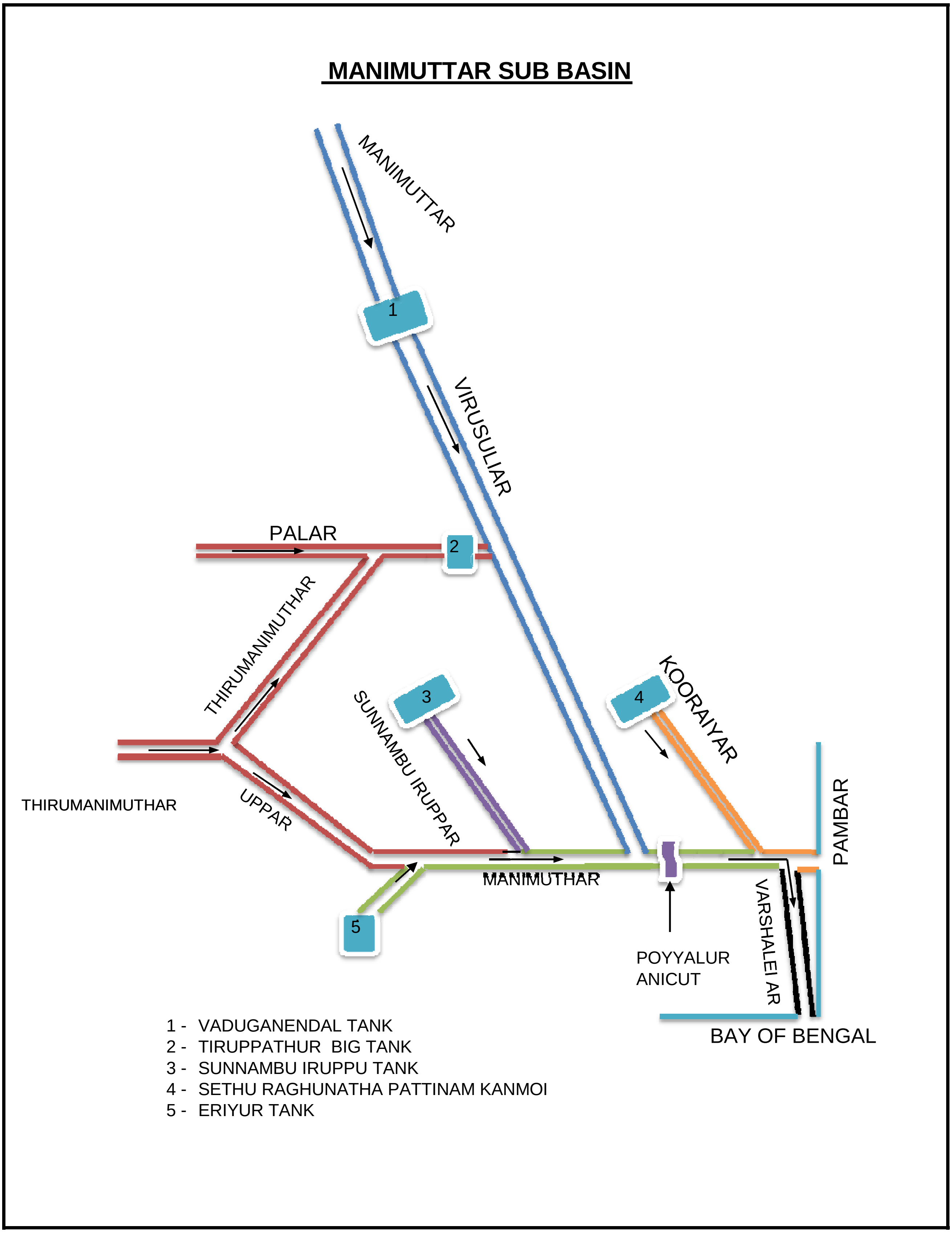


Figure 5.1 Flow diagram of Manimuttar Sub basin

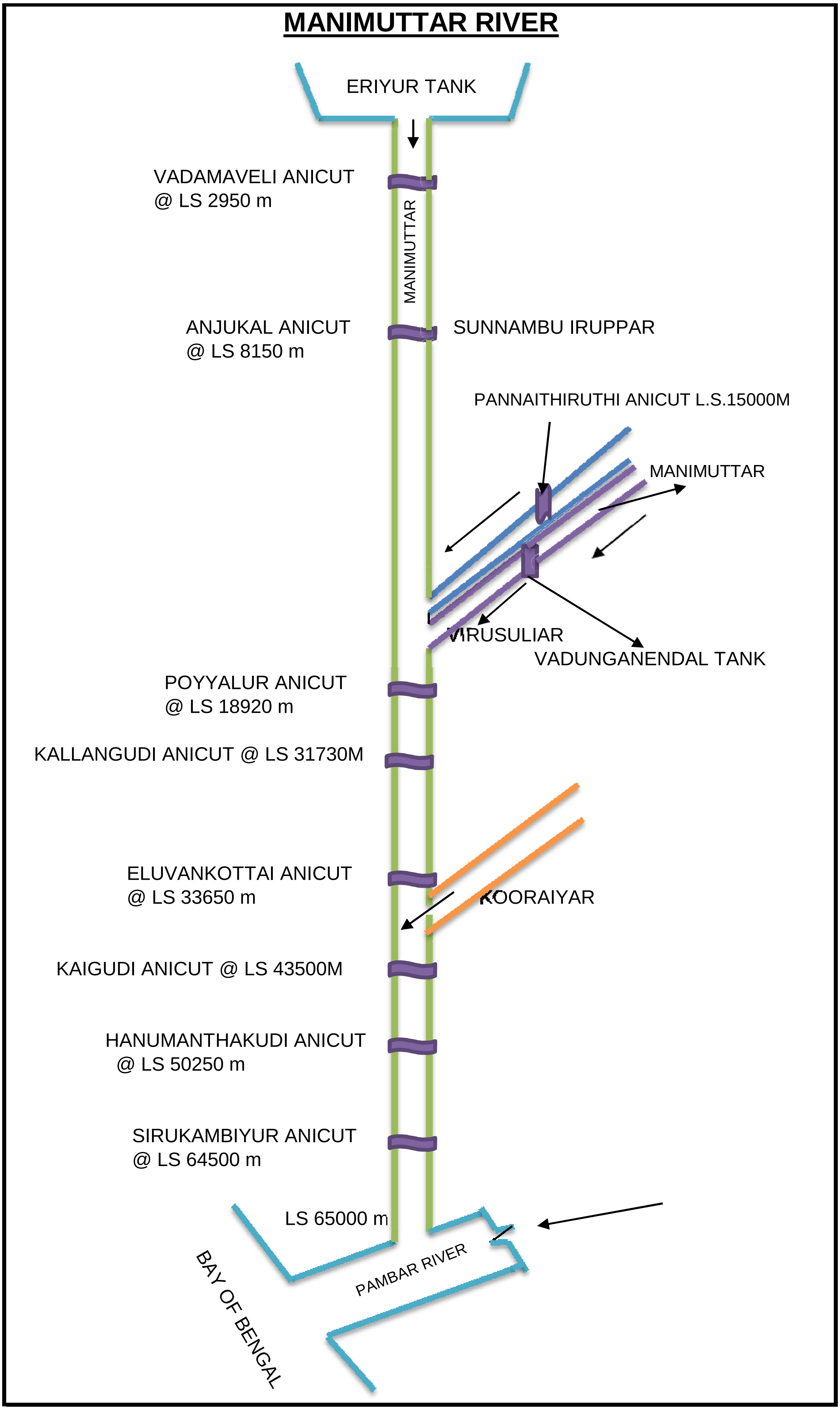


Figure 5.2 Flow diagram of Manimuttar river

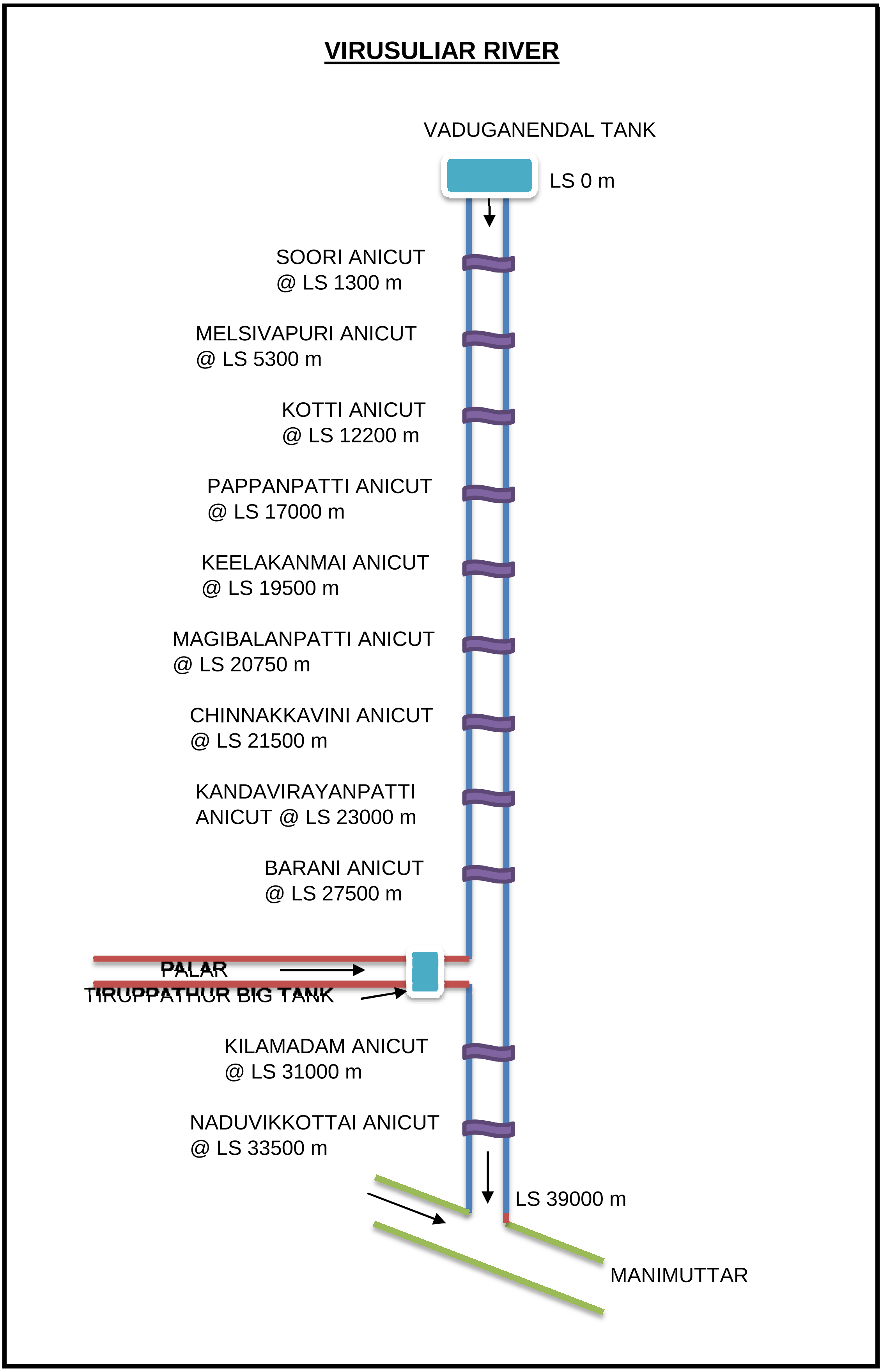


Figure 5.3 Flow diagram of Virusuliar river

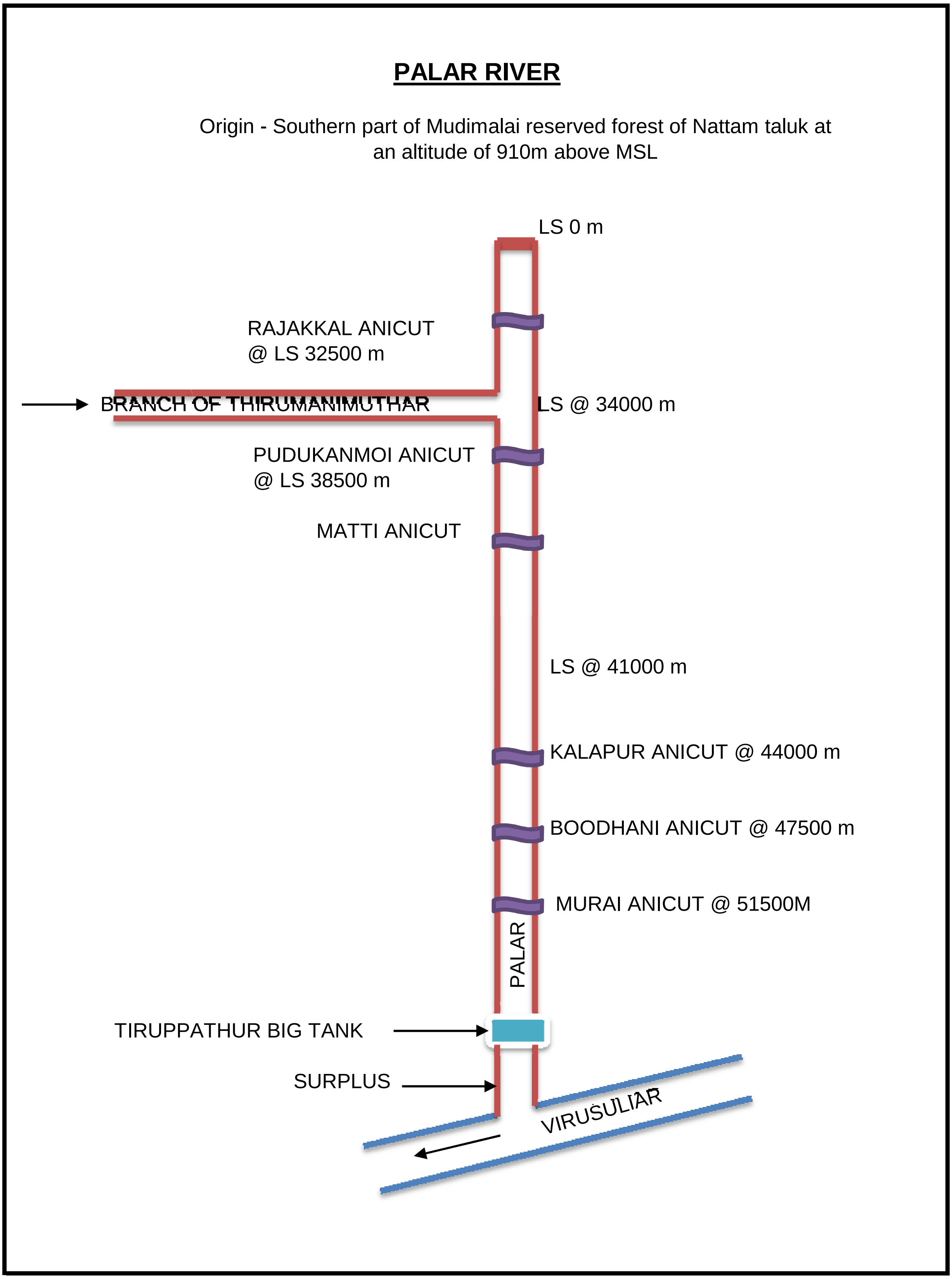


Figure 5.4 Flow diagram of Palar river

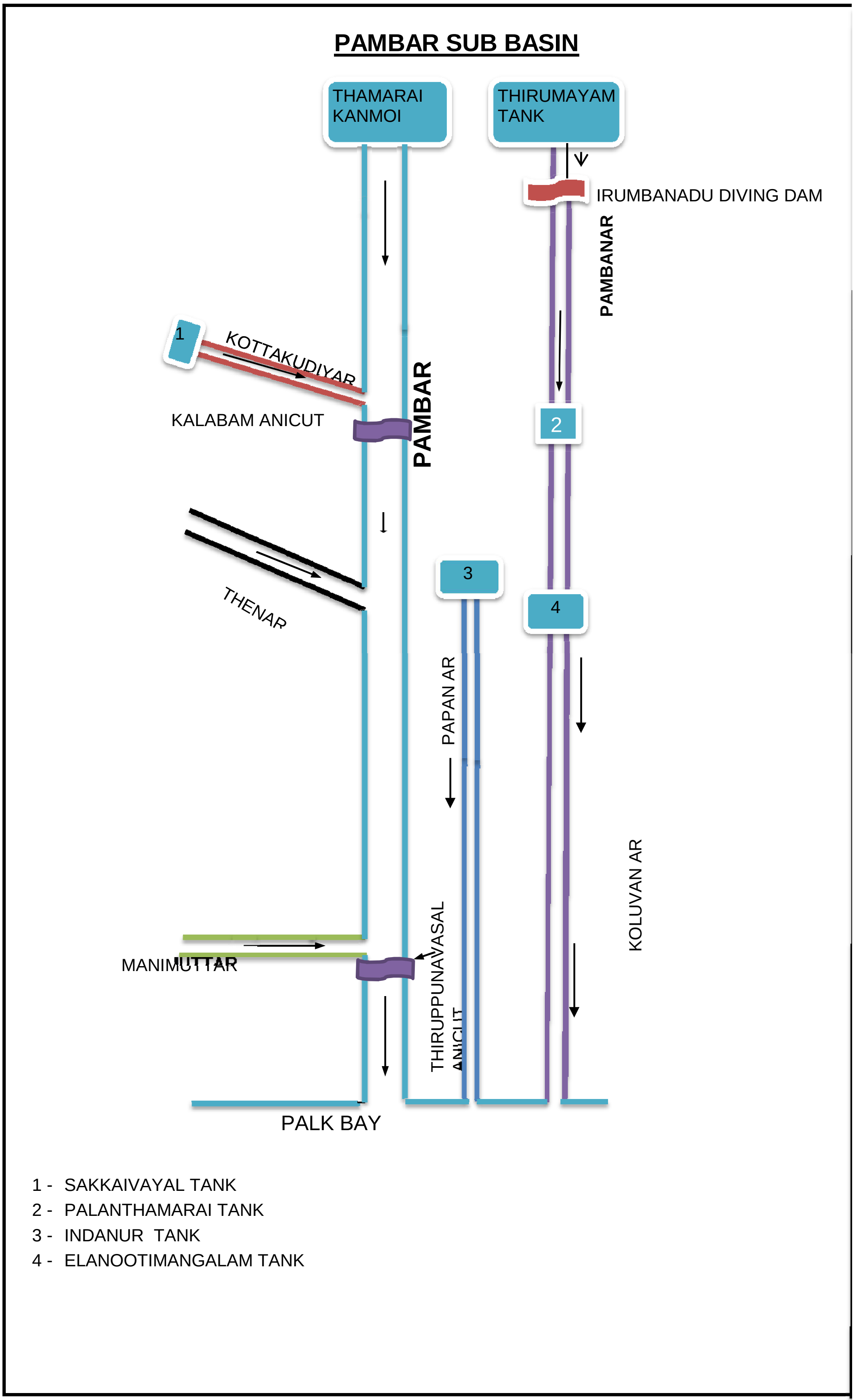


Figure 5.5 Flow diagram of Pambar Sub basin

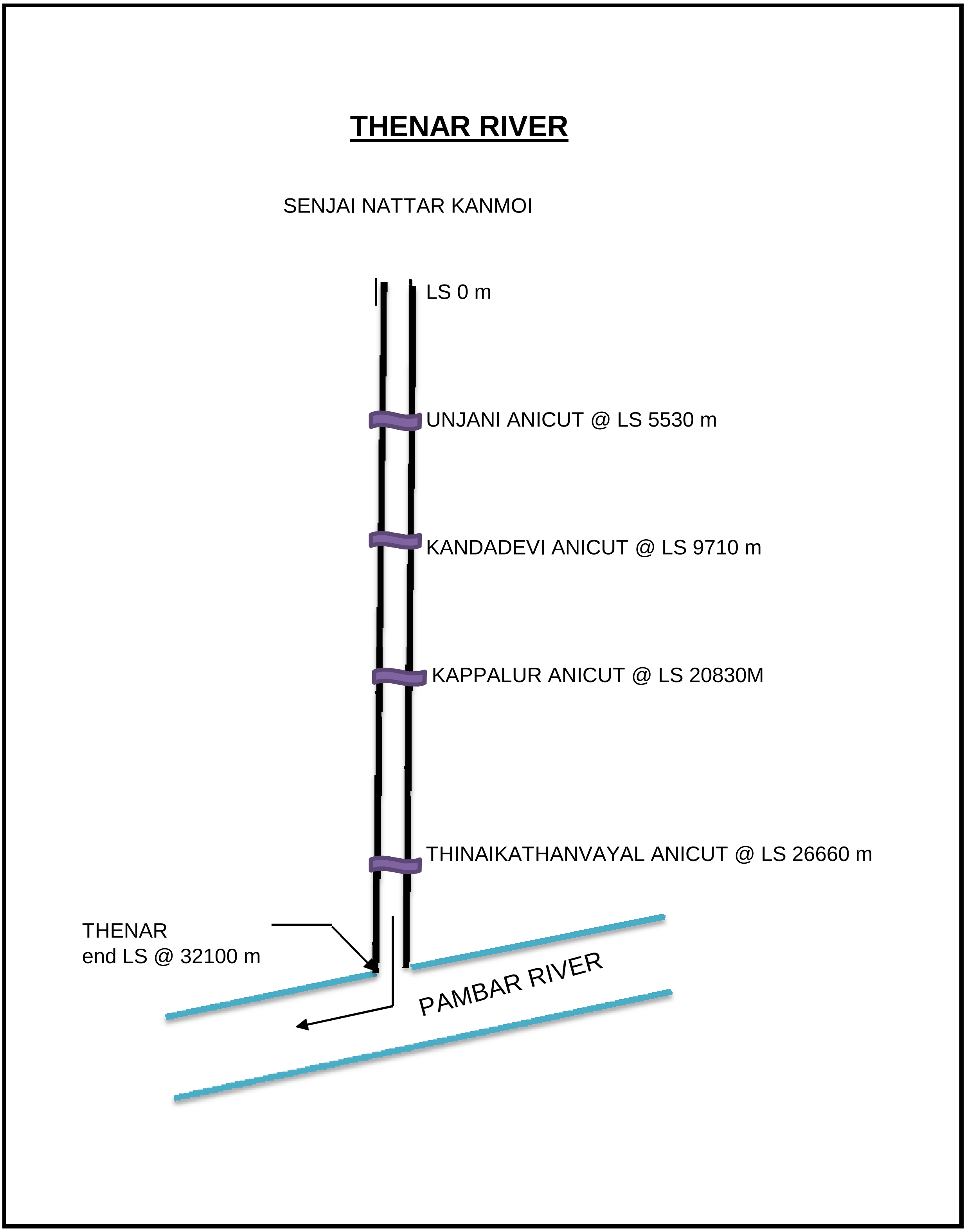


Figure 5.6 Flow diagram of Thenar river

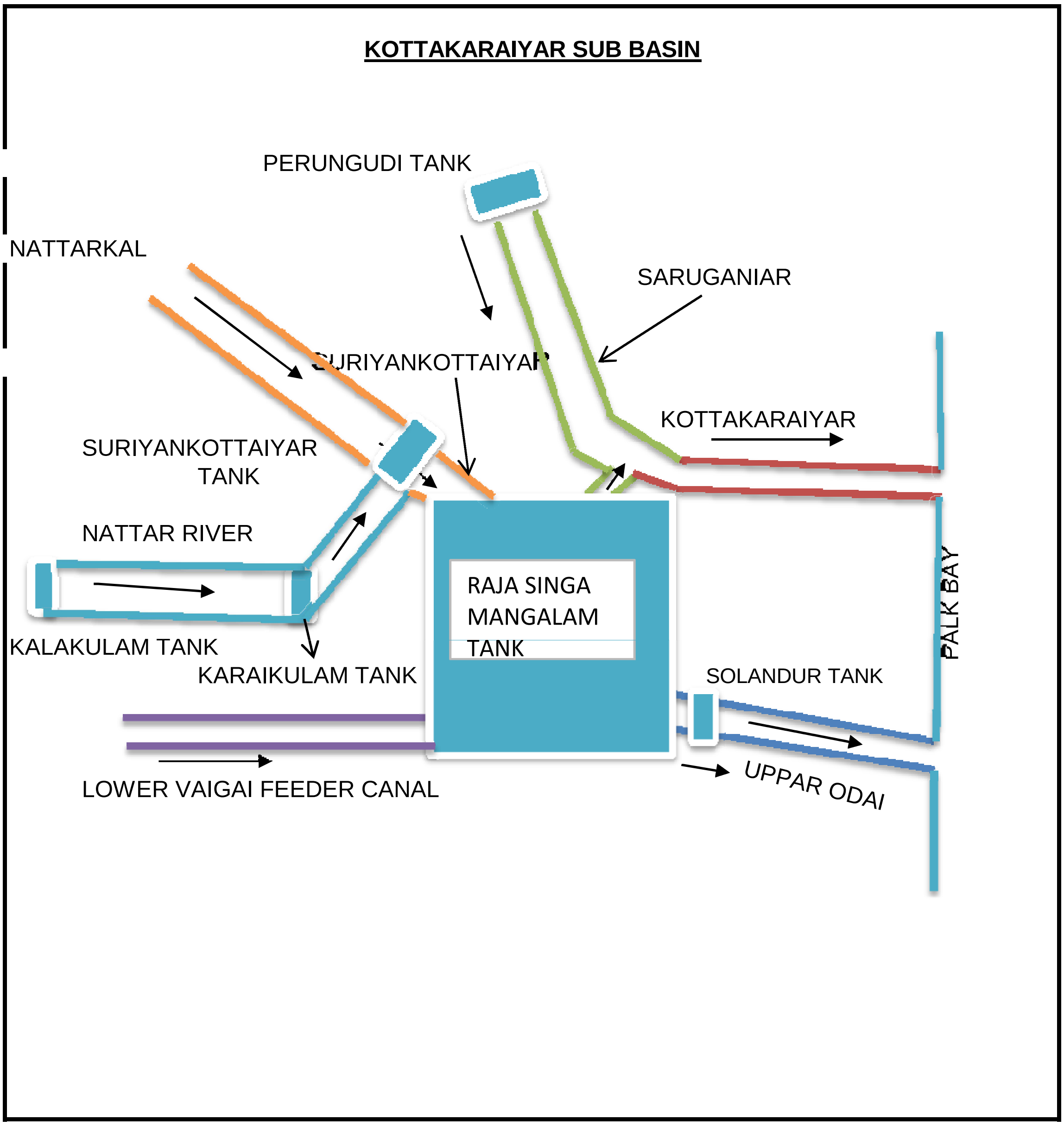
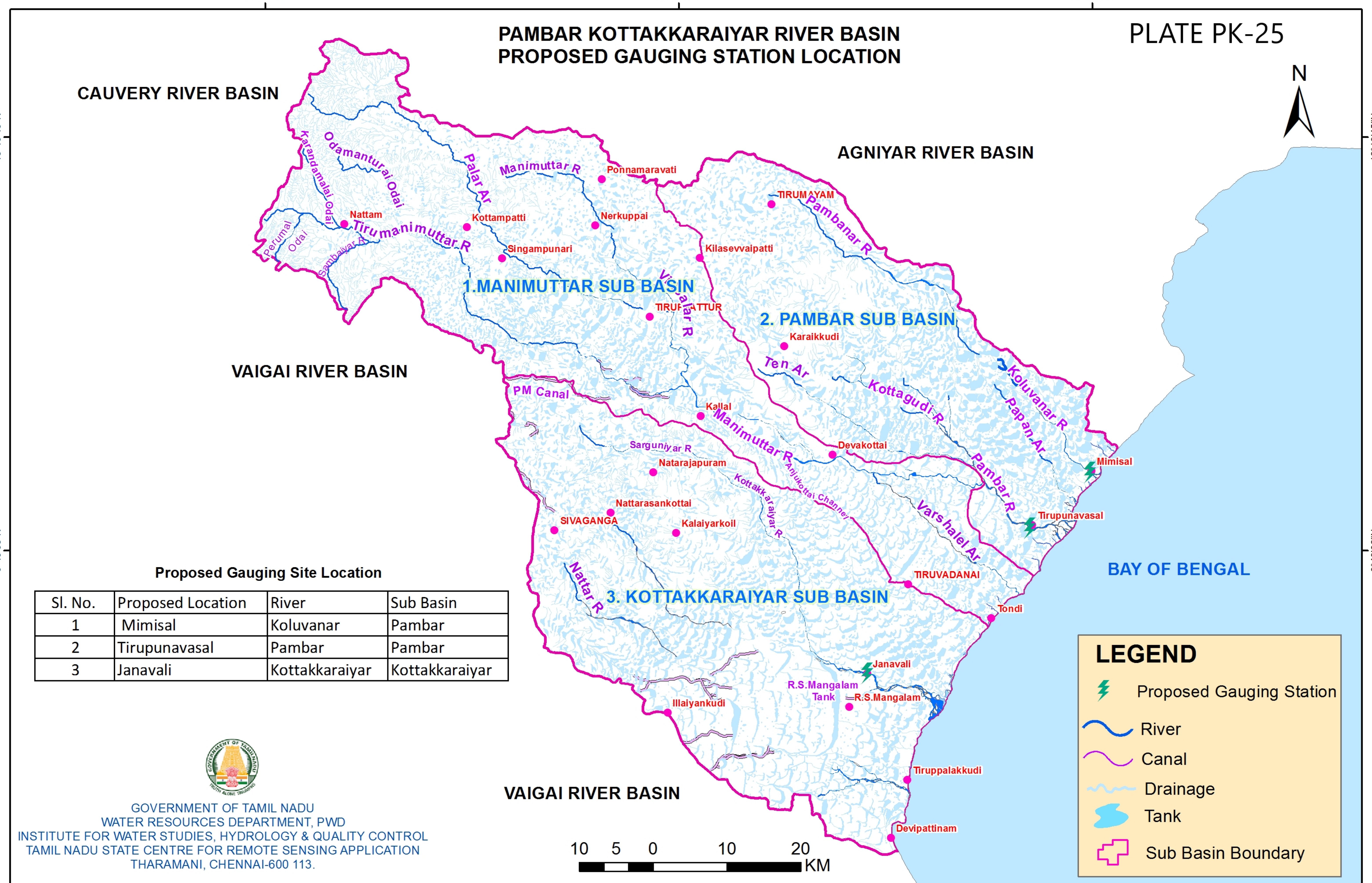


Figure 5.7 Flow diagram of Kottakkaraiyar Sub basin

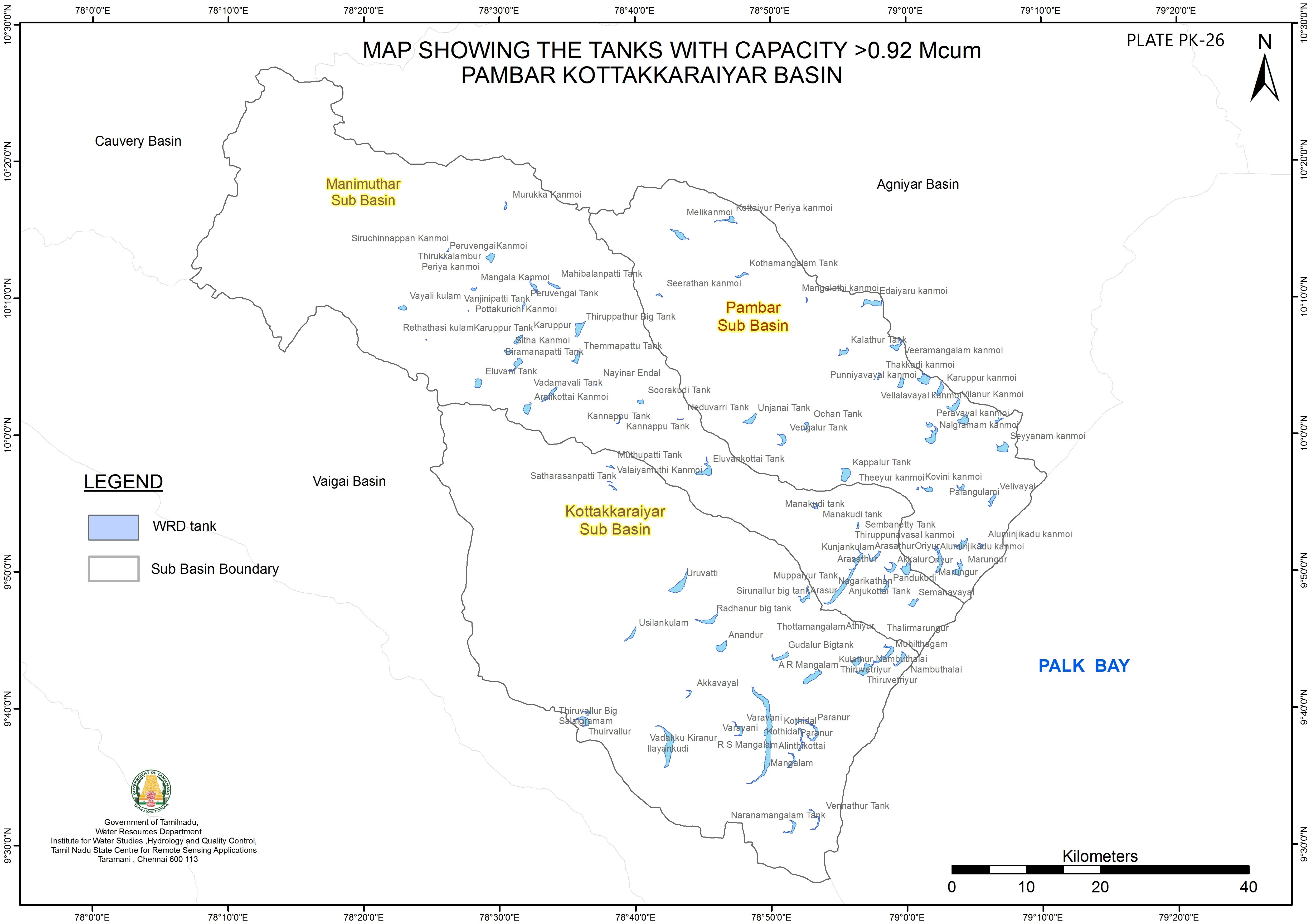
PAMBAR KOTTAKKARAIYAR RIVER BASIN PROPOSED GAUGING STATION LOCATION



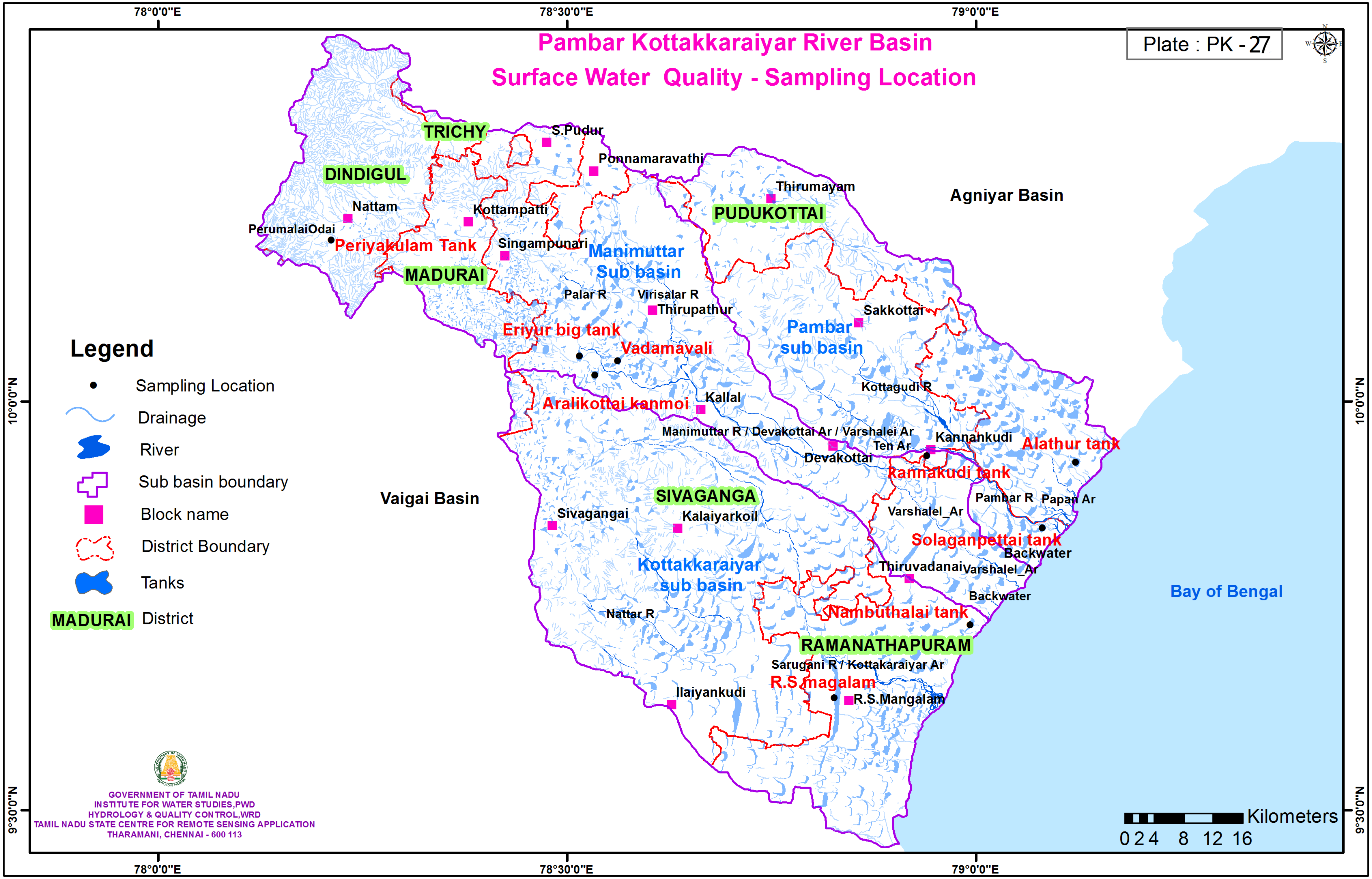
Proposed Gauging Site Location

Sl. No.	Proposed Location	River	Sub Basin
1	Mimisal	Koluvanar	Pambar
2	Tirupunavasal	Pambar	Pambar
3	Janavali	Kottakkaraiyar	Kottakkaraiyar

GOVERNMENT OF TAMIL NADU
WATER RESOURCES DEPARTMENT, PWD
INSTITUTE FOR WATER STUDIES, HYDROLOGY & QUALITY CONTROL
TAMIL NADU STATE CENTRE FOR REMOTE SENSING APPLICATION
THARAMANI, CHENNAI-600 113.



MAP SHOWING THE TANKS WITH CAPACITY >0.92 Mcum
PAMBAR KOTTAKKARAIYAR BASIN
PLATE PK-26
N
Cauvery Basin
Agniyar Basin
Vaigai Basin
PALK BAY
Manimuthar Sub Basin
Pambar Sub Basin
Kottakkaraiyar Sub Basin
LEGEND
WRD tank
Sub Basin Boundary
Kilometers
0 10 20 40
Government of Tamilnadu,
Water Resources Department
Institute for Water Studies ,Hydrology and Quality Control,
Tamil Nadu State Centre for Remote Sensing Applications
Taramani , Chennai 600 113
78°0'0"E
78°10'0"E
78°20'0"E
78°30'0"E
78°40'0"E
78°50'0"E
79°0'0"E
79°10'0"E
79°20'0"E
10°30'0"N
10°20'0"N
10°10'0"N
10°0'0"N
9°50'0"N
9°40'0"N
9°30'0"N
Murukka Kanmoi
Melikanmoi
Kottaiyur Periya kanmoi
Siruchinnappan Kanmoi
PeruvengaiKanmoi
Thirukkalambur Periya kanmoi
Mangala Kanmoi
Mahibalanpatti Tank
Kothamangalam Tank
Seerathan kanmoi
Mangalathi kanmoi
Edaiyaru kanmoi
Vayali kulam
Vanjinipatti Tank
Peruvengai Tank
Pottakurichi Kanmoi
Thiruppathur Big Tank
Rethathasi kulam
Karuppur Tank
Karuppur
Sitha Kanmoi
Biramanapatti Tank
Themmapattu Tank
Kalathur Tank
Veeramangalam kanmoi
Eluvani Tank
Nayinar Endal
Thakkadi kanmoi
Punniyavayal kanmoi
Karuppur kanmoi
Vadamavali Tank
Soorakudi Tank
Vellalavayal Kanmoi
Vilanur Kanmoi
Aralikottai Kanmoi
Neduvarri Tank
Unjanai Tank
Ochan Tank
Peravayal kanmoi
Kannappu Tank
Kannappu Tank
Vengalur Tank
Nalgramam kanmoi
Seyyanam kanmoi
Muthupatti Tank
Eluvankottai Tank
Kappalur Tank
Satharasanpatti Tank
Valaiyamuthi Kanmoi
Theeyur kanmoi
Kovini kanmoi
Palangulam
Velivayal
Manakudi tank
Manakudi tank
Sembanetty Tank
Thiruppunavasal kanmoi
Aluminjikadu kanmoi
Kunjankulam
Arasathur
Oriyur
Aluminjikadu kanmoi
Arasathur
Akkalur
Oriyur
Marungur
Marungur
Uruvatti
Muppaiyur Tank
Nagarikathan
Pandukudi
Sirunallur big tank
Arasur
Anjukottai Tank
Semanavayal
Radhanur big tank
Usilankulam
Thottamangalam
Athiyur
Thalirmarungur
Anandur
Gudalur Bigtank
Mubilthagam
Kulathur
Nambuthalai
A R Mangalam
Thiruvetriyur
Nambuthalai
Thiruvetriyur
Akkavayal
Thiruvallur Big
Salaigramam
Thuirvallur
Varavani
Kothidal
Paranur
Varavani
Kothidal
Paranur
Vadakku Kiranur
Ilayankudi
R S Mangalam
Alinthikottai
Mangalam
Vennathur Tank
Naranamangalam Tank



Pambar Kottakkaraiyar River Basin
Surface Water Quality - Sampling Location
Plate : PK - 27
78°0'0"E
78°30'0"E
79°0'0"E
10°0'0"N
9°30'0"N
TRICHY
DINDIGUL
MADURAI
PUDUKOTTAI
SIVAGANGA
RAMANATHAPURAM
S.Pudur
Ponnamaravathi
Thirumayam
Nattam
PerumalaiOdai
Kottampatti
Singampunari
Periyakulam Tank
Manimuttar
Sub basin
Palar R
Virisalar R
Thirupathur
Sakkottai
Pambar
sub basin
Eriyur big tank
Vadamavali
Kottagudi R
Aralikottai kanmoi
Kallal
Manimuttar R / Devakottai Ar / Varshalei Ar
Ten Ar
Devakottai
Kannankudi
Alathur tank
Rannakudi tank
Agniyar Basin
Vaigai Basin
Pambar R
Papan Ar
Varshalei_Ar
Sivagangai
Kalaiyarkoil
Solaganpettai tank
Backwater
Kottakkaraiyar
sub basin
Thiruvadanai
Varshalei_Ar
Backwater
Bay of Bengal
Nattar R
Nambuthalai tank
Sarugani R / Kottakaraiyar Ar
R.S.magalam
Ilaiyankudi
R.S.Mangalam
Legend
Sampling Location
Drainage
River
Sub basin boundary
Block name
District Boundary
Tanks
MADURAI District
GOVERNMENT OF TAMIL NADU
INSTITUTE FOR WATER STUDIES,PWD
HYDROLOGY & QUALITY CONTROL,WRD
TAMIL NADU STATE CENTRE FOR REMOTE SENSING APPLICATION
THARAMANI, CHENNAI - 600 113
Kilometers
0 2 4 8 12 16

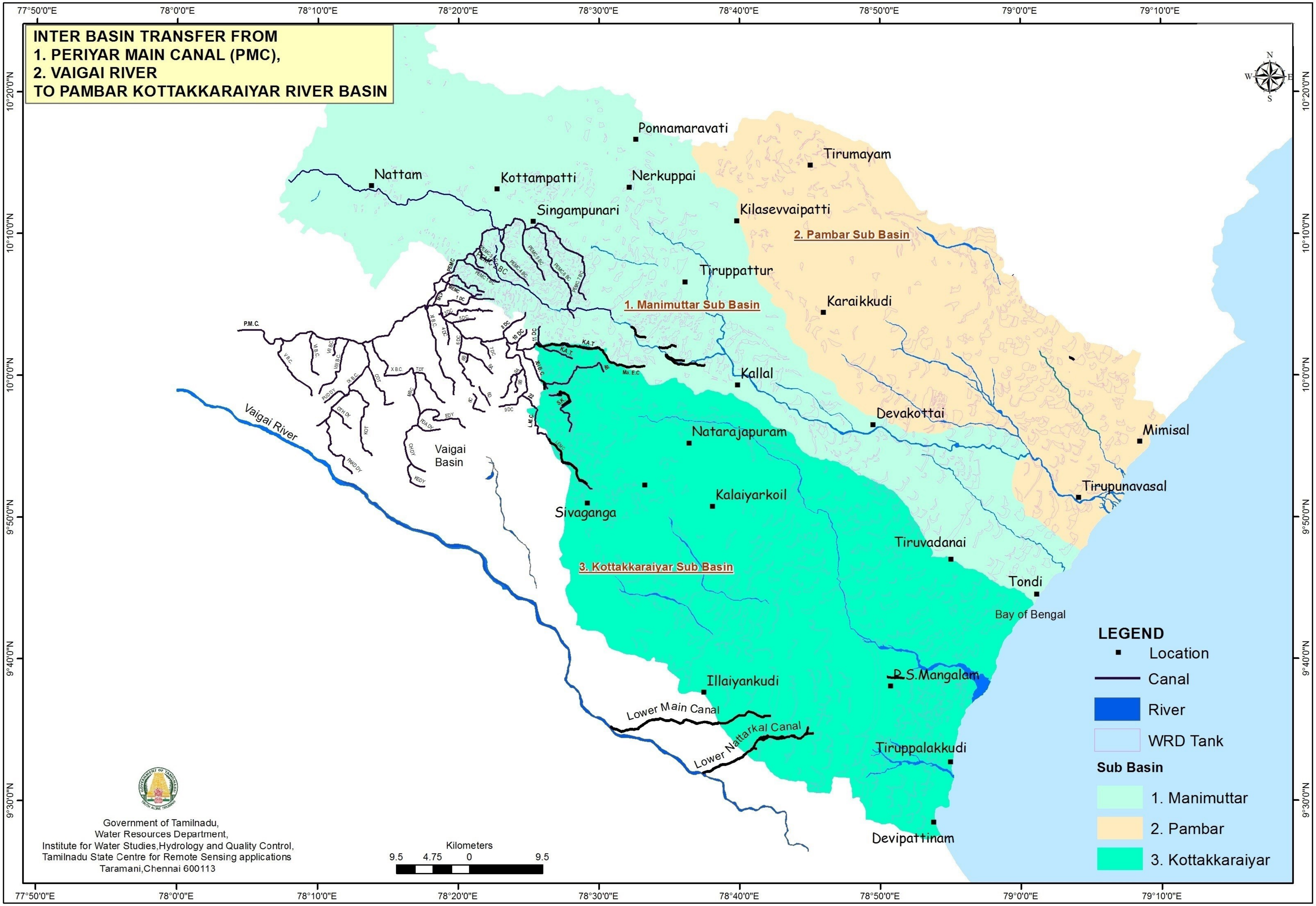


Figure 5.8 Inter basin transfer map from Periyar Main Canal, Vaigai river to Pambar Kottakkaraiyar river basin

CHAPTER - 6

GROUNDWATER RESOURCES

AND

WATER QUALITY

CHAPTER-6

GROUNDWATER RESOURCES AND WATER QUALITY

6.1 Status of Groundwater

Groundwater and surface water are the two water resources of a country and are dependent on rainfall. Minor quantity of rainfall only percolates into ground which depends on various factors such as existing moisture content, ground water table etc. A major quantity of rainfall flows as surface runoff and is stored in water bodies like reservoirs, tanks, lakes and ponds. The excessive extraction of groundwater, for various demands, results in fast depletion of groundwater. In order to improve the groundwater level effective methods are to be adopted.

For long term planning, development and management, a systematic and scientific assessment of groundwater resources is quite essential. Groundwater is a more reliable, easily available natural resource, serves as a dependable water resource during drought and in achieving food security. As per the latest assessment, ie as on **31st March 2013,** the data on **Dynamic Ground Water Resources of India** is as stated below:

- **Total annual replenishable Groundwater Resources: 447 BCM**
- **Net annual Ground Water availability : 411 BCM.**
- **Annual Groundwater draft (extraction) for all uses : 253 BCM.**
- **The stage of Groundwater Development : 62 %.**

Groundwater has steadily emerged as the backbone of India's agriculture and drinking water security. Presently, Groundwater contributes nearly 62% in irrigation, 85% in rural water supply and 45% in urban water supply (Source: Ministry of Water Resources, Rural Development & Ganga Rejuvenation).

The dynamic groundwater resource of Tamilnadu was assessed at macro size unit of Block level upto 2009. After **2011,** the assessment is being done at **micro size unit of Firka** level**.** As per the latest assessment, ie as on **31st March 2013,** the data on **Dynamic Ground Water Resources of Tamilnadu** is as stated below:

- **Total annual replenishable Groundwater Resources : 20.65 BCM**
- **Net annual Ground Water availability : 18.59 BCM.**
- **Annual Groundwater draft (extraction) for all uses : 14.36 BCM.**
- **The stage of Groundwater Development : 77 %.**

The following sections explain the groundwater availability and status prevailing in Pambar Kottakaraiayar River Basin.

6.2 Groundwater Estimation Methodology

Groundwater resources of India have been estimated based on the guidelines and recommendations of the Groundwater Estimation Committee 1997(GEC-97). Groundwater resources was assessed at a macro size administrative unit of Block upto 2009 and from 2011 onwards it is being assessed at micro size administrative unit of Firka for greater accuracy.

Groundwater recharge is estimated season-wise for both monsoon seasons and non monsoon seasons separately. Groundwater recharge is assessed based on recharge from rainfall, seepage from canal, tanks & ponds and return flow from irrigation.

6.2.1 Total annual replenishable Groundwater Resources

The Total Annual Replenishable Ground Water Resources of the area is the sum of recharge during monsoon and non monsoon seasons.

6.2.2 Net annual Ground Water availability

The Net annual ground water availability is the available groundwater resource after deducting the natural discharges (10%) during non-monsoon season from the total Annual Replenishable Groundwater Resource.

6.3 Aquifers

6.3.1 General

Groundwater is extracted from shallow aquifer. The Geologists & Engineers have used complicated datas to find reliable and representative values of the hydraulic characteristics of aquifers. The groundwater availability in aquifer depends on the type of rock formation in earth layer and hydraulic parameters of aquifer such as Conductivity, Transmissivity, Specific Yield and Storage co-efficient. Pump test in dug wells or bore wells plays a prominent role in evaluating these hydraulic properties of aquifers in different geological formations Based on the pump test results, yield and recharge rate of aquifers are being predicted.

6.3.2 Aquifer Parameters

Geologically, Pambar Kottakkaraiyar basin is divided into two regions as hard rock and soft rock. Hard rock comprises of Archaean complex suit and soft rock comprises of Shaly sandstone, Sand & silt and altered sequence of sand, silt and clay.

The aquifer parameters of the geological formations in Pambar Kottakkaraiyar River Basin are given in the following tables.

Table: 6.1 Aquifer parameter in Hard Rock

S. No	Parameters	Range
1.	Well Yield	2-5 to 250 lps
2.	Transmissivity (T) in m^2/day	1 to 65 m^2/day
3.	Storativity (S) value	$2.16x10^{-5}$ to $1.32x10^{-3}$
4	Specific Yield	2%

Table: 6.2 Aquifer parameter in Soft Rock

S. No	Parameters	Range
1.	Well Yield	75 to 500 lps
2.	Transmissivity (T) in m^2/day	1 - 10 to 500 m^2/day
3.	Storativity (S) value	$2.5x10^{-5}$ to $3.59x10^{-4}$
4	Specific Yield	12%

Note:

m^2/day = metre square per day
lps = litre per second

6.3.3 Groundwater Occurrence

264 observation wells lie in Pambar Kottakkaraiyar Basin out of which about **67** observation wells spread over the entire Pambar Kottakkaraiyar Basin have been analyzed based on the availability of data, over the period of four (4) years to forty five (45) years. The observation wells analyzed fall in Dindigul, Madurai, Pudukottai, Ramanathapuram, Sivaganga and Trichy districts. Though 4 observation wells are having data for only 4 years period, they were also considered to understand the recent trend in groundwater level. Location details of these observation wells in Pambar Kottakkaraiyar basin are presented in **Appendix 6.1 of Vol II** and it's spatial distribution are shown in **Plate: PK-28.** The periodical water level fluctuations were examined sub-basin wise and geological formation wise, to understand the hydrogeological nature and groundwater occurrence. The number of observation wells for different geological formations for the 3 sub basins are tabulated in **Table 6.3**. The ground water occurrence in the 3 sub basins are tabulated in **Table 6.4.**

Table 6.3 Number of observation wells in different Geological Formations and Extent of Forest area for three sub basins

SI. No	Type of Geological formations	No of observation wells		
		Manimuthar Sub-basin	Kottakkaraiyar Sub-Basin	Pambar Sub-basin
1	TSS	2	1	4
2	GGN	3		5
3	SDM	2	4	5
4	TEY			1
5	ALV	4	3	2
6	LTR		2	1
7	GNS	21	2	2
8	CNK	3		
9	Forest Area in Sqm	9.75	266.342	82.37
10	Forest Area in Percentage	0.68	11.68	3.74

Table 6.4 Ground water occurrence in the three sub basins are given below:

Sl. No	Sub-basin	No of Wells	Pre-monsoon		Post-monsoon	
			Minimum Water level	Maximum Water Level	Minimum Water level	Maximum Water Level
1	Pambar	20	**0.48m** (Well No: 43090 in Mar 1997)	**21.20m** (Well No: 240165 in May 2017)	**0.25m** (Well No: 43090 in Jan 1977)	**19.40m** (Well No: 24015 in Feb 2017)
2	Manimuthar	35	**0.70m** (Well No: 21021D in Mar 2011)	**26.20m** (Well No: 24004D in May 2015)	**0.25m** (Well No: 21021D in Jan 2012)	**23.90m** (Well No: 22024D in Feb 2017)
3	Kottakkaraiyar	12	**0.26m** (Well No: 83064 in Apr 2008)	**17.30m** (Well No: 21023D in May 2017)	**0.09m** (Well No: 83264 in Feb 1993)	**15.90m** (Well No: 21023D in Feb 2017)

6.4 Groundwater Flow Regime and Water Level Fluctuations

Monitoring of groundwater flow regime is an effort to obtain information on water levels. The ground water regime depends on natural and anthropogenic stresses of recharge and discharge parameters with reference to Geology, Climate, Physiographic land use pattern and hydrologic characteristics. The natural conditions affecting the regime involve climatic parameters like rainfall, evapotranspiration etc, and where as anthropogenic influences are desirable from the aquifer, recharge due to irrigation systems and other practices like waste disposal etc.

Groundwater system is dynamic and adjusts continually to short-term and long-term changes due to climate, groundwater withdrawal, and land use pattern. Water level measurements from observation wells are the principal source of information about the hydrologic stresses acting on aquifers and how these stresses affect groundwater recharge, storage, and discharge. Long-term systematic measurements of water levels provide essential data required to evaluate the changes in water resource over time to develop groundwater models and forecast trends; to design, implement and to monitor the effectiveness of groundwater management and protection programs.

It is imperative that, water level measurements must be collected from an observation well without interruption for as many years as possible in order to compile a ground water hydrology record that provides the natural water-level fluctuations and tracks it's trend over time. Though four years is relatively short period for analysis of water level data s, it is at least sufficient to provide an idea of ground water level fluctuation.

Contour maps showing the depths of groundwater table for pre monsoon and post monsoon for July 1986, January 1987, July 1996, January 1997, July 2006, January 2007, July 2016 and January 2017 have been prepared and are presented in **Plate:PK-29 to PK-36** respectively. Groundwater levels of the 67 observation wells are illustrated in the form of hydrographs in **Appendix 6.8 of Vol II** for analysis of the long-term trends.

6.4.1 Water Level Fluctuations

Hydrographs of groundwater level for the 67 observation wells have been prepared. The linear trend lines drawn in the Hydrograph of observation wells were used to interpret the long-term trend in water level fluctuation. Rise or fall in water level in the range of 0-2 metre may not be significant due to dynamic nature of groundwater (CGWB 2010). From the trend line, if there is a long term water level depletion or rise, in the range of 2-3 metre, it is classified as moderate depletion or rise. If the depletion or rise is greater than 3 metre, it is classified as high depletion or rise.

In this basin, Long-term water level rise is found in 17 observation wells and high rise in water level (more than 3.00m) is found in 2 wells. Long-term water level depletion is found in 50 observation wells and high depletion in water level (more than 3.00m) is found in 22 wells.

The details of the wells having high rise and high depletion are given below.

Table 6.5 High rise Observation Wells

Sl.No	Well No	Sub-Basin	District
1	83153	Pambar	Sivagangai
2	12011D	Manimuthar	Pudukottai

Table 6.6 High Depletion Observation Wells

Sl.No	Well No	Sub-Basin	District
1	73156	Pambar	Pudukottai
2	73162		
3	12022 D		
4	12045 D		
5	12048		
6	24015		Sivagangai
7	24023		
8	24024		
9	502029	Manimuthar	Dindigul
10	502035		
11	22023D		
12	22024D		
13	21019 D		Madurai
14	21020 D		
15	Ex-21072		
16	Ex-21073		
17	11053		Trichy
18	24004 D		Sivagangai
19	24006 D		
20	21023 D	Kottakkaraiyar	Madurai
21	24018		Sivagangai
22	24022		

i) Annual Groundwater Level Fluctuations

Annual groundwater level fluctuation is significant in the context that it indicates the level/degree of groundwater recharge. Annual water level fluctuation varies from 0.39m to 17.69m in Pambar sub-basin, 0.00m to 17.30m in Manimuthar sub-basin and 0.65m to 9.35m in Kottakkaraiyar sub-basin.

ii) Monsoon Groundwater Level Variation

- In Pambar sub-basin, pre-monsoon groundwater level varies from 0.48m to 21.20m and post monsoon groundwater level varies from 0.25m to 19.40m

- In Manimuthar sub-basin, pre-monsoon groundwater level varies from 0.70m to 26.20m and post monsoon groundwater level varies from 0.25m to 23.90m
- In Kottakkaraiyar sub-basin, pre-monsoon groundwater level varies from 0.26m to 17.30m and post monsoon groundwater level varies from 0.09m to 15.90m.

6.4.2 Groundwater Flow Regime

The occurrence and movement of groundwater and its storage are controlled by the physiography, climate and the geological formation conditions like texture, lithology and structure, etc. A water table contour map serves as an important tool for finding the direction of groundwater flow. Form the water table contour map of Pambar Kottakkaraiyar basin, it is observed that the groundwater flow is generally from west to east.

The details of Ground water level data are tabulated in **Appendix 6.2 of Vol-II**. Pre-monsoon and post-monsoon contour maps (depth to water table) one for each decade: Jul-86 & Jan-87, Jul-96 & Jan-97 and Jul-2006 & Jan-2007, Jul-2016& Jan-2017) have been prepared based on the above data and presented in **Plates PK-29 to PK-36.**

6.4.3 Groundwater Level Scenario

i) Pre-Monsoon

During July 1986 July 1996, July 2006 and July 2016: Groundwater level is deeper (109.30m to 312.90m) in upper reache,at moderate depth (47.90m to 138.40m) in middle reach and shallow (7.40m to 55.70m) in tail reach.

i**i) Post-Monsoon:**

During January 1987, January 1997, January 2007 and January 2017: : Groundwater level is deeper (109.60m to 313.70m) in upper reach, at moderate depth (48.80m to 137.40m) in middle reach and shallow (9.90m to 56.50m) in tail reach.

6.5 Categorization of Firkas

The categorization was done on a fine scale based on firkas as per latest Groundwater assessment done during 2013. The 1,139 revenue Firkas in Tamil Nadu were categorized as Safe, Semi Critical, Critical and Over-Exploited depending upon the stage of groundwater development. The criteria for categorization of Firkas are tabulated as follows:

Table 6.7 Criteria for Categorization of Firkas

Sl.No	Stage of Groundwater Development	Categorization
1	<=70%	Safe
2	>70% and <=90%	Semi Critical
3	>90% and <=100%	Critical
4	>100%	Over Exploited

In general, the prime cause of over-exploitation of groundwater is due to increase in water demand in various sectors like agriculture, industries and domestic.

Pambar Kottakkaraiyar basin encompasses 72 Firkas either fully or partially and all firkas are falling in Dindigul, Madurai, Pudukottai, Ramanathapuram, Sivaganga and Trichy districts. Map showing the categorization of firkas falling in Pambar Kottakkaraiyar Basin is presented in **Plate:PK-37.**

The list of categorization of 72 firkas in Pambar Kottakkaraiyar Basin based on the level of Ground Water Development assessment as on March 2013 is tabulated in **Table 6.8 & Table 6.9**

Table 6.8 Categorization of Firkas in Pambar Kottakkaraiyar basin

Sl. No.	Firka	Sub-Basin	District	Categorisation of Firkas
1	Aranthangi	Pambar	Pudukkottai	Safe
2	Arasamalai		Pudukkottai	Safe
3	Avudaiyarkoil		Pudukkottai	Safe
4	Embal		Pudukkottai	Safe
5	Kandadevi		Sivaganga	Safe
6	Kannakudi		Sivaganga	Safe
7	Karaikudi		Sivaganga	Safe
8	Keelanilai		Pudukkottai	Safe
9	Kottaipattinam		Pudukkottai	Saline
10	Kottur		Pudukkottai	Safe
11	Mimisal		Pudukkottai	Safe
12	Mitharavayal		Sivaganga	Safe
13	Pallathur		Sivaganga	Safe

14	Perumaruthur		Pudukkottai	Saline
15	Ponpette		Pudukkottai	Safe
16	Pullur		Ramanathapuram	Safe
17	Sakkottai		Sivaganga	Safe
18	Sengeerai		Pudukkottai	Safe
19	Silattur		Pudukkottai	Safe
20	Thirumayam		Pudukkottai	Safe
21	Virachilai		Pudukkottai	Safe
22	Ayyalur	Manimuthar	Dindigul	Over Exploited
23	Devakottai		Sivaganga	Safe
24	Ilayathakudi		Sivaganga	Safe
25	Kambiliyanpatti		Dindigul	Semi Critical
26	Karaiyur		Pudukkottai	Semi Critical
27	Karungalakudi		Madurai	Safe
28	Keelavalavu		Madurai	Safe
29	Kottampatti		Madurai	Critical
30	Mangalakudi	Manimuthar	Ramanathapuram	Saline
31	Melavalavu		Madurai	Safe
32	Natchiyapuram		Sivaganga	Safe
33	Nattam		Dindigul	Semi Critical
34	Nerkuppai		Sivaganga	Safe
35	Ponnamaravathy		Pudukkottai	Safe
36	Reddiyapatti		Dindigul	Semi Critical
37	RF		Madurai	Safe
38	Shanarpatti		Dindigul	Over Exploited
39	Senthurai		Dindigul	Semi Critical
40	Singampunarai		Sivaganga	Safe
41	SS.Kottai		Sivaganga	Safe
42	Thirukostiyur		Sivaganga	Safe
43	Thiruppattur		Sivaganga	Safe
44	Thiruvadanai		Ramanathapuram	Safe
45	Thuvarangurichi		Tricuchirapalli	Over Exploited

46	Varappur		Sivaganga	Semi Critical
47	A.Thiruvuduiar puram	Kottakkaraiyar	Sivaganga	Safe
48	Aanandur		Ramanathapuram	Safe
49	Devipattinam		Ramanathapuram	Safe
50	Ilaiyankudi		Sivaganga	Safe
51	Kalaiyarkovil		Sivaganga	Safe
52	Kallal		Sivaganga	Safe
53	Kiliyur		Ramanathapuram	Safe
54	Mallal		Sivaganga	Safe
55	Maravamangalam		Sivaganga	Safe
56	Mathagupatti		Sivaganga	Safe
57	Nainarkoil		Ramanathapuram	Safe
58	Nattarasankottai		Sivaganga	Safe
59	Okkur		Sivaganga	Safe
60	Periyakottai		Sivaganga	Safe
61	Puzhiyal		Sivaganga	Safe
62	R.S.Mangalam	Kottakkaraiyar	Ramanathapuram	Safe
63	Sarugani		Sivaganga	Safe
64	Salaigramam		Sivaganga	Safe
65	Seikalattur		Sivaganga	Safe
66	Sivagangai		Sivaganga	Safe
67	Solandhur		Ramanathapuram	Safe
68	Sooranam		Sivaganga	Safe
69	Thamarakki		Sivaganga	Safe
70	Thayamangalam		Sivaganga	Safe
71	Thondi		Ramanathapuram	Saline
72	Vellalur		Madurai	Semi Critical

Table 6.9 Summary of Categorization of Firkas

Sl.No	Category	2013 Assessment
1	Safe	57
2	Semi Critical	7
3	Critical	1
4	Over Exploited	3
5	Saline	4

6.6 Groundwater Availability

6.6.1 Groundwater Availability in the Study Area

The sub-basin wise groundwater availability and extraction (draft) are calculated from the Firkas' availability and extraction (draft) on proportionate basis i.e based on the percentage of firka area falling in the sub-basin. The balance of groundwater availability in each firka for further development is arrived by deducting the gross groundwater extraction from the net groundwater availability. If the balance groundwater availability is found to be negative, that negative value is ignored and the balance is taken as zero for that sub-basin.

The sub-basin wise groundwater availability, extraction and the balance groundwater availability and the stage of groundwater development are presented in Table **6.10.**

Table 6.10 Groundwater Availability, Extraction and Balance Availability (Based on March 2013 Assessment)

Sl. No.	Sub-Basin	Net Annual Groundwater Availability in sub basin (MCM)	Gross Annual Groundwater Extraction in sub basin (MCM)	Balance Annual Groundwater Availability in sub basin (MCM)	Stage of Development (%)
1	Pambar	334.78	30.06	304.72	**8.98**
2	Manimuthar	335.87	126.77	209.40	**37.74**
3	Kottakkaraiyar	459.28	79.68	379.60	**17.35**
	TOTAL	**1129.93**	**236.51**	**893.72**	**20.93**

The firka-wise groundwater availability, extraction and balance ground water availability are presented in **Appendix 6.5, 6.6 and 6.7 of Vol II.** The sub-basin wise groundwater availability and extraction is represented in the graph in Fig.6.1.

Fig: 6.1 Sub Basin wise Groundwater Availability and Extraction

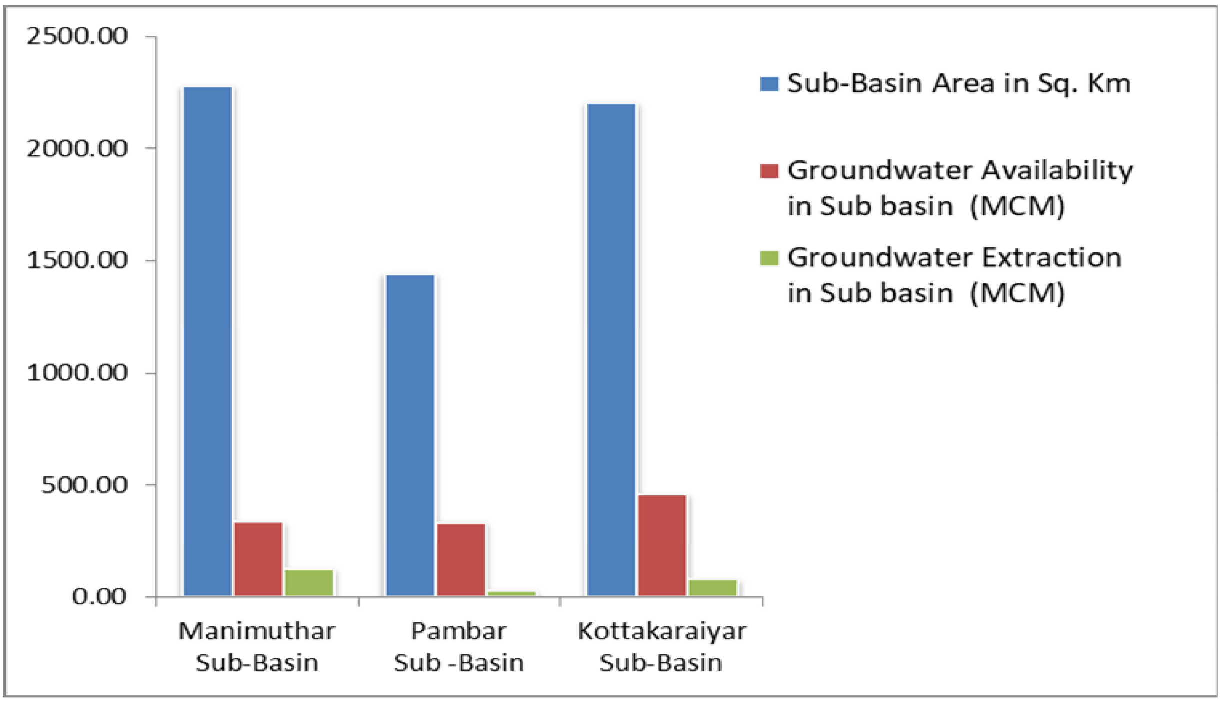
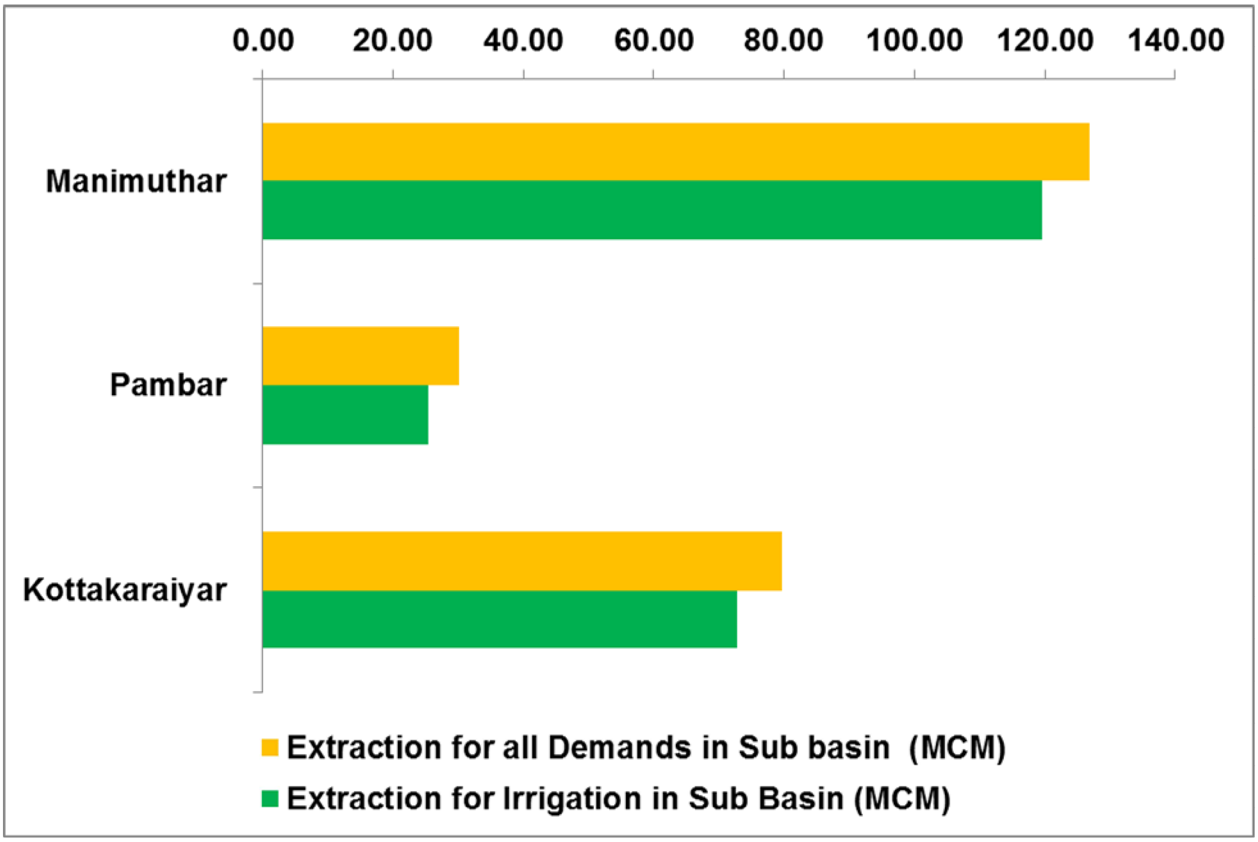


Table 6.11 shows the comparison of groundwater extraction for irrigation demand with respect to total extraction for all demands, based on 2013 assessment. The same is shown pictorially in Fig:6.2.

Table: 6.11 Groundwater extraction for all demands and extraction for irrigation demand

Sl. No	Sub Basin	Extraction for Irrigation in (MCM)	Extraction for all demands (MCM)	Percentage of Irrigation demand
1	Pambar	25.45	30.06	**84.66**
2	Manimuthar	119.61	126.77	**94.35**
3	Kottakkaraiyar	72.69	79.68	**91.23**
	TOTAL	**217.75**	**236.51**	**92.07**

Fig: 6.2 Groundwater extraction for all demands and extraction for irrigation demand



6.6.2 Comparison of Groundwater Resources

The Groundwater availability was calculated in Pambar Kottakkaraiyar earlier in 2007 based on assessment done during 2003 with Block as unit. Presently it is calculated with latest assessment done in March 2013 with Firka as unit. The comparison of the above is presented in **Table 6.12**

Table: 6.12 Comparison of groundwater assessment: 2003 and 2013

Sl. No	Sub-Basin	Net Annual Groundwater Availability in sub basin (MCM)		Gross Annual Groundwater Extraction (MCM)		Balance Annual Groundwater Availability (MCM		Stage of Development (%)	
		2003	**2013**	**2003**	**2013**	**2003**	**2013**	**2003**	**2013**
1	Pambar	312.41	334.78	15.92	30.06	296.49	304.72	5.10	**8.98**
2	Manimuthar	316.17	335.87	76.99	126.77	240.85	209.40	24.35	**37.74**
3	Kottakkaraiyar	316.05	459.28	34.22	79.68	281.83	379.60	10.83	**17.35**
	TOTAL	**944.63**	**1129.93**	**127.13**	**236.51**	**819.17**	**893.72**	**13.46**	**20.93**
	Change	**Increased by 19.62%**		**Increased by 86.03%**		**Increased by 9.10%**			

The reason for increase in Ground Water Availability of Pambar & Kottakkaraiyar River Basin is may be due to the impact of Return flow from Ground Water Irrigation.

6.7 Groundwater Quality

6.7.1 Introduction:

In recent years, the increasing threat to groundwater quality due to human activities has become a matter of great concern. The problems like growing population, sewage disposal, industrial waste, radioactive waste etc., have polluted the water resources alarmingly. The waste generated is not properly collected, treated and disposed, which leads to accumulation and infiltration, in turn causing groundwater contamination.

6.7.2 Objectives:

The main objectives of the ground water quality assessment are as follows:

1. To analyze the presence of various physico – chemical parameters of groundwater in the basin and to find its suitability for drinking, agriculture, irrigation and industrial purposes.
2. To understand the Ground water quality of the basin as an aid for optimal management of ground water resources.

6.7.3 Methodology:

SG&SWRDC, WRD, Tharamani, Chennai-113 is monitoring the Groundwater quality of the State, by collecting ground water samples from the observation wells located in all the river basins of Tamilnadu, twice a year, i.e during pre and the post monsoon period from 1972 onwards. Major cations and anions are analyzed from the water samples. There are 101 observation wells meant for water quality monitoring located in Pambar Kotakkaraiyar basin. However, the Geochemical analysis results of 101 observation wells, including the wells located adjacent to the basin boundary, were collected from SG & SWRDC and the ground water quality has been assessed spatially for the pre-monsoon period of the year 2017.

Another way of ground water quality assessment is, " Determination of Water Quality Index (WQI) ", which is adopted in this report. Water quality index provides a single number that expresses overall water quality at a certain location and time,. The idea of water quality index is to convert complex water quality data into information that is understandable and usable by the public. Water quality index based on some very important parameters is a simple indicator of water quality. In general, water quality indices incorporate data from multiple water quality parameters into a mathematical equation that rates the health of a water body / aquifer with a number.

6.7.4. Scenario of Groundwater quality of Pambar Kottakkaraiyar River Basin

Parameters such as Electrical Conductivity, pH, calcium, magnesium, sodium, potassium, bicarbonate, carbonate, sulphate, chloride, nitrate, fluoride, total dissolved solids, total hardness etc., were considered as important water quality parameters and important parameters are discussed below.

Based on the values of Total Dissolved Solids, 29 % of the basin area falls under good category, 60 % of the area falls under moderate and 11 % of the area falls under poor category as shown in figure 6.3.

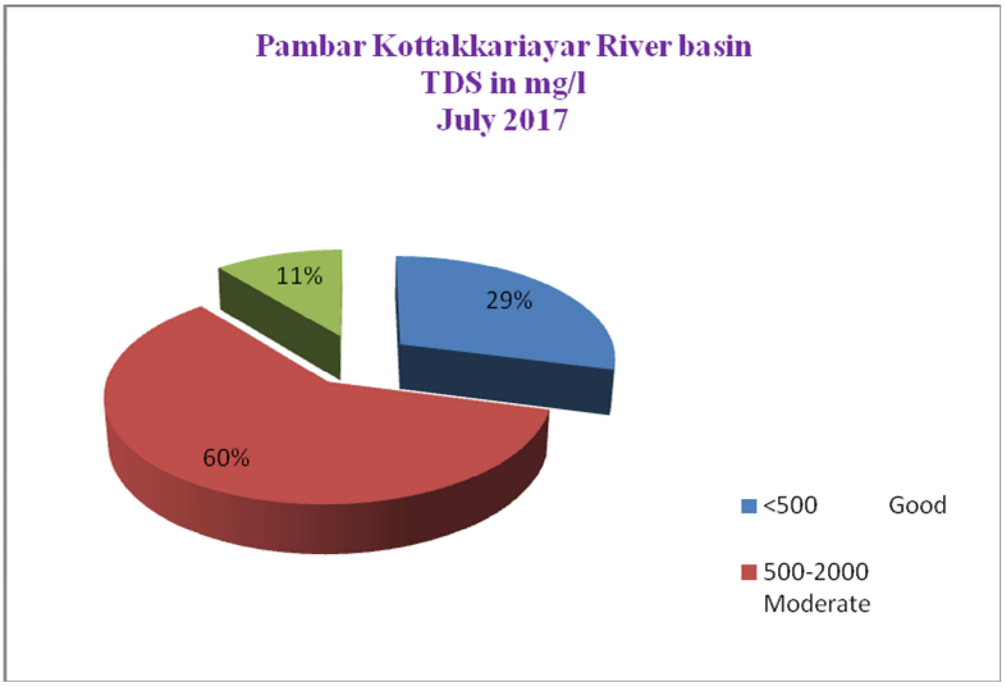


Fig. 6.3 TDS Concentration - Pre monsoon 2017

- The pH value lies within the permissible limit of 6.5 to 8.5 in almost all the wells in this basin.
- The analysis of total hardness shows that 61 % of samples have less than 300 mg / L, 27 % of samples have in the range of 300 to 600 mg / L and 12 % of samples have more than 600 mg/L as shown in **figure 6.4.**

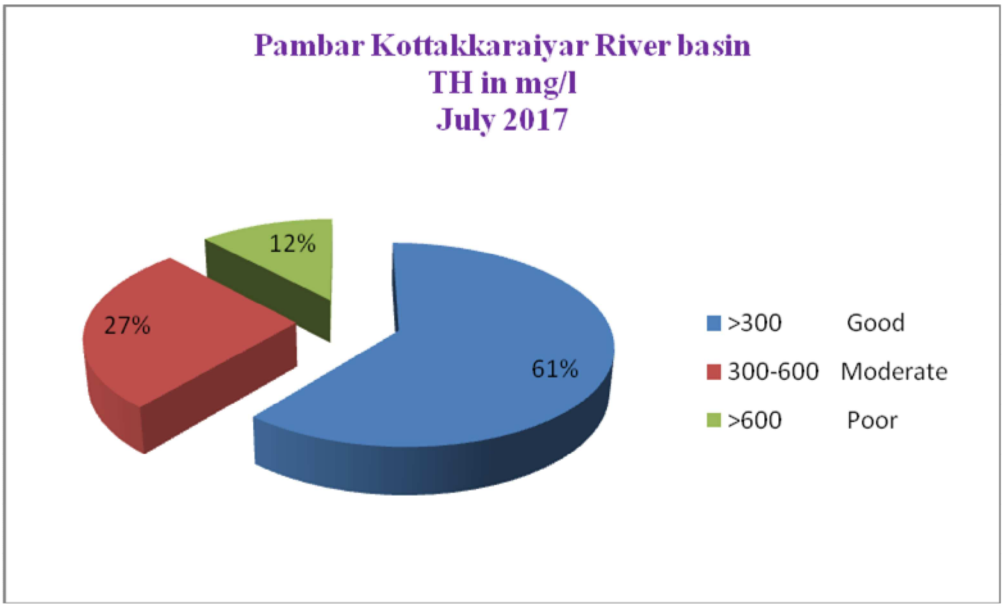
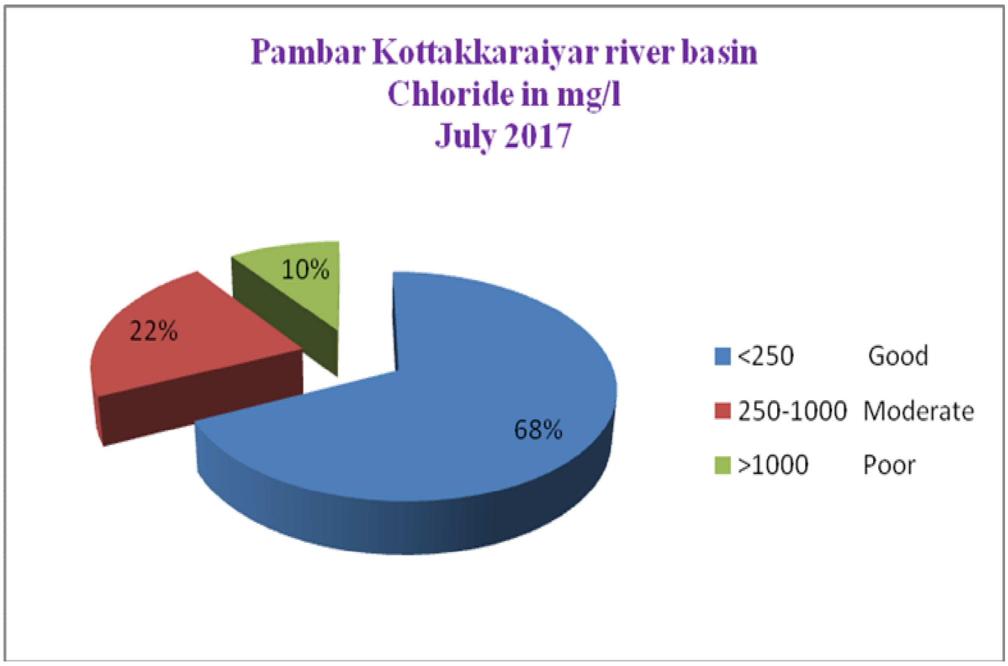


Fig. 6.4 Total Hardness Concentration - Pre monsoon 2017

- Analysis of chloride values show that 68% of samples have good quality of chloride , 22% of the samples have moderate value and 10% of samples comes under poor category.



- The nitrate value is within the permissible limit of 45 mg / L in the basin
- Fluoride value is also within the permissible limit of 1.5 mg / L in the basin.

6.7.5. Water Quality Index

For calculating the water quality index, eight important parameters such as Total Dissolved Solids (TDS), pH, Total Alkalinity (TA), Total Hardness (TH), Nitrate (NO3), Chloride (Cl), Sulphate (SO4) and Fluoride (F) were chosen and calculated by using the standards of drinking water quality, recommended by the Indian Council of Medical Research (ICMR) and Indian Standards Institution (ISI). The weighted arithmetic index method has been used for the calculation of WQI of the sampling locations. The WQI is calculated by using the expression given in equation (1)

$$\mathbf{WQI = \Sigma\, q_n W_n / \Sigma\, W_n} \qquad \text{------------- (1)}$$

Where, q_n = Quality rating of n^{th} water quality parameter

W_n = Unit weight of n^{th} water quality parameter

6.7.5.1 Quality rating (q_n)

The quality rating (q_n) is calculated using the expression given in equation (2)

$$q_n = [\,(V_n - V_{id}) / (\,S_n - V_{id})]\ x100 \text{ -------------- (2)}$$

Where,

V_n = Estimated value of nth water quality parameter at a given sample location

V_{id} = Ideal value for nth parameter in pure water

(V_{id} for pH = 7 and 0 for all other parameters)

S_n = Standard permissible value of n^{th} water quality parameter.

6.7.5.2 Unit weight

The unit weight (W_n) is calculated using the expression given in equation (3)

$$W_n = k / S_n \text{ ---------------- (3)}$$

Where,

S_n = Standard permissible value of nth water quality parameter

k = Constant of proportionality and it is calculated by using the expression given in equation (4)

$$k = [1 / (\Sigma 1 / S_{n=1,2..n})] \text{ ------------------(4)}$$

6.7.6 WQI and Status

The range of WQI, the corresponding status of water quality and their possible use are summarized in **Table 6.13.1** and the spatial distribution of the WQI is shown in **Plate PK-38.**

Table – 6.13.1 WQI and corresponding water quality status

Sl. No.	WQI	Status of water quality	Possible usages
1	0 - 25	Excellent	Drinking, Irrigation and Industrial
2	26 – 50	Good	Domestic, Irrigation and Industrial
3	51 – 75	Fair	Irrigation and Industrial
4	76 – 100	Poor	Irrigation
5	101 – 150	Very poor	Restricted use for irrigation
6	Above 150	Unfit for drinking	Proper treatment required before use.

6.7.7 Standard values and Unit Weight

For the purpose of calculation of WQI of Pambar Kottakkaraiyar basin, eight water quality parameters have been used. The higher values of water quality parameters will increase the WQI value. The standard values of water quality parameters and their corresponding ideal values and unit weight are arrived and given in **Table 6.13.2.** The calculated WQI values for all 101 sampling wells are given in **Table 6.13.3.**

Table 6.13.2 Standard values (Sn), Ideal values **(V_{id})** and Unit weight **(W_n)**

Sl.No	Parameters	S_n	Recommending agency for S_n	Ideal Value (V_{id})	K Value	Unit weight (W_n)
1	TDS	500	IS	0	0.8602	0.0017
2	pH	8.5	IS	7	0.8602	0.1012
3	TA	120	ICMR	0	0.8602	0.0072
4	TH	300	ICMR	0	0.8602	0.0029
5	NO3	45	IS	0	0.8602	0.0191
6	Cl	250	IS	0	0.8602	0.0034
7	SO4	200	IS	0	0.8602	0.0043
8	F	1	IS	0	0.8602	0.8602

Table 6.13.3 WQI values for the wells

Sl. no	Well No.	Lat	Long	$\Sigma q_n w_n$	Σw_n	$\Sigma q_n w_n / \Sigma w_n$ (WQI)
1	501054	10.1044	78.1255	62.6439	0.999999472	63
2	22072	10.3204	78.3368	38.2597	0.999999472	38
3	501016	10.0438	78.3627	13.9206	0.999999472	14
4	501017	10.0473	78.3773	23.5066	0.999999472	24
5	501019	10.1524	78.2996	22.3531	0.999999472	22
6	501020	10.0805	78.3202	25.7090	0.999999472	26
7	83096	10.0870	78.3585	25.5770	0.999999472	26
8	83505A	10.2244	78.2288	19.1135	0.999999472	19
9	21071	10.2836	78.3681	95.2003	0.999999472	95
10	179527	10.0430	78.4740	78.3742	0.999999472	78
11	24031	10.0507	78.4017	75.3173	0.999999472	75
12	24033	10.0209	78.4233	73.0938	0.999999472	73
13	26035	9.5825	78.4928	66.5085	0.999999472	67
14	504017	10.0458	78.4443	94.4728	0.999999472	94
15	504034	10.0146	78.4918	65.3467	0.999999472	65
16	504038	10.0223	78.4133	73.3005	0.999999472	73
17	504061	9.9969	78.4419	116.7144	0.999999472	117
18	504086	10.1416	78.3435	70.4192	0.999999472	70
19	504087	10.1458	78.3625	67.8596	0.999999472	68
20	504100	10.1230	78.4897	31.9275	0.999999472	32
21	83146	10.0547	78.5110	84.3061	0.999999472	84
22	83156B	10.0657	78.4728	75.9864	0.999999472	76
23	83166	10.1340	78.3158	67.7938	0.999999472	68
24	83257	10.0642	78.3606	127.5109	0.999999472	128
25	83260A	9.5745	78.5350	103.1455	0.999999472	103
26	22006D	10.2569	78.1219	77.8041	0.999999472	78
27	22011D	10.3550	78.1447	98.6889	0.999999472	99
28	22014D	10.3097	78.1419	49.5625	0.999999472	50
29	21026D	10.1383	78.1411	129.0449	0.999999472	129
30	83099	10.0750	78.1750	35.7133	0.999999472	36
31	21019D	10.1556	78.3692	47.4980	0.999999472	47

32	21020D	10.2472	78.3861	36.7777	0.999999472	37
33	21022D	10.0861	78.2917	12.9689	0.999999472	13
34	21023D	9.9983	78.4300	40.1361	0.999999472	40
35	22023D	10.2153	78.2900	49.8328	0.999999472	50
36	83095	10.0844	78.2889	75.6386	0.999999472	76
37	26003	9.8061	78.9461	134.5282	0.999999472	135
38	26004	9.7181	78.8208	101.0889	0.999999472	101
39	26006	9.5833	78.4556	132.4793	0.999999472	132
40	26009	9.4972	78.7583	148.2600	0.999999472	148
41	83139B	9.7833	78.9333	70.7206	0.999999472	71
42	83140C	9.7000	79.0181	133.2675	0.999999472	133
43	83141B	9.6391	78.8411	105.6272	0.999999472	106
44	83152	9.8464	79.0511	15.4459	0.999999472	15
45	83277	9.4097	78.7667	147.6034	0.999999472	148
46	83279A	9.4278	78.9000	40.4489	0.999999472	40
47	24001D	10.1867	78.6644	75.6762	0.999999472	76
48	24004D	10.1386	78.4808	87.9452	0.999999472	88
49	24006D	10.1372	78.4108	73.0386	0.999999472	73
50	24007A	10.2250	78.7639	72.3435	0.999999472	72
51	24008D	10.2167	78.5417	55.1497	0.999999472	55
52	24009A	10.3472	78.3975	21.1184	0.999999472	21
53	24014	10.3500	78.4750	69.5667	0.999999472	70
54	24017	9.8500	78.5500	83.5583	0.999999472	84
55	24018	9.8639	78.5528	79.9207	0.999999472	80
56	24021	10.1139	78.9292	80.6730	0.999999472	81
57	24022	9.7778	78.7417	70.2608	0.999999472	70
58	24023	10.0764	78.9181	91.3239	0.999999472	91
59	26001	9.8917	78.8833	80.7262	0.999999472	81
60	83127B	9.8500	78.6333	46.6255	0.999999472	47
61	83150	9.9108	78.7644	74.2794	0.999999472	74
62	83153	10.0458	78.9042	76.8368	0.999999472	77
63	83158	10.1417	78.6917	27.1472	0.999999472	27
64	83165A	10.0625	78.5625	86.9486	0.999999472	87

65	83239A	9.8958	78.4611	144.5593	0.999999472	145
66	83242	9.7603	78.5411	119.7509	0.999999472	120
67	83258	9.9122	78.6742	45.1235	0.999999472	45
68	83264	9.8319	78.7764	55.7444	0.999999472	56
69	73363	10.0133	78.7925	81.1577	0.999999472	81
70	11008D	10.5306	78.2389	50.4896	0.999999472	50
71	11011D	10.4903	78.3250	53.2746	0.999999472	53
72	73137	10.3889	78.3611	48.9712	0.999999472	49
73	11053	10.3231	78.3858	31.8958	0.999999472	32
74	43045	10.1722	79.0000	23.6514	0.999999472	24
75	43090	10.0333	79.0167	18.0180	0.999999472	18
76	73281A	10.1694	79.0000	66.8627	0.999999472	67
77	73370	9.9311	79.0822	92.9918	0.999999472	93
78	73371	10.1053	79.0711	69.7702	0.999999472	70
79	77324	10.0736	79.0403	52.2677	0.999999472	52
80	MMWS PDK3	10.1986	78.9667	30.1538	0.999999472	30
81	73375	9.9786	79.1986	39.5262	0.999999472	40
82	73376	10.0739	79.1181	13.3815	0.999999472	13
83	12045D	10.0542	78.9542	86.8825	0.999999472	87
84	12011D	10.3133	78.5431	69.8343	0.999999472	70
85	12022D	10.1917	78.7611	112.9945	0.999999472	113
86	12023D	10.3403	78.7542	48.5045	0.999999472	49
87	12024D	10.3569	78.5236	61.1309	0.999999472	61
88	12025D	10.2944	78.6333	23.0266	0.999999472	23
89	12026	10.2000	78.4986	62.6329	0.999999472	63
90	12027D	10.2986	78.7903	29.1299	0.999999472	29
91	73149	10.3100	78.6361	46.3374	0.999999472	46
92	73155	10.2222	78.7206	83.0191	0.999999472	83
93	73162	10.1519	78.8472	11.6945	0.999999472	12
94	73166	10.2681	78.8306	53.1509	0.999999472	53
95	73378	10.2847	78.7003	23.6322	0.999999472	24
96	73379	10.2336	78.6503	39.4582	0.999999472	39

97	12038D	10.0486	79.1639	33.6539	0.999999472	34
98	12053	9.9286	79.1467	27.6669	0.999999472	28
99	73150	10.3106	78.7261	40.8591	0.999999472	41
100	43088	9.9194	79.1417	77.5227	0.999999472	78
101	12044D	9.9028	79.0792	51.8941	0.999999472	52

Based on the index value, all the sampling wells are reclassified. The number of samples fall in the index category, qualitative status with possible usages are tabulated and given in **Table 6.13.4.**

Table 6.13.4 Classification based on WQI

Sl.No.	WQI	No of samples	%	Status	Possible usages
1	0 – 25	13	13	Excellent	Drinking, Irrigation & Industrial
2	25 -50	26	26	Good	Domestic, Irrigation & Industrial
3	51 – 75	26	25	Fair	Irrigation & Industrial
4	76 - 100	22	22	Poor	Irrigation
5	101 – 150	14	14	Very poor	Restricted use for irrigation
6	>150	Nil	Nil	Unfit	Proper treatment required.

6.7.8 Results and Discussion

WQI may be defined as the reflection of composite influence of different quality parameters on the overall quality of water. WQI of the Pambar Kottakkaraiyar river basin reveals that 13 % of the total samples are falling in excellent category, 26 % samples are good , 25 % samples are fair, 22 % samples are poor and 14 % are very poor. The pictorial representation of WQI category is shown in **figure 6.5.**

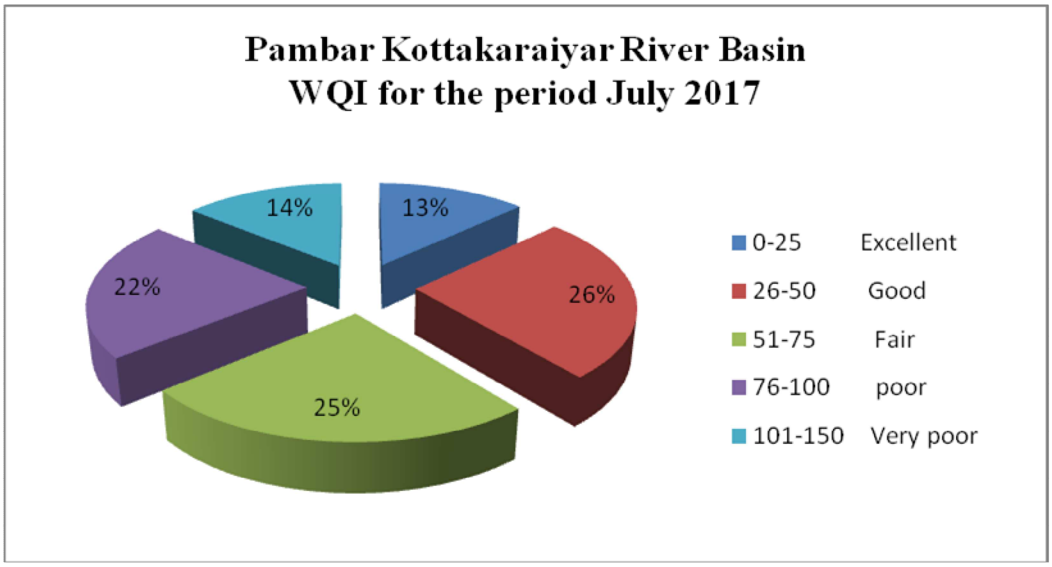


Fig. 6.5 Pictorial representation of WQI

Water Quality Index less than 25 is found in small parts of Nattam, Thirumayam, Arimalam,Thiruvadanai and Avudaiyarkoil blocks. The list of sample wells which is having less than 25 WQI value is given in **Table 6.13.5**

Table 6.13.5 Sample Wells - WQI Value Range < 25

Sl.No.	Well No	Village	WQI
1	501016	Navinipatti	14
2	501017	Keelaiyur	24
3	501019	Kasampatti	22
4	83505A	Natham forest office	19
5	21022D	Pulipatti	13
6	83152	Oriyur	15
7	24009A	K.Dharmapatti	21
8	43045	Nagaram	24
9	43090	Okkur	18
10	73376	Perumaruthur - 1	13
11	12025D	Sevalur	23
12	73162	Kallur Rayavaram	12
13	73378	Virachilai - 1	24

WQI with the range of 26-50 were found in major parts of Nattam, Kottampatti, northern part of Thirupatthur, parts of Thirumayam, Kallal, Kalaiyarkoil, Sennampattipudur central part of Arimalam,small parts of Sakkottai, Aranthangi, Avudaiyarkoil, Manamelkudi, Ponnamaravathi and Thiruvadanai blocks. The list of sample wells which having the WQI value range 26-50 is given in **Table 6.13.6**

Table 6.13.6 Sample Wells - WQI Value Range 26-50

Sl.No.	Well No.	Village	WQI
1	22072	Surapatti	38
2	501020	Sennagarampatti	26
3	83096	Thumbalapatti	26
4	504100	Melaiyur	32
5	22014D	Pudupatti	50
6	83099	Kadavur	36
7	21019D	Karungalakudi	47
8	21020D	Pallapatti	37
9	21023D	Uranganpatti	40
10	22023D	Samutrapatti	50
11	83279A	Chittarkottai	40
12	83127B	Kalayarkoil	47
13	83158	Nemam	27
14	83258	Vettiyur	45
15	11008D	Nadupatti	50
16	73137	Manjampatti	49
17	11053	Sevanthanpatti	32
18	MMWS PDK3	Aliyanilai	30
19	73375	Kottaipattinam	40
20	12023D	Peraiyur	49
21	12027D	Thekkattur	29
22	73149	Mekkinipatti	46
23	73379	Rangiyam	39
24	12038D	Manalur	34
25	12053	Mimisal	28
26	73150	Lembalakudy	41

WQI value range of 51–75 is found in small parts of Nattam, Kottampatti, Sennampattipudur, Ponnamaravathi, parts of Singampunari, Thirupatthur, Kallal, Devakottai, Kalaiyarkoil, Sakkottai, Avudaiyarkoil and Manamelkudi blocks. The list of sample wells falls in this range is given in **Table 6.13.7.**

Table 6.13.7 WQI Value Range 51-75

Sl. No.	Well No.	Village	WQI
1	501054	Manickampatti	63
2	24031	Nachiyarpuram	75
3	24033	Kuthalur	73
4	26035	Kandadevi	67
5	504034	Unjanai	65
6	504038	Alangudi	73
7	504086	Thuvar	70
8	504087	Maruthipatti	68
9	83166	Nerkuppai	68
10	83139B	Thiruvadanai	71
11	24006D	Kottaivengampatti	73
12	24007A	Nemathampatti	72
13	24008D	Nerkuppai	55
14	24014	Varappur	70
15	24022	Kulamangalam	70
16	83150	Kallankudi	74
17	83264	Kayankadu	56
18	11011D	Karuppur	53
19	73281A	Aranthangi	67
20	73371	Kidangivayal	70
21	77324	Avudaiyarkoil	52
22	12011D	Thuthur	70
23	12024D	Nagarappatti	61
24	12026	Thirukalambur	63
25	73166	Menampatti	53
26	12044D	Thiyathur	52

WQI value range of 76 – 100 is noticed in small parts of Singampunari, Thirupatthur, Sivagangai, Kalaiyarkoil, Thirumayam, Sakkottai, Kannankudi, Devakottai,Thiruvadanai and Ramanathapuram blocks.The list of wells falls in the WQI range of 76-100 is given in **Table 6.13.8.**

Table 6.13.8 WQI Value Range 76-100

Sl.No.	Well No.	Village	WQI
1	21071	Pottapatty	95
2	179527	Devakottai	78
3	504017	Kovilur	94
4	83146	Sakkottai	84
5	83156B	Kottaiyur	76
6	22006D	Vembarpatti	78
7	22011D	Kambiliampatti	99
8	83095	Pulipatti	76
9	24001D	Keelsevalpatti	76
10	24004D	S. Koilpatti	88
11	24017	Kalayarkoil	84
12	24018	Nattarasankottai	80
13	24021	Sengarai	81
14	24023	Jeyamkondon	91
15	26001	Tiruppakottai	81
16	83153	Mithiravayal	77
17	83165A	Thirukkostiyur	87
18	73363	Valmalpalaiyam (south)	81
19	73370	Ponpette	93
20	12045D	Madagam	87
21	73155	Thunaiyanur	83
22	43088	Mimisal	78

WQI value range of 101 – 150 is seen in the major parts of R.S.Mangalam, Ilaiyankudi, Nainarkoil and in the small parts of Kalaiyarkoil, Sivagangai, Ramanathapuram and Manamadurai blocks. The wells which are having the WQI value range of 101-150 are listed in **Table 6.13.9.**

Table 6.13.9 WQI Value Range 101 – 150

Sl.No.	Well No.	Village	WQI
1	504061	Alagichipatti	117
2	83257	Manakkudi	128
3	83260A	Puthurani	103
4	21026D	Senthamangalam	129
5	26003	Pandukudi	135
6	26004	Ayangudi	101
7	26006	Parthibanur	132
8	26009	S.V.Mangalam	148
9	83140C	Thondi	133
10	83141B	R.S.Mangalam	106
11	83277	Viravanendal	148
12	83239A	Pudupatti	145
13	83242	Sattarasan Kottai	120
14	12022D	Aranmanaippatti	113

6.7.9 Conclusion:

- In general, the quality of groundwater is "good to moderate" in Pambar Kottakkaraiyar river basin except in very few locations.
- The reason for higher values of physical – chemical parameter at certain wells may be due to the unscientific disposal of solid wastes, the depth of wells and the composition of rocks and soils which has direct influence on water quality.
- Recharging rain water into the aquifers helps in improving the quality of existing groundwater through dilution of certain physico chemical contents.

Table 6.14 Indian Standards For Drinking Water (BIS 10500 : 1991)

Sl.No	Substance or Characteristic	Requirement Desirable Limit	Permissible limit in the absence of Alternate source
Essential Characteristics			
1	Colour, (Hazen units), Max	5	25
2	Odour	Unobjectionable	--
3	Taste	Agreeable	--
4	Turbidity (NTU), Max	5	10
5	pH Value	6.5 to 8.5	No Relaxation
6	Total Hardness (as $CaCo_3$) mg/L, Max	300	600
7	Iron (as Fe) mg/L, Max	0.3	1
8	Chlorides (as Cl) mg/L, Max.	250	1000
9	Residual, free chlorine, mg/L, Min	0.2	--
10	Fluoride (as F) mg/L, Max	1	1.5
Desirable Characteristics			
11	Total Dissolved solids mg/L, Max	500	2000
12	Calcium (as Ca) mg/L, Max	75	200
13	Magnesium (as mg) mg/L, Max	30	100
14	Copper (as Cu) mg/L, Max	0.05	1.5
15	Manganese (as Mn)mg/L, Max	0.1	0.3
16	Sulfate (as SO_4) mg/L, Max	200	400
17	Nitrate (as NO_3) mg/L, Max	45	No Relaxation
18	Phenolic Compounds (as C_6H_5OH) mg/L, Max	0.001	0.002
19	Mercury (as Hg) mg/L, Max	0.001	No relaxation
20	Cadmium (as Cd) mg/L, Max	0.01	No relaxation
21	Selenium (as Se) mg/L,Max	0.01	No relaxation
22	Arsenic (as As) mg/L, Max	0.01	No relaxation
23	Cyanide (as CN) mg/L, Max	0.05	No relaxation
24	Lead (as Pb) mg/L, Max	0.05	No relaxation
25	Zinc (as Zn) mg/L, Max	5	15
26	Anionic detergents (as MBAS) mg/L, Max	0.2	1
27	Chromium (as Cr^{6+}) mg/L, Max	0.05	No relaxation
28	Poly nuclear aromatic hydrocarbons (as PAH) mg/L, Max	--	--
29	Mineral Oil mg/L, Max	0.01	0.03
30	Pesticides mg/L, Max	Absent	0.001
31	Radioactive Materials		
	i. Alpha emitters Bq/L, Max	--	0.1
	ii. Beta emitters pci/L, Max	--	1
32	Alkalinity mg/L, Max	200	600
33	Aluminium (as Al) mg/L, Max	0.03	0.2
34	Boron mg/L, Max	1	5

Table 6.15 (a) Standards of Water Quality for Construction

Sl.No	Parameter	Limit
1	Sodium & Potassium Carbonate & Bicarbonate	Upto 1000 ppm
2	Calcium Bicarboante and Magnesium Bicarbonate	400 ppm
3	Silt and Sediments	2000ppm

Table 6.15 (b) Tolerance Limit of Sulphate Used For Reinforced Concrete

Sl.No.	Sulphate Concentration (mg/l)	Effect on RCC
1	0 - 150	Negligible
2	150 - 1000	Positive
3	1000 - 2000	Considerable
4	Above 2000	Severe

Table 6.16. (a) Safe limits of Electrical Conductivity of water for Agriculture

Sl.No	Nature of soil	Crop growth	Upper permissible limit of EC in water µmhos/cm at 25˚C
1	Deep black soil and alluvial soils having clay content more than 30% soils that are fairly to moderately well drained.	Semi-tolerant	1500
		Tolerant	2000
2	Heavy textured soils having clay contents of 20-30% soils that are well drained internally and have good surface drainage system.	Semi-tolerant	2000
		Tolerant	4000
3	Medium textured soils having clay 10-20% internally very well drained and having good surface drainage system.	Semi-tolerant	4000
		Tolerant	6000
4	Light textured soils having clay less than 10% soil that have excellent internally and surface drainage system.	Semi-tolerant	6000
		Tolerant	8000

Table 6.16(b)
Guidelines for Evaluation of quality of water for Agriculture

Water class	Sodium (Na) %	EC µmhos/cm at 25˚C	Alkalinity hazards	
			SAR	RSC (meq/1)
Excellent	<20	<250	<10	<1.25
Good	20-40	250-750	10-18	1.25-2.0
Medium	40-60	750-2250	18-26	2.0-2.5
Bad	60-80	2250-4000	>26	2.5-3.0
Very bad	>80	>4000	>26	>3.0

Table 6.16 (c)
Rating of irrigation water based on Boron concentration in the water (U.S. Salinity Laboratory Staff)

Class of water	Boron concentration, mg/l		
	Sensitive Crops	Semi-tolerant crops	Tolerant crops
Excellent	< 0.33	< 0.67	< 1.00
Good	0.33 – 0.67	0.67 – 1.33	1.00 – 2.00
Permissible	0.67 – 1.00	1.33 – 2.00	2.00 – 3.00
Doubtful	1.00 – 1.25	2.00 – 2.50	3.00 – 3.75
Unsuitable	> 1.25	> 2.50	> 3.75

Table 6.16 (d)
Trace elements tolerance for irrigation waters (Environment Studies Board, 1973)

Trace Element	Trace elements tolerance limit mg/l	
	Acid soils or all soils in continuous use	Fine textured alkaline soils
Aluminium	5.0	20.0
Arsenic	0.1	2.0
Beryllium	0.1	0.5
Boron	0.5	1.0
Cadmium	0.01	0.05
Chromium	0.10	1.0

Cobalt	0.05	5.0
Copper	0.20	5.0
Iron	5.0	20.0
Lead	5.0	10.0
Lithium	2.5	2.5
Manganese	0.2	10.0
Molybdenum	0.01	0.01
Nickel	0.2	2.0
Vanadium	0.1	1.0
Zinc	2.0	10.0

Table 6.16 (e)
Tolerance Limits for Industrial Effluents (IS: 2490, Part-I-1981)

Sl.No	**Characteristic**	**Maximum tolerance limits for industrial effluents discharged (mg/l)**			
		Into inland surface water	**Into public sewers**	**On land for irrigation**	**Marine/Coastal Area**
1	Colour and Odour	Absent	-	Absent	Absent
2	Suspended solids	100	600	200	a)For Process waste water 100 b)For cooling water effluent 10 percent above total suspended matter of effluent
3	Particle size of suspended solids	Shall pass 850 micron IS Sieve	-	-	a)Floatable solids, max. 3 mm b)Settleable solids max 856 microns
4	Dissolved solids (inorganic)	2100	2100	2100	-
5	pH value	5.5 to 9.0	5.5 to 9.0	5.5 to 9.0	5.5 to 9.0
6	Temperature ˚C	Shall not exceed 40 in any section of the stream within 15 meters downstream from the effluent outlet	45 at the point of discharge	-	-
7	Oil and grease	10	20	10	20
8	Total residual chlorine	1.0	-	-	1.0

9	Ammonical nitrogen (as N)	50	50	-	50
10	Total kjeldahl nitrogen (as N)	100	-	-	100
11	Free ammonia (as NH3)	5.0	-	-	5.0
12	BOD (5 days at 20˚C)	30	350	100	100
13	Chemical Oxygen Demand	250	-	-	250
14	Arsenic (as As)	0.2	0.2	0.2	0.2
15	Mercury (as Hg)	0.01	0.01	-	0.01
16	Lead (as Pb)	0.1	1.0	-	2.0
17	Cadmium (as Cd)	2	1.0	-	2.0
18	Hexavalant Chromium (as Cr+6)	0.1	2.0	-	1.0
19	Total Chromium (as Cr)	2.0	2.0	-	2.0
20	Copper (as Cu)	3.0	3.0	-	30
21	Zinc (as Zn)	5.0	15	-	15
22	Selenium (as Se)	0.05	0.05	-	0.05
23	Nickel (as Ni)	3.0	3.0	-	-
24	Boron (as B)	2.0	2.0	2.0	-
25	Percent sodium	-	60	60	-

Table 6.16 (f)
Effects of water quality parameters being used in Industries

Sl.No.	Parameters	Prescribed limits IS:10500, 1991		Probable effects
		Desirable limit	Permissible limit	
1	pH value	6.5	8.2	Low pH increases corrosion of concrete, pH 7.0 is required for most of the industries, pH 2.7- 7.2 advised for carbonated beverage industry.
2	Total dissolved solids, mg/l	50	3000	Causes foaming in boilers and solids interfere with clearness, colour or taste of finished products. Low TDS value are required in most industries. High TDS leads to corrosion.
3	Iron mg/l	0.1	2.0	Recommended value for food processing units is 0.2, for paper and photographic industry iron of 0.1 mg/l is recommended, iron less than 0.1 mg/l is recommended in cooling waters.
4	Chloride mg/l	25	200	Significantly affect the rate of corrosion of steel and Aluminium.
5	Fluoride mg/l	0.2	1.0	Harmful in industries involved in production of food beverages, pharmaceuticals .
6	Calcium 20 mg/l	20	500	High calcium leads to spots on films. It has undesirable effects like forming scale, precipitations and curding.. It may interfere in formation of emulsions and processing of colloids upsetting fermentation process and electroplating rinsing operation.
7	Magnesium mg/l	5	30	-
8	Sulphate mg/l	25	250	Increases corrosiveness of water towards concrete, low sulphates (20 mg/l) is recommended for sugar industries.
9	Nitrate mg/l	15	30	Injurious to dyeing of wool and silk fabrics and harmful in fermentation process for brewing.
10	Copper mg/l	0.01	0.5	Copper is undesirable in food industry as it has colour reactions and impart fishy taste to finished products. Affects smoothness and brightness of metal deposits in metal plating, baths etc.

11	Chromium mg/l	N.A.	N.A.	It is a corrosion inhibitor
12	Zinc	N.A.	N.A.	Water having zinc should not be used in artificial beverages / soft drinks like lemonade.
13	Lead	N.A.	N.A.	Traces of lead in metal plating baths will affect smoothness and brightness of deposits.

6.8 Management of Groundwater Resources

Studies show that groundwater recharge and discharge conditions are reflection of the precipitation regime, climatic variables, landscape characteristics and human impacts. Hence, predicting the behavior of recharge and discharge conditions under changing climate is of great importance for groundwater conservation & management.

The groundwater crisis prevailing in the State is not only due to natural factors, but also due to human interventions. The number of wells drilled for irrigation ie. both for food grains and for cash crops have rapidly and indiscriminately increased. India's rapidly growing population and changing lifestyles have also increased the domestic water demand. Similarly, the industrial demand has also increased. Hence, management of groundwater is an essential requirement and it requires an understanding of balancing the management on supply side and demand side.

6.8.1.1 Supply-side Management of Groundwater

Constructing Artificial Recharge Structures like check dams, percolation ponds, recharge pits, shafts or wells are considered to be the best option in rural areas for recharging groundwater where soil condition is favourable. Accordingly favorable groundwater recharge sites are identified with the application of GIS after focusing appropriate weight-age for spatial and non-spatial parameters like geo-morphology, geology, lineament, depth to bed rock, soil, aquifer and rainfall level.On the other hand, roof-top rainwater harvesting, either as direct use or recharge into the aquifers is suited for urban habitations with its characteristic space constraints.

Many structural measures have been taken by the Government to increase the groundwater availability. Various State Government agencies namely, Water Resources Department, Agricultural Department, Agricultural Engineering Department, TWAD Board and Forest Department with and without Central Government assistance have taken up augmentation of ground water resources through artificial recharge structures.

Success of Artificial Recharge Structures (ARS) depends largely on geological and hydrological features of an area and design of ARS. Percolation ponds, check dams, recharge shafts and sub-surface barriers are effective structures in hard rock areas, recharge trench and recharge tube wells are more suitable in alluvial areas. In the coastal zone, tidal regulators which impound the fresh water upstream and enhance the natural recharge, help control salinity ingress effectively. In case of urban areas and hilly terrains with high rainfall, roof top rain water structures are most useful.

Data on Artificial Recharge Structures (ARS) constructed in the recent years were obtained from the office of Chief Engineer, Madurai Region, WRD, PWD. The list of ARS constructed in Pambar Kottakkaraiyar basin is listed in **Table 6.13**.

Table 6.17 List of ARS constructed by WRD in Pambar Kottakkaraiyar Basin

Sl. No	Name of Work	G.O. No.	Project Cost Rs. in lakh	Name of the Sub Basin	Latitude	Longitude
1	Construction of Check Dams across Virusuliyar river to feed Kummangudi tank, Nedumaram big tank and providing recharge shaft in Nedumaram big tank and Thiruppathur big tanks in Virusuliyar minor basin of Manimuthar sub basin in Thiruppathur taluk of Sivagangai district.	43PW (WR1) Dept. Dt26.2.07	74.14	Manimuthar	10°07"20'	78°36"55'
2	Construction of Check Dam across Palar River nead Muraiyur Village in Thiruppathur taluk of Sivagangai District	216 PW (WR1) Dept. Dt.6.9.13	145.50	Manimuthar	10°08"42	78°30"33
3	Construction of Check dam across Virisuliyar river near Veliyathur village of Thiruppathur taluk in Sivagangai District.	216 PW (WR1) Dept. Dt.6.9.13	46.60	Manimuthar	10°03'12"	78°38'42"
4	Construction of check dam across odai in S.F.No.5 in Reddiapatti village of Natham Taluk in Dindigul District.	243/dated PW(WR2) Dept/ dated 05.08.08	26.40	Manimuthar	10^{0}9'37	78^{0}14'45"
5	Construction of check dam across odai in S.F.No.692 in Aravankuruchi village of Natham Taluk in Dindigul District.	243/dated PW(WR2) Dept/ dated 05.08.08	18.60	Manimuthar	10^{0}16'07"	78^{0}15'00"

6	Construction of check dam across Thirumanimuthar river near Natham village of Natham Taluk in Dindigul District.	G.O.Ms.No .286/ PWD/(R2) Dept dt.04.12.09	10.35	Manimuthar	$10^0$13'12"	$78^0$14'19"
7	Construction of check dam across Thirumanimuthar river in S.F.No.47 of Natham village of Natham Taluk in Dindigul District.	G.O.Ms.No .291/PWD/ (R2) Dept dt.09.12.09	15.00	Manimuthar	$10^0$12'15"	$78^0$15'25"
8	Construction of check dam across Thirumanimuthar river in S.F.No.103 in Samudrapatti village of Natham Taluk in Dindigul District.	G.O.Ms.No .291/PWD/ (R2)Dept dt.09.12.09	15.00	Manimuthar	$10^0$12'26"	$78^0$17'00"
9	Construction of check dam across Thirumanimuthar river in S.F.No.369 in Uralipatti village of Natham Taluk.	G.O.Ms.No .291/PWD/ (R2)Dept dt.09.12.09	10.00	Manimuthar	$10^0$12'20"	$78^0$15'13"
10	Construction of check dam across Palar river in S.F.No.260 in Sirangattupatti village of Natham Taluk.	G.O.Ms.No .291/PWD/ (R2)Dept dt.09.12.09	15.00	Manimuthar	$10^0$21'39"	$78^0$15'31"
11	Construction of check dam across Kalladiyar odai near Pudupatti village hamlet of Nadumandalam village of Natham Taluk in Dindigul District.	G.O.Ms.No .312/ PWD/(R2) Dept dt.22.10.10	10.00	Manimuthar	$10^0$15'30"	$78^0$15'10"
12	Construction of check dam across Palar river to feed Alwarchettikulam tank near Pudur village hamlet of Sirangattupatti village of Natham Taluk.	G.O.Ms.No .312/ PWD/(R2) Dept dt.22.10.10	20.00	Manimuthar	$10^0$22'26.18"	78^0 16'28.33"
13	Construction of check dam across Mudimalaiyar odai in Sendurai village of Natham Taluk in Dindigul District.	G.O.Ms.No .312/ PWD/(R2) Dept dt.22.10.10	22.00	Manimuthar	$10^0$15'25"	$78^0$10'15"
14	Construction of check dam across Virisalar odai in Pudupatti village of Natham Taluk in Dindigul District.	G.O.Ms.No .312/ PWD/(R2) Dept dt.22.10.10	10.50	Manimuthar	$10^0$13'12"	$78^0$14'19"

15	Construction of check dam across Thirumanimuthar near Mulaiyur village in Natham Taluk in Dindigul District.	G.O.(3D). No.38/ PW(W1)D. / dt.19.09.18	59.31	Manimuthar	10^{0}12'29"	78^{0}09'36"
16	"Construction of an anicut across Palar river to feed Rettaikulam tank and other tanks in Pottalpatti village of Melur taluk in Madurai district".	G.O.(3D) No. 6 PW (W1)D Dt. 24.03.2017	294.72 Lakhs	Manimuthar	10°17'50"	78°22'34"
17	Rehabilitation of Palapatti old anicut, Kottankulam anicut across Palar rier at Pallapatti village and Kottankulam kanmoi surplus course of Kottampatti village of Melur taluk in Madurai District.	Go. Ms. No. 216 PW (W2) D Dt.13.10.2014	125.00 Lakhs	Manimuthar	10°17'28"	78°22'49

6.8.1.2 Artificial Recharge Measures

Even though the groundwater extraction is only 20.93% in the net groundwater availability, artificial recharge measures are proposed for further groundwater improvement.

Based on the GIS analysis, considering the different thematic layers which are favourable and influencing artificial recharge of ground water, the following locations listed in the Table 6.19 are selected which are falling in the Safe and Saline/Poor-quality category (as per 2013 Groundwater Assessment) of Firkas. Even though the many locations are falling under the Safe category, these locations are suggested for further field investigations based on the reasons given below.

Shaft 1-9 : These locations are suggested to recharge the depleting aquifer known as Sambayuthu Aquifer.

Shaft 10-18 : These locations are suggested as a proactive measure to prevent sea water intrusion since the area is vulnerable for sea water intrusion.

Shaft 19-21 : These locations are suggested to dilute the salinity of that area.

Shaft 22-24 : These locations are suggested to revive the extinct spring in Marathur village.

However, all these locations require ground validation at the time of implementation.

Table 6.18 ARS Recommended: Vertical Shaft in WRD Tanks

Shaft Sl. No.	Location	Latitude	Longitude	Tank Unique ID	Sub Basin	Firka	Category as on 2013.
1	Kalanivasal	10° 5' 17.780" N	78° 44' 29.195" E	TNPK-02-T0782	Pambar	Karaikudi	Safe
2	Kovilur	10° 4' 21.922" N	78° 44' 50.225" E	TNPK-02-T0862	Pambar	Karaikudi	Safe
3	Karaikudi	10° 4' 0.797" N	78° 45' 16.780" E	TNPK-02-T0884	Pambar	Karaikudi	Safe
4	Karaikudi	10° 3' 13.943" N	78° 44' 49.957" E	TNPK-02-T0937	Pambar	Karaikudi	Safe
5	Karaikudi	10° 3' 6.023" N	78° 45' 23.662" E	TNPK-02-T0952	Pambar	Karaikudi	Safe
6	Ariyakudi	10° 2' 14.286" N	78° 46' 47.623" E	TNPK-02-T1023	Pambar	Sakkottai	Safe
7	Ariyakudi	10° 3' 5.683" N	78° 46' 53.534" E	TNPK-02-T0955	Pambar	Sakkottai	Safe
8	Amaravathi	10° 2' 1.437" N	78° 46' 2.394" E	TNPK-02-T1035	Pambar	Karaikudi	Safe
9	Kalanivasal	10° 4' 37.982" N	78° 45' 35.608" E	TNPK-02-T0828	Pambar	Karaikudi	Safe
10	Naganendal	9° 35' 41.813" N	78° 54' 15.690" E	TNPK-03-T1997	Kottakkaraiyar	Solandur	Safe
11	Adanthanakottai	9° 36' 58.394" N	78° 53' 13.500" E	TNPK-03-T1975	Kottakkaraiyar	Solandur	Safe
12	Erumaipatty	9° 31' 13.673" N	78° 51' 35.951" E	TNPK-03-T2057	Kottakkaraiyar	Devipattinam	Safe
13	Paranur	9° 39' 5.650" N	78° 51' 58.491" E	TNPK-03-T1944	Kottakkaraiyar	Solandur	Safe
14	A.Manakkudi	9° 40' 26.313" N	78° 56' 46.410" E	TNPK-03-T1916	Kottakkaraiyar	Thondi	Saline/Poorquality
15	A.Manakkudi	9° 40' 15.006" N	78° 55' 57.412" E	TNPK-03-T1919	Kottakkaraiyar	Thondi	Saline/Poorquality
16	Kanathagudi	9° 42' 46.380" N	78° 58' 58.753" E	TNPK-03-T1866	Kottakkaraiyar	Thondi	Saline/Poorquality
17	Thalirmarungur	9° 46' 3.878" N	78° 59' 14.697" E	TNPK-01-T1778	Manimuttar	Thondi	Saline/Poorquality
18	Thalirmarungur	9° 47' 1.692" N	78° 58' 16.912" E	TNPK-01-T1765	Manimuttar	Thondi	Saline/Poorquality
19	Sirukambiyur	9° 52' 26.276" N	79° 1' 4.405" E	TNPK-02-T1582	Pambar	Pullur	Safe
20	Periyamadaipaichal	9° 57' 1.610" N	79° 9' 25.144" E	TNPK-02-T1369	Pambar	Kottaipattinam	Saline/Poorquality
21	Periyamadaipaichal	9° 56' 19.208" N	79° 9' 0.474" E	TNPK-02-T1417	Pambar	Kottaipattinam	Saline/Poorquality
22	Marakathur	9° 48' 23.338" N	78° 41' 10.400" E	TNPK-03-T1729	Kottakkaraiyar	Kalaiyarkovil	Safe
23	Marattur	9° 47' 16.241" N	78° 40' 50.230" E	TNPK-03-T1738	Kottakkaraiyar	Kalaiyarkovil	Safe
24	Neduvathavu	9° 46' 58.818" N	78° 41' 3.387" E	TNPK-03-T1751	Kottakkaraiyar	Kalaiyarkovil	Safe

In addition to above listed Vertical Shafts the following Check Dams are also proposed to artificially recharge the groundwater.

Table 6.19 ARS Recommended: Check Dams

Sl. No.	Location	Latitude	Longitude	River	Sub basin	Firka	Category
1	Sembar	9° 44' 12.488" N	78° 35' 23.137" E	Nattar River	Kottakkaraiyar	Maravamangalam	Safe
2	Nerur	9° 42' 26.917" N	78° 37' 5.764" E	Nattar River	Kottakkaraiyar	Thayamanagalam	Safe
3	Kakkulam	9° 44' 8.756" N	78° 41' 57.068" E		Kottakkaraiyar	Maravamangalam	Safe
4	Puttur	9° 42' 52.830" N	78° 47' 43.977" E	Sarugani River	Kottakkaraiyar	Anandur	Safe
5	Tirukkalyanapuram	9° 55' 11.381" N	79° 0' 11.266" E	Pambar	Pambar	Mangalakudi	Saline/Poorquality
6	Pulangudi	9° 57' 17.262" N	78° 58' 37.691" E	Pambar	Pambar	Kannankudi	Safe
7	Peranur	9° 56' 21.078" N	79° 4' 47.483" E	Papan Ar	Pambar	Ponpette	Safe
8	Nallampatti	10° 7' 44.889" N	78° 22' 40.885" E	Manimuttar	Manimuttar	Karungalakkudi	Safe
9	Pappanendal	9° 48' 11.467" N	79° 1' 17.287" E	Varshalel Ar	Manimuttar	Pullur	Safe
10	Kiliyendal	9° 56' 59.377" N	79° 9' 8.304" E		Pambar	Kottaipattinam	Saline/Poorquality

A detailed investigation has to be done on the hydrological aspects of rainfall and maximum surface runoff on every location prior to constructing the Check Dams in the above recommended locations.

6.8.2 Demand-side Management of Groundwater

In Pambar Kottakkaraiyar basin, the total groundwater extraction is **236.51 MCM** out of which the extraction for irrigation sector is **217.75**MCM.

Table: 6.20 Groundwater Availability and Extraction as per 2013 Assessment

Sl. No	Sub Basin	Net Annual Groundwater Availability in (MCM)	Gross Annual Extraction for irrigation in (MCM)	Gross Annual Extraction for other purposes in (MCM)	Gross Annual Extraction for all Sectors (MCM)	Irrigation Extraction in Total Extraction (%)
1	Pambar	334.78	25.45	4.61	30.06	**84.66**
2	Manimuthar	335.87	119.61	7.16	126.77	**94.35**
3	Kottakkaraiyar	459.28	72.69	6.99	79.68	**91.23**
	Total	**1129.93**	**217.75**	**18.76**	**236.51**	**92.07**

It is observed that the Ground water Extraction in Pambar Kottakkaraiyar basin for irrigation is 92% whereas the total ground water extraction for all demands in Tamilnadu is 77%. This raises concern on the management of the ground water resources. It is imperative to focus special attention on irrigation sector to reduce the groundwater extraction. The farmers have to be educated to understand the consequences of over exploitation of groundwater for irrigation and motivate them to switch over to more efficient mode of irrigation practices like drip irrigation and sprinkler irrigation to reduce the groundwater extraction for irrigation. The predominant crops in this basin is paddy which is water intensive crop and in order to reduce the water consumption at field level, The farmers have to be insisted to adopt the latest less water consumption agricultural technique like System of Rice Intensifications (SRI).

6.9 Summary

A total of 264 wells lie in Pambar Kottakkaraiyar Basin and data of 67 observation wells spread over the entire Pambar Kottakkaraiyar Basin has been scrutinized for study purpose. Sub basin-wise groundwater availability, extraction and balance have been worked out. Long-term trend in water level fluctuation has been analyzed and pre-monsoon & post-monsoon contours maps of shallow aquifers are prepared.

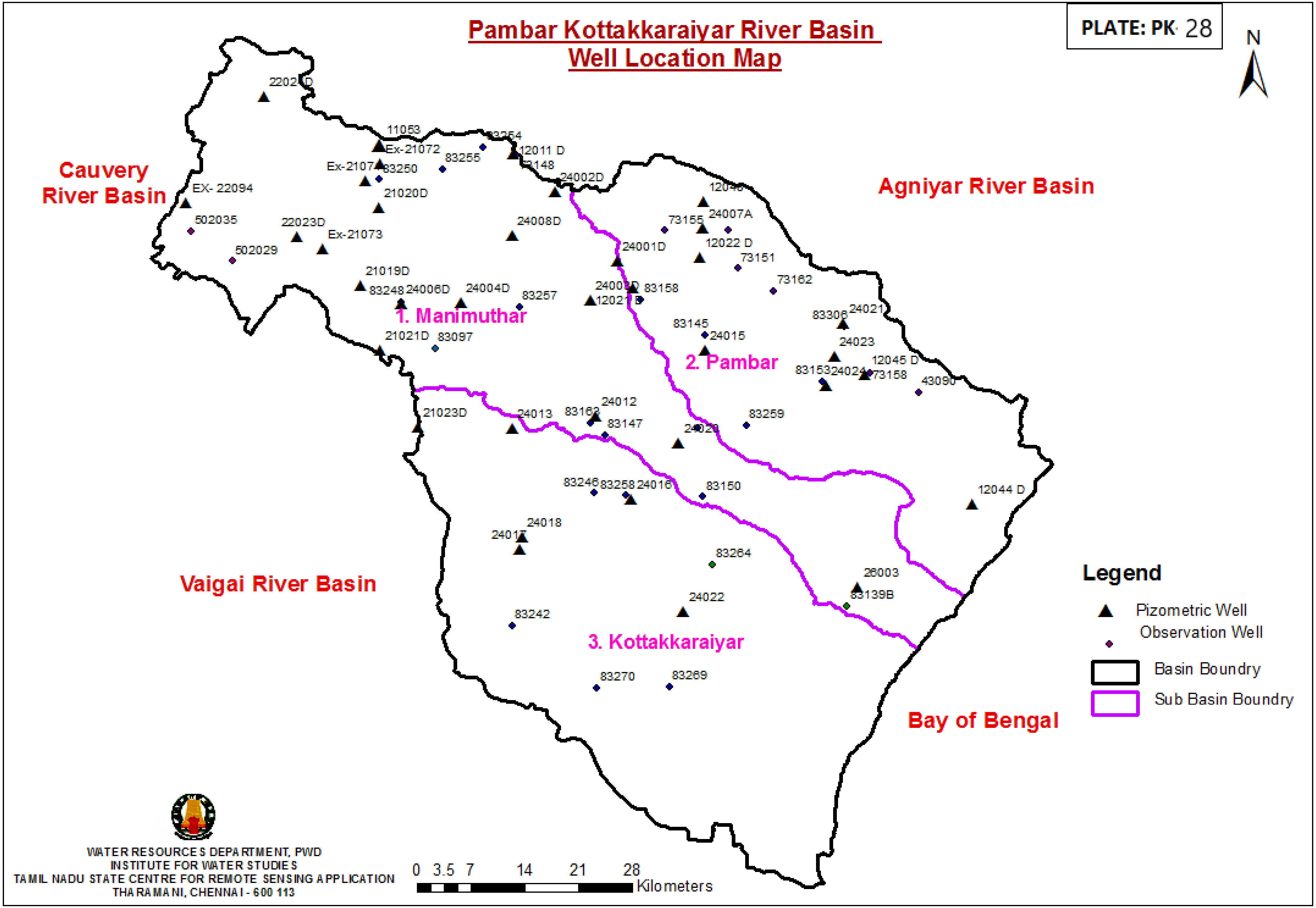
Findings:

Hydrographs of the groundwater depths for the observation wells have been prepared. It is observed that

- Long-term water level rise found in 17 observation wells and high rise in water level (more than 3.00m) found in 2 wells.
- Long-term water level depletion found in 50 observation wells and high depletion in water level (more than 3.00m) found in 22 wells.
- In Pamabar sub-basin, pre-monsoon groundwater depth varies from 0.48m to 21.20m and post monsoon groundwater depth varies from 0.25 m to 19.40m
- In Manimuthar sub-basin, pre-monsoon groundwater depth varies from 0.70 m to 26.20 m and post monsoon groundwater depth varies from 0.25m to 0.25m
- In Kottakkaraiyar sub-basin, pre-monsoon groundwater depth varies from 0.26m to 17.30m and post monsoon groundwater depth varies from 0.09m to 15.90m.
- Net annual Groundwater availability in Pambar Kottakkaraiyar Basin is 1129.93MCM and total annual groundwater extraction in the basin is 236.51MCM (20.93%). The balance groundwater available for further development is 893.72MCM.
- Whilst comparing the groundwater resources of Pambar Kottakkaraiyar Basin calculated in Appraisal report prepared in 2007 with this Reappraisal report, it is observed that the total annual groundwater availability has increased by **19.62%** (from 944.63MCM to 1129.93MCM) and total annual groundwater extraction has also increased by **86.03%** (from 127.13MCM to 236.51MCM). Even though groundwater extraction is increased the available balance of groundwater is increased by 9.10% (from 819.17MCM to 893.72MCM).
- Seventeen artificial recharge structures (15 Check Dams and 2 Anicuts) were constructed in Manimuthar Sub-basin in the last ten years.
- Annually Groundwater extracted for irrigation in Pambar Kottakkaraiyar basin is **217.75**MCM which is 92.07% in total annual groundwater extraction of **236.51**MCM for all sectoral demands.

Recommendations:

- Even though the Groundwater extraction for all demands is 20.93%, the extraction for irrigation sector in Pambar Kottakkaraiyar basin is alarmingly high at 92.07% in total extraction. In order to reduce the groundwater extraction for irrigation, modern irrigation method like drip and sprinkler irrigation and latest cultivation practices like System of Rice Intensification (SRI) have to be implemented in large scale.
- It is suggested to construct Artificial Recharge Structures (ARS), like Recharge Shafts and Check Dams as stated below:
    - 17 Vertical Shafts in Safe Firkas
    - 7 Vertical Shafts in Saline/Poor Quality Firkas
    - 8 Check Dams in Safe Firkas
    - 2 Check Dams in Saline/Poor Quality Firkas



Pambar Kottakkaraiyar River Basin
Well Location Map
PLATE: PK 28
N
Cauvery River Basin
Agniyar River Basin
Vaigai River Basin
Bay of Bengal
1. Manimuthar
2. Pambar
3. Kottakkaraiyar
11053
Ex-21072
83255
12011 D
Ex-2107
83250
24002D
EX- 22094
21020D
502035
22023D
Ex-21073
24008D
502029
21019D
83248
24006D
24004D
83257
21021D
83097
73155
24007A
12022 D
24001D
73151
73162
83158
83145
24015
83306
24021
24023
12045 D
73158
43090
21023D
24013
24012
83147
83259
83246
83258
24016
83150
12044 D
24018
83264
26003
83139B
24022
83242
83270
83269
Legend
Pizometric Well
Observation Well
Basin Boundry
Sub Basin Boundry
WATER RESOURCES DEPARTMENT, PWD
INSTITUTE FOR WATER STUDIES
TAMIL NADU STATE CENTRE FOR REMOTE SENSING APPLICATION
THARAMANI, CHENNAI - 600 113
0 3.5 7 14 21 28
Kilometers

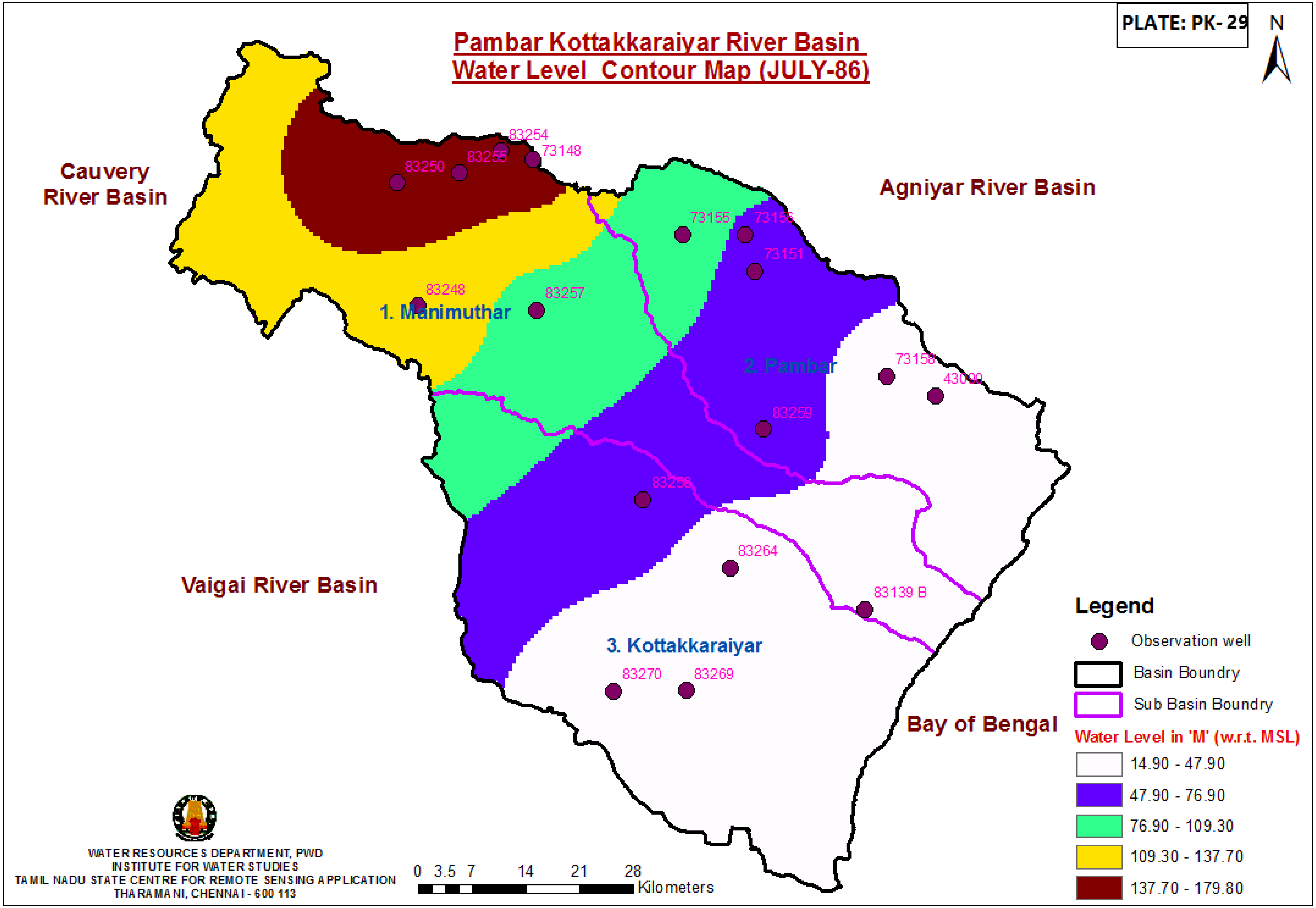
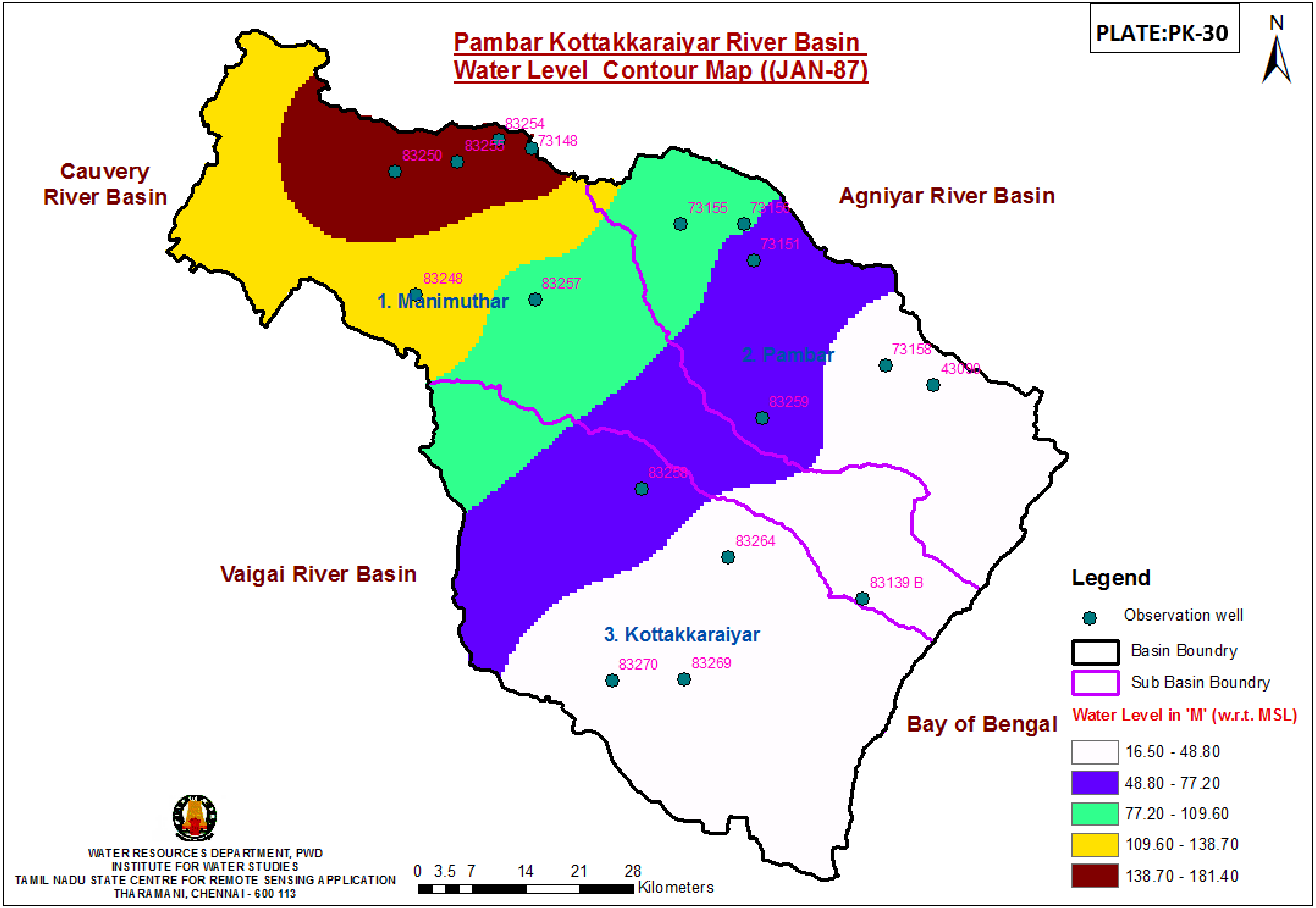
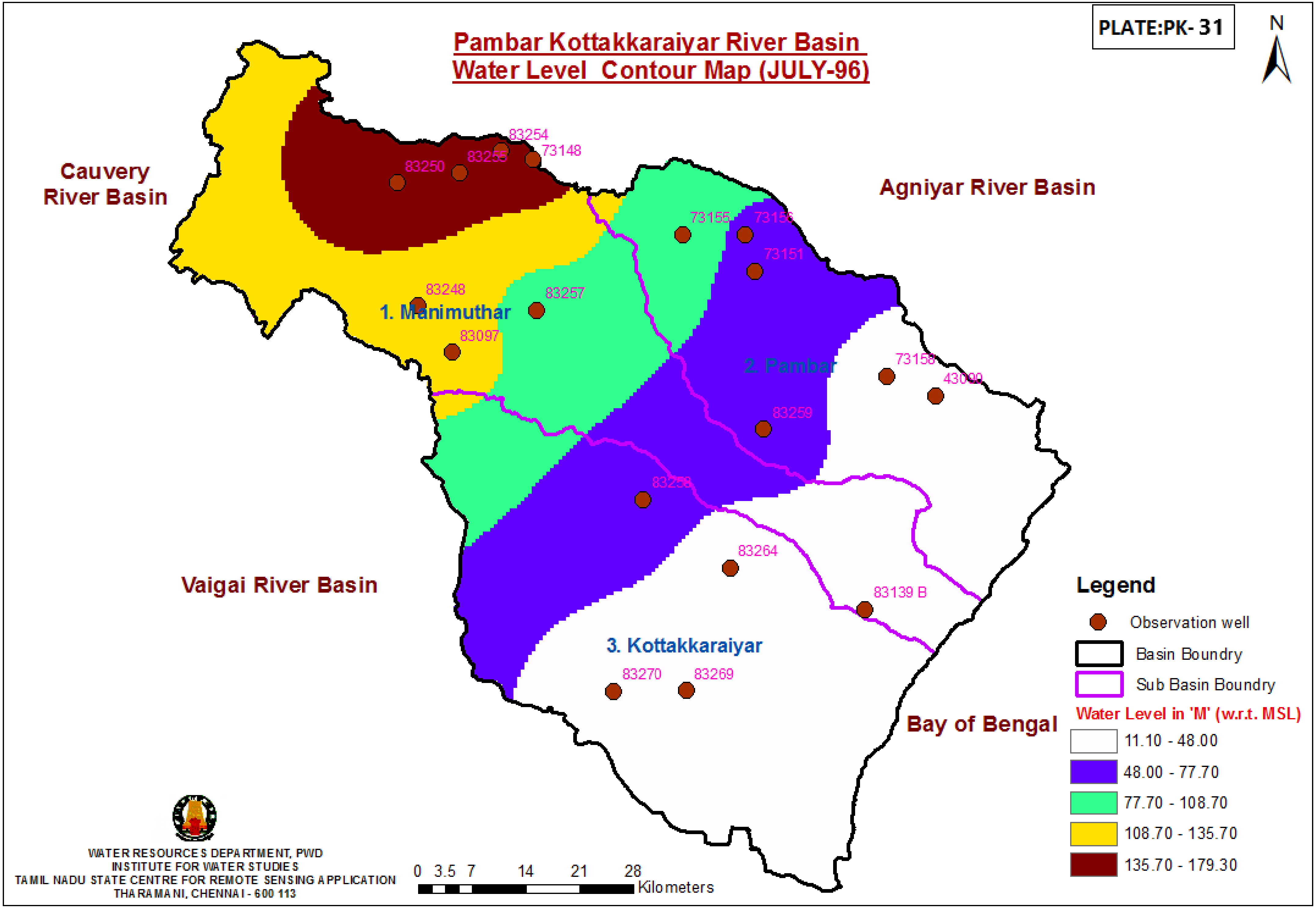


PLATE: PK- 29
N
Pambar Kottakkaraiyar River Basin
Water Level Contour Map (JULY-86)
Cauvery River Basin
Agniyar River Basin
Vaigai River Basin
Bay of Bengal
1. Manimuthar
2. Pambar
3. Kottakkaraiyar
83254
73148
83255
83250
73155
73156
73151
83248
83257
73158
43009
83259
83258
83264
83139 B
83270
83269
Legend
Observation well
Basin Boundry
Sub Basin Boundry
Water Level in 'M' (w.r.t. MSL)
14.90 - 47.90
47.90 - 76.90
76.90 - 109.30
109.30 - 137.70
137.70 - 179.80
0 3.5 7 14 21 28
Kilometers
WATER RESOURCES DEPARTMENT, PWD
INSTITUTE FOR WATER STUDIES
TAMIL NADU STATE CENTRE FOR REMOTE SENSING APPLICATION
THARAMANI, CHENNAI - 600 113


Pambar Kottakkaraiyar River Basin
Water Level Contour Map ((JAN-87)
PLATE:PK-30
N
Cauvery River Basin
Agniyar River Basin
Vaigai River Basin
Bay of Bengal
1. Manimuthar
2. Pambar
3. Kottakkaraiyar
83254
73148
83250
83255
73155
73156
73151
83248
83257
73158
83259
83258
83264
83139 B
83270
83269
Legend
Observation well
Basin Boundry
Sub Basin Boundry
Water Level in 'M' (w.r.t. MSL)
16.50 - 48.80
48.80 - 77.20
77.20 - 109.60
109.60 - 138.70
138.70 - 181.40
0 3.5 7 14 21 28
Kilometers
WATER RESOURCES DEPARTMENT, PWD
INSTITUTE FOR WATER STUDIES
TAMIL NADU STATE CENTRE FOR REMOTE SENSING APPLICATION
THARAMANI, CHENNAI - 600 113



Pambar Kottakkaraiyar River Basin
Water Level Contour Map (JULY-96)
PLATE:PK- 31
N
Cauvery River Basin
Agniyar River Basin
Vaigai River Basin
Bay of Bengal
1. Manimuthar
2. Pambar
3. Kottakkaraiyar
83254
73148
83250
73155
73151
83248
83257
83097
73158
83259
83264
83139 B
83270
83269
Legend
Observation well
Basin Boundry
Sub Basin Boundry
Water Level in 'M' (w.r.t. MSL)
11.10 - 48.00
48.00 - 77.70
77.70 - 108.70
108.70 - 135.70
135.70 - 179.30
0 3.5 7 14 21 28
Kilometers
WATER RESOURCES DEPARTMENT, PWD
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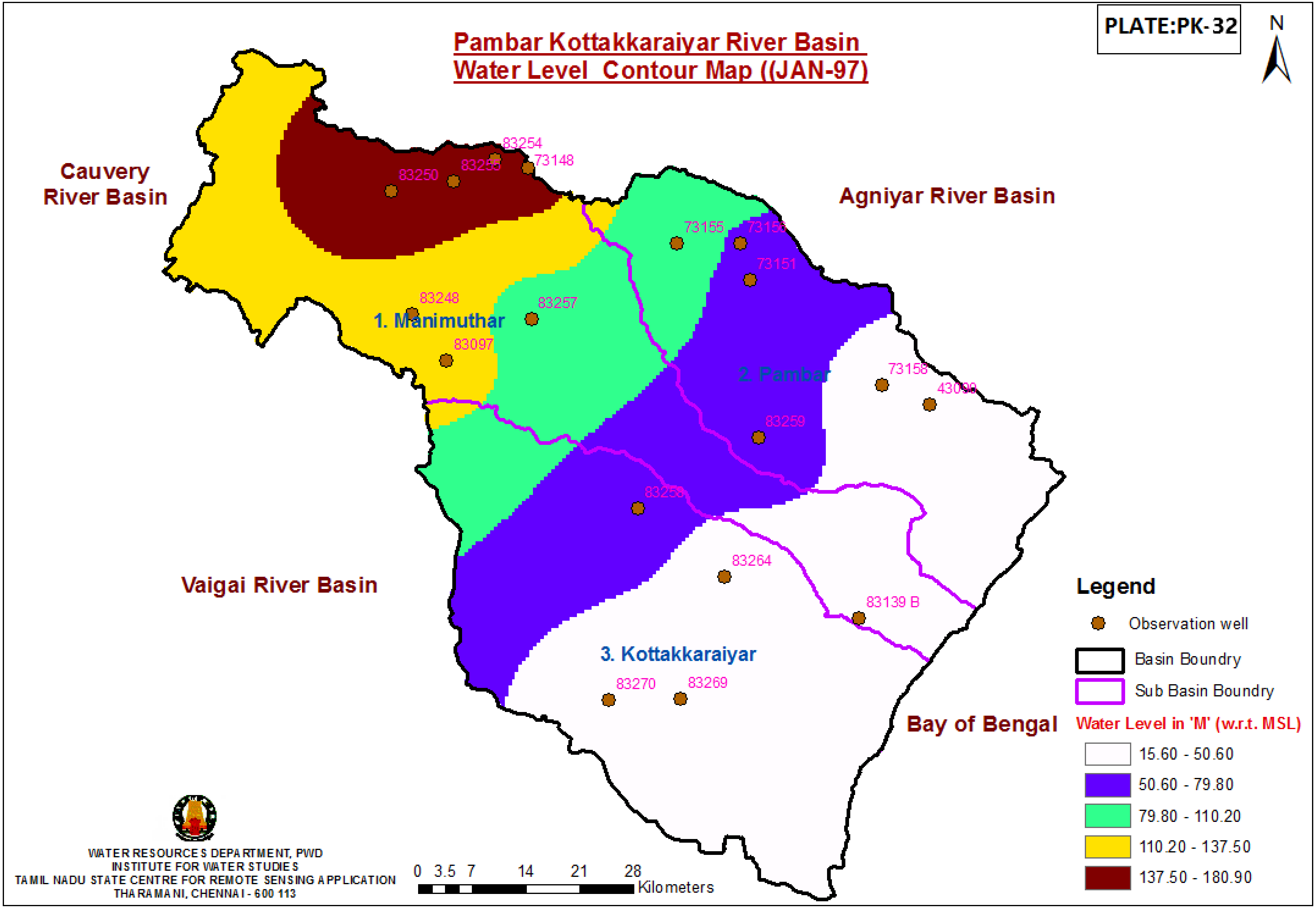

PLATE:PK-32
N
Pambar Kottakkaraiyar River Basin
Water Level Contour Map ((JAN-97)
Cauvery
River Basin
Agniyar River Basin
Vaigai River Basin
Bay of Bengal
1. Manimuthar
2. Pambar
3. Kottakkaraiyar
83254
73148
83250
83253
73155
73156
73151
83248
83257
83097
73158
43009
83259
83258
83264
83139 B
83270
83269
Legend
Observation well
Basin Boundry
Sub Basin Boundry
Water Level in 'M' (w.r.t. MSL)
15.60 - 50.60
50.60 - 79.80
79.80 - 110.20
110.20 - 137.50
137.50 - 180.90
0 3.5 7 14 21 28
Kilometers
WATER RESOURCES DEPARTMENT, PWD
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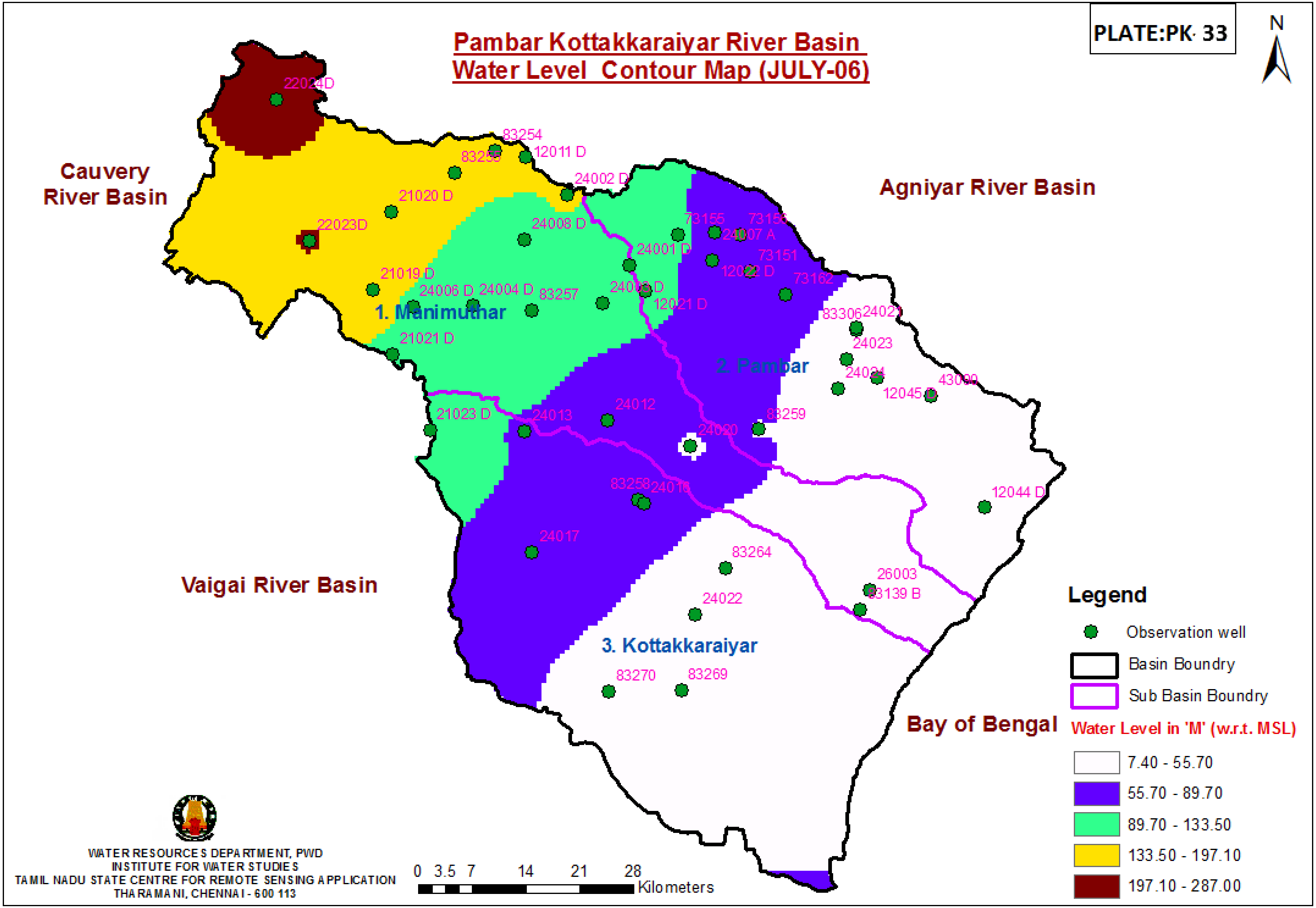
THARAMANI, CHENNAI - 600 113


Pambar Kottakkaraiyar River Basin
Water Level Contour Map (JULY-06)
PLATE:PK- 33
N
Cauvery River Basin
Agniyar River Basin
Vaigai River Basin
Bay of Bengal
1. Manimuthar
2. Pambar
3. Kottakkaraiyar
22024D
83254
12011 D
24002 D
21020 D
22023D
24008 D
73155
24001 D
73151
73162
21019 D
24006 D
24004 D
83257
12021 D
21021 D
24023
43009
83259
24020
24012
24013
21023 D
12044 D
24017
83264
26003
24022
83270
83269
Legend
Observation well
Basin Boundry
Sub Basin Boundry
Water Level in 'M' (w.r.t. MSL)
7.40 - 55.70
55.70 - 89.70
89.70 - 133.50
133.50 - 197.10
197.10 - 287.00
0 3.5 7 14 21 28
Kilometers
WATER RESOURCES DEPARTMENT, PWD
INSTITUTE FOR WATER STUDIES
TAMIL NADU STATE CENTRE FOR REMOTE SENSING APPLICATION
THARAMANI, CHENNAI - 600 113

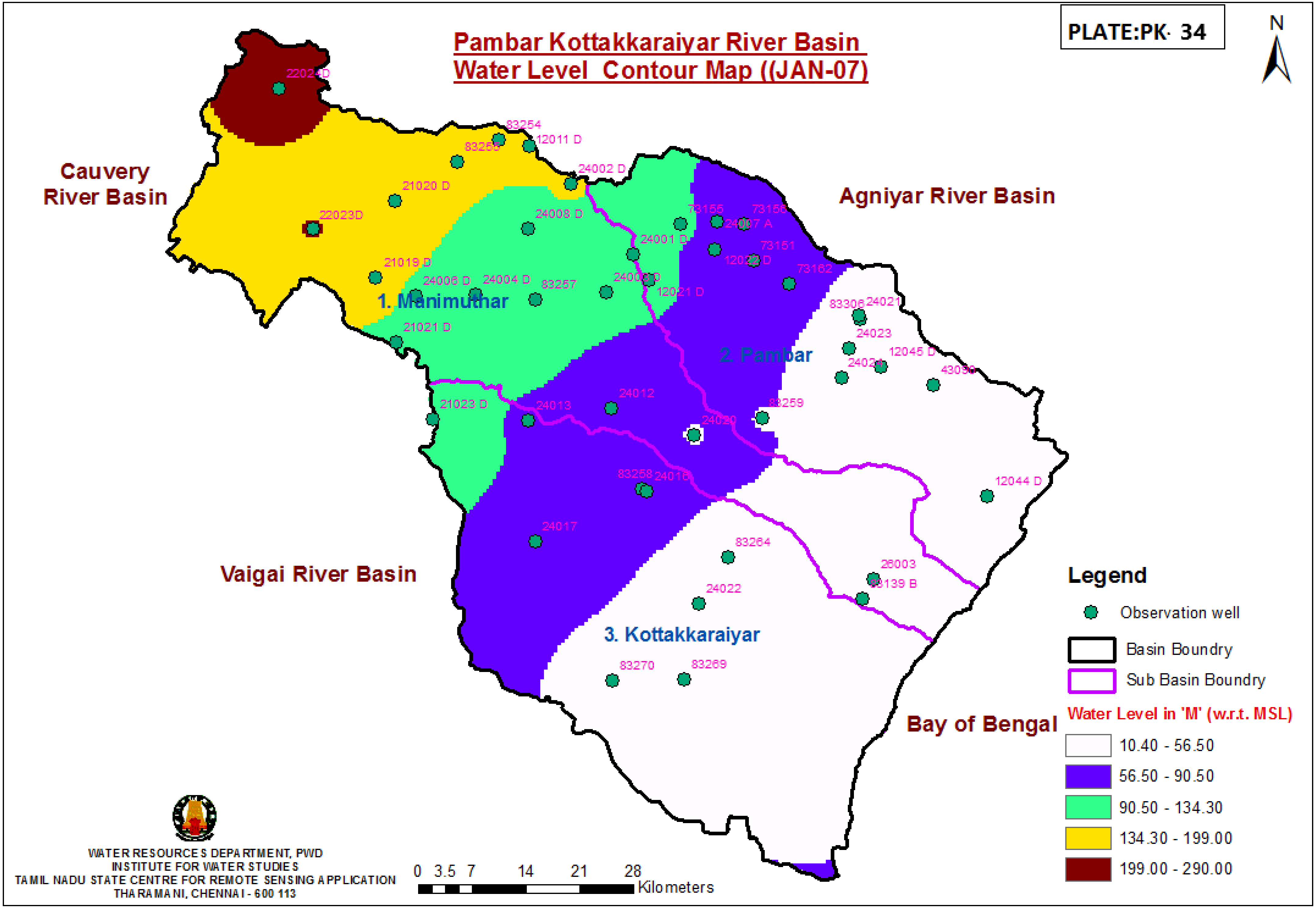


PLATE:PK- 34
Pambar Kottakkaraiyar River Basin
Water Level Contour Map ((JAN-07)
N
Cauvery River Basin
Agniyar River Basin
Vaigai River Basin
Bay of Bengal
1. Manimuthar
2. Pambar
3. Kottakkaraiyar
22024D
83254
12011 D
83255
24002 D
21020 D
22023D
24008 D
73155
73156
24007 A
24001 D
73151
12022 D
21019 D
24006 D
24004 D
83257
24003 D
12021 D
73162
83306
24021
24023
12045 D
24024
43050
21021 D
24012
83259
21023 D
24013
24020
83258
24016
12044 D
24017
83264
26003
83139 B
24022
83270
83269
Legend
Observation well
Basin Boundry
Sub Basin Boundry
Water Level in 'M' (w.r.t. MSL)
10.40 - 56.50
56.50 - 90.50
90.50 - 134.30
134.30 - 199.00
199.00 - 290.00
0 3.5 7 14 21 28
Kilometers
WATER RESOURCES DEPARTMENT, PWD
INSTITUTE FOR WATER STUDIES
TAMIL NADU STATE CENTRE FOR REMOTE SENSING APPLICATION
THARAMANI, CHENNAI - 600 113

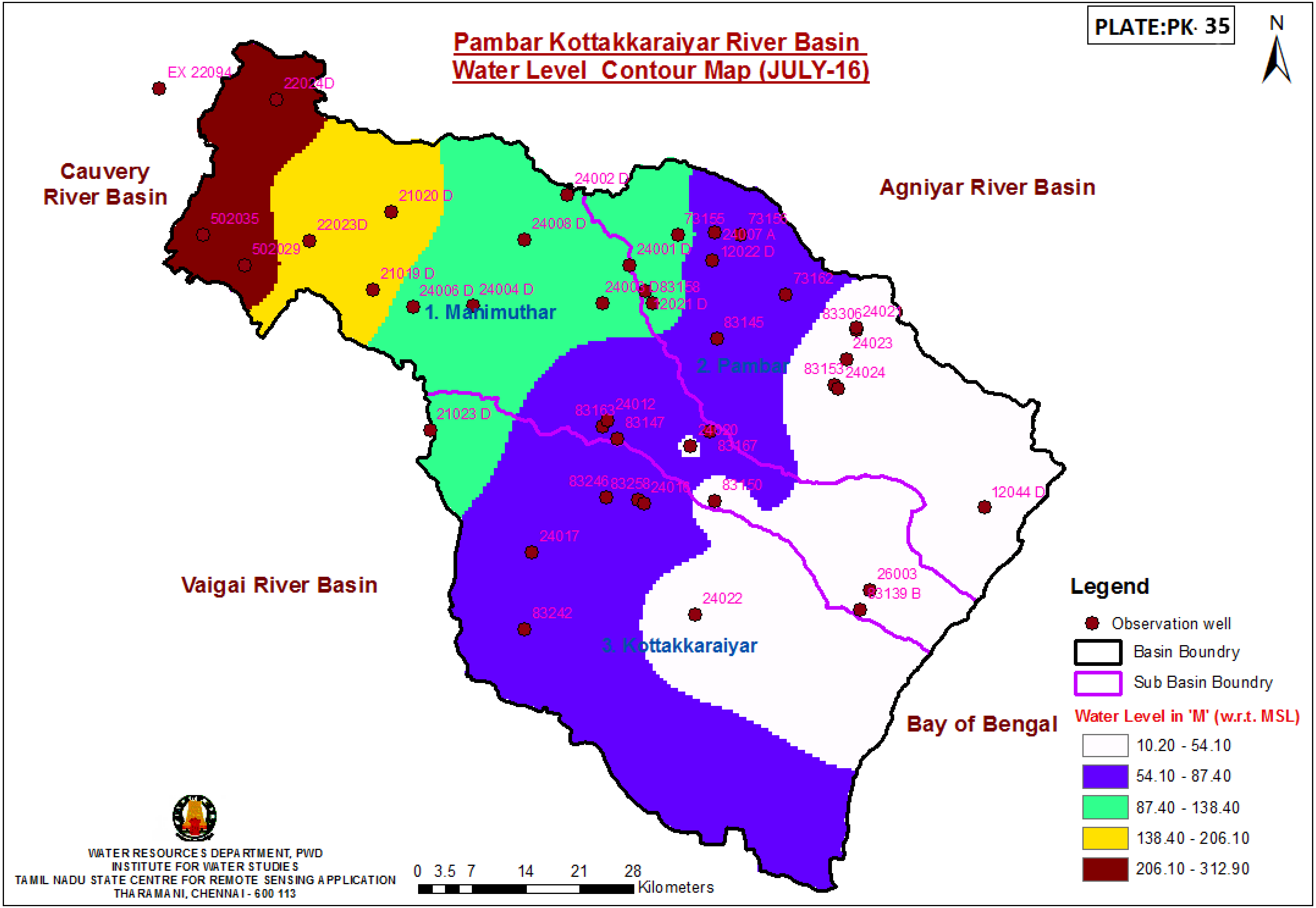


PLATE:PK- 35
Pambar Kottakkaraiyar River Basin
Water Level Contour Map (JULY-16)
N
Cauvery River Basin
Agniyar River Basin
Vaigai River Basin
Bay of Bengal
1. Manimuthar
2. Pambar
3. Kottakkaraiyar
EX 22094
22024D
21020 D
24002 D
502035
22023D
502029
24008 D
73155
73156
24007 A
24001 D
12022 D
21019 D
24006 D
24004 D
24003 D
83158
22021 D
73162
83145
83306
24021
24023
83153
24024
21023 D
83163
24012
83147
24020
83167
83246
83258
24010
83150
12044 D
24017
26003
83139 B
24022
83242
Legend
Observation well
Basin Boundry
Sub Basin Boundry
Water Level in 'M' (w.r.t. MSL)
10.20 - 54.10
54.10 - 87.40
87.40 - 138.40
138.40 - 206.10
206.10 - 312.90
0 3.5 7 14 21 28
Kilometers
WATER RESOURCES DEPARTMENT, PWD
INSTITUTE FOR WATER STUDIES
TAMIL NADU STATE CENTRE FOR REMOTE SENSING APPLICATION
THARAMANI, CHENNAI - 600 113

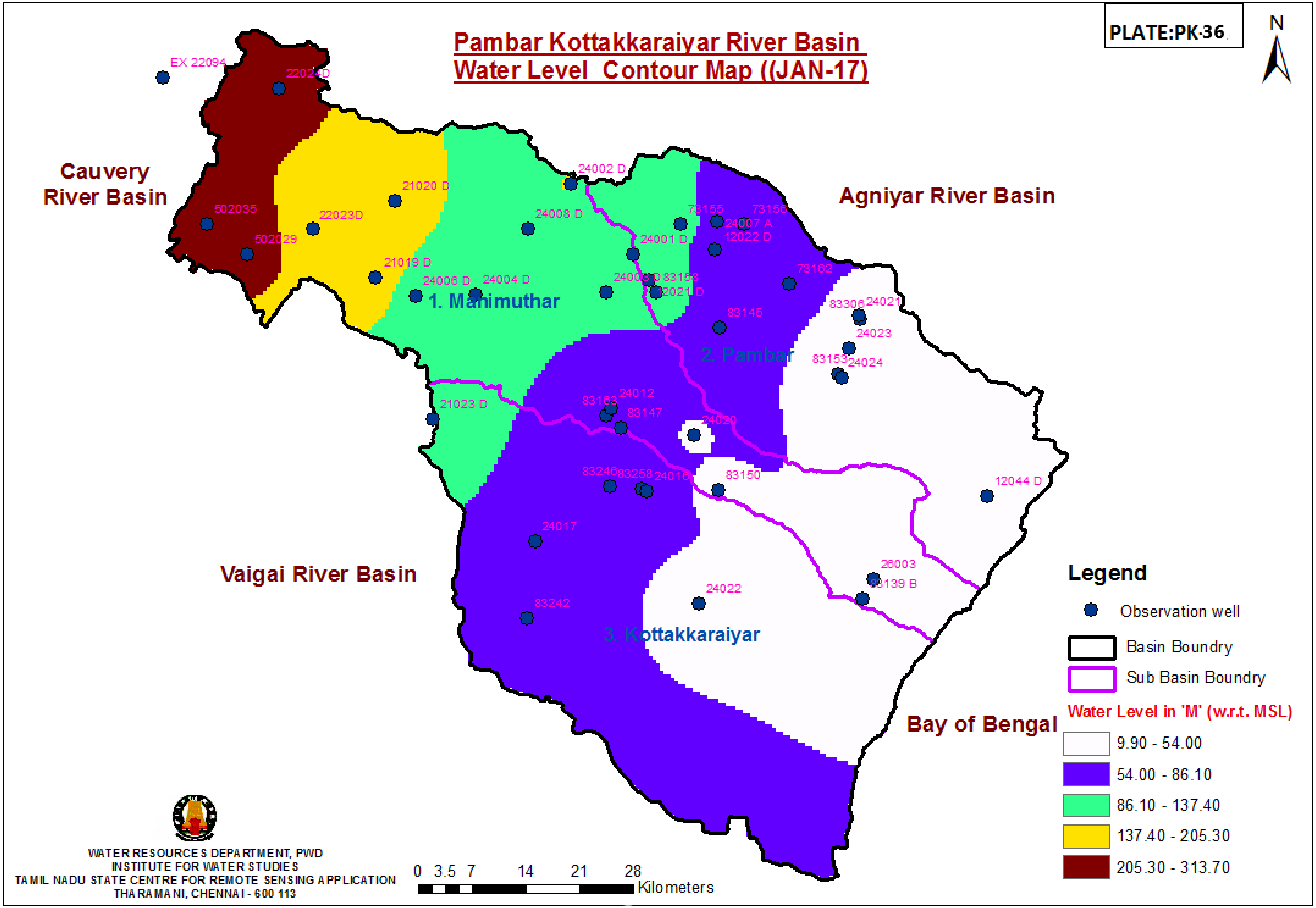
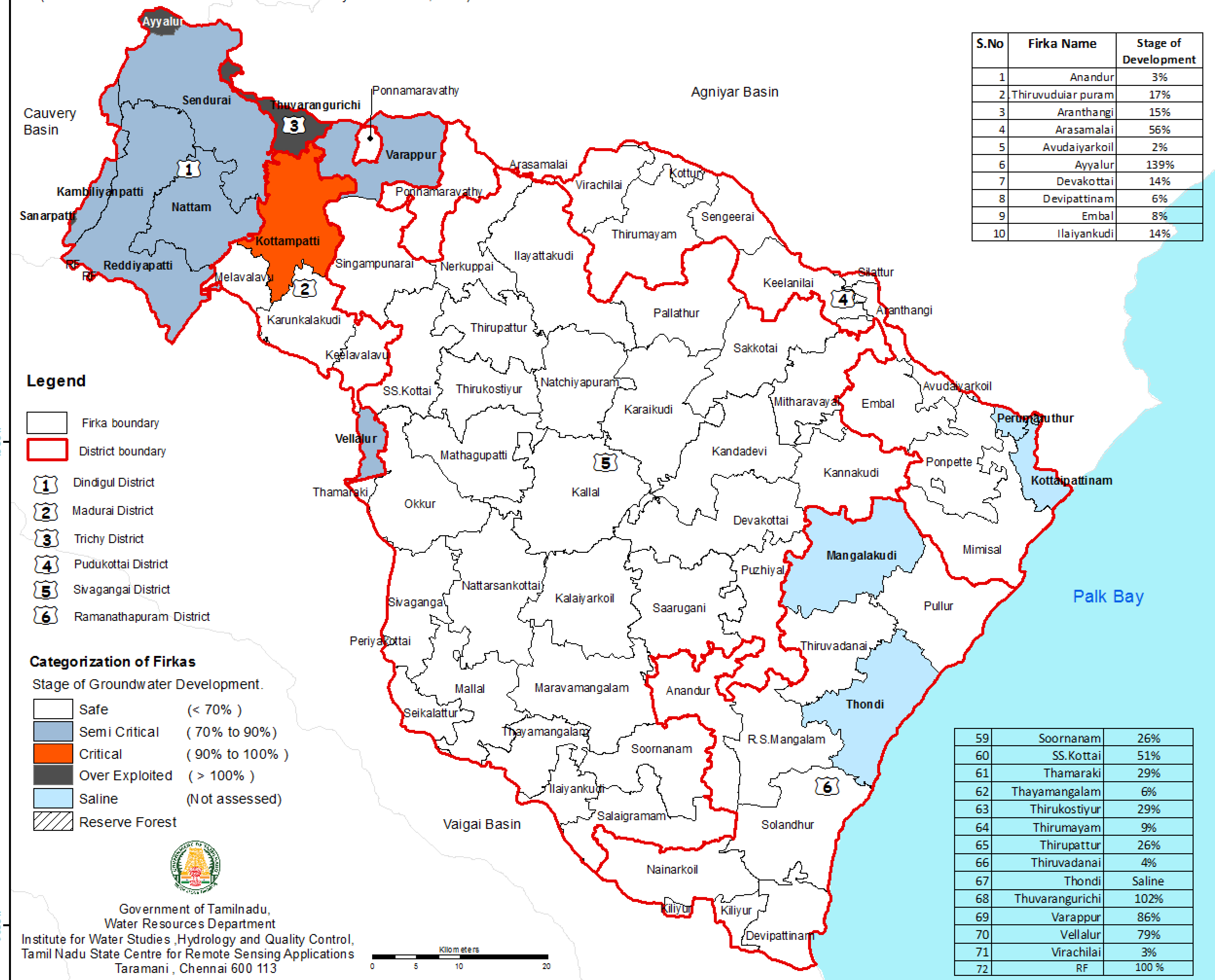


PLATE:PK-36
N
Pambar Kottakkaraiyar River Basin
Water Level Contour Map ((JAN-17)
Cauvery River Basin
Agniyar River Basin
Vaigai River Basin
Bay of Bengal
1. Manimuthar
2. Pambar
3. Kottakkaraiyar
EX 22094
22024D
502035
502029
22023D
21020 D
21019 D
24006 D
24004 D
24008 D
24002 D
24001 D
24003 D
83158
12021 D
73155
73156
24007 A
12022 D
73162
83145
83306
24021
24023
83153
24024
21023 D
83163
24012
83147
24020
83246
83258
24016
83150
12044 D
24017
26003
83139 B
24022
83242
Legend
Observation well
Basin Boundry
Sub Basin Boundry
Water Level in 'M' (w.r.t. MSL)
9.90 - 54.00
54.00 - 86.10
86.10 - 137.40
137.40 - 205.30
205.30 - 313.70
WATER RESOURCES DEPARTMENT, PWD
INSTITUTE FOR WATER STUDIES
TAMIL NADU STATE CENTRE FOR REMOTE SENSING APPLICATION
THARAMANI, CHENNAI - 600 113
0 3.5 7 14 21 28
Kilometers

Pambar Kottakaraiyar Basin- Catergorization of Firkas

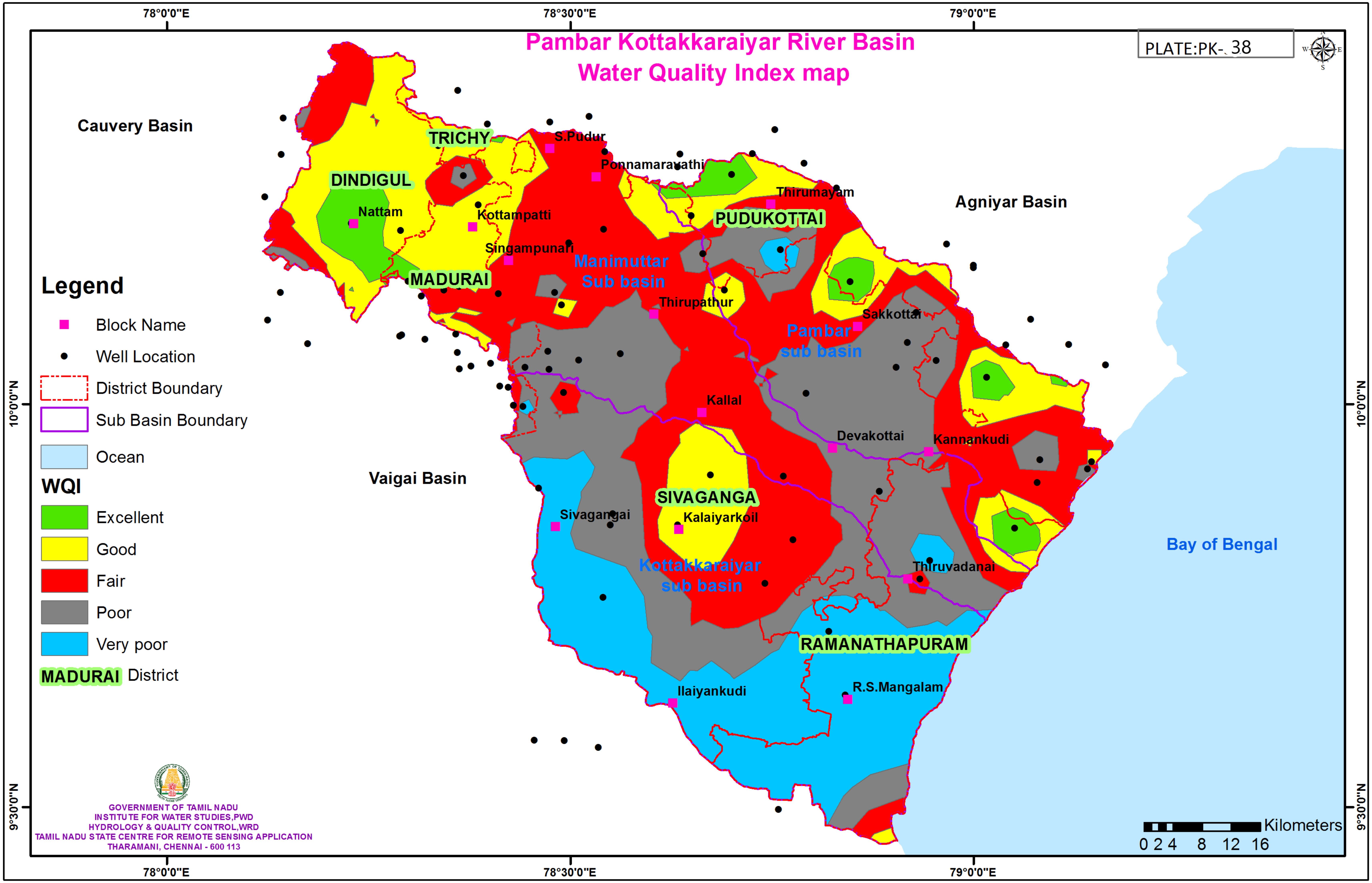
(Based on Groundwater Assessment - 2013 done by SG&SWRDC,WRD)

PLATE No : PK -37



Government of Tamilnadu,
Water Resources Department
Institute for Water Studies ,Hydrology and Quality Control,
Tamil Nadu State Centre for Remote Sensing Applications
Taramani , Chennai 600 113

S.No	Firka Name	Stage of Development
1	Anandur	3%
2	Thiruvuduiar puram	17%
3	Aranthangi	15%
4	Arasamalai	56%
5	Avudaiyarkoil	2%
6	Ayyalur	139%
7	Devakottai	14%
8	Devipattinam	6%
9	Embal	8%
10	Ilaiyankudi	14%
11	Ilayattakudi	14%
12	Kalaiyarkoil	35%
13	Kallal	11%
14	Kambiliyanpatti	81%
15	Kandadevi	11%
16	Kannakudi	2%
17	Karaikudi	14%
18	Karaiyur	71%
19	Karunkalakudi	42%
20	Keelanilai	22%
21	Keelavalavu	35%
22	Kiliyur	8%
23	Kottaipattinam	Saline
24	Kottampatti	97%
25	Kottur	30%
26	Mallal	22%
27	Mangalakudi	Saline
28	Maravamangalam	19%
29	Mathagupatti	39%
30	Melavalavu	45%
31	Mimisal	2%
32	Mitharavayal	6%
33	Nainarkoil	8%
34	Natchiyapuram	7%
35	Nattam	78%
36	Nattarsankottai	35%
37	Nerkuppai	14%
38	Okkur	34%
39	Pallathur	13%
40	Periyakottai	16%
41	Perumaruthur	Saline
42	Ponnamaravathy	64%
43	Ponpette	1%
44	Pullur	4%
45	Puzhiyal	10%
46	R.S.Mangalam	3%
47	Reddiyapatti	82%
48	Saarugani	7%
49	Sakkotai	21%
50	Salaigramam	15%
51	Sanarpatti	118%
52	Seikalattur	13%
53	Sendurai	75%
54	Sengeerai	33%
55	Silattur	17%
56	Singampunarai	26%
57	Sivaganga	24%
58	Solandhur	3%
59	Soornanam	26%
60	SS.Kottai	51%
61	Thamaraki	29%
62	Thayamangalam	6%
63	Thirukostiyur	29%
64	Thirumayam	9%
65	Thirupattur	26%
66	Thiruvadanai	4%
67	Thondi	Saline
68	Thuvarangurichi	102%
69	Varappur	86%
70	Vellalur	79%
71	Virachilai	3%
72	RF	100 %


Pambar Kottakkaraiyar River Basin
Water Quality Index map
PLATE:PK- 38
78°0'0"E
78°30'0"E
79°0'0"E
10°0'0"N
9°30'0"N
Cauvery Basin
Agniyar Basin
Vaigai Basin
Bay of Bengal
TRICHY
DINDIGUL
MADURAI
PUDUKOTTAI
SIVAGANGA
RAMANATHAPURAM
S.Pudur
Ponnamaravathi
Thirumayam
Nattam
Kottampatti
Singampunari
Manimuttar Sub basin
Thirupathur
Sakkottai
Pambar sub basin
Kallal
Devakottai
Kannankudi
Sivagangai
Kalaiyarkoil
Kottakkaraiyar sub basin
Thiruvadanai
Ilaiyankudi
R.S.Mangalam
Legend
Block Name
Well Location
District Boundary
Sub Basin Boundary
Ocean
WQI
Excellent
Good
Fair
Poor
Very poor
MADURAI District
Kilometers
0 2 4 8 12 16
GOVERNMENT OF TAMIL NADU
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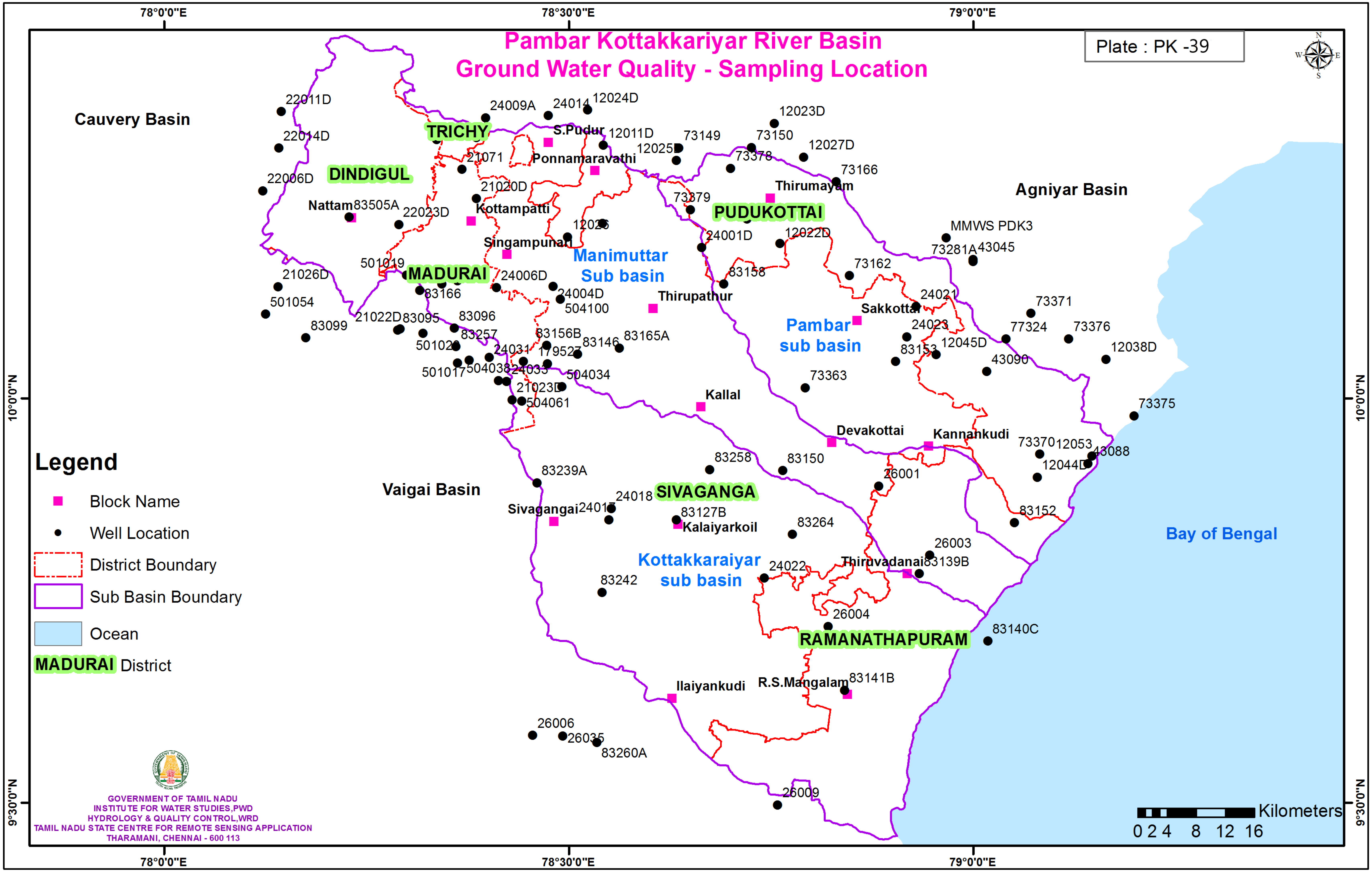
HYDROLOGY & QUALITY CONTROL,WRD
TAMIL NADU STATE CENTRE FOR REMOTE SENSING APPLICATION
THARAMANI, CHENNAI - 600 113


Pambar Kottakkariyar River Basin
Ground Water Quality - Sampling Location
Plate : PK -39
78°0'0"E
78°30'0"E
79°0'0"E
10°0'0"N
9°30'0"N
Cauvery Basin
Agniyar Basin
Vaigai Basin
Bay of Bengal
Manimuttar Sub basin
Pambar sub basin
Kottakkaraiyar sub basin
TRICHY
DINDIGUL
MADURAI
PUDUKOTTAI
SIVAGANGA
RAMANATHAPURAM
S.Pudur
Ponnamaravathi
Kottampatti
Singampunari
Nattam
Thirumayam
Thirupathur
Sakkottai
Kallal
Devakottai
Kannankudi
Sivagangai
Kalaiyarkoil
Thiruvadanai
Ilaiyankudi
R.S.Mangalam
Legend
Block Name
Well Location
District Boundary
Sub Basin Boundary
Ocean
MADURAI District
Kilometers
0 2 4 8 12 16
GOVERNMENT OF TAMIL NADU
INSTITUTE FOR WATER STUDIES,PWD
HYDROLOGY & QUALITY CONTROL,WRD
TAMIL NADU STATE CENTRE FOR REMOTE SENSING APPLICATION
THARAMANI, CHENNAI - 600 113

CHAPTER-7

PRESENT AND FUTURE WATER DEMAND

CHAPTER -7

PRESENT AND FUTURE WATER DEMAND

7.1 Water use and Water demand

The term water use and water demand are often used interchangeably. However, these terms have different meanings.

7.1.1 Water Use

Water use is the amount of water used by a household or a country, or the amount used for a given task or for the production of a given quantity of some product or crop, or the amount allocated for a particular purpose.

7.1.2 Water Demand

Water demand is defined as the volume of water required for various sectors such as domestic, irrigation, industrial, livestock, aquaculture and power generation, etc.

The estimation of amount of water available and the water demand for various sectors within the basin helps in carrying out the water balance study for River Basin. In this chapter, the requirement of water for various sectoral uses such as domestic, irrigation, industrial, livestock, aquaculture & power generation in Pambar & Kottakkaraiyar River Basin is estimated. Forecasting of the future water demand in all these sectors is also necessary to identify the options and strategies to mitigate future risks that might arise in water resource planning of river basin. Hence, the estimated water demand in various sectors of the Pambar & Kottakkaraiyar River Basin is projected to the future years 2020, 2030, 2040 & 2050 in this Chapter.

7.1.3 Improvements suggested for bridging the gap between supply and demand

In order to bridge the gap in supply and demand,the following improvements can be made,

- Improving the supply system properly by removing the sedimentation.
- Maintaining the water supply system periodically to prevent leakage.
- Artificial recharge through construction of check dams, anicuts and recharge shafts.
- Construction of rain water harvesting structures for recharging the acquifer.
- Improving the irrigation efficiency by rehabilitation of irrigation structures.
- Adoption of modern techniques agricultural practices there by reducing Irrigation demand.
- Recycling of the waste water generated where ever possible.

7.2 Domestic Water Supply

The Tamil Nadu Water Supply and Drainage Board (TWAD) is implementing Water Supply Schemes in the Pambar & Kottakkaraiyar River Basin. The combined water supply schemes (CWSS) provided by the TWAD Board for the Pambar & Kottakkaraiyar River Basin is given below in **table 7.1**. The TWAD Board is supplying 37.004MLD of water in the Pambar & Kottakkaraiyar River Basin.

Table 7.1: Water Supply Schemes by TWAD

Sl. No	District	Name of CWSS	Location	Type of Source	Designed Quantity in MLD
1	Madurai	Vadipatti & 7 habs	Irumbadi	IW	1.56
2	Dindugul	CWSS to 254 Rural Habs	Vedasandur	Covered under Dindigul CWSS	3.02
3	Dindugul	25 Rural Habs	Natham Shanarpatti	Covered under Dindigul CWSS	0.50
4	Sivaganga	Chithalur and 7 Habs.	Pachery	IW & BW	0.16
5	Sivaganga	Alanvayal and 9 Habs.	Sukkira patty	BW	0.13
6	Sivaganga	Anandur Part I and 9 Habs.	Boothavayal	BW	0.10
7	Sivaganga	Ponnalikottai and 5 Habs.	Ponnalikottai	BW	0.05
8	Sivaganga	Anukkanendal and 7 Habs.	Anukkanendal	BW	0.059
9	Sivaganga	Erivayal and 13 Habs.	Kurunthankulam	BW	0.128
10	Sivaganga	Paluvoor and 12 Habs.	Palkulam	BW	0.122
11	Sivaganga	Thirumanavayal and 10 Habs.	Kaarai	BW	0.213
12	Sivaganga	Kannankottai and 9 Habs	Kannankottai	BW	0.1
13	Sivaganga	Pidaranendal and 15 Habs.	Monni	BW	0.19
14	Sivaganga	Manavikottai and 7 Habs.	Manavi kottai	BW	0.067
15	Sivaganga	Anumanthakudi and 10 Habs.	Anumanthakudi	BW	0.11
16	Sivaganga	Unjanai and 24 Habs.	unjanai kollai	BW	0.43
17	Sivaganga	Andakudi and 45	sukra patti	BW	0.20

		Habs.			
18	Sivaganga	Anna Nagar and 7 Habs.	kovilur	BW	0.084
19	Sivaganga	Kannayiruppu and 8 Habs.	Meenachi puram	IW & BW	0.164
20	Sivaganga	Ramnad CWSS(PART) (Sivagangai District)	Mutha rasanallur	CW	13.72
21	Sivaganga	RAMNAD CWSS (PART) (Ramnad District)	Mutharasanallur	CW	5.791
22	Sivaganga	Pottagavayal and 2 Habs	Pagaivendri	IW BW	0.07
23	Sivaganga	Radhapuli and 5 Habs	Gopalpattinam	BW	0.10
24	Sivaganga	Koluvoor and 4 Habs	Manichiyendal	BW	0.14
25	Sivaganga	Thondi-Thiruvadanai and 46 Habs	Karumozhi	BW	0.49
26	Sivaganga	Kunjankulam and 34 Habs	Maangalakudi	BW	0.51
27	Sivaganga	Thondi-Nambuthalai and 37 Habs.	Thinaikathanvayal	BW	0.69
28	Sivaganga	Nagarikathan-Oriyur and 10 Habs	Nedumaram	BW	0.158
29	Sivaganga	Kattivayal and 25 Habs	Anda Oorani	BW	0.3
30	Sivaganga	Pandukudi and 34 Habs.	Kalloor	BW	0.54
31	Sivaganga	S.P.Pattinam and 24 Habs.	Kunjan kulam	BW	0.48
32	Sivaganga	DSP to Pottagavayal and 5 Habs.	Pottaga vayal	BW	0.15
33	Sivaganga	DSP to Narip paiyur and 103 Habs.	Narip paiyur	Sea Water	3.8
34	Ramanathapuram	Kunjankulam and 34 Habs	Maangalakudi	BW	0.51
35	Ramanathapuram	Thondi-Nambuthalai and 37 Habs.	Thinaikathanvayal	BW	0.69
36	Ramanathapuram	Nagarikathan-Oriyur and 10 Habs	Nedumaram	BW	0.158
37	Ramanathapuram	Kattivayal and 25 Habs	Anda Oorani	BW	0.3
38	Ramanathapuram	Pandukudi and 34 Habs.	Kalloor	BW	0.54
39	Ramanathapuram	S.P.Pattinam and 24 Habs.	Kunjan kulam	BW	0.48
				Total	**37.004**

IW- Infiltration well, BW-Bore well, OW-Open well, IG-Infiltration Gallery

7.3 Domestic Water Demand

Domestic consumption of water per capita is the amount of water consumed per person. This is an indicator of the quantity of water required to individuals of different class of habitations for their basic needs.With the increase in economic and social development of the people the per capita requirement of domestic water may also increase.

The Central Public Health and Environmental Engineering Organization (CPHEEO) recommended norms for per capita water demand is given in **Table 7.2**

Table 7.2: Recommended Norms for Per Capita Water Supply by CPHEEO

Sl. No	Classification of towns/cities	Recommended maximum water supply levels (lpcd)
1	Towns provided with piped water supply but without sewerage system	70
2	Cities provided with piped water supply where sewerage system is existing/contemplated	135
3	Metropolitan and Mega cities provided with piped water supply where sewerage system is existing/contemplated	150

In the above norms, **an additional 15%** should be added in each classification to meet "Unaccounted for Water (UFW)". The norms recommended by CPHEEO are adopted for estimating present and future domestic water demand.

The sub basin wise population of the Pambar & Kottakkaraiyar River Basin as per census 2011 given in Chapter 2 of this report is used for calculating the domestic water requirement.

7.3.1 Future Domestic Water Demand

The domestic water requirement may increase in future with the increase in population, development in living standards of the people, etc. The annual growth rate of populationis also determined in the chapter 2.10 and the projection of population in the river basin as given below

Population sector	Annual Growth Rates
Urban	2.19% per year
Rural	2.14% per year

Exponential growth formula is adopted for the population growth in the present study.

Exponential Growth Formula Method

The exponential growth formula is

$$\mathbf{P_t = P_o\,(1+X)^{t}}$$

Where P_t = Population after‘t’ years

P_o = Population in the beginning years

X = Annual growth rate

t = Period in years

Exponential interpolations of, possible changes in trends of growth rates resulting from economic or cultural development, or differences in observed growth rates between various sub-basins are taken into account in this method of population projection.

The population of Pambar & Kottakkaraiyar River Basin arrived in Chapter 2 sub basin wise is projected for the present year 2018 and the target years 2020, 2030, 2040 & 2050. The sub-basin wise population projection for the Pambar & Kottakkaraiyar River Basin for the present year 2018 and the target years 2020, 2030, 2040 & 2050 are arrived as**2.660 million, 3.178 million, 4.630 million, 8.223 million & 17.800 million** respectively and is given in **Table No. 7.3.**

Accordingly, the domestic water demand for the present year 2018 and the target years 2020, 2030, 2040 & 2050 are obtained as **100.050Mcum, 119.570Mcum, 174.200Mucm, 309.350Mcum & 669.652Mcum** respectively and are given in **Table No.7.4.**

Table 7.3 Sub basin wise Projected Population for Pambar Kottakkaraiyar River Basin

(Population in Million)

	Name of Sub basin	Population during 2018			Population during 2020			Population during 2030			Population during 2040			Population during 2050		
		Rural	Urban	Total	Rural	Urban	Total	Rural	Urban	Total	Rural	Urban	Total	Rural	Urban	Total
1	Manimuthar	0.922	0.420	1.343	1.102	0.502	1.605	1.606	0.732	2.338	2.852	1.299	4.151	6.173	2.813	8.986
2	Pambar	0.403	0.144	0.547	0.482	0.172	0.654	0.702	0.250	0.952	1.247	0.444	1.691	2.699	0.961	3.661
3	Kottakkaraiyar	0.516	0.254	0.770	0.616	0.304	0.920	0.898	0.443	1.340	1.594	0.786	2.380	3.451	1.702	5.153
	Total	**1.719**	**0.818**	**2.660**	**2.201**	**0.978**	**3.178**	**3.206**	**1.424**	**4.630**	**5.693**	**2.529**	**8.223**	**12.324**	**5.476**	**17.800**

Table 7.4 Sub basin wise Projected Domestic Water Demand for Pambar Kottakkaraiyar River Basin

(Water Demand in Mcum)

Sl. No	Name of the Sub Basin	Water Demand 2018			Water Demand 2020			Water Demand 2030			Water Demand 2040			Water Demand 2050		
		Rural	Urban	Total	Rural	Urban	Total	Rural	Urban	Total	Rural	Urban	Total	Rural	Urban	Total
1	Manimuthar	26.93	23.78	**50.71**	32.19	28.41	**60.60**	46.89	41.39	**88.29**	83.27	73.51	**156.78**	180.26	159.13	**339.393**
2	Pambar	11.78	8.13	**19.90**	14.08	9.71	**23.79**	20.50	14.15	**34.65**	36.41	25.12	**61.54**	78.82	54.39	**133.212**
3	Kottakkaraiyar	15.06	14.38	**29.44**	18.00	17.19	**35.18**	26.22	25.04	**51.26**	46.55	44.47	**91.03**	100.78	96.27	**197.047**
Total		**53.77**	**46.29**	**100.05**	**64.26**	**55.32**	**119.57**	**93.61**	**80.58**	**174.20**	**166.24**	**143.10**	**309.34**	**359.87**	**309.78**	**669.652**

7.4 Irrigation Demand

Agriculture is the prime driving force for food security, rural economy and sustainable socio economic development of farmers.

Irrigation is a vital input for food production in the State of Tamilnadu. Medium and minor irrigation schemes are implemented in the State for augmenting the water required for Irrigation.

Irrigation water demand for 75% rainfall dependability of Pambar & Kottakkaraiyar River Basin is tabulated in **Table 7.5** and the season wise Irrigation water demand (mcm) at 75 % rainfall dependability in Pambar & Kottakkaraiyar River Basin is tabulated in **Table 7.6**

The major crops cultivated in Pambar & Kottakkaraiyar River Basin are Paddy, Coconut, Fruits & Vegetables ,Sugarcane, Ground nut, and Chillies. The irrigated area for the year 2006-07 in Pambar & Kottakkaraiyar River Basin under different crops was 1,26,953 ha with paddy as the main crop of the basin cultivated in 1,04,00 ha. At present the irrigated area based on the good rainfall for the year 2015-16 is 99985Ha and has been consider for deriving the demand.

Table 7.5 Irrigation Water Demand (Mcum) At 75 % Rainfall Dependability

Sl.No	Sub Basin	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1	Manimuthar	18.79	10.67	10.19	9.49	17.83	38	21.9	22.7	6.91	37.5	10.9	36.73	241.64
2	Pambar	23.39	1.89	2.82	3.01	2.7	40.47	15.3	33.7	12.5	49.7	18.8	27.76	232.01
3	Kottakkaraiyar	27.62	7.07	7.87	7.37	2.61	63.68	34	48.9	7.61	72.2	27.4	63.95	370.22
	TOTAL	**69.8**	**19.63**	**20.88**	**19.9**	**23.14**	**142.2**	**71.2**	**105**	**27**	**159**	**57.1**	**128.4**	**843.87**

Table 7.6 Irrigation Water Demand (Mcum) At 75 % Rainfall Dependability in Pambar & Kottakkaraiyar River Basin (Season Wise)

Sub basin	Winter	Summer	Southwest	Northeast	Total
Manimuthar	29.47	37.52	89.54	85.12	241.64
Pambar	25.27	8.53	101.95	96.25	232.01
Kottakkaraiyar	34.69	17.85	154.11	163.57	370.22
Total	**89.43**	**63.90**	**345.60**	**344.94**	**843.87**

7.5 Industrial Water Demand

The department of Industries and Commerce has classified the industries as large, medium and small scale industries. The list of small, medium and large scale industries in Pudukottai, Trichy, Dindugal, Sivaganga, Madurai and Ramanathapuram districts along with their water requirement is collected from the Tamil Nadu Pollution Control Board. From that, small, medium and large scale industries falling in Pambar & Kottakkaraiyar River Basin are listed out and given in appendix 7.1 to 7.6. At present in the Pambar & Kottakkaraiyar River Basin there are 33 numbers of large and medium industries and 596 numbers of small scale industries. Accordingly, the yearly requirement of water for Large & Medium and small scale industries at present is estimated as 1.361 Mcum&1.101Mcum respectively.

7.5.1 Industrial water Demand Projection

For forecasting the water demand of Industries for future years, a simple arithmetic increase of 8% per annum (as per the Annual Survey of Industries) over the present requirement has been adopted.

The Industrial Water Demand in Pambar & Kottakkaraiyar River Basin for the year 2018 for the small scale industries is assessed as **1.101 Mcum** and for the target years 2020, 2030, 2040 and 2050 also and is given in **Table 7.7 (a).**

The Industrial Water Demand in Pambar & Kottakkaraiyar River Basin for the year 2018 for the Large & Medium scale industries is assessed as **1.361 Mcum** and for the target years 2020, 2030, 2040 and 2050 also and is given in **Table 7.7 (b).**

Table 7.7 (a) Water Demand of Small Scale Industries in Pambar Kottakkaraiyar River Basin

Sl.No.	Name of the Sub Basin	2018		2020		2030		2040		2050	
		Number of Industries	Water Demand in Mcum	Number of Industries	Water Demand in Mcum	Number of Industries	Water Demand in Mcum	Number of Industries	Water Demand in Mcum	Number of Industries	Water Demand in Mcum
1	Manimuthar	277	0.563	343	0.698	618	1.257	1113	2.262	2003	4.071
2	Pambar	238	0.344	295	0.427	531	0.768	956	1.382	1721	2.488
3	Kottakkaraiyar	81	0.194	100	0.241	181	0.433	325	0.779	586	1.403
Total		**596**	**1.101**	**738**	**1.365**	**1330**	**2.4574**	**2394**	**4.423**	**4310**	**7.962**

Table 7.7 (b) Water Demand of Large & Medium Scale Industries in Pambar Kottakkaraiyar River Basin

Sl.No.	Name of the Sub Basin	2018		2020		2030		2040		2050	
		Number of Industries	Water Demand in Mcum	Number of Industries	Water Demand in Mcum	Number of Industries	Water Demand in Mcum	Number of Industries	Water Demand in Mcum	Number of Industries	Water Demand in Mcum
1	Manimuthar	13	0.066	16	0.082	29	0.147	52	0.265	94	0.477
2	Pambar	12	0.707	15	0.877	27	1.578	48	2.840	87	5.113
3	Kottakkaraiyar	8	0.588	10	0.729	18	1.312	32	2.362	58	4.252
Total		**33**	**1.361**	**41**	**1.688**	**74**	**3.038**	**133**	**5.467**	**239**	**9.842**

Table 7.8 Total Industrial Water Demand in Pambar Kottakkaraiyar River Basin

Water Demand in Mcum

Sl. No	Name of the Sub Basin	2018			2020			2030			2040			2050		
		L&MI	SSI	Total	L&MI	SSI	Total	L&MI	SSI	Total	L&MI	SSI	Total	L&MI	SSI	Total
1	Manimuthar	0.066	0.563	**0.629**	0.082	0.698	**0.780**	0.147	1.257	**1.404**	0.265	2.262	**2.527**	0.477	4.071	**4.548**
2	Pambar	0.707	0.344	**1.051**	0.877	0.427	**1.304**	1.578	0.768	**2.346**	2.840	1.382	**4.222**	5.113	2.488	**7.601**
3	Kottakkaraiyar	0.588	0.194	**0.782**	0.729	0.241	**0.970**	1.312	0.433	**1.745**	2.362	0.779	**3.141**	4.252	1.403	**5.655**
Total		**1.361**	**1.101**	**2.462**	**1.688**	**1.366**	**3.054**	**3.037**	**2.458**	**5.495**	**5.467**	**4.423**	**9.890**	**9.842**	**7.962**	**17.804**

7.6 Live stock Water Demand

Tamil Nadu has vast resource of livestock which play a vital role in improving the socio-economic conditions of rural masses. Livestock provides nutrient-rich food products such as milk, meat, egg, dung as organic manure and domestic fuel, hides and skin, and is a regular source of cash income for rural households. In the recent decade, demand for various livestock based products has increased significantly due to increase in per-capita income, urbanization and increased awareness about food nutrition. Also with the rapid increase in human population the demand for livestock based products also increases .

The 19th livestock census 2012, collected from the Department of Animal Husbandry and Veterinary Services contains the District wise population of different categories of Livestock. The District wise livestock populations are distributed to the sub basins of Pambar & Kottakkaraiyar River Basin. The livestock population details of each sub basins are given in **Appendix 7.7, 7.8 and 7.9**

The norms of the Indian Council of Agriculture and Research for the live stock per capita water requirement have been adopted in the estimation of livestock water demand and are given in **Table 7.9**

Table 7.9 Water Requirement for Live Stock

Sl. No.	Name	Standard Norms in lpcd
1	Cattle	110
2	Buffalo	150
3	Sheep	20
4	Goats	20
5	Horses & Ponies	150
6	Donkeys	40
7	Pigs	40
8	Dogs	15
9	Rabbits	0.35
10	Poultry	0.25

Source: Indian council of Agriculture and Research

To predict the future livestock water demand in the basin, the present livestock population needs to be projected.

The census on livestock, poultry is conducted once in 5 years since 1951. The last census conducted by the Department of Animal Husbandry, Tamil Nadu during was during 2012.

Table 7.10 Sub Basin wise Projected Livestock Population in Pambar Kottakkaraiyar River Basin

Sl. No	Year	Livestock	Livestock Population			Total
			Manimuthar	Pambar	Kottakkaraiyar	
1	2012	Cattle	744182	468906	483205	1696293
		Buffallo	14400	19992	14523	48915
		Sheep	447513	258587	898065	1604165
		Goat	527494	257848	616880	1402222
		Horses & Ponies	16	22	7	45
		Donkeys	1096	9	136	1241
		Pigs	6075	7574	9483	23132
		Dog	70254	47237	77764	195255
		Rabbit	431	272	899	1602
		Backyard Poultry	750317	377334	768743	1896394
		Farm Poultry	401365	377526	89221	868112
Total			**2963143**	**1815307**	**2958926**	**7737376**
2	2018	Cattle	744182	468906	483205	1696293
		Buffallo	14400	19992	14523	48915
		Sheep	447513	258587	898065	1604165
		Goat	527494	257848	616880	1402222
		Horses & Ponies	16	22	7	45
		Donkeys	1096	9	136	1241
		Pigs	6075	7574	9483	23132
		Dog	70254	47237	77764	195255
		Rabbit	431	272	899	1602
		Backyard Poultry	750317	377334	768743	1896394
		Farm Poultry	401365	377526	89221	868112
Total			**2963143**	**1815307**	**2958926**	**7737376**

From the 19th livestock census data the sub basin wise livestock population is arrived and the same is adopted for the present year 2018 in the **table 7.10** and same value is assumed for the target years 2020, 2030, 2040 & 2050 .

Table 7.11 Sub Basin wise Livestock Water Demand in Pambar Kottakkaraiyar River Basin

Sl. No	Year	Livestock	Standard Norms in lpcd	Live Stock Water Demand in Mcum			
				Manimuthar	Pambar	Kottakkaraiyar	Total
1	2018	Cattle	**110**	29.879	18.827	19.401	68.106
		Buffallo	**150**	0.788	1.095	0.795	2.678
		Sheep	**20**	3.267	1.888	6.556	11.710
		Goat	**20**	3.851	1.882	4.503	10.236
		Horses & Ponies	**150**	0.001	0.001	0.000	0.002
		Donkeys	**40**	0.016	0.000	0.002	0.018
		Pigs	**40**	0.089	0.111	0.138	0.338
		Dog	**15**	0.385	0.259	0.426	1.069
		Rabbit	**0.35**	0.000	0.000	0.000	0.000
		Backyard Poultry	**0.25**	0.068	0.034	0.070	0.173
		Farm Poultry	**0.25**	0.037	0.034	0.008	0.079
Total				**38.380**	**24.131**	**31.900**	**94.411**

The livestock water demand during 2018, is worked out as **94.411Mcum** in the **table 7.11** and the same value is assumed for the years 2020, 2030, 2040 & 2050.There is no elephants and camel in Pambar Kottakkaraiyar River Basin.

7.7.Total Water Demand

The total water demand of four sectors, i.e., Domestic, Irrigation, Livestock and Industries of Pambar & Kottakkaraiyar River Basin for the present year 2018 and the projected target years 2020, 2030, 2040 & 2050 are worked out as 1040.793Mcum, 1060.905Mcum, 1117.976Mcum, 1257.521Mcum & 1625.737Mcum respectively and are given in Table No.7.12.

Table 7.12 Sub Basin Wise Projected total Water Demand in Pambar Kottakkaraiyar River Basin.

(Water Demand in Mcum)

Sl. No	Name of the Sub Basin	2018					2020					2030				
		Domestic	Irrigation	livestock	Industries	Total	Domestic	Irrigation	livestock	Industries	Total	Domestic	Irrigation	livestock	Industries	Total
1	Manimuthar	50.71	241.64	38.38	0.63	**331.36**	60.60	241.64	38.38	0.78	**341.40**	88.29	241.64	38.38	**1.40**	**369.71**
2	Pambar	19.90	232.01	24.13	1.05	**277.09**	23.79	232.01	24.13	1.30	**281.23**	34.65	232.01	24.13	**2.35**	**293.14**
3	Kottakkaraiyar	29.44	370.22	31.90	0.78	**432.34**	35.18	370.22	31.90	0.97	**438.27**	51.26	370.22	31.90	**1.75**	**455.12**
	Total	**100.05**	**843.87**	**94.41**	**2.46**	**1040.79**	**119.57**	**843.87**	**94.41**	**3.05**	**1060.90**	**174.20**	**843.87**	**94.41**	**5.50**	**1117.98**

Sl. No	Name of the Sub Basin	2040					2050				
		Domestic	Irrigation	livestock	Industries	Total	Domestic	Irrigation	livestock	Industries	Total
1	Manimuthar	156.78	241.64	38.38	2.53	**439.33**	339.39	241.64	38.38	4.55	**623.96**
2	Pambar	61.54	232.01	24.13	4.22	**321.90**	133.21	232.01	24.13	7.60	**396.95**
2	Kottakkaraiyar	91.03	370.22	31.90	3.14	**496.29**	197.05	370.22	31.90	5.66	**604.82**
	Total	**309.35**	**843.87**	**94.41**	**9.89**	**1257.52**	**669.65**	**843.87**	**94.41**	**17.80**	**1625.74**

The comparison between the reappraisal study of Pambar & Kottakkaraiyar River Basin carried out during 2007and 2018 is presented in the T**able 7.13**

Table 7.13 Comparison between the reappraisal studies of Pambar Kottakkaraiyar River Basin carried out during 2007 and 2018

Water Demand in Mcum

SI.No	Water Demand	Year	
		2007	**2018**
1.	Domestic Demand	63.543	100.05
2.	Irrigation Demand	1099	843.87
3.	Industrial Demand	39.39	2.462
4.	Livestock Demand	133.884	94.41
Total demand		**1335.817**	**1040.79**

The total water demand of four sectors, i.e., Domestic, Irrigation, Livestock, and Industries of Pambar & Kottakkaraiyar River Basin for the present year 2018 was worked out as 1040.793Mcum**.** But the water demand in 2007 was 1335.817. This shows that there is 22.1% decrease in water demand within 11 years for the present year, when compared to the water demand during 2007.

CHAPTER – 8

WATER BALANCE

CHAPTER – 8

WATER BALANCE

The main aim of water resources planning in each river basin is to find out whether the availability of water in the basin is enough to meet out the demand. If the availability of water is less than the requirements, then suitable measures are to be taken for optimum utilisation. If the availability of water is more than the demand, suitable utilization of the excess water has to be planned either within the basin or the excess could be transferred to nearby deficit basins. Better water management is also necessary. Hence, water balance is a tool to utilize the water optimally in a river basin.

8.1 Water Potential of Pambar and Kottakkaraiyar river basin

Total water potential is the sum of surface water potential and ground water potential. The surface water potential of Pambar and Kottakkaraiyar basin is estimated sub basin wise using Monthly Runoff Simulation Model and is furnished in **Table 5.5 of Chapter 5**. The surface water potential of Pambar and Kottakaraiyar basin from interbasin transfer is assessed and is furnished in **Section 5.8 of Chapter 5**. The surface water potential of Pambar and Kottakaraiyar basin from the reuse of waste water from domestic and industrial industrial water and return flow from irrigation demandis assessed based on the guidelines in **Chapter 7**.The ground water availability of the basin is estimated as per GEC norms and is furnished in **Table 6.10 of Chapter 6.**The total water potential of Pambar and Kottakkaraiyar basin is **2266.55Mcum** is calculated as below:

Surface water potential assessed from rainfall	= 599.36Mcum
Surface water potential assessed from inter basin transfer	= 173.40 Mcum
Surface water potential assessed from Return flow	= 363.86 Mcum
Ground water availability	= 1129.93Mcum
Total Water Potential of the basin	= **2266.55Mcum**

8.2 Water Demand of Pambar and Kottakkaraiyar river basin

Total water demand is the sum of the various sectoral demands such as Domestic demand, Irrigation demand, Livestock demand, Industrial demand, Aquaculture demand and Ecological demand. The various sectoral demands except Ecological demand are determined for the present study year and also projected for the years 2020,2030,2040 & 2050 and furnished in **Chapter 7**.The Irrigation demand is assessed in Chapter 4. In order to maintain the health and biodiversity of rivers, the Environmental Flow Requirement (EFR) is necessary. This is termed as Ecological demand. Hence in this assessment, provisions are given for ecological requirements at a rate of 0.5% of Surface Water Potential at 75% dependability for 2018 and at 1% for 2020, 2030, 2040 and 2050. This is added to total water demand. The total water demand in Pambar and Kottakkaraiyar river basin for different yearsis tabulated in table 8.1.

Table 8.1

Total Sectoral Water Demand in Pambar and KottakkaraiyarRiver Basin (75% dependability)

Sl. No.	Type of Demand	Total Demand in Mcum				
		2018	**2020**	**2030**	**2040**	**2050**
1	Domestic	100.05	119.57	174.20	309.35	669.65
2	Irrigation (including losses)	1409.26	1409.26	1409.26	1409.26	1409.26
3	Live Stock	94.41	94.41	94.41	94.41	94.41
4	Industries	2.46	3.05	5.50	9.89	17.80
5.	Ecological	3.00	5.99	5.99	5.99	5.99
	Total	**1609.18**	**1632.28**	**1689.36**	**1828.9**	**2197.11**

Table 8.2

Total Sectoral Water Demand in Pambar and KottakkaraiyarRiver Basin (50% dependability)

Sl. No.	Type of Demand	Total Demand in Mcum				
		2018	**2020**	**2030**	**2040**	**2050**
1	Domestic	100.05	119.57	174.20	309.35	669.65
2	Irrigation (including losses)	1353.82	1353.82	1353.82	1353.82	1353.82
3	Live Stock	94.41	94.41	94.41	94.41	94.41
4	Industries	2.46	3.05	5.50	9.89	17.81
5.	Ecological	4.02	8.04	8.04	8.04	8.04
	Total	**1554.76**	**1578.89**	**1635.97**	**1775.51**	**2143.73**

8.3 Water Balance at 75% dependability

Water Potential for the year 2018 = 2266.55Mcum

Water demand for the year 2018 = 1609.18Mcum

Water Balance = 657.37Mcum

% Water Balance with respect to potential = 29.00 %

Pambar and Kottakaraiyar basin as such shows a water balance by 657.37Mcum (29.00 %) for the year 2018 at 75% dependability when considering the value of both surface water potential and ground water potential.But in practice, the Ground Water potential is tapped in deep aquifers and hence tapping the water from the aquifers is difficult. Therefore, the contribution from Ground water potential is very meager.

Water balance is determined for the years 2020, 2030, 2040 and 2050. In respect of the water potential the water potential varies as the return flow differs for future years. And also the demand is different for future years as population increases. Hence the water balance for the present and the future is carried out separately and tabulated in **Table 8.3**.

Table 8.3

Water Balancing for Pambar and Kottakkaraiyar River Basin at 75% dependability

Water Potential, Demand and Deficit (Both long & short term)

Sector	2018	2020	2030	2040	2050
Water Potential in Mcum	1902.69	1902.69	1902.69	1902.69	1902.69
Return Flow in Mcum	363.86	379.95	425.61	537.24	831.82
Total Water Potential in Mcum	2266.55	2282.64	2328.30	2439.93	2734.51
Total Water Demand in Mcum	1609.18	1632.28	1689.36	1828.9	2197.11
Total water water balance in Mcum	**657.37**	**650.36**	**638.94**	**611.03**	**537.40**
Percentage of water balance with respect to potential	**29.01%**	**28.5%**	**27.45%**	**25.05%**	**19.66%**

From the table, it is observed that the Pambar and Kottakaraiyar river basin for the year 2018 appears surplus by 29.01 % of total water potenial available in the basin.

8.4 Water Balance at 50% dependability

Water balance is also worked out for 50% dependable values so that it could be adopted for years having good rainfall. For this purpose, Surface water potential value at 50% dependability obtained from MRS model, interbasin transfer and return flow is 2460.49 Mcum,. Similarly, the irrigation demand values at 50% dependable rainfall obtained from the CROPWAT model is already given in Section 4.70 and it is adopted for calculation. The corresponding values for different years are tabulated in Table 8.4. This also shows a water balance of 36.82 %.

Table 8.4

Water Balancing for Pambar and Kottakkaraiyar River Basin at 50% dependability

Water Potential, Demand and Deficit (Both long & short term)

Sector	2018	2020	2030	2040	2050
Water Potential in Mcum	2107.72	2107.72	2107.72	2107.72	2107.72
Return Flow in Mcum	352.77	368.86	414.52	526.16	820.73
Total Water Potential in Mcum	2460.49	2476.58	2522.24	2633.88	2928.45
Total Water Demand in Mcum	1554.76	1578.89	1635.97	1775.51	2143.73
Total water balance in Mcum	**905.73**	**897.69**	**886.27**	**858.37**	**784.72**
Percentage of water balance with respect to potential	**36.82%**	**36.25%**	**35.14%**	**32.59%**	**26.8%**

8.5 Water Balance for Different scenarios:

The following different planning scenarios for Pambar and Kottakkaraiyar river basin is considered:

1) **Existing scenario**

. The surface water potential and ground water availability assessed and the various sectoral demands are discussed in chapters 5, 6, 4 & 7 respectively. The water which is supplied to irrigation undergoes various losses during conveyance. According to the report "Vision document 2020-2023" the effeciency from Surface water irrigation in Tamil Nadu is 40% and Ground water irrigation is 75%. Hence taking an average the total efficiency is 57.5% i.e. approximately 60%. Hence, to account for the losses, a factor of 1.67 is used with irrigation demand.

The water balance in the above sections 8.3 and 8.4 has considered the surface water potential arrived due to rainfall alone. However, this basin has an inter basin transfer from the adjoining Vaigai basin through the Vaigai canal and also from Periyar main canal. In the present scenario the water diverted from the adjoining basin is also considered. Similarly reuse of treated waste water from domestic and industrieal demand is also consideredbased on the guidelines in Chapter 7. The return flow from irrigation demand is also considered based on the guidelines in Chapter 7.

According to the NWDA guidelines for preparation of preliminary water balance study reports, the Regeneration of domestic, industrial and irrigation water is at the rate of 80 %, 80% and 20% respectively. Hence the total water potential of the basin is now arrived by adding the quantum of water reused from the industrial waste water and the water from the interbasin transfer. Water balance sub basin wise for 75 % dependability in the existing condition considering all demands in the present study year has been carried out as above and the values are presented in tables:**Table 8.5**, **Table 8.6**, **Table 8.7, Table 8.8** and **Table 8.9** for the years 2018, 2020, 2030, 2040 & 2050 respectively.

Similar calculations are carried out for 50 % dependability and tabulated for sub basin wise in the tables **Table 8.10**, **Table 8.11**, **Table 8.12, Table 8.13** and **Table 8.14,** for the years 2018, 2020, 2030, 2040 & 2050 respectively.

2) Improved agricultural methods

This scenario is based on the identification of changes in the present cropping or cultivation pattern, which would result in, some reasonable lower limit for the future demand of irrigation water in the basin.

Paddy, which is the staple food crop of Tamil Nadu is extensively cultivated in all Districts in a normal area of 17.65 Lakh Ha. Paddy accounts for about 50% of the total irrigated area of the State. Nearly 94% of the Paddy area is raised only under irrigated condition. If the objective of better yield for a drop of water is to be achieved, then comparatively less water consuming practices of cultivation are to be considered for future planning purposes. Hence the cultivation of paddy using SRI (System of Rice Intensification) method would reduce the irrigation demand. Therefore, it is presumed that in future $2/3^{rd}$ area under paddy cultivation will be cultivated using SRI method. Accordingly, the net Irrigation demand is reworked in section 4.6 as 662.78 Mcum. Correspondingly, the net irrigation Water Demand at 50% and 75%

dependable Rainfall of Improved Agricultural method Scenario are tabulated in **Tables 4.12 and 4.13**. To account for the losses, the net Irrigation demand is multiplied by a factor of 1.67 as discussed above.

Now the water balance for this scenario is calculated for 75 % dependability for the years 2018, 2020, 2030, 2040 and 2050 and presented in the Appendix 8.1 to 8.5 of Volume II. Similarly, the water balance for this scenario is calculated for 50 % dependability for the years 2018, 2020, 2030, 2040 and 2050 and presented in the Appendix 8.11 to 8.15 of Volume II.

3) Improved Efficiency

This scenario represents an irrigation system with an improved efficiency where the existing system is rehabilated and modernised to improve the efficiency of the system. Accorrding to the report "Implementation Completion and Results report for Tamil Nadu IAMWARM project by World Bank - March 24, 2016", the efficiency of the surface water potential has been improved by 30% of the existing system. Hence the overall efficiency of the system is 70 % on an average as the surface water potential is 70% and ground water potential as 70% as discussed earlier. Hence a factor of 1.43 is multiplied to counter the irrigation losses in the field.

Now the water balance for this scenario is calculated for 75 % dependability for the years 2018, 2020, 2030, 2040 and 2050 and presented in the Appendix 8.6 to 8.10 of Volume II. Similarly, the water balance for this scenario is calculated for 50 % dependability for the years 2018, 2020, 2030, 2040 and 2050 and presented in the Appendix 8.16 to 8.20.

The bar charts for 75% & 50% dependabiliites for the years 2018, 2020, 2030, 2040 & 2050 for various scenerios are also presented in the **Figure 8.1 to Figure 8.5**.

8.6 Conclusion

Thus the Water Balance study of Pambar and Kottakaraiyar river basin for the existing scenario for the current year shows that the irrigation demand value accounts for about 85% of the total water demand.

There are many small and marginal farmers present in this region. And also the Ground water potential is trapped in deep aquifers and hence tapping the water from these aquifers by using bore holes is also costly for these farmers. Therefore, the contribution from Ground water potential for irrigation is very meager. But many industries use bore holes to tap these Ground water resources for meeting their demand.

Diversion of water from Vaigai basin through Periyar main canal and Vaigai canal is used for irrigation purpose.

Steps may be taken to improve the use of ground water and also to reduce the losses by lining canals, proper maintenance of irrigation structures, and adopting improved irrigation techniques. More artificial recharge structures such as check dams, recharge shafts and percolation ponds may be provided in suitable locations in the basin for improving the water potential.

Table 8.5

Pambar Kottakaraiyar BASIN - Sub Basin wise water balance at 75% dependability (Existing scenario)

2018

Details of Water Potential and Demand		Manimuthar	Pambar	Kottakaraiyar	Total
Water potential in Mcum	Surface water potential assessed from rainfall	211.97	169.80	217.59	599.36
	Quantity of Water diverted for Pambar and Kottakaraiyar basin through Vaigai canal and Periyar main canal	94.30	0.00	79.10	173.40
	Ground water potential	335.87	334.78	459.28	1129.93
	Total water potential	642.14	504.58	755.97	1902.69
Water demand in Mcum	Domestic demand	50.71	19.90	29.44	100.05
	Irrigation demand	403.54	387.46	618.27	1409.26
	Livestock demand	38.38	24.13	31.90	94.41
	Industrial demand	0.63	1.05	0.78	2.46
	Ecological demand	1.06	0.85	1.09	3.00
	Total water demand	494.32	433.39	681.48	1609.18
Return flow in Mcum	Quantity of waste water from domestic demand that can be reused	40.57	15.92	23.55	80.04
	Quantity of waste water from Large & Small scale Industries that can be reused	0.50	0.84	0.63	1.97
	Quantity of water from irrigation as return flow	80.71	77.49	123.65	281.85
	Total Return Flow	121.78	94.25	147.83	363.86
Total water potential in Mcum	Total water potential after considering the reuse of waste water	**763.92**	**598.83**	**903.80**	**2266.55**
Total Demand in Mcum	Total water demand	**494.32**	**433.39**	**681.48**	**1609.18**
Water Balance in Mcum		**269.60**	**165.45**	**222.32**	**657.37**
Percentage		**35.3%**	**27.6%**	**24.6%**	**29.0%**

Water Balance in Pambar Kottakaraiyar basin = **657.37** **Mcum** **29.0%**

Table 8.6

Pambar Kottakaraiyar BASIN - Sub Basin wise water balance at 75% dependability (Existing scenario)

2020

Details of Water Potential and Demand		**Manimuthar**	**Pambar**	**Kottakaraiyar**	**Total**
Water potential in Mcum	Surface water potential assessed from rainfall	211.97	169.80	217.59	599.36
	Quantity of Water diverted for Pambar and Kottakaraiyar basin through Vaigai canal and Periyar main canal	94.30	0.00	79.10	173.40
	Ground water potential	335.87	334.78	459.28	1129.93
	Total water potential	642.14	504.58	755.97	1902.69
Water demand in Mcum	Domestic demand	60.60	23.79	35.18	119.57
	Irrigation demand	403.54	387.46	618.27	1409.26
	Livestock demand	38.38	24.13	31.90	94.41
	Industrial demand	0.78	1.30	0.97	3.05
	Ecological demand	2.12	1.70	2.18	5.99
	Total water demand	505.42	438.38	688.49	1632.29
Return flow in Mcum	Quantity of waste water from domestic demand that can be reused	48.48	19.03	28.14	95.66
	Quantity of waste water from Large & Small scale Industries that can be reused	0.62	1.04	0.78	2.44
	Quantity of water from irrigation as return flow	80.71	77.49	123.65	281.85
	Total Return Flow	129.81	97.57	152.57	379.95
Total water potential in Mcum	Total water potential after considering the reuse of waste water	**771.95**	**602.15**	**908.54**	**2282.64**
Total Demand in Mcum	Total water demand	**505.42**	**438.38**	**688.49**	**1632.29**
Water Balance in Mcum		**266.53**	**163.77**	**220.05**	**650.35**
Percentage		**34.5%**	**27.2%**	**24.2%**	**28.5%**

Water Balance in Pambar Kottakaraiyar basin = **650.35** **Mcum -** **28.5%**

Table 8.7

Pambar Kottakaraiyar BASIN - Sub Basin wise water balance at 75% dependability (Existing scenario)

2030

Details of Water Potential and Demand		Manimuthar	Pambar	Kottakaraiyar	Total
Water potential in Mcum	Surface water potential assessed from rainfall	211.97	169.80	217.59	599.36
	Quantity of Water diverted for Pambar and Kottakaraiyar basin through Vaigai canal and Periyar main canal	94.30	0.00	79.10	173.40
	Ground water potential	335.87	334.78	459.28	1129.93
	Total water potential	642.14	504.58	755.97	1902.69
Water demand in Mcum	Domestic demand	88.29	34.65	51.26	174.20
	Irrigation demand	403.54	387.46	618.27	1409.26
	Livestock demand	38.38	24.13	31.90	94.41
	Industrial demand	1.40	2.35	1.75	5.50
	Ecological demand	2.12	1.70	2.18	5.99
	Total water demand	533.73	450.28	705.35	1689.36
Return flow in Mcum	Quantity of waste water from domestic demand that can be reused	70.63	27.72	41.01	139.36
	Quantity of waste water from Large & Small scale Industries that can be reused	1.12	1.88	1.40	4.40
	Quantity of water from irrigation as return flow	80.71	77.49	123.65	281.85
	Total Return Flow	152.46	107.09	166.06	425.61
Total water potential in Mcum	Total water potential after considering the reuse of waste water	**794.60**	**611.67**	**922.03**	**2328.30**
Total Demand in Mcum	Total water demand	**533.73**	**450.28**	**705.35**	**1689.36**
Water Balance in Mcum		**260.87**	**161.39**	**216.68**	**638.94**
Percentage		**32.8%**	**26.4%**	**23.5%**	**27.4%**

Water Balance in Pambar Kottakaraiyar basin = **638.94** **Mcum -** **27.4%**

Table 8.8

Pambar Kottakaraiyar BASIN - Sub Basin wise water balance at 75% dependability (Existing scenario)

2040

Details of Water Potential and Demand		Manimuthar	Pambar	Kottakaraiyar	Total
Water potential in Mcum	Surface water potential assessed from rainfall	211.97	169.80	217.59	599.36
	Quantity of Water diverted for Pambar and Kottakaraiyar basin through Vaigai canal and Periyar main canal	94.30	0.00	79.10	173.40
	Ground water potential	335.87	334.78	459.28	1129.93
	Total water potential	**642.14**	**504.58**	**755.97**	**1902.69**
Water demand in Mcum	Domestic demand	156.78	61.54	91.03	309.35
	Irrigation demand	403.54	387.46	618.27	1409.26
	Livestock demand	38.38	24.13	31.90	94.41
	Industrial demand	2.53	4.22	3.14	9.89
	Ecological demand	2.12	1.70	2.18	5.99
	Total water demand	**603.35**	**479.05**	**746.51**	**1828.91**
Return flow in Mcum	Quantity of waste water from domestic demand that can be reused	125.42	49.23	72.82	247.48
	Quantity of waste water from Large & Small scale Industries that can be reused	2.02	3.38	2.51	7.91
	Quantity of water from irrigation as return flow	80.71	77.49	123.65	281.85
	Total Return Flow	208.15	130.10	198.99	537.24
Total water potential in Mcum	Total water potential after considering the reuse of waste water	**850.29**	**634.68**	**954.96**	**2439.93**
Total Demand in Mcum	Total water demand	**603.35**	**479.05**	**746.51**	**1828.91**
Water Balance in Mcum		**246.95**	**155.63**	**208.45**	**611.03**
Percentage		**29.0%**	**24.5%**	**21.8%**	**25.0%**

Water Balance in Pambar Kottakaraiyar basin = **611.03** **Mcum -** **25.0%**

Table 8.9

Pambar Kottakaraiyar BASIN - Sub Basin wise water balance at 75% dependability (Existing scenario)

2050

Details of Water Potential and Demand		Manimuthar	Pambar	Kottakaraiyar	Total
Water potential in Mcum	Surface water potential assessed from rainfall	211.97	169.80	217.59	599.36
	Quantity of Water diverted for Pambar and Kottakaraiyar basin through Vaigai canal and Periyar main canal	94.30	0.00	79.10	173.40
	Ground water potential	335.87	334.78	459.28	1129.93
	Total water potential	642.14	504.58	755.97	1902.69
Water demand in Mcum	Domestic demand	339.39	133.21	197.05	669.65
	Irrigation demand	403.54	387.46	618.27	1409.26
	Livestock demand	38.38	24.13	31.90	94.41
	Industrial demand	4.55	7.60	5.66	17.80
	Ecological demand	2.12	1.70	2.18	5.99
	Total water demand	787.98	554.10	855.05	2197.12
Return flow in Mcum	Quantity of waste water from domestic demand that can be reused	271.51	106.57	157.64	535.72
	Quantity of waste water from Large & Small scale Industries that can be reused	3.64	6.08	4.52	14.24
	Quantity of water from irrigation as return flow	80.71	77.49	123.65	281.85
	Total Return Flow	355.86	190.14	285.82	831.82
Total water potential in Mcum	Total water potential after considering the reuse of waste water	**998.00**	**694.72**	**1041.79**	**2734.51**
Total Demand in Mcum	Total water demand	**787.98**	**554.10**	**855.05**	**2197.12**
Water Balance in Mcum		**210.02**	**140.62**	**186.74**	**537.39**
Percentage		**21.0%**	**20.2%**	**17.9%**	**19.7%**

Water Balance in Pambar Kottakaraiyar basin = **537.39** **Mcum -** **19.7%**

Table 8.10

Pambar Kottakaraiyar BASIN - Sub Basin wise water balance at 50% dependability (Existing scenario)

2018

Details of Water Potential and Demand		Manimuthar	Pambar	Kottakaraiyar	Total
Water potential in Mcum	Surface water potential assessed from rainfall	308.80	208.59	287.00	804.39
	Quantity of Water diverted for Pambar and Kottakaraiyar basin through Vaigai canal and Periyar main canal	94.30	0.00	79.10	173.40
	Ground water potential	335.87	334.78	459.28	1129.93
	Total water potential	738.97	543.37	825.38	2107.72
Water demand in Mcum	Domestic demand	50.71	19.90	29.44	100.05
	Irrigation demand	395.82	369.30	588.69	1353.82
	Livestock demand	38.38	24.13	31.90	94.41
	Industrial demand	0.63	1.05	0.78	2.46
	Ecological demand	1.54	1.04	1.44	4.02
	Total water demand	487.09	415.43	652.25	1554.76
Return flow in Mcum	Quantity of waste water from domestic demand that can be reused	40.57	15.92	23.55	80.04
	Quantity of waste water from Large & Small scale Industries that can be reused	0.50	0.84	0.63	1.97
	Quantity of water from irrigation as return flow	79.16	73.86	117.74	270.76
	Total Return Flow	120.24	90.62	141.92	352.77
Total water potential in Mcum	Total water potential after considering the reuse of waste water	**859.21**	**633.99**	**967.30**	**2460.49**
Total Demand in Mcum	Total water demand	**487.09**	**415.43**	**652.25**	**1554.76**
Water Balance in Mcum		**372.12**	**218.56**	**315.05**	**905.73**
Percentage		**43.3%**	**34.5%**	**32.6%**	**36.8%**

Water Balance in Pambar Kottakaraiyar basin = **905.73** **Mcum** **36.8%**

Table 8.11

Pambar Kottakaraiyar BASIN - Sub Basin wise water balance at 50% dependability (Existing scenario)

2020

Details of Water Potential and Demand		Manimuthar	Pambar	Kottakaraiyar	Total
Water potential in Mcum	Surface water potential assessed fro	308.80	208.59	287.00	804.39
	Quantity of Water diverted for Pambar and Kottakaraiyar basin through Vaigai canal and Periyar main canal	94.30	0.00	79.10	173.40
	Ground water potential	335.87	334.78	459.28	1129.93
	Total water potential	738.97	543.37	825.38	2107.72
Water demand in Mcum	Domestic demand	60.60	23.79	35.18	119.57
	Irrigation demand	395.82	369.30	588.69	1353.82
	Livestock demand	38.38	24.13	31.90	94.41
	Industrial demand	0.78	1.30	0.97	3.05
	Ecological demand	3.09	2.09	2.87	8.04
	Total water demand	498.67	420.61	659.61	1578.90
Return flow in Mcum	Quantity of waste water from domestic demand that can be reused	48.48	19.03	28.14	95.66
	Quantity of waste water from Large & Small scale Industries that can be reused	0.62	1.04	0.78	2.44
	Quantity of water from irrigation as return flow	79.16	73.86	117.74	270.76
	Total Return Flow	128.27	93.94	146.66	368.86
Total water potential in Mcum	Total water potential after considering the reuse of waste water	**867.24**	**637.31**	**972.04**	**2476.58**
Total Demand in Mcum	Total water demand	**498.67**	**420.61**	**659.61**	**1578.90**
Water Balance in Mcum		**368.57**	**216.69**	**312.43**	**897.69**
Percentage		**42.5%**	**34.0%**	**32.1%**	**36.2%**

Water Balance in Pambar Kottakaraiyar basin = **897.69** **Mcum** **36.2%**

Table 8.12

Pambar Kottakaraiyar BASIN - Sub Basin wise water balance at 50% dependability (Existing scenario)

2030

Details of Water Potential and Demand		Manimuthar	Pambar	Kottakaraiyar	Total
Water potential in Mcum	Surface water potential assessed from rainfall	308.80	208.59	287.00	804.39
	Quantity of Water diverted for Pambar and Kottakaraiyar basin through Vaigai canal and Periyar main canal	94.30	0.00	79.10	173.40
	Ground water potential	335.87	334.78	459.28	1129.93
	Total water potential	738.97	543.37	825.38	2107.72
Water demand in Mcum	Domestic demand	88.29	34.65	51.26	174.20
	Irrigation demand	395.82	369.30	588.69	1353.82
	Livestock demand	38.38	24.13	31.90	94.41
	Industrial demand	1.40	2.35	1.75	5.50
	Ecological demand	3.09	2.09	2.87	8.04
	Total water demand	526.99	432.52	676.47	1635.97
Return flow in Mcum	Quantity of waste water from domestic demand that can be reused	70.63	27.72	41.01	139.36
	Quantity of waste water from Large & Small scale Industries that can be reused	1.12	1.88	1.40	4.40
	Quantity of water from irrigation as return flow	79.16	73.86	117.74	270.76
	Total Return Flow	150.92	103.46	160.14	414.52
Total water potential in Mcum	Total water potential after considering the reuse of waste water	**889.89**	**646.83**	**985.52**	**2522.24**
Total Demand in Mcum	Total water demand	**526.99**	**432.52**	**676.47**	**1635.97**
Water Balance in Mcum		**362.90**	**214.31**	**309.06**	**886.27**
Percentage		**40.8%**	**33.1%**	**31.4%**	**35.1%**

Water Balance in Pambar Kottakaraiyar basin = **886.27** **Mcum** **35.1%**

Table 8.13

Pambar Kottakaraiyar BASIN - Sub Basin wise water balance at 50% dependability (Existing scenario)

2040

Details of Water Potential and Demand		Manimuthar	Pambar	Kottakaraiyar	Total
Water potential in Mcum	Surface water potential assessed from rainfall	308.80	208.59	287.00	804.39
	Quantity of Water diverted for Pambar and Kottakaraiyar basin through Vaigai canal and Periyar main canal	94.30	0.00	79.10	173.40
	Ground water potential	335.87	334.78	459.28	1129.93
	Total water potential	738.97	543.37	825.38	2107.72
Water demand in Mcum	Domestic demand	156.78	61.54	91.03	309.35
	Irrigation demand	395.82	369.30	588.69	1353.82
	Livestock demand	38.38	24.13	31.90	94.41
	Industrial demand	2.53	4.22	3.14	9.89
	Ecological demand	3.09	2.09	2.87	8.04
	Total water demand	596.60	461.28	717.63	1775.51
Return flow in Mcum	Quantity of waste water from domestic demand that can be reused	125.42	49.23	72.82	247.48
	Quantity of waste water from Large & Small scale Industries that can be reused	2.02	3.38	2.51	7.91
	Quantity of water from irrigation as return flow	79.16	73.86	117.74	270.76
	Total Return Flow	206.61	126.47	193.08	526.16
Total water potential in Mcum	Total water potential after considering the reuse of waste water	**945.58**	**669.84**	**1018.46**	**2633.88**
Total Demand in Mcum	Total water demand	**596.60**	**461.28**	**717.63**	**1775.51**
Water Balance in Mcum		**348.98**	**208.56**	**300.82**	**858.36**
Percentage		**36.9%**	**31.1%**	**29.5%**	**32.6%**

Water Balance in Pambar Kottakaraiyar basin = **858.36** **Mcum** **32.6%**

Table 8.14

Pambar Kottakaraiyar BASIN - Sub Basin wise water balance at 50% dependability (Existing scenario)

2050

Details of Water Potential and Demand		Manimuthar	Pambar	Kottakaraiyar	Total
Water potential in Mcum	Surface water potential assessed from rainfall	308.80	208.59	287.00	804.39
	Quantity of Water diverted for Pambar and Kottakaraiyar basin through Vaigai canal and Periyar main canal	94.30	0.00	79.10	173.40
	Ground water potential	335.87	334.78	459.28	1129.93
	Total water potential	738.97	543.37	825.38	2107.72
Water demand in Mcum	Domestic demand	339.39	133.21	197.05	669.65
	Irrigation demand	395.82	369.30	588.69	1353.82
	Livestock demand	38.38	24.13	31.90	94.41
	Industrial demand	4.55	7.60	5.66	17.80
	Ecological demand	3.09	2.09	2.87	8.04
	Total water demand	781.23	536.33	826.17	2143.73
Return flow in Mcum	Quantity of waste water from domestic demand that can be reused	271.51	106.57	157.64	535.72
	Quantity of waste water from Large & Small scale Industries that can be reused	3.64	6.08	4.52	14.24
	Quantity of water from irrigation as return flow	79.16	73.86	117.74	270.76
	Total Return Flow	354.32	186.51	279.90	820.73
Total water potential in Mcum	Total water potential after considering the reuse of waste water	**1093.29**	**729.88**	**1105.28**	**2928.45**
Total Demand in Mcum	Total water demand	**781.23**	**536.33**	**826.17**	**2143.73**
Water Balance in Mcum		**312.06**	**193.55**	**279.12**	**784.72**
Percentage		**28.5%**	**26.5%**	**25.3%**	**26.8%**

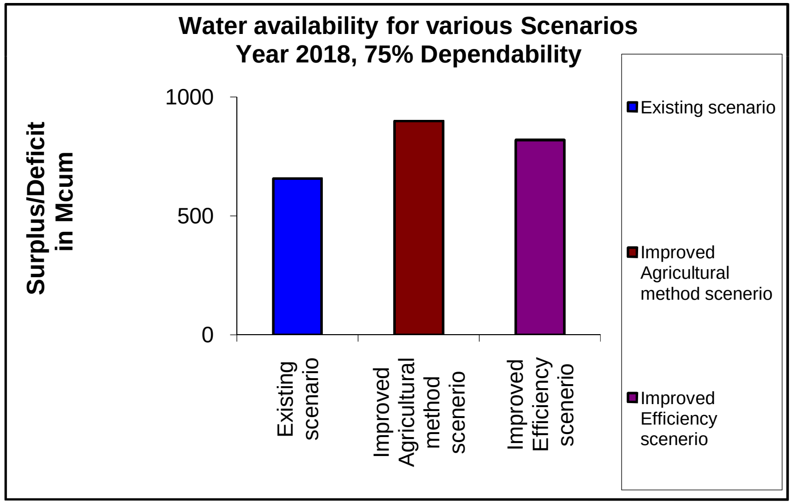
Water Balance in Pambar Kottakaraiyar basin = **784.72** **Mcum -** **26.8%**

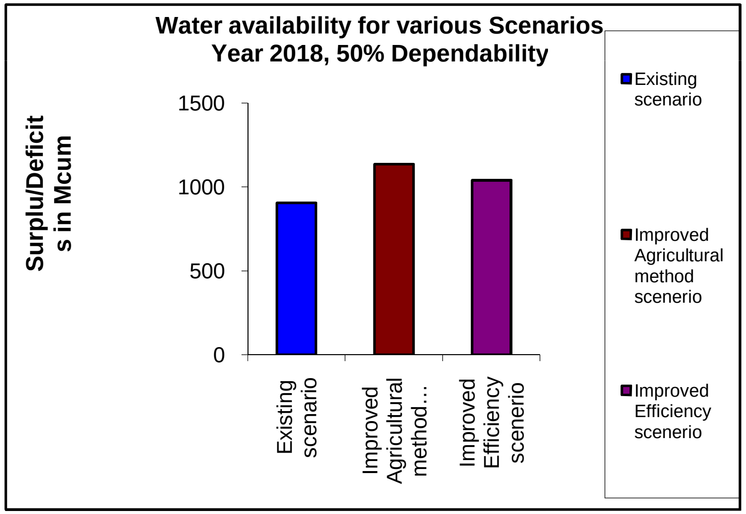
Figure - 8.1

Pambar Kottakaraiyar river basin - Water availability at 75% & 50% dependabilities during 2018 for various Scenarios

Water availability during 2018 at 75% dependability		
Sl.No.	**Scenario**	**Surplus/Deficit in Mcum**
1	Existing scenario	657
2	Improved Agricultural method scenerio	899
3	Improved Efficiency scenerio	819

Water availability during 2018 at 50% dependability		
Sl.No.	**Scenario**	**Surplus/Deficit in Mcum**
1	Existing scenario	906
2	Improved Agricultural method scenerio	1138
3	Improved Efficiency scenerio	1041





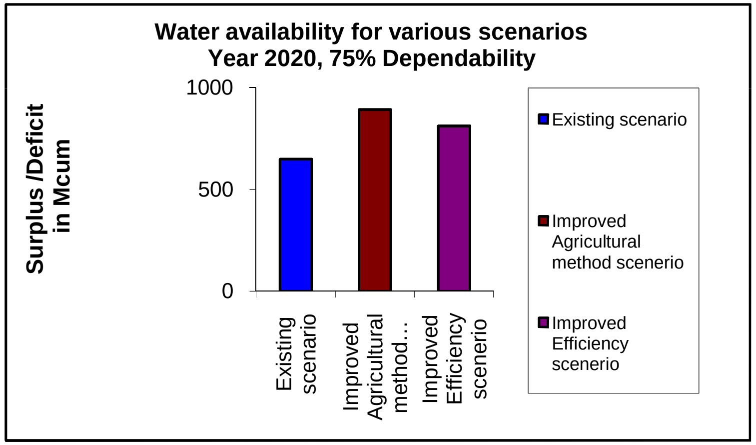
Description of Scenarios	
Existing Scenario	Present condition
Improved Agricultural method scenerio	Changes in the present cropping or cultivation pattern for Paddy by using SRI (System of Rice Intensification) method
Improved Efficiency scenerio	Condition where efficiency is increased to 75%

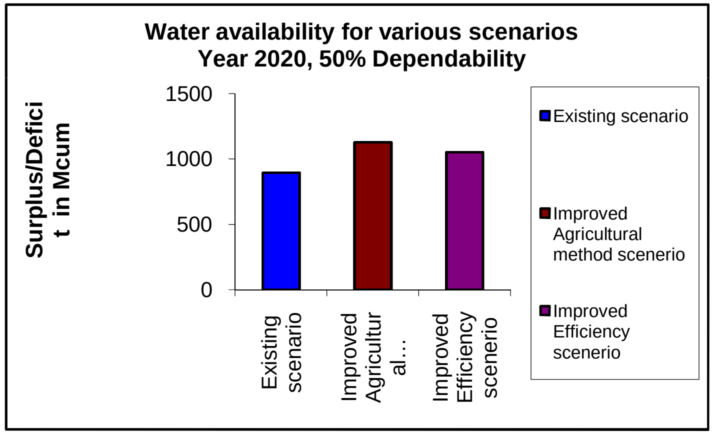
Figure - 8.2

Pambar Kottakaraiyar river basin - Water availability at 75% & 50% dependabilities during 2020 for various Scenarios

Water availability during 2020 at 75% dependability		
Sl.No.	**Scenario**	**Surplus/Deficit in Mcum**
1	Existing scenario	650
2	Improved Agricultural method scenerio	892
3	Improved Efficiency scenerio	812

Water availability during 2020 at 50% dependability		
Sl.No.	**Scenario**	**Surplus/Deficit in Mcum**
1	Existing scenario	898
2	Improved Agricultural method scenerio	1130
3	Improved Efficiency scenerio	1053





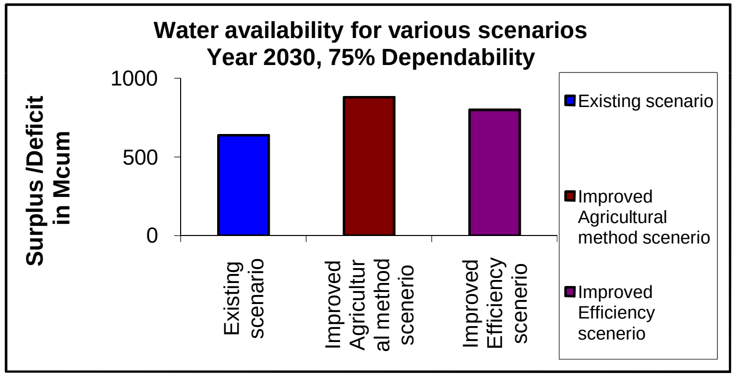
Description of Scenarios	
Existing Scenario	Present condition
Improved Agricultural method scenerio	Changes in the present cropping or cultivation pattern for Paddy by using SRI (System of Rice Intensification) method
Improved Efficiency scenerio	Condition where efficiency is increased to 75%

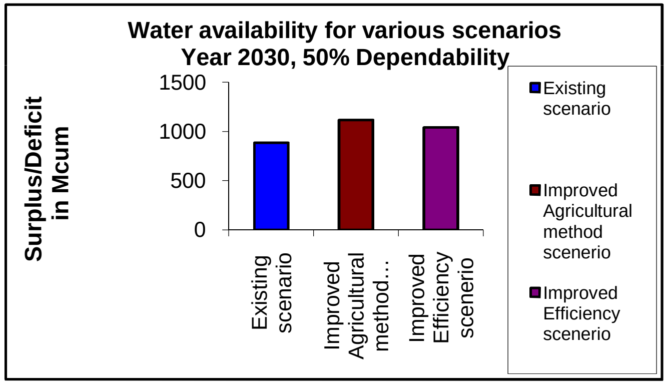
Figure - 8.3

Pambar Kottakaraiyar river basin - Water availability at 75% & 50% dependabilities during 2030 for various Scenarios

Water availability during 2030 at 75% dependability		
Sl.No.	**Scenario**	**Surplus/Deficit in Mcum**
1	Existing scenario	639
2	Improved Agricultural method scenerio	881
3	Improved Efficiency scenerio	801

Water availability during 2030 at 50% dependability		
Sl.No.	**Scenario**	**Surplus/Deficit in Mcum**
1	Existing scenario	886
2	Improved Agricultural method scenerio	1118
3	Improved Efficiency scenerio	1042





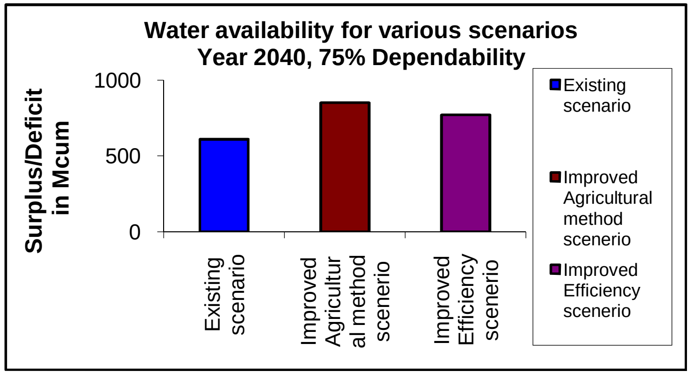
Description of Scenarios	
Existing Scenario	Present condition
Improved Agricultural method scenerio	Changes in the present cropping or cultivation pattern for Paddy by using SRI (System of Rice Intensification) method
Improved Efficiency scenerio	Condition where efficiency is increased to 75%

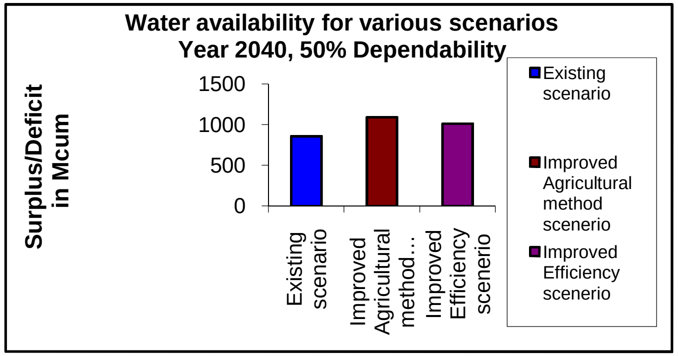
Figure - 8.4

Pambar kottakaraiyar river basin - Water availability at 75% & 50% dependabilities during 2040 for various Scenarios

Water availability during 2040 at 75% dependability		
Sl.No.	**Scenario**	**Surplus/Deficit in Mcum**
1	Existing scenario	611
2	Improved Agricultural method scenerio	853
3	Improved Efficiency scenerio	773

Water availability during 2040 at 50% dependability		
Sl.No.	**Scenario**	**Surplus/Deficit in Mcum**
1	Existing scenario	858
2	Improved Agricultural method scenerio	1091
3	Improved Efficiency scenerio	1014





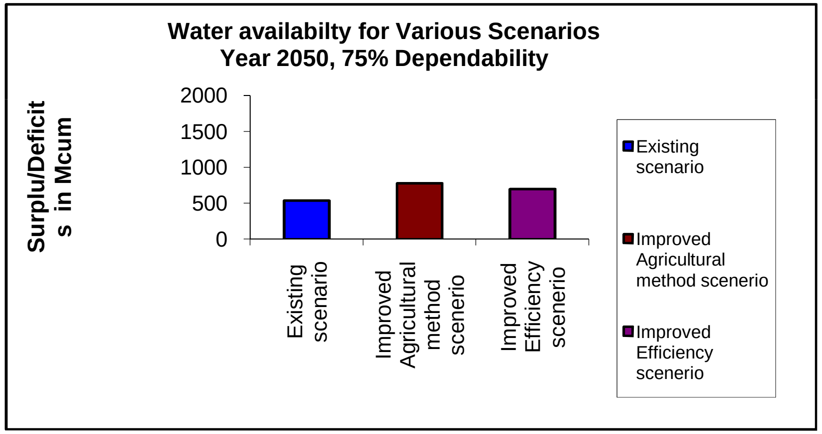
Description of Scenarios	
Existing Scenario	Present condition
Improved Agricultural method scenerio	Changes in the present cropping or cultivation pattern for Paddy by using SRI (System of Rice Intensification) method
Improved Efficiency scenerio	Condition where efficiency is increased to 75%

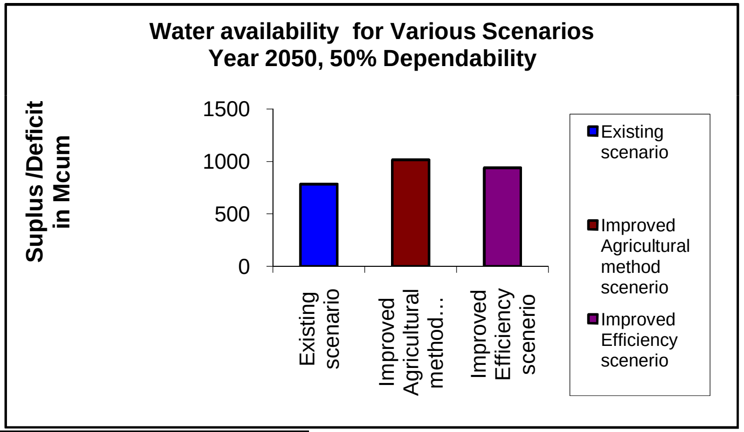
Figure - 8.5

Pambar Kottakaraiyar river basin - Water availability at 75% & 50% dependabilities during 2050 for various Scenarios

Water availability during 2050 at 50% dependability		
Sl.No.	**Scenario**	**Surplus/Deficit in Mcum**
1	Existing scenario	537
2	Improved Agricultural method scenerio	779
3	Improved Efficiency scenerio	699

Water availability during 2050 at 50% dependability		
Sl.No.	**Scenario**	**Surplus/Deficit in Mcum**
1	Existing scenario	785
2	Improved Agricultural method scenerio	1017
3	Improved Efficiency scenerio	940





Description of Scenarios	
Existing Scenario	Present condition
Improved Agricultural method scenerio	Changes in the present cropping or cultivation pattern for Paddy by using SRI (System of Rice Intensification) method
Improved Efficiency scenerio	Condition where efficiency is increased to 75%

CHAPTER – 9

ENVIRONMENTAL ASPECTS

CHAPTER - 9

ENVIRONMENTAL ASPECTS

Introduction

The word Environment is derived from the French word “Environ” which means “surrounding”. Our surrounding includes biotic factors like human beings, plants, animals, microbes, etc and abiotic factors such as light, air, water, soil, etc. Environment is a complex of many variables, which surrounds man as well as the living organisms. It includes water, air and land and the interrelation ships which exist among and between water, air and land and human beings and other living creatures such as plants, animals and micro organisms.

Environmental changes are based on factors like urbanization, population and economic growth, increase in energy consumption and agricultural intensification. The degradation has adverse impacts on human beings, plants, animals and micro-organisms.

Environmental pollution is one of the most serious problems facing humanity and other life forms on our planet today. Pollutants can be naturally occurring substances or energies, but they are considered contaminants when in excess of natural levels. Any use of natural resources at a rate higher than nature’s capacity to restore itself can result in pollution of air, water, and land.

This chapter deals with the environmental issues and remedial measures in Pambar and Kottakaraiyar River Basin.

The major environmental issues dealt in this chapter are Pollution sources, Sedimentation, Water weeds, Catchment Area Treatment, Sea water intrusion, Salinity, Fisheries, Public Health, Solid Waste Management, Forest and Wild life, Tourism, Socio-economic aspects & Legal Issues and Public Awareness & Participation.

9.1 Pollution Sources

The major sources of pollution are as follows.

1. Industries
2. Domestic
3. Agriculture

9.1.1 Industrial Pollution

Industrial activities cause series of problems relating to environmental pollution.

Industries are classified into three categories with respect to the pollution level. Highly polluting industries are categorized as **Red**, medium polluting industries are categorized as

Orange and less polluting industries are categorized as **Green**.

Tamil Nadu Pollution Control Board (TNPCB) is the authority for monitoring the quality of effluents from the industries. Individual Treatment Plants are installed by the industries. For a cluster of Industries, Common Effluent Treatment plants are installed.

9.1.1.1 Industries in Pambar Kottakaraiyar River Basin:

In Pambar Kottakaraiyar basin, the highly polluting, medium and less polluting industries are as shown in **Table 9.1**

Table 9.1 Polluting Industries in Pambar Kottakaraiyar River Basin

Sl. No.	Name of sub basin	Highly polluting industries (Red)	Medium polluting industries (Orange)	Less polluting Industries (Green)
1	Manimuthar	36	197	52
2	Pambar	45	162	30
3	Kottakaraiyar	16	53	19
Total		**97**	**412**	**101**

Source: Chapter 7

The details of the large, medium & small scale industries in the basin along with the wastewater generated is given below in **Table 9.2 (a) & Table 9.2 (b)**

Table 9.2 (a) Waste Water generated in Large & Medium Industries in Mcum / year

Sl. No.	Name of sub basin	Number of large & medium industries	Water demand in Mcum per year	Waste water generated in Mcum per year (80 % of water demand)
1	Manimuthar	13	0.066	0.053
2	Pambar	12	0.707	0.566
3	Kottakaraiyar	8	0.588	0.470
Total		**33**	**1.361**	**1.089**

Source: Chapter 7

Table 9.2(b) Waste Water generated in Small Scale industries in Mcum / year

Sl. No.	Name of sub basin	Number of small scale industries	Water demand in Mcum per year	Waste water generated in Mcum per year (80 % of water demand)
1	Manimuthar	277	0.563	0.450
2	Pambar	238	0.344	0.275
3	Kottakaraiyar	81	0.194	0.155
Total		**596**	**1.101**	**0.880**

Source: Chapter 7

Waste water from Large & medium Scale Industries	=	1.089	Mcum per year
Waste water from Small Scale Industries	=	0.880	Mcum per year
Total	**=**	**1.969**	**Mcum per year**

9.1.1.2 Effects of Industrial Pollution:

- Pollution by the industrial effluent is caused due to contamination by heavy metals, harmful chemicals, organic wastes. The water polluted for a long period causes serious impact on the health of our eco-system.
- Soil pollution due to the effluents of the industries is creating problems in agriculture, destroy local vegetation and affect the health of animals.
- Air pollution by the toxic gases affects the people in the area with deadly diseases like asthma, cancer etc.

9.1.1.3 General Mitigation measures

- Treated Effluents should be used in Industries for cooling process. The treated waste water of one industry may be used as input for cooling tower of other industries like Thermal plant, Pharmaceutical, petro chemical, Refineries, Fertilizer industries, and so on, so that the fresh water requirement for those industries getting reduced. The residue from the treatment plant may be utilized for manufacture of fertilizers.
- Agglomeration of industries shall be encouraged so that the by-product or waste of one industry may be a raw material for some other industries, which will lead to reduction of natural water requirements.
- The proper choice of the process for treatment of the solid wastes as well as gaseous and liquid effluents before discharging to the environment has to be made.
- The selection of industrial site should be properly examined considering the climatic and topographical characteristics.

9.1.2 Domestic Sector

Domestic water pollution is mainly caused by sewage.

The generation of sewage in Urban areas in Pambar Kottakaraiyar River Basin which is assumed as 80% of water demand is shown in **Table 9.3.**

Table 9.3 Generation of Sewage in Urban Areas

Sl. No.	Name of the Sub basin	Projected Population in 2018 in million	Water Demand 2018 in Mcum	Volume of sewage generated in Mcum/ year
1.	Manimuthar	0.420	23.78	19.024
2 .	Pambar	0.144	8.13	6.504
3 .	Kottakaraiyar	0.254	14.38	11.504
TOTAL		**0.818**	**46.29**	**37.032**

Source: Chapter 7

Sewage from Urban Areas = **37.032** Mcum per year

9.1.2.2 Waste Water Management:

Sewage Treatment Process:

Sewage treatment involves physical, chemical, and biological processes to remove physical, chemical and biological contaminants. The objective of the sewage treatment is to produce a disposable effluent without causing harm to the surrounding environment and prevent pollution.

In Pambar Kottakaraiyar River Basin, the sewage treatment plants have been implemented in Pudukottai and Sivagangai districts as part of an underground sewerage schemes and being executed by the Tamil Nadu Water Supply and Drainage Board. The details of ongoing Sewerage Treatment Plant in Sivagangai district is given below in **Table 9.4**

Table 9.4 Sewage Treatment Plant in Pudukottai and Sivagangai Districts

Sl. No.	Name of the District	Name of the UGSS	STP location	Technology	STP Capacity in MLD	Population benefitted in lakhs
Ongoing						
1.	Sivagangai	Karaikudi Municipality	Opposite to solid waste disposal yard @ Devakottai yard	Extended Activated Sludge Process (EASP)	16.00	1.76

Source: TWAD, Chennai

9.1.2.3 General Mitigation Measures

- A properly installed and maintained system for treating sewage will minimize the impact on ground water and surface water.
- It is recommended to recycle/ reuse waste water in a phased manner to meet the growing demand.
- For Non potable uses (Fire Fighting, Toilet Flushing etc) recycled waste water could be used and sanitary facilities have to be provided at public places.
- Awareness has to be created among the public to prevent open discharge of sewage into water bodies and to reuse the treated water effectively for different purposes like pisciculture, aquaculture, horticulture and irrigation.
- Subsidy may be given by the Government to encourage the communities for recycle and reuse of waste water.

9.1.3 Agricultural Pollution

Agricultural pollution refers to biotic and abiotic byproducts of farming practices that result in contamination or degradation of the environment and surrounding ecosystems, and/or cause injury to humans and their economic interests.

9.1.3.1 Causes of Agricultural pollution:

Pesticides & fertilizers once sprayed does not disappear completely. Some of it mixes with the water and seeps into the ground. The rest of is absorbed by the plant itself. As a result, the local streams that are supplied water from the ground become contaminated, as do the animals that consume these crops and plants.

9.1.3.2 Fertilizers and Pesticides Consumption in Pambar Kottakaraiyar River Basin:

In Pambar Kottakaraiyar basin, the main elements of agricultural pollution are phosphates, nitrates, potassium etc. The year wise consumption of fertilizers and Pesticides in major districts of Pudukottai, Ramanathapuram and Sivagangai districts is furnished in **Table 9.5 and 9.6**

Table 9.5 Consumption of Fertilizers in Pudukottai, Ramanathapuram and Sivagangai districts from 2007-08 to 2016-17

Year	N	P	K	Total (NPK) In MT
2007-08	35725	14299	12903	62927
2008-09	37158	15418	12644	65220
2009-10	36916	16387	12199	65502
2010-11	35563	17924	12872	66359
2011-12	38175	17463	13148	68786
2012-13	33731	14034	11193	58958
2013-14	24501	10784	10660	45945
2014-15	30778	15141	11475	57394
2015-16	39269	13156	7961	60386
2016-17	22275	9765	7279	39319
Total (MT)	**334091**	**144371**	**112334**	**590796**

Source: Department of Agriculture, Pudukottai, Ramanathapuram &Sivagangai

Table 9.6 Consumption of Pesticides in Pudukottai, Ramanathapuram and Sivagangai districts from 2007-08 to 2016-17

Year	Liquid (litres)	Dust /Solid (kgs)
2007-08	67321	22050
2008-09	38362	9836
2009-10	58677	15531
2010-11	104325	28283
2011-12	90532	79576
2012-13	86458	21584
2013-14	63763	24345
2014-15	74100	20193
2015-16	121885	29074
2016-17	91040	55002
Total (MT)	**796463**	**305474**

Source: Department of Agriculture, Pudukottai, Ramanathapuram &Sivagangai district

The consumption of fertilizers such as Nitrogen, phosphorus and Ammonia (in M.T) are presented as chart in **Fig 9.1** and the consumption of Pesticides in Liquid form(in litres) and Dust/Solid form (in Kgs) are depicted as chart in **Fig: 9.2**

Fig 9.1 Consumption of Fertilizers in Pudukottai, Ramanathapuram and Sivagangai districts

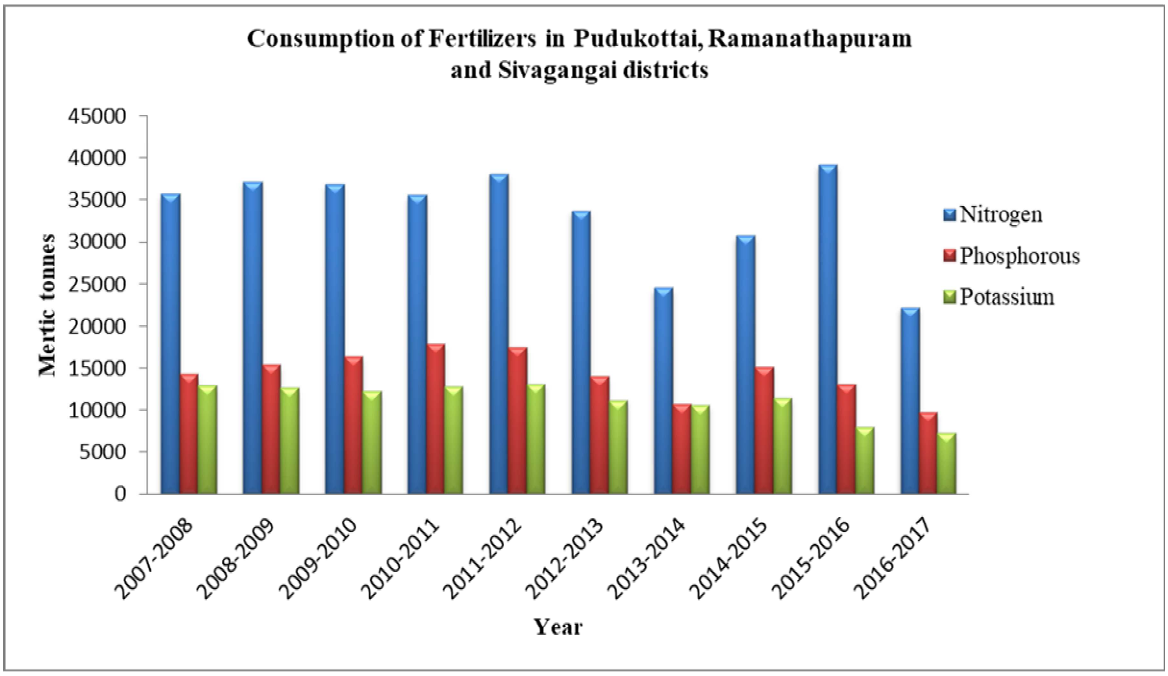
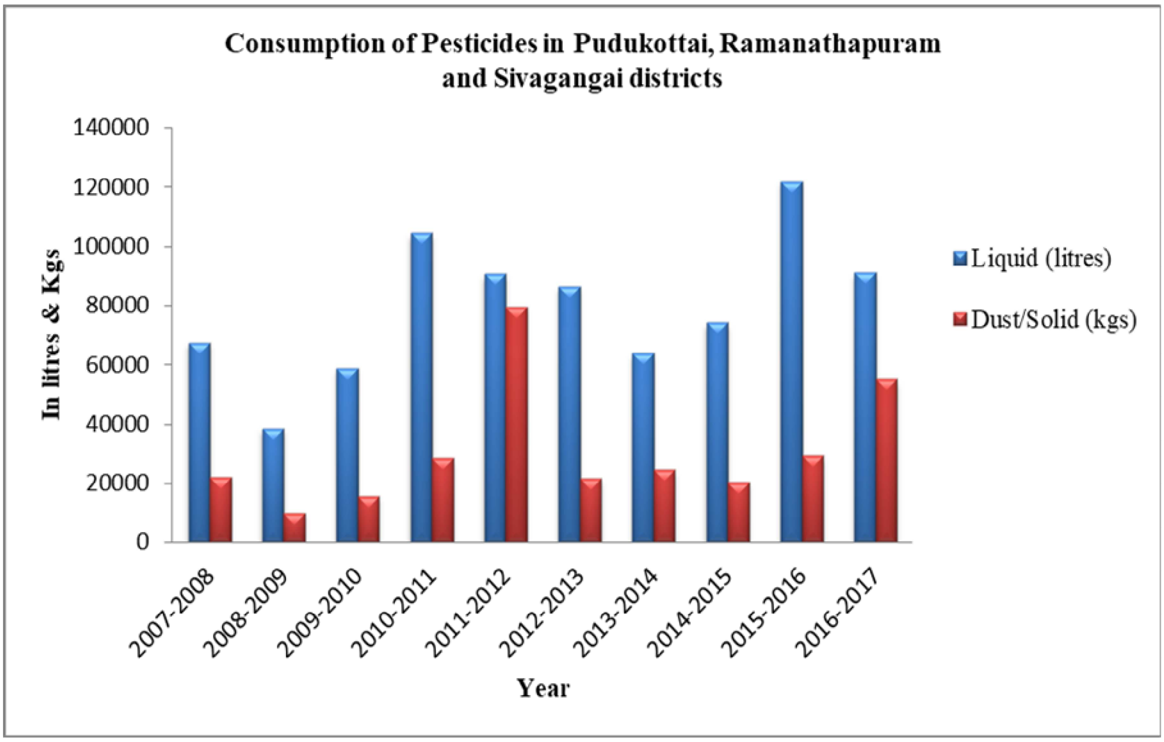


Fig 9.2 Consumption of Pesticides in Pudukottai, Ramanathapuram and Sivagangai districts



From the above graphs, it is inferred that the consumption of nitrogen fertilizer was high during the year 2015-16 and subsequently reduced during the year 2016-17. The consumption of pesticides (in liquid form) was also low during the year 2008-09 and high during the year 2015-16.

9.1.3.3 Effects of Agricultural Pollution

Fertilizers, Manure, waste and ammonia turns into nitrate that reduces the amount of oxygen present in water which results in the death of many aquatic animals.

9.1.3.4 Mitigation measures

- Managing the correct disposal of animal wastes and keeping farm animals away from water will reduce the nitrogen pollution of the water.
- Educating farmers and agro industries about reducing the nutrient loads entering the water bodies by ensuring better management of household and live stock waste in the villages, crop nutrient management, planting of buffer strips and conservation tillage.
- Strengthening Environmental State policy, regulatory enforcement and institutional capacity against agricultural nutrient pollution and also encouraging organic farming.
- Usage of Biopesticides and fungicides to control the pest and diseases has to be encouraged.

9.1.3.5 Organic farming

Organic farming is a method of crop and livestock production that involves much more than choosing not to use pesticides, fertilizers, genetically modified organisms, antibiotics and growth hormones. The principal goal of organic production is to develop enterprises that are sustainable and harmonious with the environment.

9.1.3.6 Advantages of Organic Farming

- Organic manures produce optimal condition in the soil for high yields and good quality crops. They supply the entire nutrient required by the plant (NPK, secondary and micronutrients).
- They improve the soil's physical properties such as granulation and good tilt, good aeration, easy root penetration and improved water holding capacity and soil's chemical properties such as supply and retention of soil nutrient and promote favorable chemical reaction.
- Organically grown crop provide more healthy and nationally superior food for man and animals that those grown with commercial fertilizers and it helps to avoid chain reaction in the environment for chemical spray and dusts and prevent environment degradation.

9.2 Sedimentation

Sedimentation is generally generated by the disintegration of the earth's crust mainly by the action of temperature, running water, wind, ice, vegetation, landslides, etc.,

9.2.1 Impact of sedimentation:

The environmental impact of sedimentation includes loss of important or sensitive aquatic habitat, decrease in fishery resources, loss of coral reef communities, human health concerns, changes in fish migration, loss of wetlands, changes in nutrient balance, increase in turbidity, loss of submerged vegetation, loss of recreation attributes and coastline alteration.

Considering the above facts, periodic capacity surveys and sedimentation studies are essential to assess the rate of siltation and the impact of sedimentation on the performance of the Reservoirs and tanks.

It is suggested to carry out sedimentation studies atleast in the major tanks so as to assess the present storage capacity of the tanks for its efficient utilization.

9.2.3 Mitigation measures

- Watershed management including afforestation and the promotion of farming practices which reduce soil erosion is frequently advocated as the best way of controlling sediment deposition in reservoirs.
- Ensuring environmentally acceptable methods for the disposal of dredged sediments and ensuring use of sediments for enhancement where appropriate.
- To manage sediments supply at source by putting in places the best agricultural practice and techniques.

9.3 Water Weeds

Water weeds can be defined as unwanted and undesirable vegetation that are adapted to grow and reproduce under aquatic conditions. Weeds are one of the major threats to the natural environment. They are destroying native habitats, threatening native plants and animals and choking natural systems including rivers and forests.

9.3.1 Types of Water weeds

Water weeds are broadly classified as Floating type, Submerged type and Emergent type.

1. Floating weeds – Weeds float in the surface of water and are not attached to the plant.
2. Submerged weeds – Weeds are rooted in the sediment and they usually grow entirely under the water.
3. Emergent weeds – Weeds are rooted in the lake bottom, but extended out of water.

9.3.2 Reasons for the abundance of waterweeds

- Eutrophication of riverine ecosystem due to and sewage drainage from agricultural fields and return flow.
- Lack of proper waterweed management plan.
- Lack of controlling measures of weed invasion.

9.3.3 Effect of Water Weeds:

- Creates ideal situation for breeding of mosquitoes, responsible for the spread of Malaria, Yellow fever, river blindness and encephalitis.
- Provides shelter to predatory weed fishes and mollusks which play a crucial role in the life-cycle of blood and liver flukes (parasitic worms)
- Upsets the equilibrium of physico-chemical properties of water.
- Causes imbalance in the biological oxygen demand due to excessive organic loading.
- Displaces natural vegetation and destroys aquatic life.
- Affects the fish habitat in the water bodies.
- Increases emission of CO2 and CO into the atmosphere due to decomposition of huge volume of aquatic weeds creating foul smell that are unpleasant to public convenience.
- Organic matter content of water is increased which affects the strength of the concrete structures when used for curing and mixing.

9.3.4. Water weeds in Pambar Kottakkaraiyar Basin

In Pambar Kottakkaraiyar basin, most of the tanks are predominantly covered with Prosopis Juliflora (an invasion weed). The vegetation in the Vettangudi Bird Sanctuary is dominated by the exotic tree, Prosopis Juliflora.

Fig: 9.3 Prosopis Juliflora in Thiruppathur Big Tank

Fig: 9.4 Prosopis Juliflora in RS Mangalam Tank

Prosopis Juliflora, native to South and Central America, was introduced in India to meet the fuel wood requirements of the rural poor and to restore the degraded lands. Now it has become an aggressive weed. Generally Prosopis Juliflora (Karuvelam tree) tree grows upto to a height up to 12 metres (39 ft), and has a trunk of diameter up to 1.2 metres (3.9 ft). A mature plant can produce hundreds of thousands of seeds. Seeds remain viable for up to 10 years. The tree reproduces solely by way of seeds, not vegetatively. Seeds are spread by cattle and other animals, which consume the seed pods and spread the seeds in their droppings.

Its roots are able to grow to a great depth in search of water. Karuvelam tree absorbs more than four litres of water to obtain one kilogram of biomass. It cannot even shelter birds as it produces less oxygen and more carbon dioxide. If it does not have sufficient water it begins absorbing groundwater. And if there is no groundwater, it starts absorbing humidity from the surroundings. It can also turn the groundwater poisonous.

9.3.5 Methods for controlling the water weeds:

- Plants can be removed by machine or by manually.
- Mechanical methods such as stick racking, chain pulling, bulldozer pushing and blade ploughing can be used.
- Larger trees and shrubs are killed by cutting the stem at ground level and spraying or painting the freshly cut stumps with suitable herbicide. Herbicides like Round up, Glenside Kerosene and diesel oil are used.
- Predators or pathogens are used to control the juliflora reproduction.
- Another method that has been in use is burning the stump after it has been cut. However this only works when the plant is dry (not in stage of flowering) and the root system is not too deep to survive. Otherwise regrowth will occur.

Fig 9.5 Cutting

Fig 9.6 Burning.

9.4 Catchment Area Treatment

Catchment Area Treatment is the management technique to control erosion in the Catchment Area of Reservoir/tanks. The main aim of the catchment area treatment is to rejuvenate various potential and degraded ecosystems in the catchment area.

9.4.1. Objectives of Catchment area treatment

1. To facilitate the hydrological functioning of the catchment and to augment the quantity and improve quality of water of the river and its tributaries.
2. Conservation of soil cover and to arrest the soil erosion, floods and siltation of the river and its tributaries and consequent reduction of siltation in the reservoir.
3. Rehabilitation of degraded forest through afforestation.
4. Ecosystem conservation resulting from increased vegetative cover and water retaining properties of soil.
5. Employment generation through community participation and conservation.

The study of erosion and sediment yield from catchment is of utmost importance as the deposition of sediment in reservoir reduces its capacity, thus affecting the water available for the designated use. The removal of top fertile soil from catchment adversely affects the agricultural production and silt laden water affect the turbine blades thereby affect the hydro power production.

Thus, a well-designed Catchment Area Treatment (CAT) Plan is essential to prevent the above process of soil erosion. The catchment area treatment involves the understanding of the erosion characteristics of the terrain and identifying / suggesting remedial measures to reduce the erosion rate.

9.4.2 Catchment Area in Pambar Kottakkaraiyar basin

Percentage of forest area covered in this basin is about 358.46 sq.km which accounts only 0.06% of the total basin area. There is no reservoir situated in this basin. Most of the tanks are rain fed tanks.

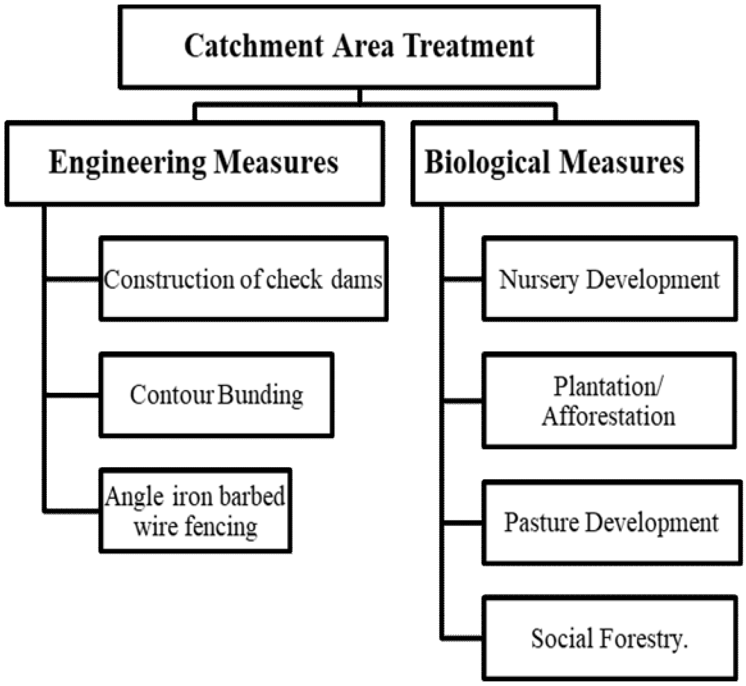
Raja Singamangalam Big Tank (R.S. Mangalam tank) is the second largest water storage tank in the State of Tamil Nadu situated in the Ramnathapuram district, that provides the supportive resources to the sustainable livelihoods for residents residing in and around. The tank is the main source for irrigation in the R.S.Mangalam block. The tank has 48 sluices to supply the water for the command area of the tank, which is 1963 hectare.

Few of small tanks in the block exist in the depleted condition, which irrigate the crop land for 2 to 4 months only. Almost all the tanks are heavily sited up and they are severely encroached by local people for various purposes such as for the bricks kiln, rice mills etc., So, majority of such tanks have been encouraged and their foreshore areas have been used by local people, for unauthorized cultivation and construction of houses and business complexes. The block is a well known place for the paddy cultivation, sugarcane, vegetables and flowers. 25 to 35 percent of the total people (32 percent in R.S. Mangalam block) belong to the fishermen community.

9.4.3 Catchment Area Treatment Plan

The basis for formulating appropriate Catchment Area Treatment Plan depends upon the parameters of the watershed such as geology, geomorphology, topography, soil, land use/ land cover, climate, hydrology, drainage pattern, etc. Considering the topographic factors, soil type, climate, land-use/land-cover in the catchment area, the following Engineering and Biological measures may be undertaken with the aim to check soil erosion, prevent/check siltation of reservoir.

Fig 9.7 Catchment Area Treatment Plan



In addition, selection of Catchment Area Treatment Measures also depends upon the type of problem encountered as given in the **Table 9.7** below.

Table 9.7 Catchment Area Treatment measures

Sl. No.	Catchment Area Treatment Measure	Basis for selection
1.	Social forestry, fuel wood and fodder grass development	Near settlements and to control tree felling
2.	Contour Bunding	Control of soil erosion from agricultural fields
3.	Pasture Development	Open canopy, barren land, degraded surface
4.	Afforestation	Open canopy, degraded surface, high soil erosion, gentle to moderate slope
5.	Barbed wire fencing	In the vicinity of afforestation work to protect it from grazing etc.
6.	Step drain	To check soil erosion in small streams, steps with concrete base are prepared in sloped area where silt erosion in the stream and bank erosion is high due to turbidity of current.
7.	Nursery	Centrally located points for better supervision of proposed afforestation, minimize cost of transportation of seedling and ensure better survival.

9.4.4 Mitigation Measures :

The following mitigation measures can be adopted to control the catchment area degradation problem.

- Prevention of soil erosion by preserving the forest area and grasslands.
- Afforestation in the degraded forest areas.
- Construction of contour stonewalls (stone terracing) and bench terracing.
- Construction of gully plugging and temporary check dams.

9.5 Sea Water Intrusion

The sea water intrusion occurs in two modes i.e. direct and indirect. Direct sea water intrusion implies a direct movement of sea water from sea to hydraulically connected aquifers, by reduction or reversal of water table gradients. Indirect sea water intrusion implies movement of sea water first into a surface water body like river which confluence with the sea, followed by intrusion of this water from the surface water body into a hydraulically connected aquifer. The extent of intrusion depends upon climatic conditions, hydrogeology of the area and the extent and pattern of ground water development, in and around the coastal stretch.

The sea water intrusion study of Pambar Kottakkaraiyar basin is based on water quality data of wells, maintained exclusively for sea water intrusion study, along the coast in Pambar Kottakkaraiyar basin. In this study, the present scenario of intrusion along the coast of Pambar Kottakkaraiyar basin is put forth by considering the water quality data for pre monsoon period of 2017, collected from State Ground and Surface Water Resource Data Centre of WRD.

9.5.1 Location

The study area of the basin is situated between Devipattinam village of Ramanathapuram district to Palangulam village of Pudukottai district, covering a coastal length of 69.73 km and width of 10 km from the coast is considered for this study. The study area is 657.569 sq.km.

9.5.2 Geological Condition

The study area is entirely covered by sedimentary formation and is a plain coastal terrain. Major sedimentary formations are coastal sand, aeolian and alluvial deposits and altered sequence of sand, silt and clay of recent age.

9.5.3 Methodology

Wells for sea water intrusion study are established over the entire coastal belt of Tamil Nadu by the SG & SWRDC, WRD and water samples are being analysed twice in a year for the months of January and July (Post monsoon and Pre monsoon).There are 12 sea water intrusion study wells located in the basin. Water quality parameters such as Chloride and Total Dissolved

Solids are analyzed for sea water intrusion study. Spatial distribution of Chloride concentration and Total Dissolved Solids are mapped in the study area using GIS software **(Plate PK-40 and PK-41).**

Chloride value less than 250 mg/l is considered as safe and 250 mg/l to 1000 mg/l as moderate. The concentration value more than 1000 mg/l is considered as poor quality, which is considered as the possibility of sea water intrusion **(Plate PK-40)**

Similarly Total Dissolved Solids concentrations in and around the study area are studied and the spatial distribution is shown in **Plate PK-41.** The presence of Total Dissolved Solids value less than 1000 mg / l is considered as good and concentration in the range of 1000 mg/l to 2000 mg/l is considered as moderate.TDS value of more than 2000 mg / l is considered as the probability of sea water intrusion.

9.5.4 Observation

The chloride concentration in most of the study area is moderate to high. Chloride concentration greater than 1000 mg / l is observed in west of Tiruvadanai, Rajasingamangalam, Ramanathapuram, and southern parts of Naiyinarkoil blocks. Also moderate value of 250 to 1000 mg / l is found in part of Pullur, Pandukudi, Telur villages of Tiruvadanai block, Vennattur village of Ramanathapuram block, Tiruvadanai, Avudayarkovil and west of Manamelkudi blocks. However some part of Pandukudi and Vennattur villages of Tiruvadanai and Ramanathapuram blocks, the chloride value is less than 250 mg / l , which is considered as good. The area with higher chloride concentration is considered as probable sea water intrusion.

Most of the study area is of poor quality in terms of TDS, i.e. the value is above 2000 mg/l. Such quality is observed in Rajasingamangalam, Tiruvadanai, Ramanathapuram and southern region of Naiyinarkoil blocks. Moderate value of 1000 to 2000 mg/l is observed in Avudayarkovil and in some parts in Tiruvadanai and Manamelkudi blocks. Safer limit of less than 1000 mg/l is found in very small areas in Pandukudi village of Tiruvadanai and Vennattur village of Ramanathapuram blocks.

9.5.5 Recommendation

- Vertical Electrical Sounding data are very much helpful for delineating sea water / freshwater interface line. Hence Geophysical survey using the electrical resistivity measurements may be conducted at proper intervals, preferably in different profiles for every five kilometers in coastal stretch. In each profile it is suggested to conduct depth probes at 1 km, 2 km, 3 km, 5 km, and 10 km away from the sea, so as to delineate sub surface layers and sea water / fresh water interface line
- Detailed analysis of more number of observation networks representing different aquifer zones is necessary for sea water intrusion study. Exclusive observation wells net works for

observing sea water intrusion need to be strengthened by erecting many observation wells along the coast with 10 km width.

- More parameters, particularly bromide and sodium chloride need to be analysed for confirmation of sea water intrusion.

9.6 Fisheries

Tamil Nadu is one of the leading States in India in fisheries development having a coastal length of 1076 km. There are 2500 species of fishes found in different aquatic environment. The fishery in the state is one of the vital source for food security. Climate Change has affected inland and offshore fisheries.

9.6.1 Types of Fisheries Sector:

The fisheries sector in TamilNadu can be broadly categorized as Inland fisheries, Marine fisheries and Aquaculture.

9.6.1.1 Inland Fisheries

Tamil Nadu ranks eighth in inland fisheries production in the country. It has 3.7 lakh hectare of waterspread area, suitable for fish culture, comprising major reservoirs (52,000 ha.), Big/small Irrigation tanks (98000 ha.), small lakes and rural Fishery Demonstration tanks (158000 ha.) and Brackish water areas, swamps, estuaries (63,000 ha.) which are amenable to culture fisheries.

9.6.1.2 Marine Fisheries

TamilNadu is one of the leading States in marine fish production with a coastal length of 1076 km (13% of the country's coast line) and continental shelf of 41,412 sq.km. The State has marine fishermen population of 2 lakh who are actively engaged in fishing from 591 marine fishing hamlets scattered along the 13 coastal districts. TamilNadu contributes 10-12 % of the total marine fish production in India.

9.6.1.3 Coastal Aquaculture

Tamil Nadu is having the second longest coastline in the country with rich natural resources in coastal areas for coastal aqua farming. The total estimated brackish water area of Tamil Nadu is about 56,000 ha.

9.6.2. Details of Fisheries in Pambar Kottakaraiyar River Basin

District wise details of Inland, Marine fish production and fishermen population in the Pambar Kottakaraiyar river basin is given in **Tables 9.8, 9.9 and 9.10.**

(Source: Fisheries Department, Chennai)

Table 9.8 Year wise Inland Fish production in Pambar Kottakaraiyar River Basin (in Tonnes)

Sl. No	Districts	2014-2015	2015-16	2016-17	2017-18
1	Dindigul	2917	4275	274	292
2	Madurai	3443	3460	2531	2648
3	Sivagangai	33881	13612	232	234
4	Trichy	1265	1583	348	368

Table 9.9 Year wise Marine Fish production in Pambar Kottakaraiyar River Basin (inTonnes)

Sl.No	Districts	2007-08	2008-2009	2009-2010	2010-11	2011-12	2012-13	2013-2014	2014-2015	2015-16	2016-17	2017-18
1	Pudukottai	54055	40949	41358	43757	43953	44253	44523	47117	44107	76380	78047
2	Ramanathapuram	78542	81570	82385	86452	86841	87433	87966	93092	89460	72043	79967

Table 9.10 Year wise Fishermen Population in Pambar Kottakaraiyar River Basin (inTonnes)

Sl.No	Districts	2007-08	2008-2009	2009-2010	2010-11	2011-12	2012-13	2013-2014	2014-2015	2015-16	2016-17	2017-18
1	Dindigul	2304	6426	6481	6546	6601	6621	6641	6661	6680	6707	6734
2	Madurai	2840	12021	12124	12245	12349	12449	12499	12499	12550	12600	12651
3	Pudukottai	_	_	_	35078	_	_	32762	_	34179	34948	35375
4	Ramanathapuram	_	_	_	151625	_	_	237861	_	248148	253232	255794
5	Sivagangai	4700	2324	2343	2367	2387	2391	2395	5500	2403	2413	2423
6	Trichy	1010	2650	2673	2700	2723	2726	2728	3131	2736	2747	2758

From the above table, it is inferred that there is tremendous decrease in inland fish production in Dindigul, Sivagangai and Trichy districts from the year 2014-2015 to 2017-2018. In Pudukottai district, the marine fish production has increased from the year 2016-17 to 2017-2018 and decreased from the year 2007-2008 to 2016-2017. In Ramanathapuram district, there is an increase in marine fish production from 2007-2008 to 2014-2015 after which there is a decrease in production. Except in Sivagangai district, the fishermen population has also increased in all the districts from the year 2007-2008 to 2017-2018.

9.6.3. Mitigation Measures

- Introduction of fish culture in Multi Purpose farm ponds/water recharge ponds and promoting ornamental fish culture as a commercial activity.
- Installation of artificial reefs which serves as the habitat for aggregation of fish stocks and excellent breeding.
- Implementation of Fisheries law for seafood safety and aquaculture regulations.

9.7 Public health

Public health is the science and practice of protecting and improving the health of the community, as by preventive medicine, health education, control of communicable diseases, application of sanitary measures, and monitoring of environmental hazards.

In TamilNadu, Public Health tasks are undertaken by the Department of Public Health and Preventive Medicine. The activities undertaken by this department are provisions of primary health care, which includes Maternity and Child Health Services, Immunisation of children against vaccine preventable diseases, control of communicable diseases, control of malaria, filaria, japanese encephalitis, elimination of leprosy, controlling iodine deficiency disorder control programme, prevention of food adulteration, health checkup for school children, health education of the community and collection of vital statistics under birth and death registration system and environmental sanitation, prevention and control of waterborne diseases like Acute Diarrheal Diseases, Typhoid, Dysentry prevention and control of sexually transmitted diseases including HIV / AIDS. Primary Health Centres at the block level of each district is taking care of the health needs of the people.

The blockwise details of diseases prevailing in Pambar Kottakaraiyar basin is depicted in **Table 9.11 to Table 9.19** *(Source: Public Health Department,Chennai).*

9.7.1 Mitigation measures

- Immunization is a successful and cost-effective public health strategy that saves lives.
- Frequent surveillance should be carried out particularly during the rainy season to control the spread of diseases.
- The sewage and industrial effluents have to be treated properly to acceptable standards before letting into any sources.
- Payer pays policy (Make the industries pay taxes for the environmental harm).
- Rain water harvesting to reduce the dependency and overuse of the water bodies.
- Agriculture pollution due to agricultural run- off has to be analysed periodically.
- The drinking water should be consumed only after boiling or chlorination or by using any electrical purifier.
- Environmental awareness campaign to the general public is the most effective way in improving health and better life.

Table 9.11 Malaria

Sl. No	Name of the Block	2007		2008		2009		2010		2011		2012		2013		2014		2015		2016		2017	
		C	D	C	D	C	D	C	D	C	D	C	D	C	D	C	D	C	D	C	D	C	D
1	Sanarpatti	0	0	10	0	17	0	4	0	0	0	6	0	1	0	1	0	1	0	0	0	2	0
2	Natham	1	0	1	0	5	0	3	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
3	Vadamadurai	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0	2	0
4	Kottampatti	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	0	NA	1	NA	NA	NA	3	NA	5	NA	6	NA
5	Melur	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	3	NA	6	NA	NA	NA	0	NA	6	NA	4	NA
6	Vadipatti	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	3	NA	2	NA	NA	NA	0	NA	1	NA	2	NA
7	Aranthangi	0	0	0	0	0	0	0	0	0	0	2	0	0	0	2	0	0	0	0	0	0	0
8	Avudaiyarkoil	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
9	Manamelkudi	5	0	3	0	4	0	2	0	1	0	6	0	0	0	249	0	37	0	4	0	0	0
10	Ponnamaravathy	0	0	0	0	0	0	0	0	0	0	1	0	1	0	1	0	2	0	1	0	2	0
11	Arimalam	1	0	2	0	1	0	0	0	0	0	2	0	0	0	1	0	0	0	0	0	0	0
12	Thirumayam	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0
13	Nainarkoil	0	0	1	0	2	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0
14	Ramanathapuram	94	0	90	0	68	0	87	0	77	0	60	0	34	0	29	0	16	0	4	0	1	0
15	Rajasinga Mangalam	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
16	Thiruvadanai	5	0	17	0	2	0	1	0	1	0	0	0	0	0	5	0	14	0	2	0	0	0
17	Singampunari	NA	NA	NA	NA	2	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
18	S.Pudur	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
19	Thiruppathur	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
20	Kallal	1	NA	NA	NA	1	NA	NA	NA	1	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
21	sakkottai	2	NA	10	NA	2	NA	NA	NA	2	NA	1	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
22	Kannangudi	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
23	Devakottai	1	NA	1	NA	NA	NA	1	NA	NA	NA	NA	NA	NA	NA	1	NA	NA	NA	NA	NA	NA	NA
24	Manamadurai	NA	NA	NA	NA	NA	NA	1	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
25	Kalayarkoil	2	NA	1	NA	NA	NA	2	NA	1	NA	NA	NA	NA	NA	NA	NA	0	NA	1	NA	NA	NA
26	Sivagangai	NA	NA	1	NA	1	NA	1	NA	1	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
27	Ilayangudi	12	NA	6	NA	3	NA	5	NA	4	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	1	NA
28	Marungapuri	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0

C- Cases D- Deaths NA- Data not available

	Table 9.12 Dengue																						
Sl. No	Name of the Block	2007		2008		2009		2010		2011		2012		2013		2014		2015		2016		2017	
		C	D	C	D	C	D	C	D	C	D	C	D	C	D	C	D	C	D	C	D	C	D
1	Sanarpatti	0	0	5	0	1	0	2	0	0	0	30	0	23	0	26	0	14	0	11	0	61	0
2	Natham	6	0	0	0	0	0	0	0	0	0	25	0	42	0	13	0	28	0	2	0	98	0
3	Vadamadurai	NA	NA	NA	NA	NA	NA	NA	NA	3	NA	14	NA	17	NA	21	NA	28	NA	12	NA	30	NA
4	Kottampatti	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	87	2	46	NA	14	NA	16	NA	13	NA	86	NA
5	Melur	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	459	5	55	NA	41	NA	12	NA	13	NA	233	NA
6	Vadipatti	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	41	0	6	NA	4	NA	2	NA	9	NA	205	NA
7	Aranthangi	34	0	29	0	39	0	47	0	52	0	47	0	34	0	37	0	22	0	36	0	29	0
8	Avudaiyarkoil	213	0	183	0	146	0	148	0	58	0	97	0	74	0	64	0	84	0	88	0	72	0
9	Manamelkudi	54	0	42	0	37	0	41	0	38	0	49	0	32	0	29	0	37	0	46	0	37	0
10	Ponnamaravathy	63	0	78	0	56	0	70	0	89	0	72	0	84	0	91	0	67	0	54	0	49	0
11	Arimalam	279	0	242	0	231	0	257	0	313	0	39	0	12	0	82	0	25	0	15	0	28	0
12	Thirumayam	69	0	76	0	33	0	49	0	56	0	24	0	11	0	46	0	52	0	38	0	49	0
13	Nainarkoil	0	0	0	0	0	0	3	0	0	0	6	0	4	0	3	0	1	0	6	0	23	0
14	Ramanathapuram	0	0	0	0	1	0	6	0	4	0	40	0	35	0	3	0	16	0	36	0	57	0
15	Rajasinga Mangalam	0	0	0	0	0	0	0	0	3	0	6	0	12	0	4	0	4	0	2	0	12	0
16	Thiruvadanai	0	0	0	0	1	0	0	0	2	0	5	0	12	0	12	0	7	0	1	0	26	0
17	Singampunari	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	10	NA	7	NA	11	NA	5	NA	2	NA	8	NA
18	S.Pudur	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	5	NA	4	NA	2	NA	2	NA	1	NA	4	NA
19	Thiruppathur	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	9	NA	10	NA	1	NA	9	NA	1	NA	1	NA
20	Kallal	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	2	NA	1	NA	4	NA	1	NA	0	NA	2	NA
21	sakkottai	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	15	NA	2	NA	6	NA	2	NA	0	NA	9	NA
22	Kannangudi	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	2	NA	0	NA	0	NA	1	NA	1	NA	0	NA
23	Devakottai	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	7	NA	0	NA	1	NA	0	NA	0	NA	0	NA
24	Manamadurai	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	23	NA	5	NA	0	NA	0	NA	0	NA	2	NA
25	Kalayarkoil	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	8	NA	6	NA	0	NA	0	NA	1	NA	1	NA
26	Sivagangai	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	15	NA	6	NA	4	NA	1	NA	0	NA	3	NA
27	Ilayangudi	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	0	NA	3	NA	3	NA	1	NA	1	NA	4	NA
28	Marungapuri	1	0	0	0	0	0	0	0	0	0	21	1	7	0	7	0	21	0	24	0	70	0

C- Cases D- Deaths NA- Data not available

	Table 9.13 Chickungunya																						
Sl. No	**Name of the Block**	**2007**		**2008**		**2009**		**2010**		**2011**		**2012**		**2013**		**2014**		**2015**		**2016**		**2017**	
		C	D	C	D	C	D	C	D	C	D	C	D	C	D	C	D	C	D	C	D	C	D
1	Sanarpatti	0	0	0	0	14	0	0	0	0	0	7	0	0	0	1	0	0	0	0	0	0	0
2	Natham	0	0	0	0	0	0	1	0	0	0	5	0	0	0	0	0	0	0	0	0	0	0
3	Vadamadurai	0	NA	NA	NA	0	NA	0	NA	1	NA	2	NA	2	NA	1	NA	2	NA	2	NA	6	NA
4	Kottampatti	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
5	Melur	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	0	NA	8	NA	3	NA	0	NA	0	NA	0	NA
6	Vadipatti	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	0	NA	2	NA	0	NA	0	NA	0	NA	0	NA
7	Aranthangi	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0
8	Avudaiyarkoil	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0
9	Manamelkudi	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0
10	Ponnamaravathy	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
11	Arimalam	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
12	Thirumayam	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
13	Nainarkoil	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
14	Ramanathapuram	0	0	0	0	0	0	1	0	2	0	1	0	0	0	0	0	0	0	0	0	0	0
15	Rajasinga Mangalam	0	0	0	0	1	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0
16	Thiruvadanai	0	0	0	0	1	0	0	0	0	0	1	0	2	0	3	0	0	0	0	0	1	0
17	Singampunari	NA	NA	NA	NA	NA	NA	NA	NA	1	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
18	S.Pudur	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	2	NA	NA	NA	NA	NA
19	Thiruppathur	NA	NA	NA	NA	NA	NA	1	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
20	Kallal	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	8	NA	NA	NA	NA	NA	NA	NA	NA	NA
21	sakkottai	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
22	Kannangudi	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
23	Devakottai	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
24	Manamadurai	NA	NA	NA	NA	NA	NA	NA	NA	1	NA	NA	NA	NA	NA	1	NA	NA	NA	NA	NA	NA	NA
25	Kalayarkoil	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	1	NA	NA	NA	NA	NA
26	Sivagangai	NA	NA	NA	NA	NA	NA	1	NA	NA	NA	NA	NA	6	NA	2	NA	2	NA	NA	NA	NA	NA
27	Ilayangudi	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
28	Marungapuri	0	0	0	0	0	0	0	0	0	0	0	0	1	0	4	0	2	0	0	0	0	0

C- Cases D- Deaths NA- Data not available

Table 9.14 Leptospirosis

Sl. No	Name of the Block	2007		2008		2009		2010		2011		2012		2013		2014		2015		2016		2017	
		C	D	C	D	C	D	C	D	C	D	C	D	C	D	C	D	C	D	C	D	C	D
1	Sanarpatti	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0
2	Natham	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	Vadamadurai	NA	NA	NA	NA	NA	NA	NA	NA	2	NA	1	NA	2	NA	NA	NA	2	NA	1	NA	1	NA
4	Kottampatti	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	26	NA	10	NA	0	NA	0	NA	0	NA	0	NA
5	Melur	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	59	NA	26	NA	4	NA	0	NA	1	NA	0	NA
6	Vadipatti	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	9	NA	14	NA	0	NA	0	NA	0	NA	10	NA
7	Aranthangi	0	0	0	0	0	0	0	0	2	0	3	0	1	0	4	0	0	0	2	0	0	0
8	Avudaiyarkoil	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
9	Manamelkudi	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
10	Ponnamaravathy	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
11	Arimalam	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
12	Thirumayam	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
13	Nainarkoil	0	0	0	0	0	0	0	0	1	0	2	0	4	0	0	0	0	0	0	0	0	0
14	Ramanathapuram	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
15	Rajasinga Mangalam	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0
16	Thiruvadanai	0	0	0	0	0	0	0	0	0	0	5	0	0	0	1	0	0	0	0	0	0	0
17	Singampunari	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	5	NA	NA	NA	11	NA	NA	NA	NA	NA	NA	NA
18	S.Pudur	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	2	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
19	Thiruppathur	NA	NA	1	NA	NA	NA	NA	NA	NA	NA	1	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
20	Kallal	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	1	NA	NA	NA	NA	NA	NA	NA	NA	NA
21	sakkottai	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	2	NA	NA	NA	NA	NA	NA	NA	1	NA	NA	NA
22	Kannangudi	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
23	Devakottai	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	1	NA	NA	NA
24	Manamadurai	NA	NA	9	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
25	Kalayarkoil	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
26	Sivagangai	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	2	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
27	Ilayangudi	NA	NA	1	NA	NA	NA	NA	NA	NA	NA	1	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
28	Marungapuri	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	6	0	2	0

C- Cases D- Deaths NA- Data not available

Table 9.15 Japanese Encephalitis

Sl. No	Name of the Block	2007		2008		2009		2010		2011		2012		2013		2014		2015		2016		2017	
		C	D	C	D	C	D	C	D	C	D	C	D	C	D	C	D	C	D	C	D	C	D
1	Sanarpatti	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	Natham	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	Vadamadurai	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4	Kottampatti	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
5	Melur	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
6	Vadipatti	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	0	NA	0	NA	0	NA	0	NA	0	NA	2	NA
7	Aranthangi	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8	Avudaiyarkoil	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
9	Manamelkudi	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
10	Ponnamaravathy	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
11	Arimalam	NA	NA	NA	NA	NA	NA	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
12	Thirumayam	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
13	Nainarkoil	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
14	Ramanathapuram	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0
15	Rajasinga Mangalam	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
16	Thiruvadanai	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0
17	Singampunari	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
18	S.Pudur	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
19	Thiruppathur	NA	NA	NA	NA	NA	NA	NA	NA	1	NA	NA	NA	1	NA	NA	NA	NA	NA	NA	NA	NA	NA
20	Kallal	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
21	sakkottai	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	3	NA	1	NA	NA	NA	NA	NA	1	NA	NA	NA
22	Kannangudi	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
23	Devakottai	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	1	NA	NA	NA	NA	NA
24	Manamadurai	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
25	Kalayarkoil	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
26	Sivagangai	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
27	Ilayangudi	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
28	Marungapuri	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0

C- Cases D- Deaths NA- Data not available

	Table 9.16 Acute Diahorroea																						
Sl. No	Name of the Block	2007		2008		2009		2010		2011		2012		2013		2014		2015		2016		2017	
		C	D	C	D	C	D	C	D	C	D	C	D	C	D	C	D	C	D	C	D	C	D
1	Sanarpatti	545	0	522	0	480	0	560	0	575	0	551	0	448	0	368	0	443	0	535	0	459	0
2	Natham	691	0	595	0	680	0	751	0	794	0	715	0	582	0	747	0	682	0	683	0	496	0
3	Vadamadurai	6	0	12	0	6	0	9	0	17	0	16	0	13	0	10	0	11	0	12	0	10	0
4	Kottampatti	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	109	NA	258	NA	664	NA	759	NA
5	Melur	NA	NA	NA	NA	125	NA	165	NA	217	NA	174	NA	95	NA	248	NA	466	NA	582	NA	468	NA
6	Vadipatti	NA	NA	NA	NA	57	NA	124	NA	487	NA	456	NA	378	NA	1337	NA	1757	NA	2044	NA	1537	NA
7	Aranthangi	796	0	789	0	618	0	613	0	340	0	237	0	217	0	183	0	176	0	163	0	156	0
8	Avudaiyarkoil	814	0	748	0	689	0	729	0	657	0	890	0	298	0	175	0	67	0	52	0	77	0
9	Manamelkudi	378	0	316	0	261	0	171	0	98	0	50	0	60	0	84	0	95	0	46	0	32	0
10	Ponnamaravathy	816	0	796	0	715	0	633	0	637	0	941	0	718	0	895	0	1096	0	1124	0	969	0
11	Arimalam	1987	0	1891	0	1871	0	2702	0	3846	0	3834	0	1171	0	990	0	848	0	1452	0	501	0
12	Thirumayam	712	0	694	0	625	0	578	0	574	0	887	0	643	0	649	0	779	0	1066	0	787	0
13	Nainarkoil	8	0	6	0	6	0	7	0	5	0	5	0	9	0	8	0	8	0	6	0	4	0
14	Ramanathapuram	23	0	33	0	36	0	29	0	41	0	15	0	28	0	31	0	26	0	39	0	34	0
15	Rajasinga Mangalam	19	0	11	0	6	0	8	0	13	0	15	0	7	0	9	0	3	0	16	0	21	0
16	Thiruvadanai	8	0	7	0	3	0	2	0	6	0	5	0	11	0	10	0	8	0	5	0	12	0
17	Singampunari	NA	NA	215	NA	374	NA	215	NA	235	NA	110	NA	256	NA	136	NA	238	NA	115	NA	65	NA
18	S.Pudur	NA	NA	56	NA	355	NA	156	NA	178	NA	96	NA	100	NA	175	NA	108	NA	36	NA	35	NA
19	Thiruppathur	NA	NA	210	NA	400	NA	215	NA	315	NA	130	NA	201	NA	216	NA	356	NA	110	NA	89	NA
20	Kallal	NA	NA	225	NA	320	NA	325	NA	335	NA	312	NA	329	NA	326	NA	345	NA	115	NA	75	NA
21	sakkottai	NA	NA	436	NA	953	NA	456	NA	326	NA	315	NA	315	NA	357	NA	316	NA	136	NA	86	NA
22	Kannangudi	NA	NA	141	NA	223	NA	241	NA	240	NA	125	NA	126	NA	245	NA	245	NA	71	NA	61	NA
23	Devakottai	NA	NA	196	NA	312	NA	206	NA	205	NA	114	NA	238	NA	210	NA	201	NA	96	NA	95	NA
24	Manamadurai	NA	NA	110	NA	356	NA	310	NA	215	NA	121	NA	214	NA	212	NA	315	NA	100	NA	101	NA
25	Kalayarkoil	NA	NA	126	NA	415	NA	336	NA	315	NA	136	NA	225	NA	338	NA	316	NA	116	NA	117	NA
26	Sivagangai	NA	NA	355	NA	710	NA	345	NA	325	NA	356	NA	371	NA	349	NA	385	NA	255	NA	135	NA
27	Ilayangudi	NA	NA	236	NA	656	NA	136	NA	156	NA	210	NA	251	NA	139	NA	256	NA	236	NA	136	NA
28	Marungapuri	352	0	410	0	492	0	463	0	752	0	850	0	613	0	776	0	628	0	641	0	565	0

C- Cases D- Deaths NA- Data not available

Table 9.17 Jaundice

Sl. No	Name of the Block	2007		2008		2009		2010		2011		2012		2013		2014		2015		2016		2017	
		C	D	C	D	C	D	C	D	C	D	C	D	C	D	C	D	C	D	C	D	C	D
1	Sanarpatti	1	0	0	0	1	0	0	0	1	0	0	0	0	0	1	0	1	0	1	0	0	0
2	Natham	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0
3	Vadamadurai	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
4	Kottampatti	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
5	Melur	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
6	Vadipatti	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
7	Aranthangi	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
8	Avudaiyarkoil	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
9	Manamelkudi	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
10	Ponnamaravathy	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
11	Arimalam	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
12	Thirumayam	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
13	Nainarkoil	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
14	Ramanathapuram	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
15	Rajasinga Mangalam	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
16	Thiruvadanai	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
17	Singampunari	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
18	S.Pudur	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
19	Thiruppathur	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
20	Kallal	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
21	sakkottai	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
22	Kannangudi	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
23	Devakottai	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
24	Manamadurai	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
25	Kalayarkoil	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
26	Sivagangai	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
27	Ilayangudi	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
28	Marungapuri	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

C- Cases D- Deaths NA- Data not available

Table 9.18 Dysentry

Sl. No	Name of the Block	2007		2008		2009		2010		2011		2012		2013		2014		2015		2016		2017	
		C	D	C	D	C	D	C	D	C	D	C	D	C	D	C	D	C	D	C	D	C	D
1	Sanarpatti	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	Natham	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	Vadamadurai	6	0	3	0	3	0	4	0	3	0	12	0	16	0	8	0	13	0	9	0	7	0
4	Kottampatti	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	3	NA
5	Melur	NA	NA	NA	NA	NA	NA	1	NA	45	NA	5	NA	NA	NA	7	NA	NA	NA	64	NA	34	NA
6	Vadipatti	NA	NA	NA	NA	NA	NA	NA	NA	10	NA	NA	NA	NA	NA	NA	NA	7	NA	166	NA	90	NA
7	Aranthangi	34	0	29	0	39	0	47	0	52	0	47	0	34	0	37	0	22	0	36	0	29	0
8	Avudaiyarkoil	213	0	183	0	146	0	148	0	58	0	97	0	74	0	64	0	84	0	88	0	72	0
9	Manamelkudi	54	0	42	0	37	0	41	0	38	0	49	0	32	0	29	0	37	0	46	0	37	0
10	Ponnamaravathy	63	0	78	0	56	0	70	0	89	0	72	0	84	0	91	0	67	0	54	0	49	0
11	Arimalam	279	0	242	0	231	0	257	0	313	0	39	0	12	0	82	0	25	0	15	0	28	0
12	Thirumayam	69	0	76	0	33	0	49	0	56	0	24	0	11	0	46	0	52	0	38	0	49	0
13	Nainarkoil	48	0	35	0	29	0	19	0	16	0	14	0	10	0	19	0	15	0	13	0	19	0
14	Ramanathapuram	41	0	12	0	34	0	27	0	36	0	5	0	25	0	2	0	39	0	2	0	0	0
15	Rajasinga Mangalam	2	0	5	0	19	0	12	0	0	0	3	0	8	0	22	0	15	0	0	0	16	0
16	Thiruvadanai	12	0	26	0	14	0	19	0	21	0	28	0	33	0	25	0	17	0	18	0	21	0
17	Singampunari	NA	NA	NA	NA	NA	NA	NA	NA	446	NA	358	NA	344	NA	893	NA	195	NA	325	NA	135	NA
18	S.Pudur	NA	NA	NA	NA	NA	NA	NA	NA	149	NA	228	NA	246	NA	456	NA	96	NA	89	NA	91	NA
19	Thiruppathur	NA	NA	NA	NA	NA	NA	NA	NA	512	NA	415	NA	512	NA	346	NA	280	NA	351	NA	136	NA
20	Kallal	NA	NA	NA	NA	NA	NA	NA	NA	638	NA	310	NA	225	NA	539	NA	345	NA	206	NA	140	NA
21	sakkottai	NA	NA	NA	NA	NA	NA	NA	NA	1052	NA	252	NA	215	NA	245	NA	411	NA	145	NA	255	NA
22	Kannangudi	NA	NA	NA	NA	NA	NA	NA	NA	801	NA	135	NA	116	NA	123	NA	211	NA	191	NA	96	NA
23	Devakottai	NA	NA	NA	NA	NA	NA	NA	NA	914	NA	740	NA	780	NA	856	NA	206	NA	201	NA	215	NA
24	Manamadurai	NA	NA	NA	NA	NA	NA	NA	NA	754	NA	802	NA	752	NA	456	NA	145	NA	270	NA	245	NA
25	Kalayarkoil	NA	NA	NA	NA	NA	NA	NA	NA	415	NA	401	NA	441	NA	320	NA	203	NA	345	NA	212	NA
26	Sivagangai	NA	NA	NA	NA	NA	NA	NA	NA	816	NA	421	NA	369	NA	890	NA	210	NA	191	NA	146	NA
27	Ilayangudi	NA	NA	NA	NA	NA	NA	NA	NA	610	NA	656	NA	170	NA	510	NA	191	NA	89	NA	115	NA
28	Marungapuri	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

C- Cases D- Deaths NA- Data not available

Table 9.19 Cholera

Sl. No	Name of the Block	2007		2008		2009		2010		2011		2012		2013		2014		2015		2016		2017	
		C	D	C	D	C	D	C	D	C	D	C	D	C	D	C	D	C	D	C	D	C	D
1	Sanarpatti	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	Natham	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	Vadamadurai	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4	Kottampatti	NA	NA	NA	NA	NA	NA	1	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
5	Melur	NA	NA	NA	NA	2	NA	2	NA	1	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
6	Vadipatti	NA	NA	NA	NA	1	NA	11	NA	3	NA	7	NA	NA	NA	NA	NA	2	NA	NA	NA	NA	NA
7	Aranthangi	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8	Avudaiyarkoil	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
9	Manamelkudi	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10	Ponnamaravathy	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
11	Arimalam	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
12	Thirumayam	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
13	Nainarkoil	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
14	Ramanathapuram	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
15	Rajasinga Mangalam	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
16	Thiruvadanai	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
17	Singampunari	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
18	S.Pudur	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
19	Thiruppathur	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
20	Kallal	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
21	sakkottai	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
22	Kannangudi	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
23	Devakottai	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
24	Manamadurai	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
25	Kalayarkoil	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
26	Sivagangai	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
27	Ilayangudi	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
28	Marungapuri	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

C- Cases D- Deaths NA- Data not available

9.8 Solid Waste Management

Solid waste is the unwanted or useless solid materials generated from combined residential, industrial and commercial activities in a given area.

9.8.1 Types and sources of solid waste:

Solid wastes are classified

- ✓ Based on their sources of origin (Residential wastes, Industrial wastes, Commercial wastes, Institutional wastes, Municipal wastes and Agricultural wastes).
- ✓ Based on physical nature (Garbage, Ashes, Combustible and non-Combustible wastes, Demolition & Construction wastes and Hazardous wastes).

Table 9.20 Classification of Solid waste sources

Source	Typical waste generators	Types of solid wastes
Residential	Single and multifamily dwellings	Food wastes, paper, cardboard, plastics, textiles, leather, yard wastes, wood, glass, metals, ash, special wastes
Industrial	Light and heavy manufacturing fabrication, construction sites, power and chemical plants	Housekeeping wastes, packaging, food wastes, construction and demolition materials, ash, special andhazardous wastes
Commercial	Stores, hotels, restaurants, markets, office buildings	Paper, cardboard, plastics, wood, food, glass, metals, special and hazardous wastes
Institutional	Schools, hospitals, prisons, government centres	Same as commercial
Municipal services	Street cleaning, landscaping, parks, beaches, other recreational areas, water and	Street sweepings, landscape and tree trimmings, general wastes from parks, beaches and other
Process (manufacturing etc.,)	Heavy and light manufacturing, refineries, chemical plants, power plants, power plants, mineral extraction and	Industrial process wastes, scrap materials, off-specification products, slay, tailings.
Agriculture	Crops, Orchards, Vineyards, dairies, feedlots, farms.	Spoiled food wastes, agricultural wastes, hazardous wastes
Construction and demolition	New construction sites, road repair, renovation sites, demolition of buildings	Wood, steel, concrete, dirt etc.,

Garbage (Biodegradable food waste)	Houses, Hotels, Dairies, meat stalls	Residual vegetable or animal waste
Ashes	Fire places, Kitchen of houses, hotels	Residues remaining after burning of wood, coal, coke
Combustible and non-Combustible wastes	House Holds, Hotels ,Offices, markets	Combustible solid waste as paper, cardboard, plastics, textile, rubber, leather, wood etc.,Non- combustible solid

9.8.2 Effects of Solid Waste

- Municipal solid wastes heap up on the roads due to improper disposal system. This type of dumping of allows biodegradable materials to decompose under uncontrolled and unhygienic conditions. This produces foul smell and breeds various types of insects and infectious organisms besides spoiling the aesthetics of the site.
- Industrial solid wastes are sources of toxic metals and hazardous wastes, which may spread on land and can cause changes in physicochemical and biological characteristics thereby affecting productivity of soils.
- Toxic substances may leach or percolate to contaminate the ground water. In refuse mixing, the hazardous wastes are mixed with garbage and other combustible wastes. This makes segregation and disposal all the more difficult and risky.

9.8.3 Solid Waste Management in Pambar Kottakaraiyar Basin

Solid waste management is the process of storage, collection, transportation and recycling, disposal and monitoring of solid waste in a systematic, economic and hygienic manner. In Pambar Kottakaraiyar river basin, the collection, transportation and disposal of solid wastes is done by the local bodies.

Dindigul city generates around 104 tonnes /day. It is estimated that about 480 gram/ day of waste is being produced by every individual. The generated waste are collected, transported and disposed as per guideline issued in solid waste management rules 2000. In Dindigul Corporation a special arrangement is done for the compost preparation. The flower Market waste are collected separately and segregated and used for the preparation of compost. Daily 10 tonnes of degradable waste are processed by windrow composting method. Daily 5 tonnes of food and vegetable waste is used in Bio Methanisation power plant. 420 KW of Power is generated from the plant and it is used for street light maintenance work.

Primary generators of solid waste in Aranthangi municipality are households, markets and commercial establishments, hotels, restaurants. Approximately 10 tonnes of waste generated daily is currently disposed through open dumping at Pudukottai road waste collection area.

The generation of solid waste in Pudukottai municipal area is 30-35 tonnes per day and the area of composting yard is 13.13 acres. Bio-degradable solid wastes are converted into bio fertilizers by using aerobic method of composting. Non- bio degradable wastes like plastic materials are segregated and sold to the recyclers. Inert materials and debris are buried in the land.

In Devakottai municipality, the total solid waste generated per day in the town is 16 tonnes and out of which 15 tonnes is cleared every day. There is no specific compost yard in this municipality.

In Karaikudi municipality, door to door collections of garbages are effectively implemented in all the 36 wards of the town by adequate tri-cycles and push carts.

Sivaganga town generates 25 tonnes of Solid Waste per day out of this nearly 22.50 tonnes of the Solid Waste being collected, transported and disposed daily, which works to per capita generation of 560 gm/day. The efficiency of the present mechanism is able to collect 80% of the total waste generated in the town.

(Source: Dindigul, Aranthangi, Pudukottai, Devakottai, Karaikudi and Sivagangai Municipality website)

9.8.4 Mitigation Measures

- Waste Minimization which includes reducing waste at source, reusing materials and recycling waste materials (3R).
- Proper waste disposal methods such as sanitary landfill, incineration, composting and pyrolysis.
- Selection of dumping sites far from residential areas.
- Reducing the usage of non-biodegradable materials such as plastic shopping bags.
- Integrated Solid Waste Management can be adopted to mitigate the effects of solid waste.
- Awareness about solid waste management should be created among the public and in institutions.

9.9 Forest and Wild Life

Tamil Nadu has been a pioneer State in Protected Area management and development of forest resources and wildlife. The total area under the protected area management is 7,072.95 sq. km. which comes to 30.92% of the State’s Forest area.

In order to cater to the needs of the booming population and rapid urbanization, the fertile swamps, marshes and many wetlands are being converted into agricultural lands and paddy fields the world over. In recent years, with the introduction of powerful dredging, draining and earthmoving machinery the conversion of wetland to farmland has become particularly profitable. The draining of wetlands not only eliminates wildlife, but also increases storm water surges and lowers the water tables.

9.9.1 Forest and Wild life scenario in Pambar Kottakaraiyar basin

The forest area covered in Pambar Kottakaraiyar river basin is about 358.46 sq.km which accounts to 0.06% of the total basin area. Thiruvadanai Taluk has more number of villages abuting the forest area. Moderately dense mangrove forests are found in Ramanathapuram district in this basin. Mangroves are the woody plants which live between the sea and the land in areas which are flooded by tides for part of the time. Mangroves are a group of plants that grow in the inter tidal area in the places where river water mixes with sea water - estuarine environment. Mangroves are called wetlands because the land support plants, which are adopted wet soil conditions - hydrophytes. The base land is predominantly underlined hydric soil. The soil is saturated with water or covered by shallow water periodically during hide tide and during the monsoon seasons.

There is no wild life sanctuary in this basin.

Fig. 9.8 Mangrove Forests

9.10 Tourism

Over the decades, tourism has experienced continued growth and deepening diversification to become one of the fastest growing economic sectors and main source of income in India. Modern tourism is closely linked to development and encompasses growing number of new destinations. These dynamics have turned tourism into a key driver for socio-economic progress.

Tamil Nadu is a State with several distinguished tourism genre and has its own unique culture and traditions. Due to its abundant tourism potential, tourists from all over the country and abroad flock the tourist spots in the State throughout the year.

Some of the distinguished tourist attractions in Pambar Kottakaraiyar sub basin are given below.

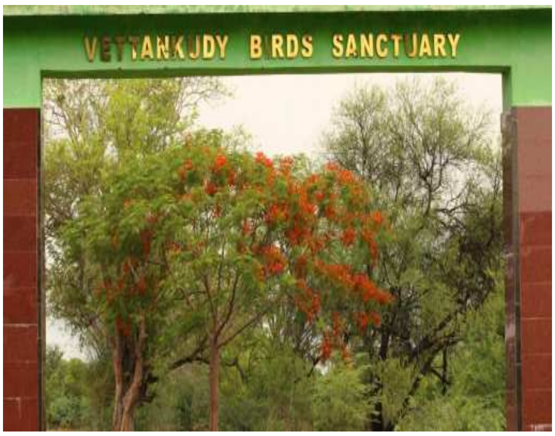
9.10.1 Pillayarpatti Temple

Fig 9.9 Pillayarpatti Temple

Karpaga Vinayagar (Pillayarpatti) Temple is one of the oldest Cave Temples (Rock Cut) of Tamilnadu situated at Pillayarpatti, which is between Pudukkottai and Karaikudi. Pillayarpatti is situated at a distance of 71kms from Madurai and 12 kms from Karaikudi on Thirupathur – Karaikudi State Highway. The village gets its name from the temple. Here Lord Vinayaga appears with 2 hands unlike in other places where he is seen with 4 hands. The six feet presiding deity is called as Karpaga Vinayagar [valampuri posture].

9.10.2 Vettangudi Bird Sanctuary

Fig 9.10 Vettangudi Bird Sanctuary



Vettangudi Bird Sanctuary is near Thirupathur and Madurai. The Vettangudi Bird Sanctuary is located at a distance of 51 kms from Madurai on Madurai – Melur-Tiruppathur road, in Savaganga District. It is located in Vettangudipatti and Periya Kollukudipatti village of Tiruppathur Taluk, Sivagnaga District. This sanctuary covers an area of 40 hectares and covers the tanks of Vettangudi, Periyakollukudi and Chinna Kollukkudi villages. The Vettangudi Bird sanctuary is the natural habitat of winter migratory birds. It is a breeding habitat for Grey Herons, Darters, Spoonbills, Wite Ibis, Asian Open Bill Stork and Night Herons.

9.10.3 Chettinad palace

The chettinad houses in Karaikudi, Pallathur, Athangudi and Kothamangalam are the most lavish and expuisite examples of architectural beauty. Located at 10 kms away from Karaikudi, Chettinad Place is a beautiful edifice situated in the Chettinad region, in Sivaganga district. It is one of the most glorious examples of chettinad's widely famed palatial mansions. It reflects the traditional style of architecture, which is characteristic of the region.

Fig 9.11 Chettinad palace

All the mansions have lovely teak, marble or granite pillars supporting a spacious verandah. The hall leads to the central courtyard, used for weddings and religious ceremonies erstwhile. The palace stands tall covering about 1900 sq.ft including 9 car sheds and a lift.

9.10.4 Aayiram Jannal Veedu

Fig 9.12 Aayiram Jannal Veedu

Aayiram Jannal Veedu is a famous landmark in the town of Karaikudi. The literal translation of the name of the place means the house with a thousand windows. The house is very famous among the tourists who make it a point to visit the place when in Karaikudi. Built in 1941 on 20,000 square feet of area, the house is very spacious and has 25 huge rooms, five large halls, 20 doors along with 1000 windows.

9.10.5 Impacts of Tourism

The impact of tourism (positive and negative impacts) can be categorized into economic, socio-cultural and of environment. While the positive impact of tourism is mainly on economic aspect such as employment opportunities, growth in income, increase in foreign exchange, infrastructure and facilities development, it also includes the socio- cultural and environmental aspects such as preservation of heritage, culture, local customs and conservation of natural habitats.

The greater concerns for the negative impact of tourism include seasonal unemployment, shortage of facilities, increased crime and possible threats to natural resources.

9.10.6 Mitigation measures

The mitigation measures recommended to reduce the negative impact of tourism are as follows

- Putting increased focus on Eco-tourism ie. tourism which is ecologically sustainable and encouraging, Green tourism ie. responsible, sustainable and ethical tourism.
- Total ban on non-biodegradable products such as plastics have an enormous positive impact on the planet's environment.
- Utilization of revenue from parks and other tourist spots for the overall development and management of environmentally sensitive areas.

- Providing environmental information and raising awareness among tourists about the environmental consequences and their remedial actions.

9.11 Socio Economic Aspects & Legal Issues

Socioeconomic refers to society related economic factors. These factors relate to and influence one another.

In Pambar & Kottakaraiyar River Basin, the total population is about 2.66 million (as projected to 2018) out of which Urban population is about 0.818 million and Rural population is about 1.718 million. Overall literacy rate of the basin is found to be 57.41%.

Agriculture is the major occupation of the people in this basin. Paddy is the main crop followed by Coconut, Fruits & Vegetables, Sugarcane, Groundnut and Chillies. The educational level of farmers are favourable to adopt modern water management practices, cropping pattern etc.

Fishing is another important source of livelihood in this basin and occupies a prime place in acceleration of socio-economic development in the basin. The major fishing villages are located along the coastline of Arantangi Taluk.

Large, medium & small scale industries in this basin provide employment opportunity to the local people. There is a good scope for food processing and agro based industries. Participation of local people in planning, implementing and monitoring of these actions is decisive for sustainable outcomes.

9.11.1. Laws/Rules

With the institutional and governance issues getting greater importance in the policy discourse in recent years, the relevance of legal aspects, which are an integral part of the governance system, is also increasing in many fields. Understandably, one of these fields relates to water a resource the scarcity or mismanagement of which could be a major constraint for food security and economic development.

9.11.2 Conservation laws

The following are the constitutional provisions available for protecting the environment. **Article 48-A:** The State shall endeavor to protect and improve the environment and to safe guard the forests and wildlife of the country.

Article 51-A (g): It shall be the duty of every citizen of India to protect and improve the natural environment including forests, lakes, rivers and wild life and to have compassion for living creatures.

9.11.3 Acts related to Water resources & Environment & Encroachment.

. Some of the major Acts / rules is given below in the **Table 9.21**

Table 9.21 Name of Acts / Rules

Sl.No	Name of Acts / Rules
	Government of Tamil Nadu Acts
1	The Water (Prevention and Control of Pollution) Act
2	The Environment (Protection) Act
3	TamilNadu Land encroachment Act
4	Tamil Nadu Protection of Tanks and Eviction of Encroachment Act
5	Tamil Nadu Farmers' Management of Irrigation Systems - Act, (TNFMIS)
	Government of Tamil Nadu Rules
1	The Environment (Protection) Rules
2	The Tamilnadu Water (Prevention and Control of Pollution) Rules
3	Manufacture, Storage and Import of Hazardous Chemical Rules
4	Solid Waste Management Rules
5	E-Waste Management Rules
6	Bio-Medical Waste Management Rules
7	Hazardous and Other Waste (Management and Transboundary) Rules
8	Plastic Waste Management Rules

9.12 Public Awareness and Participation

There is an urgent need to safeguard the environment for the future generation. Environmental pollution and degradation cannot be prevented by laws alone. Public participation is equally important with regard to environmental protection. So to prevent further degradation of the environment, it is imperative to impart Environmental Education to the general public and initiate environmental protection awareness and participation through government and non-government agencies.

9.12.1 Environmental Awareness in Pambar Kottakaraiyar river basin

Environmental awareness can be created at this basin as follows.

- At primary & secondary schools and at colleges levels to impart elementary knowledge about environmental issues and problems, understanding of environmental problems, to develop skills to tackle the management problems of natural resources, for experimentation and solution to environmental problems and methods for conservation of natural resources.

- Through Adult Education to create a collective action in solving the environmental problems.
- Through Mass-Media which plays a vital role in creating awareness among public about environment and conservation of natural resources.

Tamilnadu Pollution Control Board, Public Health Department, Department of Environment and Forest and Municipalities of the districts falling in the basin are creating awareness among public and students about proper disposal of solid waste management, prevention of diseases etc.

Plastic Ban

To make Tamil Nadu free from plastic pollution and ensure a better quality of life, on June 5th 2018 (World Environment Day), the Tamil Nadu government announced a ban on “one time use and throw away plastics” irrespective of thickness with effect from 01.01.2019 under the provisions of Environmental (Protection) Act vide G.O Ms (No) 84, Environment & Forest (EC.2) Department, dated: 25.06.18. Awareness meetings and campaigns are being conducted about plastic ban in the Pudukottai, Ramanathapuram, Trichy, Dindigul, Madurai and Sivagangai districts.

Gaja Cyclone

During the NorthEast Monsoon 2018, the Cyclonic Storm "Gaja" hit and crossed the Tamil Nadu coast between Nagapattinam and Vedaranyam on the early hours of 16.11.2018. As a result, coastal districts as well as interior districts received rainfall coupled with cyclonic winds gusting upto 110 Kmph. On 16.11.2018, the average rainfall recorded in the State was 22.31 mm with 43 stations recording very heavy rainfall in the State. Due to the magnitude of the Cyclone "Gaja", extensive damages have also been reported to the power infrastructure, affecting rural industries and having cascading effect on livelihood opportunities in formal and informal sectors. Similarly, agriculture including horticulture and plantation crops, road networks, fisheries infrastructure, drinking water supply, community assets of local bodies etc., have also been extensively damaged, leading to loss of livelihood.

The Government of Tamilandu vide G.0(Ms) No.481, Revenue and Disaster Management Department, Disaster Management Wing, D.M.II section, Dated: 10.12.2018, declared the following districts and Taluks covered in this basin as cyclone , moderately and mildly affected areas as shown in the T**able:9.22**

Table 9.22 Gaja Cyclone affected districts and Taluks in Pambar Kottakaraiyar basin

Sl.No		District	Taluk
1	Cyclone Affected	Pudukotttai	
2	Moderately affected	Tiruchirappalli	Manaparai
3	Mildly affected	Dindigul	Dindigul, Natham,Vedasandur
		Madurai	Melur, Vadipatti
		Sivagangai	Karaikudi,Thirupathur, Sivaganga, Devakottai, Manamadurai,and Ilayangudi
		Ramanathapuram	Ramanathapuram, Paramakudi, Thiruvadanai

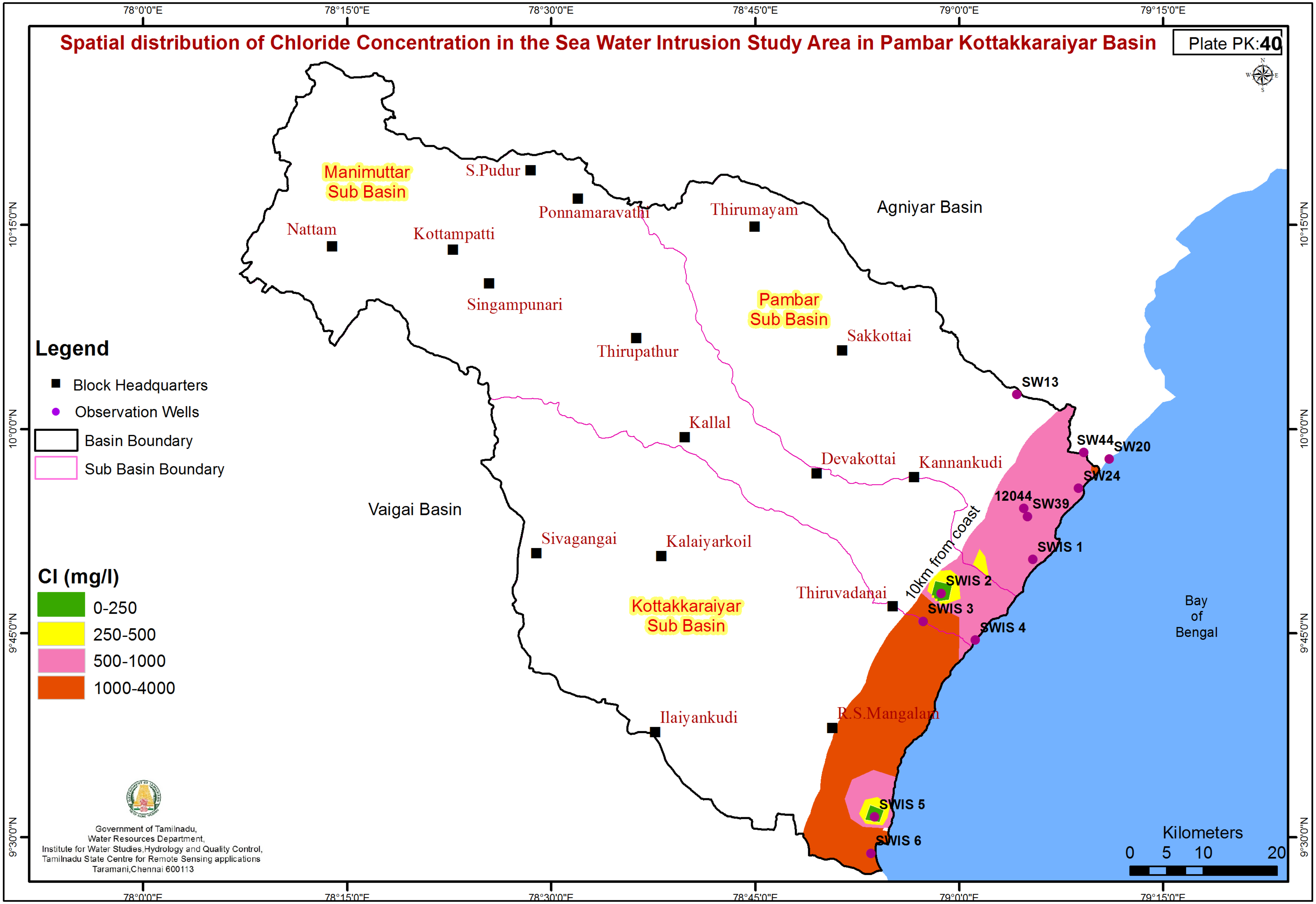
9.13 Summary

In Pambar Kottakaraiyar basin, effluent from large, medium & small scale industries and domestic sewage pollute the water bodies and also affects the public health. The consumption of fertilizers and pesticides is high in this basin for the past ten years which lead to agricultural pollution. The small and medium scale industries have been increased in this basin which does do not have proper treatment and disposal systems..The solid waste generated is also high in this basin. The inland fish production has been decreased in the past four years. Most of the tanks in this basin are predominantly covered with Prosopis Juliflora which is a major threat to the environment in this basin.

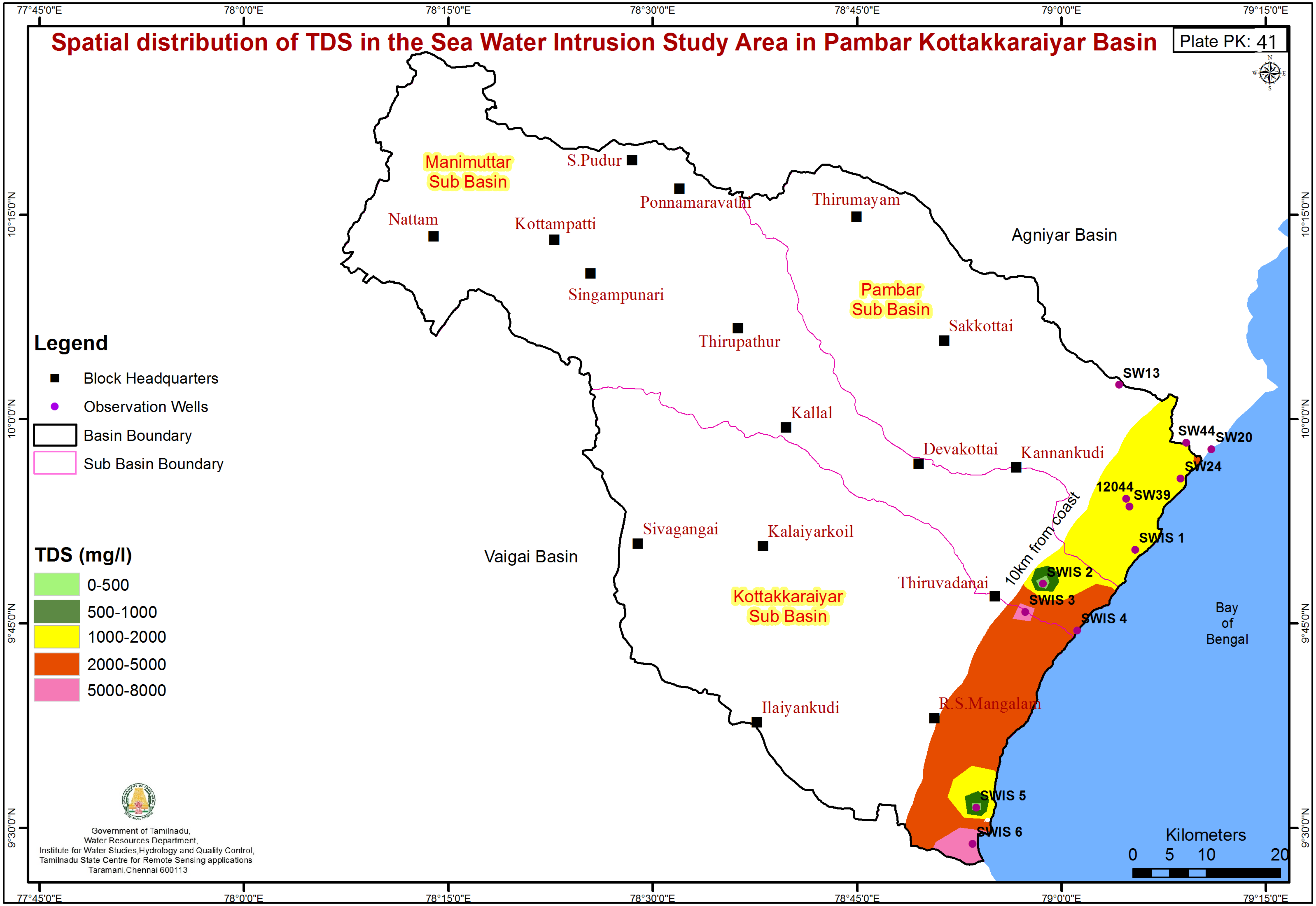
Some of the most important general mitigation measures that can be adopted to reduce the environmental degradation in this basin are given below:

1. Agglomeration of industries shall be encouraged so that the by-product or waste of one industry may be a raw material for some other industries, which will lead to reduction of natural water requirements.
2. Strengthening State policy, regulatory enforcement and institutional capacity against agricultural nutrient pollution and also encouraging organic farming.
3. Usage of Bio pesticides and fungicides to control the pests and diseases will also minimize the pollution.
4. Mechanical methods such as stick racking, chain pulling, bulldozer pushing and blade ploughing can be used for eradication of prosopis juliflora.
5. Introduction of fish culture in Multi Purpose farm ponds/water recharge ponds and promoting ornamental fish culture as a commercial activity.

6. Installation of artificial reefs which serves as the habitat for aggregation of fish stocks and excellent breeding.
7. Payer pays policy (Make the industries pay taxes for the environmental harm).
8. Organising Environmental awareness campaign.
9. Waste Minimization which includes reducing waste at source, reusing materials and recycling waste materials (3R).
10. Proper waste disposal methods such as sanitary landfill, incineration, composting and pyrolysis.
11. Integrated Solid Waste Management can be adopted to mitigate the effects of solid waste.



Spatial distribution of Chloride Concentration in the Sea Water Intrusion Study Area in Pambar Kottakkaraiyar Basin
Plate PK:40
78°0'0"E
78°15'0"E
78°30'0"E
78°45'0"E
79°0'0"E
79°15'0"E
10°15'0"N
10°0'0"N
9°45'0"N
9°30'0"N
Manimuttar Sub Basin
S.Pudur
Ponnamaravathi
Thirumayam
Agniyar Basin
Nattam
Kottampatti
Singampunari
Pambar Sub Basin
Sakkottai
Thirupathur
SW13
Kallal
Devakottai
Kannankudi
SW44
SW20
SW24
12044
SW39
10km from coast
SWIS 1
SWIS 2
SWIS 3
SWIS 4
Vaigai Basin
Sivagangai
Kalaiyarkoil
Thiruvadanai
Kottakkaraiyar Sub Basin
Bay of Bengal
Ilaiyankudi
R.S.Mangalam
SWIS 5
SWIS 6
Legend
Block Headquarters
Observation Wells
Basin Boundary
Sub Basin Boundary
Cl (mg/l)
0-250
250-500
500-1000
1000-4000
Kilometers
0 5 10 20
Government of Tamilnadu,
Water Resources Department,
Institute for Water Studies,Hydrology and Quality Control,
Tamilnadu State Centre for Remote Sensing applications
Taramani,Chennai 600113


Spatial distribution of TDS in the Sea Water Intrusion Study Area in Pambar Kottakkaraiyar Basin
Plate PK: 41
Manimuttar Sub Basin
Pambar Sub Basin
Kottakkaraiyar Sub Basin
Agniyar Basin
Vaigai Basin
Bay of Bengal
S.Pudur
Ponnamaravathi
Thirumayam
Nattam
Kottampatti
Singampunari
Thirupathur
Sakkottai
Kallal
Devakottai
Kannankudi
Sivagangai
Kalaiyarkoil
Thiruvadanai
Ilaiyankudi
R.S.Mangalam
SW13
SW44
SW20
SW24
12044
SW39
SWIS 1
SWIS 2
SWIS 3
SWIS 4
SWIS 5
SWIS 6
10km from coast
Legend
Block Headquarters
Observation Wells
Basin Boundary
Sub Basin Boundary
TDS (mg/l)
0-500
500-1000
1000-2000
2000-5000
5000-8000
Kilometers
0 5 10 20
77°45'0"E
78°0'0"E
78°15'0"E
78°30'0"E
78°45'0"E
79°0'0"E
79°15'0"E
10°15'0"N
10°0'0"N
9°45'0"N
9°30'0"N
Government of Tamilnadu,
Water Resources Department,
Institute for Water Studies,Hydrology and Quality Control,
Tamilnadu State Centre for Remote Sensing applications
Taramani,Chennai 600113

CHAPTER -10

PRESENT INSTITUTIONAL SETUP

CHAPTER - 10

PRESENT INSTITUTIONAL SETUP

Institutional arrangements are sets of working rules that are used to determine who is eligible to make decisions in some area, and what actions are allowed or constrained in management of water resources in a river basin. Suitable institutional arrangements are necessary to enable effective water management in River Basins.

10.1 Present Institutional Set Up

The various Departments / Institutions of the Government of Tamil Nadu / Government of India vested with water resources management are detailed as below;

Tamil Nadu Water Supply and Drainage Board (TWAD)

Tamilnadu Water Supply and Drainage Board is responsible for implementation of Water Supply and Sewerage facilities to the public of the entire State of Tamilnadu except for Chennai Metropolitan city. Pambar&Kottakkaraiyar River Basin falls under the jurisdiction of the Chief Engineer,TWAD Board, Thanjavur, Madurai, Superintending Engineer, Trichy, Sivaganga, Madurai, under the control of Engineering Director, Chennai implements the various schemes in Pambar&Kottakkaraiyar River Basin with the assistance of their Executive Engineers. Details of water supply schemes implemented in urban and rural areas of Pambar&Kottakkaraiyar River Basin are collected from the TWAD Board.

Tamil Nadu Pollution Control Board (TNPCB)

Tamilnadu Pollution Control Board is functioning with the Chairman as its head, Member Secretary, 2 Additional Chief Environmental Engineers, 10 Joint Chief Environmental Engineers, 32 District Environmental Engineers and 2 Assistant Environmental Engineers. The Chief Environmental Engineers are implementing the Pollution Control Legislations and Rules and Notifications framed therein, collects and disseminates data relating to water, air and land pollution, lays down standards for sewage / trade effluent and emissions. This Board monitors the industrial effluents discharges into water bodies from pollution point of view. The Board has established 5 Advanced Environmental Laboratories, 10 District Environmental Laboratories to assist in the analytical and scientific side by experimental analysis and conducting research in abating pollutants. The District offices of Tamilnadu Pollution Control Board functioning with the District Environmental Engineer as its head is located at Sivaganga, Dindugal ,Madurai

,Pudukottai, ,Trichy, Ramanathapuram. The District Environmental Engineer monitors and controls the Industrial Pollution in Pambar&Kottakkaraiyar River Basin. The District Environmental Engineers handles the issues regarding pollution in the District, issue renew the consent to orange & green industries, renews consent to red small industries, issues show cause notice to the erring industries.etc.

List of industries, type of industries, water requirement, treatment method adopted and sewage effluent are collected from the TNPCB office. These details are used to arrive the industrial demand at present and in future.

Public Health and Preventive Medicines Department

This department takes care of preventive and control measures in the event of outbreak of epidemics, undertakes the testing of water samples, educate the public on water borne and water related diseases. This department is headed by a Director (Public Health & Preventive Medicines) at Chennai. The Deputy Director of Health services at Pudukottai, Trichy, Dindugal, Sivaganga,Madurai and Ramanathapuram districts covers Pambar&Kottakkaraiyar River Basin area. The details of registered births and deaths in Districts falling under Pambar&Kottakkaraiyar River Basin as per the Statistical Handbook of Tamil Nadu 2016 are collected from the above department. These details are used to document the population dynamics inPambar&Kottakkaraiyar River Basin.

Animal Husbandry & Veterinary Science Department

Animal Husbandry Department is headed and governed by the Director, Animal Husbandry & Veterinary Sciences, along with Additional Director at Chennai. The Regional Joint Director at Pudukottai, Trichy, Dindugal, Sivaganga ,Madurai and Ramanathapuram districts along with their Assistant Directors are responsible for all the activities of this Department in Pambar&Kottakkaraiyar River Basin. The Livestock sector provides livestock based food products such as milk, egg, meat, raw materials like wool for industries, manure etc,. The Animal Husbandry Department provides comprehensive veterinary assistance and health cover to all livestock and poultry across the State of Tamil Nadu. With the implementation of cross breeding programme and various other schemes by the department, livestock farming has become economically viable and remunerative to large number of rural households.

The functions of department are as follows (i)Augmenting the production potentialities of livestock and poultry and thus increasing the production of milk, egg and meat(ii) Providing necessary and timely modern veterinary assistance and health cover to the livestock and poultry(iii) Implementing various central and state Government schemes for the upliftment of rural poor (iv)Providing information and training on basic and latest animal husbandry practices(v) Protecting human health by preventing major zoonatic diseases of animals.

The district wise of livestock census details inPambar&Kottakkaraiyar River Basin were collected from the Animal Husbandry & Veterinary Sciences Department, Chennai.. These details were used to arrive the Livestock Water demand at present and in future.

Water Resources Department (WRD)

The Water Resources Department is a part of the Public Works Department. The Water Resources Department is responsible for the maintenance & rehabilitation of all the Irrigation Structures and improving the irrigation infrastructure as well as monitoring floods. One of the main objectives of the Water Resources Department is to ensure effective management and distribution of surface and ground water to achieve optimum utilization in a rational and scientific way for maximizing the production and productivity of all the sectors requiring water in the State of Tamil Nadu.

Water Utilization Committee

The Government constituted Water Utilization Committee and Technical sub Committee to Water Utilization Committee inorder to take final decision on the proposals seeking permission for surface/ ground water drawl,by various organizations / institutions. The various proposals seeking requisition for water drawl from surface / ground water are scrutinized based on the assessment of the available surface and ground water potential and existing scenario of water demand at which drawl is requested.

Participatory Irrigation Management (PIM)/Water User’s Association

Under the Water Resources Consolidation Project & IAMWARM project, farmer’s organizations are formed in the project implementation areas, to regulate the use of water among the various users, to manage the operation and maintenance of the irrigation systems. The farmer’s organization comprises of Water User Association, Distributory Committee, Project Committee and Apex Committee with each having various functions.

Participatory Irrigation Management (PIM)

This Component aims to improve farmers' (water users) involvement in management and operation of irrigation system. For this purpose, the project would work towards integrating Participatory Irrigation Management (PIM) practices into operations of the WRD. The subcomponent will assist in establishing and strengthening Water Users Associations (WUAs), including operationalizing WUAs to undertake operation and maintenance of field channels, and equitable water distribution within their command areas.

Water Users Associations are delineated based on the command area of the major / medium irrigation system. Water Users Association at the primary level consists of all the water users in such association area as members. A Water User Association can be called by its local distinct name. Every Water User Association shall be divided into Territorial Constituencies (TC) which should not be less than four and not greater than ten. A Territorial Constituency means a contiguous block of command area of one or more sluices under a Water Users Association area. There is a Management Committee for every Water User Association and a President of the Management Committee is elected by the members of the Water Users Association.

A competent authority, an officer of the Water Resources Department is appointed by the Government to Farmers organization to implement and execute the decisions taken by the farmer's organization. The farmer's organization shall extend its assistance and co-operation to the competent authority.

The farmer's organization may, for carrying out the purposes of this Act, and or achieving the objects of such organization and performing its functions, levy and collect such fees not exceeding five hundred rupees per hectare per year from every water user, as prescribed, from time to time. The other sources of funds to the farmers organization are grants received from Government as a share of water charges, Central / State Government fund for development of that area, resources raised from any financial agency for undertaking any economical development activities, income from properties and assets attached to the irrigation system as granted by the Government.

Functions of WUA

1. To prepare and implement an operational plan and a rotational water supply for each irrigation season. consistent with the operational plan, prepared by the distributor committee and the project committee and based upon the entitlement area soil and cropping pattern as approved by the managing committee or as the case may be of the project committee.

2. To prepare a plan for the maintenance of irrigation system in the area of its operation at the end of each crop season and carry out the maintenance works of both distributary system, water courses and field drains in its area of operation with the funds of the water users association from time to time.

3. To regulate the use of water among the various sluices under its area of operation according to the rotational water supply.

4. To assist the authorities of the revenue department of the government in the preparation of demand and collection of water charges.

5. To prepare and maintain an inventory of the irrigation system within the area of operation.

6. To resolve the disputes if any between the members of the water users association in its area of operation.

7. To conduct general body meeting in such a manner as may be prescribed.

8. To encourage avenue plantation on canal and tank poromboke and to protect and maintain such plantations.

9. To conduct regular water budgeting and also to conduct periodical social audit as may be prescribed.

10. To remove the encroachments on canal drains and tank poromboke in the area of jurisdiction of the water users association.

The sub-basin wise WUA details ofPambar&Kottakkaraiyar river basin is as below,

PAMBAR KOTTAKKARAIYAR RIVER BASIN (WUA Details)

WUA'S Details under IAMWARM & WRCP				
SI. No.	**Name of Division**	**No. of WUA Formed**		
		UNDER IAMWARM	UNDER WRCP	TO BE FORMED
1	Manimuthar	132	29	-
2	Pambar	31		-
3	Kottakkaraiyar			-
	Total	**163**	**29**	

List of WUAS formed

SI. No.	Name of the sub basin	President -Details			TC Members -Details		
		Total	Elected as on Date	Balance left out	Total	Elected as on Date	Balance left out
1	Manimuthar	Tenure Completed. Election to be conducted					
2	Pambar						
3	Kottakkaraiyar						

Basin Management
(Main Activities and Agencies Responsible)

Activities in Basin	Agency Responsible	Key Functions
Providing drinking water and sanitation facilities	Tamil Nadu water supply and Drainage Borad	Provides rural and urban water supply (except for Chennai city) also meeting the industrial water needs-Execution of sanitation schemes.
Pollution Prevention	Tamil Nadu Pollution Control Board	Monitors the effluents released by industries. Accords permission for starting new industries from the environmental point of view.
Water Resources Management	Water Resources Department/PWD	Planning,Designing and Execution of New Irrigation projects. operation and maintenance of existing Irrigation systems.
Ground water level and quality monitoring	State Ground and Surface Water Resources Data Centre, WRD.	Installation & Maintenance of Observation wells and Piezometers. Collection and Testing of water samples from Observation wells and Piezometers. Construction of Artificial Recharge Structures.

		Observation, Documentation and Supply of Ground Water Data. Accords Ground Water clearance for environmental, Institutional and financial point of view.
Surface water and hydrological data collection.	State Ground and SurfaceWaterResources Data Centre, WRD.	Installation & Maintenance of Rain gauge Station, Climatic Stations, Automatic Weather stations and Gauge discharge station. Observation, Documentation and supply of Rainfall and Hydro meteorological data. Collection and Testing of water samples from rivers at selected locations.
Clearance for new irrigation projects	Revenue Department	Clearance for Irrigation schemes to be sanctioned.

CHAPTER – 11

CONCLUSION AND ACTION PLAN

CHAPTER – 11

CONCLUSION AND ACTION PLAN

11.1 Conclusion

11.1.1 Introduction and Methodology

River basins refer to the hydrological area draining through a system of streams and rivers to the same outlet. Basins are often recognized as the practical unit of water resources management.

The first National Water Policy summarizes the idea of River Basin Planning and Management as, "Water resources development and management will have to be planned for a hydrological unit such as drainage basin as a whole or for a sub-basin, multi-sectorally, taking into account surface and ground water for sustainable use, incorporating quantity and quality aspects as well as environmental considerations".

There are 34 river basins in Tamil Nadu consisting of major, medium and minor basins and they are grouped into 17 major river basins for the purpose of hydrological studies and water resources planning activities. These river basins are subdivided into 127 sub basins.Considering the developments in the river basins, basin studies are to be updated periodically and adopting new methodology and software. Micro level reappraisal studies for Kodaiyar, Vaigai, Vaippar, Vellar, Tamiraparani, Palar, Pennaiyar, Paravanar and Varahanadhi river basins were completed. Now, the micro level reappraisal study of Pambar Kottakkaraiyar basin has been carried out, for which, earlier study was carried out in March 2007.

River basin planning and management is a process of assessing the limited water resource availability in the basin and equitable distribution to meet the competing demands of various sectors.

The general methodology adopted for this reappraisal study includes the data collection, sorting and validation of those data used for the study.

The first report on Pambar Kottakkaraiyar river basin was prepared in this Institute as a Water Resources Assessment of Pambar Kottakkaraiyar River Basin under UNDP (1988)**.** The second report was brought out by Dr. S. Subramaniyan and Dr. R. Kadirvelu on "Crop water requirement and Irrigation Scheduling - A Guide for Tamil Nadu". The third report on “Assessment of Water Resources of Tamil Nadu" was published by the Sub Committee of State Planning Commission during the year 1987.

11.1.2 Description of the Basin

Pambar Kottakkaraiyar river basin is the seventh basin from the Chennai basin based on the geographical location. The basin is delineated into three sub basins viz., Manimuttar, Pambar and Kottakkaraiyar. The total area of the basin is 5926.10 sq.km and the basin is located in between N. Latitude 10° 28’ 30” - 09° 27’ 15” and E. Longitude 78° 05’ 30” - 79° 10’ 30”. Pambar Kottakkaraiyar basin spreads over parts of Dindigul, Madurai, Sivaganga, Pudukottai and Ramanathapuram districts and Sivaganga district covers major part of the basin. The important towns located in the basin are Tirumayam, Devakottai, Karaikkudi, Tiruppattur, Tiruvadanai, Devipattinam, Ilayangudi, Kalayarkovil, Sivaganga, Tiruppalakkudi and Tondi.

There are 23 taluks including 28 blocks cover this basin of which, only 8 blocks are fully covered and the remaining blocks are partly covered; 72 firkas are partially/fully covered in the basin.

The area of this basin is 5,926.10 Sq.km and the sub-basins areas are follows:

Manimuttar: 2,279.60 Sq.km

Pambar: 1,441.58 Sq.km

Kottakkaraiyar: 2,204.91 Sq.km

There are fifteen rivers/streams namely , Palar, TiruManimuttar, Manimuttar, Virisalar, Varshalel Ar, Pambanar, Ten Ar, Kottagudi Ar / Pambar, Koluvanar, Papan Ar, Sarguniyar / Kottakkaraiyar, Nattar and Uppar which drain in this basin. Koluvanar, Papanar, Pambar, Varshalel Ar, Kottakkaraiyar and Uppar rivers confluence with Bay of Bengal. All these rivers are seasonal.

Various branch canals of the Periyar Main Canal and its extension from Vaigai basin enters into this basin near Saruguvalapatti and feeds many tanks in the northern part of the basin. Similarly Lower Vaigai Canal and Nattankal from Vaigai river enters the Kottakkaraiyar sub basin and feeds various tanks including R.S Mangalam tank.

The Pambar Kottakkaraiyar basin geologically divided into two regions as hard and soft rocks by a contact zone traversing in the middle of the basin. Hard rock formations occur in the upper reaches of the basin comprised of Archaean complex suit. In the lower reach of the basin, towards east and south to contact zone, soft rock types makes the prominent lithology. Soft rock is comprised of Upper Gondwana sediments known as Sivagangai formation, Cuddalore formation and recent to sub recent sediments.

In Pambar Kottakkaraiyar river basin, 171 boreholes were taken for hydro geological studies, out of these, 116 were drilled in sedimentary formations and 55 bore wells located in hard crystalline formation.

The study of the landforms constitutes geomorphology. It deals with the morphological characteristics of the earth's surface and its genesis. The study is necessary in many disciplines such as hydrology, groundwater, environmental aspects, natural hazards/ disasters, land use / land cover flood mitigation etc. Geomorphologic maps are extremely useful to planners, scientists and economists.

Land use and land cover study is necessary for planning, development and land management activities of the agricultural sector. Comparison of land use and land cover patterns of the same area in two different periods helps in understanding the variation in utilization and degradation of lands.

The lineaments are controlling the flow pattern of major river courses of this basin. Some of them are probable fault, fractured zones and contact zone of geological formations.

Electrical Resistivity methods are widely used to delineate the subsurface formations including aquifer. This method involves measurement of resistances of different layers of sub surface by sending current into earth through metal electrodes using different methods of electrode configurations.

The development of a particular city, town or a region depends upon natural, physical and socio-economic factors. Among these factors the population assumes significance in determining the future pattern of progress and development.

The population of Pambar Kottakaraiayar as per 2011 Census is **2.315 Million** of which 1.627 Million people live in rural area**,** 0.688 Million people live in urban area. The exponential population growth rate observed for the census period 2001-2011 is 2.14% for rural area and 2.19% for urban area. According to the above growth rate the population is calculated for the year 2018 and the population in **2018** is **2.660 Million of** which **1.870 Million** population in rural area and **0.790 Million** in urban area.

11.1.3 Hydro-meteorological Characteristics

The study of hydrometeorology includes analysis of the space-time properties of climatological parameters such as precipitation, minimum and maximum temperatures and sunshine and their influence on river systems and water bodies.

There are 34 rain gauge stations in and around the basin from which 14 rain gauge stations were selected for detailed analysis based on spatial distribution of rain gauge stations in the basin and the stations having long term records. Rainfall data were acquired from the aforesaid fourteen (14) rain gauge stations for 46 years from 1971 to 2017.

Details of 14 Selected Rain Gauge Stations

S. No.	Name of subbasins	Sub basin area (sq.km.)	Raingauge stations	No. of Raingauge Stations
1	Manimuthar	2,279.60	Pulipatti, Thaniyamangalam, Thondi, Thiruppathur	4
2	Pambar	1,441.58	Aranthagi, Karaikudi (Railway), Theerthandathan, Thirumayam	4
3	Kottakkaraiyar	2,204.91	Dindigul, Ilaiyangudi, Manamadurai, Paramakudi, Sivagangai, Thiruvadanai	6
	Total	**5,926.09**		

Probable Mean Areal rainfall analysis at 25%, 50%, 75% & 90% dependability is determined. The season wise average rainfall for southwest, northeast, winter, summer and also the annual rainfall for all three sub basins have been analysed.

- Annual average rainfall of the Pambar Kottakkaraiyar River Basin at 75% dependability is 869.17 mm.
- In the previous appraisal study of this basin carried out in 2007, the annual average rainfall was reported as 898mm for the period 1971 to 2005.

Though Kunrakudi weather station is situated inside basin and Kamatchipuram weather station lies adjacent to the basin, considering the station having long term records, Kamatchipuram weather station data is taken for analysis.

❖ Hence, it is suggested to collect meteorological data continuously for long period from Kunrakudi weather station which is situated inside basin.

11.1.4 Irrigation and Agriculture

Irrigation means artificial supply of water for agriculture activities. The net irrigated area in Tamilnadu State is **29.12 lakh Ha of which 58.78% of the area sown is benefitted through irrigation.** The total Gross Irrigated area of Pambar Kottakkaraiyar

Basin is **99,845 Ha as per 2016-17 crop area.** The main crops cultivated in this basin are paddy, sugarcane, groundnut, chillies and coconut in addition to fruits and vegetables.

Agricultural lands are getting reduced due to growing urbanization, industrialization and infrastructure development and resulted in decreased agricultural activities. The land holding details of this basin are as detailed below.

- **The total number of land holding : 6,37,884**
- **Marginal farmers (area less than 1 Ha) : 5,29,574 (83.02%)**
- **Small farmers (1 to 2 Ha) : 72,945 (11.44%)**
- **Semi-medium farmers (2 to 4 Ha) : 27,965 (4.38%)**
- **Medium farmers (4 to 5 Ha) : 6,585 (1.03%)**
- **Large farmers (more than 5 Ha) : 815 (0.13%)**

The gross irrigated area in Pambar Kottakkaraiyar Basin is 99,985 Ha of which about 77% is under paddy cultivation, 10% is under coconut cultivation, 4% under fruits and vegetables and in the remaining area sugarcane groundnut, pulses and millets are cultivated.

- **Net Irrigation demand of this basin at 75% dependable rainfall and without considering losses is 843.87 Mcum.**

Whilst comparing the cultivated area reported in the previous micro level study prepared in 2007 with this present study, it is found that the total irrigated area has decreased from 1,26,953 Ha to 99,985 Ha.

By adopting modern water saving cultivation techniques water that could be saved in Pambar Kottakkaraiyar Basin basin is as stated below:

Sl. No.	Crop	Modern water saving cultivation techniques	Cultivating area (Ha)	Water requirement in conventional method (Mcum)	% of water saving	Water Saving in (Mcum)
1	Paddy	SRI*	77,868	646.71	40.00	258.69
2	Sugarcane	SSI	2,604	31.21	40.00	12.48
3	Coconut	Coir pith as soil mulch	10,813	99.83	63.00	62.89
4	Groundnut		1,265	5.70	49.40	2.81
5	Vegetables		4,349	44.07	29.00	12.78
					Total	**349.66**

*This technique is considered for future net irrigation demand calculation in lower limit scenario.

- ❖ By adopting water saving techniques in agriculture, approximately 33% of irrigation water can be saved.

  In general,

  - ✓ Crop production can be increased when unirrigated area of this basin is brought under irrigation.
  - ✓ Extraction of ground water can be minimized.
  - ✓ Frequency / Intensity of Irrigation can be improved from prevailing intensity of 1.

- ❖ During poor rainfall years, suitable cropping pattern may be adopted with crops that require lesser irrigation like Cotton, Maize, Sorghum, Pulses, etc.

11.1.5 Surface Water Resources and Irrigation System

Pambar Kottakkaraiyar basin is drained by three major rivers namely, Manimuttar, Pambar and Kottakkaraiyar and accordingly divided into three sub basins.

Surface runoff is the response of a catchment to precipitation reflecting the integrated effects of a wide range of parameters like orientation and shape of the catchment, climate and intensity of precipitation, duration, the direction of storm, slope, soil, land use, etc.

The basin is generally dominated by tanks and eventually surface water is drawn from tanks. There is no reservoir in this basin. Most of the channels are surplus courses of tanks or supply channels. This basin has about 1922 tanks and 83 anicuts.

The Rajasingamangalam tank of this basin is one of the biggest tanks in Tamil Nadu. Its bund is 20.8 Km long and has two large masonry weirs on either flanks to surplus the flood flows.

Details of Tanks

Sl.No.	Name of the Sub Basin	System Tanks			Non System tanks		
		Number	Capacity in Mcum	Ayacut in Ha	Number	Capacity in Mcum	Ayacut in Ha
1	Manimuthar	486	28.01	8223.4	478	151.84	18620.51
2	Pambar	-	-	-	452	183.47	24551.99
3	Kottakkaraiyar	289	93.02	9844.14	217	107.08	13940.29
Total		**775**	**121.03**	**18067.54**	**1147**	**442.39**	**57112.79**

National Water Development Agency in the interlinking of rivers programme has proposed interlinking of Godavari-Krishna-Pennar-Cauvery-Vaigai-Gundar rivers. The Cauvery Gundar link passes through Pambar Kottakkaraiyar basin. By this proposal, the basin will get benefitted.

In Pambar Kottakkariayar river basin, surface water quality monitoring network is sparse. The SG&SWRDC of WRD is monitoring the surface water quality in Rajasingamangalam and Thiruvadanai tanks only and the CWC surface water quality monitoring location is not falling within the basin. Hence the surface water samples were collected from 9 tanks by traversing across the basin.

The water samples were analyzed in the Geochemical Laboratory of SG&SWRDC, located at Madurai and found that the TDS value ranges from 104 mg / l to 289 mg / l which is within the permissible limit. Therefore, the water can be used for drinking and other domestic purposes.

The important parameters for judging the degree of suitability of water for irrigation are Electrical Conductivity (EC), Sodium Adsorption Ratio (SAR) and Residual Sodium Carbonate (RSC). Tests were conducted for the above parameters and were observed that the values of the parameters are within permissible limit. Hence, surface water is safe for irrigation.

Tank irrigation is one of the ancient irrigation systems in India, has a glorious history of extremely well organised governance and execution of all critical functions of water management such as maintenance, water sharing and arbitrating the conflicts that arise among users from time to time. This basin is predominantly irrigated by tanks throughout the year. At present the overall efficiency of tank irrigation system is low.

The Surface Water Potential estimated at 75% dependability rainfall by the following methods:

1. **Rainfall – Run-off Co-efficient Method : 631.29 Mcum**
2. **MRS Model : 599.36 Mcum**
3. **NWDA Approach : 682.09 Mcum**

In this basin, there is an inter basin transfer of water from Vaigai basin through two main canals, 1.Periyar main canal and its extensions and 2. Vaigai main canal. The total quantum of water contribution from Vaigai basin into this basin is 173.40 Mcum.

The Surface Water Potential has decreased from 648 Mcum during the year 2004-05 to 599.36 Mcum during the year 2016-17.

In order to manage the surface water potential effectively the following suggestions are advocated.

1. Improving the performance of the existing irrigation system by suitable structural measures.
2. Lining of canals to improve the efficiency by reducing conveyance loss of water.
3. Renovating old tanks and ponds, de-silting of supply channels and constructing water harvest structures to improve irrigation potential.
4. Equitable distribution of irrigation water by better water management.
5. Conjunctive use of surface and ground water wherever possible.
6. Planning for effective rainwater harvesting and diverting surface water, that surpluses into the sea during the flood times.
7. Desilting of tanks in order to restore its original capacity.

11.1.6 Groundwater Resources and Water Quality

Groundwater and surface water are the two water resources of a country, but both are dependent on rainfall. For long term planning, development and management of Water Resources, a systematic and scientific assessment of groundwater resources is quite essential.

The dynamic groundwater resource of Tamilnadu was assessed at Block level which is a macro unit when compared to Firkas upto 2009. After **2011,** the assessment is being done at **micro unit of Firka** level**.**

Pambar Kottakkaraiyar basin encompasses 72 Firkas either fully or partially falling in the basin and the categorization summary is as stated below:

Sl.No	Category	2013 Assessment
1	Safe	57
2	Semi Critical	7
3	Critical	1
4	Over Exploited	3
5	Saline	4

As per the latest assessment, ie as on **31st March 2013,** the data on **Dynamic Ground Water Resources of Tamilnadu** is as stated below:

- **Total annual replenishable Groundwater Resources : 20.65 BCM**
- **Net annual Ground Water availability : 18.59 BCM.**
- **Annual Groundwater draft (extraction) for all uses : 14.36 BCM.**
- **The stage of Groundwater Development : 77 %.**

Groundwater extracted from shallow aquifer is being assessed. The Geologists & Engineers have used complicated data to find reliable and representative values of the hydraulic characteristics of aquifers.

In Pambar Kottakkaraiyar basin an inventory of about 67 observation wells spread over entire Pambar Kottakkaraiyar basin has been analyzed based on the availability of data, period ranging from four (4) years to forty five (45) years.

Groundwater system is dynamic and adjusts continuously to short-term and long-term changes in climate, groundwater withdrawal, and land use pattern. Water level measurements from observation wells are the principal source of information about the hydrologic stresses acting on aquifers and how these stresses affect groundwater recharge, storage, and discharge.

Hydrographs of groundwater level of the 67 observation wells have been prepared. The linear trend lines drawn in the Hydrograph of observation wells were used to interpret the long-term trend in water level fluctuation.

High rise in groundwater level (more than 3.00m) found in 2 wells and high depletion in groundwater level (more than 3.00m) found in 22 wells.

- Net annual groundwater availability is **1,129.93 Mcum,**
- Total groundwater extraction for all sectoral demands is **236.51 Mcum** which is **20.93%** in net groundwater availability.
- Groundwater extraction for irrigation alone in the basin is **217.75 Mcum.**
- Balance groundwater available for further development is **893.72 Mcum**.

In previous Micro Level study prepared in 2007, the 2003 Groundwater assessment data was adopted and in this Reappraisal study, 2013 Groundwater assessment data is adopted. The comparison between 2003 and 2013 data is as below.

Net Annual Groundwater Availability (MCM)		Gross Annual Groundwater Extraction (MCM)		Balance Annual Groundwater Availability (MCM		Stage of Development (%)	
2003	**2013**	**2003**	**2013**	**2003**	**2013**	**2003**	**2013**
944.63	**1,129.93**	**127.13**	**236.51**	**819.17**	**893.72**	**13.46**	**20.93**
Increased: 19.62%		**Increased: 86.03%**		**Increased: 9.10%**			

In recent years, the increasing threat to groundwater quality due to human activities has become a matter of great concern. Geochemical analysis results of 101 observation wells, including the wells located adjacent to the basin boundary, were collected from SG & SWRDC and the ground water quality has been assessed spatially for the pre-monsoon period of the year 2017.

Parameters such as Electrical Conductivity, pH, calcium, magnesium, sodium, potassium, bicarbonate, carbonate, sulphate, chloride, nitrate, fluoride, total dissolved solids, total hardness etc., were considered as important water quality parameters for determining the Water Quality Index. The status of Water Quality Index of 101 samples is as listed below.

Sl. No.	Water Quality Index	No of samples	Status	Possible usages
1	0 – 25	13	Excellent	Drinking, Irrigation & Industrial
2	25 - 50	26	Good	Domestic, Irrigation & Industrial
3	51 – 75	26	Fair	Irrigation & Industrial
4	76 - 100	22	Poor	Irrigation
5	101 – 150	14	Very poor	Restricted use for irrigation
6	>150	Nil	Unfit	Proper treatment required

The groundwater quality in Pambar Kottakkaraiyar basin is generally “good to fair”. In 36% of the locations, it is found to be poor.

The groundwater crisis prevailing in the basin and in the entire State is not only due to natural factors, but also due to human interventions. Constructing Artificial Recharge Structures like check dams, percolation ponds, recharge pits, shafts or wells where soil condition is favourable are considered to be the best option in rural areas for recharging groundwater to improve its quality and quantity.

In general the Ground water status in Pambar Kottakkaraiyar Basin can be summarized as below.

- ❖ Long-term water level rise found in 17 observation wells and high rise in water level (more than 3.00m) found in 2 wells.
- ❖ Long-term water level depletion found in 50 observation wells and high depletion in water level (more than 3.00m) found in 22 wells.
- ❖ Seventeen artificial recharge structures (15 Check Dams and 2 Anicuts) were constructed in Manimuthar Sub-basin in the last ten years.
- ❖ Annually groundwater extracted for irrigation in Pambar Kottakkaraiyar basin is **217.75**MCM which is 92.07% of the total annual groundwater extraction of **236.51**MCM for all sectoral demands.
- ❖ Recharging of aquifers by rain water will help in improving the quality of existing groundwater through dilution of certain physico chemical contents.
- ❖ Groundwater extraction in Pambar Kottakkaraiyar basin for irrigation is 92% whereas the total ground water extraction for all demands in Tamilnadu is 77%. Hence, it is imperative to focus special attention on irrigation sector to reduce the groundwater extraction through modern irrigation method like drip and sprinkler irrigation and latest cultivation practices like System of Rice Intensification (SRI) in large scale.
- ❖ Favourable locations have been identified to construct construct Artificial Recharge Structures of 24 Vertical Shafts and 10 Check Dams in the basin to augument the groundwater.

11.1.7 Present Future Water Demand

The major sectors that are considered in water demand study are domestic, irrigation, livestock and industry.

The domestic demand is of primary importance and depends on the population.The Central Public Health and Environmental Engineering Organization (CPHEEO) recommended norms for per capita water demand in the domestic sector is as stated below.

Sl. No	Classification of towns/cities	Recommended maximum water supply levels (lpcd)
1	Towns provided with piped water supply but without sewerage system	70
2	Cities provided with piped water supply where sewerage system is existing/contemplated	135
3	Metropolitan and Mega cities provided with piped water supply where sewerage system is existing/contemplated	150

An additional 15% should be included above the norms in each classification to meet "Unaccounted for Water (UFW)"

The annual growth rate adopted in this basin for estimation of population growth from 2011 census is as given below:-

Sector	**Annual Growth rates**
Urban	2.19% per year
Rural	2.14% per year

The domestic water demand for the year 2018 and the target years 2020, 2030, 2040 & 2050 are computed as **100.050Mcum, 119.570Mcum, 174.200Mucm, 309.350Mcum & 669.652Mcum** respectively.

The domestic water requirement may increase in future due to increase in population, development in living standards of the people etc.

Irrigation water demand at 75% dependable rainfall in Pambar Kottakkaraiyar basin is **843.87 MCum** and this quantity is maintained for the target years 2020, 2030, 2040 & 2050 without increasing the demand.

There are 33 large & medium industries and 596 small scale industries in Pambar Kottakkaraiyar basin and its demand is calculated as **1.361 MCum and 1.101 MCum** respectively. The total industrial water demand is **2.462 Mcum**. The future water demand is forecasted at 8% annual increase as per the Annual Survey of Industries.

As per 19th livestock census 2012, the livestock strength in Pambar Kottakkaraiyar basin is **77,37,376** . Maintaining these values for the current year its current water demand is **94.411 MCum.**

The total water demand of all sectors in Pambar & Kottakkaraiyar basin for the year 2018 is 1040.79 MCum.

According to previous micro level appraisal study report prepared in 2007, the total water demand was 1335.817 MCum and comparing 2018 water demand of 1040.79 Mcum, the water demand is reduced by 22.08% within 11 years. This is attributed to the decrease in industries and irrigation demand due to reduction in cultivable area.

11.1.8 Water Balance Study

The main aim of water resources planning in each river basin is to find out whether the availability of water in the basin is enough to meet out the demand. If the availability of water is less than the requirements, then suitable measures are to be taken for effective utilization.

Different planning scenarios for Pambar and Kottakkaraiyar river basin are considered:

1. Exisiting Scenario
2. Improved Agricultural Methods
3. Improved Efficiency.

In the Existing Scenario, the assessed quantity of surface water and groundwater potential are taken and the demands as computed in chapter 5 are considered. To account for the losses due to conveyance, a factor of 1.67 is used with irrigation demand.

The Improved Agricultural Methods scenario is based on the identification of changes in the present cropping or cultivation pattern, which would result in, some reasonable lower limit for the future demand of irrigation water in the basin.

The Improved Efficiency scenario represents an irrigation system with an improved efficiency where the existing system is rehabilitated and modernized canals are lined to improve the efficiency of the system by reducing the losses.

The present water potential of Pambar Kottakaraiayar Basin:

- Surface water potential – 599.36 Mcum (At 75% dependability rainfall)
- Surface water potential from inter basin transfer – 173.40 Mcum
- Surface water potential assessed from Return flow – 363.86 Mcum
- Ground water availability – 1,129.93 Mcum
- **Total Potential – 2,266.55 Mcum**

Total sectoral water demand in Pambar Kottakaraiayar river basin at 75% dependability for the current year is

- Domestic – 100.05 Mcum
- Irrigation (including the losses) – 1,409.26 Mcum
- Livestock – 94.41 Mcum
- Industrial – 2.46 Mcum
- Ecological – 3.00 Mcum
- **Total Damand – 1,609.18 Mcum**

Water Balance

- Water Potential for the year 2018 – **2,266.55 Mcum**
- Water demand for the year 2017 – **1,609.18 Mcum**
- Balance – **657.37 Mcum**

11.1.9 Environmental Aspects

Environment means "surrounding" which includes biotic factors like human beings, plants, animals, microbes in addition to inorganic factors. It is a complex aspect with many variables, that surrounds man as well as the living organisms.

Environmental pollution is one of the most serious problems faced by humanity and other life forms on our planet today. The major sources of pollution are Industries, Domestic and Agriculture.

Industries are classified into three categories with respect to the pollution level. Highly polluting industries are categorized as Red, medium polluting industries are categorized as Orange and less polluting industries are categorized as Green.

There are 33 large & medium industries and 596 small scale industries in this basin and the waste water generated from the industries is as stated below.

- ✓ Waste water from Large & Medium Scale Industries : 1.089 MCum per year
- ✓ Waste water from Small Scale Industries : 0.880 MCum per year
- ✓ **Total Industrial waste water :1.969 MCum per year**

Domestic pollution is mainly caused by sewage. The generation of sewage in Pambar Kottakkaraiyar is assumed as 80% of water demand and accordingly the quantity of sewage generated is **37.032 Mcum per year.**

Sewage treatment involves physical, chemical and biological processes to remove physical, chemical and biological contaminants.

Agricultural pollution refers to biotic and a-biotic byproducts of farming practices that result in contamination or degradation of environment and surrounding ecosystems, and/or cause injury to humans and their economic developments. Pesticides & fertilizers are main source causing agriculture pollution and the consumption in this basin is as given below.

- ➢ Consumption of fertilizers in Pudukottai, Ramanathapuram and Sivagangai districts from 2007-08 to 2016-17: Total NPK - 5,90,796 MT
- ➢ Consumption of pesticides in Pudukottai, Ramanathapuram and Sivagangai districts from 2007-08 to 2016-17: Liquid- 7,96,463 Litre, Dust /Solid- 3,05,474 kg

Water weeds are unwanted and undesirable vegetation that are adapted to grow and reproduce under aquatic conditions and that are one of the major threats to the natural environment. In Pambar Kottakkaraiyar basin, most of the tanks are predominantly covered with Prosopis Juliflora (an invasion weed).

The sea water intrusion occurs in two modes i.e. direct and indirect. There are 12 sea water intrusion study wells located in the basin. Water quality parameters such as Chloride and Total Dissolved Solids are analyzed for sea water intrusion study. The chloride concentration in most of the study area is moderate to high. The TDS value is above 2000 mg/l in most of the study area which is poor in quality.

In Pambar Kottakkaraiyar basin, diseases like Malaria, Dengue, Chickungunya, Leptospirosis, Acute Diarrohea Jaundice are prevalent public health issues but the number of cases are reducing from the year 2007 to 2017.

Solid waste is the unwanted or useless solid materials generated from combined residential, industrial and commercial activities. Solid waste management is the process of storage, collection, transportation and recycling, disposal and monitoring of solid waste in a systematic, economic and hygienic manner.

In Devakottai municipality, the total solid waste generated per day is 16 tonne and out of which 15 tonne is cleared every day. There is no specific compost yard in this municipality.

In Karaikudi municipality, door to door collection of garbage is effectively implemented in all the 36 wards of the town by adequate tri-cycles and push carts.

Sivaganga town generates 25 tonne of solid waste per day and out of this nearly 22.50 tonne is being collected, transported and disposed off daily.

In recent times tourism is rapidly growing. With more tourists travelling throughout Tamilnadu has an impact in environment. Some of the prominent tourist place in this basis are Karpaga Vinayagar Temple at Pillayarpatti, Vettangudi Bird Sanctuary near Thirupathur, and the Chettinad houses which are most lavish and exquisite examples of architectural beauty in Karaikudi, Pallathur, Athangudi and Kothamangalam.

Some of the most important general mitigation measures that can be adopted to reduce the environmental degradation in this basin are given below:

1. Agglomeration of industries shall be encouraged so that the by-product or waste of one industry may be a raw material for some other industries, which will lead to reduction of natural water requirements.
2. Treated Effluents should be used in Industries for cooling process. The treated waste water of one industry may be used as input for cooling tower of other industries like Thermal plant, Pharmaceutical, petro chemical, Refineries, Fertilizer industries, and so on, so that the fresh water requirement for those industries getting reduced.
3. Usage of Bio pesticides and fungicides to control the pests and diseases will also minimize the pollution.
4. Mechanical methods such as stick racking, chain pulling, bulldozer pushing and blade ploughing can be used for eradication of Prosopis juliflora.
5. Organizing Environmental awareness campaign.
6. Waste minimization which includes reducing waste at source, reusing materials and recycling waste materials (3R).

7. Proper waste disposal methods such as sanitary landfill, incineration, composting and pyrolysis.
8. Integrated Solid Waste Management can be adopted to mitigate the effects of solid waste.

11.1.10 Present Institutional Setup

Water Resources Department of PWD is the apex organization of the Government of Tamilnadu. in overall management of Water Resources in Tamilnadu State with the technical guidelines from Central Water Commission, and support from Central Groundwater Board functioning under Ministry of Water Resources, New Delhi. The other departments, Agriculture Department, Agricultural Engineering Department, Statistics and Economics Department, Tamil Nadu Water Supply and Drainage Board, Forest Department, Tamil Nadu Pollution Control Board, Industries & Commerce Department, Animal Husbandry & Veterinary Sciences Department, Public Health & Preventive Medicines Department, Census Operation Department, Fisheries Department and Tamil Nadu Generation and Distribution Corporation are the line departments connected with water resources and data were obtained from those departments for Pambar Kottakkaraiyar Basin Micro Level Reappraisal Study.

Government of Tamilnadu has constituted the Water Utilization Committee and the Technical Sub-Committee to Water Utilization Committee to take decision on the proposals seeking permission for drawl of surface/groundwater by various Boards, institutions and organizations.

Participatory Irrigation Management (PIM) system aims to improve farmers' (water users) involvement in management and operation of irrigation system and Water Users Association (WUA) are formed in each project to manage and operate irrigation system of that particular project. In Pambar Kottakataiyar basin 192 WUAs were formed till date.

11.2 Strategic Objectives and Action Plan

- **Strategic Objective 1: Installation of Weather Station**

Sl. No	Issues	Strategies Recommended	Action to be Taken by
1.1	Only one Weather station is functioning in this basin and that too long term data are not available. The hydro-meteorological data from the adjacent basin is adopted for analysis which will not produce desired accuracy in the result.	Suggested to install few Weather stations in this basin and record data continuously throughout the year without break.	**The Chief Engineer, SG&SWRDC, Chennai**

- **Strategic Objective 2: Weather Station Data Collection at Regular Interval**

Sl. No	Issues	Strategies Recommended	Action to be Taken by
2.1	No Gauging arrangement is installed in this basin; hence surplus water let into the sea could not be measured.	Install Gauging arrangement in Thiruppunavasal Anicut which is last anicut across Pambar to measure the surplus water let into sea and eventually take necessary action to control the surplus water let into the sea and suitable utilization of the surplus water could be formulated.	**The Chief Engineer, Madurai Region, WRD, Madurai.**

- **Strategic Objective 3: Sustainability of Environment**

Sl. No	Issues	Strategies Recommended	Action to be Taken by
3.1	Use of chemical pesticides is on the increase from 2010 to 2018	Suggested to use bio-pesticides and fungicides to control the pests and diseases instead of using chemical pesticide in order to minimize the environmental pollution.	**Agriculture Department**
3.2	No Sewage Treatment Plant (STP) is available in urban areas in this basin except one STP is under construction in Sivaganga town.	Suggested to construct more STP in urban areas to in order to control the land pollution contaminated by raw sewage.	**TWAD Board, Chennai and the concerned municipalities.**

Even though **Pambar Kottakkaraiyar Basin is not a deficit basin** considering the availability of Groundwater also for sustained development of the basin, the aforesaid suggested action plans have to be implemented without any lapse by **Water Resources Department** in co-ordination with **Tamil Nadu Water Supply and Drainage Board** and **Agriculture Department.**

WATER IS BECOMING MORE AND MORE SCARCE COMMODITY DAY BY DAY, THEREFORE EFFICIENT USE OF SINGLE DROP OF WATER IS MANDATORY IN THE PRESENT SITUATION.

Chief Engineer & Director, WRD
Institute for Water Studies,
Hydrology & Quality Control,
Chenni-113

PAMBAR KOTTAKKARAIYAR RIVER BASIN ACTION PLAN MAP

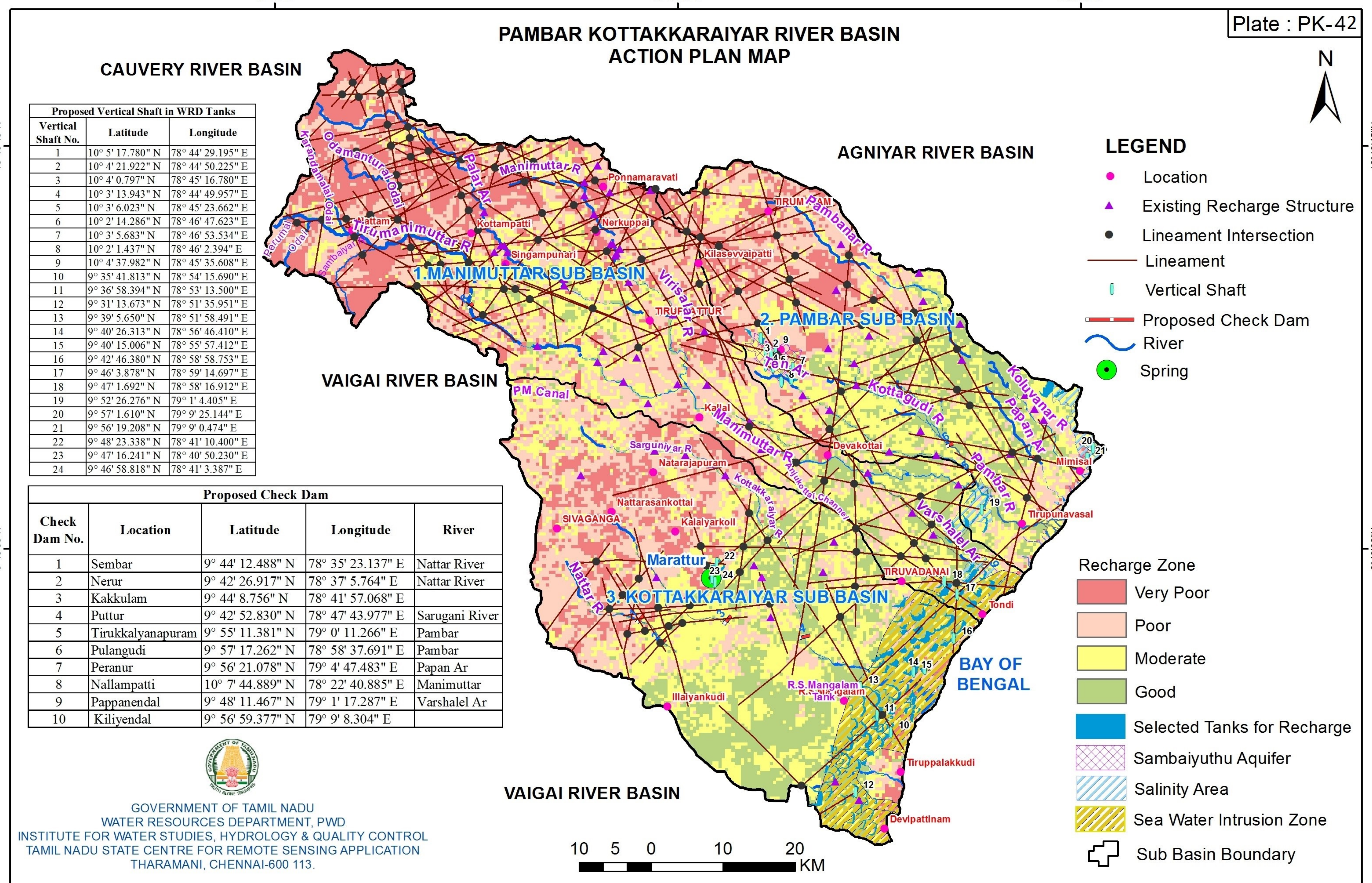
Plate : PK-42

Proposed Vertical Shaft in WRD Tanks

Vertical Shaft No.	Latitude	Longitude
1	10° 5' 17.780" N	78° 44' 29.195" E
2	10° 4' 21.922" N	78° 44' 50.225" E
3	10° 4' 0.797" N	78° 45' 16.780" E
4	10° 3' 13.943" N	78° 44' 49.957" E
5	10° 3' 6.023" N	78° 45' 23.662" E
6	10° 2' 14.286" N	78° 46' 47.623" E
7	10° 3' 5.683" N	78° 46' 53.534" E
8	10° 2' 1.437" N	78° 46' 2.394" E
9	10° 4' 37.982" N	78° 45' 35.608" E
10	9° 35' 41.813" N	78° 54' 15.690" E
11	9° 36' 58.394" N	78° 53' 13.500" E
12	9° 31' 13.673" N	78° 51' 35.951" E
13	9° 39' 5.650" N	78° 51' 58.491" E
14	9° 40' 26.313" N	78° 56' 46.410" E
15	9° 40' 15.006" N	78° 55' 57.412" E
16	9° 42' 46.380" N	78° 58' 58.753" E
17	9° 46' 3.878" N	78° 59' 14.697" E
18	9° 47' 1.692" N	78° 58' 16.912" E
19	9° 52' 26.276" N	79° 1' 4.405" E
20	9° 57' 1.610" N	79° 9' 25.144" E
21	9° 56' 19.208" N	79° 9' 0.474" E
22	9° 48' 23.338" N	78° 41' 10.400" E
23	9° 47' 16.241" N	78° 40' 50.230" E
24	9° 46' 58.818" N	78° 41' 3.387" E

Proposed Check Dam

Check Dam No.	Location	Latitude	Longitude	River
1	Sembar	9° 44' 12.488" N	78° 35' 23.137" E	Nattar River
2	Nerur	9° 42' 26.917" N	78° 37' 5.764" E	Nattar River
3	Kakkulam	9° 44' 8.756" N	78° 41' 57.068" E	
4	Puttur	9° 42' 52.830" N	78° 47' 43.977" E	Sarugani River
5	Tirukkalyanapuram	9° 55' 11.381" N	79° 0' 11.266" E	Pambar
6	Pulangudi	9° 57' 17.262" N	78° 58' 37.691" E	Pambar
7	Peranur	9° 56' 21.078" N	79° 4' 47.483" E	Papan Ar
8	Nallampatti	10° 7' 44.889" N	78° 22' 40.885" E	Manimuttar
9	Pappanendal	9° 48' 11.467" N	79° 1' 17.287" E	Varshalel Ar
10	Kiliyendal	9° 56' 59.377" N	79° 9' 8.304" E	



GOVERNMENT OF TAMIL NADU
WATER RESOURCES DEPARTMENT, PWD
INSTITUTE FOR WATER STUDIES, HYDROLOGY & QUALITY CONTROL
TAMIL NADU STATE CENTRE FOR REMOTE SENSING APPLICATION
THARAMANI, CHENNAI-600 113.

Mangrove at S.P.Pattinam coast, Pambar Sub Basin

Salt Pan at Pudupattinam, Pambar Sub Basin

Pambar River, Pambar Sub Basin

Thondi Port, Pambar Sub Basin

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