

**WATER RIGHTS, PRESENT AND FUTUTRE WATER DEMAND AND
CONSEQUENCES OF WATER TRANSFER AMONG DIFFERENT SECTORS
IN LOWER BHAVANI BASIN, TAMIL NADU**

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COIMBATORE - 641003
2003**

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Thesis submitted in part fulfillment of the requirements for the degree of

Doctor of Philosophy in Agricultural Economics
to the Tamil Nadu Agricultural University, Coimbatore

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CERTIFICATE

This is to certify that the thesis entitled “**WATER RIGHTS, PRESENT AND FUTURE WATER DEMAND AND CONSEQUENCES OF WATER TRANSFER AMONG DIFFERENT SECTORS IN LOWER BHAVANI BASIN, TAMIL NADU**” submitted in part of the fulfillment of the requirements for the degree of **Doctor of Philosophy in Agricultural Economics** to the Tamil Nadu Agricultural University, Coimbatore is a record of bonafide research work carried out by **A.MALAISAMY** under my supervision and guidance and that no part of this thesis has been submitted for the award of any other degree, diploma, fellowship or other similar titles or prizes and that the work had not been published in part or full in any scientific or popular journal or magazine.

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“A mother is a mother still, the holiest thing alive”.

It is my mother god always, everything and everywhere. Overwhelmed...with the benediction of my mother.

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A.MALAISAMY

ABSTRACT

**WATER RIGHTS AND PRESENT AND FUTURE WATER DEMAND AMONG
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**Degree : Doctor of Philosophy in
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The National water policy enunciated by the Government of India in 1987 has recognized that the water is a prime natural resource, a basic human need, and a precious National asset. Water is one of the most crucial elements in the developmental planning. The State too has formulated its water Policy 1994 and the importance of growing demand for water and its sectoral distributional implications have been realized. The National and State policies provides first priority for meeting drinking water needs of the population followed by water use in agriculture and industry.

Population and economic growth in developing countries will pose serious challenges for humanity in simultaneously meeting food requirements and water demands. Competition for limited water resources increasingly occurs between different stakeholders and at different levels. Agriculture still accounts for the majority of global water withdrawals, and is often responsible for 80 percent or more of total withdrawals for consumptive uses in developing countries, but, it is likely that significant amounts of water will be reallocated from agricultural uses to higher valued domestic and industrial water demands. This study presents the results of the study undertaken in the Bhavani river basin regarding the transferring water out of agriculture and allocation among different water using sectors.

The specific objective of the study are i) to quantify the demand for and supply of water in different sectors (*viz.*, agriculture, domestic and industries) ii) to study the existing water rights in different sectors in the basin, iii) to examine the extend and nature of water transfer in different sectors, iv) to study the cost and productivity of water in different sectors, v) to work out optimal plan for water use in three sectors, vi) to study the consequences of water transfer and vii) to suggest suitable policy measures for managing the water in the basin.

Primary data collected to find out the water transfer at farm level, random sampling procedure was adopted in the study representing Head, Middle and Tail regions of canal based on the location with respect to the distance from the Bhavanisagar reservoir. From each region, 50 farmers were selected using random sampling procedure. Thus the total size of sample was 150, consisting of 50 farmers in Head region, 50 farmers in Middle region and 50 farmers in Tail region.

Total supply and demand for water of agricultural sector showed the total supply of surface water and groundwater was 1516.12 MCM and 490.85 MCM respectively. So, total basin supply of water is 2006.97 MCM. Demand for water was 3283.56 MCM in the basin. The quantity of supply and demand gap was 1276.59 MCM in agriculture sector. Demand for water was higher than supply in domestic sector. The supply and demand gap was 42.66 MCM/year in intra basin supply of water. The projected total demand thus ranges from 93.69 MCM in 2001 to about 114.12 MCM in 2021. Excess quantity of 30.03 MCM/year water supplied to Noyyal basin from Bhavani basin. Demand for water in authorized industrial sector was 39.15 MCM/year. The total industrial water requirement increase from present demands 39.15 MCM 2001-01 to 47.37 MCM in 2021.

Old ayacut farmers have riparian rights. They got water from April 15 to February 15 (10-11 months). Ayacut area and water availability of old ayacut was 16100 ha, 725.76 MCM respectively.

Farmers under Number I sluice of new ayacut were allowed to raise paddy crop from 15th August – 15th December. Number II turn sluices were given water from 16th December to 15th April but permitted to raise only irrigated dry crops. Ayacut area and water availability of new ayacut was 85056 ha, 1088.64 MCM respectively.

In water transfer, the average cost in agricultural sector of 1 KL of water was Rs.3.54 in river pumping scheme from and Rs.2.53 water pumping in farm well. Incurred cost in water sale was Rs.6.68, Rs.15, Rs.60, Rs.100 for 1000 liters for farmer, tanker, barrel and bullock operator respectively. Cost of Water in TWAD Board per 1000 liters for municipalities, town panchayats, panchayats union was Rs. 3.44., Rs. 3.24 and Rs.3.50 respectively. The water charge in industries is only Rs. 200- Rs. 500 per 1000 KL and cost of alternate supply of water (tanker) was Rs.50/KL.

In agricultural productivity, in old ayacut the productivity of water was high in sugarcane (24 kg/mm) and in new ayacut productivity of water was high in Tapioca (14.29 kg/mm) than other crops. One kg of sugarcane is equivalent to 10.26 kg of rice. The productivity of domestic sector water transfer per 1000 liters was high in bullock owner (Rs 0.27/1000 liters) and very low in agricultural farmer sell (Rs 0.01/1000 liters).

The gross income in optimum plan I of old, Turn I and Turn II of new ayacut was increased from Rs. 2328.244 million to Rs. 2414.061 million and Rs. 1277.51 million to Rs. 1459.66 million and Rs. 310.81 million to Rs. 326.561 million respectively from existing plan. The gross income declined in old ayacut from Rs. 2328.244 million to Rs. 2304.561 million, from Rs. 2328.244 in million to Rs. 2323.452 in million from existing plan to plan II and plan III respectively. For Turn I, gross income increased from Rs. 1277.51 million to Rs. 1673.940 million and from Rs. 1277.51 million to Rs. 1674.32 million from existing plan to plan II and

plan III respectively. For Turn II, gross income increased from Rs. 310.81 million to Rs. 379.32 million and from Rs. 310.81 million to Rs. 385.67 million from existing plan to plan II and plan III respectively.

Policies here, on the supply side improving the storage capacity of the reservoir, avoiding delivery losses along the river delivery system could help. On the demand side biggest gains have to come from rationalizing water use in the agricultural sector. The government has to effectively delegate the powers of appropriation and management of the water resources in the basin to local representative bodies perhaps under the framework of the enacted irrigation management legislation. Management should take care in case of authorized farm withdrawal should also be counted as ayacut area as it should not affect original ayacut area. To control this water transfer among inter-sectoral, appropriate water policies are to be formulated. Optimization exercise reveals that through reallocation of resources and appropriate combination of crops, and there exist potentials to meet the growing domestic and industrial sector water demand. future demand for non-agriculture purpose should be met from the existing supplies, LBP could be severely affected. Hence redefining the rights between old and new ayacuts is necessary.

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CHAPTER I

INTRODUCTION

Setting

In terms of water sources, India is endowed with vast water and land resources. The geographical area of India is about 329 million hectare (m.ha) with a wide range of physiographical and climatic variations. India is among the foremost countries in the world in exploiting its river water resource. India's has an excellent network of river systems, which have been categorized into 20 major river basins. There are 12 major river basins that are Inter-State in nature, with a combined catchment area of 256 m. ha, 46 medium basins of catchment sizes varying from 20 to 200 m. ha. covering an area of about 25 m. ha, and other water bodies including tanks and ponds draining a total area of 7 m. ha. The total water resources (surface and ground water) have been estimated at about 2300 Billion Cubic Meters (BCM), of which the surface water resources are estimated by the Central Water Commission as 1870 BCM, and the ground water potential assessed by the Central Ground Water Board to be about 431 BCM. The total utilizable flow is estimated as 1086 BCM (surface water 690.03 BCM and 395.6 BCM. of groundwater), of which 37 per cent surface water and 38 per cent ground water have been utilized so far.

The modern methods of water resources development had started only during 19th century under the British regime. At that time, the concept was just to provide supportive irrigation while at the same time ensuring beneficial return of service charges or revenue over the project investment. Systematic water resources development works have been carried out through successive Five-Year Plans that followed since 1951. In the last nearly five decades, a large number of water resource projects for irrigation, power generation, drinking water, industrial uses, civic supplies etc., have been implemented, and several others are under construction or under consideration around country. The number of large dams constructed including those under construction has gone up from 300 to 4300 in the last 5 decades. (Ninth Five year Plan, 1997-2002).

The main water consumers are agriculture, households and industry. On the assessment of the availability and requirement of water for various sectors in the country have estimated (1248.63 BCM in 2025) of which the largest demand for water is from the agricultural sector i.e., 520 BCM (78.5%) by 2000, 909 BCM (72.8%) by 2025 and 1072 BCM (64.7%) by 2050. (Indian Water Resources Society, (IWRS), 2000)

Supply-Demand Gap for Water

The increasing demand over supply of water, the worked out supply-demand gap based on the growth rates of irrigated crops is 2.12 m.ha.m (44.72 per cent). The gap based on National Commission on Agriculture's estimate is 0.48 m.ha.m. (10.12 per cent) (Palanisami, Paramasivam and Rajagopal, 1990). In India, average food grain consumption at present (1999 estimate) is 550 gram per capita per day whereas the corresponding figures in China and USA are 980 g and 2850 g respectively. Present annual requirement on the basis of present consumption level (550 g) for the country is about 200 million tonnes (MT). A moderate rise in consumption level of 750 g per capita per day is considered to be realistic for assessment of future needs. The annual food grain requirement of the country thus works out to be 450 MT by the year 2050. The real challenge is providing additional irrigation water to increase food production while satisfying the rising demand for water from other competing sectors. Since irrigation sector being the largest consumer of water, greater attention in water management is needed in this sector. That is, almost all the utilizable potential will have to be harnessed to meet the demand for agriculture, industry, energy generation and domestic consumption. Even among the user sectors, the consumption of water in India is highly skewed. (Ministry of Water Resources, Govt. of India, in 1998).

The National Water Policy (2002) gives overriding priority to drinking water over other uses. The policy states that all water resources development projects should invariably include a drinking water component. Wherever there are no alternative sources of drinking water, needs of human beings and animals should be the first priority of any available water.

Theoretically, only the consumptive use can be taken as urban requirement. It is generally accepted that consumptive use should be only about 20 per cent of the gross demand. The demands of mega cities, metropolitan cities and smaller urban agglomerations differ. However, taking an average of 200 liters per capita per day (lpcd), the urban demand for water for population of 1000 million (2002 estimate) would be 73.17 BCM of which consumptive use should only be 14.63 BCM (20%). A quantity of 14.63 BCM is too small compared to the total potential to pose any problem of supply. Losses between source and treatment plant, in the distribution system, at the domestic level and above all lack of wastewater management put the demand as a high of 60 BCM instead of the low 14.63 BCM, the minimum need (Ministry of Water Resources, 2000).

It is estimated that by 2050, India's population would be around 1.64 billion and 50 per cent of them would live in rural areas. Domestic water demand of this 820 Million (M) rural population (taking into consideration ever increasing aspirations for more water including piped water supply system even in rural areas) shall be at the rate of 100 liters per capita per day. As such the rural drinking water demand by 2050 shall be 29 BCM per year, whereas the present (1998 estimate) drinking requirement at the rate of 40 lpcd is 10 BCM. (Census of India, 2001).

Demand for Water in Tamil Nadu

Tamil Nadu specifically, has a geographical area of 130069 km² divided into 17 river basins. The average annual rainfall of the State is 945 mm.

In Tamil Nadu in terms of water sources, there are about 60 reservoirs irrigating about 1 Mha. There are 39,000 irrigation tanks having a command area of about 0.8 M ha. More than 1.6 M wells are available irrigating about 1.2 Mha. The recent estimate had indicated that the utilizable groundwater recharge will be about 2.24 MHM. Thus, in any case the total water potential of Tamil Nadu would be about 4.74 MHM i.e., 2.50 MHM from surface water and 2.24 MHM from groundwater sources. (Working Group on the Estimation of Groundwater Resource, 2000). The entire surface water and more than

60 per cent of the replenishable ground water is harvested and utilized. More than 90 per cent of the water is used for agriculture and the demand is still increasing responding to the need to produce more food for the growing population. Irrigation in the State has traditionally been the largest consumer of water and continues to be so. It consumes about 85 per cent of the available water resources at present and much attention should be given on the agricultural water need, its present and future utilization pattern etc. The State's endowed irrigation potential in per capita terms only about 0.08 hectare compared to all - India average of 0.17 hectare (Season and Crop Report, 2002).

At the same time, the water demand for industries and municipal purposes are also increasing every day. The domestic and industrial uses of water at present claim a share about 15 per cent in the total resources and this share is likely to be about 25 per cent in the year 2025 AD with increased industrialization, urbanization and growing needs of rural areas for improved facilities for drinking water.

Limited groundwater replenishment along with heavy power cuts has characterized groundwater use during years of poor rainfall. Additionally, private exploitation of groundwater by numerous individual farmers has tended to result in the indiscriminate and unregulated proliferation of wells and, consequently, a decreased water table in several regions of the State. Since the available water supply is constant, it has to be shared by various users in an optimal way and this has assumed very significance at present in the state (Indian Water Resources Society, (IWRS), 2000). However, with the growth of population, improved economy, increased urbanization, high degree of industrialization and most importantly the need for sustainable environmental and ecological management, there is multiple and serious competition for water from high value non-agriculture sectors. Therefore, the rapidly growing urban and industrial water demands will need to be met increasingly from water transfers out of irrigated agriculture. This inter-sectoral transfer of water is now one of the major water issues in Tamil Nadu.

The Bhavani Basin is one of the important basins in the State both in terms of agricultural and industrial development, intersectoral water transfer are prevalent

in a large scale in urban and rural/industrial use. In addition, as urban areas and non-agricultural economy grow, water is allocated to high value; generally non-agricultural uses through water transfer and the consequences of such transfer are still fully not studied.

Problem Focus

Water being a limited resource, its efficient use is very vital and basic to the very survival of the ever-increasing population. Every effort must be made for the best use of available water so as to make possible a high level of continuous production per unit volume of water, per unit area of cropped land and per unit time. Water is a precious commodity that will become even more valuable as time goes by. Hence great emphasis is to be given for efficient use of this scarce resource but valuable resource especially in the command areas of the irrigation projects in order to reap the benefits offered by the technological innovations in farming.

The principle sources of irrigation in Tamil Nadu are canals, wells and tanks. Because large areas of Tamil Nadu are relatively arid, mechanisms for allocating scarce water are critically important to the welfare of the country's citizens. Water contributes to welfare in several ways: health, agriculture and industry (e.g., hydroelectric power). Transferring water from rural agricultural use to drinking and industrial uses of urban area affects not only agricultural but it also affects rural domestic use, livestock, fishing and other enterprises requirements.

Most discussion and evaluation of intersectoral transfer have focused on technical/ economic efficiency; much less attention has been given to equity, landscape and livelihood consequences for farmers and other groups in the rural areas. The aim of providing optimum water and ensuring equity in distribution of water to all the beneficiaries of the canal irrigation system has not been given due recognition. Policy makers require answers to questions related to the cost and benefit structure of water transfer, its productivity from agriculture to industrial use its related impacts from agriculture to industrial use and design incentive structure that makes water conservation

and management measures more attractive. An important task is to appraise the actual extent and nature of water transfer from agriculture to urban/industrial uses, optimize water among different sectors its related impacts. This is possible only if an appropriate assessment framework and tools are available that allow for the identification, quantification and nature of water transfer from agriculture to urban/industrial use. The proposed study was taken up in Bhavani Basin where water transfer has been an increasing phenomenon over years. The study will examine the institutional and legal arrangements for taking water out of agriculture, the types of water rights that are recognized in the process and assess the productivity of water transfer ,optimize water among different sectors and assess the impact of transfers for equity, landscape and livelihood.

Hypotheses

The above background has led to the following hypotheses

1. Demand and supply gap of water exists in different sectors and potentially increasing in future.
2. Productivity of water increases in alternate uses.
3. Present pattern of water use leaves much scope to meet out different sectors water demand through optimal use of water.
4. Water transfer results in shift in agricultural cropping pattern, labour employment and migration

Objectives

The overall objective of the present study is to optimize water among different sectors. More specifically, this study aims;

1. to quantify the demand for and supply of water in different sectors, (viz., agriculture, domestic and industries)
2. to study the existing water rights in different sectors in the basin,
3. to examine the extent and nature of water transfer in different sectors,

4. to study the cost and productivity of water in different sectors,
5. to work out optimal plan for water use in three sectors,
6. to study the consequences of taking water transfer from agriculture sector, and
7. to suggest suitable policy measures for managing the water in the basin.

Scope of the Study

Though several studies have been taken up in the past to identify and delineate the problem of water exploitation, studies specifically focusing on the optimization of water use and water transfer from one sector to other sector and, its implications and corrective measures. Comprehensive reforms are required to improve the incentives at each level of the water allocation process in order to improve the efficiency of agricultural water use and sustain crop yields and output growth to meet the rising food demand while allowing transfers of water out of agriculture. Institutional and legal environment reforms must empower water users to make their own decisions regarding their resource use, while at the same time providing a structure that reveals the real scarcity value of water. Hence, an attempt has been made in the present study to identify and evaluate water transfer using field level evidences. In addition, the present study is an attempt to provide a basis to estimate the productivity of water in different sectors. This will be useful for policy makers and future researchers in water economics to derive and apply optimal water allocation and management norms among different sectors.

Limitations of the Study

The study is primarily based on the field level data collected through interviews and discussions with the officials and farmers. Hence, the usual limitations resulting from the recall bias of the farmers apply to this study as well. A key limitation (or) problem is the high degree of interconnectedness within and between ecosystem and the lack of knowledge about the true nature of economy-environment interaction. This study was done in a specific agro-climatic region and hence, adequate care should be taken to apply this optimizing method for other areas.

In spite of these limitations, the study could serve as a basic quantitative and methodological contribution. Data inputs can not be based solely on proxy estimate and more effort has to be made in identifying problems and quantifying into monetary values.

Organization of the Thesis

Presentation of the thesis is organized under the following six chapters:

- Chapter I : **Introduction:** Setting, problem focus, hypotheses, objectives, scope and limitations of the study are dealt with.
- Chapter II : **Concept and Review:** Concepts and methodologies used in the earlier studies and the methodologies and policies related to current study are reviewed.
- Chapter III : **Design of the study:** Sampling design, methods of collection of data and methods of analysis are described.
- Chapter IV : **Description of study area:** Demographic and agro-climatic features of the sample districts and the taluks are described.
- Chapter V : **Results and Discussion:** Results of the analyses are presented, discussed and drawn the inferences.
- Chapter VI : **Summary and Conclusion:** Salient findings are summarized, conclusion is drawn and policy measures are suggested.

CHAPTER II

CONCEPTS AND REVIEW

A detailed review of literature relevant to the present study is presented in this chapter. Various concepts and issues – both theoretical as well as empirical – relating to water rights, water transfer from agriculture to urban uses, water markets, water pricing and its productivity, inter sectoral demand for water and optimization of water are discussed. The review is organized under the following seven sections:

2.1. Regulation of water allocation among different sectors

2.2. Water rights

2.3. Water market

2.4. Determinants of water over-development

2.5. Cost and productivity of water

2.6. Consequences of water transfer from agricultural sector

2.7. Analytical tools

2.1. Regulation of Water Allocation Among Different Uses

Groundwater development has been growing at an exponential rate in recent years due to increasing demand for good quality water among different sectors. In addition to governmental support for groundwater development, private investment has been substantial. Competition between agriculture and domestic water users is growing. Competition is not just an issue of availability. The broad array of problems, uses and impacts, approaches to groundwater management need to be integrated. In this view many past studies were reviewed and presented below.

Palanisami and Murali (1995) inferred that non-agricultural demand would increase by 100 per cent in another 5 years and 160 per cent in another 10 years. The demand would increase by 320 per cent within the next two decades indicated the importance of sharing the common water resources between the agriculture and non-agriculture sectors. Since the Bhavani river sector of the basin had the riparian rights, the rice area would not be affected much in spite of the growth non-agriculture demand. However, area under semi-irrigated crops would be drastically reduced particularly in the second season under the Lower Bhavani sector. The second season might be abandoned from 2010 onwards to accommodate the increasing non-agriculture demand. Productivity of water in non-agriculture sector would be about Rs.80 millions to Rs.68 millions in agriculture sector.

Wijdemans (1995) indicated that competition between agricultural and domestic water users was growing. Overdraft in the Jaipur area was also a potential source of tension. In Gujarat, groundwater extraction for agricultural uses was increasing rapidly in aquifers developed to supply 200-kilometer long rural water supply schemes constructed

by the Indo-Dutch project. Rapid drops in the water table and associated increases in fluoride threaten the rural projects. Similar issues were presenting adjacent to urban areas in Rajasthan.

Reddy (1996) argued that integrated ecological approaches were required rather than legislature or technical controls. Tanks, which were sources for groundwater recharge have to be rehabilitated, sinking of bore wells even with private funds has to be regulated. Peoples' participation's required to control the number of wells, area to be irrigated and distance between the wells, and to achieve all this, author suggested the declaration of groundwater as a common property.

Vohra (1996) insisted that the exploitation of groundwater should be controlled to ensure that withdrawals do not exceeded sustainable limits – the CGWB and state government water boards should be vested with the necessary administrative and legal powers to achieve this end and also suitably strengthened.

In the proposed study would analyze the needs and opportunities for the solutions to allocation problems. In addition, as urban areas and the non-agricultural economy grows, mechanisms must be found to ensure that water is allocated to high value, generally non-agricultural uses. Access to water can be a major tool for poverty alleviation and economic development in rural areas. There is a large social value in increasing rural agricultural incomes and slowing migration of the poor to urban areas. Re-allocation must therefore, not be at the expense of maintaining a viable agricultural economy.

2.2. Water Rights

Water rights in India are currently tied users. Especially, in the case of groundwater, land ownership currently possesses rights. Individual landowners have the right to construct wells in whatever manner they desire and extract as much groundwater as they can. It is clear that debates over water law and regulation would necessary to

solve the problem at the earliest. In this direction to explore alternatives for appropriate water management some of the water rights concepts were reviewed and discussed in detail.

Sinha and Sharma (1987) studied and expressed that under common law in India, groundwater extraction rights were belongings to land. Extraction of percolating waters with no limit on quantity was the right of every landowner. Water rights cannot be transferred to other users except by transferring the dominant heritage – the land. These statutory rights reflect customary practice. Landowners generally regard wells as their own and view others, including the government, as having no right to restrict or otherwise control their "right" to extract water. Furthermore, with water rights tied intimately to land, there has been no opportunity to develop water markets beyond those in which individual landowners sell water adjacent agricultural users or, on more limited basis, to neighboring towns and urban centers.

Rosegrant and Binswanger (1994) indicated that establishment of tradable water rights could play an important role in improving the efficiency, equity and sustainability of water use in developing countries. Well defined tradable rights formalize and secure the existing water rights held by water users; economizing the transaction costs; induce water users to consider the full opportunity cost of water, and provide incentives for water users to internalize and reduce many of the non-negative externalities inherent in irrigation. The institutional requirements, potential and feasibility of developing markets in tradable water rights should receive increased attention from researchers and policy makers.

Hsiao ChingKai (1997) stated that different water users and sectors increasingly compete for limited water supplies in Taiwan and that water resources should be used more efficiently. This study constructed a framework to evaluate the feasibility of making the transition from water rights to water markets, and makes some recommendations on how existing water policies and laws could be modified to better define such rights in order to facilitate water transfers. The analytical result showed that the transition to water markets can be facilitated by low transaction costs, by elastic demand for products. It was

noted that the government has a role in administering water transfers and water rights due to the return-flow aspects of the water.

Moench (1998) stated that to identify a social basis for groundwater rights reforms in India, identifying governance structures capable of ensuring that stakeholder values were reflected in the water allocation decision-making process was imperative. This study considered the philosophical divides between the treatment of water as a commodity versus a common ownership. Customary and statutory rights structures governing groundwater and surface water in India were discussed followed by current debates over reforms. Thoughts towards new rights and governance structure drawing on key features in existing practice were outlined. Concluded that governance structures must be designed to create a balance of power in water use decision between private (either individual or group) right holders and common rights that reflect the common ownership nature of water resources.

In the present study, groundwater rights was defined as an owner of the water who decides whether transfers to non-agricultural uses or use it for agricultural use. In India inadequate effective rules and regulation to manage the groundwater resources are the cause for the degradation and to overcome this, measures such as artificial recharge of groundwater and conservation through economic water use will have to be ensured on sustainability in use.

2.3. Water Market

A growing threat to groundwater supplies is degradation of quality. The slow movement of groundwater relative to surface water ensures that groundwater is very much localized resources; it requires effective means for protection of the resource. Here to examine how groundwater marketing is serving the areas of success as well as that warranted effective improvement over the existing. Here related concepts and approaches were reviewed and presented.

Griffin and Boadu (1992) studied the surface water marketing as it was conducted in Texas, USA, was identified areas of success as well as those meriting

improvement. Surface water markets have assisted the state in responding to changed conditions. There was need for policy to repair the deficiencies of existing institutions. Concerned with the extension of market policy to groundwater management. It was argued that the absolute ownership doctrine employed for Texas groundwater should be removed in favour of a market oriented groundwater derived from surface water law and experience. Recommendations for modifying both surface water and groundwater law were offered.

According to Janakarajan (1994), there existed as part of inter-linked factor markets and tend to become instruments of "power and accumulation". In the absence of control over-extraction, informal could encourage groundwater overdraft.

In a different context, Saleth (1994) attributed the problem of groundwater over-exploitation neither to groundwater market nor to private exploitation *per se* but to the *de facto* water rights system within which users' operates. Private exploitation, either with or without groundwater market, leads to overexploitation essentially because there were no legally set and enforced limits for both individuals and collective water withdrawals. Consequently, the current system provided a wrong incentive for competitive water withdrawals.

Saleth (1994) indicated that superficial efficiency and equity benefits, a number of research studies have projected the groundwater markets as an alternative institutional option for better groundwater utilization and management. Such an euphoric projection however missed the legal vacuum within which the currently observed water markets operated but also users' fundamental negative ecological, equity, and efficiency effects. Taking fresh look at the water marketing activities from a legal, ethical, and institutional perspective, this paper tried to understand the current legal regimes governing groundwater resources in India, water markets are: (i) Extralegal and inconsistent with any ethically grounded equity notions, (ii) instruments of rent-seeking behaviour contributing to widespread aquifer depletion and (iii) Transitional as rental markets for irrigation assets (i.e., wells/pump sets) emerge when water marketing ceases with the dissipation of the Ricardian rent due to intense competition among water sellers. Finally,

the study identified the legal and institutional conditions under which groundwater markets could have their maximum efficiency and equity benefits that too without violating the sustainability requirements of the groundwater resource system.

Reddy and Barah (1995) studied the groundwater markets in Rayalaseema in Andhra Pradesh; found that the establishment of a cooperative sugar mill in a low rainfall and scarcity region has led to the depletion of groundwater resources. Since most of the farmers who enjoyed the profit from sugarcane cultivation started drilling bore-wells or in-well bores which were financed by the cooperative sugar mills.

Rosegrant *et al.*, (1995) inferred that the rapid liberalization of developing countries encourages agricultural diversification and commercialization. Prevailing water allocation methods have tended to limit the flexibility of farmers in reallocating resources in response to changing incentives. Reforms of water allocation mechanisms has been lagged behind other input sectors, largely because the physical, technological and economic characteristics of water resources pose special problems to establishment of water rights and market-based allocation of water. The study indicated the considerable evidence of sufficient physical flexibility in most irrigation systems to permit crop diversification; that water allocation and crop planting choices respond to the scarcity value of water. Markets in tradable water rights could be effectively implemented with appropriate design of water law, institutions, and regulations.

Singh (1995) was of the view that the overexploitation of groundwater in arid, semi-arid, and hard rock areas was due to the existing system of lack of well-defined property rights, rapid growth in water markets, and widespread use of modern water-extracting technologies.

Easter *et al.*, (1999) stated that countries facing water shortages should consider water marketing as a way to reallocate water resources. It reviewed the conditions necessary to establish successful water markets, discusses the gains from water markets and organizational constraints, identifies potential problems and offers mitigating strategies. It also used examples of several informal and formal water markets (India, Pakistan, USA, Canada, Chile, and Spain) already in operation to illustrate these

problems and the solutions to them. The evidence indicated that appropriately designed water markets, supported by sound institutions, are an effective mechanism for reallocating scarce water within or between sectors (agriculture, urban, industrial uses).

In the present study it could be concluded that water is completely amenable to market allocation, but through potentially for extending market principals to groundwater is evaluated. Because groundwater management is particularly problematic for the hard rock areas, since the present study is taken up in these areas, extra attention is emphasized.

2.4. Determinants of Water Transfer Over-Development

Goals and the criteria against which the social desirability of present development patterns of groundwater could be measured are important. Under the sustainable yield approach followed in India, over exploitation was typically recognized when long term water table declined or water balance estimates suggest that extraction was greater than recharge. Other criteria, such as changes in water quality, seasonal fluctuations in availability, equity in access, and the economic rationality or financial viability of further development were rarely integrated in analyses of development levels.

Moench (1992) defined over-development in technical sense as the point where extraction exceeded recharge. Under the economic efficiency objectives, over-development would occur when the social cost of development exceeds the social benefits.

According to Dhawan (1995), overexploitation took the form of annual withdrawals from groundwater stock exceeded total annual replenishment or recharge of this stock from rainfall infiltration; seepage from tanks, lakes, canals and ponds.

In the present study, groundwater overexploitation was defined as a situation wherein the annual withdrawal of groundwater over a given geographical area exceeds the annual recharge into the groundwater aquifer over the same area. According to this definition, groundwater overexploitation did not mean over pumping from individual wells, since it was not possible to quantify the recharge into the aquifer in individual

wells. It could be measured only over a sufficiently large area such as blocks/basins, given the fugitive and flowing nature of groundwater resources.

2.5. Cost and Productivity of Water

With growing population and limited water resources, there is an increasing need worldwide to manage water resources better. This is especially true when all or nearly all water resources in a basin are allocated to various uses. Effective strategies for obtaining more productivity while maintaining or improving the environment must be formulated. Productivity of Water (PW) can either be related to the physical mass of production or the economic value of produce per unit volume of water. Water accounting is a procedure for analyzing the uses, depletion, and productivity of water in a water basin context. It is a supporting methodology useful in assessing impacts of field level agricultural interventions in the context of water basins, the performance of irrigated agriculture, and allocation of water among users in a water basin.

Heady (1952) defined productivity as the quantity of output turned out in a farm.

Battacharjee (1955) defined the term productivity to denote the output per unit of input in farm business.

Lal (1961) defined productivity as a measurable relationship between well-defined inputs and output in relation to a given period of time.

Radhakrishna (1964) defined productivity as a relationship between inputs and output in agriculture.

Saxon (1965) defined the term productivity as the physical relationship between output and input which give rise to that output.

According to Ruttan (1968), the measure of productivity or efficiency of a particular activity is an evaluation of the output of the activity in relation to the total set of inputs or cost elements required to achieve the objectives.

Anbalagan (1977) defined productivity as net output per unit, the unit being hectare of land or a man day of labour or a rupee of investment.

Korgonkar (1977) defined the term productivity as the ratio of output to inputs.

Singh (1980) defined productivity as the output flow per unit of resource input.

According to Allan Gowan (1980), productivity measures the efficiency with which the inputs are transformed into output.

Sagar and Ray (1985) observed that agricultural productivity of an area or region may be referred to as the outcome of factors like soil productivity, climatic conditions, level of technology and utilization of resources.

Molden (1997) stated that productivity of water can be measured against gross or net inflow. Productivity of water (inflow) is productivity divided by net inflow. For an irrigated service area, these are external indicator of system performance relating the output of irrigated agriculture to its main input, water.

Aiken and Stockton (2001) stated that available soil water can limit sunflower productivity by direct effects on canopy function, as well as indirect effects on canopy and seed development. Supplemental water treatments were applied to sunflower during vegetative, reproductive, or both growth stages. Seed yields ranged from 2100 to 2700 lbs/a in 2000, and were reduced by 38% in 2001. Reduced yields in 2001 are attributed to severe sunflower moth infestation (24% reduction) and inadequate irrigation amounts (14% reduction). Crop water use appears to be limited by available soil water when relative soil water (in the wettest soil layer) is less than 60% of water holding capacity. Available water affects crop canopy development as well. Results from related studies suggest control of insect pests is required to achieve yield potential of supplemental water for improved water use.

Droogers (2001) stated with the increasing scarcity of water and the need for real water saving measures a clear understanding of the productivity of water is essential. For a basin in western Turkey, simulation modeling at three different scales, field, irrigation scheme and basin level, was performed to obtain all terms of the water balance. These water balances were used to calculate the Productivity of Water (P_W) at the three levels.

The four P_w s considered were: $P_{W_{irrigated}}$ (yield / irrigation), $P_{W_{inflow}}$ (yield / net inflow), $P_{W_{depleted}}$ (productivity / depletion), and $P_{W_{process}}$ (productivity / process depletion), all expressed in kg yield per m³ water.

Geoff (2001) showed that values of yield and P_w irrigated distributed across the SRB irrigation scheme for a dry year (1989) and a wet year (1995). The yields showed much spatial variation, with high values in areas that are dominated by maize/ wheat and low values in areas with a high percentage of uncropped areas. Yields were lower in 1989 as a consequence of the lower irrigation inputs, although the maize/wheat areas suffered to a lesser extent from the drought, as the wheat was not irrigated. Also, the grapes suffered less from the drought as the deeper roots induced a higher capillary rise from the groundwater. Differences in the P_w irrigated between the 2 years were very high, with areal average values for P_w irrigated of 1.11 kg m⁻³ and 0.76 kg m⁻³ for 1989 and 1995, respectively. The lower values in 1995 occurred despite higher yields as a result of substantially higher irrigation inputs. Again, areas with a higher percentage of grapes and maize/wheat show higher P_w irrigated values.

Two cotton fields were considered at the field scale and it was found that the more upstream field performed better than the field at the tail -end. This was mainly the result of the location of the two fields: upstream vs. downstream. At the irrigation scheme level P_w irrigated was higher than at the individual cotton field level, since non-irrigated crops were also included. Other P_w values were lower as crops more sensitive to drought were also found in the irrigated areas. Basin scales P_{ws} are lower than those at the irrigation scheme, as large areas of the basin were covered with less productive land types. It is concluded that P_w indicators are useful to represent water dynamics with clearly understandable numbers, and that simulation models can be helpful in estimating these indicators.

Herve (2001) stated that agriculture is not seen to be making beneficial use of water.

He computed that water productivity for different uses and support services. For

Paper/pulp industry PW was 84 Rands/m³, Mining 106 Rands/m³, Citrus 2.78 Rands/m³ and Irrigated Sugar small growers 0.65 Rands/m³

Perry (2001) has made extensive studies of the gross value of water per unit of water applied and per unit of water diverted and consumed. These values range from \$0.03 per m³ for rice (water applied) to \$0.50 per m³ (water consumed) for vegetables and fruits. Typical gross values per unit of water consumed range from \$0.10 per m³ to \$0.20 per m³, and these values compare well with data from Zayandeh Rud for a range of crops, which was based on the crop budgets and the calculated water requirements for the area. He used here, local prices have been used, which appear to be somewhat below world prices.

Murray (2003) was conducted study for productivity of water in the head, middle and tail reaches of the basin. This analysis could be the focus was on the productivity of the three major crops (cotton, wheat and rice). Yields of cotton average around 2.9 t/ha, generally higher in the upper parts of the basin, and decline towards the tail (table 5). Wheat yields are very similar. They average 2.8 t/ha throughout the basin. In the tail reach (Kzylorda) 100 percent of the irrigated area is moderately or highly saline. In the upper each (Osh and Djalalabad) only 2.3-5.0 percent of the irrigated land is saline. Rice yields in Kzylorda average 4.3 t/ha. Other provinces grow little or no rice and comparison is meaningless. From the perspective of unit location within a province there are no significant differences in rice.

In the present study, the output of crop per hectare of land per unit of water has been considered as productivity.

2.6. Consequences of water transfer from agriculture to non-agricultural uses

Water transfers had become a recent concept and increased in importance as a way to solve the growing water demands in non-agricultural uses. In general, water was transferred from areas of surplus to areas of shortage as well as with less economic use to

more economic use. There were lot of economic and environmental issues due to water transfer that need a detailed review the cause and effect and the regulatory mechanisms for allocation of scarce resource among different uses.

Colby (1990) studied water laws evolved to protect those who divert water for off-stream uses such as mining and agriculture, granting property rights in water for these early uses. Historically, the primary concern in evaluating proposed water transfers has been protection of water right holders. Broader access to property rights in water and to the transfer approval process can allow a wider array of externalities to be considered and will make water transfers more expensive than previously. There is chance of affecting the more important values by water transfer. High, Policy Induced Transaction Costs (PITC) reflect the substantial and multiple economic benefits associated with water in various uses, benefits that can be impaired by a transfer. PITC are high in areas where new water supplies are locally unavailable and expensive to import, demand for water is increasing and water rights are valuable property. PITC are lower in states and in river basins where unclaimed water is still available, there is a less pressure for transfers and water rights are in lower value. Transaction costs generated by state policies are a reasonable means to account for social costs of water transfer given the immense centralized information requirements for an optimal tax on transfers. The present institutional structure gives affected parties, each weighing their own costs and benefits, an incentive to generate information on transfer impacts and to negotiate transfer conditions and mitigation of externalities. State water transfer criteria are not arbitrary hindrances imposed upon the market place. These policies protect existing investments by water right holders, and as they can reflect public good values affected by water use and transfer.

Charney and Woodard (1990) studied the impact of rural-to-urban transfers that result in loss of irrigated agricultural did not resulted in significant economic impacts when viewed from a state perspective. When viewed from country level, such impacts were substantial but not devastating. Similarly, fiscal impacts were real but not catastrophic. However, the impacts tend to be highly concentrated because the factors that make particular parcels suitable water farms could result in geographic clustering of

purchases. Therefore, if water transfers result in the levels of economic gains claimed for buyers, strong arguments could be made for mitigation and compensation. However, some of the more important potential losses associated with transfer including loss of autonomy and reduced option for future development, could be neither estimated nor compensated.

Howe, *et al.*, (1990) concluded that at the state level, none of the water transfer scenarios analyzed results in significant loss to the state agricultural or general economy. Historical transfers appear to have imposed total costs in terms of employment and personal income that would easily have been offset by cost savings and alternative expenditures in the importing urban areas. The incidence of the costs was always on the area of origin, while the benefits accrue to the area of new use. If water was transferred from agriculture to expanding uses in the same economic region, then many of the negative effects were offsets locally. Most of the time, however, transfers were occurred for uses outside the agricultural economic area. In such cases, significant compensation costs were imposed on the local economy. These effects were exacerbated by the use of sales proceeds to repay heavy farm debt.

Finally, the results thus indicated that states should not fear water transfers: transfers would not wreck basins of origin (or) state economies. However, that transitional assistance was warranted to help those parties suffering uncompensated externalities and indirect displacement by transfers. Areas of origin warrant assistance.

Moench (1992) concluded that falling water tables have some major social and economic consequences: competition between rural and urban users was growing and has resulted into conflict in some instances; it also exacerbates economic divisions among the rural communities. Poor farmers were forced to abandon irrigation as fell water tables limit access to those who could not afford to deepen wells. On a larger scale, dropping water tables increase the pumping energy needed to produce the same irrigation service. Depletion of economically accessible groundwater resources could, over the long run, represented a threat to food security; farmers who could not afford to deepen their wells were forced to return to rainfed agriculture and run a higher risk of crop failure. Falling

water tables could thus reduce crop production and increase drought exposure long before. There was significant depletion of groundwater reserves in any absolute sense.

Zhang and Hatchett (1998) stated that more than two million-acre feet (MAF) of water transferred from agriculture to urban and in stream were discussed and debated in California. Used a regional agricultural production and water transfer model to evaluate potential third party impacts of transferring one MAF of water from the Central Valley of California was evaluated. A range of impacts was estimated under three different scenarios. The base scenario showed that the adverse economic impacts in the area or origin include a 4170 net personal income loss for each acre foot of water transferred, and eight job losses for each thousand acre feet of water transferred.

Zhang *et al.*, (1999) explained the Central Valley Production and transfer Model (CVPTM) developed for the analysis of CVPIA (Central Valley Project Improvement Act) alternatives. The study focussed on CVPTM's structures and its linkages to other economic and hydrologic models. Results from a model confirmed that the CVPIA water transfer provision – allowing CVP water service contract and exchange water to be transferred – would significantly affect water transfer market in California. The transfer demands by both municipal and industrial and agricultural buyers were expected to increase due to the greater availability of less expensive CVP water closer to buying region. Central and south coast municipal and industrial users were expected to be the largest buyers under all the alternatives, followed by the municipal and industrial users in San Francisco Bay Area.

Zachariah and Rollins (1999) studied and indicated that rural-urban conflict was common in communities where tea quantity or quality of water was compromised by over extraction or contamination. This study presented an investigation into quantification of the cost of potable water using the case of the aquifer beneath Wilmot Township (Ontario, Canada). An overview of economic justification of policy decision regarding water quality management was studied.

Hearne and Easter (1997) studied the economic and financial aspects of water markets; crop budgets were used to estimate the value of water in agricultural production.

The value of water-use rights to urban water-supply companies was estimated using the avoided cost of an alternative investment in a water-storage reservoir. The analysis demonstrated that the water transfer of water-use rights did produce substantial economic gains-from-trade in both the Elqui and Limari Valley in Chile. Economic gains produced rents for both buyers and sellers. Sellers, Especially farmers growing profitable crops who buy water-use rights and individuals buying water-use rights for potable water supply, received higher rents than sellers.

Ise and Sunding (1998) indicated that the pressure was increasing to reallocate water from agriculture to the environment. In this study the performance of federal program in Nevada's Lahontan Valley under which water rights were purchased from willing sellers for environmental restoration. Based on data set combining information on growers' personal and financial characteristics with physical characteristics of their farms, a model was estimated that explained who sell their water rights to the government. Results indicated that personal characteristic; especially short-term financial constraints had a powerful influence on the sales decision. This finding suggested that the environmental agencies might wish to more actively target growers operating on poor quality soils or on the periphery of irrigation projects to attain a more efficient outcome.

Kittu (1995) argued that groundwater exploitation has been rapid due to increasing demand for water from domestic, irrigation and industrial sectors due to the advantages inherent with groundwater – dependability as a source, ease of rapid development, better quality, low capital costs and availability at the location desired.

Veltrop (1996) stated that water would be the issue for the 21st century. It is not only essential for life: it is the cornerstone of economic development, and the limiting factor on growth. But water is also a finite resource, unevenly distributed over time and space. Some areas, water scarcity already caused hunger, disease and poverty, Water resources development on the scale of river basins was necessary to avoid conflict, maintain peace and promote sustainable living conditions.

Palanisami and Flinn (1989) studied and inferred that the direct and indirect impacts of varying irrigation water supplies on yields were estimated for set of tank

irrigation systems in South India. The relationship between rice yields, water supply, production inputs, and management and quantified through a simultaneous equation model. The model captured the direct effect of varying water supplies on rice yield through the influence of moisture stress on crop growth, and indirect effects through its influence on farmer's use of complementary inputs such as fertilizer and crop management. Factors contributing to high and low on-farm rice yields were examined. In water-surplus years, sub-optimal crop management contributed about 57% to rice yield difference between low and high yielding rice farms. In water-deficit years, inadequate water supplies accounted for about 60% of the rice yield difference with poor crop management (34%) the second most important factors.

Velayutham Saravanan and Paul Appasamy (1999) studied and concluded that competition and conflict over water use between sectors, regions, and stakeholders has a long history in Tamil Nadu. Higher water demands in urban areas have been triggered by population and industrial growth. As early as the 1890s, scarcity and poor water quality in Coimbatore led inter basin transfer proposals. Difficulties in compensating users led to the rejection of several schemes for water diversion. Contamination was a problem even in the early part of the century. Proposed schemes were often rejected due to multiple factors. In addition to cost, common problems with proposed schemes included water quality, land acquisition issues, and questionable supply reliability. As early as the 1890s cost sharing was prevalent between Kerala and Tamil Nadu soon after the States were separated during state reorganization in 1956. Large-scale river water diversion for irrigation combined with contamination of available sources added to water scarcity in Tiruppur in the early 20th century. Numerous potential sources were investigated for Tiruppur water supply. People protested against delaying the implementation of water projects. Proposals for inter-basin water transfer to meet irrigation needs in Palladam and Coimbatore were made during the 1890s but rejected due to cost. The state had major role in making decisions over water allocation. Conflicts over water reflect tension between the state's claim of ultimate ownership over water resources and the perspectives of municipalities. Farmers protested against diversion of water from irrigation for municipal use as early as 1930. Water transfer represents a continuing point of tension

between agricultural and non-agricultural water users. History suggests that an effective approach to water management may be to allocate equitable shares among stakeholders.

According to the Ministry of Water Resources (1996), it could be inferred that in hard rock areas the specific capacity of wells often declines rapidly after a short period of pumping, indicating limited storage conditions. As a result, depletion often occurs on a seasonal basis even where long-term overdraft problems are not present.

The above review makes it amply clear that water transfer from one sector to another sector would cause the direct and indirect impacts on the origin of the water transfer. Definitely it is a typical case of market failure because of flow and common property nature of the resource. This is further aggravated by the demand driven factors such as less remunerative from agricultural produce, rapid urbanization and industrialization, high cost of agricultural inputs, high agricultural wage coupled with low productivity of labour etc.

2.7. Review on Analytical tools

2.7.1. Compound Growth Rate

Alagh and Sharma (1980) used linear and log linear forms to study the pattern of growth of area under different crops between 1960-61 and 1978-79 and also the nature of decelerations.

Venkataraman and Prahladachar (1980) estimated the growth rates in area, yield and output of major crops in 6 states viz., Punjab (including Haryana), Rajasthan, Uttar Pradesh, Bihar, Maharastra and Andhra Pradesh during 1950-51 to 1974-75. They also studied the impact of growth rates of crops on cropping pattern in these states.

Bhatia (1981) using time series data estimated compound growth rates of food grain crops by fitting an exponential function. He found that the growth rate of rice production in India during 1960-61 to 1978-79 was 2.05 per cent per annum against 2.64 per cent per annum during 1967-68 to 1978-79. For wheat the growth rate of production

was 7.54 and 6.02 per cent per annum respectively in long run and in the later period. The growth rate of food grains production was 2.56 per cent and 2.71 per cent respectively, during the above period.

Desai and Patel (1983) used both linear and log linear forms for deriving growth of production and linear form to estimate productivity in the western region of India.

Sawant (1983) had computed the compound growth rate of production of major food grains and non-food grains at all India level using the log linear form.

Ram (1999) used the compound growth rates (CGR) to study the diversification of cropping pattern in Orissa from 1980-81 to 1993-94 and noticed an overall departure from cereals towards pulses, oilseeds and vegetables.

Ranjith (2000) found that in general, agriculture and allied products has grown at the rate of 14 per cent, while rice and coffee had become the most promising exportable commodities with compound growth rates of 27.72 per cent and 26.55 per cent respectively, for a period from 1990-91 to 1997-98.

2.7.2. Productivity of Water

To know the efficiency of the resources used in a farm it is necessary to know the marginal product rather than the average product. The marginal product could be known if full technical relationship between output and input is known.

Israelsen and Hansen (1962) presented a theoretical analysis of input- output relation in irrigation in terms of production wherein output was that of a single crop and the production factors were land and water.

Heady and Haxem (1980) had worked out water production for different crops under varying climatic situation and with other input factors.

Flemming (1983) indicated that description of the benefit valuation for a benefit-cost analysis of a management programme for two watersheds in Nepal. Use of change in productivity approach in which actual market prices were used as a measure for valuing

the benefits of environmental improvements. In this study, physical changes in production brought about by the project were valued using market or where appropriate, shadow price for inputs and for outputs. The productivity effects of both introducing the project and of not doing so (with and without project analysis) were evaluated. Both on-site and off-site effects were included in the analysis.

Dixon *et al.*, (1994) indicated that changes in productivity was comprehensive from different perspectives. As a financial analysis, it is taken up from the vantagepoint of the individual firm, i.e. farm household. As an economic analysis the vantagepoint was whole society.

Mary (2001) used that the residual method, based on a producer-level profit maximization model, to calculate the value of irrigation water in irrigated paddy production. Under this approach, all costs of production, except water, are subtracted from the value of production. This remaining (or residual) value provides an estimate of the value of irrigation. Economic returns measured per unit of water delivered over the whole Kirindi Oya area average Rs 0.93/m³. However, economic returns per unit of delivered water in the New Area (Rs 0.62/m³) are more than doubled in the Old Area (Rs 1.41/m³). This difference reflects higher water delivery requirements needed to meet the irrigation demands of the relatively well-drained soils of the New Area. This indicates that efficiency improvements could be achieved by reallocating water from the New Area to the Old Area to achieve higher per-unit returns. These results demonstrate that the way in which water is measured influences the estimates of the economic value of water.

Molden and Sakthivadivel (2001) stated that standardized gross value of production (SGVP) was used in order to present agriculture production in monetary units. To obtain the SGVP, calculated an equivalent yield of rice for all crops in each subbasin. The equivalent yields are based on the farm-gate prices such that if 1 kg of wheat is worth 20 cents and 1 kg of rice is worth 10 cents, then 1 kg of wheat is equivalent to 2 kg of rice. Then converted the equivalent yields to a standardized gross value of production using world market prices. This allows us to draw comparisons within and between

systems where multiple crops are grown. But, to increase productivity of available supplies, the water conserved must be directed to beneficial and productive uses.

In the present study standardized gross value of production method was employed for two ayacuts to examine the relationship between the crop output and other specified variables.

2.7.3. Optimization Models for Water Resource Use

In recent years, the Economists have employed quantitative methods to solve irrigation management problems. Various analytical tools were used and a number of econometric models have been developed for this purpose. There are many optimization techniques available which have been used in planning, development and allocation of water resources besides functional analysis. They are (i) mathematical programming approach; (ii) simulation model approach, (iii) dynamic programming approach and (iv) stochastic dynamic programming approach are the popular analytical tools. Brief reviews of mathematical programming approach studies conducted in the past to optimize the water resource use are presented here.

Mathematical Programming Approach

In the recent past, programming has become the most popular approach to solve problems related to water resource optimization. This tool could handle varied and complex water resource systems, as it could cover a fairly large extent of decision space. Besides, it could simultaneously consider a number of decision variables also. In addition to the number of economic consideration, the physical and hydrological feature of the system such as soil type, expected inflow to the reservoir, the capacity of water shortage and water distribution system and number of other restrictions could also be incorporated in the model which would determine the optimal production pattern within the frame work of these constraints. It could also be designed to accommodate the required change in variables

and shift in resource constraints. To find out the optimum utilization of resources for maximization of profits, linear programming is considered an appropriate tool.

Dorfman *et al.*, (1958) defined linear programming as an analysis of problems in which linear functions of a number of variables is to be maximized when the variables are subject to a number of restraints in the form of linear inequalities.

Castle and Lindeberg (1960) used linear programming technique allocate water optimally between two agricultural regions. The linearity concept underlying the problem was that the water users in the two regions would expand their use of other inputs of production in proportion to the additional water made available to regions.

Moore (1963) divided the irrigation seasons into 12 time periods and used the water supply consisting of both surface and ground water as constraint to show how linear programming model could be used to estimate the value of water stored for irrigation purposes.

Anderson *et al.*, (1966) estimated the optimum allocation of alternative levels of available water among crops in Western Oklahoma using linear programming analysis on typical farms with different water levels.

Rogers and Smith (1970) used a regional water balance approach based on particular geohydrologic and technologic conditions as the bases for developing linear programming model for land and water allocation with 54 activities and 77 constraints. The main interaction between the surface and ground water were considered in the model.

Burt and Stauber (1971) indicated that the wider use of the programming techniques on water allocation problem.

Bernard and Nix (1973) argued that the limitations of the linear programming as an optimization tool is relaxed to a certain extent through parametric programming, dynamic programming, integer programming and quadratic programming.

Heady *et al.*, (1973) employed linear programming model to determine optimal water and land allocation and agricultural water needs in the year 2000 A.D. They concluded that the problem in United States was not water shortage for agriculture but an improved allocation of this resource.

Hiremath (1973) classified the linear programming methods that were extensively used for the analysis of water resource problems as spatial linear and dynamic linear programming models. The distinguishing features of these models lay in their conceptualization and not in term of their computational procedure once the model was formulated and the coefficients were specified.

Dudley (1974) used a linear programming model to select the best combination for given quantities of water available in summer and for inter-seasonal water allocation.

Hiller and Leberman (1974) observed that linear programming typically deals with the problems of allocation of limited resources among competing activities in the best possible way.

Tavakoli (1974) used linear programming model to obtain the optimal cropping pattern in the greater Teheran Metropolitan Area.

Condra *et al.*, (1975) developed a linear programming model for Texas high plains to adjust the crop mix or input cost according to the limitations in quantities of water available for irrigation.

Lakshminarayana *et al.*, (1977) in their study on the problems of optimal cropping pattern and water release from canals and tube wells in the Bari basin used linear programming for a water resource system consisting of canals, tube wells and drainage.

Newton (1977) reported that the regional farm linear programming model provides a valuable tool in water resource planning, because of its ability to reflect agricultural adjustments to a dynamic water situation.

Badenhop and Cash (1979) determined through linear programming the most profitable crop that could be grown in the black soils of Tungabhadra irrigation project under the alternate set of land and water use regulation that might be adopted by project officials.

Eswaramoorthy (1980) developed optimum water use pattern for Lower Bhavani Project area in Tamil Nadu taking into consideration the ground water use also. Linear programming technique was used to allocate water among competing crops and at

different time periods with monthly water budget constraints and labour constraints. He concluded that programming seemed to be the best optimization for handling water allocation problems.

Hiremath and Sirohi (1980) employed linear programming to evolve irrigation practice for optimal, inter-temporal, linear-regional and inter-crop allocation of irrigation water with the objective function of maximizing the total value output from irrigated crops.

Kaushik and Gangwar (1980) used linear programming to study the optimum utilization of irrigation water for synthetic farm situation in the Jui lift canal area.

Palanisami (1980) used linear programming model for the farms to optimize the water use at farm level for Head, Middle and Tail region under canal with well source of irrigation.

Panghal and Singh (1980) in their study to allocate water optimally among various crops grown in different canal zone in Haryana used linear programming as the analytical tool. In the first model the existing water of different canal branches was optimally allocated among different crops at the existing and improved levels of technology. In the second model water was optimally allocated among branches as well as crops simultaneously at the existing and improved levels of technology. The model in all included five major zones, 302 crop activities and 187 constraints including 60 upper bound constraints of real activities and four categories of land.

Singh and Sirohi (1980) followed linear programming technique and worked out the economic optimal pattern of distribution of available water supplies for maximizing returns to irrigation water in the command area of Upper Ganga canal in Western U.P.

Subramanian *et al.*, (1980) used linear programming model as one sector in the Recursive Adaptive Hybrid model to maximize net return from crop production subject to land and irrigation water constraints.

Duggal and Khepar (1981) used linear programming model to examine certain aspects of the capacity and operation of irrigation system comprising both of canal and tube well water supplies input and crop output relationship.

Selvarajan and Subramanian (1981) studied the economic impact of resource use optimization and water augmentation. In order to empirically estimate the effect of optimization of water resource on cropping pattern and cropping intensity and of the representative farm, four optimum plans were developed using simple linear programming techniques. They concluded that there exists ample scope for increasing farm income and employment through optimization and water augmentation.

Elumalai (1982) used linear programming technique to develop optimum cropping pattern for a portion of irrigation command area of Parambikulam Aliyar Project in Tamil Nadu for effectively utilizing water and other source.

Alvin (1984) stated that linear programming and its off shoots are the most widely used methods of operations research applied particularly in areas of resource optimization such as water.

Sharif (1989) used linear programming technique both at farm level (Head, middle, tail regions) and at regional level. The objective function of the model was to maximize net income at farm and regional level treating land, irrigation water, labor and capital as the constraints.

Subbarayan and Singh (1989) made an attempt to develop decision rule for the optimal irrigation management and cropping pattern in the Eastern Canal Command Area in Uttar Pradesh. The objective function was to maximize the net returns to fixed factors subject to physical, economic and other infrastructure constraints. On optimization the total water use in the command area was about 88 per cent of the existing utilization. Optimal allocation of water among various crops resulted in an increase of 24 per cent in net returns when compared with the existing situation.

Verma and Banga (1989) applied linear programming technique to develop optimal cropping pattern for the command area. The optimal cropping pattern in turn resulted in optimal distribution of irrigation water of the reservoir. The optimal water release pattern will utilize about 98 per cent of the water available in the reservoir. The cropping intensity will increase from about 160 per cent to 200 per cent. Net returns will increase by about 76 per cent.

Singh and Kalra (2000) concluded that optimization of water allocation and cropping pattern using a linear programming model increased farm returns by 14.96 and 30.91 per cent in Megachappar and Mitali areas respectively of Haryana state.

Application of linear programming technique in the field of water resource has been well established from the aforesaid studies. If data are obtainable, linear programming is the most suitable model when there are large numbers of processes and constraints are to be considered. Besides, it also takes into soil types, their crop adaptability, characteristics, variations in seasonal supplies of water and their demand. Other economic and institutional constraints can also be well included in the model as compared to any other optimization technique.

Considering these, the linear programming technique was made at basin level in this study and the detailed description of its analytical frame work is presented in Chapter III.

CHAPTER III DESIGN OF THE STUDY

This chapter provides a detailed outline of the methodology followed for the study. The focus of the study is to value the water transfer and optimizing water transfer on agriculture, domestic, livestock and industrial sectors. In this chapter, sampling design, selection of study area, sampling procedure followed for the selection of farms, sources of data, nature of data collected and quantitative/ statistical tools employed for analysis of data are discussed in detail

3. I. Sampling Design

In this section, choice of the study area and sampling procedure followed for selecting the farm household are outlined.

3.1.1. Selection of Study Area

Bhavani Basin in Tamil Nadu State has been purposively selected for the study in the context of its well-known history of the industrial development and particularly in the field of rayon, textiles and related industries, predominance of canal and well irrigation and water overexploitation. This basin is in the forefront of agricultural and industrial development in the entire state. Because of its historic dynamism, demand for water to industries in the basin is very high and after using the water transferred from agricultural sector in industrial production process, these industrial units let out the effluent water into river Bhavani, which leads to serious pollution problem in the downstream farms. In general, abandoning of agriculture by farmers is very common in the areas especially, farms situated near to the towns/cities and industrial locations due to large quantum of water transfer for industrial and domestic purposes which are increasing at an increasing rate. Another reason for the purposive selection of the basin is that, there has been no study on the optimizing of water transfer from agriculture to urban use and its productivity by such transfers. Following the selection of the basin, the further sampling was done in head, middle and tail end of the main canal to select the farmers.

3.1.2. Sampling Method

To find out the water transfer at farm level, random sampling procedure was adopted in the study representing Head, Middle and Tail regions of canal based on the location with respect to the distance from the Bhavanisagar reservoir. From each region, 50 farmers were selected using random sampling procedure. Thus the total size of sample was 150, consisting of 50 farmers in Head region, 50 farmers in Middle region and 50 farmers in Tail region.

Table 3.1 Region Wise Distributions of Sample Farmers

Sl. No	Region	Sample Size (Number of farmers)
1.	Head	50
2.	Middle	50
3.	Tail end	50
Total		150

Period of Study

The data collected were pertaining to the agricultural year 2001-02 and the field enquiries were made between June 2002 and June 2003.

3.2. Method of Data Collection

A reconnaissance survey for each region (Head, Middle and Tail end) was undertaken with a view to assess the nature and extent of water transfer and productivity of water by such water transfer. To collect the required information an interview schedule was prepared, pre-tested and then used.

3.2.1. Data Requirement

Personal interview method was followed for collecting the primary data to analyze the trend and intensity of water transfer and its relationship with other factors, information on water sales like quantity, number of unauthorized pumping, cost of water sales, investment made on water sales, data on asset position, income sources, cost of cultivation, reduction in irrigated area and socio-economic conditions were collected from the sample farms. Besides, the secondary data pertaining to particulars on agro-climatic features, water released, rainfall, cropping pattern, profile of industries and infrastructure facilities available in the study area were collected from the published and unpublished records available in various departments.

3.3. Methods of Data Analysis

The analyses of data were taken up with the help of different econometric models using the both primary and secondary level data to derive relevant policy options.

3.3.1. Conventional Analysis

Simple average and percentage were worked out to compare the optimum and existing plans and consequences of water transfer. To analyze the cropping pattern change, cost and productivity of water the percentage analysis was used.

3.3.2. Projection of Demand for Water in Domestic sector

Once an estimate is made of existing water drawal for domestic purposes, the next logical task is to estimate the likely growth in the future water requirement of the domestic sector. Projections are usually associated with certain assumptions and past experiences.

For projection, population data of this basin was collected from the decadal census reports. Annual population growth rates in this basin were estimated using decadal changes in the census data. The decadal changes are governed by the relationship

$$P_t^i = P_b^i (1+r)^{10}$$

where

P_t^i = Projected year population

P_b^i = Base year population

From the above relationship, the annual population growth rate was computed as

$$r^i = [P_t^i / P_b^i] - 1$$

and was used for projecting the population of the basin at different points of time in the future. With projections of population to be served by the basin water, the actual requirement was worked out assuming that the population is to be served at existing norms of 90 liters/person/day (LPCD) in rural areas and 110 liters/person/day in urban areas. The requirement of water (MCM) for any time period would be

$$R^t = [(P_t^r \times 90) + (P_t^u \times 110)] \times 365 / 0.03531 \times 10^6$$

Where

R^t is water requirement in year t in MCM,

P_t^r is the projected population in rural area and

P_t^u is projected population in urban areas in year t.

3.3.3. Analysis of Growth of Demand for Water in Industries

The existing industrial water withdrawal was estimated based on the actual water drawn by the licensed industries. The industries are usually permitted a fixed quantity of water that they can draw from the river. This represents the maximum quantity that they can draw. Actual withdrawal varied among industries and over a period of time. The licenses to draw water are granted over specific time periods and the industries are expected to renew their licenses periodically if they continue their operation and require river water.

In making future projections of industrial water requirement as a first approximation it is assumed that the existing industries will continue their operations and their drawls would grow according to past trends. The industries are assumed to have followed a pattern of compound growth trend in the past, commensurate with their business activities. Growth rates are used to measure the past performance of industrial water uses. It was used to find out the future projections of domestic and industrial water requirement.

In general, the past drawal by each industry (I_t^i) is assumed to have followed the growth path,

$$I_t^i = I_o^i (1+r)^t$$

where

I_t^i is the water drawan by the i^{th} industry in year t , which has follwed a growth rate of r , from an initial drawal of I_o^i .

The estimation proceed via regression estimation of log transformed version of the above expression

The compound growth rate was obtained for the logarithmic form of the equation as below

$$\ln I_t^i = \ln I_o^i + t \ln (1+r)$$

Then, the compound growth rate (r) was computed by using the relationship

$$r = (\text{Antilog of } b-1) \times 100$$

The compound growth rates were tested for their significance by the statistics given by

$$t = r / \text{SE}(r)$$

where,

$$\text{SE}(r) = [100b \times \text{SE}(\ln b)] / \ln e.$$

where,

b=Regression Co-efficient

e=Error term

The growth rate in water drawl calculated as above for industry at any future point gives the total industrial water requirement at that point.

3.3.4. Standardized Gross Value of Production Analysis

Increasing productivity of water in agriculture by producing more agricultural output with the same amount of available water is a key strategy for addressing water scarcity. Obtaining more crop production from the same amount of water is a means of expressing the physical productivity of water in agriculture. Productivity of water can also be related to economic or social objectives, such as obtaining more value per unit of water used. If the social objective of water resource development is targeted at eliminating poverty, water benefiting poor people by providing more jobs and income is considered more productive than water benefiting wealthier people even when the value of output produced by rich and poor is the same. Thus, a comprehensive assessment of the productivity of water requires a combined physical unit (kgmm⁻¹) and monetary unit (Rs mm⁻¹) analysis of water use.

A standardized gross value of production (SGVP) is used in order to present agriculture production in monetary units. To obtain the SGVP, an equivalent yield of rice for all crops in each ayacut was calculated. The equivalent yields are based on the farm-gate prices such that if 1 kg of sugarcane worth Rs. 20 and 1 kg of rice is worth Rs.10, then 1 kg of sugarcane is equivalent to 2 kg of rice. Then converted the equivalent yields to a standardized gross value of production using world market prices. This allows to draw comparisons within and between systems where multiple crops are grown.

$$SGVP = \left\{ \sum_{i=1}^n A_i Y_i \frac{P_i}{P_b} \right\} \times P_{world}$$

Where:

SGVP is the standardized gross value of production

Y_i is the yield of crop i

p_i is the local price of crop i

p_{world} is the value of the base crop (paddy) traded at world prices

A_i is the area cropped with crop i

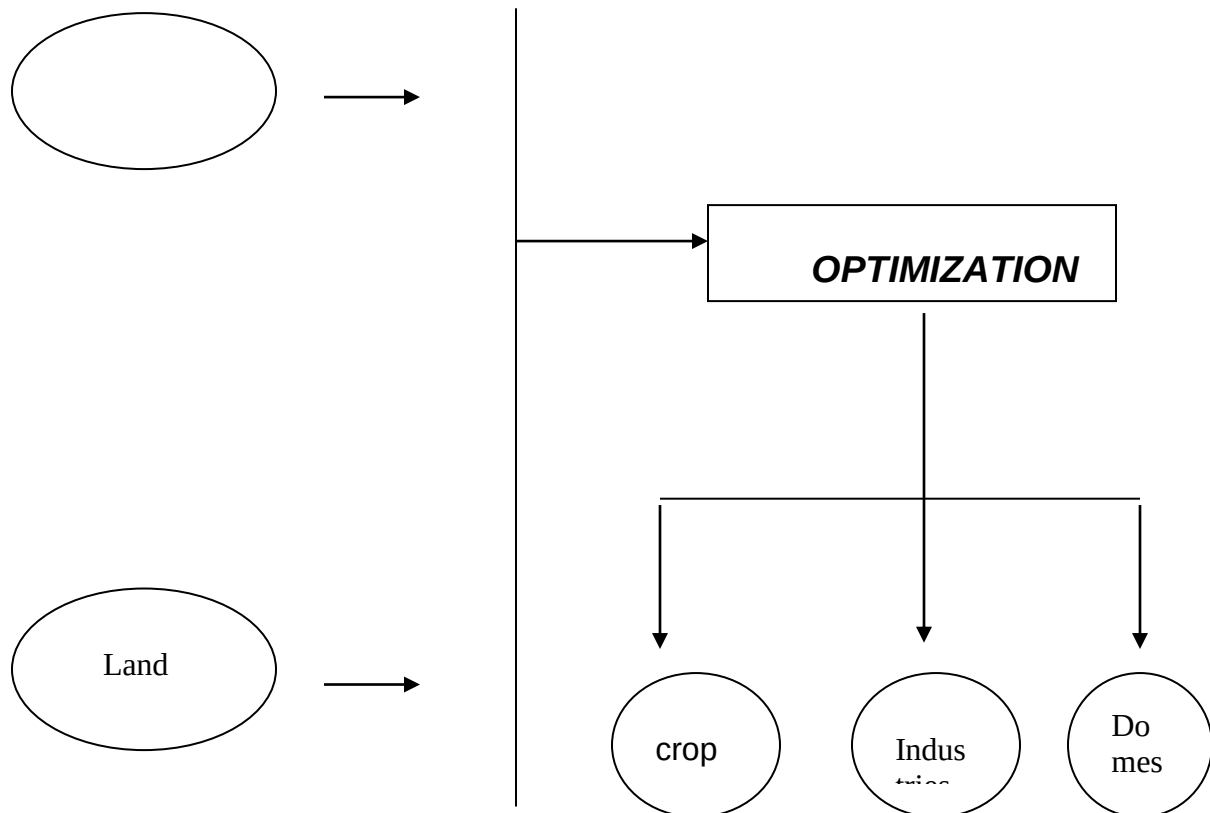
p_b is the local price of the base crop (paddy)

3.3.5. The Optimization Model

The growing water scarcity is beginning to cast its impact on the state economy. In the absence of any new known sources for supply of fresh water, greater emphasis is being laid on developing strategies and action plans to address the issues of efficient inter sectoral water allocation and management with the goal of maximizing the productivity per unit of water. To assess the direct impact of deficit in water availability due to increased demand for water and to assess the economic value of additional water for different water users, an optimization model has been formulated.

Estimation of direct and indirect impacts of increase in water demand on the economy has been assessed through an inter-related modeling process. (see diagram for a schematic of the linkages of the models)

Figure 3.5 Optimization of Water among Different Sector



It will quantify the impact of changes in water allocation on the output of sectors directly affected by water allocation, namely agricultural crop outputs (rice, cotton, sugarcane, turmeric, banana, tapioca, gingelly, coconut) and output of major industries.

The model is an integrated model covering the entire basins for intra-basin allocation of water (1) amongst alternative water using sectors and (2) amongst alternative choice variables within the individual water using sectors viz., agriculture, livestock, industry and domestic. The complexity of the decision making process has been captured in the framework of three period Linear Programming (LP) model for current and future year, 2001, 2011 and 2021.

The structure of the model emphasized the need for an economically efficient utilization of the available water by a proper evaluation of the alternative options available so as to maximize the overall economic value. This analysis will provide a basis for taking appropriate decisions on water allocation, water tariffs and investment options for water conservation and under the given constraints of availability of surface water and groundwater.

Activities

All the activities or choice variables have been defined at the basin level. In the case of agriculture sector the activities are different crops that can be grown in different crop seasons. For some of the water-intensive crops (e.g. paddy) cropping activities have been defined in such a way that the effect of reduced water input is reflected in a reduction in crop yield (reflecting a production function for crop- yield and water). All major crops grown in the basin have been included in the analysis.

In order to formulate optimum crop plan, it was necessary to select those crops, which are technically and economically feasible with respect to available resources. All the crops which are more popular among the farmers and which were popularized by the State Department of Agriculture were included in the programme. The selection was also based on factors like feasibility of growing them in different types of soils, input availability and market facilities. The unit used in defining these activities was hectare in thousand of harvested crop. The crop activities selected for the programming are given in Table 3.2.

Table 3.2 Crop Activities Selected for the Programming Model

Season	Month	Crop Selected
1.	August 15 - December 15	Paddy -I, Sugarcane, Banana, Turmeric, Coconut, Tapioca
2.	December 16 - April 15	Paddy-II, Sugarcane, Turmeric, Banana, Pulse, Groundnut, Maize, Cotton, Gingelly

3.	April 15 - August 14	Paddy -III, Cotton, Groundnut, Pulse, Gingelly
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In the case of industry, the following nine major industries included in the analysis. (see Table 3.3 for a list of industries included in the analysis).

Table 3.3 List of Industries Included for Analysis in the Basin

Sl.No	Industry	Number
1	<i>Aromatics</i>	<i>1</i>
2	Synthetic Gem	1
3	Paper	6
4	Mills	2
5	Textile	3
6	Sugar	2
7	Granite	1
8	Rayon	1
9	Distillery	1

In the case of domestic sector, separate water supply requirement for rural and urban households have been defined. The individual household connections have differences in level of supply (90 lpcd and 110 lpcd for rural and urban respectively).

Livestock sector requirement has been arrived at 40 lpcd.

Resource constraints

The important resources constraints are

1.Availability of cultivated land in each season for the basin

Land is the most important limiting factor, as it is not possible to increase the area in a particular basin in a short period by way of new purchases or leasing in. But if irrigation potential is increased, the intensity of land use can be increased. A crop grown

in a particular season in these lands was considered as a separate activity as its input coefficient and returns differed from one season to another. In the present study, the land resource was classified season wise for programming and the three seasons were:

- | | | | | |
|---------------|---|-------------|---|-------------|
| a) season I | - | August 15 | - | December 15 |
| b) season II | - | December 16 | - | April 15 |
| c) season III | - | April 15 | - | August 14 |

2. Water availability constraints for the three seasons in old and two seasons in new ayacut

This is the most important constraint, which was greatly influencing the area under the crop in the study area. Canal and tank were the sources of surface water in old and new ayacut. Canal water was available in three seasons in old ayacut and two seasons in new ayacut, since farmers were supplementing canal water with well water, constraints were given for canal and well water as a whole.

3. Constraint requiring that industrial sector must get their water demand

Industrial water demand must be met from available surface water. So, industrial water drawal from river is equal to its demand.

4. Constraint requiring that domestic sector must get a minimum amount of allocation water

Domestic sector of rural and urban population must get their water at recommendation level. So, domestic sector water supply must equal to water demand.

5. Constraint requiring that domestic sector must get a minimum amount of inter-basin allocation of water

Domestic sector's inter-basin water demand must equal to water supply.

6.Constraint requiring that livestock sector must get a minimum amount of allocation water

Livestock sector of water demand must equal to water supply.

7.Constraint requiring that optimal plan must get each crop with minimum of 25 per cent of existing area of the crop

Cropping pattern could not be changed completely at a time in an ayacut. So, the proposed plan must include each crop a minimum of 25 per cent of its existing area.

To take care of differences in water demand and supply during different seasons of the year, the year has been divided into three seasons in old and two seasons in new ayacut broadly coinciding with the crop cultivation seasons. The water requirements for all activities and water availability have been defined according to these seasons.

The Objective Function

Having defined the activities of the model and the resource availability constraints, which limit the inclusion of some of these choice variables, now define the objective function of the model. The objective function of the single period static model sets to maximize the economic value of water in alternative uses subject to given constraints.

1. Agriculture Sector

Gross Value Product

In the present study gr_{asc} denoted the gross value product per hectare of each crop activity. The gross income of each crop in each of the ayacut area was estimated by considering actual yield and price of the product.

2. Domestic Sector

The value of water is based on willingness to pay (WTP) by rural and urban households. The WTP is based on household charges with respect to household connection in rural Rs 2.25/1000 liters (Rs. 2.25 million per MCM) or Rs 3.50/1000 liters (Rs. 3.50 million per MCM) in urban areas.

3. Industries Sector

WTP by the industry has been reflected on the basis of PWD charge (Rs 500/1000m³ or Rs. 0.5 million per MCM) for water supply for the industry.

Algebraic Formulation of the Linear programming Model

The algebraic formulation of the optimization model is given Table 3.4. The activities, parameters and constraints are described below.

Table 3.4 Algebraic Formulation of the Model

Sl. No	Sector	Activities / Choice variables	Notation/ Index	Explanation
1	Agriculture	Area under crop (000 ha)	X_c	c=1,2,..13 (crops)
2	Industries	Water requirement (MCM)	I_s	s=1,2,3 season
3	Rural Population	Water requirement (MCM)	R_{as}	s=1,2,3 season a=ayacut 1,2
4	Urban Population	Water requirement (MCM)	U_{as}	s=1,2,3 season a= ayacut 1,2
5	Livestock	Water for livestock (MCM)	L_{as}	s=1,2,3 season a=ayacut 1,2
6	Inter - Basin Transfer of Reservoir Water	Transfer of reservoir water from Bhavani Basin to Noyyal Basin (MCM)	ITB_s	s=1,2,3 season
7	Reservoir Water	Utilization of reservoir water (MCM)	SWR_{as}	s=1,2,3 a= ayacut 1,2

8.	Tank Water (MCM)	Utilization of tank water (MCM)	$TSWR_{as}$	s=1,2,3 a= ayacut 1,2
9	Groundwater	Extraction of groundwater (MCM)	GW_{as}	s=1,2,3 a=ayacut 1,2

Parameters

- gr_{asc} = Gross Return from crop c in ayacut a during seasons
(in Million Rs per 1000 hectares)
- wr_s = WTP for water by household in rural area (in Million Rs/MCM)
- wu_s = WTP for water by household in urban area (in Million Rs/MCM)
- wi_s = WTP for water by industries i in season s (in Million Rs/MCM)
- cw_{asc} = Gross water requirement in MCM per 1000 ha for crop c during season s in ayacut a
- iw_s = Fresh water requirement in MCM by industries in season s
- rw_s = Rural water requirement in MCM during season s
- uw_s = Urban water requirement in MCM during season s
- l_{as} = Quantity of water required in MCM for livestock in ayacut a during season
- a_{as} = Cultivable land area available in 000 ha in ayacut a during season s
- y_{sc} = Yield of crop c (quintals/1000ha) in season s
- s_{ras} = Quantity of reservoir water in MCM available in ayacut a in season s
- s_{tas} = Quantity of tank water in MCM available in ayacut a in season s
- g_{as} = Groundwater potential available in MCM in ayacut a in season s
- t_{bs} = Amount of water transfer from Bhavani basin to Noyyal basin in season s

The objective function was to maximize the aggregate gross income from the crop activities plus domestic sector plus industrial sector subject to technical constraints and level of resource availability.

The Model

$$\text{Maximize } Z = \sum_{s=1}^3 \sum_{c=1}^{13} gr_{asc} X_{sc} + \sum_{i=1}^3 wr_s + \sum_{i=1}^3 wu_s + \sum_{i=1}^3 wi_s$$

Resource Constraints

The optimization programming problem is justified on the fact that atleast some of the resources are limited in supply. The possible major constraints that were included in the present study were land and water.

Land Constraints

Land was a constraint in all the three seasons. The area under different crops in a particular season should not exceed the available land.

$$\sum \varepsilon_{sc} X_c \leq a_{as} \quad \forall s, a \quad (1)$$

where

$$\begin{aligned} \varepsilon_{sc} &= 1 \text{ if crop } c \text{ occupies the land during season } s \text{ at ayacut } a \\ &= 0 \text{ otherwise} \end{aligned}$$

The equation explains that the area under different crops should not exceed the total available land during the season period.

Fresh Water Demand and Supply for Agriculture

For season 1

$$\sum_c cw_{asc} X_{sc} - SWR_{as} - SWT_{as} - GW_{1as} - GW_{2as} - GW_{3as} = 0 \quad (2)$$

for s=1 and $\forall a$

For season 2

$$\sum_c cw_{asc} X_{sc} - SWR_{as} - SWT_{as} - GW_{1as} - GW_{2as} - GW_{3as} = 0 \quad (3)$$

for s=2 and $\forall a$

For season 3

$$\sum_c cw_{asc} X_{sc} - SWR_{as} - SWT_{as} - GW_{1as} - GW_{2as} - GW_{3as} = 0 \quad (4)$$

c

for s=3 and $\forall a$

The equation explains that for every irrigation season 's' the total water requirement for different crop activities during each season should not exceed the water supply made available during that season.

Fresh Water Demand and Supply for Domestic Sector
For Season 1

$$\sum r w_s R_{as} - SWR_{as} - GW_{1as} - GW_{2as} - GW_{3as} = 0 \quad (5)$$

s=1

$$\sum u w_s U_{as} - SWR_{as} - GW_{1as} - GW_{2as} - GW_{3as} = 0 \quad (6)$$

s=1

For Season 2

$$\sum r w_s R_{as} - SWR_{as} - GW_{1as} - GW_{2as} - GW_{3as} = 0 \quad (7)$$

s=2

$$\sum u w_s U_{as} - SWR_{as} - GW_{1as} - GW_{2as} - GW_{3as} = 0 \quad (8)$$

s=2

For Season 3

$$\sum r w_s R_{as} - SWR_{as} - GW_{1as} - GW_{2as} - GW_{3as} = 0 \quad (9)$$

s=3

$$\sum u w_s U_{as} - SWR_{as} - GW_{1as} - GW_{2as} - GW_{3as} = 0 \quad (10)$$

s=3

Fresh Water Demand and Supply for Industrial Sector

For Season 1

$$\sum i w_s I_s - SWR_{as} - GW_{1as} - GW_{2as} - GW_{3as} = 0 \quad (11)$$

s=1

For Season 2

$$\sum i w_s I_s - SWR_{as} - GW_{1as} - GW_{2as} - GW_{3as} = 0 \quad (12)$$

s=2

For Season 3

$$\sum i w_s I_s - SWR_{as} - GW_{1as} - GW_{2as} - GW_{3as} = 0 \quad (13)$$

s=3

Fresh Water Demand and Supply for Livestock Sector

For Season 1

$$L_{as} - SWR_{as} - GW_{1as} - GW_{2as} - GW_{3as} = 0 \quad (14)$$

s=1

For Season 2

$$L_{as} - SWR_{as} - GW_{1as} - GW_{2as} - GW_{3as} = 0 \quad (15)$$

s=2

For Season 3

$$L_{as} - SWR_{as} - GW_{1as} - GW_{2as} - GW_{3as} = 0 \quad (16)$$

s=3

$$L_{as} = l_{as}$$

Surface Water Availability

The surface water availability constraint for each season requires that the sum of surface water used in all the production activities (agriculture, domestic, and industry) plus the surface water transferred to season 2 plus surface water transferred (out) to the basin to other basin (Noyyal) should be less than or equal to given amount of surface water. A similar explanation holds for season 2 and 3.

$$SWR_{as} + TSWR_{as} + ITB_s \leq sr_{as} \quad (17)$$

s=1,2,3 for a = old ayacut

s = 1,2 for a = new ayacut

Tank Water Availability

$$SWT_{as} \leq st_{as} \text{ for all } a \text{ and } s \quad (18)$$

Groundwater Availability

$$g_a = g_{as} \quad \forall a \quad (19)$$

Limits on Groundwater Extraction

In first season, canal water supplement with rainwater to irrigate the ayacut. There is less dependence on groundwater source to irrigate in this season. In second season, there is no rain, as a result groundwater extraction is more. Hence the assumption is 30 per cent of ground water used in season I and remaining 70 percent used in season II.

$$g_{as} = 0.3 g_a \quad s = 1$$

$$g_{as} = 0.7 g_a \quad s = 2$$

Input Coefficient

The coefficients of the crop activities in the constraint equation were referred to as input coefficient. The input coefficients in the technological matrix are the resource requirements (water) per unit of the process and activity (domestic and industries) included in the programme. For the enterprises that were being adopted in the representative farm, the input coefficients were computed from the data collected. The input coefficients were obtained separately for the old and new ayacut.

Gross Value product

In the present study gr_{asc} denoted the gross value product per hectare of each crop activity of each ayacut. The gross value of product was estimated by actual yield and price of the product.

Resource Availability

Assessing the quantity of the resource available and the requirement of resource for each crop activity is a pre-requisite for identifying the restrictive resource. This constitutes the resource vector of the program. For the present analysis, the resource availability in the command area was estimated from the surveyed primary and secondary data.

Programming Situations

Programming was first done with the existing resources only. Once an estimate is made of existing water drawl for domestic purposes, the next logical task is to estimate the likely growth in the future water requirement of the domestic sector. Since the urban demand will be expanding due to government priority for drinking water, it is necessary to project the future demands. Every year, water availability of the basin is changed. For future optimum plan year 2011 and 2021 to capture the effect of possible fluctuations in resource availability of water, three-year (i.e., 1999-2000, 2000-01 and 2001-02) average water supply was taken and model was estimated with this average quantity of water to manage domestic and industrial demand for water requirement expanding.

CHAPTER IV

DESCRIPTION OF THE STUDY AREA

An understanding of the location, physiography, hydro-ecology, agriculture and socio-economic aspects of the study area would facilitate the proper conduct of the study as well as analysis and drawing inferences. Such an understanding will help in locating the distinct and basin nature of the geographical and socio-economic aspects of the districts and basin and their interrelationships in contrast to the other parts of the state. Therefore, this chapter provides a brief profile of the natural endowments, topography and physiography, water resources and infrastructural facilities available in the study area of Coimbatore and Erode districts of the basin area.

Location

The Cauvery is the single largest river basin in Tamil Nadu, which is spread over three states. Total area of the basin is 81155 sq.km of which 54% of the area is located in Tamil Nadu, 42% in Karnataka and 4% in Kerala. Cauvery basin within Tamil Nadu occupies 34% of geographical area of the State. The Cauvery river system consists of 21 principal tributaries each with a catchment area exceeding 250 sq.km.

One of the major tributaries of Cauvery river within Tamil Nadu is Bhavani River. The other major tributaries within Tamil Nadu are Noyyal and Amaravathi. The Bhavani is the fourth largest and second longest tributary of Cauvery river. From the point of view of contribution of flow to the Cauvery river System, Bhavani is one of the most important tributaries.

Bhavani river starts from the silent valley forests of Kerala and flows in north-south direction upto Mukkaliyar and then in the north-easterly direction upto the confluence of Moyar tributary. Its major tributaries are the Siruvani on its right side, and Pykara, Kundah, Kallar and Moyar joining on its left side. After an eastward running of 217 Km, it confluences with Cauvery river at a town called Bhavani. The river receives floods during South West Monsoon period.

State/District-wise catchment area of Bhavani sub basin

Total drainage area of the basin is 6154 Sq. km., which spreads over Tamil Nadu (87%), Kerala (9%) and Karnataka (4%). The basin lies between north latitudes 10°56'33" and 11°46'14", and east longitudes 76°24'41" and 77°41'11". The Bhavani sub-basin constitutes 7.58% of the Cauvery basin. The Table 4.1 shows the district-wise catchment area of the Bhavani sub-basin in three States.

Table 4.1. Catchment's Areas of Bhavani Sub Basin

State/ District	Catchments Area (Sq.Km)	Percentage
Tamil Nadu		
1.Nilgiris	1881	31
2.Coimbatore	1002	16
3.Erode	2469	40
Total	5352	87
Kerala		
1. Palakkadu	562	9
Karnataka		
1.Mysore	240	4
Grand Total	6154	100

Source: Water Balance Study of Cauvery basin, NWDW, New Delhi 1993 p.10.

In this total catchment area, Coimbatore and Erode catchment area comes under Lower Bhavani Basin. The Figure 4.1 shows the catchment's areas of Bhavani River Basin.

Topography and Physiography

The Bhavani sub-basin is surrounded by Chaliyar sub-basin on the western side, Thirumanimuthar sub basin on the eastern side, Kabini, Suvarnavathi and Palar sub-basins on the northern side and Noyyal sub basin on the southern side. The basin is covered by hills on the northern and western sides and by plain lands on the southern and eastern sides. The basin area is broadly classified as Western Ghats, Eastern Ghats, Plateau region and Bhavani valley. The western part of the basin is a hilly terrain with elevation ranging from 300 m to 2439 m above MSL. On the northern and the northeastern, the southern and south-eastern sides of the basin lies a row of rugged discontinuous hills designated as hill ranges of and Bhavani respectively. Their elevations range from 300 to 1000 m above MSL. Three different plateaus occur in the basin. The first is the upland plateau, which consists of Ooty and Wellington towns, Upper Bhavani, Avalanche and Emerald (elevation 1800 to 2200 m). The second is the plateau consisting of part of Hasanur plateau (600 to 900 m). The third is the Coimbatore plateau on the southern part extending from the foothills of Western Ghats to Nambiyur and Perundurai (300 to 625 m). The total area under the plateau is 5,315 km². Bhavani valley starts from the foothills of Nilgiris and extends upto the confluence of river Bhavani with Cauvery (300 to 625 m). The average length of the basin is 138 km and the average width is 57 km. The basin elevation ranges from 166 m above the MSL in the plains to 2634 m in the hills.

Revenue Division and Taluks in Bhavani Basin

The details of the revenue divisions and Taluks were presented in Table 4.2. It could see from the table that 47 and 539 Revenue Firkas and Revenue Villages are in Erode districts. In case of Coimbatore, 7 and 57 are Revenue Firkas and Revenue villages respectively. The Figure 4.2 shows the locations of the municipalities, town panchayats and panchayat unions in the lower Bhavani River Basin.

Table 4.2 Revenue Division and Talks of Lower Bhavani Basin

Sl. No	District	Revenue Division	Revenue Taluks	Revenue Firkas	Revenue Villages
1	Erode	Erode	Erode	9	94
			Perundurai	7	121
2		Gobi	Bhavani	7	57
			Gobi	7	76
			Sathy	6	76
3		Dharapuram	Kangayam	4	44
			Dharapuram	7	71
Total				47	539
4	Coimbatore				
		Coimbatore	Karamadai	2	19
			Avanashi	3	34
			Annur	2	22
			Total	7	57

Land Use Pattern of Lower Bhavani Basin

The details of land utilization pattern of the districts are presented in Table 4.3. It could be seen from the table that the geographical area in Coimbatore and Erode districts was 131035 ha and 668296 ha respectively. The net sown area was 20535 ha and 135959 ha in Coimbatore and Erode respectively. Area sown more than once was 2066 ha and 7174 ha in Coimbatore and Erode respectively.

Table 4.3 Land Use Pattern of Lower Bhavani Basin

Sl.No	Classification	(ha)	
		Coimbatore	Erode
1	Forest	28897	228749
2	Barren & Uncultivable uses	13038	7073
3	Land put to non-agriculture	14989	76049
4	Cultivable waste	852	621
5	Permanent pasture & other grassing land	706	189
6	Lands under miscellaneous tree crops & grass not included in net area sown	503	923
7	Current fallow	46436	153787
8	Other fallow land	5079	64946
9	Net area sown	20535	135959
10	Geographical area	131035	668296
11	Total cropped area	22601	143133
12	Area sown more than once	2066	7174

Source: Assistant Director of Statistics, Erode and Coimbatore 2000-01.

Occupation

The details on occupational status of the population as per the 2001 census are given in Table 4.4. It could be understood that the non-workers constitute the major share of the population (more than 50 per cent on an average). Main workers and marginal workers constitute the rest even though there exists a small variation in different

districts and taluks under study. Among the main workers agricultural labourers (38.79 per cent) constitute the major share followed by cultivators (23.77 per cent). The most significant feature of the occupational status of the population indicates that more than 50 per cent of the agricultural labourers are women and among the non-workers more than 63 per cent are females.

Table 4.4 Population and Occupation Pattern in Lower Bhavani Basin

Sl. No	Categories	Sex	2001	
			Coimbatore	Erode
1	Total Population		381231	2320363
2	Total Main Worker	T	47.08	49.63
		M	35.30	64.78
		F	11.77	33.87
3	Cultivators	T	9.36	23.77
		M	8.68	25.32
		F	11.42	20.70
4	Agricultural labourers	T	14.12	38.79
		M	10.40	30.21
		F	25.26	55.89
5	Household industry	T	3.88	5.24
		M	3.75	5.10
		F	4.28	5.51
6	Other than Household Industry	T	47.14	32.20
		M	48.80	39.37
		F	42.17	17.90
7	Construction	T	4.29	1.88
		M	4.46	2.33
		F	3.79	0.81
8	Other Workers	T	21.20	18.95
		M	23.91	23.16
		F	13.08	10.18
9	Marginal Workers	T	0.60	2.32
		M	0.03	0.38
		F	0.58	4.33
10	Non-Workers	T	59.58	50.75
		M	64.67	38.99
		F	87.65	63.31

Source: Population Census 2001

Drainage

Bhavani and Moyar are the main rivers in the basin. Siruvani river joins with Bhavani on its right side and Kundah river joins on its left side. Kallar river draining from Wellington and Coonoor joins on its left near Mettupalayam. After this junction Moyar river, which originates in Mukurthi hills and drains the slopes of Nilgiris hills, joins with Bhavani at the beginning of Erode District. The Lower Bhavani Reservoir is constructed across Bhavani river just below its confluence with Moyar in Sathiyamangalam taluk, 32 km below Mettupalayam and 16 km above Sathiyamangalam. From the reservoir 200 km length of Lower Bhavani Project canal has been constructed. Downstream of the reservoir, Bhavani river runs in an easterly direction till it joins with Cauvery river at Bhavani. Downstream of Sathiyamangalam, Kodiveri anicut was constructed across the river in the ancient period to divert water into Arakkankottai and Thadapalli canals on either side of the river. Before its confluence with the Cauvery river, Kalingarayan anicut has been constructed across the river to divert the water into Kalingarayan canal.

Geology

The geological rock formation of the sub-basin is Dharwar, Charnokites, Peninsular Gneiss and Intrusive. The dominant rock type is the peninsular gneiss which is very composite in nature, having hornblendic, biotic and genetic ferrous varieties (NWDA 1993). Chinnamani and Sakthivadivel (1981) presented satellite / land sat imagery to represent geological feature of the basin. According to them, in the Western Ghats hill ranges, thick forests are underlain by charnockitic rocks and granite rock on the southern extreme of the basin and eastern Nilgiris. In between these areas, mixed gneiss appears. The charnockite rocks occupy major area of the basin, followed by mixed gneiss, which forms a good source for ground water exploitation.

Climate

The climate of the sub-basin is characterized by a mild summer and a mild winter. The climatic condition of the basins significantly influence two distinct monsoons viz south-west monsoon (from June to September) and north-east monsoon (from October to December).

Humidity

The relative humidity is low in dry weather and high in the monsoon seasons. The mean daily relative humidity varies from 29% in the month of March as observed at Coimbatore IMD observatory to 91% in the month of July – August as observed at Ooty IMD observatory (NWDA 1993). Monthly relative humidity averaged over the years is 77 % in Ooty and 60% in plains (Chinnamani and Sakthivadivel, 1981).

IMD observatory. Monthly relative humidity averaged over the year is of the order of 77% in Ooty and 60% in the plains. It is observed that hail occurs only once or twice in a year during pre-monsoon period. Mist and fog are common in the hillside of the basin. Dew is observed in the whole basin from December to March.

Temperature

Temperature details for the basin area available from three IMD observatories at Coimbatore, Coonoor and Ooty. The average daily maximum temperature is 34.7 °C (March), 23.5°C (April) and 22.1°C (June) and average daily minimum is 19.2°C, 8.50 C and 5.1°C (all in January) for the IMD observatories respectively. Zero and sub-zero temperature has been observed in Upper Bhavani and Ooty. A maximum temperature of 44.1°C has been observed at Bhavanisagar.

Potential evaporation

The rainfall and potential evaporation are 1622 mm and 612 mm respectively for Coimbatore, 1550 mm and 773 mm for Coonoor and 1303 mm and 690 mm for Ooty [Chinnamani and Sakthivadivel, 1981]

Soils of the Basin

The major soil types of the basin are given in Table 4.5. It is red soils, alluvial soils, colluvial soils and forest soils. The Figure 4.3 shows the distribution of soils in Bhavani Sub-Basin. Major soil orders of the basin are entisol, alfisol, inceptisol and vertisol. There are thirty soil series in the basin. The Central Ground Water Board classified the soils of the sub-basin into five broad groups viz (i) red sandy clay loam soils (crops cultivated are ragi, bajra, jower, paddy, etc); (ii) black clay soils (cotton, jower and paddy); (iii) rock outcrops with loamy sand soils (irrigated as well as rain-fed crops like ragi, jower, millets, pulses and oilseeds) (iv) brown clay loam soils (cotton, jower, pulses, chillies, onion, groundnut, etc and natural vegetation are palmyrah, neem and agave species); and (v) recent / old alluvial soils (paddy, sugarcane, jower, groundnut, chillies, pulses, etc)

Table 4.5 Soil Classification

Sl. No	District	Type of Soil	Place in District
1	Erode	Red Loam	Sathy, Gobi
2		Lateritic soil	Bhavani, Sathy, Kangayam, Dharapuram
3		Block soil	Dharapuram
4		Red sandy soil	Erode, Perundurai, Bhavani, Dharapuram
5	Coimbatore	Red Calcareous soil	Mettupalayam
6		Red Calcareous soil	Avanashi, Annur

Water Resources in the basin

Water resources in study are rainfall, rivers, major and minor reservoirs, water diversion ayacut, canal, tanks, wells, and ground water.

Rainfall Pattern in the Study Area

The rainfall statistics for most of the rain gauges spread in our study area are available since 1901-02. The Figure 4.4 shows the spatial rainfall pattern in lower Bhavani Basin. They are Mettupalayam, Thalavadi, P.N. Palayam, Bhavanisagar, Sathiamangalam, Kodiveri, Gobichettipalayam and Bhavani, which lie within the basin and Annur, Avinashi and Perundurai, which are adjacent to the basin.

The spatial rainfall pattern indicated that the average annual rainfall during the period 1901-02 and 1988-89 varied from 583 mm in Annur to 870 mm in Mettupalayam, which is located at the foot of Nilgiris hills if one, considers the long length of record. Generally, when compared to other areas, the rainfall is high in the western and northern parts of the study area of the basin. The only exception is the town Bhavani, which also receives comparatively high rainfall. Mettupalayam receives the highest rainfall, followed by P.N.Palayam, Sathiyamangalam and Bhavanisagar, which are the places located in the western and the northern parts. Rain gauges in Perundurai, Annur and Avinashi registered lesser rainfall. Most parts of the basin in the plains receive lesser rainfall than the State annual average of 950 mm since such areas lie in the rain shadow areas of the Western Ghats.

A study of the recent statistics indicates that the rainfall pattern has slightly changed. The average rainfall was given in Table 4.6 and has improved slightly when the data for the last 10 years ending 2000-01 are considered. The North-eastern monsoon is the main source of rainfall and the South-west monsoon also yields rainfall to some extent. During the winter and summer seasons, the rainfall is very lean.

Table 4.6 Annual Average Rainfall in Lower Bhavani River Basin

(mm)

SL · N O.	NAME OF THE STATION	MA Y	JU	JL Y	AU G	SE P	OC T	NO V	DE C	MONSO ON TOTAL	J A N	FE B	MA RCH	AP R	NON- MONS OON	ANNU AL TOTAL
1	Mettupalayam	86	26	33	43	66	200	176	68	698	28	37	39	68	172	870
2	Bhavani Sagar PWD (29/1)	104	18	28	37	86	179	106	65	623	7	18	18	52	95	718
3	Bhavani Sagar (R) (9/7)	84	13	25	24	89	126	113	86	560	0	6	13	25	44	604
4	Thalavadi (88)	140	47	46	75	114	158	87	22	689	7	6	18	72	103	792
5	Sathiyamangala m	95	32	35	66	97	186	132	33	676	11	14	21	55	101	777
6	P.N.Palayam	95	26	30	46	76	194	155	53	675	18	19	23	67	127	802
7	Kodivery (39/10)	92	30	36	59	93	181	116	40	647	6	8	21	43	78	725
8	Gobichettipalay am	93	39	43	73	106	188	116	33	691	15	14	21	52	102	793
9	Bhavani (88)	95	44	52	81	107	173	110	42	704	9	12	23	50	94	798
10	Annur (82/2)	88	29	37	55	74	154	112	34	583	1	7	17	54	89	725

											1					
11	Avanashi (88)	92	32	37	58	95	173	110	39	636	1 3	7	18	51	89	725
12	Perundurai (88)	98	27	46	65	106	159	111	39	651	1 2	11	13	41	77	728

Note : Figures in bracket indicate the number of years and months

Source: NWDA, Water Balance study of the Bhavani sub-basin of Cauvery Basin, New Delhi 2001-02

Rivers

As reported earlier, the main rivers of the sub-basin are Bhavani and Moyar. Bhavani river starts from the silent valley forests of Kerala and flows in north-south direction upto Mukkaliyar and then in the north-easterly direction upto the confluence of Moyar tributary. Its major tributaries are the Siruvani on its right side, and Pykara, Kundah, Kallar and Moyar joining on its left side. After an eastward running of 217 Km, it confluences with Cauvery river at Bhavani of Erode district. The river receives floods during South West Monsoon period. The total drainage area of the river is 6154 sq.km.

Fifteen hydel power Reservoirs have been constructed in the various tributaries and Bhavani river. Another two are under construction. Six new hydel power projects are under consideration. All the hydel power reservoirs exist in the upstream of Bhavanisagar.

The Bhavani river water is stored in Lower Bhavani Reservoir in order to regulate flow and divert water into Lower Bhavani Project Canal System. Kodivery Anicut, with its old canal system diverts water to Arakkankottai and Thadapalli areas and is located across the Bhavani river at a distance of 30 km downstream of Lower Bhavani Reservoir. Kalingarayan Anicut is another diversion structure for feeding the Kalingarayan channel and is located just above the confluence of Bhavani river with Cauvery river.

Major Reservoirs

In the basin, different types of Reservoirs exist. Lower Bhavani Reservoir is a multipurpose Reservoir, mainly constructed for water storage and distribution through canal system. This Reservoir is also used for hydel power generation and pisciculture. Minor Reservoirs viz., Gunderipallam, Varattupallam and Perumpallam are located in the plains and they are utilised for irrigation and to some extent for pisciculture. Apart from this, water diversion anicut viz. Kodiveri and Kalingarayan are used to divert water into different canal systems.

Hydel Power Reservoirs

Presently, 15 minor hydel power projects are under operation. Tamil Nadu Water Resource Consolidation Projects report states that the power generation capacity of these projects is 658 MW and the water storage capacity is worked out 382 Mcm. National Water Development Agency (1993) worked out the power generating capacity of these projects as 641 MW. The total evaporation loss in 15 working hydel power reservoirs is worked out as 33 Mcm (NWDA 1993).

Lower Bhavani Reservoir

Lower Bhavani Reservoir (LBR) is the only major reservoir in the sub-basin and the second largest, after the Mettur Reservoir, in Tamil Nadu. It was originally conceived as a flood controlling water storage reservoir, in order to save the Cauvery delta region, since the Bhavani is a major tributary of river Cauvery. Before constructing the reservoir and LBP canal system, more water was released to the river Cauvery after fulfilling three old canal systems in the Bhavani basin. During the period under proposal of the reservoir, farmers of famine affected areas of integrated Coimbatore district strongly demanded irrigation water for their area. A special division was formed in 1905 to explore the possible scheme in Bhavani river. After a detail investigation it was suggested to have two alternative schemes, one on the Upper Bhavani for an irrigated dry crops and other for reservoir on the Lower Bhavani for wet crop. However, the Government dropped the Upper Bhavani proposal and accepted the Lower Bhavani project. There was much controversy among agricultural, revenue and engineering departments on matters like nature of crops to be raised in the proposed area, suitability of the tract from the irrigation point of view, water requirements, basis of duty etc. Finally, the government allowed them to construct a reservoir in Lower Bhavani project to provide irrigation of dry crops. After formation of the National Government, the then Madras State sanctioned the execution of Lower Bhavani Project (LBP) on 19th September 1947.

Bhavanisagar Dam

The Lower Bhavani Dam is located in the Bhavani River just below the confluence of River Moyar and River Bhavani. The Bhavanisagar Dam is 16 km (10 miles) west of Sathyamangalam and about 36 km (23 miles) North East of Mettupalayam in Erode District of Tamil Nadu.

The Lower Bhavani project is the first major project executed in Tamil Nadu after independence. It was executed during 1948-1955 at a cost of Rs.1034 lakhs in the First Five Year Plan. The dam is the longest Earthen Dam of its kind in the State measuring 8696 meters of which 464 meters is in masonry in the river bed portion. The Bhavanisagar Dam is the second largest reservoir in Tamil Nadu with a capacity of 929 Million Cubic meters (32.80 TMCFT).

The Dam consists of a Central portion across the river for a length of 464.21 M (1523'). The Masonry Dam consists of 120.70 M (396') of overflow section providing for an overflow (20') over the Crest. Four nos. of 8; diameter Penstock pipes have been provided for Power Generation.

The Earth Dam is built for a length of 4.8 km (3 miles) in the left flank and for 3.6 km (2¼ miles) on the right flank. The total length of the dam is 8.86 km (5½ miles) including masonry portion. The Earth Dam on either sides of the masonry section was formed by use of combined machinery and manual labour. Bhavanisagar Dam is the first dam of its kind in India where an Earth Dam of this magnitude is constructed.

There are 9 river sluices having a size of 1.83 M x 3.05 M (6'0" x 10'0") with sill at 248.41 M (815.00 Ft.) and about 34,700 cusecs can be discharged through these river sluices at M.W.L. condition.

There are 5 canal sluices of size 1.83 M x 3.05 M (6' x 10') with sill at 256.032 M (840.00 ft.).

There are 9 nos. of spillway gates of size 10.97 M x 6.10 M (36' x 20') with crest 274.32 M (900.00 ft). It is capable of discharging 3156 cumecs (1, 11,500 cusecs).

In the Masonry portion of the Bhavanisagar Dam a drainage gallery of size 1.52 x 2.13 m (5'00" x 7'0") has been provided with three exits one either flank and third at the centre adjacent to the guide wall separating spillway and river sluices. This facilitates inspection inside of the Dam and also enables further drilling and grouting if heavy seepage in any reach warrants it at any time.

The inflow and outflow data is available for very long period. On an average between 1950-51 and 2000-01, the total outflow from the reservoir is estimated as 1,994.03 MCM, in which 46% was released into to LBP canal and the balance of 54% to Bhavani river (Annexure 1,2,3). The 54% of the water released was for both the old canal systems and Cauvery is estimated as 16% and thus we account for 16% of water released to the old canal systems (from the Kodiveri and Kalingarayan anicut). The quantum of water issued to Cauvery delta is highly erratic and nil for many years.

Anicut

Kodiveri Anicut

Kodiveri anicut is the oldest anicut (constructed in the 14th century) located at a distance of 30 km downstream of Lower Bhavani Reservoir. This is an old anicut built during the regime of Hindu kings of Mysore in 17th century. This anicut is located on a rocky bed and the masonry structure is made up of very big boulders, tied together with iron bars. The total length of the anicut is 151.18 m (496 feet). Around 1950, the crest level of the anicut was raised by 0.762 m (2.50 feet) by providing steel automatic falling shutters over the masonry structure for the entire length of the anicut, for getting full supply in the two canals. it merely regulates the flow of the river to feed irrigation canals. Two canals take off from the anicut. On the left flank Arakkankottai canal runs for a distance of 32 km and on the right flank, Thadapalli canal runs for a distance of 77 km. The ayacut area under this anicut is 9921 ha. The maximum discharging capacity of

Arakkankottai channel is 379 c/s and that of Thadapalli channel is 735 c/s. The catchment area of river above the anicut is 1900 square miles and maximum discharge as computed is 1, 22,066 c/s.

Thadapalli channel runs for a length of 48-1-410 miles and finally empties into Ananthasagaram Tank. The total ayacut under this channel is about 17,650 acres, including the tank ayacut. Arakkankottai channel runs for a total length of 20-1-0 miles. The total ayacut under the channel is 6,850 acres. Irrigation season is 16th April to 15th February and closure period of channel is from 16th February to 15th April.

Kalingarayan Anicut

Kalingarayan anicut is located just above the confluence of Bhavani river with Cauvery river at Bhavani town. This was constructed by a Chieftain named Kalingarayan some centuries back and diverts water from Bhavani river to Kalingarayan channel, which runs for a distance of 90 km and irrigates 6,300 ha. The total length of the anicut is 2,061 feet. Kalingarayan channel takes off from Kalingarayan anicut in the right flank and runs for total length of 90 km. It irrigates a total ayacut of 17,766 acres in Erode and Karur taluks. The discharging capacity of Kalingarayan channel is 580 c/s.

Canals

Two different canal systems exist in the Bhavani river basin. Old canal systems consists Arakkankottai and Thadapalli canals run from Kodiveri anaicut in taluk, and Kalingarayan canal runs from Kalingarayan anaicut at town Bhavani. The new canal – Lower Bhavani Project canal runs from the Lower Bhavani Reservoir itself (Refer Figure 4.5 shows locations of different water resources like rivers, reservoirs, anaicut and canals in the basin). Old canals were established more than 400 years ago. The Lower Bhavani Project (LBP) canal system was constructed between 1948 and 1955. It is obvious that the irrigation systems date back centuries; farmers of such systems have legal or riparian rights over water. If there is any new scheme implemented, government and courts ensure such rights of the farmers in old systems. In the same manner, farmers of Thadapalli, Arakkankottai and Kalingarayan canal have riparian rights over Bhavani river water.

Arakkankottai and Thadapalli Canals (Old ayacut)

In the ancient periods, Tamils built number of anaicuts and canals to irrigate food crops like paddy. During the Pre-British period, the then Mysore Government was extended upto Sathyamangalam and taluk of present Erode district. More than 400 years ago, the period in which there was no sophisticated technology, a Rayar King of Mysore Government built up the Kodiveri anaicut across the river Bhavani and Arakkankottai and Thadapalli canal systems. The Arakkankottai canal is located in the left side of the anaicut and runs parallel to the river for a distance of 32 Kms. and gives irrigation to 2,740 ha. through 207 canal sluices. Two branch canals viz., Vaniputhur branch in the first half and Perumugai-Athani branch in second half also serve in distributing water to the ayacut. The total length of the main and branch canals is 55 kms. The full supply discharge in the canal is 10.3 cumecs. Remodeling works such as construction of drips, aqueducts, outlets strengthening of bunds and reduction of number of sluices by regrouping in the ayacut were taken up in the canal area during 1975. Most of the work were taken up were completed. However, the work like reduction of number of sluices by regrouping was not implemented due to stiff resistance from the farmers of the canal area. The Figure 4.6 shows the Arakkankottai canals and it's branches.

The Thadapalli canal is located right side of the anaicut and it is also runs parallel to the river Bhavani for a distance of 76.8 kms and irrigates 7060 ha through 448 sluices. This canal having two branches viz., Singiam branch and Kugalur branch, both at the first half of the main canal. The total length of main and branch canals is 145 kms. The full supply discharge in the canal is 20.8 cumecs. An important tank viz., Ananthasagaram tank, also located in the tail end of the Thadapalli canal. The ayacut of the tank is also included in the registered ayacut of canal. The tank serves both for irrigation and to some extent for fisheries. In some places, the seepage water of LBP canal (LBP canal command overlaps Thadapalli canal command) and local drains in falls into the Thadapalli canal. The Figure 4.7 shows the Thadappalli canals and it's branches.

In both the canals, the water supply for irrigation through sluices is controlled with steel shutters and locking arrangements. Since they are old canal systems, they have different bed widths and slopes at various places. Some of the sluices were provided at higher level and get water while allowing minimum supply in the canals. There is no individual field bothies for each and every sluices upto the last field of irrigation. Presently, field to field irrigation is followed in the entire irrigation period of whole ayacut. Most of the sluices have an ayacut size of less than 10 acres. The period of irrigation for these canals normally commences from 15th April and ends on 15th February of every year (10 months). Commonly, farmers in this canal command raise two paddy crops. Farmers in the tail ends cultivate cash crops like sugarcane.

Apart from this, numbers of unauthorized pump sets on the right side of the canal numbering 1200 irrigating an extent of 2354 ha. Most part of the canal commands of latter two canals lie outside the basin. The head sluices of Thadapalli and Arakkankottai channels will be opened for irrigation at 6 PM on 15th April. The channels will be closed from 6 PM on 15th February to 6 PM on 15th April of each year for annual repairs

Kalingarayan Canal

A Chieftain from former South Coimbatore by name Kalingarayan had built the Kalingarayan anaicut and canal just before the confluence of Bhavani river with Cauvery. The canal runs 90 kms distance, which irrigates 6,300 ha of land through 786 canal sluices (Department of Agriculture reported that total command area of the canal is 5083 ha). The full supply discharge in the canal is 16.4 cumecs. This canal runs parallel to river Cauvery and command area of the canal is very narrow. The command area located in 25 villages comes under Erode, Modakurichi and Kodumudi Engineering Sub-divisions. Of this, a single village viz., Mettunasuvampalayam alone lies in our basin area (This village is also benefited through LBP canal). The area irrigated by the canal within the basin becomes nearly 6%. In other words, 94% (if we assume water is distributed equally to all area) of the water issued into the canal is exported to the Noyyal, an adjacent basin. The Figure 4.8 shows the Kalingarayan canals and it's branches.

Apart from this, numbers of unauthorized pump sets on the right side of the canal numbering 753 irrigating an extent of 2160 ha. This canal is opened for irrigation from 16th June to 30th April every year (for 10.5 months in a year). Cropping intensity is very high in the canal area when compared to the rest of the areas in Erode district. Farmers cultivate three successive paddy crops in a single year. Because of the fertility of the soil, its texture, topography and climatic conditions, turmeric is cultivated extensively in this area. Erode is a marketing centre for turmeric, which controls the price of all over India.

During 1974-75, remodeling of canal was started with a cost of Rs.6.6 million. Most of the proposed work were executed, except re-grouping of sluices and excavating the water courses below the newly constructed outlets since there was a stiff opposition from the farmers for regrouping and reduction of sluices from 786 to 226. The head sluices of the Kalingarayan channel will be opened for irrigation at 6 PM on the 16th June. The channel will be closed from 6 7PM on 30th April to 6 PM on the 16th June of each year for annual repairs.

The Table 4.7 shows the summaries of the net irrigated area and water availability of the old ayacut.

Table 4.7 Command Area of Old Ayacut

Scheme / Canal	Net area irrigated (ha)	Water availability (MCM)
<i>Arakkankottai canal</i>	2740	123.41
<i>Tadapalli canal</i>	7060	319.40
<i>Kalingarayan canal</i>	6300	283.13

Source: Joint Director of Agriculture, Erode.

It is important to note that the entire commands of Arakkankottai and Thadapalli canals are located in Gobichettipalayam taluk. So, the entire command area lies in the basin, unlike Kalingarayan and Lower Bhavani Project canal commands. The table indicated that Thadapalli canal contains major ayacut area and water availability among the other two canals of old ayacut.

Lower Bhavani Project Canal (New ayacut)

The Lower Bhavani Project (LBP) main canal takes off from the right side of the reservoir, with a carrying capacity of 65.55 cumecs. This is an unlined canal. There are 371 distributaries taking off from the canal. There are 118 direct sluices in the canal. The length of the main canal is 200 km., of the distributaries and minors is 1120 km. and of the field bothies is 1920 km.

The project was started to give irrigation to 83,770 ha of land with the main canal of 143 kms length. During the project under construction, farmers of famine affected Dharapuram (of Erode district) and Karur (present Karur district) taluks need extension of canal to their areas. Their demand was approached sympathetically, and government sanctioned the extension of main canal from proposed 143 kms to 200 kms. But the government has not changed the designed command area of 83,770 ha. To compensate the extended area, government has uniformly cut 12.5% of previously proposed area in each village. The excluded area in the original design is called 'Dharapuram cut'.

The project was originally started to supply irrigation water for irrigated dry crops mainly for cotton, a predominant crop in those days, cultivation. Hence, it was called as 'Cotton Growing Project'. Later, 4050 ha. out of 83,770 ha. total command was permitted to cultivate (since they were in low lying packets) paddy crop and remaining for irrigated dry crops like cotton and millet.

When the canal construction progressed, in the initial stage of step-by-step increase in canal command, water was available in abundance for the farmers. It is obvious that farmers would like to cultivate water intensive crop like paddy rather than

proposed (by the government) irrigated dry crops. It was happened in the initial stage command of LBP. Farmers were not ready to follow crop specification by the government, even though it was penalized severely. The cultivation of wet crops encouraged by factors like large availability of water in head reach, heavy seepage (due to porous nature of soil), and heavy rainfall in the monsoon period. When project was completed during 1955, as a result of heavy usage in head reach, the tail enders were affected by scarcity of water. Even though there was a good storage in the reservoir, the distributing authority was unable to send water to the tail end successfully.

After a detailed consultation with implementing machinery and farmers representatives of command area, a new method was framed. It was decided that the total irrigation period should be divided into two turns of four months each. First turn is from August 15th to December 15th, and second turn is from 16th December to 15th April. The pure irrigated dry crop project was changed into partially wet crop and partially irrigated dry crop project. Since the north-east monsoon, which gives major portion of rainfall, fall in the first turn period, first turn was chosen for wet crop and planned to issue 725.26 MCM water to that turn. For the second turn, in which irrigated dry crops cultivated, 362.88 MCM water to be issued. Entire command area is divided into two parts on the basis of odd mile canal sluices and even mile canal sluices. In the every odd number fasali years, odd mile sluices will be kept open during the first turn and even mile sluices in the second turn. In the every even number fasali year, even mile sluices will be kept open for first turn and odd mile sluices in the second turn. Continuous water supply for the wet season (first turn) and for the dry season (second turn). These practices are continuous without any problem in normal years and partially successful in the bad years.

The main canal is under the control of the Executive Engineer, PWD, WRO, Lower Bhavani Basin division, Erode except the head reach from 0/0 to 1-1-560 M which is under the control of the Executive Engineer, PWD, Bhavanisagar Dam Division, and Bhavanisagar. The details of command area of LBP canal is given in Table 4.8.

Table 4.8 Command Area of the LBP Canal

(ha)				
Sl.No	Name of the Taluk	Area Irrigated in Turn I	Area irrigated in Turn II	Total area irrigated
1	Sathiyamangalam	2163	2117	4280
2	Gobichettipalayam	5714	5469	11183
3	Bhavani	2679	3237	5916
4	Erode	23403	21923	45326
5	Perundurai	4337	4324	8661
6	Kangeyam	4059	4080	8139
7	Total	42355	41150	85057

Source: Joint Director of Agriculture Erode.

The command area of the LBP canal is spread out in six taluks of Erode district and one taluk of newly formed Karur (previously in integrated Tiruchirappalli district. As previously reported 173 villages are either completely or partially benefited by the canal. It is worked out 33.6% of the command area of the canal alone lies in the basin area. In other words, 66.4% of the water (it is assumed that the water is equally distributed) issued into the canal is exported to the Noyyal basin.

Regenerated and Return Flow in Old and New Canal Systems

In the old canal systems water supply per acre is very high (the duty is about 20-25 acres/cusec), which indicates that the water loss is also very high. The soil of LBP command is porous one. Therefore, one can expect the water loss through seepage and percolation is also high. Sivanappan (1995) has estimated that the percentages of water regenerated and return flow in the total water issued to the different canal – LBP canal, Arakkankottai and Thadapalli systems in the Bhavani basin. For that he has used water flow data at three sites viz., Lower Bhavani Reservoir (where water is diverted into Bhavani river and LBP canal), Kodiveri anaicut (where water is diverted into Arakkankottai and Thadapalli canals) and Kalingarayan anaicut (where water is diverted into Kalingarayan canal and also water issued into River Bhavani which joins the River Cauvery). The author utilized flow data for three years between 1991 and 1994. He observed that the rate of maximum regenerated/return flow for the old canals is 50% and the average is about 25 to 30% excluding the water taken for industries, municipal

purposes and river pumping for irrigation which is worked out 10 to 20% of the regenerated flow. If the On Farm Development works implemented properly, we can save 50% of water issued into the old canal systems. At the same time, the regenerated and return flow in the LBP canal is about 20 to 25% excluding the water used for industry, domestic and agriculture purposes by pumping. If this water is taken into account the regenerated and return flow may be about 25 to 40%. The lower values in the above ranges indicate that water loss in hot seasons and the higher values indicate that loss in rainy wet seasons.

Seepage Water in LBP Command and Water Harnessing Schemes

As already reported the soil of the LBP command is very porous one. Due to this reason heavy water seepage occurs during first turn period. The unutilized seepage water along with local rain water (the north-east monsoon falls in the first turn period) generated streams and go back to the river. So government implemented 34 water harnessing schemes in various sizes to utilize this drainage water effectively in the command area. Such schemes are framed in the tail ends of all major distributaries. All such schemes were implemented during 1960s. Total command of these schemes before 6,995 ha. In which Koranganpallam and Perumpalam schemes have a command area of 1415 ha and 980 ha respectively. Previously, these entire command of harnessing schemes was included LBP canal command area. After the implementation of the harnessing schemes, 6,995 ha excluded from LBP and an equal extent of new area added to the LBP command. Thus, the new command areas included in LBP canal command is called as "Compensatory Commands".

However, harnessing schemes have not satisfied water needs of farmers. Because the seepage water will reach the lands under the harnessing scheme very slowly, since all the schemes located in the tail end of the distributaries. Seepage water generation normally takes place one to 1.5 month after the water released in the main canal. The seepage water will generate in full swing when the north-east monsoon sets successfully. As a result of these there is a definite difference in the crop periods of lands under

harnessing schemes and lands under LBP canal, even though they are located in same villages. The seepage water is suddenly stopped when main canal is closed (whatever the water available in the canal after stoppage of issue is completely utilized by the canal command farmers itself) and there is a higher possibility of crop failure, since they are in half-way (of total crop period). Apart from this, farmers of canal command area frequently disturb the seepage water flow by making cross bunds and pumping water from the drainage water course. This reduces the water availability for farmers under harnessing schemes. Another striking fact that there is no chance for seepage water during the second turn period. So, farmers of harnessing schemes are forced to leave their land ideally for one year. It means, if a harnessing scheme is located in odd mile sluice area, then lands of such scheme will get water only during the odd fasali year (for 3 months). Next turn will come in alternative years.

Due to the obstacles in successful water feeding to lands under water harnessing schemes, government decided to arrange water supply from the LBP canal for short periods. It becomes easier since all the schemes located in the tail ends distributaries. The supply of water to such schemes has not affected water supply to the regular command area of LBP, because of the size of schemes and their water needs are limited.

There is no much information on location of the water harnessing schemes. So, problem arises in deciding water schemes lies in the basin and outside the basin. It is clear that, Koranganpallam scheme is located in the tail end of Unjalur distributory of LBP canal. This distributory is located outside the basin. Hence, the remaining command area of the harnessing schemes becomes 5580 ha. If the schemes are located equally on all the distributaries, the commands of such schemes located within the basin area worked out are 1875 ha. (i.e. Total commands of all harnessing schemes except commands of Koranganpallam scheme $\times 0.336$).

Tanks in Lower Bhavani Basin

Tanks are an important source of irrigation more or less in all parts of the basin. They serve three important roles to farming community. They provide water for cropping

and livestock; help to improve the local ground water level; and, these micro watersheds harvest local rain water and which controls heavy floods and environmental problems like soil erosion and sedimentation in rivers and reservoirs. In due course, tanks in many areas lose their importance since poor maintenance by respective authorities and encroachment of water spread area by the vested interest people. An increasing use of ground water also reduces the importance of these micro watersheds.

Tanks are generally classified on the basis of ownership (and maintenance) and source of water. On the basis of ownership and maintenance tanks are classified PWD tanks and non-PWD tanks. PWD tanks are owned and maintained by State Public Works Department. Normally, these tanks have larger water spread as well as command area when compared to non-PWD tanks. They will serve for cropping practices. Non-PWD tanks are owned and maintained mostly by local bodies (Panchayat Union) and few by Government Departments like Fisheries and Forestry. They are generally in smaller size and give few wettings in the total crop period. On the basis of source of water, tanks are classified system tanks and rainfed tanks. System tanks get water from the canals. They feed water to the crops for longer period. But, rainfed tanks wholly depend upon local rain for water. They will lose their storage within limited days.

In the study area of our basin, totally 81 tanks are there. In which, 86 is non-PWD tanks and 21 is PWD tanks. Six non-PWD tanks are feed by LBP main canal and remaining tanks rainfed. Among the 21 PWD tanks 5 is system tanks, feed by Varattupallam (reservoir) canal system and Thadapalli canal system.

Non-PWD Tanks in the Bhavani basin

The details of the Non-PWD tanks are given in Table 4.9. Tank-wise command area is not available for non-PWD tanks. Even though these are smaller in size, these are helpful to improve local well water level, give few wettings to crops and fulfill livestock water requirement to a reasonable time. So, it is as an important water source. The table indicated that most of the non-PWD tanks are located in

Sathiyamangalam taluk. The tank intensity is also high in this taluk, followed by Perundurai taluk.

PWD tanks in the Bhavani basin

The details of the PWD tanks are given in Table 4.10. PWD tanks in the Lower Bhavani Basin have a total storage capacity of 451.51 Mcft with the registered ayacut of 1984 ha. But in practice, during many years the tanks are unable to give irrigation for all registered ayacut. The statistics collected from Agriculture Department shows that the gross area is irrigated by all type of tanks in the basin area are 1443, 279, 65 ha and 86 ha in 1983-84, 1984-85 1985-86 and 1995-96 respectively (Joint Director of Agriculture, Erode). It is understood that the area irrigated by tanks are highly fluctuated over the period of time.

Table 4.9. Taluk-Wise Distribution of Non-PWD Tanks in Lower Bhavani Basin

Sl. No.	Name of the Taluk	No. of Tanks in the basin	Tank Intensity (No. of tanks per lakh ha.)
1	Sathiyamangalam	24	15.43
2	Gobichettipalayam	10	12.85
3	Bhavani	12	8.12
4	Perundurai	12	14.64
5	Erode	2	9.31
6	Karamadai	2	6.60
7	Avanashi	24	4.00
	<i>Total</i>	86	14.87

Source: Joint Director of Agriculture, Erode.

Table 4.10 Details of PWD Tanks In Lower Bhavani Basin

Sl .N o	Name of the Tank	Name of the village in which tank located	Taluk	Catchment area (in sq.miles)	Capacity of tank (in Mcft.)	Regis- tered ayacut (in ha.)
1	Varadhampalaya m tank (RF)	Varadhampalayam	Sathy	7.46	21.35	118
2	Karuvankobai tank (RF)	Chikkarasampalaya m	Sathy	10.04	18.66	109
3	Kovilpudur (RF)	Punjaipuliyampatti	Sathy	17.80	17.80	105
4	Ukkaram tank (RF)	Kavilipalayam	Sathy	15.67	51.17	164
5	Mottanam tank (RF)	Mottanam	Gobi	3.60	9.98	248
6	Koshanam tank (RF)	Koshanam	Gobi	7.00	9.49	50
7	Vemmandampala yam (RF)	Vemmandampalaya m	Gobi	n.a.	21.00	128
8	Sanjeevarayan (Anaicut-RF)	Perundurai	Gobi	-	17.00	90
9	Odathurai tank (RF)	Odathurai	Bhavan i	n.a.	45.88	70
Sl .N o	Name of the Tank	Name of the village in which tank located	Taluk	Catchment area (in sq.miles)	Capacity of tank (in Mcft.)	Regis- tered ayacut (in ha.)
10	Appakudal tank (S)	Appakudal	Bhavan i	-	16.50	23
11	Thanneerpallam tank (RF)	Thanneerpallam	Bhavan i	n.a.	7.00	40

12	Ennamangalam tank (RF)	Ennamangalam	Bhavan i	n.a.	25.00	46
13	Kettisamudram tank (S)	Kettisamudram	Bhavan i	-	10.80	93
14	Anthiyur tank (S)	Anthiyur	Bhavan i	-	41.80	177
15	Brammadesam tank (S)	Brammadesam	Bhavan i	-	16.50	51
16	Vempathi tank (S)	Vempathi	Bhavan i	-	33.20	77
17	Karumparipallam tank (RF)	Karumparipallam	Bhavan i	n.a.	28.47	138
18	Murali tank (RF)	Murali	Bhavan i	n.a.	18.12	88
19	Chennampatti tank (RF)	Chennampatti	Bhavan i	n.a.	24.16	98
20	Pallapalayam (RF)	Pallapalayam	Perundur ai	n.a.	17.63	71
	All Tanks				451.51	1984

Source: **Executive Engineer, Lower Bhavani Basin, Erode Division.**

Notes: 1. Anathasagaram tank in Gobichettipalayam is not included in the table since its command area included in the Thadapalli canal command.

2. RF– Rainfed tanks, S – System tanks; Sathy – Sathiyamangalam and Gobi – Gobichettipalayam.

Ground Water in the Lower Bhavani Basin

Ground water plays a major role in the non-command area agriculture. Farmers in non-command area solely depend upon ground water for irrigation. Subsistence paddy and commercial irrigated dry crops like groundnut, sugarcane, banana, tobacco, tapioca and other crops are cultivated in a larger extent with the help of ground water. In

command, particularly in LBP canal areas farmers widely use ground water conjunctively with surface water.

Ground Water Level

The rainfall and return seepage from canals, tanks and reservoirs are the important sources of ground water recharge. Ground water study conducted in Erode district by the CGWB (2000) reports that the depth of water table varies from 2.45 to 29.8 M below the ground level during the post-monsoon period (January 2000) and it is from 1.5 to 30.6 M during the pre-monsoon period (May 1999). In the canal command areas of the district, shallow water table conditions exist and the fluctuation in water table is also limited.

Nearly 1400 sq.km. in the basin area is covered by the hills of the Western Ghats. The steep slopes generate high run-off after precipitation. According to CGWB the presence of joints and fractures act as recharge avenue in the foot hills. The nature of soil, colluvial deposits, bordering the foot hill areas also act as recharge zones. The most common rock types in many places are the mixed gneisses and charnokites and other associated rocks. Ground water occurs in weathered mantle of the rocks under paretic conditions. As the thickness of weathered mantle of the hard rocks is limited varying from less than a metre to as such as 20 meter and subjected rapidly to the seasonal fluctuations. The weathered mantle essential consists of disintegrated material followed by jointed and fractured crystalline rock constitute the shallow water table aquifer and these in major parts occur within the depth of 20 m while in the western and extreme north-eastern parts, they are more than 20 m. The water table aquifer under favourable conditions is generally tapped by means of large-diameter open wells, down to depth of 45 m. The hydrological conditions in the canal command areas are totally different due to the heavy recharge from canals during the flow periods. Also the return flow seepage from applied irrigation varies and the aquifers and more or less completely saturated during the canal flow period. The canals, in general, are kept opened for irrigation during August and closed in January. During the flow periods of canals, the depth of water level is almost nearly surface and after the cessation of flow in the canals, the water table

becomes progressively deeper. In LBP area, the depth of water table lies within 10 m below the ground level.

Ground Water Potential in the Lower Bhavani Basin

National Water Development Agency (1993) has estimated the ground water potential of the entire Bhavani Sub-basin on the basis of information provided by the Central Ground Water Board (CGWB) for entire Nilgiris, Coimbatore and Erode districts. According to the CGWB, the ground water potential of the three districts is 2553 MCM and estimated existing draft is 1495 MCM. The balance ground water is 1058 MCM. The NWDA has estimated ground water potential, existing draft and balance of the entire Bhavani sub-basin (with the proportion factors of – i.e., district-wise area fall in the basin – 13.38%, 29.96% and 73.79% are 617 MCM, 330 MCM and 287 MCM respectively.

But the present study intends to estimate the ground water potential of Lower Bhavani basin, which consist geographical area 11.42% and 56.59% of Coimbatore and Erode districts, respectively. On the basis of information provided by the CGWB, this study estimates that the ground water potential, existing draft and balance as 891 MCM, 522 MCM and 369 MCM.

Earlier a study by Srinivasan (1979) estimated that the ground water potential for the Lower Bhavani Project canal command alone. The author estimated source-wise ground water recharge. According to him, 7160 ha.m. is recharged from the rainfall. 17,380 ha.m from recycling of pumped well resulting in a net ground water recharge of 60,780 ha.m.

Chinnamani and Sakthivadivel (1981) have estimated the ground water balance in the LBP area 18,450 ha.m.

The Central Ground Water Board is categorized Development Blocks, on the basis of ground water development. Table 4.11 presents the status of ground water development of the Development Blocks, which lie in the lower Bhavani Basin area.

Table 4.11 Ground Water Development in Lower Bhavani Basin

District	Dark Block		Grey Block	White Block
	Upto 100%	85% - 100%	65% - 85%	> 65%
Coimbatore	Avinashi		Karamadai	
	Annur			
<i>Erode</i>	Nambiyur	Erode	Sathy	Thalavadi
	Andiyur	Uthukuli	Bhavani	
	Bhavanisagar		Gobi	
			Perundurai	
			Ammamet	

Source: **Central Ground Water Board, 2000.**

Note : **Figures in % denote level of ground water development.**

CHAPTER V

RESULTS AND DISCUSSION

The overall objective of the study is to analyze water resource optimization in Lower Bhavani basin and extent and nature of water transfer from agriculture to urban/industrial sectors. The data collected during the field enquiry were tabulated and the analyzed within the frame work of the specified methodology and also with specific reference to each of the objectives set forth for the present study. The sample for the study included agricultural sector, domestic sector and industrial sectors. The results are presented and discussed in this chapter under the following six major sections.

- 5.1 Supply of and demand for water in different sectors
- 5.2 Extent and nature of the water transfer
- 5.3 History of water allocation/ riparian rights of water
- 5.4 Cost and productivity of water in different sectors
- 5.5 Optimization of water among different sectors
- 5.6. Consequences of water taken from agriculture sector
- 5.7 Suitable policy measures for managing the water.

5.1. Supply of and Demand for Water in Different Sectors

5.1.1. Supply of Water for Agriculture Sector

Agriculture accounts for the majority of water withdrawals (more than 70 percent) in the basin. Surface and ground water are the main sources of water supply for agriculture in the basin.

5.1.1. a. Surface Water Sources

- (a) Canal
- (b) Minor Reservoir
- (c) Direct river and canal Pumping
- (d) Tank irrigation

5.1.1. b. Ground Water Sources

Well are energized by

- a) Electric power
- b) Diesel power
- c) Bullock power

5.1.1.a. Surface Water in the Lower Bhavani Basin

The different source of the surface water schemes, water release in different canals and water availability of Bhavani basin are given in Tables 5.1, 5.2 and 5.3. It could be noted from the table that the surface water quantity of all sources in the Lower Bhavani basin is 1516.12 MCM.

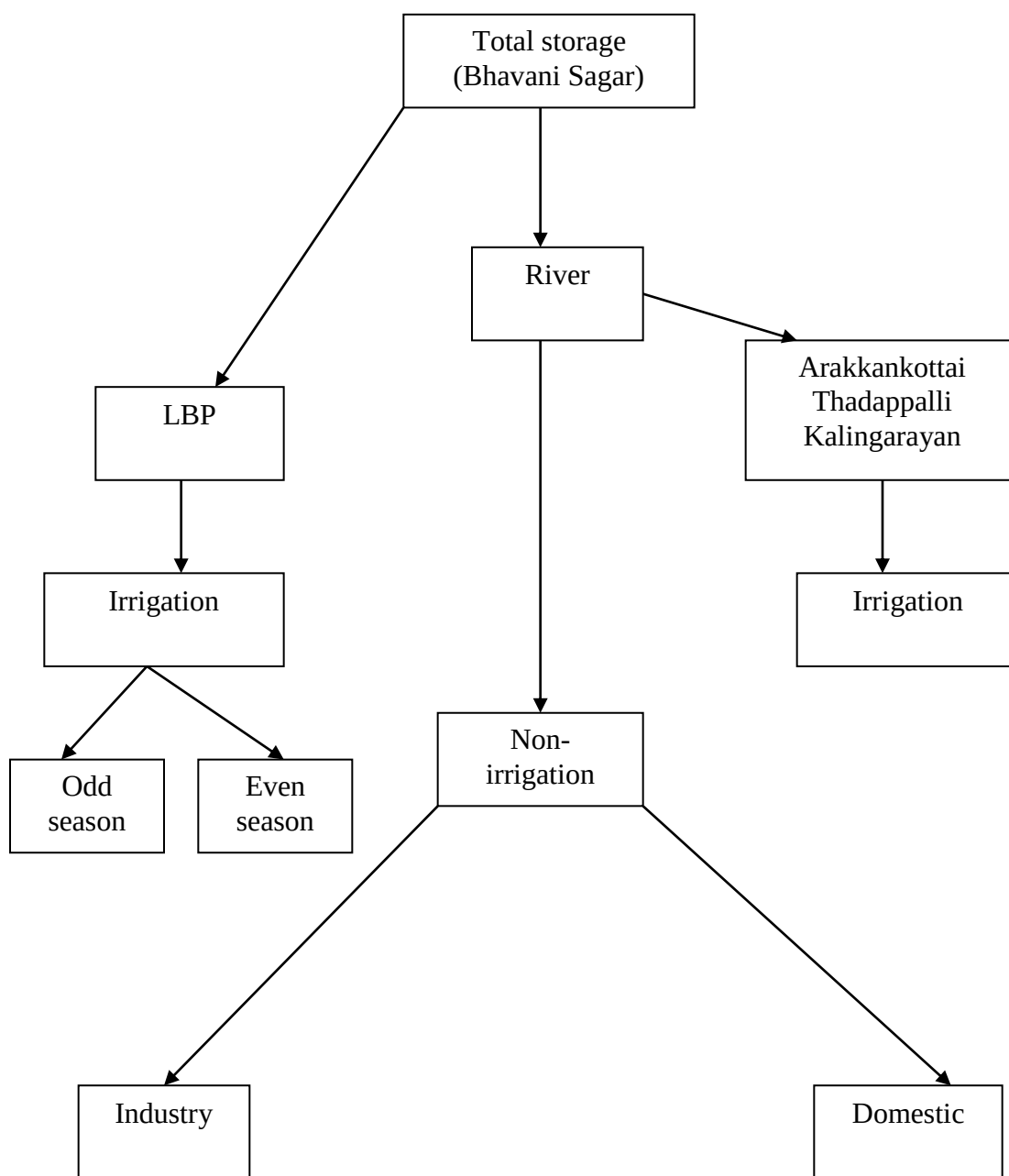


FIGURE 5.0 FLOW OF WATER IN THE LOWER BHAVANI BASIN

Table 5.1 Annual Inflow / Outflow of Lower Bhavani Sagar

(MCM)

Year	Inflow into BVS	Release to LBP (new)	Release to old Ayacut			Total release for ayacut	Surplus over spill-way	Surplus over Kalinga rayan Anicut	Cauvery Credit
			A&T	K	Total				
1961-62	4619.9	1442.3			585.3	2027.6	1714.2	0.0	0.0
1962-63	2984.9	1351.6			712.6	2064.2	827.7	0.0	11.1
1963-64	1620.8	915.1			915.8	1830.9	344.4	0.0	0.0
1964-65	2806.5	1418.1			755.7	2173.8	310.0	0.0	0.0
1965-66	1141.9	253.1			601.7	854.9	0.0	0.0	515.8
1966-67	1680.0	669.7			549.8	1219.5	0.0	0.0	39.0
1967-68	1321.9	755.6			520.3	1275.8	0.0	0.0	140.7
1968-69	1161.9	665.9			604.0	1269.8	0.0	0.0	0.0
1969-70	1492.1	879.1			464.5	1343.6	0.0	0.0	0.0
1970-71	1397.1	529.9			734.8	1264.6	0.0	0.0	0.0
1971-72	1933.7	1079.3			743.3	1822.6	0.0	0.0	0.0
1972-73	1913.4	1106.5			615.5	1721.9	223.3	0.0	0.0
1973-74	1968.6	1087.4			743.0	1830.4	0.0	610.8	0.0
1974-75	1538.4	658.2			888.0	1546.2	0.0	668.7	102.5
1975-76	2085.0	1185.0			799.7	1984.7	0.0	503.9	0.0
1976-77	1067.6	330.9			664.6	995.5	0.0	537.0	226.3
1977-78	2126.4	958.3			679.4	1637.8	0.0	660.1	0.0
1978-79	2419.5	1247.8			694.5	1942.2	215.3	2302.7	0.0
1979-80	3648.2	1211.8			614.1	1825.6	1279.3	1484.4	678.3
1980-81	2106.4	1187.8			824.8	2012.6	84.7	547.8	291.4
1981-82	2074.2	1059.4	451.8	212.0	663.8	1723.2	0.0	520.5	239.1
1982-83	1224.9	563.0	478.7	70.0	548.8	1111.	0.0	402.5	0.0

						8			
1983-84	1567.0	835.1	424.9	186.0	588.2	1423.2	0.0	230.7	29.3
1984-85	1532.0	890.8	504.4	149.7	654.2	1544.9	0.0	208.4	164.4
1985-86	1141.6	108.3	494.9	155.0	649.9	758.2	0.0	438.6	0.0
1986-87	1174.1	566.3	437.7	190.7	628.4	1194.7	0.0	85.4	0.0
1987-88	1035.5	348.2	371.9	152.8	524.7	873.0	38.8	167.9	0.0
1988-89	1191.5	568.9	423.8	235.2	659.0	1227.9	0.0	80.7	0.0
1989-90	1266.8	549.3	430.1	233.5	691.8	1241.1	0.0	152.2	0.0
1990-91	1273.4	618.1	426.9	195.7	622.6	1240.7	0.0	229.6	0.0
1991-92	1649.4	933.7	439.2	220.4	659.6	1593.4	0.0	178.2	0.0
1992-93	2368.4	1107.8	504.6	182.4	686.9	1794.7	242.9	367.1	0.0
1993-94	1581.3	923.5	445.0	152.9	572.4	1495.9	0.0	0.0	0.0
1994-95	2198.1	1155.4	459.8	210.8	670.6	1826.0	196.8	0.0	0.0
1995-96	1343.2	732.2	432.3	177.2	609.5	1341.7	0.0	0.0	285.5
1996-97	1765.9	982.8	487.0	191.7	678.8	1661.6	0.0	0.0	0.0
1997-98	1980.4	956.0	456.4	179.1	635.4	1591.5	0.0	0.0	0.0
1998-99	1725.3	993.7	482.2	194.0	676.2	1669.9	0.0	0.0	0.0
1999-00	1432.7	964.5	529.6	168.5	698.1	1662.6	0.0	0.0	0.0
2000-01	1535.9	989.7	469.2	133.1	602.3	1592.0	0.0	0.0	0.0
2001-02	1370.1	721.7	600.0	181.5	781.5	1503.2	0.0	0.0	0.0

Source: Executive Engineer, Bhavani Sagar, Erode 2002. BVS=Bhavani Sagar; LBP=Lower Bhavani Project; A&T=Arakkankottai and Thadappalli; K=Kalingarayan

Table 5.2 Water Supply Scheme, Supply System and Benefiting Blocks in Lower Bhavani Basin

Sl.No	Name of the Scheme	Ayacut Area (ha)	Period of supply	Benefited blocks	Major crop cultivated
1	Thadapalli-Arakkankottai	9800	April 15 to February15	Bogi, T.N.Palayam	Paddy, Groundnut,

					Sugarcane
2	Kalinkaraiyan	6300	June16-April 30	Erode, Modakurichi Kodumodi	Paddy, Sugarcane, Turmeric
3	Lower Bhavani Project	42355 (I turn)	Aug15-Dec 15	Bhavanisagar, Sathy, Gobi, Nambiyur, T.N.Palayam, Bhavani, Perundurai	Paddy, Sugarcane, Turmeric
		41150 (II turn)	Dec15-Apr15	Chennimalai, Kangayam, Vellakoil, Erode, Modakurichi, Kodumodi	Groundnut, Gingelly

Source: 1. Joint Director of Agriculture, Erode.
2. Executive Engineer, Bhavani Sagar, Erode.

Table 5.3 Surface Water Resources of the Lower Bhavani Basin

Scheme / Canal	Ayacut area (ha)	Water availability* (MCM)
<i>Arakkankottai canal and Thadapalli canal</i>	9800	599.97
<i>Kalingarayan canal</i>	6300	181.52
<i>LBP canal</i>	83505	721.66
Water Pumping scheme	8228***	**
Tanks	1984	12.97
Total	101589	1516.12

Source: Executive Engineer, Erode and Bhavanisagar 2002.

Notes: 1. * Figures furnished for three old canal systems and LBP are 2001-02.
2. **Water availability under water pumping scheme reported here considers the direct water lifting from the rivers and canals and quantum of water available is not reported separately. It is included in the old ayacut canal system itself.
3. ***It irrigate non-ayacut area. So, not included in the total.

5.1.1. b. Groundwater Sources

Rainfall in the Lower Bhavani Basin

Rainfall is the major source of ground water. There are three India Meteorological Department (IMD) observatories at Coimbatore, Coonoor and Ooty. There are more than 200 rain gauges, which are being monitored by different agencies in the basin area. Annual rainfall of the basin varies from 700 to 4600 mm. The lowest annual rainfall recorded is 468 mm at Mangalpatty, a place between Lower Bhavani and Kedarhalla and the highest is 6330 mm at Mukurthi hilltop. It is clear that the western part of the basin receives heavy rain during June to September through southwest monsoon and the eastern part as well as the southern part of the basin receives significant amounts of rainfall during October to December through northeast monsoon. During non-monsoon periods, the rainfall is very meager.

Quantitatively the western part of the basin receives an annual rainfall between 2000 mm and 4600 mm, central part between 1300 mm and 2000 mm and the eastern part of the plains and some areas of Karnataka and Kerala receive rainfall between 500 mm and 1750 mm. Table 5.4 shows the rainfall from the rain gauge stations.

Table 5.4 Average 12 years Annual Rainfall (1989-90 to 2001-02)

Sl.No	Name of the Rain gauge	Rainfall (mm/year)	Probability (%)
1	Mettupalayam	708.6	50.00
2	Bhavanisagar	617.3	83.33
3	Thalavadi	1121.5	8.33
4	Sathiyamangalam	756.1	33.33
5	T.N. Palayam	888.6	16.67
6	Kodiveri	801.3	25
7	Gobichettipalayam	691.0	58.33
8	Bhavani	654.0	75
9	Annur	247.9	91.67
10	Avinashi	677.5	66.67
11	Perundurai	728.0	41.67

Source: Assistant Directorate of Statistics, Coimbatore and Erode.

The details of the ground water sources of the Bhavani basin are depicted in Table 5.5. The ground water sources indicated that number of electrified well has more at all level i.e. black, basin and non-command area level and its gross irrigated area was also large than diesel and without power wells.

Table 5.5 Sources of Ground Water Extraction at Different Levels

Particulars	Command area level	Non-command area level	Total
1. Total no. of wells	52053	29260	81313
a) Electrified	43898	25055	68953
b) diesel engine	7744	3910	11654
c) without power	411	295	706
2. Net area irrigated (ha.)	41837	23739	65576
3. Gross area irrigated (ha)	69675	35049	104724

Source: Calculated on the basis of figures provided by Assistant Directors of Statistics of Coimbatore and Erode.

The ground water availability of Lower Bhavani basin is given in Table 5.6. It could be noted from the table that the ground water resource in the Bhavani basin is 627.78 MCM. The net ground water draft is 490.85 MCM and the balance ground water available is 59.84 MCM.

Table 5.6 Ground Water Potential of the Basin

Particulars	Quantity (MCM)
Ground water recharge	627.78
Utilizable ground water recharge	550.68
Net Ground water draft	490.85
Balance ground water available for development	59.84

Source: Calculated on the basis of figures furnished by Central Ground Water Board, "Ground Water Resources and Development Prospects in Coimbatore District & Periyar District", Hyderabad, 1994

5.1.2. Cropping Pattern in Agricultural Sector

5.1.2.1. Old Ayacut

Agricultural demand constitutes the major sectoral demand in the basin. There are two anicuts namely Kodivery and Kalingarayan and three canals namely Arakankottai, Thadapalli and Kalingarayan canals irrigating about 16,000 ha of land. Water is allowed for about 10-½ months in the 1st and 2nd channels and 11 months for 3rd channel. Continuous supplies help in raising a short duration crop of paddy like IR-50, followed by medium duration paddy. After the two paddy crops, the land is used grow a green manure crop like sun hemp or fodder sorghum.

Sugarcane, turmeric and cotton are the important commercial crops and grown in the old ayacut areas in locations where drainage does not pose a problem when paddy is grown in the neighborhood. Sugarcane is cultivated widely in Gobichettipalayam, Bhavani, Anthiyur, T.N.Palayam, Ammapet and Sathiyamangalam blocks.

Important crops of the basin of the old ayacut are Paddy, Groundnut, Sugarcane, Banana, Pulses, Cumbu, Cholan, Cotton, vegetables, etc. In the canal command area, paddy is largely cultivated. Paddy is mostly cultivated twice in Arakkankottai and Thadapalli canal and thrice in Kalingarayan canal.

Groundnut is the second largest crop cultivated in most part of the basin as irrigated or unirrigated crop. Banana is largely cultivated in Mettupalayam, Bhavanisagar, Sathiyamangalam and T.N.Palayam areas.

5.1.2.2. Cropping Pattern in Agricultural Sector New Ayacut

The original cropping pattern designed for the Lower Bhavani Project (LBP) consisted of raising irrigated dry crops (ID crops) like groundnut, millets and cotton. Paddy was limited to seepage affected area of over 4,000 ha. The pattern of ayacut development had indicated that the area under paddy rose over the years at the expense of other crops. The analysis had indicated that the area sown to different crops is determined by the availability of water in reservoir, distribution pattern of rainfall and ground water

supplies. In the LBP ayacut, based on the water availability there was two seasons i.e. Wet season and Dry season.

5.1.2.2. a. Wet Season

In wet season, water is let-in the canals from August 15 to December 15 for 50 per cent of the ayacut / command area out of total 83505 ha of ayacut. Paddy is the most important crop grown. Lands in the higher elevation are planted with sugarcane and turmeric depending upon the availability of water in the wells to support such crops during non-canal periods. During this season, the fairly heavy northeast monsoon rains benefit the crops

In the remaining 50 per cent of the total area (83505 ha), when irrigation supplies from the canal are not available, only rainfed crops like fodder sorghum or groundnut are raised. Farmers having wells prefer to grow sugarcane, turmeric, cotton and other food crops depending upon the availability of the well water.

5.1.2.2. b. Dry Season

When water is let in (50 per cent out of the total 83505 ha ayacut) from December 16 to April 15 for irrigated dry crops, groundnut is extensively grown and is the dominant crop. Farmers owning wells in this turn also normally grow a groundnut crop following harvest of paddy. Sugarcane and turmeric are also grown where adequate well water becomes available. The remaining 50 per cent of the total ayacut will cultivate dry crops and also irrigated crops if well water facilities available.

In the wet season (August 15– December 15) if water is not released in the canals due to poor storage in the reservoir, farmers preference is to go for fodder sorghum under rainfed conditions. On the other hand, if water is not let in during December-April due to poor storage, the land has to remain fallow since summer rains are too meager to support any crop.

The cropping pattern in the Lower Bhavani basin for the study period year 2001-02 is given in Table 5.7.

Table 5.7 Cropping Pattern in Lower Bhavani Basin

(ha)

Crops	Coimbatore District			Erode District			Basin			Percentage to total area
	Ayacut area	Non-ayacut Area	Total Area	Ayacut area	Non-ayacut Area	Total Area	Ayacut area	Non-ayacut Area	Total Area	
Paddy	700	0	700	24488	0	24488	25188	0	25188	15.20
Cumbu	376	500	876	376	2103	2479	752	2603	3355	2.02
Cholam	609	312	921	2391	5401	7792	3000	5713	8713	5.26
Maize	155	250	405	2341	650	2991	2496	900	3396	2.05
Ragi	110	50	160	7098	6833	13931	7208	6883	14091	8.50
O.Small Millets	701	213	914	1520	34	1554	2221	247	2468	1.49
Red Gram	106	550	656	149	1149	1298	255	1699	1954	1.18
B.Gram	100	570	670	668	853	1521	768	1423	2191	1.32
G.Gram	30	300	330	501	1000	1501	531	1300	1831	1.10
Other pulses	46	710	756	102	3295	3397	148	4005	4153	2.51
Groundnut	319	914	1233	9985	6374	16359	10304	7288	17592	10.61
Gingelly	0	789	789	3000	229	3229	3000	1018	4018	2.42
Coconut	724	0	724	4426	0	4426	5150	0	5150	3.11
Caster	10	68	78	337	1581	1918	347	1649	1996	1.20
Sunflower	0	9	9	304	1	305	304	10	314	0.19
Other oil seeds	320	0	320	1300	470	1770	1620	470	2090	1.26
Cotton	800	550	1350	2560	2228	4788	3360	2778	6138	3.70
Sugarcane	250	150	400	6050	2978	9028	6300	3128	9428	5.69
Chillies	141	0	141	476	0	476	617	0	617	0.37
Turmeric	350	150	500	2981	2145	5126	3331	2295	5626	3.39
Arecanut	534	0	534	37	0	37	571	0	571	0.34
Tobacco	367	0	367	3059	0	3059	3426	0	3426	2.07
Banana	150	250	400	783	750	1533	933	1000	1933	1.17
Tapioca	117	75	192	2088	1248	3336	2205	1323	3528	2.13
Other Crops	2753	6423	9176	10126	16665	26791	12879	23088	35967	21.70
Gross Cropped Area	9768	12833	22601	87146	55987	143133	96914*	68820	165734	100.00

Source: Joint Director of Agriculture Erode 2002.

Note: *In year 2001-02, 4675 ha out of total ayacut area was not cultivate due to non availability of water and put under current fallow land

Based on the cropping pattern in the ayacut area of the basin, the relative percentage of area under major crops in the ayacut was calculated and given in Table 5.8. It could be seen from the table that paddy occupied major area (24.13%) among major crops and followed by groundnut (10.14%) and sugarcane (6.20%) in ayacut area. In total ayacut and non-ayacut area, paddy occupied 15.20 % and followed by groundnut 10.61%.

Table 5.8 Cropping Pattern in Lower Bhavani Basin (Ayacut)

Sl. No	Crop	Area (ha)	Percentage to Ayacut Area
1	Paddy	25188	24.79
2	Sugar cane	6300	6.20
3	Banana	933	0.92
4	Turmeric	3331	3.28
5	Groundnut	10304	10.14
6	Cotton	3360	3.31
7	Pulse	1702	1.68
8	Gingelly	3000	2.95
9	Tapioca	2205	2.17
10	Maize	2496	2.46
11	Chollam	3000	2.95
12	Coconut	5150	5.07
13	Others	34620	34.08
Gross Cropped Area		101589	100.00

Source: Joint Director of Agriculture Erode 2001-02.

5.1.3. Demand for Water in Agricultural Sector

The use of water in the agricultural sector has been estimated on the basis of unit crop water requirement. One could estimate total irrigation water need of agriculture sector by multiplying individual crop area by the unit crop water requirement. The demand for water in agricultural sector at gross water requirements level is given in the Table 5.9. Water requirement was calculated at 40 per cent efficiency of water

recommendation of each crops (Cauvery Basin Report by PWD, 2000). It could be seen from the tables that the gross water requirement is about 3283.56 MCM.

Table 5.9 Demand for Water in Agricultural Sector in Lower Bhavani Basin

Crops	Lower Bhavani Basin						
	Ayacut Area*	Non Ayacut Area*	Water Requirement**/ha		Water Demand*** (MCM)		Total Water Requirement MCM Col 6+7
			Ayacut	Non Ayacut	Ayacut Col 2*4	Non Ayacut Col 3*5	
1	2	3	4	5	6	7	8
Paddy	25188	0	3000	0	755.64	0.00	755.64
Cumbu	752	2603	1125	675	8.46	17.57	26.03
Cholam	3000	5713	1625	975	48.75	55.70	104.45
Maize	2496	900	1500	900	37.44	8.10	45.54
Ragi	7208	6883	1125	675	81.09	46.46	127.55
O.Small Millets	2221	247	1125	1000	24.99	2.47	27.46
Red Gram	255	1699	1250	750	3.19	12.74	15.93
B.Gram	768	1423	1250	750	9.60	10.67	20.27
G.Gram	531	1300	1250	750	6.64	9.75	16.39
Other pulses	148	4005	1250	750	1.85	30.04	31.89
Groundnut	10304	7288	1750	1050	180.32	76.52	256.84
Gingelly	3000	1018	625	375	18.75	3.82	22.57
Coconut	5150	0	3750	3750	193.13	0.00	193.13
Caster	347	1649	1000	600	3.47	9.89	13.36
Sunflower	304	10	1125	675	3.42	0.07	3.49
Other oil seeds	1620	470	1125	675	18.23	3.17	21.40
Cotton	3360	2778	3250	1950	109.20	54.17	163.37
Sugercane	6300	3128	6250	6250	393.75	195.50	589.25
Chillies	617	0	1250	1125	7.71	0.00	7.71
Turmeric	3331	2295	3750	3750	124.91	86.06	210.98
Arecanut	571	0	1125	1000	6.42	0.00	6.42
Tobacco	3426	0	1500	1500	51.39	0.00	51.39
Banana	933	1000	5000	5000	46.65	50.00	96.65

Tapioca	2205	1323	1750	1250	38.59	16.54	55.13
Other Crops	12879	23088	1250	1125	160.99	259.74	420.73
Total					2334.56	948.99	3283.56

* Source: Joint Director of Agriculture Erode 2002.

Note : **Water requirement at 40 per cent efficiency level.

*** Effective Rainfall is not included

Col: Column

5.1.4. Supply-Demand Gap for Water in Agricultural Sector

The details of total supply and demand for water of agricultural sector were calculated and presented in the Table 5.10. It could be seen from the table that the total supply of surface water and groundwater was 1516.12 MCM and 490.85 MCM respectively. So, total basin supply of water is 2006.97 MCM. Demand for water was 3283.56 MCM in the basin. The quantity of supply and demand gap was 1487.49 MCM.

Table 5.10 Supply - Demand Gap for Water in Agriculture in 2001-02

Sl.No	Particulars	MCM
1	Supply:	
	Surface water	1516.12
	Ground water*	490.85
	Total	2006.97
2	Demand	3283.56
3	Supply -Demand Gap	-1276.59 9

Source: * Calculated on the basis of figures furnished by Central Ground Water Board, "Ground Water Resources and Development Prospects in Coimbatore District & Periyar District", Hyderabad, 1994

5.1.5. Supply of and Demand for Water in Domestic Sector

5.1.5. a. Supply of Water

The domestic requirements of Bhavani river basin as also the adjacent Noyyal basin are met partly by surface water in Bhavani river. The river provides water to several municipalities, town panchayats and village panchayats for domestic consumption. The municipalities pump water for domestic requirements directly from the river.

The annual drawl from the river for the existing schemes and the schemes that are proposed in the future by the TWAD Board is of the order of 174 MCM. There are two water supply circles for household water requirements in Lower Bhavani Basin i.e.

1. Coimbatore circle and 2. Erode circle. The details of the various schemes and their water supply are given in Tables 5.11 and 5.12.

The table indicates that 9 schemes are running to provide drinking water supply to Coimbatore Circle. The total drawl from Bhavani river for this circle is 378.50 mld (0.38 MCM) and yearly 138.5 MCM. Among the nine schemes, five schemes running to give 335.86 mld (0.34 MCM) and yearly (122.58 MCM) of water to Noyyal Basin. There are 32 schemes are running to give drinking water to Erode Circle. The total drawl from Bhavani river in this circle is 97.126 mld (0.09 MCM) and yearly 35.45 MCM. Hence, the total drinking water drawl from Bhavani river is both for Coimbatore and Erode circles, which is 475.626 mld (0.48 MCM) and yearly it is 173.60 MCM

Table 5.11 Drinking Water Supply Schemes in Coimbatore Circle

Sl.No	Scheme	Quantity of drawl (mld)
1	Coimbatore corporation 20 town panchayats and 523 rural habitations	131.25
2	Tiruppur municipality and 412 wayside habitations	82.49
3	Karamadai T.P.I	2.95
4	Thekkampatty CWSS	0.72
5	Siruvani WSS	101.4
6	Mettupalayam municipality	20.94
7	Sirumugai	3.64

8	CWSS to Annur – Avanashi	15.11
9	CWSS to Koundampalayam and Vadavalli T.PTS	20.00
Sub Total -1		378.50

Source: Tamil Nadu Water Supply and Drainage Board, Erode 2002.

mld: million liters per day

Table 5.12 Drinking Water Supply Schemes in Erode Circle

Sl.No	Scheme	Source	Quantity drawl (mld)
1	WSIS to Sathyamangalam Municipality	Thalakarai	20.40
2	WSS to Gobichettipalayam Municipality	Sengalakarai	9.50
3	WSS to Bhavani Sagar	Bhavani Sagar Canal	0.80
4	WSS to Kothamangalam and 4 other village panchayats in Bhavani & Sathy Union	Kothamangalam	2.86
5	WSS to Kembanaickanpalayam RTP	Periyakoduveri	0.88
6	CWSS to Kasipalayam and 12 other habitation in T.N Palayam	Makkinam Kompai	1.07
7.	CWSS to Periyapuliyur and 10 other habitations in Bhavani Union	Siraimetan palayan	0.30
8	CWSS to Kadayampatti and 4 other habitations in Bhavani Union	Thalavaipettai	0.48
9	WSS to Jambei RTP in Bhavani Union	Thalavaipettai	1.59
10	CWSS to Vellalapalayam,Vellankoil and 54 other Habitations in Gobi Union	Nanjayagoundanpalayam	1.66
11	CWSS to Doddampalayam and 116 wayside Habitations in Erode district	Bagadu Durai	3.23
12	CWSS to Periya Kodiveri and 7 other village panchayats in T.N.Palayam Union	Kodiveri	4.10
13	CWSS to Kugalur and Athani T.P.	Kuppandam palayam	2.88
14	WSS to Nambiyur and 5 other V.P.	Makkinam Kompai	1.75
15	CWSS to Mahalipudur and 7 other habitations in Nambiyur in Sathy union	Makkinam Kompai	1.06
16	CWSS to Goundampalayam and 7 other habitations in Gobi and Bhavani Unions	Perunthalaiyur	1.10
17	CWSS to Olagadam RTP and 4 VPRTs in Ammapet and Bhavani Union	Thalavai pettai	1.16
18	WSS to Appakudal RTP in Erode district	Kotham Poondi	1.00
19	CWSS to Kavunapadi, P.Mettupalayam and Salangapalayam town panchayat	Perunthalaiyur	2.21

20	CWSS to Pudukothukadu and 4 other habitations in Sathy and Bhavani sagar	Ariyappam palayam	0.72
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Sl.No	Scheme	Source	Quantity drawl (mld)
21	CWSS to Kalingayam, Kolapalur, Kunnathur and Siruvallur RTP	Sengalakarai	5.18
22	CWSS to Vemmandampalayam and 7 other village PTS in Nambiyur Union	Pudukothukadu	2.35
23	WSS to Ariyapampalayam RTP and Konamoor village panchayat	Pudukothukadu	2.95
24	CWSS to Nallampatty, Pethampalayam, Kanjikoil and Pallapalayam RTPs	Siraimetan - Palayam	6.65
25	CWSS to Elathur, Nambiyur RTP and Kosanam, Thalkuni VPTs in Erode	Arasur	8.633
26	CWSS to Nagalur and 2 other panchayats in Anthiyur Union	Near Athani	1.89
27	CWSS to 17 habitation s in Chinnapuliyur	Vairamangalam	0.44
28	WSS to Punjaipuliyampatti UTP	Bagadu Durai	2.94
29	WSIS to Anthiyur UTP	Athani	2.62
30	CWSS to Kavundapadi, V.P.	Kuttipalayam	3.30
31	CWSS to Moongilpatti, Kilvani, Vempanthi	Moongilapatti	0.80
32	WSIS to Siruvalur VP	Kavundapadi	0.50
Sub Total-II			97.13
Total			475.63mld 174 MCM/year

Source: Tamil Nadu Water Supply and Drainage (TWAD) Board, Erode 2002.

Note: CWSS : Combined Water Supply Scheme
WSS : Water Supply Scheme
WSIS : Water Supply Improvement Scheme
mld:million liters per day

5.1.5. b. Demand for Water in Domestic Sector

The requirement of water in the domestic sector has been estimated on the basis of per day water recommended level by TWAD board. The total water need of domestic sector was estimated by multiplying population of the basin by the per day water allocation norms of TWAD board. Tamil Nadu Water Supply and Drainage Board

recommendation level per day for rural areas was 90 lpcd (liters per capita per day) and urban, municipalities, corporation areas were 110 lpcd. The water requirement (demand) for domestic sector is given in Table 5.13. It could be seen from the table that the demand is about 93.68 MCM per year (256.66 MLD) and supply is 51.01 per year (139.76 MLD) in the basin. The gap is 42.66 MCM / year (116.9 MLD)

Table 5.13 Domestic Demand for and Supply of water in Lower Bhavani Basin for 2001-02

Sl. No	Population	Old Ayacut	New Ayacut	Total Population	Recommend water supply** (LPCD)	Total MLD
I	Demand:					
1	Rural	1053090	972084	2025174	90	182.26
2	Urban	351738	324682	676420	110	74.40
	Total	1404829	1296765	2701594		256.66
II	Actual drawl:					
a	Coimbatore Circle					42.64
b	Erode Circle					97.12
	Total				139.76	
III	Demand - Supply Gap				-116.9 42.66 MCM/year	

LPCD: Liters per capita per day

MLD: million liters per day

Source: * Unpublished population statistics 2001, Assistant Director of Statistics, Erode and Coimbatore.

** Tamil Nadu Water Supply and Drainage Board, Government of Tamil Nadu

5.1.5. c. Demand for Water and Supply in Noyyal Basin from Bhavani River

The details of The supply and demand for water in Noyyal basin to be met out from Bhavani river is given in Table 5.14. From the table it is found that 335.86 MLD (133.25 MCM yearly) of water supplied from Bhavani river and 253.56 MLD (92.54 MCM) demanded in Noyyal basin. The excess water supply was 82.3 MLD (30.03 MCM).

Table 5.14 Domestic Demand for Water in Noyyal Basin and Supply from Bhavani River for 2001-02

Sl. No	Population	Total Population	Recommend water supply** (LPCD)	Total MLD
I	Demand:			
1	Rural	1085682	90	97.71
2	Urban Population	1416822	110	139.66
	Total	2502504		253.56
II	Supply Coimbatore Circle			335.86
III	Demand - Supply Gap		+82.3 30.03 MCM/year	

Source: * Unpublished Population Statistics 2001, Assistant Director of Statistics, Coimbatore.

** Tamil Nadu Water Supply and Drainage Board recommendation level.

Note: LPCD: Liters per capita per day and MLD: Million liters per day.

5.1.6. Industrial Water Supply and Demand

The Water Resource Organization (WRO) has permitted 20 industries to draw a total quantity of 39.152 MCM (1,383 Mcft)/year. Out of 20 industries, 7 industries are on the upstream side of Bhavanisagar and the remaining 13 industries are on the downstream. Water demand (Table 5.15) for these industries is fully met out by this supply. Hence, in the case of industries, demand for and supply of water are equal.

Table 5.15 Industries Permitted by the Government to Draw Water from Bhavani River

Sl.No.	Name of Industry	Quantity (M ³ / year)
1	M/s Encee Aromatics, Mettupalayam.	30,405
2	M/s Indo Swiss Synthetic Gem Manufacturing CO, MTP.	5,67,341
3	M/s Nanjiah Lingammal Polytechnic, Mettupalayam.	16,593
4	M/s Sudarasan Paper Mills Mothepalayam, Sirumugai	5,97,213
5	M/s Sri Vishnedevis Mills Pvt.Ltd. Jedayampalayam.	2,19,000
6	M/s Siruvani Textile (p) Ltd, Jedayampalayam.	41,482
7	M/s Micro Tex India Limited Tiruppur.	1,82,500
8	M/s South India Viscose Ltd, Sirumugai.	2,15,55,060
9	M/s T T Maps Pungar Bhavani Sagar, Sathy Taluk.	16,60,750
10	M/S Sam Turbo Industry Bhavani Sagar	7,30,000
11	M/s Sri Karthikega Paper and Board Limited, Rajanagar.	1,83,000
12	.M/s Talent Paper Board (P) Ltd Rajanagar	14,60,000
13	M/s Bannariamman Sugars Ltd, Sathy Taluk	16,32,645
14	M/s Bannariamman Sugars(Granite Division)Sathy Taluk	7,87,991,54,750
15	M/s Bannariamman Educational Trust, Alathukombai, Sathy.	54,750
16	M/s KPR Mills (P) Ltd Indiampalayam, Sathy Taluk.	54,750
17	Sri Bhavani Textiles (P) Ltd Akkaraikodivery, Erode.	1,36,875
18	M/s Sathy Sugars Ltd, Appakudal, Bhavani Taluk.	39,81,420
19	Tamilnadu Newsprint & Paper Ltd, Kagithapuram, Karur.	88,635
20	M/s Coimbatore Alcohol & Chemicals Ltd, Bhavani.	51,76,153
	Total	3,91,52,563 (or) 39.15MCM

5.1.7. Different Sectors Demand and Supply of Water in Bhavani Basin

The details of different sectoral water demand and supply are presented in Table 5.16 and Figure 5.4.1. It could be seen from the table that in all the sectors water demand is higher than the supply except in inter basin domestic water supply (82.3 MCM).

Table 5.16 Different Sectors Water Demand and Supply in Bhavani Basin

Sl.No	Sectors		Demand	Supply	Gap
1	Agriculture (MCM)		3283.56	2006.97	-1276.59
2	Domestic				
	(a) Intra basin	(MLD)	256.66	139.76	-116.90
		(MCM)	93.68	51.01	-42.67
	(b) Inter basin	(MLD)	253.56	335.86	+82.3
		(MCM)	92.54	133.25	+30.03
3	Industry (MCM)		39.15	39.15	0.00

5.1.8. Projection of water Demand in Domestic and Industrial sector

With projections of population to be served by the basin water, the actual requirement was worked out assuming that the population is to be served at existing norms of 90 liters/person/day in rural areas and 110 liters/person/day in urban areas. Thus Demand for water for domestic sector requirement for any time period in MCM (for year 2011 and 2021) was calculated by the following method and presented in Table 5.17.

$$\begin{aligned}
 r_i &= [(p_{2001}/p_{1991})^{1/10}] - 1 \\
 r_i &= [(2025174/1746993)^{0.1}] - 1 \\
 r_i &= 0.01 \\
 p_{r2011} &= p_{r2001}(1+r_i)^{10} \\
 p_{r2011} &= 17.47 \times 1.01^{10} \\
 &= 20.25 \text{ lakhs}
 \end{aligned}$$

Where, p_r =rural population

Table 5.17 Projection of Demand for Water in Domestic Sector

Sl .No	Population	Population (lakhs)			Growth Rate	2001 Water requirement /MCM	2011 Water requirement /MCM	2021 Water requirement /MCM
		2001	2011	2021				
1	Rural	17.47	20.25	22.35	10.1	66.53	73.42	81.04
2	Urban	5.73	6.76	7.47	10.2	27.16	29.97	33.08
	Total	23.20	27.02	29.82	10.15	93.69	103.40	114.12

It could be seen from the table that domestic sector demand for water based on existing supply norms projected as varied from about 66.53 MCM in 2001 to about 81.04 MCM in 2021 in rural areas. Similarly in urban areas with the present supply norms, the projections varied from about 27.16 MCM in 2001 to about 33.08 MCM in 2021.

The projected total demand thus ranges from 93.69 MCM in 2001 to about 114.12 MCM in 2021.

Considering industrial demand for water, the existing level as estimated based on quantities drawn by the licensed industries is about 39.15 MCM representing about 1.92 percent of the basin resources. The Water Resource Organization (WRO) has permitted 20 industries. The compound growth rate was worked out for major water drawl industry (sugar, paper, rayon and distillery industries) in the basin and is given in Table 5.18. It could be seen from the table that rayon industries water requirement is high (24.25 MCM) in next decade followed by sugar (6.35 MCM), distillery (5.89 MCM) and paper (5.15 MCM).

Table 5.18 Compound Growth Rate (CGR) of each Category of Industries

Sl.No	Category of Industry	GCR	't' value	Demand for water (MCM)		
				Present	2011	2021
1	Sugar (N=2)	13.30	1.73 (0.445)	5.61	6.35	7.20
2	Paper (N=6)	9.23	14.57 (0.006)	4.72	5.15	5.66
3	Rayon (N=1)	12.48	2.821 (0.041)	21.56	24.25	27.16
4	Distillery (N=2)	13.71	5.57 (0.023)	5.18	5.89	6.69

The other each minor industry water requirement for last 10 years (1992-93 to 2001-02) was not available. Take average compound growth rate of major industries and assume this compound growth rate (12.18 %) for minor industries. So, the total industrial water requirement increase from present demands 39.15 MCM 2001-01 to 47.37 MCM in 2021. It is important to analyze why this gap between demand for and supply of water occur among different sectors. What are the factor contributing for this drawl by agriculture and industries, what the rights enjoyed by different sectors. The following section explains the history of water allocation/rights in the basin.

5.2. History of Water Allocation/ Riparian Rights of Water

It is important to bridge the supply-demand gap either by reducing the demand or by increasing the supply level to match the growing demand in future through existing water allocation rights. Therefore, analysis of water rights is one of the important objectives of this study. Careful analysis and assessment of the different water allocation rights in water transfer in the Lower Bhavani basin will thus helpful to plan its allocation between different uses by efficient water management practices and technique to meet the growing demand for industrial and municipal uses.

According to the Indian Constitution, water is placed at the disposal of the states. In actual practice, however, the central government/state relationship is more complex in nature, since the central government allocates revenue for development purposes and the states depend on the central government for national and international funds (Chhatrapati Singh, 1989).

State sovereignty over water began with the Easement Act of 1882, which legitimized customary rights regarding surface water and provided two rules for recognition of those rights: length of usage (prescription) and local custom (Chhatrapati Singh, 1991). Thus, the act recognized customary water rights that allow certain people to take surface water from another's land. It did not, however, grant natural or customary rights over groundwater, whether collected from a well, from springs, or from undefined sources.

5.2.1. Statutory Rights

The laws subsequent to the Easement Act (1882) slowly shifted the emphasis on people's water rights from natural to proprietary or usufruct rights. In general, 84 per cent of the total land in India is owned and held under proprietary rights: 71 per cent is owned by proprietors with rights to transfer the title, and 13 per cent by proprietors without such rights. Only 2 per cent of land is held in the form of land tenure. The principle that there should be an absolute limit to the amount of land one individual may held was accepted in the country's First Five Year Plan (1951-1955).

In the case of command area of surface irrigation systems, farmers have the right to get water from a water project, depending upon its availability; water charges are linked to land revenue. In the case of areas benefited by rivers and streams, farmers have riparian rights for getting water supplies.

5.2.2. Riparian Rights

Riparian owners – those who own land abutting a body of water – have the right to use water from the body of water that flows past their land equally with other riparian

owners. Riparian owners also are entitled to have the water come to them undiminished in flow, quantity, or quality, and to have it go beyond their land without obstruction. Therefore, the upstream riparian owner is subject to the downstream riparian owner's right to have water flow down to him or her in the customary manner. The courts do, however, recognize the custom that the upstream riparian owner has the right to use as much water as convenient for irrigation, as long as the owner does not diminish the amount the downstream owner can use. Similarly, the downstream riparian owner does not have the right to inundate or submerge the land of the upstream owner by obstructing or building a dam on the body of water in question.

5.2.3. Groundwater Rights

The basic rights for groundwater in India are riparian rights: Ownership of the overlying land rights allows farmers to tap underground water. However, there are significant statutory limitations on these rights in Tamil Nadu. For example, spacing norms for pumps have been prescribed based on guidelines issued by the National Bank for Agricultural and Rural Development (NABARD) for the area between two minor irrigation structures. These range from 150 m for any two dug wells to 600 m for any two deep tube wells. These rules apply even to new wells that have been financed with commercial loans, or to existing wells that have been deepened. In Tamil Nadu, however, groundwater development is mostly done by private individuals with their own finances, so very few groundwater rules are being followed (Public Works Department, 1994).

In coastal areas, groundwater development has been extensive because of the areas' favourable hydro geological conditions. As a precautionary measure, certain restrictions have been imposed on financing minor irrigation schemes that involve groundwater located up to 10 km from the coast of Tamil Nadu.

In the study area, there are separate water sharing rights for both old and new anicut.

5.2.4. Water Sharing Rights in Old Anicut

The old anicut was constructed 400 years back. This was only to divert the river water into the canals. There is no storage of water. The flow in the old channels was continuous throughout the year except in the period of repairs/maintenance. The farmers are growing 2 or 3 paddy crops or sugarcane as water is available always. Even in the scarcity year, it was reasonable to give water to 10 – 11 months since the duration of the paddy crop was about 5-6 months and to take 2 crops, they require water for 10-11 months. The duty for the old system works out about 20-30 acres/cusec (282 ha/cumec).

Riparian rights under the old project comprising the Thadapalli, Arakkankottai, and Kalingarayan canals (TAKC) are prevalent in the basin. These rights allow farmers to draw extra water from the Bhavani River and Reservoir. (These farmers were enjoying a greater amount of water supplies before the Lower Bhavani Project (LBP) was constructed in 1953).

The farmers' organization in the TAKC project is constraining LBP authorities from diverting excess water from the old project. Meanwhile, the government is making efforts to divert considerable quantities of water from the Bhavani River for municipal and industrial uses, giving domestic requirements top priority.

As for any other basin in the state, the most crucial issue facing the Bhavani Basin is supply. With demand for water exceeding supply, basin authorities are addressing the problem by reallocating available water between the old and new projects by modifying the rights of farmers in the old project, changing crop patterns, and fostering conservation through improved water use efficiency.

Farmers along the three TAKC canals have riparian rights from the Bhavani River and receive irrigation supplies in two seasons (10 to 12 months total). Mostly wet crops, such as rice, sugarcane, banana and turmeric, are grown in the region. Total water availability is based on the duty concept (Duty refers to the continuous rate of water flow desired to irrigate a certain area according to its crops' irrigation needs during the growing season). For example, 60 duty means 60 cusec of water, or 60 cubic feet per second, are to be maintained in a canal continuously over the growing season to irrigate a

certain area in the command). In the TAKC canals, total water availability based on 60 duty is about 725.26 MCM (24 TMC) (Authority, Chief Engineer (Irrigation) Memo No.9989/53 NEP, dated 9th August 1954), compared with the total water availability of about 1814.40 MCM in the Bhavani Reservoir.

5.2.5. Water Rights in the New Anicut (LBP)

There was a proposal to construct Lower Bhavani dam as early as 1834, but it could materialize only during 1947 after the country got independence. The construction of the dam and canal net work was started in 1948 and completed in 1955. The new ayacut was thrown open for irrigation in stages from 1952-53 onwards. The main canal covers a distance of 200 km and has 72 distributaries. The main canal is taken on contours and the distribution is on ridges.

The system was considered only for irrigated dry crops like cotton, millets, groundnut etc; Paddy was limited to seepage affected valleys of about 4000 ha originally. The intermittent system of irrigation was introduced. As per this, water was allowed in the field bothies for 5-1/4 days for irrigating the ayacut and then for subsequent 5-1/4 days the supply was stopped. The crop restriction was imposed under which except in the seepage affected areas paddy was prohibited. This is because the project was designed to give irrigation only for dry crops. But once the water was let in, the farmers raised paddy crop in large area. Consequently farmers in the tail reaches experienced acute scarcity of water. Further, it was observed that during intermittent system, the field getting water in the first 5-1/4 days became dry during the closure and were taking away full quantity of water as soon as the water was let in the next 5-1/4 days. This caused serious hardship to the tail end farmers and as a result the method failed.

In 1959, the Government in consultation with farmers introduced zonal system of irrigation. Under this the entire system was divided into 2 zones. For dividing the ayacut, the sluice in the odd miles of the main canal and odd miles in the distributaries were all numbered as Number I turn sluice. The sluice in the even miles was all numbered as Number II turn sluice. Water was made available continuously for each zone for one season for a period of 4 months. Farmers were permitted to raise any crop they decided

and crop restriction was removed. Again from the year 1969-70, modified turn system (zonal system) or year-to-year rotation was introduced. Under this system, farmers under Number I sluice were allowed to raise paddy crop from 15th August – 15th December.

Continuously supply of water was ensured and there was no restriction on the kind of crops to be raised. The designed duty is 60 acres/cusec (846 ha/cumec). The total water that will be let out will be 725.26 MCM.

Following this, Number II turn sluices were given water from 16th December to 15th April but permitted to raise only irrigated dry crops. Water was regulated by giving full supply for 8 to 10-½ days immediately followed by no supply for another 7-½ days. The designed duty is 60 acres/cusec (846 ha/cumec). Water that would be let out will be 362.88 MCM. Then from 15th August – 15th December, water was allowed for farmers under Number II turn sluice for raising paddy and from 16th December to 15th April, the Number I sluice received water for raising dry crops and so on.

In practice during a calendar year a farmer will get water to raise the dry season crops followed by wet season crops. This system referred to a year rotation, since the water releases are in a year wise succession in a definite order.

The LBP irrigates about 83,800 ha. Irrigation is based both on river flow and reservoir storage, and the project's main canal runs 198 km to feed 124 distributaries. The entire command area is irrigated in two turns – half the area in each turn. A uniform duty of 60 and 120 in the wet and dry seasons, respectively, is adopted throughout the command. Total water available in the LBP amounts to 1088.64 MCM (725.76 MCM in the wet season and 362.88 MCM in the dry season) (Palanisami, 1984).

5.2.6. Compendium of Rules of Water Regulation in Old and New Ayacut Control

Regulation of supply from the reservoir shall be under the control of the Officer in charge of the Bhavanisagar called 'Controlling Officer' for purposes of regulation under this compendium of rules.

5.2.6.1. Impounding in the Reservoir

1) Impounding shall be done taking into account (a) the inflow into Mettur Reservoir, (b) inflow into Bhavani Reservoir and (c) the limit flows given in rule 3 below, which include discharges for old Bhavani and Cauvery irrigation and (d) the discharges for old Bhavani Irrigation under rule 1 (2). The quantities that may be impounded shall not exceed either (a) plus (b) minus (c) or the sum of inflows into Mettur and Bhavani Reservoirs less the limit flows of (b) minus (d). Bhavani inflows less Bhavani old irrigation discharge whichever of the two is less.

2) The quantities that are not impoundable under this rule shall be passed down through the river sluices as far as possible and over the spillway. This is with a view to pass down the silt laden flows through the river sluices.

5.2.6.2. Limit flows into Mettur and Bhavani Reservoirs for impounding in the Bhavani Reservoir

Irrespective of actual issues from Mettur, the limit flows for purposes of impounding in Bhavani Reservoir (c) in Rule 2, shall be taken as shown in Table 5.19.

Table 5.19 Limit Flow into Mettur and Bhavani Reservoirs

Sl.No	Month	Quantity (Cusecs)
1	12 th June to 30 th June	13,300
2	July	21,500
3	August	28,000
4	September	22,400
5	October I Half	19,400
6	October II Half	15,400
7	November	13,400
8	December	13,250

9	January I Half	11,200
10	January II Half	5,000
11	February I Half March to June 12 th	As per rule 4.

Source: Authority, Chief Engineer (Irrigation) Memo No.9989/53 NEP, dated 9th August 1954.

5.2.6.3. Issues for Bhavani old Irrigation

The requirements of Bhavani old Irrigation are included in the limit flows specified in Rule 3 and in the quantities mentioned in Rule 2.2.

Whenever the discharges through the river sluices or the spillway or both exceed the figures shown in the Table 5.19, such discharges shall be taken to include the requirements of Bhavani Irrigation. Whenever the natural flows are less than the figures shown in Table 5.20, regulation may be done as follows:

Table 5.20 Discharges through the River Sluices or the Spillway

Sl.No.	Month	Quantity (Cusecs)
1	June I Half	1,000
2	June II Half	1,400
3	July and August	1,600
4	September, October and November	1,500
5	December and January	1,350
6	February I Half	1,100
7	February II Half	650
8	March	450
9	April	350
10	May	500

Source: Authority, Chief Engineer (Irrigation) Memo No.9989/53 NEP, dated 9th August 1954.

The natural flows may be passed down without impounding in the reservoir and no issues shall be made from the storage in the reservoir. The Executive Engineer in charge of Bhavani old Irrigation shall however have the discretion to limit these natural flows to the average irrigation demand at the time and ask for the difference between natural flows and the actual demand to be temporarily impounded in the reservoir. The figures in Table 5.21 show the average monthly demand may serve as a guide in regulating the issues, and impounding the excess in the absence of other specific instructions. This temporary impounding shall be treated as credit to the Bhavani old Irrigation. The quantity so impounded to the credit to the Bhavani old Irrigation shall not exceed 16.95 MCM at any time.

Table 5.21 Average Monthly Demand for Water in the Basin

Sl.No.	Month	Quantity (Cusecs)
1	June I Half	900
2	June II Half	1,300
3	July and August	1,500
4	September, October and November	1,400
5	December	1,250
6	January	1,200
7	February I Half	1,000
8	February II Half	600
9	March	400
10	April	300
11	May	450

Source: Authority, Chief Engineer (Irrigation) Memo No.9989/53 NEP, dated 9th August 1954.

5.2.6.4. Regulation of Bhavanisagar

1. The regulation at Bhavanisagar shall be done twice everyday at 8 a.m. and 6 p.m. respectively and will normally be on the basis of figures for 6 p.m. of the previous

day for 8 a.m. regulation and 8 a.m. of the same day for 6 p.m. regulation. If these figures are not available the figures immediately previous to them shall be taken. But during floods and on other similar occasions, the controlling officer shall have discretion to adopt even later figures of discharges of Mettur Reservoir, Kodiveri anicut and Bhavanisagar so far as he is able to obtain these by telephone or in any other way so that opportunities to impound water in the Bhavanisagar are not missed. Any wrong impounding based on such figures in the light of later actual figures should be corrected within the following 48 hours.

2. The limit flows for impounding given in Rule 3 are for normal working conditions. Whenever due to local rains or contribution from lower catchment, issues from Mettur for Cauvery irrigation are less than the figures given in Rule 3 minus the discharges issued for Bhavani old irrigation, such figures plus Bhavani issues shall be substituted for the quantity given in Rule 3.

3. Notwithstanding the provision in Rules 2 and 3, the Chief Engineer for Irrigation may order (1) raising or lowering of impounding or other limits specified in rules (3) and (4), (2) release of water stored in the Reservoir either for Cauvery or Bhavani old irrigation or for other purposes.

5.2.6.5. Issues for New Irrigation

On or before September every year, the date of opening of the new canal and the area opened for irrigation will be notified. The canal will normally be opened for irrigation of its ayacut from 15th September to 15th March in the year following, when it will be closed unless otherwise notified.

The supplies for new irrigation between 15th September and 31st December will be for the area thrown open or irrigation. Half the area opens for irrigation may grow cotton and the other half shall grow only irrigated dry food crops. The supply between 1st January and 15th March will be only for cotton crops unless otherwise notified before 1st January.

The maximum supply for the above irrigation during the period September to December will normally be 2,260 cusecs for the full area of 207,000 acres and during January to March 1,130 cusecs for half the area under cotton crop unless otherwise directed, subject to such modifications that may be necessary with reference to the working instructions.

5.2.6.6. Miscellaneous

1. The Controlling Officer shall have discretion to impound a quantity less than that prescribed under the rules into the river with a view to reduce the reservoir water levels in special circumstances such as safety of the reservoir. He should report of such action immediately to the Chief Engineer for Irrigation and also to the Superintending Engineers, Coimbatore and Tanjore and Executive Engineers, Mettur and Coimbatore Divisions by telegrams and post-copies in confirmation should be immediately posted. He should report the reasons for this action to the Chief Engineer for Irrigation and to other officers to whom he is administrative subordinate.

2. The Controlling Officer shall not impound in excess of any level prescribed by the Chief Engineer for Irrigation. Details of regulation both normal and flood shall be promptly recorded and reported in water report forms. Separate rules for flood regulation are issued as in the case of Mettur. (Copy of G.O.Ms. No. 2367, Revenue Department, dated 21st September 1964.) Subject – Irrigation – Major – Coimbatore District – Lower Bhavani Project – Revised Pattern of Irrigation and cropping – Orders passed.

Read again –

G.O.Ms.No.2534, Revenue, dated 21st August 1963.

G.O.Ms.No.2843, Revenue, dated 21st September 1963.

Read also –

From the Joint Collector of Coimbatore Reference No.32413/63.48, dated 27th September 1963.

From the Board of Revenue Reference No.D2/3380/53, dated 25th October 1963.

From the Board of Revenue Reference No.H4/7630/63-2. dated 20th October, 1963.

From the Board of Revenue Reference No.H2/3386/63-16, dated 29th February 1964.

5.2.6.7. Order of New Ayacut

The Lower Bhavani Project was commissioned in 1954. The targeted ayacut of the Project is 2.07 lakhs acres, lying in the districts of Coimbatore and Tiruchirappalli. The Project was originally designed as an "all dry" project for raising cotton and millets, setting apart 10,000 acres of low-lying seepage affected lands for raising paddy. Actual experience during the first five years since the opening of the project showed that the original objectives of the project could not be achieved as the extent under paddy increased to 65,668 acres as against the original estimate of 10,000 acres. This was because of the highly porous nature of the soil, making paddy cultivation easy and cotton cultivation difficult. It therefore became necessary to operate the project as a 'diversified dry-wet project' with paddy as the largest single crop on one half of the total ayacut. The 'Seasonal sluice turn system' was introduced in fasli 1369 and is in force now. Under this system, supply of water is normally allowed in two separate seasons, the first from 15th August to 15th December and the second from 15th December to 15th March. In every odd number fasli, odd turn sluices are kept open during the first season and even turn sluice during the second season and in every even number fasli, even turn sluices are kept open during the first season and odd turn sluices during the second season. Crop restrictions were removed. The result was that cultivation of paddy increased enormously as indicated below:

Fasli 1369	-	28800 hectares
Fasli 1370	-	32800 hectares
Fasli 1371	-	40000 hectares
Fasli 1372	-	52000 hectares

The question of restricting the increase in paddy cultivation in the Lower Bhavani Project area, Coimbatore district in order to conserve and economically distribute the available supply of water in the Project to the best public advantage, has been engaging the attention of the Government for some time past. In G.O. Ms.No.2843, Revenue, dated 21st September 1963 the Government ordered the zoning of the ayacut with wet, garden and dry with a ceiling on paddy cultivation at 60,000 acres and sanctioned staff to do the

zoning work. Based on the findings of a pilot investigation conducted by a skeleton staff from out of the staff sanctioned, the Board has reported that zoning, with a reasonable limit for wet zone, could hardly be successfully carried out due to various reasons like induced seepage, ryots feeling against interference with their own judgment of the crop to be raised, etc. The Board has, therefore, submitted revised proposals for crop restrictions. It has proposed that, in the first turn, the ryots should have the freedom to raise the crops of their own choice and that, in the second turn; only irrigated dry crops should be allowed without concession, even with respect to the fields affected by natural seepage. It has also stated that the total commitments which the project can sustain being 36 thousand million cubic feet of water, the supply of 24 thousand million cubic feet can be allowed during the first spell, which will be sufficient for raising wet crops on 90,000 acres, and that the balance of 12 thousand million cubic feet can be let out during the second spell, which will be sufficient for raising irrigated dry crops on 90,000 acres thus bringing the total extent irrigated to 1.80 lakhs acres.

The Government has examined the Board's proposals carefully and has also discussed them with the Heads of Departments concerned and passes the following orders.

(i) In the first season (15th August to 15th December) the ryots entitled to water in the turn under the present system will enjoy complete freedom in cropping and can raise any crops they like, subject only to the restriction that the total quantity of water that will be let out for irrigation will be approximately 24 thousand million cubic feet (725.76 MCM) only.

(ii) In the second season (15th December to 15th March) the ryots in the other turn will be allowed to raise any irrigated dry crop they like, subject to the restriction that the total quantity of water available will be approximately 12 thousand million cubic feet (362.88 MCM) only.

(iii) Raising of any wet crop in the second season will be completely prohibited and heavily penalized.

(iv) If, in the second season, after meeting the requirements of the ryots in the turn entitled to water, water is still available in the reservoir, such surplus water may be made

available to the ryots in the other turn, to the extent of availability, and subject to specific orders of Government.

(v) The Chief Engineer will regulate the supply of water so as to allow approximately 24 thousand million cubic feet of water in the first season and approximately 12 thousand million cubic feet in the second season. If, in the second season, after meeting the requirements of the ryots in the turn entitled to water, there is any excess water in the reservoir, the Chief Engineer will arrange to allow the excess water to the ryots in the other turn, to the extent of availability and subject to specific orders of Government.

The Chief Engineer will also see that the supply of water in the second season is so regulated as to reduce seepage and make the raising of wet crops impossible.

(vi) These arrangements will take effect from the current fasli 1374, beginning from 1st July 1964 and will constitute the permanent pattern hereafter.

4. In paragraph 3 of G.O.Ms.No.2534, Revenue, dated 21st August 1983, the Government ordered that the staff sanctioned in that G.O. for azmoish of crops in the Lower Bhavani Project area should be disbanded, if the special staff for zoning of the area was sanctioned before the date of expiry of the period of sanction of the azmoish staff viz., 15th April 1964. The special staff for zoning was subsequently sanctioned in G.O.Ms.No. 2843, Revenue, dated 21st September 1963 but only a skeleton staff was actually employed for conducting a pilot investigation, as stated in paragraph 2. In view of this, the Board has allowed the continuance of the azmoish staff sanctioned in G.O.Ms. No.2534, Revenue, dated 21st August 1963 for the sanctioned period. The Board's action is ratified.

This order is issued with the concurrence of the Finance Department vide its U.O. No.42004-A/E8/64-1, dated 10th April 1964. (Source: By order of the Governor, Secretary to Government.)

5.2.7. Kodiveri Anicut

1. The Sector Officer in charge of Kodiveri anicut at Gobichettipalayam shall be in charge of the water regulation and he will act under the directions of the

Sub-Divisional Officer, Gobi (Regular) and Executive Engineer, Public Works Department, Bhavanisagar Division at Bhavanisagar having jurisdiction over the Kodiveri anicut, Thadapalli and Arakkankottai channels.

2. The head sluices of Thadapalli and Arakkankottai channels will be opened for irrigation at 6 p.m. on 15th April. Any alteration in time and date shall be made only with the prior approval of the Chief Engineer (Irrigation), Madras and the Collector of Periyar District and in such cases the date of postponement will be published in the District Gazette of Periyar District.

3. In rule 4 of the Rules and Regulation of Bhavanisagar the demand for the old Bhavani irrigation is given month wise. The realization at Kodiveri anicut thus depends upon the issues allowed from Bhavanisagar for Kodiveri anicut, Kalingarayan anicut and also at times the supply allowed to the Cauvery delta for supplementation. Hence from the realization at Kodiveri anicut the requirements for the Kalingarayan channel ayacut and also the issues for the Cauvery delta if allowed, should be deducted and the balance alone is to be taken for the ayacut under Kodiveri anicut.

4. The Water Registrar at Kodiveri anicut shall regulate the supply through the head sluices of Thadapalli and Arakkankottai channels in the ratio of 2:1 which is the proportionate quantity drawn in the two channels in the past years. The Thadapalli channel receives the drainage of the ayacut area of Lower Bhavani canal.

5. The quantity of water required shall be increased gradually upto full supply discharge as ordered at the discretion of the Officers in charge of regulation, depending upon the requirements to send down supplies to the tail end within the stipulated time.

6. Irrigation shall normally commence on the 18th April or from the date when water reaches the tail end and if the same reaches earlier, the opening of the sluices for irrigation shall be from the tail end upward, reach by reach, as shown in the statement.

7. The duration of supply for raising seedlings, transplantation and irrigation shall be so adjusted by the ryots and kept upto the total irrigation period fixed for each crop as noted in the statement. However, the Executive Engineer shall change the total period of irrigation for one crop as and when required only after obtaining the concurrence of the Collector and the Superintending Engineer.

8. The full supply discharge at the head sluice shall be that for the requirements of the direct ayacut plus the requirements of the water rate lands including the transmission losses and this full supply discharge will be fixed by the Executive Engineer, Bhavanisagar Division. The discharge required to be given in both the channels will be based on the actual requirement to the fields according to the condition of crop and availability of supply.

9. Supplies through sluices shall be regulated depending on the actual requirements at various stages of cultivation and equitable and uniform supply shall be maintained throughout the channels. For this purpose all the sluices should be provided with shutters and locking arrangements and care should be taken to regulate the supplies as above more judiciously. However, any reduction in supply during rainy season or for any other reason such as temporary fall in supply at anicut etc. shall be done by the Section Officer with the approval of the Sub-Divisional Officer and intimation of such reduction should be given to the Executive Engineer within a period of 24 hours after such reduction.

10. During rainy season, floods and other emergency, regulation of water shall be done by the Section Officer at his own discretion to safeguard the canal banks, masonry works and other properties and intimation of such regulation shall be given to the Sub-Divisional Officer within three hours and to the Executive Engineer within six hours.

11. Irrigation (except through authorized sluices or similar authorized sources) in any other manner than those specified above shall be considered irregular.

12. (a) If the supply in the channels are to be allowed to the minimum requirements due to the non availability or limited storage available in the reservoir, then the available supply shall be distributed uniformly until required full supply is achieved. If the

supply is restricted due to adverse seasonal conditions, the Executive Engineer on intimation from the Sub-Divisional Officer order in writing for proposing irrigation by turn system after forming the ryots through the Revenue Department as under given in Table 5.22.

Table 5.22 Order of Rotation in Kodivery Anicut

Sl.No	Order of Rotation of Reach	Period of supply
Thadapalli channel		
1	Tail end to 32/0	5 days
2	Reach 32/0 to 0/0 and Kugalur and Singiam branch channels	4 days
Arakkankottai channel		
1	Tail end to 17/0 of Arakkankottai channel Perumugai Athani channels, Vaniputhur Branch and Extension channels	5 days
2	Reach 0/0 to 17/0 of Arakkankottai channel	4 days

Source: Chief Engineer (Irrigation) Memo. No. C3/43169/83 dated 30th July 1984.

12(b). The above order of rotation will be repeated at the end of the continuous cycle of 9 days. On receipt of such orders from the Executive Engineer, the Sub-Divisional officer shall intimate the Tahsildar, Gobichettipalayam in writing the order of the Executive Engineer proposing the turn-system, with date and time of introduction of turn system and request him to appraise the ayacutdars immediately by beat of tom-tom in all the villages concerned. The Tahsildar in turn shall arrange to give wide publicity within 24 hours on receipt of information from the Sub-Divisional Officer. The turn system referred to above will be put into operation from 6.00 a.m. on the day following the intimation given to the Tahsildar.

12(c). The Sub-Divisional Officer shall communicate the Executive Engineer the exact date and time of the introduction of the turn system immediately. Due intimation of the turn system shall be given by the Executive Engineer to the Collector and Superintending Engineer within 24 hours of the commencement of the turn system. The turn system will be continued until such time the supply in the reservoir becomes favourable for the continuous supply without turn system in both channels. The actual regulation of each sluice will be done by the lascars under instruction and Supervision of the Channel

Superintendents. The Section Officer in charge is responsible for the equitable distribution of water in all sluices from head to tail including the sluices to branch channels based on the supply allowed in the head sluice of each channel according to the availability within the limit flows. When such condition of low supply arises, the ryots and the Tahsildar should be informed.

13. The channels will be closed from 6 p.m. on 15th February to 6.00 p.m. on 15th April of each year for annual repairs. Any deviation in the time and date of closing of the channels for the annual repairs shall be done with the prior approval of the Collector and the Superintending Engineer. Due intimation of the deviation of the closure period shall be given by the Superintending Engineer to the Chief Engineer (Irrigation).

14. Special release of water to the standing sugarcane crops under Arakkankottai channel and Thadapalli channel during their closure period (i.e.) from 16th February to 15th April can be allowed subject to the following conditions:

- (i) There should be sufficient storage in Lower Bhavani reservoir or normal flows in the river to meet the requirements of the special wettings.
- (ii) the closure works of the channel should not be interfered with, and
- (iii) the quantity of supply to be allowed and number of days for which supply may be given will be decided by the Superintending Engineer in consultation with the Collector of Periyar district.

(Vide G.O.Ms.No.980, P.W.D., 29th April 1968 and G.O.Ms.No.139, P.W.D., 30th January 1968).

15. The water registrar at Kodiveri anicut will regulate the supply through the channels for normal irrigation as per the instructions by the Section Officer and will maintain the water register of the channels and head works and submit daily discharge calculations of the head sluice and anicut to the Section Officer, Sub-Divisional Officer and Executive Engineer. Any change in water regulation shall be recorded in the water register then and there and it should be recorded specifically in the daily reports submitted. The Channel Superintendents will record the water readings at the several gauges in their reaches during the day at the intervals fixed by the Executive Engineer and send them to the Section Officer,

who in turn will compile them and submit a consolidated daily water report to the Sub-Divisional Officer and Executive Engineer. A water register with daily water reading should be maintained by the Section Officer. The Channel Superintendents will, in addition to the daily water readings, maintain a register showing the regulation at sluices to show whether regulation is done as per these water regulation rules. Any change in the opening of the sluice except those provided for in the rules shall be intimated to the Section Officer, Sub-Divisional Officer and the Executive Engineer direct by the Channel Superintendents. Should any person unauthorized interfere or attempt to interfere with any sluice or with the bank, a report shall be made immediately by the Public Works Department channel establishment to the Concerned Village Munsif or the nearest Police Officer or to both of them according to the gravity of the case and a copy thereof sent at once to the Section Officer.

16. Flood Regulation – (i) Due to the cross drainages entering into the channels besides the seepage water from Lower Bhavani Project area in the lower reaches of Thadapalli channel, vigilant watch should be kept by the Channel Establishment over the channel banks throughout the day.

(ii) The Section Officer should watch the conditions all over the area and use his discretion either to completely cut off the supply or to effect partial reduction at the head based on the intensity of the rains and consequent inflow of flood water into the channel. The action taken by the Section Officer in this regard should be reported to the Sub-Divisional officer and Executive Engineer immediately.

17. No open cut will be allowed for taking water direct to water ticket lands and necessary regulating sluice has to be constructed so that the required flow for the ayacut specified alone can be taken. During drought conditions and in turn system period, the supply to these lands can be given without detriment to the registered ayacut of the channel from head to tail end. The old ayacut channel opening period is given in Table 5.23.

Table 5.23 Old Ayacut Channel Opening Period**Source:** Chief Engineer (Irrigation) Memo. No. C3/43169/83 dated 30th July 1984.*5.2.9. Kalingarayan Anicut and Channel*

The following rules for the regulation of water in the Kalingarayan Channel shall be adopted from Fasli 1374 of 1964-65.

1. The Section Officer in charge of the Kalingarayan channel shall be in direct charge of the water regulation and he will act under the directions of the Sub-Divisional Officer and Executive Engineer having jurisdictions over the Kalingarayan

Sl. No.	Name of the channel	Crop	Crop period
Thadapalli Channel			
1	Ananthasagaram tank, Tailend to Mile 35/0 of Thadapalli channel	I Crop II Crop	18 th April to 31 st August 1 st September to 15 th January
2	Thadapalli channel Mile 35/0 to 22/0	I Crop II Crop	27 th April to 15 th September 16 th September to 22 nd January
3	Thadapalli Channel Mile 22/0 to 15/0	I Crop II Crop	3 rd May to 22 nd September 23 rd September to 29 th January
4	Thadapalli Channel Mile 15/0 to 0/0	I Crop II Crop	9 th May to 29 th September 30 th September to 15 th February
5	Kugalur and Singiam branch channels	I Crop II Crop	29 th May to 20 th October 21 st October to 15 th February
Arakkankottai Channel			
1	Tail end to Mile 16/0	I Crop II Crop	18 th April to 31 st August 1 st September to 15 th January
2	From Mile 16/0 to Mile 12/0	I Crop II Crop	27 th April to 15 th September 16 th September to 22 nd January
3	From Mile 12/0 to Mile 6/5	I Crop II Crop	3 rd May to 22 nd September 23 rd September to 29 th January
4	From Mile 6/5 to Mile 0/0, Perumugai Athani Channel and Vaniputhur Branch Channel	I Crop II Crop	29 th May to 29 th September 30 th September to 15 th February

channel.

2. The head sluice of the Kalingarayan channel will be opened for irrigation at 6.00 p.m. on the 16th June. Any alteration in the time and date shall be made only with the prior approval of the Chief Engineer for Irrigation and the Collector of Coimbatore and in such cases the date of postponement will be published in the District Gazette of Coimbatore District.

3. The discharge to be allowed at the time of opening of the head sluice shall not be more than half full supply discharge and shall be increased gradually upto full supply discharge, as ordered, as the discretion of the officers in charge of regulation depending upon the requirements to send down supplies to the tail end within the stimulated time.

4. Irrigation shall normally commence on the 19th June or from the date when water reaches the tail end if the same is earlier and opening of the sluices and irrigation shall be from the tail end.

5. The duration of supply for raising seedlings, transplantation and irrigation shall be so adjusted by the ryots and keep upto the total period of irrigation for one crop as noted in the statement I. However, the Executive Engineer shall change the total period of irrigation for one crop as and when required, only after obtaining the concurrence of the Collector and the Superintending Engineer.

6. The full supply discharge at the head sluice shall be that for the requirements of registered direct flow ayacut at 32 duty plus the requirements of normal water rate lands at 32 duty plus 160 cusecs for the wastage and transmission losses, and this full supply discharge shall be fixed by the Executive Engineer. Any discharge in excess of the full supply discharge shall be let down only after obtaining the prior approval of the Executive Engineer in writing. While allowing the full supply discharge the Executive Engineer should also take into consideration the seepage and field drainage water of Lower Bhavani Project Canal and its ayacut entering the channel on its right and only the quantity actually required may be sent.

7. Supplies through sluices shall be regulated at 60 duty for raising seedlings at 35 duty for transplantation and at 40 duty for irrigation after transplantation and equitable

and uniform supply shall be maintained throughout the channel. For this purpose all the sluices should be provided with shutters and locking arrangements and care should be taken to regulate the supplies as above more judiciously. Any increase in supply over and above those fixed shall be done, only with the prior approval of the Executive Engineer in writing. However any reduction in supply during rainy season or for any other season such as temporary fall in supply, etc., shall be done by Section Officer with the approval of the Sub-Divisional Officer and intimation of such reduction should be given to the Executive Engineer within a period of 24 hours after such reduction.

8. During rainy season, during floods and other emergency regulation of water shall be done by the Section Officer at his own discretion to safeguard the canal banks, masonry works and other properties and intimation of such regulation shall be given to the Sub-Divisional Officer within 3 hours and the Executive Engineer within 6 hours.

9. Irrigation (except through authorized sluices or similar authorized sources) in any manner than those specified above shall be considered irregular.

10. If the supply in the river falls below the requirements of ayacut at 40 duty, then the available supply shall be distributed uniformly until this uniform duty falls to 60 duty. If however, the supply falls short of even 60 duty due to adverse seasonal conditions the Executive Engineer on intimation from the Sub-Divisional Officer shall order in writing for proposing irrigation by rotation system as under given in Table 5.24.

Table 5.24 Order of Rotation of Kalingarayan Anicut and Channel

Sl.No	Order of Rotation of Reach	Period of supply
1	Tail reach from M. 4½ tail end including Avadayamparai extension channel	3 days
2	Reach from M. 23 / 7½ to 41 / 2½ including Malayampalayam branch channel	3 days
3	Reach from M O/O to M. 23 / 7½	3 days

Source: Authority G.O. Ms. No. 2647, P.W.D. dated 2nd November 1966.

There will be an interval of 2 days between the turns of first and last reaches. The above order of rotation will be repeated at the end of one continuous cycle of 11 days. On receipt of such orders from the Executive Engineer, the Sub-Divisional Officer shall intimate the Tahsildar in writing the orders of the Executive Engineer, proposing the turn system, with date and time of introduction of turn system and request him to appraise the ayacutdars immediately be beat of tom in the villages concerned. The Tahsildar in turn shall arrange to give wide publicity within 24 hours on receipt of information from the sub-divisional officer. The turn referred to above will be put into operation from 6 a.m. on the day following the intimation given to the Tahsildar. The Sub-Divisional Officer shall communicate the Executive Engineer the exact date and time of the introduction of the turn system immediately. Due intimation of the turn system shall be given by the Executive Engineer to the Collector and the Superintending Engineer within 24 hours of the commencement of the turn system. The turn system will be continued until such time, the supply in the river raises enough to permit distribution of water at 60 duty at each sluice. The actual regulation of each sluice will be done by the lascars under instructions and supervision of channel Superintendents. When the supply falls below that required at 40 duty at each sluice but at the same time is more than that required to supply at 60 duty at each sluice the Section Officer is responsible to watch the head sluice discharge so as to ensure uniform discharge through all the sluices from head to tail end including the sluices in the branches. When such contingency arises, the ryots and the Tahsildar should be informed.

11. To provide for the needs of the right side ayacut irrigated by open cuts, the water level at M. 2 / 2½ aqueduct gauge will be maintained at 5.9 feet for one day in a week, viz., from 6 a.m. of Sunday to 6.00 a.m. of Monday. Any change in this regulation for the right side ayacut shall be ordered by the Executive Engineer.

12. The channel will be closed from 6.00 p.m. on 30th April to 6.00 p.m. on the 16th June of each year for annual repairs. Any deviation in the date and time of closing of the channel for the annual repairs shall be done with the prior approval of the Collector and the Superintending Engineer. Due intimation of the deviation of the closure period

shall be intimated by Superintending Engineer and Collector to the Chief Engineer (Irrigation) and Government respectively.

13. The Water Registrar at Bhavani PWD will regulate the supply through the channel for normal irrigation as per instructions by the Section Officer and will maintain the water register of the channel and head works and submit daily discharge calculation of the head sluice and anicut to the Section Officer, Sub-Divisional Officer and the Executive Engineer. Any change in water regulation shall be recorded in the water register then and there as it should be recorded specifically in the daily reports submitted. The channel superintendents will record the water readings at the several gauges in their reaches during the day at intervals fixed by the Executive Engineer and send them to the Section Officer, who in turn will complete them and submit a consolidated daily water report to the Sub-Divisional Officer and Executive Engineer. A water Register with daily water readings should be maintained by the Section Officer. The Channel Superintendents will in addition to the daily water readings, maintain a register showing the regulation at sluices to show whether regulation is done as per this water regulation rules. Any change in the opening of the sluices except those provided for in the rules shall be intimated to the Section Officer, Sub-Divisional Officer and the Executive Engineer direct by Channel Superintendents. Should any person unauthorized interfere or attempt to interfere with any sluice or with the bank a report shall be made immediately by the Public Works Department channel establishment to the concerned village Munsif or the nearest Police Officer or to both of them according to the gravity of the case and a copy thereof sent at once to the Section Officer.

14. Flood regulation and operation of outlet – Due to the cross drainages entering into the channel besides the seepage water of Lower Bhavani Project Canals and its ayacut vigilant watch should be kept by the channel establishment over the channel banks throughout the day in and day out. A statement showing the various outlets along the channels with respective maximum water levels and normal water levels that have to be maintained is appended. If the water level rises above the maximum reading at each point the concerned outlets should be opened to such an extent and the excess water over the normal water level, depleted and when the flow from various drains begin to subside,

care should be taken to lower the shutters of the outlets and maintain the normal water level at each point.

15. The channel Superintendents and lascars should immediately report after opening the outlet to the Section Officer, Kalingarayan channel by a special messenger or over phone. The Section Officer should watch the conditions all over the area and use his discretion either to completely cut off the supplies or to effect partial reduction at the head based on the intensity of the rains and consequent inflow of floodwater, into the channel. The action taken by the Section Officer in this regard should be reported to the Sub-Divisional Officer and Executive Engineer immediately.

When the supply in the river Bhavani is plenty, the sluices would be operated one day in a week and preferably to keep it open as long as conditions of supply in the river permit. The outlets at M. 0-4-110 and M. 1-2½-240 which also serve as sluices should also be opened regularly to clear of any silt that gets accumulated during floods to keep the channel in an efficient condition and to maintain a steady rear gauge reading at the head sluices. Maximum Water Level and Normal Water Level in the Kalingarayan Channel are given in Table 5.25.

Table 5.25 Maximum Water Levels and Normal Water Level in the Kalingarayan Channel

Sl. No.	Details of outlet	Gauge readings at F.S.L. Unit	Normal gauge readings	Maximum gauge readings
1	Outlet at M 0-4-110	8.43	7.90	8.90
2	Outlet at M 1-2-240	9.76	9.25	10.25
3	Outlet at M 5-4½-127	8.30	7.80	8.80
4	Outlet at M 8-2½-50	4.81	4.30	5.30
5	Outlet at M 14-0-20	2.28	1.80	2.80
6	Outlet at M 15-0½-135	6.17	5.70	6.70
7	Outlet at M 15-4½-195	7.25	6.75	7.75
8	Outlet at M 24-1-203	2.72	2.20	3.20

9	Outlets at M 33-6-94	5.00	4.50	5.50
10	Outlet at M 35-3-35	5.97	5.50	6.50
11	Outlet at M 38-4½-190	3.85	3.35	4.25
12	Outlet at M 43-3½-90	3.42	2.90	3.90

Source: Authority G.O. Ms. No. 2647, P.W.D. dated 2nd November 1966.

The details of Kalingarayan channel opening period are presented in Table 5.26.

Table 5.26 Kalingarayan Channel Opening Period

Sl. No	Name of the channel	Crop	Crop period	Period of supply
1	Tail end to M.41/2 ½ Avadayaparai extension channel	I Crop	19 th June to 22 nd September	19 th June to 22 nd September
		II Crop	23 rd September to 23 rd January	23 rd September to 23 rd January
		III Crop	24 th January to 30 th April	24 th January to 30 th April
2	M.41 / 2½ to M.23 / 7½ Malayampalayam Branch channel	I Crop	20 th June to 25 th September	20 th June to 25 th September
		II Crop	26 th September to 25 th January	26 th September to 25 th January
		III Crop	26 th January to 30 th April	26 th January to 30 th April
3	M.23/7½ to M.14/0	I Crop	21 st June to 26 th September	21 st June to 26 th September
		II Crop	27 th September to 27 th January	27 th September to 27 th January
		III Crop	28 th January to 30 th April	28 th January to 30 th April
4	M.14/0 to M. 0/0	I Crop	22 nd June to 22 nd November	22 nd June to 22 nd November
		II Crop	23 rd November to 22 nd April	23 rd November to 22 nd April

Source: Authority G.O. Ms. No. 2647, P.W.D. dated 2nd November 1966.

For the entire length of the channel under normal water rate lands, paddy and other commercial crops like plantain, turmeric, sugarcane and castor are being raised.

5.2.12. Summary of Rules and Regulations of Water

Summary of rules and regulations of Kodiveri anicut and Kalingarayan anicut and canals of old and new ayacuts were presented in Table 5.27.

Table 5.27 Summary of Rules and Regulations of Water in Anicuts and Canals in Old and New Ayacut

Anicut/Channel/Reservoir	Opening Date	Closing Date	Water Availability (MCM)	Ayacut Area (ha)	Rules and Regulations
Kodiveri Anicut	April 15	February 15	442.81	9800	The Water Registrar at Kodiveri anicut regulated the supply through the head sluices of Thadapalli and Arakkankottai channels in the ratio of 2:1 (379 c/s in Arakkankottai channel and 735 c/s in Thadapalli). Special release of water to the standing sugarcane crops under Arakkankottai channel and Thadapalli channel during their closure period (i.e.) from 16 th February to 15 th April can be allowed subject to sufficient storage in Lower Bhavani reservoir or normal flows in the river to meet the requirements of the special wettings.
Kalingarayan Anicut	June 16	April 30	283.13	6300	The full supply discharge (580 c/s) at the head sluice for the requirements of registered direct flow ayacut was at 32 duty plus 160 cusecs for the wastage and transmission losses. Supplies through sluices were regulated at 60 duty for raising seedlings at 35 duty for transplantation and at 40 duty for irrigation after transplantation and equitable and maintained uniform supply throughout the channel. If the supply in the river falls below the requirements of ayacut at 40 duty, irrigation by rotation would be followed in turn. There would be an interval of 2 days between the turns of first and last reaches. The order of rotation

					would be repeated at the end of one continuous cycle of 11 days.
Old Ayacut					Old ayacut have riparian rights Water is released for 10 ½ months. The flow in the old channels was continuous throughout the year except in the period of repairs/maintenance. The farmers are growing 2 or 3 paddy crops or sugarcane as water is available always. The duty for the old system works out about 20-30 acres/cusec (282 ha/cumec)
1. Arakkankottai Channel	April 15	February 15	123.41	2740	
2. Thadapalli Channel	April 15	February 15	319.40	7060	
3. Kalingarayan	June 15	April 30	283.13	6300	
Total			725.94 (or) 24 TMC		
New Ayacut					There are no riparian rights. Water is available for 4 months for season I and 4 months for season II. Season I is for wet crops such paddy, sugarcane etc., and season II is for irrigated dry crops such as groundnut , gingelly, cotton etc.,. The designed duty is 60 acres/cusec (846 ha/cumec). Turn system is followed. The sluice in the odd miles of the main canal and odd miles in the distributaries were all numbered as Number I turn sluice. The sluice in the even miles was all numbered as Number II turn sluice. Farmers under Number I sluice were allowed to raise paddy crop from 15th August to 15th December. Number II turn sluice were given water from 16th December to 15th April but permitted to raise only irrigated dry crops. Water was regulated by giving full supply for 8 to 10-½ days immediately followed by no supply for
1. Season I	August15	December 15	680	42528	
2. Season II	December 16	April 15	340	42528	
Total			1020 (or) 36 TMC		

					another 7-½ days. From next 15 th August to 15 th December, water was allowed for farmers under Number II turn sluice for raising paddy and from 16 th December to 15 th April, the Number I sluice received water for raising dry crops and so on. In practice during a calendar year a farmer will get water to raise the dry season crop followed by wet season crops.
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5.2.13. Deviation of Rules and Regulation of Water Release

The deviation of rules and regulations of water release in Arakkankottai , Thadapalli and Kalingarayan canals of old Ayacut and Lower Bhavani Project (LBP) main canal of new ayacut are presented in Table 5.28. Water released in the Arakkankottai , Thadapalli , Kalingarayan canals and LBP canal for last 40 years is given in Table 5.1 and their probability is given in Annexures 1-3.

Table 5.28 Deviation from Rules and Regulations of Canal Water Release in Lower Bhavani Basin

Channel	Quantity of Water to be Release as per Rules (MCM)	Actual Quantity of Water Released in 2001-02 (MCM)	Deviation from Rules and Regulations	Remarks
Old Ayacut				
1.Arakkankottai and Thadapalli Channel	442.81	599.97	(i) As per the Government Order (G.O) 2274/30.8.1963, water should be released into the old ayacut for second crop cultivation only after ensuring that new ayacut farmers would not be affected. But here, excess 55.55 MCM quantity of water was released into old ayacut and it turned into affect new ayacut's water quantity release.	No luskars appointment after retirement. So works are not performed properly. Due to insufficient staff position not able to control the entire area of operation. Appoint more luskars.
2.Kalingarayan	283.13	181.52	(ii) Water released in Kalingarayan canal in 2001-02 was also less (101.63 MCM) than water quantity mentioned in riparian rights (283.13 MCM). As per the G.O.2319-2322/1969, PWD was planned to reduce the numbers of sluice in Kalingarayan canal 776 into 256 to regulate water release and water assurance to it's tail end farmers. For this purpose Rs.64 lakhs was allotted in 1974 by Tamil Nadu government to Public Works Department. But so far this work was not yet to be started and allotted fund was returned to government in 1980.	Release design level of water in Arakkankottai and Thadapalli channel and divert excess water in Kalingarayan Channel.
Total	725.94 (or)	781.49 (or)	(iii) The duration of Kalingarayan canal is June 15 to	Desilt main canal once in a year. Desilt sluices, remove

			April 30. But Kalingarayan canal tail end farmers told that last 10 years water was not available during January to April months.	damaged shutters and provide new shutters. Restrict unauthorized water pumping.
New Ayacut Turn I (2001-02)				Supply designed quantity of water in old ayacut channel.
1. Season I	725.94	480.66	(i) Old ayacut (Turn I) in season I received only 480.66 MCM quantity of water in 2001-02. This was 245.77 MCM of quantity of water less than water quantity to be released into the canal. Season II also received 124.66 MCM of water quantity less than water quantity to be released into the canal. Both these canal water reduction was due to already mention of G.O. 2274 violation.	
2 Season II	365	240.33		
Total	1090.94	721	(ii) The project was originally started to supply irrigation water for irrigated dry crops mainly for cotton cultivation. Hence, it was called as 'Cotton Growing Project'. Later, 4050 ha out of 83,770 ha total command was permitted to cultivate paddy crop and remaining for irrigated dry crops like cotton and millet. The farmers now raised paddy crop in Turn I alone 10260 ha in 2001-02. This was because of the highly porous nature of the soil, making paddy cultivation easy and cotton cultivation difficult. (iii) Past 38 years in LBP canal Turn system was followed in water regulation. In 2002-03 water turn should be released to Turn II ayacut farmers. But at the first time water release, Turn I ayacut farmers	Changes of cropping pattern to design level will reduce water requirement. Political interference affects canal maintenance. Government cases should be framed properly avoiding procedural lacuna to prevent conflicts. There should be

			used political power to change Turn II quota into Turn I and released water to their ayacut. Turn II ayacut farmers approached (Hindu dated 1.1.2003) high court and got stay to stop water release to Turn I and second water for their ayacut. Turn I ayacut also went to court and told that our ayacut farmers raised one dry crops due to first time water release and got stay to third time water. So, both turn ayacuters was not benefited in 2002-03 fasli year.	proper legalization of government cases.
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5.3. Extent and Nature of Water Transfer in Lower Bhavani Basin

The existing rights are such that farmers are not restrictive for their water transfer. Competition for limited water resources increasingly occurs between different stakeholders and at different levels: between farmers within an irrigation system; between irrigation systems in the same river basin; between the agricultural sector and other rural uses, such as fisheries or domestic water supply and drinking water; and more and more between agricultural and urban and industrial users and uses.

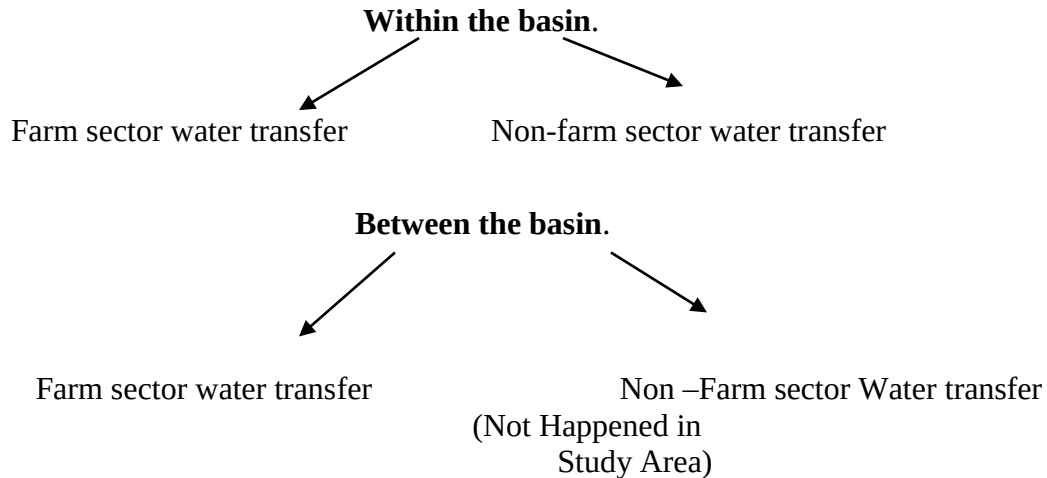
The increase in demand will be higher for urban and industrial uses than for agriculture. A portion of the growing demand for water will be met through new investment in irrigation and water supply systems, and some potential exists for expansion of nontraditional sources of water supply. However, supply expansion will not be sufficient to meet increasing demands. Therefore, the rapidly growing urban and industrial water demands will need to be met increasingly from water transfers out of irrigated agriculture. Hence, it is one of the important objectives in this study and 150 samples were analyzed and assessed the extent and nature of water transfer in the lower Bhavani basin and the results are discussed in this section.

The Public Works Department (PWD) controls water allocation up to the distributory level, while farmers are responsible for farm-level water distribution. In the wet season, water is distributed (both old and new *Ayacut*) via continuous flooding of the fields; in the dry season, farmers rotate their turns (in LBP) during alternate weeks only. This policy indicates how the allocation of water in Tamil Nadu has evolved to become user based, which is a prerequisite for market-based water allocation.

In an eight-day period of water supply (in LBP) to a distributory from the canal, water allowance to a farmer is calculated (WA), where water allowance (WA) is the time (minutes or hours) multiplied by the area owned. This determines the total time of water use allowed for each farmer. Farmers who have wells and farmers whose water requirements not need from their turn exchanges their turns with their neighbours

(eg.Thindal distributory of the LBP) using the concept of water allowance defined in terms of number of hours per unit area.

Currently, two major forms of water transfer have been observed in the Lower Bhavani basin.



5.3.1. Water Transfer within the Basin

Water was transferred in all three sectors in different ways in the Lower Bhavani Basin. Here, the ways of water transferred and quantity in these 3 sectors was studied and presented one by one.

5.3.1.1. Farm Sector Water Transfer

5.3.1.1. a. Mode of Exchange/ Transfer between farmers

The following observations characterize the exchange of water between farmers in the LBP:

1. Transfer of water in LBP occurs mostly between farmers of the same sluice and to a limited extent between farmers of different sluices.
2. When farmers are not irrigating their turns (fixed timing), they give them to relatives or neighbours who may return the turn the next time. (eg.Thindal distributory of the LBP)

3. Farmers whose fields are located near canals receive seepage water rather than canal water for irrigation. In such cases, they give their canal turns to other farmers and wait to use their turn next time.(eg. Mogagounda valasu)
4. In many cases, farmers who grow sugarcane instead of rice give their excess water to neighbours who grow rice. (eg. Velliyangiri pudur)
5. According to a farmer from Chitode, about 10 per cent of the farmers in his distributory exchange water. When the farmers in the tail end have acute water shortages, well owners use their well water and leave their canal turns to others in the sluice without expecting compensation.
6. According to a farmer in Allampalayam Village (Muthur), canal turns are given to others because electricity is free. If farmers charged for electricity, they would ask the recipients to pay the electricity bill according to the number of hours pumped.

5.3.1.1. b. Direct Lift Irrigation in Agricultural Sector

Large numbers of farmers, who have their land along with the Bhavani river course are engaged in lifting water from the river. In some cases, farmers who have lands far away from the river also are engaged in water lifting. These farmers owning cultivated lands in far off locations from the river course, buy small pieces of land usually around five to ten cents nearby the river in which they dig wells, lay pipelines to their holdings and pump water. Farmers lift water either directly from the river or from dug wells established by them in the river side. If lands are located near the river bank, they will set pumpsets individually. If lands are located within a reasonable distance, then they will jointly engage in lifting water, because of high establishment and running costs. This practice is illegal, because wells within 200 m of the river are considered to be recharged directly from the river. Thus, pumping from these wells diverts water to which the pump owner has no rights. The pucca well constructions are made with reinforced concrete and conduits are laid from them to the interior fields. PVC, GI, and HDPE pipes of large dimensions are used. Farmers use both electric motors and diesel engines to lift water. In most cases farmers use diesel pump sets in these types of operations, although some use electricity by transferring their existing electric connections to the new wells. This practice further compounds the illegality of river pumping: Selling water from pumps that use electrical power is prohibited because electricity is provided free for direct agricultural purposes

only. Despite the illegality of the practice, farmers/pumpers often simply pay the necessary penalties and continue the water selling business, which generates more than adequate revenues to cover the modest fine.

This lift irrigation exists both in upstream (Mettupalayam taluk of Coimbatore district) and downstream (Erode district) of Bhavanisagar. In the case of electric pump sets, the horse power used to lift water varies from 5 to 15. Most of the farmers use 5 HP electric motors. In the case of diesel engines, it varies from 2.5 to 10 HP. Most farmers use 5 and 10 HP diesel engines.

In 1990, water pumping from river was allowed as authorized activity. The authorization was given to patta land owner. These patta landowner paid water charge (Rs 150 for wet crops) to revenue department like others and was not needed to give any extra rupee to revenue department for water pumping activity. Due to non-extra payment to authorization pumping, every landowner wanted to take water from river and got authorization (G.O.3339/12/12/1962). Now, in the upstream of Bhavanisagar, the authorized 845 farmers lift water with the help of electric motors and diesel engines to irrigate 1023 ha land. In the downstream of Bhavanisagar, the authorized 1012 farmers in Sathiyamangalam, Gobichettipalayam and Bhavani taluks set diesel engines and electric motors to lift water. By the water pumping in downstream irrigation they irrigate 2691 ha land. The total authorized river-pumping irrigation 3714 ha and quantity of water pumped 31.38 MCM.

The authorization of water pumping activity in head and middle regions of river had affected the tail end farmers resulting in government stopping the authorization process. Hence, unauthorized river water pumping arisen. The details of numbers, area under irrigation through authorized and unauthorized driver pumping and quantity of water pumped from river are indicated in Table 5.29. From the table, it can be seen that 2961 numbers lift water directly from river by authorized or unauthorized and 49.36 MCM of water was lifted. Hence, 8228 ha is irrigated in non-command area in the basin by river water pumping.

Table 5.29 Number and Area under Authorized and Unauthorized Pumping

Sl. No.	Nature of Water Pumping	Number of Units	Area Covered (ha)	Quantity of Water Pumped (MCM)
1	Authorized river and canal pumping	1,857	3714	31.38
2	Unauthorized river and canal pumping	1,064	4514	17.91
	Total	2921	8228	49.36

Source: PWD Department, Erode, Survey data.

5.3.1.2. Domestic Sector

5.3.1.2. By Farmers/Individuals

Intersectoral water markets are operating in and around the LBP basin, particularly near the tail region of the canal system. Farmers/well owners sell water to tanker operators, who transport the water to urban centers and sell it to barrel operators, who in turn sell it to households. These water markets are described below.

Tankers supply water to textile industries, households, and other groups in Vellakoil within a radius of 5 to 10 km from the pumping point. They currently cover a distance of about 25 km, but during peak demand may cover up to 40 km. Each tanker has a capacity of 13,500 liters and makes six to seven trips per day (up to 22 trips per day during peak demand). Approximately water is being sold from more than 200 wells to non-agricultural purposes and 500 tankers were operated daily in the basin. Hence, 47.25 million liters per day (mld) or 17.24 MCM per year water was transferred in lean season and 148.5 mld or 54.18 MCM per year in peak season to drinking purposes from agricultural sector.

5.4. Cost and Productivity of Water in Different Sectors

Growing urban and industrial water demands would be met increasingly from water transfers out of irrigated agriculture. In this transfer process, to analyze and assess the cost and productivity of water in different sectors (agricultural sector, domestic sector and industrial sector) is a key strategy for addressing water scarcity.

5.4.1. Cost of Water in Agricultural Sector

In agricultural sector, there are cases i.e. water pumping in field itself or pumping from 1-3 km distance from river by authorized or unauthorized. The cost difference between these two cases was in pipe cost (water transfer to long distance) and well cost. The cost of pumping of one kilo liter of water is given in Tables 5.30 and 5.31. It could be seen from the tables that in case of water pumping from long distance of river, the cost of pipe for 1 km distance was Rs. 122500 at Rs.35 per feet and well cost Rs.41000 was incurred and these two costs in the case of field itself water pumping, water transfer pipe cost was nil and well cost was Rs.95500 (Tables 5.30 and 5.31). The average cost of 1 KL of water was Rs.3.54 in pumping scheme from to river and Rs.2.53 in water pumping.

Table 5.30 Cost Analysis of 1 Kilo Liter Water pumping from 1 km Distance from River

Sl.No		Amount
1	Well (200 ft) at 70 /ft cost Rs.	14000
2	Pipe for 200 ft well at Rs.35/ft	7000
3	Wiring and labour fitting cost	20000
4	Pipe for 1 Km distance field Rs.35/ft	122500
5	Total Cost of well (Rs.)	163500
6	Land value of 5 cent near to river at Rs.3000 / cent	15000
7	Average life of wells (Years)	30
8	Assumed land duration (Years)	100
9	Average life of electric motors (Years)	15
10	Age of well/electric motor (2003-year of construction)	1
11	Interest rate @ 12 per cent	0.12
12	Cost of Electric motor and accessories (Rs.)	24000
13	Electric motor and accessories (hp)	5
14	Compounded cost of well (Rs.)	183120
15	Compounded cost of land	16800
16	Compounded cost of motor & accessories (Rs./year)	26880
17	Annualised cost of well (Rs./year)	22733.19
18	Annualised cost of land (Rs/year)	2016.024

19	Annualised cost of motors (Rs./year)	3946.636
20	Total annualised cost (Rs./year)	28695.85
21	Total hours of pumping(hrs/day for 300 days)	1200
22	Energy consumption (kwh)	4476
23	Quantity of water pumped M3	15120
24	Labour cost in rupees per year(@Rs.70/day)	10500
25	Maintenance cost (Rs/year)	480
26	Electricity cost (Rs.3.1/kwh/year)	13875.6
27	Total irrigation cost (Rs.3.1/kwh/year) case	53551.45
28	Total cost in field itself case	51535.42
29	Cost of river pumping scheme (Rs./M3 of water)	3.54

Assumptions

Interest rate is 12 per cent

Amortized cost of well = [(Capital cost of well) $\times (1+i)^{AL} \times i$] $\div [(1+i)^{AL}-1]$

Where

AL = Average life of wells

Constructed during 2002 I.e. age of well is 1 year

Table 5.31 Cost Analyze of 1 Kilo Liter Water pumping in Farm Well

Sl.No		Amount
1	Well (650 ft) cost Rs.	45500
2	Pipe	30000
3	Wiring and labour fitting cost	20000
4	Total Cost of well (Rs.)	95500
5	Average life of wells (Years)	30
6	Average life of electric motors (Years)	15
7	Age of well/electric motor (2003-year of construction)	1
8	Interest rate @ 12 per cent	0.12
9	Cost of submerged motor and accessories (rs.)	30000
10	Electric motor and accessories (hp)	5
11	Compounded cost of well (Rs.)	106960
12	Compounded cost of motor & accessories (Rs./year)	33600
13	Annualised cost of well (Rs./year)	13278.41
14	Annualised cost of motors (Rs./year)	4933.29
15	Total annualised cost (Rs./year)	18211.70

16	Total hours of pumping(hrs/day for 360 days)	1620
17	Energy consumption (kwh)	6042.6
18	Quantity of water pumped M3	20412
19	Labour cost in rupees per year(@Rs.70/day)	14175
20	Maintenance cost (Rs/year)	500
21	Electricity cost for commercial purpose(Rs.6 per kwh)	18732.06
22	Total cost (Rs./year)	51618.76
23	Cost of water pumping (Rs./M3 of water)	2.53

Assumptions

Constructed during 2002 I.e. age of well is 1 year

Interest rate is 12 per cent

5.4.2. Cost of Water in Domestic Sectors

Inter sector water transferred in study area basin was occurred by two ways i.e. one by farmers and another by TWAD Board. Productivity of water in these two cases was worked out separately.

5.4.2.1. Farmers /Individuals Water Supply Case

Farmers or individuals transferred water from farm wells or house wells near to agricultural fields to domestic sectors. The number of tanker trips on a given day depends upon the price of water as well as demand. Farmers sold water for Rs.15 per 1000 liters and Rs. 200 per tanker (13500 liters), and tankers would sell it for about Rs.60 per 1000 liters and Rs 800 per load. One kwh power in 5 minutes was needed to fill the 1000 liters. Farmers incurred cost in electricity to pump water for commercial sale 6.50 per kwh per 1000 liters (Table 5.34). Depending upon demand, farmers may increase their rates during some seasons to Rs.40 per 1000 liters and Rs. 540 per load. Because farmers own both the land and the well, they face no authorized constraint in pumping out well water to sell, and, the government does not interfere in the process.

In several cases, tanker operators deliver water in huge tanks to barrel operators, who then sell it in small quantities, such as Rs.12 per barrel of 200 liters, Rs.20 per barrel to bullock-cart owners. The bullock-cart owners in turn sell the water to households at

about Rs.35 per barrel. The cost analysis furnished in Table 5.32 shows cost of 1 KL of water and the profit margins farmers make from selling water from their wells. It could be seen from the table that the cost of 1 KL of water was Rs. 6.68 and farmers got Rs.2310 per day for 21 loads on a normal day. Farmers whose wells are near cities and are serviced by relatively good road facilities have the best market potential to sell water.

Table 5.32 Cost and Return in Non-Farm Sectoral Water Transfer

Sl.No	Particulars	Amount
1	Quantity of water pumped in a day	283.5
2	Average cost of water to the farmer* /tanker	
	a. Electricity pumping cost	87.75
	b. Labour cost (at Rs.50/day)	2.38
	Total Cost	90.13
3	Farmer's selling price	200
4	Profit to farmer (13500 liters / tank)	110
5	Profit to farmer per day (@ 21 loads on normal day)	2310
6	Cost of 1 KL of water	
	a. Electricity pumping cost	6.5
	b. Labour cost	0.18
	Total Cost	6.68

Note : * Well cost not included in the calculation per tanker water filling.

As noted above, demand for water varies depending on the season, but it also changes according to the level of water in the wells and the pricing mechanisms used. For example, in the summer season, each well has water sufficient for only 10 to 15 tankers, as canal water is stopped during this time and recharge is comparatively less (Actually these wells are capturing the canal flows indirectly, as evidenced from the recharge pattern and the quantity of water sold). However, markets handle variability in supply and price very well. During water scarcities, farmers will activate wells located farther away. Similarly, tanker operators will reduce their intake from farmers who have increased their rates. In the rainy season, demand is comparatively less.

The details of the profits and cost of tanker operators in the inter-sectoral water transfer are given in Table 5.33. It could be observed from the table that tanker operators got profit Rs.3770.06 per day in normal period and Rs.13307.25 per day in demand period.

Table 5.33 Cost and Profit Margins of Tanker Operators among Non-Farm Sectoral Water Market Sellers

Sl.No	Particulars	Rs/ tanker
	Normal period	
1	Tanker operator's purchase price (13500 liters)	200
2	Tanker operator's purchase price (1000 liters)	15
3	Tanker operator's selling price	800
4	Operational cost per load within 5 km	
	a. Driver (Rs 150/day)	21.42
	b. Cleaner (Rs 70/day)	10
	c. Fuel charge and so on	30
	Total	61.42
5	Profit	538.58
6	Profit per day(@7 loads per day)	3770.06
	Demand period	
7	Farmer's selling price (Rs 40/1000 liters)	540
8	Tanker operator's selling price	1500
9	Operational cost per load within 5 km	
	a. Driver	28.57
	b. Cleaner	14.28
	c. Fuel charge and so on	30
	Total	72.85
10	Profit	887.15
11	Profit per day (@15 loads per day)	13307.25

The details of the profits and cost of barrel operators in the inter-sectoral water transfer are given in Table 5.34. It could be observed from the table that barrel operators got profit Rs.550 per tanker in normal period and it was doubled during peak demand.

Table 5.34 Cost and Profit Margins of Barrel Operators among Water Market Sellers

Sl.No	Particulars	Rs.
	Normal period	

1	Tanker operator's selling price/tanker (13500 liters)	800
2	Barrel operator's selling price/barrel (1=200 liters)	20
3	Total income (one tanker accommodates 67.5 barrels) per tanker	1350
4	Profit /tanker	550

The details of the profits and cost of bullock-cart operators in the inter-sectoral water transfer are given in Table 5.35. It could be observed from the table that bullock-cart operators got profit Rs.1012.5 per tanker (or) Rs.15/= per barrel (or) Rs. 175/= per 1000 liters in normal period and it was doubled in demand period.

Table 5.35 Cost and Profit Margins of Bullock – Cart Owners among Water Market Sellers

Sl.No	Particulars	Rs
	Normal period	
1	Barrel operator's selling price/barrel	20
2	Bullock-cart operator's selling price to household/barrel	35
3	Final price of water to household	2362.5/tanker (or) 175/1000 liters
4	Profit	1012.5/tanker (or) 15/barrel (or) 75/ 1000 liters.

The details of the profits and cost of different type of operators in the inter-sectoral water transfer are given in Table 5.36. It could be observed from the table that Bullock operators got profit Rs.75 per kilo liter than other operators in normal period and it was doubled during peak demand.

Table 5.36 Cost and Profits of Different Type of Operators in the Inter-Sectoral Water Transfer

Sl.No	Operators	Incurred Cost Rs / 1000 liters Water	Profits Rs / 1000 liters Water
1	Farmers	6.68	8.15

2	Tankers	15	39.85
3	Barrel	60	40.74
4	Bullock	100	75.00

According to the farmers, water selling as such is uncommon in agriculture, particularly in the head and middle regions of the system, because water is sufficient even during scarcity periods. Also, it is difficult to take water to farmers who need it, as their locations may be too distant to transfer the water cost-effectively. Conversely, in the tail region of the LBP command area, water selling has been quite common. Farmers in **Chitode, Thindal, Allampalayam, Velliangavalasu, Manthapuram** and **Muthur** are familiar with water selling. There, water is being sold from more than 200 wells to non-agricultural purposes.

When asked about their freedom to reserve their quota for reservoir water to use later as they choose, whether for agricultural or nonagricultural purposes, the farmers indicated that they understood the importance of such water rights.

Many farmers in the area say that selling water for nonagricultural purposes is more profitable than using it for agricultural purposes, due to labour problems and unfavourable crop prices. In several cases, farmers have grown coconut and other perennial crops that consume less water, thereby releasing water for sale. Among the farmers who are selling water, about 55 per cent have been growing coconut and other orchard crops mainly to minimize labour and water consumption. When well-owning farmers were asked why they had begun to sell water, most said they did so to alleviate labour problems (for example, hiring and keeping farm workers) and because the high demand for water in urban markets makes the market promising.

5.4.2. 2. Cost of Water for TWAD Board

In the Lower Bhavani Basin, there are 5 Municipalities, 29 Town Panchayats and 16 Panchayat Unions pump water for domestic requirement directly from the river Bhavani. Factor Cost Method used to find out the value of water. To find out the value of water by using Factor Cost Method, the fixed cost, maintenance cost and the total quantity of water supply for every scheme was needed. Different Schemes were implemented by the TWAD Board in different years in the Lower Bhavani Basin. The TWAD Board had fixed the ultimate life of the schemes as 30 years. The scheme were implemented using loans from L.I.C. etc., annuity value at 10.25 interest for 30 years was added to the total fixed cost.

The cost of water per 1000 liters for 5 municipalities, 6 town panchayats and 22 Combined Water Supply Schemes was calculated.

1. Cost of Water for Municipalities in Lower Bhavani Basin

Five water supply schemes are implemented by the TWAD Board for the 5 municipalities in the Lower Bhavani Basin. The details of fixed cost, maintenance cost and the total quantity of water supply was collected and furnished in the Table 5.37.

Table 5.37 Fixed Cost, Maintenance Cost and the Total Quantity of Water Supply in Municipalities

Sl.No	Name of the Municipalities	Year of Starting	Year of Completion	Fixed Cost (Rs. in lakhs)	Maintenance Cost (Rs. in lakhs)	Total Quantity of water Supply (MLD)
1	Mettupalayam	1948	1962	240.15	207.66	20.94
2	Sathyamangalam	1963	1967	443.76	222.31	20.40
3	Gobichettipalayam	1954	1958	304.76	84.59	9.59
4	Bhavani	1964	1969	112.82	20.20	2.15
5	Bhavani Sagar	1955	1959	75.95	3.07	0.80
Total				1177.44	537.83	53.88

Source: Concerned Municipal Administration Report 2000.

Total fixed cost for 5 municipalities	= Rs.1177.44 lakhs
Annuity at 10.25 interests for 30 years	= Rs.140.58 lakhs
Total annual Maintenance cost	= Rs. 537.83 lakhs
Total cost	= Rs. 678.41 lakhs
Total quantity of water supplied per annum	= 53 .88 MLD x 365 = 19666.20 MLD.
Cost of water per 1000 liters for 5 Municipalities	= $678.41 \times 10^5 / 19666.20 \times 10^3$ = Rs. 3.44

It was seen that the cost of water per 1000 liters for 5 municipalities was Rs. 3.44. The municipalities collected Rs.3.50 per 1000 liters in the form of water charge. Flat rate is Rs 30 per month.

2. Cost of Water for Town Panchayats

The TWAD Board in 6 town panchayats located in the Lower Bhavani Basin implemented 6 Independent Water Supply Schemes. The details of fixed cost, maintenance cost and the total quantity of water supply was collected and furnished in the Table 5.38. The cost of water per 1000 liters for town panchayats was calculated.

Table 5.38 Fixed Cost, Maintenance Cost and the Total Quantity of Water Supply in Town Panchayats

Sl. No	Name of the Town Panchayats	Year of Starting	Year of Completion	Fixed Cost (Rs. in lakhs)	Maintenance Cost (Rs. in lakhs)	Total Quantity of water Supply (MLD)
1	Sirumugai	1963	1966	110.20	8.13	3.64
2	Karamadai	1990	1966	340.00	25.27	2.95
3	Anthiyur	1981	1985	102.25	16.70	2.62
4	Puliampatti	1969	1973	87.98	10.04	3.20
5	Vaniputhur	1982	1986	59.24	3.32	0.67
6	Appakudal	1983	1987	64.50	12.21	1.00
Total				764.17	75.67	14.08

Source: Tamilnadu Water Supply and Drainage Board, Maintenance Division, Erode.

Total fixed cost for 6 Town Panchayats	= Rs. 764.17 lakhs
Annuity at 10.25 interests for 30 years	= Rs.91.24 lakhs
Total annual Maintenance cost	= Rs. 75.67 lakhs
Total cost	= Rs. 166.91 lakhs
Total quantity of water supplied per annum	= 14 .08 MLD x 365 = 5139.20 MLD.

Cost of water per 1000 liters for 6
town panchayats

$$= 166.91 \times 10^5 / 5139.20 \times 10^3$$
$$= \text{Rs. } 3.24$$

It is seen that the cost of water per 1000 liters for 6 town panchayats was Rs. 3.24. In town panchayats, flat rate of Rs 30 per month or Rs.3.50 per 1000 liters was collected per month.

3. Cost of Water for Town Panchayat and Panchayat Unions

TWAD Board implemented 22 Combined Water Supply Scheme (CWSS) for Town Panchayats (TP) and Panchayat Unions (PU) in Lower Bhavani Basin. The cost details for 22 CWSS are given in the Table 5.39.

Table 5.39 Fixed Cost, Maintenance Cost and the Total Quantity of Water Supply in 22 CWSS for TP and PU

Sl.No	Name of the CWSS	Year of Starting	Year of Completion	Fixed Cost (Rs. in lakhs)	Maintenance Cost (Rs. in lakhs)	Total Quantity of water Supply (MLD)
1	Thekkampatty	1985	1990	125.95	3.25	0.72
2	Annur – Avanashi	1994	1997	182.65	370.04	15.11
3	Periya Kodiveri and 7 other village panchayats in T.N.Palayam Union	1977	1983	71.49	27.92	4.1
4	Vellalapalayam,Vellankoil and 54 other Habitations in Gobi Union	1991	1995	376.00	31.99	1.66
5	Kugalur and Athani T.P	1985	1989	119.65	24.17	2.88
6	Mahalipudur and 7 other habitations in Nambiyur	1987	1990	65.96	16.92	1.06
7	Nambiyur and 5 other V.P.	1979	1982	34.52	12.86	1.75
8	Kasipalayam and 12 other habitation in T.N Palayam	1989	1991	58.76	6.89	1.07
9	Kalingayam, Kolapalur, Kunnathur and Siruvallur	1987	1994	590.11	60.72	5.18
10	Goundampalayam and 7 other habitations in Gobi and Bhavani Unions	1986	1989	45.20	13.37	1.01
11	Kavunapadi	1988	1991	108.22	12.94	2.21
12	Pudukothukadu and 4 other habitations in Sathy and Bhavani sagar	1985	1986	18.5	11.32	0.72
13	4 VPRTs in Ammapet and Bhavani Union	1990	1994	114.20	15.60	1.16
14	Kattur	1986	1991	142.00	31.44	1.89

Sl.No	Name of the CWSS	Year of Starting	Year of Completion	Fixed Cost (Rs. in lakhs)	Maintenance Cost (Rs. in lakhs)	Total Quantity of water Supply (MLD)
15	Periyapuliyur and 10 other habitations in Bhavani Union	1985	1987	20.00	5.40	0.3
16	Kadayampatti and 4 other habitations in Bhavani Union	1986	1988	142.00	9.12	0.48
17	Jambei RTP	1990	1992	115.40	7.89	1.59
18	Ariyapampalayam RTP and Konamoor VP	1994	1997	167.41	11.00	2.95
19	Olagadam RTP	1992	1997	272.30	4.70	1.16
20	Elathur, Nambiyur RTP and Kosanam, Thalkuni VPTs	1994	1997	1118.0	33.50	8.63
21	Kembanaickanpalayam RTP	1989	1993	110.29	12.23	0.88
22	Vemmandampalayam and 7 other village PTS	1995	1998	611.53	18.01	2.35
Total				3492.14	741.27	58.86

Source: Tamilnadu Water Supply and Drainage Board, Maintenance Division, Erode 2000.

Total fixed cost for 22 CWSS	= Rs. 3492.14 lakhs
Annuity at 10.25 interests for 30 years	= Rs.416.95 lakhs
Total annual Maintenance cost	= Rs. 741.27 lakhs
Total cost	= Rs. 1158.22 lakhs
Total quantity of water supplied per annum	= 58 .86 MLD x 365
	= 21483.90 MLD.
Cost of water per 1000 liters for 22 CWSS	= $1158.22 \times 10^5 / 21483.90 \times 10^3$
	= Rs. 5.39

It could be seen from the calculation that the cost of water per 1000 liters was Rs.5.39 for CWSS to TP and PU and it was higher than Municipalities and Town panchayats water supply schemes. In CWSS of town panchayats and panchayats unions, flat rate of Rs 20 per month (or) Rs.2.25 per 1000 liters was collected per month from each individual household water connection.

4. Cost of Water for All Schemes in the Lower Bhavani Basin

Total fixed cost for all schemes	= Rs.5433.75 lakhs
Annuity at 10.25 interest for 30 years	= Rs.648.78 lakhs
Total maintenance cost	=Rs.1354.77 lakhs
Total cost	= Rs. 2003.55 lakhs
Total quantity of water supplied per annum	=46289.3 MLD
Cost of water per 1000 liters	= $2003.55 \times 10^5 / 46289.3 \times 10^3$
	= Rs. 4.38

It could be seen from the calculation that the cost of water per 1000 liters in Lower Bhavani Basin was Rs 4.38.

5.4.2.3. Cost and Profit of Water Supply for Noyyal Basin from Bhavani River

One independent water supply schemes (WSS) and three Combined Water Supply Schemes (CWSS) were implemented by the TWAD Board for the Noyyal basin domestic needs from Bhavani river. The details of fixed cost, maintenance cost and the total quantity of water supply was collected for two CWSS furnished in the Table 5.40 and remaining one WSS (for Tiruppur municipality) and CWSS (proposed scheme Vadavalli T.P) cost details are not available.

Table 5.40 Fixed Cost, Maintenance Cost and the Total Quantity of Water Supply in 2 WSS and CWSS for Noyyal Basin Needs

Sl. No	Name of the WSS and CWSS	Year of Starting	Year of Completion	Fixed Cost (Rs. in lakhs)	Maintenance Cost (Rs. in lakhs)	Total Quantity of water Supply (MLD)
1	Coimbatore corporation 20 town panchayats and 523 rural habitations (Pillur dam water)	1985	1994	12257	1301.56	131.25
2	Siruvani CWSS to Koundampalayam and Vadavalli T.PTS (Siruvani dam water)	1979	1984	1616	1005.55	101.4
Total				13873	2307.11	232.65

Source: Tamilnadu Water Supply and Drainage Board, Maintenance Division, Coimbatore 2000.

Total fixed cost for WSS and CWSS = Rs. 13873.00 lakhs

Annuity at 10.25 interests for 30 years = Rs.1656.41 lakhs

Total annual Maintenance cost = Rs. 2307.11 lakhs

Total cost = Rs. 3963.52 lakhs

Total quantity of water supplied per annum = 232.65 MLD x 365

= 84917.25 MLD.

Cost of water per 1000 liters for

WSS and CWSS = $3963.52 \times 10^5 / 84917.25 \times 10^3$

= Rs. 4.66

The cost of water per 1000 liters to Noyyal basin from Bhavani river was Rs.4.66 but government collected Rs.3.50 per 1000 liters from each water household connection.

5.4.3. Industries Sectors

Industrial sector's water requirement is met out either through TWAD Board water supply schemes or primary (well) and tertiary sources (tanker). The Water Resource Organization (WRO) has permitted 20 industries to draw water from river. Cost of water supply by TWAD board schemes and primary and tertiary sources were calculated in this section.

5.4.3.1. Cost of TWAD Board Water Schemes Case

The industries, which are located in different part of the Lower Bhavani Basin (LBB), have been broadly classified in two categories, namely major water consuming industries (MWCI) and low water consuming industries (LWCI). MWCI use large quantities of water for processing purposes. Most of these units pump water directly from the river. Presently 2251 total industries are located in the basin. But in water consumption point of view, 35 MWCI units and 222 LWCI units are located in Lower Bhavani River Basin.

Factor cost method as the cost of providing the goods or services to the final user was used to estimate the productivity of water in industries water. In industrial sector, it reflects the cost incurred by the government for providing water to industrial sector or the cost incurred by the industrial sector itself. So far there are no separate water supply schemes for industries, which located in Lower Bhavani River Basin. Hence it is assumed here that if the cost incurred by the government sector which reflects in terms of charges and cess levied by concerned government agencies. If the cost has incurred by the industry itself, it may be in the form of market price (if water market exists) paid by the industry per unit of water or the cost of extracting the water – such as through digging bore wells, installing pump sets etc.

In Lower Bhavani River Basin, 20 industrial units are extracting water from river and these units are paying water charges for PWD. Remaining number of units (15 MWCI and 222 LWCI) are extracting ground water. But unfortunately, individual industries water extraction costs are not be available from published source. Moreover, there

is no wells had been exclusively for water extraction for industries. That is, most of the wells are used for multi-purpose (agriculture, domestic etc).

The study relies heavily on secondary sources for its data, which are based on the amount of the water used. Detailed data on water charges that were available with Public Works Department (PWD) were collected and presented in Table 5.41. It could be seen from the table that cost of pumping water directly from river to government was Rs.166.52 lakhs.

Industries are paying water charges to PWD on the basis of two methods such as Rs. 200 and Rs.500 for 1000 KL of water depending on the year of establishment. If industries were established in the earlier years before 1990-91, the water charge is only Rs. 200 per 1000 KL and otherwise Rs. 500 per KL.

Table 5.41 Annual 'Water Charge' Collected by PWD from Water Drawing Industries

Sl. No	Taluk	Basis of Rs.200 per 1000 KL		Rs.500 per 1000 KL		Total	
		No. of units	Amount Rs. Lakhs	No. of units	Amount Rs. Lakhs	No. of units	Total Rs. Lakhs
1	Mettupalayam	5	0.98	3	113.61	8	114.58
2	Sathiyamangalam	3	3.40	2	12.10	5	15.50
3	Gopichettipalaya m	0	0	1	0.27	1	0.27
4	Avinashi	-	-	-	-	-	-
5	Palladam	-	-	-	-	-	-
6	Perundu-rai	-	-	1	0.68	1	0.68
7	Bhavani	3	15.13	1	19.91	4	35.04
8	<i>Karur</i>	-	-	1	0.44	1	0.44
	<i>Total</i>	11	19.51	9	146.57	20	166.52

Source: Public Works Department, Erode 2002.

From the table, 11 units are paying water charges on Rs.200 per 1000 KL water with a sum of Rs. 19.51 lakhs. Among this 3 units at Bhavani taluk paying Rs.15.13 lakhs. 9 units are paying their water charge on the basis of Rs. 500 per 1000 KL of water and it comes at 146.57 lakhs. In total annually PWD collecting Rs. 166.52lakhs from the 20 industrial units which draw water from Bhavani river.

The cost value of 1 KL water pumped from the river had estimated in Table 5.42. The PWD was not incurred any fixed and maintenance cost to supply water to industries. It could be noted from the table that PWD collected Rs. 0.43 per 1000 liters from industries and it was less than domestic sector water charge per 1000 liters.

Table 5.42 Cost of 1KL Water in 20 WSS for Industries Sector

Sl.No	Particulars	Amount
1	No of Industries Units	20
2	Total Annual Water Charge	16651892
3	Daily Charge	$16651892 / 365$ $=45621.62$
4	Total Quantity of Water Pumped	107278.25 KLD
5	Average charge for 1 KL water	$45621.62 / 107278.25$ $=0.43$

5.4.3.2. Cost of Alternate Water Supply Source Case

The average cost of alternate supply of water to industries from primary source (well) and treasury sources (tanker) were estimated. The alternate cost of 1 KL of water for industries in primary and tertiary sources was presented in Table 5.43. It could be seen from the table that the average cost of 1 KL of water was Rs. 3.39, which was higher than TWAD board water supply charge.

Table 5.43 Cost of Water in Alternate (Primary) Source for Industries

Sl. No		<i>Amount</i>
1	Well (650 ft) cost Rs.	45500
2	Pipe cost Rs.	30000
3	Wiring and labour fitting cost Rs.	20000
4	Total Cost of well (Rs.)	95500
5	Cost of submerged motor and accessories (rs.)	30000
6	Average life of wells (Years)	30
7	Average life of electric motors (Years)	15
8	Age of well/electric motor (2003-year of construction)	1
9	Compounded cost of well (Rs.)	106960
10	Compounded cost of motor & accessories (Rs./year)	33600
11	Annualized cost of well (Rs./year)	13278.41
12	Annualized cost of motors (Rs./year)	4933.29
13	Total annualized cost (Rs./year)	18211.70
14	Total hours of pumping(hrs/day for 360 days)	1620
15	Energy consumption (kwh)	6042.6
16	Quantity of water pumped M3	20412
17	Labour cost in rupees per year(@Rs.70/day)	14175
18	Maintenance cost (Rs/year)	500
19	Electricity cost for commercial purpose(Rs.6 per kwh)	36255.60
20	Total cost (Rs./year)	69142.30
21	Cost of water pumping (Rs./M3 of water)	3.39

Assumptions

Interest rate is 12 per cent

Amortized cost of well = $[(\text{Capital cost of well}) * (1+i)^{AL} * i] \div [(1+i)^{AL}-1]$

Where

AL = Average life of wells

Constructed during 2002 I.e. age of well is 1 year

5.4.3.3. Cost of Tertiary Water Supply Source

Tanker fetched water for sale as Rs. 60 per KL. So both primary and tertiary sources were higher than TWAD board water supply cost and would not be worthwhile to industries.

5.4.3.4. Productivity of Water in Agricultural Sector

Obtaining more crop production from the same amount of water is a means of expressing the physical productivity of water in agriculture. Productivity of water in agriculture sector was calculated either by yield in quantity terms (kg) or monetary terms (Rs) per unit of water. The productivity of water for old and new ayacut of the basin was estimated and the results are presented in Tables 5.44 and 5.45.

Table 5.44 Productivity of Water in Agricultural Sector in Old Ayacut

Sl.No	Crops	Yield Kg/ha*	Water used (mm)**	Average Productivity of water (kg/mm)
1	Paddy	6100	3000	2.03
	Season I			
	Season II	5030	3000	1.68
2	Blackgram	630	1250	0.50
3	Sugarcane	150000	6250	24.00
4	Turmeric	4500	3750	1.20
5	Banana	45500	5000	9.10
6	Cotton	1750	3250	0.54
7	Groundnut	1400	1750	0.80
8	Coconut	19000	3750	4.21

Note: * Field survey data given in Annexure 4

**** Water recommendation of each crops / at 40 per cent efficiency**

(Source: Cauvery Basin Report by PWD,2000).

Table 5.45 Productivity of Water in Agricultural Sector in New Ayacut

Sl.No	Crops	Yield Kg/ha*	Water used (mm)**	Productivity of water (kg/mm)
1	Paddy	5030	3000	1.68
2	Blackgram	700	1250	0.56
3	Sugarcane	85000	6250	13.60
4	Turmeric	4000	3750	1.07
5	Banana (No)	2125	5000	7.83
6	Cotton	1675	3250	0.52
7	Groundnut	961.53	1750	0.55
8	Coconut (Nuts)	19000	3750	4.67
9	Tapioca	25000	1750	14.29
10	Maize	3200	1625	1.97
11	Sorghum	2752	1625	1.69
12	Gingelly	6250	625	10.00

Note: * Field survey data given in annexure 4

**** PWD River Basin Report, 2000**

It could be seen from the table that in old ayacut the productivity of water was high in sugarcane (24 kg/mm), Banana (9.10 kg/mm) than paddy (2.03 kg/mm) crop. In new ayacut, productivity of water was high in Tapioca (14.29 kg/mm), sugarcane (13.60 kg/mm), gingelly (10 kg/mm) than paddy (1.68 kg/mm) crop.

A standardized gross value of production (SGVP) is used in order to compare agriculture production in monetary units. To obtain the SGVP, calculated an equivalent yield of rice for all crops in each ayacut. The results are presented in Tables 5.46, 5.47 and 5.48.

$$SGVP = \left\{ \sum_{i=1}^n A_i Y_i \frac{P_i}{P_b} \right\} \times P_{world}$$

Where:

SGVP is the standardized gross value of production

Y_i is the yield of crop i

p_i is the local price of crop i

p_{world} is the value of the base crop (paddy) traded at world prices

A_i is the area cropped with crop i

p_b is the local price of the base crop (paddy)

Table 5.46 Standardized Gross Value of Production in Old Ayacut

Sl.No	Crops	Area (ha)	Yield Kg/ha	Total production (tonnes)	Farm Harvest Price (Rs/tonnes)	Base crop (paddy) price (Rs/tonnes)	World paddy price (Rs/tonnes)	SGVP	In terms of paddy SGVP
		A_i	Y_i	$A_i Y_i$	P^i	p^b	$P_{\text{world}} = \text{u\$ } 343.23$	Rs. Million	
1	Paddy	14928	6100	91060.80	5160.2	5160.2	16475.33	1500	1.00
2	Blackgram	1750	630	1102.50	21008.4	5160.2	16475.33	74	0.05
3	Sugarcane	3650	150000	547500.00	880.57	5160.2	16475.33	15393	1.74
4	Turmeric	1326	4500	5967.00	14531.3	5160.2	16475.33	277	0.18
5	Cotton	109	1750	190.75	16972.5	5160.2	16475.33	10	0.01
6	Groundnut	3000	1400	4200.00	12775.9	5160.2	16475.33	171	0.11

Table 5.47 Standardized Gross Value of Production in New Ayacut

Sl.No	Crops	Area (ha)	Yield Kg/ha	Total production (tonnes)	Farm Harvest Price (Rs/tonnes)	Base crop (paddy) price	World paddy price (Rs/tonnes)	SGVP	In terms of paddy SGVP
		A_i	Y_i	$A_i Y_i$	p^i	p^b	$P_{world} = \text{u\$ } 343.23$	Rs. Million	
1	Paddy	10260	5030	51607.80	5160.2	5160.2	16475.33	850	1.00
2	Blackgram	3168	700	2217.60	21008.4	5160.2	16475.33	149	0.17
3	Sugarcane	3650	85000	310250.00	880.57	5160.2	16475.33	8723	1.03
4	Turmeric	2005	4000	8020.00	14531.3	5160.2	16475.33	372	0.44
5	Cotton	160	1675	268.00	16972.5	5160.2	16475.33	15	0.02
6	Groundnut	2804	961.5	2696.13	12775.9	5160.2	16475.33	110	0.13
7	Tapioca	2205	25000	55125.00	1421.5	5160.2	16475.33	250	0.29
8	Maize	3000	5200	15600.00	4814.4	5160.2	16475.33	240	0.28
9	Sorghum	3000	2752	8256.00	6001.2	5160.2	16475.33	158	0.19
10	Gingelly	8500	6250	53125.00	17019.9	5160.2	16475.33	2887	3.40

Table 5.48 Comparison of SGVP of Water in the Bhavani Basin

Sl.No	Crops	Old Ayacut	New Ayacut
1	Paddy	1.00	1.00
2	Black gram	0.05	0.17
3	Sugarcane	1.74	1.03
4	Turmeric	0.18	0.44
6	Cotton	0.01	0.02
7	Groundnut	0.11	0.13
9	Tapioca	---	0.29
10	Maize	---	0.28
11	Sorghum	---	0.19
12	Gingelly	---	3.40

The equivalent yields are based on the farm-gate prices. It could be seen from the tables that SGVP of water in sugarcane was 1.74 and 1.03 times more than paddy crop in both old and new ayacut respectively. So, 1 kg of sugarcane is equivalent to 1.74 kg of rice. Similarly SGVP of water in gingelly was 3.40 time more than paddy crop in new ayacut and one kg of gingelly is equivalent to 3.40 kg of paddy indicating the possibility for crop substitution.

5.5.5. Gross Margin in Water Sales in Domestic Sector

In domestic sector, water transfer was happened by two categories i.e., 1.farmers, and 2.TWAD Board.

5.5.5.1. Farmers and Other Sellers

Farmers, tankers, barrel operators and bullock owners came under these categories. They supplied water to near by town and cities to meet out daily demand of domestic sector. This was worked out after deducting all cost except water cost from gross revenue and expressed as Rs/1000 liters.

The gross margin of water transfer in these cases was calculated per 1000 liters in monetary terms and presented in the Table 5.49. From the table that, the gross margin of water per 1000 liters was high in bullock owner (Rs 0.27/1000 liters) and very low in agricultural farmer sell (Rs 0.01/1000 liters).

Table 5.49 Gross Margin in Water Sales by Farmers and Other Sellers
(Rs/1000 liters)

Sl.No	Operators	Gross Revenue	Total variable Cost*	Gross margin of water {(Col 3 -Col 4)/1000}
1	2	3	4	5
1	Farmers	14.81	6.68	0.01
2	Tankers	59.25	4.54	0.07
3	Barrel	100.00	4.54	0.15
4	Bullock	175.00	4.54	0.27

Note : *Cost include all cost except water cost

5.5.5.2. TWAD Board

Another category of water transfer in domestic sector was TWAD board. TWAD board supplied water to corporation, town panchayats and village panchayats in the basin and to near basin from Bhavani river. The gross margin of water transfer per 1000 liters in municipalities, town panchayats and village panchayats and near basin was calculated and presented in Table 5.50. It could be seen from the table that gross margin of water in Bhavani and Noyyal basin water transfer was high in municipalities (Rs.3.49/1000 liters) and low in village panchayat union (Rs.2.49/1000 liters).

Table 5.50 Gross Margin in Water Sales by TWAD Board
(Rs/1000 liters)

Sl.No	Operators	Gross Revenue	Total variable Cost	Gross margin of water {(Col 3 -Col 4) /1000}
1	2	3	4	5
Bhavani Basin				
1	Municipalities	3500.00	2.73	3.49
2	Town Panchayats	3000.00	1.47	2.99

3	Panchayat Unions	2500.00	3.45	2.49
Noyyal Basin				
4	Municipalities and surrounding 525 Habitat	3500.00	2.71	3.49

5.5. Optimization of Water among Different sectors

After cost and gross margin of water in different sectors are analyzed, then one of the other important objectives of the study is to optimize water use among agricultural, domestic, livestock and industrial sectors. This is important since due to increasing competition among different sectors for water, as well as high WTP order industries, it is expected that industry sector may demand more water. Also the Tamil Nadu state water policy 2002 given first priority for domestic water needs. Hence agriculture may face more competition. However by optimal allocation of the available supplies, it is also possible to maximize the return from water. In the present study, profit maximization has been assumed as the objective at the ayacut level and attempts were made to develop optimum plan for old and new ayacuts (Turn I and II). The initial matrix is given in Annexure.

5.5.1 Optimum Plan for Old Ayacut

Once an estimate is made of existing water drawl for domestic purposes, the next logical task is to estimate the likely growth in the future water requirement of the domestic sector. Since the urban demand will be expending due to government priority for drinking water, it is necessary to project the future demands. Projections are usually associated with certain assumptions and past experiences.

In making future domestic water requirement assessment, the immediate task is to predict the growth in population of areas likely to be served by the Bhavani basin. Population data of this basin was collected from the decadal census reports. Annual population growth rates in this basin were estimated using decadal changes in the census data.

The model was first run with existing year (2001-02) water supply level. In the model, the crop activities included were mostly the activities currently practiced. The model also included domestic sector, livestock and industrial sector; besides water transfer activities to take care of the surplus water. Constraints included were land by

three seasons, irrigation water for three seasons, rural water requirement, urban water requirement, livestock water requirement and industrial water requirement. The model was solved in General Algebraic Modeling System (GAMS) and optimum plans were obtained. The efficiency of the optimum plans was examined in terms of change in crop enterprises and resource gross margin. The details of the Technological matrix for plan I, plan II and plan III was given in Annexure 6,7 and 8 and results of the programme was given in annexure 9,10 and 11. The programme result obtained crop-mix in the existing plan and optimum plan I, plan II, and plan III for year 2001-02, 2011-12 and 2021-22 respectively are presented in Table 5.51.

A perusal of the existing and optimum plan in the study area clearly showed that optimum plan promises significant changes in the land use different seasons. Due to optimization, only the crops suited for the region under the given resource constraint got included in the respective optimum plan.

As could be seen from table that the optimums plan suggested lesser area for wet crops than the existing plan. The existing plan consisted of paddy I, paddy II, paddy III, sugarcane, turmeric, banana, cotton, groundnut, and coconut. In the existing plan, paddy I and paddy II was cultivated over 7.174 hectares and 6.004 hectares of land in two season i.e., from July- November and December-April. Paddy III was cultivated starting from April-July in 1750 hectares of land. Groundnut were grown more than 7000 hectares i.e., 7500 hectares in season III. Sugarcane, turmeric and pulses were grown more than 1000 hectares i.e., 2650 hectares, 1326 hectares and 1102 hectares respectively. The other crops namely banana, cotton and coconut were grown less than 1000 hectares i.e., 580 hectares, 3200 hectares and 650 hectares respectively. The existing plan also included inter basin and intra basin domestic sector (rural and urban), livestock and industrial sector water supply for three seasons. The cropping intensity was 234.72 per cent. The gross income was computed to be Rs. 2,328.24 million.

Table 5.51. Comparison of Existing and Optimum Plan in Old Ayacut

(Area in '000 ha)

Sl.No	Crops	Notation/ Index	Programme Variables	Existing Plan	Optimum Plan-I	Optimum Plan-II (2011)	Optimum Plan-III (2021)
1	Paddy I	X1	X1	7.174	6.561 (-8.54)	4.835 (-32.60)	4.544 (-36.66)
2	Paddy II	X2	X2	6.004	5.334 (-11.16)	4.117 (-31.43)	3.827 (-36.26)
3	Paddy III	X3	X3	1.750	1.500 (-14.30)	1.500 (-14.30)	1.500 (-14.30)
4	Pulses	X4	X4	1.102	1.000 (-9.25)	1.000 (-9.25)	1.000 (-9.25)
5	Sugarcane	X5	X5	2.650	3.000 (-13.21)	3.000 (-17.80)	3.000 (-17.80)
6	Turmeric	X6	X6	1.326	1.000 (-24.60)	1.000 (-24.60)	1.000 (-24.60)
7	Banana	X7	X7	0.580	1.000 (+72.40)	1.000 (+72.40)	1.000 (+72.40)
8	Cotton	X8	X8	3.200	2.000 (-37.50)	2.000 (-37.50)	2.000 (-37.50)
9	Groundnut	X9	X9	7.500	10.049 (+33.99)	8.798 (+17.31)	8.301 (+10.68)
10	Coconut	X10	X10	0.650	1.000 (+53.80)	1.000 (+53.80)	1.000 (+53.80)
11	Gross cropped area	Ha	Ha	37.79	39.444	35.25	34.172
12	Net cropped area	Ha	Ha	16.100	16.100	16.100	16.100
13	Cropping intensity	Ha	Per cent	234.72	244.99	218.94	212.25

Sl.No	Crops	Notation/ Index	Programme Variables	Existing Plan	Optimum Plan-I	Optimum Plan-II (2011)	Optimum Plan-III (2021)
14	Industries I (MCM)	I 11	X11	13.05	13.05	14.33 (+10.00)	15.79 (+20.00)
15	Rural sector I (MCM)	R12	X12	22.17	22.17	24.47 (+10.37)	27.01 (+21.83)
16	Urban sector I (MCM)	U13	X13	9.06	9.06	9.99 (+10.26)	11.02 (+21.63)
17	Livestock sector I (MCM)	L14	X14	3.83	3.83	3.64 (+4.96)	3.49 (+8.87)
18	Industries II (MCM)	I 15	X15	13.05	13.05	14.33 (+10.00)	15.79 (+20.00)
19	Rural Sector II (MCM)	R16	X16	22.17	22.17	24.47 (+10.37)	27.01 (+21.83)
20	Urban sector II (MCM)	U17	X17	9.06	9.06	9.99 (+10.26)	11.02 (+21.63)
21	Livestock Sector II (MCM)	L18	X18	3.83	3.83	3.64 (+4.96)	3.49 (+8.87)
22	Industries III (MCM)	I 19	X20	13.05	13.05	14.33 (+10.00)	15.79 (+20.00)
23	Rural Sector III (MCM)	R20	X21	22.17	22.17	24.47 (+10.37)	27.01 (+21.83)
24	Urban Sector III (MCM)	U21	X22	9.06	9.06	9.99 (+10.26)	11.02 (+21.63)
25	Livestock Sector III (MCM)	L22	X23	3.83	3.83	3.64 (+4.96)	3.49 (+8.87)
26	Water Availability (MCM)			1245.26	1245.26	1157.75	1157.75

27	Gross Income (Rs Million)	2328.244	2414.061	2304.561	2323.452
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Source: Income of different sectors is given in Annexure-4

Note: Number in parentheses indicates percentage change over the existing plan

The optimum plan I (2001-02), area under paddy I, paddy II, paddy III, declined from 7.174 hectares to 6561 hectares, 6.004 hectares to 5334 hectares, 1750 hectares to 1500 hectares respectively. This was a decline in paddy I (8.54 %), paddy II (5.33 %), paddy III (14.30 %) from existing plan. Sugarcane has increased in optimum plan I from 2650 hectares to 3000 hectares i.e., 13.21 per cent increased. Turmeric and pulses declined marginally from 1326 hectares to 1000 hectares, 1102 hectares to 1000 hectares respectively. This was and turmeric (24.60 %) and pulses (9.25 %) declined from existing plan.

As in the case area under banana and coconut has increased from 580 hectares to 1000 hectares (42%), 650 hectares to 1000 hectares (35%) respectively. Area under cotton has declined from 3200 hectares to 2000 hectares in the third season. The area under groundnut has highly changed in the optimum plan. It is competing with cotton in same season (Third season) of old ayacut. But in terms of gross income groundnut crop fetched more gross income than cotton. The cropping intensity in optimum plan I has increased from the existing plan (243.72 to 244.99 per cent).

Due to government priority for drinking water for domestic and livestock, water demand has not changed in optimum plan. In industrial cases, government could not reduce the production of industries. So, water requirement of industrial needs has also not changed in optimum plan. Hence, in optimum plan I domestic sector, livestock sector and industrial sector water requirement level was same as like existing plan. The gross income has increased from Rs. 2328.244 million to Rs. 2414.061 million. Even with the inter and intra basin water transfer, the agricultural sector survives in optimum plan I with marginal decline in paddy I area (8.5%), paddy II (11.15 %) and paddy III (14.28 %) after water transferred from agriculture to non-agriculture sectors.

Since an optimum plan I is making use of existing water drawl for domestic livestock and industrial purposes along with agricultural sector, the next logical task is to arrive an optimum plan for the future years covering the three sectors. So, optimum plan II and plan III

for year 2011-12 and 2021 -22 respectively was worked out to examine the impact of future transfer out of agriculture and choosing appropriate combination of crops.

In optimum plan II (2011), the same cropping pattern as witnessed in optimum plan I was noticed except decline in area of paddy I and paddy II i.e., paddy I declined from 7.174 hectares to 4.835 hectares (32.5%) and paddy II 6.004 hectares to 4.117 hectares (31.4%) respectively. The gross cropped area declined from 31910 hectares to 28250 hectares. The cropping intensity declined from 198.36 to 175.47 percent.

The water requirement for rural and urban sector has increased from 93.69 MCM to 103.38 MCM. The industrial water use has increased from 39.15 MCM to 42.99 MCM. The water requirement for livestock has declined from 11.49 MCM to 10.92 MCM as the livestock population has declined as the area under fodder crops has also declined. The gross income has declined from Rs. 2328.244 million to Rs. 2304.561 million (4.5 %).

In optimum plan III (2021), there was a slight change in cropping pattern from optimum plan II in area under paddy I and paddy II i.e., paddy I declined from 4835 hectares to 4544 hectares and paddy II declined from 4117 hectares to 3827 hectares. In optimum plan III (2021), area under paddy I (36.66 %) and Paddy II (36.26 %) has declined from the existing plan. The cropping intensity has also declined from 198.36 to 168.77 percent from existing plan (10.63%).

The water requirement for rural and urban sector has increased from 93.69 MCM to 114.09 MCM. The industrial water use has increased from 39.15 MCM to 47.37 MCM. The water requirement for livestock has declined from 11.49 MCM to 10.47 MCM. The gross income declined from Rs. 2434.430 million to Rs. 2089.229 million.

Though there was increase in demand for water in non-agricultural sectors, it was noticed in the optimum plan II and plan III that the gross cropped area and cropping intensity had remained almost the same. It would again indicate the sign of bringing in

sustainability of the productive capacity of the agricultural sector along with increased water transfer to domestic (93.69 MCM to 114.09 MCM) and industries sector (39.15 MCM to 47.37 MCM) in optimum plan-II and III from optimum plan-I.

The details of resource constraints and their shadow prices of old ayacut optimum plan are shown in Table 5.52, which represents the marginal value productivities (MVPs) derived from the optimum solution. These shadow prices have been further used to examine the resource productivities and also the direction of resource use pattern among different plans and within the region. Cost and return per unit from different sectors in plan II and plan III are assumed as in plan I keeping other things constant. The marginal value product of land and water in the optimum plans are as follows.

Table 5.52 Shadow Prices of Resource Constraints in Old Ayacut

Sl.No	Resource	Optimum Plan I*	Optimum plan II*	Optimum plan III *
1	Water Season 1	1.400	1.400	1.400
2	Water Season 2	1.167	1.167	1.167
3	Water Season 3	2.143	2.143	2.143

Source: Annexures- 9,10 and 11

***Assumption of cost and return per unit from different sectors in plan II and plan III is as such in plan I**

It could be seen from the table that land in all seasons in all optimum plans, has no shadow price because land remains unutilized due to inadequate availability of water. Farmers who owned wells only irrigate the land to some extent, while the rest keep the land fallow till the release of water from the canal. Since the land is left fallow, the shadow price is zero in all optimum plans.

It was inferred from the optimum plans that if one MCM of water is increased in season I, season II and season III, the gross income over variable cost will increase by

Rs. 1.40 million, Rs. 1.167 million and Rs. 2.143 million respectively. Water was completely exhausted in all seasons.

5.5.2. Optimum Plan for New Ayacut (Turn I and Turn II)

The finding of the programming model for the new ayacut was given as Turn I and Turn II separately. The method of optimum plan calculation for both turn area of new ayacut was same as that of old ayacut. But in new ayacut area, there is no industrial water allocation, as all industrial allocation was made from main river.

The model was first run with existing water drawl (2001-02) level. The details of the Technological matrix for plan I, plan II and plan III was given in Annexure 12,13 and 14 and results of the programme was given in annexure 15,16 and 17. The programme result obtained crop-mix in the existing plan and optimum plan I, plan II, and plan III for year 2001-02, 2011-12 and 2021-22 for Turn I respectively are presented in Table 5.53.

For Turn-I, the existing plan consisted paddy I, sugarcane, turmeric, banana, cotton, groundnut, coconut, tapioca, maize, chollam, and gingelly. In the existing plan, paddy I was cultivated over 10260 hectares of land in one season i.e., from August and December. Sugarcane was grown as second largest crop i.e., 2647 hectares. Groundnut was grown next to sugarcane area i.e., 2602 hectares. Tapioca was cultivated in 1735 hectares. The other crops namely turmeric, chollam, cotton and coconut were grown in 1860 hectares, 2500 hectares, 80 hectares and 2600 hectares respectively and gingelly was cultivated 2500 hectares.

The gross cropped area was 41082 hectares. The cropping intensity was

96.99 per cent. The existing plan also included livestock sector water supply

for three seasons. The livestock sector water requirement in existing plan was

about 11.49 MCM. The total gross income in existing plan was computed to be

Rs. 1277.51 millions.

Table 5.53. Comparison of Existing and Optimum Plan in New Ayacut (Turn I)

(Area in '000 ha)

Sl.No	Crops	Variables	Existing Plan	Optimum Plan-I	Optimum Plan-II (2011)	Optimum Plan-III (2021)
1	Paddy	X1	10.260	9.202 (-10.31)	12.955 (+26.21)	12.960 (-26.32)
2	Pulse	X2	0.350	0 (-100.00)	0 (-100.00)	0 (-100.00)
3	Sugarcane	X3	2.647	2.000 (-24.41)	2.000 (-24.41)	2.000 (-24.41)
4	Turmeric	X4	1.860	4.500 (-61.14)	4.500 (-61.14)	4.500 (-141.94)
5	Banana	X5	0.253	0.750 (+196.44)	0.750 (+196.44)	0.750 (+196.44)
6	Cotton	X6	0.080	0.000 (-100.00)	0.000 (-100.00)	0.000 (-100.00)
7	Groundnut	X7	2.602	3.861 (+48.39)	7.178 (+175.86)	7.187 (+176.21)
8	Coconut	X8	2.600	1.500 (-42.31)	1.500 (-42.31)	1.500 (-42.31)
9	Tapioca	X9	1.735	1.000 (-42.36)	1.000 (-42.36)	1.000 (-42.36)
10	Maize	X10	2.000	0.000 (-100.00)	3.115 (+55.85)	3.124 (+4.13)

Sl.No	Crops	Variables	Existing Plan	Optimum Plan-I	Optimum Plan-II (2011)	Optimum Plan-III (2021)
11	Chollam	X11	2.500	0.000 (-100.00)	0.000 (-100.00)	0.000 (-100.00)
12	Gingelly	X12	2.500	6.000 (-140.00)	6.000 (-29.41)	6.000 (+140.00)
13	Gross cropped area	Ha	41.082	40.063	50.248	50.271
14	Net cropped area	Ha	42.355	42.355	42.355	42.355
15	Cropping intensity	Per cent	96.99	94.59	118.64	118.69
16	Livestock Sector I (MCM)	L13	3.83	3.83	3.64 (-4.96)	3.49 (-8.87)
17	Livestock Sector II (MCM)	L14	3.83	3.83	3.64 (-4.96)	3.49 (-8.87)
18	Livestock Sector III (MCM)	L15	3.83	3.83	3.64 (-4.96)	3.49 (-8.87)
19	Water Availability	MCM	793.800	793.800	964.05	964.05
	Gross Income (Rs Million)		1277.51	1459.66	1673.940	1674.329

Source : Income of different sectors are given in Annexure-5

Note: Number in parentheses indicates percentage change over the existing plan

In the optimum plan I (2001-02), area under paddy I, had declined from 10260 hectares to 9202 hectares (10.3 %). Sugarcane declined marginally from 2.647 hectares to 2000 hectares. Turmeric and groundnut increased from 1860 hectares to 4500 hectares and 2602 hectares to 3861 hectares respectively. This was turmeric (61.14 %) and groundnut (48.39 %) increased from existing plan.

The area under banana has increased from 253 hectares to 750 hectares (196.44 %).

Area under cotton, pulse, maize and chollam was removed in optimum plan. The gross cropped area declined from 41082 hectares to 40063 hectares. The crop intensity declined from 96.99 to 94.59 percent.

Due to government priority for drinking water for livestock, water requirement for domestic use has not changed in optimum plan. Hence, in optimum plan-I livestock sector water requirement level was same as like existing plan. The gross income has increased from Rs. 1277.51 million to Rs. 1459.66 million. Even while the cropping intensity has declined 2.4 per cent, the agricultural sector survives plan with marginal decline in area after water transferred from agriculture to non-agriculture sectors.

Once the optimum plan I is made of existing water drawl for livestock purposes along with agricultural sector, the next logical task is to attempt for developing optimum plan for the likely growth in the future water requirement of these sectors. So, optimum plan II and plan III for years 2011 and 2021 respectively was determined for optimizing water among water transfer out of agriculture and choosing appropriate combination of crops.

In optimum plan II (2011), the same cropping pattern as witnessed in optimum plan I was noticed except increase in area of paddy I i.e., paddy I increased from 10260 hectares to 12955 hectares in plan II from plan I. In optimum plan-II for 2011, paddy I (26.21 %) crop area was increased from existing plan. The gross cropped area increased from 41082 hectares to 50248 hectares.

The cropping intensity also increased from 96.99 to 118.64 percent. The main reason for increased cropping intensity in the optimum plan-II from plan-I, was due to increase in the area of paddy and inclusion of maize crop. Because of adequacy of water, wet crop like paddy entered in optimal plan-II.

The water requirement for livestock has declined from 11.49 MCM to 10.92 MCM as the livestock population has declined due to non-availability of fodder. However the gross income increased from Rs. 1277.51 million to Rs. 1673.940 million.

In optimum plan III (2021), there was a slight change in cropping pattern from optimum plan II as area under maize increased from 3115 hectares to 3124 hectares. The cropping intensity slightly increased 118.64 from to 118.69 percent from existing plan. The water requirement for livestock declined from 11.49 MCM to 10.47 MCM. The gross income increased from Rs. 1277.51 million to Rs. 1674.329 million.

The details of resource constraints and their shadow prices are shown in Table 5.54, which represents the marginal value productivities (MVPs) derived from the optimum solution. The marginal value products of land and water in the optimum plans are as follows.

Table 5.54 Shadow Prices of Resource Constraints in New Ayacut Turn I

Sl.No	Resource	Optimum Plan I	Optimum Plan II	Optimum Plan III
1	Water Season 1	1.167	1.167	1.167
2	Water Season 2	1.429	1.429	1.429

Source: Annexures- 15,16 and 17

***Assumption of cost and return per unit from different sectors in plan II and plan III is as such in plan I**

It could be seen from the table that land in all seasons in all optimum plan; land remains unutilized due to inadequate availability of water. Farmers who owned wells only irrigate the land to some extent, while the rest keep the land fallow till the release of water from the canal. Since the land is left fallow, the shadow price is zero in all optimum plans.

It is inferred from the optimum plan that if one MCM of water is increased in season I, season II, keeping other things constant, the gross income over variable cost will increase by Rs. 1.167 million and Rs. 1.429 million respectively. Water was completely exhausted in all seasons.

For Turn-II, there was no water supply from canal if Turn-I gets water supply from canal. The details of the Technological matrix for plan I, plan II and plan III was given in Annexure 18,19 and 20 and results of the programme was given in annexure 21,22 and 23. The programme result obtained crop-mix in the existing plan and optimum plan I, plan II, and plan III for year 2001-02, 2011-12 and 2021-22 for Turn II respectively are presented in Table 5.55.

The existing plan consisted of sugarcane, turmeric, banana, cotton, groundnut, coconut, tapioca, maize, cholam, and gingelly. In the existing plan, sugarcane was grown as the largest crop (i.e., 1003 hectares). Maize and groundnut were grown next to sugarcane area i.e., 500 hectares and 202 hectares. Tapioca was cultivated in 470 hectares. The other crops namely turmeric and cotton were grown less 470 hectares and 80 hectares respectively.

The gross cropped area was 11168 hectares. The cropping intensity was 27.14 per cent.

Existing plan also included livestock sector. The livestock sector water requirement in existing plan was about 11.49 MCM. The gross income was computed to be Rs.310.81 millions.

Table 5.55. Comparison of Existing and Optimum Plan in New Ayacut (Turn II)

(Area in '000 ha)

Sl.No	Crops	Variables	Existing Plan	Optimum Plan-I	Optimum Plan-II (2011)	Optimum Plan-III (2021)
1	Pulse	X2	0.250	0.000	0.000	0.000
2	Sugarcane	X3	1.003	1.000 (-0.03)	1.000 (-0.03)	1.000 (-0.03)
3	Turmeric	X4	0.145	1.748 (+1100.00)	2.27 (+1467.59)	2.414 (+1564.83)
4	Banana	X5	0.100	0.100	0.100	0.000
5	Cotton	X6	0.080	0.100 (-25.00)	0.000 (100.00)	0.000 (100.00)
6	Groundnut	X7	0.202	0.100 (-50.50)	0.000 (100.00)	0.000 (100.00)
7	Coconut	X8	1.900	0.000 (-100.00)	0.000 (100.00)	0.000 (100.00)
8	Tapioca	X9	0.470	0.100 (-78.72)	0.000 (100.00)	0.000 (100.00)
9	Maize	X10	0.500	0.100 (-80.00)	0.000 (100.00)	0.000 (100.00)

Sl.No	Crops	Variables	Existing Plan	Optimum Plan-I	Optimum Plan-II (2011)	Optimum Plan-III (2021)
10	Chollam	X11	0.500	0.100 (-80.00)	0.000 (100.00)	0.000 (100.00)
11	Gingelly	X12	0.500	1.500 (-80.00)	0.014 (97.20)	0.014 (97.20)
12	Gross cropped area	Ha	11.168	7.78	6.76	6.84
13	Net cropped area	Ha	41.15	41.15	41.15	41.15
14	Cropping intensity	Per cent	27.14	18.90	16.43	16.62
15	Livestock Sector I (MCM)	L13	3.83	3.83	3.64 (4.96)	3.49 (8.88)
16	Livestock Sector II (MCM)	L14	3.83	3.83	3.64 (4.96)	3.49 (8.88)
17	Livestock Sector III (MCM)	L15	3.83	3.83	3.64 (4.96)	3.49 (8.88)
	Profit (Rs. Million)		310.81	339.21	379.323	385.67

Source : Income of different sectors are given in Annexure-5

Note: Number in parentheses indicates percentage change over the existing plan

In the optimum plan-I (2001), area under sugarcane has declined from 1003 hectares to 1000 hectares (0.03 %). The other crops namely banana, cotton, groundnut, coconut, tapioca, maize and chollam were present in optimum plan I with each 100 ha. The area under turmeric increased from 145 hectares to 1748 hectares. The gross cropped area declined from 11168 hectares to 7780 hectares. The cropping intensity has declined from 27.14 to 18.90 percent.

Due to government priority for drinking water for livestock, water requirement for it was not changed in optimum plan. Hence, in optimum plan I livestock sector water requirement level was same as like existing plan. The gross income was increased from Rs. 310.81 million to Rs. 339.21 million. Even while the cropping intensity has declined from 8.48 percent, the agricultural sector survives in optimum plan with decline in area.

In Turn-II, there was no canal water supply. So, optimum plan-II and III for year 2011 and 2021 respectively was determined for optimizing available ground water among choosing appropriate combination of crops.

In optimum plan II (2011-12) and plan-III (2021-22), the same cropping pattern as witnessed in optimum plan I was noticed except increase in area of turmeric i.e., turmeric increased from 2270 hectares in plan-I to 2414 hectares in plan III. Plan III, the gross cropped area (6840 hectares) and cropping intensity (16.62 per cent) were almost same as witnessed in optimum plan II. The gross income increased by optimizing from Rs. 310.81 million to Rs. 385.67 million with no canal water supply from optimum plan-I to plan-III.

The details of resource constraints and their shadow prices are given in Table 5.56. which represents the marginal value productivities (MVPs) derived from the optimum solution. The marginal value product of land and water in the optimum plans are as follows.

Table 5.56 Shadow Prices of Resource Constraints In New Ayacut Turn II

Sl.No	Resource	Optimum Plan I	Optimum Plan II	Optimum Plan III
1	Season 1 Water	1.440	5.387	5.387
2	Season 2 Water	6.827	1.440	1.440

Source: Annexure-21,22 and 23

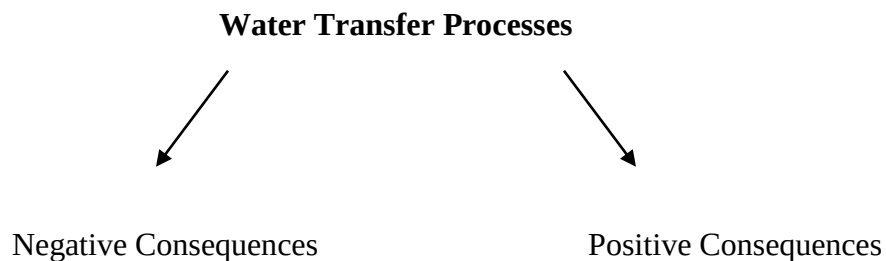
***Assumption of cost and return per unit from different sectors in plan II and plan III as such plan I**

It could be seen from the table that land in all season in all optimum plans, land remains unutilized due to inadequate availability of water.

It is inferred from the optimum plan that if one MCM of water is increased in season I and II in optimum plan I, the gross income over variable cost will increase by Rs. 1.440 million and Rs. 6.827 million respectively. In all optimum plan water was completely exhausted in all seasons.

5.6 Consequences of Water Transfer in the Lower Bhavani Basin

Water was transferred from Bhavani river to agricultural and industrial sectors either by authorized or unauthorized. In domestic sector, water demand met by authorized way only. These water transfer process made two types of consequences on livelihoods of the people and environment of the basin. i.e.,



Negative consequences of these water transferred either authorized or unauthorized is organized under the following four sections

5.6.1. Consequences in agricultural sector

5.6.2. Consequences in livestock sectors

5.6.3. Consequences in fisheries sectors

5.6.4. Consequences in livelihood

Positive consequences of these water transferred is organized under the following two sections.

5.6.5. Consequences by domestic sector

5.6.6. Consequences by industrial sector

5.6.1. Consequences in Agricultural Sectors in the Lower Bhavani Basin

The details of water transfer in different villages were presented in Table 5.57. It could be seen from the table that Bhavani basin contains nine taluks and twenty-three blocks. In these twenty-one blocks, this river benefits sixteen blocks. Avanashi, Annur, Uthukuli, Anthiyur Ammapet, Dharapuram, Kundadam and Mulanur blocks were not benefited by this Bhavani river. The table indicted that the total quantity of water transfer from ayacut area to non-ayacut area was 49.36 MCM in 2001-02. Water transferred was very high in Vellakoil block (8.9 MCM) followed by Bhavani block (7.2 MCM). Least water transferred was happened in Mettupalayam (4.2 MCM) due to it was located in Head region.

Table 5.57 Block Level Details of Water Transfer to Non Ayacut Areas of the Basin

Sl. No	Taluks	Blocks	Villages	Source of Irrigation	Remarks on Water Transfer	Quantity MCM
1	Erode	Erode	Pethampalayam	LBP	Nil	
		Modakurichi	Modakorichi, Velampalayam	LBP	Nil	
		Kodumudi	V.Puthupalayam	Kalingaraiyan	Happening	5.38
2	Peruntudurai	Perundurai	Nasiyanur	LBP	Nil	
		Chennimalai	Vellode	LBP	Nil	
		Uthukuli	Not Benefited	---	---	
3	Gobi	Gobi	Karattipalayam	Thadapalli	Happening	6.2
		Nambiyur	Kurumanthur	LBP	Nil	
		T.N. Palayam	Kallipatti	Arakkankodai	Happening	6.17

4	Sathyama n-galam	Sathy	Koombupallam	(i) Old Ayacut	Happening	7.01
				(ii)LBP	Nil	
		Bhavanisaga r	Thodanpalaya m	Old ayacut	Happening	4.3
			Thopanpalaya m	LBP	Nil	
		Thalavadi	Not Benefited	----	----	

Sl. No	Taluks	Blocks	Villages	Source of Irrigation	Remarks on Water Transfer	Quantity MCM
5	Bhavani	Bhavani	Jambai	Bhavani	Happening	7.2
		Anthiyur	Not Benefited	----	----	
		Ammamet	Not Benefited	----	----	
6	Dhara- puram	Dharapuram	Not Benefited	----	----	
		Kundadam	Not Benefited	----	----	
		Mulanur	Not Benefited	----	----	
7	Kanga- yam	Kangayam	Nathaikataiyur	LBP	Nil	
		Vellakoil	Manthapuram	LBP	Happening	8.9
8	Avanashi	Annur	Nil	Nil	Nil	
		Avanashi	Nil	Nil	Nil	
9	Mettu- palayam	Karamadai	Odanthurai	Main River	Happening	4.2

Source: Executive Engineer, Bhavani Sagar, Erode.

5.6.1.1. Cropping Pattern Changes in the Lower Bhavani Basin

The cropping pattern depends mostly on a host of factors like soil characteristics, irrigation, rainfall distribution etc. Farmers changed their water intensive crop to dry crop due to water scarcity through water transfer. The details of substitute crop in sample farms were given in Tables 5.58 and 5.59.

Table 5.58 New Substitute Crops in Sample Farms in Lower Bhavani Basin

Sl.No	Blocks	Villages	Old crop*	Alternate crop*
1	Erode	Pethampalayam	1P,GI,GUCH,S,T U	1P,GI,GU,TA
2	Modakurichi	Modakurichi, Velampalayam	1P,GI	1P,TA
3	Kodumudi	V.Puthupalaya m, Kodumudi	2P,T,S,O	1P,T,S,O,TA
4	Perundurai	Nasiyanur	1P,S,CH	1P,TA

5	Chennimalai	Vellode	1P,CH	1P,TA
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Sl.No	Blocks	Villages	Old crop*	Alternate crop*
6	Uthukuli	Not Benefited	---	----
7	Gobi	Karattatipalayam	2P,B,S	1P,S,GU,GI,TA
8	Nambiyur	Kurumanthur	1P,S,GU,GI	1P,TA,GI
9	T.N. Palayam	Kallipatti	2P,S	2P,S,TA
10	Sathy	Koombupallam	B,CO,2P,S	B,CO,1P,S,GU,GI,TA
11	Bhavanisagar	Thodanpalayam	1P,CH	1P,TA
12	Thalavadi	Not Benefited	---	---
13	Bhavani	Jambai	2P,S,CH	2P,S,CH
14	Kangayam	Nathaikataiyur	1P,GI,C,CH	1P,TA
15	Vellakoil	Manthapuram	1P,S,TU	1P,CH,TA
16	Karamadai	Odanthurai	B,CH	B,CH

Note: *1P- One season paddy; 2P- Two season paddy; TA- Tapioca; GI- Gingelly;
CO- Coconut; Gu- Groundnut; CH- Cholam; S- Sugarcane;
O- Onion; T- Turmeric; B- Banana; C- Cotton;

Table 5.59 New Cropping Pattern in Lower Bhavani Basin

Sl.No	Crop	Area in 1990 (ha)	Present Area (ha)	% Change
1	Paddy	29807.48	25188	-18.34
2	Sugar cane	7750.89	6300	-23.03
3	Banana	948.5811	933	-01.67
4	Turmeric	4847.271	3331	-45.52
5	Groundnut	8063.91	10304	21.74
6	Cotton	1747.53	3360	47.99
7	Pulse	1599.88	1702	06.00
8	Gingelly	5286.9	3000	-76.23
9	Tapioca	805.9275	2205	63.45
10	Maize	3313.44	2496	-32.75
11	Chollam	3856.8	3000	-28.56
12	Coconut	6254.675	5150	-21.45
13	Others	41055.86	34620	-18.59
Gross Cropped Area		115339.10	101589	-13.54

Source: Joint Director of Agriculture, Coimbatore and Erode.

It could be seen from the table that there was marked difference between last 10 years in terms of percentage area under varies crops. V. puthupalayam village in Kodumudi block, Karattatipalayam village in Gobi block and Koombupalam village in sathy block of old ayacut areas were grown only one season of paddy instead two seasons due to water scarcity. It could be seen from the table that in all blocks tapioca (63.45 %) and cotton (47.99 %) was substituted for water intensive crops such as paddy (-18.34 %), sugarcane (-23.03%) and Banana (-1.67).

5.6.1.2. Cropping Intensity in the Sample Farms of the Lower Bhavani Basin

Cropping intensity is an important indicator that reflects the extent of double cropping, which is influenced by availability of irrigation water. Therefore, the details on the same were collected and analyzed. The results are furnished in Table 5.60.

Table 5.60 Cropping Intensity in the Sample Farms

Sl. No	Basin Region	Cropped area (ha)		Cropping intensity (%)
		Net	Gross	
1	Head Region	1.95	3.74	191.79
2	Middle Region	1.61	2.89	179.50
3	Tail end Region	1.54	2.67	173.00
4	All farms	1.70	3.10	181.43

It could be observed from the table that in the case of Head region, the average net cropped area are worked out to 1.95 ha and Tail end region was 1.70 ha Hence the Head region cropping intensity was higher than other region. This might be due to the damage caused by the water transfer in Head and Medial regions from surface as well as ground water in the wells and consequent low gross margin and reduced cropping intensity in the Tail end region. The over all average of net cropped area was 1.70 ha.

5.6.1.3. Irrigation Intensity in the Sample Farms

Irrigation intensity in a way reflects the cropping intensity. Therefore, the details on the same were collected and analyzed. The results are presented in Table 5.61. It could be observed from the table that the average net irrigated area in Head region (1.82) ha was found to be higher than that in Tail end region (1.48 ha). The overall average of the irrigation intensity was 1.64 ha.

Table 5.61 Irrigation Intensity in the Sample Farms of the Lower Bhavani Basin

Sl. No	Basin Region	Irrigated area (ha)		Irrigation intensity (%)
		Net	Gross	
1	Head Region	1.82	3.19	175.00
2	Middle Region	1.53	2.61	170.58
3	Tail end Region	1.48	2.05	138.51
4	All farms	1.64	2.66	162.07

5.6.1.4. Consequences on Well Ownership in Lower Bhavani Basin

The details of well ownership of the three regions are presented in the in Table 5.62.

Table 5.62 Pattern of Well Ownership in Sample Farms of the Basin

Regions	(No. of wells/farm)					
	1990-91			2001-02		
	Open well	Dug cum Bore	Bore well	Open well	Dug cum Bore	Bore well
Head	1	0	1	1	1	2
Middle	2	1	1	2	1	2
Tail end	1	1	1	1	2	3

It could be seen from the table that the average number of open wells owned was 1, 2 and 1 respectively for Head Middle and Tail end regions farmers during 1990-91 and also same for Head, Middle and Tail end during 2000-2001. Because open well without

bore was not viable to irrigate in water scarcity period. It is interesting to note that the number of bore wells owned by all regions of farmers has increased over a decade

(from 1, 1, 1 respectively for Head, Middle and Tail end to 2, 2 and 3 respectively Head, Middle and Tail end). Declining groundwater table due to over exploitation of groundwater force the farmers to go for installation of new bore wells.

5.6.1.5. Effects on Well Working Hours and Depth in Middle and Tail End Region

The details of well average depth; horsepower and working hours per day were presented in Table 5.63.

Table 5.63 Average Depth of Wells and Pump Horsepower of Sample Farmers in Middle and Tail End

Particulars	1990-91			2001-02		
	Average depth (ft)	Hp	Working hrs /day	Average depth (ft)	Hp	Working hrs /day
Open well	75	5	24	85	10	18
Dug cum Bore	100	5	20	165	12	10
Bore well	200	5	22	450	7.5	7

It could be seen from the table that the power of electric pump is generally dictated by two factors such as what horsepower is available (the minimum pump size is 3 HP) and what is needed to draw groundwater to the surface. For instance, Middle and Tail end may be forced to install a larger pump than is economically justified by the area they do cultivate, but larger horsepower of pumps may be a necessity in areas where water table is too deep. It is evidenced that the average size of horsepower of electric motors has significantly increased over the periods in Middle and Tail end. In case of Head region there was negligible change happened in the same periods. Working hours of pump per day was decreased from 22 hours to 7 hours.

5.6.1.6. Consequences on Ground Water Level in Bhavani Basin

The water level fluctuations are cyclic and are in response to the incidence of the monsoon rainfall and extraction of ground water. In order to better understanding of the ground water status of the study area, we need some chronic analysis. Thus, the present study has utilized data furnished by the Ground Water Cell of State PWD to analyze ground water status of Lower Bhavani Basin. For this purpose 14 observations wells, which represent all parts of the basin, are selected. Water levels of these wells are available since 1971. Locations of these wells are presented in Figure. The description of the study wells and ground water status are summarized in Tables 5.64.

Table 5.64 Water Level in the Observation Wells in Lower Bhavani Basin
(Meter)

Sl.No	Well No	Location of Well	Depth of Well	1972	1982	1992	2000
1	63319	Sirumgai	9.90	1.32	1.60	1.60	2.78
2	63326	Irumbarai	17.80	2.56	2.80	5.10	2.95
3	63324	T.Palayam	40.75	5.60	14.98	21.43	6.80
4	63038	Tignari	17.47	1.37	6.10	1.51	0.95
5	63004	Panayampalli	15.40	6.28	11.13	7.40	1.52
6	63020	Shenbagapudur	14.14	0.98	2.23	1.36	2.24
7	63001	Emmapoondi	22.80	4.52	6.75	9.16	5.78
8	63022	Periyakodiveri	13.35	3.37	7.30	1.22	5.32
9	63034	Savandapur	7.20	0.97	2.80	2.06	0.95
10	63111	Brammadesam	19.00	2.24	3.00	3.87	2.50
11	63118	Keserimangalam	18.00	5.37	3.00	8.85	5.30
12	63105	Jambai	11.70	1.05	1.70	1.06	1.65
13	63245	Nasiyanur	16.10	0.74	1.20	1.56	1.52
14	63234	Karandipalayam	23.90	2.83	3.00	13.81	4.10

Source: Ground Water Cell, State Public Works Department, and Government of Tamil Nadu.

Out of 14 wells taken for the study 6 are located in the different canal command areas and 8 in the non-command areas. Wells of command area are located in new LBP canal area, old canal systems and Mettur West Bank canal area. Remaining eight wells of non-command area are located in the following manner: one at closure to river bank (Sirumugai), one is just away from the river (Irumburai), one in the hill ranges (Tignari), another one near to reserve forests (Brammadesam), and remaining four located in the eastern (Thandukarampalayam and Panayampalli) and the southern parts (Emmapoondi and Karandipalayam) of the plain area. From the table we can observe approximately the trend of water level during the period between 1972 and 2000.

It could be seen from the table that the water level was declined in the well. The water level in the wells dropped below average 10 m -40 m in the sample farmers. The water table rise or groundwater recharge is not in significant proportion to the rainfall, as learnt from the farming community. Most of the farmers are using pump with a Horse Power of 5 to 7.5 and only few farmers going for 10 HP. Mostly mono-block pumps and submersible pumps are used. The average running hours of electric motors is worked out to 10 hours even during summer months leading to over irrigation of fields and drastic depletion of water table.

5.6.1.7. Additional Cost of Cultivation of the Major crops in the Lower Bhavani Basin

The cost of cultivation was calculated to find out the effect of water on net farm income. In Head region because of plenty of water available, there is no need to put additional cost in construction of pipe line from long distance from river or own well. Hence net income reduction was negligible. In Tail region of both ayacut (old and new) water availability is less. Farmers have to incur heavy reduction in net farm income when go for water lifting from long distance from river or own well. In previous Table 5.30 it could be seen that the average cost of 1 KL of water was Rs.3.54 in pumping scheme from river and Rs.2.53 in water pumping from own well. In this connection, net farm income was reduced in Middle and Tail end regions.

51.1.8. Yield Losses of the Sample Farms

The crops yield was reduced between year 1990 and 2002 due to non availability of water by water transfer process to non ayacut area and non farm sectors. The extent of yield reduction was presented in the Table 5.65.

Table 5.65 Average Yield Reductions of the Sample Farms in Lower Bhavani Basin

(tonnes/ha)

Sl. No	Crops	Yield Before 10 years			Present Yield		
		H	M	T	H	M	T
1	Paddy	5.63	5.25	4.75	5.5	5.0	3.5 (-26.31)
2	Sugar Cane	125	125	125	122.5	122.5	100.0 (-22.50)
3	Turmeric	4.75	4.75	4.625	4.625	4.625	2.94 (-36.23)
4	Groundnut	2.25	2.25	2	2.2	2.2	1.4 (-30.00)
5	Banana (numbers)	2500	2500	2500	2500	2500	1750 (-30.00)
6	Gingelly	1	1	1.95	0.975	0.975	0.95 (-51.28)
7	Maize	3.5	3.5	3.2	3.5	3.5	3.0 (-6.25)
8	Coconut (Numbers)	20000	17500	15750	19750	17000	13000 (-17.43)
9	Cotton	---	2.0	1.86	---	0.8	1.75 (-10.00)

Figures in parentheses indicated the percentage changes in yield reduction

Note: H: Head; M: Middle; T: Tail end

It could be seen from the table that there was considerable crop yield reduction in Tail end region due to non-availability of water by water transfer in Head and Middle

regions. In the Head and Middle regions there was negligible difference in yield reduction. In 1990-91, per hectare yield of paddy is 4750 kg / ha in Tail regions. But now farmers got only 3500 kg/ ha from the large inputs. This was 26.31 per cent reduction in yield in the last ten years. This was due to non-availability of water. Presently not only paddy crop yield affected, all crops yield was reduced in range between 6 percent (Maize) to 52 per cent (Gingelly) from the yield got in 1990.

5.6.1.9. Income Reduction of Sample Farms in Tail End

In case of Head and Middle region farms got the same yield with negligible difference and income reduction also negligible. There was considerable income reduction in Tail end region due to yield reduction. The details of farm income reduction were presented in Table 5.66. The value of output was calculated based on the total yield of the crop.

Table 5.66 Income Reduction of Sample Farms in Tail End Region

Sl.No	Crop	Income (Rs.)/ha/year			% Change
		In 1990	In 2002	Reduction	
1	Paddy	34444.28	25380.42	9063.86	-35.71
2	Sugar Cane	87500.21	70000.34	17499.87	-20.00
3	Turmeric	10,5000.32	66,001	38999.54	-37.14
4	Groundnut	15,750.57	9,800	5950.43	-37.78
5	Banana	170000.47	149000.5	21000.02	-30.00
6	Gingelly	19000.12	10,000	8999.85	-49.00
7	Tobacco	25000.86	20,000	5000.45	-20.00
8	Jasmine	20,000.45	15,000	5000.08	-25.00
9	Coconut	72,000.45	52,001	19999.73	-33.33
10	Cotton	42570.95	31250.34	11320.61	-27.79

It could be seen from the table that in tail end region in earlier period, the farms were getting normal gross return, but now due to yield reduction from 6 per cent to

52 per cent, the farm's income was also reduced. Gross income reduction was high in gingelly (49 %) followed by groundnut (37.78%), turmeric (37.14 %) paddy (35.71 %). Tobacco growing farm was less affected in gross income reduction (20%).

5.6.2. Consequences of Water Transfer on Livestock Sector

Livestock is the main allied activity in the rural economy. The village population used the livestock for transporting the agriculture goods to the market, ploughing, milk yield etc. The details of livestock population between 1989 and 1998 in the lower Bhavani basin are given in the Table 5.67.

Table 5.67 Livestock Population in Lower Bhavani Basin (Numbers)

Sl.No	Particulars	In 1989	In 1998	% Change
1	Cattle	385228	320732	-20.11
2	Buffaloes	261029	251010	-3.99
3	Sheep	400126	375854	-6.46
4	Goats	265799	298329	10.90

Source: Annual Statistical Abstract of Tamil Nadu 1999-2000.

It could be seen from the table that the population of cattle (-20.11 %), buffaloes (-3.99%) and sheep (-6.46 %) were declined between 1990 and 1998 period due to 13.15 per cent reduction (see Table 5.3) in gross cropped area between these years. Hence non- availability of fodder leads to reduction in livestock population. The goat population in these periods was increased by 10.9 % due to increase in rainfed crops such as pulses (7%) and it's by products of pulse was also increased, which is used as fodder purposes.

5.6.3. Consequences of Water Transfer on Fisheries Sector

Aquaculture has been a remarkable economic growth sector in this basin. In canal and river water the normal values of dissolved oxygen, pH and temperature for aquaculture will be 6.5 to 9, 7.5 to 9 and 28 to 30 respectively. It is well suited for aquaculture. It has been observed that water quality of LBP and Arakkankottai canals is

good. Advanced fingerlings could potentially be reared in this basin. Fishing activities take place in the Bhavani basin, mainly in the Bhavani Sagar reservoir. There are 3 other minor reservoirs viz gunderipallam, Varattupallam, Perumpallam and also in Odathurai tank which operates under FFDA. Apart from this, subsistence and some extent of commercial fishing is practiced in Bhavani River and different canals. However, the fish catch statistics for canal and riverine fishing is not available.

In earlier period (1980) pollution is also present but its level is within tolerable limits due to less industrialization. But presently, all the authorized and unauthorized water pumping industries took water from river. Authorized industries took 39.15 MCM total quantity of water from river and poured their effluents without treatments into main river. It changed the values of dissolved oxygen, pH and temperature of the river water. It becomes unsuitable to fingerlings breeding .It also leads to high level of death of young ones. So, high level of industrialization leads to reduction in fish populations and revenue in river and canals. It indirectly affects the food security in this basin. The Table 5.68 shows total fish quantity yield in all reservoir of the lower Bhavani basin and Table 5.69 shows total fish quantity yield profit and loss account in Bhavanisagar dam and map 1 shows details of fish reservoir in study area.

Table 5.68 Total Fish Quantity Yield in Lower Bhavani Basin Reservoir (tonnes)

Year	Major Reser-voirs	Major irrigation Tanks	Seasonal tanks and Ponds	FFDA tanks	River and Canals	Rice field swamps	Total
1990-91	547	40	85	135	445	50	1302
1995-96	345	50	90	171	335	45	1036
1999-00	83	300	391	365	192	37	1368

Source: Annual Statistical Abstract of Erode 1999-2000

Table 5.69 Profit and Loss Account of Bhavani Sagar Fishing (Rs. in lakhs)

Sl.	Year	Rearing	Harvesting	Marketing	Total
-----	------	---------	------------	-----------	-------

No		Profit	Loss	Profit	Loss	Profit	Loss	Profit	Loss
1	1991-92	0.051	Nil	Nil	2.800	2.392	Nil	2.443	2.800
2	1999-00	1.206	Nil	Nil	0.901	1.360	Nil	2.566	0.901

Source: Tamil Nadu Fisheries Development Corporation (TNFDC), Bhavanisagar.

It could be seen from the table that the total basin fish quantity harvested was 1302 tonnes in 1990-91 and it was reduced to 1036 tonnes in 1995-96 due to heavy effluents poured into main river without treatments by South India Viscose (SIV). After SIV closed, the total fish quantity was increased to 1368 tonnes in 1999-2000 from 1036 tonnes in 1995-96. Similarly fish quantity harvested in Bhavanisagar dam profit was also increased from 2.443 lakhs in 1990-91 to 2.566 lakhs in 1999-00 and loss was reduced from 2.80 lakhs to 0.90 lakhs in the same periods.

5.6.4. Consequences of Water Transfer on Livelihood in Lower Bhavani Basin

5.6.4.1. Value of Farm Assets of the Sample Farms

The details of asset position are presented in Table 5.14. The value of the farm assets gives an idea with reference to the financial position of the farmer and his capacity to mobilize resources for cultivation. Therefore, the details of the same were analyzed and the results are furnished in Table 5.70.

Table 5.70 Average Asset Position of Sample Farms in Lower Bhavani Basin

Particulars	1990-91			2001-02		
	Head	Middle	Tail end	Head	Middle	Tail end
Land (ha)	1.91	1.72	1.68	1.95	1.61	1.54
Land Value (Rs/farm)	4,53,333 (50.07)	3,90,056 (66.56)	2,23,333 (66.40)	5,76,667 (53.46)	4,90,008 (66.22)	2,02,667 (64.39)

Buildings (Rs)	175000 (19.33)	80000 (13.65)	60000 (18.39)	250000 (23.18)	120000 (16.22)	70000 (17.76)
Livestock (Rs)	92000 (10.16)	21000 (13.65)	6000 (1.78)	52000 (4.82)	28000 (3.38)	8500 (2.05)
Irrigation equipments (Rs)	120000 (13.25)	65000 (11.09)	20000 (5.95)	160000 (14.83)	80000 (10.81)	32000 (7.73)
Small Implements (Rs)	65000 (7.18)	30000 (5.12)	17000 (5.05)	40000 (3.71)	25000 (3.38)	17000 (4.10)
Total Rs. per farm (lakhs)	905333 (100.00)	586056 (100.00)	326333 (100.00)	1078667 (100.00)	740008 (100.00)	330167 (100.00)
Rs/ ha	2,37,347	2,26,776	1,32,936	2,95,726	3,04,352	1,30,303

5.6.4.1. a. Land

Land is the basic asset on which the entire farming depends upon and hence the details on the same are furnished in Table 5.70. It could be seen from the table that the farm size of Middle and Tail end farms has reduced from 1.72 to 1.61 ha and 1.68 to 1.54 ha respectively during the period from 1990-91 to 2001-02 and the Head region, farm size has increased in the same time periods. As the scope for agricultural production declines due to failure of monsoon and consistent depletion of groundwater through water transfer to other sectors or non ayacut areas, the farmers, Head and Middle region farmers in particular, only can manage cropping activities with more investment in watering and got less profit. The land was the major item of the farm asset and it accounted for more than 50 per cent of the total farm assets of all regions. On an average, the total land value per farm was 4.5 lakhs in Head region and 2.2 lakhs in Tail end region in 1990-91 and it was increased in Head region (Rs 4.53 lakhs to Rs 5.76 lakhs) and was decreased in Tail end region (Rs2.23 lakhs to Rs 2.02 lakhs). So the per ha value was increased (Rs 2.37 lakhs to Rs 2.95 lakhs) in Head region due to water availability and in case of Tail end region, it was decreased (Rs 1.32 lakhs to Rs 1.30 lakhs) due to non- availability of water.

5.6.4.1. b. Building

Buildings are the next set of assets that influences the farm operations. Next to land, buildings accounted for the major share of assets, with the higher percentage share in Head region (19.33 % in 1990-91 and 23.18 % in 2001-02) when compared to Tail end region (18.39 % in 1990-91 and 17.76 % in 2001-02).

5.6.4.1. c. Livestock

Livestock are the next set of assets that influences the farm operations. In most of the farms livestock is maintained in order to get milk for the family as well as the animal power for farm operation. Next to land and buildings, livestock accounted for the major share of assets, with the higher percentage share in Head region (10.16 % in 1990-91 and 4.82 % in 2001-02) when compared to Tail end region (1.78 % in 1990-91 and 2.05 % in 2001-02) due to increase in goat population.

5.6.4.1. d. Irrigation and Small Implements

Tractors, tillers, pump sets and motors are the major implements found in the farms and therefore their value were asserted and presented in Table 5.70. The percentage value of irrigation and small implements to total assets was found more in Head region (13.25 % in 1990-91 and 14.83 % in 2001-02).as compared to Tail end region (5.95 % in 1990-91 and 7.73 % in 2001-02).

5.6.4.2. Household Income Distribution

Income level has significant bearing on the level of living of the farm families. It also influences the quantity and timeliness of using inputs in the farms. Households need cash income to supplement agricultural production to purchase commodities in the market, to pay for social obligations, school fees and health care. Therefore, income levels of the sample farmers were estimated and the results are furnished in Table 5.71. It could be inferred from the table that though the crop production was the major source of income to the farm families, they received supplementary income from livestock and non-farm activities.

In recent years due to income reduction in agricultural activity by water scarcity, income was generated through off-farm and non-farm income activities.

Table 5.71 Average Income Sources of the Household in Lower Bhavani Basin

(Rupees/year/household)

Region	1990-91				2000-01			
	Own farm	Off farm	Non farm	Gross Return	Own farm	Off farm	Non farm	Gross Return
Head	245000 (88.45)	0.00 (0.00)	32000 (11.55)	277000 (100.00)	264000 (83.02)	0.00 (0.00)	54000 (16.98)	318000 (100.00)
Middle	43000 (70.03)	6400 (10.42)	12000 (19.55)	61400 (100.00)	29000 (27.99)	4600 (4.44)	70000 (67.57)	103600 (100.00)
Tail end	28000 (47.10)	16450 (27.67)	15000 (25.23)	59450 (100.00)	14600 (17.63)	8225 (9.93)	60000 (72.44)	82825 (100.00)

It was evidenced from the table that the income from own farm activities such as crop and livestock sources have decreased over the period in Tail end and Middle than Head region. In case the income from own farm activities for the Tail end farm households accounts 47.10 per cent, 1990-91, which has, decreased to 17.63 per cent during 2000-2001 and in off-farm and non-farm income activities increased particularly due to water scarcity to get additional income for their subsistence needs.

With the declining scope for agricultural production due to growing water scarcity farm households diversified their economic activities through involving non-farm income generation activities. It is evidenced from the survey that there is a major shift in economic activities towards non-agricultural activities and this is more pronounced among Tail and Middle farm households

5.6.4.3. Employment Reduction in Farm Activities

On farm and off farm employment plays a vital role for providing employment to the rural people of the basin. Due to water scarcity, the on farm and off farm employment is continuously declining in Tail end region farms. The declining farm income and small size of farm resulted in limited employment opportunities to these households' members. Hence, it was imperative for these households' members to seek employment in the non-farm sectors. These farm labourers were shifted to non-farm employment within the basin or go to out of the basin. In some cases, farmers were going to other State (eg. Kerela) to employment in non-farm activities (such as cable line digging). Even though they got lower wages per day in non-farm employment, they are ready to take this employment due to scarcity of farm employment. This would provide additional and regular income by means of wages and salaries, so as maintain a reasonable level of living. The details of farm employments are presented in Table 5.72.

Table 5.72 Employment Pattern of the Sample Farmer Household

(mandays/years)

Regions	1990-91			2001-02		
	Own farm	Off farm	Non farm & Leisure	Own farm	Off farm	Non farm & Leisure
Head	460	360	275	320	180	195
Middle	720	140	235	480	100	815
Tail end	680	0	415	370	0	715

It could be seen from the table that the number of days of employment in different activities across region groups indicates that there is a significant change in the employment pattern among the farm households. For instance, on an average the Head farm sample households employed for 460 man days per year days in own farm activities, which has significantly reduced to 320 labour days over a period of ten years. Non farm employment of the same category farmers also increased from 275 in 1990 to 195 man days in 2001-02 .The similar trends is visualized in other farm regions. But in case of Tail end region of the basin area, non-farm employment was dominated due to water scarcity.

5.6.4.4. Consumption Expenditure Pattern Changes

Even though farm income reduced due to water less availability, the higher income derived through off-farm income, non-farm activities enable the rural households to purchase commodities in the market and thereby enhance nutritional security by the households. Consumption expenditure pattern changes were given in the Table 5.73. From the table it could be seen that analysis of pattern of consumption expenditure of the rural households across regions of the basin reveal that the per household per year consumption expenditure worked out to Rs.28,000 during 1990-91 which has increased to Rs.30,500 during 2001-02 in Head region and in Tail region has increased from Rs. 30800 to Rs. 57200 during the same period.

Table 5.73 Consumption Expenditure Pattern in Lower Bhavani Basin

Regions	1990-91			2001-02		
	Food	Non food	Total	Food	Non food	Total
Head	18000 (64.29)	10000 (35.71)	28000 (100.00)	16500 (54.10)	14000 (45.90)	30500 (100.00)
Middle	17200 (60.56)	11200 (39.44)	28400 (100.00)	15800 (43.17)	20800 (56.83)	36600 (100.00)
Tail	17800 (57.79)	13000 (42.21)	30800 (100.00)	18200 (31.82)	39000 (68.18)	57200 (100.00)

5.6.4.5. Diarrhoeal Illness

The industrial effluents damaged not only soil health, also the human health. Unauthorized pumping Industries were more in 1990-91 and its effluents are high in those period. Health hazards like diarrhoea, skin rashes etc were caused by the industrial effluents due to polluted ground water in the nearby areas of the industrial location. The effluents from authorized and unauthorized pumping industries had a profound influence on the incidence of diarrhoeal illness. Hence government closed many polluting industries in the basin. So, incidence of diarrhea illness was reduced. The details of occurrence of diarrhoeal illness among members of the farm families and agricultural labour families in the study area are exhibited in Table 5.74. The collected sample was assumed as five people per household. So, the total number of people was 250 in each region.

Table 5.74 Occurrence of Diarrhoeal Illness in the Basin Area

Sl.No	1990-01			2001-02		
	Head	Middle	Tail end	Head	Middle	Tail end
Adult	2	3	10	1	3	10
Male	1	5	5	1	2	3
Female	3	8	15	2	5	13
Children	10	12	27	5	10	15

(Number)

Total	16	28	57	9	20	41
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(Rs)

Sl.No	1990-01			2000-01		
	Head	Middle	Tail end	Head	Middle	Tail end
Adult	300	450	1500	150	450	1500
Male	150	750	750	150	300	450
Female	450	1200	2250	300	750	1950
Children	1500	1800	4050	750	1500	2250
Total	2400	4200	8550	1350	3000	6150

It could be observed from the table that in the case of Head region the total number of persons affected by diarrhoeal illness was 16 out 250 and Tail region was 57 out of 250 people. The affected people number was reduced from 16 to 9 in Head region and from 57 to 41 persons in Tail region during 1990-02. The reason for high incidence of diarrhoeal illness occurred in Tail region was due to all authorized and unauthorized industries poured their effluent into river in Head regions. The children were more prone to diarrhoeal illness (10 children out of 16 affected people in Head region and 15 children out of 41 affected people in Tail regions). The total expenses of treatment cost in Head regions was low (Rs.2400) than in Tail regions (Rs.6150) and reduced from Rs.2400 to Rs.1350 and Rs.8550 to Rs.6150 in Head and Tail region respectively between 1990-91 to 2001-02 year due to problem was controlled to some extent by closing of unauthorized pumping industries.

5.6.4.6. Skin Rashes

Yet another important health hazard caused by the pumping industrial effluent in the study area was the skin rashes on the household members. This skin rash was occurred through poor quality of drinking and bathing water. The details of occurrence of skin rashes among members of the farm families and agricultural labour families in the study area are presented in Table 5.75.

Table 5.75 Occurrence of Skin Rashes in the Basin Area

(Number)

Sl.No	1990-01			2001-02		
	Head	Middle	Tail end	Head	Middle	Tail end
Adult	7	15	6	4	4	5
Male	4	5	3	2	2	3
Female	3	10	3	1	2	2
Children	2	16	10	1	3	4
Total	16	46	22	8	11	14

(Rs)

Sl.No	1990-01			2001-02		
	Head	Middle	Tail end	Head	Middle	Tail end
Adult	1400	3000	1200	1000	1000	1250
Male	800	1000	600	500	500	750
Female	600	2000	600	250	500	500
Children	400	3200	2000	250	750	1000
Total	3200	9200	4400	2000	2750	3500

It could be observed from the table that in the case of Head region the total number of persons affected by skin rashes was 16 out 250 and Tail region was 22 out of 250 people during 1990-02. It was reduced 50 per cent and 30 per cent in Head regions and Tail regions respectively. The total cost of the treatment for skin rashes was reduced from Rs 3200 to Rs 2000 in Head region and Rs 4400 to Rs. 3500 in Tail regions between 1990-02 year. Now this problem was controlled to some extent by closing of both authorized unauthorized polluting pumping industries.

5.6.5. Consequences of Water Transfer by Domestic Sector in Lower Bhavani Basin

The rural population depends on sources like open wells, rivers, tanks etc for drinking before 1990. For providing protected drinking water supply to the rural areas, the TWAD Board has implemented different schemes. Most of these schemes are

recently implemented (1990). Agricultural sector has been seriously affected by this increasing water demand of household sector. In general the population growth, urbanization, industrialization etc are all factors, which are responsible for increasing water demand in this basin, which compels the TWAD Board to introduce water supply schemes. According to TWAD Board there are 9 schemes are running to give drinking water for Coimbatore and 32 schemes are running for Erode Circle. The water transfer to domestic sector create major source of revenue to government. The total revenue generated per year was given in Table 5.76.

Table 5.76 Total Revenue to Government through Water Transfer in Domestic Sector

Sl. No	Name of Administration Units	Total Quantity of water Supply /year (MLD)	Revenue of water per 1000 liters (Rs)	Total Revenue to Government Sector (Rs Million)
1	Municipalities	19666.20	3.50	68.83
2	Town Panchayat	5139.20	3.50	17.98
3	Panchayat Unions	21483.90	2.25	48.33
Total		46289.30		135.15

It could be seen from the table that the total drinking water taken from river is 46289.30 MLD per year (million liters per day) which generate revenue Rs 135.15 per year. But at time it will affect water availability to Tail end region farms.

5.6.6. Consequences of Water Transfer by Industry in Lower Bhavani Basin

Industrial users in the basin approach the government through the WRO and get individual appropriation orders for specific periods, subject to renewal of drawl permits and other terms and conditions. The operational details, contracts and collection of charges are handled by the WRO. In most cases, when the industries satisfy procedural

requirements including pollution control board clearance, the industries get their request sanctioned. As of now, approval of industrial appropriation seems not to have considered in the context of agricultural sector loosing its share.

The industries which are located in different part of the Lower Bhavani River Basin (LBRB) have been broadly classified in two categories, namely major water consuming industries (MWCI) and low water consuming industries (LWCI). MWCI use large quantities of water for processing purposes and generate trade effluents. Most of these units pump water directly from the river. Presently 2251 total industries are located in the basin. But in water consumption point of view, 35 MWCI units and 222 LWCI units are located in Lower Bhavani River Basin.

The Water Resource Organization (WRO) has permitted 20 industries in the Bhavani river to draw a total quantity of **39.152 MCM** / year. Out of 20 industries, 8 industries are on the upstream side of Bhavanisagar that is Coimbatore district and the remaining 12 industries are on the downstream (Erode district). From the PWD report, it is seen that the total water released in the ayacut is 1370.14 MCM in 2001-02. So, share of industrial water to the total release water is 2.85 per cent. But many industries draw water illegally from main River and canal for laborers purpose (drinking) or mixing with raw materials.

Detailed data on water charges and water cess, which were available with Public Works Department (PWD) and Pollution Control Board (PCB) respectively, were collected and presented in Table 5.77. Industries are paying water charges to PWD on the basis of two norms such as Rs. 200/ and 500/ for 1000 KL of water depending on the year of establishment and approval sanctioned by PWD. If industries were established in the earlier years before 1990-91, the water charge is only 200/- per 1000 KL and otherwise Rs. 500 per KL.

Table 5.77 Annual 'Water Charge' Collected by PWD from Industries

S. No.	Taluk	Basis of Rs.200/- per 1000 KL		Rs.500 per 1000 KL		Total	
		No. of units	Amount Rs. Lakhs	No. of units	Amount Rs. Lakhs	No. of units	Total Rs. Lakhs
1.	Mettupala-yam	5	0.98	3	113.61	8	114.58
2.	Sathiya-mangalam	3	3.40	2	12.10	5	15.50
3.	Gopichet-tipalayam	0	0	1	0.27	1	0.27
4.	Avinashi	-	-	-	-	-	-
5.	Palladam	-	-	-	-	-	-
6.	Perundurai	-	-	1	0.68	1	0.68
7.	Bhavani	3	15.13	1	19.91	4	35.04
8.	<i>Karur</i>	-	-	1	0.44	1	0.44
	<i>Total</i>	11	19.51	9	146.57	20	166.52

Source: Public Works Department, Erode 2002.

It could be seen from the table that 11 units are paying water charges on Rs.200/ per 1000 KL water with a sum of Rs. 19.51 lakhs. Among this 3 units at Bhavani taluk paying Rs.15.13 lakhs. 9 units are paying their water charge on the basis of Rs. 500 per 1000 KL of water and it comes at 146.57 lakhs. In total annually PWD collecting Rs. 16.65 million from the 20 industrial units, which draw water from Bhavani river.

5.6.6.7. Other Potential Positive Effects for Rural Population due to Water Transfer

The following Table 5.78 shows other positive consequences by water transfer to non-ayacut and non-farm sector and 5.79 shows farmers' opinion about water transfer.

Table 5.78 Other Potential Positive Effects for Rural Population due to Water Transfer

Sl.No	Consequences	Before	After
1	New industries, services, livelihood options	Farmers mainly depend on farm income in earlier period.	Brick industries, dying industries, Paper and pulp industries, Cotton textiles, leather products and Tobacco,& its products was started
2	Employment in new industries	Employment in farm activity occupies major portion in household employments.	Labourers shifted from their farm employment to non-farm employment. Even though the wages per day in non-farm employment is less than farm wage, farm laborers forced to take employment in non-farm sector due to shrink ness of farm employment opportunity.
3	Drinking water system	Population depend on sources like open wells, rivers, tanks etc for drinking. So, earlier households depend on unprotected water sources for drinking purposes.	TWAD Board has implemented different schemes. Most of these schemes are recently implemented for providing protected drinking water supply to the rural areas.
4	Land Value	Previously agricultural land only fetches high land value.	Now, due to urbanization the barren land also fetches high land value if it is lay near to the town. Due to high population growth and water scarcity problems, agricultural land is shrinking and also fetches low land value because uncertainty of outputs.
5	Improved tax base	Government got less tax from this basin area. Because earlier this basin was occupied by agricultural sectors. According to Indian constitution Act, this is no tax for agricultural income	Many new industries were started in this basin. Agricultural area is shrinking. This area was converted into urban center. By this way of urbanization, government got more tax from broad base.

Table 5.79 Farmer's Opinion about Water Transfer in the Study Area

Sl.No	Name of the farmer & Village	Name of the Canal association.	Problems and remedy solution
1	T.A. Addi Gounder President Thukka Naigan Palayam	Arakkan kottai	<i>Problems:</i> Water is sold to nearby area through lorries for Bricks industries. Lorry trips on a day is ten and above depending upon the season. One load of water is 6000 liters. Daily 60 loads in total of water are taking from this canal for this activity. <i>What they want:</i> Water sells for non-agriculture purposes should be stopped.
2	K.K.Ramasamy President Kallipatty	Vaniputhtur sub canal	<i>Problems:</i> Water is taken illegally for agriculture and non-agriculture purposes. Unauthorized agriculture water pumping area is more or less equal to authorized area in this sub canal. <i>What they want:</i> Unauthorized pumping should be controlled.
3	K.N. Sokkalingam President Gouthampady	Perumugai sub canal	<i>Problems:</i> Water is illegally pumping from this sub canal to Kondaiyampalayam and Thuraiyanpalaym. The number of farmers is nearly 150 member (1000 acres) involved in this activity. These areas were located out of the basin area. <i>What they want:</i> Irrigation for out of basin area should be reduced and put proper monitoring

			authorities to regulate water in the canal.
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Sl.No	Name of the farmer & Village	Name of the Canal association.	Problems and remedy solution
4	K.K.K. Sugumar President Mulavaikkal	Athani sub canal	<i>Problems:</i> Water is taken illegally to Anthiyur, which are out of the basin area for agriculture and non-agriculture (House construction) purposes. <i>What they want:</i> Water to house construction through unauthorized pumping should be stopped.
5	Velumani President Chettiyar Thodam	Thadappalli	<i>Problems:</i> More than 250 members (2000 acres) are irrigating water through unauthorized pumping in this sub canal. <i>What they want:</i> Proper punishment law should be implemented to avoid un authorized tapping
6	K.V.Thanaselan President Karattadipalayam	Kugalur Sub canal	<i>Problems:</i> Water is taken for drinking purpose to nearby Town Panchayat and Village panchayat area. <i>What they want:</i> Water is taken for drinking purpose should be minimized.

Sl.No	Name of the farmer & Village	Name of the Canal association.	Problems and remedy solution
7	N.G. Palanisamy President Ayanpalayam	Singam and Ammapalayam sub canal	<i>Problems:</i> Old ayacut canal is not maintained properly. It leads to seepage lose and water availability for agriculture is reduced. <i>What they want:</i> Canal should be lined with concrete to avoid seepage loses.
8	A.N. Raju President Ammamet	Kalingaraiyan	<i>Problems:</i> Water is not received as per compendium of rules. This is due to unauthorized pumping for agriculture area, which is faraway from canal. <i>What they want:</i> In basin area water should be given as per compendium of rules.
9.	C. Nallasamy President Erode	LBP	<i>Problems:</i> Tail end farmers are not received the released water level from Bhavanisagar dam due to unauthorized pumping in the head and middle area of LBP <i>What they want:</i> Authority officers should ensure to deliver water to tail end farmer in LBP.
10	Dr.S.Sathiasundhari President Gobichettipalayam	Bhavani Nadhi	<i>Problems:</i> In old ayacut area, nearly 2000 acres is irrigated by illegally tapping. Industries also let their polluted water into the river. It affects water use for agriculture. <i>What they want:</i> Unauthorized pumping and industries effluent should be stopped.

5.80 SWOT Analysis of Water Transfer in the Bhavani Basin

Strengths	Weaknesses	Opportunities	Threats
1. TWAD Board got revenue Rs 135.15 millions through water sales to domestic sector. 2. PWD department got revenue Rs 16.65 millions through water sales to industrial sector. 3. Improving conveyance efficiency by no seepage & percolation loss in pipeline water transfer in agricultural sector either legal or illegal. 4. Increased Water use efficiency (WUE) in non-ayacut areas. 5. Area under crops in non-ayacut areas increased.	1. Area of more water consumed agricultural crops declined. 2. Productivity per ha in all crops reduced. 3. Additional input cost as pipeline water transfer incurred and leads to reduction in farm net income. 4. Number of bore well per farm increased and also failure of bore high. 5. Farm employment working days reduced. 6. Water quality and quantity was affected. Water is unsafe for both drinking and bathing with out pretreatments.	1. Water is available and farmers can cultivate in non-ayacut areas. 2. Due to urbanization through water taken from river industries, the barren land also fetches high land value if it is lay near to the town. 3. Due to high population growth and water scarcity problems, agricultural land is shrinking and also fetches low land value because uncertainty of outputs. 4. Farmers got more income in water sales instead of agricultural activity in same quantity of water. 5. TWAD Board has implemented different	1. Pollution due to water taken industries leads diarrhoeal illness and skin rashes 2. It also leads to reduction in fish population and its profit. 3. Farm labourers would sift to non-farm employment within the basin or go to out of the basin. 4. Tail end farmers could not get the specified quantity. So, it will lead to increase conflicts. 5. Due to water scarcity problems, agriculture is declining. Farmers is also changed their cropping pattern. So, non-availability of fodder and polluted environment leads to decline in livestock

	7. Working hours of the pump per day was reduced 8. Unauthorized pumping water transfer area was equal to old ayacut areas. 9. For domestic sector purposes 475.26 MLD water and industries sectors purposes 39.15 MCM water was transferred from agriculture sector as resource outflow. 10. Water was taken continuously from river in Head and Middle region for agricultural purposes either legal or illegal due to free of electricity affects Tail end farmers	schemes. Most of these schemes are recently implemented for providing protected drinking water supply to the rural areas. 6. Water scarcity leads to formation of WUA & regulate water sharing.	population and fish population. Hence, unsafe food security situation will arise.
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Annexure-1

Frequency Analysis of Bhavani sagar Inflow Water

Sl.No	Inflow Quantity (MCM)	Year	Probability (%)
1	130.51	1961-62	2.38
2	84.32	1962-63	7.14
3	45.79	1963-64	47.62
4	79.28	1964-65	9.52
5	32.26	1965-66	90.48
6	47.46	1966-67	42.86
7	37.34	1967-68	73.81
8	32.82	1968-69	88.10
9	42.15	1969-70	61.90
10	39.47	1970-71	66.67
11	54.62	1971-72	33.33
12	54.05	1972-73	35.71
13	55.61	1973-74	30.95
14	43.46	1974-75	54.76
15	58.90	1975-76	23.81
16	30.16	1976-77	95.24
17	60.07	1977-78	19.05
18	68.35	1978-79	11.90
19	103.06	1979-80	4.76
20	59.50	1980-81	21.43
21	58.59	1981-82	26.19
22	34.60	1982-83	80.95
23	44.27	1983-84	52.38
24	43.28	1984-85	59.52
25	32.25	1985-86	92.86
26	33.17	1986-87	85.71
27	29.25	1987-88	97.62
28	33.66	1988-89	83.33
29	35.79	1989-90	78.57
30	35.97	1990-91	76.19
31	46.59	1991-92	45.24
32	66.90	1992-93	14.29
33	44.67	1993-94	50.00
34	62.09	1994-95	16.67
35	37.94	1995-96	71.43
36	49.88	1996-97	38.10
37	55.94	1997-98	28.57

38	48.74	1998-99	40.48
39	40.47	1999-00	64.29
40	43.39	2000-01	57.14
41	38.70	2001-02	69.05

Annexure-2

Frequency Analysis of Old Ayacut Water Release

Sl.No	Release Quantity (MCM)	Year	Probability (%)
1	585.28	1961-62	83.33
2	712.60	1962-63	23.81
3	915.85	1963-64	2.38
4	755.68	1964-65	14.29
5	601.72	1965-66	78.57
6	549.83	1966-67	88.10
7	520.25	1967-68	95.24
8	603.95	1968-69	73.81
9	464.49	1969-70	97.62
10	734.77	1970-71	21.43
11	743.31	1971-72	16.67
12	615.45	1972-73	66.67
13	742.99	1973-74	19.05
14	887.99	1974-75	4.76
15	799.66	1975-76	9.52
16	664.60	1976-77	45.24
17	679.44	1977-78	35.71
18	694.46	1978-79	28.57
19	614.12	1979-80	69.05
20	824.80	1980-81	7.14
21	663.81	1981-82	47.62
22	548.76	1982-83	90.48
23	588.16	1983-84	80.95
24	654.15	1984-85	54.76
25	649.92	1985-86	57.14
26	628.36	1986-87	61.90
27	524.72	1987-88	92.86
28	659.01	1988-89	52.38
29	691.84	1989-90	30.95
30	622.63	1990-91	64.29
31	659.63	1991-92	50.00
32	686.95	1992-93	33.33
33	572.40	1993-94	85.71

34	670.62	1994-95	42.86
35	609.49	1995-96	71.43
36	678.76	1996-97	38.10
37	635.42	1997-98	59.52
38	676.19	1998-99	40.48
39	698.11	1999-00	26.19
40	602.34	2000-01	76.19
41	781.50	2001-02	11.90

Annexure-3

Frequency Analysis of LBP Water Release

Sl.No	LBP Release Quantity (MCM)	Year	Probability (%)
1	1442.34	1961-62	2.38
2	1351.58	1962-63	7.14
3	915.06	1963-64	52.38
4	1418.08	1964-65	4.76
5	253.14	1965-66	95.24
6	669.69	1966-67	69.05
7	755.59	1967-68	61.90
8	665.88	1968-69	71.43
9	879.07	1969-70	57.14
10	529.86	1970-71	88.10
11	1079.32	1971-72	28.57
12	1106.47	1972-73	23.81
13	1087.40	1973-74	26.19
14	658.16	1974-75	73.81
15	1185.00	1975-76	16.67
16	330.88	1976-77	92.86
17	958.33	1977-78	42.86
18	1247.77	1978-79	9.52
19	1211.81	1979-80	11.90
20	1187.80	1980-81	14.29
21	1059.38	1981-82	30.95
22	563.02	1982-83	83.33
23	835.08	1983-84	59.52
24	890.76	1984-85	54.76
25	108.28	1985-86	97.62
26	566.30	1986-87	80.95
27	348.25	1987-88	90.48
28	568.93	1988-89	78.57
29	549.27	1989-90	85.71

30	618.05	1990-91	76.19
31	933.73	1991-92	47.62
32	1107.77	1992-93	21.43
33	923.53	1993-94	50.00
34	1155.40	1994-95	19.05
35	732.23	1995-96	64.29
36	982.80	1996-97	38.10
37	956.05	1997-98	45.24
38	993.73	1998-99	33.33
39	964.52	1999-00	40.48
40	989.69	2000-01	35.71
41	721.67	2001-02	66.67

CHAPTER VI

SUMMARY AND CONCLUSION

The present study was carried out to examine the productivity of water in different sectors and to optimize water use among sectors. The specific objectives are, (i) to study the existing water rights in different sectors viz., agriculture, domestic and industries in the basin, (ii) to examine the extend and nature of water transfer in different sectors, (iii) to quantify the demand for and supply of water in different sectors (iv) to study the cost and productivity of water in different sectors (v) to work out optimal plan for water use in three sectors, (vi) to study the consequences of taking water transfer from agriculture sector and (vii) to suggest suitable policy measures for managing the water in the basin.

The sample for the study included 150 respondents comprising Head, Middle and Tail end farms. The findings are summarized, the conclusions are drawn and the policy implications are outlined in this chapter.

6.1.1. Demand for and Supply of Water in Different Sectors

6.1.1.1. Supply of and Demand for Water in Agriculture Sector

The supply of water included all the sources i.e. surface water and ground water available in the basin. The estimation has shown that all sources of surface water supply in the basin were 1516.12 MCM and ground water supply was 490 MCM. The agriculture water demand was estimated by area of individual crop and their water requirement.

The estimation was done for ayacut and non-ayacut farms separately. The water demand for ayacut crops was 2334.56 MCM and non-ayacut crops were 948.99 MCM. The total water demand in agriculture sector was 3283.56 MCM.

6.1.1.2. Supply of and Demand for Water in Domestic Sector

Domestic water demand (256.66 MLD or 93.64 MCM) was estimated as per TWAD Board recommended water requirement per person and was found to be higher than the supply of water (139.76 MLD or 50.99 MCM) in the basin.

Daily water supply for drinking purposes from Bhavani river to Noyyal basin was estimated at 335.86 MLD (122.54) and demand in Noyyal basin was estimated at 253.56 MLD (92.51 MCM). There was an excess withdrawal 82.3 MLD (30.30 MCM) of water from Bhavani river to Noyyal basin to meet new areas' domestic demand in Noyyal basin.

6.1.1. 3. Supply of and Demand for Water in Industries Sector

The Water Resource Organization (WRO) has permitted 19 industries to draw water from Bhavani river to meet their demand. These legally approved industries demand for water was estimated at 39.15 MCM and supply of water was equal to this amount.

6.1.1.4. Projection of Demand for Water in Domestic and Industrial Sector

The urban demand will be expanding due to government priority for drinking water, it is necessary to project the future demands. Projections of population to be served were made at existing norms of 90 liters/person/day in rural areas and 110 liters/ person/ day in urban areas. Domestic sector demand for water based on existing supply norms has varied from 66.53 MCM in 2001 to 81.04 MCM in 2021 in rural areas. Similarly in urban areas with the present supply norms, the projections varied from about 27.16 MCM in 2001 to about 33.08 MCM in 2021. The projected total demand thus ranges from 93.69 MCM in 2001 to about 114.12 MCM in 2021. The total industrial water requirement increase from present demands 39.15 MCM 2001-01 to 47.37 MCM in 2021.

6.1.2. History of Water Allocation/ Riparian Rights

6.1.2.1. Riparian Rights

Water is released according to riparian rights in old ayacut of Arakkankottai Channel and Thadapalli Channel from April 15 to February 15 and Kalingarayan channel from June 15 to April 30 and the total water that will be let out will be 680 MCM . In the case of new ayacut, canal is opened during September 15 to March 15 and the total water available in the LBP amounts to 1088.64 MCM (725.76 MCM in the wet season and 362.88 MCM in the dry season)

6.1.2.2. Water Sharing Rights in Old Ayacut and New t Ayacut

The duty for the old system works out about (282 ha/cumec) is about 727.2 MCM and new ayacut-designed duty is (846 ha/ cumec) is about 1088.64 MCM with the total water availability of 1814.4 MCM in the Bhavani Reservoir. The supply through the head sluices of Thadapalli and Arakkankottai channels in the ratio of 2:1 (379 c/s in Arakkankottai channel and 735 c/s in Thadapalli) and in Kalingarayan was 580 c/s. In minor reservoir, Gunderipallam reservoir capacity was 3.06 MCM. Only dry crops are irrigated. The total ayacut was 989.6 ha at 4.8 ha per 0.03 MCM. The Varattupallam reservoir capacity was 3.95 MCM. The total ayacut was 1196 ha at 4.8 ha per 0.03 MCM of dry crops.

6.1.2.3. Deviation of Rules and Regulation of Water Release in Old Ayacut and New Ayacut

In Arakkankottai and Thadapalli of old ayacut, excess 55.55 MCM quantity of water was released in 2001-02 and it turned into affect new ayacut's water quantity release. It was violation of government order (G.O) 2274/30.8.1963. Water released in Kalingarayan canal in 2001-02 was less (101.63 MCM) than water quantity mentioned in riparian rights (283.13 MCM). As per the G.O.2319-2322/1969, PWD was planned to reduce the numbers of sluice in Kalingarayan canal 776 into 256 to regulate water release and water assurance to it's tail end farmers. So far this work was not yet to be started. The duration of Kalingarayan canal is June 15 to April 30. But Kalingarayan canal tail end farmers for last 10 years was not getting water during January to April months.

In LBP, quantity of Water to be Release as per rules to season I is 725.94 MCM and season II is 365 MCM. Season I and season II received 480.66 MCM and 240 .33 MCM quantity of water in 2001-02 respectively. This was 245.77 MCM and 124.66 of quantity of water less than water quantity to be released into the canal. Both these canal water reduction was due to already mention of G.O. 2274/30.8.1963 violation. The project was originally started to supply irrigation water for irrigated dry crops mainly for cotton cultivation. Paddy permitted area is 4050 ha out of total ayacut 83,770 ha. Farmers now raised paddy crop in season I alone 10260 ha in 2001-02. In 2002-03, water turn should be released to Turn II ayacut farmers. But both turn ayacuters was not benefited in 2002-03 fasli year.

6.1.3. Extent and Nature of water Transfer in the Lower Bhavani Basin

6.1.3.1.1. Farm Sector Water Transfer within Basin

There are large numbers of pumpsets that draw water from the Bhavani river, partly legally and mostly unauthorized. In the upstream of Bhavanisagar, the authorized 845 farmers lift water with the help of electric motors and diesel engines to irrigate 1023 ha land. In the downstream of Bhavanisagar, the authorized 1012 farmers in Sathiyamangalam, Gobichettipalayam and Bhavani taluks set diesel engines and electric motors to lift water. The total authorized river-pumping irrigation 3714 ha and quantity of water pumped 31.38 MCM.

The unauthorized 1064 farmers lift water with the help of electric motors and diesel engines to irrigate 4514 ha land, 49.36 MCM of water was lifted. 8228 ha is irrigated in non-command area in the basin by river water pumping.

6.1.3.1.2. Non-Farm Sector water Transfer within Basin

Inter-sector water transfer through tanker, barrel operator and bullock operator from agriculture to domestic sector was estimated 47.25 MLD (17.24 MCM) in lean season and 148.5 MLD (54.18MCM) of water in peak season were transferred.

The TWAD Board has permitted 37 schemes to draw a total quantity of was about 93.68 MCM per year (256.66 MLD) in the basin.

The Water Resource Organization (WRO) has permitted 19 industries in the Bhavani river to draw a total quantity of 39.152 MCM / year. The total water released in the ayacut is 1370.14 MCM in 2001-02. So, share of industrial water to the total release is 2.85 per cent. But many industries draw water unauthorized from main river and canal for domestic use or mixing with raw materials.

Livestock is the main allied activity in the rural economy. The number of cattle, buffaloes and sheep were declined from 385228 to 320732, 261029 to 251010 and 400126 to 375854 respectively between 1989 to 1998 period due to lack of fodder. The total annual water used by livestock sector was 19.16 MCM calculated at the rate of 40lpcd.

6.1.3.2.2. Non-Farm Sector (Drinking Purpose) Water Transfer between Basins

Four water-transferring schemes are running to give water from Bhavani basin to Noyyal basin for drinking purpose. 335.86 MLD (122.58 MCM yearly) of water was supplied from Bhavani river to Noyyal basin.

Total drinking water taken from river is 475.626 MLD (173.60 MCM) in which 335.86 MLD (122.58 MCM) of water was transferred from Bhavani basin to Noyyal basin for drinking purpose. It is given to households in alternate days for one hour. If TWAD Board is made arrangement to give water to all areas on daily basis then the quantity of water taken from river will be doubled (951.25 MLD or 347.20 MCM) and it will affect water availability to Tail end region in the basin.

6.1.4. Cost and Productivity of Water in Different Sectors

6.1.4.1. Cost of water in Agricultural Sector

Water pumping from long distance from river, the cost of pipe for 1 km distance was Rs. 122500 at Rs.35 per feet and well cost Rs.41000 was incurred and farm well cost was Rs.95500.

The average cost of 1 KL of water was Rs.3.54 in river pumping scheme from and Rs.2.53 water pumping in farm well.

6.1.4.2. Cost of Water in Domestic Sectors

6.1.4.2.1. Farmers /Individuals Water Supply Case

Incurred cost was Rs.6.68, Rs.15, Rs.60, Rs.100 for 1000 liters for farmer, tanker, barrel and bullock operator respectively.

6.1.4.2.2. Cost of Water in TWAD Board

The cost of water per 1000 liters for 5 municipalities, 6 town panchayats and 22 Combined Water Supply Schemes was calculated. The cost of water per 1000 liters for 5 municipalities was Rs. 3.44. The municipalities collected Rs.3.50 per 1000 liters in the form of water charge. Flat rate is Rs.36 per month.

The cost of water per 1000 liters for 6 town panchayats was Rs. 3.24. In town panchayats union , flat rate of Rs 30 per month or Rs.3.50 per 1000 liters was collected per month.

The cost of water per 1000 liters was Rs.5.39 for Combined Water Supply Scheme (CWSS) to town panchayat and panchayat union and it was higher than Municipalities and Town panchayats water supply schemes. In CWSS of town panchayats and panchayats unions, flat rate of Rs 20 per month (or) Rs.2.25 per 1000 liters was collected per month from each individual household water connection. The overall cost of water per 1000 liters in Lower Bhavani Basin was Rs 4.38.

6.1.4.2.3. Cost and Profit of Water Supply for Noyyal Basin from Bhavani River

One independent water supply schemes (WSS) and three Combined Water Supply Schemes (CWSS) were implemented by the TWAD Board for the Noyyal basin domestic needs from Bhavani river. The cost of water per 1000 liters to Noyyal basin from Bhavani river was Rs.4.66 but government collected Rs.3.50 per 1000 liters from each water household connection.

6.1.4.3. Cost of Water in Industries Sectors

6.1.4.3.1. Cost of TWAD Board Water Schemes

In Lower Bhavani River Basin, 20 industrial units are extracting water from river and these units are paying water charges for PWD on the basis of two methods such as Rs. 200 and Rs.500 for 1000 KL of water depending on the year of establishment. If industries were established in the earlier years before 1990-91, the water charge is only Rs. 200 per 1000 KL and otherwise Rs. 500 per KL. The cost value of one-kilo liter water pumped from the river had estimated Rs 0.43 and it was less than domestic sector water charge per 1000 liters. The PWD was not incurred any fixed and maintenance cost to supply water to industries.

6.1.4.3.2. Cost of water in Alternate Source in Industrial Sectors

The average cost of 1 KL of water from primary sources (well) was Rs. 3.39, which was higher than TWAD board water supply charge. The cost of alternate supply of water (tanker) was Rs.50/KL.

6.1.4.4. Productivity of Water in Agricultural Sector

Productivity of water in agriculture sector was calculated either by yield in quantity (kg) or monetary terms. In terms of quantity, in old ayacut the productivity of water was high in sugarcane (24 kg/mm), Banana (9.10 kg/mm) than paddy (2.03 kg/mm) crop. In new ayacut productivity of water was high in Tapioca (14.29 kg/mm), sugarcane (13.60 kg/mm), gingelly (10 kg/mm) than paddy (1.68 kg/mm) crop.

A standardized gross value of production (SGVP) is used in order to compare agriculture production in monetary units. SGVP of water in sugarcane was 10.26 times more than paddy crop in both old and new ayacut. So, 1 kg of sugarcane is equivalent to 10.26 kg of rice. Similarly SGVP of water in gingelly was 3.40 time more than paddy crop in new ayacut and one kg of gingelly is equivalent to 3.40 kg of paddy.

6.1.4.5. Gross Margin in Water Sales in Domestic Sector

In domestic sector, water transfer was happened by two categories i.e., 1.farmers and 2.TWAD Board.

Farmers

Chitode, Thindal, Allampalayam, Velliangavalasu, Manthapuram and Muthur are familiar with water selling. The farmer got profit Rs 110/tanker (13500 liter) and Rs 2310 per day. The tank operator got profit Rs 600 per tank (13500 liters) in lean period and Rs 90 /tank in peak period. Tank operator got profit Rs 420/day in lean period and Rs.960/day in peak period. . The barrel operator got profit Rs.40.74/1000 liters. The bullock cart operator got profit Rs.75/1000 liter. The gross margin in water sales per 1000 liters was high in bullock owner (Rs 0.27/1000 liters) and very low in agricultural farmer sell (Rs 0.01/1000 liters).

TWAD Board

TWAD board supplied water to corporation, town panchayats and village panchayats in the basin and to near by basin from Bhavani river. Gross margin in water sales in Bhavani and Noyyal basin water transfer was high in municipalities (Rs.3.49/1000 liters) and low in village panchayat union (Rs.2.49/1000 liters). In town panchayat, it was Rs 2.99/1000 liters.

6.1.5. Optimization of Water among Different Sectors

6.1.5.1. Optimal Plan for Old Ayacut

The linear programming technique was used to optimize water use for old and new ayacut. It was noticed that during the three seasons via I, II, III, the optimum plan cover all major crops. It also included domestic, livestock and industries sectors.

In old ayacut, in the existing plan, paddy I and paddy II was cultivated over 7.174 hectares and 6.004 hectares of land in two seasons. Paddy III was cultivated in 1750 hectares of land. Sugarcane, turmeric and pulses were grown more than 1000 hectares i.e., 2650 hectares, 1326 hectares and 1102 hectares respectively. The existing plan also included domestic livestock and industrial sector water supply for three seasons. The cropping intensity was 198.20 per cent. The gross income was Rs. 2,328.24 millions.

The optimum plan I (2001-02), area under paddy I, paddy II, paddy III, declined from 7.174 hectares to 6561 hectares (8.54 %), 6.004 hectares to 5334 hectares (5.33 %), 1750 hectares to 1500 hectares (14.30 %) respectively. Sugarcane increased in optimum plan I from 2650 hectares to 3000 hectares i.e., 13.21 per cent increased. Turmeric and pulses declined marginally from 1326 hectares to 1000 hectares (24.60 %), 1102 hectares to 1000 hectares (9.25 %) respectively. Banana (42.00 %) and coconut (35.00 %) had increased over the existing plan. The cropping intensity in optimum plan I increased from existing plan (234.72 to 244.99 %). The gross income was increased from Rs. 2328.244 millions to Rs. 2414.061 millions.

In optimum plan II (2011), paddy I (32.60 %) and Paddy II (31.43 %) crop area has declined from existing plan. The gross cropped area declined from 37790 hectares to 35250 hectares. The cropping intensity declined from 234.72 to 218.94 percent. The water requirement for rural and urban sector increased from 93.69 MCM to 103.38 MCM. The industrial water use has increased from 39.15 MCM to 42.99 MCM. The water requirement for livestock declined from 11.49 MCM to 10.92 MCM due to livestock population declined. The gross income declined from Rs. 2328.244 millions to Rs. 2304.561 millions from existing plan to plan II.

In optimum plan III (2021), paddy I declined from 4835 hectares to 4544 hectares (36.66 %) and paddy II declined from 4117 hectares to 3827 hectares (36.26 %) from existing plan. The cropping intensity declined from 234.72 to 212.25 percent from existing plan. The water requirement for rural and urban sector increased from 93.69 MCM to 114.09 MCM. The industrial water use increased from 39.15 MCM to 47.37 MCM. The water requirement for livestock declined from 11.49 MCM to

10.47 MCM. The gross income declined from Rs. 2328.244 in millions to Rs. 2323.452 in millions from existing plan to plan III.

Regarding shadow price, water was completely exhausted in all seasons. If one MCM of water is increased in season I, season II, season III, the gross income over variable cost will increase by Rs. 1.40 millions, Rs. 1.167 millions and Rs. 2.143 millions respectively. The shadow price per unit of water is Rs.1.40, 1.16 and 2.14 per 1000 liter in season I, season II and season III.

6.1.5.2. Optimal Plan for New Ayacut

In Turn-I, the existing plan consisted of paddy I, sugarcane, turmeric, banana, cotton, groundnut, coconut, tapioca, maize, cholam, and gingelly. In the existing plan, paddy I was cultivated over 10260 hectares in one season. Sugarcane was grown as second largest crop i.e., 2647 hectares. Groundnut was grown next to sugarcane area i.e., 2602 hectares. Tapioca was cultivated in 1735 hectares. The cropping intensity was 69.38 per cent. The existing plan also included livestock sector water supply for three seasons. The livestock sector water requirement in existing plan was about 11.49 MCM. The total gross income in existing plan was computed to be Rs. 1277.51 millions.

In the optimum plan I, paddy I, has declined from 10260 hectares to 9202 hectares (10.31 %), sugarcane from 2.647 hectares to 2000 hectares (24.31 %) from existing plan. Turmeric, groundnut and banana increased from 1860 hectares to 4500 hectares (61.14 %), 2602 to 3861 hectares (48.39 %) and 253 hectares to 750 hectares (196.44 %) respectively from existing plan. The gross cropped area declined from 41082 hectares to 40063 hectares. The crop intensity declined from 96.99 to 94.59 percent. The gross income was increased from Rs. 1277.51 millions to Rs. 1459.66 millions.

In optimum plan II (2011), paddy I has increased from 10260 hectares to 12955 hectares (26.21 %) from existing plan. The gross cropped area increased from 41082 hectares to 50248 hectares. The cropping intensity also increased from 96.99 to 118.64 percent. The water requirement for livestock declined from 11.49 MCM to 10.92 MCM due to livestock

population declined. The gross income increased from Rs. 1277.51 millions to Rs. 1673.940 millions.

In optimum plan III (2021), maize increased from 3115 hectares to 3124 hectares. The cropping intensity slightly increased from 118.64 percent to 118.69 percent from optimum plan III. The water requirement for livestock has declined from 11.49 MCM to 10.47 MCM. The gross income increased from Rs. 1277.51 millions to Rs. 1674.32 millions.

Water was completely exhausted in all seasons. If one MCM of water is increased in season I and season II, the gross income over variable cost will increase by Rs. 1.167 millions and Rs. 1.429 millions respectively.

Turn-II, there was no water supply from canal if Turn-I get water supply from canal. In the existing plan, sugarcane were grown as the largest crop i.e., 1003 hectares. Maize and groundnut were grown next to sugarcane area i.e., 500 hectares and 202 hectares. Tapioca was cultivated in 470 hectares. The other crops namely turmeric and cotton were grown 145 and 80 hectares respectively. In existing plan, the gross cropped area was 11168 hectares. The cropping intensity was 27.14 per cent. The livestock sector water requirement in existing plan was about 11.49 MCM. The gross income was Rs.310.81 millions.

In optimum plan-I, sugarcane has declined from 1003 hectares to 1000 hectares (0.03 %) from existing plan. The area under turmeric increased from 0.145 hectares to 1748 hectares. The gross cropped area declined from 11168 hectares to 7780 hectares. The crop intensity declined from 27.14 to 18.90 percent. The gross income has increased from Rs. 310.81 millions to Rs. 339.21 millions.

In optimum plan II and plan-III, the same cropping pattern as witnessed in optimum plan I was noticed except an increase in area under turmeric i.e., turmeric increased from 1748 hectares in

plan-I to 2414 hectares in plan III. Plan III, the gross cropped area (6840 hectares) and cropping intensity (16.62 per cent) were almost same as witnessed in optimum plan II. The gross income increased by optimizing from Rs. 310.81 millions to Rs. 385.67 in millions with no canal water supply from in optimum plan-I to plan-III.

In optimum plan II and plan III water was completely exhausted in all seasons. The shadow price was Rs. 5.387 millions and 1.440 millions in season I water and season II water respectively. It was higher (Rs.3.98 per 1000 liter) than old ayacut in season I.

6.1.6. Consequences of Water Transfer from Agriculture Sector

The study is to analyze and assess the consequences of water transfer on agricultural sector, livestock sector, fisheries sector and livelihood as negative consequences and on domestic sector and industrial sector as positive consequences.

6.1.6.1. Consequences in Agricultural Sectors in the Lower Bhavani Basin

Cropping pattern

Due to water scarcity problem the farmers mostly cultivated paddy in one season only instead of two seasons. For the second season, they cultivated Tapioca and cotton. In all blocks tapioca (63.45 %) and cotton (47.99 %) was substituted for water intensive crops such as paddy (-18.34 %), sugarcane (-23.03%) and Banana (-1.67).

Cropping Intensity

In the case of Head region, the average net cropped area is worked out to 1.95 ha and Tail end region was 1.70 ha. Hence the Head region cropping intensity was higher than other region.

Irrigation Intensity

The average net irrigated area in Head region (1.82) ha was found to be higher than that in Tail end region (1.48 ha). The overall average of the irrigation intensity was 1.64 ha. The average gross irrigated area of Head (3.19 ha) and Middle (2.61 ha) region farms was found to be higher than that in Tail end (2.05 ha) region farms and over all the gross irrigated average being 2.66 ha. The cropping intensity in Head (175.00) had higher than the Tail end (138.51) region.

Well Ownership

The average number of open wells owned was 1, 2 and 1 respectively for Head Middle and Tail end regions farmers during 1990-91 and also same for Head, Middle and Tail end during 2000-2001. Because open well without bore was not viable to irrigate in water scarcity period. It is interesting to note that the number of bore wells owned by all regions of farmers has increased over a decade (from 1, 1, 1 respectively for Head, Middle and Tail end to 2, 2 and 3 respectively Head, Middle and Tail end).

Effects on Well Working Hours and Depth in Middle and Tail End Region

The average size of horsepower of electric motors has significantly increased over the periods in Middle and Tail end. In case of Head region there was negligible change happened in the same periods. Working hours of pump per day was decreased from 22 hours to 7 hours.

Consequences on Ground Water Level in Bhavani Basin

The water level in the wells dropped below average 10 m -40 m in the sample farmers. The water table rise or groundwater recharge is not in significant proportion to the rainfall, as learnt from the farming community.

Additional Cost of Cultivation of the Major crops in the Lower Bhavani Basin

For irrigation to one hectare, the additional cost of water transfer from river (there Km distance) was Rs. 1,00,000/= incurred per person. The average additional cost of 1 KL of water was Rs.3.54 in pumping scheme from river and Rs.2.53 in water pumping from own well. In this connection, net farm income was reduced in Middle and Tail end regions.

Yield Losses of the Sample Farms

In the Head and Middle regions there was negligible difference in yield reduction. In 1990-91, per hectare yield of paddy is 4750 kg / ha in Tail regions. But now farmers got only 3500 kg/ ha from the large inputs. This was 26.31 per cent reduction in yield in the last ten years. Similarly in maize 6 percent and 52 per cent in gingelly yield was reduced from the yield got in 1990.

Income Reduction of Sample Farms in Tail End

Due to yield reduction from 6 per cent to 52 per cent, the farm's income was also reduced. Gross income reduction was high in gingelly (49 %) followed by groundnut (37.78%), turmeric (37.14 %) paddy (35.71 %). Tobacco growing farm was less affected in gross income reduction (20%).

6.1.6.2. Consequences of Water Transfer on Livestock Sector

The population of cattle (-20.11 %), buffaloes (-3.99%) and sheep (-6.46 %) were declined between 1990 and 1998 period due to 13.15 per cent reduction in gross cropped area between these years. The goat population in these periods was increased by 10.9 % due to increase in rainfed crops such as pulses (7%) and it's by products of pulse was also increased, which is used as fodder purposes.

6.1.6.3. Consequences of Water Transfer on Fisheries Sector

The total basin fish quantity harvested was 1302 tonnes in 1990-91 and it was reduced to 1036 tonnes in 1995-96 due to heavy effluents poured into main river without treatments by South India Viscose (SIV). After SIV closed, the total fish quantity was increased to 1368 tonnes in 1999-2000 from 1036 tonnes in 1995-96. Similarly fish quantity harvested in Bhavanisagar dam profit was also increased from 2.443 lakhs in 1990-91 to and 2.566 lakhs in 1999-00 and loss was reduced from 2.80 lakhs to 0.90 lakhs in the same periods.

6.1.6.4. Consequences of Water Transfer on Livelihood in Lower Bhavani Basin

Value of Farm Assets of the Lower Bhavani Basin

Land accounted for more than 65 per cent of the total assets value in all regions in two periods. As could be expected, the value of land in Head and Middle regions was higher than that in Tail end region and the land value per ha was Rs 2,95,726 lakhs in Head region farms and Rs.1,30,303 lakhs in Tail end region farms in 2001-02 and in 1990-91 also the same trend was found . Next to land, buildings showed the maximum of assets value, with the higher percentage

share in Head (23.18%) and Middle (16.22%) region farms than in Tail end (17.76%) region farms in 2001-02 and it was increased from 19.33%, 13.65 and 18.39% respectively Head, Middle and Tail end regions. The availability of cattle population was higher in the case of Head (4.82%) and Middle (3.38%) region farms. The least share was accounted in Tail end (2.05%) region farms. The percentage value of irrigation equipments and small implements to total assets was higher in both Head (14.83%) and Middle (10.81%) region farms as compared to that in Tail end (7.73%) region farms. On an average, the Head and Middle region farms had higher value of assets (Rs. 905333 and Rs. 586056 respectively for Head and Middle region in 1990-91) than in Tail end region farms (Rs. 326333 lakhs in 1990-91) and the same trends was found in 2000-01.

Household Income Distribution

The crop production was the major source of income to the farm families, they received supplementary income from livestock and non-farm activities in 1990-91. In recent years due to income reduction in agricultural activity (reduction 20 % to 49.01%) due to water scarcity, income was generated through off-farm (27.67% to 9.93 %) and non-farm (25.23% to 72.44%) activities in Tail end region in year between 1991-02.

Employment Reduction in Farm Activities

Average Head farm sample households employed for 460 man days per year days in own farm activities, which has significantly reduced to 320 labour days over a period of ten years. Non farm employment of the same category farmers also increased from 275 in 1990 to 195 man days in 2001-02 .The similar trends is visualized in other farm regions. But in case of Tail end region of the basin area, non-farm employment was dominated due to water scarcity.

Consumption Expenditure Pattern Changes

The per household per year consumption expenditure worked out to Rs.28,000 during 1990-91 which has increased to Rs.30,500 during 2001-02 in Head region and in Tail region has increased from Rs. 30800 to Rs. 57200 during the same period.

Diarrhoeal Illness

In the case of Head region the total number of persons affected by diarrhoeal illness was 16 out 250 and Tail region was 57 out of 250 people. The affected people number was reduced from 16 to 9 in Head region and from 57 to 41 persons in Tail region during 1990-02. The reason for high incidence of diarrhoeal illness occurred in Tail region was due to all authorized and unauthorized industries poured their effluent into river in Head regions. The children were more prone to diarrhoeal illness (10 children out of 16 affected people in Head region and 15 children out of 41 affected people in Tail regions). The total expenses of treatment cost in Head regions was low (Rs.2400) than in Tail regions (Rs.6150) and reduced from Rs.2400 to Rs.1350 and Rs.8550 to Rs.6150 in Head and Tail region respectively between 1990-91 to 2001-02 year due to problem was controlled to some extent by closing of unauthorized pumping industries.

Skin Rashes

The total cost of the treatment for skin rashes was reduced from Rs 3200 to Rs 2000 in Head region and Rs 4400 to Rs. 3500 in Tail regions between 1990-02 year. Now this problem was controlled to some extent by closing of both authorized unauthorized polluting pumping industries.

6.1.6.5. Consequences of Water Transfer by Domestic Sector

Population depends on sources like open wells, rivers, tanks etc for drinking. So, earlier households depend on unprotected water sources for drinking purposes. TWAD Board has

implemented different schemes (20 schemes in Coimbatore circle and 32 schemes in Erode circle). Most of these schemes are recently implemented for providing protected drinking water supply to the rural areas.

Water transfer in domestic sector produced positive consequences to the Bhavani basin as income point of view. The total drinking water taken from river is 46289.30 MLD per year (million liters per day) which generates revenue Rs 135.15 per year. But at time it will affect water availability to Tail end region farms.

6.1.6.6. Consequences of Water Transfer by Industry in Lower Bhavani Basin

Farmers mainly depend on farm income in earlier period. But in later period, non-farm employment was major share (72.44% in Tail end) in household income. Brick industries, dying industries, Paper and pulp industries, Cotton textiles, leather products and Tobacco, & its products was started in later period in and around ayacut areas and it gave major non-farm employment for basin households.

Water transfer in industrial sector also produced positive consequences to the Bhavani basin as income point of view. 11 units are paying water charges on Rs.200/ per 1000 KL water with a sum of Rs. 19.51 lakhs. Among this 3 units at Bhavani taluk paying Rs.15.13 lakhs. 9 units are paying their water charge on the basis of Rs. 500 per 1000 KL of water and it comes at 146.57 lakhs. In total annually PWD collecting Rs. 16.65 million from the 20 industrial units, which draw water from Bhavani river.

Land Value

Previously agricultural land only fetches high land value. Now, due to urbanization the barren land also fetches high land value (Rs 2, 37,347 to Rs. 2, 95,726) if it is lay near to the town. Due to high population growth and water scarcity problems, agricultural land is shrinking (-13.54 %) and also fetches low land value (Rs.1, 32,936 to Rs. 1, 30,303) because uncertainty of outputs.

Policy Implications

The findings of the study have the following policy implications

1. The existing requirement and supply management itself is under stress as discussed above. In future as the demand for non-agricultural sectors is likely to grow, the stress on the system will be more pronounced. Management becomes critical on both supply and demand sides. On the supply side, improving the storage capacity of the reservoir, avoiding delivery losses along the river delivery system could help. On the demand side, biggest gains have to come from rationalizing water use in the agricultural sector. This might involve reorganizing the cropping pattern, substituting high water intensive crops with economically comparable less water intensive crops of lesser duration. For intensive paddy, to be extent possible, may be substituted with crops like cotton and groundnut.
2. On the water rights side, the government has to effectively delegate the powers of appropriation and management of the water resources in the basin to local representative bodies perhaps under the framework of the enacted irrigation management legislation. The Water Resource Organization (WRO) should be made on the effective coordinating body and all the local stakeholders including local bodies, TWAD Board and other water users made accountable to the quantum of water used by them to the WRO. The WRO might in turn strengthen its house keeping operation in terms of maintaining adequate field staff to effectively manage the water distribution, properly recording the flows of water at various delivery points and the actual quantum of water used by different sectors. Dispute settlement mechanism should be strengthened under the purview of the provision of the legislation and long delays eliminated. For instance the issue of settlement of the royalty payable by the licensed industries has been shuttling between the judiciary and the government with no effective solution so far. Arbitration committee could be appointed and the issues resolved at the earliest.

3. In future the authorized and unauthorized withdrawal to farm and non-farm sectors likely to grow. Management should take care in case of authorized farm withdrawal should also be counted as ayacut area as it should not affect original ayacut area and in case of unauthorized withdrawal is to levy penal levies to the tune of 10 to 15 times the normal levies and electricity for these pump sets is to be priced to regularize the water withdrawal.
4. The study revealed intra regional variation in gross margin of water in agricultural sector. This suggested large-scale ground water development to supplement canal water supply and thereby increase the productivity of water in crops. Gross margin in water sales in non-agricultural sector was comparatively higher than agricultural sector. It will leads to scarcity of water to agricultural sector. To control this water transfer among inter- sectoral, appropriate water policies are to be formulated. Groundwater utilization in the basin, supplementing the canal and tank water needs to be rationalized by taking into consideration the potential and actual recharge in the basin.
5. Optimization exercise reveals that through reallocation of resources and appropriate combination of crops, and there exist potentials to meet the growing domestic and industrial sector water demand. Presently, industrial water charge for one MCM is lower than rural and urban water charge. So, water charge for industrial sector should be increased. Clarity of future course of action would perhaps be necessary in the context of increasing advocacy of moving to realm of market economy.
6. Since old ayacut enjoys the rights for getting water for 10 ½ month, it is important that careful examination of the existing rights be done so that new ayacut (LBP) gets due share to increase the crop productivity and income since future demand for non-agriculture purpose should be met from the existing supplies, LBP could be severely affected. Hence redefining the rights between old and new ayacuts is necessary.
7. On the effect of water withdrawal side, study found that there was considerable reduction in crop area, crop yield and agricultural income per hectare due to water scarcity and hence the government has to play a decisive role in water allocation of ayacut area by elimination of unauthorized water withdrawal. Agricultural labour migration through participation in non-

farm employment was also witnessed in the study area. This may have serious repercussions in ensuring the food and nutritional security in the long run. Therefore, suitable location specific employment oriented programme may be implemented in providing employment opportunities for the landless agricultural labourers and marginal farmers. The health hazards viz., the occurrence of diarrhoeal illness and skin rashes were mainly due to the authorized water withdrawal industries. Therefore, government should not renew the license of these polluting industries and give regular supply of good quality protected water drinking to people for drinking purpose.

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