CHAPTER – 1

INTRODUCTION AND METHODOLOGY

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INTRODUCTION AND METHODOLOGY

1.1 BACKGROUND AND PURPOSE OF THE STUDY

There are 34 river basins in Tamilnadu. For the purpose of taking up micro level hydrological studies and water resources planning activities, the 34 river basins are grouped into 17 major river basins. Nambiyar river basin is one among them. This report deals with scientific assessment of Water Resources in the river basin (Surface & Groundwater) using the latest technology like Remote Sensing and GIS techniques available, for computing the sectoral demands for various sectors like domestic, agriculture, industries, livestock, power generation, environment and other uses and future planning of water resources in the state for the benefit of the society.

1.2. RIVER BASIN AS A NATURAL PLANNING UNIT

River basins are inherently complex systems comprising of many interdependent components. Development activities have to be given full consideration to the regional, social, environmental and economic implications. Integrated planning approach covers wide range of matters, including water quantity and quality, environmental considerations. Hence there is an urgent need to adopt a strategy towards a river basinwise approach to tackle the issues.

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 optimise 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. FOCUS ON RIVER BASIN PLANNING AND REGIONAL PLANNING

The development of water resources in a river basin is not a goal by itself, but a means to reach the socio-economic objectives of production, income, employment and quality of life. Therefore, water resources development should be considered in the wider context of regional planning. Regional planning integrates all resources and considers and includes economic and social sectors. The emphasis of regional planning is on the spatial distribution of population and resources. The key question is whether "to bring the resources to the people" or "people to the resources." This entails studies of local potentials and constraints, population growth and density, the settlement hierarchy, the service functions of towns for the rural area, transportation and communication network. From here, policies, strategies and projects will be evolved for an optimal use of natural resources for the benefit of the society.

1.4. BASIN – SPECIFIC DATA

Water Resources planning is people oriented and resource based. Data relating to rainfall, geology, soil, geomorphology, hydrogeology, hydrology, climatology, water quality, environment, socio-economic, health, agricultural, population, livestock, industries, etc. are to be collected for analysis. For the sake of consistency, other types of data should be treated in the same way. Socio-economic, agricultural and livestock statistics are collected and presented on the basis of administrative units, which generally, do not coincide with river basin boundaries. To obtain basin-specific socio-economic data, one has to re-group data of administrative units into river basins. For administrative units situated in two or more river basins, the value of the variables will be split between those basins in proportion to the area contained in the respective river basins.

1.5. OVERALL CONSISTENCY

Regrouping of data according to river basins is to be done consistently and systematically in order to strike consistency between basin and the entire State. Many issues related to water demand could better be dealt for the whole State by dividing it

into a number of basins. This would be better, to ensure consistency, more efficient in data collection and analysis and it would avoid unnecessary repetition.

1.6. RESOURCE BASED PLANNING, CARRYING CAPACITY AND SELF SUFFICIENCY

Water plays an important role in development of a society. Water Resources planning follows a resource based approach to development especially for attaining self-sufficiency in food production. The rationale of resource based planning is the assumption that economic developments depend on the natural resources available in the region as these are assumed to provide the main income opportunities for the population of that region.

A resource based plan calculates the maximum population that can be supported given the production technologies used and standards set for income or food consumption. In this view, the carrying capacity determines the limits of growth.

The concept of carrying capacity suggests that the region is a closed system for transfer of resources (water) without links to other systems, such as trade and migration. Consequently the region has to be self sufficient in all respects.

Natural resources are assets but not the decisive factor for the economic growth. Equally important are adequate infrastructure, well functioning markets, education, efficient Government Institutions, private sector developments, political stability and sound economic policies. Growth can be achieved by exploiting comparative advantages through trade.

In this aspect, a complete assessment of possible inter-basin linkages is only possible when all basin plans are ready and can be put together in a state frame work water resources plan. Until then each basin can be treated as a closed system.

1.7. MATCHING WATER SUPPLY AND WATER DEMAND

Considering the river basin as a unit, assessment of water resources, water demand and water balance of the basin are prepared. This water balance for the basin indicates the level of utilisation of water resources for various sectoral demands and finally shows whether the basin is surplus or deficit. The assessment of water demand is according to accepted development scenarios in all sectors, norms specified for per

capita utilisation, the rate of growth of population and its standard of living, and of all production sectors, agriculture as well as industries. In this respect there is scope to make use of the decision- support systems like optimization models, and simulation models for judicious planning of the scarce water resources in the state. These models include also priority rules by sectors as prescribed in the National and State Water Policies. These models also include the inter-basin and intra basin transfer capacities from source to users, basinwise and local unmet demands and unused water are thus defined as problems to be solved in the planning process.

Agriculture sustains life and irrigation sustains agriculture. Productivity is the index for the development of the State and Nation. Hence any water conservation and management in the agriculture sector, which consumes less than 85% of the water resource will lead to appreciable savings in water which can be allocated to other sectors.

1.8 ADDITIONAL PROBLEM AREAS

In addition to mismatch problems between demands and resources also other important problems that hamper the safe water supply are considered. The important problems are water logging, salinity, pollution, environmental degradation, inefficient use of water underutilisation of resources, seawater intrusion in coastal regions, natural calamities like floods and droughts, etc and health related problems. These problems are locally assessed and possible solutions are evaluated in the planning process for decision making at higher levels.

1.9 STRATEGIC PLANNING

The State Water Plan (SWP) can be formulated following the identification in each basin of: (i) problems and issues of strategic importance to the State and (ii) options for their solution. SWP can however be finalized only at State level. The study on river basin level can lead this planning process.

Based on socio-economic and environmental criteria, the best option to solve a problem is on a river basin level. Prioritisation of the issues and project plans and their classification into short, medium and long term action plans should be done on a state level, taking into account the goals and objectives of the state and considering the

limited resources. The constraining resources to be considered are: Public budgets, private investments, performance capacity, expertise insistence facilities and know-how. Goals and objectives consider the sustainable livelihoods of people, growth and equity, reduced vulnerability of water users, protection and conservation of water.

1.10 ECONOMIC ANALYSIS AND PRIORITISATION

The economic analysis carried out for the prioritization of the development plan is focused on estimating the Net Benefit (NB) to investment ratio. This factor, if positive means that a project is economically feasible. This value also indicates a descending ranking order for prioritization. This reflects the objective of receiving maximum economic returns for public investments.

The benefits in the Net Benefit estimate reflect the economic value of using the water for irrigation. For projects evaluation it is assumed that there will be a gradual transition of agro-technology and efficiency from the present level to a future improved and upgraded level.

For projects which are not related (directly or indirectly) to the increase of agricultural product value, the benefits are in the domain of increasing other human well being services (drinking water, public health) or enhancing environmental sustainability.

All the projects proposed for solving the strategic problems were economically evaluated by the same method, by estimating the projects' cost and benefit cash flows and calculating their net present value (NPV), using a common discount rate.

Prioritisation of projects is carried out by considering other criteria also in addition to the leading Irrigation Net Benefit to investment ratio criterion. These are: contribution to domestic and industrial water supply, level of exploitation of the water resource, level of pollution and quality degradation and the need for water (such as fraction of area under rainfed cultivation).

The prioritization process with these criteria is programmed to obtain an action plan phased over time.

1.11 FEEDBACK BETWEEN RIVER BASIN PLANS AND THE STATE WATER PLAN

The main results of the river basin plan to be included in the state water plan are: (1) Inventory of development plans and attributes of the plans which are relevant to their prioritisation; (2) institutional and legal deficiencies revealed in the basin with their proposed modifications. The feedback is schematically presented in Fig. A.

1.12 UPDATES AND REVISIONS

The planning process is considered as a continuous effort. The present report is a snap-shot of the state-of-the-art for the year 2006. The planning process as demonstrated in this report is based on tools and database such as GIS and simulation, which have to be continuously updated. According to variations in results for the future-planning horizon, the recommended "Action Plan" will have to be revised and updated. The various models and data base used have been revised accordingly for an adjustable scientific assessment of water resources and of sectoral water demands at present and for the future, under different socio-economic development scenarios.

The process of the present planning study which is proposed for its updating is presented concisely in Fig.B.

1.13 PRESENT REPORT

There are 34 river basins in Tamilnadu including minor river basins. For the purpose of hydrological studies and, water resources planning activities, the adjacent minor basins have been grouped together into 17 major river basins. Of the total 17 major river basins, three river basins were selected under 'water planning' by the "Twinning consultancy program". The reports of the three river basins viz. Palar, Vaippar and Kodaiyar illustrate a joint effort by the Institute for Water Studies and the management consultancy and technical assistance team of M/s. Tahal, Isreal. These reports will serve as a model to be followed by the Institute for Water Studies for the preparation of report on other river basins in Tamil Nadu. In this way the Institute for Water Studies has prepared the reports for Vaigai, Tamiraparani, Ponnaiyar, Gundar, Varahanadhi, Vellar and Kallar river basins.

At present the Nambiyar river basin micro level water planning study has been commenced on 1st January 2006. The following are the earlier studies that had been carried out in Nambiyar river basin:

1. Water Resources Assessment and Management strategies for Nambiyar basin-prepared by Institute for Water Studies-1989.
2. World Bank aided Water Resources and Management Studies (WRMS) project –phase II, the basin was studied in details and report submitted to the Government of Tamil Nadu in the year 1994 –1995.
3. State Frame Work Water resources plan-Nambiyar river basin by Institute for Water Studies-1999.
4. Rehabilitation Action Plan for project affected persons of Nambiyar Reservoir scheme by operation Research Group –Madras -1995.
5. Micro level Environmental Status Report for Nambiyar River Basin. Including Hanumanadhi and Karamaniar by St.Xavier College-Palayamkottai, 2005.

The present report is the state-of-art for the year 2006, and the planning process demonstrated in this report is based on tools and database such as GIS and simulation models, which have to be continuously updated. Accordingly the variation in results for the future planning horizons, the recommended action plan will also be revised and updated periodically.

FIG. A. FLOWCHART OF WATER PLANNING – STATE AND RIVER BASIN PLANS

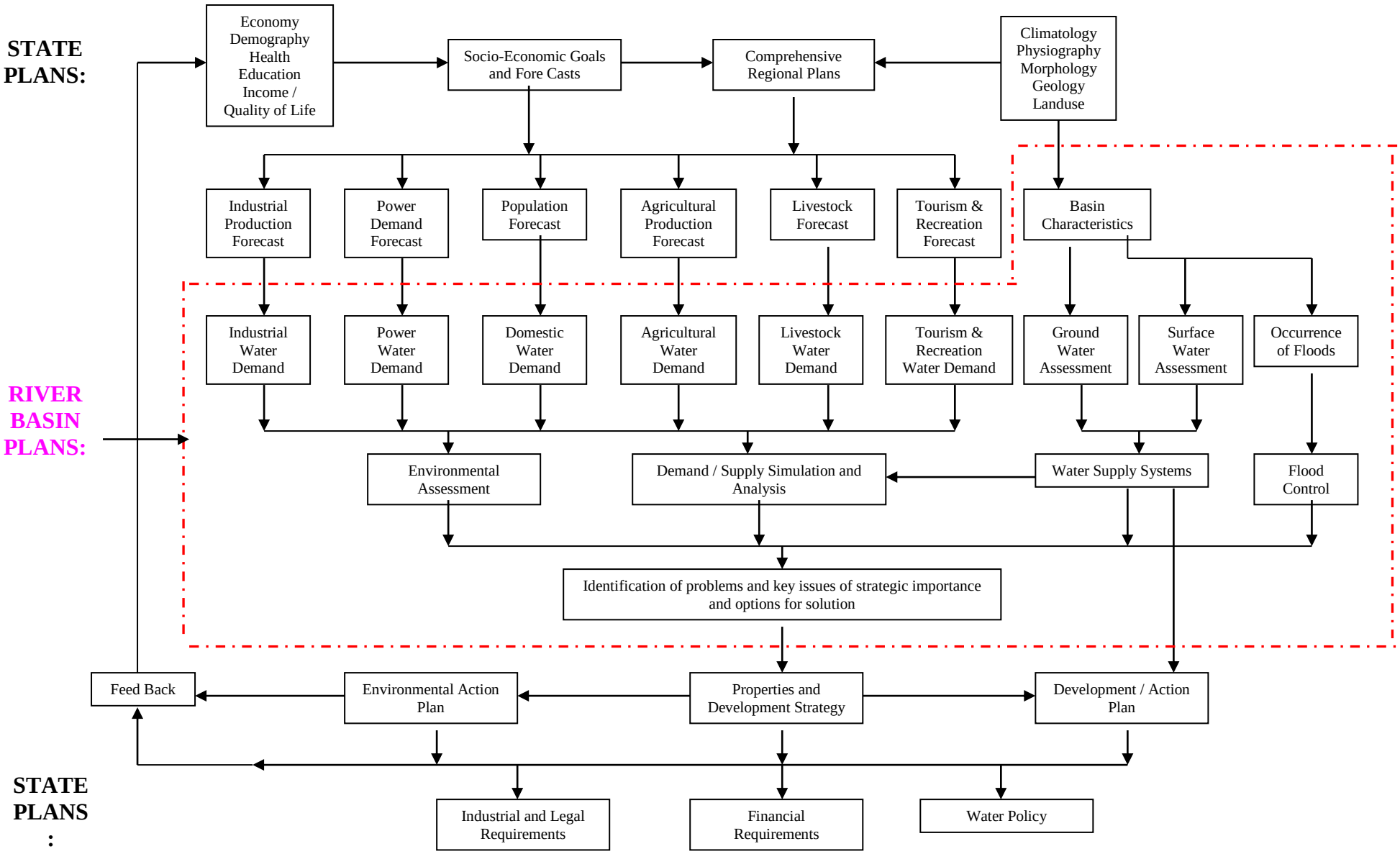
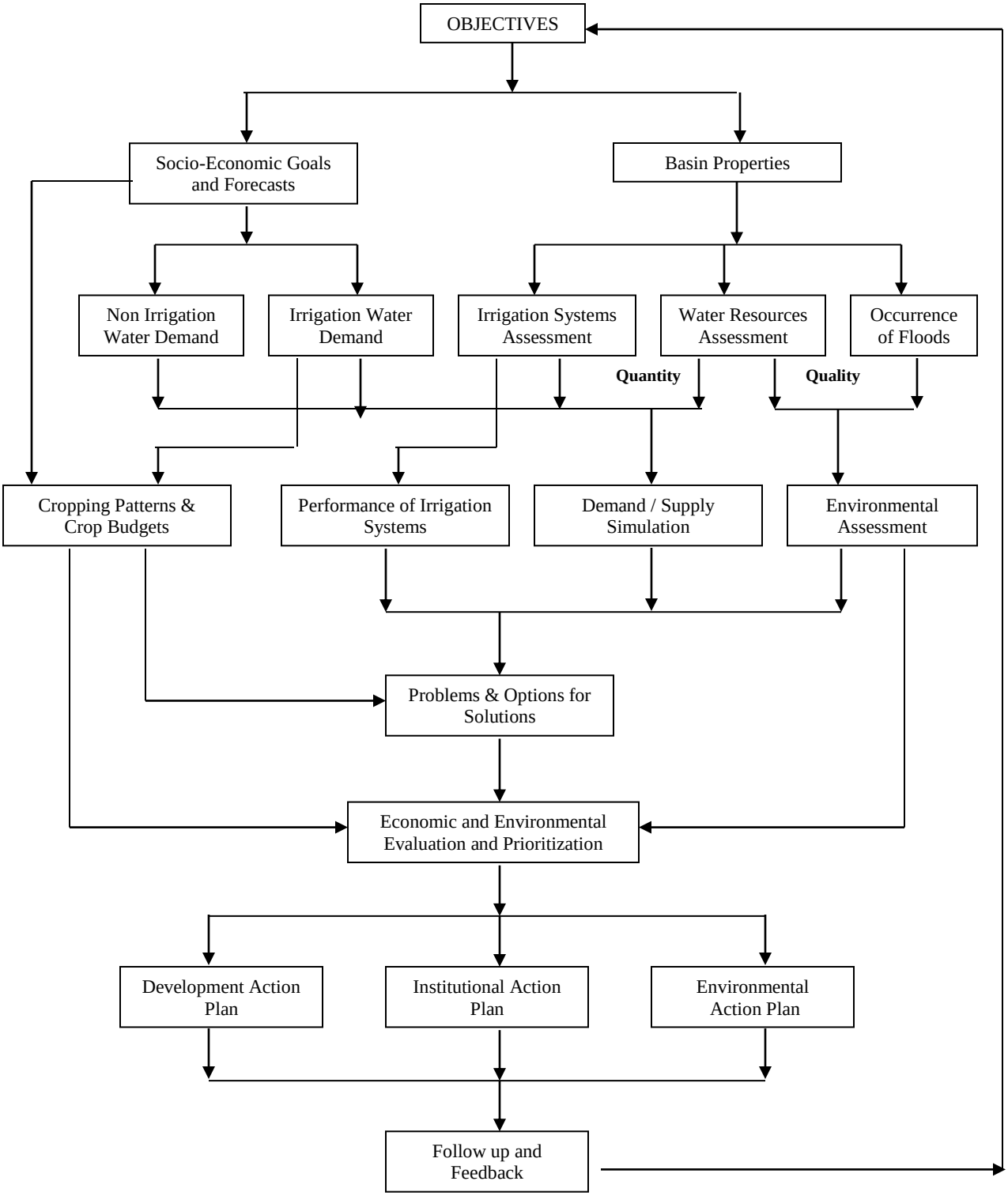
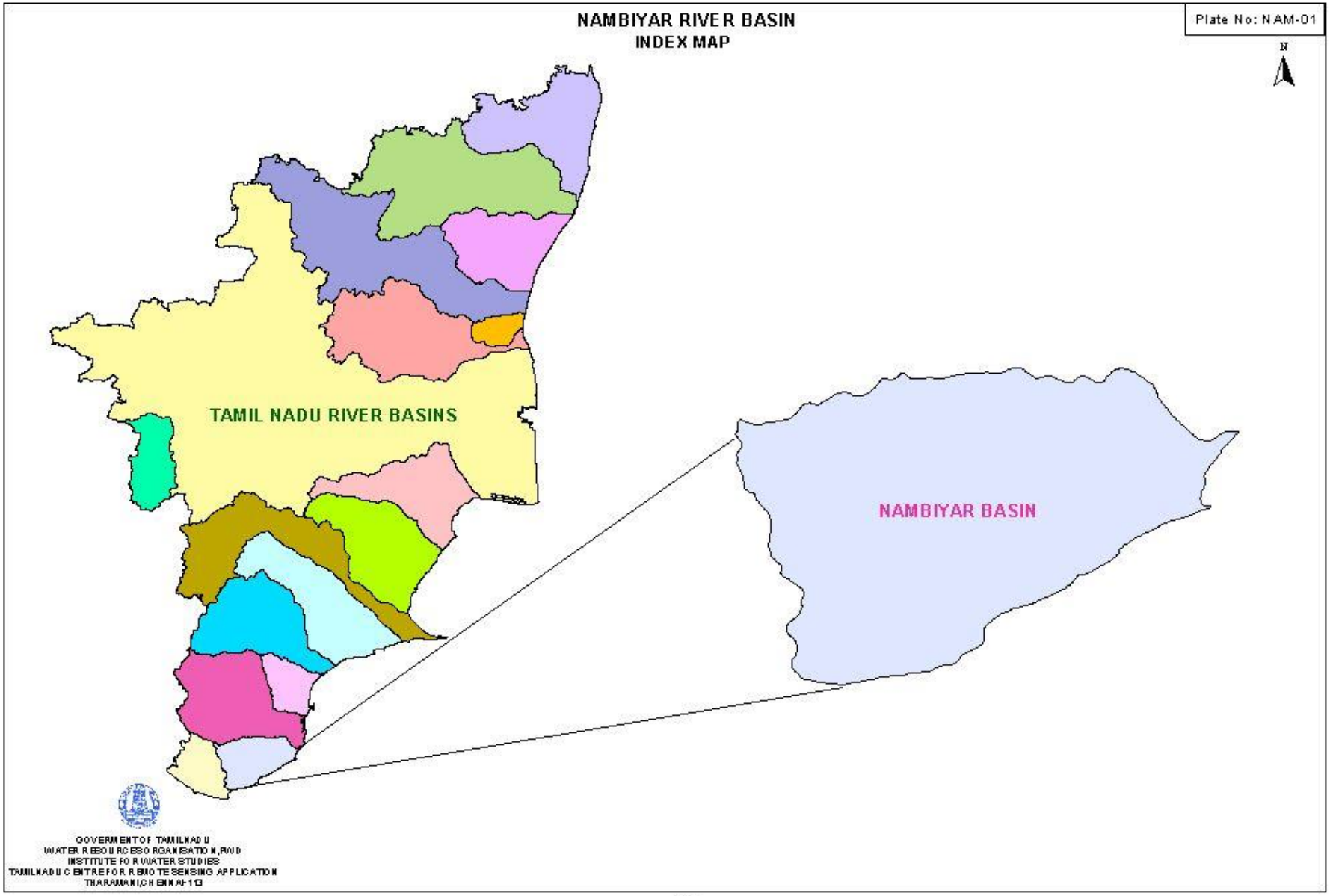


Fig. B. FLOWCHART OF RIVER BASIN PLANNING




NAMBIYAR RIVER BASIN
INDEX MAP
Plate No: NAM-01
N
TAMIL NADU RIVER BASINS
NAMBIYAR BASIN
GOVERNMENT OF TAMILNADU
WATER RESOURCES ORGANISATION, PWD
INSTITUTE FOR WATER STUDIES
TAMILNADU CENTRE FOR REMOTE SENSING APPLICATION
THARAMANI, CHENNAI-113

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CHAPTER – 2

DESCRIPTION OF THE BASIN

CHAPTER –2

DESCRIPTION OF THE BASIN

2.1 GENERAL

The earth is known as “Blue Planet” or “Water planet”. The presence of water makes it unique and is the sole reason for the sustenance of life on the earth about 70.7% of the earth is covered by water and the remaining is land. However, out of this vast coverage of water only 1% is available for human consumption. The remaining 97% of water is in the ocean and 2% in the Polar regions in the form of glaciers. The 1% consumable quality of water is available on the surface of the earth as well as underground. In Tamil Nadu nearly 98% of the surface water resources and 73% of ground water resources have been exhausted. Unless we have better planning to harness, to conserve, manage and utilize the water resources, we have face a day of severe crisis for water. This has necessitated the micro level planning of the water resource river basin wise. This report deals with the various studies that have been carried out to achieve the objective of water balance in Nambiyar basin

The Nambiyar basin falls in Tirunelveli, Thoothukudi and Kanyakumari districts. There are three rivers in this basin. The Karamaniyar is in the northern part of the basin and Hanumanadhi river is in the southern part of the basin and the Nambiyar river is in between these two rivers. Tamiraparani basin on north and Kodaiyar basin on south and the Gulf of Mannar on the east surround this basin.(Plate No.NAM.02)

The Nambiyar river basin falls in part of the Survey of India toposheets 58H and 58L and it lies between the following co-ordinates. North- Latitudes 08° 08’00” - 08° 33’ 00” and East - Longitude 77° 28’00” - 78° 15’ 00”.

This basin is sandwitched between Tamiraparani basin on the north and Kodayar basin on the west. The total area of the basin is 2018.4 sq.km and it covers the part of Kanyakumari, Tirunelveli and Thoothukudi districts.

The administrative setup of the Nambiyar basin is given below. (Plate No. NAM. 03).

Sl. No.	District	Taluk	Block	Block area falling in the basin in sq.km
1.	Tirunelveli	1.Nanguneri	1. Nanguneri (P)	363.322
		2.Radhapuram	2. Kalakadu (P)	185.687
			3.Radapuram (F)	458.572
			4.Valliyur (F)	433.425
2.	Thoothukudi	3.Tiruchendur	5.Tiruchendur (P)	4.438
		4.Sattankulam	6.Alwarthirunagari (P)	68.187
			7.Udankudi (P)	134.413
			8.Sattankulam (F)	294.43
3.	Kanyakumari	5. Thovalai	9. Thovalai (P)	68.169
		6. Agasteeswaram	10. Agateeswaram (P)	7.798
Total				2018.44

2.2 PHYSIOGRAPHY:

Physiograpically, Nambiyar basin is divided into western hilly region and eastern plain undulating topography. Western hilly region extents from Agsthayarmalai in the north and Kanyakumari town in the south and it acts as the western boundary of the basin. All the rivers flowing from the eastern slope of Western Ghats at various altitudes.

A Stream from the east of Kalakkadu village joins with the Manimuthar Main canal and surplus from Vijayanarayanam tank forms the Karamaniyar river. Numerous streams in the downstream joins the river Karamaniyar. Its width is increasing from Sathankulam till its end.

The river, Nambiyar originates in the eastern slopes of the Western Ghats near Nalikkal Mottai about 9.6km west of Thirukkarangudi village at an altitude of about 1646 m above MSL. Kalankal odai is a tributary of Nambiyar river which originates near Kannanallur area, after traversing 6.5km and finally it joins Nambiyar at 37th km near Kovankulam.

Hanumanadhi originates in the eastern slopes of the western ghats at an altitude of 1100m above MSL in the Mahendragiri hill region. Uppar river originates in the eastern slopes of the western ghats near Takkumalai east forest at an altitude of about 808m above MSL.

The elevation of the Western ghats ranging from +300m to +1200m above MSL in this basin area. There are several peaks which are raised above +1000m.MSL. They are Kaniyini mottai ▲1663 m, Mahendragiri hills ▲1657m, Kottankaitatti mottai ▲1530m and Thiruvannamalai hills ▲1402m.

The eastern plain is an undulating topography with its elevation varying from +100m to +15m. All the rivers starting in the Western Ghats regions flows in the plains towards east, southeast and south direction. There are two reservoirs in Nambiyar basin, the first one Namibiyar and the other Kodumudiyar. There is one big tank located at Vijayanarayanam village called Vijayanarayanam Eri.

In the eastern part of the basin, two patches of sand dunes are noticed and they are deposited by wind action. These sands are reddish white in colour and they are locally called as "Teri sands". One patch of Teri sand dunes occur north of Tisaiyanvilai is called Ittamalai Teri, and another one which occur at the northeast of Sattankulam is called as Kudiramoli Teri, with considerable thickness ranging from 20 to 30 m above ground level. Ittamalai Teri rises above 60m MSL.

2.3 DRAINAGE:

Nambiyar river basin is constituted by rivers like Nambiyar, Karamaniyar, Hanumanadhi. Nambiyar and Hanumanadhi originates in the eastern slopes of the Western Ghats at an altitude of about 1000m MSL. Karumaniyar river originates from the surplus water from Vijayanarayanan tank of about 100 m. The watershed area comprises the hilly region of Mavadirottai, Kakamunikal mottai, Thiruvannamalai and Mahendragiri hills.

SUB BASINS DESCRIPTION:

Karamaniyar River:

It has a number of small seasonal streams and gets its flows mainly from the surpluses of Vijayanarayanan tank and from monsoon rainfall. Manimuthar main canal joins with the river near Pillaikulam village. After traversing a total distance of 56.5 km, the Karamaniyar river flows into the Gulf of Mannar near Manapadu villages in Tirunelveli district. The Karamaniyar river feeds about 75 tanks and has a

registered ayacut of 2976 hectares. The total extent of this sub basin is 903.93 sq.km. Covering blocks of Alwarthirunagari, Tiruchendur, Sathankulam, Udankudi, Kalakkadu, Nanguneri and radhapuram either part or full.

Nambiyar river :

Nambiyar river originates in the eastern slopes of the western ghats near Nalikkal Mottai about 9.6 km west of Thirukkarangudi village at an altitude of about 1060m. This river is constituted by three branches of seasonal streams, like Tamaraiar, Kombaiar and Kodumudiar. Kombaiyar and Kodumudiyar originates at the eastern slope of western ghats at an altitude of about 1600 mm. near Mahendragiri hills. Nambiyar then takes an easterly course up to the Tirunelveli-Nagercoil trunk road crossing and flows in a south-easterly direction. Parattaiyar originates in the eastern slopes of the western ghats at an altitude of about 1200 m. near Kakamunjikai Mottai and joins with another arm of Nambiyar at the foot of the hills. After feeding number of small tanks, this finally joins with Nambiyar again near Ervadi at 18.5 km.

Kalankal odai is another tributary which originates near Kannallur area in Nanguneri taluk of Tirunelveli district. It gets flows from the surpluses of a few tanks dependent on other streams. After traversing a distance of 6.5 km and finally joins with the Nambiyar near Kovankulam.

Another tributary which originates near Vadakku Valliyur area in Nanguneri taluk of Tirunelveli district at an altitude about 90m gets flows from the surpluses of small tanks dependent on other streams. After traversing a distance of 10.5 km finally the tributary joins with Nambiyar near Sankarapuram village. Finally the Nambiyar river flows into the Gulf of Mannar after traversing a total distance of 59km from the origin of Nambiyar river.

The Nambiyar river has a total of 9 small anicuts viz. 1. Mailannani anicut, 2. Dalavaipuram anicut, 3. Rajakkamangalam anicut, 4.Malapudur anicut 5.Kannanallur anicut, 6. Vijayan anicut, 7.Kovankulam anicut, 8. Islapuram anicut, 9. Pulimangalam anicut. The total extent of this sub basin area is 604.32 sq.km covering blocks of Kalakkadu, Nanguneri, Valliyoor, Radhapuram in Tirunelveli district and Thovala block in Kanyakumari district, either part or full.

Hanumanadhi River:

Hanumanadhi originates in the eastern slopes of the western ghats at an altitude of 1100m in the Mahendragiri hill region on the north west of Panakkudi village in Nanguneri Taluk of Tirunelveli district. It has a number of jungle streams. After feeding a few tanks, they join with Hanumanadhi river at various points. It flows in the hill ranges for about 5.6 km and reaches 6.4 km west of Panakkudi village in Nanguneri taluk. It traverses entirely in Nanguneri taluk for a distance of about 32km and flows into the Gulf of Mannar. There are 11 small anicuts across this river viz. 1. Sivanpilli anicut, 2.Senthilkathayan anicut, 3.Thandayarkulam anicut, 4. Sanjetti anicut, 5. Perungudi anicut, 6. Vadakkankulam anicut, 7. Adankarkulam anicut, 8. Sakkilianparai anicut and 9. Kanjaneri anicut 10. Alaganeri Anicut, 11.Koliankulam Anicut The total area of the sub basin is 510.179 sq.km covering blocks of Kalakkadu, Valliyur, Radhapuram in Tirunelveli district and Thovala and in Kanyakumai district either part or full.

Further Description of the basin:

A canal known as Radhapuram canal crosses into this basin from the adjacent Kanyakumari district. Radhapuram canal starts from Pechiparai reservoir in Kanyakumari district. At its starting point this canal is called Kodayar left bank canal. Another canal from Perunchani dam joins this Kodayar left bank canal at the 17^{th} km. After the confluencing point the downstream of the canal is called Thovalai channel. After entering Tirunelveli district near Thirumulangar village, it is called Radhapuram canal. After feeding a number of tanks through supply channels, it crosses Hanumanadhi river near Adankarkulam anicut. Finally the canal feeds Mahendrakulam near Radhapuram after feeding one supply channel in Hanumanadhi basin.

2.4 RELIEF:

The highest elevation of different ranges 1657m, 1585m and 1530m are found in Kalakkadu reserved forest, Mahendragiri Reserved forest and the minimum elevation is 500m at the foot hills at the western part of this basin. Adjacent to this hill ranges the 100m contour runs across this basin from north to south.

The remaining part of the basin is generally a plain terrain with gentle slope towards south and east. There is a sand dunes namely ‘Teri sand’ in the south of

Sattankulam having an elevation of 67 m. There is also a similar type of structure in and around the villages Kuttam and Uvari in the south of Thisaiyanvilai.

The river Karamaniyar flows in the basin at the eastern part of the basin from northwest to southeast, passing through Sattankulam and confluences with Gulf of Mannar at Kulasekaranpattinam.

Nambiyar river originates at an elevation of 1479 in Nalikkal Mottai in Kallakadu reserved forest. It traverses through Pudukulam, Pettaikulam and confluences in Gulf of Mannar at Thiruvambalampula.

The river Hanumanadhi originates at an elevation of 1100m in Mahendragiri reserved forest. It traverse through Panakkudi, Vadakankulam and finally confluences with the Gulf of Mannar at th south of Erukkamkulam.

2.5 GEOLOGY:

The various rock types traversed and the structural details of Nambiyar river basin were collected from the Geological Survey of India. The basin area comprises of rocks of khondalite and charnockite groups of Archaean age major part of the basin area. Migmatite gneiss of Archaean age also occur in the plains. The coastal plains host rocks of Misocene, Quaternary and Recent age.(Plate No.NAM.07).

The Khondalite group consists of garnet-biotite sillimanite gneiss with or without graphite. It consists of sheets of sillimanite needles, biotite, occasional lenses of graphite with red and pink garnet. These rocks exhibit fine foliation and perfect parallel banding. Influx of granitic material has resulted in the formation of quartzo feldspathic gneiss in many places.

Charnockite occurs mostly as concordant bands and lenses of varied dimensions in association with khondalite with diffused contacts. It grades into gneiss and vice versa both along and across the strike. Generally, it is garnetiferous near the contact with gneiss and non-garnetiferous in the middle portion. The rocks show granblastic texture and are mostly intermediate to acidic.

The migmatite complex consists of granite gneiss. The rocks of the migmatite group are widely distributed and interlayed with charnockite in the central and southern part of the area. Garnet-biotite gneiss occurs as bands and lenses and stands out as raised ridges. It is characterised by the presence of biotite foliae and concentration of garnet in layers. At places, the garnet, biotite gneiss also carries segregations of graphite flacks.

In the eastern part of the basin, a few outcrops of hard marine sand stone and shell limestone with intercalations of pebble beds of miocene age, unconformably overlie the rocks of the Archaean age. The pebble bed consists of angular to sub-angular and coarse fragments of quartz, in a matrix of ferruginous clay. The formation comprises of hard sandstone and calcareous shelly limestones are encountered north of Sattankulam, Tisaiyanvilai called as Panambarai sandstone and are equivalent of Cuddalore sandstone formation. The sandstone is seen as patches extending from southwest to northeast direction parallel to the coast. The shell limestone is compact and consists of corals, shells of gastropods and are embedded in a fine grained calcareous matrix.

Quaternary grit, sandstone and shell limestone overlie the Miocene rocks with a distinct unconformity marked by a bed of conglomerates in the southeastern corner of Nanguneri taluk.

Kankar and tuffaceous limestone of recent age occurs along the nallahs of the Karamaniyar, Nambiyar and its tributaries is seen over a width of 200m to 300m and extends over a length of 6 km and more. It is generally hard, massive and shown modular structure.

In the southeastern part of the basin, beyond Sattankulam and Tisayanvilai, recent to sub-recent quaternary alluvial plains extends with isolated friable sandstone and shell limestone. Teri sands occur north of Tisaiyanvilai (Ittamali Teri) and Northeast of Sattankulam (Kudiramoli Teri) with a considerable thickness ranging from 20 to 35 m. These are reddish in colour and medium to coarse grained.

HYDROGEOLOGY:

Sixty four boreholes (45 in hard rocks and 19 in sedimentary formation) drilled by Public Works Department, Groundwater wing and 4 boreholes drilled by Central Groundwater Board were studied to know the sub-surface conditions of the basin. Thirty three pumptests (23 in hard rock and 10 in sedimentary formation) were studied to know the aquifer parameters.

In hard rocks, weathered zone exists upto 25 m.bgl underlain by fractures upto 30m bgl as per lithology of boreholes. In Nanguneri, Vadaku Valliyur and Vijaynarayanapuram areas the yield of the borewells range from 45 to 295 lpm. Transmissivity of the aquifer is 10-20 m^2/day. Weathered zones exist upto 20m.bgl.

followed by fractures upto 40 m bgl. Yield of the borewells in this area range from 25 to 100 lpm. Transmissivity of the formation vary from 5-10 m^2/day. In the western part of the basin (Panagudi and Radhapuram areas) weathered mantle persist from 30-45 mbgl and fractures continued upto 50 m bgl. The yield of the boreholes, range from 15 to 80 lpm. Transmissivity of the aquifer is from 2 to 40m^2/day. In the southern part of the basin, south of Radhapuram and Kudankulam, the weathered zone exist 15-25 m bgl and fractures continues upto 30 mbgl. Transmissivity of the aquifer in this region is 2 to 30 m^2/day.

In the southern part of the basin near Kudangulam, sandstone occurs upto 15 m bgl underlain by gneisses.

In coastal alluvium, south and south east of Tisaiyanvilai, sandstone is encountered upto 33 mbgl near Nadaruvari and it goes upto 90 mbgl near Pailanthuruvai underlain by gneisses. Water level excess at 5 mbgl and the yield of the bore is 155 lpm. Transmissivity of the aquifer is 135 m^2/day. E.C value of groundwater is 2100 microsiemens. In Kundal area sandstone contain upto 120mgbl with intervening limestone and clay. Water level is at 26 mbgl. and the yield is 583lpm. The transmiisivity of the aquifer is 43 m^2/day. Specific conductance of groundwater is 655 microsiemens.

Sandstones occurs south of Kudankulam as local patches. Sandstone encountered upto 14 mbgl is underlain by gneisses and charnockites (BH.No.92121 and 92122) SWL exists at 20 mbgl. The yield is poor in BH 92122 and 90 lpm in BH 92121. Transmissivity of the aquifer is 34 m^2/day.

In general yield of borewells in Teri sands in sedimentary formations range from 200 to 1950 lpm and in Tertiary sandstones in coastal alluvium area ranges from 75 to 1045 lpm. In hard rocks, the yield of the boreholes range from 45 to 295 lpm.

SALIENT FEATURES OF BOREHOLES -HARD ROCK AREA

Sl. No.		Minimum	Maximum	General occurrence
1	Rock Type			Gneiss and Charnockite
2	Weathered zone in m.b.g.l	0.60-BH (92016,92057)	16.50 (BH 92055)	1-5
3	Fractured zone in m.b.g.l.	7 (BH 92128)	46.60 (BH92021)	10-30
4	Discharge in LPM	2.50 (BH 92087)	950 (BH 92167)	40-200
5	Transmissivity m^2/day	2 (BH 92008)	251 (BH 92167)	2-20
6	Storativity co-efficient	-6 8.8 E-6 (BH 92073)	-4 1.77 E-4 (BH92041)	-5 4.2 x 10
7	Electrical conductivity (in microsiemens)	300 (BH 92016) (BH92087)	5900 (BH 92126)	300-800 (24 Nos.) 3800-5900(8 Nos.
8	Static Water Level in m.b.g.l.	0.45 (BH 92147)	20.84 (BH 92122)	2-6
No.of wells studied - 45				

SALIENT FEATURES OF BOREHOLES -SEDIMENTARY AREA

Sl.No.		Minimum	Maximum	General occurrence
1	Rock Type	--	--	Sand, sand stone and clay
2	Discharge in LPM	77 (BH 92058)	1954 (BH 92005)	100-500
3	Transmissivity m^2/day	2 (BH 92008)	14220 (BH 92002)	--
4	Storage co-efficient	3.5×10^{-8} (BH 92010)	1.08×10^{-1} (BH92143)	--
5	Electrical conductance at 25°C	150 (BH 92003)	2000 (BH 92002)	250-1000
6	Static Water Level in m.b.g.l.	1.32 (BH 92002)	2256 (BH 92121)	4-12
No. of wells studied – 19.				

2.6 Geomorphology:

Detailed Geomorphological mapping is one of the principle means of studying the morphology, genesis distribution and age of landforms which in turn helps to interpret the geomorphic history of any evolved landscape. The detailed analysis of land form is an important aspect of any environmental or resources analysis and planning. Geomorphological survey primarily concerned with the classification and mapping of relief landforms through differentiation of morphographic patterns with respect to their genesis and processes. The synoptic coverage and high precision of remotely sensed data coupled with marked cost effectiveness and time efficiency in data acquisition and analysis procedures have made geomorphological mapping an extremely effective tool for management of natural resource and environment.

Geomorphological analysis:

Geomorphological processes are generally complex and reflect inter-relationship among the variable such as climate, geology, soil and vegetation. In the present study, landforms have been analysed based on the satellite image characteristics and geometry of relief forms in terms of crest types, valley side/ground slope element and shape of valley floors. The geomorphic units distinctly separated each other by topographic change in slope segments similar to the morphological mapping techniques. The delineated geomorphic units have been broadly grouped into denudational & depositional origin.

Denudational landforms:

The denudational geomorphological processes are actively involved in the landscape reduction processes. The physio chemical and biological weathering and multiple slope high drainage density pattern and precipitation condition leads to the development of the different units. The different geomorphic units observed in Nambiyar basin and its groundwater occurrence is tabulated below.

Description of geomorphic units in Denudational Zone

Sl. No.	Geomorphic unit	Lithology	Texture	Description	Ground water prospects
1.	Structural hill	Varying lithology	Coarse	Linear to arcuate hills showing definite trend lines	Very poor – moderate along valleys
2.	Pediment composed of duricrust	Varying lithology	Fine to medium	Rock cut surface with thin veneer of soil cover outcrops subjected to less and partial weathering;	Poor
3.	Pediment composed of black cotton soil	Varying lithology	Fine to medium	Black cotton soil underlained by rocks with less and partial weathering;	Poor
4.	Pediment	Varying lithology	Fine to medium	Rock cut surface with thin veneer of soil cover mostly thin sheet wash material cover at the top and the underlained rocks are with less and partial weathering	Poor - varies with underlying lithology. Presence of fracture/ lineaments may become promising.
5.	Buried pediment shallow	Shallow over burden of weathered material of varying lithology	Fine to medium	Flat and smooth. Buried pediplain/pediment with over burden of 5m thickness	Moderate – Poor
6.	Buried pediment medium	Moderately thick over burden of weathered material of varying lithology	Medium	Flat and smooth. Buried pediplain/pediment with over burden of 5m to 10m thickness.	Good- Moderate
7.	Buried pediment deep	Very thick over burden of weathered material of varying lithology	Fine	Flat and smooth buried pediplain/ pediment with over burden of more than 10m	Good

DEPOSITIONAL LANDFORM

The depositional landforms are formed under the influence of corrosive and erosive dynamics and slope retreat processes. Active physio chemical weathering accompanied by sheet wash and strip removal of debris are responsible for development of various depositional landforms.

Description of geomorphic units in depositional zone

Sl. No.	Geomorphic unit	Lithology	Texture	Description	Ground water prospects
1.	Palaeo channel	Constitute gravel, sand, silt & clay of varying lithology;	Fine	Comprises of fluvial deposits of varying grain size and lithology	Very good
2.	Valley fill	Varying lithology	Fine	Unconsolidated sediments – boulders, pebbles, gravels, sand and silt	Good – Very good
3.	Duricrust	Constitute gravel, silt & clay of varying lithology; silt dominates.	Fine to medium	Poor drainage facility. Induced evaporation and percolation cause thin salt incrustation. Very fine silty clay	Very poor

COASTAL LAND FORM

The coastal landforms are classified into coastal sand, coastal sand dune, coastal ridges, swales and back water. The quality of ground water varies according to the deposition of coastal geomorphic units. Many coastal (beach) ridges occurring in the eastern part of the area, control surface water flows. The classification of geomorphic units and their characteristics are as follows:

Description of geomorphic units in Coastal Zone

Sl. No.	Geomorphic unit	Lithology	Texture	Description	Ground Water Prospects
1	Coastal sand	Primarily comprises of unconsolidated materials like gravels, sand, silt.	Fine	Unconsolidated materials – gravels, sand & silt	Good
2	Coastal ridges	Primarily comprises of unconsolidated materials like gravels, sand, silt.	Fine	A flat surface adjacent to a stream / river and parallel to coastal line composed of unconsolidated aeolian and fluvial sediments.	Good

3	Swales	Constitute gravel, sand, silt & clay of varying lithology.	Fine	Formed by extensive deposition of aeolian deposits and alluvium deposits brought by wind. This unit is normally flat/gently undulating surface between ridges Has shallow water table.	Moderate - Good
4	Back water	Constitute silt & clay of varying lithology.	Fine	Comprises of fluvial deposits and having poor quality of water.	Quality of water poor

Generally geomorphologic units like valley fill, sediments, paleo channel are having good to very good groundwater potential. Sinking a well in these units will be sustainable for pumping, hence the farmers will be much benefited. Buried pediment deep, buried pediment moderate of denudational origin are having moderate to good groundwater potential where as the buried pediment shallow is poor to moderate ground water potential. Geomorphic units like coastal sand, coastal ridges are of good groundwater potential units and swales are of moderate groundwater potential, with varying quality.

2.61 Geomorphology and Lineament study:

IRS 1C and P6 LISS III False Color Composite imageries have been used for the structural studies. Interpretation of structural trends and lineaments clearly show the presence of folds, faults and fractures in the study area. Detailed studies have been made on the nature of fold, fault and fractures, lineaments and their influences on the development of geomorphic units of the Nambiyar Basin area. Satellite imagery interpretation followed by extensive field visits in the study area confirm the interpreted structural and lineament pattern.

To understand the nature of lineaments which could be faults, probable faults, deep fractures, contact zones of rock types and folds, IRS 1C and P6 FCC were used for analysis, based on that the lineament map was prepared on 1:250,000 scale (Plate No.NAM.11).

Only limited field check has been carried out in Nanguneri – Moolakkaraippatti road and Emankulam area. Two dugwells, which are located in the

lineament intersection zone are yielding good amount of ground water. In Nambiyar Basin five sets of lineaments are identified which are

1. NNE-SSW trending lineament
2. N-S trending lineament
3. NE-SW trending lineament
4. E-W trending lineament
5. NW-SE trending lineament

Intersections of lineaments are proven to be a good groundwater potential zones. A detailed investigation can be undertaken to demarcate the intensity and depth of hydrofracture in this zones for future groundwater development.

Zone 1: Frequency of lineaments and intersection points of lineaments are more in Karungulam and Punnae area.

Zone 2: Though the area between Vadakku Valliyur and Radhapuram falls in pediment, run off zone, the existence of lineaments in this area influences ground water contribution.

Zone 3: The intensity and frequency of lineaments are more on the north and NE part ie. between Nanguneri and Sathankulam. All these three zones can be concentrated for exploitation of groundwater in the near future.

After the identification of lineaments in the field, terrain conductivity survey has to be done to identify the fractured zones and their magnitude to conform the suitable locations for drilling boreholes.

Already the entire shallow aquifer zone has been exploited for agriculture purpose in hard rock areas. Hence to meet the future demand a detailed investigation is warranted in the fractured aquifers. This will help for modeling the fracture density in this basin area. Suitable sites can be identified in the fractured zones for construction of artificial recharge structures.

This will facilitate percolation of rainwater into the groundwater reservoir for further augmentation of groundwater.

Ground water potential zones

The ground water potential zones are identified and classified into different zones qualitatively (vide ground water potential zones map Plate No.NAM.11A). Prior to execution of any wells the present groundwater extraction in this semi arid region have too be taken into account in the Nambiyar river basin area.

In general contact zones are proven to be potential zones. Three contact zones have been identified by integrating geomorphology, lineament and geology layers.

CZ1 - Crystalline/Teritiary

CZ2 - Garnet Biotite Gneiss / Garnet-Biotite – sillimanite Gneiss.

CZ3 - Garnet Biotite Gneiss / Garnet-Biotite – sillimanite

Note: Lineament intersection points located in the contact zones are very good potential zone.

Groundwater potential lineament zones

Lineament Zone I (frequency closely spaced)	It is demarcated in the SW corner area between Karunkulam – Punnae.
Lineament Zone II (multidirectional)	The area in between Radhapuram and Tisaiyanvilai.
Lineament Zone III (more number of lineaments)	The east to west corridor covering the zone in between Nanguneri – Sathankulam.

These three zones can be exploited after conducting basic geophysical survey before commencing the exploration work. The occurrence of groundwater in the intersection points of lineaments zone will improve the groundwater condition to certain to extent.

2.7 Landuse

Large pressure of growing population, increased demand for food and fuelwood combined with industrial activities have led to rapid change in landuse/ land cover patterns. Planning for development of natural resources without endangering the environment is very essential for regularizing the use of landuse resources. The study of landuse/land cover provides information about present landuse and forms a baseline study for the sustainable landuse planning and rural development. A landuse map plays a vital role for various planning activities including watershed planning.

In order to study the landuse/land cover patterns of Nambiyar basin at micro level, the False Colour Composite image LISS III of IRS 1C satellite data acquired during the month of March 2001 was used and classified into various categories of landuse through visual interpretation techniques and analysed the tone, texture, pattern, and associated features of the area. The Nambiyar river basin is categorized into five broad groups namely, builtup land, agricultural land, forestland, waste lands and water bodies under level I and these groups are further classified into various landuse features under level II classification. These classifications were made based

on the technical guidelines of the Integrated Mission for Sustainable Development (IMSD) of NRSA, Department of Space, Hyderabad as follows.

Sl.No.	Level I	Level II
1.	Built-up land	Villages/Towns
2.	Agricultural land	Cropland, mixed crop, plantation (paddy, sugarcane, banana) Grooves & Orchards, Cotton crops in Black cotton soil area.
3.	Forest	Medium to low dense forest
4.	Wastelands	Barren rocky/Stony waste Barren land Barren Sand Barren -Teri sand Land with Scrub/Shrub Land affected by Alkalinity /Salinity
5.	Water bodies	River/Stream Canals Swampy Reservoir/Tank

2.7.1Buildup land:

Rapid growth in population over the past 20 years, development of residential houses, conversion of cultivable lands into settlements and growth of industrial activities, have led to a rapid growth of built-up level land in the basin area. The basin is constituted mostly of rural settlements and a few urban settlements like Nanguneri, Tisaiyanvilai, Radhapuram and Sattankulam. This category shows light blue tone with definite shape in the satellite imagery.

2.7.2 Agricultural land:

Agriculture is a primary landuse, put into use for production of food and fiber. This category includes paddy, sugarcane, cotton, groundnut, cholam, ragi, pulses, mixed crops and plantations such as casuarina, coconut trees, cashew nut, garden crops, floriculture etc. Paddy and sugarcanes are cultivated mainly in the command area, a part of land along the Nambiyar and Karamaniyar river courses and some pockets in the western portion of the basin area covering the villages of south western part of Vadakku Valliyur, Eruvadi, Vijayanarayanam, Mudalur, north western part of

Nanguneri and south eastern part of Panaikudi. In general the dry crops are predominant and cover a major part of the basin.

The plantations like coconut and casuarinas, cashewnut etc., are raised mainly in the eastern part of the basin covering the villages of Ramayapuram, Meignanapuram, Padukkapattu.

2.7.3 Forest:

Medium dense to low dense forest falls in Mahendiragiri Reserved Forest is bounded by the western part of the basin.

2.8 Wasteland:

The land which can be considered as wasteland includes degraded land, land which is deteriorating for want of soil management or on account of natural causes, lands with inherent or imposed disabilities such as by location, environment, chemical and physical properties of soil and also by financial or management constraints. National Wasteland Development Board, (NWDB) has developed 13 categories of wasteland classification system. Out of which Nambiyar basin comprises of 6 categories such as Barren rocky/Stony waste, Barren land, Barren Sand, Teri sand (barren), Land with Scrub/Shrub, land affected by Alkalinity /Salinity.

Wastelands are categorized based on the analysis of tone, colour, texture, pattern, shape, size, location, associated features etc., in the imagery and classified as follows.

Barren rocky/ Stony waste

It is an area of rock exposures of varying lithology often barren and devoid of soil cover and vegetation. The barren rocky/ stony waste covers the west, northwestern part of the basin area. Barren rocky/stony waste partially devoid of vegetation covers the area of Anaikkulam village, western part of Sattankulam, eastern part of Nanguneri, Radhapuram and surroundings and Samugarangapuram villages.

Barren land:

Area consisting of rocky surface, steep slopes and land poorer in sub soil moisture are the form of barren land. The major part of the basin area is covered by this cateogory. Some important villages and area falling in this category are Vadugapatti, Udayattur, Kanakkankulam, Kalavur and Western part of Vijayanarayanam etc.

Barren Sand:

The barren sand occurs in the coastal plain. It is characterized by white tone in the imagery. It is highly porous and facilitates quick infiltration of water into the aquifer.

Teri Sand:

Due to aeolian action the typical type of red sands locally called as "Teri sand" which is deposited in the eastern part of the basin area. It is demarcated by typical tone, texture, pattern etc., and characterized by light yellow to greenish tone in the satellite imagery. It is a highly porous and facilitates direct infiltration of rainwater. Eastern part of Ittamozhi, Adaippanvilai, Kuttam, Idaiyankudiyiruppu, eastern part of Nazareth villages are falling in this type of soil.

Land with Shrub/Scrubs:

This category has been widely observed in the basin area. It has light red to grey tones in the imagery and covering the villages of Vinayagapuram, Kesavaneri, Kaliyanipuram, Pudukulam villages.

Land affected by Salinity/Alkalinity (Coastal or Inland)

Salt affected land is generally characterized as land that has adverse effects on the growth of most plants due to the action or presence of excess soluble salts (Saline) or high exchangeable sodium. The predominant salts are carbonates and bicarbonates of sodium. Coastal saline soils may be with or without ingress or inundation by seawater. Some of the villages like Vedakottaivalai, Vellalanvilai, Manappad, Alagappapuram etc., falling in the coastal region of the basin are affected by the above land use category.

WASTELAND

Wasteland is described as degraded land which can be brought under vegetative cover with reasonable effort and which is currently underutilized and land which is deteriorating for lack of appropriate water and soil management or on account of natural causes. Wastelands can result from inherent/ imposed disabilities

such as by location, environment, chemical and physical properties of the soil or financial or management constraints.

The wasteland for Nambiyar river basin is studied using the IRS IC satellite imagery following the guidelines of Technical Task Force Group, National Remote Sensing Agency, Department of Space, Hyderabad.

WASTELAND MAPPING

Wasteland map was generated by interpreting the false colour composite image of LISS III IRS-1C satellite data acquired during the period of March 2001 for the entire Nambiyar river basin (Plate-). Visual interpretation technique was applied for the classification of wastelands. The wasteland and other than land categories are identified using remote sensing techniques in Nambiyar basin are as below.

Sl. No.	Wasteland category
I	**Wasteland**
1.	Barren rocky/Stony waste
2	Barren land
3	Barren Sand
4	Barren -Teri sand
5	Land with Scrub/Shrub
6	Land affected by Alkalinity /Salinity
II	**Forest land**
7.	Medium to low dense forest
III	**Water bodies**
8.	River
9.	Tank
IV	**Other features**
10.	Settlements
11.	Other than waste land

2.9 Wasteland and lineament study

The lineament map was generated using False Colour Composite image of IRS 1C and P6 satellite data. The structure of the rock, geology of the area, tone, texture and shape of each features were interpreted for the preparation of lineament map. Lineaments are weak planes, which provide effective secondary porosity to the

underlying rocks and hence there is possibility for the accumulation of groundwater resources in these zones. The lineaments map is superimposed with wastelands map and many lineaments intersections locations are identified in the wasteland area. The lineament intersection zones falling in the wasteland area can be considered for the development of productive lands. NE-SW and NW-SE direction lineaments are predominant in this basin. Some of the lineament and lineament intersection zones are identified are exhibited in the map for the development of wastelands in the Nambiyar basin.

2.10. Soils:

Soil is one of the natural resources which has the most direct impact on agricultural development. In an agrarian country like India, it becomes necessary to take steps for its proper conservation and management. Soil survey provides the nature of soils, their extent and physico chemical characteristics etc.

The soils of the Nambiyar Basin has been shown in Plate No.NAM17. The predominant soil types found in this river basin are Inceptisols, Alfisol, and Entisol. Due to different stage of weathering of parent material, the above soil types are met with in combination. The types of soils along with their sub groups are described below.

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 or faster than most diagnostic horizons can form. 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 Ustorthents:

These are reddish brown to red, light to medium textured and mostly non calcarious soils. They are well drained and the permeability is moderate to rapid. Soil erosion is the major concern in these soils. 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 with depth is common.

These are confined to river systems. Intensive agriculture is being followed on these soils both irrigated and rainfed.

d). Typic Ustipsamments:

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

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 rainfed conditions.

Alfisols:

This 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 permiability. 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 resumble typic Haplustalfs except that they have base saturation less than 75 % in the texterual 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 textural B horizon has a colour hue of 5 YR or Yellower in some part or has a value moist of 4 or more. They do not have secondary carbonates in the sub surface.

h) Vertic Natrudalfs:

This consists of dark grayish brown, very deep, medium textured, calcareous and imperfectly drained soils. They are alkaline in nature and have sodium accumulation in the diagnestic horizon with exchangeable Sodium of 1.50 % .

i) Plinthustalfs:

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

Soil Classification maps have been 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 list of mapping units falling in the Nambiyar River Basin are given below.

Table 2.10.1 Tamil Nadu Soils- Nambiyar River Basin

Mapping Unit	Description	Classification
133	Rock Outcrops	Rock Outcrops
145	Rock outcrops; associated with; Very deep Well drained; loamy soils on moderately steeply sloping, high hills and escarpments, severely eroded.	Rock land Fine loamy Ustropepts.
148	Rock outcrops; associated with; deep well drained; loamy soils on undulating, low hills , severely eroded.	Rock land Fine loamy Ustropepts.

161	Very deep, excessively drained, clayey soils on gently sloping lands, severely eroded; associated with; very deep, well drained, loamy soils on very gently sloping lands with moderate erosion.	Sandy, mixed, Psammentic Paleustalfs. Fine-loamy, mixed, Rhodic Paleustalfs.
162	Deep, moderately well drained, clayey soils on gently sloping lands, slightly eroded; associated with; very deep, well drained, clayey soils on nearly level lands.	Clayey skeletal, mixed,Rhodic Paleustalfs. Fine- mixed, Rhodic Paleustalfs.
185	Deep, well drained, gravelly loam soils on gently sloping lands, moderately eroded; associated with; moderately shallow, well drained, gravelly clay soils on level lands.	Fine loamy, mixed, Typic Haplustalfs. Fine- mixed, Typic Haplustalfs.
195	Very deep, excessively drained, Sandy soils on very gently sloping lands, moderately eroded;	Mixed, Typic Ustipsamments.
196	Very deep, excessively drained, Sandy soils on gently sloping sand hills, severaely eroded;	Mixed, Typic Ustipsamments.
197	Very deep, excessively drained, Sandy soils on gently sloping lands, severaely eroded;	Mixed, Typic Ustipsamments.
220	Deep, imperfectly drained, calcarious clayey soils on nearly level low lands, slightly eroded;	Fine, mixed, Typic Ustrapepts.
223	Very deep, moderately well drained, clayey soils on nearly level low lands, slightly eroded; associated with; moderately deep, moderately well drained, loamy soils.	Fine, mixed, Typic Ustropepts.
283	Periodically flooded lands, Salt affected	Marsh.

The basin soil category and the corresponding soil unit numbers are given below.

Sl No	Soil Category	Soil Unit Numbers
1	Entisol	195,196 & 197
2	Inceptisol	133, 145,148, 220 & 223.
3	Alfisol	161, 162 & 185

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 , the irrigable soils of the

Nambiyar River Basin were identified. The irrigable soils main properties are summarized in Table 2.10.2 and their interpretative classifications for land capability for crop production, irrigability and suitability for rice, sugarcane, groundnuts and cotton are given in Table 2.10.3

Table 2.10.2. Soil Major Properties

Type	Unit(*)	Drainage	Ground water Depth (m)	Surface texture	Available water (mm/m) (**)	Depth (cm)	Slope (%)
	195	S.W.Excess	>5	S	50-150	100-150	
	196	S.W.Excess	>5	S	50-150	100-150	1-3
	197	S.W.Excess	>5	S	50-100	50-150	
	145	Well	>5	Ls	150-200	100-150	
I	148	Well	>5	Ls	150-200	100-150	1-3
	161	Extensively	>5	cl	150-200	100-150	
	162,	Mod well	2-5	Cl	<50-150	100->150	
	185	well	>5	ls	<50-150	100-150	
II	220	Impr.	>5	Cl	<50-150	25-150	1-3
	223	Mod well	>5	cl	<50-150	100-150	
IV	133	Poor	2-5	Rocky	150-200	>150	1-3

Drainage

Mod. = Moderately
S.w.exc = Some what excessive
Impr = Imperfect

Texture

s = sandy
scl = sandy-clay-loam
ls = loamy-sand
sl = sandy-loam
c = clay
cl = clay loam

(*) Soil association according to NBSS Publication No.46 1997

(**) Per 1 m of soil depth if the soil is shallower.

Table 2.10.3 Land Classification

Type	Unit	Capability	Irrigability	Rice	Groundnuts	Cotton	Sugarcane
	195	II s	3s	NR	S2	S3	NR
I	196	II s	3d	NR	S3	S3	NR
	197	II s	3d	NR	S2	S3	NR
	145	II s	2s	NR	S3	S3	NR
II	148	IIes	2d	NR	S2	S2	NR
	161	IIs	2d	NR	S3	S3	
	162,	IIIs	2s	S2	S2-S3	S1	S2
III	185	IIIs	2s	S2	S2-S3	S1	S2
	220	II s	2d	S1-S2	S2-S3	S2	S2

	223	IIs	2d	S1-S2	S2-S3	S2	S2
IV	133	IIIs-IIs	3s-2d	S3	NR	NR	S3

NR= Non –relevant. S= Suitability.

The land capability classes II & III are good and moderately good cultiviable respectively, and the corresponding s and e denote water holing capacity(fertility) & drainage predominant limitations for sustained use under irrigation respectively and the corresponding s and d denote the soil fertility and drainage predominant limitations. The crop suitability classes S1,S2 and S3 denote high, moderate and marginal suitability for the crop under consideration. NR denote land non-relevant.

Based on the soil properties and their classification the Basin soils were grouped for irrigation planning purposes, into 5 major groups denoted Type-I to Type-V. The intention is to determine uniform cropping patterns which would be associated to the soil types, mainly for the assessment of future scenarios. The soil types are described as follows:

Type-I soils. They are mostly with medium texture, well and moderately well drained, mostly moderately deep to deep, mostly with 1-3 % slope and with none to various degrees of erosion problems. These soils are classified for irrigation mainly as 3s & 3d, for land capability as II to IV, and for crop suitability: rice – NR, sugarcane NR, groundnuts – S2 and S3 and cotton – S1 to S3. The soils are irrigable and suitable for crops like groundnuts, cotton, pulses, millets, maize, sorghum, vegetables and tree crops.

Type-II soils. They are of fine texture, imperfectly drained, moderately deep to deep, with 1-3% slope, with none to moderate erosion problems. These soils are classified for irrigation as 2s, 2d, 3s & 3d, for land capability as II, and for crop suitability: rice – NR, sugarcane NR, groundnuts – S3 and cotton – mainly S1 and some S3. The soils are irrigable and suitable for field crops relatively tolerant to imperfect drainage such as cotton, sorghum and some fodder crops. In spite of the above mentioned NR classification for sugarcane it can be concluded that in the future

with improved irrigation methods and systems, Type-II soils with lower slopes, could also be cultivated by sugarcane.

Type-III soil. They are mostly of fine texture, mostly imperfectly drained, moderately deep to deep, mostly with 1-3 % slope, with none to moderate erosion problems. These soils are classified for irrigation mainly as 2d and 2s, for land capability as II & III, and for crop suitability: rice – mainly S2, sugarcane – mainly S2, groundnuts – mainly S3 and cotton – mainly S2. Type-III soils are irrigable and suitable to rice and sugarcane and also to relatively tolerant to imperfect drainage other crops such as cotton, sorghum and some fodder crops.

Type-IV soils. They are similar to Type-III soils, however due to salinity and sodicity problems those soils could be sustainablly irrigated if corrective measures to those problems would be taken.

Type-V soils. Those soils include non-irrigable soils, such as rock outcrops, dunes, flooded areas, steep slopes, etc.

Based on this study and the corresponding soil map, the irrigable soils of the Nambiyar Basin were identified. The soils were classified for crop suitability purposes into four types:

Type 1 : Irrigable, fruits, vegetables and field crop soils
Type 2 : Irrigable crop soils
Type 3 : Irrigable rice soils
Type 4 : Non-Irrigable soils

The main properties for this classifications are summarized in Table 2.10.2 and the interpretative classifications for land capability for crop production, irrigability and suitability for rice, sugarcane, groundnuts and cotton are given in Table 2.8.3. Based on the soil properties and their classification the Basin irrigable soils could be grouped for planning purposes into major soil-crop suitability groups denoted Type-1, Type-2 and Type-3. Type-1 soils are coarse and medium texture, well drained, medium depth and

1-3 % slope and are suitable for crops like groundnuts, cotton, pulses, millets, maize, sorghum, and vegetables. Type-2 soils are mostly of medium texture, well to moderately well drained, deep and flat and are suitable to various degrees to all kind of crops. Type-3 soils are mostly of fine texture, some of them are imperfectly drained, deep and flat and are suitable mainly for crops such as rice, sugarcane and some fodder crops. The rest non-irrigable soils are defined as Type-4.

2.11. GEOPHYSICS

Determination of aquifer depth

2.11.1. Introduction

Different techniques are in use for targeting groundwater and identification of aquifers in the heterogeneous hard rock terrains. In view of this an integrated approach of geophysical survey and correlating hydrogeological data already collected, were used for interpreting the different lithological units. Further borehole drilling and litholog data are also considered to delineate the thickness of the aquifer. However, identification of deep water bearing fracture horizons below 80 – 100 m is a challenging one due to heterogeneous nature of fracture in hard rock. Hence, interpreting the VES data and determining the subsurface hydrogeological conditions in the deeper horizon remain uncertain particularly in the coastal sedimentary tract due to the occurrence of poor quality water.

2.11.2.Methodology

The extent of Nambiyar river basin, is approximately 2019 sq.km. The database in the simulation of aquifer geometry of this basin consists of 95 borehole litholog data, which are shown, in plate NAM-15. The data of Vertical Electrical Soundings (VES) conducted in this basin area are analysed and appropriately used in order to have better interpolation. Geologically, the basin is traversed by hard rock such as garnetiferous biotite gneiss, garnetiferous sillimanite gneiss and charnockite. Sedimentary rock represented by sandstone, limestone and alluvium (sand/clay) occurs on the eastern part of the basin. Based on the borehole litholog data the aquifers are distinguished as alluvium/sandstone/limestone, weathered, fractured and jointed rock aquifers. The information thus obtained is used as attributes in the GIS environment for the creation of thematic map showing the spatial distribution of depth to bedrock of the basin.

2.11.3.Depth to bedrock

The spatial extent of depth to bedrock of this basin is shown as surface plot in plate NAM-16. The depth to bedrock is grouped into three general categories viz. 1. depth to bedrock at shallow depth (8-25 m bgl), 2. at intermediate depth (25-40 m bgl) and 3. at deeper depth (40-160 m bgl). This theme gives an understanding of the basin, about aquifer thickness at different depth. Shallow (dark red) aquifer made up of weathered rock exists in the central and northern parts of the basin. In this area the depth to bedrock is found to occur between 8 and 25 m. In the central, northern and western parts of the basin, the depth to bedrock is found to occur between 25 and 40 m from ground level. In the entire eastern part of the basin and also some of the western parts of the basin, the depth to bedrock is extending 40 to 160 m from ground level.

In general, based on the analysis of data, it is inferred that the weathered rock aquifer of this basin exists upto a depth of 8 to 25 m below ground level; fractured rock aquifer occurs upto a depth of 25 to 60 m below ground level. In sedimentary region the depth to bedrock exists at a depth of 40 to 160 m below ground level. The weathering / fracturing or both seems to be more in the gneissic region than charnockitic region, may be due to weak zones resulting from fault zone, shears zones, folds, lineaments etc.

In the regions where the depth to bedrock is shallow, dugwell would be the better structure for augmenting groundwater especially in the hard rock regions. In the areas where the depth to bedrock is at moderate or at deeper depth, borewell would be the suitable structure for tapping groundwater. This is common for both sedimentary and hard rock areas.

2.11.4. Conclusion

The borehole litholog data of the borewells drilled in Nambiyar basin area are analysed. The weathered zone / the shallow aquifer is extending from 8 to 25 m from ground level on the central and northern parts of the basin as isolated pockets. The depth to bedrock is extending from 25 to 40 m from ground level in the central, western and northern part of the basin in the areas in and around Nanguneri, Tirukurangudi, Vadakkuvalliyur, Kudankulam and west of Tisaiyanvilai. In these areas fractured rock aquifer exists. The area falling in and around as well as in between Panaikkudi and Radhapuram in the western part of the basin comprises deep fracture zones existing up to a depth of 40 to 160m bgl. The areas in and around

Sathankulam, Tisaiyanvilai and Kulasekarappattinam, the sedimentary aquifer made up of alluvium exists up to a depth of 40 to 160 m below ground level. The aquifer of this region may be productive zones where it is saturated with potable groundwater.

2.12 DEMOGRAPHIC AND SOCIAL CHARACTERISTICS

Population trend and population dynamics are important indicators of future water requirement. So also, the social characteristics of the population such as literacy level, level of housing, electrification, in house facilities, urbanisation trend, are having indirect bearing on water planning. Land utilisation pattern, size of land holdings, nature of agricultural employment and industrial employment also would reflect on the water requirement of the population. An analysis of all these parameters, with reference to Nambiyar river basin is described hereunder.

2.12.1 Population Size: Urban and Rural

The Nambiyar basin covers three districts in parts namely Tirunelveli, Thoothukudi and Kanyakumari. The rural population for Tirunelveli, Thoothukudi and Kanyakumari districts are 0.300 Million, 0.116 Million and 0.017 Million respectively. The urban population for Tirunelveli, Thoothukudi and Kanyakumari districts are 0.127 Million, 0.042 Million and 0.077 Million respectively. The total Urban and Rural population is 0.433Million and 0.246 Million respectively.The basin is divided into three sub basins. The sub basin wise population is given below.

The Urban and Rural Population as per census 2001 (in Million)

Sl. No.	Name of the Sub basin	Urban Population	Rural Population	Total Population
1	Hanumanadhi	0.069	0.127	0.196
2	Nambiyar	0.084	0.103	0.187
3	Karamaniyar	0.093	0.203	0.296
TOTAL		0.246	0.433	0.679

2.12.2 Population Density

The population density is the highest in Hanumanadhi (385 Persons per sq.km) and the lowest in Nambiyar (310 Persons per sq.km) as shown in the following table. The average population density for the entire basin is 337 persons / sq.km which is well below the State average of 480 persons / sq.km

Sl.No	Name of the sub basin	Area (Sq.km)	Total Population in Million	Density Persons/sq.km
1	Hanumanadhi	510.179	0.196	385
2	Nambiyar	604.324	0.187	310
3	Karamaniyar	903.937	0.296	327
Average population density for the basin				337

2. 12. 3 Population by Sex

Sex wise distribution of population for the entire basin is given below

Name of the Basin		**Male**	**%**	**Female**	**%**
Nambiyar	Rural	206932	51	218318	52
	Urban	196899	49	202136	48
	Total	403831	100	420454	100

The basin wise Male – Female sex ratio is given below:

Sl.No.	**Basin**	**Sex ratio**
1.	Nambiyar	1041 Female / 1000 Male

2. 12. 4 Literacy Level

The Literacy level of the population is also a vital social indicator of the standard of living and development status. An analysis of the literacy rate of the Nambiyar basin is given below:

Sl.No	**Basin**	**Literacy Population in Million**		
		Male	**Female**	**Total**
1	Nambiyar	316524	273721	590244

2. 12. 5 Employment

Agriculture is the main occupation of the population in the Nambiyar Basin. However, certain trends in the migration of agricultural labourers to other industries have been noticed of late and this has led to a shortage of labour in agricultural sector and consequent reduction in farm outputs.

2. 12. 6 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 life expectancy at birth is higher for both males and females in Tamil Nadu in comparison with All India Statistics.

2. 12. 7 Family Welfare & Impact of Family Planning

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 favoured method, followed by the use of IUD (Intra – Uterine Device).

The Tamil Nadu Government has adopted various propaganda methods to spread family planning messages. Small family norm, "We two, Ours One" is given wide publicity through posters and other media.

To reduce Maternal Mortality Rate (MMR), parental, natal and postnatal advice on immunization, diet care and health check-up is given. The message on the care of the mother during lactation period, the importance of cholesterol for the baby, baby care etc. is spread through pamphlets in Tamil Female literacy and guaranteeing the survival of the girl child is insisted. "Male and Female child being equal" messages are promoted, along with the message that the girl child also could be given the right to light the funeral pyre.

Zero growth rate is aimed by Tamil Nadu by 2010. It is expected that population would stabilize at 7.2 crores by 2010. With this aim in mind, parity-wise deliveries are being monitored in the State. The present (9^{th} Oct 2003) 3 rd order deliveries amount to 16.5% and the 4^{th} order deliveries amount to 8.0%.

2. 12. 8 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.

2. 12. 9 Industrial employment

The basic objectives of the industrial policy pursued by the State Government are: massive increase in employment opportunities, utilisation of local resources, explorations of new sectors hitherto untapped and development of backward areas. In accordance with this policy, promotion of large and medium scale industries as well as small-scale industries have been aimed at the districts of the Tamil Nadu, in collaboration with Tamil Nadu Industrial Investment Corporation (TIIC), Tamil Nadu Industrial Development Corporation (TIDCO) and Tamil Nadu Corporation for Industrial Infrastructure Development (TACID).

The State's new industrial policy accords the highest priority to infrastructure development through TACID. Besides identifying and rectifying the existing gap in the infrastructure, TACID will also have a window for building up soft infrastructure such as hospitals, schools, etc. in areas newly industrialized.

There are about 15 large and Medium industries in this basin at present. It has been estimated that the projected number of large and medium industries during 2010 and 2020 will be 19 and 31 respectively.

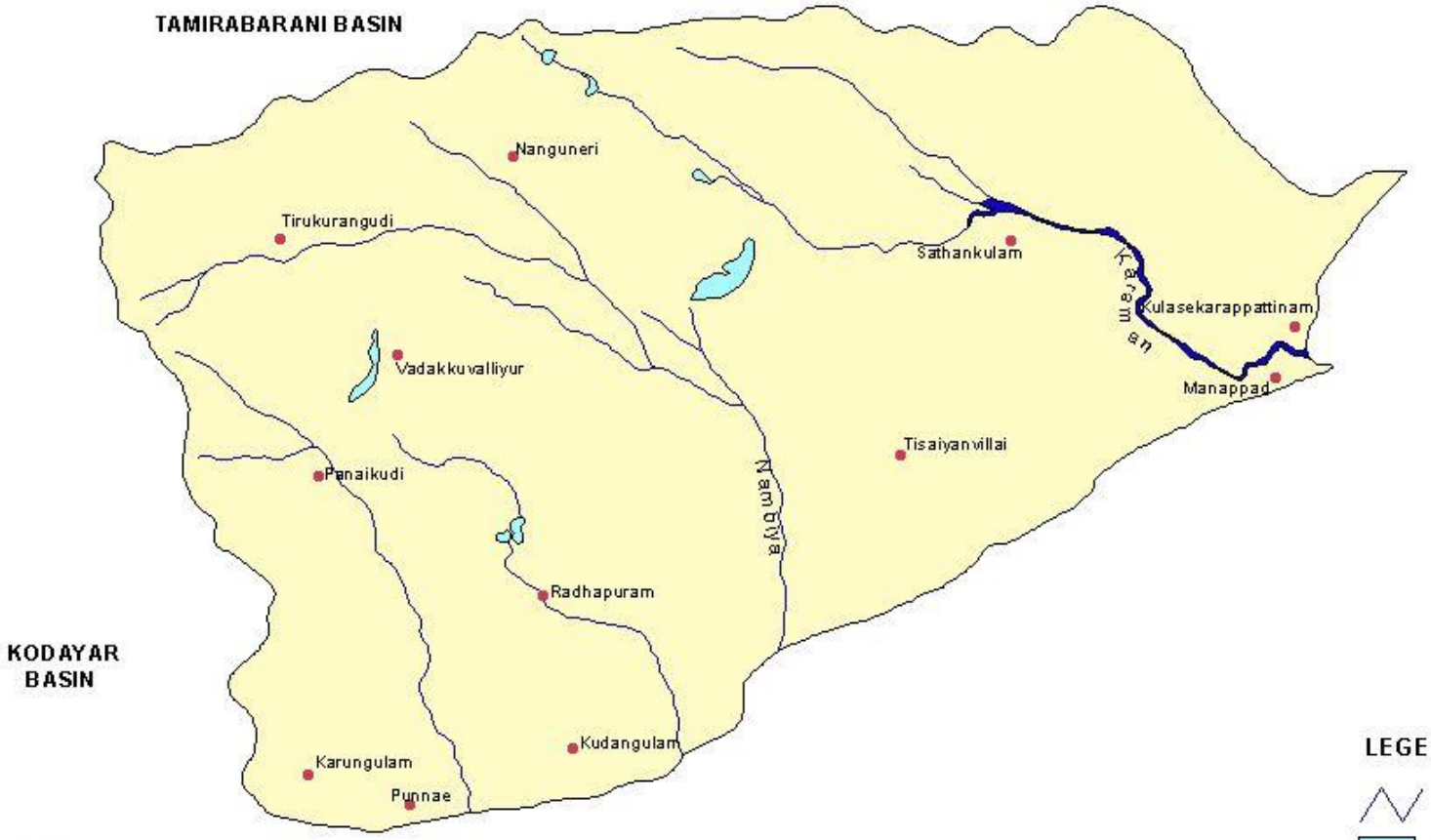
There are about 5413 small scale industries available in the basin. The projected number of small scale industries during the years 2010 and 2020 will be 6712 and 11043 respectively.

2. 12.10 Agro- based Industries

These industries provide employment opportunities to the agricultural labourers during the off-season and thereby enhance their income to a certain extent.

NAMBIYAR RIVER BASIN
BASE MAP

Plate No: NAM - 02



LEGEND

- Streams
- Tank
- River
- Basin Boundary

SCALE

4 0 4 Kilometers

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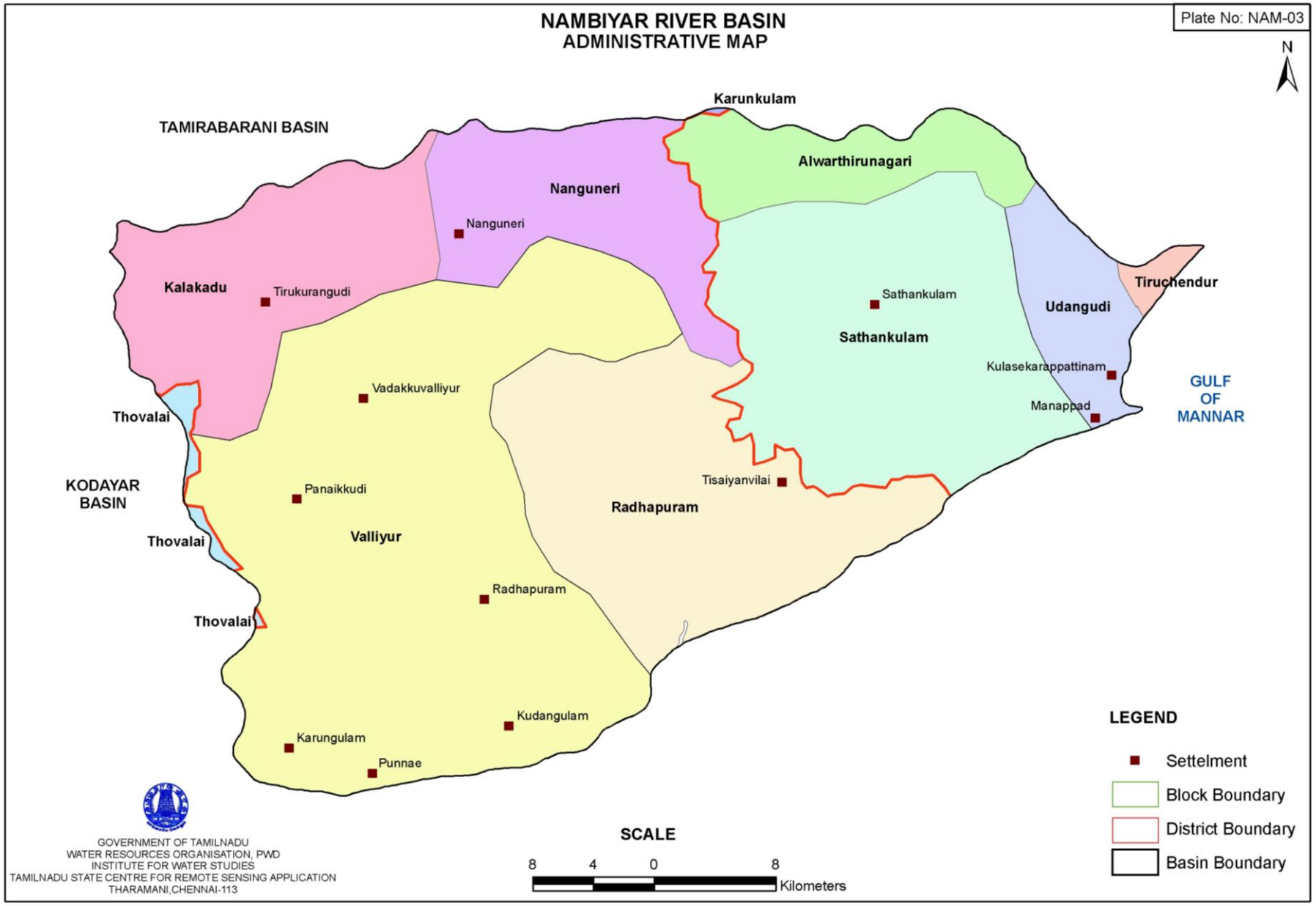
NAMBIYAR RIVER BASIN
ADMINISTRATIVE MAP

Plate No: NAM-03



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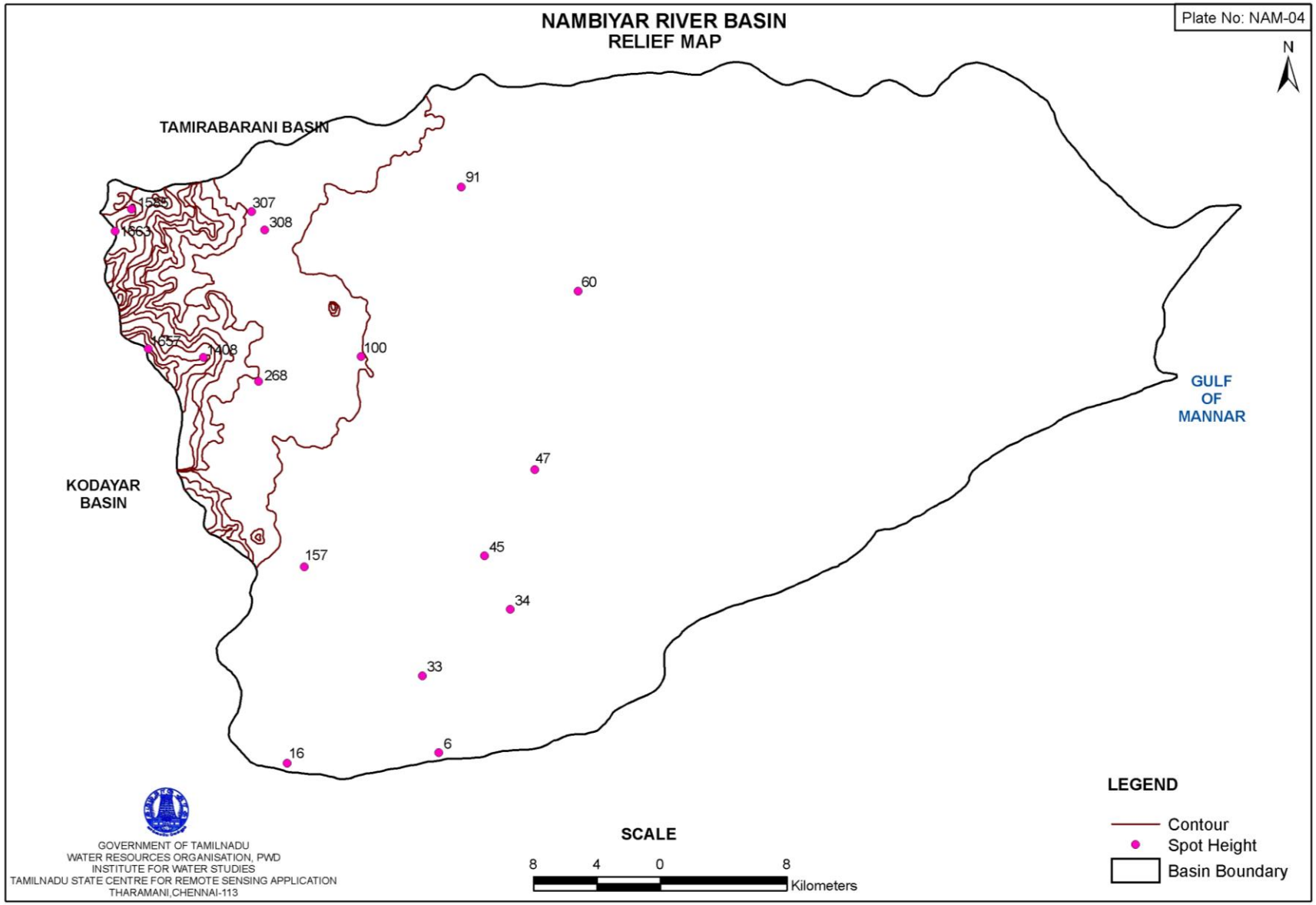
NAMBIYAR RIVER BASIN
RELIEF MAP
Plate No: NAM-04
N
TAMIRABARANI BASIN
KODAYAR BASIN
GULF OF MANNAR
91
307
308
1563
60
100
1408
268
47
157
45
34
33
16
6
LEGEND
Contour
Spot Height
Basin Boundary
SCALE
8 4 0 8
Kilometers
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NAMBIYAR RIVER BASIN
DRAINAGE MAP

Plate No: NAM-05

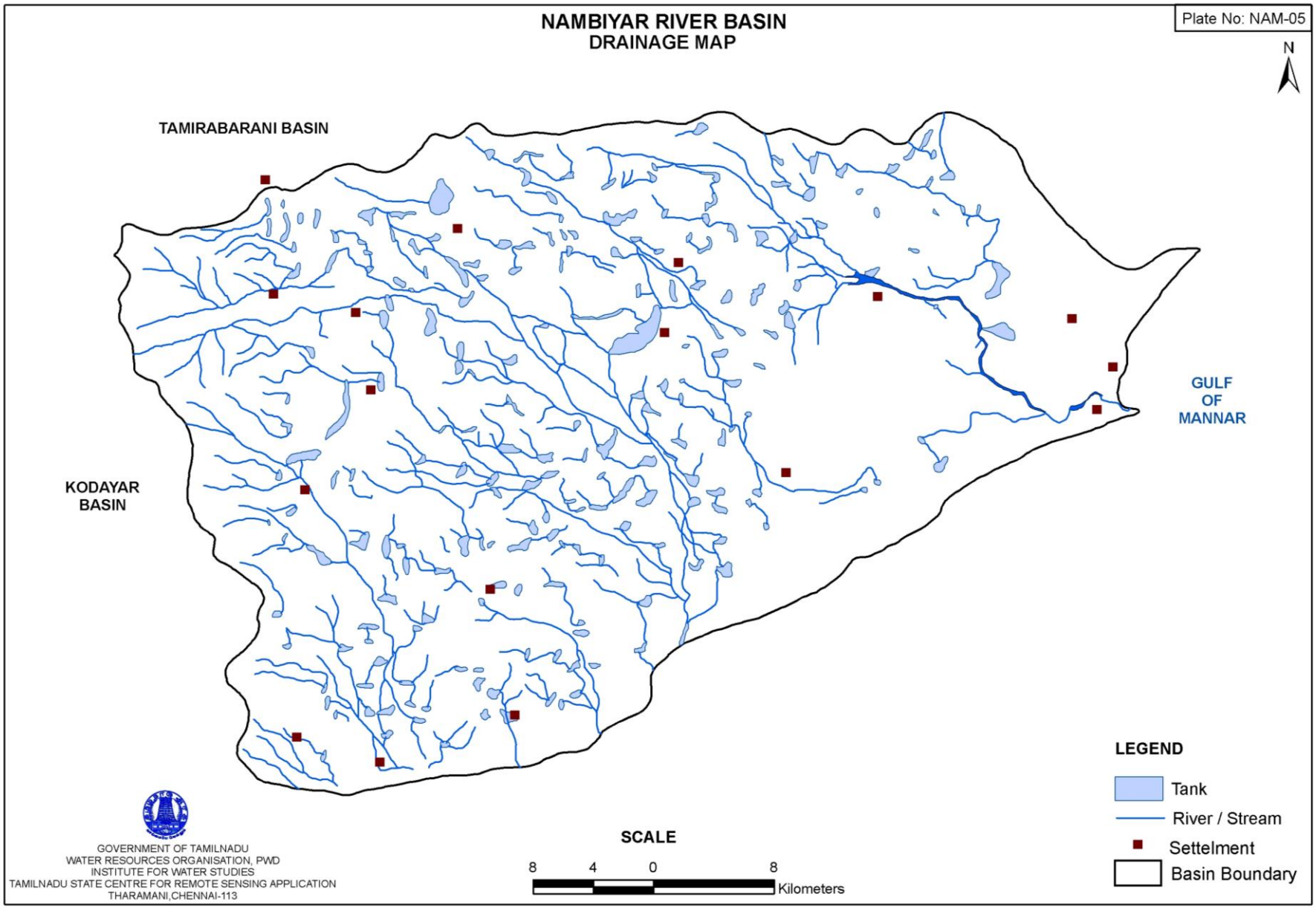

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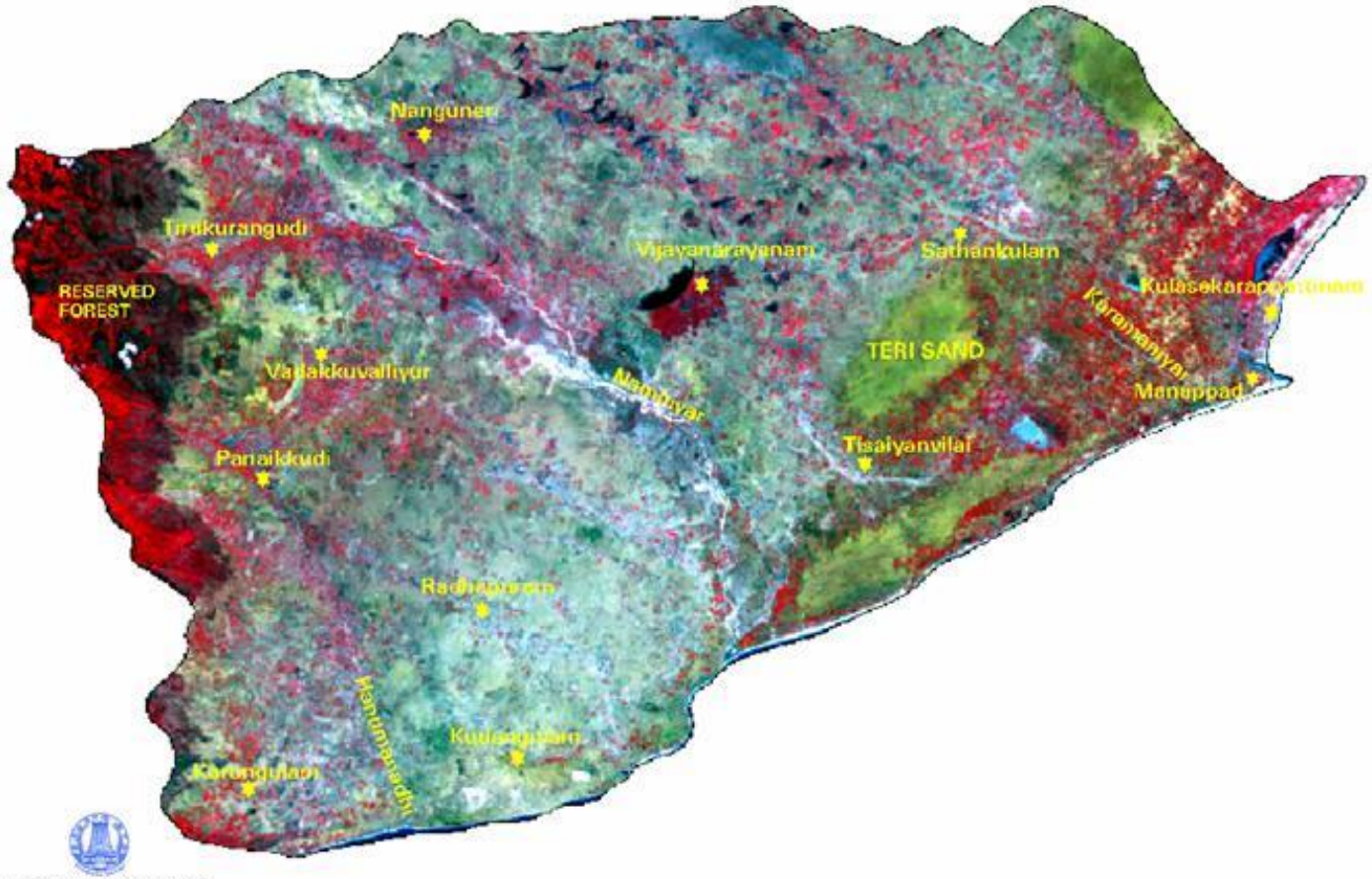
Plate No.: NAM - 06

NAMBIYAR RIVER BASIN
SATELLITE IMAGE MAP



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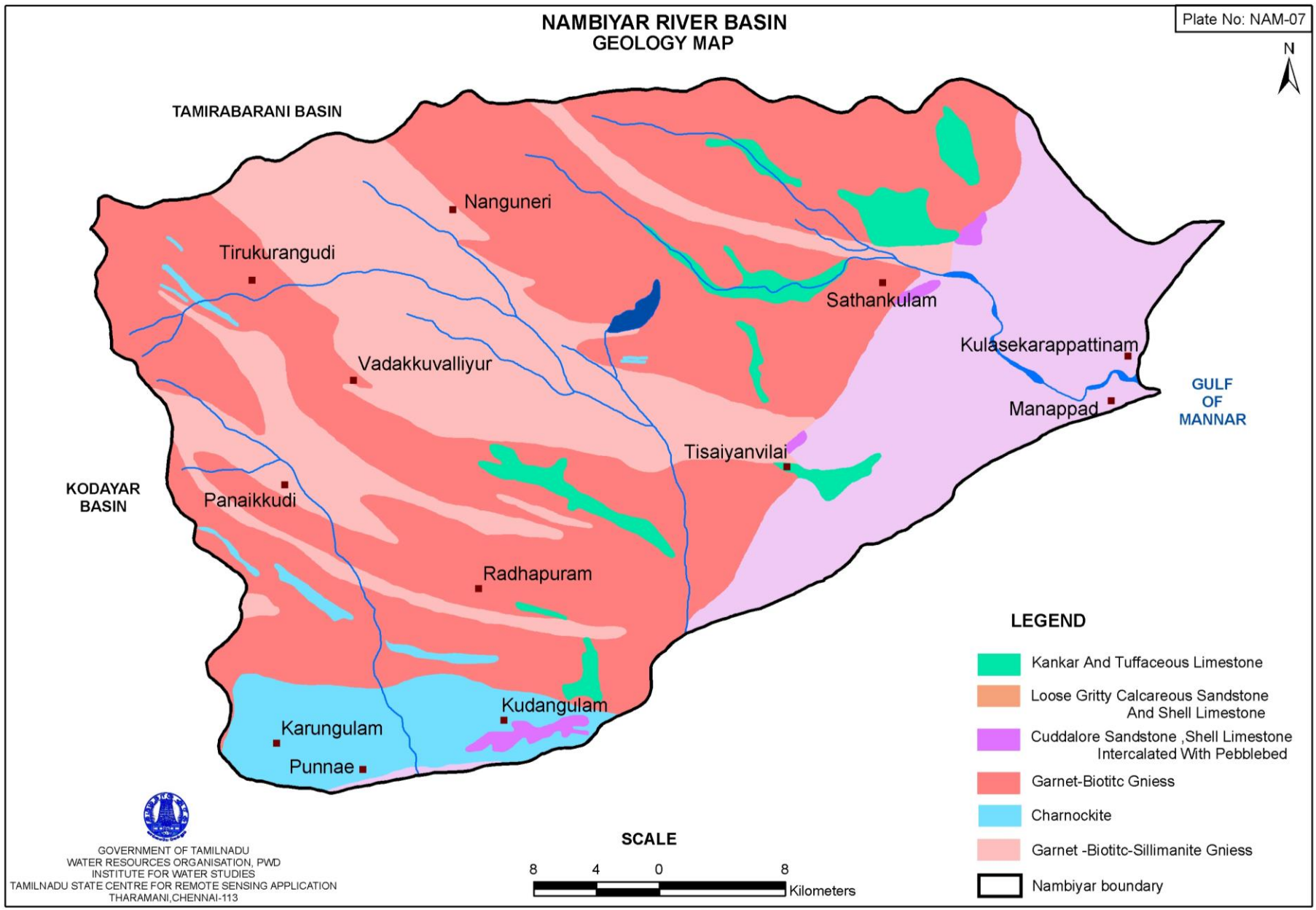
THARAMANI, CHENNAI – 600 113.

Scale
10 0 Kilometers

IRS ID LISS III MAR 2004

NAMBIYAR RIVER BASIN
GEOLOGY MAP

Plate No: NAM-07



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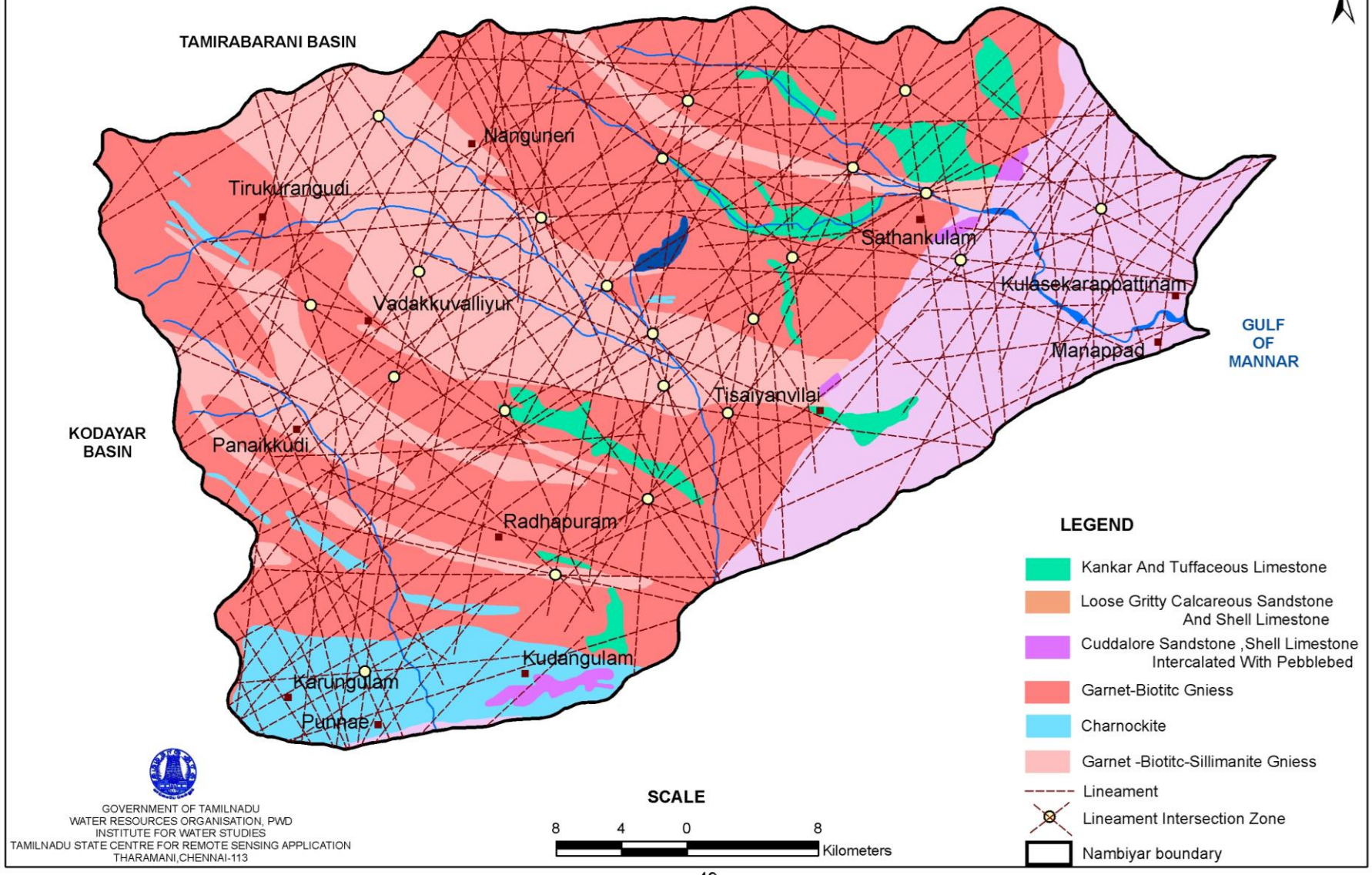
NAMBIYAR RIVER BASIN
GEOLOGY WITH LINEAMENT MAP

Plate No: NAM-08



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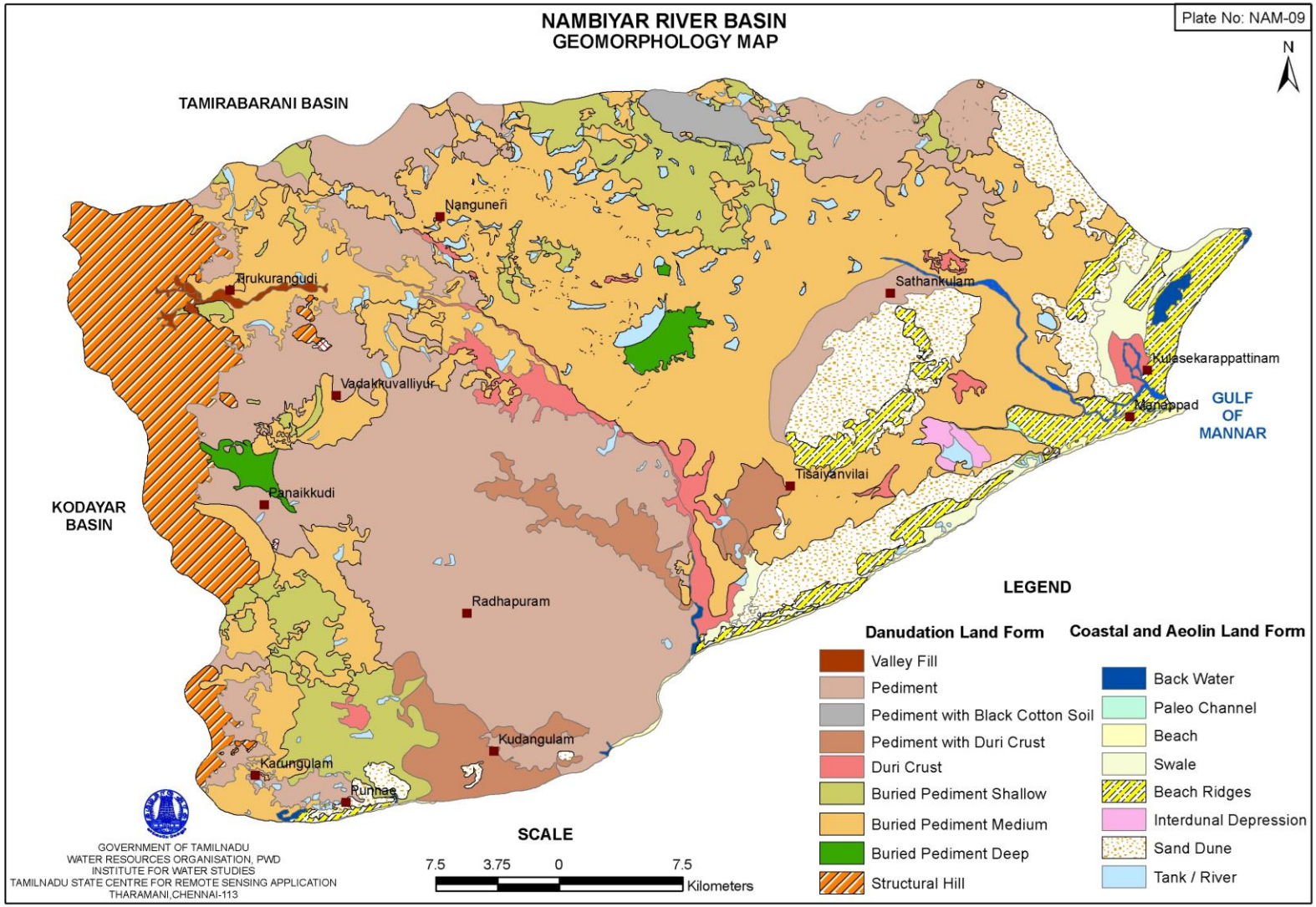
NAMBIYAR RIVER BASIN
GEOMORPHOLOGY MAP
Plate No: NAM-09
N
TAMIRABARANI BASIN
Nanguneri
Thrukurangudi
Vadakkuvalliyur
Panaikkudi
KODAYAR BASIN
Radhapuram
Kudangulam
Karungulam
Punnai
Sathankulam
Kulasekarappattinam
Manappad
GULF OF MANNAR
Tisaiyanvilai
LEGEND
Danudation Land Form
Valley Fill
Pediment
Pediment with Black Cotton Soil
Pediment with Duri Crust
Duri Crust
Buried Pediment Shallow
Buried Pediment Medium
Buried Pediment Deep
Structural Hill
Coastal and Aeolin Land Form
Back Water
Paleo Channel
Beach
Swale
Beach Ridges
Interdunal Depression
Sand Dune
Tank / River
SCALE
7.5 3.75 0 7.5
Kilometers
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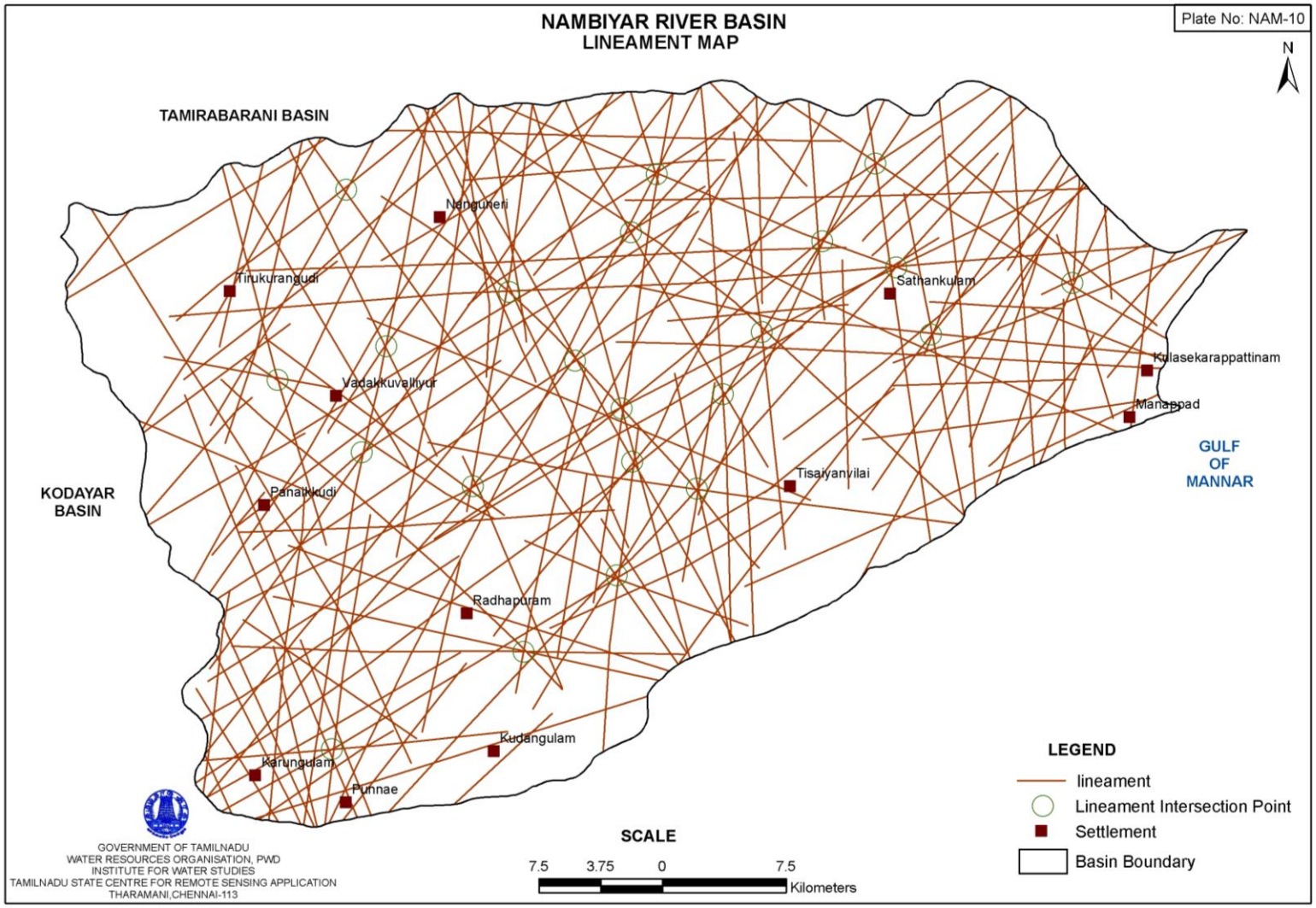
NAMBIYAR RIVER BASIN
LINEAMENT MAP
Plate No: NAM-10
N
TAMIRABARANI BASIN
Nanguneri
Tirukurangudi
Sathankulam
Kulasekarappattinam
Vadakkuvalliyur
Manappad
GULF
OF
MANNAR
KODAYAR
BASIN
Tisaiyanvilai
Panaikkudi
Radhapuram
Kudangulam
Karungulam
Punnae
LEGEND
lineament
Lineament Intersection Point
Settlement
Basin Boundary
SCALE
7.5 3.75 0 7.5
Kilometers
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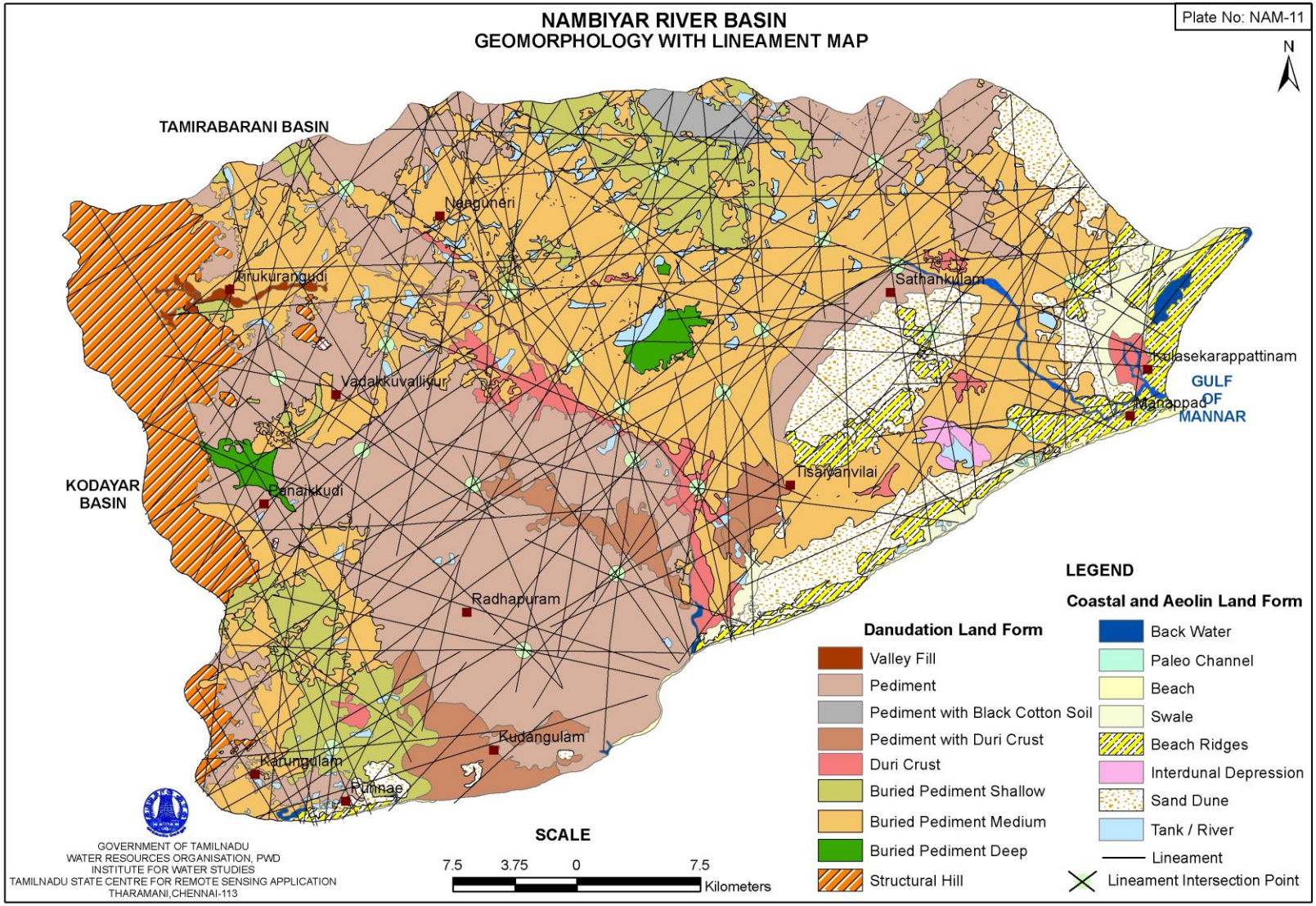
NAMBIYAR RIVER BASIN
GEOMORPHOLOGY WITH LINEAMENT MAP
Plate No: NAM-11
N
TAMIRABARANI BASIN
KODAYAR BASIN
Nanguneri
Tirukurangudi
Vadakkuvalliyur
Panaikkudi
Radhapuram
Kudangulam
Karungulam
Punnae
Sathankulam
Kulasekarappattinam
Manappad
GULF OF MANNAR
Tisaiyanvilai
LEGEND
Danudation Land Form
Valley Fill
Pediment
Pediment with Black Cotton Soil
Pediment with Duri Crust
Duri Crust
Buried Pediment Shallow
Buried Pediment Medium
Buried Pediment Deep
Structural Hill
Coastal and Aeolin Land Form
Back Water
Paleo Channel
Beach
Swale
Beach Ridges
Interdunal Depression
Sand Dune
Tank / River
Lineament
Lineament Intersection Point
SCALE
7.5 3.75 0 7.5
Kilometers
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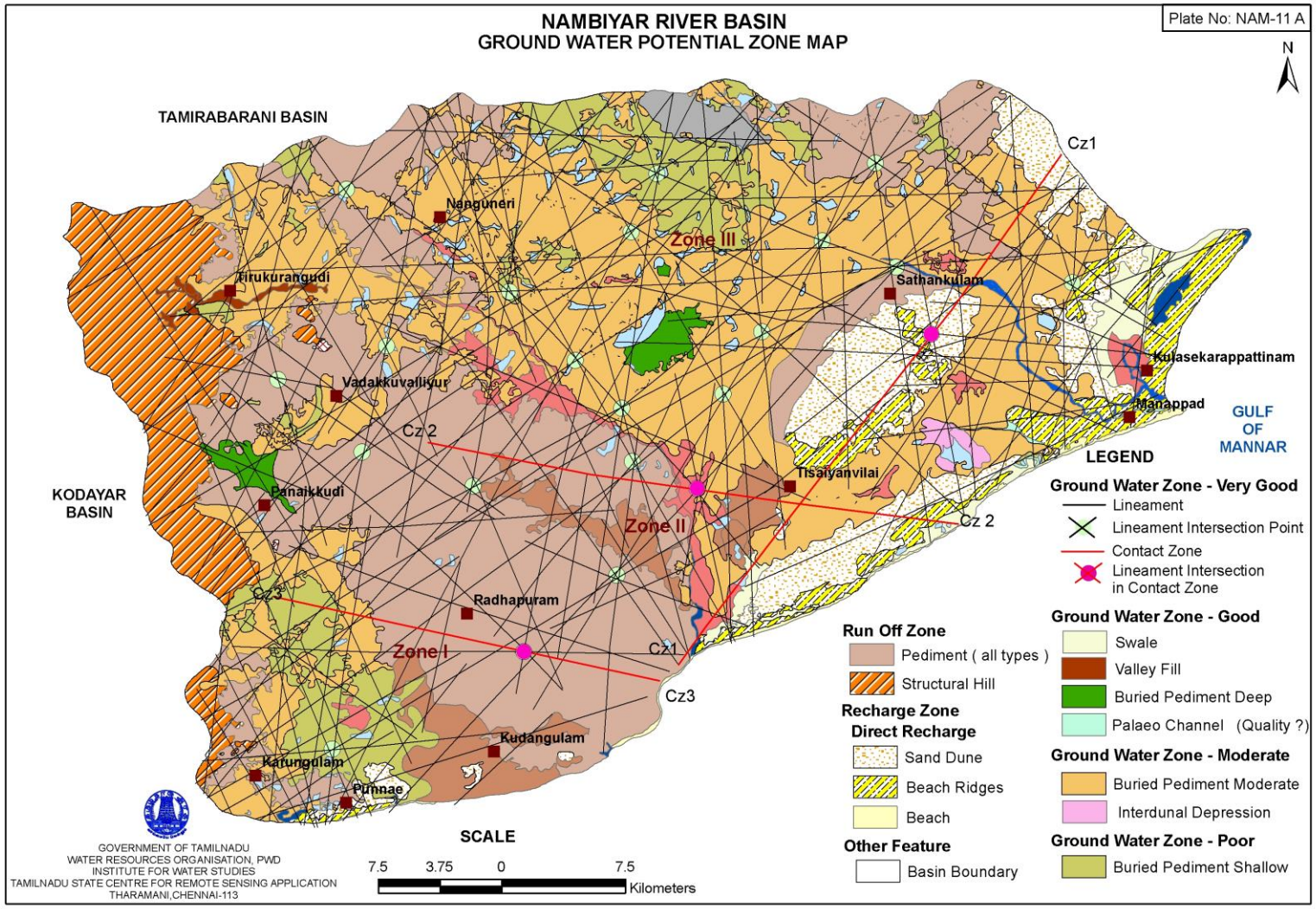
NAMBIYAR RIVER BASIN
GROUND WATER POTENTIAL ZONE MAP
Plate No: NAM-11 A
N
TAMIRABARANI BASIN
KODAYAR BASIN
GULF OF MANNAR
Cz1
Cz 2
Cz3
Zone I
Zone II
Zone III
Nanguneri
Tirukurangudi
Vadakkuvalliyur
Panaikkudi
Radhapuram
Kudangulam
Kattungulam
Punnae
Sathankulam
Kulasekarappattinam
Manappad
Tisaiyanvilai
LEGEND
Ground Water Zone - Very Good
Lineament
Lineament Intersection Point
Contact Zone
Lineament Intersection in Contact Zone
Ground Water Zone - Good
Swale
Valley Fill
Buried Pediment Deep
Palaeo Channel (Quality ?)
Ground Water Zone - Moderate
Buried Pediment Moderate
Interdunal Depression
Ground Water Zone - Poor
Buried Pediment Shallow
Run Off Zone
Pediment (all types)
Structural Hill
Recharge Zone
Direct Recharge
Sand Dune
Beach Ridges
Beach
Other Feature
Basin Boundary
SCALE
7.5 3.75 0 7.5
Kilometers
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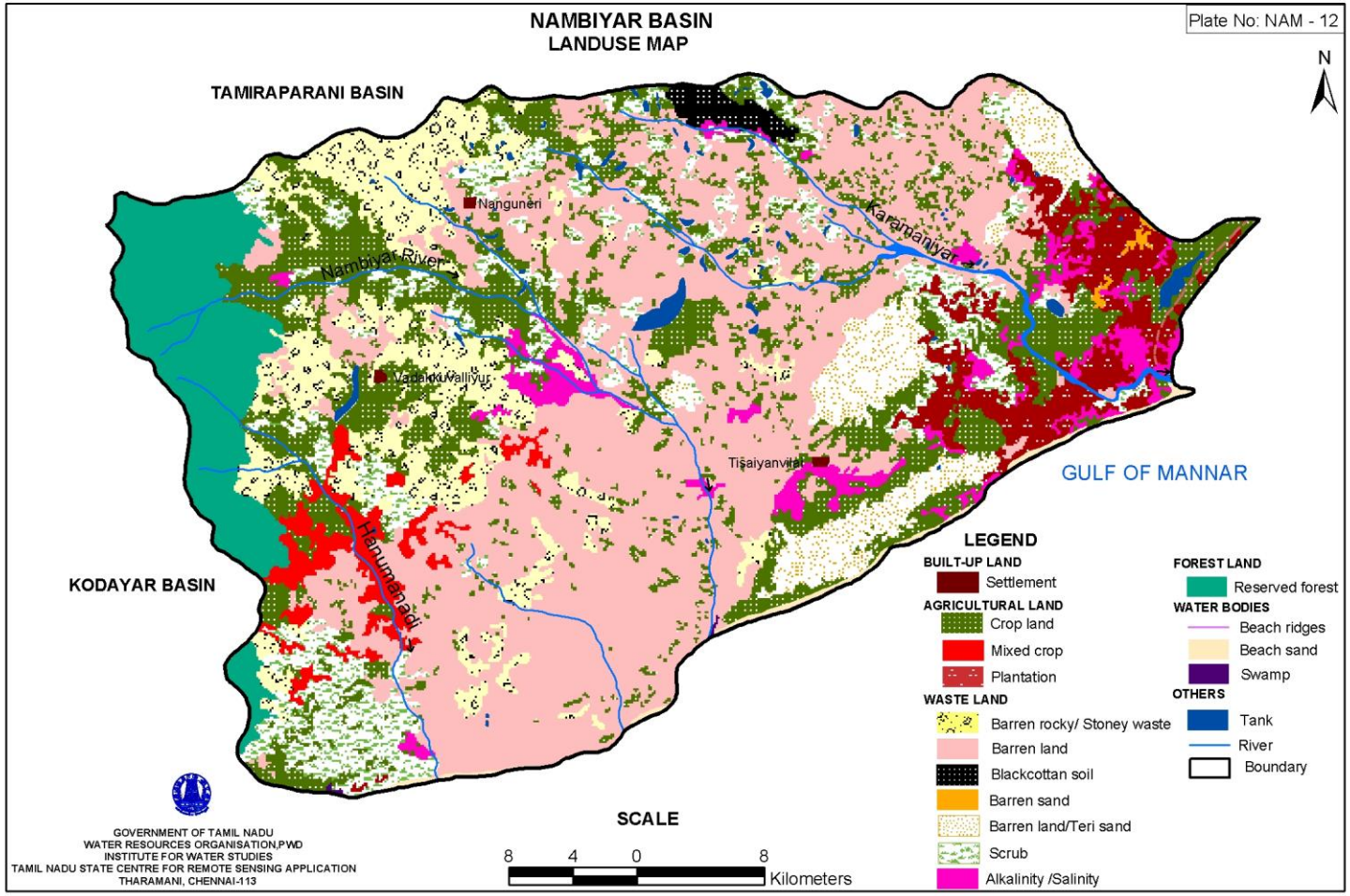
NAMBIYAR BASIN
LANDUSE MAP
Plate No: NAM - 12
N
TAMIRAPARANI BASIN
Nanguneri
Nambiyar River
Karanganiyar
Vadakkuvalliyur
Tisaiyanvilai
GULF OF MANNAR
KODAYAR BASIN
Hanumanadi
LEGEND
BUILT-UP LAND
Settlement
AGRICULTURAL LAND
Crop land
Mixed crop
Plantation
WASTE LAND
Barren rocky/ Stoney waste
Barren land
Blackcottan soil
Barren sand
Barren land/Teri sand
Scrub
Alkalinity /Salinity
FOREST LAND
Reserved forest
WATER BODIES
Beach ridges
Beach sand
Swamp
OTHERS
Tank
River
Boundary
SCALE
8 4 0 8
Kilometers
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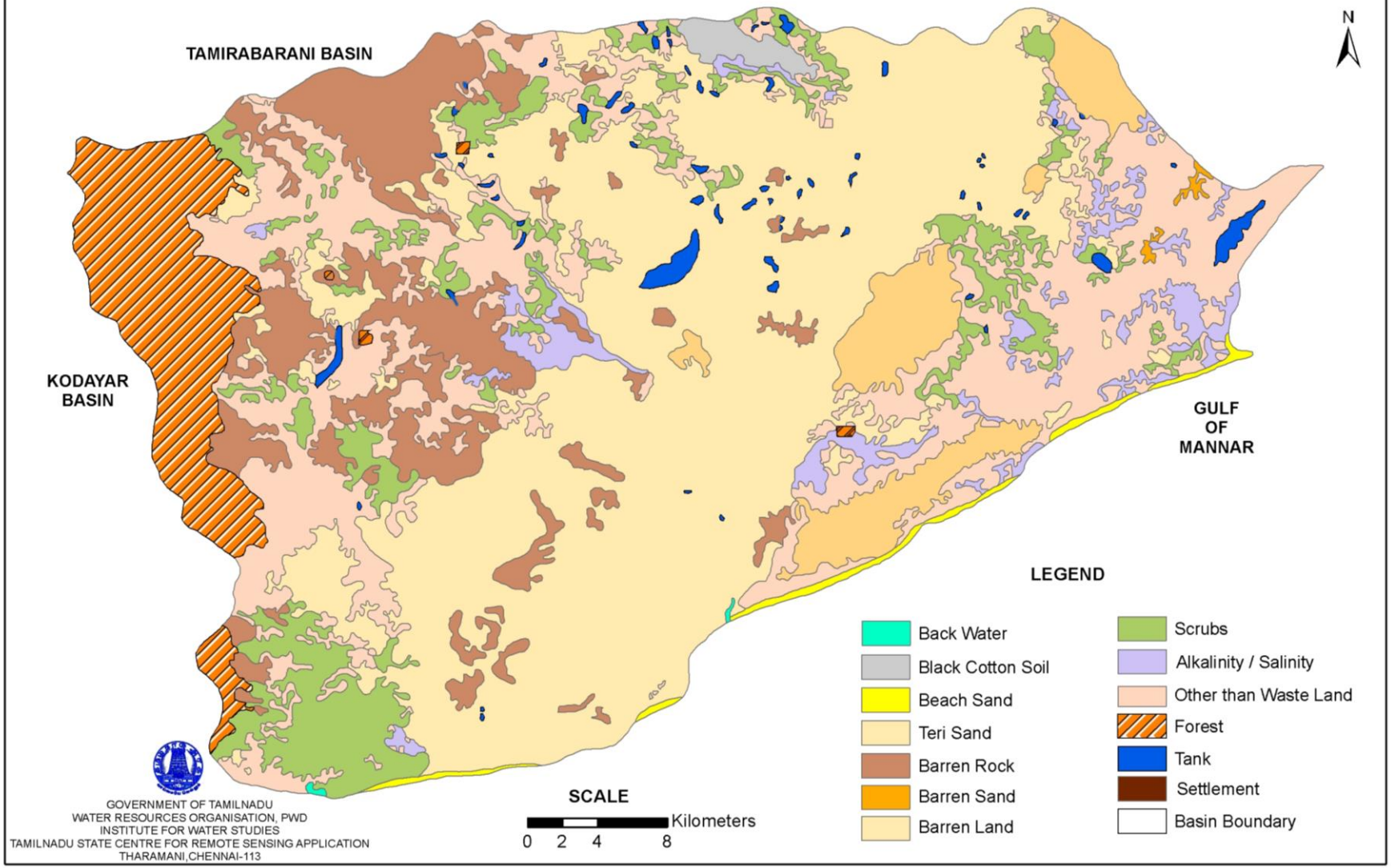
NAMBIYAR RIVER BASIN
WASTE LAND MAP

Plate No : IAM - 13



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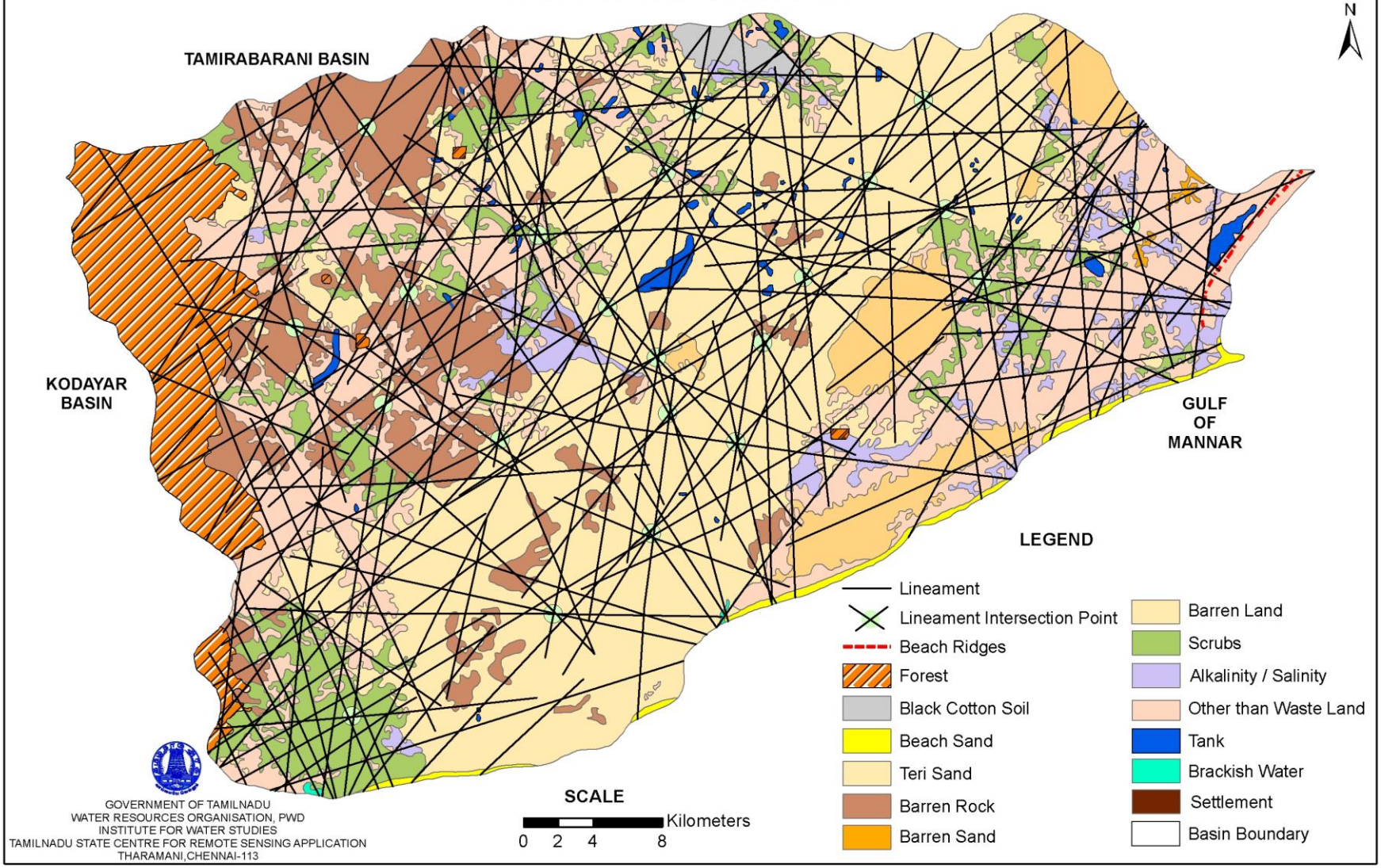
NAMBIYAR RIVER BASIN

WASTE LAND WITH LINEAMENT MAP

Plate No : IAM - 14



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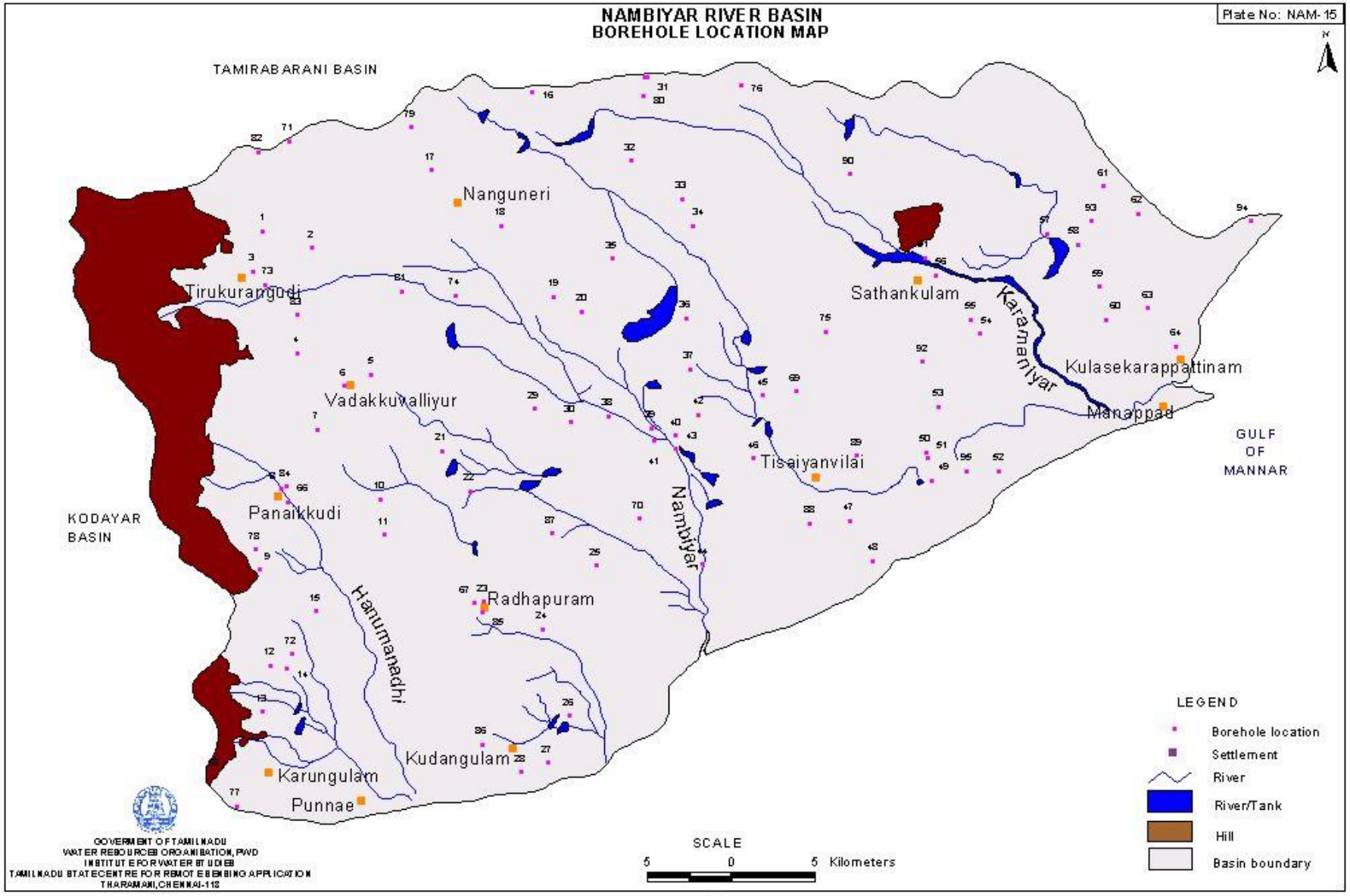
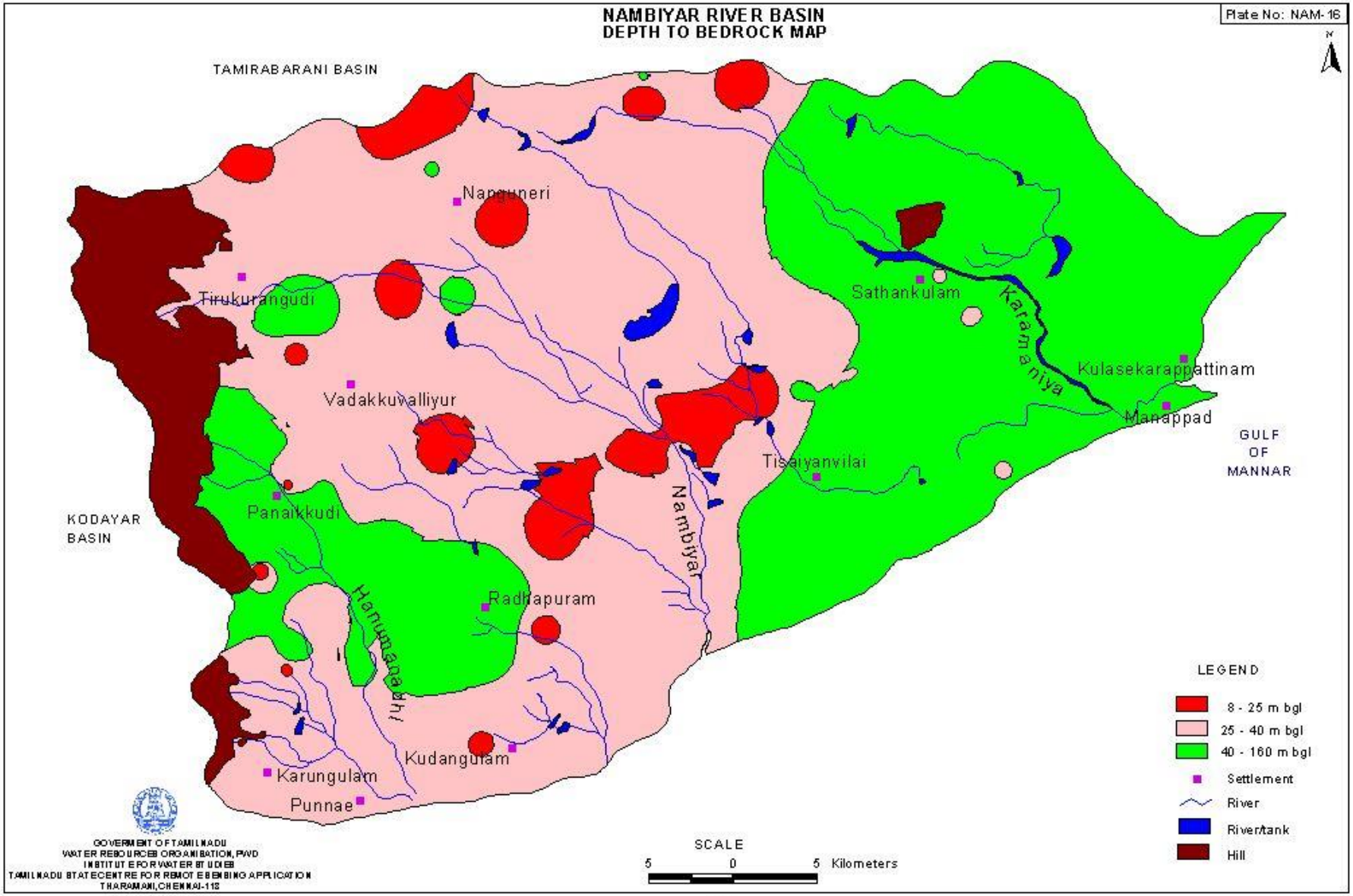
TAMILNADU STATE CENTRE FOR REMOTE SENSING APPLICATION
THARAMANI,CHENNAI-113


NAMBIYAR RIVER BASIN
BOREHOLE LOCATION MAP
Plate No: NAM-15
TAMIRABARANI BASIN
KODAYAR BASIN
GULF OF MANNAR
Nanguneri
Tirukurangudi
Vadakkuvalliyur
Panaikkudi
Radhapuram
Karungulam
Punnae
Kudangulam
Sathankulam
Tisaiyanvilai
Kulasekarappattinam
Manappad
Hanumanadhi
Nambiyar
Karamaniyar
LEGEND
Borehole location
Settlement
River
River/Tank
Hill
Basin boundary
SCALE
5 0 5 Kilometers
GOVERMENT OF TAMILNADU
WATER REBOURCES ORGANISATION, PWD
INSTITUTE FOR WATER STUDIES
TAMILNADU STATE CENTRE FOR REMOTE SENSING APPLICATION
THARAMANI, CHENNAI-113


NAMBIYAR RIVER BASIN
DEPTH TO BEDROCK MAP
Plate No: NAM-16
TAMIRABARANI BASIN
Nanguneri
Tirukurangudi
Vadakkuvalliyur
Panaikkudi
KODAYAR
BASIN
Radhapuram
Hanumanadhi
Nambiyar
Kudangulam
Karungulam
Punnae
Sathankulam
Karamaniya
Kulasekarappattinam
Manappad
GULF
OF
MANNAR
Tisaiyanvilai
LEGEND
8 - 25 m bgl
25 - 40 m bgl
40 - 160 m bgl
Settlement
River
River/tank
Hill
SCALE
5 0 5 Kilometers
GOVERNMENT OF TAMILNADU
WATER RESOURCES ORGANISATION, PWD
INSTITUTE FOR WATER STUDIES
TAMILNADU STATE CENTRE FOR REMOTE SENSING APPLICATION
THARAMANI, CHENNAI-113

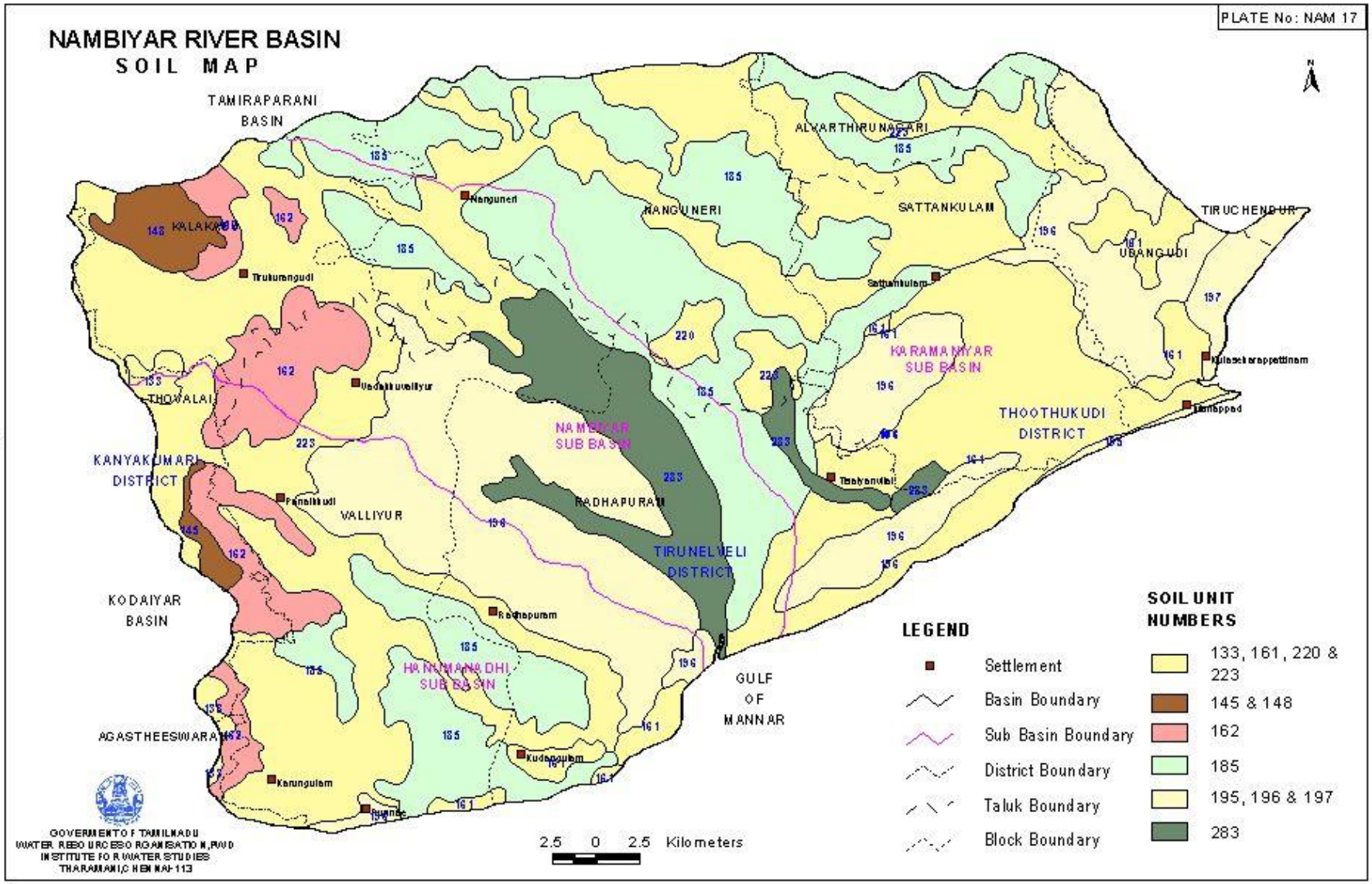


PLATE No: NAM 17
NAMBIYAR RIVER BASIN
SOIL MAP
TAMIRAPARANI BASIN
ALVARTHIRUNAGARI
NANGUNERI
SATTANKULAM
TIRUCHENDUR
UDANGUDI
KALAKAD
Thuluvangudi
Nanguneri
Sattankulam
Kulasekarappattinam
Tiruppad
KARAMANIYAR SUB BASIN
THOOTHUKUDI DISTRICT
THOVALAI
Udayathuvellyur
NAMBIYAR SUB BASIN
KANYAKUMARI DISTRICT
Thisayanvilai
Pansithudi
VALLIYUR
RADHAPURAM
TIRUNELVELI DISTRICT
KODAIYAR BASIN
Radhapuram
HANUMANADHI SUB BASIN
GULF OF MANNAR
AGASTHEESWARAM
Kudangulam
Kanyakumari
Kalkulam
LEGEND
Settlement
Basin Boundary
Sub Basin Boundary
District Boundary
Taluk Boundary
Block Boundary
SOIL UNIT NUMBERS
133, 161, 220 & 223
145 & 148
162
185
195, 196 & 197
283
2.5 0 2.5 Kilometers
GOVERNMENT OF TAMILNADU
WATER RESOURCES ORGANISATION, PWD
INSTITUTE FOR WATER STUDIES
THARAMANI, CHENNAI-113

CHAPTER – 3

HYDRO METEOROLOGICAL CHARACTERISTICS

CHAPTER – 3

HYDROMETEOROLOGICAL CHARACTERISTICS

3.1. GENERAL

For any water resources evaluation, planning, development and management studies, the details of the rainfall over the basin area as well as other hydrometeorological features are a pre-requisite. The basic factors, which influence agriculture are climatological features such as rainfall, temperature, humidity, wind speed, sunshine, evaporation etc..

Rainfall is the major input for the water resources in a basin and is a vital component to be studied in detail. Another important hydrometeorological parameter is evaporation. As Tamil Nadu falls in the tropical zone, (arid, semi-arid climatic regions) evaporation plays a major role in agriculture and the same has to be studied in detail.

The study now made on the hydrometeorological characteristics of the Nambiyar river basin includes analysis of rainfall, temperature, humidity, wind speed and sunshine. The study of the rainfall pattern, its distribution in time and space and its variability and probability of occurrence is highly useful for water resources evaluation and planning.

A detailed study has been made on the hydrometeorological parameters for Nambiyar basin and the results are furnished in the following paragraphs.

3.2 RAINFALL

3.2.1 Raingauge Stations

The Nambiyar basin has an area of 2018.44 sq.km. spread over in Tirunelveli, Kanyakumari and Thoothukudi District.

There are 16 non-recording raingauge stations in and around the basin. The various agencies are maintaining these raingauge stations, and the number of raingauge stations maintained by each agency are listed below:

S. No.	Name of the Agency	Numbers
1	Public Works Department	11
2	Revenue	4
3	Salt Department	1
	Total	**16**

Considering the distribution of raingauge stations and the availability of data, only 9 raingauge stations having long term records in and around the basin are considered for the detailed analysis. The details of the raingauge stations such as, their location, geographical coordinates and the study period are shown in Table A. For the purpose of rainfall analysis, month is taken as a time step.

3.2.2 Monsoon and non-monsoon periods

Nambiyar river basin lies within the tropical monsoon zone. Based on the hydrometeorological features of the basin, year is divided into 2 periods (i.e.) 1) Monsoon period spanning from June to December and 2) Non-monsoon period spanning from January to May. The monsoon period is further sub-divided into Southwest monsoon period spanning from June to September (4 months) and Northeast monsoon period spanning from October to December (3 months). Similarly, the non-monsoon period is further sub-divided into Winter period spanning January and February (2 months) and Summer period spanning from March to May (3 months). As the monsoon period brings heavy rainfall, it improves the recharging of groundwater as well as storage of surface water. Hence, the monsoon period is hydrologically significant for water resources analysis. But in the case of non-monsoon, the rainfall is insignificant.

The monthly and seasonwise rainfall for the 9 rain gauge stations are given in the Appendix 3.1 (Volume II). Probable mean area rainfall analysis for 25%, 50%, 75%, 90% dependabilities and the average for southwest, northeast, winter, summer and annual rainfall for all the 9 rain gauge stations have been analysed and are tabulated in Table B to F. The seasonwise rainfall contour maps (Plate NAM-16A, 16B, 16C, 16D and 16E) are presented.

3.2.3 Frequency Analysis

The range of annual rainfall and their frequency have been analysed and furnished in Table G. From the table it is noticed that rainfall exceeding 1000mm occurred only in minimum number of years in all the 9 stations. The frequency of rainfall 400-600mm and 600-800mm have occurred in more than 50% of the years. Out of the 34 years of study period 200-400mm has occurred in 5 years in Radhapuram and 4 years in Srivaikundam. Less than 200mm has occurred for 2 years in Nelaparai and 1 year in all other stations except Aralvaimozhi , Nanguneri and Srivaikundam. 800-900mm and 900-1000mm have occurred in less than ¼ of the the study period in all the stations except Aralvaimozhi.

3.2.4 Moving Average

The 5 years moving average graph for the annual rainfall has been drawn for all the 9 raingauge stations.

A linear fit has also been shown along with moving average curve. The details are given in Appendix 3.2 (Volume II) and Appendix 3.3 (Volume II) respectively.

3.2.5 Maximum, minimum and average rainfall

The maximum, minimum and average annual rainfall for various raingauge stations have been analysed and tabulated. The following observations are made. Kulasekarapattinam received the minimum annual rainfall of 47mm and Tiruchendur received the maximum annual rainfall of 1599mm . Average annual rainfall varies from 618 mm at Radhapuram to 776 at Aralvaimozhi.

3.2.6 Seasonal Rainfall

The southwest monsoon maximum rainfall varies from 70mm to 628 mm and the minimum rainfall varies from 0 to 41 mm. For southwest monsoon, the average varies from 17mm to 194mm. The northeast monsoon maximum rainfall varies from 714mm to 1360mm and the minimum varies from 40 to 159 mm. The northeast average rainfall varies from 388mm to 590mm for the basin. In winter, the maximum rainfall varies from 143 mm to 304 mm and the minimum is 0. The average varies from 26 to 69 mm. In summer, the maximum rainfall varies from 227 to 413 mm and the minimum varies from 0 to 33 mm. The summer average varies from 85 mm to 149 mm for the basin. The annual maximum rainfall varies from 1075 mm to 1599 mm and the minimum varies from 47mm to 392mm. The annual average rainfall varies from 618 mm to 776mm for the basin.

3.2.7 Statistical Analysis

The statistical analysis for the rainfall data has been done for all the stations for the various seasons namely southwest, northeast, winter, summer and annual. The statistical results namely, Arithmetic Mean, Standard Deviation, Coefficient of variation, Skewness and Kurtosis have been analysed and tabulated in Table H.

3.2.8 Aridity Index for Climatic Classification

A study has also been made on the aridity factor existing in the basin area. The aridity index is defined as the ratio of water deficit to the potential evapotranspiration. The region is dry humid if the value of aridity index is from 0 to 33.3%, Semi Arid if the value is between 33.3% to 66.67% and arid if the value is above 66.67%. The region is humid if the value is less than 0. The aridity index (la) for all the 9 raingauge stations have been worked out and the classification is shown in

Table I. The entire Nambiyar basin comes under Semiarid except 2 stations in Radhapuram and Srivaikundam which are coming under arid region.

3.2.9 Summary

Nambiyar basin is divided into three sub-basins based on the topography. The subbasin wise influencing raingauge stations, area of influence of each raingauge station, area of the subbasin and weighted area of the influenced raingauge station, the annual average rainfall and the annual average weighted rainfall for each subbasin are given in Table J.

3.3 CLIMATE

The weather station considered is furnished below:

Name of the weather station	Maintained by
Aralvaimozhi	PWD (GW)

The climatological values of this river basin are given below.

Climatological Parameters

S. No	Climatological Parameter	Aralvaimozhi
1	Average monthly temperature Maximum. in. ^{0} Celsius	33.16
2	Average monthly temperature Minimum. in. ^{0} Celsius	25.65
3	Average mean temperature in ^{0} Celsius	29.25
4	Average relative humidity in %	68.56
5	Average wind velocity in km/hour	9.32
6	Average Sunshine hours / day	7.08
7	Average ETO mm/ Month (PET)	154.67

3.4 TEMPERATURE

The meteorological features of the basin have been studied from the data collected from Aralvaimozhi weather station. Temperature is one of the basic factors under climatological features and it is one of the main parameters to calculate the crop water requirement (i.e.

evapotranspiration). The average mean, average minimum and average maximum temperature for the above meteorological stations have been computed and tabulated in Appendix 3.4 (Volume II).

The maximum and minimum monthly mean temperature observed in the above climatological station are given below:

Maximum and Minimum in Mean temperature

Name of the Climatological Station	Minimum in Mean Temperature	Maximum in Mean Temperature
Aralvaimozhi (1975 – 2005)	21.48° C in September 1980	38.55° C in May 1980.

The monthly average maximum temperature varies from 28.23ºC (July 89) to 38.52ºC (March 1996) and the average Minimum temperature varies from 14.12° C (March 1984) to 30.94° C (May 2003).

3.5 RELATIVE HUMIDITY

The monthly average relative humidity varies from 30.63% (Jan - 1983) to 88.03% (November 1999) vide Appendix 3.4 (Volume II).

3.6 WIND SPEED

Wind velocity is an important meteorological parameter which has considerable influence on evaporation and evapotranspiration phenomena. Wind has direct impact on climate and vegetation and is linked with circulation pattern of the monsoon. The average monthly wind velocity varies from 0.90 km/hour to 21.41 km/hour vide Appendix 3.4 (Volume II).

3.7 SUNSHINE

The monthly average sunshine hours varies from 3.00 hour (October 1992) to 10.58 hour (March 1981) vide Appendix 3.4 (Volume II).

3.8 EVAPOTRANSPIRATION

The monthly average ETo in mm for the climatological station is estimated using Penman Montietch Method. The estimated ETo values for the station are given in Appendix 3.4 (Volume II).

3.9 DROUGHT ASSESSMENT

India 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) given by

$$Di = \frac{Pi - \overline{P}}{\overline{P}}$$

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

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 all the 9 raingauge stations. The drought severity such as no, mild, moderate and severe drought for 9 stations for the available data were found out and presented in Table K and an abstract also given in Table L. It is observed from the table K & L that M_0 (No Drought) is more than the M_1, M_2 & M_3 (Mild, Moderate and Severe Drought) except Tiruchendur and Kulasekarapattinam. Severe Drought has occurred in Radhapuram for 4 years, Nelaparai for 3 years, Srivaikundam, Tiruchendur and Kulasekarapattinam for 2 years, Aralvaimozhi and Kalakkadu for one year. M0= M1 + M2 +M3 in Aralvaimozhi, Radhapuram and Sathankulam.

Table A - Raingauge Stations in Nambiyar Basin

S.No	Name of Raingauge Station	District	Latitutde	Longitude	Years
1	**Aralvaimozhi**	Kanyakumari	$8^0 14' 56"$	$77^0 31' 45"$	1971-2005
2	**Nanguneri**	Tirunelveli	$8^0 29' 47"$	$77^0 38' 47"$	1971-2005
3	**Radhapuram**	Tirunelveli	$8^0 15' 50"$	$77^0 51' 14"$	1971-2005
4	**Nelaparai**	Tirunelveli	$8^0 19' 58"$	$77^0 28' 48"$	1974-2005
5	**Kalakkadu**	Tirunelveli	$8^0 30' 44"$	$77^0 33' 31"$	1987-2005
6	**Sathankulam**	Thoothukudi	$8^0 26' 25"$	$77^0 54' 40"$	1971-2005
7	**Srivaikundam**	Thoothukudi	$8^0 38' 00"$	$77^0 55' 00"$	1971-2005
8	**Tiruchendur**	Thoothukudi	$8^0 30' 00"$	$78^0 07' 00"$	1971-2005
9	**Kulasekarapattinam**	Thoothukudi	$8^0 23' 56"$	$78^0 03' 16"$	1971-1993
10	**Eruvadi**	Tirunelveli	$8^0 26' 48"$	$77^0 36' 12"$	1988-2005
11	**Panagudi**	Tirunelveli	$8^0 19' 20"$	$77^0 34' 19"$	1987-1998 & 2002-2005
12	**Pazhavur**	Tirunelveli	$8^0 12' 02"$	$77^0 24' 33"$	1988-1999 & 2002-2005
13	**Moolakaraipatti**	Tirunelveli	$8^0 32' 12"$	$77^0 46' 00"$	1982-2005
14	**Vijayanarayanapuram**	Tirunelveli	$8^0 25' 14"$	$77^0 47' 23"$	1988-1995 1997-2002 & 2005
15	**Nambiyar Reservoir site**	Tirunelveli	$8^0 22' 09"$	$77^0 44' 23"$	1999-2005
16	**Kodumudiyar Reservoir Site**	Tirunelveli	$8^0 25' 21"$	$77^0 31' 22"$	1994-2005

Table B - Southwest Monsoon – Dependable Rainfall

Sl. No.	Raingauge Stations	25%	50%	75%	90%
1	**Aralvaimozhi**	230	177	112	54
2	**Nanguneri**	111	87	53	11
3	**Radhapuram**	105	61	36	12
4	**Nelaparai**	244	187	83	0
5	**Kalakkadu**	156	105	29	0
6	**Sathankulam**	92	37	26	5
7	**Srivaikundam**	83	51	28	10
8	**Tiruchendur**	30	17	10	2
9	**Kulasekarapattinam**	24	11	1	0

Table C -Northeast Monsoon – Dependable Rainfall

Sl. No.	Raingauge Stations	25%	50%	75%	90%
1	**Aralvaimozhi**	561	368	290	184
2	**Nanguneri**	609	403	291	212
3	**Radhapuram**	541	374	245	110
4	**Nelaparai**	614	338	208	0
5	**Kalakkadu**	559	468	369	238
6	**Sathankulam**	576	453	308	171
7	**Srivaikundam**	529	413	264	115
8	**Tiruchendur**	772	531	331	225
9	**Kulasekarapattinam**	726	561	354	158

Table - D Winter Dependable Rainfall

Sl. No.	Raingauge Stations	25%	50%	75%	90%
1	**Aralvaimozhi**	54	4	0	0
2	**Nanguneri**	75	34	4	0
3	**Radhapuram**	64	14	0	0
4	**Nelaparai**	39	4	0	0
5	**Kalakkadu**	71	18	12	0
6	**Sathankulam**	80	29	5	0
7	**Srivaikundam**	72	15	3	0
8	**Tiruchendur**	101	39	10	0
9	**Kulasekarapattinam**	62	14	0	0

Table E - Summer Dependable Rainfall

Sl. No.	Raingauge Stations	25%	50%	75%	90%
1	**Aralvaimozhi**	183	141	97	51
2	**Nanguneri**	155	95	71	31
3	**Radhapuram**	132	89	50	13
4	**Nelaparai**	157	124	71	30
5	**Kalakkadu**	170	132	68	34
6	**Sathankulam**	148	100	52	24
7	**Srivaikundam**	136	94	54	32
8	**Tiruchendur**	114	73	22	8
9	**Kulasekarapattinam**	149	31	19	0

Table F- Annual Dependable Rainfall

Sl. No.	Raingauge Stations	25%	50%	75%	90%
1	**Aralvaimozhi**	927	774	654	509
2	**Nanguneri**	832	708	552	426
3	**Radhapuram**	766	584	407	291
4	**Nelaparai**	956	767	569	221
5	**Kalakkadu**	802	778	681	479
6	**Sathankulam**	813	666	540	425
7	**Srivaikundam**	741	638	533	291
8	**Tiruchendur**	887	681	537	397
9	**Kulasekarapattinam**	957	703	580	358

Table G - Annual Rainfall Frequency Distribution

S. No.	Name of Stations	Study Period in Yrs	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	**Aralvaimozhi**	34	5	5	6	11	6	1	-
2	**Nanguneri**	34	3	1	7	13	8	2	-
3	**Radhapuram**	34	2	2	2	11	11	5	1
4	**Nelaparai**	26	5	1	3	7	6	1	2
5	**Kalakkadu**	18	2	1	3	8	3	-	1
6	**Sathankulam**	34	2	4	3	13	10	1	1
7	**Srivaikundam**	34	1	1	4	15	9	4	-
8	**Tiruchendur**	34	6	2	3	11	9	2	1
9	**Kulasekarapattinam**	22	3	3	2	8	2	3	1

Table H - Statistical Parameters

MONTHS	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	S.W	N.E	WINTER	SUMMER	ANNUAL
Raingauge Station: ARALVAIMOZHI																	
St. dev	71.79	45.36	39.37	55.15	95.45	109.34	70.04	17.57	32.28	41.83	51.68	47.00	122.73	166.89	38.78	76.06	192.92
Co-Vari	0.99	1.15	1.24	1.06	0.55	0.62	1.25	2.35	1.73	1.26	0.74	1.00	0.63	0.41	1.48	0.51	0.25
Skew	2.64	2.84	2.10	2.12	0.68	0.92	1.63	2.75	2.06	2.57	0.41	0.86	1.61	0.23	1.47	0.58	-0.24
Kurtosis	9.88	9.92	5.08	6.67	0.18	0.41	2.37	7.44	3.91	8.44	-1.18	-0.58	3.90	-0.96	1.36	-0.08	-0.72
Raingauge Station: NANGUNERI																	
St. dev	19.40	23.48	14.77	31.87	99.80	110.29	95.68	28.36	47.36	45.54	41.80	32.36	48.95	189.67	63.33	67.39	194.56
Co-Vari	1.13	1.51	1.36	0.75	0.65	0.57	0.94	1.44	1.48	1.55	0.82	1.03	0.57	0.42	1.22	0.60	0.28
Skew	2.25	1.96	1.39	0.73	1.04	1.18	1.09	1.28	1.51	2.86	1.33	1.19	0.96	0.51	1.47	1.20	0.06
Kurtosis	6.92	2.89	0.99	-0.12	1.39	1.47	0.13	0.20	1.22	10.33	2.23	0.25	2.89	-0.42	1.57	2.91	-0.84
Raingauge Station: RADHAPURAM																	
St. dev	35.27	38.92	23.65	22.11	85.06	140.27	87.90	30.52	31.36	32.18	50.39	51.54	81.33	219.17	44.09	74.35	253.40
Co-Vari	1.07	1.74	2.02	1.18	0.65	0.75	1.15	1.93	1.63	1.46	0.96	1.67	0.95	0.55	1.26	0.73	0.41
Skew	2.18	3.30	3.36	1.56	0.47	1.27	1.47	2.79	1.80	1.72	0.46	2.63	2.04	0.84	1.18	1.07	0.42
Kurtosis	5.84	11.82	13.22	2.23	-0.48	1.63	1.62	8.94	2.37	1.99	-1.15	6.79	4.52	1.13	0.48	1.44	0.04
Raingauge Station: NELAPARAI																	
St. dev	89.54	48.88	39.21	37.92	71.48	144.56	83.37	22.35	34.57	38.78	60.76	39.39	136.52	226.31	40.34	66.33	236.26
Co-Vari	1.07	1.10	0.97	0.92	0.53	0.65	1.32	2.05	2.23	1.02	0.99	1.29	0.73	0.57	1.57	0.52	0.32
Skew	2.52	2.69	1.14	0.78	0.37	0.92	1.82	2.35	2.52	0.69	1.52	1.85	1.60	0.17	1.84	0.12	-0.09
Kurtosis	8.56	8.39	0.08	-0.59	-0.67	0.32	2.32	4.77	5.78	-1.02	2.00	2.98	4.55	-0.94	3.02	-0.51	-0.17

Raingauge Station: KALAKKADU																	
MONTHS	**JUN**	**JUL**	**AUG**	**SEP**	**OCT**	**NOV**	**DEC**	**JAN**	**FEB**	**MAR**	**APR**	**MAY**	**S.W**	**N.E**	**WINTER**	**SUMMER**	**ANNUAL**
St. dev	44.60	33.99	14.42	16.18	78.94	143.09	80.56	25.24	45.72	59.20	49.58	28.84	75.21	207.63	56.05	63.58	244.57
Co-Vari	1.15	1.36	0.93	0.53	0.56	0.60	0.79	1.12	1.60	1.54	0.75	0.91	0.78	0.46	1.16	0.50	0.34
Skew	1.11	2.13	0.45	0.22	0.53	1.14	0.77	1.09	1.86	1.85	0.12	0.90	0.58	0.25	1.49	-0.30	-0.67
Kurtosis	0.44	4.07	-1.05	-0.76	0.69	0.82	-0.44	-0.08	2.55	3.05	-1.08	0.34	-0.58	1.60	2.07	-0.31	2.65

Raingauge Station: SATHANKULAM																	
St. dev	15.27	13.79	17.07	31.94	103.51	114.13	96.04	37.13	49.63	45.86	45.08	35.63	51.06	196.79	66.67	77.98	207.50
Co-Vari	1.69	1.58	1.73	0.98	0.71	0.54	0.96	1.54	1.65	1.63	0.80	1.41	0.85	0.43	1.23	0.72	0.31
Skew	3.60	2.37	3.30	1.11	1.66	0.63	1.19	2.44	3.08	3.04	0.87	1.74	1.32	0.32	1.98	1.98	0.06
Kurtosis	15.89	5.78	13.10	-0.07	3.04	0.47	0.46	6.87	10.73	11.25	0.73	2.28	1.19	-0.16	4.37	6.65	0.50

Raingauge Station: SRIVAIKUNDAM																	
St. dev	17.45	14.98	21.81	30.82	90.01	118.83	102.00	47.59	43.51	42.03	36.35	38.73	46.49	182.49	64.19	58.51	188.93
Co-Vari	2.70	1.93	2.04	0.77	0.67	0.71	0.94	2.08	1.66	1.61	0.87	0.99	0.72	0.45	1.31	0.55	0.30
Skew	4.55	3.31	3.20	2.37	0.61	0.97	0.72	3.04	2.32	2.51	1.25	0.97	1.33	-0.01	1.64	0.75	-0.14
Kurtosis	22.83	13.29	11.59	7.87	-0.55	0.63	-1.15	9.95	5.96	6.44	1.32	-0.16	1.34	-0.31	2.19	0.22	0.40

Raingauge Station: TIRUCHENDUR																	
St. dev	9.06	10.56	7.49	17.99	110.40	169.19	139.65	46.42	53.14	37.67	44.89	39.25	25.18	294.10	76.45	70.22	294.44
Co-Vari	2.32	1.86	1.62	1.32	0.71	0.63	0.97	1.46	1.41	1.48	1.15	1.89	0.91	0.52	1.10	0.82	0.39
Skew	4.58	2.99	1.84	2.82	1.09	0.55	1.43	2.13	2.08	2.05	1.42	2.98	1.70	0.81	1.53	1.21	0.93
Kurtosis	23.47	10.99	2.51	9.25	0.84	-0.75	1.29	5.60	4.86	5.01	1.42	10.24	2.91	0.38	2.03	1.41	1.65

Raingauge Station: KULASEKARAPATTINAM																	
St. dev	7.96	9.48	2.53	11.10	143.87	149.06	144.16	53.55	54.87	65.45	58.86	26.92	18.02	308.68	84.13	101.83	330.99
Co-Vari	1.96	2.14	2.11	1.46	0.86	0.56	0.93	2.05	2.03	2.33	1.30	2.33	1.04	0.52	1.58	1.20	0.44
Skew	2.87	2.75	3.08	1.73	0.84	-0.15	1.40	2.73	2.75	3.63	1.28	3.68	1.42	0.44	2.11	1.78	0.36
Kurtosis	9.48	7.11	10.98	2.33	0.29	-0.54	1.23	7.78	7.91	14.24	0.36	14.89	2.17	0.15	4.00	3.24	0.52

Table I – Aridity Index (Ia) for Climatic Classification

S. No.	Name of Stations	Annual Ave. Precipitation P mm	PET mm	Total deficit P-PET mm	Ia Aridity Index (%)	Classification
1	Aralvaimozhi	776	2011	-1235	-61.4	Semi Arid
2	Nanguneri	698	2011	-1313	-65.3	Semi Arid
3	Radhapuram	618	2011	-1393	-69.3	Arid
4	Nelaparai	713	2011	-1298	-64.5	Semi Arid
5	Kalakkadu	729	2011	-1282	-63.7	Semi Arid
6	Sathankulam	678	2011	-1333	-66.3	Semi Arid
7	Srivaikundam	630	2011	-1381	-68.7	Arid
8	Tiruchendur	749	2011	-1262	-62.8	Semi Arid
9	Kulasekarapattinam	745	2011	-1266	-63.0	Semi Arid

Table J - Influencing Raingauge Stations of each subbasin

Sl.No	Sub Basin	Raingauge Station	RG Station Influencing Area	Sub basin Area	Weight in %	Annual Average rainfall in mm	Annual average weighted rainfall for the subbasin in mm
1	Hanumanadhi	Aralvaimozhi	345.106	510.179	0.68	776	525
		Nanguneri	0.019		0.01	698	7
		Radhapuram	104.223		0.20	618	126
		Nelaparai	60.831		0.11	713	78
2	Karamaniyar	Nanguneri	161.265	903.937	0.18	698	125
		Radhapuram	117.601		0.13	618	80
		Kalakkadu	3.750		0.01	729	7
		Sathankulam	451.262		0.50	678	338
		Srivaikundam	13.328		0.01	630	9
		Tiruchendur	3.920		0.01	749	7
		Kulasekarapattinam	152.808		0.16	745	119
3	Nambiyar	Aralvaimozhi	12.157	604.324	0.01	776	8
		Nanguneri	244.614		0.40	698	283
		Radhapuram	169.931		0.28	618	174
		Nelaparai	62.737		0.10	713	74
		Kalakkadu	112.642		0.19	729	136
		Sathankulam	2.241		0.01	678	7
		Basin Total Area	**2018.435**		**3.0**		

Table K - Meteorological Drought in Nambiyar River Basin using IMD Method

Sl. No.	Raingauge Stations	Year wise Drought																
		1971-72	1972-73	1973-74	1974-75	1975-76	1976-77	1977-78	1978-79	1979-80	1980-81	1981-82	1982-83	1983-84	1984-85	1985-86	1986-87	1987-88
1	Aralvoimozhi	M0	M0	M0	M2	M2	M1	M0	M1	M0	M1	M0	M2	M0	M2	M1	M3	M0
2	Nanguneri	M0	M0	M0	M2	M2	M0	M0	M0	M0	M0	M2	M1	M0	M2	M2	M2	M0
3	Radhapuram	M0	M2	M0	M3	M2	M1	M0	M0	M0	M0	M2	M3	M1	M3	M3	M2	M0
4	Nelaparai	- -	- -	- -	M3	M1	M1	M0	M0	M0	M0	M0	M2	M0	M1	M1	M1	M0
5	Kalakkadu	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	M2
6	Sathankulam	M0	M0	M1	M2	M3	M0	M0	M0	M0	M1	M2	M1	M0	M1	M0	M2	M1
7	Srivaikulam	M0	M1	M0	M3	M2	M0	M0	M0	M0	M1	M0	M1	M0	M1	M1	M3	M0
8	Tiruchendur	M0	M0	M0	M2	M3	M1	M0	M0	M0	M1	M1	M0	M1	M1	M1	M2	M1
9	Kulasekarapattinam	M1	M1	M0	M2	M3	M0	M0	M0	M0	M1	M1	M1	M0	M1	M0	M3	M1

Sl. No.	Raingauge Stations	Year wise Drought																
		1988-89	1989-90	1990-91	1991-92	1992-93	1993-94	1994-95	1995-96	1996-97	1997-98	1998-99	1999-2000	2000-01	2001-02	2002-03	2003-04	2004-05
1	Aralvoimozhi	M2	M0	M1	M0	M0	M0	M0	M1	M1	M0	M0	M1	M0	M1	M0	M2	M1
2	Nanguneri	M1	M0	M0	M0	M0	M0	M0	M2	M2	M0	M0	M1	M0	M1	M1	M1	M1
3	Radhapuram	M1	M2	M0	M0	M0	M0	M0	M1	M0	M2	M2	M0	M0	M1	M1	M0	M0
4	Nelaparai	M2	M1	M1	M0	M0	M0	M0	--	M3	M0	M0	M3	--	--	--	--	--
5	Kalakkadu	M0	M0	M0	M1	M0	M0	M0	M2	M1	M0	M1	M0	M0	M0	M2	M3	M0
6	Sathankulam	M1	M2	M0	M0	M1	M0	M0	M2	M2	M0	M0	M0	M0	M1	M1	M1	M0
7	Srivaikulam	M1	M1	M0	M0	M0	M0	M1	M2	M2	M0	M0	M1	M0	M1	M0	M1	M0
8	Tiruchendur	M2	M1	M0	M2	M2	M0	M0	M2	M3	M0	M0	M2	M0	M2	M1	M1	M0
9	Kulasekarapattinam	M2	M1	M0	M1	M1	--	--	--	--	--	--	--	--	--	--	--	--

Table L – Abstract (Drought)

Sl. No.	Raingauge Stations	M_0	M_1	M_2	M_3
1	**Aralvaimozhi**	17	10	6	1
2	**Nanguneri**	19	7	8	-
3	**Radhapuram**	17	6	7	4
4	**Nelaparai**	13	7	2	3
5	**Kalakkadu/**	11	3	3	1
6	**Sathankulam**	17	10	6	1
7	**Srivaikundam**	18	11	3	2
8	**Tiruchendur**	14	10	8	2
9	**Kulasekarapattinam**	8	10	2	2

Plate No: NAM - 18

NAMBIYAR RIVER BASIN

RAINFALL CONTOUR MAP - SOUTH WEST MONSOON

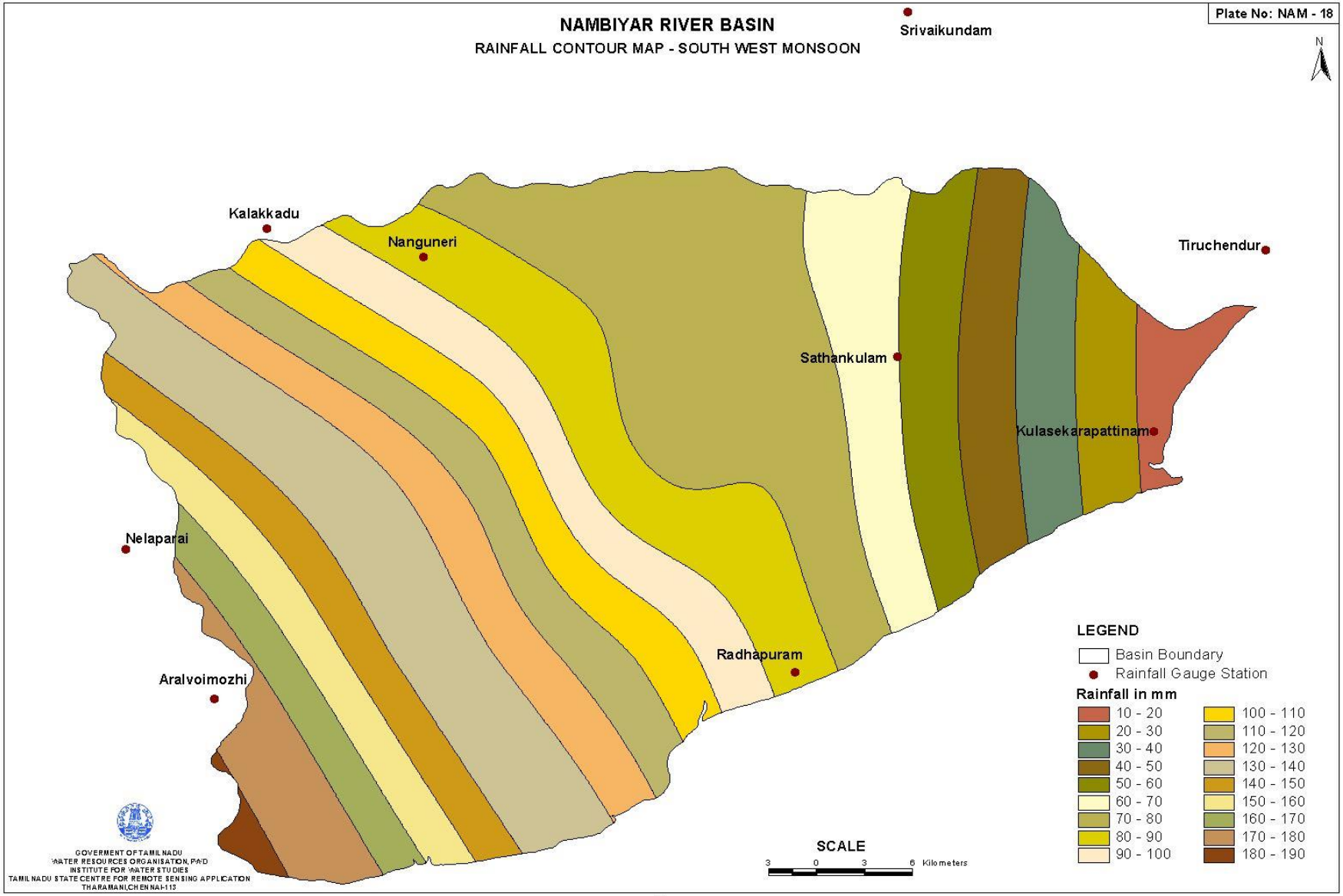
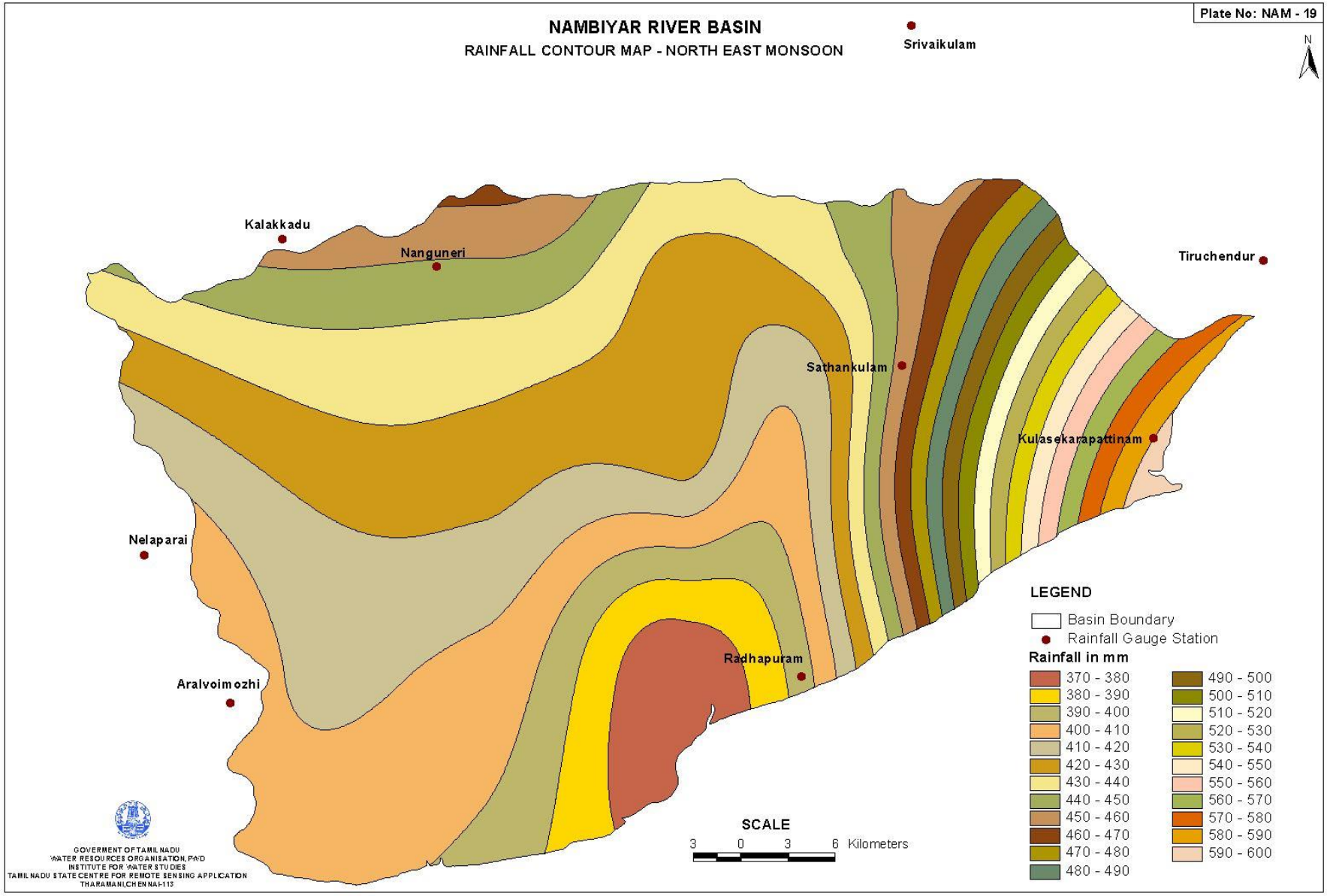


Plate No: NAM - 19

NAMBIYAR RIVER BASIN

RAINFALL CONTOUR MAP - NORTH EAST MONSOON



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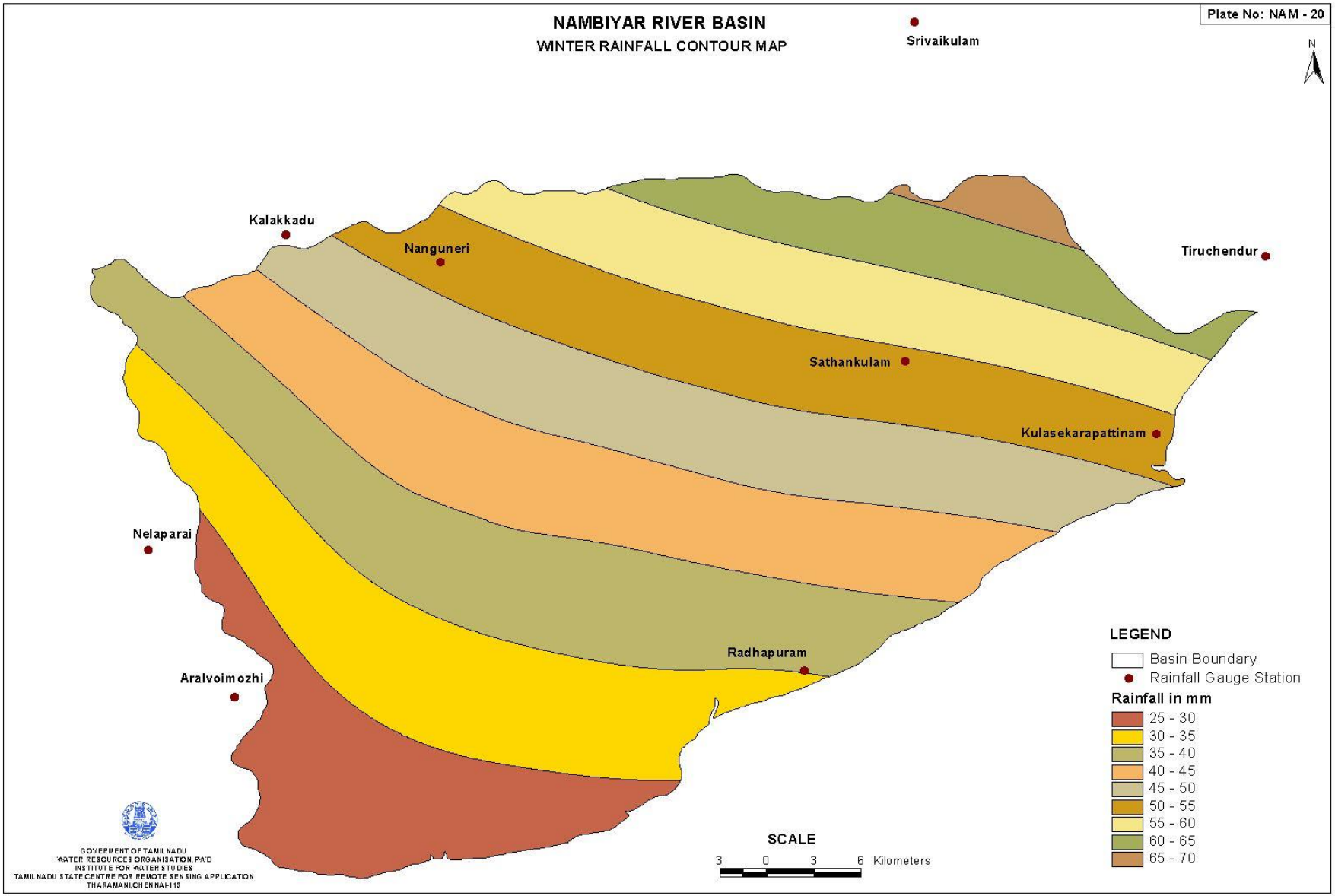
NAMBIYAR RIVER BASIN
WINTER RAINFALL CONTOUR MAP
Plate No: NAM - 20
N
Srivaikulam
Kalakkadu
Nanguneri
Tiruchendur
Sathankulam
Kulasekarapattinam
Nelaparai
Radhapuram
Aralvoimozhi
LEGEND
Basin Boundary
Rainfall Gauge Station
Rainfall in mm
25 - 30
30 - 35
35 - 40
40 - 45
45 - 50
50 - 55
55 - 60
60 - 65
65 - 70
SCALE
3 0 3 6 Kilometers
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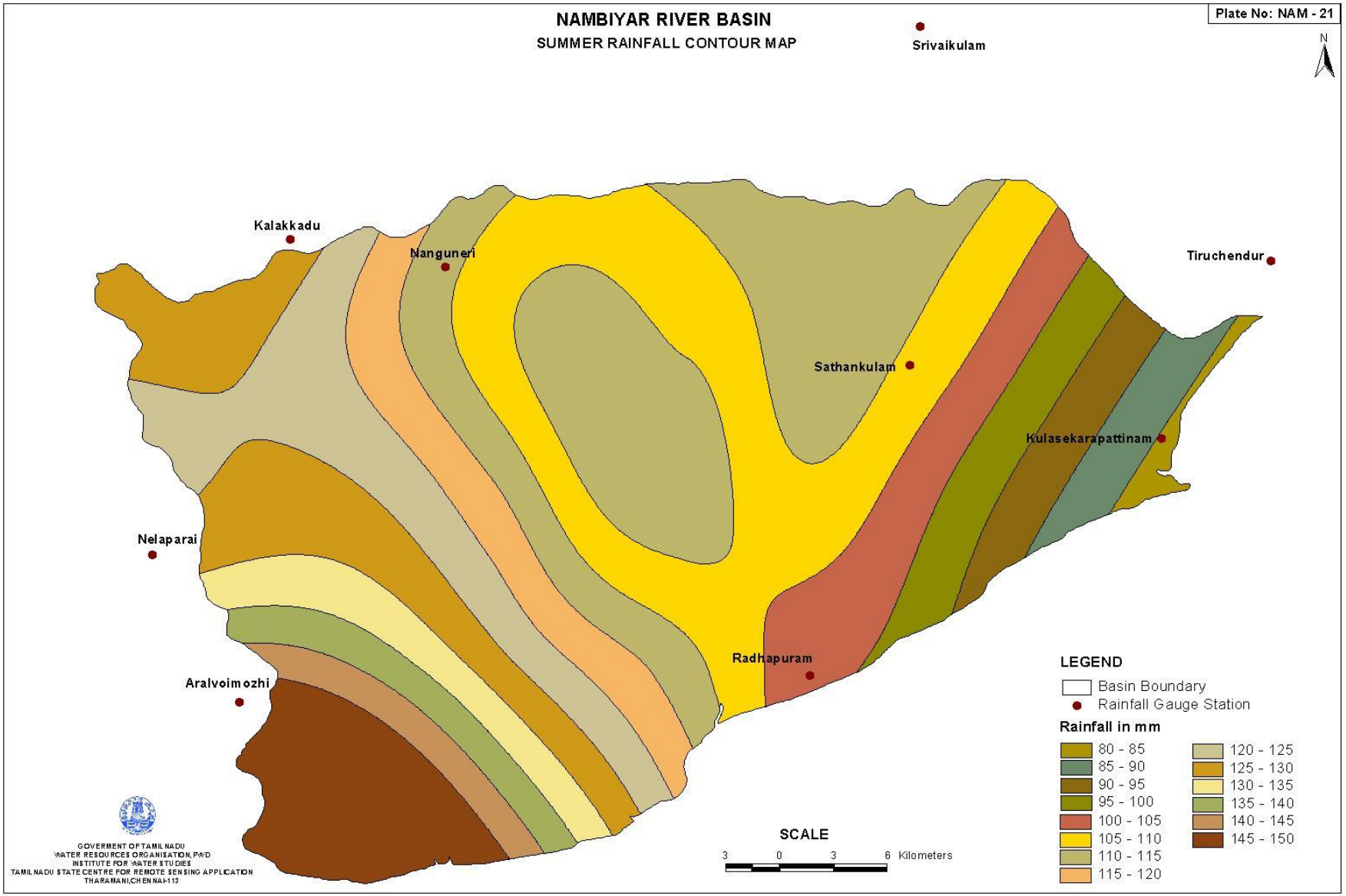
NAMBIYAR RIVER BASIN
SUMMER RAINFALL CONTOUR MAP
Plate No: NAM - 21
N
Srivaikulam
Kalakkadu
Nanguneri
Tiruchendur
Sathankulam
Kulasekarapattinam
Nelaparai
Radhapuram
Aralvoimozhi
LEGEND
Basin Boundary
Rainfall Gauge Station
Rainfall in mm
80 - 85
85 - 90
90 - 95
95 - 100
100 - 105
105 - 110
110 - 115
115 - 120
120 - 125
125 - 130
130 - 135
135 - 140
140 - 145
145 - 150
SCALE
3 0 3 6 Kilometers
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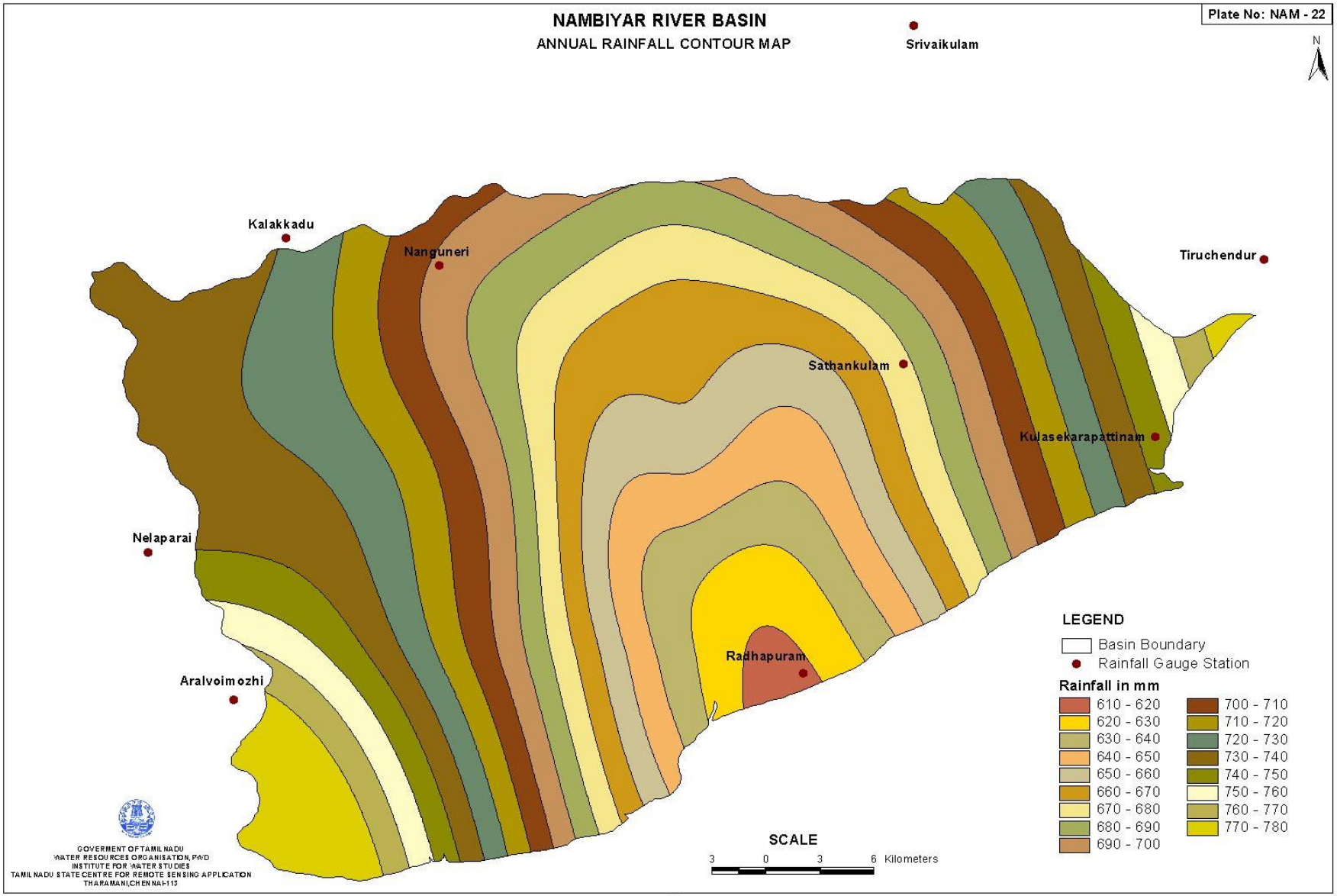
NAMBIYAR RIVER BASIN
ANNUAL RAINFALL CONTOUR MAP
Plate No: NAM - 22
N
Srivaikulam
Kalakkadu
Nanguneri
Tiruchendur
Sathankulam
Kulasekarapattinam
Nelaparai
Radhapuram
Aralvoimozhi
LEGEND
Basin Boundary
Rainfall Gauge Station
Rainfall in mm
610 - 620
620 - 630
630 - 640
640 - 650
650 - 660
660 - 670
670 - 680
680 - 690
690 - 700
700 - 710
710 - 720
720 - 730
730 - 740
740 - 750
750 - 760
760 - 770
770 - 780
SCALE
3 0 3 6 Kilometers
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CHAPTER – 4

SURFACE WATER RESOURCES AND IRRIGATION SYSTEM

CHAPTER–4

SURFACE WATER RESOURCES AND IRRIGATION SYSTEM

4.1 THE RIVER BASIN

Nambiyar river basin geographically extends from the western ghats in the west to the Bay of Bengal in the east and lies in between Latitude $8^0$08'N – $8^0$33'N and Longitude $77^0$28' E –$78^0$05'E, covering an area of about 2018 Sq.Km. The basin lies in Thoothukudi, Tirunelveli and Kanyakumari districts. Nambiyar basin is surrounded by Tamiraparani basin on the North, Pazhayar and Valliyar river basin on the West, Bay of Bengal on the East and the Indian Ocean on the South.

4.1.1 RIVER SYSTEMS

The basin is drained by the major river Nambiyar and other three separate minor rivers known as Karumeniar, Hanumanadhi and Uppar. The Nambiyar river basin can be studied under three sub basins namely Nambiyar sub basin, Karamaniyar sub basin and Hanumanadhi sub basin.

NAMBIYAR SUB BASIN

The river Nambiyar which is the main source of irrigation in Nanguneri taluk, originates on the eastern slopes of the western ghats at an altitude of about 1646m above M.S.L in the Kalakkadu reserve forest area of Tirunelveli District. It traverse a distance of about 9.6km in the hilly region towards east, comes down to plains near Thirrukkurunkudi village and continues to flow towards east upto Tirunelveli- Nagercoil road crossing and therafter tales south eastern direction. It covers a distance of 48 km totally before emptying itself into the Gulf of Mannar.

In the course of its run two major tributaries, namely Thamaraiyar and Parattayar join the Nambiyar river. Thamaraiar starting from the confluence of Kombaiyar and Kodumudiyar which originates in the eastern slopes of western ghats at an altitude of about 600m near Mahendragiri hills, joins the Nambiyar below first anicut namely Mailamani anicut. Parattaiyar originates in the eastern slopes of the Western Ghats at an altitude of about 1200m near Kakamunjikal Mottai and joins with another arm of Nambiyar at the foot of the hills. After feeding number of small tanks, this finally joins with Nambiyar again near Ervadi at 18.5Km.

Kalankal odai is another tributary which originates near Kannanallur area in Nanguneri taluk of Tirunelveli district. It gets flows from the surpluses of a few tanks dependent on other streams. After traversing a distance of 6.5Km this finally joins with the Nambiyar near Kovankulam.

Another tributary which originates near Vadakku Valliyur area in Nanguneri taluk of Tirunelveli district at an altitude about 90m gets flows from the surpluses of small tanks dependent on other streams. After traversing a distance of 10.5Km, finally the tributary joins with Nambiyar near Sankarapuram village.

Finally the Nambiyar river flows into the Bay of Bengal downstream of Sankarapuram village in Nanguneri Taluk of Tirunelveli district.

KARAMANIYAR SUB BASIN

Karamaniyar river originates in east of Kalakadu village of Tirunelveli district at an altitude of about 1000m above M.S.L. It has a number of small streams and gets its flows mainly from the surpluses of a few tanks. After traversing a distance of 2Km Manimuthar main canal joins with the river near Pillaikulam village. After traversing a total distance of 56.5Km, the Karamaniyar river flows into the Bay of Bengal near Manapadu village in Thoothukudi district. The Karamaniyar river feeds about 75 tanks and has a registered ayacut of 2976 hectares.

At present there is no major source fed by Karamaniyar river lying in between Manimuthar canal XIth distributory and Nambiyar river. The main source of supply for the river is the drainage water from the tanks fed by Pachayar river, Manimithar canal and Nambiyar river. As such the river has no appreciable catchment to get copious water.

Below the confluence of Vijayanarayanan tank surplus course with Karamaniyar, the terrain on both sides of the river is Sandy teri. Hence the catchment area is bad in nature and receives very low runoff. There is one anicut called Sadayaneri anicut across Karumeiyar below Sathankulam which is also not able cater to the needs of Sadayaneri tank.

HANUMANADHI SUB BASIN

Hanumanadhi river is one of the rivers in the basin area which originates in the eastern slopes of the western ghats at an altitude of 1100m in the Mahendragiri hill region above north west of Panakkudi village in Nanguneri Taluk of Tirunelveli District. It has a number of jungle streams. After feeding a few tanks, they join with Hanumanadhi river at various points. It flows in the hill ranges for about 5.6Km and reaches 6.4Km west of

Panagudi village in Nanguneri taluk. It traverses entirely in Nanguneri taluk for a distance of about 32Km and flows into the Gulf of Mannar in the limits of Chettikulam village. Kallandi Odai, Kuthiraipanchan Odai and Sooravali Odai are the three tributaries of this river.

Uppar river is also another river in the basin area which originates in the eastern slopes of the western ghats near Takkumalai east forest at an altitude of about 808m. A number of streams, after feeding a few tanks, join with Uppodai river at various places. After traversing a distance of 11Km, the Uppodai confluences with Gulf of Mannar 1Km west of the confluence point of Hanumanadhi river. It has 64 tanks with a registered ayacut of 436 hectares in total.

A canal known as Radhapuram canal crosses into this basin from the adjacent Kanyakumari District. Radhapuram canal starts from Pechiparai Reservoir in Kanyakumari district. At its starting point this canal is called Kodayar left bank canal. Another canal from Perunchani dam joins this Kodayar left bank canal at the 17thkm. After this confluence the canal is called Thovala Channel. After entering Tirunelveli district near Thirumulangar village, it is called Radhapuram canal. After feeding a number of tanks through supply channels in Uppar minor river basin, it crosses Hanumanadhi river near Adankarkulam anicut. Finally the canal feeds Mehandarkulam near Radhapuram after feeding one supply channel in Hanumanadhi basin.

4.2 SURFACE WATER DATA

In this basin, there are two newly constructed reservoirs namely Nambiyar reservoir and Kodumudiyar reservoir. Storage in Nambiyar reservoir commenced from 2000 and in Kodumudiyar reservoir, it commenced from 2003.

Sl.No.	Name of the Reservoir	Capacity in Mcum	Annual storage in Mcum	Ayacut in Ha
1	Nambiyar	2.33	2.59	705.65
2	Kodumudiyar	3.58	7.56	2340.00

`4.2.1 OUT FLOW TO SEA

The sub basin wise last anicuts are furnished below for Nambiyar river basin.

1. Nambiyar sub basin - Pulimankulam Anicut
2. Karamaniyar sub basin - Sadayamangalam Anicut
3. Hanumanadhi sub basin - Kanchaneri Anicut

The gauging of flow is done at Pulimankulam Anicut only. There is no gauging station at Sadayamangalam Anicut and Kanchaneri Anicut. The surplus from Pulimankulam Anicut assessed as 187.33mcft.

4.3 SURFACE WATER POTENTIAL

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

Monthly Runoff Simulation (MRS) Model assesses the surface water potential for 75% dependable yield for southwest, northeast and non-monsoon periods. The following influential rainfall stations having long-term records are considered for analysis.

Raingauge stations considered for analysis

S. No.	Name of subbasins	Subbasin area (sq.km.)	Raingauge stations
1	Hanumanadhi	510.179	Aralvaimozhi,Nangunei, Radhapuram,Nelaparai.
2	Karamaniyar	903.397	Nanguneri, Radhapuram, Kalakkadu, Sathankulam,Srivaikundam,Tiruchendur, Kulasekarapattinam.
3	Nambiyar	604.324	Aralvaimozhi,Nanguneri,Radhapuram,Nelaparai,Kalakkadu, Sathankulam.
Total		**2018.435**	

SURFACE WATER POTENTIAL BY MRS MODEL

(i) About the MRS Model

The Monthly Runoff Simulation (MRS) model belongs to a class of 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 their various components, and their computational time-steps. Generally speaking, the shorter the time-step, the larger are the number of watershed parameters operated on by the model, and the more accurate is the model's output, conditional to the availability of data.

Perhaps, the most reputable watershed model is that developed by Stanford University, U.S.A., in the nineteen-sixties. 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 observations led to the development of the present monthly model, requiring easily accessible monthly rainfall as input. 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

The MRS model is a conceptual, distributed, deterministic model performing hydrological water balance computations in monthly time-steps. The inputs to the model are monthly rainfalls associated with catchment areas, mean monthly potential evapotranspiration and several empirical parameters such as a runoff coefficient and a soil moisture retention capacity. The outputs of the model are the total flow in the river, its surface and baseflow 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, which are described in the next chapter. Detailed MRS Model descriptions are given in Appendix 4.2 (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.

It is a good practice to start calibration by force-closing the water balance (Rainfall versus all flow and groundwater components), adjust PET by way of V. Should V fall out of range, the calibration should be stopped and the input data reconsidered.

Having calibrated the model, it is then applied to long-term rainfall data, maintaining the same in Thiessen network and potential evapotranspiration.

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

V	(evapotranspiration adjustment factor)	0.6 – 1.0
Z	(coefficient of runoff)	0.01 – 0.4
P	(fraction of impervious area)	0 – 1.0
M	SMAX (upper limit of SM)	20 – 300
C	(base flow recession rate)	0.5 – 0.98
G	GWMAX (upper limit of GW)	0 – 1000
B	(fraction of recharge becoming base flow)	0 – 1.0

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 "best fit" criteria are:

- Similarity in the annual means.
- Regression analysis yielding the highest correlation coefficient together with a small intercept in the annual regression equation.
- Same as above but monthly.

The model provides tabular and graphical facilities to implement the above mentioned comparisons and regression analysis.

Now, the following model parameters are adopted for assessment of surface water potential.

V	(evapotranspiration adjustment factor)	1.0
Z	(coefficient of runoff)	0.15
P	(fraction of impervious area)	0.11
M	SMAX (upper limit of SM)	30
C	(base flow recession rate)	0
G	GWMAX (upper limit of GW)	500
B	(fraction of recharge becoming base flow)	0.05

75% Dependable Surface Water Potential for the Nambiyar River Basin

Sl. No.	Name of Sub basin	75% Dependable Surface Water Potential in Mcum			
		SW	NE	NM	Annual
1.	Hanumanadhi	**5.96**	**28.63**	**7.22**	**41.81**
2.	Karamaniyar	**6.05**	**61.11**	**18.92**	**86.07**
3.	Nambiyar	**7.22**	**43.61**	**24.42**	**75.26**
Total		**19.23**	**133.35**	**50.56**	**203.14**
South West Monsoon Potential		**19.23 (or) 19 Mcum**			
North East Monsoon Potential		**133.35 (or) 133 Mcum**			
Non Monsoon Potential		**50.56 (or) 43 Mcum**			
Annual Potential		**203.14 (or) 203 Mcum**			

Surface Water Potential of Nambiyar Basin is 203 Mcum.

The Subbasinwise MRS simulation runoff is given in Appendix 4.2 (Volume II).

4.4 THE EXISTING SURFACE WATER SUPPLY SYSTEMS

There are two reservoirs in this basin namely Nambiyar and Kodumudiyar reservoir.

4.4.1.Reservoirs

Kodumudiyar Reservoir

Kodumudiyar Reservoir is constructed across the jungle streams, namely Kodumudiyar and Kombaiyar, at the confluence point where it is called Thamaraiyar, the main tributary to Nambiyar river in Thirrukkurunkudi village of Nanguneri taluk in Tirunelveli District. The reservoir is having the capacity of 3.58mm^3 (126.53Mcft) and provide assured supply to a total registered ayacut of 2340Ha under Thamaraiyar system, through existing three canals viz. Valloyoorankal, Padalayarkal and Vadamalayankal and 44 tanks. The scheme provide irrigation facilities by stabilization of 791 hectares of land

and bridging a gap of 799 hectares in Nanguneri taluk. The total cost of scheme is Rs.3050 Lakhs.

Nambiyar Reservoir

Nambiyar Reservoir is constructed across the river Nambiyar between 7th and 8th anicut, in Kottaikarungulam village of Radhapuram taluk in Tirunelveli District.The reservoir is having a capacity of 2.33mm^3 and provide irriagation facilities to 1743.67 acres through two canals and 44 tanks in Radhapuram taluk. An extent of 910.93 acres gets stabilized, besides bridging the gap of 457.74 Acres. 375Acres of new dry aycut is also befitted by this scheme. The total cost of the scheme is Rs.2050Lakhs.

The surface water is drawn for usage from tanks. The tanks are classified as System tanks and Non system tanks. The non-system tanks use surface water of the direct runoff from their own catchments. Whereas the system tanks are filled from the canal flow diverted by the anicuts across the river apart from the direct runoff from their own catchments.

4.4.2.ANICUT DETAILS

1.Anicuts In Nambiyar Sub Basin

Sl. No.	Anaicut Name	Ayacut in Acres	Taluk
1	Mailamani	2072.45	Nanguneri
2	Thamaraiyar	1223.25	Nanguneri
3	Dalavaipuram	3445.46	Nanguneri
4	Rajakkamangalam	1027.92	Nanguneri
5	Mylapudhur	192.45	Radhapuram
6	Kannanallur	315.73	Radhapuram
7	Vijayan	1972.67	Radhapuram & Nanguneri
8	Kovankulam	330.04	Radhapuram
9	Tutikulam	85.76	Radhapuram
10	Pulimankulam	131.47	Radhapuram
11	Checkdam at Athankarai Pallivasal	476.70	Radhapuram

2.Anicuts In Karumeniar Sub Basin

Sl. No.	Anicut Name	Ayacut in Acres	Taluk
1	Sadayaneri anicut	44.88	Tiruchendur

3.Anicuts In Hanumanadhi Sub Basin

Sl. No.	Anicut Name	Ayacut in Acres	Taluk
1	Sakkilian Parai Anicut	52.82	Radhapuram
2	Adangar Kulam Anicut	-	Radhapuram
3	Koliankulam Anicut	60.20	Radhapuram
4	Alaganeri Anicut	-	Radhapuram
5	Vadakkankulam Anicut	40.29	Radhapuram
6	Perungudi Anicut	241.33	Radhapuram
7	Sanjetti Anicut	630.83	Radhapuram
8	Thandayarkulam	78.06	Radhapuram
9	Senthilkathayan Anicut	298.20	Radhapuram
10	Sivanpillai Anicut	870.10	Radhapuram
11	Kanjaneri Anicut	188.80	Radhapuram

4.4.3 TANKS

There are about 559 system tanks and 38 non- system tanks by which 33,615 ha are being irrigated. The approximate storage capacity of these tanks is 94.54 Mcm. Hence the approximate total storage capacity of tanks and reservoirs in this basin is 100.45 Mcum.

4.5 ISSUES IN THE MANAGEMENT OF SURFACE WATER RESOURCES

4.5.1 Problems in Tanks Irrigation

In a modernised agrarian context, as witnessed in several parts of Tamil Nadu the surface sources of irrigation are becoming scarce year by year. Choosing crops, date of sowing / harvesting under tank / canal irrigation, ultimately depends upon the availability and the timing of the release of water from reservoir / tanks.

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.

4.5.2 Suggestions For Meeting Future Needs

The Surface Water Potential of this basin has been fully utilized. The maximum quantity of surface water, i.e. 85 to 90% is consumed by agriculture. But the overall efficiency of this sector is 30 to 40%. If about 10% of this consumption could be reduced, it would result in considerable savings and the quantum of water could be spared for other purposes. The following short term measures are suggested for reducing the consumption of water for irrigation.

1. Equitable distribution of irrigation water by better water management.
2. Improving the performance of the existing irrigation system by suitable structural measures.
3. Introducing Micro irrigation like, drip and sprinkler irrigation.
4. Conjunctive use of surface and ground water wherever possible.
5. Renovating old tanks and ponds, desilting of supply channels and constructing water harvest structures to improve irrigation potential.
6. Planning for effective rainwater harvesting and saving surface water, which is let into sea during the flood.
7. Adopting better agricultural practices such as crop rotation, raising garden crops and other less water consuming crops.

4.5.3 Inter Basin Transfer Of Water

Karamaniyar sub basin of Nambiyar river basin receives water from Tamiraparani river basin through Manimuthar IX canal and surplus from the tanks fed by Manimuthar XI Distributory. Hanumanadhi sub basin receives water from Kodaiyar river basin through Radhapuran canal.

U/S View of Kodumudiyar Reservoir

D/S View of Kodumudiyar Reservoir

View of Kodumudiyar Reservoir

View of of Valliooranka l offtaking from Kodumudiyar Dam

SALIENT FEATURES

1	Name of the project	**: KODUMUDIYAR RESERVOIR PROJECT**
2	Location of the Project	: At the confluence point of Kodumudiyar and Kombaiyar
	District	**:** Tirunelveli
	Taluk	**:** Nanguneri & Radhapuram
	Village	**:** Thirukkarangudi (head work)
3	Geographical Location of Head work	
	Latitude	**:** 8 ^{0} 26 ’ 00’’ (Topo sheet No 58H/1)
	Longitude	**:** 77 ^{0} 32’ 00’’
4	Total number of Villages Benefited	**:** 17 Nos.
5	Total number of Tanks benefited	**:** 44 Nos.
6	Ayacut benefited	
	a) Stabilisation	**:** 1954.00 Acre (790. 79 Hec)
	b) Gap to be Bridged	**:** 1925 .00 acre (779.79 Hec)
	c) Present Cultivable Extent	**:** 1902.00 Acre (769.54 Hec)
	Total	**: 5781 Acres (2339.50 Hec)**
	Direct Ayacut	936.90 Ac (379.16.0 ha)
	In direct Ayacut	4844.01 Ac (1960.34.0 ha)
7	Anticipated additional food production	**:** 2517 tonnes
8	Scheme cost	**:** Original :Rs. 2104..42 Lakhs vide G.O Ms. No.78 / PW (P2) dt.25.2.96 **:** Revised : Rs. 3050 Lakhs vide G.O Ms.No. 128 / PW(P2) dt 31. 3. 2003
9	Year of construction	**:** 2000 - 2003
10	No. of channels under the scheme	**:** i) Valliioorankal, iii) Vadamalayankal ii) Padalayarkal,

HYDRAULIC PARTICULARS:

1	Total Length of Dam	:	411.00 m
	a) Length of Earth Dam	:	267.80 m (From Ls 0m to 267.80m)
	b) Length of Masonry Dam	:	143.20 m (From Ls 267.80m to 411m)
	i)Length of Uncontrolled Spillway	:	49.00 m(From Ls 267.80m to 316.80m)
	ii) Length of Controlled Spillway	:	15.20 m (From Ls 316.80m to 333m)
	iii) Length of Canal & River Sluices	:	13.00 m(From Ls 333m to 346m)
	iv) Length of Non Over flow Section	:	66.00 m(From Ls 346m to 411m)
2	Full Reservoir Level (FRL)	:	+158.00 m
3	Maximum water Level (MWL)	:	+ 159.80 m
4	Crest Level of Controlled Spillway	:	+ 155.40 m
5	Sill Level of Canal & River Sluices	:	+ 142.00 m
6	Top Bund Level (TBL)	:	+161.80 m
7	Deepest river bed level	:	+133.880 m
8	Free Board over MWL	:	2.00 m
9	Maximum Height of Dam	:	28.50 m
10 (a)	Top Width of Earth Dam	:	6.00 m
(b)	Front slope of earth dam	:	3:1
(c)	Rear slope of earth dam	:	2:1
(d)	Rear berm level	:	+ 151.800 , +141.800
(e)	Berm width	:	3m
(f)	Cut off trench (From Ls 60m – 220m) width	:	4.00m
(g)	Cut off trench side slope	:	1:1
(h)	Top level of impervious zone	:	+159.800
(i)	Side slope of impervious zone	:	1:1
j)	Top width of impervious zone	:	3m
11	Top Width of Masonry Dam	:	5.00 m

12 (a)	Canal Sluice number and size	:	1 No- 1.50 m x 1.80 m
(b)	River Sluice number & size	:	1 No – 1.50 x 1.80 m
13 (a)	Designed discharging capacity of River /Canal Sluice	:	12.742 Cumec (450 Cusecs)
(b)	Maximum discharging capacity of River / Canal Sluice	:	28.32 Cumec (1000 Cusecs)
14	Storage Capacity of Reservoir		
	Live Storage	:	3.45 M. Cum (121.84 M. Cft)
	Dead Storage	:	0.13 M. Cum (4.59 M. Cft)
	Total	:	3.58 M. Cum (126.53 M. Cft)
15	Total storage capacity of System tanks	:	13.02 M. Cum (459.80 M. Cft)
16	Over all storage capacity of Reservoir + Tanks	:	16.60 M. Cum (586.53 M. Cft)
17	Number of Fillings	:	2.11 Nos.
18	Annual Storage	:	
	From Reservoir	:	7.55 M. Cum (266 M. Cft)
	From System Tanks	:	27.43 M. Cum (970.M.Cft)
	Total annul storage	:	34.98 M. Cum (1236.M.Cft)
19	Catchment area to the Reservoir	:	
	Hill	:	8.60 Sq. Miles (22.27 Sq. Km)
	Plain	:	1.00 Sq. Miles (2.59 Sq. Km.)
	Total	:	9.60 Sq. Miles (24.86 Sq. Km)
20	'C' value adopted in Rive's Formula	:	2000
21	Water Spread area of Reservoir	:	53.38 hec. (131.90 Acres)
22	Flood Discharging Capacity of the Reservoir	:	
	a) Uncontrolled Spillway	:	258.80 Cumec (9140 Cusecs)
	b) Controlled Spillway	:	224.96 Cumec (7944 Cusecs)
	Total	:	483.76 Cumec (17084 Cusecs)

NAMBIYAR RESERVOIR

U/S view of Nambiyar Reservoir

U/S and D/S view of Nambiyar Reservoir

D/S view of Nambiyar Reservoir

D/S view of Nambiyar Reservoir

Salient features

Name of the river across which the Reservoir is constructed	:	Nambiyar river
Origin of the river	:	Eastern slopes of west Ghats
Length of the river	:	48.00 Km
Confluence into the sea	:	Gulf of Mannar
Location of the project :		
District	:	Tirunelveli
Taluk	:	Radhapuram
Village	:	Kottaikarunkulam
Geographical Location		
Latitude	:	$8^0$22’25” N
Longitude	:	$77^0$44’15” E
Rain fall Station	:	Radhapuram
Total No. of villages benefited	:	8 Nos.
Total No. of tanks benefited	:	40 Nos
Ayacut Benefited:	:	1743.67 Acres
Stabilization	:	910.93 Acres
Providing the gap	:	457.74 Acres
New dry	:	375 Acres
Land acquisition	:	149.23.0 Ha Patta lanc
	:	132.15.0 Ha – Paramboke land
Anticipated additional food production	:	3695 Tonnes
Scheme cost R.E	:	Rs. 2050 Lakhs
Original cost	:	Rs. 1205.87 Lakhs
G.O. Ms. No.	:	80 PW (P2) dt. 12.1.1996
Channels under the scheme	:	LMC from LS 0m to 10220m
	:	RMC from LS 0m to 10645m
Year of construction	:	1998-2000

HYDRAULIC PARTICULARS

Components of Dam

Total length of the dam	:	2605m
Length of the earthdam	:	2365m
Length of surplus weir	:	240m
Live storage	:	1.83 Mcum (64.74 Mcft)
Dead storage	:	0.50 Mcum (17.43 Mcft)
Total storage	:	2.33 Mcum (82.17 Mcft)
No. of fillings	:	2.5 Nos
Annual storage	:	4.59 Mcum (162 Mcft)
FRL	:	+ 53.000M
MWL	:	+ 54.800 M
TBL	:	+ 56.600 M

Features of Weir

Crest level of weir	:	+53.00M
Rear water level	;	+50.80M
Apron level	:	+46.00M
Rear slope	:	0.6:1
Front slope	:	0.11:1
Type of weir	:	
Bottom width of surplus weir	:	8.31M
Free board	:	1.80 M
Deepest bed level	:	+ 45.76 M

Depth of storage	:	7.24 M
Sill level of scour sluice	:	+46.00M
Sill level of river sluice	:	+50.00
Maximum flood discharge	:	1247 cumecs or 45000 c/s
Depth of flow over crest	:	1.80 M

Features of Earth dam

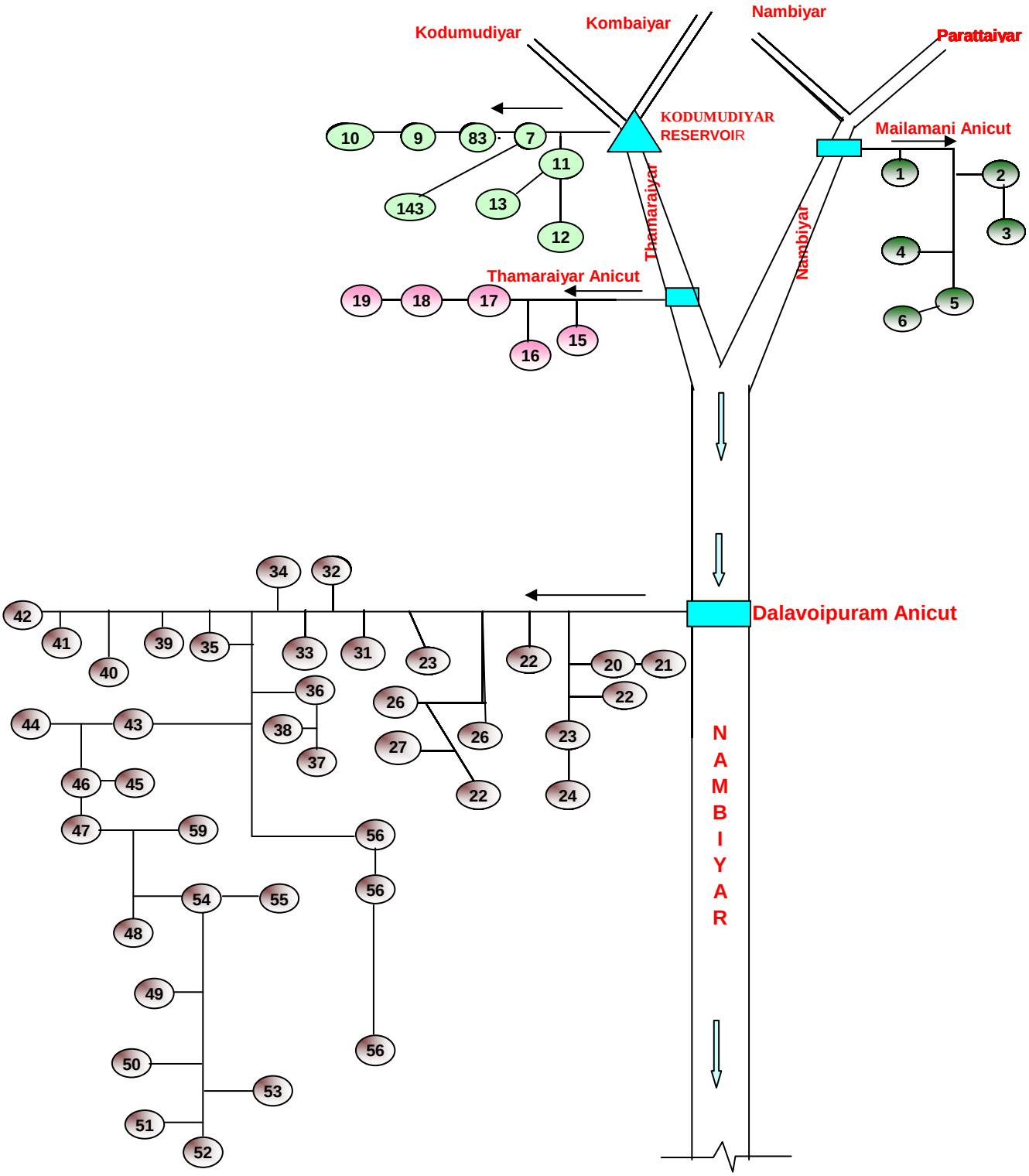
Length of Earth dam	:	2365 M
Top width of Earth dam	:	3.65 M
Side slope (Front & Rear slope)	:	2:1
TBL	:	+56.600 M
Road top level	:	+56.900 M
Parapet top level	:	+57.300 M
Water spread area	:	376 Acres
Catchment area:	:	
Free	:	18.40Sq.miles
Intercepted	:	54.18 Sq. miles
Total	:	72.58 Sq.miles
C Value Hilly	:	2000
C Value Plains	:	2000

STATEMENT SHOWING THE HYDROLOGY OF NAMBIYAR RIVER

Sl. No.	Name of Anicut across the River	Catchment area in square mile			Yield in Mcft / Sq miles	Yield Available	Surplus available from upper anicut Mcft	Yield from Tank Mcft	Contribution from sub tributory if any in Mcft	Total yield available (7+8+9) Mcft	Registered Ayacut in Acress		Requirement of Tanks		Registered ayacut for Rainfed Tanks in Acres			Requirement for the Rain of Tanks		Total require ment under the anicut MCFT (15 + 16)	Surplus (11-16) MCFt	Deficit in Mcft (16-11)	Remarks
		Free	Inter- cepted	Com- bined							S.C.	D.C.	6 acres Mcft for SC	4.02 Mcft for DC	No. of tanks	S.C	D.C	For S.C 6 acres/ Mcft for SC	For D.C 4.02 Ares/ Mcft for SC				
1	2	3	4	5	6	7	8	9	10	11	12		13		14			15		16	17	18	19
1	Mailamani Anicut	12.17 H	-	12.17H	8.00	634.11	-	117.21		751.32	807.96	1264.46	134.66	314.54	-	-	-	-	-	449.20	302.12		
		0.86P	-	0.86P																			
2	Kodumudiyar	8.6 H	-	8.6H	8.00	323.80	-	56.97	-	397.77	767.69	526.88	127.9	131.06						258.96	138.81		
		1p	-	1P																			
3	Thamaraiyar Anicut	0.04H	8.6H	8.64H	9.76	138.81	-	86.45	-	235.02	914.98	308.27	152.49	76.68	-	-	-	-	-	229.17	5.85		
		1.18P	1P	2.18P																			
4	Thalavaipuram Anicut	3.18H	12.17H	15.35P	8.00	25.44	302.12	443.68	5.85	777.09	2523.13	922.33	420.52	229.44	-	-	-	-	-	649.96	127.13		
			0.86P	0.86P																			
5	Rajakamangalam Anicut	1.98H	15.35H	17.33H	8.00	167.85	127.13	16 (-) 117.21	-	193.77	886.57	141.35	64.43	35.16	12	571.9	211.50	95.32	52.61	247.52	-	53.75	
		17.35P	0.86P	18.21P																			
6	Mylaputhoor Anicut		17.33H	17.33H	8.00	16.72	-	24.00	-	40.72	191.96	0.49	31.99	0.12	-	-	-	-	-	32.11	8.61		
		2.09P	18.21P	20.30P																			
7	Kannanalloor Anicut		17.33H	17.33H	8.00	2.16	8.61	17.20	-	27.97	315.73	-	52.62	-	-	-	-	-	-	52.62	-	24.65	
		0.27P	20.30P	20.57P																			

8	Vijayan Anicut		17.33H	17.33H	8.00	42.16	-	312.80 (-) 23.20	-	331.76	1775.74	196.93	295.92	48.99	1	20.48	-	3.41	-	348.32	-	16.56	
		5.27P	20.57P	25.84P																			
9	Kovankulam Anicut		17.33H	17.33H	8.00	8.08	-	110.40	-	118.48	330.04	-	55.01	-	-	-	-	-	-	55.01	63.47		
		1.01P	25.84P	26.85P																			
10	Nambiyar Reservoir		17.33H	17.33H	8.00	147.20	63.47	0.52	-	211.19	Stablisation=910.93acre Bridging the Gap=457.74acre New Dry=375.00acre					Water Requirement =162Mcft As per Nambiyar Reservoir Estimate				162.00	49.19		
		18.47P	26.85P	45.25P																			
11	Thttikulam Anicut		17.33H	17.33H	8.00	158.80	49.19	8.40	-	216.39	85.76	-	14.29	-	13	242.2	3.51	40.36	0.87	55.52	160.87		
		19.85P	45.25P	65.10P																			
12	Pulimankulam Anicut		17.33H	17.33H	8.00	14.96	160.87	18.00	-	193.83	131.47	-	21.91	-	1	11.15	-	1.86	-	23.77	170.06		
		1.87P	65.10P	66.97P																			
13	Check Dam at Athankarai Pallivasal		17.33H	17.33H	8.00	558.48	170.06	(-) 326.05	-	402.49	476.70	-	79.45	-	31	690.5	122.96	#####	30.62	215.16	187.33		
		69.81P	66.97P	136.78																			
14	Confluence with Sea		17.33H	17.33H	-	-	235.00	-	-	187.33	-	-	-	-	-	-	-	-	-	-	187.33		
			136.78P	136.78P																			

Nambiyar Sub Basin Flow Chart



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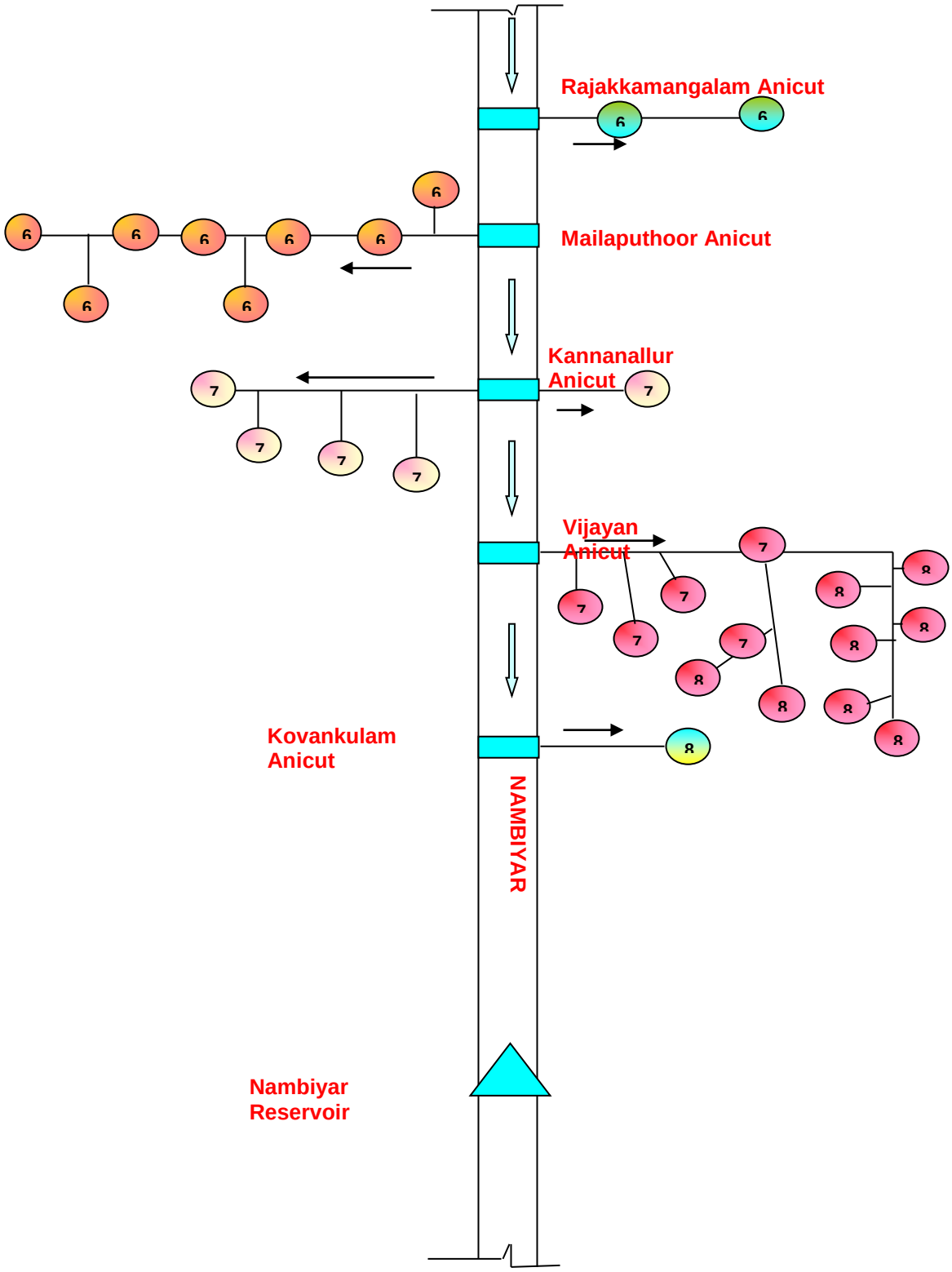
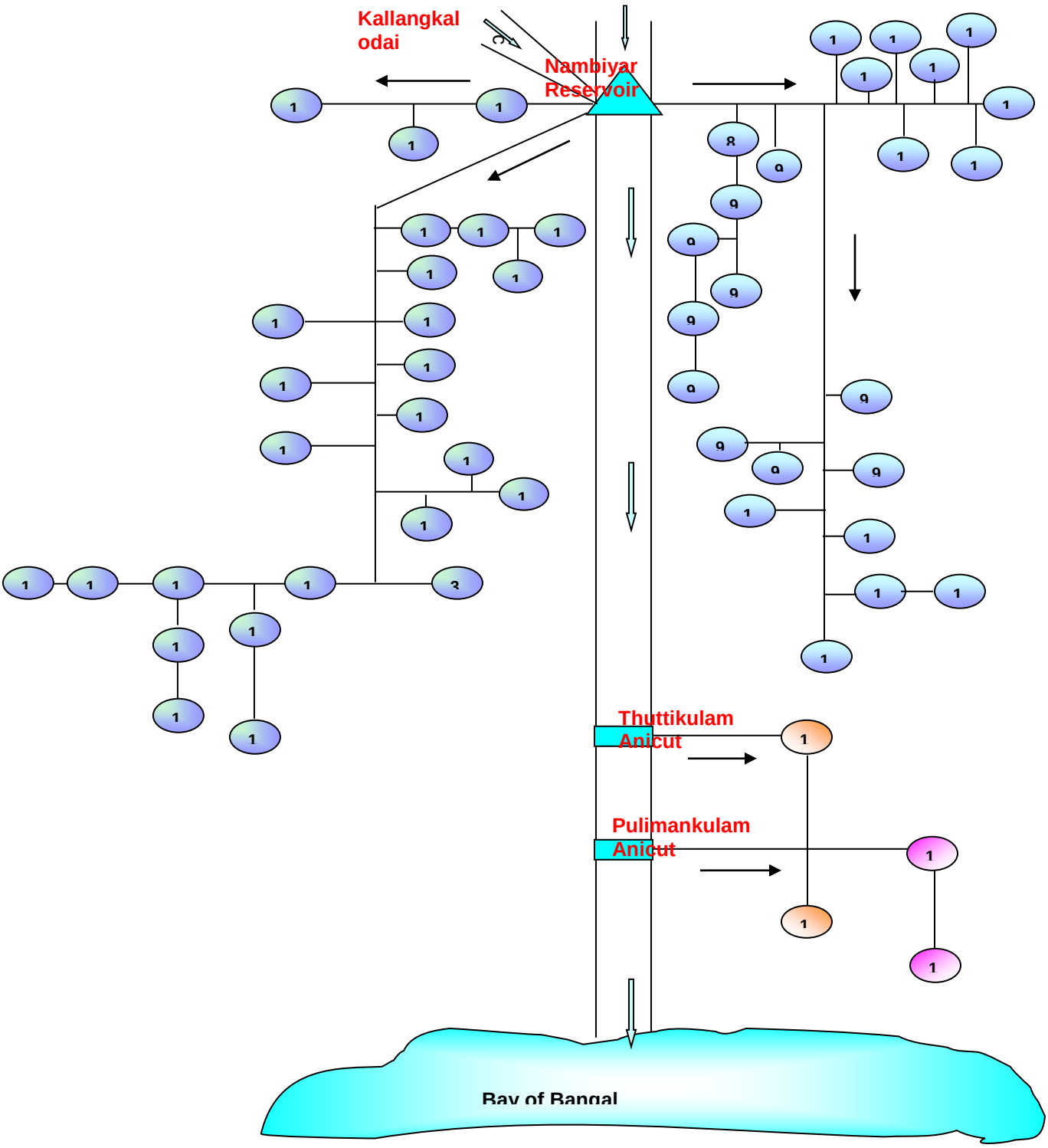
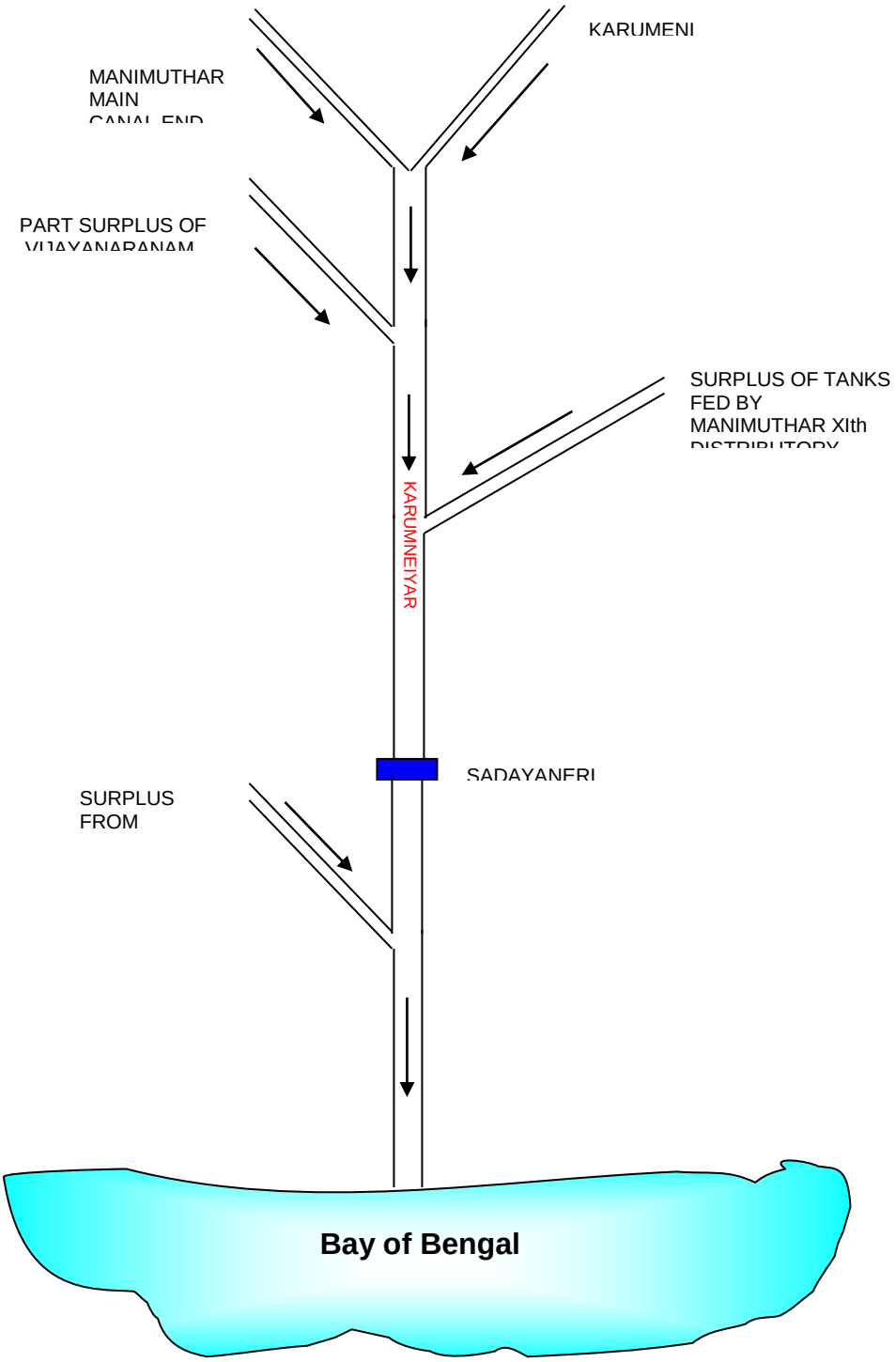

Rajakkamangalam Anicut
Mailaputhoor Anicut
Kannanallur Anicut
Vijayan Anicut
Kovankulam Anicut
NAMBIYAR
Nambiyar Reservoir

Contd…



FLOW DIAGRAM OF KARAMANIYAR RIVER


KARUMENI
MANIMUTHAR
MAIN
PART SURPLUS OF
SURPLUS OF TANKS
FED BY
MANIMUTHAR XIth
KARUMNEIYAR
SURPLUS
FROM
Bay of Bengal

HANUMANADHI FLOW DIAGRAM

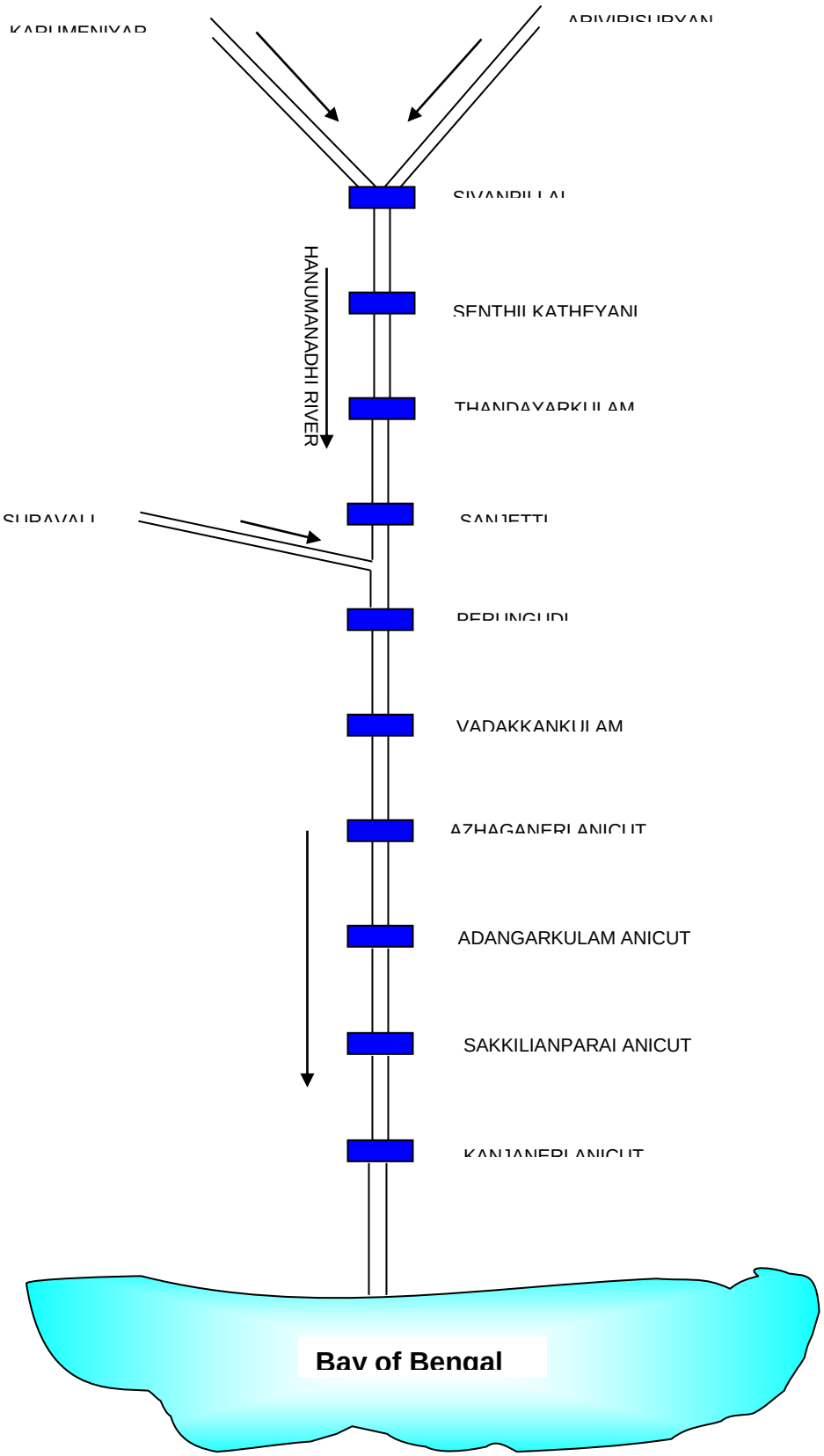
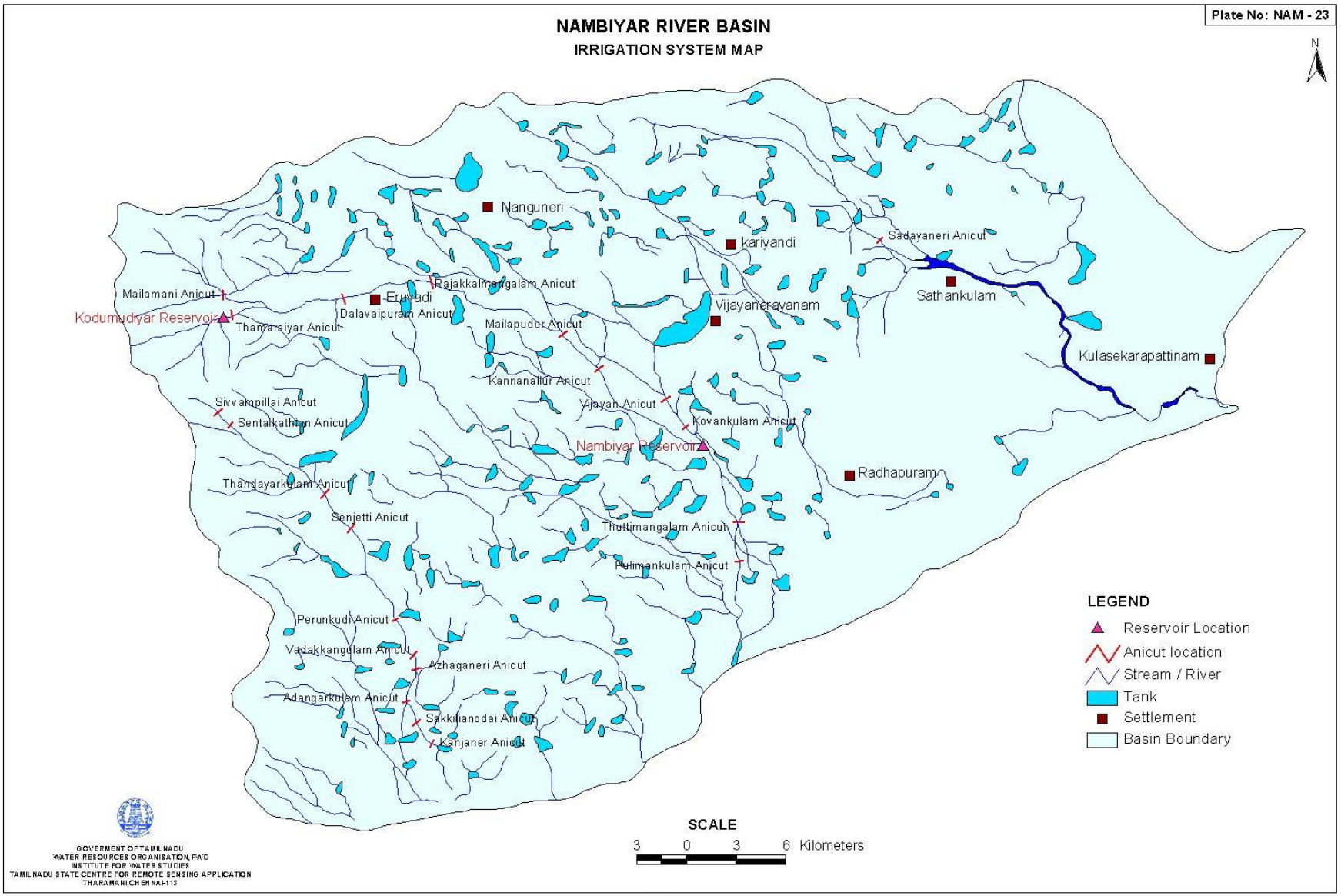


Plate No: NAM - 23

NAMBIYAR RIVER BASIN

IRRIGATION SYSTEM MAP



GOVERMENT OF TAMIL NADU
WATER RESOURCES ORGANISATION, PWD
INSTITUTE FOR WATER STUDIES
TAMIL NADU STATE CENTRE FOR REMOTE SENSING APPLICATION
THARAMANI,CHENNAI-113

CHAPTER – 5

GROUND WATER RESOURCES AND QUALITY

CHAPTER – 5
GROUND WATER RESOURCES AND QUALITY

5.1 PREAMBLE

Tamil Nadu being an agrarian State, its economy is based on agriculture. Agriculture production depends upon the availability of water resources. Since, the available surface water resources are fully harnessed, groundwater is the only alternative source for agricultural development. The area irrigated by wells constitutes about 48% of the total irrigated area in the State. It is estimated that about 78% of the available groundwater resources is being utilised, leaving a balance of only 22% which is mainly concentrated in command areas of reservoirs and tanks and in coastal sedimentary belts. Largely, there is no much scope for further development of groundwater for irrigation on large scale. It is felt that the strategy for development of groundwater in Tamil Nadu in future, especially for agriculture, must be management oriented. In addition to groundwater for agriculture, most of the demands for domestic water supply for urban and rural population are being met out from groundwater resources only. Even, the industrial sector mostly depends on groundwater for the water requirement of small, medium and major industries. Tamil Nadu is one of the pioneer States in utilizing the groundwater to the maximum, to meet its various demands. The groundwater also substitutes surface water sources at the time of drought, which is a recurring phenomenon in Tamil Nadu. Due to increased development of groundwater in Tamil Nadu the following problems are identified:

- Depletion of groundwater table below the economic pumping level and excess mining of the available groundwater resources above the optimum level.
- Increasing trends in critical and over exploited blocks.
- Seawater intrusion in the coastal region.

Since, groundwater has become a major source for irrigation, the groundwater scenario of the basin should be watched and timely action has to be taken for ground water regulation management, conservation and augmentation of this natural resource. Keeping in view of these aspects, an attempt has been made to assess the groundwater potential on a micro level.

Unlike stream flows, which depend on monsoon, groundwater is very dependable even though its exploitation requires technology and energy. It is very useful for providing

assured supply of water for domestic requirement, irrigation and other purposes during breaks, late onset or early withdrawal of the monsoon and during non-monsoon periods and where surface water resources are limited. For long term planning, development and management, a systematic and scientific assessment of groundwater resources is quite indispensable. The development of groundwater may be for irrigation or other uses in industries and water supply sectors. For proper evaluation of groundwater resources, data on rainfall, geological conditions, occurrence of geomorphic units, hydro geological environments, physiographic features, land use patterns, etc. are necessary. The following sections summaries the groundwater availability and status prevailing in the basin.

5.2 GROUNDWATER OCCURRENCE

5.2.1 General

The occurrence of groundwater depends on geological and physiographical setting as well as on climatic conditions. Further, the degree of structural deformation and weathering of the geological formation control the distribution of groundwater both in vertical and lateral directions. The geological background of the Nambiyar basin is detailed in Chapter 2.

The appraisal of groundwater occurrence is based on geological evaluation and observation wells. An inventory of about 29 observation wells spread over the entire basin has been scrutinised and the periodical water level fluctuations were examined sub-basin wise, to study the hydro geological nature and groundwater occurrence. The list of 29 observation wells considered for the study is indicated in Table A.There are about 9 rain gauge stations in the Nambiyar basin. The occurrence of groundwater depends mainly on the geological conditions, physiographical condition and climatic conditions of the basin. Further the degree of structural deformation and weathering in the formations control the distribution of groundwater in lateral and vertical directions. The appraisal of groundwater occurrence is based on the analysis of sub-surface geological data of the observation wells and lithologies of other deep bore wells along with the water level fluctuation data of the shallow observation wells and the deeper bore wells.

In hard rocks.

In the hard rock areas, the groundwater occurs under water table condition in the top loose formations and weathered zones. It occurs under semi confined and confined conditions in the fractured and fissured zones at deeper depths.

In Valley fill

The valley fill sediments are distributed in the valley portions of the area of the western part of Nambiyar basin. Groundwater occurs under water table condition in general but in clay and silt formations, semi confined condition has been observed.

In Alluvium

In the alluvial patch, the groundwater occurs under water table conditions as well as in the semi-confined conditions. The alluvium is the highly porous and permeable, developing into potential zones.

In Sedimentary rocks

The sedimentary formations encountered in this basin area includes grit, tertiary formations of sand stone and shale with recent to sub recent laterite and alluvium as the top layer in general. Groundwater occurs under pheriotic and semi confined conditions.

5.2.2 Occurrence of groundwater in the Three sub basins of Nambiyar River Basin

Nambiyar sub basin

The Nambiyar orginates from eastern slope of western ghats of Tirunelveli district. The drainages namely the Nambiyar, Paraliyar, Kombaiyar and Kodumudiyar are originating from the western part and passes through Kodumudiyar Resrvoir , Mailamani anicut ,Kallankal odai and ends at Gulf of Mannar. The main source of Irrigation for Nanghuneri Taluk is from Nambiyar . It has an area of about 604 sq km. The predominant soil types found in this river basin is hard rock and some pockets having sedimentary formation in the coastal belt . There are thirteen observation wells in this sub basin. The winter water level varies from 4.50 to 19.00 m and the summer water level ranges from 19.00 to 19.40 m below ground level.

Hanumanadhi sub basin.

Hanumandhi originates in the eastern slope of western ghats from Hanumanadhi river and Arivirisuryan river and passes through Sivan pillai anicut and flows in to the Gulf of Mannar. The entire sub basin is underlain with hard rock formation.The area of this sub

basin is 510 sq km. There are four observation wells in this sub basin. The winter water level varies from 3.50 to 11.00 m and the summer water level varies from 11.00 m to 11.50 m

Karamaniyar sub basin

Karamaniyar river orginates from east of kalakkadu village of Tirunelveli district The Karamaniyar passes through Sadayaneri anicut and flows in to Gulf of Mannar .The soil types found in this river basin is Gneiss formations where includes Alluvium . The sub basin has an areal extent of 904 sq km. There are ten observation wells in this sub basin. The winter water level varies from 4.00 to 13.50 m and the summer water level ranges from 13.50m to 15.50 m.

5.3. AQUIFERS

5.3.1 Methodology.

While working on large and small-scale problems of groundwater hydrology, the Geologists or the Engineers constantly faced the question of finding reliable and representative values of various hydraulic characteristics of aquifers. Pumping tests have proved to be the most suitable means of achieving this objective. The practical use and application of such tests have been enlarged by our recent understanding of groundwater hydraulics along with the development of methods of using the test data to calculate the principal factors for finding out the aquifer performance.

The hydro geological regime of an aquifer is determined by its hydraulic parameters and aquifer recharge and discharge. The hydraulic parameters i.e. conductivity, transmissivity, specific yield and storage coefficient are evaluated by pumping tests and water balances. These parameters are also used for analyzing and selecting optimum scenarios of groundwater development and management. Geophysical studies have also been carried out to help determine aquifer depth and configuration.

For a quantitative understanding of most problems in hydrogeology, it is necessary to have an accurate knowledge of the aquifer parameters like Co efficient of Transmisivity (T), Co efficient of Storativity (S) and the Permeability (K). Among the various methods available for the determination of aquifer parameters, techniques involving pumping tests enjoy a leading position.

Essentially, a pumping test consists of discharging a well and observing the rate of change of water level in the pumped well itself or in the nearby well. Consequent to the well discharge a pressure gradient is created in the vicinity of the pumped well resulting in the forming of a cone of depression, which induces the necessary flow of water to sustain the well discharge. The behaviour of the cone of depression in space and time is a function of several factors, such as the aquifer parameters and aquifer configuration and the rate of well discharge. Conversely if the physical behaviour of the cone of depression is known by the time - draw down or the distance - draw down relationships observed during a pumping test, the aquifer parameters can be easily computed. Pumping tests are being carried out in the bore wells also to determine one or more of the following.

- The aquifer characteristics to assist in the evaluation of the groundwater potential of the basin during a broad groundwater investigation.
- To determine the existence and the location of sub surface boundaries which may affect the basin beneficially or adversely.
- To determine the long term pumping rate from a particular bore well.
- To check the performance of a particular groundwater basin.

5.3.2 Aquifer bottom

The predominant soil types found in this river basin is Genessis formations include Alluvium, and partly Sedimentary rock formations are found in many parts of the basin. Crystalline formation comprises of granite gneisses, charnockites and hybrid gneisses and sedimentary formations comprise of cretaceous and tertiary sandstones and quaternary alluvial formations are also seen..

Results of geophysical resistivity survey conducted in the basin, lithological details of available boreholes drilled by various Government agencies, the pump test details of boreholes and chemical analysis of groundwater samples collected from the observation wells and the bore wells were studied in details to know the hydro geological conditions of the basin.

5.3.3 Aquifer Transmissivity and Hydraulic Conductivity.

The Central Ground Water Board (CGWB) has drilled many deeper bore wells to identify the area extent of aquifers in our area of interest. Those datas have been considered for this report. The Pumping test datas are given in Table 5.1 to 5.4.

Table : 5.1 Aquifer parameter in Hard Rocks.

Sl No	**Aquifer Parameter**	**Minimum**	**Maximum**
1.	Transmissivity (T) (m^2/day)	2.51	284
2.	Well Yield (liters per second.)	2.53	5.36
3.	Specific Capacity (lpm/m draw down)	5.37	197
4.	Storativity (S)	$1.75x10^{-6}$.	$7.85x10^{-6.}$

The higher Transmissivity value indicates the presence of lineaments and well developed fractures in the formations. The lesser value of Transmissivity indicates the less jointed zones with more compact nature of rocks.

Table :5.2 Aquifer Parameter in Vally Fills.

Sl No	**Aquifer Parameter**	**Minimum**	**Maximum**
1.	Transmissivity T (m^2/day)	51	485
2.	Well Yield (Liters per second)	1.23	7.50
3.	Storativity S	$1.75x10^{-6}$	$5.75x10^{-6}$

Table 5.3 Aquifer parameters in Alluvial Formations.

Sl No	**Aquifer Parameter**	**Minimum**	**Maximum**
1.	Transmissivity T. (m^2/day)	0.70	2450
2.	Well Yield (Liters per second)	0.30	21
3.	Storativity S	$2.11x10^{-6}$	$6.80x10^{-6}$

Table :5.4 Aquifer Parameters in Sedimentary Rocks.

Sl No	**Aquifer Parameter**	**Minimum**	**Maximum**
1.	Transmissivity T. (m^2/day)	4.25	452
2.	Well Yield (Liters per second)	0.20	21
3.	Storativity S	$1.31x10^{-6}$	$1.25x10^{-6}$

5.4 SPACING OF WELLS

The following spacing norms have been issued by NABARD in 1992 for adoption between any two minor irrigation structures. These range from 150 m (between two dug wells) to 600 m (between any two deep tube wells). These spacing norms are applicable for the entire State of Tamil Nadu for construction of new structures for development of groundwater for minor irrigation purposes.

The guidelines for the minimum spacing to be adopted between any two structures as issued by NABARD, the agency that releases the industrial finance are as follows:

1.	Two dug wells	150 m
2.	Two shallow tube wells	175 m
3.	Two filter points	175 m
4.	Two dug cum bore wells	175 m
5.	Two medium tube wells	600 m
6.	Two deep tube wells	600 m
7.	Medium tube wells and deep tube wells	600 m
8.	Shallow tube wells and medium tube wells	387.5 m
9.	Dug wells and shallow tube wells	162.5 m
10.	Dug wells and medium tube wells	375 m
11.	Dug wells and deep tube wells	375 m

These spacing norms are followed even for deepening of existing wells. However, spacing needs to be observed for further deepening of wells also where institutional finance has already been availed for digging of well itself. The construction of new wells will be permitted only in safe category blocks and to some extent in semi critical blocks. Clearance will not be issued for sinking new wells in critical and over exploited blocks in view of increased groundwater exploitation.

Groundwater development has been extensive in the coastal districts in view of the favourable hydro geological condition existing along the coastal area. Over-extraction in the coastal area may lead to seawater intrusion and suitable management strategy is to be adopted in this zone. As a precautionary measure, certain restrictions have been imposed for

financing of minor irrigation schemes involving development of groundwater to a distance of 10 km from the coast of Tamil Nadu.

5.4 .1 Groundwater Flow Regime and W.L. Fluctuations

Totally twentynine observation wells in the basin are considered for the study (PLATE: NAM - 24). The list of these observation wells is presented in Table A.

The storage in Excel spread sheets of the historical (1971 – 2005) groundwater levels in the twentynine observation wells of the basin has been completed. Contour maps showing the depths to groundwater table for premonsoon and post monsoon (below ground level) for July 84, Jan - 85, July 94, Jan - 95, July 04 and Jan - 05 have been prepared and are shown in PLATE: NAM – 25, 26, 27, 28, 29 and 30 respectively. The hydro geological regime of the aquifer is also characterized by this groundwater level fluctuations and flow directions. Groundwater levels are displayed in the form of hydrographs for analysis of the long term trends and in the form of contour map for analysis of flow directions for the wells listed in the Table A, vide Appendix 5.1 (VOL – II)

5.4.2 Water Level Fluctuations

Long-term hydrographs (1971–2005) of the groundwater levels for all the observation wells have been prepared. In some wells, changes can be seen in the long-term trend. A groundwater level depletion can be noticed in some of the observation wells (93039, 93039A, 93066, 93106A, 93107 A and 93110). The depletion in water table ranges from 10.00 m to 11.00 m.

The maximum summer water level and minimum winter water level of individual observation well is taken into account for calculating the fluctuation. The fluctuations differ from well to well and are found to be in the range of 12.00 to 19.50 m.

5.4.3 Groundwater Flow Regime

As can be seen from maps (contour map of July- 84, Jan – 85, July -94, Jan - 95, July - 04 and Jan - 05), the groundwater flow direction is in general from north to east towards the sea with gradients getting smaller along the flow lines. In some locations, the flow is diverted towards the river.

5.5 GROUNDWATER POTENTIAL

Methodology of Groundwater Assessments

The purpose of a groundwater study in an area is to enable large-scale development and optimum utilization and conservation of the groundwater resources. It is necessary to assess the groundwater potential and groundwater availability of the basin under study.

The methods of evaluation of groundwater potential are based mostly on water level fluctuations and specific yield approach. This methodology is also applied by the CGWB and the State Ground and Surface Water Resources Data Centre (SG & SWRDC) to assess groundwater potential. However, if detailed data are available, the detailed groundwater balance components can be assessed separately, otherwise components are lumped as inflows or outflows

The Groundwater Estimation Committee constituted by the Government of India has also recommended norms and standards for specific yields of different types of geological formations in the zone of water level fluctuation (2% to 4% for granites and 1 to 3% for weathered rocks etc.), seepages and return flows from canals and irrigation, well abstraction, etc.

Aquifer recharge is mainly from rainfall infiltration and seepages from irrigation canals, tanks, ponds, ditches and streams.

Groundwater is the main source of irrigation in Kharif season and it is the only source of irrigation in Rabi season. The irrigation wells in the study area are broadly grouped as dug wells, dug-cum-bore wells and shallow bore wells.

The groundwater extraction is worked out based on the cropping pattern and the existing number of wells and their categories.

Groundwater Potential in the Study Area

The balance groundwater potential available for further development has been arrived by deducting the total groundwater extraction from the net groundwater recharge available. Table B shows the sub basin wise groundwater balance potential of the basin. The total available groundwater potential as on Jan 2003 is worked out as 163 Mcum and the total extraction of groundwater is worked out as 116 Mcum and are shown in Table B & Table C. The block wise status for the year 2003 Groundwater Assessments and problem areas in general is also indicated in the Table B.

Stage of Groundwater

Intensified use of groundwater without proper management results in the over-exploitation of most of the areas in this basin. The Chief Engineer (State Ground and Surface Water Resources Data Centre), PWD, WRO, Chennai is the authority for according approval for sanctioning Institutional Finance for farmers who are in need of the financial facility. The Chief Engineer (SG&SWRDC) has classified as on January'2003, the 385 administrative blocks in the state as Safe, Semi Critical, Critical and overexploited depending upon the present stage of groundwater development.

Categorisation of Block

Sl. No.	**% of Development**	**Category of block**
1	Groundwater Development less than 70% of the annual recharge	Safe area
2	Groundwater Development more than 70% but less than 90% of the annual recharge	Semi critical
3	Groundwater Development more than 90% but less than 100%	Critical
4	Groundwater Development more than 100% of the annual recharge	Over-exploited area

The classification of blocks as safe, semi-critical, critical and over exploited in respect of blocks in the basin is given below:

Classification of Blocks based on the level of Groundwater Development

Sl.No.	**DISTRICT**	**BLOCK**	**LEVEL**
1	Tirunelveli	Kalakkadu	Safe
2	Tirunelveli	Valliyur	Over Exploited
3	Tirunelveli	Radhapuram	Over Exploited
4	Tirunelveli	Nanguneri	Safe
5	Kanyakumari	Thovalai	Safe
6	Kanyakumari	Agastheeswaram	Safe
7	Tuticorin	Alwarthirunagar	Semi Critical
8	Tuticorin	Tiruchendur	Semi Critical
9	Tuticorin	Sattankulam	Over Exploited
10	Tuticorin	Udankudy	Over Exploited

The domestic water demand is expected to increase by 200% in the year 2045 and hence a decision has to be taken by the Government of Tamil Nadu to meet the increased demand in 2045. One of the recommended strategies is to construct small storage reservoirs, check dams etc. to conserve the surface runoff flows in to the sea. New reservoirs / tanks could be designed exclusively as a drinking water resource instead of bringing new area under irrigation.

5.6 INSTITUTIONAL SETTINGS

The Government of Tamil Nadu has recently created the State Water Resources Organisation, under which the State Ground and Surface Water Resources Data Centre, headed by a Chief Engineer has been formed.

All activities connected with groundwater survey, irrigation, development and management are carried out by three circles (at Chennai, Thanjavur and Madurai) each headed by a Superintending Engineer. The entire range of fieldwork and data generation is carried out by 10 field divisions (each headed by Executive Engineers), 34 Engineering Sub-divisions, 3 Geo chemical sub-divisions, and 19 Geological sub-divisions.

The CGWB is operating in the State through its recently created Regional office for Tamil Nadu State headed by a Regional Director supported by multidisciplinary team of officers.

Agricultural Engineering Department of Government of Tamil Nadu is carrying out groundwater exploration and borehole drilling for the public.

Chennai Metropolitan Water Supply and Sewerage Board (CMWSSB) is looking after the drinking water supply to Chennai Metropolitan area.

Tamil Nadu Water Supply and Drainage Board (TWAD) is responsible for rural and urban water supply in the State.

The Institute for Water Studies is in charge of scientific assessement of water resources and detailed studies including water resources planning.

5.7 ISSUES IN THE MANAGEMENT OF GROUNDWATER RESOURCES

5.7.1 Augmentation of Aquifer Replenishment / Groundwater Recharge

At appropriate sites, check dams across the rivers and streams are the means to augment aquifer replenishment by enhancing infiltration of surface flow to underground.

Additional Special Studies in the Nambiyar River Basin

An additional special study for a more accurate evaluation of return flows from irrigation, seepage from tanks and development of rainfall-replenishment relationships in small representative basins is suggested. In the Tiruchendur , Sattankulam, Udankudy, Valliyur and Radhapuram blocks, pollution studies have to be undertaken including groundwater flow and quality modelling.

Additional strategies may achieve the modest improvements in water use efficiency. A package of on-farm developments, shorter land preparation and rotational irrigation of paddy and expansion of irrigated dry cropping appear to be appropriate in this sub basin.

It is recommended to carry out a special study for determination of mass transport parameters and removal of pollutants and nutrients through the unsaturated layer and in the aquifer from point source pollution. This will be achieved by analysis of the groundwater quality data and the effluent quality and quantity discharged around the sites. The results will help to formulate regulations relating to effluent treatment and discharge, to the use of fertilizers and delineation of wellhead protection zones to assure safe drinking water. Observation wells at various distances from the point source effluent discharge and to various depths, both in the unsaturated layer and in the aquifer will be required in order to trace the migration of pollutants.

Table A - Details of Observation Well

Sl. No.	Observation Well No.	Observation well		Depth to water table in m bgl		Depth to water table in m bgl		Depth to water table in m bgl	
		Latitude North	Longitude East	Jul-84	Jan-85	Jul-94	Jan-95	Jul-04	Jan-05
1	93028	08°32'30"	77°43'00"	0.90	9.13	7.40	10.70	12.20	0.30
2	93031	08°27'23"	77°37'07"	3.72	4.15	4.90	4.38	6.45	3.05
3	93032	08°25'33"	77°43'52"	6.2	11.60	7.6	5.70	17.2	4.5
4	93032A	08°25'42"	77°43'40"	4.02	8.46	9.95	10.10	17.20	1.80
5	93033A	08°22'55"	77°50'20"	3.63	5.18	4.45	5.40	10.85	3.60
6	93039A	08°16'00"	77°34'16"	18.10	21.25	7.86	10.05	26.20	26.20
7	93040A	08°15'46"	77°40'46"	6.12	11.85	8.10	6.78	14.05	12.00
8	93041	08°16'12"	77°53'33"	7.91	8.12	8.00	7.80	8.60	7.50
9	93043	08°08'15"	77°33'55"	4.32	5.20	8.10	6.63	12.05	2.60
10	93060	08°19'00"	77°34'47"	4.82	7.25	8.52	6.18	15.64	6.45
11	93061	08°22'45"	77°36'32"	5.48	7.31	7.40	5.52	12.27	3.10
12	93062	08°29'27"	77°39'32"	5.27	6.10	5.20	3.78	7.00	3.05
13	93063	08°25'37"	77°47'27"	3.89	4.75	4.55	3.36	8.15	2.60
14	93064	08°32'45"	77°46'12"	3.08	4.54	5.55	2.60	7.60	3.60
15	93065	08°20'17"	77°41'37"	3.20	7.35	5.70	4.70	11.70	5.30
16	93066	08°10'32"	77°34'32"	14.31	14.63	11.87	8.92	-	-
17	93067	08°11'40"	77°45'00"	3.92	4.36	2.85	2.16	7.30	4.60
18	93068	08°18'29"	77°45'50"	3.64	6.69	7.40	5.90	12.84	9.10
19	93069	08°21'57"	77°48'28"	3.48	5.35	7.05	5.40	10.50	3.50
20	93071	08°31'30"	77°47'25"	6.07	7.77	6.15	7.42	10.75	7.20
21	93106	08°29'30"	77°52'45"	7.05	11.90	5.00	7.00	13.65	-
22	93106A	08°29'45"	77°53'00"	6.28	11.10	5.50	7.00	13.55	-
23	93107	08°30'00"	77°56'00"	7.54	12.00	6.20	8.00	11.43	11.43
24	93107A	08°29'07"	77°55'50"	11.05	15.15	8.85	10.00	21.65	-
25	93108	08°29'00"	78°01'30"	7.99	8.24	10.00	9.40	9.75	-
26	93110	08°25'00"	78°57'00"	11.57	12.50	10.00	10.10	15.50	-
27	93111	08°21'45"	77°59'00"	8.24	8.64	9.32	7.90	9.32	9.32

Table B - Groundwater potential

Sl. No	Name of Sub Basin	Name of Block	Total Block Area sq.km	Block Area falls in sub basin sq.km	% of block falls in sub basin	100 % Block Net potential Mcm	Block Net potential in sub basin Mcm	Total Sub basin Net potential Mcm	Level of Exploitation
1	Hanumanadhi	Kalakadu	440.940	2.401	0.0054	41.3576	0.2252	37.7672	Safe
		Valliyur	433.425	297.738	0.6869	27.7882	19.0889		Over Exploited
		Radhapuram	458.572	140.327	0.3060	24.4471	7.4810		Over Exploited
		Thovalai	369.070	61.915	0.1678	51.6508	8.6649		Safe
		Agastheeswaram	138.020	7.798	0.0565	40.8345	2.3071		Safe
2	Nambiyar	Kalakadu	440.940	172.347	0.3909	41.3576	16.1651	47.2898	Safe
		Nanguneri	502.590	78.006	0.1552	66.0175	10.2464		Safe
		Valliyur	433.425	135.687	0.3131	27.7882	8.6993		Over Exploited
		Radhapuram	458.572	212.031	0.4624	24.4471	11.3037		Over Exploited
		Thovalai	369.070	6.254	0.0169	51.6508	0.8752		Safe
3	Karamaniyar	Alvarthirunagar	212.620	68.187	0.3207	33.6417	10.7889	78.0121	Semi Critical
		Tiruchendur	135.680	4.438	0.0327	16.7310	0.5473		Semi Critical
		Sattankulam	294.430	294.430	1.0000	10.8154	10.8154		Over Exploited
		Udangudi	145.390	134.413	0.9245	12.6496	11.6946		Over Exploited
		Kalakadu	440.940	10.939	0.0248	41.3576	1.0260		Safe
		Nanguneri	502.590	285.316	0.5677	66.0175	37.4776		Safe
		Radhapuram	458.572	106.214	0.2316	24.4471	5.6624		Over Exploited
	Total			**2018.441**			**163.0690**	**163.0690**	

or 163 M.cum

Table C - Total Groundwater Extraction

Sl.No.	Name of Sub Basin	Name of Block	Total Block Area sq.km	Block Area falls in subbasin sq.km	% of block falls in subbasin	100 % Block Gross extraction Mcm	Block Gross Extraction in sub basin Mcm	Total Sub basin Gross Extraction Mcm	Level of Exploitation
1	Hanumanadhi	Kalakadu	440.940	2.401	0.0054	17.4927	0.0953	27.1381	Safe
		Valliyur	433.425	297.738	0.6869	27.3529	18.7899		Over Exploited
		Radhapuram	458.572	140.327	0.3060	24.2454	7.4193		Over Exploited
		Thovalai	369.070	61.915	0.1678	3.1415	0.5270		Safe
		Agastheeswaram	138.020	7.798	0.0565	5.4274	0.3066		Safe
2	Nambiyar	Kalakadu	440.940	172.347	0.3909	17.4927	6.8372	30.4472	Safe
		Nanguneri	502.590	78.006	0.1552	24.3759	3.7833		Safe
		Valliyur	433.425	135.687	0.3131	27.3529	8.5630		Over Exploited
		Radhapuram	458.572	212.031	0.4624	24.2454	11.2104		Over Exploited
		Thovalai	369.070	6.254	0.0169	3.1415	0.0532		Safe
3	Karamaniyar	Alvarthirunagar	212.620	68.187	0.3207	1.8257	0.5855	58.5484	Semi Critical
		Tiruchendur	135.680	4.438	0.0327	11.4093	0.3732		Semi Critical
		Sattankulam	294.430	294.430	1.0000	15.8807	15.8807		Over Exploited
		Udangudi	145.390	134.413	0.9245	23.6034	21.8213		Over Exploited
		Kalakadu	440.940	10.939	0.0248	17.4927	0.4340		Safe
		Nanguneri	502.590	285.316	0.5677	24.3759	13.8380		Safe
		Radhapuram	458.572	106.214	0.2316	24.2454	5.6157		Over Exploited
	Total			**2018.441**			**116.1337**	**116.1337**	

or 116 M.cum

Table D - Balance Groundwater potential available for development

Sl.No	Name of Sub Basin	Name of Block	Block Net potential in subbasin Mcm	Block Gross Extraction in sub basin Mcm	Balance potential available in block Mcm	Balance potential available in sub basin Mcm	Level of Exploitation
1	Hanumanadhi	Kalakadu	0.2252	0.0953	0.1300	10.6291	Safe
		Valliyur	19.0889	18.7899	0.2990		Over Exploited
		Radhapuram	7.4810	7.4193	0.0617		Over Exploited
		Thovalai	8.6649	0.5270	8.1379		Safe
		Agastheeswaram	2.3071	0.3066	2.0005		Safe
2	Nambiyar	Kalakadu	16.1651	6.8372	9.3279	16.8425	Safe
		Nanguneri	10.2464	3.7833	6.4631		Safe
		Valliyur	8.6993	8.5630	0.1363		Over Exploited
		Radhapuram	11.3037	11.2104	0.0933		Over Exploited
		Thovalai	0.8752	0.0532	0.8220		Safe
3	Karamaniyar	Alvarthirunagar	10.7889	0.5855	10.2034	34.6558	Semi Critical
		Tiruchendur	0.5473	0.3732	0.1741		Semi Critical
		Sattankulam	10.8154	15.8807	0.0000		Over Exploited
		Udangudi	11.6946	21.8213	0.0000		Over Exploited
		Kalakadu	1.0260	0.4340	0.5920		Safe
		Nanguneri	37.4776	13.8380	23.6396		Safe
		Radhapuram	5.6624	5.6157	0.0467		Over Exploited
	Total					**62.1274**	

or 62 M.cum

5.8 GROUNDWATER QUALITY

Water is the most abundant liquid in this planet and is essential to the survival of every living being. As the population of the world continues to grow at a rapid rate, clean water for drinking, suitable water for agricultural and industrial use is becoming ever more scarce. Although the earth's surface is nearly 71% covered by water, most of this water is salty ocean water. The amount of the fresh water available on the planet for drinking, bathing and agricultural is quite small and is less than 1% of the total. In some areas, there may be plenty of water in one season of the year, but none at other times. Most communities get their drinking water from either surface water or from ground water through wells. Groundwater is water that has percolated through the soil and trapped in layers of porous rock under the ground. The process of percolation results in filtration and purification of the water and is one of the reasons that ground water is often used as a source of fresh water for human use.

Water beneath the ground has been exploited for domestic use, livestock and irrigation activities since the earliest times. Successful methods for bringing the water to the surface have been developed and ground water use has grown consistently ever since. It is however, common for the dominant role of ground water in the fresh water part of the hydrological cycle to be overlooked. In this basin also the use of ground water is more predominant for various uses principally community water supply, farming which includes both livestock and irrigated cultivation and industrial purposes etc. In this basin the ground water quality assessment is invariably directed towards factors, which may lesser the suitability of pumped ground water with respect to its potability and use in domestic and agriculture. The overall goal of a water quality assessment report is to obtain a comprehensive picture of the spatial distribution of ground water quality and of the changes in time that occur, either naturally, or under the influence of human activities.

The ground water quality data has been collected from the office of the State Ground and Surface Water Resources Data Centre, PWD, Tharamani, Chennai – 113. They collect the ground water sample from the observation wells, one in pre-monsoon in the month of July and other one in post monsoon in the month of January every year from 1972 onwards for analyzing the major cations, anions present in it. For this basin water quality assessment has

be made for pre-monsoon data for the year of 1984, 1994 and 2004. Of the total water quality constituents, we use total dissolved solids, chloride, total hardness, alkalinity, sulphate and nitrate as the deciding parameter for discussion. By using the Arc view and Arc info softwares, the water quality contour of Total Dissolved Solids, Total Hardness and Chlorides are generated as per Bureau of Indian Standard norms.

For getting proper spatial distribution of contour and exact assessment of the water quality, the neighbouring basin observation wells have also been taken in to account. In this basin nearly 20 numbers of observation wells data have been used to create the maps for ascertaining the water quality status. The sub basin wise water quality status is discussed as below. The water quality maps for different parameters for the period of pre-monsoon 1984, 1994 and 2004 are given in the plate Nos. 31, 32 and 33. The test characteristics for drinking water is being given in Table below:

TEST CHARACTERISTICS FOR DRINKING WATER

Sl. No	Substance or Characteristic	Requirment (Desirable Limit)	Undesirable Effect outside the desirable limit	Permissible limit in the Absence of Alternate Source	Remarks
(1)	(2)	(3)	(4)	(5)	(6)
Essential Characteristics					
1.	Colour, Hazen units, Max	5	Above 5, consumer acceptance decreases	25	Extended to 25 only if toxic substance are not suspected in absence of alternate source.
2.	Colour	Unobjectionable	-	-	a) Test cold and when heated b) Test at several dilutions.
3.	Taste	Agreable	-	-	Test to be conducted only after safety has been established
4.	Turbidity, NTU, Max	5	Above 5, Consumer acceptance decreases	10	-
5.	Ph Value	6.5 to 8.5	Beyond this range the water will affect the mucous membrance and /or water supply system	No relaxation	-

6.	Total hardness (as $Caco_3$), mg/l, Max	300	Encrustation in water supply structure and adverse effects on domestic use	600	-
7.	Iron (as Fe) mg/Max	0.3	Beyond this limit taste/ appearance are affected has adverse effect on domestic uses and water supply structures, and promotes iron bacteria.	1	-
8.	Chloride (as Cl, mg/ I,Max)	250	Beyond this limit taste, corrosion and palatability are affected	1000	-
9.	Residual, free chlorine mg/I, Min	0.2	-	-	To be applicable only when water is chlorinated. Tested at consumer end. When protection against virual infection is required, it should be Min 0.5 mg/l.
10.	Dissolved solids mg/l , Max	500	Beyond this palatability decreases and may cause gastro intestinal irrigation.	2000	-
11.	Calcium (as Ca) mg/I, Max	75	Excrustation in water supply structure and adverse effects on domestic use	200	-
12.	Magnesium (as Mg), mg/I, max	30	Excrustation in water supply structure and adverse effects on domestic use	100	-
13.	Copper (as Cu) mg/I, Max	0.05	Astringent taste, discoloration and corrotion of pipes, fitting and utensils will be caused beyond this.	1.5	-
14.	Manganese (as Mn) Mg/I, Max	0.1	Beyond this limit taste/ appearance are affected, has adverse effect on domestic use and water supply structure	0.3	-
15.	Sulphate (as So_4), mg/I, Max	200	Beyond this causes gastro intestinal irrigation when magnesium orsodium are present	400	May be extended upto 400 provide (as Mg) does not exceed 30
16.	Nitrate (as No_3) mg/I, Max	50	Beyong this mathemoglobinemia	No relaxation	-
17.	Fluoride (as F) mg/I, Max	1	Fluoride may be kept as low as possible. High fluoride may cause fluorosis	0.002	-
18.	Phenolic compounds (as	0.001	Beyond this, it may cause objectionable taste and	0.002	-

	C6 H5OH) mg/I, Max		odour		
19.	Mercury (as Hg) mg/I, Max	0.001	Beyond this, the water becomes toxic	No relaxation	To be tested when pollution is suspected.
20.	Cadmium (as Cd) mg/I, Max	0.01	Beyond this, the water becomes toxic	No relaxation	do
21.	Selenium (as Se), mg/I, Max	0.01	Beyond this, the water becomes toxic	No relaxation	do
22.	Arsenic as (As), mg /I, Max	0.05	Beyond this, the water becomes toxic	No relaxation	do
23.	Cyanide (as CN), mg/I, Max	0.05	Beyond this, the water becomes toxic	No relaxation	do
24.	Lead (as Pb), mg/I, Max	0.05	Beyond this, the water becomes toxic	No relaxation	do
25.	Zinc (as Zn), mg/I,Max	5	Beyond this, it can cause astringent taste and an opalescence in water	15	To be tested when pollution is suspected.
26.	Anionic detergents (as MBAS), mg/I, Max	0.2	Beyond this, it can cause a light froth in water	1.00	do
27.	Chromium (as cr6+), mg/I, Max	0.05	May be carcinogenic above this limit	No relaxation	do
28.	Polynuclear aromatic hydrocarons (as PAH) g/I, Max	-	May be carcinogenic	-	-
29.	Mineral Oil mg/I,Max	0.01	Beyond this limit undesirable taste and odour after chlorination take place	0.03	To be tested when pollution is suspected
30.	Pesticides mg/I, Max	Absent	Toxic	0.001	-
31.	Radio active material: a) Alpha emitters Bq/I, Max b) Beta emitters pci/I, Max	-	-	 0.1 0.037	-
32.	Alkalinity mg/I, Max	200	Beyond this limit taste becomes unpleasant	600	-
33.	Aluminium (as Al) mg/I, Max	0.03	Cumulative effect is reported to cause dementia	0.2	-
34.	Boron mg/I, Max	1	-	5	-

HANUMANADHI SUB BASIN:

The western part of this basin is covered by Hills. Almost the entire area covered under the classification of medium quality. The Total Dissolved Solids nearby Panaikudi in Valliyur block and Kudankulam in Radhapuram block is higher than the BIS standard in the pre-monsoon period of 1984 and 1994. Here the maximum value is found to be 5014 mg/l in the year of 1984 at Vijayapathy village throughout the decade. Near Panangudi, the value of TDS is higher in the year of 1994; which may be due to local contamination or lowering of water level. The Chloride value also coincides with the value of TDS. Wherever the TDS is higher, the Chloride value is also higher. The maximum value of Chloride (3228 mg/l) was observed during 1994 pre monsoon period. The Total Hardness value is almost above the permissible level. Except for a few pockets near the east and western portion of the sub basin, a high range of Total Hardness occupies the entire sub basin. The maximum value of 3450 mg/l was observed during the year of 1994 pre monsoon.

NAMBIYAR SUB BASIN:

Nearly 6 observation wells maintained by the state groundwater department available to ascertain the water quality of this sub basin. The top western portion of the sub basin is fully covered by hilly region. The Total Dissolved Solid is almost under medium range of quality in the entire basin. Generally the TDS is within the acceptable limit of 2000 mg/l. But in places like Vadakkuvalliyur village and some part of Radhapuram block, the TDS value is higher than the acceptable limit. The maximum value of 3888 mg/l of TDS is noticed near Kasuthrirangapuram during the period of 2004 pre monsoon. The northern part of this basin remains in good quality since 1984. While considering the Chloride value, it almost same effect as Total Dissolved Solids. There is no appreciable deviation from the value of TDS. The maximum value of Chloride (1843 mg/l) observed in Kasthurirangapurm during the period of 2004 pre monsoon. Most part of the sub basin, the Total Hardness is higher than the BIS limit of 600 mg/l. During the 1984, almost more than half of the basin is under higher TH values, but during the later decades 1994 the geographical area covered by higher TH has decreased. The maximum value of 2440 mg/l is observed in the same village during the year of 2004.

KARAMANIYAR SUB BASIN

Most of this sub basin, the medium quality Total Dissolved Solids is observed. Since 1984, there is no appreciable change. In some pockets like Udangudi, Anandapuram and Padukkapathu villages, the TDS value is above the acceptable range in the year of 2004. The maximum value of 3610 mg/l is noticed in the year of 1984 in Vijayanarayanam. This may be due to the lowering of water level or any local contamination. Similar changes is observed in Chloride value also. The maximum value of 1631 mg/l is observed in the same village in the same period. The Total Hardness, is almost over the acceptable limit in both Nambiyar and Hanumanadhi sub basins, here it is covered only part of the basin. The maximum value of TH observed is 1400 mg/l in Vijayanarayanam village

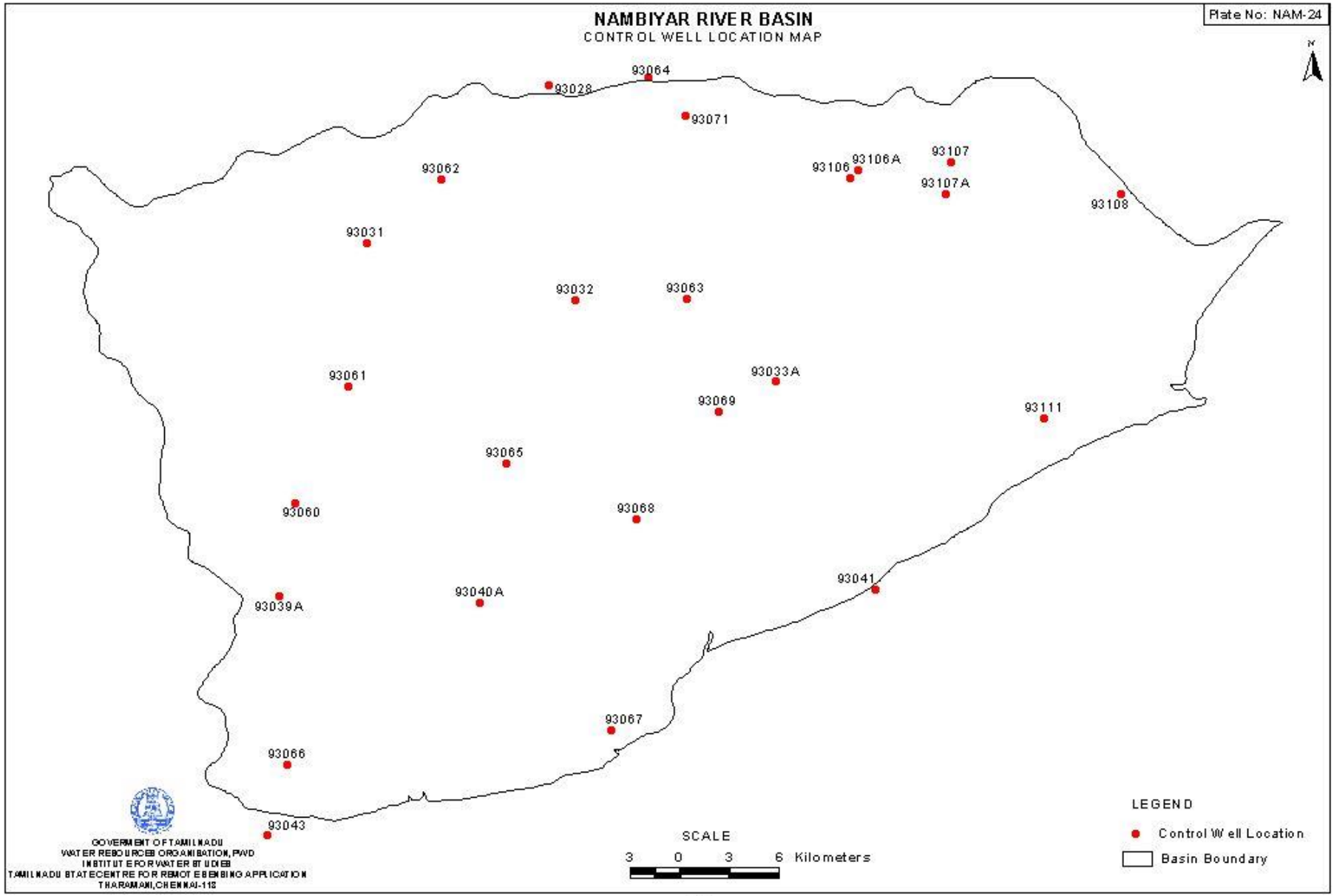
CONCLUSION:

1. In general the quality of groundwater in Nambiyar Basin is good and moderate in most of the observations wells. Saline pockets are observed in certain areas like Vadakku Valliyur, Vijayanarayanam, Padukkapathu, Anandapuram and Udangudi. The main reason for the presence of larger amount of dissolved solids may be due to geological formation or seepage from fertilizers or local contamination. This may cause high salinity.

2. Generally the P^H of the water has a small variation due to buffering action of water with Carbon-di-oxide. Regarding the Nambiyar Basin the P^H value range lies within the permissible limit except in few places. The higher PH observed in this basin is found to be above 8.5 in Moolakaraipatti, Sundarapuram and Itamozhipudur. This may be due of to Calcium carbonate bearing rock formations.

3. The Chloride concentrations in all the wells of this basin are found to be within the maximum limit except in few wells. When the salt concentration is increased, it is difficult for plants to extract water. Chlorides are more toxic to some plants.

4. The quality of ground water depends on the different types of rocks encountered. Major portion of the Nambiyar basin is covered with hard rock area and the tail end of this basin with sedimentary rock formation. Hardness is due to presence of Calcium, Magnesium, Bicarbonate and Chloride ions. The concentration of Nitrate in most of the wells are within the maximum acceptable limit except in some places Valliyoor, Udangudi, Vijayanarayanam and Karunkadal. The increased concentration of Nitrate may be due to excessive application of nitrogen fertilizers or decay of plants and animals' residue or disposal of industrial wastewater or sewage or by increased cultivation of leguminous plants. The toxicity of Nitrate leads to cardiovascular effects at higher dose level and methomoglobinemia at lower dosage limits.The concentration of Fluoride is found to be within the permissible limit in most of the areas. When the intake of Fluoride is above the permissible limit, it leads to skeletal and dental fluorosis. The Fluoride contamination is these pockets may be due to the presence of fluoride rich minerals like fluorite and appetite.


NAMBIYAR RIVER BASIN
CONTROL WELL LOCATION MAP
Plate No: NAM-24
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93033A
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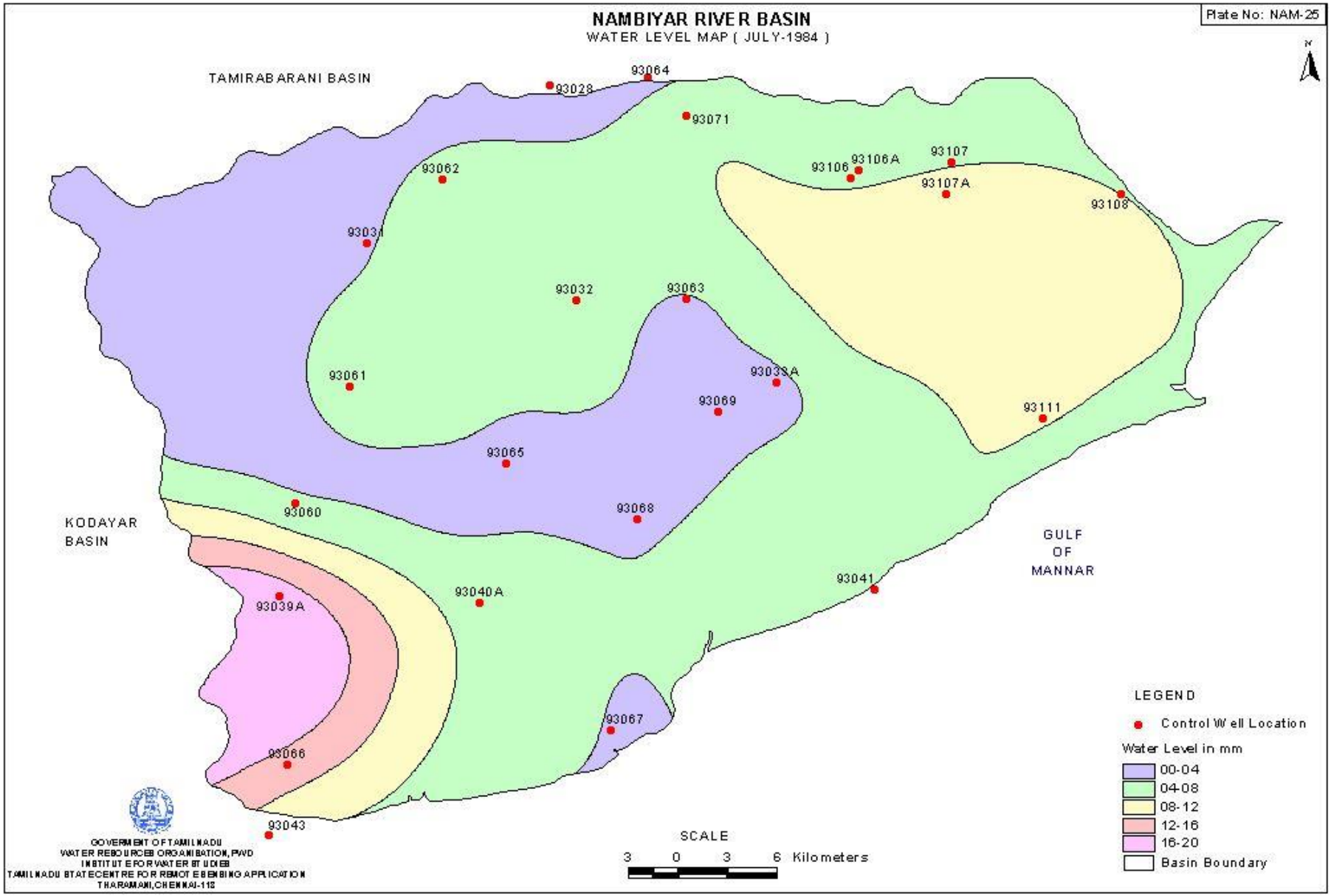
93060
93068
93041
93040A
93039A
93067
93066
93043
SCALE
3 0 3 6 Kilometers
LEGEND
Control Well Location
Basin Boundary
GOVERNMENT OF TAMILNADU
WATER RESOURCES ORGANISATION, PWD
INSTITUTE FOR WATER STUDIES
TAMILNADU STATE CENTRE FOR REMOTE SENSING APPLICATION
THARAMANI, CHENNAI-113


NAMBIYAR RIVER BASIN
WATER LEVEL MAP (JULY-1984)
Plate No: NAM-25
TAMIRABARANI BASIN
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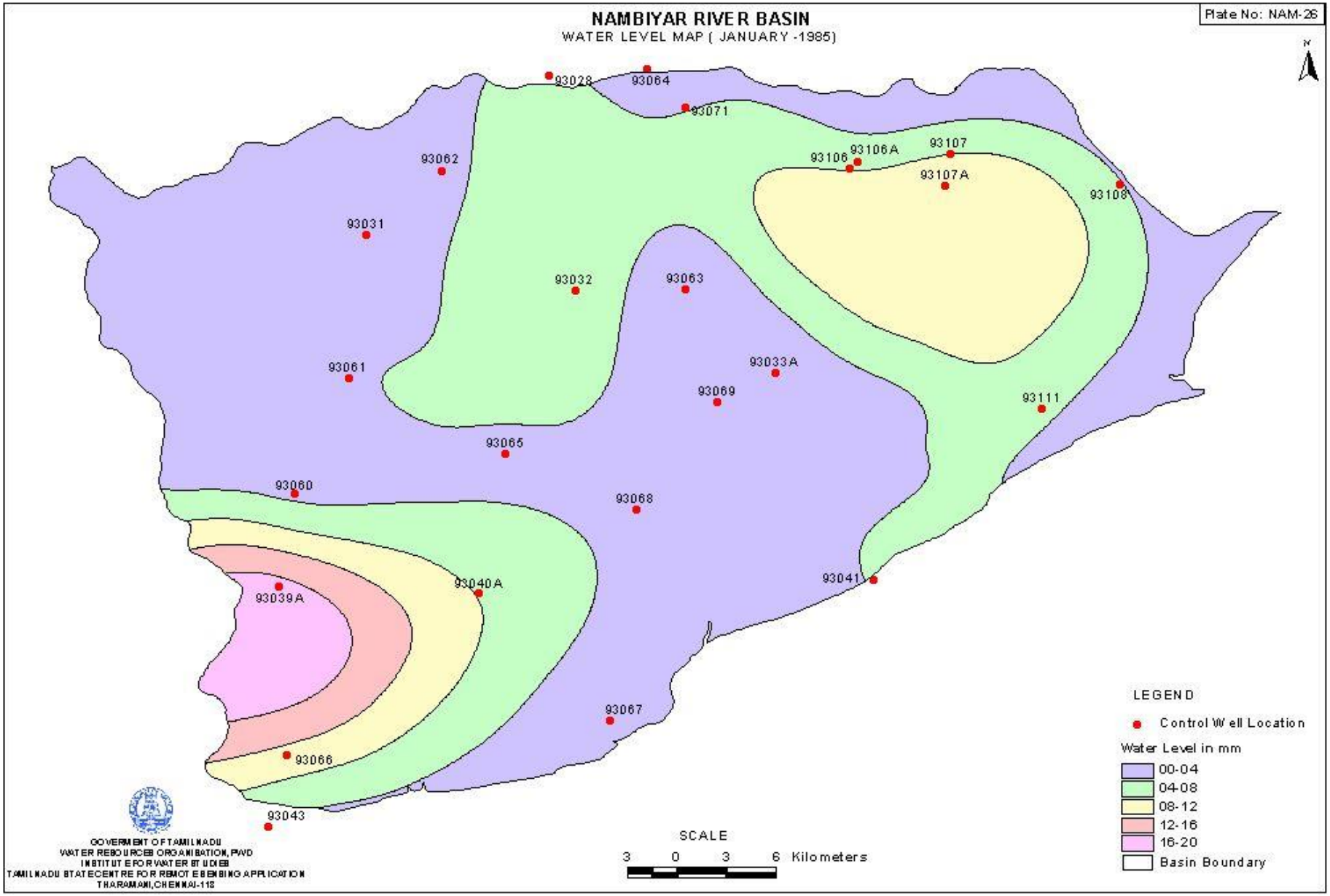
GOVERNMENT OF TAMILNADU
WATER RESOURCES ORGANISATION, PWD
INSTITUTE FOR WATER STUDIES
TAMILNADU STATE CENTRE FOR REMOTE SENSING APPLICATION
THARAMANI,CHENNAI-113


NAMBIYAR RIVER BASIN
WATER LEVEL MAP (JANUARY -1985)
Plate No: NAM-26
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LEGEND
Control Well Location
Water Level in mm
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08-12
12-16
16-20
Basin Boundary
SCALE
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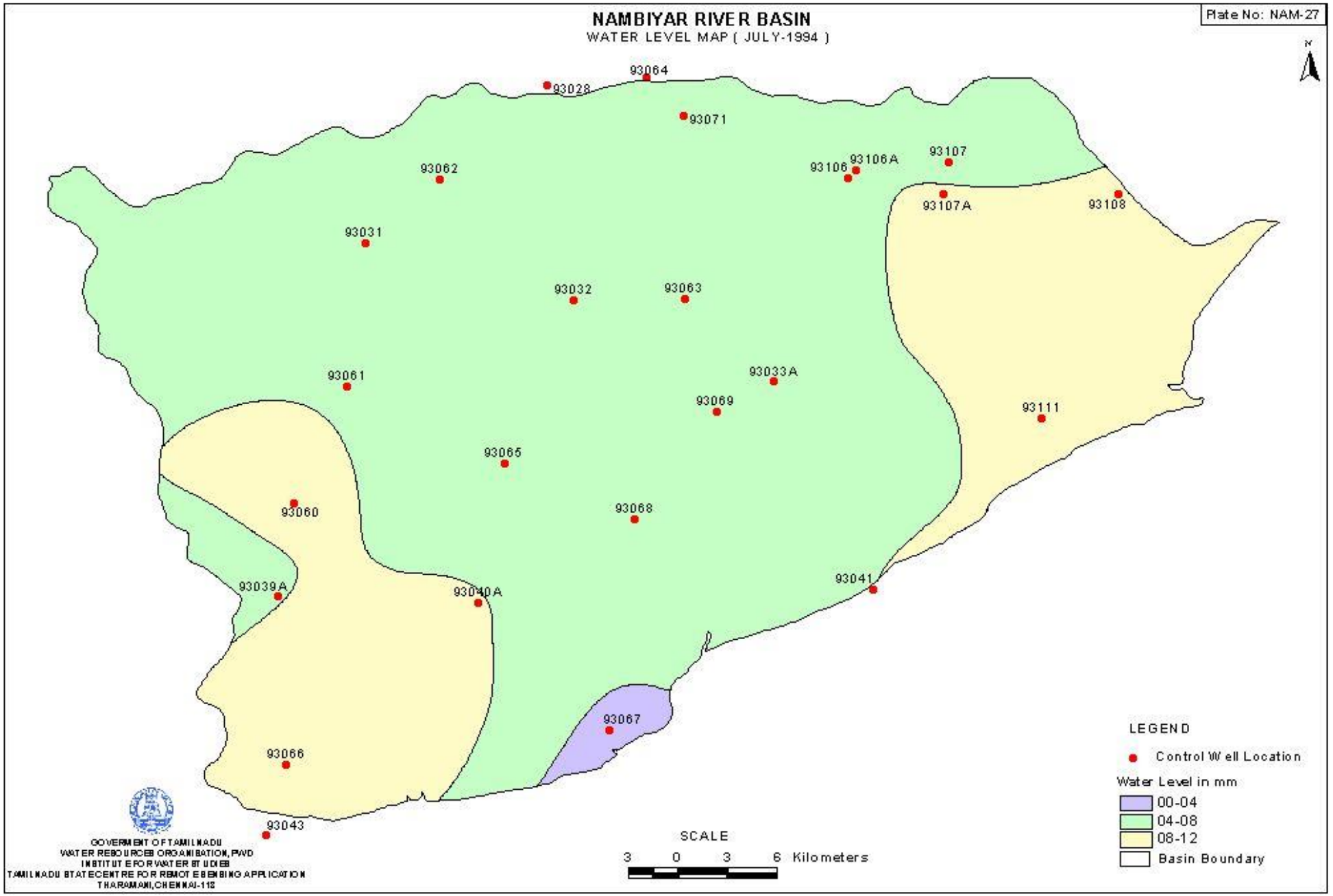
GOVERMENT OF TAMILNADU
WATER REBOURCES ORGANIBATION, PWD
INSTITUTE FOR WATER STUDIES
TAMILNADU STATECENTRE FOR REMOT ESENSING APPLICATION
THARAMANI,CHENNAI-113


NAMBIYAR RIVER BASIN
WATER LEVEL MAP (JULY-1994)
Plate No: NAM-27
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LEGEND
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Water Level in mm
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Basin Boundary
SCALE
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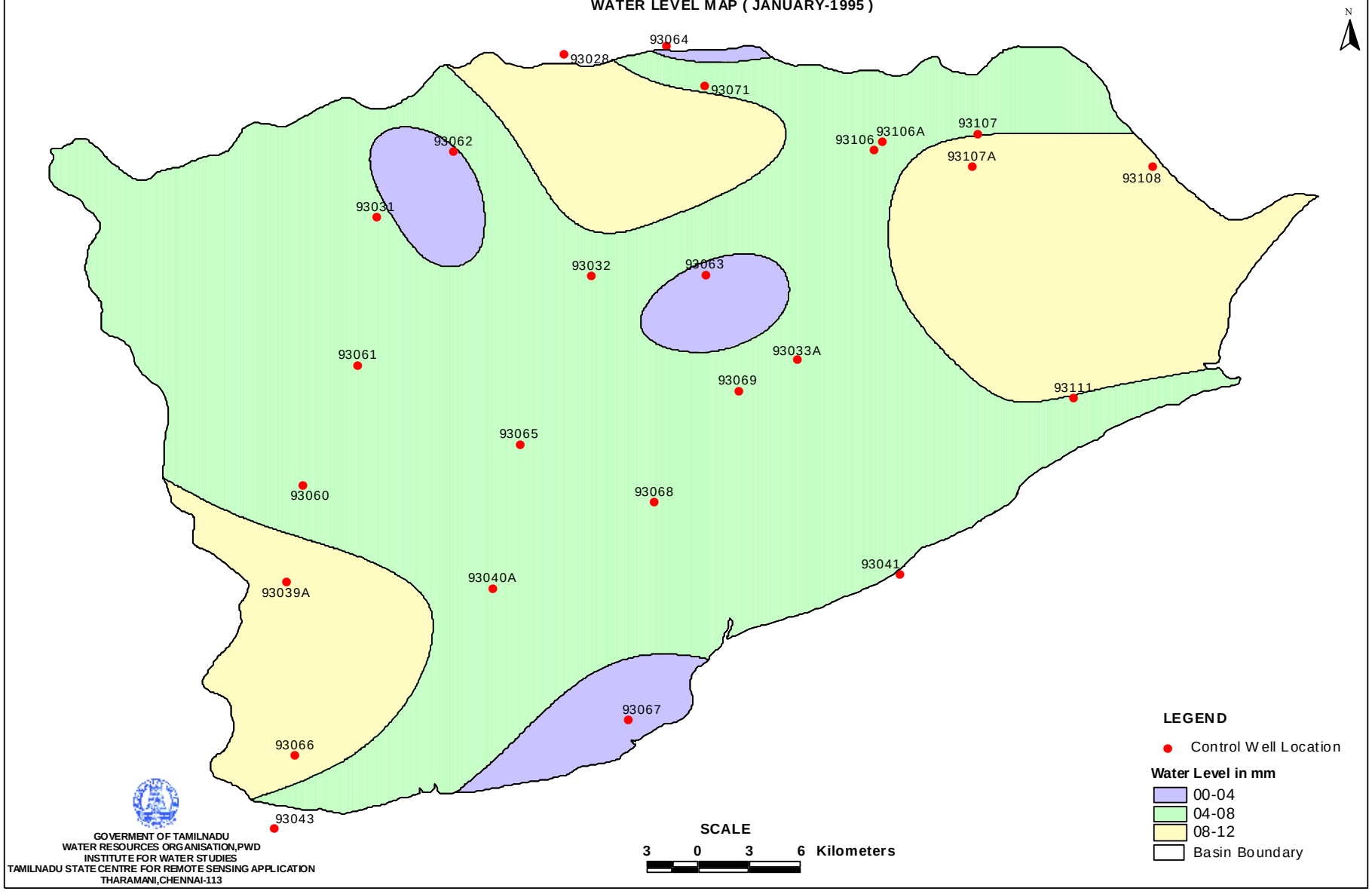
NAMBIYAR RIVER BASIN

WATER LEVEL MAP (JANUARY-1995)

Plate No: NAM-28



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INSTITUTE FOR WATER STUDIES
TAMILNADU STATE CENTRE FOR REMOTE SENSING APPLICATION
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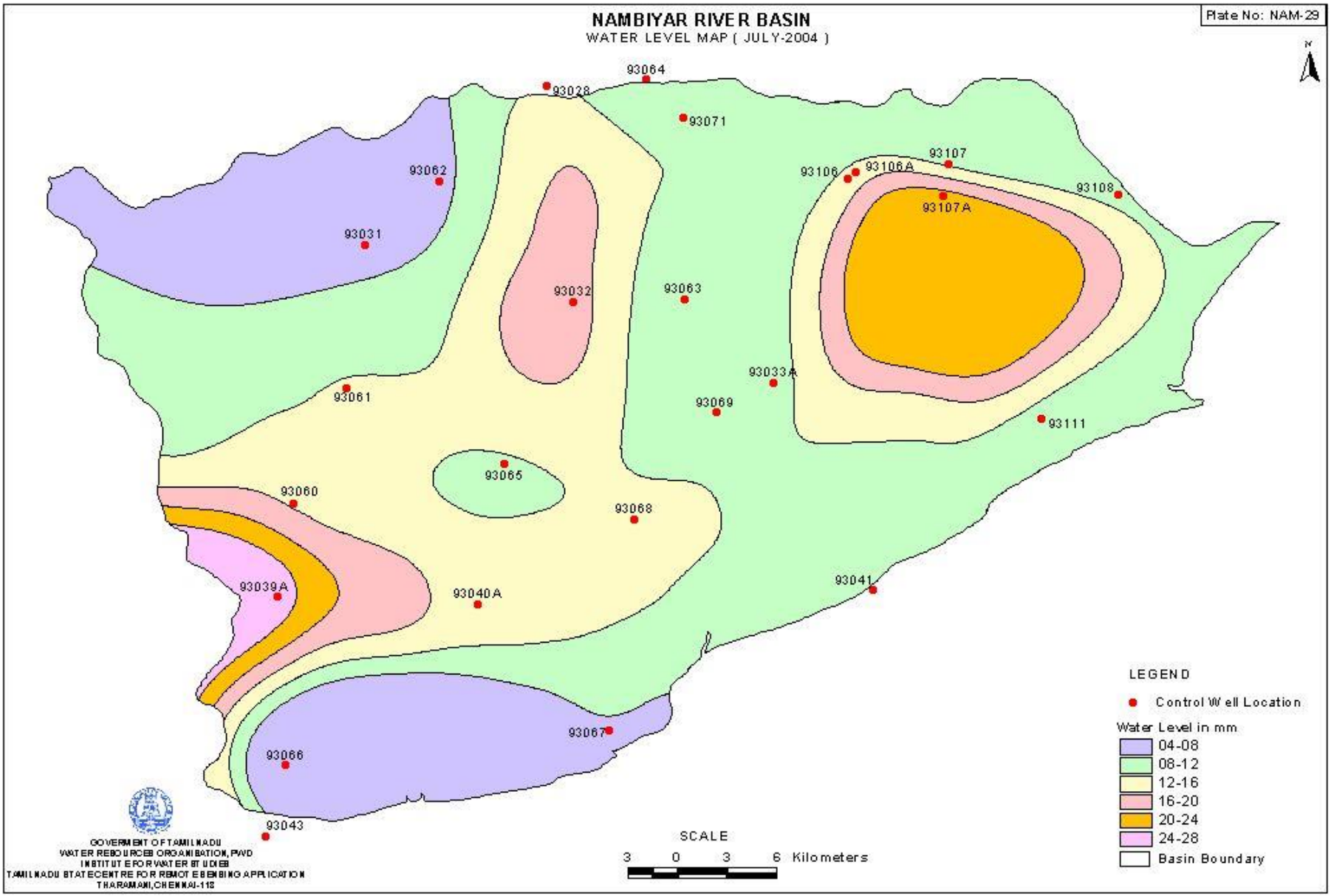
NAMBIYAR RIVER BASIN
WATER LEVEL MAP (JULY-2004)
Plate No: NAM-29
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LEGEND
Control Well Location
Water Level in mm
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12-16
16-20
20-24
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Basin Boundary
SCALE
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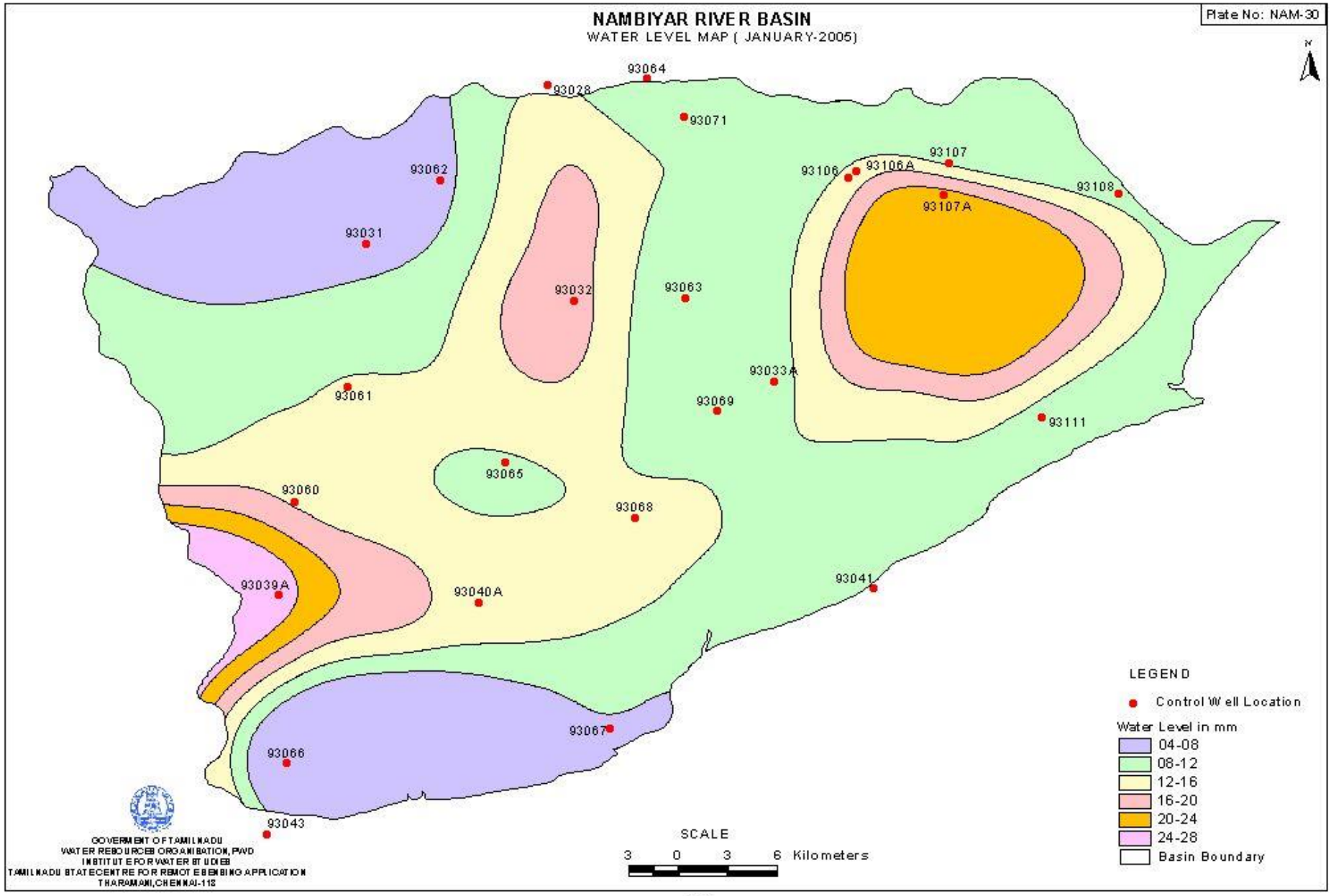
GOVERNMENT OF TAMILNADU
WATER REBOURCEB ORGANIBATION, PWD
INBTITUTE FOR WATER BTUDIEB
TAMILNADU BTATE CENTRE FOR REMOT EBENBING APPLICATION
THARAMANI,CHENNAI-113


NAMBIYAR RIVER BASIN
WATER LEVEL MAP (JANUARY-2005)
Plate No: NAM-30
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LEGEND
Control Well Location
Water Level in mm
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Basin Boundary
SCALE
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GOVERMENT OF TAMILNADU
WATER REBOURCEB ORGANIBATION, PWD
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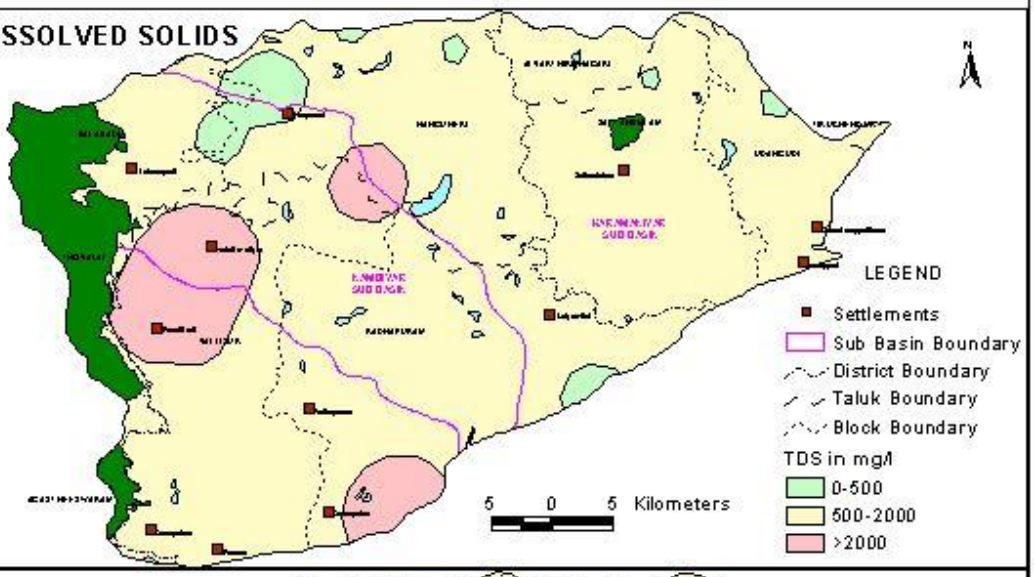
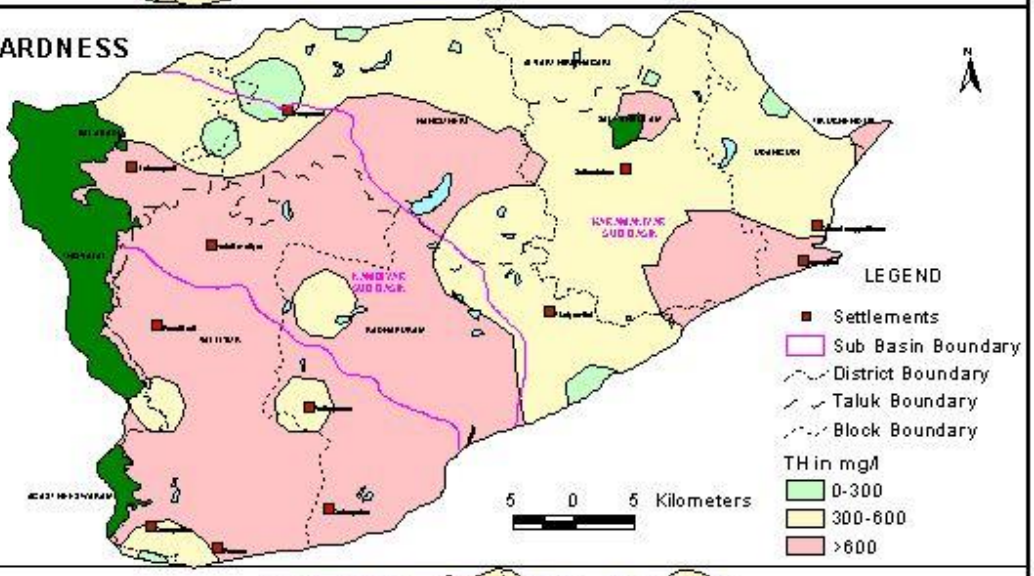
PLATE: NAM - 31

WATER QUALITY MAP - PRE MONSOON 1984

TOTAL DISSOLVED SOLIDS



TOTAL HARDNESS



CHLORIDE

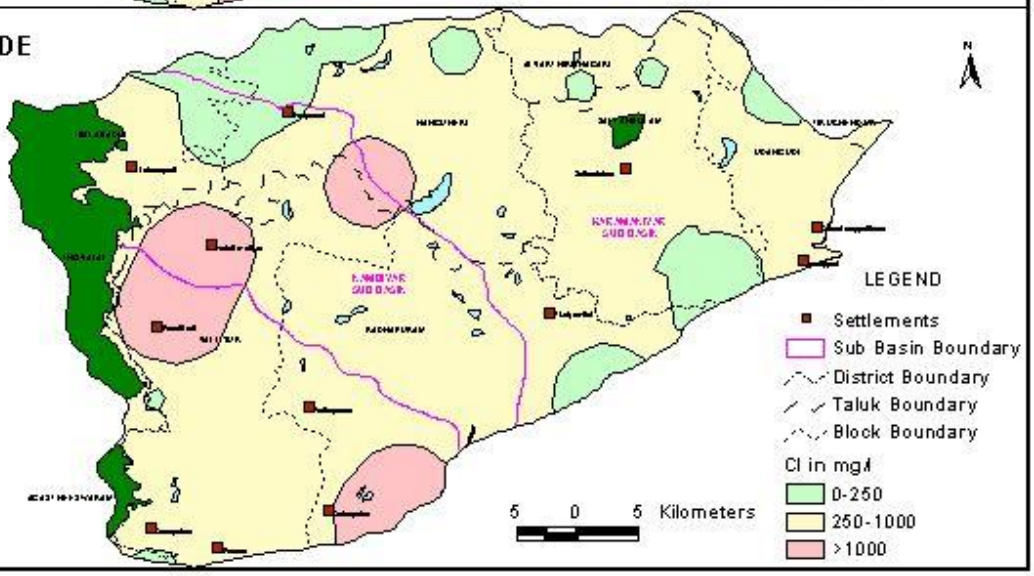
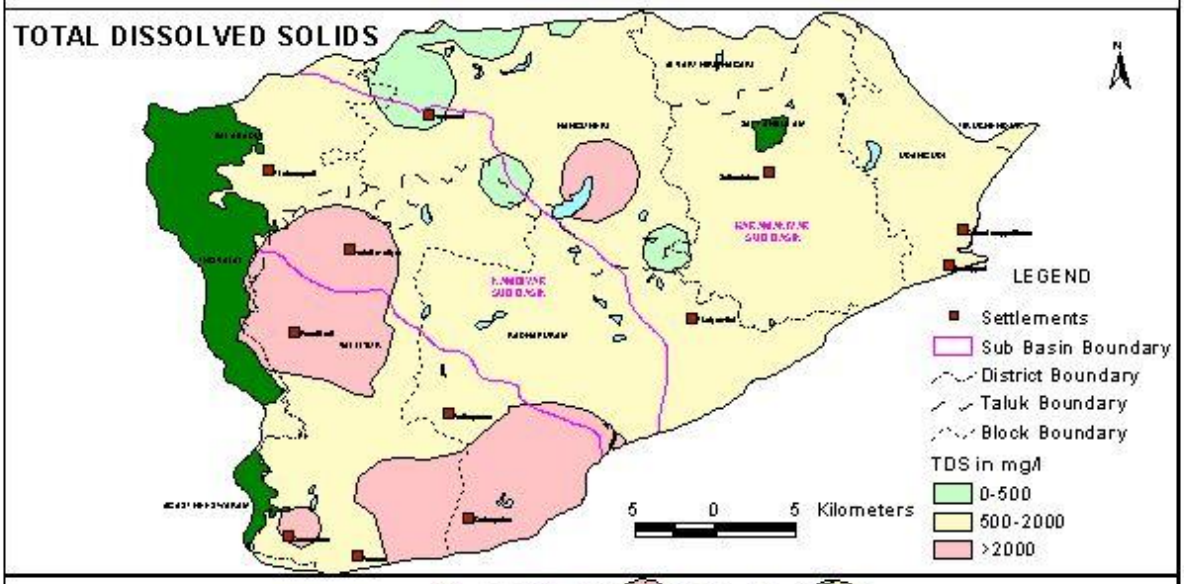
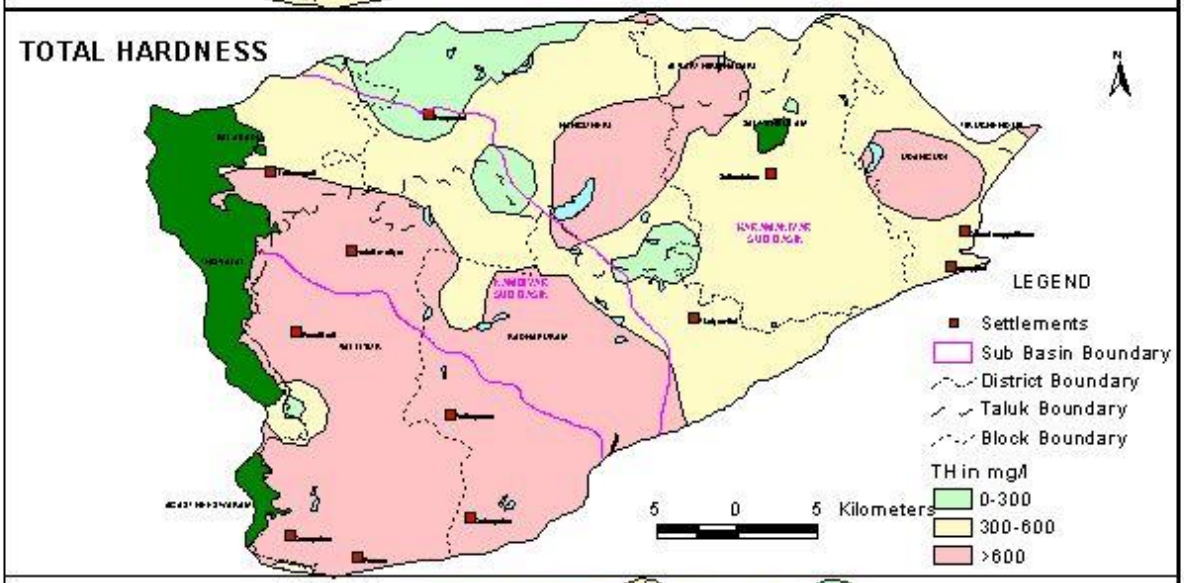


PLATE: NAM - 32

WATER QUALITY MAP - PRE MONSOON 1994





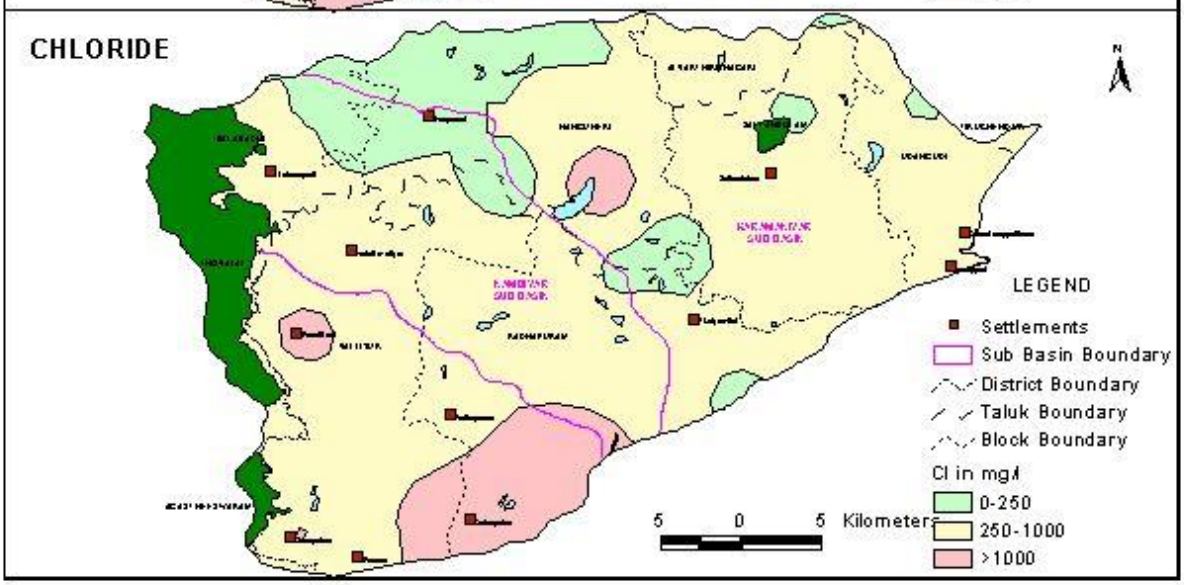
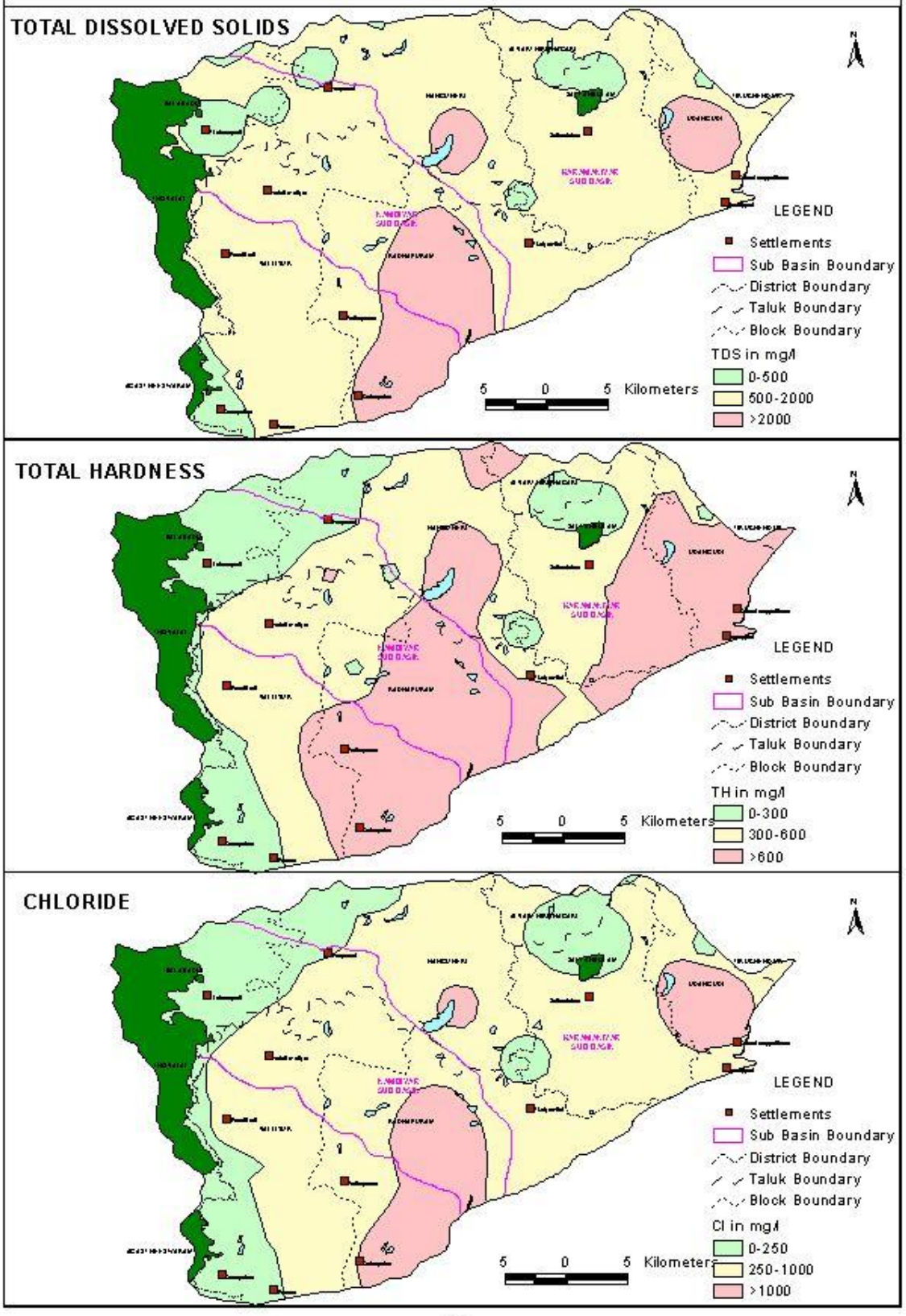


PLATE: NAM - 33

WATER QUALITY MAP - PRE MONSOON 2004



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CHAPTER – 6

PRESENT AND FUTURE

WATER DEMANDS

CHAPTER -6
PRESENT AND FUTURE WATER DEMANDS

6.1 LONG TERM ECONOMIC FORECASTS

Long-term economic forecasts are needed to support various other analysis for water planning which are presented in this chapter.

- Domestic water demand is a function of population size and per capita daily water consumption. Water consumption varies with income level. A first distinction is made between rural and urban areas. In Tamil Nadu, the income disparity between rural and urban areas is about 1:3. But within rural and urban areas, there is a social stratification into different household income levels, which reflects itself in housing conditions and the use of water demanding household appliances. Hence, a reasonable estimate of future domestic water consumption can only be made if the magnitude of future income and its distribution over rural and urban area is known.
- Industrial and Domestic water consumptions in future also depend on expected growth of these sectors.
- Population growth itself is closely related to the general increase of income and (female) employment.
- Agricultural water demand depends on the future cropping pattern, which has to be forecasted in relation to the demand for agricultural products, and on the cost of agricultural production. This depends on future income levels and population size. The production costs depend on agro-technologies and costs of inputs.

6.2 POPULATION PROJECTION

6.2.1 Methodology Description

Two approaches are applied for population projection in the Nambiyar river basin. The 2001 census figures were taken as a starting basis. The population projections are made for the target years 2006, 2010, 2020 & 2045 respectively.

Exponential scenario

The exponential growth formula is

$$P_t = P_o (1+X)^t$$

Where P_t = Population after 't' years

P_o = Population in the beginning years

X = Annual growth rate

t = Period in years

6.2.2 Population

The Nambiyar River basin is divided into three sub basins. The sub basin wise population of the Nambiyar basin is given in the Table A. The basic population figures of villages are taken according to the relative sub basins in which the villages are falling.

The growth rate to be used for the water planning procedure is as follows.

Population Sector	**Annual Growth rates**
Urban	0.020 (2 % per year)
Rural	0.013 (1.3 % per year)

6.2.3 Population Projection for the Target years by Sub-basins (Exponential method)

The accepted average growth rate as described above is applied to the population figures at the point of departure. Thus, projected figures for the various target years (per sub basin, per population type) are calculated, and summed up and furnished in Table A.

These population data are used further for the projection of domestic water demand throughout the Nambiyar river basin.

6.3 DOMESTIC WATER DEMAND PROJECTION

6.3.1 Methodology

The total domestic water demand in the basin will grow over the years due to two factors

- The increase of the total population,
- The increase of per capita water demand

6.3.2 Per capita water consumption by Accepted Norms

The technical sub-committee for Urban, Rural, Domestic, Livestock Water Supply & Sanitation Sector of the Water Resources Control and Review Council (WRCRC) has recommended the water demand norms to be used for Water planning and the same is adopted for estimating the water demands in the Nambiyar basin (i.e. 100 lpcd for Urban and 70 lpcd for Rural population).

6.3.2 Water Demand Estimates by Housing Categories – Definition of Categories

(i) Urbanisation is an important determining factor for per capita water consumption in urban areas, which is significantly higher than in rural areas. The difference between per capita urban and rural water consumption is partly attributable to the fact, that average urban income is higher than average rural income (in Tamil Nadu about 3 times as high). Housing and living standards are higher in urban areas. But there is also a physical factor playing a role. The concentration of people in urban areas allows a higher level of water supply services (piped water with individual house connections) than in a more scattered rural settlement pattern. A critical mass and density of population is needed to make piped water systems economically feasible. However, the difference between urban and rural per capita water consumption tends to diminish with increasing level of development. In highly developed countries, the difference is practically nil. In our projections we will allow for a narrowing gap.

(ii) In both urban and rural areas, water consumption varies between different household categories. These categories can be defined according to the type of water source and availability of other amenities, according to data available in the official census reports:

Types of water source are broadly divided into reliable sources (tap, well, hand pump, tube well) and less reliable sources (river, canal, tank and others). Among the reliable sources, a tap is considered superior to a well, hand pump or tube well. A further distinction is made whether the water

source is situated within or outside the premises, indicating the level of access to water.

For housing conditions, statistics on two relevant indicators are used: availability (or non-availability) of electricity and availability (or non-availability) of a toilet.

(iii) Of these two, electricity is not a direct indicator for level of water consumption but it can facilitate water usage, e.g. if a well is available within the premises, water could be pumped to a water tank. Electricity would also allow for the use of water - consuming household appliances such as washing machines. Electricity adds to water consumption only if the water source is located within the premises. Evidently, electricity in relation to water consumption is a more significant factor in urban than in rural areas. In rural areas, availability of electricity often means hardly more than being able to burn an electric lamp.

(iii) Availability of a toilet directly contributes to water consumption but, again, it does so more in urban areas than in rural areas. Indeed, in rural areas "toilets" refer mainly to pit latrines and not to flush toilets, as is the case in urban areas.

(iv) On the whole, in rural areas housing conditions are a less discriminating factor than in urban areas. What counts in the former is mainly the type of water source and its location. It is therefore reasonable to postulate that the differentiation in water use will be less in rural than in urban areas. Taking this into account, the following Tables show the categorisation that is adopted (A is the highest class, E the lowest).

Definition of Domestic Consumer Categories (DCC); Urban

Source of Water	Location of Water Supply	Electricity Available		Electricity Not Available	
		Toilet Available	Toilet Not Available	Toilet Available	Toilet Not Available
Tap	Within premises	**A**	**C**	**B**	**C**
	Outside premises	**C**	**D**	**C**	**D**
Well/handpump/ tube well	Within premises	**B**	**C**	**B**	**C**
	Outside premises	**C**	**D**	**D**	**E**
River/canal/tank/ Others	Within premises	**C**	**D**	**C**	**D**
	Outside premises	**D**	**E**	**D**	**E**

Definition of Domestic Consumer Categories (DCC); Rural

Source of Water	Location of Water Supply	Electricity Available		Electricity Not Available	
		Toilet Available	Toilet Not Available	Toilet Available	Toilet Not Available
Tap	Within premises	**A**	**B**	**A**	**B**
	Outside premises	**B**	**C**	**B**	**C**
Well/hand ump/ tube well	Within premises	**B**	**C**	**B**	**C**
	Outside premises	**C**	**D**	**C**	**D**
River/canal/tank/ Others	Within premises	**C**	**D**	**C**	**D**
	Outside premises	**D**	**E**	**D**	**E**

6.3.4 Per Capita Water Demand by Housing Categories

For each one of these categories the following per capita norms have been assumed.

Assumed lpcd Norms

DCC	Urban	Rural
A	260	85
B	165	62
C	77	40
D	50	40
E	40	40

These assumptions are based on analysing the components of the domestic water requirements.The National Building Code gives a breakdown of approximate water requirements for various domestic purposes, in litres per capita per day (lpcd) as follows:

S.No.	Purpose	Lpcd
1	Drinking	3-5
2	Cooking	5-10
3	House washing and cleaning vessels	12-25
4	Bath	45-90
5	Washing	25-40
6	Water Closets	30-40
	Total	**120-210**

The Manual on Water Supply and Treatment issued by the Ministry of Urban Development, GOI, New Delhi, prescribes 70 to 100 lpcd as the minimum domestic needs of urban communities, as well as an additional 25 to 100 lpcd for non-domestic needs (street washing or watering, flushing of sewers, watering of public parks, and small-scale industries in a limited number), depending on size and economic importance of the urban community. The manual also specifies the following general rates as the minimum for domestic and non-domestic needs, in lpcd:

For communities with population up to 20,000

- Water supply through stand posts 40 lpcd
- Water supply through house services connection 70-100 lpcd

For communities with population of 20,000 to 100,000 100-150 lpcd

For communities with population above 100,000 150-200 lpcd

Based on the above, and bearing in mind the conditions in Tamil Nadu, the following domestic and non-domestic water consumption norms for the five DCC's above are adopted for the purpose of this study, as shown in the following Table.

Domestic Urban Water Requirements, lpcd

Purpose	**DCC - Domestic Consumption Category**				
	A	**B**	**C**	**D**	**E**
Drinking	5	5	5	5	5
Cooking	10	10	7	5	5
House washing and utensil cleaning	25	15	10	5	5
Bath	90	60	25	15	10
Washing of clothes	40	30	20	15	15
Water closets	40	30	10	5	0
Sub Total	*210*	*150*	*77*	*50*	*40*
Non-domestic, minimum needs	50	15	0	0	0
Total	**260**	**165**	**77**	**50**	**40**

The requirements of water for drinking, i.e. excluding bathing, laundering and toilet water, amount to the following percentages of the total domestic requirements:

DCC No.	**A**	**B**	**C**	**D**	**E**
% Drinking water	15	18	29	30	38

6.3.5 Additional Demands

The above norms do not include an allowance for public amenities in cities, and these have to be added as 10% over the total domestic demand in cities.

In addition, an allowance for leakage and unaccounted for water in existing systems has to be made for cities and towns at rates varying over time. It is assumed that efforts will be made by urban water supply utilities to reduce water losses and thus the percentage of unaccounted water will decrease over the Planning Stages.

6.3.6 Comparison of the Two Approaches for the Estimates of Domestic per capita Water Consumption

Based on total domestic water demands, the comparison for the following three methods is shown in the table below..

i. The norms adopted by IWS and used in the present study
ii. The results of the Housing category method
iii. The results of the Housing category method with the addition of public amenities and leakage/unaccounted water

In the Rural sector the forecasts according to the second method are smaller whereas in the urban sector the estimates are much higher.

Comparison of Domestic per capita Water Consumption by Various Methods (lpcd)

Year	Norms adopted by IWS	Housing Category method	Housing Category method including Public Losses
i. Municipalities			
2000	91	108	194
2006	92	109	197
2020	95	129	222
2045	100	160	251
ii. Town Panchayats			
2000	73	108	194
2005	76	109	197
2020	85	129	222
2045	100	160	251
iii. Rural			
2000	43	41	45
2006	46	41	45
2020	55	44	49
2045	70	56	62

6.3.7 Total Domestic Water Demand by Housing Categories

As already mentioned, neither the high-low population scenarios (Section 6.2.1(ii)), nor the domestic water demand projections by housing categories (Sections 6.3.3 to 6.3.5) are adopted in the present study. Exponential growth formula is adopted for the population growth in the present study.

6. 3. 8 Water Demand projections (by Tamil Nadu Norms)

As stated above, the per capita water demand projections of the WRCRC are adopted in this report. These norms were multiplied by the corresponding accepted population projection in all the three sub basins of Nambiyar river basin. The result gives the projected annual domestic water demand for each sub basin, for each target year and for each population sector - Table-A.

6.4 IRRIGATION WATER DEMAND PROJECTIONS

6.4.1.Introduction

The present gross irrigated area in the basin under different crop is 34707 Ha. Under irrigated conditions, Paddy (20421 ha) is the main crop irrigated in this basin, followed by Coconut (3739 ha), Banana (3492 ha), Vegetables (3119 ha), Groundnut(1745ha), Cotton (1143 ha) and chillies, Onion, Flowers, Pulses, Gingelly, and Sugarcane are also grown. The rainfed crops area in this basin is about 12100 Ha. Under rainfed conditions Cholam, Cumbu, Greengram, Blackgram, Redgram, Gingelly, Groundnut, and Cotton are grown. As the rainfed crops are purely dependent on rainfall only, rainfed area is not considered for calculating the crop water requirements. Only, the irrigated crops raised with surface water and groundwater or both are considered for calculating the crop water requirement.

6.4.2. Present crops and Irrigated area

The data on irrigated area for various seasons were collected from the Economics and Statistics Department. The block wise crop area and the system and non system crop area (mostly paddy) of the irrigation system was used as basis arriving the present crop area. The block wise crop area cultivated was transformed to the subbasin area by its block area proposition to this subbasin..Present crop area in Nambiyar basin sub

basinwise is shown in table D. For the irrigation demand calculation, a simplification of crop data was considered by uniforming the crop planting and duration of crops in different sub-basins.

6.4.3.Rainfall

Weighted rainfall of each sub basin was used to present the rainfall conditions for a given sub basin. For each sub basin monthly distribution with dependability of 25%, 50%, 75% and 90% were computed (Table E) and used for calculating crop water requirement. The total rainfall was taken as effective because the predominant irrigation method are basin irrigation (check basin),border irrigation and furrow irrigation.

6.4.4.Reference crop Evapotranspiration (ETo)

The climatic station located nearby basin is Aralvoimozhi. The ETo values as discussed in Chapter 3 are taken for calculating Crop Water Requirement.

6.4.5. Crop Water Requirements

The crop irrigation requirements computational procedure 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.

Technical irrigation is given if specified. 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 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 within the irrigation period, if regular irrigation is applied, replenishment is 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, defined 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 if still exist or percolates below the root zone otherwise. Similarly, excess moisture from the lower layer if still exists, percolates also below the root zone.

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

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

In this respect 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 in this case in the overall balance of the basin sources and demands which are performed by running the River Basin Simulation Model Tamil Nadu (see: Chapter 8).

The computer program of the crop irrigation requirement is composed of VBA routine and Excel – 1997 spread sheets file.

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 states of 25%, 50%, 75% and 90% for the weighted rainfall in accordance with the discussion in section 6.4.3 of this chapter were used.

Reference Crop Evapotranspiration (ETo)

ETo values calculated for the Arlvoimozhi station as discussed is section 6.4.4 were used in all the cases.

Crop Parameters

The crop parameters used in the model are presented in Table-E. The Kc stages and coefficients were taken from FAO irrigation Paper No. 56. The Kc stages and coefficients for the permanent crops were adjusted to approximate the Kc variation of these crops for the entire year.

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) was prescribed for all the crops except the coconut, fruit crops and the paddy crops as technical irrigation. For the paddy crops the following depths of irrigation were taken as technical ones.

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 technical irrigation data are given in Table-F.

Crop water requirement

The crop water requirement was calculated for the weighted rainfall and four probability situations for the 3 subbasins by simulation model as described above. An example of the output results for Hanumanadhi sub basin with probability of exceedance of 75% is given in the Table-G.

6.4.6. 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 rainfall dependability states. The irrigation demand calculated is the balance of the rainfall, the crop actual evapotranspiration, change of storage and the technical irrigation requirements and include direct field deep percolation as a result of excessive technical irrigation and paddy infiltration. A sample calendar of net irrigation demand for dependability of 75% for Hanumanadhi sub basin is given in Table-H.

Present sub basin irrigation water demand for the three sub basins are given in Tables-I,J, K,& L . These data are considered in basin simulation model (Chapters 8) as irrigation water demand..The net irrigation demand for Nambiyar basin is given inTable -M

Irrigation efficiency

On farm irrigation losses include a variety of components having physical and management nature. An important component of the irrigation losses are those due to non uniformity in the water application. Since, the irrigation methods in the area are mostly small basins and closed furrows losses of this nature could be controlled and considered to be relatively small.

Apart from that, off farm conveyance and operation losses should be accounted. The on farm and off farm losses are taken into account with the hydrologic balance of the basin within the River Basin Simulation Model (RBASIMIN) (Chapter 8).

6.4.7.Nambiyar Basin Future Net Irrigation Water Demand

6.4.7.1. General

There is very little scope for increasing the area under cultivation as most of the water resources in this basin are harnessed except for any extraordinary flood. Hence, the irrigation water requirement for the future also remains the same (Present irrigation demand).

Irrigation area

The scope for increasing the irrigated area is apparently limited within the basin as the water potential is limited.

6.4.7.2. Upper Limit for the future Irrigation Water demand

The upper limit for the future irrigation water demand for this basin has not been considered, since water potential in this basin is limited and importance has to be given for domestic demand.

6.5 LIVE STOCK WATER DEMAND

The district wise livestock population census data for Nambiyar basin has been collected from the office of the Director of Economics and Statistics, Chennai. It was then converted for sub basins and presented in Table-B**.** The assumption of the Animal Husbandry Department that no growth in the animal population is expected in the future was adopted for forecasting.

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 requirement.

The norms suggested are as follows:

Buffalo	150	1pcd
Cattle	110	1pcd
Sheep	20	1pcd
Goats	20	1pcd
Pigs	40	1pcd
Dogs	15	1pcd
Others	50	lpcd
Poultry	0.25	1pcd

The live stock water requirement in each sub basin has been worked out and shown in Table - C **.**

6.6 INDUSTRIAL WATER DEMAND

6.6.1 Present Stage

The Nambiyar basin comprises of 15 numbers of Large and Medium Industries and 5413 numbers of Small Scale Industries. The Small Scale Industries are of

confectionaries, leather goods making, ornamental, tailoring, basic metal Industries etc. whereas the large and medium industries are of mills, Crushers, rubber industries, Aqua farms, etc. The norms for water requirement is adopted as 2500 cum / day for large and medium industries and 2.5 cum / day for small scale industries.

Accordingly, the yearly requirement of water for small scale industries during the year 2006 is assessed as 4.94 Mcum and for the large and medium industries it is assessed as 13.69 Mcum. Hence, the total annual water requirement for Industries in this basin is18.63 Mcum.

6.6.2 Demand Projection

For forecasting the water demand of Industries for future years, a simple arithmetic increase of 8% per annum over the present requirement has been adopted. The computed values for the years 2006, 2010, 2020 and 2045 have been tabulated.

S.No	**Type of Industries**	**2006**	**2010**	**2020**	**2045**
1.	Small Scale Industries	5413	6712	11043	21869
2.	Large and Medium Industries	15	19	31	61
	Total	5428	6731	11074	21930

6.6.3 Industrial Water Demand

The annual water demand for the Industries during the planning periods for each sub basin is given below:

Sl.No.	**Name of the Sub-Basin**	Annual water Demand in Mcum			
		2005	**2010**	**2020**	**2045**
1	Hanumanadhi	5.93	7.82	12.57	24.43
2	Nambiyar	6.71	8.86	14.23	30.11
3	Karamaniyar	14.20	18.75	30.11	58.51
	Total	**26.84**	**35.43**	**56.91**	**113.05**

6.7 Power Generation

At present there is no power generation unit in this basin except the proposed Koodankulam Atomic power plant in the Tirunelveli District.

TABLE - A NAMBIYAR RIVER BASIN – DOMESTIC WATER DEMAND										
Sl. No.	Name of the Sub Basin	2001	2006		2010		2020		2045	
		Total Population in Million	Total Population in Million	Total Water Demand in Mcum	Total Population in Million	Total Water Demand in Mcum	Total Population in Million	Total Water Demand in Mcum	Total Population in Million	Total Water Demand in Mcum
1	Hanumanadhi	0.196	0.212	6.242	0.225	6.655	0.263	7.816	0.389	11.747
2	Nambiyar	0.187	0.203	6.192	0.216	6.620	0.254	7.830	0.383	11.974
3	Karamaniyar	0.296	0.319	9.280	0.339	9.883	0.395	11.574	0.581	17.269
		0.679	**0.733**	**21.715**	**0.780**	**23.158**	**0.912**	**27.221**	**1.352**	**40.990**
Water Requirement for Milky Cattle & Buffaloes				2.771		2.771		2.771		2.771
	Total Water Requirement			**24.486**		**25.929**		**29.992**		43.761

TABLE - B NAMBIYAR BASIN - LIVESTOCK POPULATION															
Sl.No.	Name of the Sub Basin	Cattle	Buffaloes	Bovines	Sheep	Goat	Ovines	Horses & Ponies	Mules & Donkeys	Pigs	Dogs	Rabbits	Fowls	Ducks	Other Birds
1	Hanumanadhi	3423	7775	27702	19167	15544	34712	17	190	1530	4922	15	273680	1242	27
2	Nambiyar	27468	9802	37270	25930	18298	44228	23	256	1824	3902	5	53094	1021	7
3	Karamaniyar	34046	11627	45673	38514	39491	78004	12	590	4272	5950	8	87458	1178	5

TABLE - C NAMBIYAR BASIN - LIVESTOCK ATER DEMAND

Sl.No.	Name of the Sub Basin	Cattle	Buffaloes	Bovines	Sheep	Goat	Ovines	Horses & Ponies	Mules & Donkeys	Pigs	Dogs	Rabbits	Fowls	Ducks	Other Birds	Total Water Requirement in Mcum
		110	150	110	20	20	110	150	40	40	15	15	0.25	15	50	
1	Hanumanadhi	0.137	0.426	1.112	0.140	0.113	1.394	0.001	0.003	0.022	0.027	0.000	0.025	0.007	0.000	**3.408**
2	Nambiyar	1.103	0.537	1.496	0.189	0.134	1.776	0.001	0.004	0.027	0.021	0.000	0.005	0.006	0.000	**5.298**
3	Karamanar	1.367	0.637	1.834	0.281	0.288	3.132	0.001	0.009	0.062	0.033	0.000	0.008	0.006	0.000	**7.657**
	Total Water Requirement in Mcum	**2.607**	**1.599**	**4.442**	**0.610**	**0.535**	**6.301**	**0.003**	**0.015**	**0.111**	**0.081**	**0.000**	**0.038**	**0.019**	**0.001**	**16.363**

TABLE-D

SUB BASINWISE IRRIGATED AREA OF CROPS (Ha.)

Sl.No	Crop name	Hanumanadhi	Nambiyar	Karamaniyar	Total
1	Coconut- Per	1057	910	1772	3739
2	Flowers - Per	169	74	8	251
3	Paddy-June	1300	1803	1500	4603
4	Paddy-Oct	2100	5779	3006	10885
5	Paddy - Feb	450	2983	1500	4933
6	Pulses-Mar	139	190	123	452
7	Chillies-Feb	80	98	68	246
8	Sugarcane-Jan	6	5	3	14
9	ONION-Feb	24	14	2	40
10	Banana- Jan	300	680	891	1871
11	Banana- APRIL	321	500	800	1621
12	Gingelly-Mar	3	5	10	18
13	Groundnut - Mar	381	372	992	1745
14	Cotton - Feb	231	288	624	1143
15	Veg-Jun	441	900	430	1771
16	Veg. Feb	300	416	632	1348
17	Fodder	10	10	7	27
TOTAL		7312	15027	12368	34707

Table -E

NAMBIYAR RIVER BASIN

Weighted Rainfall

Hanumanadhi Sub basin

Dependability	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
25%	5.91	3.98	0.00	16.87	29.98	55.59	47.39	20.89	72.02	257.99	187.37	152.26	850.24
50%	0.00	0.00	24.68	126.14	58.85	13.90	78.23	0.00	86.24	223.88	56.27	41.66	709.84
75%	0.45	63.08	38.56	77.64	5.66	77.90	3.26	38.33	32.97	82.79	160.66	20.11	601.41
90%	3.09	0.40	21.35	31.13	42.89	56.00	17.72	6.14	0.00	128.19	156.28	5.98	469.17

Nambiyar Sub basin

Dependability	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
25%	4.83	62.16	12.47	10.97	10.95	16.69	6.73	3.28	16.26	177.31	271.08	147.29	739.99
50%	0.00	29.20	1.67	27.94	11.60	10.32	47.88	6.56	31.56	206.15	77.91	200.17	650.96
75%	31.30	0.70	0.79	33.56	103.98	17.73	16.74	5.26	0.00	56.61	216.59	15.92	499.17
90%	0.00	0.00	52.00	34.87	11.58	36.24	29.85	23.92	61.74	54.13	61.77	27.85	393.94

Karamaniyar Sub basin

Dependability	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
25%	0.00	24.15	4.20	32.56	7.65	9.38	31.64	0.72	15.35	248.90	113.94	276.72	765.21
50%	6.72	33.80	6.31	12.00	12.83	10.03	5.11	23.60	71.94	91.71	275.29	72.11	621.46
75%	152.81	37.00	23.41	22.73	4.71	8.47	2.24	0.00	50.12	26.67	191.44	0.02	519.61
90%	41.32	0.02	9.35	56.38	11.19	0.58	1.62	17.45	46.22	92.03	26.76	88.67	391.57

Table-F

Crop parameters

Crop No.	Crop Name	Planting Date		Irrigation period	Kc Stages				Data for Kc calculations			Effective root		Allow-able deplet-ion
					Stage-1	Stage-2	Stage-3	Stage-4	Wetting Interval (Stage-1)	Kc mid season (Period-3)	Kc at harvest	Full depth	Time to Full depth	
		Month	Day	(days)	(days)	(days)	(days)	(days)	(days)			(cm)	(days)	(%)
1	Coconut- Per	1	1	365	1	124	120	120	2	1.00	1.00	100	1	40
2	Flowers -Dec	1	1	110	20	30	40	20	4	0.95	0.85	100	50	20
3	Paddy-June	6	25	110	25	1	64	20	1.2	1.10	0.90	15	1	33
4	Paddy -Oct	10	25	135	25	1	84	25	1.2	1.10	0.90	15	1	33
5	Paddy -Feb	2	25	110	25	1	64	20	1.2	1.1	0.9	15	1	33
6	Pulses - Mar	3	15	70	10	20	30	10	7	1.00	0.35	80	30	50
7	Chillies-Feb	2	15	165	30	40	75	10	5	1.05	0.90	75	70	30
8	Sugarcane-Jan	1	10	300	30	70	150	50	6	1.25	0.75	150	100	65
9	Onion-Feb	2	15	95	20	30	25	20	6	1.05	0.90	50	35	30
10	Banana- Jan	1	1	290	30	70	160	30	6	1.10	1.00	75	100	35
11	Banana- April	4	1	290	30	70	160	30	6	1.10	1.00	75	100	35
12	Gingelly-Mar	3	1	70	15	25	20	10	8	1.00	0.25	125	60	55
13	Groundnut - Mar	3	15	95	20	25	40	10	7	1.00	0.60	70	45	50
14	Cotton - Feb	2	15	130	30	40	30	30	8	1.15	0.70	140	45	65
15	Vegetables-June	6	5	115	10	35	35	35	5	1.05	0.90	50	35	30
16	Vegetables-Feb	2	15	115	10	35	35	35	5	1.05	0.90	50	35	30
17	Fodder - March	3	10	70	10	20	30	10	8	1.00	0.30	125	40	55

Table-G

Technical Irrigation Data

Crop No.	Crop Name	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												
2	Flowers -Dec												50
3	Paddy-June						264	112	162	36			
4	Paddy -Oct	62	24								276	110	162
5	Paddy -Feb		273.4	112	160	42							
6	Pulses - Mar			50									
7	Chillies-Feb		50										
8	Sugarcane-Jan	50											
9	Onion-Feb		50										
10	Banana- Jan	50											
11	Banana- April				50								
12	Gingelly-Mar			50									
13	Groundnut -Mar			50									
14	Cotton - Feb		50										
15	Vegetables-June						50						
16	Vegetables-Feb		50										
17	Fodder - March			50									

Table-H

Crop water Requirements forRainfall Probability of exceedance P=0.75(incliding technical irrigation)

Crop No.	Crop Name	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1	Coconut- Per	156	71	117	70	171	78	159	136	136	56	0	111	1262
2	Flowers -Dec	140	111	132	0	0	0	0	0	0	0	0	50	433
3	Paddy-June	0	0	0	0	0	318	279	316	187	0	0	0	1100
4	Paddy -Oct	231	115	0	0	0	0	0	0	0	326	110	286	1069
5	Paddy -Feb	0	332	251	259	233	0	0	0	0	0	0	0	1076
6	Pulses - Mar	0	0	50	122	109	0	0	0	0	0	0	0	281
7	Chillies-Feb	0	50	70	79	186	86	97	0	0	0	0	0	568
8	Sugarcane-Jan	75	0	174	115	222	117	199	180	173	0	0	0	1256
9	Onion-Feb	0	50	77	90	108	0	0	0	0	0	0	0	325
10	Banana- Jan	92	55	136	107	192	94	175	154	151	0	0	0	1155
11	Banana- April	76	0	0	50	119	76	172	154	153	70	0	122	993
12	Gingelly-Mar	0	0	100	128	0	0	0	0	0	0	0	0	227
13	Groundnut -Mar	0	0	50	60	187	0	0	0	0	0	0	0	297
14	Cotton - Feb	0	50	89	110	200	0	0	0	0	0	0	0	449
15	Vegetables-June	0	0	0	0	0	50	171	144	113	0	0	0	478
16	Vegetables-Feb	0	50	103	91	175	0	0	0	0	0	0	0	419
17	Fodder - March	0	0	50	161	0	0	0	0	0	0	0	0	211

Table- I

Hanumanathi sub basin Net Crop Water Requirement in MCM (P=0.75)

Crop No.	Crop Name	Crop Area (Ha.)	Crop Water Requirement in MCM												
			Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1	Coconut- Per	1057	1.65	0.75	1.24	0.74	1.81	0.83	1.68	1.44	1.44	0.59	0.00	1.17	13.34
2	Flowers -Per	169	0.24	0.19	0.22	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.08	0.73
3	Paddy-June	1300	0.00	0.00	0.00	0.00	0.00	4.14	3.63	4.10	2.43	0.00	0.00	0.00	14.30
4	Paddy -Oct	2100	4.85	2.43	0.00	0.00	0.00	0.00	0.00	0.00	0.00	6.85	2.31	6.01	22.44
5	Paddy -Feb	450	0.00	1.49	1.13	1.17	1.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4.84
6	Pulses - Mar	139	0.00	0.00	0.07	0.17	0.15	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.39
7	Chillies-Feb	80	0.00	0.04	0.06	0.06	0.15	0.07	0.08	0.00	0.00	0.00	0.00	0.00	0.45
8	Sugarcane-Jan	6	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.08
9	Onion-Feb	24	0.00	0.01	0.02	0.02	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.08
10	Banana- Jan	300	0.27	0.16	0.41	0.32	0.58	0.28	0.52	0.46	0.45	0.00	0.00	0.00	3.47
11	Banana- April	321	0.24	0.00	0.00	0.16	0.38	0.24	0.55	0.49	0.49	0.23	0.00	0.39	3.19
12	Gingelly-Mar	3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01
13	Groundnut -Mar	381	0.00	0.00	0.19	0.23	0.71	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.13
14	Cotton - Feb	231	0.00	0.12	0.21	0.25	0.46	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.04
15	Vegetables-June	441	0.00	0.00	0.00	0.00	0.00	0.22	0.75	0.64	0.50	0.00	0.00	0.00	2.11
16	Vegetables-Feb	300	0.00	0.15	0.31	0.27	0.52	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.26
17	Fodder	10	0.00	0.00	0.01	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02
Total		**7312**	**7.26**	**5.34**	**3.87**	**3.43**	**5.86**	**5.78**	**7.23**	**0.60**	**5.32**	**0.90**	**2.31**	**7.66**	**68.88**

Table - J

Nambiyar River Basin Present Net Sub Basin Irrigation Water Demand (Mcum)

Rainfall probability of Exceedance P= 0.25

Sl. No.	Sub Basin	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1	Hanumanathi	7.04	7.76	5.14	5.69	5.15	6.51	5.81	7.76	3.99	5.79	2.31	3.49	66.4
2	Nambiyar	15.53	18.18	12.09	14.95	12.63	12.84	10.24	11.76	8.23	15.94	6.36	9.40	148.2
3	Karamaniyar	11.17	13.67	11.12	12.07	13.84	13.48	9.36	12.43	9.23	8.29	3.31	4.87	122.9
Total		**33.75**	**39.61**	**28.35**	**32.71**	**31.62**	**32.83**	**25.42**	**31.95**	**21.45**	**30.03**	**21.98**	**17.76**	**337.44**

Table - K

Nambiyar River Basin Present Net Sub Basin Irrigation Water Demand (Mcum)

Rainfall probability of Exceedance P= 0.50

Sl. No.	Sub Basin	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1	Hanumanathi	7.28	7.92	4.48	1.62	4.60	8.48	4.64	8.47	3.50	5.79	4.52	6.91	68.2
2	Nambiyar	15.91	21.62	12.86	13.93	12.60	13.39	8.22	11.60	7.50	15.94	6.58	9.40	149.6
3	Karamaniyar	10.74	12.98	10.91	13.54	13.46	13.42	10.81	11.19	6.18	9.47	3.31	8.64	124.7
Total		**33.93**	**42.52**	**28.26**	**29.10**	**30.65**	**35.29**	**23.67**	**31.27**	**17.17**	**31.20**	**14.40**	**24.95**	**342.4**

Table - L

Nambiyar River Basin Present Net Sub Basin Irrigation Water Demand (Mcum)

Rainfall probability of Exceedance P= 0.75

Sl. No.	Sub Basin	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1	Hanumanathi	7.26	5.34	3.87	3.43	5.86	5.78	7.23	0.60	5.32	0.90	2.31	7.66	68.88
2	Nambiyar	13.43	24.59	13.08	13.63	6.33	13.31	9.75	11.66	9.01	21.60	6.36	18.49	161.2
3	Karamaniyar	2.31	13.08	9.69	12.41	14.00	13.56	10.97	12.47	7.35	14.96	3.31	12.67	126.76
Total		**23.00**	**43.01**	**26.64**	**29.47**	**26.19**	**32.65**	**27.95**	**24.73**	**21.69**	**37.46**	**11.98**	**38.81**	**356.88**

Table - M

Nambiyar River Basin Present Net Sub Basin Irrigation Water Demand (Mcum)

Rainfall probability of Exceedance P= 0.90

Sl. No.	Sub Basin	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1	Hanumanathi	7.16	7.90	4.57	5.13	4.71	6.49	6.85	8.26	6.45	5.79	2.31	8.15	73.8
2	Nambiyar	15.91	24.67	10.24	13.35	12.54	10.09	9.11	10.77	6.05	21.78	10.66	17.63	162.8
3	Karamaniyar	8.49	15.41	11.05	10.47	13.53	14.88	10.97	11.53	7.56	8.78	10.55	6.97	130.2
Total		**31.56**	**47.98**	**25.86**	**28.96**	**30.78**	**31.46**	**26.93**	**30.56**	**20.07**	**36.35**	**23.52**	**32.75**	**366.77**

Table -N

Net irrigation demand at field level in Nambiyar basin

for 75% depentability rainfall.

Sl. No.	Sub Basin	Present Net irrigation demand (Mcum)
1	Hanumanadhi	68.90
2	Nambiyar	161.20
3	Karamaniyar	126.80
Total		356.90

Note: The above tabulation shows the net Irrigation water demand at field level only Gross Irrigation demand after considering all losses and field efficiency is worked out and given in Chapter 8. .

6.8 ECONOMIC BENEFITS DERIVED FROM WATER SUPPLY FOR IRRIGATION

The economic analysis carried out for the development and action plan (Chapter 13) is focused mainly on prioritization of developmental projects based on estimating some economic indicators such as Net Present Value (NPV), Internal Rate of Return (IRR), Benefit Cost Ratio (BCR) and the Net Present

Value to Investment ratio (NPV/I) for each one of the proposed projects. The benefits in this analysis reflect the economic value of using the water for irrigation.

The benefits assigned to new irrigation projects are assessed by estimating the net income per irrigated hectare. This is then multiplied by the additional irrigated area enabled by the project to derive the total irrigation benefit of the project.

Crop budgets were prepared for the main irrigated crops in the Nambiyar basin. They were first given in physical terms and then (with proper economic prices) in monetary terms. The result is the net income per crop per hectare as shown in the table below.

Net Income Per Hectare Estimates for Irrigated crops in Nambiyar Basin

Irrigated Crops	Net Income (Rs./ha)
Paddy 1st Crop	9280
Paddy IInd and single Crop	9539
Coconut	42311
Banana	57899
Sugarcane	34297
Pulses	2750
Gingelly	6788
Cotton	13569
Groundnut	12172
Other Crops	10000

It could be seen that nearly 34707 ha is under irrigation under various sub and minor basins in Nambiyar basin. The net economic benefits that could be derived from the existing cropping practices under optimal yield conditions annually are presented in the following table below.

Net Economic Benefits under existing irrigated crop area under optimal yield conditions in Nambiyar Basin

Sl. No.	Crops	Area in ha	Annual benefits (Rs.Lakhs)
1	Paddy	20421	1921.5
2	Coconut	3739	1582.01
3	Banana	3492	2021.83
4	Sugarcane	14	4.8
5	Pulses	452	12.43
6	Gingelly	18	1.22
7	Cotton	1143	155.09
8	Groundnut	1745	212.4
9	Other Crops	3683	368.3
Total		**34707**	**6279.58**

It could be seen that the annual net economic benefits to farmers under irrigated crops in an area of 34707 ha would be in the order of Rs.6280 lakhs under optimal yield situations. However, the average yields in the basin is less than half of the optimal yield and would atleast yield a benefit of Rs.3140 lakhs annually.

The developmental plan for Nambiyar basin as specified in Chapter 12, indicates 2 projects that directly benefits agriculture by bringing in additional area or stabilizing existing irrigated area. The below table indicates the additional area. By assuming that the current cropping pattern would be followed in the additional area to be benefited by developmental interventions, the net economic benefit that could be realized after implementation of all the developmental projects are summarized in the table below.

New projects and additional area that could be benefited in Nambiyar basin.

Developmental Actions	Units	Estimate Amount in Rs. Lakhs	Ayacut Benefited in Ha	Net Annual Benefit (Rs. Lakhs)
A. Formation of Ponds	1	21.95	21.46	2.02
B. Formation of Reservoir	1	219.00	19.43	1.83
Total	**2**	**240.95**	**40.89**	**3.85**

It could be seen that the net annual benefits by implementing the above developmental activities in the basin would be Rs.3.85 lakhs.

CHAPTER – 7

ENVIRONMENTAL ASPECTS

CHAPTER – 7
ENVIRONMENTAL ASPECTS

7.1 INTRODUCTION

This chapter deals with the environmental issues viz deterioration of water quality due to the discharge of trade effluent and domestic waste into the water bodies and land and over extraction of groundwater, sea water intrusion, etc. The other related issues dealt with are pollution, solid waste management, weed growth, encroachment, sand mining, sedimentation, catchment area degradation, salinity, flood, drought, wasteland development, public health, wild life, tourism, fisheries, institutional issues, socio-economic aspects, problem area, etc.

The development of water resources has always been given due recognition and importance to meet out the food requirements. History contains description of numerous irrigation and water bodies constructed from time to time in order to fulfill the water requirements of agricultural, municipal and other needs of the people.

A few decades ago environmental issues were not a matter of concern. For a developing country like India, protection of environment is an essential part of development. Without addressing environmental issues, development will be unsustainable and without development, resource will be inadequately or ineffectively harnessed.

The urbanization and increase in population caused environmental degradation and inturn reduced the efficiency of the irrigation structures considerably. It has also led to the realization that the water resources development should be planned in such a manner that it leads to enhancement in the quality of environment rather than its degradation.

More precisely, the environmental impacts on resources contribute to the human welfare but it should be noted that these resources are becoming more and more scarce that ultimately impairs the welfare of the human beings. All the developmental activities connected with the natural environment needs are to be carefully planned and controlled. Development of water resources is a major challenge to be accomplished in an environmentally sound manner for achieving economic development. In this context, it is more appropriate to discuss the environmental issues and remedial measures in the Nambiyar basin.

7.2 POLLUTION SOURCES

The major pollution sources identified in the basin are as follows.

- Industries
- Domestic
- Agriculture.

7.2.1 INDUSTRIAL POLLUTION

Industrialization caused series of problems relating to environmental pollution. The problems relating to the disposal of industrial solid wastes are associated with lack of infrastructural facilities and negligence of industries to take proper safe guards. The large and medium industries located in identified industrial areas have some arrangements to dispose solid wastes. However, the problem persists with small-scale industries. In a number of cities and towns, small-scale industries find it easy to dispose wastes here and there and make it difficult for local bodies to collect such wastes. The industries are discharging their effluents directly into the water bodies or land. This may lead to indirect effect on environmental concerns of the basin and also cause serious problems to the aquatic life.

The Tamil Nadu Pollution Control Board (TNPCB) is the authority for monitoring the quality of effluents from the industries, individual treatment plants installed by the industries and the Common Effluent Treatment Plants (CETP). Industries are classified into three categories with respect to the level of pollution: High polluting industries are categorised as **Red**, moderately polluting industries are categorised as **Orange** and less polluting industries are categorised as **Green**.

Industries like palmyrah industry, safety matches, handloon weaving, beedi rolling, net weaving, bricks and tiles, stone crushers are located in the basin. Cottage industries like appalam production, artificial flowers, cane furnitures, country bricks and pottery are also done in the basin.

The requirement of water for large and medium scale industries is taken as 2500 cum per day based on the norms prescribed by Director of Industries and Commerce department. The wastewater generated is assumed as 80% of the water utilized. The total cost including capital and treatment cost is taken as Rs. 2354 lakhs per Mcum. The cost benefit analysis is given below. The calculations are given in the Table A.

Total Treatment cost including capital and treatment cost	**= Rs.**	**2354**	**Lakhs**
Benefits by using treated industrial effluents,			
Total quantity of water utilised by the industries	=	13.69	Mcum per year
Assuming that 80% wastewater can be reused for irrigation, 80% of total quantity of water utilised	=	10.95	Mcum per year
Total irrigable area adopting duty of 85 ha/Mcum	=	931	ha
Adopting paddy production as 3.5 Tonnes/ha, possible paddy production	=	3258	Tonnes
Procurement rate per quintal	=	550	Per Qtl
Total revenue expected	**=**	**179**	**Lakhs/Year**

7.2.2 DOMESTIC SECTOR

The Municipalities and Panchayats along the bank of the river are letting the raw sewage directly into the water bodies only. The discharge of the sullage water in the open land, leads to poor sanitation facilities and defecation leads to groundwater pollution.

Small Towns are discharging the sewage directly into the drains and streams nearby. Majority of the villages are not having any proper drainage system. The sewage from the houses is let out into the roads through small channels. Foul smelling drainage water, which harbored plenty of bacteria and disease causing microbes, flow through the road, thus creating a suitable environment for the multiplication of insect vectors like housefly and mosquitoes. The agricultural drains and the raw sewage contain more Nitrogen, Potassium and Phosphate load that causes eutrophication, which in turn reduces the efficiency of the irrigation structures. The aquatic life in the water bodies are also affected. A detailed statement is furnished hereunder regarding the quantity of domestic effluent generated, assuming 80% of the percapita water supply. The quantity of wastewater reusable and their treatment cost including laying of pipelines, construction of structures for treatment plant etc are also shown in the statement. Since, most of the blocks in the region are drought prone, the reuse of domestic effluent generated from the Municipalities and Town Panchayats is warranted. The expected pollution load in terms of Nitrogen and Phosphate for every 100,000 inhabitants is 900 Kg/day and 200 Kg/day respectively. This is in addition to the Nitrogen, Potassium and Phosphate load in the agricultural run off. This causes more eutrophication problem in the water bodies.

The wastewater generated from domestic sector has been calculated based on the per capita water supply norms adopted by the TWAD Board for Municipalities, Town panchayats, etc. The total cost including collection and treatment has been taken as Rs. 215 lakhs per Mcum. The calculations are given in the Table B and the cost benefit analysis is given below.

Benefits by using treated domestic effluent,

Sewage from Town Panchayats	=	3.39	Mcum per year
Assuming that 80% waste water can be reused for irrigation, 80% of total effluents	=	2.71	Mcum per year
Total irrigable area adopting duty of 85 ha/Mcum	=	231	Ha
Adopting paddy production as 3.5 Tonnes/ha, Possible paddy production	=	808	Tonnes
Procurement rate per quintal	= Rs.	550	/Qtl
Total revenue expected	**= Rs.**	**44**	**Lakhs/year**
Total cost including collection and treatment	**= Rs.**	**4152**	**Lakhs**

7.2.3 AGRICULTURAL RUNOFF

After the green revolution, the farmers have switched over from the natural manures to the chemical fertilizers and pesticides. To increase the food production to meet out the demand due to the increase in population, excessive chemical fertilizers are being applied. The chemical residues in the agricultural runoff join the mainstream and induce the unwanted growth of the waterweeds. This reduces the velocity and also leads to more evapotranspiration losses.

Various types of fertilizers like compost, urea, DAP, complex, potash, etc., and pesticides like demacron, rocker, ekaulux, monocil, endosulphan, monochrotophos, etc. are used in the entire ayacut of this basin as well as pesticides applied on the crops contribute to pollution in the river. Hence, immediate action may have to be taken to encourage the farmers to go for natural manures.

7.3 SURFACE WATER QUALITY

The main factors responsible for increasing water pollution are exponential growth of population, urbanization, industrialization and agricultural revolution. Eventhough this river is a seasonal river, dumping of solid wastes of domestic and industrial origin in the river path would adversely affect the ecosystem when there is a

flow of water in the river. Most of the villages dumped the waste in the outer of the village in barren lands.

The drainage of the villages is of open type and during the rainy season this sewage is flushed into ponds and ooranies which are constructed for water storage which in turn affects the water quality.

It has been observed that no hazardous chemicals or effluents are discharged in the river or channel or tanks.

MITIGATION

Sewage treatment plants may be installed with proper operation and maintenance. The industries may be forced to treat the effluent to the required standards and to connect to the main sewer line or could be discharged into the river as per the standards prescribed.

The basic facilities of sewage treatment to be coupled with production of energy and manure. Sanitary facilities may be provided for public. Awareness about pollution to be encouraged and the community may be awarded for preventing pollution in water bodies. Industries may be encouraged to reuse water for different purposes like Pisciculture, Aquaculture, Horticulture and Cooling. Funds may be provided to the community and industries for treating wastewater.

7.4 PUBLIC HEALTH

The major possible pollution is the dust pollution due to many crusher mills, limestone and blue metal industries. This leads to bronchial diseases. People involved in beedi industries has health problems. The diseases prevailing in the basin are given in the Table C.

From the statistics and analysis, it is observed that the main cause for the diseases is the polluted water. Hence, it is suggested that the domestic and trade effluents have to be treated before letting it into any source after ascertaining the permissible limits. The standards fixed for perennial water bodies have to be revised to suit to the seasonal flowing rivers in Tamil Nadu. In addition to that the agricultural pollution due to the agricultural run-off has to be analysed periodically.

7.5 SOLID WASTE MANAGEMENT

Solid waste is the term used to describe non-liquid waste materials arising from domestic, trade, commercial, agricultural, industrial activities and from public services. Its main sources are residential premises, business establishments and street sweepings. It is a mixture of vegetables and organic matter, inert materials like glass, metal, stones, ashes, cinders, textiles, wood, grass etc.

Indian cities/towns generate solidwaste on an average of 300-500 gm/capita/day. Various types of solid waste generated in India per annum are 25 million tonnes, agricultural residues 320 million tonnes, cattle manure 210 million tonnes and poultry manure 3.3 million tonnes. Generation of Municipal solid waste in a city/town is directly proportional to the population. The quantity of solid waste will also bear a relation with socio-economic conditions of the society, the climatic condition of the city/town, the city/town growth, density of population, development of residential and commercial areas/activities and degree of salvaging waste at source. The quantity of solid wastes and manure generated from Town Panchayats and Municipalities in this basin are shown in separate statements, vide Table D.

The solid waste generated from various sectors has been calculated based on the norms prescribed in the study of "Modelling of groundwater pollution due to solid waste dumping at Perungudi" by Centre for Environmental Studies, Anna University, for Indian Cities, Municipalities and Town panchayats. The total cost including the collection, conveyance and dumping of the solidwaste works out to Rs. 750 per tonne. Out of the total solid waste, 60% of the solid waste can be converted as manure. From the convertible solid waste, 60% of manure can be produced. Based on the same, the calculation has been done and the same is presented in Table E.

Domestic and community solid waste may be centrally collected in a place from where the local body should take the responsibility for disposing the solid waste in a suitable place where there is no habitation and where there is no chance of contaminating water bodies with measures as per BIS code for solid waste management. The local bodies have to impose the Solid waste Management and Handling rule-2000 to prevent environment degradation and health hazards.

Most of the villages are having ponds, ooranies, lakes, etc but are maintained in poor condition. The ponds and ooranies are the common waste dumping site for majority of villages.

The solid wastes in Indian cities consist of mainly three types of components.

1. Recyclables (20%) such as paper, plastics, glass, metal, leather, rubber etc.
2. Compostable or combustible material (40-50%) such as kitchen waste, vegetable and fruit waste, dry grass, mutton and fish waste, dry leaves etc.
3. Inert material (40%) such as construction wastes, debris, road dust, ash etc.

Impacts of solid waste in Water Resources Organisation (WRO).

1. Groundwater and surface water pollution
2. Reduction in infiltration rate
3. Artificial flooding
4. Reduction in capacity of Reservoir and tanks
5. Reduction in carrying capacity of Rivers, Streams, canals and channels
6. Health problems
7. Odour and flies
8. Socio-economic problems (People dislike to live near the solid waste dumping site and migration of people in and around the dumping site and also reduction in land value)

One of the most vital and persistent public health challenges faced by the State and local bodies today is the disposal of solid waste.

The solid waste generation by some technological process is shown in the chart A and the activities associated with the management of municipal solid wastes is shown in the chart B

MITIGATION

Solid wastes have to be segregated into the following three categories at the source itself.

(i) Recyclables
(ii) Compostables or combustible materials
(iii) Inert materials

By recycling, the quantity of solid waste dumping can be reduced and recycling leads to the mobilization of income for survival of downtrodden people.

By Vermi composting and Indigenous composting method, the combustible solid waste can be made as organic manure. This is one way of disposing the solid waste and due to this, the usage of chemical fertilizers also gets reduced.

The debris and the inert materials can be used as filling materials, so that the quarrying of filling sand in riverbed can be reduced to some extent.

7.6 ENCROACHMENTS

Many rivers, channels and tanks in our basin area are encroached for agricultural purposes for cultivation of crops by the inhabitants of the villages. Constructions of houses, shops and other such buildings are also reported in some places of the banks of rivers and tanks. Due to such encroachments the free flow of water is prevented during rainy season and the water is diverted and wasted.

Solid waste disposal of domestic and agricultural wastes is also observed in many places especially in tanks and the bank of the rivers, which lead to severe water pollution. This is one of the main reasons for water borne diseases such as cholera, Typhoid, Dysentery and Skin diseases etc.,

The capacity of tanks and channels is also considerably reduced due to encroachment mainly by solid waste disposal. Encroachment also leads to soil erosion and water logging in many places.

Non degradable pollutants such as polythene and plastics pose a severe pollution problem. This reduces the ground water percolation, ground water recharge and ground water table.

MITIGATION

Effective steps have to be taken by the Government machineries to avoid encroachments in water bodies. Periodic monitoring has to be done to avoid the encroachments. Awareness regarding the importance of the water bodies to the human livelihood is to be created among the public.

7.7 WEED GROWTH

Most of the basin area is covered with the following water weeds.

- Eichornia crassipes (Mart.) Solms.Lamb.
- Ipomea carnea Jacq.
- Prosopis cineraria (L.) Druce.

Due to the encroachment of these weeds the flow of water and groundwater

potential are severely affected. Besides these weeds other minor weeds are also seen in the basin.

Among the various energy alternatives the development of energy from biomass is one area which has considerable promise in the developing countries and is receiving increasing attention. Biomass energy is a general term that refers to the energy that can be derived from plant and animal materials, through a variety of conversion and end use processes. A significant portion of 70 to 80 million biogas plants can be run with fresh or dry bio mass residues. There are many plants available in large quantities as weeds in our basin area which can be used in biogas plants. This will solve the problem of weed menace in an eco friendly manner.

IMPACT OF PROSOPIS JULIFLORA

Prosopis Juliflora DC (Velikaruvai or Seemai Karuvai) is an exotic evergreen tree native of arid regions of West Indies, Central America and Mexico. Prosopis is a fast spreading weed at every place in waste land (Poramboke land) tank beds and farmlands also. The farmers, the charcoal producers and the traders are responsible for the prosopis cultivation.

MERITS IN GROWING OF PROSOPIS

1. It was found to add maximum phosphorus and potassium through litter fall.
2. Soils under prosopis Juliflora were found two or three times richer in organic matter and Nitrogen than the soil which is at a distance from the trees.
3. The population of bacteria, fungi, actinomycetes and Nitrogen fixing bacteria were found to be higher beneath the Prosopis tree compared to barren soil.
4. It is used as fuel wood for the economically poor people and raw material for generating power.
5. The pods of the tree are a good fodder for livestock.
6. It is also used for charcoal making which is of a high calorific value.

DEMERITS IN GROWING OF PROSOPIS

1. Prosopis affected the water quality of both surface and groundwater.
2. It does not allow any plants to grow in and around. Hence this could be avoided in the place where cultivation is in practice.
3. It absorbs atmospheric moisture.

7.8 SAND MINING

Illegal sand mining is predominantly noticed in many places along the river course. Almost, the sand layer has been taken from the bed exposing the barren surface of the river.

Sand mining has resulted in the destruction of local eco-system and depletion of water for all purposes. Riverbeds, rich with sand cover, are a natural resource, environmental preservative and defender of livelihood and human rights of millions of people. This nature's bounty is being rapidly destroyed by mindless mining by various means. The level of river bed goes down because of excess sand mining and feeder canals for irrigation from river beds stand high and dry. The Government of Tamilnadu issued orders and given powers to WRO, Public Works Department to sell the sand in the notified areas to avoid excess sand mining and illegal mining.

GOVERNMENT APPROVED SAND MINING SITES

VILLAGE	TALUK	RIVER
Rajakalmangalam	Nanguneri	Nambiyar
Anaikulam	Radhapuram	Nambiyar
Kannanalur	Radhapuram	Nambiyar
Karankulam	Radhapuram	Nambiyar
Kovankulam	Radhapuram	Nambiyar
Urumankulam	Radhapuram	Nambiyar
Kasthurirengapuram	Radhapuram	Nambiyar

Impact due to sand mining

Rapid reduction of groundwater especially over the last 10 years.

River bridges, irrigation structures and railway tracks are severely damaged.

Drainage channels to lakes/ponds/tanks are blocked since there is no water flow.

The potable nature of available drinking water is affected as the sweet water aquifers (recharge and purifier) are destroyed.

Reduction in agricultural productivity, flooding of agricultural lands, migration of agricultural labourers.

Loss in vegetative cover, loss of ecology, destruction of sand dunes and the mangrove ecosystem.

MITIGATION

Alternative materials for sand in construction practices have to be introduced by conducting active research programme.

Greater assured interactions between the concerned inter departments.

By involving the local people and their representatives at the site of structure and vulnerable stretches of the rivers.

Judicial powers have to be given to the WRO, PWD to take action against the violators. River Protection Force has to be established.

Sand mining is done in the following approved sites. Illegal sand mining is carried out in many places. Sand mining is one of the major reasons for scarcity of water and reduction in groundwater level. Due to sand mining the water holding capacity of the soil is lost and water is not percolated in the soil which leads to groundwater.

7.9 SALINITY

Salinity is one of the environmental concerns. It contaminates both surface and groundwater and creates socio-economic problem. Salinity is of two types. One is due to the geological formation of the soil and another is due to seawater intrusion. Salinity not only contaminates the water resources but also reduces the agricultural productivity. Marine aquaculture farms in the seashore areas are the main reasons for the salinity in the adjacent groundwater tables. The most marginal of the coastal saline areas have to be brought into productive use. The most economically distressed portion of the coastal population (i.e. Fishermen) has to be offered an alternate economic activity. This will reduce the pressure on the coastal fisheries, forests and other natural resources. The demerits of this are, rapid expansion of brackish water aquaculture which will lead to encroachment, bio accumulation of metals and pesticides in the shrimp tissue that could create health hazards.

A continuous supply of water in excess of that required by growing crop and without adequate drainage, results in rising of the water table to levels from which salts can be drawn by capillary water movement and evapotranspiration by crops.

In the seawater intrusion, the groundwater meets the sea, an interface is formed between the seawater with high salt content and relatively fresh groundwater. A decrease in the depth of fresh groundwater above the interface leads to the salinity intrusion.

Groundwater is rendered unfit for human consumption, soil salinity adversely affects plant life, recovery of coastal aquifer is impossible and land subsidences are some of the impacts due to salinity.

Salinity occurs in almost all the coastal villages of Ammanpuram, Odakkarai, Rani Maharajapuram,Madhavankurichi and Kuttam.

Presence of saltpan is one important factor that led to saline soil condition. The saline water discharged from saltpans percolates into the groundwater table and also mixes with the coastal seawater.

MITIGATION

Proper leaching with good quality of water drains the excess salts and repeating the same until the soil retains its normalites.

Artificial recharge structures such as sub surface dykes, check dams may be constructed at suitable sites to prevent seawater intrusion in the coastal areas and improve the ground water quantity and quality.

Adopting non structural measures like rainwater harvesting, temporary modification of the water pricing structure to encourage reduction of water use, temporary restrictions on certain types of water use such as fining of violations, regulating enerzisation of wells, etc.

7.10 DROUGHT

Direct losses due to droughts result from reduced crop yields, pasture deterioration and livestock deaths, which include reduced returns of most agricultural products. Financial losses result from transport of emergency food supplies, establishment of emergency water supplies either by additional bore wells for

immediate use or surface water storage for future use. Estimates for indirect losses result from crops not planted and population production from animals by not conceiving, also the losses due to abandonment of lands and changes in land use.

The annual average rainfall at all the rain gauge stations is less than **704.14mm.** This clearly indicates that the basin is drought prone.

DROUGHT MANAGEMENT

To mitigate the severity of drought, Drought Prone Area Programme (DPAP) sponsored by the Government of India and Government of TamilNadu has been in operation for over a decade. This has to be continued. Intensive activities should be strengthened to develop watershed under short term and long-term basis. A comprehensive watershed development programme has to be prepared and implemented in addition to a contingency plan for mitigating drought.

SHORT-TERM MEASURES

Site-specific rainwater harvesting structures can be devised. Assessed ground water deficit areas have to be developed to sustain the drought condition. Ecological situation of the area should be thoroughly understood for environmental protection and improvement of the area so as to make the region for sustaining any kind of drought.

Credit facilities for purchase of inputs by the farmers have to be made available. As the livestock supports the economy of rural population, cultivation, storage and supply of fodder crops have to be encouraged and supported. Drought preparedness in terms of storage of food grains and other agricultural inputs will relieve the people from severe shortages. Informal and formal statutory organisation at local, district and regional levels with representation from all sections have to be guided properly before and during the course of drought.

LONG-TERM MEASURES

Drought information system will assist the policy makers to a great extent. Strategic management for policy support and guideline for drought proofing and mitigation should form a national priority as the country is reeling under droughts

very frequently. Integrated plan for drought preparedness, mitigation and relief would bring in coordinated efforts for drought combating.

There should be a National Governmental policy support for drought management taking it on a war footing as drought causes great economic loss and brings in many hardships to the people. Interlinking of rivers proposed is one of the options to mitigate drought. Even phase by phase linking of perennial and non-perennial rivers would be a great step in this direction. Watershed management as a national priority is a right step for drought mitigation and proofing. Crop management as adoption of low water consumption cash crops to suit the drought atmosphere would prove to be a sustainable agriculture practice in the long run in perennial drought regions.

Propagation of information on all aspects of drought and mitigation measures would help people, NGOs, local bodies, People's representatives to work together to fight against drought mitigation. Extension activities have great relevance in adopting to appropriate crop practices, water management and conservation practices in drought prone areas. Non-farm management have to be promoted to augment the losses in terms of labour absorption, productivity and income levels in drought prone areas to reduce migration.

Animal husbandry and dairy development would be a viable source of income to cope with drought atmosphere. The income generated by dairy development activities would promote more employment and support for livestock population. Afforestation, social forestry and plantation activities would bring in environmental balance in the mitigation of drought situation in drought prone areas. Satellite aided research and resource programme should form a base for the study and research on drought in a continuous basis for suggesting policy measures to government and local bodies for drought mitigation and drought proofing. Vegetation index satellite imagery as macro indicator of water scarcity conditions which will help to evolve strategies for preparedness.

The static and dynamic databases for drought monitoring, management and proofing will go a long way in helping the administrators, water resources managers for adopting various measures to mitigate the sufferings of the people.

7.11 CATCHMENT AREA DEGRADATION

No soil erosion due to run off, as there is seldom any flow in this river is noticed for the past few years. Wind acts on the soil and transports them to a low lying area. The human settlements, cutting of trees and disappearing of vegetable cover cause soil erosion in the basin.

MITIGATION

Suitable afforestation, construction of check dams, contour bunding and increasing vegetative cover has to be proposed and implemented.

7.12 WASTELAND DEVELOPMENT

At the behest of the National Waste Land Development Board (NWDB), the classification of wasteland has been made distinguishing 13 categories (Compared to 7 in the original NRSA Scheme) as detailed below.

WASTELAND CLASSIFICATION SYSTEM (NWDB)

1. Gullied and / or ravinous land
2. Undulating upland with or without scrub.
3. Surface water logged land and marsh.
4. Salt affected land (Land affected by salinity / alkalinity – coastal / inland).
5. Shifting cultivation area.
6. Degraded forest land.
7. Degraded pastures / grazing land.
8. Degraded non-forest plantation land.
9. Sands – inlands / coastal.
10. Mining / industrial waste lands.
11. Barren rocky / stony wastes / sheet rock area.
12. Steep sloping area.
13. Snow covered and / or glacial area.

It is also recommended that the NWDB classification schemes for land use and wastelands should be adopted in the state for detailed and meaningful classification in preference to the conventional nine fold land use classification. In order to measure the cultivable land area, it is very essential to develop the useful wasteland in this basin.

By reusing the domestic and industrial wastewater, the wasteland suitable for agriculture can be irrigated. The blockwise details of the wasteland and the area in sq.km are given in the Table F. This area is calculated by multiplying wasteland area of the block with percentage of block area covered in this basin.

7.13 WILD LIFE

A small bird sanctuary in Koonthankulam village is located in this basin.

7.14 TOURISM

A small bird sanctuary in Koonthankulam village is located in this basin attracts tourists.

7.15 FISHERIES

Fishing is an important source of livelihood for a larger section of the population particularly for the economically weaker segments. This sector occupies a prime place in acceleration of socio-economic development of the state. Besides being an employment provider and foreign exchange earner, this sector stimulates a number of subsidiary industries. It is also a source of cheap and nutritious food for the people.

Fishermen residing in the villages along the coastal area undertake activities such as fishing, seaweed, coral reefs and firewood collection and diving for collection of chunks. Fishermen are engaged in fishing activities with mechanized and also conventional non mechanized fishing crafts.

The fisheries department is entrusted with the marine and inland fish production in the state, implements fishermen welfare schemes like fisherman group accident insurance schemes, free housing schemes, funeral expenses, subsidy schemes towards the purchase of aluminium vessels, bicycle etc., infrastructure facilities like fishing harbour and jetties, aquaculture activities and training to fishermen.

Sl. No	District	Mechanised		Non-Mechanised		Motorised		Shore siene		Total	
		2001-02	2002-03	2001-02	2002-03	2001-02	2002-03	2001-02	2002-03	2001-02	2002-03
1	Thoothukudi	23611	15279	1656	254	16156	16054	0	0	41423	31587
2.	Thirunelveli	0	0	523	498	6019	5433	0	0	6542	5931
3.	Kanniyakumari	5744	332	41209	12523	2172	3354	826	3434	49951	19643

7.16 INSTITUTIONAL SETUP AND ISSUES

7.16.1 INSTITUTIONS WITHIN WRO

ENVIRONMENTAL UNIT AT INSTITUTE FOR WATER STUDIES, WRO, PWD, CHENNAI.

The environmental unit at Institute for Water Studies (IWS) prepares environmental studies at micro level for all river basins in consultation with other State, Central and Non Government Organisations. The preparation of guidelines, procedures, policy documents and codes are the responsibility of environmental unit at Institute for Water Studies. The environmental unit will also liaise with other units of the WRO to see that the recommended procedures are followed. Environmental Impact Assessment (EIA) will be reviewed before they are presented to the Water Resources Control and Review Council (WRCRC) for approval. The environmental unit manages the research programme and special studies with Institute of Hydraulics and Hydrology, WRO, PWD, and Universities.

ENVIRONMENTAL CELL AT O/O OF CHIEF ENGINEER, PLAN FORMATION (PF), WRO, PWD, CHENNAI.

An environmental cell established in the office of the Chief Engineer, PF is headed by an Executive Engineer who is being assisted by two Assistant Executive Engineers and two Assistant Engineers. This is be the main functional wing of the environmental units within WRO. It is responsible for ensuring that all projects or activities carried out by the WRO are in accordance with statutory requirements. If an EIA is required, the cell will prepare Terms of reference (TOR) for the work to be carried out by consultants and will supervise and review their work. If the Central Government clearance is required for completed EIAs, the Institute for Water Studies would review and place in WRCRC prior to the submission to the funding agency. However, if environmental clearance is required only from the State authorities this could be obtained directly by the Chief Engineer, PF.

The cell will provide feedback to the IWS on procedures and guidelines so that they can be updated based on experience. The head of the cell at the office of the Chief Engineer, PF will closely work with the Institute for Water Studies to ensure that no environmentally sensitive work is carried out by WRO without prior clearance from WRCRC and the statutory authorities. The cell will also be responsible for preparing mitigating measures or preparing alternative solutions to the designers. The cell will co-ordinate with the river basin managers to get feedback on activities at the

field level and to ensure that the field staff carryout appropriate measures to achieve environmental enhancement under the WRCP. The cell also contributes in drafting water policy document and new legislation such as the Water and Groundwater Acts. This cell will play an active role in the awareness-building programme at the field level.

ENVIRONMENTAL CELL DIVISIONS UNDER THE CONTROL OF CHIEF ENGINEER, PF, WRO, PWD.

The environmental cell divisions are responsible for monitoring environmental quality with respect to their jurisdiction at field level.

These units will systematically monitor water quality, both surface and groundwater and report any episodal pollution events which affect water resources. The cells will interact with Farmers Council and local NGOs and other sectoral agencies such as Tamil Nadu Pollution Control Board (TNPCB), Agricultural Engineering Department (AED) and other line departments with respect to relevant environmental issues within their basin. These cells will be supported by field and mobile laboratories for systematic monitoring of water quality of reservoirs, rivers, drains and canals. The laboratory will also collect data from other agencies such as TNPCB and the Director of Public Health and Preventive Medicine. To avoid duplication of data collection and laboratory analysis, this will be done in co-ordination with other responsible units within the basins.

The laboratory facilities should be adequate to allow soil and water sampling for conventional physical, chemical and biological parameters stipulated under water quality standards. In addition, periodic monitoring is required. The staff of the cells will be required to participate and assist external experts or consultants in any special studies, EIAs or research work relevant to the environment.

The cells are also responsible for creating and managing the eco gardens and ecologically restored areas.

THE STATE GROUND & SURFACE WATER RESOURCES DATA CENTRE (SG&SWRDC), WRO, PWD.

The SG&SWRDC of WRO monitor both surface and groundwater quality and the groundwater fluctuations continuously. The quality of groundwater is monitored twice in a year immediately before and after the monsoon period. The surface water quality is also monitored under the Hydrology Project. Whenever there is flow in the

river, the samples are taken and analysed for various parameters. The water quality data are stored after validation. The groundwater potential is assessed and reported districtwise in bulletins. The data are also given to the other departments, universities etc for the government purposes by collecting nominal rates.

7.16.2 REGULATORY AGENCIES

TAMIL NADU POLLUTION CONTROL BOARD (TNPCB)

The TNPCB is the organisation dealing with Air Pollution and water pollution caused by industries and municipalities. Their function is to monitor, advice and control the environmental issues related to industries and the domestic effluents from local bodies. The monitoring is done on point sources as and when brought to their attention. The Tamil Nadu Pollution Control Board advises the industries and municipalities for sticking to the standards. In case of non compliance by the industries, the Tamil Nadu Pollution Control Board takes up controlling measures like stoppage of power supply, withdrawal of licenses, etc. In addition, the TNPCB conducts basic and applied research studies. The Effluent treatment plants (ETPs) installed are reducing Biochemical oxidation demand (BOD), Chemical oxidation demand (COD) and other metals presented in the effluent. The TNPCB has to insist the polluting industries to install Reverse osmosis (RO) plant to reduce the Total dissolved solids (TDS) as per the standards.

7.16.3 OTHER SUPPORTING DEPARTMENTS AND AGENCIES

TAMIL NADU WATER SUPPLY AND DRAINAGE BOARD (TWAD BOARD)

The TWAD board is responsible for providing protected drinking water supply throughout the state except Chennai and its superb. The TWAD board is also monitoring the groundwater quality for their supply throughout Tamil Nadu. The TWAD board has to take up number of artificial recharge structures to improve the water quality and quantity.

TAMIL NADU AGRICULTURE DEPARTMENT

Tamil Nadu Agriculture department is responsible for the agricultural practices and training the farmers to know about modern techniques in agriculture activities. The Agricultural department is keeping the records about the fertilizers,

pesticides and the yield of various crops irrigated in Tamil Nadu. The wasteland development programme is also one of the main activities of this department. Now, a separate board has been formed to deal this issue. Presently, the Joint Director, Agricultural department is the nodal officer for this programme at district level.

AGRICULTURE ENGINEERING DEPARTMENT

Agriculture Engineering department is responsible for implementing command area development programme, control measures for soil conservation in watershed, land shaping, contour bunding, constructing minor check dams, farm ponds, water harvesting structures, percolation ponds, on farm development works, etc.

FOREST DEPARTMENT

The Forest department is responsible for protecting the forest and other related activities. The Forest department is also playing major role in the environmental side to maintain the eco-system. Afforestation, contour bunding and other works are also carried out by this department to restore the forest from degradation.

DEPARTMENT OF ENVIRONMENT

The Directorate of environment is responsible for all the environmental issues in TamilNadu State. The Environmental Directorate is preparing the district wise environment profile and liaison with national and international level. The Environmental Information System (ENVIS) node of the department of environment, TamilNadu has been established under the ENVIS. The environment management capacity building technical assistance project (EMCBTAP) of the Ministry of Environment and Forest (MoEF), Government of India to facilitate generation and dissemination of information on various facets of environment of TamilNadu. Publishing environmental status report of TamilNadu, creation of database on river cleaning projects and database on biodiversity in TamilNadu are the other activities carried out by the Department of environment.

7.16.4 INTRA DEPARTMENTAL ISSUES

Environment is the vast subject covering all the aspects. Hence a single agency or department is not sufficient for the collection of data and implementation.

But the data collected by various line departments have to be shared with departments associated with water resources and problems should be discussed in coordination with line departments and stakeholders to evolve solution.

7.17 SOCIO ECONOMIC ASPECTS

As per 2001 census, nearly 64% of the populations live in rural areas. The population density of this basin is 337 persons per sq.km as against the State average of 480 persons per sq.km. Agriculture is the main occupation of the rural people. Beside this, some large and medium industries have provided jobs for the labourers.

Most of the land holdings are with the small and medium farmers. The farmers find employment during off seasons in industries like textile mills, rice mills, oil mills, match factories, etc. There are also some stretches of fishing villages along the coast. However, the people involved in traditional agriculture are also getting involved in fish culture because of their reduced level of income from agriculture. For the past two decades, the migrations of labourers from the drought prone blocks in this basin are predominant. The people supplement their income through animal husbandry, forestry, etc.

Certain trends in the migration of agricultural labourers to other industries have been noticed and the labourers are also migrating to nearby places. This is a major concern regarding the economic and environmental point of view of the region, since the farmers are not getting sufficient labourers for agricultural activities. So, they leave their land as barren. This will lead to the decrease in agricultural production and create some illegal activities in the abandoned agricultural lands. The educational levels of farmers are favourable to adopt modern water management practices, cropping pattern etc. The Water Users Association (WUA) is vested with more powers and they are actively participating in the developmental activities. Overall economic status of the people is poor. This has to be improved by creating job opportunities to the people in agriculture and also in farm activities and developing eco friendly industries.

Efforts should be taken to stabilize the present area under cultivation and to step up productivity of crops through better water management practices.

7.18 PROBLEM AREAS

In water planning, identification of problem areas is the most important aspect, since the policy makers and the planners have to give top priority for the problematic areas of the basin. For generation of problematic area map, two environmental issues are considered.

State ground water (SG&SWRDC) and Central ground water organisations have certain blocks as overexploited blocks as the annual extraction exceeds annual recharge.

In general the quality of groundwater in Nambiyar Basin is good and moderate in most of the observations wells. Saline pockets are observed in certain areas like Vadakku Valliyur, Vijayanarayanam, Padukkapathu, Anandapuram and Udangudi. The main reason for the presence of larger amount of dissolved solids may be due to geological formation or seepage from fertilizers or local contamination. This may cause high salinity.

Generally the P^H of the water has a small variation due to buffering action of water with Carbon-di-oxide. Regarding the Nambiyar Basin the P^H value range lies within the permissible limit except in few places. The higher PH observed in this basin is found to be above 8.5 in Moolakaraipatti, Sundarapuram and Itamozhipudur. This may be due of to Calcium carbonate bearing rock formations.

The Chloride concentrations in all the wells of this basin are found to be within the maximum limit except in few wells. When the salt concentration is increased, it is difficult for plants to extract water. Chlorides are more toxic to some plants.

The quality of ground water depends on the different types of rocks encountered. Major portion of the Nambiyar basin is covered with hard rock area and the tail end of this basin with sedimentary rock formation. Hardness is due to presence of Calcium, Magnesium, Bicarbonate and Chloride ions. The concentration of Nitrate in most of the wells are within the maximum acceptable limit except in some places Valliyoor, Udangudi, Vijayanarayanam and Karunkadal. The increased concentration of Nitrate may be due to excessive application of nitrogen fertilizers or decay of plants and animals' residue or disposal of industrial wastewater or sewage or by increased cultivation of leguminous plants. The toxicity of Ntrate leads to cardiovascular effects at higher dose level and methomoglobinemia at lower dosage limits.

The concentration of Fluoride is found to be within the permissible limit in most of the areas. When the intake of Fluoride is above the permissible limit, it leads to skeletal and dental fluorosis. The Fluoride contamination is these pockets may be due to the presence of fluoride rich minerals like fluorite and appetite.

Table A Reuse of Industrial Waste Water and Economic Evaluation
Cost of Treatment of Industrial Effluents

Water requirement for large and medium scale industry is 2500 Mcum/day
Wastewater generated is 80% of water requirement

Sl. No.	Sub basin	Number of large & medium industries	Water utilised in Mcum per year	Waste water generated in Mcum (80%) per year	Treatment cost per Mcum Rs in lakhs	Total cost in lakhs per year
1	Hanumanadhi	8	7.30	5.84	215	1255.6
2	Nambiyar	4	3.65	2.92	215	627.8
3	Karamaniyar	3	2.74	2.19	215	470.9
	Total	**15**	**13.69**	**10.95**	**645**	**2354.3**

Table B Generation of sewage in Town Panchayat

Collection of sewage is assumed as 80% of 70 lpcd (Based on TWAD board estimates)
Cost including collection and treatment per capita is Rs. 2500/-

Sub basin	Town Panchayat	Population as on 2001	Growth rate in %	Estimated population in 2005	Volume of sewage generated in Mcum per year	Treatment cost per capita in Rs	Total treatment cost in lakhs per year
Hanumanadhi	Thiruparappu	21736	2.00	23546	0.48	2500	589
	Alagappapuram	8121	2.00	8797	0.18	2500	220
	Ganapathipuram	13711	2.00	14853	0.30	2501	371
	Panagudi	25501	2.00	27625	0.56	2502	691
Nambiyar	Kumarapuram	13938	2.00	15099	0.31	2500	377
	Aralvoimozhi	19211	2.00	20811	0.43	2500	520
	Eruvadi	14755	2.00	15984	0.33	2500	400
	Thirukarungudi	8875	2.00	9614	0.20	2501	240
	Vadakkuvalliyur	24023	2.00	26024	0.53	2502	651
	Nanguneri (Part)	3379	2.00	3660	0.07	2500	92
Karamaniyar	Alwarthirunagari	8883	2.00	9623	0.20	2501	241
	Udangudi	19390	2.00	21005	0.43	2502	526
	Sathankulam	14206	2.00	15389	0.31	2503	385
	Kalakkad	27090	2.00	29346	0.60	2504	735
	Thisaiyanvilai	19559	2.00	21188	0.43	2505	531
	Nanguneri (Part)	3379	2.00	3660	0.07	2506	92
	Total	**153250**		**166014**	**3.39**		**4152**

Table C Districtwise Prevalent Diseases
DYSENTRY

District	1999		2000		2001		2002		2003	
	A	D	A	D	A	D	A	D	A	D
Thoothukudi	5163	0	5800	0	5390	0	2620	0	2304	0
Thirunelveli	795	0	2281	0	5429	0	6185	0	4699	0
TOTAL	5958	0	8081	0	10819	0	8805	0	7003	0

ADD(Acute Diarroheal Disease)

District	1999		2000		2001		2002		2003	
	A	D	A	D	A	D	A	D	A	D
Thoothukudi	717	1	774	4	394	3	599	2	524	0
Thirunelveli	107	0	169	2	217	1	854	2	241	3
TOTAL	824	1	943	6	611	4	1453	4	765	3

CHOLERA

District	1999		2000		2001		2002		2003	
	A	D	A	D	A	D	A	D	A	D
Thoothukudi	0	0	0	0	0	0	1	0	0	0
Thirunelveli	0	0	0	0	2	0	3	0	8	0
TOTAL	0	0	0	0	2	0	4	0	8	0

JAPANESE ENCEPHLATIS

District	1999		2000		2001		2002		2003	
	A	D	A	D	A	D	A	D	A	D
Thoothukudi	3	1	0	0	0	0	0	0	0	0
Thirunelveli	0	0	0	0	0	0	0	0	2	0
TOTAL	3	1	0	0	0	0	0	0	2	0

LEPTOSPIROSIS

District	1999		2000		2001		2002		2003	
	A	D	A	D	A	D	A	D	A	D
Thoothukudi	0	0	0	0	0	0	0	0	0	0
Thirunelveli	1	0	1	0	0	0	0	0	1	0
TOTAL	1	0	1	0	0	0	0	0	1	0

MALARIA

District	1999		2000		2001		2002		2003	
	A	D	A	D	A	D	A	D	A	D
Thoothukudi	2998	0	1313	0	1079	0	1029	0	1594	0
Thirunelveli	126	0	622	0	31	0	91	0	73	0
TOTAL	3124	0	1935	0	1110	0	1120	0	1667	0

DENGUE

District	1999		2000		2001		2002		2003	
	A	D	A	D	A	D	A	D	A	D
Thoothukudi	0	0	0	0	0	0	3	0	11	0
Thirunelveli	0	0	0	0	0	0	1	0	9	0
TOTAL	0	0	0	0	0	0	4	0	20	0

A- Admitted D – Death

(Source: Director of Public Health and Preventive Medicine, Chennai)

Table D Generation of solid waste in Town Panchayat

The solid waste is assumed as 0.3 Kg/capita/day (Based on the study report "Modelling of GW pollution due to solid waste dumping at Perungudi" by Centre for Environmental Studies, Anna University, Chennai)

Sub basin	Town Panchayat	Population as on 2001	Growth rate in %	Estimated population in 2005	Solid waste generated in tonnes per year	Collection, conveyance and dumping cost per tonne in Rs	Total cost in lakhs per year
Hanumanadhi	Thiruparappu	21736	2.00	23546	2578	750	19.3
	Alagappapuram	8121	2.00	8797	963	750	7.2
	Ganapathipuram	13711	2.00	14853	1626	750	12.2
	Panagudi	25501	2.00	27625	3025	750	22.7
Nambiyar	Kumarapuram	13938	2.00	15099	1653	750	12.4
	Aralvoimozhi	19211	2.00	20811	2279	750	17.1
	Eruvadi	14755	2.00	15984	1750	751	13.1
	Thirukarungudi	8875	2.00	9614	1053	752	7.9
	Vadakkuvalliyur	24023	2.00	26024	2850	753	21.5
	Nanguneri (Part)	3379	2.00	3660	401	754	3.0
Karamaniyar	Alwarthirunagari	8883	2.00	9623	1054	755	8.0
	Udangudi	19390	2.00	21005	2300	756	17.4
	Sathankulam	14206	2.00	15389	1685	757	12.8
	Kalakkad	27090	2.00	29346	3213	758	24.4
	Thisaiyanvilai	19559	2.00	21188	2320	759	17.6
	Nanguneri (Part)	3379	2.00	3660	401	760	3.0
	Total	**102218**		**110731**	**12125**		**90.9**

Table E Generation of manure in Town Panchayat

The solid waste is assumed as 0.3 Kg/capita/day (Based on the study report "Modelling of GW pollution due to solid waste dumping at Perungudi" by Centre for Environmental Studies, Anna University, Chennai)

Sub basin	Town Panchayat	Population as on 2001	Growth rate in %	Estimated population in 2005	Solid waste generated in tonnes per year	Manure generated in tonnes per year	Cost per Tonne in Rs	Revenue from manure in lakhs per year
Hanumanadhi	Thiruparappu	21736	2.00	23546	2578	928	500	4.6
	Alagappapuram	8121	2.00	8797	963	347	500	1.7
	Ganapathipuram	13711	2.00	14853	1626	586	501	2.9
	Panagudi	25501	2.00	27625	3025	1089	502	5.5
Nambiyar	Kumarapuram	13938	2.00	15099	1653	595	508	3.0
	Aralvoimozhi	19211	2.00	20811	2279	820	500	4.1
	Eruvadi	14755	2.00	15984	1750	630	500	3.2
	Thirukarungudi	8875	2.00	9614	1053	379	500	1.9
	Vadakkuvalliyur	24023	2.00	26024	2850	1026	500	5.1
	Nanguneri (Part)	3379	2.00	3660	401	144	501	0.7
Karamaniyar	Alwarthirunagari	8883	2.00	9623	1054	379	502	1.9
	Udangudi	19390	2.00	21005	2300	828	503	4.2
	Sathankulam	14206	2.00	15389	1685	607	504	3.1
	Kalakkad	27090	2.00	29346	3213	1157	505	5.8
	Thisaiyanvilai	19559	2.00	21188	2320	835	506	4.2
	Nanguneri (Part)	3379	2.00	3660	401	144	507	0.7
	Total	**242378**		**262565**		**10350**		**52.0**

'Table F Wasteland details (area in sq.km)

THIRUNELVELI DISTRICT

Sl.No.	Name of the Block	1	2	4	6	8	9	10	11	12	Total
1	Nanguneri	0.02	5.03	4.97	-	0.00	0.01	0.02	0.12	-	10.17
2	Kalakkad	0.02	1.25	0.15	1.56	-	-	0.00	0.13	0.35	3.47
3	Radhapuram	0.34	67.59	47.33	-	-	34.30	0.29	0.11	-	149.95
4	Valliyur	0.64	59.45	58.31	9.22	-	4.54	0.45	1.98	0.09	134.68

THOOTHUKUDI DISTRICT

Sl.No.	Name of the Block	2	3	4	6	8	9	10	11	Total
1	Sathankulam	13.09	-	12.12	-	-	30.00	-	0.65	55.85
2	Alwarthirunagari	0.08	-	0.24	-	0.02	0.02	-	-	0.36
3	Udankudi	0.34	0.01	0.32	1.44	-	0.11	-	0.00	2.23
4	Thiruchendur	0.00	-	0.01	-	-	0.01	0.00	-	0.02

KANNIYAKUMARI DISTRICT

Sl.No.	Name of the Block	1	2	6	8	9	11	12	Total
1	Agastheeswaram	0.00	0.03	0.03	0.02	0.01	0.00	0.00	0.10
2	Thovala	0.03	1.49	2.87	-	-	-	0.43	4.81

Fig: A SOLID WASTE GENERATION BY SOME TECHNOLOGICAL PROCESSES

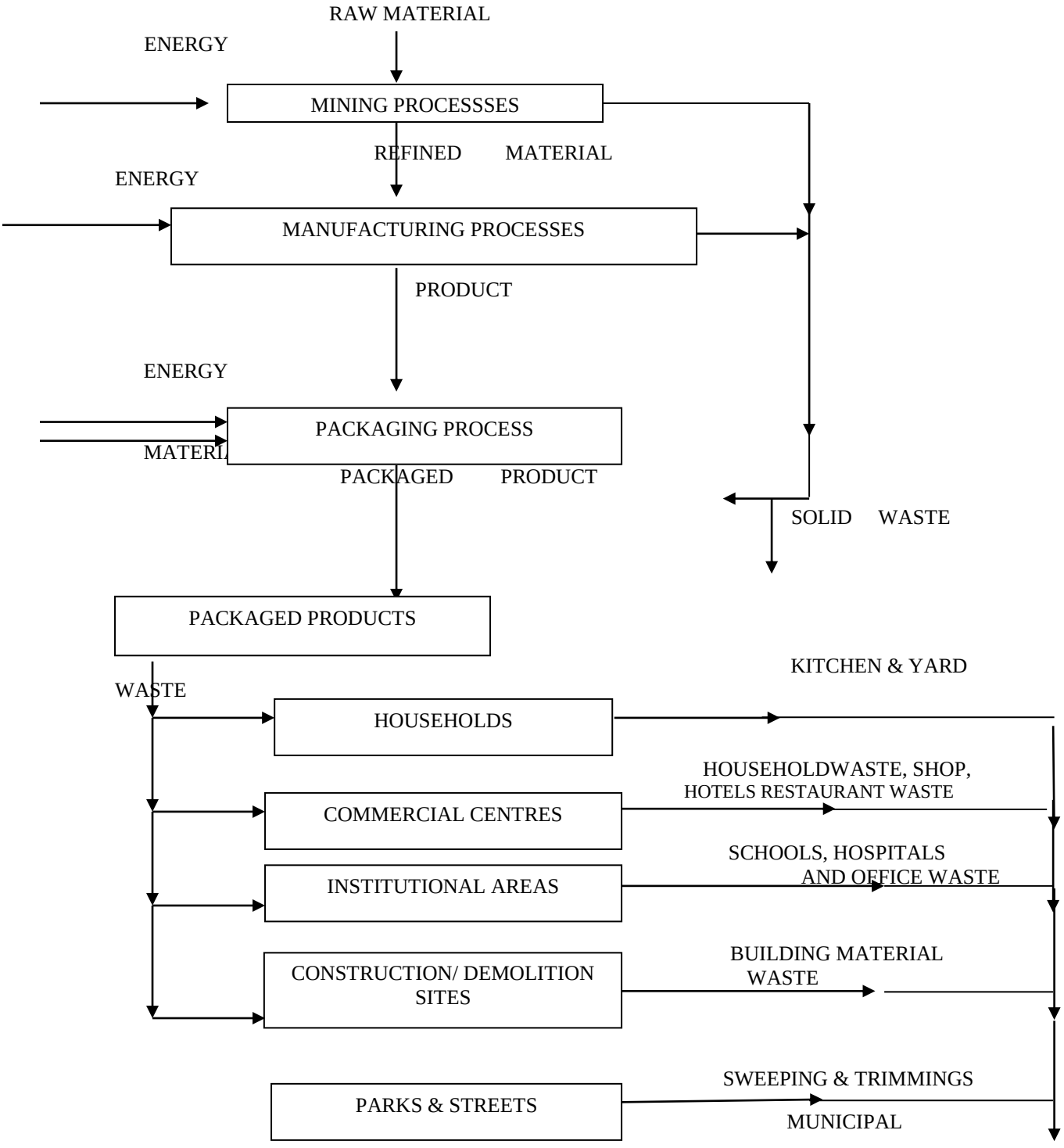
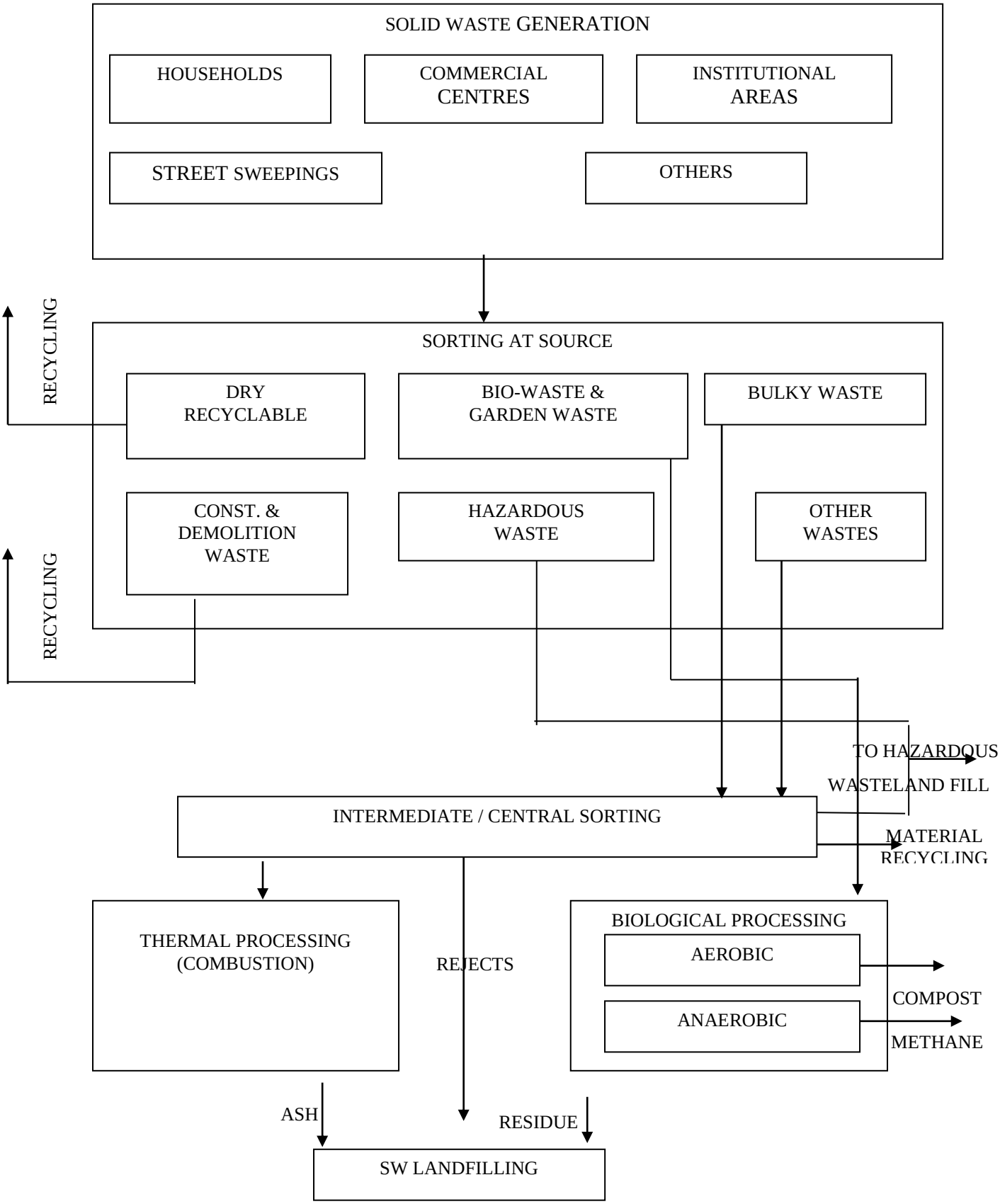


Fig: B DETAILED STRUCTURE OF A MUNICIPAL SOLID ASTEMANAGEMENT SYSTEM



CHAPTER – 8

SIMILATION STUDIES

FOR WATER PLANNING

CHAPTER - 8

SIMULATION STUDIES FOR WATER PLANNING

8.1 Introduction

The River BAsin SImulation Model for Tamil Nadu (RBASIMTN) is used for simulation of Nambiyar basin.

The model presents the water resources operation and development activities at the sub basin level. It considers the water demand for various sectors, the availability of groundwater and surface water resources and evaluates the probable water balance, under different conditions.

In this basin, the water is required for domestic, irrigation, livestock and industries. The water sources are: river flows, reservoirs, tanks and groundwater.

8.2 Principles of the Monthly Simulation Model

8.2.1 Introduction

The RBASIMTN is a general purpose model based on monthly time step to simulate the water distribution from the available water sources to the consumers and to do a statistical balance of the water resources in a river basin. The simulation is carried out on long term hydrological series and on socio economic development plans. Its purpose is to analyse the various water resources development and management scenarios in a river basin.

8.2.2 General Characteristics of the Model

The model analyses the water balance between demand and resources (surface and groundwater) of a river basin, taking into account all existing and future water sources and projects, and the water demand for different types of consumers.

The simulation is carried out at monthly time steps for 4 different Planning Stages (PS) and for hydrologic series up to 35 years. In the case of Nambiyar river basin, the four PS are 2006, 2010, 2020 and 2045 and the hydrologic series is for 34 year period. Most of the limiting dimensions can be modified if necessary. However, increasing some limits causes more outputs, larger formats and a need for more input data.

The model can be used to simulate river basin as a whole. However, to account for the spatial variations in water demands and availability, it is recommended to divide the river basin into smaller units called Balance Units. A natural division may be sub basin rather than administrative divisions (as they may change in time). Apart from taking into account surface and groundwater resources, the model is also capable of simulating the use of recycled water.

8.2.3 Water Sources

The model considers both surface water and groundwater sources.

- Surface water sources may be controlled (C) or uncontrolled (U). Controlled surface water sources are reservoirs and tanks, and the meaning of controlled is that the water can be stored and used in a later time period. On the other hand, the uncontrolled sources are direct diversions from a river (with or without a pumping station). Water from the uncontrolled sources may be used only when there is a flow in the riverbed.
- Groundwater sources use the water stored in the aquifer by natural replenishment through direct rainfall and by seepage from irrigated areas, canals and reservoirs. For different reasons not all the water stored in the aquifer may be used. For this reason, a minimum operational level will be prescribed for the aquifer and the groundwater above this level is considered as utilisable groundwater or the groundwater source (G). In some cases, in very dry periods, it may happen that very important consumers (e.g. domestic consumers) have no other alternative except this source and the groundwater level reached the minimum operation level. For this reason, the model allows defining as an additional logical source called in this model “deep water” (D) which physically is the same source but below the minimum operation level down to the physical bottom of the aquifer.

An additional source of water may be, the recycled water i.e. treated return water from domestic sewage / industrial effluents. All the return flows may be directed to a surface water source or recharged after treatment into the aquifer and represent an inflow to the recipient source.

As surface water yield series, the model uses monthly flows generated (measured) data from the Monthly Runoff Simulation (MRS) Model. This balance unit flow data are divided by the model into uncontrolled sources and controlled sources (tanks and reservoirs) proportionally to their free and intercepted catchments areas.

The usual data available for groundwater natural replenishment is the Normalised Natural Replenishment (NNR). This is a multi-annual average (Chapter 5). Monthly recharge series for groundwater sources are worked out by distributing annual normalised natural replenishment on the monthly pattern of groundwater recharge series (.RCH files) resulting from MRS model**.**

Yields of recycled water sources are automatically computed by the model based on the percentage of return flows from domestic/industrial consumers.

The model enables spills or surpluses from one source to be directed to a downstream source. This is done by indicating in the input data of each source, the code of the other source to which the spills or surpluses are to be directed.

8.2.4 Reservoirs

Since, there are more number of reservoirs in a river basin, it is convenient for simulation purposes to cluster these reservoirs in each balance unit and treat them as a single controlled equivalent surface water source. Reservoir data may be entered separately for each reservoir and the model computes the live storage and operational parameters for the source by adding up relevant parameters of individual reservoir.

The following data have to be entered for each controlled surface water source:

- Name and code
- Number of reservoirs in the balance unit
- Spill destination for controlled as well as uncontrolled surface water
- Related MRS .SIM file
- Percentage of live storage at start of simulation
- Groundwater source to which percolation losses are to be directed

The following data have to be entered for individual reservoirs in the source:

- Name of the reservoir
- Free catchment area, sq. km.
- Dead storage capacity, Mcum
- Gross storage at Full Reservoir Level (FRL), Mcum
- Water surface area at FRL, ha
- Monthly conveyance capacity, Mcum
- Year of commissioning

With the addition of new reservoirs in a balance unit in future Planning Stages (for example in 2010, 2020 or 2045) according to the specified year of commissioning, the added intercepted area may result in increase of corresponding controlled surface water availability and decrease of uncontrolled surface water availability, which is automatically taken care of by the model.

The model is also capable of taking into account reduction in storage capacity of reservoirs due to sedimentation. For this purpose, average annual sedimentation rate (cum/sq. km) for the basin and the percentage, indicating fraction of sedimentation trapped in live storages has to be given as input to the model.

8.2.5 Aquifers

Since groundwater data are available for different blocks in a river basin, it is convenient for simulation purposes to cluster these in each balance unit and treat them as a single groundwater source (aquifer). Furthermore, in each balance unit, the aquifer is divided into two. One is the general-purpose groundwater source and the other part represents the industrial user. In areas with highly polluted groundwater, the polluted part of the aquifer is eliminated from the potential source.

The following data have to be entered for each groundwater source in each balance unit:

- Name and code
- Spill destination
- Area of the aquifer, sq. km.
- Normalised Natural Replenishment (NNR - corrected for Simulation), Mcum
- Related MRS .RCH file for the mode of distribution of NNR
- Initial depth of water below ground, m
- Maximum depth of water below ground, m
- Operation threshold water depth (policy level) below ground, m
- Minimum physical depth of water below ground, m
- Monthly pumping capacity, Mcum
- Specific yield
- Regulation factor (between 0.0 and 1.0), to facilitate multi-annual regulation of surface and groundwater resources in the basin

Since, the above data may change from one Planning Stage to another, the same has to be specified separately for each Planning Stage.

8.2.6 Consumers

(i) General

The program can handle upto seven consumer types: Domestic, Irrigation, Industrial, Livestock, Environment, Artificial Recharge, Export and other. The reason for consumer type "Other" is to cover all kind of other types of users not specifically named (for example: Power Stations). Each Balance Unit can have any number of consumers of a particular type. Demand data generally differ from one consumer type to the other, although different consumer types may call for similar data, as shown below.

Water to each consumer can be supplied from one or more sources. The model has the facility to specify a maximum of four source preferences.

(ii) Consumer Type: Irrigation

- Label: IRRIG
- Number of consumers

  For each consumer

- Name
- Balance unit
- Supply priority
- Irrigation Demand Zone (IDZ) number
- Area (entire or part of IDZ)
- Losses (conveyance efficiencies, off/on farm percolation losses in %)
- Source preferences (in order of preference)
- Destination of return flows (i.e. groundwater source code to which the return flows are to be directed)

Different types of losses may be adopted depending upon type of conveyance system (pipe, lined or unlined canal, etc) and type of supply source (surface/ground water).

Command area in each of the Balance Unit can be related to one/more Irrigation Demand Zone (IDZ), as defined for the purpose of irrigation demand projections. Therefore, a separate consumer will have to be created for each IDZ in a Balance Unit.

The monthly patterns of utilisation of water for irrigation are input data based on cropping pattern, soil and climatic conditions.

(iii) Consumer Type: Domestic

- Label: DOME
- Number of consumers

  For each consumer:
- Name
- Balance unit
- Supply priority
- Annual demand, Mcum
- Source preferences (in order of preference)
- Percentage of distribution losses
- Percentage of reclaimed flow
- Destination of distribution losses (ground water source code)

- Destination of reclaimed flows (i.e. code of water source to which the return flows are to be directed)
- Monthly distribution of annual demand, %

(iv) Consumer Types: Industrial, Livestock and other

- Label: INDU/LIVE/OTHE
- Number of consumers

  For each consumer:

- Name
- Balance unit
- Supply priority
- Annual demand, Mcum
- Source preferences (in order of preference)
- Percentage of reclaimed flow
- Destination of reclaimed flows (i.e. code of water source to which the return flows are to be directed)
- Monthly distribution of annual demand, %

(v) Consumer Type: Artificial Groundwater Recharge

This is treated as a consumer since water is utilised from a surface water source.

- Label: RECH
- Number of recharge projects

  For each recharge project:

- Name
- Supply priority
- Annual amount of water for recharge, Mcum
- Recharge efficiency (%)
- Surface water sources (in order of preference)
- Destination of recharged water, (i.e. code of groundwater source to which the recharge is to be directed)
- Maximum recharge, Mcum/month

(vi) Consumer Type: Export

- Label: EXPO
- Number of export consumers

  For each consumer:

- Name
- Supply priority
- Annual amount of water to be exported, Mcum
- Water source preferences (in order of preference)
- Monthly distribution of the annual export as %

8.2.7 Inputs and Outputs

A detailed description of inputs and outputs of the monthly model, their formats and description are given in the User's Manual: "River Basin Simulation Model for Tamil Nadu (RBASIMTN). The complete input file for the Nambiyar basin is given in Appendix 8.1 (VOL - II) for a Basic Scenario. The outputs for the same scenario are also given in Appendix 8.1 (VOL - II).

8.2.8 Executive Summaries of the monthly Model

The results of the monthly model are summarized in executive summaries that are presented in the next sections. These summaries show annual total for the planning stages (2006, 2010, 2020, 2045) and for the four climatic states (drought (90%), normal (75%), medium (50%) and wet (25%)) in Table D or monthly data for a selected planning stage and climatic state (Table E). These executive summaries are for the entire basin but they can also be taken for each subbasin.

The results reported in these executive summaries are grouped as detailed below:

(i)	Gross Water Supply	:	Domestic, Industrial, Livestock, Irrigation.
(ii)	Gross Water Demand	:	Domestic, Industrial, Livestock, Irrigation.
(iii)	Unmet Demand	:	Domestic, Industrial, Livestock, Irrigation. (Which is the difference between (i) and (ii))
(iv)	Water Sources Potential	:	Surface water (virgin flows), Groundwater (including both Natural replenishment and return flows/seepage's).

(v)	Water Sources used	:	Groundwater, Tanks and Reservoirs, other surface water (The difference between (v) and (i) are conveyance losses).
(vi)	Unused Water	:	Groundwater Spills – (evaporation) and buildup – (increase of water in storage), Surface water surpluses-flow to the sea.
(vii)	Over exploitation	:	Groundwater depletion (reduction of water in storage), Net Groundwater overexploitation (negative when buildup) in each climatic state and average overexploitation over all climatic states.

8.2.9 Sensitivity Analysis Report

For comparing different planning scenarios, a report is presented with results of different simulations (Section 8.5.4).

For a selected planning stage and climatic state, the following results are compared among scenarios:

(i) Gross Water Supply

(ii) Gross Water Demand

(iii) Unmet Demands

(iv) Water Resources Used

(v) Unused Water and Overexploitation of Groundwater

8.3 Monthly Simulation Model Inputs

A detailed RBASIMTN file is given in Appendix 8.1 (VOL – II). A report on input data, presents the input files in the format specified in RBASIMTN users manual.

8.3.1 Water Demands

The water demand by sectors for each subbasin is presented in Table B for the four planning stages. The monthly value for the year 2006 and 75% dependability is shown in Table C. The monthly distribution of all sectors over the year is assumed to be uniform except for irrigation. The monthly distribution of irrigation is depending on the cropping pattern and is discussed in Chapter 6. The input data for simulation are gross water demands. On farm water losses have to be added to the net crop water requirements.

8.3.2 Water Resources

The water resources potential by sub basins are reported in Table B. The monthly values for 75% dependability are shown in Table C.

8.3.3 Efficiencies and Losses

The following losses are considered in the model. Their parameters are given as inputs and the results are reported in the output files.

(i) On farm irrigation losses as well as water losses in urban distribution systems are included in the gross water requirements. Parts of these losses are percolation losses, which are carried over to groundwater balances. The percentage of percolation losses out of the gross water requirements are given as inputs and are assumed to be 25% in the reference scenario.

(ii) Conveyance losses are applied to tank and reservoir releases and are defined by the conveyance efficiency, which is assumed as 53% in the reference scenario.

(iii) Tank loss parameters are given as part of the tank data. Evaporation losses are calculated in the simulation based on the varying water surface and climatological inputs. Seepage losses are given as input and assumed as 35mm/month.

8.4 Monthly Model Validation and Calibration

The RBASIMTN is a complex model includes many variables. Parts of the components of the model are usually modified to fit the conditions of the basin under study. But during the test run itself, the conditions of the Nambiyar basin have been satisfied. Hence, calibration has not been required.

8.5 Monthly Simulation Model Results

8.5.1 Outputs

After finalising the phase of calibration, a complete run off forecasts was performed and analysed. The annual executive summary of the total basin is shown in Table D and for subbasins in Appendix 8.1 (VOL – II). An example of one subbasin (Manimukthanadhi) is shown in Table E. The main results of Table C are also represented in Fig. A, Fig. B-1 & B-2. The monthly distribution of the total for the year

2006 and 75% dependability is shown in Table F. Monthly distribution for all dependability is shown in Appendix 8.1 (VOL – II).

8.5.2 General Results for the basin

The monthly River Basin Simulation Model is run for all the combination of the following.

Planning Stages	Climatic States
2006	90%
2010	75%
2020	50%
2045	25%

The results of the basin scenario are summarised in Table D and in Fig. A, Fig. B-1 & B-2. The irrigation water demand is estimated as constant, for all the planning periods, but it is varying with climatic state, the livestock water demand is constant, where as the water requirements for domestic and industries are increasing with time.

The gross water demand range at present (between wet and dry year) is between 507 Mcum and 546 Mcum. In 2045, it is expected to increase to 594 Mcum and 633Mcum. Unmet demand in 2006 ranges between 206 Mcum and 294 Mcum. In 2045, it is expected to increase, between 229 Mcum and 315 Mcum.

At present, there is overexploitation of , 18 Mcum at 90% dependability. In 2045 there will be overexploitation of 3 Mcum at 75% and 29Mcum at 90% dependability. Unused water is expected in all dependability in all the planning periods.

At present (2006) the unmet demand (75% dependability) for

Irrigation - 254 Mcum (54%)

In 2045, the unmet demand (75% dependability) will be

Irrigation - 261 Mcum (55%)

8.5.3 Detailed Results by subbasins

Executive summaries by sub basins are given in Appendix 8.1 (VOL – II). An example is shown in Table E. Detailed monthly results of the River Basin Simulation monthly module by sub basins and sectors for the year 2006 and climatic state 75% dependability for the Basic Scenario are shown in Appendix 8.1 (VOL – II). Table A summarizes unmet demand data by sub basins also for the year 2006 & 2020 for 75% dependability.

For analysing the results, the water balance in each subbasin for the planning period 2006 with 75% dependability is discussed as follows:

8.5.3.1 Hanumanadhi subbasin

There will be unmet demand of 16 Mcum (17%) for irrigation.and 1Mcm for livestock The water requirement for domestic, and industries will be met.

8.5.3.2 Karumeniyar subbasin

The water requirement for irrigation 169Mcm and livestock 3Mcm all the sectors will be met.

8.5.3.3 Nambiyar subbasin

There will be unmet demand of 111 Mcum (52%) for irrigation and . The water requirement for domestic livestock and industries will be met.

WATER BALANCING

Water Potential, Demand and Deficit (Both long & Short Term)

Sector	2006	2010	2020	2045
Total Gross Water Potential in Mcum	400	400	400	191
Total Water Supply in Mcum	268	273	290	249
Total Water Demand in Mcum	533	540	559	620
Total water deficit in Mcum	254	256	258	277

8.5.4 Monthly Simulation Model - Sensitivity Analysis

After the reference scenario, which will be used for the mainstream of planning, sensitivity analysis has been carried out to assess the impacts of the following possible changes:

- Increase of Tanks capacity, both storage volume and release capacity
- Decrease the potential of groundwater resources (due to pollution)
- Increase pumping capacity in groundwater extraction
- Decrease of siltation in Tanks and reservoirs
- Increase and decrease of on and off farm irrigation efficiency
- Decrease of future irrigated area
- Increased domestic water requirements

The list of scenarios is shown in the Table below

Sensitivity Analysis Scenarios

No.	Acronym	Description
1	Reference	Reference Scenario
2	Double tank	Tank volumes multiply by 2 ie., 2 fillings
3	Groundwater quality	Decrease the Area of polluted groundwater sources
4	Increase pumping capacity	Increased pumping capacity of ground water by 100%
5	No Silt	Siltation factor reduced to 0
6	On-farm Efficiency	Increase on-farm irrigation efficiency from 50% to 75%
7	Off-farm Efficiency	Increase off-farm irrigation efficiency from 53% to 80%
8	On and Off farm efficiency	Increase on-farm irrigation efficiency from 50% to 75% & off farm 53% to 80%
9	Decrease in Irrigation	Increase future irrigated area according to agricultural plan
10	Increase in Domestic	Increase Domestic water requirement as High variant

A comparative summary of results is shown in Table below and also in Table G. The details are furnished in the Appendix 8.1 (VOL – II).

The results of the Nambiyar simulation sensitivity scenario show that the results are not much sensitive to the increase in tank capacity, release capacity and silt. The increase in irrigation efficiency reduces the unmet demand to a certain extent. Whereas, the results to the increase in domestic demand is sensitive in terms of unmet demand and overexploitation. The unmet demand is also highly sensitive to the decrease in groundwater potential.

Summary of Comparison of scenarios for the Year 2006 and 75% dependability

Sl. No	Scenario	Total Unmet Demand (Mcum)	Groundwater overexploitation
1.	Reference	254	0
2.	Double Tank	289	44
3.	Groundwater quality	262	71
4.	Pumping capacity	280	0
5.	No silt	280	0
6.	On-farm efficiency	212	0
7.	Off-farm efficiency	231	0
8.	On & Off farm efficiency	157	0
9.	Increase domestic	287	1

8.6 Conclusions

In 2006, at 75% dependability, there will be no unmet demand for the domestic industrial sectors. Nambiyar sub basin is deficient in meeting the water requirement for livestock and irrigation. Hanumanadhi sub basin is deficient in meeting the water requirements for irrigation and livstock. There will be unmet demand for , irrigation, i and livestock in Karumeniyar subbasin.

8.6.1 Conclusions by sub basins

All the sub basins are water deficit in 2006.

8.6.2 Conclusions by Water Demand Sectors

(i) Supply of Domestic Water Demands

In 2006, there will not be any problem in meeting the needs of domestic and industries water requirements anywhere in the basin.

(ii) Supply of Irrigation Water Demands

All the sub basins are deficient in meeting the water requirements for Irrigation.

(iii) Supply of Livestock Water Demands

There will not be any problem in meeting the needs of livestock water requirements, in Nabiyar sub basin.There will be marginal deficit in other sub basins

(iv) Supply of Industrial Water Demands

No sub basin is deficit in meeting the water requirements for industries.

8.6.3 Increasing the Tank Capacity

The capacity of the non-system tanks is to be increased in Nambiyar and subbasins to utilize the surface water potential to meet the irrigation demand.

Suggestions:

Nambiyar basin gets rainfall and run off mainly during the northeast monsoon and several tanks in the head, middle and especially tail reaches get partially filled, in this season. In this basin, Monsoon failure occurs frequently and surface water scarcity is more.

Table A - Nambiyar River Basin Monthly Simulation Model

Summary of Unmet Demand by Sub Basins at 75% Dependability

Sl. No	Subbasins	Sector	2006		2020	
			Qty (Mcum)	%	Qty (Mcum)	%
1	Nambiyar	Domestic	-	-	-	-
		Irrigation	111	52%	111	52%
		Livestock	-	-	-	-
		Industries	-	-	-	-
		Total	**111**	**48%**	**111**	**48%**
2	Kodumudiyar	Domestic	-	-	-	-
		Irrigation	-128	75%-	-128	75%-
		Livestock	-3	34%-	-3	33%-
		Industries	-	-	-17	56%-
		Total	131-	66%-	-147	65%-
3	Hanumanadhi	Domestic	-	-		
		Irrigation	17	18%	17	18%
		Livestock	-1	-32%	1-	32%-
		Industries				
		Total	**18**	**17%**	**18**	**17%**

TABLE-B

NAMBIYAR RIVER BASIN MONTHLY SIMULATION MODEL INPUTS -RUN1 REFERENCE SCENARIO

ANNULA BASIN SUMMARY, Mcum

YEAR:			2005			2010			2020				2045		
CLIMATIC STATE (DEPENDABILITY):			90%	75%	50%	90%	75%	50%	90%	75%	50%		90%	75%	50%
Gross Demand	Hanumanadhi	Domestic	6	6	6	7	7	7	8	8	8	8	12	12	12
		Industrial	9	9	9	11	11	11	18	18	18	18	35	35	35
		Livestock	3	3	3	3	3	3	3	3	3	3	3	3	3
		Irrigation	98	92	91	98	92	91	98	92	91	88	98	92	91
	Karamaniyar	Domestic	11	11	11	13	13	13	14	14	14	14	20	20	20
		Industrial	5	5	5	6	6	6	10	10	10	10	30	30	30
		Livestock	8	8	8	8	8	8	8	8	8	8	8	8	8
		Irrigation	173	169	166	173	169	166	173	169	166	163	173	169	166
	Nambiyar	Domestic	6	6	6	7	7	7	8	8	8	8	12	12	12
		Industrial	5	5	5	6	6	6	10	10	10	10	21	21	21
		Livestock	5	5	5	5	5	5	5	5	5	5	5	5	5
		Irrigation	217	214	199	217	214	199	217	214	199	197	217	214	199
	TOTAL	Domestic	24	24	24	26	26	26	30	30	30	30	44	44	44
		Industrial	19	19	19	23	23	23	38	38	38	38	85	85	85
		Livestock	16	16	16	16	16	16	16	16	16	16	16	16	16
		Irrigation	488	475	456	488	475	456	488	475	456	449	488	475	456
Natural Water Sources Potential	Hanumanadhi	Surface Water	27	55	73	27	55	73	27	55	73	126	27	55	73
		NNR - GR IND	63	30	25	63	30	25	63	30	25	53	63	30	25
		NNR - GR IRG	22	11	9	22	11	9	22	11	9	18	22	11	9
	Karamaniyar	Surface Water	60	113	150	60	113	150	60	113	150	212	60	113	150
		NNR - GR IND	75	36	45	75	36	45	75	36	45	47	75	36	45
		NNR - GR IRG	17	8	11	17	8	11	17	8	11	11	17	8	11
	Nambiyar	Surface Water	62	84	96	62	84	96	62	84	96	149	62	84	96
		NNR - GR IND	21	17	11	21	17	11	21	17	11	19	21	17	11
		NNR - GR IRG	18	15	9	18	15	9	18	15	9	16	18	15	9
	TOTAL	Surface Water	149	251	319	149	251	319	149	251	319	488	149	251	319
		NNR - GR IND	159	84	81	159	84	81	159	84	81	119	159	84	81
		NNR - GR IRG	57	34	28	57	34	28	57	34	28	46	57	34	28

TABLE - C

NAMBIYAR RIVER BASIN MONTHLY SIMULATION MODEL EXECUTIVE SUMMARY -RUN1 REFERENCE SCENARIO

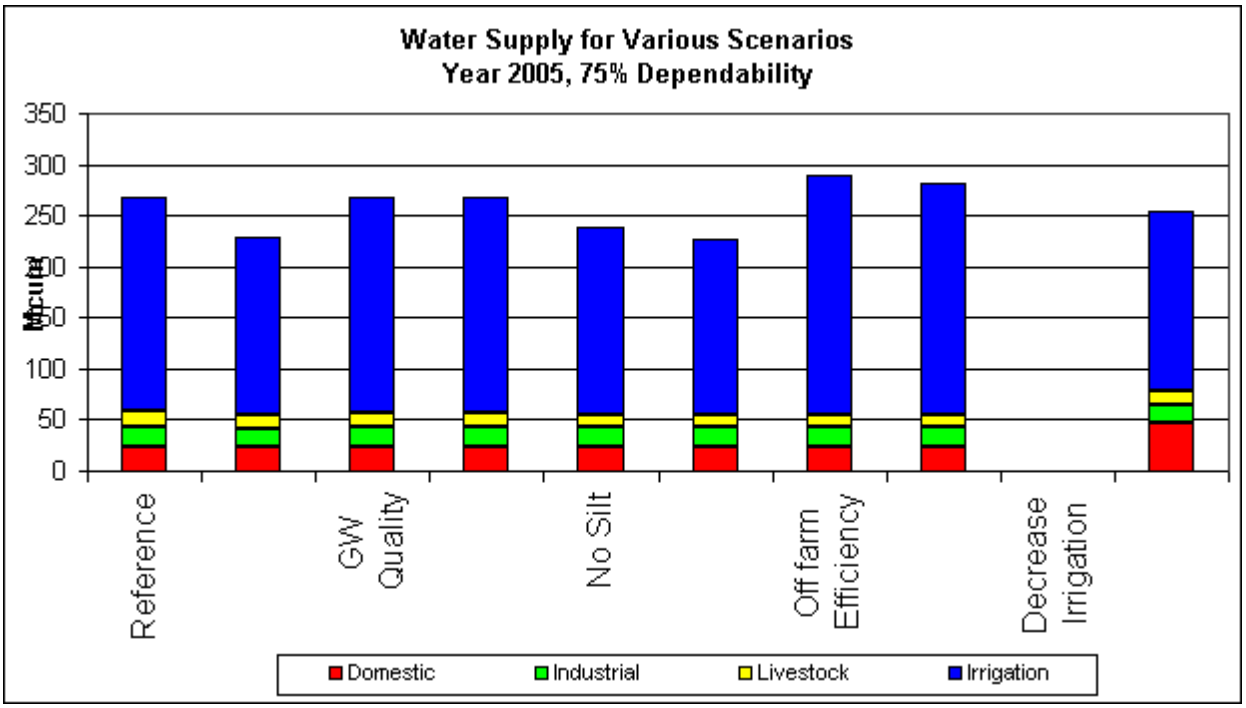
ANNUAL BASIN SUMMARY, Mcum

		YEAR:	2005				2010				2020				2045			
		CLIMATIC STATE (DEPENDABILITY):	90%	75%	50%	25%	90%	75%	50%	25%	90%	75%	50%	25%	90%	75%	50%	25%
WATER SUPPLY AND DEMAND	TOTAL GROSS SUPPLY MCM	Total	254	268	296	295	260	273	301	300	277	290	319	317	320	332	364	359
		Domestic	24	24	24	24	26	26	26	26	30	30	30	30	44	44	44	44
		Industrial	19	19	19	19	23	23	23	23	38	37	38	37	71	69	75	70
		Livestock	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16
		Power	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Irrigation Export	196 0	209 0	238 0	237 0	195 0	208 0	236 0	235 0	193 0	207 0	235 0	234 0	189 0	203 0	230 0	230 0
	TOTAL GROSS DEMAND MCM	Total	546	533	514	507	553	540	521	514	572	559	540	533	633	620	601	594
		Domestic	24	24	24	24	26	26	26	26	30	30	30	30	44	44	44	44
		Industrial	19	19	19	19	23	23	23	23	38	38	38	38	85	85	85	85
		Livestock	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16
		Power	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Irrigation Export	488 0	475 0	456 0	449 0	488 0	475 0	456 0	449 0	488 0	475 0	456 0	449 0	488 0	475 0	456 0	449 0
	UNMET DEMAND MCM	Total	294	254	221	206	296	256	222	207	297	258	223	209	315	277	239	229
		Domestic	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Industrial	0	0	0	0	0	0	0	0	0	1	0	1	14	17	10	15
		Livestock	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Power	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Irrigation Export	294 0	254 0	221 0	206 0	296 0	256 0	222 0	207 0	297 0	257 0	223 0	209 0	302 0	261 0	228 0	213 0
WATER RESOURCES	WATER SOURCES POTENTIAL MCM	Total	382	400	455	687	382	400	455	687	382	400	455	687	382	400	455	687
		Surface water	149	251	319	488	149	251	319	488	149	251	319	488	149	251	319	488
		Groundwater	176	115	107	154	176	115	107	154	176	115	107	154	176	115	107	154
		Groundwater - IND	57	34	28	46	57	34	28	46	57	34	28	46	57	34	28	46
	WATER SOURCES USE MCM	Total	305	339	364	370	310	345	369	376	327	362	387	393	370	403	433	435
		River	10	10	11	12	10	10	11	12	10	10	11	12	10	10	11	12
		Tanks & Reservoirs	159	227	215	235	159	227	215	235	159	226	215	235	159	226	215	236
		Groundwater - IRR	117	83	121	103	120	86	123	106	131	95	134	116	165	130	168	150
		Groundwater - IND	18	20	18	20	20	22	21	23	27	30	28	29	36	37	39	37
	UNUSED WATER SOURCES MCM	Total	60	12	0	49	39	7	0	49	37	1	0	50	27	2	0	52
		Groundwater - Buildup	22	1	0	49	22	1	0	49	22	1	0	50	27	2	0	52
		Groundwater - Spills	38	11	0	0	17	5	0	0	15	0	0	0	0	0	0	0
		Flow to sea	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	OVER EXPLOITATION MCM	Total	18	0	31	0	3	0	32	0	19	2	34	0	29	3	40	0
		Groundwater - Deplition	18	0	31	0	3	0	32	0	19	2	34	0	29	3	40	0
		Groundwater - IND	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Net Over-exploitation	-3	-1	31	-49	-19	-1	32	-49	-3	0	34	-50	3	2	40	-52
		Average Over-exploitation	-12				-13				-11				-8			

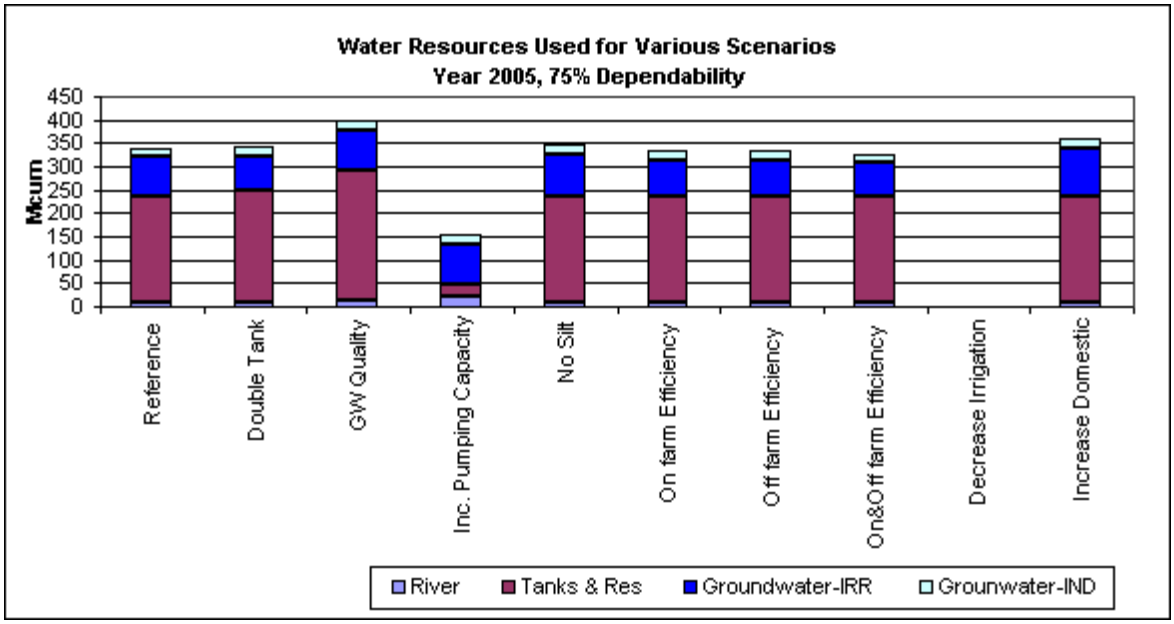
Table D : Nambiyar Results - Comparison of Scenarios

Summary for the Year 2005 and 75% Dependability

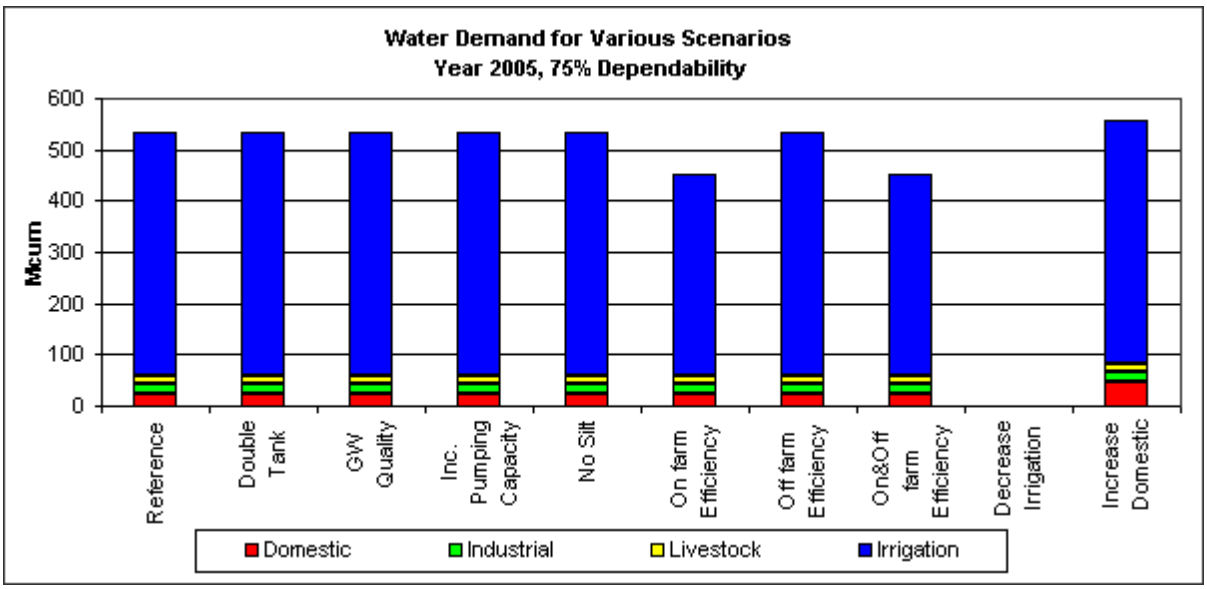
Scenario		Gross Supply			
No.	**Title**	**Domestic**	**Industrial**	**Livestock**	**Irrigation**
Scen1	Reference	24	19	16	209
Scen2	Double Tank	24	18	13	175
Scen3	GW Quality	24	19	14	211
Scen4	Inc. Pumping Capacity	24	19	14	211
Scen5	No Silt	24	19	13	184
Scen6	On farm Efficiency	24	19	13	172
Scen7	Off farm Efficiency	24	19	13	233
Scen8	On&Off farm Efficiency	24	19	13	227
Scen9	Decrease Irrigation	0	0	0	0
Scen10	Increase Domestic	47	18	13	177



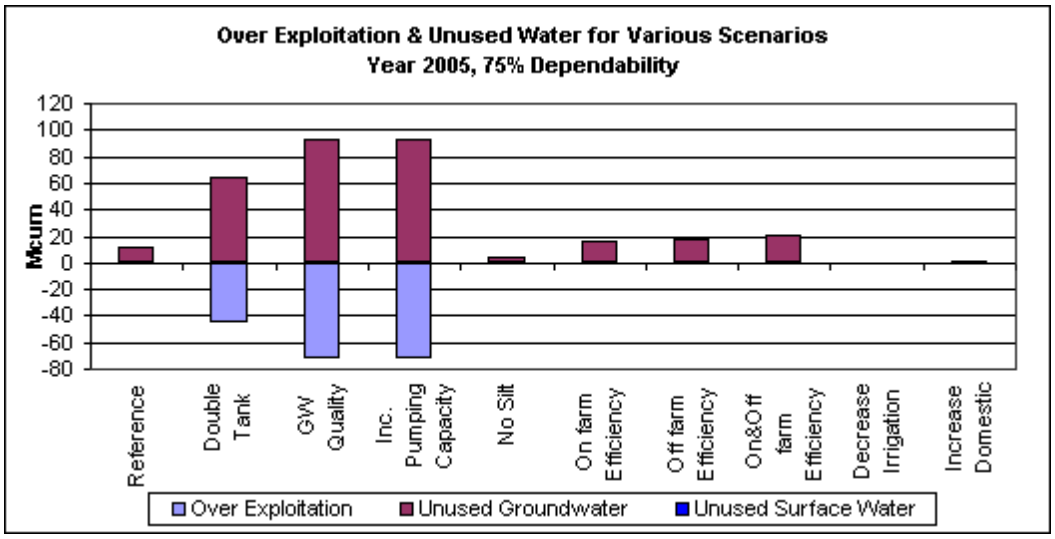
Scenario		Water Resources Used			
No.	Title	River	Tanks & Res	Groundwater-IRR	Grounwater-IND
Scen1	Reference	10	227	83	20
Scen2	Double Tank	10	239	73	19
Scen3	GW Quality	13	278	87	21
Scen4	Inc. Pumping Capacity	24	24	87	21
Scen5	No Silt	10	226	89	20
Scen6	On farm Efficiency	10	226	76	20
Scen7	Off farm Efficiency	10	225	79	20
Scen8	On&Off farm Efficiency	10	224	73	20
Scen9	Decrease Irrigation	0	0	0	0
Scen10	Increase Domestic	10	226	103	22



Scenario		Gross Demand			
No.	**Title**	**Domestic**	**Industrial**	**Livestock**	**Irrigation**
Scen1	Reference	24	19	16	475
Scen2	Double Tank	24	19	16	475
Scen3	GW Quality	24	19	16	475
Scen4	Inc. Pumping Capacity	24	19	16	475
Scen5	No Silt	24	19	16	475
Scen6	On farm Efficiency	24	19	16	393
Scen7	Off farm Efficiency	24	19	16	475
Scen8	On&Off farm Efficiency	24	19	16	393
Scen9	Decrease Irrigation	0	0	0	0
Scen10	Increase Domestic	47	19	16	475



Scenario		Unused Water Resources & OverExploitation		
No.	**Title**	**Over Exploitation**	**Unused Groundwater**	**Unused Surface Water**
Scen1	Reference	0	12	0
Scen2	Double Tank	-44	64	0
Scen3	GW Quality	-71	92	0
Scen4	Inc. Pumping Capacity	-71	92	0
Scen5	No Silt	0	5	0
Scen6	On farm Efficiency	0	16	0
Scen7	Off farm Efficiency	0	18	0
Scen8	On&Off farm Efficiency	0	21	0
Scen9	Decrease Irrigation	0	0	0
Scen10	Increase Domestic	-1	1	0



Scenario		Unmet Demand			
No.	**Title**	**Domestic**	**Industrial**	**Livestock**	**Irrigation**
Scen1	Reference	0	0	0	254
Scen2	Double Tank	0	1	4	289
Scen3	GW Quality	0	0	3	252
Scen4	Inc. Pumping Capacity	0	0	3	252
Scen5	No Silt	0	0	3	280
Scen6	On farm Efficiency	0	0	3	212
Scen7	Off farm Efficiency	0	0	3	231
Scen8	On&Off farm Efficiency	0	0	3	157
Scen9	Decrease Irrigation	0	0	0	0
Scen10	Increase Domestic	11	1	3	287

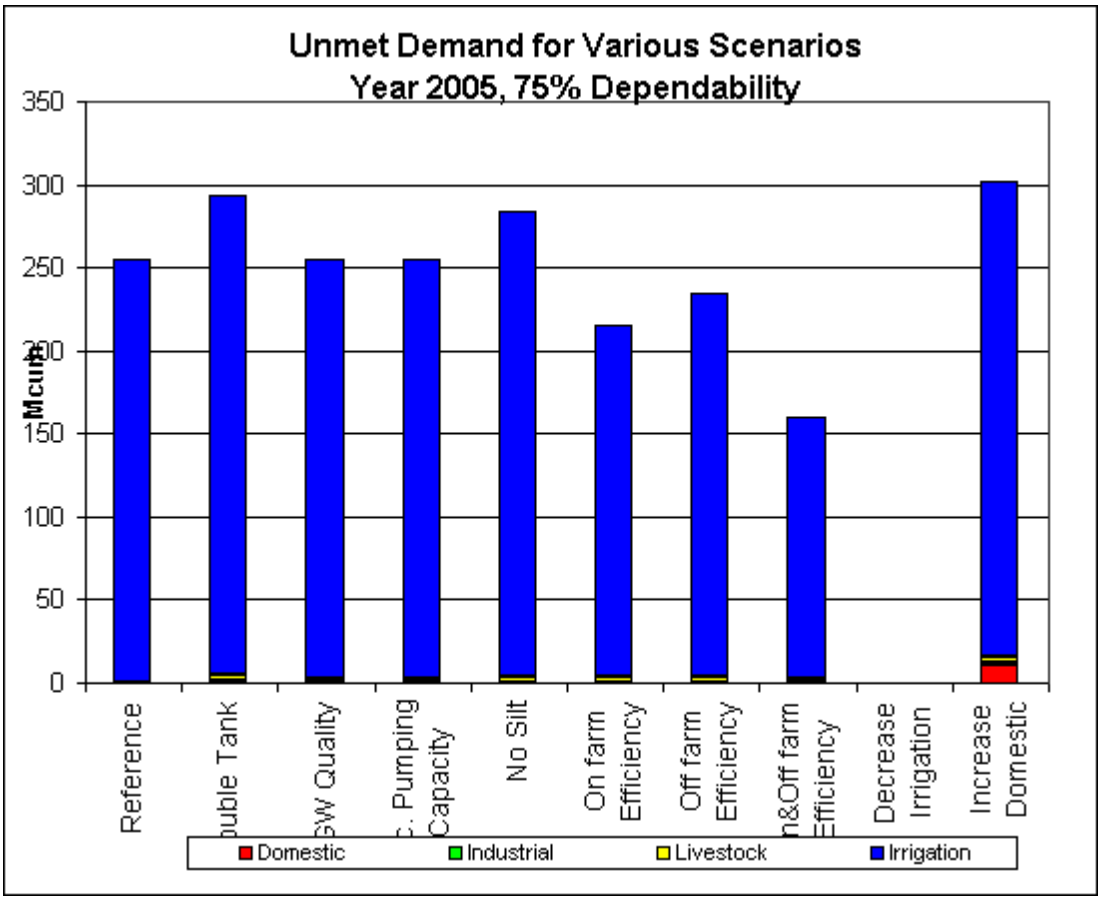
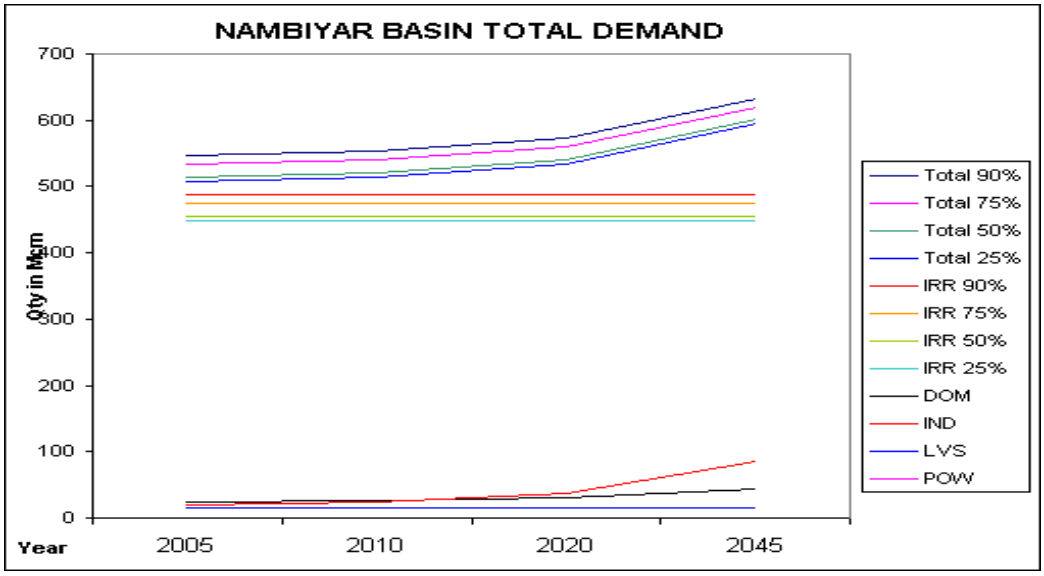
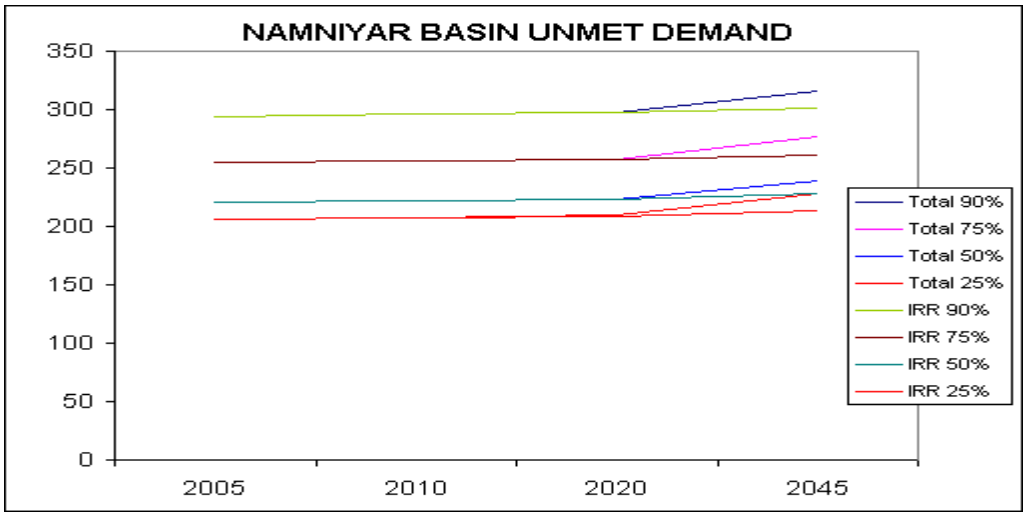
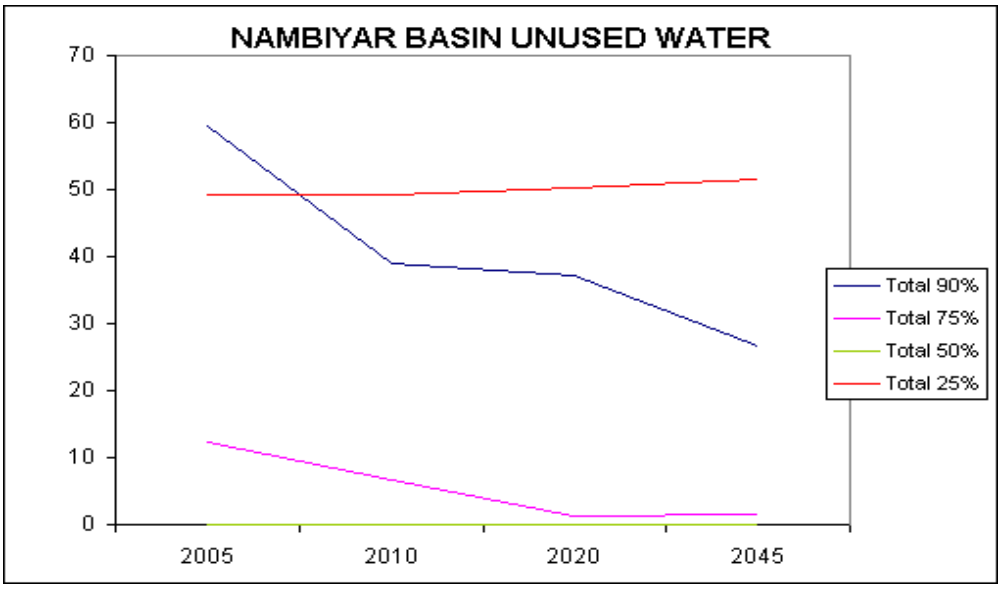
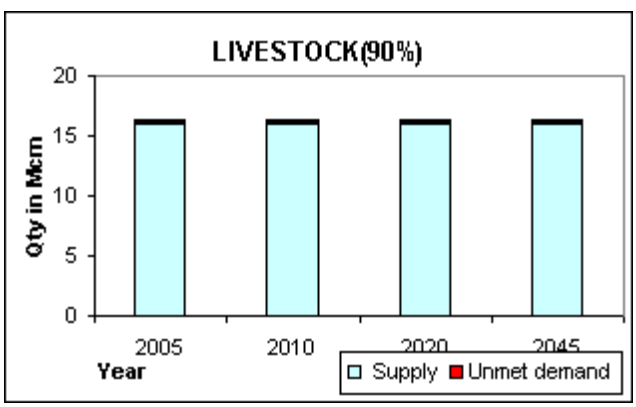


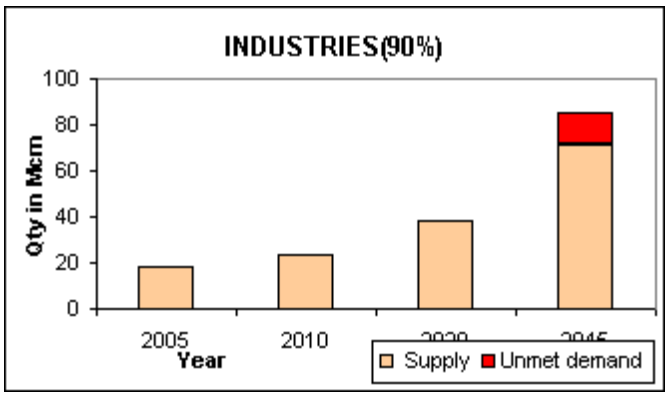
FIG A - UNMET DEMAND AND UNUSED WATER IN NAMBIYAR BASIN - MONTHLY

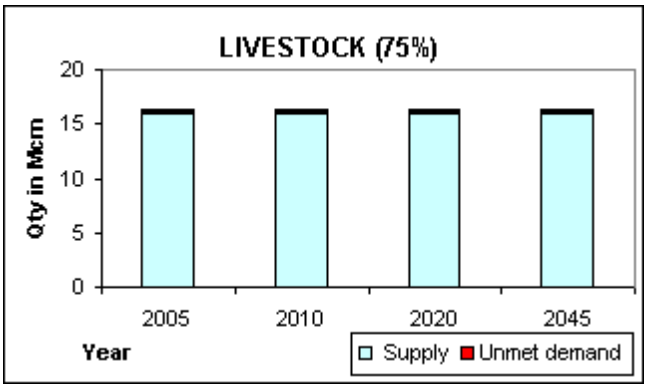


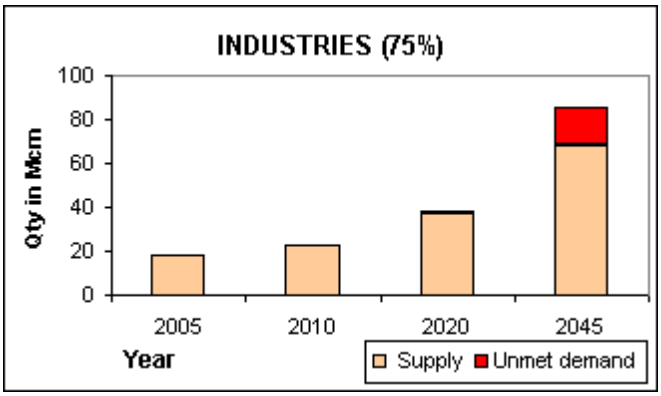


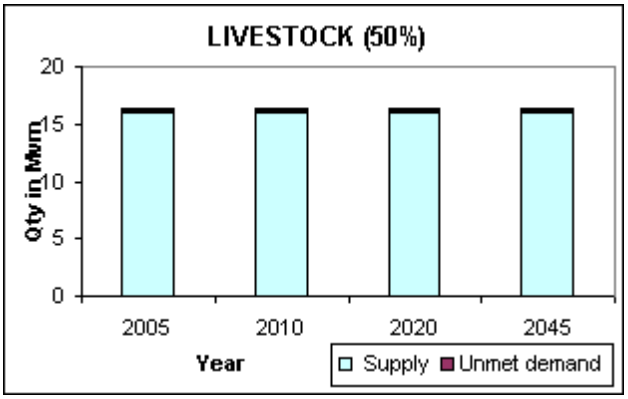


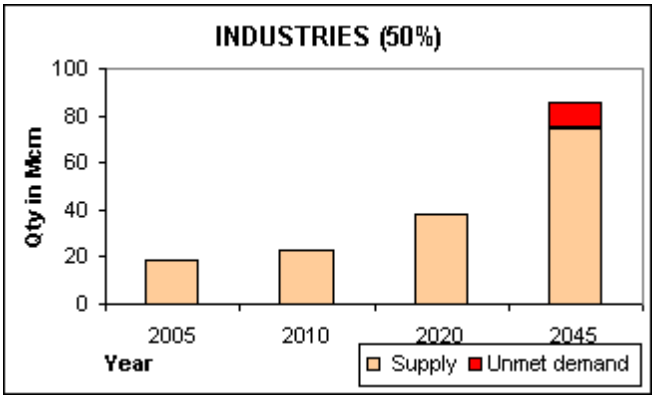


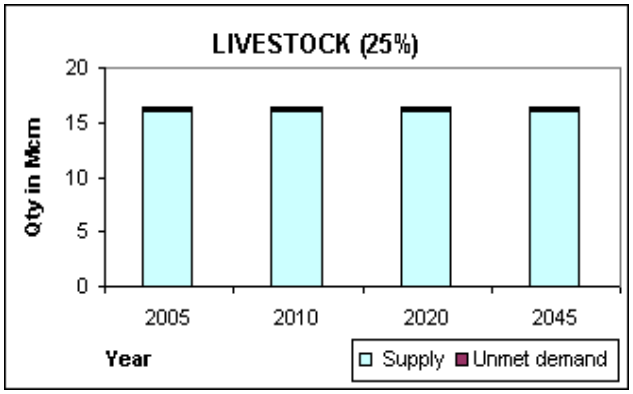












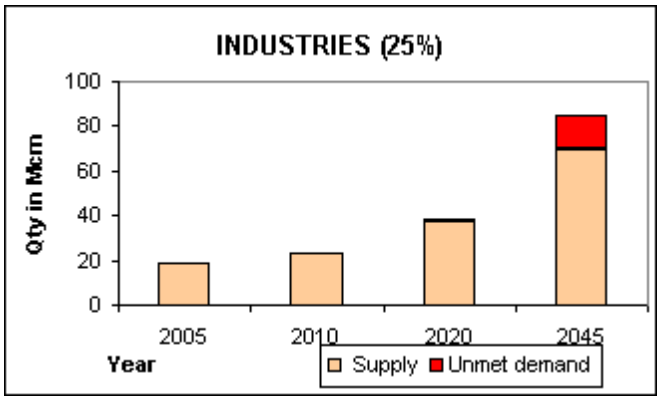
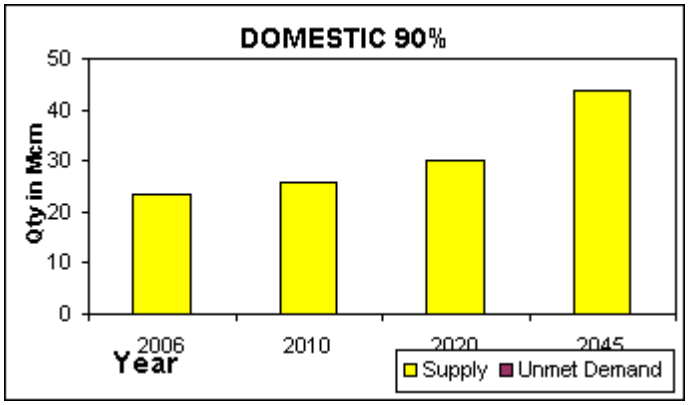
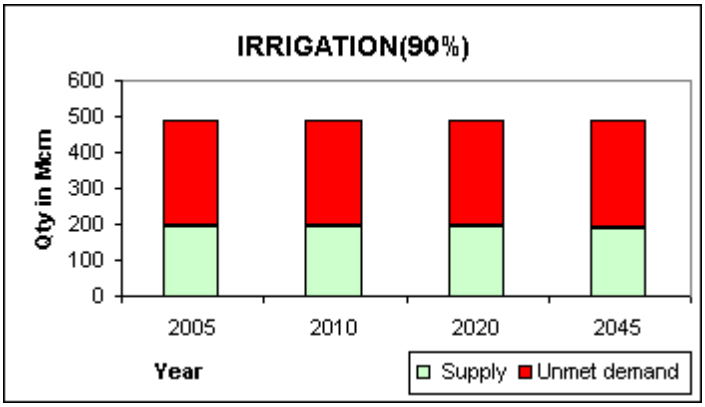
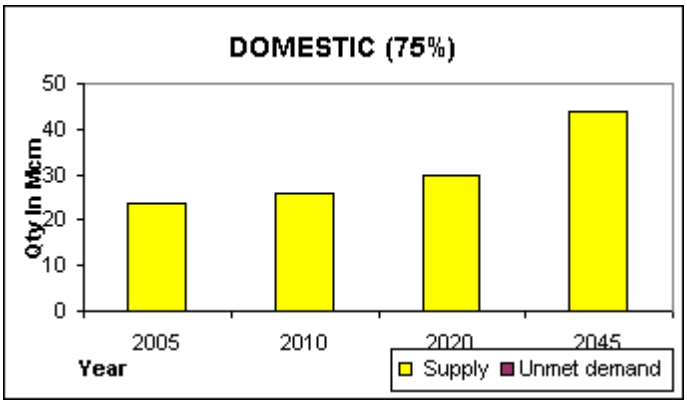
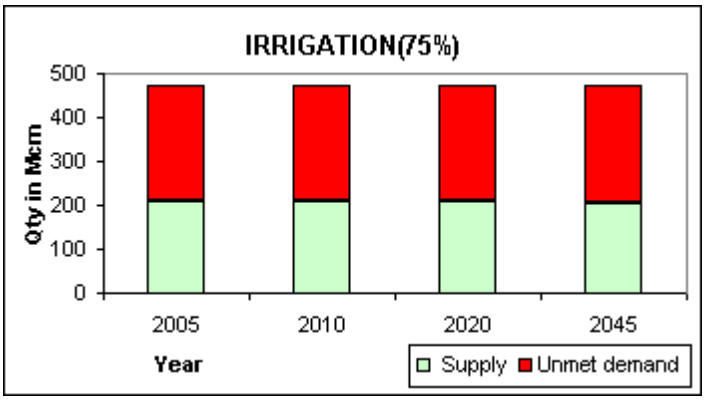


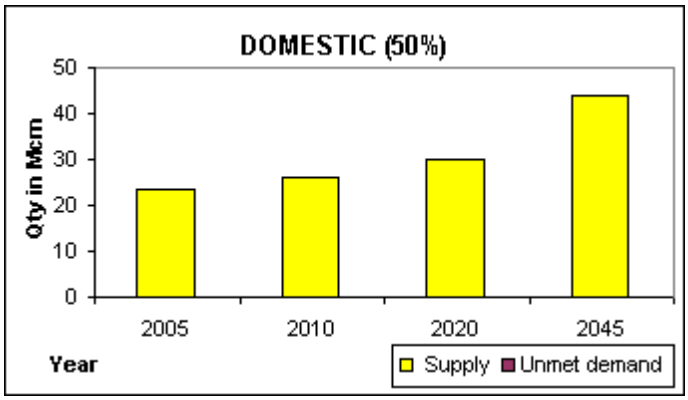
Fig. 8.5 SUMMARY OF RESULTS – MONTHLY RIBSIM MODEL – REFERENCE SCENARIO (CONT)

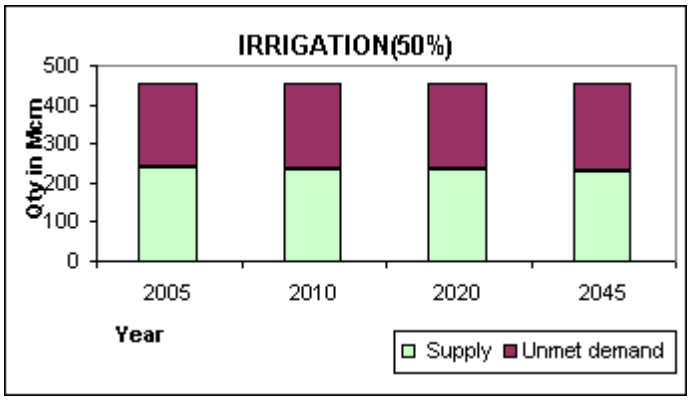

DOMESTIC 90%
Qty in Mcm
50
40
30
20
10
0
2006
2010
2020
2045
Year
Supply
Unmet Demand


IRRIGATION(90%)
Qty in Mcm
600
500
400
300
200
100
0
2005
2010
2020
2045
Year
Supply
Unmet demand


DOMESTIC (75%)
Qty in Mcm
50
40
30
20
10
0
2005
2010
2020
2045
Year
Supply
Unmet demand


IRRIGATION(75%)
Qty in Mcm
500
400
300
200
100
0
2005
2010
2020
2045
Year
Supply
Unmet demand


DOMESTIC (50%)
Qty in Mcm
50
40
30
20
10
0
2005
2010
2020
2045
Year
Supply
Unmet demand


IRRIGATION(50%)
Qty in Mcm
500
400
300
200
100
0
2005
2010
2020
2045
Year
Supply
Unmet demand

CHAPTER – 9

PRESENT INSTITUTIONAL SETUP AND ISSUES

CHAPTER–9

PRESENT INSTITUTIONAL SETUP AND ISSUES

9.1 BACKGROUND

9.1.1 Existing Institutions

The following Institutions of the Government of Tamil Nadu (GOTN) are vested with different categories of responsibilities in water resources management and supply:

Municipal Administration and Water Supply Department (MAWS) is responsible for:

- Drinking water supply to Chennai Metropolitan City & rural and urban areas of Tamil Nadu.
- Executing sewage disposal schemes for Tamil Nadu.

Tamil Nadu Water Supply and Drainage Board (TWAD)

- Meets the industrial water supply needs.
- Executes drinking water supply and sanitation schemes for Rural and Urban areas in Tamil Nadu other than Chennai city.

Chennai Metro Water Supply and Sewerage Board (CMWSSB)

- Executes drinking water supply and sewerage schemes for Chennai city.
- Responsible for meeting the drinking water needs of Chennai city.
- Maintains sewerage schemes for Chennai city.

Revenue Department through district administration is responsible for:

- Assessment and collection of water charges for Irrigation use.
- Acquiring land for execution of projects.
- According clearance for Irrigation Schemes to be sanctioned, Executing relief measures for flood and drought affected areas.

Water Resources Control and Review Council (WRCRC)

- Establishes priority norms for water use for different sectors.
- Formulates water management policy for State basin water development, control and management.
- Establishes principles, standards and procedures for allocation of water.

Public Works Department/Water Resources Organisation (WRO) is responsible for:

- Water Resources Management activities of Tamil Nadu.
- Execution of new projects.
- Responsible for Operation and Maintenance of existing Irrigation Systems
- Monitors groundwater quality.
- According groundwater clearance from Environmental, Institutional and Financial point of view.
- Surface water and hydrological data collection.
- Monitoring rainfall data in the basin, besides Indian Meteorological Department (IMD).

Agriculture Department/Directorate of Agriculture is responsible for:

- Providing facilities to farmers to carry out agricultural activities, including providing all inputs.

Agricultural Engineering Department (AED)

- Executes on farm development works.
- Water shed development works in the catchment areas.
- Adopts measures for preventing soil erosion.
- Hiring agricultural machineries (Implements for farmers).

Environment and Forest Department is responsible for:

- Protecting the forest cover of Tamil Nadu.
- According clearance for release of forest area for non-forest purposes.
- Protecting the flora and fauna in Tamil Nadu.
- Environmental protection including water quality.

Tamil Nadu Pollution Control Board (TNPCB) is responsible for:

- Monitoring pollution level of effluents released by the industries.
- Clearances accorded for starting new industries from pollution and environment point of view.

The links among these Institutions are shown in Fig A.

9.1.2 Activities in Basin Management

Table A shows the main activities in water resources management, water supply and the agencies responsible for these activities.

9.2 WATER RESOURCES CONTROL AND REVIEW COUNCIL (WRCRC)

Tamil Nadu Water Resources Consolidation Project (TNWRCP) program, stresses the need for the State Water Policy which emphasises management of water as a scarce resource and planning holistically for all uses of water and prioritising water allocation to maximise productivity. In order to create the institutional capability to handle water planning and allocation, a Water Resources Control and Review Council (WRCRC) chaired by the Honourable Chief Minister of Tamil Nadu has been constituted as per G.O.Ms.No. 1404 / PWD (X1) / dated 30.09.1993.

WRCRC shall establish allocation priority norms for water use for different Sectors, with provision for drinking water being given the highest priority. No schemes proposed for exploitation of water shall be excluded from the purview of WRCRC. The council will formulate Water Management Policy, monitor and implement in an effective manner. The council will examine the impact of extraction, utilisation and conservation of water on the other users. It will formulate water policies for the State basin water development, Control and management. It will establish principles, standards and procedures for allocation of water. It will serve as an advisory and coordinating body in relation to water matters. It will review and approve State and River basin master plans, prioritisation of different sectoral water needs. It will review and approve macro planning in consideration of the water needs of the different Sectors. Small schemes like drinking water supply schemes less than 10 Mgd need not be referred to WRCRC. It will review

and approve for publication, an annual assessment of adequacy of supplies of water necessary to meet the present and their projected State and basin water requirements.

Water Resources and related projects and programs shall be submitted by the agencies to WRCRC. The conflicts/problems during normal administration /maintaining irrigation systems shall not be referred to the Council. On going Central and State schemes like Command Area Development, executed by Agricultural Engineering Department (AED) Macro Irrigation Schemes, Watershed Development programs under River Valley Project shall be excluded from the purview of the Council.

With regard to the regulation of conflict arising from projects and agreements, the council would resolve it by public hearing or by any other suitable and practicable method.

9.3 MULTI-SECTORAL TECHNICAL WORKING GROUP

Institutional mechanisms need to be created or strengthened in particular at State grass roots and basin levels. To assist the WRCRC, the Government have constituted 5 Sub Committees known as Multi Sectoral Technical Working Groups. They are as follows:

1. Irrigation and Agricultural Sector
2. Urban, Rural, Domestic, Livestock, Water Supply & Sanitation Sector
3. Power and Industrial Sector
4. Ground Water Regulation Sector
5. Environmental Sector

To assist WRCRC a sub committee under the chairmanship of Chief Secretary, Government of Tamil Nadu for scrutinizing the proposals to be placed before WRCRC was constituted with 9 members as per G.O.Ms.No.9 / PWD Dated 06.01.2003.

9.4 WATER RESOURCES ORGNAISTION (WRO)

Water Resources Organisation (WRO) has been reorganised around functional specialisation and decentralisation along river basin lines. Planning, allocation and

management of water resources capabilities have been improved by activities at basin and State levels in a manner that assists political and administrative decision about overall resources occurrence and use including future regulatory aspects. The full range of water services provided by WRO is being managed through four Regional Chief Engineers positioned at Chennai, Trichy, Pollachi and Madurai. In addition to the above regional Chief Engineers, the functional Chief Engineers for Plan Formulation(PF), Design Research Construction and Support(DRCS), Operation & Maintenance(O&M) , State Ground and Surface Water Resources Data Centre (SG&SWRDC) and the Chief Engineer & Director, Institute for Water Studies (IWS) are functioning in Chennai.

9.5 WATER UTILISATION COMMITTEE

In November 1979, the Government have issued orders constituting "Water Utilisation Committee" consisting of Secretary to Government – PWD, Secretary to Government – Industries Department, Secretary to Government – Rural Development and Administration Department, Managing Director – TWAD Board, Chief Engineer (Investigation) PWD, Chief Engineer (SG&SWRDC) PWD, Chief Engineer (Irrigation) PWD, Chief Engineer, TWAD. In this order, the Government have directed that all the water supply schemes costing over Rs. 10.00 lakhs and all Medium Irrigation Schemes costing Rs. 25.00 lakhs and above should be placed before the Committee which will consider the schemes and make its recommendations to Government, regarding the utilisation of water resources for irrigation, drinking water and industrial purposes.

In March 1980, a Technical Sub-Committee was constituted with Chief Engineer PWD (Irrigation) (as convenor), Chief Engineer PWD (SG&SWRDC), Engineering Director TWAD Board, Director of Industries and Commerce as members to scrutinise the schemes to be placed before the Water Utilisation Committee.

In October 1996 the Water Utilisation Committee constituted as detailed above was reconstituted with Secretary to Government, PWD (convenor), the Secretary to Government – Industries Department, the Secretary to Government – Municipal Administration and Water Supply Department, the Secretary to Government – Agriculture Department, the Managing Director TWAD Board, the Engineer-in-Chief, WRO & Chief Engineer (General), PWD, the Chief Engineer (SGSWRDC) WRO, the

Chief Engineer (Operation and Maintenance) WRO, the Chief Engineer (DRCS) WRO, the Director of Agriculture, the Engineering Director, TWAD Board as members. The Government also directed that all water supply schemes involving drawal of water of one MGD and above, be placed before the said committee for consideration and clearance.

In October 1996 a Technical Sub-Committee was reconstituted with the Engineer-in-Chief WRO & Chief Engineer (General), PWD, as the Convenor and the Chief Engineer (PF) WRO, the Chief Engineer (SGSWRDC), WRO, the Chief Engineer (DRCS), the Chief Engineer (O&M), the Regional Chief Engineers, WRO, the Chief Engineer & Director, IWS, the Chief Engineer (Agriculture Engineering) and Chief Engineer (TWAD) Board are as members.

9.6 FARMERS ORGANISATION AND TURNOVER (FOT) PROGRAMME, O&M RESPONSIBILITIES AND COST RECOVERY

Under the WRCP, farmers organisations are being formed at distributory level to handover the O&M responsibilities to these organisations after the rehabilitation of the systems.

The Government of Tamil Nadu, vide G.O.Ms.No.402 / Revenue (LA-3(2)) Dept / Dated24.09.2003, has directed that an additional water cess of Rs.70.00 per acre for wet crops and Rs.60.00 per acre for dry crops shall be collected and shall be apportioned between Water Resources Organisation (70%) and Water Users Association (30%).

As regards water charges, the present system of area based assessment and collection by Government agencies i.e by Revenue department will continue.

The Tamil Nadu Farmers Management of Irrigation Systems (TNFMIS) Act 2000 already passed by the legislature would be implemented effectively including the Farmers Turn Over (FOT) programme. The cost-recovery method including O&M finance would change depending upon the Government policy on functioning of farmers organisation and their role in water management.

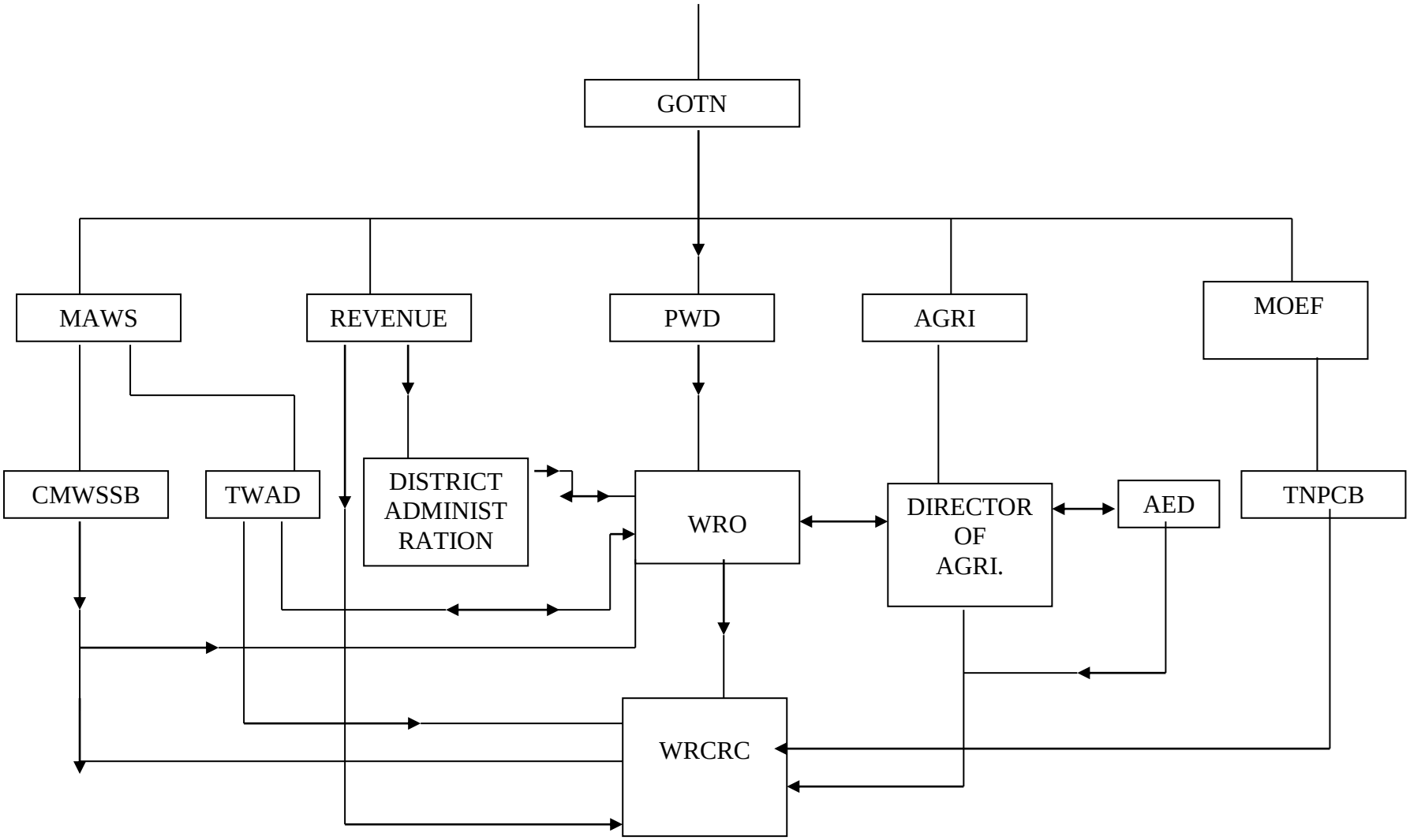
Groundwater management and the development and operation of community wells should also be under the responsibility of FOT's. Single small-holding farmers are unable to progress in this direction.

Table A Basin Management

(Main Activities and Agencies Responsible)

Activities in Basin	Agency Responsible
Pollution Prevention.	TNPCB has the main responsibility. Monitors the effluents released by industries. Accords permission for starting new industries from the environmental point of view.
Water Resources Management.	Water Resources organisation / PWD; responsible for execution of new projects & operation and maintenance of existing systems. Monitors groundwater quality. According ground water clearance from environmental, Institutional and financial point of view.
Providing drinking water and sanitation facilities.	Tamil Nadu Water Supply and Drainage Board – Provides rural and urban water supply (except for Chennai city) Also meeting the industrial water needs - Execution of sanitation schemes.
Agricultural Development.	Agriculture department; providing facilities to the farmers including supply of fertilisers, pesticides and seeds etc.
Command area development including On Farm Development (OFD) works.	Agricultural Engineering Department; It executes watershed management works also.
Ground water level and quality monitoring.	State Ground and Surface Water Resources Data Centre / WRO. It also disseminates the data.
Surface water and hydrological data collection.	WRO / PWD. It also monitors the rain fall data in the basin. Besides the WRO, IMD is also monitoring the hydrometerological data.
Assessment of cultivated area and collection of water charges.	Revenue department.
Clearance for new irrigation projects.	Revenue Department.

Fig. A Existing Institutional Linkages



CHAPTER – 10

SUMMARY OF PROBLEMS

CHAPTER 10
SUMMARY OF PROBLEMS

10.1 SCOPE

The present chapter summarises the problems encountered in the basin natural, technical and institutional inadequacies which are the causes of some of these problems. Possible strategies and actions to solve these problems are summarized and discussed in the next chapter.

The problems envisaged in the Nambiyar Basin are listed below:

(i) Sea Water Intrusion

(ii) Soil Quality

(iii) Floods

(iv) Policy and Institutional Issues

(v) Legal Issues

The following sections summarise these problems.

10.2 GROUNDWATER CONSERVATION

10.2.1 Extent of Groundwater Exploitation and Conjunctive Use

No major irrigation storage reservoir exists in the Nambiyar Basin. Only recently some schemes have been approved and they are under execution. As a result there is a sharp increase in the percentage of the area irrigated by wells in the districts falling in the Nambiyar Basin. The area under Well Irrigation has increased quite sharply and the area under Surface Irrigation has decreased. Groundwater irrigation has become the dominant source. Hence a proper management and conjunctive use of surface and groundwater in the command areas of the tanks is necessary.

In some cases tanks, are used basically as a percolation pond for recharging into groundwater in the command area by closing the sluices permanently. Sometimes this directly affects those who do not have access to groundwater, in particular the poor farmers who rely on traditional irrigation methods. It also results in the neglect of inlet channels and structural features of tanks.

A detailed study is therefore required to recommend conjunctive use of surface and groundwater in these commands considering socio-economic as well as hydrologic-technical aspects.

10.2.2 Overexploitation and Monitoring

Intensified use of groundwater with improper management results in over-exploitation. There are a number of critical, semi critical and over exploited blocks in theThirunelveli, Thoothukudi and Kanniyakumari districts. (The definition of safe, critical, semi critical and over exploited area is as per the classification of State Ground Water Resources Data Centre, WRO, PWD, in consultation with National Agricultural Bank for Rural Development (NABARD), issued as an order in January 1998 by the Government of Tamil Nadu).

Classification of Blocks based on the level of Groundwater Exploitation

Sl.No.	DISTRICT	BLOCK	LEVEL
1	Tirunelveli	Kalakkadu	Safe
2	Tirunelveli	Valliyur	Over Exploited
3	Tirunelveli	Radhapuram	Over Exploited
4	Tirunelveli	Nanguneri	Safe
5	Kanyakumari	Thovalai	Safe
6	Kanyakumari	Agastheeswaram	Safe
7	Tuticorin	Alwarthirunagar	Semi Critical
8	Tuticorin	Tiruchendur	Semi Critical
9	Tuticorin	Sattankulam	Over Exploited
10	Tuticorin	Udankudy	Over Exploited

The domestic water demand is expected to increase by 200% in the year 2045 and hence a decision has to be taken by the Government of Tamil Nadu to meet the increased demand in 2045. One of the recommended strategies is to construct small storage reservoirs, check dams etc. to conserve the surface runoff flows in to the sea. New reservoirs / tanks could be designed exclusively as a drinking water resource instead of bringing new area under irrigation.

Similarly, a number of blocks are found in the over exploited category in Thoothukudi and Thirunelveli Districts. It is necessary to monitor the trend of groundwater levels particularly after introducing free power for agriculture. Appropriate decisions have to be made to manage the groundwater resources, in line with the Government for groundwater legislation.

10.3 FLOODS AND OCCURRENCE OF FLOODS

The Nambiyar basin receives an average annual rainfall of 704.14 mm which is well below the State average. As this basin is situated in drought prone area, it is not much affected by surface floods. Also most of surface water has been harnessed through tanks, anicuts etc. Generally North East monsoon brings copious rain in this basin and at times it affects normal life in the coastal belt of the basin.

10.4 WATER LOGGING:

The drainage problem in Nambiyar basin is only minimal as most of surface water resources is harnessed. However, the irrigation structures such as anicuts, tanks, canals and drainage courses have to be properly maintained to avoid water logging.

10.5 SILTATION

Data on sedimentation in respect of this basin is not available. Sedimentation studies can be conducted in Vijayanarayanam tank.

10.6 OPERATION AND MAINTENANCE

The tanks were managed efficiently in the past by their beneficiaries. The turn system in sluice operation; rationing and maintaining of field channels were attended by beneficiaries. The recent development of wells in the command area, which got boosted up in the form of heavily subsidized (ultimately free) electricity, the increase of institutional finance and the recent agrarian reforms have improved the management system. The past tank management has to be revived. The farmers are also to be educated to understand that the tank irrigation system is not to be neglected in favour of wells, as the aquifer is not always persistent.

10.6.1 Operation of Reservoirs and Tanks

Most of the big tanks are provided with shutters on the surplus weir, which can be manually controlled. There are very few tanks with uncontrolled weirs. However, the surplus weirs of all the small tanks are uncontrolled.

10.7 WATER CHARGES

At present, there are different systems of water charges applied in Tamil Nadu:

(a) **Wet Assessment**: Wet assessment is applicable to lands which were classified originally as wet lands under survey and settlements of land and revenue. These lands are charged as basic land revenue, which includes charges for irrigation also. The old irrigation projects including minor irrigation works come under wet assessment.

(b) **Additional Wet Assessment**: Since 1st July 1962 an additional assessment to the extent of about 50 percent of basic assessment is levied on Wet lands.

(c) **Standard rates of Water**: When dry lands are brought under irrigation from government sources, standard water rates are levied. In addition to this an additional water cess is also levied to the extent of about 75 percent of standard water rates.

(d) **Special rates of water cess**: They are levied in respect of new project works taken up as major and medium projects after independence.

(e) **Crop based water rates**: Crop wise water rates are levied only in the case of projects which were designed for irrigation of dry or short term crop.

Water rates are again classified on the basis of duration of water supply as follows:

Class I : Water supply throughout the year
Class II : 8 to 10 months water supply
Class III : 6 to 8 months water supply
Class IV : 3 to 5 months waters supply
Class V : less than 3 months water supply

10.7.1 Local Cesses

In addition to water rates, local cesses are levied on water rates as per Tamil Nadu Panchayat Act. These cesses are applicable for all systems of water rates but not for

additional assessment / water cess. These cesses constitute about six times that of basic water rates.

10.7.2 General rates of water charges per hectare

Though there are different systems of water rates, on an average, the water rate is about Rs.50/ hectare. In addition, the local cesses (which are about six times of basic water rates) are about Rs. 300 / ha. Thus on an average the water charges including cesses are about Rs. 350 per hectare. Typical examples of water charges and cesses on different irrigation classes of wetlands are given below

Water Charges For Wet Lands Including Cesses For Different Categories Of Lands (Rs/Ha)

Class of Irrigation Sources	Basic Assessment	Maximum Assessment including additional assessment	Local Cess (LC)	Local Cess Surcharge (LCSC)	Total
I Class	41	45	41	205	291
II Class	32	45	32	160	237
III Class	26	30	26	130	186
IV Class	21	30	17	105	156
V Class	17	30	17	85	132

Additional Water Cess for (Class I and II sources only) should be collected and remitted as apportioned under two separate head of Accounts as shown below:

Sl.No	Details	Amount of Additional Cess collected	Due to	
			WRO	WUA
1	Wet Land	Rs.70/- per acre	Rs. 49/-	Rs.21/-
2.	Dry Land	Rs. 60/ - per acre	Rs. 42 /-	Rs. 18 /-

10.7.3 Financial results of Irrigation Projects

The statement of financial results of irrigation projects in Tamil Nadu is prepared every year by the revenue department and submitted to the office of the Accountant General. These statements give information on area irrigated by seasons and amount of water charges

collected from different projects. We have compared the revenue per hectare with the maintenance expenses per hectare of ayacut of individual project.

However, the following observations are noted:

a) The water charges accounting by Accountant General office does not include local cesses but only water rates.
b) The ratios of maintenance expenses to revenue are more than one in almost all the projects. Many projects are on a higher level.

Thus the financial position of many projects is unsatisfactory when we consider water charges per se without local cesses. The rationalization committee, which has studied the water cesses, recommended that the extent of cesses levied not to exceed one and half times of basic water rates and a large portion of them allocated for the benefits of local bodies.

Hence it is clear that the local cesses need to be treated separately from water charges as they are not assessed specifically for irrigation purposes and are annually apportioned among local bodies. The problems associated with area based water rates would diminish as the scheme of bulk water supply and volumetric charges are implemented on a large scale, and the assessment and collection of water charges are left to water users association.

10.7.4 Present System of Assessment and Collection in Tamil Nadu

At present the Revenue Department is involved in both assessment of water charges and collection. The village officials are supposed to inspect the fields and record the cropped area and classify it to the area under government sources of irrigation like canal / tank, crop conditions etc. A sample check is supposed to be done by higher officials like Revenue Inspector / Deputy Tasildhars. At the end of the Fasli (agriculture) year, the accounts are prepared and water charges are collected along with land revenue. The actual settlement of accounts under different heads is done at the time of annual ‘ Jamabandhi ‘ meeting. Thus at present both the collection and assessment are done by the Revenue Department and Water Resources Organisation is not at all involved in it.

10.7.5 Inadequacies in the existing system of assessment and collection

With the present system of revenue accounting, it is understood that the data on actual collection of water charges are not available separately. However, it is reported that

the overall collection of land revenue including water charges is about 70 percent of the annual demand. Apart from arrears on current / annual demand, there is a sizeable amount of accumulated arrears over a period. If we include the accumulated arrears, the actual collection rate is about 50 percent.

Apart from the problem in revenue collection, there is also an inadequacy in the existing system of assessment. It is reported in many studies that there is a significant extent of under-recording of area irrigated as there is a large extent of area under un-authorised irrigation. The committee on pricing of irrigation water has recommended an independent checking of the area irrigated on a sample basis using remote sensing techniques to improve the assessment of area irrigated.

10.7.6 Assessment and Collection in other States

There are different arrangements existing as regards to assessment and collection of water charges in different states. In some States, irrigation department does both assessment and collection (eg. Bihar, Madhya Pradesh, Maharashtra, Gujarat and Rajasthan). Revenue department in States like Karnataka, Andhra Pradesh, Kerala, Tamil Nadu and Orissa do both, whereas in Haryana, Uttar Pradesh and West Bengal, the assessment is done by irrigation department and the collection by revenue department.

10.7.7 Water Service Charges Committee

At present, there is no system for the accounting of service charges from different uses of water such as agriculture, domestic, and industrial purposes. Government of Tamil Nadu have constituted a Water Service Charges Committee (WSCC) with Commissioner of Land Revenue as the Chairman and Engineer-in-Chief, WRO as the Member Secretary. One of the members is appointed as a Consultant in the field of Economics. The Economist is given the task of establishing a system for annual review of costs and service charges from different uses of water supply.

10.7.8 Need for Effective Monitoring of Budgetary Allocation received from other Departments

Besides budgetary allocation received from the State Government for maintaining and repairing water bodies and canals, the funds are also received by WRO as the line department in charge of Water Resources Management, through the District Collectors and

other departments for desilting of tanks and supply channels, standardisation and Improvement of Irrigation tanks, and Flood relief works.

The works are under the following schemes:

District decentralized plan

Member of Parliaments- Local Area Development Programme (MP-LADP)

Jawahar Velai Vaippu Thittam (JVVT)

Employment Assurance Scheme

Million well schemes

Hilly area development programme

Western ghats development programme

The funds for carrying out these repairs and maintenance works is received directly by the Executive Engineer of WRO concerned.

10.8 BUDGETING AND DEVELOPMENT PROJECTS

10.8.1 Required Budgeting procedures

The study of budgeting procedures at the state level (Engineer-in-Chief and Regional Chief Engineer's Office, Chennai) reveals the following required procedure:

The proposals for the budget are supposed to be received by the Engineer-in-Chief 's office in the month of September and submitted to the finance department during September-October. After scrutiny, the final budget allocation for WRO is expected to be informed by the finance department in November / December. The Chief Engineers are to be informed of their budget allocation after it has been duly voted in the legislative assembly. The Chief Engineers are expected to inform their Superintending Engineers and Executive Engineers of their budgets and authorize the finance department to issue letter of credit (LOC) to them directly to meet system maintenance expenditures. It is also stipulated that the LOC's are issued directly to the Executive Engineers on a quarterly basis.

10.8.2 Existing Procedure

However, in practice, the following problems are observed in the budgeting procedures:

Delays in the preparation of budget proposals at different levels of the WRO and their submission to the finance department constitute the main problem area. Errors in the preparation of the proposals like change of account head and non-provision of adequate

information are noted as main reasons for the delay. As a result, the process lasts up to December and the final figures on allocations are arrived at only in January.

As budget preparation requires particular skills, those who are engaged on such exercise should not be subjected to frequent transfers. As for head quarters computerization of procedures would go a long way in avoiding delays. Training of the personnel involved is another point for consideration.

10.9 POLICY AND INSTITUTIONAL ISSUES

10.9.1 Need for Policy Framework

The policy development process in Tamilnadu is seriously flawed. Policy development is the responsibility of individual departments and there is no ongoing co-ordination of the policy development process among departments at State level. Similarly there is no specified process of public participation in policy development. Thus the individual departments can determine the nature and extent of external involvement in the process. The apprehension that such participation would create significant delays and "Unduly complicate" the policy process and such participating groups may lack technical expertise to contribute to the policy and programme design may be the reason for the absence of such participation.

A key recommendation of the WRCP was the development of a State water policy. The State water policy was formulated by WRO in conjunction with representatives of water management agencies in the State and members of several water research Institutes. The consultation while framing the policy was limited to the Government sector and more specifically to the water management sector.

There is need for enhanced state co ordination of the policy development process to ensure that sectoral policies are more fully integrated into the overall policy framework of the State. Perhaps, the State Planning Commission (SPC) would be a logical organization to assume responsibility for managing the policy design and evaluation process at this level since State Planning Commission is currently directing the states Five Year Plan process and it could identify policy and programme conflicts, assess policy framework for individual departments and monitor departmental performance in the policy area.

10.9.2 Formulation of State Water Policy

In 1987, the Government of India, Ministry of Water Resources has formulated a National Water Policy. The National Water Policy lays down general guidelines for preparing basin wise master plans, priorities for water use, inter basin water transfer etc. The Government of India has revised the water policy in 2002.

Taking into account the Government of India' s National Water Policy 2002, the draft State Water Policy has been formulated and sent to the Government for approval and is in active consideration of the Government of Tamil Nadu.

The policy allocates the highest priority for drinking water. The IWS is presently preparing water balance studies and preparing micro level basin plans taking river basin as one unit.

Efficient management and optimum planning of water resource depends on substantial changes in sectoral policies and upgrading of institutional capabilities in water related departments. In India' s federal structure, the State is the key administrator unit for water planning and management. Hence it is at the State level where policy / institutional changes make greater impact on the optimal utilization of scarce water resources. Under the World Bank assisted Water Resources Consolidation Project (WRCP) in Tamil Nadu, planning and management of water resources is being attempted in all functional areas, including in water allocation, planning and management. Planning and management of water resources is attempted on a holistic basis through a multi sectoral approach using the natural hydrological unit, the river basin, to incorporate ground as well as surface water and include environmental aspects in addition to quality considerations.

10.9.3 Draft Revised State Water Policy

The Government of Tamil Nadu has formulated a water policy for the State in July 1994. Subsequently, the same has been revised in line with the National Water Policy 2002 and sent to the Government for approval. The stated Goals and Objectives of the policy are: "Establish allocation priorities for water use by different sectors with provision of drinking water being the highest priority". The National Water Policy (NWP) 1987 gives drinking water the highest priority. NWP also states that drinking water needs of human beings and animals should be the first priority on the available water.

10.10 LEGAL ISSUES

10.10.1 Need for Legislative Framework for Water Management

Twenty-eight separate union territory and state statutes impinge upon Water Management in Tamil Nadu. Water management with exception of inter state rivers, is exclusively delegated to the states under the constitution of India. The union (Central) Government has enacted various statutes related to environmental management, which have a direct impact on water management of greatest significance. They are:

Water (Prevention and Control of Pollution) Act1974, which provides for the establishment of state pollution control boards: the Water (Prevention and Control of Pollution) Cess Act 1977, which allows for the levying of effluent charges and the Environmental (protection) Act of 1986,which provides for water quality standards, control of the discharge of pollutants, regulation of supply and requirements for environmental impact assessment.

Tamil Nadu's legislative framework has evolved in an incremental fashion over 130 years. Consequently, the statutes have disparate, often-dated water management statutes, which were passed to address specific needs. Examples: Tamil Nadu conservancy Act: Bhavani Reservoir Irrigation Cess Act (1933): Tamil Nadu Irrigation works (Repairs, improvement and Construction) Act 1943): Tamil Nadu Irrigation Works (Construction of field bothies) Act (1955): Tamil Nadu Additional Assessment and Additional Water Act(1963): Tamil Nadu Water Supply Act(1987). The strongest mandate for water management was allocated to the Revenue Department through its responsibilities for levying and collecting water related charges. Key aspects of the water management including groundwater management and coastal zone management are not explicitly addressed in the existing legislative framework.

A robust legislative framework to provide legitimisation to policy, regulatory and organizational frameworks is a key requirement for integrated water management. In Tamil Nadu previous studies highlighted significant weakness in legislature framework. Critical concerns included a fragmented legislative base, exclusion of key elements, most notable groundwater management.

Individual departments were utilizing Government Orders issued directly by Government as executive orders. Integrated water management through statutory back up will have a significant impact on the implementation of reforms in the water management.

10.10.2 Need for Irrigation Act

The Ministry of Water Resources, Government of India is in the process of hammering out a National Irrigation management policy wherein one of the main thrust areas is "Enacting suitable legislation to give legal support for better water management".

There is no comprehensive law for irrigation as on date and model act has been attempted several times but not yet passed. There is need for a statutory provision with the enactment of a comprehensive Irrigation Act for the State for enforcing discipline in water use, equity, removing obstruction to flow, encroachment, etc and providing Managers of the river basins with adequate powers to make the best use of the water.

"Tamil Nadu Farmers' Management of Irrigation Systems (TNFMIS) Act" has been enacted during 2000 and the Act is under implementation with effect from 01-10-2002 in all the command areas covered under WRCP, in the first instance, this will be extended to the balance Non-WRCP command areas, maintained by WRO of PWD in due course. This Act empowers and encourages farmers' (water users) involvement in all the decision making and other activities related to other activities related to irrigation management covering all the systems under the management control of WRO of PWD.

10.11 PUBLIC AWARENESS AND PARTICIPATION

There should be great public awareness about the impact of the over-exploitation of groundwater in Tamil Nadu. The problems arising out of the overexploitation are manifold. It includes declining of groundwater levels, seawater intrusion in the coastal areas, pollution of groundwater due to industrial effluents and application of fertilizers and pesticides, rising cost of groundwater pumping, inequity in access to groundwater potential, declining agricultural production and loss of rural livelihood from over extraction of groundwater.

To create public awareness on the detrimental effects of over exploitation of Groundwater, the Government have decided to launch a campaign through:

(i) T.V advertisements, either in the regular programmes of Doordharshan or Environment Control programmes like " Living on the Edge", without too much expenditure commitment for the Government.

(ii) News papers.

(iii) Agricultural extension programmes / Educational programmes.

(iv) Public Works Department field level officers like Lascars/ Gumastas, etc.

(v) Posters, Wall paintings, etc.

As the proposal has good objective operationalisation of the scheme, will call for good deal of thinking. Government are of the opinion that such a task should be taken up by a committee involving officers, professionals and NGOs.

The Government of Tamil Nadu have constituted a committee under the Chairmanship of Engineer-in-Chief, WRO & Chief Engineer (General), PWD with representatives from Information and Public Relation Department officers, professionals and few reputed NGOs to decide the modalities.

The Committee has so far met four times and is in the process of preparing a documentary film for public viewing to spread the message on the ill effects of over exploitation of ground water.

10.12 SEA WATER INTRUSION:

In Thoothukudi district, sea water – fresh water interface is taken place in the central part and southern part (Udankudi), the reason is due to the heavy pumping by the farmers and poor rainfall which results in the fall in the water level below M.S.L.

In Thirunelveli district, Valliyoor block is affected by sea water intrusion for particularly Chettikulam and Sri ranganarayanapuram. Because of heavy pumping for intensive coconut plantations coupled with hydro morphological set up of the region.

CHAPTER – 11

POLICIES, LEGISLATION AND INSTITUTIONAL

CHAPTER-11

POLICIES, LEGISLATION AND INSTITUTIONAL STRENGTHENING

11.1 SCOPE

The present chapter summarises the different non-structural measures required to solve the problems and inadequacies that are brought out in the previous chapters.

The following are the objectives of the institutional and legal improvements required in the NAMBIYAR RIVER BASIN :

(i) Provide safe drinking water sufficiently.

(ii) Increase rain water harvesting.

(iii) Protect ground water for drinking water purposes.

(iv) Avoid groundwater pollution.

(v) Control of seawater intrusion.

(vi) Improve soil conservation.

(vii) Modernise irrigation systems.

(viii) Assist farmers in the management of poor quality of soil

(ix) Assist farmers to increase their income and their ability to pay for improved irrigation.

11.2 GROUNDWATER MANAGEMENT

11.2.1 Need for an Act for Regulating Groundwater Extraction

Due to over exploitation, the following problems are encountered in Tamil Nadu.

They are:

(i) Lowering of water table beyond replenishable limit.

(ii) Seawater intrusion towards inland groundwater aquifers due to over exploitation in coastal areas etc.,

(iii) Increase in the number of critical and semi-critical blocks.

In view of the above problems, it is felt necessary that some management strategies are to be adopted. One of the management strategies is regulation of the

utilisation of groundwater by way of legislation. The proposed legislation would expand the State control of groundwater resources in order to enhance the regulatory capability of the Government over the resource. However, an extensive "Public Education Programme" regarding the groundwater management is a pre-requisite for the introduction of legislation, since the water management sector is a sensitive one. As the irrigation is the dominant water use, the impact of changes in the water management sector will be evident in the rural areas.

11.2.2 Preparation of Tamil Nadu State Groundwater Development and Management Act

With a view to protect groundwater resources, to safeguard against hazards of over exploitation and to ensure planned development and proper management of this vital and limited resources, suitable legislation for development and management of groundwater is necessary.

The Government of Tamil Nadu has formulated and passed the Tamil Nadu Groundwater (Development and Management) Act 2003.

11.2.3 Ensuring Minimum Spacing Between Two Minor Irrigation Structures

The Chief Engineer (State Ground and Surface Water Resources Data Centre), PWD, WRO, Chennai is the authority for according approval for sanctioning institutional finance for farmers who need them. The guidelines for the minimum spacing to be adopted between any two structures as issued by NABARD, the agency who releases the institutional finance are given in Chapter 5.

The Chief Engineer (SG&SWRDC) has classified in January'2003 the 385 administrative blocks as Safe, Semi Critical, Critical and over exploited depending upon the stage of groundwater development. The details of classification of blocks based on the level of groundwater development are given in Chapter 5.

11.2.4 Legal Aspects

Although there are numerous laws dealing with rights to and management of surface water for irrigation, some of them also deal with allocation to domestic or urban water supplies (with the notable exception of metropolitan area Chennai for which special legislation has been made). However the Municipalities Act and

Panchayat Act of 1958 make these local bodies responsible for domestic water supply fit for human consumption.

11.2.5 Co-ordination

The provision of safe water supply has been given the highest priority by the Government of Tamil Nadu. Competing demands exist for Tamil Nadu scarce resources, with some organization viz. Water Resources Organisation (PWD), enjoying a strong lobby for allocation for irrigation needs.

Therefore it is suggested that at least 20% of live storage of new reservoirs should be ear-marked for domestic needs. Besides this, when a new storage structure is created, such a proposal should be communicated to TWAD by the Public Works Department (WRO), and their views are to be obtained. A suitable institutional administrative arrangement should be created for this purpose of co-ordination.

11.3 POLLUTION CONTROL

No specific action can be recommended at this stage due to insufficient information on the extent of the problem and its sources. A detailed field study is recommended to establish this information and to identify the required action. Special emphasis will be given in such a study to identify domestic sewage disposal outlets, industrial wastes and other solid waste sites. The study will propose plans for treatment and safe disposal of these pollution sources, including reuse of effluent for irrigation.

The Loss of Ecology (prevention and payments of compensation) Authority for the State of Tamil Nadu constituted by the Central Government under the Environment protection Act, started functioning from 23rd September 1998. The Central Government constituted the Authority , based on the Honourable Supreme Court's Judgement. The powers and the functions of the Authority as per the notification are as follows:

1. Exercise powers under Section 5 of the said Act, for issuing directions and for taking measures with respect to matters referred to in Clause (v), (vi), (vii), (ix), (x) and (xii) of sub-section 2 of section 3 of the said Act;

2. To assess the loss to the ecology and environment in the affected areas and also identify the individuals and families who have suffered because of the

pollution and assess the compensation to be paid to the said individuals and families;

3. To determine the compensation to be recovered from the polluters as cost of reversing the damaged environment;

4. To lay down the procedure for actions to be taken under (1) to (2) above;

5. To compute the compensation under two heads, namely, for reversing the ecology and for payment to individuals;

6. To direct the closure of any industry or class of industries owned or managed by a polluter in case of evasion or refusal to pay the compensation awarded against the polluter. This shall be in addition to the recovery from the polluter as arrears of land revenue;

7. To frame scheme or schemes for reversing the damage caused to the ecology and environment by pollution in the State of Tamil Nadu in consultation with expert bodies like National Environmental Engineering Research Institute, Central Pollution Control Board, etc. These schemes shall be executed by the State Government of Tamil Nadu under the supervision of the Central Government;

8. To review the case of all the industries which are already operating in the prohibited area and direct the relocation of any of such industries;

9. To close the tanneries permanently or direct their relocation, which have not provided treatment facilities and not having valid certificate from the Tamil Nadu State Pollution Control Board;

10. To comply with the orders issued by the Madras High Court and Supreme Court from time to time;

11. To deal with any other relevant environment issues pertaining to the State of Tamil Nadu, including those, which may be referred to it by Central Government in the Ministry of Environment and Forests.

The members of the Authority are: Secretary to Government of Tamil Nadu, Environment and Forests Department, Member-Secretary, Central Pollution Control Board.

As may be seen from the functions of the Authority, listed above, the first task is to assess the loss to the ecology and environment in the affected areas. Next is to identify the individuals and families who have suffered because of the pollution and assess the compensation to be paid to the said individuals and families. The compensation amount is to be recovered from the polluters. Also, compensation from the polluters is to be recovered for reversing the damaged ecology. This implies that the authority has to identify schemes for reversing the ecology.

11.4 DRINKING WATER AVAILABILITY

11.4.1 Need for Drinking Water

The domestic demand in Nambiyar basin is expected to increase from 24.486 Mcum in 2006 to 43.761Mcum in 2045 (Table-A under Chapter 6). An intensive development of tourism is also expected in this basin. Such development would result in, increased need of domestic water supply to meet the needs of the inflow of tourism into the Basin.

Hence a policy decision is to be taken by the Government of Tamil Nadu for evolving the strategies to meet the increased demand in 2045. One of the strategies could be to construct small storage reservoirs, check dams etc. to conserve the surface runoff. This has been discussed in chapter 12 under Development Plan.

11.4.2 State Water Policy

In 1987, the Government of India, Ministry of Water Resources has formulated a National Water Policy. The National Water Policy lays down general guidelines for preparing basin wise master plans, priorities for water use, inter basin water transfer etc. The Government of India has revised the water policy in 2002.

Taking into account the Government of India's National Water Policy 2002, the draft State Water Policy has been formulated and sent to the Government for

approval and is under active consideration of the Government of Tamil Nadu . (It is dealt in detail under Chapter 10).

11.5 DROUGHT MANAGEMENT PLANNING

11.5.1 Need for Planning

Frequent droughts in different parts of the state in the past have focused on the need for developing an effective drought management plan for implementation at the state level.

Well-drawn contingency plan for each drought prone area is a must and organized coordination and collaboration at the block, district and state level is required for monitoring and execution of well-drawn strategies.

According to the existing provision of drought management in the state, the reports submitted by district collectors include expected trend of principal crop production, trends and supply conditions of food grains and fodder, food grain price trend, extent of population movement in search of employment, health distress such as malnutrition among children etc. Past experience shows that the planning for droughts in India is done during drought period and were usually handled more as a crisis management rather than in a planned organized way.

The critical needs to deal with drought management, which could be identified, are:

Reliable and timely information about drought, current status of water availability and alternate assistance measures readily available for implementation.

1. Improved impact assessment techniques, specially in agriculture sector, for use by Government to identify period of abnormal risk and to trigger assistance measures.

2. Stand by assistance measures that encourage appropriate level of risk management, which would be equitable, consistent and predictable.

An assessment and response systems should be designed in such a way that the information on drought would be collected, and analysed and disseminated in a timely and systematic way by regular monitoring of factors causing drought. The

identification of scarcity condition and determination of starting and winding up of assessment and response activities should be reliable and effective. The provision of evaluation of response activities would provide added information for selection of alternate strategies of drought management. The recommendations are:

- Sufficiency of data is an essential input not only at the planning and design stage of drought-combating measures, but also at the operation stage.

- It is necessary that all the drought-affected taluks / districts of the state should develop their own drought plan suitable to their regional priorities and needs.

- The assessment procedures must be developed to provide reliable and timely information on problems related to water supply and potential impacts. To accomplish this goal a data collection, analysis and dissemination system must be assembled well in advance of drought related water shortages.
- The responsibilities of local state Government and other agencies involved in various sectoral tasks must be well defined.
- Since preparedness is the key to proper management, an office of emergency Preparedness must be set at the district level where droughts are known to occur.

11.5.2 Drought Prone Area Programme in Tamil Nadu

The basic objectives are:

a. To minimize the adverse effects of drought through development of the natural resource base and adoption of appropriate technologies.

b. To achieve ultimately drought proofing through integrating other schemes and

c. To conserve, develop and harness land, water and other natural resources for restoration of ecological balance.

The blocks are included under the programme based on the following criteria:

	Annual Rainfall	% Irrigated Area to Net Sown Area
Criteria for inclusion of blocks	Below 750 mm	Below 20%
	750-1,125 mm	Below 15%
	Above 1,125 but below 1,650 mm	Below 10%

11.5.3 DROUGHT MITIGATION MECHANISM

The following are the measures adopted as detailed below:

1. Short term measures
2. Long-term measures.

11.5.3.1 Short-term measures

The short term drought measures may range from providing food, fodder and fuel, intense groundwater exploitation programs of domestic and livestock consumption and life saving irrigation, soil moisture conservation measures, supply of drinking water through tankers, crash employment programme and appropriate contingency plans to raise crop and fodder with limited water. The short term drought measures may also include strengthening of public distribution system, public health measures and supplementary nutritional programme to nursing mothers and children and public awareness campaign for frugal use of water for domestic and irrigation purposes.

11.5.3.2 Long-term measures

The long-term drought proofing measures are essential to combat permanent drought effects. These include programmes for installation of tube wells, construction of ponds and percolation tanks for irrigation and domestic water supply purposes, desilting of tanks and canals, establishing soil conservation and water harvesting structures, regulations on land use, afforestation, grass land and waste land development, measures to reduce water loss through seepage and evaporation and groundwater exploitation policies etc.

The dry land farming policy has to be encouraged for raising production in semi arid and arid regions in the basin, so that the risk due to drought is minimised. Establishment of less-water consuming industries has to be encouraged in this basin.

The crisis management approach should be replaced with programs of sustained and direct result yielding actions.

11.6 FLOOD MANAGEMENT

Under the Constitution of India, flood control is a state subject. At National level there are no laws at present to regulate the flood management. In Tamil Nadu, there is no law to regulate the flood plains. However, Tamil Nadu has well formulated comprehensive anti-disaster management plan, which is implemented during floods.

Flood protection works are undertaken by Revenue department, local bodies and general public as soon as the message of flood and the damages is reported.

The field officers of PWD, WRO will inspect the site and report the damages in the prescribed form to the Executive Engineer. The Executive Engineer will send a consolidated report to the Accountant General and simultaneously the intimation is sent to his Superior Officers namely, Superintending Engineer and Chief Engineer.

Initially till 1980, the officers of the department were vested with powers to award the works on NOMINATION to the contractors, as the works of this nature are emergent. These flood relief works will be delayed, if the usual procedures of calling for tenders' etc. are followed.

Government in 1980 dispensed with the system of nomination altogether except in the event of emergencies, which may be specified by Government orders issued from time to time. When there is not enough time to obtain prior orders of Government, work may be entrusted on nomination on the orders of the Chief Engineer in anticipation of Government approval, provided ratification of Government is obtained immediately thereafter.

All flood relief works are to be carried out as emergency works. The flood relief works have to be undertaken immediately to conserve the monsoon runoff

without any time delay. Any delay in the execution of works would result in losing the precious flows.

The expenditure would be made under the head of account specified by the Chief Engineer. However the list of flood works undertaken will be sent to Collectors concerned for information and for special funds in the event of emergency due to natural calamities declared by the Government, under calamity relief fund. The Government allots the calamity relief fund to the Collectors only, who in turn allots it to the line departments who are in charge of relief works.

It is suggested, therefore that a special budgetary grant will have to be made available every year at the rate of 20% of the annual grant provided for maintenance and repair of irrigation system, to meet emergency flood control measures.

This special budgetary provision will be operated by the officers based on specific permission accorded by the Engineer-in-Chief, WRO, TNPWD in emergent situations. The unspent amount, if any should not be diverted for other purposes.

11.7 HYDROLOGICAL STUDIES

Some clear relationships between the rainfall in the various zones of the basin and the runoff measured at the various locations have to be established to estimate the sub-basin yield. Such relationships have to replace the empirical methods adopted by WRO in the planning.

The following procedure is proposed to carry out these hydrological studies:

a. Data base preparation. The database should include the following items (monthly time basis) for all catchment studies:
   - Rainfall details for all stations within the catchment areas and beyond these boundaries but in their vicinity.
   - All runoff records, which are available for the catchment area. If the Stream-flow series is not natural, i.e., there are upstream diversions for irrigation or for domestic use, the metered diverted volumes should be added to the metered stream-flow in the site under consideration, to obtain the natural stream-flow series. If the diverted volumes are not metered, they should be estimated from the knowledge of the size the

Population, which utilizes the water at the catchment, and the agricultural information of the catchment, i.e., type and area of the irrigated parts in the catchment.

- Average potential evapotranspiration data. If such information is unavailable, the potential evapotranspiration may be evaluated by using a common computation method, e.g., Modified Penman on Penman – Monteith methods

b. From Remote Sensing data the following parameters should be obtained:

- Catchment area.
- Geological and geomorphologic features of the catchment
- Soil cover within the catchment boundary, including soil groups identification.

c. Application of a monthly rainfall-runoff model such as MRS model. The application of the model should basically include:

- Model calibration for the period where a natural stream-flow series exists.
- A long stream-flow series simulation based on the calibrated model and the long series of rainfall records.

d. Use of the simulated stream-flow series to establish the water potential by a direct statistical analysis of the series, with the possibility to determine any chosen dependability for a monthly, seasonal or annual flow.

e. Having the results obtained in ‘d’ above, it is possible to establish runoff coefficient for various dependabilities, at least on annual basis, by using rainfall depths and water potential values having the same dependabilities. These values may be used for establishing water potential of ungauged catchment, which have similar characteristics as obtained from ‘b’ above, and rainfall records only.

CHAPTER – 12

DEVELOPMENT PLAN

CHAPTER – 12

DEVELOPMENT PLAN

12.1 SCOPE OF DEVELOPMENT

The problems highlighted in the first Chapter may be resolved by non-structural measures as summarized in the previous Chapter 11 and by structural measures that are discussed in this Chapter.

12.2 PRIORITISATION OF FUTURE DEVELOPMENT

Future development should be based on the following priorities:-

- ✓ Sustainable drinking water schemes.
- ✓ Improving the overall irrigation efficiencies in stages.
- ✓ Adopting sprinkler and drip irrigation wherever possible and feasible.
- ✓ Planning effective rainwater harvesting measures to harness surface water which flows into sea during the flood.
- ✓ Conjunctive use of surface and ground water in all sectors.
- ✓ Developing less water consuming Projects/Industries in drought prone areas.

The following types of development projects are proposed now in the Nambiyar basin:-

A. Formation of Reservoirs.
B. Formation of Ponds.

The details of the proposed development actions in the Nambiyar basin are given in Table A.

12.3 IMPROVEMENT OF DRINKING WATER SUPPLY

The domestic water demand is expected to increase by nearly 56% in 2045. Hence a policy decision has to be taken by the Government of Tamil Nadu to meet the increased demand in 2045. One of the recommended strategies is to construct tanks / ponds to conserve the surface runoff. New tanks could be designed exclusively as a drinking water source instead of bringing new area under irrigation. This is justified since drinking water is of high priority.

12.4 MODERNISATION AND REHABILITATION OF EXISTING WORKS

Most of the existing irrigation systems in Tamil Nadu have unlined canal systems in which considerable loss of water takes place. The introduction of high yielding crop varieties since 1965 requires upgrading of canal performance since the yield from these crops is adversely affected if application of appropriate quantities of water is not provided at the right time and at the right place.

These deficiencies can be corrected by modernising the systems. Such modernization not only lead to considerable savings in water use and extension of irrigated area but also leads to other benefits by way of minimizing problems of water logging and soil salinity, etc.

Under WRCP, rehabilitation works were carried out to main canals, branch canals, and distributaries in selected systems in the river basins except Cauvery and 620 tanks in three river basins namely Palar, Vaigai and Tamiraparani. A study by the Centre for Water Resources, Anna University as part of modernisation of tanks, under EEC assisted project, has shown that the overall efficiency of the system increased to about 60% leading to savings in water.

Such an increase in efficiency if modernisation of Nambiyar Basin tanks is carried out would result in conserving water which may be diverted to other high priority sectoral demands, such as domestic and industrial needs in the Nambiyar basin.

Modernisation of irrigation systems does not involve merely improvement in the system components such as lining of canals and distribution systems and improvements and modifications to the structures but also application of a complex combination of different activities intended to upgrade the performance of irrigated agriculture. These activities would be concerned with the following:

- Revision of crop pattern and crop calendar to make the best use of the soil in a command with regard to its suitability for different crops;
- Avoid excessive losses in the distribution system and field channels;
- Reappraisal of the irrigation water requirements and the frequency of water application;

- Conjunctive use of ground water to the extent possible;
- Improvements in the drainage conditions of the command area;
- Modifications of canal structures and construction of new structures as necessary,
- Adequate on-farm development,
- Proper water management and
- Adequate funding for satisfactory maintenance of the system periodically.

12.5 DESILTING AND RECLAMATION OF EXISTING TANKS

Desilting–cum–reclamation (DCR) of tanks is felt necessary now. The tanks lost their original capacity due to siltation of the tank beds over a period of time. Most of the tanks require desilting to restore their storage capacity in order to enable adequate supply to the entire ayacut. The restoration of the tanks to the full capacity can be achieved by desilting.

12.6 WASTE WATER REUSE

Background

Much of the water used for domestic purposes and for industrial activities are not consumed in the true sense. For instance, 41 numbers of the large and medium industries located in the basins utilize about 37.41Mcum, out of which about 30 Mcum (80%) of waste water is being generated. It can be systematically collected and treated for removing the harmful ingredients and can be reused. This will augment the availability of water. The most favourable factor is that water can be treated and recycled for repetitive use relatively with much greater ease compared to other resources. Given the large pool of scientific and modern technology and manpower and the new conservation techniques available, natural adversities shall be overcome.

12.7 REUSE OF SEWAGE EFFLUENTS FOR IRRIGATION

Generally 80% of the water supply may be expected to reach the sewers. However, sewers should be designed for a minimum wastewater flow of 100 lpcd. (Ref; Manual on Sewerage & Sewage Treatment, CPHEEO, Ministry of Urban Development, New Delhi, 1993).

The expected generation of domestic sewage in the corporations, municipalities and town panchayats have been worked out and presented in the Chapter 7.

The collected sewage has to be treated since these municipalities lack full fledged sewage collection, treatment and disposal systems. Untreated sewage is discharged into the nearby streams and disposed on land. All the townships and panchayats have to take steps for sewage collection, treatment and disposal by installing sewage treatment plants. This should form part of the action plan for the Nambiyar basin.

The estimated total cost of primary and secondary treatment of the domestic sewage generated by the municipalities and the town panchayats in the Nambiyar Basin are discussed in detail in Chapter 7.

The local bodies have to carry out a minimum primary treatment to make it suitable for land spreading or disposing it to water bodies so that it doesn't cause environmental damage. The sewage after primary treatment must conform to certain minimum standards prescribed by Tamil Nadu Pollution Control Board (TNPCB).

12.8 INDUSTRIAL RECYCLING AND REUSE

The World Bank studies have shown that the water use efficiency in the industrial sector is poor when compared to similar industries in other countries. Substantial water savings can be obtained by introducing water saving technologies, treatment, and reuse of water and changing industrial processes.

It is necessary to introduce wastewater-recycling at least in major industries. It has been demonstrated by M/s. Madras Fertilizers Ltd., that 68% of water needs can be met by treatment of secondary treated sewage received from CMWSSB.

M/s. Tamil Nadu News Paper Ltd., Karur have shown that cost of treatment of effluents would be Rs. 1,500/1,000cum (94-95). Industrial recycling is under the responsibility of the users and is not included in the present development plan.

12.9 WATER HARVESTING

Percolation Ponds

In order to harness the available water resources and utilize them effectively, rain water harvesting is of greater importance. Usually, percolation ponds play a vital role in this respect.

The percolation pond is an ideal structure for water harvesting in the plain areas by storage of water and recharge of groundwater in the surrounding area through infiltration and percolation. It is constructed across natural watercourses, gullies, and drainage points of watersheds to impound the runoff water and retain it for a longer time. It effectively increases the water level in the surrounding irrigation and drinking water wells.

The benefits of percolation ponds are:

1. It raises the ground water table in irrigation and drinking water wells.
2. It reduces the soil erosion.
3. It improves the agricultural activities within its zone of influence and provides employment in the rural sector.
4. It helps the local people to use the water for their domestic use.
5. The evaporation loss from percolation ponds is estimated as 7.2 percent of the stored quantity.

12.10 FLOOD RELIEF WORKS

Scope of the Problem

Heavy flood damage can endanger both life and property loss to a great extent. During high floods, breaches occur in tanks and allied structures due to various reasons.

The main reasons attributed are:

- Poor maintenance
- Encroachment
- Siltation

TABLE –A PROPOSED DEVELOPMENT ACTION PLAN IN NAMBIYAR BASIN					
Sl.No.	**District**	**Taluk**	**Name of the Scheme**	**Estimate cost (Rs.in Lakhs) 2004 - 05**	**Ayacut Benefitted in Hectares**
1.	Thirunelveli	Radhapuram	Formation of a new pond near Sanganapuram in Kasthurirengapuram	**21.95**	**21.46**
2.	Thirunelveli	Nanguneri	Formation of reservoir across Kuruviyuthu odai Malayadipudur village.	**219.00**	**19.43**

Remedial Measures for Protecting Breaches in Tanks and Supply Channels

Flood relief works are carried out whenever flood damages occur. Small breaches in tank bunds, supply channel bund etc. are temporarily closed by forming semi circular ring bunds in front of the breach in order to store the water for successful harvest. Permanent closing of the breaches is done by earthwork with extra consolidation, when the tank/ channel becomes dry. According to the size of the damage in the bund / bank, one layer of sand bags on the inside slope of bund is generally provided to avoid erosion in the rectified portion of the bund due to wave action. Considerable time ranging from 2 to 3 years is given for natural seasonal consolidation for the affected portion and necessary revetments are provided. Retaining walls are constructed if the depth of storage exceeds 3 metres.

The rehabilitation works for tanks would help to reduce the breaches in the tanks and supply channels during heavy rainfalls and floods. Such rehabilitation works would also help to conserve the surface water generated during floods.

12.11 SOIL CONSERVATION

Soil Conservation techniques are universally adopted to conserve the soil by taking the energy of erosive forces through the package of well-knit techniques. Soil Conservation works have proved to be effective in controlling soil erosion, increasing the crop yield reducing the sedimentation and maintaining Ecology.

The main objectives of the soil conservation programmes are:

- To protect and preserve the fertile top soil of the Agricultural,
- To improve the land capability and moisture regime in the watersheds and
- To develop peoples involvement in water shed development activities.

In Nanguneri taluk and Radhapuram taluk of Nambiyar river basin, the On farm development works and Rotational water supply scheme works have been carried out to the cost of Rs.18.58 lakhs and the area benefited is 401 ha.

Under Western Ghats Development Programme, the various soil conservation work like Contour Bunding, Veg. Fencing, Water Harvesting structure, major check dam, silt detention tank, Rotational Water Supply and Farm ponds etc. have been carried out in the Nanguneri and Radhapuram taluks of Nambiyar basin. The area benefited is 1324 ha.

Under Soil Conservation Scheme, Soil Conservation Works carried out by Agricultural Engineering department in Nanguneri taluk. The area benefited is 2848 ha.

CHAPTER – 13
ACTION PLAN –ECONOMIC EVALUATION AND PRIORITISATION OF PROJECTS

CHAPTER – 13

ACTION PLAN – ECONOMIC EVALUATION AND PRIORITISATION OF THE PROJECTS

13.1 INTRODUCTION

An action plan deals with the actual application of the development projects presented in Chapter 12 and of the policy, legislation and institutional measures summarized in Chapter 11.

The process of action plan formulation is described in the following sections with its application to the Nambiyar river basin.

13.2 OBJECTIVES

The objectives of a River Basin Plan and of other related State and regional Plans have to match the 10th five-year plan, which sets out the following objectives:

"Improvement of rural income and employment by promoting sustainable agricultural production, provision of basic services like drinking water and building up of infrastructures like power, transport and roads" etc.

In addition such plans should also consider environmental sustainability which go beyond the 5 years horizon.

13.3 DOMAINS OF REQUIRED ACTIONS

An action plan in this river basin will deal with the following identified options to solve the problems of strategic importance summarised in Chapters 11 & 12:

- Sustainable drinking water schemes.
- Improving the overall irrigation efficiency in stages.
- Adopting sprinkler and drip irrigation wherever possible and feasible.
- Planning effective rain water harvesting and saving surface water which is now and then let into sea during the flood.
- Conjunctive use of surface and ground water in all sectors.
- Developing less water consuming industries in drought prone areas
- Treatment & Management of Sewage and Solid wastes in the Basin

13.4 PROPOSED ACTIONS

A set of development actions / projects has been proposed to achieve the objectives of the plan.

Details on projects of the development plan as presented in Chapter 12 are summarised in Table A. These details were used to priorities and develop an action plan for project implementation. The list of projects includes

A. Formation of a Pond.

B. Formation of a Reservoir.

13.5 ECONOMIC ANALYSIS OF WATER RESOURCES AUGMENTATION PROJECTS

Different agencies carry out varying prioritising criteria and economic analysis to rank projects. But, the underlying principle behind all these is to realise good returns to their investment and/or to mitigate the loss that would occur in the absence of such projects. Benefit Cost (BC) ratio has been used time and again as one of the yard sticks for financial institutions to fund these developmental projects. However, the per ha cost of development of irrigation infrastructure and the project cost together plays a vital role in prioritising projects.

13.6 FINANCIAL REQUIREMENTS

The total investment required for implementing the actions proposed here in Nambiyar basin is about Rs. 240.95 lakhs (at 2004-05 prices) which would directly or indirectly benefit 101.03 ha in the Basin. It is presumed from discussion held with office of the Chief Engineer (Plan Formulation), WRO, PWD, that State funding for Plan schemes are very meagre when compared to the financial requirement. Further, the time overrun in projects results in cost overruns and in most cases the cost overruns are disproportionate to the time over run.

Funding for smaller projects such as tank rehabilitation etc. are now made available through the Rural Infrastructure Development Fund (RIDF) facility of National Bank for Agriculture and Rural Development (NABARD). Larger projects needs to be accommodated in Plan Schemes or Externally funded projects similar to Water Resources

Consolidation Project (WRCP). Mobilisation of more financial sources, like by privatization may accelerate the implementation of the plan. However, some of the financial resources may be linked to certain actions. Economic growth is the main concern of regular Banks and they may assign low priority to environmental protection and public health.

13.7 PRIORITISATION

A full spectrum of actions is required for achieving the objectives of the plan. However in the absence of information for economic analysis an attempt has been made to prioritize the proposed actions and development plans and to classify them into Short Term, Medium and Long Term action plans. The highest priority actions are entered into the Short Term plan.

Prioritization is done by assigning values of criteria to each one of the proposed actions and development plans, and ranking the projects accordingly. The priority criteria should reflect the different objectives as defined in 13.2 above.

The principle underlying the prioritisation of these projects are in the following order of their priority

- Lower per ha cost of development of infrastructure
- Lower investment levels
- Projects that help restore original registered Ayacut
- Projects that help recharge groundwater
- New projects wherever technical feasibility exists.

The resulting ranked lists of projects are given in Tables A, and B .

13.8 ACTION PLAN

The process of prioritisation, is often a political process rather than technical. Prioritization requires interactions with the stakeholders based on technical information provided in this report. This process is to be applied on a State level and not on river basin level and has not yet started. Therefore, the following action plan proposed is tentative and is only a starting point for the expected dialogue, between policy makers and stakeholders.

The proposed grouping of projects into Short and Long term action plans are also shown in Table A and B respectively.

The first ranking projects should be further elaborated on a feasibility study level. In such a study, the input data of all components will be further reviewed, revised, and updated.

(i) Short Term Action Plan

The short-term action plan will be a combination of selected projects: formation of tanks, excavation of channels, construction of check dams, formation of ponds, modernisation of existing tanks etc. The priority order in respect of the Nambiyar basin is shown in Table B. An expenditure of about Rs.21.95 Lakhs (at 2004-05 prices) would be required to execute these projects. The ayacut benefited is 53.03 Ha. The average investment for these projects would be Rs. 42,000 / Ha.

(ii) Medium Term Action Plan

The medium term action plan will include construction of check dams, formation of ponds, excavation of supply channels and formation of tanks etc. The cost per hectare is one lakh and above, as there is no projects in respect of the Nambiyar basin and has not been prioritized for medium term.

(iii) Long Term Action Plan

This will include the formation of reservoir across Kuruviyuthu odai in Malayadipudur village. This project is sufficiently big and cost of development work is rather high. The time gain (Time available) shall effectively be utilized to plan this project in such a way that the economic benefits realized from this project is increased considerably. Defering such project provides ample scope for introspection at a later date. The expenditure that would be necessary to implement this projects will be around Rs. 219.00 Lakhs. and the expected returns at Rs.228.00 Lakhs

Table A Cost of Proposed Development Actions in the Nambiyar Basin

Sl. No.	Name of Work	Estimate Amount in Rs. Lakhs (2004-05)	Total Ayacut Benefited in Ha	Cost (Rs.Lakhs) per Ha ayacut
A. Formation of Ponds				
1	Formation of a new Pond near Sanganapuram in KasthurirengapuramVallinayakipuram.	21.95	21.46	1.02
Total - Formation of Ponds		***21.95***	***21.46***	
B. Formation of Reservoir				
1	Formation of Reservoir across Kuruviyuthu odai in Malayadipudur village.	219.00	19.43	11.27
Grand Total		***219.00***	***19.43***	

Table B Prioritisation of Projects

Sl. No.	Name of Work	Estimate Amount in Rs. Lakhs (2004-05)	Total Ayacut Benefited in Ha	Cost Rs.Lakhs per Ha.
Short term action plan				
1	Formation of a new Pond near Sanganapuram in Kasthurirengapuram .	21.95	21.46	1.02
Short term Investment		***21.95***	***21.46***	***1.02***

Sl. No.	Name of Work	Estimate Amount in Rs. Lakhs (2004-05)	Total Ayacut Benefited in Ha	Cost (Rs.Lakhs) per Ha
Long term action plan				
1	Formation of Reservoir across Kuruviyuthu odai in Malayadipudur village.	219.00	19.43	11.27
	Long term Investment	219.00	19.43	11.27

ARTIFICIAL RECHARGE IN THE COASTAL AREA OF NAMBIYAR BASIN – PROPOSED FROM EXCESS WATER FROM TAMIRAPARANI RIVER – FLOOD CARRIER CHANNEL FROM CHOKKALINGAPURAM

INTRODUCTION:

Excavation of flood carrier channel to a length of 58.20 km from Tamiraparani to drought prone areas of Sathankulam and Tisayanvilai in Nambiyar river area was formulated by Plan Formulation wing of WRO, PWD from Kannadian channel near Kallidaikurchi, in order to recharge the coastal aquifer zones.

The capacity of this flood carrier channel will be around 1000 cusecs. Out of which 300 cusecs is proposed to be let out into Karamaniar odai (two checkdams are proposed). Further 300 cusecs is proposed to be let into Suviseshapuram channel to recharge wells. The remaining 400 cusecs will be let into Itamozhi Teri. Direct infiltration of flood water down below the Teri into the underlying weathered and fracture rock will enhance the recharge of the wells in the surrounding villages and the water level and improve the quality of water also.

The Chief Engineer (Plan Formulation) has requested the Chief Engineer & Director, Institute for Water Studies, during October 2004 to prepare an alternative economically feasible route for flood carrier Kannadian channel to Tisayanvilai, Sathankulam and Suviseshapuram surrounding areas in the coastal zone using Remote Sensing and GIS techniques. A remote sensing study in GIS environ was carried out using remotely sensed data and completed using multi layer thematic maps. The cost effective scheme namely “Remote Sensing study under GIS environ for the proposed route of flood carrier channel from Tamiraparani river” (Chokkalingapuram to Sattankulam & Tisaiyanvilai drought prone areas of Tirunelveli district) was sent to the Chief Engineer, Plan Formulation during December 2004 for further necessary action.

CONCLUSION AND RECOMMENDATION

This study was undertaken and completed using Remote Sensing Data by visual and digital interpretation methods under GIS environ.

For this study various different thematic layers such as drainage, physiography, geology, geomorphology, lineament and road network are superimposed and integrated to

generate the course of flood carrier channel map and the proposed channel route was drawn accordingly by taking care of all technical aspects.

Further all available collateral data are also integrated in evolving the cost effective best possible route for forming the flood carrier channel from the tail end of Kannadian channel to teri sand dunes in Sattankulam and Tisaiyanvilai areas of Tirunelveli district.

The floodwater reaches the bottom of teri sand and infiltrate around the wells so that the dissipation of floodwater into the aquifer will be uniform to the core by this gravity recharge method.

In hard rock terrain the lineaments are the natural subterranean interconnected network of jointed and fractured zones and these absorb water instantaneously wherever the flood carrier canal crosses. Thus the groundwater storage into the aquifer is rejuvenated.

Geophysical Resistivity Survey have to be conducted in selected specific locations at different stretches to assess the litho characteristics of sub surface formations before execution of the scheme.