PERFORMANCE EVALUATION OF IRRIGATED AGRICULTURAL SYSTEMS

A DISSERTATION

Submitted in partial fulfillment of the requirements for the award of the degree

of

MASTER OF TECHNOLOGY

in

IRRIGATION WATER MANAGEMENT

By

B.A. KANTHI CHANDRALATHA

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ROORKEE -247 667 (INDIA)

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Encl : As mentioned

(S.K. Mishra)
Assistant Professor
28/06/07

CANDIDATE'S DECLARATION

I hereby certify that the work which is being presented in the dissertation entitled **"PERFORMANCE EVALUATION OF IRRIGATED AGRICULTURAL SYSTEMS"** in partial fulfillment of the requirement for the award of degree of MASTER OF TECHNOLOGY in Irrigation Water Management and submitted in the Department of Water Resources Development and management of Indian Institute of Technology Roorkee is record of my work carried out during a period from July 2006 to July 2007 under the supervision of Prof. Raj Pal Singh and Dr. S.K.Mishra in Department of Water Resource Development and Management, Indian Institute of Technology Roorkee, India.

The matter embodied in this dissertation has not been submitted by me for the award of any other degree.

B.A.K.Chandralatha

Dated : 18/06/2007.

B.A.Kanthi Chandralantha

This is to certify that the above mentioned statement made by the candidate is correct to the best of our knowledge.

Prof. Raj Pal Singh
Professor
Department of Water Resources Development,
I.I.T. Roorkee,
Roorkee-247667
INDIA

Dr. S. K. Mishra
Assistant Professor
Department of Water Resources Development,
I.I.T. Roorkee-247667
INDIA

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B.A.K.Chandralatha

Roorkee, B.A.KANTHI CHANDRALATHA

Date : June 15, 2007

Abstract

Performance assessment is a tool for improving the level of service or operation between irrigation related institutions and, in turn the efficiency with which resources are being used. It is important to ensure that indicators that are selected to quantify the performance of a system describe it in respect to the objectives established for that system. A meaningful indicator can be used in two distinct ways. It tells managers in all levels, what the current performance of the system is and, in conjunction with other indicators, may help them to identify the correct course of action to improve performance within that system. In this sense the use of the same indicator over time is important because it assists in identifying trends that may help before the remedial measures become too expensive or too complex. The ultimate purpose of performance assessment is to achieve efficient, productive and effective irrigation and drainage systems by providing relevant feedback to the management at all levels. As such, it may assist management or policy makers in determining whether performance is satisfactory and, if not, which corrective actions need to be taken to remedy the situation.

This dissertation discusses indicators that can be used for assessing long term performance, including physical, economic and social sustainability. The primary focus is on the management of canal systems for agricultural production which is more important for food security of the country. Agriculture sector in Sri Lanka contributes about 18 % to the Gross Domestic Product (GDP) and provides 34 % of the total employment. About 85 % of population resides in rural areas, where agriculture is the main economic activity. Dry Zone is the granary area and produces 2.1 million tons of paddy, 80% of the national production is the main economic activity of small farm holder in the rural areas. Paddy production heavily depends on irrigation, which enables stable production in the wet season and expanding cropped area in the Dry season. Due to government efforts, irrigation development is accelerated since 1970 until self sufficiency level of paddy from 42 % in 1970 to 95 % in 1995 is achieved. Sometimes it fluctuates between 75 % and 99 %. Under this situation, the role of paddy production is in macro-economic view point.

In this study, Nachchaduwa, Rajangana and Thuruwilla are takenfor evaluation, which shows different features. Nachchaduwa irrigation scheme can be characterized as follows. Present farm holder are descendant of relatively old settlement in 1930s, located nearby the large town of Anuradapura, fluctuating irrigation area in dry seasons. More than 50 % of farm land is cultivated under tenant and or lease, with crop diversification towards vegetables. Rajangana irrigation scheme is characterised as relatively new settlement in 1960s located 40 - 50 Km from Anuradapura, relatively stable irrigation area in dry season, land fragmentation and small owner ships, crop diversification, in a small part, towards mainly Banana and Papaya. Thuruwilla irrigation scheme is characterised as farm household originated from old traditional villages, farmers dependent on paddy cultivation without crop diversification. However these three schemes can be considered to have been playing a significant role in all activities in the farm sector.

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CHAPTER 1

1.0 Introduction

Traditionally, the main areas of food production consist of relatively fertile soils, have adequate supply of water, and favorable climatic conditions. Because of the increasing demand for agricultural products by rapidly growing world population, agriculture has expanded horizontally even into areas where conditions for production are less favorable. It has also expanded vertically by increasing production per unit area of land through intensification. As a result of horizontal and vertical expansion, agricultural production has increased considerably. Figure 1.1 shows the rate of change in world grain production per person since 1950 (FAO 1993). This figure shows an increase of annual world food production (and also agricultural) averaging 3.5 kg per person per annum until about 1975. Much of the increased production has been realised by the development of new irrigation projects and the use of high yielding varieties. But a condition for the successful use of high-yielding varieties is the optimum management of land and water. Figure 1.1 also illustrates the danger of a decline in per capita agricultural production. Hence, the world food and water problems will worsen with the growth of population. Food and fibers presently are grown on about 1500 million hectares rain-fed land and 250 million hectares irrigated land. The latter 14% of the agricultural area, however, produces 40% of all crops. Hence, irrigation and drainage play a major role in feeding the world. Due to the concentrated agricultural production, the total cultivated area can remain as little as possible leaving the remaining land to nature. It invokes the need for evaluation of irrigation commands.

The irrigation area in Sri Lanka is 600,000 ha, 73% of which is occupied by major and medium schemes with more than 80 ha, and 27% of which are categorized into minor irrigation schemes having less than 80 ha. Since independence, the government institutions have managed the major and medium irrigation schemes, while the community has managed with schemes. Early 1980s management expenses of irrigation facilities including Operation & Maintenance become a heavy burden to the government and corresponding to the advice from international organizations, the handing over of O & M and water management of

Distributory - canals and or minors to Farmer Organizations commenced in the early 1990s under the participatory irrigation management policy

Grain production in Kg/ person

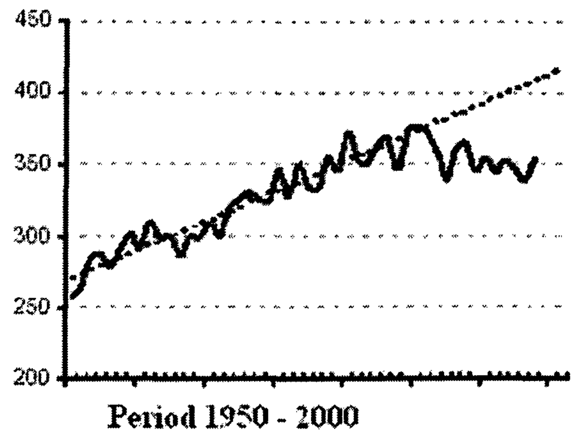

Figure 1.1: World Grain Production per person (FAO 1993)

1.1 Necessity of Evaluation of Commands

The main purpose of any irrigation system is to enhance the economic welfare of people at large and command areas in particular. The economic welfare is manifested in higher income, better standard of living and capacity of investment for further development. Irrigation systems play a vital role in development since 70% of the population depends on agriculture. Performance evaluation of an irrigation system is a stock taking exercise to assess achievements of the system in which large investments of money and human efforts have been made. This evaluation process will highlight the deficiencies in project planning and implementation. It helps to improve techniques of project formulation and implementation to ensure optimum performance. Considering the present level of performance of irrigation and drainage in command areas, we expect considerable room for improvement so that the contribution of irrigated agriculture to world food production can also increase. However there are four major constraints in the agriculture sector:

1) LAND is the traditional constraint.

2) WATER is the ever more important constraint.

3) FUNDS are essential for effective management of irrigation and drainage projects.

4) SKILLS are required for changing responsibilities of the project staff and for introduction of new concepts and technology.

1.2 OBJECTIVE

Paddy production is the main economic activity of small farm holders in the rural areas in Sri Lanka. Paddy production in this dry zone is heavily dependant on irrigation. The irrigated paddy cultivation in this area is characterized by the following:

1. Household income is still low due to low profitability of paddy cultivation.
2. Although participatory irrigation management policy has been already promulgated, farmers largely depend on government supports for operation and maintenance of distributory(D) and field(F) canal level facilities. Before implementation of participatory irrigation management policy, D and F canals were maintained by the government support.
3. Effective water utilization is required because of general decrease in rainfall amount largely due to global warming.

Based on the above, the performance of Rajangana, Thuruwila and Nachchiduwa irrigation systems of Sri Lanka is evaluated with the following objectives:

(i) Integrated management considering operation, water supply and use, agriculture, strategic, socio economic, environment aspects.

(ii) Possibility of increasing irrigation development by expanding irrigated areas or increasing agricultural productivity in the same areas.

(iii) Develop and introduce a cost effective performance assessment program to Manage irrigation systems

1.3 Scope of work

Based on the analysis the existing conditions of the study area, issues and problems in each sector are identified and analysed using the performance indicators employing constraints of sustainable O & M of irrigation facilities, efficient water management, and increase of farmer income. The scope of the work is presented in the form of chapters as follows:

Chapter 1

Chapter 1 introduces the problem of performance evaluation and presents the objective and scope of work.

Chapter 2

Chapter 2 describes the terminology used in dissertation work.

Chapter 3

Chapter 3 describes the performance indicators used in the present study.

Chapter 4

Chapter 4 describes the study area and data availability

Chapter 5

Chapter 5 presents the estimates of performance indicators.

Chapter 6

Chapter 6 presents the results and their discussion.

Chapter 7

Chapter 7 presents the conclusion and recommendations.

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CHAPTER 2

LITERATURE REVIEW

This chapter presents the terminology used in the forthcoming text and then a review of literature on performance evaluation of irrigation commands.

2.1 Definition of Terms

(a) Actual value

It is the actual value of a parameter that can be measured or determined, such as measured flow rate, crop yield, irrigation fee, ground water depth, etc.

(b) Intended value

This is the value of a measurable parameter that the service-providing organization is trying (intends) to achieve. The intended value should be based on the (agreed) service level or on the strategy.

(c) Critical value

The critical value of a key parameter quantifies the physical process whereby the limits of that value if passed, it will affect the other parameters. For example, the salinity of irrigation water has a critical value that reduces crop yield and on the other side, if excess drainage passed beyond critical value, creates flood.

(d) Target value

The target value reflects the objectives of managers at different levels. A system manager is most likely to base targets on the outcome of the annual or seasonal planning process higher level agency managers and donors use design criteria as their targets, because these were the basis for initial investment decisions. The policy makers concerned with very broad objectives usually think in terms of potential performance at system or sector level.

(e) Standard value

A standard value reflects site specific conditions. They are influenced by the overall ecological conditions, and the size of the irrigation system or sub-system.

(f) Adequacy

A fundamental concern of water delivery system is to deliver the amount of water required to adequately irrigate crops. The required amount is determined as that needed to achieve the given agricultural policy, as a function of the area of land irrigated, crop consumptive use requirements, crop water production functions, application losses, and cultural practices such as land preparation and salt leaching. Adequacy depends on water supply, specified delivery, capacity of hydraulic structures to deliver water according to the schedule, and operation and maintenance of the structure.

(g) Efficiency

Resource conservation plays an important role in water delivery because water saved reduces expenditure on infrastructure and is able to irrigate more land. Conveyance efficiency indicates the relative amount of water lost in a reach due to canal seepage and overflow. But the overuse or downstream losses of water is not directly reflected in the concept of conveyance efficiency. A water delivery system that delivers greater than adequate supply does not conserve water resources. Sometime excess water deliveries to farmers create the condition of waterlogging and salinity. Water delivery efficiency incorporates the concept of conveyance efficiency, since water requirement at a point of delivery includes the expected downstream losses.

(h) Flexibility

In operation it is necessary to match the water deliveries to allocations, which may be less than maximum demand. If water is delivered to the farmers in accordance with the schedules prepared during the planning process, the supply is considered to be Flexible; otherwise the supply is not flexible.

(i) Dependability

Dependability is defined as temporal uniformity of the delivered amount of water to the required or scheduled amount. Dependability of water delivery is important to farmers because it allows for proper planning. If system dependably delivers inadequate amount of water, it may be more desirable than the one that delivers on an average adequate yet unpredictable supply. A farmer can plan for dependable delivery of inadequate supply of water by planting less or growing different crops or adjusting other farming inputs. However a farmer cannot easily plan when the supply of water is unpredictable.

(j) Equity

Equity can be defined as the delivery of fair share of water to users throughout the system. A share of water represents the right to use the specified amount. The fair share of water may be based on a legal right for water as in a prior appropriation system or may be set as a fixed proportion of a water supply as is done in many rotational delivery schemes. Measuring of equity is a difficult task because there are many other factors that determine the meaning of a fair share. Sometimes it represents subjectively. However it is important to define measures relating to equity. Then systems can be designed or rehabilitated to deliver water to users served by the system in and impartial manner. Therefore equity is defined as spatial uniformity of the ratio of the delivered to required or scheduled amount.

(k) Productivity

The productivity is related to output from the system and corresponds to the input added to the system. There are several indicators for description of productivity. The main indicators are the crop produce or its economic equivalence and the area irrigated. The productivity can be indicated by measuring these outputs in gross terms or relative to input utilized. These need to be assessed seasonally or annually. The inputs are land, water and finance. The productivity is relevant when the outputs are measured in terms of whichever input is scarce, such as: total production, total net benefits, total area irrigated, and area irrigated per unit of water utilized.

(l) Reliability

In operation it is necessary to match the water deliveries to allocations, which may be less than maximum demand, as in case of deficit irrigation. If water is delivered to the farmers in accordance with the schedules prepared during the planning process, the supply is considered to be reliable; otherwise the supply is unreliable. The reasons for unreliable supply are

1) water availability in the irrigation scheme is less than estimated during the allocation process,
2) unexpected demands arise from sectors other than irrigation,
3) inappropriate consideration of the capacity of the water distribution system,
4) canal breakage and theft and management capacity or capability of the irrigation organization to deliver the scheduled supply.

In practice most of the farmers may be happier with a water delivery system in irrigation scheme that delivers an inadequate, but reliable supply, than with the adequate but unreliable supply. If the farmers are sure that the deliveries are according to the schedule, they can plan their activities accordingly, resulting in higher productivity. If the farmers think that the supply is unreliable, they cannot plan to use the water efficiently. Instead of trying to use water cautiously they adjust their cropping plan, which of course, affects the productivity.

(m) Sustainability

The environment of an irrigation scheme is defined by its sustainability. Sustainability is the performance measure related to upgrading, maintaining, and degrading. According to Abernethy (1986), sustainability is the most difficult aspect to encompass and refer the issue of leaching, drainage and salinization which, if not attended properly, may shorten the system's life. Though most of the researches require a lot of effort on indicators of performance measures such as productivity, equity, adequacy, etc, but only a few attempts have been made to define the indicators for sustainability.

The irrigation authorities can better assess which management strategy or option is more sustainable or environmental friendly while the scheme is in operation. Inefficient irrigation leads to deep percolation or runoff. For a heterogeneous irrigation scheme with rotational water supply it is difficult, though not impossible, to produce allocation plans which will not cause any return flow or percolation deep into the groundwater. However it should be noted that the return flow is desirable when the salt accumulated in the crop root zone needs to be leached away. The experience on these schemes shows that deep percolation over the years will cause the groundwater table to rise into the root zone of crop if adequate drainage systems are not adopted.

2.2 REVIEW

Definition of irrigation systems

Irrigation can be defined as human intervention to modify the spatial or temporal distribution of water occurring in natural channels, depressions, drainage ways or aquifers and to manipulate all or part of this water for the production of agricultural crops. This definition emphasizes the importance of the actions of people in modifying a natural distribution of water. It also restricts the types of action under consideration to those tapping and utilizing water that has been concentrated naturally before being exploited. The definition of irrigation thus encompasses large pump and conventional gravity schemes as well as a variety of types of traditional small-scale schemes where water is raised from wells or diverted from streams, or where receding flood waters are captured in bunded fields. It excludes the water from micro-catchments.

The capacity of available water resources and technologies that can be used to satisfy the demands of the growing population for food and other agricultural commodities remains uncertain. Considering the role of WATER AS A GOOD in social, economic fields it should be reflected in demand management mechanisms. Same time it can be visualised through resource assessment, water conservation and water reuse. The challenge for irrigated agriculture today is to contribute to the world's food production and to improve food security. However within a river basin water is used by numerous users, upstream, nature, storage, irrigated agriculture industries, and downstream wetlands. The major objectives of water management is to deliver water in sufficient quantities, according to a time schedule that matches the requirement for healthy plant growth , and with fair distribution among many users.

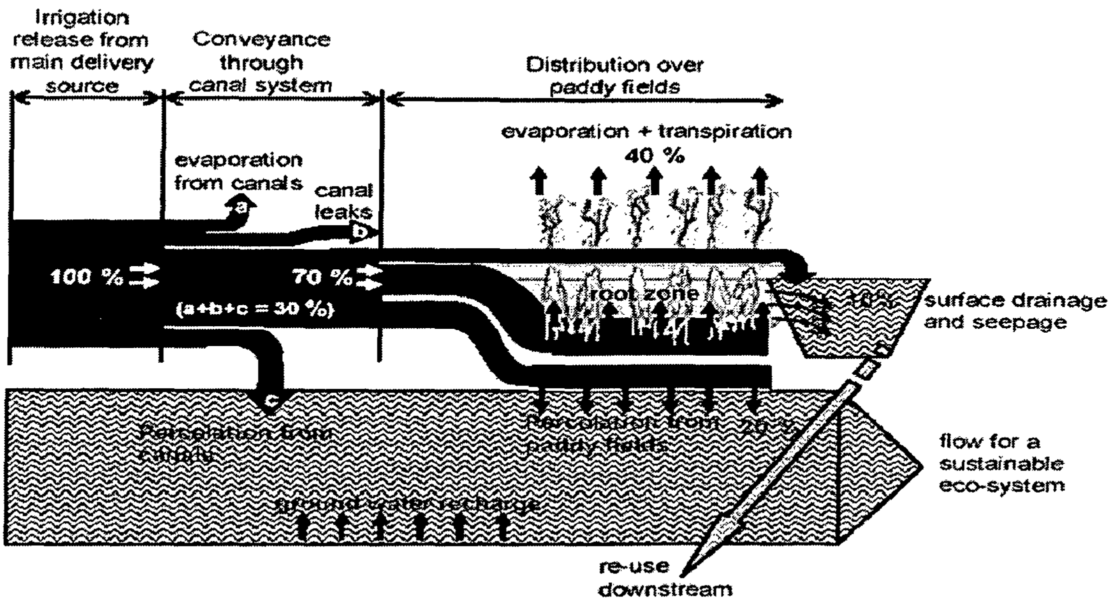


Fig .2.1 Irrigation water supply for paddy crop (Bandara 2006)

Performance assessment can be defined as the systematic observation, documentation, and interpretation of the management of a project with the objective of ensuring that the input of resources, water delivery schedules, intended outputs and required actions proceed as planned. The ultimate purpose of performance assessment is to achieve an efficient and effective project performance by providing relevant feedback to the management at all levels such as operational level and strategic level. It may assist the management to determine whether the performance is satisfactory and, if not, which and where corrective actions need to be taken in order to remedy the situation (Murray-Rust & Snellen 1994).The performance can as such be assessed in terms of (Fig.2.2) operational; strategic; water supply; agricultural; economic; social; environmental performance as follows.

(a) Operational performance is concerned with the routine implementation of the agreed (or pre-set) level of service. It specifically measures the extent to which intentions are being met at any moment in time, at every considered level of the scheme, and thus, requires the actual inputs of resources and the related outputs measured.

(b) Strategic Performance is a long term activity that assesses the extent to which all available resources have been utilised to achieve the service level efficiently, and explores whether achieving this service also meets the broader set of objectives. Strategic management involves not only the system manager, but also higher level staff in agencies at the national planning and policy levels. Strategic management requires a broader view. It must look at a range of different indicators, and identify the trends associated with values collected over several years. A simple example using depth to groundwater may help to illustrate the difference. A typical target is that the water level should be more than 1.5 meters below the ground. As long as each reading verifies that this is the condition, no immediate action is required from the operational staff of an agency. Strategic managers should be concerned with the trend: if the water table is still below 1.5 meters but it is rising each year, then this is a clear signal that some broader strategic decisions and action are required. The specific remedial measure, tile drainage, tubewell drainage, reducing surface water deliveries, etc. will vary according to local conditions and available resources.

Figure 2.2. Management hierarchy of the irrigated agriculture sector in Sri Lanka. (Bandara 2006)

Small & Svendsen (1990) attempted to overcome some of this level of decision confusion by describing irrigation as a set of nested systems, each of which has its own particular set of objectives. The primary linkage between these systems is that the outputs from one system become part of the inputs into the next system, establishing a means-end framework. They incorporate five systems (Fig. 2.3) into their model:

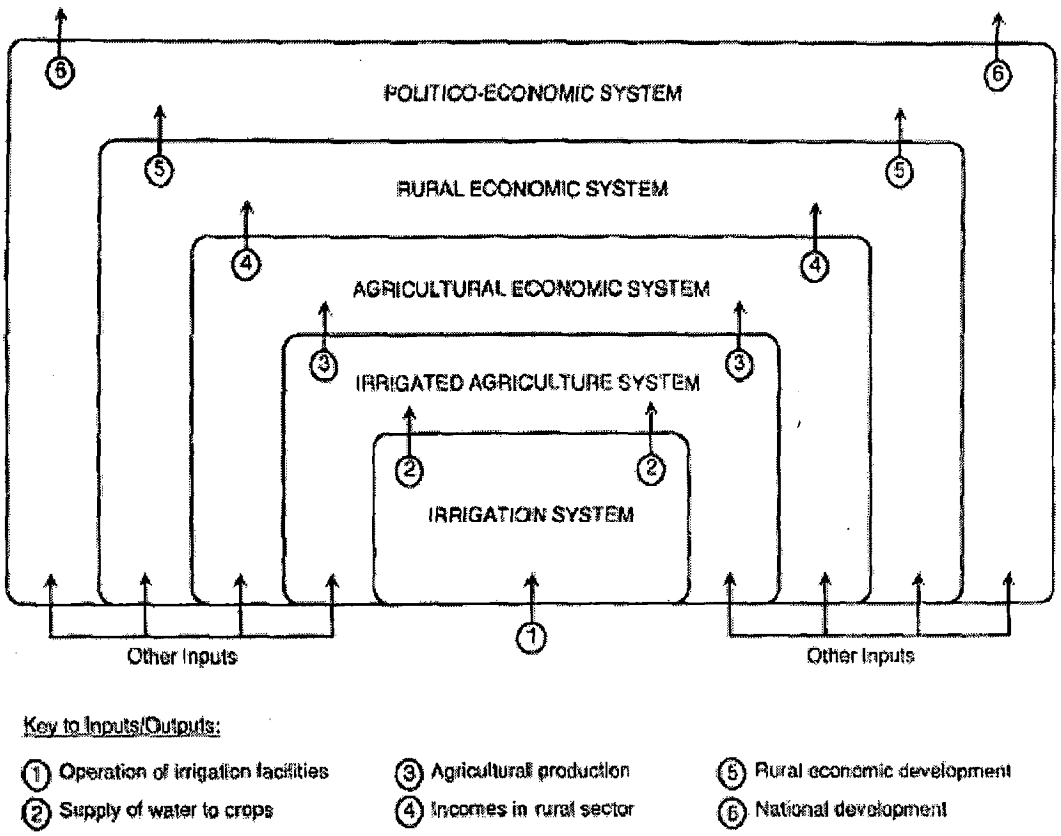


Fig. 2.3. **Inputs and outputs: irrigation in the context of nested systems (Small & Svendsen 1990).**

(c) Water supply performance. This is categorized into capture, allocation and conveyance of water from available source to field by management of irrigation facilities, which is the basic task of irrigation managers. Performance indicators address several aspects of this task. They cover the volumetric component that is primarily concerned with matching supplies to crop demand, as well as the rather more subjective concept of reliability that may affect the users' capacity to manage water efficiently, and the socially oriented aspects of equity. Efficiency of conveying water from one location to another, the extent to which agencies maintain irrigation infrastructure to keep the system running efficiently, and the service aspects of water delivery which include such concepts as predictability and equity.

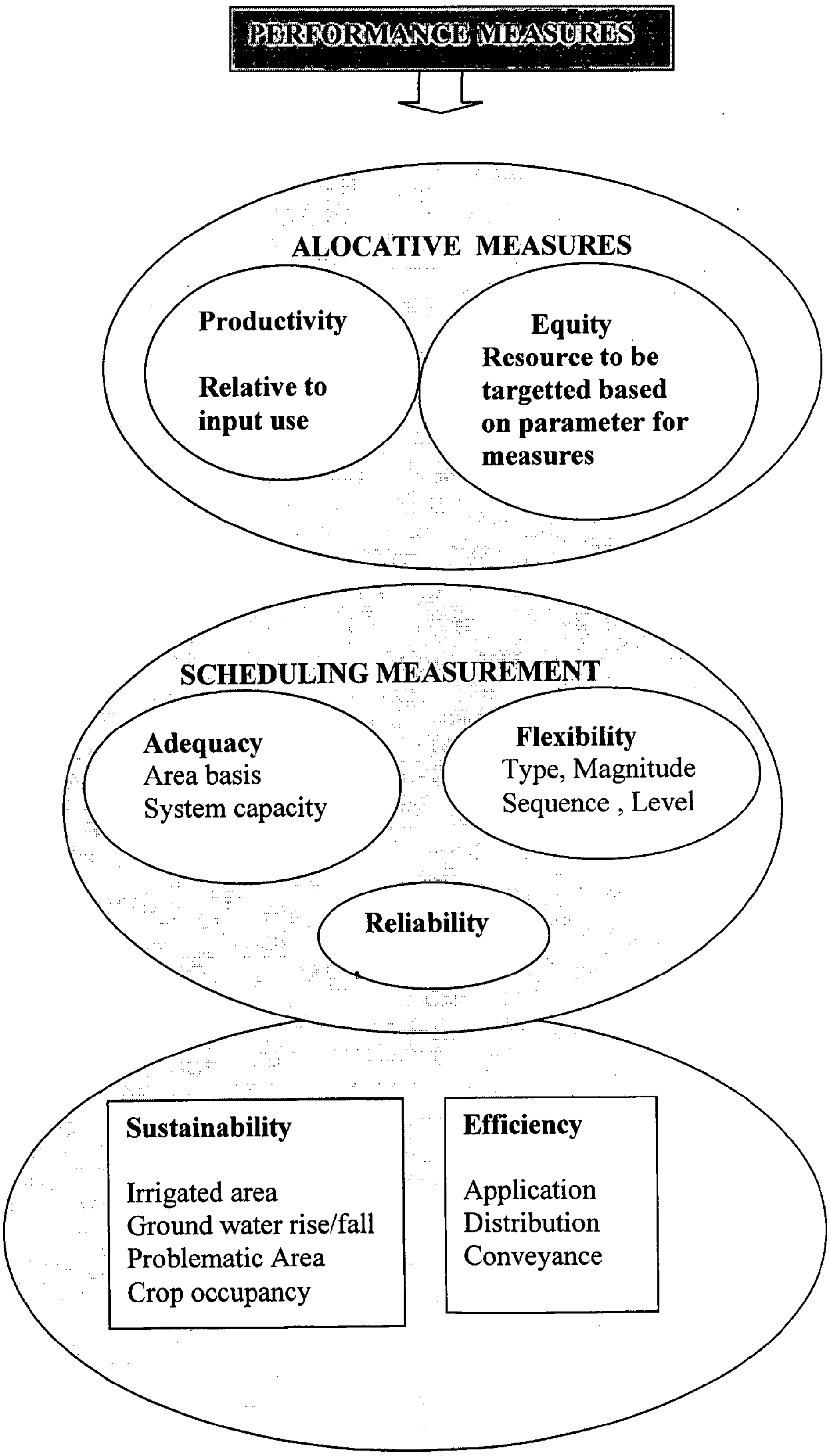
(d) Agricultural performance. This addresses the direct impact of operational inputs in terms of such aspects as area actually irrigated and crop production, over which an irrigation manager may have some but not full responsibility. Agricultural performance is a 'direct outcome' of water delivery performance in Small & Svendsen's(1990) terms. Assessment of agricultural performance is important because it links the within season indicators of hydraulic or conveyance performance with the wider agricultural economic and rural economic systems as discussed by Small & Svendsen (1990).

(e) Economic, social and environmental performance. This deals with the impact of both operational and agricultural inputs on the viability and sustainability of irrigated agriculture. These impacts include both physical and socio-economic sustainability of irrigated agriculture. This type of 'impact' performance is considered an 'effect' in Small & Svendsen's terms because it is further removed from water delivery performance causally as well as in time and space.

2.2.1 PERFORMANCE MEASURES FOR EVALUATEION OF IRRIGATION OF WATER DELIVERY SYSTEMS. (Modern and Gates - 1990)

Performance measures play major role in analysis of irrigation water delivery systems and are described in terms of adequacy, efficiency, dependability and quality of water delivery. These measures provide a quantitative assessments of overall system performance, suggesting quantitatively the contribution of structural and management components of the system. Spatial and temporal distributions of required, scheduled, deliverable and delivered water are used to calculate the performance measures. These variables may be estimated by combinations of field measurement and simulation techniques. The different types of performance measures in the process of irrigation water management are shown in Figure 2.4

Fig. 2.4. different types of performance measures in the process of irrigation water management



(a) Allocative type performance measures

The allocative type performance measures are those which need to be attended primarily during the allocation of the resource at the planning stage. Allocation of the resource influences production, area to be irrigated, net return, distribution of the resource to the users based on certain considerations, or combinations of these. Hence we classify the performance measures as Productivity, Equity.

(b) Scheduling type performance measures

The irrigation schedule (consisting of temporal or intraseasonal distribution of the resource to different users) needs to be prepared for the allocation plans developed according to the objectives of the scheme. Depending on these objectives, the schedule should be such that water deliveries are adequate both in planning and operation, reliable when in operation considering all the complexities in the irrigation scheme, flexible and sustainable. Depending on the objectives of the scheme following five scheduling type performance measures are defined as adequacy, reliability, flexibility, efficiency, sustainability. All these terms are defined earlier.

The above two allocate and five scheduling type performance measures could also be grouped as follows:

1. Economic: - Productivity.
2. Social: - Equity
3. Environmental: - Sustainability
4. Management: - Reliability, adequacy, efficiency and flexibility

All the performance indicators available in literature are described below.

2.2.2 Performance Indicators

(a) General features of performance indicators

A good indicator can be used in two distinct ways. It tells a manager what is the current performance of the system, and, in conjunction with other indicators, it may help him to identify the correct course of action to improve performance within that system. In this sense the use of the same indicator over time is important because it assists in identifying trends that may need to be reversed before the remedial measures become too expensive to afford or too complex to evaluate meaningfully.

It is important to ensure that the indicators selected for a system will describe its performance in respect of the objectives established for that system. It is this process that links the use of indicators to the overall performance assessment framework. Failure to take this into account may lead to managers to assess in terms of activities that were not included in their initial brief. Moreover, the same indicator can be used by planners and policy makers to make comparisons in performance between systems. The importance of this is two-fold. It helps determine who is a better manager so that appropriate rewards or incentives can be given. It enables future investment decisions to be made in areas most likely to produce the greatest benefit. From the perspective of operational performance, performance indicators are comparatively easy to define. They will normally be simple ratios of actual to target conditions, and the result of the performance assessment process will be to either change operational inputs so as to better achieve the target, or modify the target itself because it proved to be unrealistic or impossible.

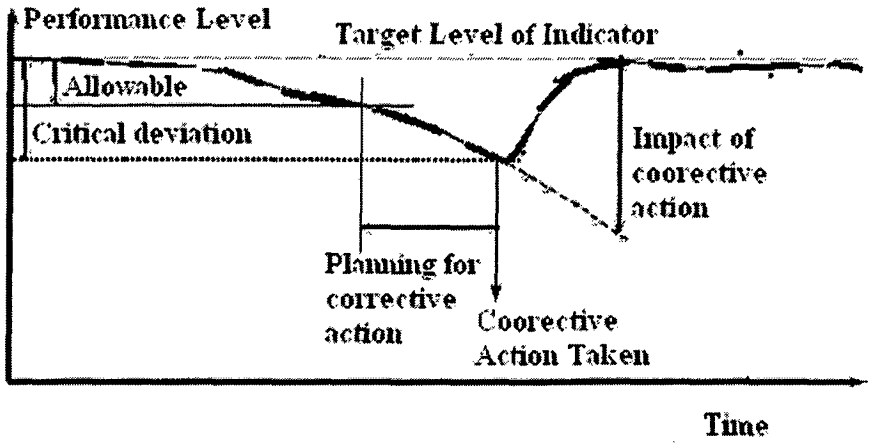


Figure 2.5 assessing performance as a function of time

(b) Attributes of performance indicators

(i) Scientific basis

The indicator should be based on an empirically quantified, statistically tested causal model of that part of the irrigation process it describes. Discrepancies between the empirical and theoretical basis of the indicator must be explicit, i.e., it must not be hidden by the format of the indicator. To facilitate comparison of performance assessment studies carried out elsewhere, indicators should be formatted identically or analogously as much as possible (Bos & Nugteren 1990, ICID 1978, Wolters 1992}.

(ii) The indicator must be quantifiable

The data needed to quantify the indicator must be available or obtainable (measurable) with available technology. The measurement must be reproducible.

(iii) Reference to a target value

This is, of course, obvious from the definition of a performance indicator. It implies that relevance and appropriateness of the target values and tolerances can be established for the indicator. These target values (and their margin of deviation) should be related to the level of technology and management (Bos et al. 1991).

(iv) Provide information without bias

Ideally, performance indicators should not be formulated from a narrow ethical perspective. This is, in reality, extremely difficult as even technical measures contain subjective values (Small, 1992).

(v) Provide information on reversible and manageable processes

This requirement for a performance indicator is particularly sensible from the irrigation manager's view point. Some irreversible and unmanageable processes may provide useful indicators, although their predictive meaning may only be indirect. For example, the frequency and depth of rainfall is not manageable, but information from a long time series of data may be useful in planning to avoid water shortage, and information on specific rainfall events may allow the manager to change water delivery plans.

(vi) Nature of the indicator

An important factor influencing the selection of an indicator has to deal with its nature: the indicator may describe one specific activity or may describe the aggregate or transformation of a group of underlying activities. Indicators ideally provide information on an actual activity relative to a certain target value. The possibility of combining such dimensionless ratios into aggregate indicators should be studied, in the same way as many indicators used for national economic performance are amulgmated.

(vii) Ease of use and cost-effectiveness

Particularly for routine management, performance indicators should be technically feasible, and easily used by agency staff given their level of skill and motivation. Further, the cost of using indicators in terms of finances, equipment, and commitment of human resources, should be well within the management resources.

(c) Available indicators

The performance indicators available in literature are defined as follows:

1) $Delivery\ Performance\ Ratio\ (DPR) = \dfrac{Actual\ Discharge}{Target\ Discharge}$

2) $Water\ Delivery\ Performance = \dfrac{Actual\ Volume}{Target\ Volume}$

3) $Overall\ Project\ Efficiency = \dfrac{Crop\ Irrigation\ Water\ Requirment}{Total\ Inflow\ into\ Canal\ System}$

4) $Conveyance\ Efficiency = \dfrac{Total\ Water\ supplied\ by\ the\ Conveyance\ System}{Total\ Inflow\ into\ The\ Conveyance\ System}$

5) $Distribution\ Efficiency = \dfrac{Total\ Water\ Delivery\ To\ Fields}{Total\ Inflow\ into\ the\ Delivery\ System}$

6) $Field\ Application\ Efficiency = \dfrac{Crop\ Irrigation\ Water\ Requirement}{Water\ Delivery\ To\ Field}$

7) $Effectiveness\ Of\ Infrastructure = \dfrac{Number\ of\ Functionning\ Structures}{Total\ Number\ of\ Structure}$

8) $Equipment\ Effectiveness = \dfrac{Actually\ Functioning\ Equipment}{Total\ Equipment\ Provided}$

9) $Relative\ Water\ Supply = \dfrac{Irrigation + Effective\ Rainfall}{Evapotranspiration + Seepage + Percolation}$

10) $Dependability\ of\ Supply = \dfrac{Actual\ Duration\ of\ Water\ Delivery}{Planned\ Duration\ of\ Water\ Delivery}$

11) $\text{Regularity of Deliveries} = \dfrac{\text{Actual Interval of Water Delivery}}{\text{Planned Interval of Water Delivery}}$

12) $\text{Modified Interquartile Ratio} = \dfrac{\text{Average DPR of Best 25\% of the System}}{\text{Average DPR of Worst 25\% of the System}}$

13) $\text{Head:Tail Equity Ratio} = \dfrac{\text{Average DPR of Upper 25\% of the System}}{\text{Average DPR of Tail 25\% of the System}}$

14) $\text{Irrigated Area Performance} = \dfrac{\text{Actual Area}}{\text{Target Area}}$

15) $\text{Cropping Intensity Performance} = \dfrac{\text{Actual Cropping Intensity}}{\text{Target Cropping Intensity}}$

16) $\text{Production Performance} = \dfrac{\text{Total Production}}{\text{Target Production}}$

17) $\text{Yield Performance} = \dfrac{\text{Actual Yield}}{\text{Target Yield}}$

18) $\text{Water Productivity Performance} = \dfrac{\text{Actual Water Productivity}}{\text{Target Water Productivity}}$

19) $\text{Total Financial Viability} = \dfrac{\text{Actual O\&M Allocation}}{\text{Total O\&M Requirements}}$

20) $\text{Fee Collection Performance} = \dfrac{\text{Irrigation Fee Collected}}{\text{Irrigation Fee Due}}$

21) $\text{Area Based profitability} = \dfrac{\text{Incremental Benifit / Unit Area}}{\text{Total Irrigation Expenses / Unit Area}}$

22) $\text{Water Based Profitability} = \dfrac{\text{Incremental Benifit / Unit Water}}{\text{Total Irrigation Expenses / Unit Water}}$

23) $\text{Irrigation Empoloyment Generation} = \dfrac{\text{Annual Person days / ha Labour in Scheme}}{\text{Anual Number official working days}}$

24) $\text{Irrigation Wage Generation} = \dfrac{\text{Anual Average Rural Income}}{\text{Anual National (or Regional) Average Income}}$

25) $\text{Relative Prospirity} = \dfrac{\text{Percent Population Above Poverty Line in Scheme}}{\text{Percent Population Above Poverty Line in Nationally}}$

26) $\text{Technical Knowladge Of Staff} = \dfrac{\text{Number of Staff with Knowledge Required to Fullfill Job}}{\text{Total Number of Staff}}$

27) $\text{Users' Stake in Irrigation System} = \dfrac{\text{Number of Active Water Users Organizations}}{\text{Total Number of Water Users Organizations}}$

28) $\text{Sustainability of Irrigated Area} = \dfrac{\text{Current Irrigable Area}}{\text{Intial Irrigable Area}}$

29) $\text{Rate of Change of Depth to Groundwater} = \dfrac{\text{New depth} - \text{Old depth}}{\text{Old depth}}$

30) $\text{Impact of Flooding} = \dfrac{\text{Area Subject to Flooding}}{\text{Total Irrigable Area}}$

31) $\text{Salt over Crop yield Ratio} = \dfrac{\text{Salt Yield}}{\text{Crop Yield}}$

32) $\text{Relative Change of Water Level} = \dfrac{\text{Change of Level}}{\text{Intended Water Level}}$

33) $\text{Relative Soil Wetness} = \dfrac{\theta \text{ actual (actual water content in root zone)}}{\theta \text{ field capacity (Soil water content in field capacity)}}$

34) $\text{Biomass yield over irrigation supply} = \dfrac{\text{Biomass production}}{\text{Volume of Irrigation supply}}$

(d) Number of Indicators to Be Used

A series of indicators, as above, are defined to assess the performance of irrigation and drainage. This assessment can be viewed from the institutions and from the 'technical / professional' perspective of the water manager, water user, environmentalist, economist, sociologist, etc. Combining these institutions and disciplines into a matrix yields many fields from which the performance of irrigation and drainage can be viewed. This complexity resulted to long-list of about 34 indicators that can be used to quantify the system performance.

The level of detail with which performance is assessed depends on the purpose of the assessment (Figure 2.6). Researchers tend to assess performance in full detail. Depending on the disciplines involved, the entire long-list of indicators may be used. The cost of collection and handling of all related data, however, is not justified for day-to-day operational management of the system. In this study, 34 indicators were employed for performance evaluation of Nachchiduwa, Thuruwila and Rajangana irrigation system and these are described in greater detail in the forthcoming chapter.

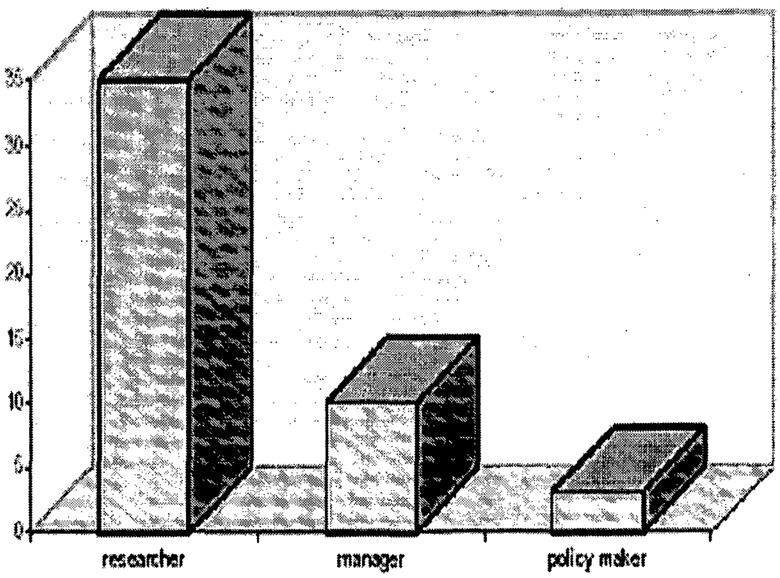


Figure2.6 Recommended number of performance indicators as a function of the audience.

WRD&M - IIT Roorkee

CHAPTER III

Master of Technology Thesis

B.A. KANTHI
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Chapter 3

Performance Indicators

3.1 Description of performance Indicators

1. Delivery Performance Ratio (DPR)

The simplest, and yet probably the most important, operational performance indicator is the delivery performance ratio (DPR) and it is described as below:

$$Delivery\ Performance\ Ratio\,(DPR) = \frac{Actual\ Discharge}{Target\ Discharge} \text{----------------(1)}$$

This measure enables a manager to determine the extent to which water is delivered as planned at any moment in time and at any location in the system. The primary utility of Delivery Performance Ratio is that it allows for instantaneous checking of whether discharges at any location in the system are more or less as intended. It is obvious that the more frequent the measurement the greater the likelihood that managers can match actual to target discharges.

2. Water Delivery Performance (WDP)

The water delivery performance (WDP) is described as follows:

$$Water\ Delivery\ Performance\,(WDP) = \frac{Actual\ Volume}{Target\ Volume} \text{------------------(2)}$$

Over a longer period of time, it may be more useful to modify the ratio by changing discharges into volumes. This results in a slightly different indicator. Over a sufficiently long time frame (e.g., monthly, or over three or four rotational time periods) it can be assumed that if total volume delivered is close to intended, then the management inputs must be effective.

3. Overall Project Efficiency

It is described as follows:

$$3)\ Overall\ Project\ Efficiency = \frac{Crop\ Irrigation\ Water\ Requirment}{Total\ Inflow\ into\ Canal\ System} \text{------------------}(3)$$

In most cases, efficiencies deal with volume delivered within a set time period rather than instantaneous discharge. Efficiency is a measure of hydraulic conditions in spatial context over a specific time period:

4. Conveyance Efficiency

The conveyance efficiency is described as follows:

$$Conveyance\ Efficiency = \frac{Total\ Water\ supplied\ by\ the\ Conveyance\ System}{Total\ Inflow\ into\ The\ Conveyance\ System} \text{-----------}(4)$$

It indicates the losses occurring in conveying the irrigation water through the channel network from head sluice to distributory system.

5. Distribution Efficiency

The distribution efficiency is defined as follows:

$$Distribution\ Efficiency = \frac{Total\ Water\ Delivery\ To\ Fields}{Total\ Inflow\ into\ the\ Delivery\ System} \text{------------------}(5)$$

It indicates the water losses occurring in conveying the irrigation water through the channel network from distributory level to field level system

6. Field Application Efficiency

$$Field\ Application\ Efficiency = \frac{Crop\ Irrigation\ Water\ Requirement}{Water\ Delivery\ To\ Field} \text{---------------}(6)$$

It indicates the losses occurring in field such as deep percolation, and runoff from the field. The calculation period of the *Field Application Efficiency* depends on the (average) interval between water applications to the fields. If the period is too short, the number of water applications varies per period. It is recommended to use a calculation period that contains at least two water applications. One month is a suitable minimal period. In arid and semi-arid areas the field application efficiency with a calculation period of one irrigation season should remain below 0.90 to avoid salt accumulation in the root zone of the irrigated crop. Hence, from a sustainability point of view it does not make sense to try to be "too efficient" in irrigation water management.

7. Effectiveness of Infrastructure

The Effectiveness of Infrastructure is defined as follows:

$$Effectiveness\ Of\ Infrastructure = \frac{Number\ of\ Functionning\ Structures}{Total\ Number\ of\ Structure} \text{---------------(7)}$$

The discharge capacity ratio can also be used to quantify the effective functioning of flow control structures in the canal system. Depending on the type of structure, the actual discharge then must be measured under the same (design) differential head (submerged gates, culverts, etc.) or under the same upstream sill-referenced head (free flowing gates, weirs, flumes, etc.). Generally, a deviation of more than 5% would signal the need for maintenance or rehabilitation for flow control structures. Maintenance is needed to keep the system in operational condition. For this to occur, (control) structures and water application systems must be operational as intended. For the analysis to be effective, however, it must divide structures up into their hierarchical importance (main, secondary or tertiary level) and the analysis completed for each level. It is assumed that on a system by system basis more specific guidelines will be developed. In general, however, a structure is functional if it can be operated or utilized to perform its intended function within an accepted level of accuracy.

8. Equipment Effectiveness

The Equipment Effectiveness is described as follows:

$$Equipment\ Effectiveness = \frac{Actually\ Functioning\ Equipment}{Total\ Equipment\ Provided} \quad \text{-------------------(8)}$$

Another important indicator of maintenance is the extent to which equipment provided for use by system managers to maintain and use the infrastructure is in good working condition. Again there is some degree of subjective ness in this ratio but it certainly gives an indicative measure of the extent to which capital investment for maintenance is being properly looked after.

9. Relative Water Supply (RWS)

The Relative Water Supply is defined as follows:

$$Relative\ Water\ Supply = \frac{Irrigation + Effective\ Rainfall}{Evapotranspiration + Seepage + Percolation} \quad \text{-------------------(9)}$$

Determination of Relative Water Supply(RWS) is not entirely straightforward. Demand may be based solely on technical criteria, such as evapotranspiration demand for particular crops or cropping patterns, it may include soil water requirements such as those used for estimating land preparation water requirements, and it may include water lost through natural seepage and percolation. Demand can, however, also include allowances for cultural practices, such as use of water for weed control in rice cultivation, for leaching if salt needs to be removed from the root zone, and it may include assumptions about desired responses to rainfall.

RWS needs to be measured over a time period. The selection of the time period depends very much on the way in which demand is defined in the original equation, but will normally refer to the adequacy of water during an agronomically relevant time period. The standard approach is to assess adequacy over the cycle of water deliveries within an irrigation system. This cycle of deliveries is frequently used for rotational irrigation: typically these are week, ten days or fourteen days, during which period each user gets the same number of water delivery turns or the same percentage of total volume delivered. In some cases, particularly for crops with lower water requirements such as wheat, millet or gram, the gap between individual irrigations may be much longer.

10. Dependability of Supply

$$Dependability\ of\ Supply = \frac{Actual\ Duration\ of\ Water\ Delivery}{Planned\ Duration\ of\ Water\ Delivery} \text{----------------(10)}$$

The pattern in which water is delivered over time is directly related to the overall consumed ratio of the delivered water, and has a direct impact on crop production. The rationale for this is that water users apply more irrigation water if there is an unpredictable variation in timing of delivered water. Also, they may not use other inputs such as fertilizer in optimal quantities if they are more concerned with crop survival (because water is not delivered) than crop production. The primary indicator proposed for use in measuring dependability of water supply is concerned with the time between deliveries compared with the plan or subscription.

11. Regularity of Deliveries

The Regularity of deliveries defined as follows:

$$Regularity\ of\ Deliveries = \frac{Actual\ Interval\ of\ Water\ Delivery}{Planned\ Interval\ of\ Water\ Delivery} \text{-------------------(11)}$$

The pattern in which water is delivered over time may significantly affect the overall adequacy of water delivered, and hence may have a direct impact on crop production. The rationale for this is that water users may be less efficient in water use if there is an unpredictable variation in volume or timing, and they may not use other inputs such as fertilizer in optimal quantities if they are more concerned with crop survival than crop production.

12. Modified Interquartile Ratio

The modified interquartile ratio is defined as follows:

$$Modified\ Interquartile\ Ratio = \frac{Average\ DPR\ of\ Best\ 25\%\ of\ the\ System}{Average\ DPR\ of\ Worst\ 25\%\ of\ the\ System} \text{------------(12)}$$

A potential flaw in many of the proposed indicators is that there is an implicit assumption that equity is the same as equality, and can therefore be easily addressed by statistical measures of deviation from the mean. The allocation process is effective in achieving a fair (but not necessarily equal) distribution of water. Then the primary objective of the irrigation manager is to determine whether the water allocation plan is actually being accomplished. A simple indicator, based on the Interquartile Ratio of Abernethy (1986), which uses Delivery Performance Ratio (DPR) can be used to give a quick view of overall equity:

13. Head to tail Equity Ratio

The Head to Tail Equity Ratio is defined as follows:

$$Head{:}Tail\ Equity\ Ratio = \frac{Average\ DPR\ of\ Upper\ 25\%\ of\ the\ System}{Average\ DPR\ of\ Tail\ 25\%\ of\ the\ System} \text{-------------}(13)$$

In some circumstances, particularly when looking at performance of a particular canal, it may be more useful to look at the difference between the head and tail of the canal

14. Irrigated Area Performance

The Irrigated Area Performance is defined as follows:

$$Irrigated\ Area\ Performance = \frac{Actual\ Area}{Target\ Area} \text{------------------------------}(14)$$

The target area refers to the total irrigable area during the design of the system or following the latest rehabilitation. If the area ratio is averaged over one year, it quantifies the intensity with which the irrigable area is used.

15. Cropping Intensity Performance

The Cropping Intensity Performance is defined as follows:

$$Cropping\ Intensity\ Performance = \frac{Actual\ Cropping\ Intensity}{Target\ Cropping\ Intensity} \text{-------------------}(15)$$

Direct indicators for assessing performance in terms of area irrigated include cropped area, cropping intensity, and irrigation intensity. However, to more clearly understand the performance, it is useful to compare these values with an expected target. Without targets, efforts to improve performance will be largely ineffective. Two indicators based on those proposed by Mao Zhi (1989) are suggested for use in assessing agricultural performance in respect to area. Those are a). Irrigated Area Performance, b) Cropping Intensity Performance.

16. Production Performance

The Production Performance is defined as follows:

$$Production\ Performance = \frac{Total\ Production}{Target\ Production} \text{------------------------}(16)$$

This indicator requires the development of target of national goal. Therefore it is important to keep on assessing the performance continuously. Target production is always close to the National goal which is self sufficiency and security of foods.

17. Yield Performance

The yield performance is defined as follows:

$$Yield\ Performance = \frac{Actual\ Yield}{Target\ Yield} \text{-------------------------------}(17)$$

This indicator is also same as production indicator. It does not give much different indicator to the evaluation.

18. Water Productivity Performance

The water productivity performance is defined as follows:

$$Water\ Productivity\ Performance = \frac{Actual\ Water\ Productivity}{Target\ Water\ Productivity} \text{------------------}(18)$$

All above three of these indicators require the development of targets. The most promising ways to do this include the following: a simple percentage increase over existing levels, a comparison to national targets or norms, or an empirical value which represents the actual performance of the top ten or twenty percent of farmers in the system. This last method of determining targets has the advantage that it is site specific but certainly achievable by a larger number of farmers than is currently the case.

19. Total financial viability

The Total Financial Viability is defined as follows:

$$Total\ Financial\ Viability = \frac{Actual\ O\&M\ Allocation}{Total\ O\&M\ \mathrm{Re}quirements} \text{------------------------}(19)$$

There has been increasing concern in recent years over the levels of recurrent costs required to keep irrigation systems functioning. One set of concerns has been with efforts to raise revenues from water users that help support operation and maintenance costs, and often some or all of the capital costs of individual irrigation systems. In many countries there are, or have been, moves towards privatization of agencies to make them more financially self-supporting, or transfer of certain operational or maintenance tasks to farmers. The total O&M requirements should be based on a detailed budget which is approved through a good budgeting system. If such a system is not in place, a budget can be based on the estimated O&M expenditure per hectare. The indicator is admittedly subjective because 'requirements' greatly depend on the number of persons employed by the agency per unit irrigable area However, it gives an indication of the extent to which the agency is expected to be self-financing. The above income of the agency (users' association, irrigation district, irrigation department, etc.) may have different sources of income, e.g. subsidies from central government, water charges, sale of trees along canals, hydraulic energy, etc.

20. Fee Collection Performance

The Fee Collection Performance is defined as follows:

$$Fee\ Collection\ Performance = \frac{Irrigation\ Fee\ Collected}{Irrigation\ Fee\ Due} \text{--------------------------}(20)$$

In many irrigated areas, water charges (irrigation fees) are collected from farmers. The fraction of the annual fees (charges) due to be paid to the Water User Association (WUA) and/or the irrigation district is an important indicator for level of acceptance of irrigation water delivery as a (public) service to the customers (farmers).

21. Area Based Profitability

The Area Based Profitability is defined as follows:

$$Area\ Based\ profitability = \frac{Incremental\ Benifit\,/\,Unit\ Area}{Total\ Irrigation\ Expenses\,/\,Unit\ Area} \text{------------------}(21)$$

This indicator requires evaluation of farm level economics, and can be modified to include or exclude the discounted value of the capital cost of the system depending on whether or not capital is considered a sunk cost.

22. Water Based Profitability

The water Based Profitability is defined as follows:

$$Water\ Based\ \Pr ofitability = \frac{Incremental\ Benifit\,/\,Unit\,Water}{Total\ Irrigation\ Expenses\,/\,Unit\ Water} \text{-------------------}(22)$$

Water is the scarcer resource, it is more logical to substitute water for land in the above equation the primary economic concern for planners and policy makers is the economic performance of investments, or the return to capital employed. Typical indicators used for this purpose include Economic Internal Rate of Return or Financial Internal Rate of Return. These two indicators, Area based Profitability and Water Based Profitability are calculated using the same basic data but are used in slightly different ways in project evaluation. They help determine whether an investment in irrigation yields an overall profit, and also help in deciding whether the investment might have been better made in another sector. Unless there are compelling social or political reasons, these indicators also help to prioritize which particular investment opportunities should be pursued at the expenses of other, less beneficial alternatives.

23. Relative Water Cost

The Relative water cost is defined as follows:

$$Relative\ Water\ Cost = \frac{Total\ Cost\ of\ Irrigation\ Water}{Total\ Production\ Cost\ of\ major\ Crop} \text{------------------(23)}$$

From the perspective of the farmer, the relative cost of irrigation water application plus the cost of drainage can also quantify the economics of irrigation. The total production cost includes cost of water (including fees, energy for pumping), seeds, fertilizer, pesticides, labour, etc. For surface irrigation, this ratio often ranges between 0.03 and 0.04; if pumped groundwater is used, the ratio may become as high as 0.10. If the ratio becomes higher, farmers may abandon irrigation.

24. Price Ratio

The Price Ratio is defined as follows:

$$Price\ Ratio = \frac{Farm\ Gate\ Price\ of\ Crop}{Nearest\ Market\ Price\ of\ Crop} \text{------------------------------------(24)}$$

At the end of the irrigation season the farmer needs a ‘reasonable’ farm gate price for his crop. In this context ‘reasonable’ is compared with the price of the same crop at the nearest market. Low values of this ratio occur with inadequate distribution and marketing systems and if the distance to the nearest market is long. A low price ratio is a common reason for the farmer to change crop or stop irrigation entirely.

25. Irrigation Employment Generation

The Irrigation Employment Generation is defined as follows:

$$Irrigation\ Employment\ Generation = \frac{Annual\ Person\ days\,/\,ha\,Labour\ in\ Scheme}{Annual\ Number\ of\ official\ working\ days} \text{----}(25)$$

Annual Person days is depending on days which are running the systems. That is totally deviate from the annual official working days. From the perspective of the farmers this indicator more tends to satisfaction of the agency services.

26. Irrigation Wage Generation

The Irrigation Wage Generation is defined as follows:

$$Irrigation\ Wage\ Generation = \frac{Annual\ Average\ Rural\ Income}{Annual\ National\ (or\ Regional)\ Average\ Income} \text{-----}(26)$$

This is the most important indicator for social impact and effect of irrigation on people. Irrigation wage generation and Relative prosperity both has same value for asses the performance. More details are given below.

27. Relative Prosperity

The Relative Prosperity is defined as follows:

$$Relative\ Prosperity = \frac{Percent\ Population\ Above\ Poverty\ Line\ in\ Scheme}{Percent\ Population\ Above\ Poverty\ Line\ Nationally} \text{-----------}(27)$$

Considering social impact, effects of irrigation on people, social organization, and livelihoods. Measurements can include comparisons of irrigated and adjacent non-irrigated areas, variation over time and space within the irrigated area, and variations among socio-economic classes on specific social parameters. In multipurpose projects measures of the benefits of non irrigation uses of water, such as recreation or fishing, could also be incorporated. Managers and policy makers need to decide on the priority issues, and can develop their own indicators for these.

The most effective way of obtaining the data required to measure social impacts is through sample surveys. If an agency is able to contract periodically with a local research group to carry out such 'market research' it could be very useful. Sometimes this indicator can be used as an indirect measure of farmer satisfaction. The higher the ratio, the more the satisfaction. Other feasible approaches to measuring farmer satisfaction include carefully recording the number, types, and temporal and spatial variation in farmers' complaints received either in writing, or through intermediaries, or through meetings with farmers. In many countries, there are departments of agriculture, labor, or census which collect basic agricultural and economic data. These can be used very easily by irrigation managers as sources of information on socio-economic impacts trends, such as employment, wages and poverty levels.

28. Technical Knowledge of staff

The technical knowledge of staff is defined as follows:

$$Technical\ Knowledge\ of\ Staff = \frac{Number\ of\ Staff\ \ with\ Knowledge\ \mathrm{Re}quired\ to\ Fullfill\ Job}{Total\ Number\ of\ Staff}$$

(28)

Actual technical knowledge of staff can be ascertained through simple tests, while required knowledge is inherent in the job description. Social capacity such as distinguished from physical, biological, or economic capacity of people and organizations for managing and sustaining the irrigated agriculture system are also important factors.

29. Users' Stake in Irrigation System

The Users' Stake in Irrigation System is defined as follows:

$$Users'\ Stake\ in\ Irrigation\ System = \frac{Number\ of\ Active\ Water\ Users\ Organizations}{Total\ Number\ of\ \ Water\ Users\ Organizations} \quad \text{-----}\mathbf{(29)}$$

'Activeness' of water users associations can be measured using easily acquired data, such as percent holding regular (or the minimum required) meetings, percent of users participating in meetings, or number of organizations fulfilling agreed upon tasks, such as fee collection, maintenance, or rotating water. All these indicators are crude, and relatively untested; but they constitute useful and implementable first step to begin paying greater attention to the social viability of irrigation.

30. Sustainability of Irrigated Area

The Sustainability of Irrigated Area is defined as follows:

$$Sustainability\ of\ Irrigated\ Area = \frac{Current\ Irrigable\ Area}{Intial\ Irrigable\ Area} \text{------------------------}(30)$$

This ratio can be modified to specifically refer to waterlogged or saline areas as a percentage of the total irrigable area. An individual manager will, of course, need to know what the cause was of losing or gaining the land from production. The bias towards water supply within irrigation systems is demonstrated by the comparative paucity of performance indicators that deal with drainage even though many of the adverse environmental impacts of irrigation are related to ineffective drainage, or delay in constructing drainage systems in comparison to the supply infrastructure.

31. Rate of Change of Depth to Groundwater

The Rate of Change of Depth to Groundwater is defined as follows:

$$Rate\ of\ Change\ of\ Depth\ to\ Groundwater = \frac{New\,depth - Old\,depth}{Old\,depth} \text{------------------}(31)$$

If drainage is not adequate then there are risks of water tables rising to levels where production is affected and, there may be reduced opportunities for leaching salts from the soil. All ratios of Ground water depth, impact of flooding, salt intrusion ratios gives the indicator for sustainability.

32. Impact of Flooding

The Impact of flooding is defined as follows:

$$\text{Im}\,pact\ of\ Flooding = \frac{Area\ Subject\ to\ Flooding}{Total\ Irrigable\ Area} \text{------------------------(32)}$$

In humid zone areas there may be a risk of flooding in the wet season if there is inadequate drainage (or if irrigation deliveries are continued during periods of rainfall). The degree of severity can be assessed from above equation.

33. Salt over Crop yield Ratio

The Salt over Crop yield Ratio is defined as follows:

$$Salt\ over\ Crop\ yield\ Ratio = \frac{Salt\ Yield}{Crop\ Yield} \text{---------------------(33)}$$

This quantifies threaten for crop yield. If the ratio is high crop yield is low. Irrigated area performance also includes some areas which are not cultivating due to salanisation.

34. Relative change of water level

The Relative change of water level is defined as follows:

$$\text{Re}\,lative\ Change\ of\ Water\ Level\ in\ canal = \frac{Change\ of\ Level}{Intended\ WaterLevel} \text{-----------------(34)}$$

This quantifies the need for maintenance of canal system. System components identify weather it needs repair or replacement. During the design of a canal system, a design discharge and related water level is determined for each canal reach. The hydraulic performance of a canal system depends greatly on the degree to which these design values are maintained. For example, higher water levels increase seepage and cause danger of overtopping of the embankment. Both lower and higher water levels alter the intended division of water at canal bifurcation structures. The magnitude of this alteration of the water distribution depends on the hydraulic flexibility of the division structures (Bos, 1976). This change of head (water level) over structures in irrigation canals is the single most important factor disrupting the intended delivery of irrigation water (Bos, 1976; Murray-Rust and van der Velde, 1994).

35. System Drainage Ratio

The System Drainage Ratio is defined as follows:

$$System\ Drainage\ Ratio = \frac{Total\ Drained\ Volume\ of\ water\ from\ System}{Total\ Flow\ into\ the\ System} \text{---------------(35)}$$

With the increasing scarcity of water, particularly in arid and semi-arid regions, the question of the quantity (volume per month or year) of water that is available for new water users becomes increasingly significant. This question can be posed at different scales, e.g. river basin system, tributary, drainage system, and can be quantified by the drainage ratio.

36. Biomass yield over irrigation supply

The Biomass yield over irrigation supply is defined as follows:

$$Biomass\ yield\ over\ irrigation\ supply = \frac{Biomass\ production}{Volume\ of\ Irrigation\ supply} \text{-------------------(36)}$$

The biomass yield over irrigation water supply ratio is a surrogate of the productivity of water. It relates the crop growth expressed as aboveground dry biomass growth (kg/ha per month) with the volume of irrigation water supplied to the irrigated area (m3/month).

3.2 Relation between Performance measures and indicators

The following two paragraphs discuss about the performance measures and performance indicators. Forthcoming Table 3.1 describes the relation between performance measures and indicators.

(a)Irrigation Performance measures

Irrigation Performance measures are out puts the results of design and operating decisions. To be useful they need to predictably quantify the effects of design and operating decisions on the extent to which the purpose of irrigation is achieved, and how efficiently the purpose was achieved.

(b) Irrigation performance Indicators

Indicator gives an information, that determined the related degree of satisfaction, a systematic and timely flow of actual (measure or collected) data on key aspects of a project. It must be compared with intended or limiting (critical) values of these data.

Table 3.1 Relation between Performance measures and indicators

Criteria	Performance Indicator	Remarks
Operational performance		
Efficiency	Effectiveness of Infrastructure	The chosen allocation plan is put into the operation and the manager then needs to monitor the performance of this plan when in operation, to allow For continuous assessment and improvement of performance of irrigation water management of the irrigation scheme. Firstly because of spatial and temporal variation in climate, secondly because of the inappropriate consideration of complexity and variability in the physical aspects of the scheme (different
	Equipment Effectiveness	
Predictability	Dependability of Supply	
	Regularity of Deliveries	
Equity	Modified Inter quartile Ratio	

	Head to Tail Equity Ratio	characteristics of the water distribution network, variable soils, etc.) and managerial aspects (on demand/ continuous / rotational water supply, etc.) while developing the allocation plan and thirdly due to different types of interventions.

Strategic Performance		
Social Impacts	Irrigation Employment Generation	Assessment of strategic management may be undertaken by looking at the relative values and rates of change of a set of indicators. The same way that national economies are assessed by indicators such as inflation rate, trade balance, unemployment etc.
	Irrigation Wage Generation	
	Relative Prosperity	
	Economic Internal Rate of Return	
	Financial Internal Rate of Return	
Water Supply Performance		
Conveyance indicators	Delivery Performance Ratio	Shows changes in quality of service to water users
	Water Delivery Performance	
Efficiency.	Overall Project Efficiency	The main purpose in differentiating between these four levels of efficiency is that the target audience is likely to change as one moves from system level to field level.
	Conveyance Efficiency	
	Distribution Efficiency	

	Field Application Efficiency	
Adequacy.	Relative Water Supply	

Agricultural Performance		
Productivity – Area based	Irrigated Area Performance	This addresses the direct impact of operational inputs in terms of such aspects as area actually irrigated and crop production, over which an irrigation manager may have some but not full responsibility. Agricultural performance is a 'direct outcome' of water delivery Performance.
	Cropping Intensity Performance	
Productivity –yield based	Production Performance	
	Yield Performance	
	Water Productivity Performance	
Profitability of irrigated agriculture.	Area Based Profitability	
	Water Based Profitability	

Economic, Social and Environmental Performance		
Economic		
Equity	Water Productivity	Quantifies change in crop yield or value per m3 water supplied

	Land Productivity	Quantifies change in crop yield or value per unit area
Finacial viability	O & M funding Fee collection Ratio Relative water cost Price Ratio	The total MO&M requirements should be based on a detailed budget which is approved through a good budgeting system. If such a system is not in place, a budget can be based on the estimated MO&M expenditure per hectare. The indicator is subjective because 'requirements' greatly depend on the number of persons employed by the agency per unit irrigable area. However, it gives an indication of the extent to which the agency is expected to be self-financing.
	Social viability	
Social impact	Irrigation Employment Generation Irrigation Wage Generation Relative Prosperity	Social viability is a very broad and complex component of irrigated agriculture, covering all levels. Conceptual understanding, a pre-requisite for identifying meaningful performance indicators, is primitive. Many social characteristics have either no direct relationship to irrigation, or a relationship that is so tenuous and complex that they are not very useful for assessing operational irrigation performance - as important as they may be for a more complete understanding of irrigated agriculture, and for assessing strategic management performance.
Social capabilities	Technical Knowledge of Staff Users' Stake in Irrigation System	
Environment	Sustainability of Irrigated Area Rate of change of depth to groundwater	Irrigation; water is imported into an area to grow a crop that would not grow without this imported water. In reverse, drainage discharges water from an area to improve crop growth, accessibility of fields, discharge salts from the area, etc. Besides the intended impacts, there are

	Impact of Flooding	unintended impacts (usually labeled negative, but can be positive). The intended impacts are mostly restricted to the irrigated (or drained) area, while the unintended impacts may spread over the irrigated area, the river basin downstream of the water diversion and the drainage basin downstream of the drained area.

Boundary conditions for the performance assessment

Proper quantification of water uses requires careful definition of **boundary both laterally and vertically**. Boundary conditions in the irrigated system mainly depend on time scale. The significance of spatiotemporal changes over the system operations is also important, and the stakeholder requirements are the same. In Sri Lanka upper lateral boundary levels are established on the basis of district administration of the country. Lower lateral boundary in strategic levels i.e. ministry and line organization, boundaries are defined to each irrigation scheme. At the operational level boundary is based on the type of system administration of each scheme. The performance assessment should start from each sub-scheme level. According to the situational requirements and objective of the assessment, performance assessment could be extended to the secondary or tertiary levels of the command area. According to the time scale, the field data are acquired and processed on daily basis for operational activities. In the seasonal cultivation plan, one common water delivery schedule is prepared for each sub-scheme i.e. within the sub-scheme, the starting date and the last date of water delivery, are fixed. Similar crop varieties with the same growing period are also recommended. However in practice, these schedules are subject to change with the change in field conditions. For paddy cultivation, water deliveries are modified every 1 or 2 weeks. Hence, the temporal extent of the performance assessment could begin with 10 day intervals. Given the broader perspective of irrigated agriculture in Sri Lanka, the purpose of assessing irrigation performance is not restricted to the individual farm level problems. The managers may have to attend to the problems of public (e.g. malaria breading caused by stagnant water) as well as of subordinating staff (e.g. resources constraints of field workers). Therefore, the boundaries are not always confined to system level operations. The internal and the external environment of the scheme may influence over the functioning of the irrigation scheme. Considering the extents of such influences other boundaries should be defined, which are sometimes less clear and rather difficult to understand i.e. some physical limits on the external environment. However, they influence the systems' performance and consequently the attainment of goals. The most common of such boundaries are socio-economic, political, physical, and on resources constraints. **Vertical boundary** is much more difficult to define. For an individual field the bottom of the root zone is commonly taken as the lower vertical boundary. It is difficult to measure vertical flow below the root zone, and in many cases, this is taken as the only unknown or remainder in water balance. With shallow water tables, since neither deep percolation nor groundwater uptake can be easily estimated. However including shallow groundwater in the water balance is also problematic.

WRD&M - IIT Roorkee

CHAPTER IV

Master of Technology Thesis

B.A. KANTHI
6/15/2007

CHAPTER 4

STUDY AREA AND DATA AVAILABILITY

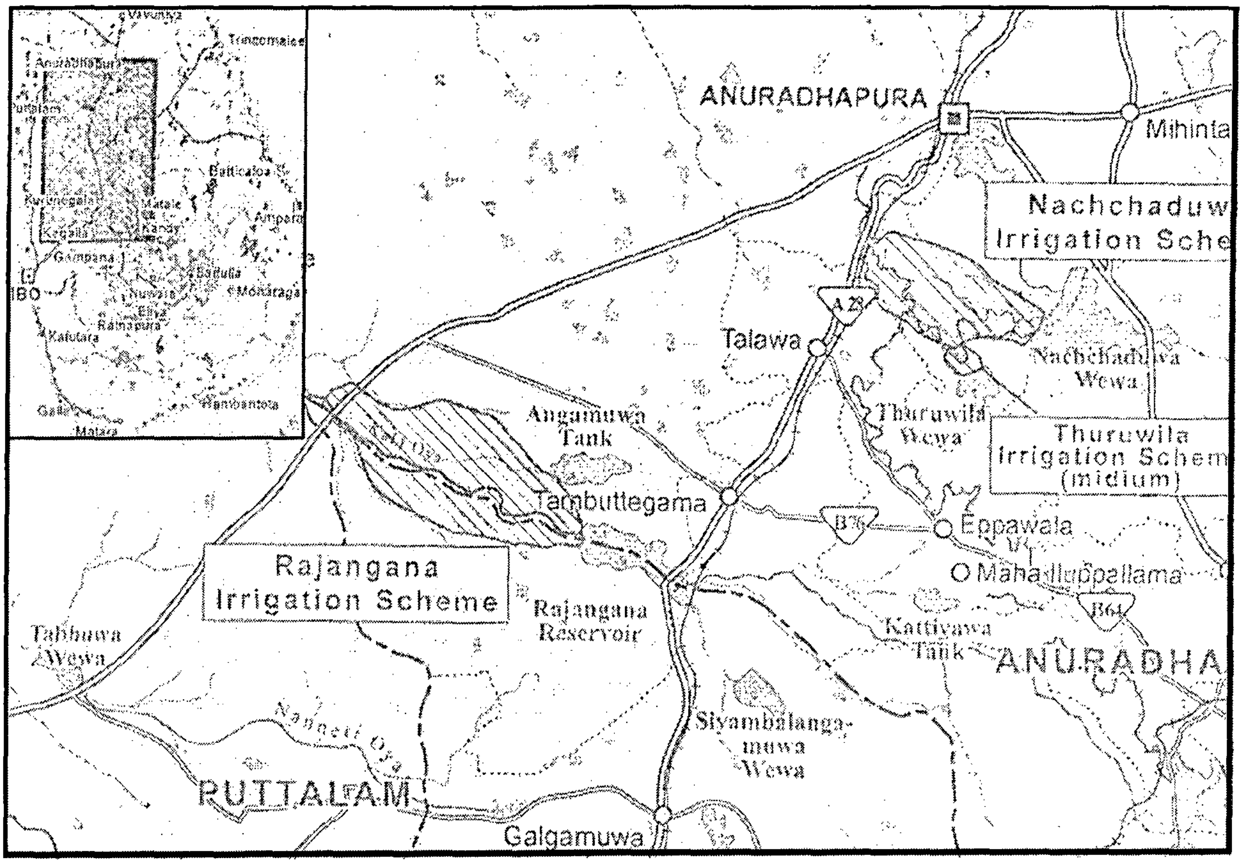


Figure 4.1 Location map of the study Area

4.1 General

The study area (Fig.4.1) is located in the Dry Zone of Sri Lanka covered by North Central province and North western province. Nachchaduwa and Thuruwila irrigation schemes are located in Anuradapura District. Rajangana scheme is extended to over three districts namely Anuradapura, Kurunagala and Puttalama. In Anuradapura, the major part of the study area is located 210 Km from Colombo capital of Sri Lanka. The population of the district is about 746,000 and the density is 112 persons / Km^2. In the 286 000 of the employed, 52.2 % is engaged in agriculture. Agriculture sector in Sri Lanka contributes about 18 % to the Gross Domestic Product (GDP) and provides 34 % of the total employment. About 85 % of population resides in rural areas, where agriculture is the main economic activity. Dry Zone is the granary area and produces 2.1 million tons of paddy, 80% of the national production is the main economic activity of small farm holders in rural areas. Paddy production heavily depends on irrigation, which enables stable production in the wet season and expanding cropped area in the Dry season. Due to government efforts, irrigation development is accelerated since 1970 until self sufficiency level of paddy from 42 % in 1965 to 95 % in 1995 is achieved. Sometimes it fluctuates between 75 % and 99 %. Under this situation, the role of paddy production sector from the macro-economic view point has been changing from "increases of paddy supply" to "staple supply of quality paddy" in the national food security policy.

The Dry Zone covers 17 districts, and Anuradapura is geographically located at the central position of the zone. Paddy production and average unit yield in Anuradapura district are ranked at 8 th to 10 th among the 17 districts falling in the Dry Zone (Annual Report 2004, Central Bank of Sri Lanka). In Anuradapura district, 93 % of the total population resides in rural areas, and 53 % of labor force is engaged in the agriculture. Most of them are engaged in paddy production. However, employment (by age groups) in agriculture is 46 % in the age group of 10 to 39 years old, and more than 60 % in the age group of 40 years and over.

In the study area, Nachchaduwa, Rajangana and Thuruwilla show different features. Nachchaduwa irrigation scheme can be characterized as follows. Present farm holders are descendant of relatively old settlement in 1930s, located nearby the large town of Anuradapura, fluctuating irrigation area in dry seasons. More than 50 % of farm land is cultivated under tenant and or lease, with crop diversification towards vegetables. Rajangana irrigation scheme is characterised as relatively new settlement in 1960s located 40 - 50 Km from Anuradapura, relatively stable irrigation area in dry season, land fragmentation and small ownerships, crop diversification, in a small part, towards mainly Banana and Papaya. Thuruwilla irrigation scheme is characterised as farm household originated from old traditional villages, farmers dependent on paddy cultivation without crop diversification.

However these three schemes can be considered to have been playing a significant role in all activities in the farm sector. The other salient features of the study area are given in Table 4.1.

Table 4.1. Details of study scheme

No	Subject	unit	Nachchaduwa	Rajangana	Thuruwila
1	Major Restoration or Construction	year	1926	1957-72	Before 1900
2	Latest Rehabilitation	year	1989	1989	2005
3	Area Extent (Max) (Original plan)	Ha	2384	5371	173
4	Wet season (Max) (Present)	Ha	2905	6639	193
5	Dry Season (Max and Min) (Present)	Ha	2905 - 0	6515 - 3397	193
6	Farmer Families	Nos	2935	7400	280
7	Farmer Organization Members	Nos	2448	6340	140
8	Operation Area per Farmer	Ha	0.99	0.90	0.69

4.2 Agro- climatic condition

4.2.1. Agro-ecology

The study area falls under agro-ecological region designated as DL 1b. The characteristics of DL 1b is 75% probable annual rainfall is greater than 900 mm , Ground Elevation less than 300 m MSL and undulating terrain of Reddish Brown (REB) or Low Humic Gley (LHG) soil association. The land use consists of rain-fed upland crops, paddy, scrub, mixed home gardens and forest plantations.

4.2.2 Rainfall

Rainfall is the main important factor governing the irrigation practices. While formulating capacity development plan for irrigation sector, changes in long - term rainfall pattern must be understood. The long term rainfall trend in entire Sri Lanka has been recently analyzed by Initial National Communication (NIC) to study the climate change in 2000. The analysis was performed using the annual rainfall data for the period 1880 - 2003. The characteristics of rainfall pattern is distinguished by its high variability from year to year. The analysis showed alternating dry and wet periods till about 1970, and a significant change is recognized during the period of 1970 when the annual rainfall was below average, except during only three years over a period of 30 years. Analysis was carried out for the reference periods of 1931-60 and 1961-90 as shown in Figure 4.1. The analysis results showed that the average annual rainfall decreased by 7% from 2005 mm in 1931-60 to 1861mm in 1961-90. Cleary seasonal disparity is also observed that May-Sept even increase while Dec-Feb, The middle of Maha cultivation season, significantly reduced by nearly 20%. Overall tendency of rainfall decrease for entire country with seasonal disparity is recognized.

From the district-wise analysis it was found that the average annual rainfall decreased by different degree in all the districts except Colombo and Matara. In Anuradapura district, change in annual mean rainfall from 1931-60 to 1961-90 showed the decrease of nearly 150 mm per annum. In the study area, the annual rainfall of 1000-1500 mm, is distributed in a well expressed bi-model pattern. The north-east monsoon period, which accounts for more than 70% of the annual rainfall, occurs during December to February. The first inter-monsoonal period is unstable, but the convectional and depressional rainsoccur in the second Inter-monsoon, and October-November period is more balanced.

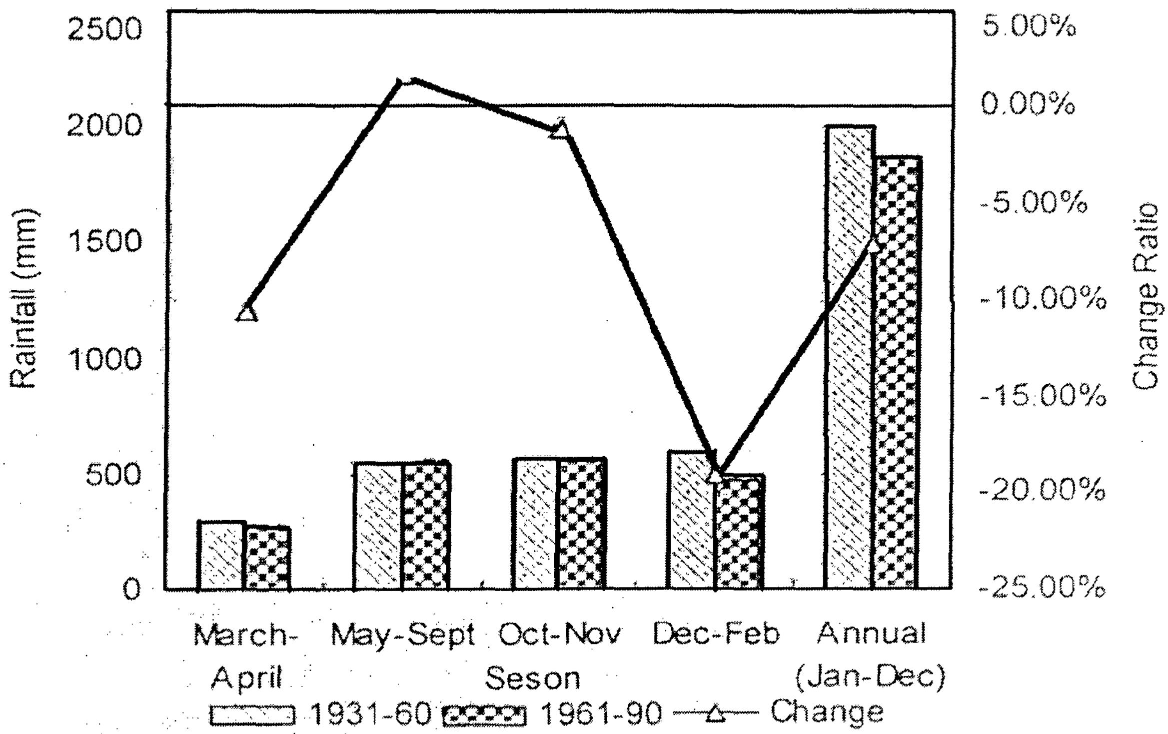


Figure 4.2 Rainfall Long Term Trend Seasonal Basis (Period 1931 – 60 & 1961- 90)
Source; Jayatilaka. et.al (2004)

Table 4.2 explain the mean monthly rainfall in Anuradapura District (1999-2003) . For this calculation these data are used. Long term average is has deviation from the recent average.

Table 4.2: Mean Monthly Rainfall in Anuradapura District (1999-2003)

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Rainfall(mm)	133	68	41	151	20	42	31	28	76	193	268	181	1231

Source: Statistical abstract – 2004, Department of census and Statistics

4.2.3. Soil

Soil types of the study area are Reddish Brown (RBE) and Low Humic Gley (LHG). These occur in a catenary sequence with the well drained RBH in the upper and mid slopes of the undulating terrain, and the poorly drained LHG in the lower slopes and valley bottoms. Due to impervious basement rock, ground water level in the soil builds up rapidly during the rainy season. The bottom lands remain poorly drained while the mid slopes of the valley imperfectly drained during a greater part of year. Almost all the command areas of tanks in the dry zone are made of LHG soils.

4.2.4. Temperature

The average monthly variation in temperature is low, the lowest recorded in the months of January and February (25.4^0 C) and the highest in April and May (29.2^0 C) (Table 4.3). The range of temperature experienced in area is not a limiting factor for agriculture. The other meteorological data required for computation of monthly crop water requirement is shown in Table 4.4

Table 4.3: Mean monthly temperature in Anuradapura (1999-2003)

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Tc
Temperature(^{0}C)	26.1	27.2	29.1	29.4	29.7	29.0	29.4	29.2	29.7	28.0	27.0	26.3	28

Source: Statistical Abstract – 2004 , Department of Census and Statistics

Table 4.4: Data for Crop water requirement calculation

Project : Udawalawe — Climatic Station : Udawalawa - 2004

Latitude : 8" North Lat. — Altitude : 65.00 metre

Month	Temp 0c	Humidity	Windspeed (Km/day)	Sunshine Hours	Radiation MJ/m2/d	ETo– Penman Mm/day
January	25.9	88	49	6.3	17.1	3.20
February	26.8	85	56	7.1	19.4	3.80
March	27.8	83	49	7.5	21.0	4.30
April	27.7	83	125	6.6	19.7	4.20
May	28.1	77	135	6.7	19.3	4.30
June	30.7	73	156	7.1	19.4	4.7
July	28.5	70	310	8.2	21.2	5.60
August	27.9	71	181	8.7	22.5	5.20
September	28.1	72	168	7.1	20.3	4.7
October	27	84	146	4.7	16.0	3.50
November	26.5	88	65	6.0	16.9	3.40
December	26.3	89	52	7.4	18.2	3.50

4.3 Crop Production

Nearly 10% of the national cultivation area lies in Anuradapura district in both wet and dry seasons (Table 4.6). This region also contributes significantly to national production of highland crop as well. Details of production are given in Table 4.6- 4.8

Table 4.5: Paddy Extent sown and harvested: Irrigation scheme in Anuradapura

Season	Sown Area (ha)				Harvested Area (ha)			
	Major	Minor	rainfed	Total	Major	Minor	rainfed	Total
Wet 1999/2000	25577	29446	1520	56543	24554	28268	1460	54282
Dry 2000	15514	5699		21213	14583	5244		19827
Wet 2000/2001	19068	21220	511	40799	18972	21114	509	40595
Dry 2001	11846	5661		17507	11846	5629		17475
Wet 2001/2002	25187	21365	639	47191	25161	21265	639	47065
Dry 2002	9360	2987		12347	8892	2838		11730
Wet 002/2003	27351	35173	3531	66055	25983	33415	3355	62753
Dry 2003	16425	7145		23570	15111	6573		21684

Table 4.6.Paddy production and average yield per ha in Anuradapura district

Season	**Production (000'mt)**	**Av. Yield (Kg)**
Wet 2000/2001	146	4474
Dry 2001	207	4873
Wet 2001/2002	198	4627
Dry 2002	40	4190
Wet 2002/2003	219	4341
Dry 2003	68	3891

Note; mt – metric ton Source : Statistics Abstract – 2004, Department of Census and Statistics

Paddy production in study area is given below. Different season get different production though the extent is same. Table 4.7 gives Nachchiduwa details.

Table 4.7: Paddy production and yield per ha in Study Area

Nachchaduwa

Wet Season	Extent (ha)	Production(t)	Yield (t /ha)	Dry Season	Extent (ha)	Production(t)	Yield (t /ha)
98/99	2510	11069	4.41	1998	1472	5741	3.90
99/00	2510	11320	4.51	1999	2462	10464	4.25
00/01	2510	12600	5.02	2000	2510	10668	4.25
01/02	2510	14985	5.97	2001	941	4291	4.56
02/03	2510	11320	4.51	2002	992	4276	4.31
03/04	2800	13496	4.82	2003	2800	11060	3.95
04/05	2800	13776	4.92	2004	128	-	-

Rajangana

Wet Season	Extent (ha)	Production(t)	Yield (t /ha)	Dry Season	Extent (ha)	Production(t)	Yield (t /ha)
97/98	5459	23637	4.33	1998	6280	25748	4.10
98/99	6000	28320	4.72	1999	6000	26280	4.38
99/00	6000	27000	4.50	2000	5457	23574	4.32
00/01	5457	28267	5.18	2001	4080	19339	4.74
01/02	5610	27826	4.96	2002	6229	28467	4.57
02/03	5610	26479	4.72				

4.4.1 Socio Economic Condition

Socio-economic condition data were gathered under different heads to evaluate several aspects such as household occupants and contribution to farm labor , Land Tenure, Farm holding, Housing Condition, Home appliances, Transport, Farm Machinery and Equipment, Household income, household expenditure. These data are prepared by Japan International Cooperation Agency study team by selecting random sample of 97 respondents.

(1) Household Occupants and Contribution to Farm Labour.

The mean family size in the survey sample was between 4-5 members, and the total number of occupants per house hold was 4.8. The mean house hold or family labour condition for farm work was 1.7, the highest recorded at Thuruwila.

Table 4.8: Household Occupants and Contribution to Farm Labour

Items	Categary	Unit	Nachchaduwa	Thuruwila	Rajangana
	Total family	Nos	4.8	4.1	4.3
	Others	Nos	0.4	0.4	0.4
	Total Households	Nos	5.2	4.5	4.7
	Labour contri.field	Nos	1.4	1.9	1.7

Source ; JICA study team 2005

(2) The land tenure

The land tenure showed a wide variation among the 3 areas studied. The main tenure categories recognized are (a) own land, which may be inherited by law or tradition, or land purchased by the farmers, and (b) lands operated on leased basis, (c) land operated by tenant, and (d) lands operated on rotation basis. Over 88% of the farmers in Rajangana and 60% in Thuruwila were owner operators. Rotation system was most prevalent in Thuruwila at 7.5%., while it was insignificant in the other locations. The percentage of tenant farmers was highest in Nachchiduwa. Table 4.10 shows more details.

Table 4.9 The land tenure

Categary	Unit	Nachchaduwa	Thuruwila	Rajangana
Own	%	34	60	89
Leased	%	24	11	0
Tennent	%	28	21	11
Thattumaru	%	0	8	0

Source ; JICA study team 2005

(3) Farm Holding

Farm holdings with irrigated extents owned by the operator in Nachchiduwa and Rajangana were around 0.5 ha, while it was slightly larger in Thuruwila at 0.6 ha. Nachchiduwa farmers had larger homesteads (0.41) and in Thuruwila and rajangana, the average extent was about 0.29 ha. The other component classified under farm holding included agricultural lands located outside the scheme, and are usually highlands. These may be privately owned or lands obtained under annual LDO permits. The average total farm holding ranged between 1.1 ha and 1.7 in the 3 areas studied. Table 4.11 gives the analysis of the irrigation paddy lands by size showed that the distribution is highly skewed with over 42% of the respondents operating on land area of 0.4 ha (1 acre) or less in extent. Thuruwila had the highest proportion of farmers (58%) holding 0.4 ha or less.

Table 4.10 Farm Holding

Categary	Unit	Nachchaduwa	Thuruwila	Rajangana
0.4 ha & below	%	36	58	28
0.4 to 0.8 ha	%	20	18	50
0.8 to 1.2 ha	%	36	8	16
More than 1.2 ha	%	8	16	
Avg operation size	ha	1.1	0.8	0.7

Source ; JICA study team 2005

(4) Housing condition

On an average, nearly 90% of the houses in the surveyed area were in permanent condition with asbestors or tiled roofs, brick walls and cement floors.

Table 4.11 Housing Condition

Categary		Unit	Nachchaduwa	Thuruwila	Rajangana
	No of rooms	Nos	2.6	2.8	3.3
	Toilet	Nos	1.0	1.0	1.0
	Water supply				

	Own well	%	88.0	66.7	63.6
	Common well	%	20.0	58.3	39.4
	Tube well	%	12.0	5.7	12.1
House Construction					
	Roof				
	Cadjan	%	16	3	3
	Asbestos	%	56	58	6
	Tin Sheets	%	0	3	0
	Tile	%	28	36	91
	Floor				
	Cement	%	88	86	85
	Mud	%	12	14	15
	Electricity	%	84	81	67

Source ; JICA study team 2005

(5) Home Appliances.

Over 80% of the families covered in the survey had TV sets which are battery operated if electricity is not available, nearly 80% possessed radios and 25% telephones, either land or mobile. It is important to notice that household appliances were beyond the scope of the present study. It was apparent that most of them have been purchased by the children who are employed in non-farm sectors.

Table 4.12 Home Appliances

Categary	Unit	Nachchaduwa	Thuruwila	Rajangana
TV	%	81	82	79
Radio	%	82	76	78
Phone	%	42	21	12
Sawing Machine	%	35	39	33
Fan	%	23	39	33
Fridge	%	19	16	3
Kitchen Equipment	%	42	18	18

Source ; JICA study team 2005

(6) Transport.

The most common means of family transport was push-cycle or bicycle, each family owned at least one unit. 40% of the respondents had motorcycles, while little over 4% owned 3 wheelers. However, in most instances, the motor cycles and particularly, the 3 wheelers belonged to independent children who were employed outside the farm.

Table 4.13 Transport

	Car/ van	%	0	3	0
	Truck	%	0	3	0
	Motorbike	%	31	53	36
	Pushbike	%	154	118	127
	3-Wheeler	%	8	5	0

Source ; JICA study team 2005

(7) Farm Machinery and Equipment

More than half of the families in the survey owned sprayers while 22% owned 2 wheel tractors, Thuruwula leading with 29%. 18% of the farmers owned rotovators.

Table 4.14: Farm Machinery and Equipment

Categary	Unit	Nachchaduwa	Thuruwila	Rajangana
4W tractor	%	0	11	6
2W tractor	%	19	29	18
Thresher	%	0	5	0
Sprayer	%	54	61	39
Water Pump	%	12	11	3
Trailer	%	12	11	9
Rotorvator	%	19	26	9
Tyne Tiller	%	0	5	6

Source ; JICA study team 2005

(8) Household Income

The net income derived from 6 pre-determined sources was collected. Income from outside source was categorized under 'others', as there was a wide variation as well as inconsistencies in the data collected. Depending on the source, the income was recorded on monthly, seasonal or annual, and later converted to annual base. The net household income in the survey area averaged to Rs. 133,000 of which 72% was derived from agricultural operations. Paddy reserved for household consumption, settlement of land tenancies and leases were excluded in computing the income, as were crop such as coconut, fruits, etc. that were consumed by the family. Income from foreign and local remittances is categorized under 'Others'. This also included 6 farmer fishermen who were engaged inland fishery industry in the Thuruwila tank. In the computation, salaries and wages earned by family members, married or single, and lived in or away from the house were not accounted. Because of respondents clamed that they were independent children and were not contributing significantly to the household expenses. At the same time foreign remittances were not included because they were not regular but periodical. Other main income came from the earnings from labour work.

House hold income can be separate in two parts. On- Farm and Off – farm. Forth coming calculations are easy if on- farm is separate. Table 4.15 shows the details.

Table 4.15 Household Income

Item	Nachchiduwa	Thuruwila	Rajangana
On – Farm Income	123,885	73,847	94,419
Off – farm Income	39,382	36,290	30,822
Total Annual Family Income	163,267	110,137	125,241

Source ; JICA study team 2005

Distribution of annual agricultural income by households is explain in the Table 4.16. Poverty line considered as Rs 25,000 per annum.

Table 4.16 Distribution of Annual Agricultural Income by Households (unit%)

Annual Income (Rs)	Nachchiduwa	Thuruwila	Rajangana
25,000 and less	15.4	23.5	21.2
>25,000 – 50,000	23.1	21.1	18.2
>50,000 – 75,000	19.2	15.8	21.2
>75,000 – 100,000	23.1	13.2	3.0
>100,000 – 125,000	3.8	2.6	12.1
>125,000 – 150,000	3.8	5.3	15.2
>150,000 – 175,000	0.0	5.3	6.1
>175,000 – 200,000	0.0	0.0	3.0
>200,000	11.5	13.2	0.0

Source ; JICA study team 2005

In the study area distribution of annual income by households is describe Table 4.17.

Table 4.17 Distribution of Total Annual Income by Households (unit%)

Annual Income (Rs)	Nachchiduwa	Thuruwila	Rajangana
25,000 and less	0.0	5.3	12.1
>25,000 – 50,000	23.1	7.9	15.2
>50,000 – 75,000	11.5	31.6	21.2
>75,000 – 100,000	23.1	15.8	3.0
>100,000 – 125,000	11.5	7.9	12.1
>125,000 – 150,000	7.7	2.6	15.2
>150,000 – 175,000	3.8	7.9	9.1
>175,000 – 200,000	0.0	5.3	3.0
>200,000	19.2	15.8	9.1

Source ; JICA study team 2005

Table 4.18 gives the detail explanation about the house hold expenditure. Among three systems Rajangana takes the higher place for expenditure. In income distribution(Table 4.17) shows that the Rajangana is in the lowest areas.

Table 4.18 Household Expenditure

Item	Nachchiduwa	Thuruwila	Rajangana
Payment of Interest	**3100**	**1900**	**5200**
Food & Beverages	**38,300**	**44,900**	**36,600**
Clothing	**7,400**	**6,600**	**6,400**
Transport	**9,500**	**9,300**	**9,600**
Functions	**6,100**	**4,200**	**7,300**
Health	**5,100**	**4,900**	**6,200**
Education	**7,000**	**3,600**	**9,500**
Entertainment	**2,800**	**3,700**	**4,400**
Electricity	**1,200**	**2,300**	**2,200**
Others	**2,900**	**5,200**	**3,500**
Total	**83,400**	**86,000**	**90,000**

Source ; JICA study team 2005

4.5. Marketing Aspects

Marketing aspects consider price fluctuations of paddy and other governing pricing factors. For agricultural marketing, Government policies usually consider export and import of agricultural products, supply / demand , pricing and price formula, marketing facilities ,etc now a days. Government is promoting crop diversification of paddy and higher productivity of paddy cultivation. In the study area an increasing trend of diversification to vegetables and fruit crops is observed. The per capita consumption rate of vegetables and fruits in Sri Lanka is low compared to world standard. It is 29 Kg/person/Year fruit and 46 kg/person/year vegetable.

On the other hand , import amount of Maize, Green gram and Chilies is regularly high in Sri Lanka. The domestic demand for those importing items can be full filled by immediate local supply if countermeasures are taken effectively.

4.6 Paddy Production

(i) Land preparation

In the first ploughing the soil is penetrated to a depth of 20-25 cm using either mould-board or disc plough . But to do this 4 wheel tractor is needed. It is costlier than 2 wheel farm tractors and insufficient 4 wheel tractors discourage this practice. Therefore, 2 wheel tractors with rotavator are more popular. Rotavator can only plough up to the depth of 10 – 14 cm . In the Rajangana scheme fields are ploughed two times, but in Nachchiduwa and Thuruwila, it is three times: starting from first irrigation , 6-10 days and 15-20 days . The final ploughing is followed by field leveling and then separating out seed beds by making shallow drains inside the field . Some farmers still dig deep drains around the field for salt water removing

(ii) Crop establishment

Over 98% farmers practice broadcasting of pre-germinated seeds because transplanting is not common due to high labour requirements. Small farm holders engage their own family members as labours. The pre-germination procedure includes the emerging the paddy seeds (kept in poly-woven bags), in water for continuous 2 days and then taking out turning side up and down after 2-3 days. Normal seeding rate per ha is 100-130 kg depending on paddy variety.

(iii) Nutrition

In this case, due to environmental awareness, the government is promoting use of carbonic fertilizers like recycled strew, animal manure (cow dung, goat dung), green manure, husk charcoal. As on today only about 15-20 % farmers actually practice recycling the strew. Despite the fact that the Government invests significantly on demonstration in its field programmes, the farmers do not tend to take it up voluntarily partly due to lack of follow up and partly due to their being only tenants and lease holders and, in turn, having no long time interest in improving the soil condition.

In case of basal fertilizers applied immediately after ploughing all farmers do not apply according to the recommended practice. Basal is applied to augment the deteriorating green manure, and other hard manure, in the soil. It reduces the land preparation time. Most of the farmers get a loan from the government bank for cultivation and these institutions take time to complete their procedure. In Sri Lanka nearly all farmers apply urea indiscriminatly as a booster application. Table proportion and timing of fertilizer are recommended by the Agriculture department. 70-80 % of the farmers applied TDM or self made mixture (N-P205-K20) with out consideration to recommendations based on age and class of variety and production output.

(iv) Weed Control

Weed control being the major concern due to non- transplanting. Several preventive measures are practiced as follows:

(1) keeping the bunds and drains clean of weeds,

(2) using good quality seed material, and

(3) not washing seeds with canal water.

More than 75% farmers in the systems employ herbicide for weed removal.

(v) Pest and Disease Control

Decease problems are relatively low in the study area. However, it is common to apply pesticides in a routine manner even without requirement, even when crop damages are not observed. Farmers frequently consult the pesticide dealers for recommendations for use of pesticides. Field visits of agriculture instructors are sometimes restricted due to unavailability of transport facilities. The practice of Integrated Pest Management (IPM) was not always satisfactory as the tract (yaya) operations. There also exist some other barriers such as shortage of farm machinery and labor and shortcomings in irrigation infrastructure.

(vi) Harvesting and Threshing

The ideal time to harvest the crop is when 85% of the panicles turn golden yellow when the moisture content is about 22% and dry weather persists. However, on account of logistics of contract arrangements for reaping and threshing, harvesting is not done at the proper time. Reaping is done manually, and over 29 labour units are required per hectare. In the study area, particular in Nachchiduwa and Thuruwila where farm labour is in short supply. Contract harvesting is common practice. The harvested paddy is drawn to the threshing floors and heaped for threshing. Three methods are used for threshing in the study area. The 4 wheel tractor which was popular at one time is gradually being replaced by 2 wheel tractor driven small capacity thresher units. The high capacity combine thresher, which is recent introduced to the area, has wide popular among farmers, particularly in Nachchiduwa and Thuruwila. About 12 units are in the area. Cost of threshing by the 3 methods is about the same, but the high capacity units are preferred by farmers as it gives good clean seeds (separate winnowing operation as in other methods is not required), needs less labour for the operation (operation is done on contract basis inclusive of labour) and the operation is fast(about 4 hours per ha). It also gives chopped straw which is more convenient to back to the paddy field for soil enrichment.

Table 4.19 Data for computation of paddy production cost in Nachchiduwa

Particulars	Material			Machinery			Labour (Mandays)		
	Type	Unit	Rate	Qty/ha	Unit	Qty/ha	Rate	Rate	Qty/ha
1.Land preparation									
Clearing of bunds	H'cide	1	520	2.5				450	2
Ploughing					times	2	3543.5	400	1
Reshaping								400	8
2.Crop Establishment									
Seed bed preparation	Seeds	kg	28	102				400	10
&sowing									
3.Fertilizer application									
Basal dressing	V1	kg	32	100				400	1
14 DAS	Urea	kg	13	62				400	1
30 DAS	Urea	kg	13	125				400	1
45-50 DAS	TDM	kg	18	105				400	1
4. Weed control	H'cide	1	520	4				450	2
5.P&D Control	P'cide	1	520	2.5				450	1
6. Irrigation								400	20
7.Harvesting								400	1
								Labout contract	10000
8.Threshing				Contract; H/C thresher					
9.Transport	Bags	No 8	100	Tractor & Trailer				400	2

H'cide = Herbicide P'cide = Pesticide V1 = Basal fertilizer

Table 4.20 Data for computation of paddy production cost in Thuruwila

Operation	Material			Machinery			Labour (Mandays)	
	Type	Unit	Qty/ha	Unit	Rate	Qty/ha	Rate	Qty/ ha
1.Land priparation								
Clearing of bunds	H'cide						350	2
Ploughing				Time	2	3106	350	1
Reshaping							350	8
2.Crop Establishment								

Seed bed preparation	Seeds	kg	103				350	10
&sowing								
3.Fertilizer application								
Basal dressing	V1	kg	62				350	1
14 DAS	Urea	kg	62				350	1
30 DAS	Urea	kg	87				350	1
45-50 DAS	TDM	kg	88				350	1
4. Weed control	H'cide	1	4				350	2
5.P&D Control	P'cide	1	2.5				350	1
6. Irrigation							350	20
7.Harvesting							350	1
						Labour	contract	10000
8.Threshing				Contract; H/C thresher				
9.Transport	Bags	No	100	Tractor & Trailer			350	2

Table 4.21 Data for computation of paddy production cost in Rajangana

Operation	Material				Machinery			Labour (Mandays)	
	Type	Unit	Rate	Qty /ha	Unit	Rate (Rs)	Qty/ha	Rate (Rs)	Qty/ha
1.Land priparation									
Clearing of bunds	H'cide	1	520	3				350	3
Ploughing					Time	2	3075	350	1
Reshaping								350	9
2.Crop Establishment									
Seed bed preparation	Seeds	kg	30	110				350	6
&sowing									
3.Fertilizer application									
Basal dressing	V1	kg	32	63				350	1
14 DAS	Urea	kg	13	62				350	1
30 DAS	Urea	kg	13	87				350	1
45-50 DAS	TDM	kg	18	44				350	1
4. Weed control	H'cide	1	500	4				350	1
5.P&D Control	P'cide	1	550	2.5				350	1
6. Irrigation								350	20
7.Harvesting								350	23

							Labour	contrac t	10000
8.Threshing					Contract; H/C thresher			350	3
9.Transport	Bags	No	8	100	Tractor & Trailer			350	2

4.7. Indirect factors affecting for cost of paddy production

In Sri Lanka, trade policy is generally based on quantitative restrictions on imports Table(4.21). The official import duty rates imposed on paddy and other commodities are changed from time to time with the change in local production and or political requirements. Until 1990, private traders were allowed to import and maintain buffer stocks subjected to the payment of import duties when stocks were released to the local market; licenses and seasonal restrictions were imposed on import of Potatoes, Chilies and Onions. Table 4.22 shows the relative price of paddy, vary according to the fertilizer and labour charges during past 20 years. This the main problem of unit price of paddy is not in satisfaction level to the farmers.

Table 4.22. Relative price of paddy

Ratio(Paddy price/imput price, consumer price)	1982	1992	2002
Paddy/Fertilizer (Rs/Kg)	1.37	0.70	0.78
Paddy / Labor Changes (Rs/hour)	0.80	0.69	0.45

4.8. Condition of paddy or rice marketing in the study area

Many farmers borrow cultivation funds in advance from middleman or shop-owners in a village. For settlement of such loans, farmers normally rush to sell their paddy for cash soon after harvest despite the selling prices being at the lowest level. The quality of paddy is not much consideration in transactions, leading to poor quality control by farmers. In the study area, paddy is harvested during Feb - Mar for wet season (Maha) and August for dry (Yala) season. The selling prices normally drop in Mar-Apr and rise during May-June. Most commercial rice millers and paddy collectors stock paddy after harvest season for use in Wet season, and paddy prices do not drop sharply during Sep - Oct after the harvest in Dry season.

In both Nachchaduwa and Thuruwila Schemes, there are a number of commercial rice mills in actively operation (25 commercial mills and 28 village mills/custom mills). But in Rajangana Scheme, there are only 2 small commercial rice mills in operation but huge no. of village mills are working (69 in right bank and 64 in left bank, total 133 mills). Most farmers in Nachchaduwa and Thuruwila sell paddy directly to the commercial mills but farmers in Rajangana can only sell to collectors / middlemen. In Rajangana, local brokers play a mediator role in paddy marketing, as buyers and sellers.

There is no wholesale market for paddy/rice in the study area unlike other field crops, such as vegetables, fruits which are everyday commodities to be taken by wholesalers / collectors and producers (farmers) to the economic centers (wholesale market). Table 4.23 shows the average monthly producer price of paddy in Anuradapura district.

Table 4.23 Average monthly producer price of paddy in Anuradapura District 2000-2004 (Unit price: Rs/Kg)

	2000	2001	2002	2003	2004	Aver
Jan	12.25	12.19	14.44	15.26	15.32	13.89
Feb	10.93	12.26	13.38	11.15	14.79	12.50
Mar	7.94	11.98	12.38	11.08	13.23	11.32
Apr	10.83	10.75	12.71	10.95	11.88	11.42
May	9.54	11.68	13.02	10.45	13.64	11.67
Jun	10.50	11.53	12.76	12.05	14.14	12.20
Jul	10.43	12.09	12.25	11.01	15.23	12.20
Aug	12.75	12.24	12.54	10.71	15.80	12.81
Sep	10.06	11.77	11.99	10.87	18.01	12.54
Oct	10.48	12.49	12.25	11.42	15.42	1547

Nov	10.38	12.24	13.24	13.65	13.37	15.25
Dec	11.59	12.88	15.00	14.10	16.30	13.97
Annual ave	10.64	12.01	13.01	11.87	14.92	12.49

4.9 Present condition of the Irrigation systems

(a) Nachchaduwa Scheme

The Nachchaduwa reservoir is one of the ancient tanks in Sri Lanka. It receives water from Mahaweli system (which is the biggest project in Sri Lanka) through Kalawewa feeder canal in addition to the water from own catchments. There are two Main canals on the left bank, one is High Level (HL) and the other is Low Level Main Canal. There is only one LB sluice, which is divided into two canals just downstream of the sluice. At the station 14.5 Km of HL main canal, the Tissawewa Feeder canal from Kalawewa RB Canal joins the HL Main Canal as feeder canal. The maximum command area of the Nachchaduwa scheme is 2904 hectares. The HL main canal cuts the command area of the Thuruwila scheme, causing drainage problems as the section of siphon crossing the HL Main Canal may not be adequate. There are many irrigation structures, which require rehabilitation and improvement. The salient features of schems are shown in Table 4.24.

Table 4.24. Present condition of the system.

Item	Nachchaduwa	Thuruwila	Rajangana
Main canal & Brach canal	40 Km	2 Km	59 Km
D & F canals	107 Km	11 Km	389 Km
Canal density of D & F canals (pilot area)	62.3 m/ha	66.4 m/ha	62.8 m/ha
Condition of D & F canals	Full functioning 4 % Partly functioning 41% Not Functioning well 26% Completely not functioning 29%	Full functioning 4 6% Partly functioning 46% Not Functioning well 8% Completely not functioning 0%	Full functioning 53 % Partly functioning 30% Not Functioning well 12% Completely not functioning 5%

Conditioning of structures at D & F Canals	Full functioning 7 % Partly functioning 34% Not Functioning well 40% Completely not functioning 19%	Full functioning 58 % Partly functioning 25% Not Functioning well 10% Completely not functioning 7%	Full functioning 60 % Partly functioning 16% Not Functioning well 16% Completely not functioning 8%
No. of Turnouts (pilot area)	Concrete 84% No structure 16% PVC pipe 0%	Concrete 68% No structure 32% PVC pipe 0%	Concrete 93% No structure 7% PVC pipe 1%
Water management	Rotation in 3 to 4 day interval	Continuous	Rotation in 3 to 4 day interval
No. of FCs No. of FCG	Total D canal area; 2420 14 FOs, 150 FCGs, 2118 members	Command area; 188 ha 1 FO, 24 FCGs, 140 members	Command area; 5742 ha, 32 FOs, 513 FCGs, 6538 members
Appointment of Water master	50 % (7 out of 14 FOs)	100%	91% (29 FOs out of 32)

Note:
FC – Fields Canals FCG – Field Canal Groups, D&F – Distributory and Field canal, FO- Farmer Organization.

Table 4.25 shows the water releases of three systems from 1999 to 2004 according to the seasons. Water releases were varied according to the extent. Decisions were taken according to the water availability of the tank in corresponding season.

Table 4.25: Total Water releases from the tank - 1999 to 2004

Season	**Nachchaduwa**		**Thuruwilla**		**Rajangana**	
Dry	**Water Release (MCM)**	**Extent (Ha)**	**Water Release (MCM)**	**Extent (Ha)**	**Water Release (MCM)**	**Extent (Ha)**
1990 – dry	**29.7**	**2573**	**4.6**	**192.9**	**118.1**	**5909**
1991- dry	**8.4**	**332**	**4.6**	**192.9**	**162.0**	**6075**
1992 – dry	**12.1**	**830**	**4.6**	**192.9**	**160.2**	**5809**
1993 – dry	**13.6**	**1701**	**4.7**	**192.9**	**116.0**	**5394**
1994 – dry	**30.5**	**2603**	**4.5**	**192.9**	**161.3**	**6071**
1995 – dry	**40.9**	**2490**	**4.5**	**192.9**	**179.1**	**4813**
1996 – dry	**10.1**	**581**	**4.5**	**192.9**	**141.1**	**5038**

1997 – dry	0.0	0.0	4.4	192.9	113.4	3397
1998 – dry	25.4	1527	4.4	192.9	138.8	6515
1999 – dry	38.6	2554	4.4	192.9	161.9	6224
2000 – dry	41.2	2603	4.3	192.9	153.3	5661
2001 – dry	14.9	976	4.1	192.9	140.8	4232
2002 – dry	10.1	1030	4.0	192.9	111.3	6461
2003 – dry	43.9	2905	4.0	192.9	-	-
Season	Nachchaduwa		Thuruwilla		Rajangana	
Wet						
90/91-wet	30.1	2573	4.0	192.9	154.6	5505
91/92-wet	42.8	2573	4.1	192.9	164.8	5909
92/93-wet	25.1	2573	4.1	192.9	94.9	5505
93/94-wet	21.9	2573	4.0	192.9	98.7	2357
94/95-wet	27.6	2603	4.1	192.9	156.6	5842
95/96-wet	16.9	2063	4.1	192.9	170.1	6379
96/97-wet	28.8	2603	4.3	192.9	206.3	6639
97/98-wet	47.6	2603	4.0	192.9	157.4	5663
98/99-wet	25.0	2603	4.0	192.9	148.7	6224
99/00-wet	30.0	2603	3.8	192.9	95.0	6224
00/01-wet	14.6	2603	3.7	192.9	137.8	5661
01/02-wet	19.2	2603	3.7	192.9	139.0	5820
02/03-wet	14.9	2603	3.7	192.9	101.7	5820
03/04-wet	42.7	2905	3.4	192.9	-	-
04/05-wet	26.8	2905	3.5	192.9	-	-

4.10: Crop Calendar

Before season is started Project manager calls a meeting with Farmer Organizations, District secretary, Irrigation engineer, Agriculture Director, Insurance company and all necessary parallel agency for cultivation period. In that meeting following decisions are taking with legally validity even go for a court case.

Table 4.26 Summary of Kanna Meeting ; Crop Calendar

(a) Nachchaduwa; Maha (wet) season

No	Item	2005/06	2005/04	2003/04	2002/03	2001/02
1	Cultivation area (ha)	2800	-	1504	2800	2800
2	Paddy (ha)	2800	-	1504	2800	2800
3	Varieties (Duration month)	3.0 - 3.5	-	3.0 – 3.5	3.0 – 3.5	3.5 – 4.0
4	OFC (ha)					
5	Final date for clearing bunds and canals	25.10.05	-	26.11.03	31.10.02	20.10.01
6	Water issue for land preparation	01.11.05	-	25.11.03	01.11.02	01.11.01
7	Last date for sowing	25.11.05	-	15.12.03	25.11.02	30.11.01
8	Last date for planting OFC			10.01.04		
9	Last date to pay insurance premium	25.11.05	-	15.12.03	28.11.03	30.11.01
10	Removing cattle/ tractors from tract	25.11.05	-	05.12.03	25.11.02	30.11.01
11	Stating date of water rotation	15.12.05	-	22.12.03	10.12.02	15.12.01
12	Last date of water rotations	25.02.06	-	22.03.04		15.03.02
13	Last date to notify crop damage	25.02.06	-		25.03.03	15.03.02
14	Commence harvesting	01.03.06	-	01.04.04		
15	Complete harvesting	31.03.06	-	20.04.04	31.03.03	01.04.02
16	Letting cattle into the tract	31.03.06	-	30.04.04	10.03.03	
17	Fine for not cleaning canals					
	Field canal Rs/ 2m	100	-	100	100	
	Distributary canal RS/2m	150	-	100	100	
18	Contribution to Agrarian services Fund	20kg/.4 ha	-	10 kg/ .4 ha	10 kg/ .4 ha	10 kg/ .4 ha

(b) Nachchaduwa; Yala (Dry) season

No	Item	2005	2004	2003	2002	2001
1	Cultivation area (ha)	2800	-	2800	1070	1000
2	Paddy (ha)	1400	-	2100	110	
3	Varieties (Duration month)	3.0 - 3.5	3 – 3.5	3.0 – 3.5	3.0 – 3.5	3.5 – 4.0
4	OFC (ha)	1400		700	960	
5	Final date for clearing bunds and canals	25.10.05	-	17.04.03	10.05.02	27.04.01
6	Water issue for land preparation	17.04.05	20.05.04	17.04.03	10.05.02	27.04.01
7	Last date for sowing	18.04.05	21.05.04	18.04.03		30.11.01
8	Last date for planting OFC			12.05.03	05.06.02	15.05.01
9	Last date to pay insurance premium	25.04.05	05.06.04	12.05.03	05.06.03	15.05.01
10	Removing cattle/ tractors from tract	26.04.05	05.06.04	12.05.03	05.06.02	16.05.01
11	Stating date of water rotation	04.05.05	10.06.04	18.04.03		20.05.01
12	Last date of water rotations	25.07.25	08.09.04	12.08.03		10.08.01
13	Last date to notify crop damage	25.07.05	20.09.04	12.08.03	05.09.02	10.08.01
14	Commence harvesting		20.09.04			
15	Complete harvesting	28.08.05	30.09.04	15.09.03	25.09.02	10.09.01
16	Letting cattle into the tract	26.07.05		25.08.03		
17	Fine for not cleaning canals					
	Field canal Rs/ 2m	100	100	100	100	75
	Distributary canal RS/2m	150	100	100	100	100
18	Contribution to Agrarian services Fund	20kg/.4 ha	10 kg/ .4 ha	10 kg/ .4 ha	Rs100/ .4 ha	

(c) Rajangana ; Maha (wet) season

No	Item	2005/06	2005/04	2003/04	2002/03	2001/02
1	Cultivation area (ha)	6200	6200	6200	6200	6200
2	Paddy (ha)	4440	4440	4440	4440	4440
3	Varieties (Duration month)	3.0 - 3.5 -4	3 – 3.5	3.0 – 3.5	3.5 – 4	3. – 3.5
4	OFC (ha)	1760	1760	1760	1760	1760
5	Final date for clearing bunds and canals	05.10.05	15.10.04	30.09.03	01.10.02	30.10.01
6	Water issue for land preparation	05.10.05	25.10.04	15.01.03	07.10.02	05.11.01
7	Last date for sowing	01.11.05	25.11.04	10.11.03	30.10.02	26.11.01
8	Last date for planting OFC					
9	Last date to pay insurance premium		25.11.04			26.11.04
10	Removing cattle/ tractors from tract	01.11.05	25.11.04	10.10.03	30.10..02	26.11.01
11	Stating date of water rotation		16.12.04			
12	Last date of water rotations	05.03.06	02.03.05		24.03.02	01.03.02
13	Last date to notify crop damage		20.02.05		14.02.03	26.02.02
14	Commence harvesting	01.03.06	06.03.05			
15	Complete harvesting	01.04.06			05.03.03	01.03.02
16	Letting cattle into the tract	01.04.06	15.04.05	31.03.04	07.10.05	05.11.01
17	Fine for not cleaning canals					
	Field canal Rs/ 2m	50	25	50	25	25
	Distributary canal RS/2m	500	200	100	200/day	200/day
18	Contribution to Agrarian services Fund	10kg/.4 ha	10kg/.4 ha	10 kg/ .4 ha	10 kg/ .4 ha	10 kg/ .4 ha

(d) Rajangana; Yala (Dry) season

No	Item	2005	2004	2003	2002	2001
1	Cultivation area (ha)	6200	-	6200	6200	6200
2	Paddy (ha)	4440	-	44040	4440	4440
3	Varieties (Duration month)	3.0 - 3.5	-	3.0 – 3.5	3.0 – 3.5	3.0 – 3.5
4	OFC (ha)	1760	-	1760	1760	1760
5	Final date for clearing bunds and canals	10.04.05	-	15.03.03	15.04.02	17.04.01
6	Water issue for land preparation	10.04.05	-	17.04.03	10.05.02	21.04.01
7	Last date for sowing	15.05.05	-	10.04.03	15.05.02	20.05.01
8	Last date for planting OFC					
9	Last date to pay insurance premium	15.05.05	-	10.04.03	15.05.02	20.05.01
10	Removing cattle/ tractors from tract	15.05.05	-	10.04.03	15.05.02	20.05.01
11	Stating date of water rotation	22.05.05	-			20.04.01
12	Last date of water rotations	15.08.05	-		15.08.02	20.08.01
13	Last date to notify crop damage	25.08.05	-	15.06.03	26.07.02	20.08.01
14	Commence harvesting	15.08.05	-			
15	Complete harvesting	15.09.05	-	30.07.03	25.09.02	30.09.01
16	Letting cattle into the tract			15.03.03	15.04.02	20.04.01
17	Fine for not cleaning canals					
	Field canal Rs/ 2m	25	-	25	25	25
	Distributary canal RS/2m	250	-	200	200	200/day
18	Contribution to Agrarian services Fund	10kg/.4 ha	-	100/ ha	10Kg/ .4 ha	100/ha

Source; Minutes of cultivation meetings Rajangana RPM office.

WRD&M - IIT Roorkee

CHAPTER V

Master of Technology Thesis

B.A. KANTHI
6/15/2007

Chapter 5

Calculation of Performance Indicators

As discussed in the previous chapters, performance evaluation is imperative for not only assessment of the system of the status of irrigation schemes but also for improved performance. To this end, three schemes namely Nachchiduwa, Thuruwila and Rajangana (Chapter 4) were selected for evaluation and performance indicators (Chapter 3) are computed and this chapter presents their computation using the data described in Chapter 4. Here it is noted that while calculating the performance indicators some assumptions need to be made to initiate computation under different stages and these are mentioned at the required places.

5.1 Delivery Performance Ratio

The delivery performance ratio is described as follows;

$$Delivery\ Performance\ Ratio = \frac{Actual\ Discharge}{Target\ Discharge} \text{------------------(1)}$$

It is the most important, operational performance indicator. Since only one system (Nachchiduwa) has complete data set, from sluice discharge to field application level. Therefore DPR is computed only for this system. The other two systems which are Thuruwila and Nachchiduwa did not have such reliable measurements, and therefore, omitted in DPR computation.

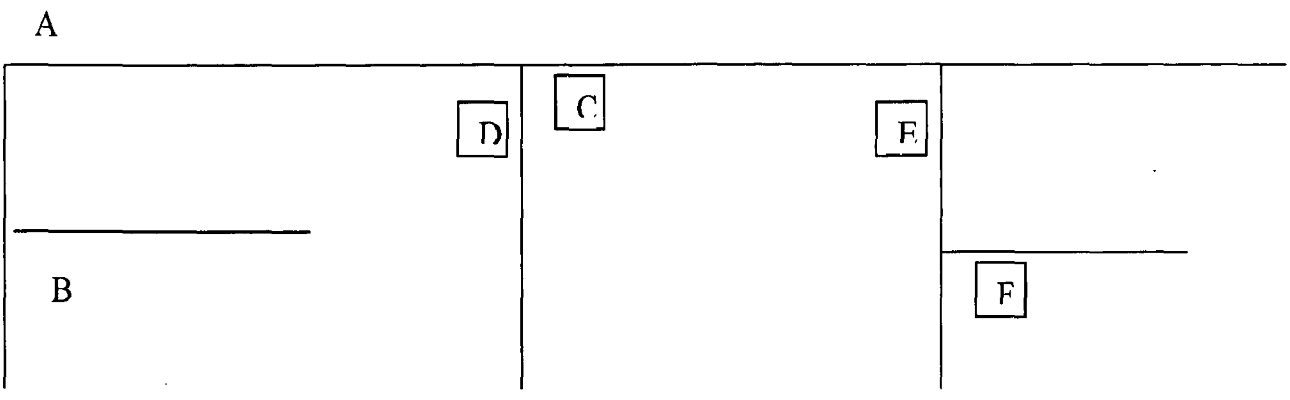


Figure: 5.1 Line diagram of Nachchiduwa system which represent only considered points for calculation.

In any system maximum amount of water is delivered during land preparation period. Therefore, DPR is computed for above 6 points of delivering the Nachchiduwa system. Details of fug 5.1 are provided in Appendix -1. The measured daily discharges are given in Tables 5.1 and 5.2.

Table 5.1 Daily Discharge measurements.

Point A Discharge(m3/s)			Point B Discharge(m3/s)			Point C Discharge(m3/s)		
Actual	Target	DPR	Actual	Target	DPR	Actual	Target	DPR
6.87	6.8	1.010	0	1.22	0	0	2.83	0
6.75	6.8	0.993	0	1.22	0	3.499	2.83	1.236
5.34	6.8	0.785	1.039	1.22	0.852	2.845	2.83	1.005
4.63	6.8	0.681	1.209	1.22	0.991	2.058	2.83	0.727
4.73	6.8	0.696	1.395	1.22	1.143	1.916	2.83	0.677
4.63	6.8	0.681	1.180	1.22	0.967	2.058	2.83	0.727
5.23	6.8	0.770	1.331	1.22	1.091	2.107	2.83	0.745
5.76	6.8	0.847	1.094	1.22	0.897	3.375	2.83	1.193
4.73	6.8	0.696	1.039	1.22	0.852	3.017	2.83	1.066
5.03	6.8	0.740	1.363	1.22	1.117	2.107	2.83	0.745
5.76	6.8	0.847	1.039	1.22	0.852	2.256	2.83	0.797
6.64	6.8	0.976	1.363	1.22	1.117	2.41	2.83	0.852
6.75	6.8	0.993	1.012	1.22	0.830	2.733	2.83	0.966
6.52	6.8	0.959	0.959	1.22	0.786	2.902	2.83	1.025
6.19	6.8	0.910	1.180	1.22	0.967	2.733	2.83	0.966
6.19	6.8	0.910	1.180	1.22	0.967	3.254	2.83	1.150
0.00	6.8	0.000	0.000	1.22	0.000	1.823	2.83	0.644
6.08	6.8	0.894	1.151	1.22	0.943	1.778	2.83	0.628
6.52	6.8	0.959	1.300	1.22	1.066	1.733	2.83	0.612
6.64	6.8	0.976	0.985	1.22	0.807	2.959	2.83	1.046
0.00	6.8	0.000	1.039	1.22	0.852	2.902	2.83	1.025
5.23	6.8	0.770	1.239	1.22	1.016	2.256	2.83	0.797
4.63	6.8	0.681	1.151	1.22	0.943	1.778	2.83	0.628
4.63	6.8	0.681	1.151	1.22	0.943	2.206	2.83	0.780
5.34	6.8	0.785	0.834	1.22	0.684	2.156	2.83	0.762

Average DPR 0.802 0.904 0.845

Table 5.2 Daily Discharge measurements.

Point D Discharge(m^3/s)			Point E Discharge(m^3/s)			Point F Discharge(m^3/s)		
Actual	Target	DPR	Actual	Target	DPR	Actual	Target	DPR
0	2.83	0	0.833	1.22	0.683	0.000	3.5	0
0	2.83	0	0.97	1.22	0.795	0.000	3.5	0
1.798	2.83	0.635	0.883	1.22	0.724	0.168	3.5	0.048
2.04	2.83	0.721	0.628	1.22	0.515	0.056	3.5	0.016
2.294	2.83	0.811	0.431	1.22	0.353	0.000	3.5	0
2.617	2.83	0.925	0.406	1.22	0.333	0.000	3.5	0
2.617	2.83	0.925	0.512	1.22	0.420	1.008	3.5	0.288
3.192	2.83	1.128	0.784	1.22	0.643	1.344	3.5	0.384
2.841	2.83	1.004	0.752	1.22	0.616	0.756	3.5	0.216
2.4	2.83	0.848	0.512	1.22	0.420	0.056	3.5	0.016
2.4	2.83	0.848	0.72	1.22	0.590	0.392	3.5	0.112
2.617	2.83	0.925	0.689	1.22	0.565	0.252	3.5	0.072
2.956	2.83	1.045	0.643	1.22	0.527	0.112	3.5	0.032
3.073	2.83	1.086	0.72	1.22	0.590	3.416	3.5	0.976
3.073	2.83	1.086	0.883	1.22	0.724	4.172	3.5	1.192
3.192	2.83	1.128	0.987	1.22	0.809	2.212	3.5	0.632
2.453	2.83	0.867	0.613	1.22	0.502	1.736	3.5	0.496
2.294	2.83	0.811	0.673	1.22	0.552	0.392	3.5	0.112
2.294	2.83	0.811	0.569	1.22	0.466	0.000	3.5	0
3.073	2.83	1.086	0.817	1.22	0.670	0.168	3.5	0.048
2.956	2.83	1.045	0.752	1.22	0.616	1.176	3.5	0.336
3.073	2.83	1.086	0.752	1.22	0.616	0.252	3.5	0.072
2.4	2.83	0.848	0.583	1.22	0.478	0.000	3.5	0
1.99	2.83	0.703	0.752	1.22	0.616	0.000	3.5	0
2.507	2.83	0.886	0.918	1.22	0.752	1.540	3.5	0.44

Average DPR 0.923 0.56 0.22

Table 5.3 summary of DPR value

Points	A	B	C	D	E	F
Average DPR	0.802	0.904	0.845	0.92	0.56	0.22

5.2 Water Delivery Performance Ratio

The water delivery performance is defined as follows. It is deviated from DPR though it look alike. DPR is based on discharge and WDP is based on volume.

$$Water\ Delivery\ Performance = \frac{Actual\ Volume}{Target\ Volume} \text{ -----------------(2)}$$

To calculate target volume intended water supply to the field is 10.62 mm/day according to the crop water requirement. Then field application efficiency is 85 % which is calculated as below. Distributory and conveyance efficiencies are 63 % and 70% respectively.

Then Target volume=[{Intended water supply (mm/day) * Area cultivated }/Efficiencies] + Land preparation water volume.(ave.5 million cubic meter)

Here effective rainfall is not considered, because volume is calculated for hole system. Sometime the overall system may not receive rainfall uniformly. However some extent of it is reflected in actual discharge volume. The related data are given in following Tables of 5.4-5.8.

Table 5.4 useful data for crop water requirement calculation

Project : Udawalawe		Climatic Station :	Udawalawa - 2004			
Latitude : 8" North Lat.		Altitude :		65.00"		
Month	Temp 0 C	Humidity	Wind speed (Km/day)	Sunshine Hours	Radiation $MJ/m^2/d$	ETo–Penman mm/day
January	25.9	88	49	6.3	17.1	3.2
February	26.8	85	56	7.1	19.4	3.8
March	27.8	83	49	7.5	21	4.3
April	27.7	83	125	6.6	19.7	4.2
May	28.1	77	135	6.7	19.3	4.3
June	30.7	73	156	7.1	19.4	4.7
July	28.5	70	310	8.2	21.2	5.6
August	27.9	71	181	8.7	22.5	5.2
September	28.1	72	168	7.1	20.3	4.7
October	27	84	146	4.7	16	3.5
November	26.5	88	65	6	16.9	3.4
December	26.3	89	52	7.4	18.2	3.5

Table 5.5 Calculation of Crop water requirement

Season ; Dry (Yala)
Starting date ; 17-May-2004
Crop ; Paddy
Crop periad ; 105 days

Period	E_{to} mm/day	Eto for the month (mm)	Crop coeficiant K_c	Etc = E_{to}*K_C mm	seepage & perco. (assum 5 mm/day)	Total requirment (mm)
17May/26May	4.3	43	1.2	51.6	50	101.6
27May/5Jun	(4.3 *5+4.7*5)/10	45	1.2	54	50	104
6Jun/15Jun	4.7	47	1.2	56.4	50	106.4
16Jun/25Jun	4.7	47	1.2	56.4	50	106.4
26Ju/5Juy	(4.7*5+5.6*5)/10	51.5	1	51.5	50	101.5
6Juy/15Juy	5.6	56	1	56	50	106
16Juy/25Juy	5.6	56	1.1	61.6	50	111.6
26Juy/4Aug	(5.6*6+5.2*4)/10	54.4	1.1	59.84	50	109.84
5Aug/14Aug	5.2	27.5	1.1	60.5	50	110

Table 5.5 refers the period with corresponding month. But in the calculations it took as Initial stage, Mid stage, Development stage, Later stage.

Table 5.6: Calculation of Average Delivery Performance for Nachchiduwa

Season	(1) Actual Water volume (MCM)	Extent(Ha)	(2) Target volume (MCM)	(3) Water Delivery Performance = (1) / (2) (MCM)	Average delivery performance
1990	29.7	2573	29.18324	1.018	
1991	8.4	332	3.765579	2.231	
1992	12.1	830	9.413947	1.285	
1993	13.6	1701	19.29292	0.705	
1994	30.5	2603	29.5235	1.033	
1995	40.9	2490	28.24184	1.448	
1996	10.1	581	6.589763	1.533	
1997	0.0	0.0	0.0	0.0	
1998	25.4	1527	17.31939	1.467	
1999	38.6	2554	28.96774	1.333	
2000	41.2	2603	29.5235	1.395	
2001	14.9	976	11.06989	1.346	
2002	10.1	1030	11.68237	0.865	
2003	43.9	2905	32.94882	1.332	1.307
90/91	30.1	2573	29.18324	1.031	
91/92	42.8	2573	29.18324	1.467	
92/93	25.1	2573	29.18324	0.860	
93/94	21.9	2573	29.18324	0.750	
94/95	27.6	2603	29.5235	0.935	
95/96	16.9	2063	23.39876	0.722	
96/97	28.8	2603	29.5235	0.975	
97/98	47.6	2603	29.5235	1.612	
98/99	25.0	2603	29.5235	0.847	
99/00	30.0	2603	29.5235	1.016	
00/01	14.6	2603	29.5235	0.495	
01/02	19.2	2603	29.5235	0.650	
02/03	14.9	2603	29.5235	0.505	
03/04	42.7	2905	32.94882	1.296	
04/05	26.8	2905	32.94882	0.813	0.932

Table 5.7: Calculation of Average Delivery Performance for Rajangana

Season	(1) Actual Water volume (MCM)	Extent (ha)	(2) Target volum (MCM)	3) Water Delivery Performance = (1) / (2) (MCM)	Average delivery performance
1990	118.1	5909	137.6637	0.857888	
1991	162.0	6075	141.5311	1.144625	
1992	160.2	5809	135.334	1.183738	
1993	116.0	5394	125.6656	0.923085	
1994	161.3	6071	141.4379	1.14043	
1995	179.1	4813	112.1299	1.597255	
1996	141.1	5038	117.3718	1.202163	
1997	113.4	3397	79.14092	1.432887	
1998	138.8	6515	151.7819	0.91447	
1999	161.9	6224	145.0024	1.116533	
2000	153.3	5661	131.886	1.162367	
2001	140.8	4232	98.59416	1.428076	
2002	111.3	6461	150.5238	0.739418	1.142
2003	-	-	0		
90/91	154.6	5505	128.2516	1.205443	
91/92	164.8	5909	137.6637	1.19712	
92/93	94.9	5505	128.2516	0.739952	
93/94	98.7	2357	54.91173	1.79743	
94/95	156.6	5842	136.1028	1.150601	
95/96	170.1	6379	148.6135	1.14458	
96/97	206.3	6639	154.6708	1.333801	
97/98	157.4	5663	131.9326	1.193033	
98/99	148.7	6224	145.0024	1.0255	
99/00	95.0	6224	145.0024	0.655162	
00/01	137.8	5661	131.886	1.044842	
01/02	139.0	5820	135.5903	1.025147	
02/03	101.7	5820	135.5903	0.750054	1.097

Table 5.8: Calculation of Average Delivery Performance for Thuruwila

Season	(1) Actual Water volume (MCM)	Extent (ha)	(2) Target volum (MCM)	3) Water Delivery Performance = (1) / (2) (MCM)	Average delivery performance
1990- Dry	4.6	192.9	4.494	1.024	
1991	4.6	192.9	4.494	1.024	
1992	4.6	192.9	4.494	1.024	
1993	4.7	192.9	4.494	1.046	
1994	4.5	192.9	4.494	1.001	
1995	4.5	192.9	4.494	1.001	
1996	4.5	192.9	4.494	1.001	
1997	4.4	192.9	4.494	0.979	
1998	4.4	192.9	4.494	0.979	
1999	4.4	192.9	4.494	0.979	
2000	4.3	192.9	4.494	0.957	
2001	4.1	192.9	4.494	0.912	
2002	4.0	192.9	4.494	0.890	
2003	4.0	192.9	4.494	0.890	0.979
90/91-Wet	4.0	192.9	4.494	0.890	
91/92	4.1	192.9	4.494	0.912	
92/93	4.1	192.9	4.494	0.912	
93/94	4.0	192.9	4.494	0.890	
94/95	4.1	192.9	4.494	0.912	
95/96	4.1	192.9	4.494	0.912	
96/97	4.3	192.9	4.494	0.957	
97/98	4.0	192.9	4.494	0.890	
98/99	4.0	192.9	4.494	0.890	
99/00	3.8	192.9	4.494	0.846	
00/01	3.7	192.9	4.494	0.823	
01/02	3.7	192.9	4.494	0.823	
02/03	3.7	192.9	4.494	0.823	
03/04	3.4	192.9	4.494	0.757	
04/05	3.5	192.9	4.494	0.779	0.868

Tables 5.6, 5.7, 5.8 show the delivery performances of more than 13 different seasons. Calculations have been done for wet and dry seasons separately for understanding seasonal difference. Dry season always shows the higher delivery performance because of less rainfall. If the rainfall is high required delivery amount of water is less.

Table 5.9: Summary of water delivery performance.

Description	Nachchiduwa	Thuruwila	Rajangana
Dry Season	1.307	0.979	1.142
Wet Season	0.932	0.868	1.097

5.3 Overall Project efficiency

The Overall Project Efficiency is defined as follows:

$$3)\ Overall\ \mathrm{Pr}oject\ Efficiency = \frac{Crop\ Irrigation\ Water\ \mathrm{Re}quirment}{Total\ Inflow\ \mathrm{int}o\ Canal\ System} \text{-----------------(3)}$$

Total inflow of the canal system is varied according to the irrigable area and the corresponding rainfall of the particular season. Therefore overall project efficiency is calculated for a season and its average represent the desired value. Crop water requirement for 85 days is 10.45 mm/day and for 5 days 5.23 mm/day. Calculations are prepared as Tables 5.10, 5.11, 5.12 Nachchiduwa , Thuruwila, and Rajangana respectively.

Table 5.10: Calculation of Overall project efficiency in Nachchiduwa Dry

Season Dry	(1) Water Issues(MCM)	Extent(Ha)	(2) Crop water requirement volume(MCM)	Overall project efficiency=(2)/(1)	Average efficiency
1990	29.7	2573	22.17926	0.746776	
1991	8.4	332	2.86184	0.340695	
1992	12.1	830	7.1546	0.591289	
1993	13.6	1701	14.66262	1.078134	
1994	30.5	2603	22.43786	0.735668	
1995	40.9	2490	21.4638	0.524787	
1996	10.1	581	5.00822	0.495863	
1997	0.0	0.0	0		
1998	25.4	1527	13.16274	0.518218	
1999	38.6	2554	22.01548	0.570349	
2000	41.2	2603	22.43786	0.544608	
2001	14.9	976	8.41312	0.564639	
2002	10.1	1030	8.8786	0.879069	
2003	43.9	2905	25.0411	0.570412	.6277

Table 5.10: Calculation of Overall project efficiency in Nachchiduwa Wet

90/91-Wet	30.1	2573	22.17926	0.736852	
91/92	42.8	2573	22.17926	0.518207	
92/93	25.1	2573	22.17926	0.883636	
93/94	21.9	2573	22.17926	1.012752	
94/95	27.6	2603	22.43786	0.812966	
95/96	16.9	2063	17.78306	1.052252	
96/97	28.8	2603	22.43786	0.779092	
97/98	47.6	2603	22.43786	0.471384	
98/99	25.0	2603	22.43786	0.897514	
99/00	30.0	2603	22.43786	0.747929	
00/01	14.6	2603	22.43786	1.53684	
01/02	19.2	2603	22.43786	1.168639	
02/03	14.9	2603	22.43786	1.505897	
03/04	42.7	2905	25.0411	0.586443	
04/05	26.8	2905	25.0411	0.934369	.9097

Table 5.11: Calculation of Overall project efficiency in Thuruwila

Season	(1) Actual Water Issues(MCM)	Extent (ha)	(2) Crop water requirement volume(MCM)	Overall project efficency=(2)/(1)	Average efficiency
1990-Dry	4.6	192.9	1.662798	0.361478	
1991	4.6	192.9	1.662798	0.361478	
1992	4.6	192.9	1.662798	0.361478	
1993	4.7	192.9	1.662798	0.353787	
1994	4.5	192.9	1.662798	0.369511	
1995	4.5	192.9	1.662798	0.369511	
1996	4.5	192.9	1.662798	0.369511	
1997	4.4	192.9	1.662798	0.377909	
1998	4.4	192.9	1.662798	0.377909	
1999	4.4	192.9	1.662798	0.377909	
2000	4.3	192.9	1.662798	0.386697	
2001	4.1	192.9	1.662798	0.40556	
2002	4.0	192.9	1.662798	0.4157	
2003	4.0	192.9	1.662798	0.4157	0.378867
90/91-Wet	4.0	192.9	1.662798	0.4157	
91/92	4.1	192.9	1.662798	0.40556	
92/93	4.1	192.9	1.662798	0.40556	
93/94	4.0	192.9	1.662798	0.4157	
94/95	4.1	192.9	1.662798	0.40556	
95/96	4.1	192.9	1.662798	0.40556	
96/97	4.3	192.9	1.662798	0.386697	
97/98	4.0	192.9	1.662798	0.4157	
98/99	4.0	192.9	1.662798	0.4157	
99/00	3.8	192.9	1.662798	0.437578	
00/01	3.7	192.9	1.662798	0.449405	
01/02	3.7	192.9	1.662798	0.449405	
02/03	3.7	192.9	1.662798	0.449405	
03/04	3.4	192.9	1.662798	0.489058	
04/05	3.5	192.9	1.662798	0.475085	0.428112

Table 5.12: Calculation of Overall project efficiency in Rajangana

	Water Issues(MCM)	Extent (ha)	(2) Crop water requirement volume(MCM)	Overall project efficency=(2)/(1)	Average efficiency
1990-Dry	118.1	5909	50.93558	0.431292	
1991	162.0	6075	52.3665	0.32325	
1992	160.2	5809	50.07358	0.312569	
1993	116.0	5394	46.49628	0.40083	
1994	161.3	6071	52.33202	0.324439	
1995	179.1	4813	41.48806	0.231647	
1996	141.1	5038	43.42756	0.307779	
1997	113.4	3397	29.28214	0.25822	
1998	138.8	6515	56.1593	0.404606	
1999	161.9	6224	53.65088	0.331383	
2000	153.3	5661	48.79782	0.318316	
2001	140.8	4232	36.47984	0.25909	
2002	111.3	6461	55.69382	0.500394	0.3378
90/91-Wet	154.6	5505	47.4531	0.306941	
91/92	164.8	5909	50.93558	0.309075	
92/93	94.9	5505	47.4531	0.500033	
93/94	98.7	2357	20.31734	0.205849	
94/95	156.6	5842	50.35804	0.321571	
95/96	170.1	6379	54.98698	0.323263	
96/97	206.3	6639	57.22818	0.277403	
97/98	157.4	5663	48.81506	0.310134	
98/99	148.7	6224	53.65088	0.360799	
99/00	95.0	6224	53.65088	0.564746	
00/01	137.8	5661	48.79782	0.354121	
01/02	139.0	5820	50.1684	0.360924	
02/03	101.7	5820	50.1684	0.493298	0.3606

Tables 5.10, 5.11, 5.12 show the Overall project efficiency of more than 13 different seasons. It gives the different values between the systems rather than seasons. Rajangana and Thuruwila give the very low efficiency compare to the Nachchiduwa. Summary of overall project efficiency is given in Table 5.13.

Table 5.13: Summary of overall project efficiency.

Description	Nachchiduwa	Thuruwila	Rajangana
Dry Season	**0.6277**	**0.378867**	**0.3378**
Wet Season	**0.9097**	**0.428112**	**0.3606**

5.4 Conveyance efficiency

The conveyance efficiency is defined as follows:

$$Conveyance\ Efficiency = \frac{Total\ Water\ \text{sup}\,plied\ by\ the\ Conveyance\ System}{Total\ Inflow\ \text{int}\,o\ The\ Conveyance\ System} \quad \text{------(4)}$$

In this system total water supplied by the conveyance system is discharge at **A***. Total inflow into the conveyance system is discharge at **A**. For this calculation 2004 dry season data is used and it divided in to 10 periods. They are Land preparation, Initial stage 1,2, Development stage 1,2,3, Middle stage 1,2, Later stage 1,2. Total land preparation period is consider as a one group. Because of that period water discharge cannot compare with the irrigation requirement. It has a big different with the requirement due to uneven land preparation starting. Water issue period is 100 days for crop and it devided in to 10 stage as explained above. Table 5.14 shows the calculation for conveyance efficiency.

Figure: 5.2 Line diagram of Nachchiduwa system which represent only considered points for calculation.

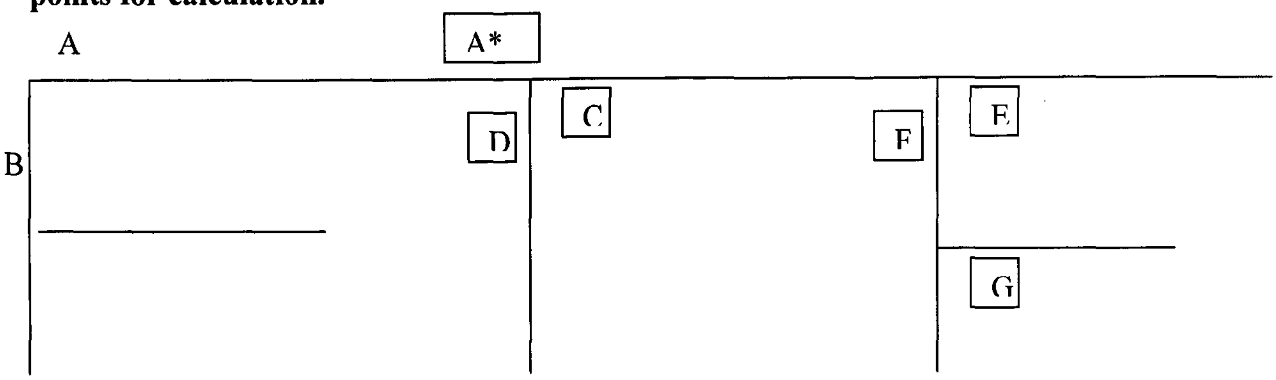


Table 5.14: Calculation of Conveyance efficiency in Nachchiduwa

Period 10 days	Discharge at A MCM	Discharge at A* MCM	Rain Fall mm	CWR mm	A-A* 355 ha Requirement MCM	Total Inflow MCM	Conveyance efficiency
Land (25days) preparation	117.38	141.81	185	0	0	0	0
Ini_1	34.14	29.49	5.6	101.6	4.50	29.64	1.00
Ini_2	32.57	28.94	59.9	104	4.61	27.97	1.03
Dev_1	41.39	34.91	3.2	106.4	4.71	36.68	0.95
Dev_2	41.76	33.47	0	106.4	4.71	37.05	0.90
Dev_3	38.85	33.14	0	101.5	4.50	34.35	0.96
Mid_1	38.20	32.00	0	106	4.70	33.50	0.96
Mid_2	41.31	32.07	0	106	4.70	36.61	0.88
Mid_3	41.23	32.96	0	104.4	4.62	36.61	0.90
Lat_1	38.69	31.26	0	110	4.87	33.82	0.92
Lat_2	40.32	32.86	13.4	110	4.87	35.45	0.93
					Average conveyance eff.		0.944

5.5 Distribution Efficiency

The distribution efficiency is defined as follows:

$$Distribution\ Efficiency = \frac{Total\ Water\ Delivery\ To\ Fields}{Total\ Inflow\ \text{into}\ the\ Delivery\ System} \text{------------}(5)$$

In this system total water supplied by the distributory system is discharge at F. Total inflow into the conveyance system is discharge at G. For this calculation 2004 dry season data is used as previous and it divided in to 9 periods. Calculation is same as above, and shown in Table 5.15.

Table 5.15: Calculation of Distributory efficiency in Nachchiduwa

Period 10 days	Discharge at F MCM	Discharge at G MCM	Rain Fall mm	CWR mm	F-G 60 ha Requirement MCM	Total Inflow MCM	Distributory efficiency
	19.83	0.70	185				
Ini_1	4.81	0.09	5.6	101.6	4.20	4.29	1.12
Ini_2	4.31	0.14	59.9	104	4.30	4.44	0.97
Dev_1	6.49	0.02	3.2	106.4	4.40	4.42	1.47
Dev_2	3.47	0.28	0	106.4	4.40	4.68	0.74
Dev_3	3.71	0.26	0	101.5	4.19	4.45	0.83
Mid_1	4.51	0.65	0	106	4.38	5.03	0.90
Mid_2	4.15	0.87	0	106	4.38	5.25	0.79
Mid_3	5.14	0.55	0	104.4	4.31	4.86	1.06
Lat_1	3.05	0.14	0	105	4.34	4.48	0.68
Lat_2	5.13	0.39	0	110	4.54	4.93	1.04
Lat_3	5.88	0.48	0	110	4.54	5.02	1.17

According to the calculation, total inflow get minus values. Because requirement is high. It is covered by rainfall in some stage. Dividing of this time period is according to the theory. But in practical situation excess water has been released and period is long. It means inside the field stager system is implemented. That is why total inflow and total outflow gives practical value.

Total delivery to field = 50.65
Total inflow into the delivery system = 51.84

Distribution Efficiency = 50.65/51.84
= **0.977**

5.6 Field Application Efficiency

The Field Application Efficiency is defined as follows:

$$Field\ Application\ Efficiency = \frac{Crop\ Irrigation\ Water\ \text{Requirement}}{Water\ Delivery\ To\ Field} \text{---------(6)}$$

Table 5.16.gives the field requirement of water and actual supply to the field. It shows in the Mid -1, Mid – 2, Mid – 3 periods actual supply is very high. But in the Initial stage there is no even field requirement. But it seems that rainfall is managing the field requirement.

Table 5.16: Calculation of Field Application efficiency in Nachchiduwa

Period	Discharge at G (MCM)	Rain Fall mm	CWR mm	CWR (MCM)	Field Application Efficiency
Land preparation	0.7	185			
Ini_1	0.09	5.6	101.6	0.31	3.44
Ini_2	0.14	59.9	104	0.32	2.32
Dev_1	0.02	3.2	106.4	0.33	19.09
Dev_2	0.28	0	106.4	0.33	1.18
Dev_3	0.26	0	101.5	0.31	1.21
Mid_1	0.65	0	106	0.33	0.50
Mid_2	0.87	0	106	0.33	0.38
Mid_3	0.55	0	104.4	0.32	0.59
Lat_1	0.14	0	104.8	0.32	2.36
Lat_2	0.39	0	110	0.34	0.88
Lat_3	0.48	13.4	110	0.34	0.70
Total	3.86			3.58	

Field Application Efficiency = 3.58 / 3.86

= 0.73

5.7 Effectiveness of Infrastructure

The Effectiveness of Infrasructure is defined as follows.

$$Effective\,ness\ Of\ Infrastructure = \frac{Number\ of\ Functionning\ Structures}{Total\ Number\ of\ Structure} \text{-----------(7)}$$

According to the Fig 5.3, 5.4, 5.5 following table is prepared. Fore the effectiveness of the structures Fully functioning and partly functioning were taken as functioning structures. Others are taken as not functioning. Table 5.17 shows that functioning structure is higher in Rajangana than others. But both Nachchiduwa and Rajangana rehabilitate in 1989. It seems that Rajangana scheme is intensively managed by the Irrigation Department. Generally, a deviation of more than 5% of actual discharge from calibrated would signal the need for maintenance or rehabilitation for flow control structures. Maintenance is needed to keep the system in operational condition

Table 5.17 Calculation of Effectiveness of Infrastuctures

Description	Nachchiduwa	Thuruwila	Rajangana
Fully functioning	15	126	146
Partly functioning	73	54	40
Not functioning well	86	22	39
Completely not functioning	41	16	19
Total functioning structure	88	180	186
Total number of structure	214	218	244
Effectiveness of structure	0.41	0.83	0.76

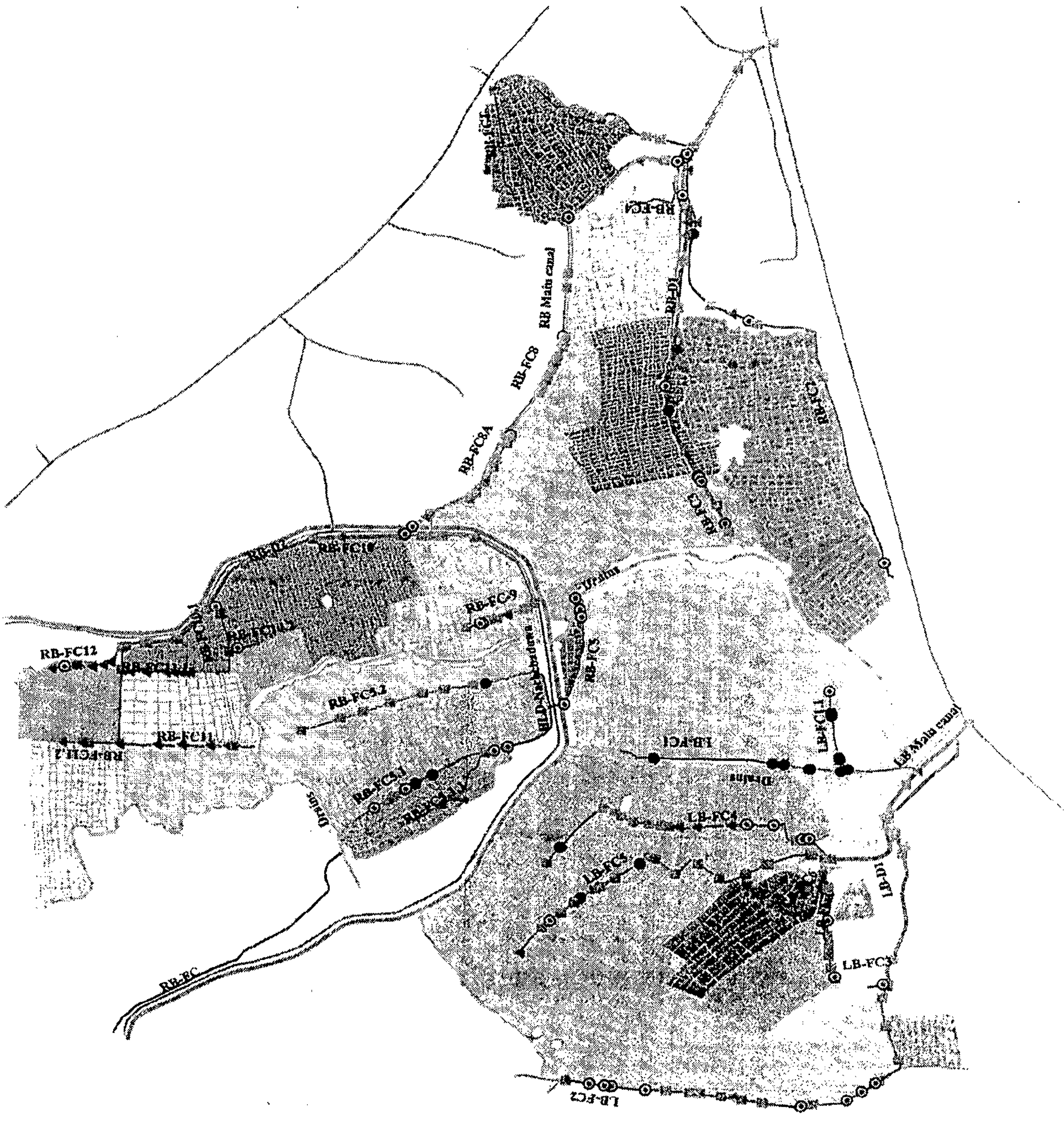


Figure 5.3 Sample area from Thuruwilla scheme

Figure 5.4 Sample area from Rajangana scheme

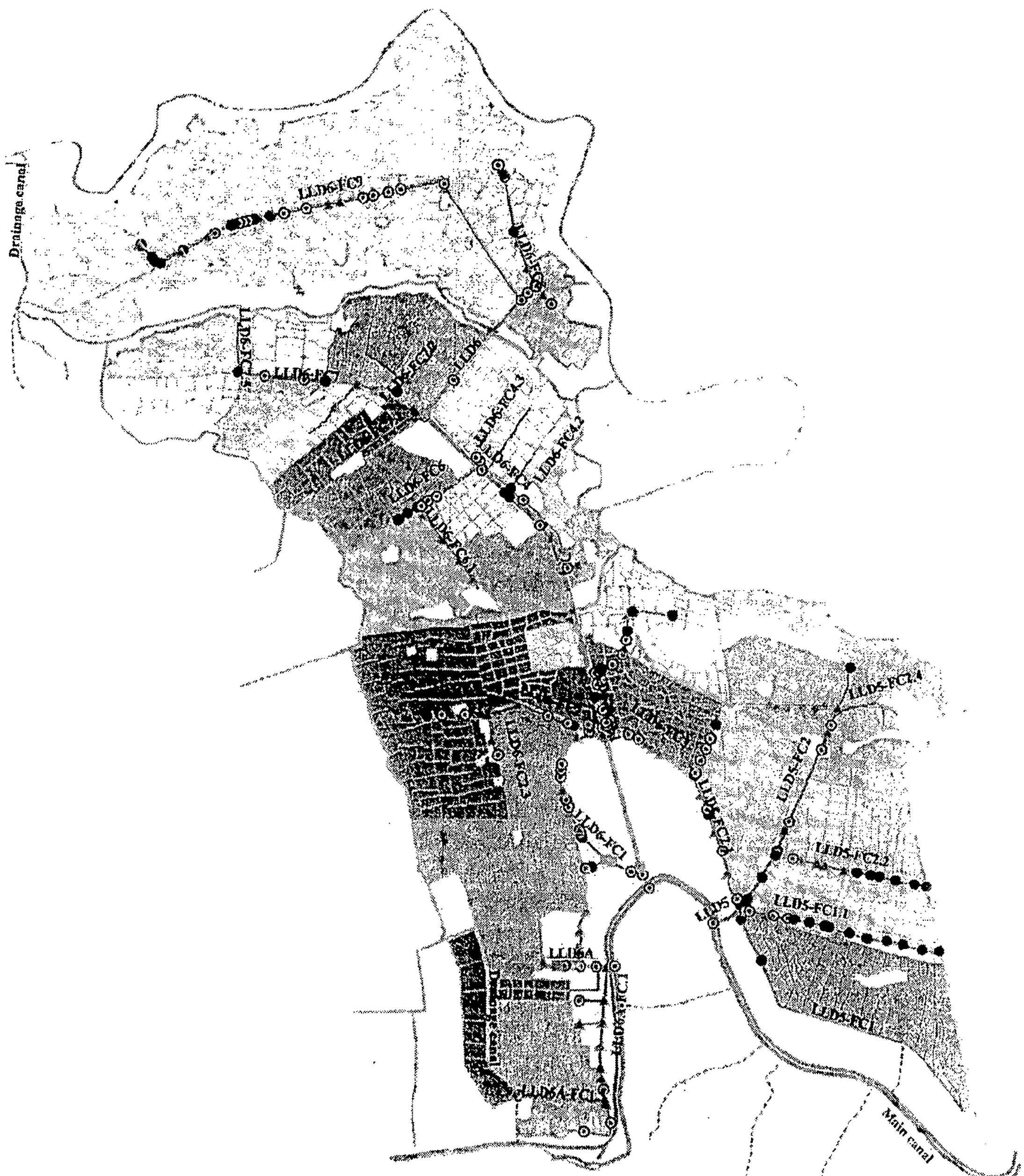


Figure 5.5 Sample area from Nachchiduwa scheme

5.8 Equipment Effectiveness

The Equipment Effectiveness is defined as follows:

$$Equipment\ \ Effectiveness = \frac{Actually\ \ Functioning\ \ Equipment}{Total\ \ Equipment\ \ \Pr ovided} \text{ ------------(8)}$$

Although this is an important indicator of maintenance, it is difficult to calculate for one system. Because, most of the time equipment is sharing with other neighboring systems, due to lack of resources. The extent to which equipment provided for use by system managers to maintain and use the infrastructure is in good working condition. Considering Concrete Mixers, Tamping Rollers, Backhoe, Vibrators, Draggers, etc. Therefore there is some degree of subjective ness in this ratio. But it gives an indicative measure of the extent to which capital investment for maintenance is being properly allocated. Table 5.18 shows the detail about for three system.

Table 5.18 Calculation of Equipment Effectiveness

Nachchiduwa	Actually functioning equipment	8
	Total equipment provided	12
	Equipment Effectiveness	0.67
Ragangana	Actually functioning equipment	5
	Total equipment provided	10
	Equipment Effectiveness	0.5
Thuruwila	Actually functioning equipment	5
	Total equipment provided	10
	Equipment Effectiveness	0.5

5.9 Relative Water Supply

The Relative Water Supply is defined as follows:

$$\text{Relative Water Supply} = \frac{\text{Irrigation} + \text{Effective Rainfall}}{\text{Evapotranspiration} + \text{Seepage} + \text{Percolation}} \text{-----------(9)}$$

Determination of Relative Water Supply is not entirely straightforward. Demand totaly based on technical criteria, such as evapotranspiration demand for particular crops or cropping patterns, and it may include water lost through natural seepage and percolation. Demand , also include allowances for cultural practices, such as use of water for weed control in rice cultivation, for leaching if salt needs to be removed from the root zone, and it may include assumptions about desired responses to rainfall. The standard approach is to assess adequacy over the cycle of water deliveries within an irrigation system.

Irrigation + Effective Rainfall

According to the FAO (1986) effective rain fall (Pe)

1. Pe = 0.8 P – 25 if P is less than 75 mm/month
2. Pe = 0.6 P – 10 if P is greater than 75 mm/month

Table 5.19 Calculation of Irrigation + Effective Rainfall

Period	Irrigation (l/s) For 2855 ha	Irrigation (mm) (1)	Effective rainfall (mm) (2)	(3) = (1) + (2)
Land Pri. (25days)	136486		145	
Ini_1	39693	1201	0	1201
Ini_2	37875	1146	27.4	1173
Dev_1	48126	1456	0	1456
Dev_2	48560	1469	0	1469
Dev_3	45172	1366	0	1366
Mid_1	44418	1344	0	1344

Mid_2	48033	1453	0	1453
Mid_3	47944	1450	0	1450
Lat_1	44988	1360	0	1360
Lat_2	46882	1418	0	1418

Assume seepage and percolation in the field is 5 mm / day. Seepage through canal is given by latest formula Punjab $P = 5 * Q^{0.0625}$ unlined canal. Using above formula corresponding Main, distribution and Field canal losses are calculated in Table 5.20.

Table 5.20 Calculation of Seepage Losses

Canal	Discharge m^3/s	$P = 5 * Q^{0.0625}$ ft^3/s / million ft2	Canal length (km)	Bed width (m)	Full supply Depth (m)	Seepage losses (mm/day)
Main	6.81	6.93	13	3.8	1.4	16.16
Dry-1	2.83	6.56	7	3.65	0.92	15.29
Dry-2	2.5	6.51	22	3.0	0.93	15.18
Dry-3	1.22	6.22	4	2.0	0.75	14.51
FCS	0.5	4.79	150	0.6	0.3	6.21
Total						67.35

Table 5.21 is giving total evapotrancepiration, Seepage, Percolation losses with in the 10 days interval. Here demand for cultural practices such as weed control and salt leaching are not considered.

Table 5.21 Calculation of Total Losses

Period	(1) Evapotranspir ation(mm)	(2) Seepage (mm)	(3) Percolati on (mm)	(4) Total = (1)+(2)+(3)
Land (25days) preparation				
Ini_1	51.6	611.4	50	775.1
Ini_2	54	611.4	50	777.5
Dev_1	56.4	611.4	50	779.9
Dev_2	56.4	611.4	50	779.9
Dev_3	51	611.4	50	774.5
Mid_1	56	611.4	50	779.5
Mid_2	61.6	611.4	50	785.1

Mid_3	60	611.4	50	783.5
Lat_1	60.5	611.4	50	722
Lat_2	60.5	611.4	50	722

Table 5.22 gives the relative water supply for different intervals. Normally RWS is in the range of 1.2 to 1.5. But the Developing and the Middle stage exceed the range.

Table 5.22 Calculation of Relative Water Supply

Period	Irrigation + Effective rain fall	Seepage + Percolation + Evapotrancepiration	Relative water supply (1) / (2)
Land (25days) preparation			
Ini_1	1201	775.1	1.55
Ini_2	1173	777.5	1.51
Dev_1	1456	779.9	1.87
Dev_2	1469	779.9	1.88
Dev_3	1366	774.5	1.76
Mid_1	1344	779.5	1.72
Mid_2	1453	785.1	1.85
Mid_3	1450	783.5	1.85
Lat_1	1360	722.0	1.88
Lat_2	1418	722.0	1.96

5.10 Dependability of supply

The Dependability of Supply is defined as follows:

$$Dependability\ of\ Supply = \frac{Actual\ Duration\ of\ Water\ Delivery}{Planned\ Duration\ of\ Water\ Delivery} \text{----------}\mathbf{(10)}$$

To calculate the actual duration and plan duration, data from Table 4.26 and Table 4.27 is sumarised as follows. Since Nachchiduwa and Thuruwila seasonal decision is taking in one meeting and duration also same for both system. Table 5.23 gives two wet season details and Table 5.25 for dry season. This decision is taking in the seasonal meeting, which gather all parallel agencies with the farmer organizational leaders. Rajangana and Thuruwila systems considered as one. Therefore Thuruwila dependability of supply is same as Rajangana. Table 5.24 and Table 5.26 represent the calculation of Dependability of supply.

Table 5.23 Dependability of supply for wet season

Rajangana				**Nachchiduwa**			
Plan		Actual		Plan		Actual	
Start	Stop	Start	Stop	Start	Stop	Start	Stop
07-10-2002	24-03-2003	11-10-2002	31-03-2003	01-11-2002	22-03-2004	01-11-2002	09-03-2003
15-10-2003	30-03-2004	10-10-2003	28-03-2003	25-11-2003	20-03-2004	25-11-2003	15-03-2004

Table 5.24 Dependability of supply for wet season

Rajangana			**Nachchiduwa**		
(1) Plan duration(days)	(2) Actual Duration(days)	Dependability (3) = (2) / (1)	Plan duration(days)	Actual Duration(days)	Dependability (3) = (2) / (1)
168	169	1.006	142	129	0.9
165	168	1.02	135	110	0.81

Table 5.25 Dependability of supply for dry season

Rajangana				**Nachchiduwa**			
Plan		Actual		Plan		Actual	
Start	Stop	Start	Stop	Start	Stop	Start	Stop
17-04-2003	30-09-2003	01-04-2003	30-09-2003	17-04-2003	12-08-2003	13-04-2003	12-08-2003
10-05-2002	19-10-2002	10-05-2002	22-10-2002	10-05-2002	04-09-2002	10-05-2002	06-09-2002

Table 5.26 Dependability of supply for dry season

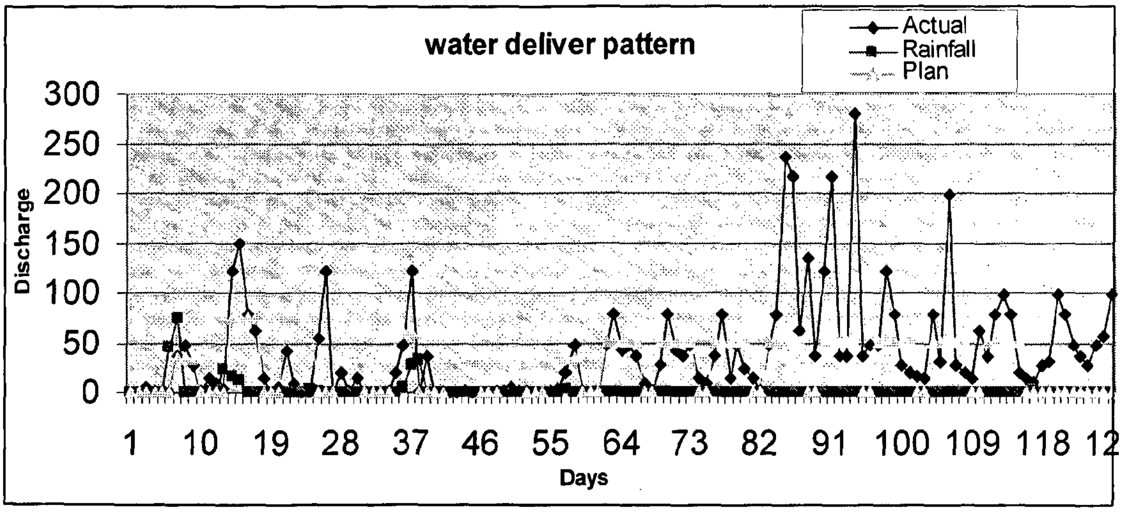
Rajangana			**Nachchiduwa**		
(1) Plan duration(days)	(2) Actual Duration(days)	Dependability (3) = (2) / (1)	Plan duration(days)	Actual Duration(days)	Dependability (3) = (2) / (1)
167	183	1.1	117	121	1.03
162	165	1.0	117	119	1.02

5.11 Regularity of Deliveries.

The Regularity of the Deliveries is defined as follows.

$$\text{Re}\,gularity\ of\ Deliveries = \frac{Actual\ Interval\ of\ Water\ Delivery}{Planned\ Interval\ of\ Water\ Delivery} \text{------------}(11)$$

Chart shows that the pattern delivered has significant different with the planed delivery. But every canals are not this much fluctuations. This field canal is in the tail end. In the initial stage after 7 days water has reached to the field. Water is delivered over time may significantly affect the overall adequacy of water delivered, and direct impact on crop production also. Different between total volume of Planed and actual, there is no unpredictable variation in volume or timing. If it is so farmers are not use other inputs such as fertilizer in optimal quantities, quality seeds. Planning interval is always regular. But actual interval is not regular, because always it is meet the climate condition and water availability. In this cause it is difficult to calculate actual interval of water delivery. Figure 5.6 shows clearly the water delivery pattern.



Figur 5.6 Actual and Plan water delivery pattern for 2004 dry season in Nachchiduwa.

5.12 Modified Interquartile Ratio

The Modified Interquartile Ratio is defined as follows:

$$Modified\ Interquartile\ Ratio = \frac{Average\ DPR\ of\ Best\ 25\%\ of\ the\ System}{Average\ DPR\ of\ Worst\ 25\%\ of\ the\ System} \text{-----(12)}$$

To calculate DPR field application efficiency is taken as 0.73 which is calculated in 5.6 paragraph. Selecting best and worst areas are also some what difficult. In this calculation the best part selected from close to the sluice and worst part was taken from tail end. In some circumstances, particularly when looking at performance of a particular canal, it may be more useful to look at the difference between the head and tail of the canal.

Table 5.27: (a) DPR of best 25 % of the system

Table 5.28: (b) DPR of worst 25 % of the system

(a) Point B Discharge(m3/s)			(b) Point E Discharge(m^3/s)		
Actual	Target	DPR	Actual	Target	DPR
0	1.22	0	0.833	1.22	0.683
0	1.22	0	0.97	1.22	0.795
1.039	1.22	0.852	0.883	1.22	0.724
1.209	1.22	0.991	0.628	1.22	0.515
1.395	1.22	1.143	0.431	1.22	0.353
1.18	1.22	0.967	0.406	1.22	0.333
1.331	1.22	1.091	0.512	1.22	0.42
1.094	1.22	0.897	0.784	1.22	0.643
1.039	1.22	0.852	0.752	1.22	0.616
1.363	1.22	1.117	0.512	1.22	0.42
1.039	1.22	0.852	0.72	1.22	0.59
1.363	1.22	1.117	0.689	1.22	0.565
1.012	1.22	0.83	0.643	1.22	0.527
0.959	1.22	0.786	0.72	1.22	0.59
1.18	1.22	0.967	0.883	1.22	0.724
1.18	1.22	0.967	0.987	1.22	0.809
0	1.22	0	0.613	1.22	0.502

1.151	1.22	0.943	0.673	1.22	0.552
1.3	1.22	1.066	0.569	1.22	0.466
0.985	1.22	0.807	0.817	1.22	0.67
1.039	1.22	0.852	0.752	1.22	0.616
1.239	1.22	1.016	0.752	1.22	0.616
1.151	1.22	0.943	0.583	1.22	0.478
1.151	1.22	0.943	0.752	1.22	0.616
0.834	1.22	0.684	0.918	1.22	0.752
Average DPR value		**0.904**			**0.56**

Average DPR of best 25 % of the system = 0.904

Average DPR of worst 25 % of the system = 0.56

Modified Interquartile ratio = 0.904 / 0.56

= 1.61

5.13 Head to Tail Equity ratio

The Head to Tail Equity ratio can calculate as follows:

$$Head:Tail\ Equity\ Ratio = \frac{Average\ DPR\ of\ Upper\ 25\%\ of\ the\ System}{Average\ DPR\ of\ Tail\ 25\%\ of\ the\ System} \text{------------}(13)$$

Same as earlier to calculate DPR field application efficiency is taken as 0.73 which is calculated in 5.6 paragraph. Selecting upper and Tail areas are also not difficult. In this calculation the upper part selected from close to the sluice and tail part was taken according to the distance away from the sluice. Particularly when looking at performance of a particular canal, it may be more useful to look at the difference between the head and tail of the same canal. Table 5.29 shows the DPR of upper and tail in Table 5.30.

Table 5.29: (a) DPR of upper 25 % of the system
Table 5.30 :(b) DPR of lower 25 % of the system

(a) Point B Discharge(m3/s)			(b) Point F Discharge(m^3/s)		
Actual	Target	DPR	Actual	Target	DPR
0	1.22	0	0	3.5	0
0	1.22	0	0	3.5	0
1.039	1.22	0.852	0.168	3.5	0.048
1.209	1.22	0.991	0.056	3.5	0.016
1.395	1.22	1.143	0	3.5	0
1.18	1.22	0.967	0	3.5	0
1.331	1.22	1.091	1.008	3.5	0.288
1.094	1.22	0.897	1.344	3.5	0.384
1.039	1.22	0.852	0.756	3.5	0.216
1.363	1.22	1.117	0.056	3.5	0.016
1.039	1.22	0.852	0.392	3.5	0.112
1.363	1.22	1.117	0.252	3.5	0.072
1.012	1.22	0.83	0.112	3.5	0.032
0.959	1.22	0.786	3.416	3.5	0.976
1.18	1.22	0.967	4.172	3.5	1.192
1.18	1.22	0.967	2.212	3.5	0.632
0	1.22	0	1.736	3.5	0.496
1.151	1.22	0.943	0.392	3.5	0.112
1.3	1.22	1.066	0	3.5	0
0.985	1.22	0.807	0.168	3.5	0.048
1.039	1.22	0.852	1.176	3.5	0.336
1.239	1.22	1.016	0.252	3.5	0.072
1.151	1.22	0.943	0	3.5	0
1.151	1.22	0.943	0	3.5	0
0.834	1.22	0.684	1.54	3.5	0.44
Average DPR		**0.904**			**0.22**

Average DPR of upper 25 % of the system = 0.904

Average DPR of lower 25 % of the system = 0.22

Head to Tail interquatile ratio = 0.904 / 0.22

= 4.11

5.14 Irrigated Area Performance

The calculation of Irrigated Area Performance is as follows:

$$Irrigated\ Area\ Performance = \frac{Actual\ Area}{Target\ Area} \text{----------------}(14)$$

Table 4.1 shows the data in scheme wise. But the real picture of district gives the Table 4.8 data. Though irrigated major scheme running properly, average district figures are not in acceptable limit for dry season. This indicator is more useful in strategic level for decision making. When planning for importing quantity of rice, this is the main factor considering to tally with consumption level.

Table 5.31(a): Calculation of Irrigated Area Performance in the case study Areas

Nachchiduwa	Actual area (ha)	2800
	Target area (ha)	2800
	Irrigated area performance	1
Ragangana	Actual area (ha)	6200
	Target area (ha)	6515
	Irrigated area performance	1.05
Thuruwila	Actual area (ha)	193
	Target area (ha)	193
	Irrigated area performance	1

tion of Irrigated Area Performance in Anuradapura district

	tal Sown Area (ha)	(2)Total harvested area (ha)	(3) Irrigated area performance (3) = (2)/(1)
	56543	54282	0.96
[illegible]	40799	40595	0.99
/02	47191	47065	0.99
et 02/03	66055	62753	0.95
Dry 2000	21213	19827	0.93
Dry 2001	17507	17475	0.99
Dry 2002	12347	11730	0.95
Dry 2003	23570	21684	0.92

5.15 Cropping Intensity Performance

The Cropping Intensity Performance is defined as follows:

$$Cropping\ Intensity\ Performance = \frac{Actual\ Cropping\ Intensity}{Target\ Cropping\ Intensity} \text{-------------}(15)$$

Target cropping intensity for paddy is 2 per year. If the crops are different types like vegetable, it will reach up to 3. That is three times per year can cultivate. Mainly these systems were designed for paddy. Only main two seasons are cultivating. According to the Table 4.26 summary is as follows:

Table 5.32 Calculation of Target Cropping Intensity In Nachchiduwa.

Scheme	Description	Year				
		2005	2004	2003	2002	2001
Nachchiduwa	Total cultivation area	5600	2800	4304	3870	3800
	Max. cultivation area	2800	2800	2800	2800	2800
	(1)Cropping intensity	2	1	1.54	1.38	1.36
	(2) Target cropping intensity	2	2	2	2	2
	(3)Cropping intensity performance (3) = (1)/(2)	1	0.5	0.77	0.69	0.68

Table 5.32 Calculation of Target Cropping Intensity In Rajangana

Scheme	Description	Year				
		2005	2004	2003	2002	2001
Rajangana	Total cultivation area	12400	6200	12400	12400	12400
	Max. cultivation area	6200	6200	6200	6200	6200
	(1)Cropping intensity	2	1	2	2	2
	(2) Target cropping intensity	2	2	2	2	2
	(3)Cropping intensity performance (3) = (1)/(2)	1	0.5	1	1	1

5.16 Production Performance

The production Performance is calculated as follows:

$$Production\ Performance = \frac{Total\ Production}{Target\ Production} \text{---------------}(16)$$

From Table 4.10.Paddy production details in Study Area are taken to calculate. Table 5.33 represent the Production performance in each schemes wet and dry season separately. Accoding to the demand in Sri Lanka target production is 5 tons per hectare. But some schemes are achieving more than 5 tons per hectare.

Table 5.33 Production performance for dry season in Nachchaduwa

Dry Season	Extent (ha)	Actual Production(t)	Target Production(t)	Production Performance
1998	1472	5741	7360	0.78
1999	2462	10464	12310	0.85
2000	2510	10668	12550	0.85
2001	941	4291	4705	0.91
2002	992	4276	4960	0.86
2003	2800	11060	14000	0.79

Average **0.84**

Table 5.34 Production performance for wet season in Nachchaduwa

Wet Season	Extent (ha)	Total Production(t)	Target Production(t)	Production Performance
98/99	2510	11069	12550	0.88
99/00	2510	11320	12550	0.90
00/01	2510	12600	12550	1.00
01/02	2510	14985	12550	1.19
02/03	2510	11320	12550	0.90
03/04	2800	13496	14000	0.96
04/05	2800	13776	14000	0.98

Average **0.98**

Table 5.35 Production performance for wet season in Rajangana

Wet Season	Extent (ha)	Production(t)	Target production(t)	Production Performance
97/98	5459	23637	27295	0.87
98/99	6000	28320	30000	0.94
99/00	6000	27000	30000	0.90
00/01	5457	28267	27285	1.04
01/02	5610	27826	28050	0.99
02/03	5610	26479	28050	0.94
		Average		**0.95**

Table 5.36 Production performance for dry season in Rajangana

Dry Season	Extent (ha)	Production(t)	Target production(t)	Production Performance
1998	6280	25748	31400	0.8
1999	6000	26280	30000	0.9
2000	5457	23574	27285	0.9
2001	4080	19339	20400	0.9
2002	6229	28467	31145	0.9
		Average		**0.90**

Table 5.37 Summary of production performance

	Nachchiduwa	Rajangana
Yield performance -wet	0.84	0.95
Yield performance -dry	0.98	0.90

5.17 Yield Performance

The Yield Performance is calculate as follows:

$$Yield\ Performance = \frac{Actual\ Yield}{Target\ Yield} \text{ ---------------(17)}$$

Though the target yield is 5 t/ha. System has reached to above that level. Maximum attainable limit is 6 t/ha. On an average of hole system. Some individual farmers attend even 9 t/ha. For the calculation 5 t/ha is taken as a target yield. Table 4.10 production and yield per ha in Study Area

Table 5.38 Yield performance in wet and dry seasons Nachchiduwa

Wet Season	Actual Yield (t /ha) - (1)	Target Yield (t /ha)- (2)	Yield Performance (3) = (1)/(2)
98/99	4.41	5	0.88
99/00	4.51	5	0.90
00/01	5.02	5	1.00
01/02	5.97	5	1.19
02/03	4.51	5	0.90
03/04	4.82	5	0.96
04/05	4.92	5	0.98

Dry Season	Actual Yield (t /ha)	Target yield (t/ha) -(2)	Yield Performa (3) =(1) /
1998	3.90	5	0.78
1999	4.25	5	0.85
2000	4.25	5	0.85
2001	4.56	5	0.91
202	4.31	5	0.86
2003	3.95	5	0.79

Average Yield performance = 0.97

Average = 0.84

Table 5.39 Yield performance in wet and dry season Rajangana

Wet Season	Yield (t /ha) (1)	Target Yield (t /ha)- (2)	Yield Performance (3) = (1)/(2)
97/98	4.33	5	0.87
98/99	4.72	5	0.94
99/00	4.50	5	0.90
00/01	5.18	5	1.04
01/02	4.96	5	0.99
02/03	4.72	5	0.94

Dry Season	Yield (t /ha) – (1)	Target Yield (t /ha)- (2)	Yield Performance (3) = (1)/(2)
1998	4.10	5	0.82
1999	4.38	5	0.88
2000	4.32	5	0.86
2001	4.74	5	0.95
2002	4.57	5	0.91

Average Yield performance = 0.95 **Average = 0.88**

Table 5.40 Yield performance in wet and dry season Thuruwila

Wet Season	Yield (t /ha) (1)	Target Yield (t /ha)- (2)	Yield Performance (3) = (1)/(2)
97/98	4.98	5	0.99
98/99	5.00	5	1.00
99/00	5.01	5	1.00
00/01	4.96	5	0.99
01/02	5.00	5	1.00
02/03	5.01	5	1.00

Dry Season	Yield (t /ha) – (1)	Target Yield (t /ha)- (2)	Yield Performance (3) = (1)/(2)
1998	4.98	5	0.99
1999	4.93	5	0.98
2000	5.01	5	1.00
2001	4.86	5	0.97
2002	5.00	5	1.00

Average Yield performance = 0.996 **Average = 0.998**

Table 5.41: Summary of Yield Performance

	Nachchiduwa	Thuruwila	Rajangana
Yield performance -wet	0.97	0.996	0.95
Yield performance -dry	0.84	0.998	0.88

5.18 Water Productivity Performance

The water productivity performance is calculated as follows:

$$Water\ Productivity\ Performance = \frac{Actual\ Water\ Productivity}{Target\ Water\ Productivity} \text{----------------(18)}$$

To calculate actual water productivity data from Table 4.27 and Table 4.10 is used. Target water productivity varied from 0.5 to 1.1 kg/m3. This is totally depend on environmental conditions, soil and other factors. Therefore 0.8 is average of 0.5 and 1.1, has taken for calculation.

Table 5.42: Actual Water Productivity - 1998 to 2004 in Nachchiduwa

Season	Water Issues (MCM)	Extent (ha)	Production (t)	Productivity (kg/m3)	Target Productivity kg/m^3	Performance
1998-Dry	25.4	1472	5741	0.226	0.8	0.28
1999	38.6	2462	10464	0.271	0.8	0.34
2000	41.2	2510	10668	0.258	0.8	0.32
2001	14.9	941	4291	0.288	0.8	0.36
2002	10.1	992	4276	0.423	0.8	0.53
2003	43.9	2800	11060	0.252	0.8	0.32
98/99-Wet	25.0	2510	11069	0.442	0.8	0.55
99/00	30.0	2510	11320	0.377	0.8	0.47
00/01	14.6	2510	12600	0.863	0.8	1.08
01/02	19.2	2510	14985	0.780	0.8	0.98
02/03	14.9	2510	11320	0.759	0.8	0.95
03/04	42.7	2800	13496	0.316	0.8	0.40
04/05	26.8	2800	13776	0.514	0.8	0.64

Table 5.43: Actual Water Productivity - 1998 to 2003 in Thuruwila

Season	Water discharge	Production (t)	Actual water productivity (kg/m3)	Target Productivity kg/m³	Performance
1998	4.4	965	0.219	0.8	0.27
1999	4.4	981	0.223	0.8	0.28
2000	4.3	984	0.229	0.8	0.29
2001	4.1	975.8	0.238	0.8	0.30
2002	4.0	986.03	0.246	0.8	0.31
2003	4.0	964.6	0.241	0.8	0.30
98/99	4.0	990.5	0.247	0.8	0.31
99/00	3.8	969.4	0.255	0.8	0.32
00/01	3.7	966.7	0.261	0.8	0.33
01/02	3.7	962.3	0.26	0.8	0.33
02/03	3.7	983.9	0.266	0.8	0.33
03/04	3.4	965.6	0.284	0.8	0.36
04/05	3.5	965.5	0.275	0.8	0.34

Table 5.44: Actual Water Productivity - 1998 to 2002 in Rajangana

Season Dry	Water Issues	Production (t)	Actual water production (kg/m3)	Target Productivity kg/m³	Performance
1998	138.8	25748	0.185	0.8	0.23
1999	161.9	26280	0.162	0.8	0.20
2000	153.3	23574	0.153	0.8	0.19
2001	140.8	19339	0.137	0.8	0.17
2002	111.3	28467	0.255	0.8	0.32
98/99	148.7	28320	0.190	0.8	0.24
99/00	95.0	27000	0.284	0.8	0.36
00/01	137.8	28267	0.205	0.8	0.26
01/02	139.0	27826	0.20	0.8	0.25
02/03	101.7	26479	0.26	0.8	0.33

Table 5.45: Summary of water productivity performance

	Nachchiduwa	Thuruwila	Rajangana
Water productivity performance -wet	0.36	0.29	0.22
Water productivity performance -dry	0.72	0.37	0.29

5.19 Total Financial Viability

The Total Financial Viability is calculated as follows:

$$Total\ Financial\ Viability = \frac{Actual\ O\&M\ Allocation}{Total\ O\&M\ Requirements} \text{-------------}\mathbf{(19)}$$

All over the world, the recurrent cost, required to keep irrigation systems functioning is more concerning in recent years. One set of concerns has been with efforts to raise revenues from water users that help support operation and maintenance costs, and often some or all of the capital costs of individual irrigation systems. In Sri Lanka there is not such revenue collection system. Next performance indicator gives detail about the Fee collection. The total O&M requirements should be based on a detailed budget which is approved through a good budgeting system. If such a system is not in place, a budget can be based on the estimated O&M expenditure per hectare. Table 5.43 shows the Total financial viability.

Table 5.46: Calculation of Total Financial Viability

No	Item	unit	Nachchiduwa	Thuruwila	Ragangana
1.	Operation Budget Ratio to irrigable area	Rs Rs/ha	134,200 46	9,000 46	281,600 42
2	Maintenance Budget Ratio to irrigable area	Rs Rs/ha	874,600 301	58,500 303	1,835,900 277
	(a) Total actual O&M	Rs	1,008,800	67,500	2,117,500
	(b) O&M requirement	Rs	1,452,500	96,500	2,754,000
3	Total financial viability = (a)/ (b)		0.69	0.70	0.77

5.20 Fee Collection Performance

The Fee Collection Performance is defined as follows:

$$Fee\ Collection\ Performance = \frac{Irrigation\ Fee\ Collected}{Irrigation\ Fee\ Due} \text{ ---------------(20)}$$

In many countries, water charges (irrigation fees) are collected from farmers. But in Sri Lanka there is no practice like water charges. Table 5.44 is shows the condition of fee collection. Acreage Tax payment is 100%. Even membership fee collection also 100%. O & M fee collection is in very poor stage. Therefore it is difficult to calculate Fee collection Performance.

Table 5.47: Details of different Fee Collections

No	Item	unit	Nachchiduwa	Thuruwila	Ragangana
1.	Acreage Tax paid to ADC	Rs/Ha/Annum	15	16	15
	Ratio of collection	%	100	100	100
2	Membership Fee				
	1.Entrance	Rs/ Annum	100	130	100
	Ratio of collection	%	100	100	100
3	O & M Fee for Jalapalaka & Maintenance	Rs / Ha / Annum	1500 (1 bushel/crop /acre)	750 (300 / acre / year)	1500 (1 bushel / crop / arcs)
		%	Very poor	Poor	80-90

5.21 Area Based Profitability

The Area Based Profitability is defined as follows:

$$Area\ Based\ profitability = \frac{Incremental\ Benifit\,/\,Unit\ Area}{Total\ Irrigation\ Expenses\,/\,Unit\ Area} \text{ --------------(21)}$$

This indicator requires evaluation of farm level economics. It can be modified to include or exclude the discounted value of the capital cost of the system depending on whether or not capital is considered a sunk cost. But here it is consider as farm level economics. Table 5.45 gives the calculation of incremental benefit in Nachchiduwa.

Table 6.45 Calculation of Paddy Production in Nachchiduwa

Operation	Material					Machinery				Labour (Mandays)			Tatal cost
	Type	Unit	Rate	Qty/ha	cost/ha	Unit	Qty/ha	Rate	Cost/ha	Rate	Qty/ha	Cost/ha	(Rs/ha)
1.Land preparation													
Clearing of bunds	H'cide	1	520	2.5	1300					450	2	900	2200
Ploughing						times	2	3544	7087	400	1	400	7487
Reshaping										400	8	3200	3200
2.Crop Establishment													
Seed bed preparation &sowing	Seeds	kg	28	102	2856					400	10	4000	6856
3.Fertilizer application													
Basal dressing	V1	kg	32	100	3200					400	1	400	3600
14 DAS	Urea	kg	13	62	806					400	1	400	1206
30 DAS	Urea	kg	13	125	1625					400	1	400	2025
45-50 DAS	TDM	kg	18	105	1890					400	1	400	2290
4. Weed control	H'cide	1	520	4	2080					450	2	900	2980
5.P&D Control	P'cide	1	520	2.5	1300					450	1	450	1750
6. Irrigation										400	20	8000	8000
7.Harvesting										400	1	350	350
										Labout contract		10000	10000
8.Threshing						Contract; H/C thresher			6250				6250
9.Transport	Bags	No	8	100	800	Tractor & Trailer			500	400	2	800	2100
Total with full labour					14557				13837		51	30600	58994
Total without full labour					14557				13837	350	32	21200	49594

Table 6.46 Calculation of Paddy Production in Thuruwilla

Operation	Material					Machinery				Labour (Mandays)			Total cost
	Type	Unit	Rate	Qty/ha	Cost/ha	Unit	Rate	Qty/ha	Cost/ha	Rate	Qty/ha	Cost/ha	(Rs/ha)
1.Land priparation													
Clearing of bunds	H'cide									350	2	900	2200
Ploughing						Time	2	3106	6212	350	1	400	7487
Reshaping										350	8	3200	3200
2.Crop Establishment													
Seed bed preparation &sowing	Seeds	kg	29	103	2987					350	10	4000	6856
3.Fertilizer application													
Basal dressing	V1	kg	32	62	1984					350	1	400	3600
14 DAS	Urea	kg	13	62	806					350	1	400	1206
30 DAS	Urea	kg	13	87	1131					350	1	400	2025
45-50 DAS	TDM	kg	18	88	1584					350	1	400	2290
4. Weed control	H'cide	1	520	4	2080					350	2	900	2980
5.P&D Control	P'cide	1	570	2.5	1425					350	1	450	1750
6. Irrigation										350	20	8000	8000
7.Harvesting										350	1	350	350
											Labout contract	10000	10000
8.Threshing						Contract; H/C thresher			6250				6250
9.Transport	Bags	No	8	100	800	Tractor & Trailer			500	350	2	700	1200
Total with full labour					11997				12962		51	25350	50309
Total without full labour					11997				12962	350	26	16600	41559

Table 6.47 Calculation of Paddy Production in Rajangana

Operation	Material					Machinery				Labour (Mandays)			Total cost
	Type	Unit	Rate	Qty/ha	Cost/ha	Unit	Rate	Qty/ha	Cost/ha	Rate	Qty/ha	Cost/ha	Cost/ha
1.Land priparation													
Clearing of bunds	H'cide	1	520	3	1560					350	3	1050	
Ploughing						Time	2	3075		350	1	350	
Reshaping										350	9	3150	
2.Crop Establishment													
Seed bed preparation &sowing	Seeds	kg	30	110	3300					350	6	2100	
3.Fertilizer application													
Basal dressing	V1	kg	32	63	2016					350	1	350	
14 DAS	Urea	kg	13	62	806					350	1	350	
30 DAS	Urea	kg	13	87	1131					350	1	350	
45-50 DAS	TDM	kg	18	44	792					350	1	350	
4. Weed control	H'cide	1	500	4	2000					350	1	350	
5.P&D Control	P'cide	1	550	2.5	1375					350	1	350	
6. Irrigation										350	20	7000	
7.Harvesting										350	23	8050	
											Labout contract	10000	10000
8.Threshing						Contract; H/C thresher			6000	350	3	1050	6000
9.Transport	Bags	No	8	100	800	Tractor & Trailer			500	350	2	700	2000
Total with full labour					12220				12650		73	25550	50420
Total without full labour					12220				12650	350	43	15050	39920

Table 5.51: Calculation of Incremental Benefit in Nachchiduwa

Season	unit	Ave. yield (kg/ha)	unit price Rs/ kg	Income Rs/ ha	Total expenses Rs/ha	Incremental benefit Rs
2002 – dry	Kg/ha	4,678	13.01	60,860.78	49594	11266
2002/03-wet	Kg/ha	5,218	13.01	67,886.18	49594	18,292.18

Table 5.46 shows the Operation and Maintenance expenses in Irrigation Department for 2001 to 2005. After 2001 allocation was reduced due to various reasons. But three years period it was understood that allocation was not enough and increased it same level.

Table 5.52: Total irrigation expenses in Sri Lanka for Operation and Maintenance

No	Vote Particulars	2001	2002	2003	2004	2005
1	O & M Gravity Allocation	238	195	155	156	269
2	Improvement to major works	15	10	9	9	11
3	Improvements to water management	15	10	9	9	11
4	Flood damage repairs Allocation	25	12	10	10	20
5	Strength of head works allocation	21	9	15	14	13
6	Drainage and flood protection	16	10	15	14	13
7	O & M Gravity (wages)	18	12	18	18	30
8	Maintenance of department roads	15	10	10	11	11
	Total	363	268	241	241	378

Total Irrigation expenses 268 million Rs. For 272,000 ha.

For 1 hectare Total Irrigation expenses = 378000000 / 272000
= 1390 Rs/ha

Table 5.53: Area Based Profitability in Nachchiduwa

Season	Area based profitability = Incremental benefit/Total irrigation expenses
2002 – dry	8.1
2002/03 - wet	13.2

Table 5.54: Calculation of Incremental Benefit in Thuruwila

Season	unit	Ave.yield (kg/ha)	unit price Rs/ kg	Income Rs/ ha	Total expenses Rs/ha	Incremental benefit Rs
2002 – dry	Kg/ha	5,003	13.01	65,089	41,559	23,530
2002/03-wet	Kg/ha	5,003	13.01	65,089	41,559	23,530

Table 5.55: Area Based Profitability in Thuruwila

Season	Area based profitability = Incremental benefit/Total irrigation expenses
2002 – dry	16.92
2002/03 - wet	16.92

Table 5.56: Calculation of Incremental Benefit in Rajangana

Season	unit	Ave.yield (kg/ha)	unit price Rs/ kg	Income Rs/ ha	Total expenses Rs/ha	Incremental benefit Rs
2002 – dry	Kg/ha	4,959	13.01	64,516.60	39,920	24,596
2002/03-wet	Kg/ha	5,114	13.01	66,533.14	39,920	26,613

Table 5.57: Area Based Profitability in Rajangana

Season	Area based profitability = Incremental benefit/Total irrigation expenses
2002 – dry	17.69
2002/03 - wet	19.14

5.22 Water Based Profitability

The water based profitability defined as follows:

$$Water\ Based\ \Pr ofitability = \frac{Incremental\ Benifit\,/\,Unit\,Water}{Total\ Irrigation\ Expenses\,/\,Unit\ Water} \text{-----------}(22)$$

When calculating water based profitability, incremental benefit per unit water is needed. For that, total expenses per unit water are required. Total expenses include farmer side and government side both. Farmer's expenditure can be easily calculated. There is no limit for government expenses. All parallel agencies up to ministry level, indirect and direct other expenses should be taken in to account. In this stage it is not possible to collect all the details. Therefore it has limited up to farm level economics.

Table 5.58: calculation for Incremental benefit per unit water for Nachchiduwa

Season	Water productivity (kg/m^3)	unit price Rs / kg	Income Rs / m^3	Total expenses Rs/m^3	Incremental benefit Rs/m^3
2002	0.464	13.01	6.03	5.06	0.97

Expenses for paddy cultivation = 49594 Rs/ ha

Total expenses for 1030 ha cultivation = 1030 * 49594

= Rs. 51,081,820.00

Total expenses per unit water = 51,081,820 / 10.1(10^6)

= 5.06 Rs/m^3

Total irrigation expenses for 10.1 MCM is Rs 1008800 from Table 4.25 and 5.43

= 1008800/ 10.1(10^6)

= 0.1 Rs/ m^3

Water based profitability = 0.97 / 0.1

= 9.7

Table 5.59: calculation for Incremental benefit per unit water for Thuruwila

Season	Water productivity (kg/m^3)	unit price Rs/ kg	Income Rs/ m^3	Total expenses Rs /m^3	Incremental benefit Rs
2002	0.23	13.01	3.1	2.00	1.55

Expenses for paddy cultivation = 41,559 Rs/ ha

Total expenses for 1030 ha cultivation = 193 * 41559

= Rs. 8,020,887.00

Total expenses per unit water = 8,020,887.00/ 4(10^6)

= 2.00 Rs/m^3

Incremental benefit = 3.1 - 2.00

= 1.55

Total irrigation expenses for 4 MCM is Rs 67500 from Table 4.25 and 5.43

= 67500 / 4(10^6)

= 0.16 Rs / m^3

Water based profitability = 1.55 / 0.16

= 9.68

Table 5.60: calculation for Incremental benefit per unit water for Rajangana

Season	unit	Water productivity (kg/ha)	unit price Rs/ kg	Income Rs/ m^3	Total expenses Rs/m^3	Incremental benefit Rs
2002 – dry	Kg/m^3	0.22	13.1	2.88	4.89	-2.01

Expenses for paddy cultivation = 39,920 Rs/ ha

Total expenses for 1030 ha cultivation = 13642 * 39920

= Rs. 544,588,640.00

Total expenses per unit water = 544,588,640 / 111.3(10^6)

= 4.89 Rs/m^3

Incremental benefit = 2.88 – 4.89

= 1.55

Total irrigation expenses for 111.3 MCM is Rs 2754000 from Table 4.25 and 5.43

= 2754000 / 111.3(10^6)

= 0.025 Rs / m^3

Water based profitability = -2.01 / 0.025

= -80.2

Table 5.61: Summary of water based profitability

System	Nachchiduwa	Thuruwila	Rajangana
water based profitability	9.7	9.7	-80.2

5.23 Irrigation Employment Generation

The Irrigation Employment Generation is defined as follows:

$$Irrigation\ Employment\ Generation = \frac{Annual\ Person\ days\,/\,ha\ Labour\ in\ Scheme}{Anual\ Number\ official\ working\ days} \text{-(23)}$$

In these systems two seasons are cultivating per year. Almost nine months systems are functioning. Though annual office working days are 252, continues attention during operation period is needed. Therefore annual persons days are 340. Table 5.56 shows further detail three system.

Table 5.62: Irrigation Employment Generation

	Nachchiduwa	Thuruwila	Rajangana
Annual persons days/ha	340	340	340
Annual no. of officials working days	252	252	252
Irrigation Employment Generation	1.35	1.35	1.35

5.24 Irrigation Wage Generation

The Irrigation Wage Generation is defined as follows:

$$Irrigation\ Wage\ Generation = \frac{Anual\ Average\ Rural\ Income}{Anual\ National\ (or\ \mathrm{Re}gional)\ Average\ Income} \text{---(24)}$$

Annual average income is taken from Table 4.14 and annual National average is taken as Rs. 100,000.

Table 5.63: Irrigation wage generation

Systems	Nachchiduwa	Thuruwila	Rajangana
Annual average income (Rs)	163,267	110,137	125,241
Annual National average income (Rs)	100,000	100,000	100,000
Irrigation Wage Generation	1.63	1.1	1.25

5.25 Relative Prosperity

The relative Prosperity is calculated as follows:

$$Relative\ Prosperity = \frac{Percent\ Population\ Above\ Poverty\ Line\ in\ Scheme}{Percent\ Population\ Above\ Poverty\ Line\ in\ Nationally} \quad \text{------}(25)$$

Table 5.64: District wise official poverty lines

	National	Colombo	Gampaha	Kalutara	Kandy	Matale	Nuwara Eliya	Galle	Matara	Hambantota	Kurunegala	Puttalam	Anuradhapura	Polonnaruwa	Badulla	Monaragala	Ratnapura	Kegalle
Base Year 2002	1423	1537	1508	1523	1451	1395	1437	1466	1395	1338	1352	1423	1380	1366	1409	1366	1451	1437
2003	1513	1634	1604	1619	1543	1483	1528	1558	1483	1422	1437	1513	1468	1453	1498	1453	1543	1528
2004	1628	1758	1725	1742	1660	1595	1644	1676	1595	1530	1546	1628	1579	1563	1611	1563	1660	1644
2005	1817	1963	1926	1944	1853	1781	1835	1872	1781	1708	1726	1817	1763	1744	1799	1744	1853	1835
2006	2066	2231	2190	2210	2107	2024	2086	2128	2024	1942	1962	2066	2004	1983	2045	1983	2107	2086
2006 Nov.	2240	2419	2374	2397	2285	2195	2262	2307	2195	2106	2128	2240	2173	2150	2218	2150	2285	2262
2006 Dec:	2291	2474	2428	2451	2337	2245	2314	2360	2245	2154	2176	2291	2222	2199	2268	2199	2337	2314
2007Jan.	2323	2509	2462	2486	2369	2277	2346	2393	2277	2184	2207	2323	2253	2230	2300	2230	2369	2346
2007 Feb.	2292	2475	2430	2452	2338	2246	2315	2361	2246	2154	2177	2292	2223	2200	2269	2200	2338	2315
2007 Mar.	2254	2434	2389	2412	2299	2209	2277	2322	2209	2119	2141	2254	2186	2164	2231	2164	2299	2277
2007 Apr:	2252	2432	2387	2410	2297	2207	2275	2320	2207	2117	2139	2252	2184	2162	2229	2162	2297	2275

Official Poverty line at national level for April 2007 is Rs. 2252
Department of Census & Statistics - Sri Lanka

These data were collected in 2005. According to the Table 5.13 Anuradapura district poverty line is Rs. 1763. In 2006, 2173 Rs. Average annual Income rage consider as Rs.25,000. Table 5.16 shows the % below poverty line.

Table 5.65: Relative prosperity

	Nachchiduwa	Thuruwila	Rajangana
% Population above poverty line in Scheme (1)	100	94.7	87.9
% Population above poverty line in Nationally (2)	75	75	75
Relative Prosperity (3) = (1) / (2)	1.33	1.23	1.17

5.26Technical Knowledge

The Technical Knowledge of staff is calculated as follows:

$$Technical\ Knowledge\ Of\ Staff = \frac{Number\ of\ Staff\ with\ Knowledge\ Required\ to\ Fullfill\ Job}{Total\ Number\ of\ Staff}$$

------------(25)

Irrigation department is very keen to fulfill the carder of technical staff which is required for the field. But Agriculture and other department did not take in to considerations. Actual technical knowledge of staff can be ascertained through simple tests, while required knowledge is inherent in the job description

Table 5.66: Technical Knowledge of staff

Description	Nachchiduwa	Thuruwila	Ragangana
No.of person in staff with knowledge required	3	3	3
Total no. persons in staff	3	3	3
Technical Knowledge of staff	1	1	1

5.27 Users' Stake in Irrigation System

The Users' Stake in Irrigation System is calculated as follows:

$$Users'\ Stake\ in\ Irrigation\ System = \frac{Number\ of\ Active\ Water\ Users\ Organizations}{Total\ Number\ of\ Water\ Users\ Organizations} \text{-(26)}$$

Water user organization is named as farmer Organisation also. Activeness of WUS depending on the personal characters. If sectary chairmen treasure is active all the activities are going on smoothly. Here activeness is considered taking some essential activity continuation.. Farmer meeting monthly, annually. Book keeping, account balancing, Fee collection etc.

Table 5.67: Users' Stake in Irrigation system

Description	Nachchiduwa	Thuruwilla	Rajangana
Total no of water use organization	14	1	32
No of active water users organisation	14	1	25
Users' Stake in Irrigation system	1	1	0.71

5.28 Sustainability of Irrigated Area

The sustainability of Irrigation Area is defined as follows:

$$Sustainability\ of\ Irrigated\ Area = \frac{Current\ Irrigable\ Area}{Intial\ Irrigable\ Area} \text{---------}(27)$$

Background of the schemes is showed in Table 5.58, restoration of below three systems, are 1926, 1900 and 1957 respectively. With the time being land consolidation and maximum use of drainage water were taken placed. Past 15 years record showed current irrigable areas have not changed. Table 5.62 describes the essential details.

Table 5.68: Sustainability of Irrigated area

Description	**Nachchiduwa**	**Thuruwila**	**Rajangana**
Original Plan Irrigable area (ha)	2384	173	5371
Current irrigable area (ha)	2905	193	6639
Sustainability of Irrigated area	1.22	1.12	1.24

5.29 Impact of Flooding

The Impact of flooding is defined as follows:

$$\text{Im}\,pact\ of\ Flooding = \frac{Area\ Subject\ to\ Flooding}{Total\ Irrigable\ Area} \text{------------}\mathbf{(29)}$$

Flooding can be in two directions. One is excess drainage and other is rainfall during the season. Table 5.69 showing the area subjected to flooding is mainly due to excess drainage while land preparation period.

Table 5.69: Sustainability of Irrigated area.

Description	Nachchiduwa	Thuruwila	Rajangana
Total Irrigable area (ha)	2905	193	6639
Area subjected to flooding (ha)	165	7	263
Sustainability of Irrigated area	0.056	0.036	0.039

WRD&M - IIT Roorkee

CHAPTER VI

Master of Technology Thesis

B.A. KANTHI
6/15/2007

Chapter 6

Results and Discussion

This chapter presents the results of the study and discusses them in sequence of the computation of performance indices. Figure 6.1 shows the Nachchiduwa line diagram which represents the canal system and the points of discharge measurement. Appendix-I shows its details. For convenience in description, line AC represents the main canal, line CE is conveyance canal or D-canal, lines EF, AB, and all other lines represent the distributary canals. Point A represents the canal inlet, or Point A is main delivery point, where the supply comes from the sluice system. Here, it is noted that, because of the nonavailability of comprehensive data, Delivery Performance Ratio, Distribution Efficiency, Field Application Efficiency, Modified Inter quartile Ratio, and Head to Tail Equity Ratio indices were computed only for Nachchiduwa system, and the others for all the three systems.

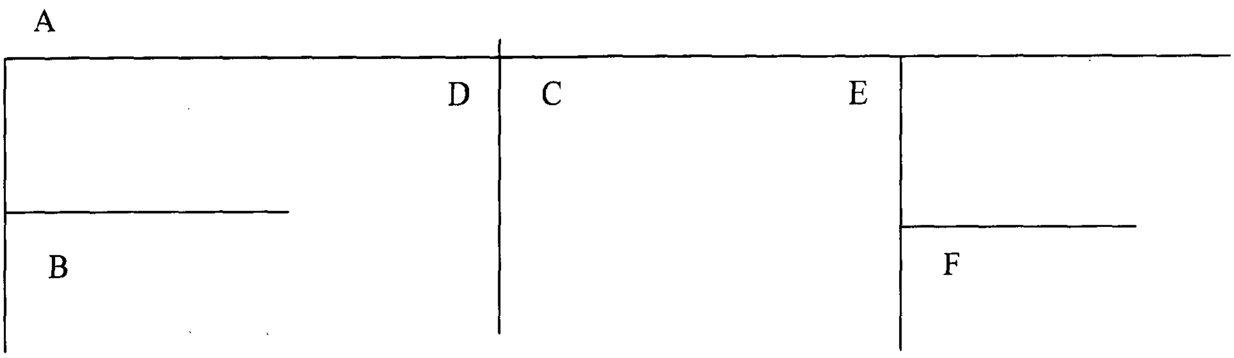


Figure: 6.1 Line diagram of Nachchiduwa system which represents only considered points for calculation

6.1 Delivery Performance Ratio

As also stated earlier, DPR is computed as:

$$Delivery\ Performance\ Ratio = \frac{Actual\ Discharge}{Target\ Discharge} \text{-------------(1)}$$

The summary of computed DPR values (Table 5.1) is given in Table 6.1. The table shows that the DPR decreases at the tail end, i.e. DPR gradually decreases along C-E-F. The increasing trend between AB, AC, and AD is largely attributed to the local rain contributions, as these are contoured canals. The significantly low DPR values at points E and F are indicative of poor quality of service, besides several others such as the design cross-sections of the old system are frequently ill-maintained to the extent that the hydraulic gradient may not be maintained throughout the system.

Table 6.1: summary of delivery performance ratio

DPR	Point A	Point B	Point C	Point D	Point E	Point F
Average DPR	0.802	0.904	0.845	0.923	0.56	0.22

6.2 Water Delivery Performance

Table 6.2 and Fig. 6.2 summarize for both dry and wet seasons, the values of water delivery performance (Table 5.9) computed as:

$$Water\ Delivery\ Performance = \frac{Actual\ Volume}{Target\ Volume} \text{------------------(2)}$$

Table 6.2: Summary of water delivery performance

Season	Nachchiduwa	Thuruwila	Rajangana
Dry Season	1.307	0.979	1.142
Wet Season	0.932	0.868	1.097

It is of common experience that, over a long period of time, it may be more useful to modify the DPR by changing discharges into volumes. Over a sufficiently long time frame it can be assumed that if total volume delivered is close to the intended, then the management inputs must be effective. In the field level, stager system may be implemented. In such a case, WDP cannot show the clear picture of the water supply system. If delivery performance is close to 1, performance is high. In this case, Thuruwila shows a good performance for both dry and wet seasons.

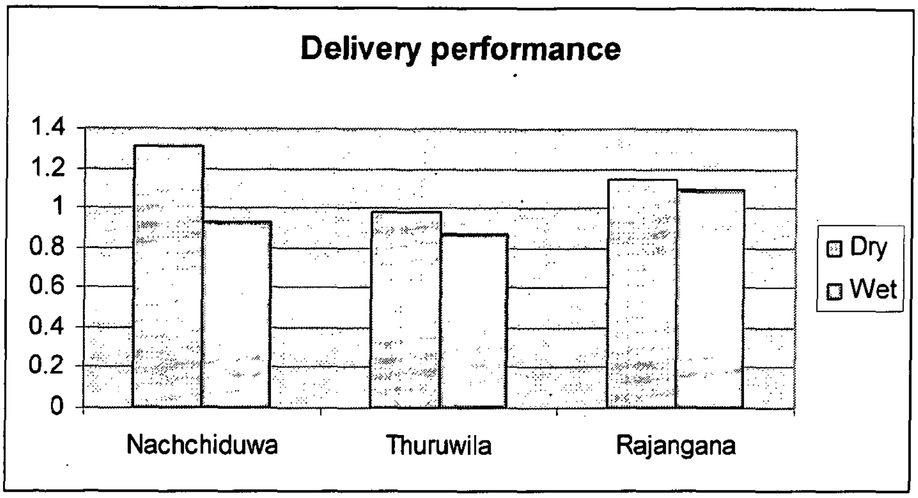


Figure 6.2 Delivery Performance of three systems

6.3 Overall Project Efficiency

Table 6.3 and Fig. 6.3 summarize the values of Overall Project Efficiency which is computed from

$$Overall\ Project\ Efficiency = \frac{Crop\ Irrigation\ Water\ Requirement}{Total\ Inflow\ into\ Canal\ System} \text{------------(3)}$$

Table 6.3: Summary of overall project efficiency

Season	Nachchiduwa	Thuruwila	Rajangana
Dry Season	0.63	0.38	0.34
Wet Season	0.91	0.43	0.36

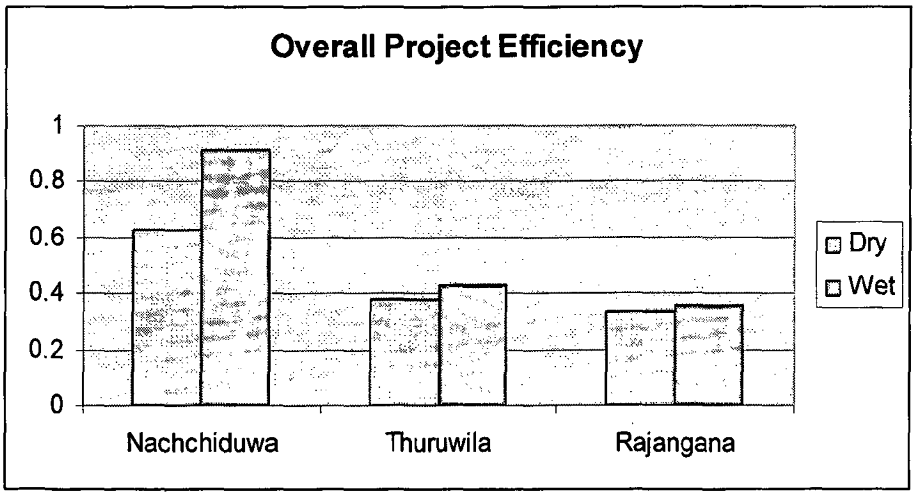


Figure 6.3 Overall Project Efficiencies of three systems

As efficiencies are calculated using the volume delivered within a set time period, rather than instantaneous discharges. Tables 5.10-5.12 show the overall project efficiency of more than 13 different seasons. As seen, the values differ greatly from one to the other systems, rather than seasons. Rajangana and Thuruwila yield very low efficiency compared to Nachchiduwa. As seen, overall project efficiency in Nachchiduwa is close to 1, and the other two exhibit even less than 0.5. Notably, the overall project efficiency is one of the measures of hydraulic conditions in spatial context over a specific time period.

6.4 Conveyance Efficiency

Table 6.4 summarizes the computations of conveyance efficiency, which is derived from

$$Conveyance\ Efficiency = \frac{Total\ Water\ supplied\ by\ the\ Conveyance\ System}{Total\ Inflow\ into\ The\ Conveyance\ System} \text{----(4)}$$

Table 6.4: Conveyance Efficiency

Period 10 days	Discharge at A MCM	Discharge at A* MCM	Rain Fall mm	CWR mm	A-A* 355 ha Requirement MCM	Total Inflow MCM	Conveyance efficiency
Land (25days) preparation	117.38	141.81	185	0	0	0	0
Ini_1	34.14	29.49	5.6	101.6	4.50	29.64	1.00
Ini_2	32.57	28.94	59.9	104	4.61	27.97	1.03
Dev_1	41.39	34.91	3.2	106.4	4.71	36.68	0.95
Dev_2	41.76	33.47	0	106.4	4.71	37.05	0.90
Dev_3	38.85	33.14	0	101.5	4.50	34.35	0.96
Mid_1	38.20	32.00	0	106	4.70	33.50	0.96
Mid_2	41.31	32.07	0	106	4.70	36.61	0.88
Mid_3	41.23	32.96	0	104.4	4.62	36.61	0.90
Lat_1	38.69	31.26	0	110	4.87	33.82	0.92
Lat_2	40.32	32.86	13.4	110	4.87	35.45	0.93
					Average conveyance eff.		0.944

As seen from Table 6.4, conveyance efficiencies of 10 days interval for Ini_1 to Dev_3 are 1.00, 1.03, 0.95, and 0.96, respectively. Since the efficiency can not exceed 1.0, the computed values do not show the correct picture of the system performance. Values more than 1.0 are largely attributed to local catchment runoff to the canal, which is, if not impossible, extremely difficult to measure.

6.5 Distribution Efficiency

Table 6.5 summarizes the computations of distribution efficiency which is computed as:

$$Distribution\ Efficiency = \frac{Total\ Water\ Delivery\ To\ Fields}{Total\ Inflow\ into\ the\ Delivery\ System} \text{ --------------(5)}$$

As seen from Table 6.5, the values of efficiency are more than 1.0, which is unrealistic. It is largely due to the local catchment contributions. The high efficiency values are indicative of the good performance of the Nachchiduwa system.

Table 6.5: Distribution Efficiency for Nachchiduwa

Period 10 days	Discharge at F MCM	Discharge at G MCM	Rain Fall mm	CWR Mm	F-G 60 ha Requirement MCM	Total Inflow MCM	Distributary Efficiency
Land Preparation	19.83	0.70	185				
Ini_1	4.81	0.09	5.6	101.6	4.20	4.29	1.12
Ini_2	4.31	0.14	59.9	104	4.30	4.44	0.97
Dev_1	6.49	0.02	3.2	106.4	4.40	4.42	1.47
Dev_2	3.47	0.28	0	106.4	4.40	4.68	0.74
Dev_3	3.71	0.26	0	101.5	4.19	4.45	0.83
Mid_1	4.51	0.65	0	106	4.38	5.03	0.90
Mid_2	4.15	0.87	0	106	4.38	5.25	0.79
Mid_3	5.14	0.55	0	104.4	4.31	4.86	1.06
Lat_1	3.05	0.14	0	105	4.34	4.48	0.68
Lat_2	5.13	0.39	0	110	4.54	4.93	1.04
Lat_3	5.88	0.48	0	110	4.54	5.02	1.17

6.6 Field Application Efficiency

Fig. 6.4 summarizes the computations of field application efficiency, which was calculated as follows:

$$Field\ Application\ Efficiency = \frac{Crop\ Irrigation\ Water\ Requirement}{Water\ Delivery\ To\ Field} \text{ --------------(6)}$$

The Field Application Efficiency for the Nachchiduwa system can be computed as 3188.98 / 4324 = 0.73 from the data of Table 5.16, showing a reasonably satisfactory performance of the system. Here, it is noted that values of Table 5.16 were much unreasonably higher than 1.0 and these are largely due to the considered calculation period or the (average) interval between water applications to the fields, on which Field Application Efficiency largely depends. In arid and semi-arid areas, the field application efficiency with a calculation period of one irrigation season generally falls below 0.90, for obviating salt accumulation in the root zone of the irrigated crop. Hence, from sustainability view point, it does not make sense to try to be "too efficient" in applying irrigation water.

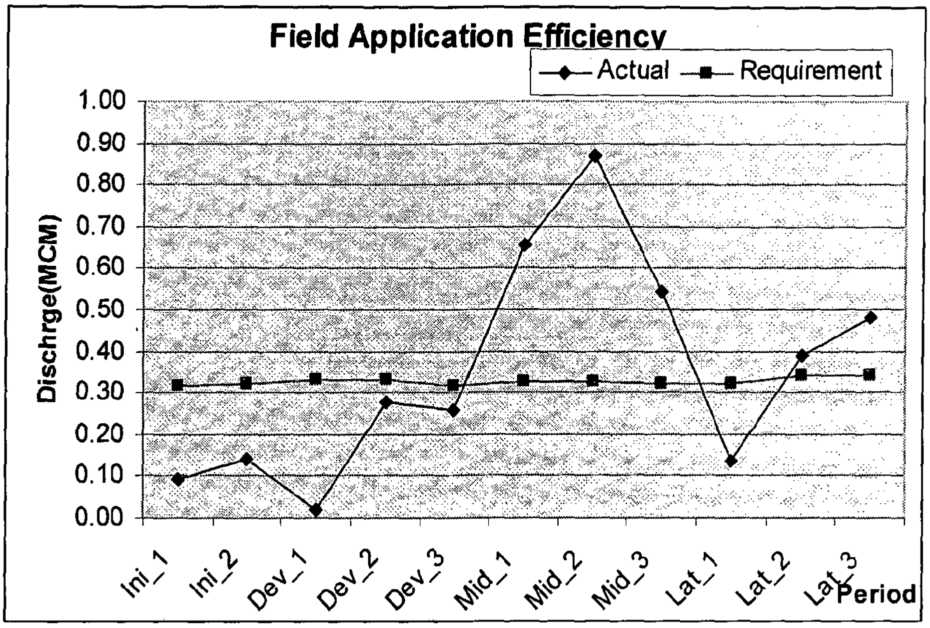


Figure 6.4 Field Application Efficiency

6.7 Effectiveness of Infrastructure

Table 6.6 provides a summary of the quantitative values for the Effectiveness of Infrastructure (Table 5.17), which is computed as:

$$\textit{Effectiveness Of Infrastructure} = \frac{\textit{Number of Functionning Structures}}{\textit{Total Number of Structure}} \text{--------(7)}$$

Table 6.6 shows that the effectiveness, or the good functioning, of irrigation structures in Rajangana is higher, or better, than others. Here, it is noted both Nachchiduwa and Rajangana systems were modernized (or rehabilitated) in 1989 and since then the

Rajangana scheme was intensively monitored/managed by the Irrigation Department. Since this indicator does not account for the type of irrigation structure, a major weakness of the indicator. Notably, the type of structure greatly affects the actual discharge. For example, the differential head in submerged gates, culverts, etc. or under the same upstream sill-referenced head in free flowing gates, weirs, flumes, etc., generally a deviation of more than 5% of actual discharge from the calibrated one signals the need for maintenance or rehabilitation of the flow control structures. It follows that maintenance is needed to keep the system operational. The indicator however sums up all the above four categories of structures. For the analysis to be effective, it is necessary that the structures be divided into their hierarchical importance, viz., main, secondary or tertiary level, and analyzed for each level. In general, a structure is functional if it can be operated or utilized to perform its intended function within the accepted level of accuracy.

Table 6.6: Effectiveness of Infrastructure

Description	Nachchiduwa	Thuruwila	Rajangana
Fully functioning	15	126	146
Partly functioning	73	54	40
Not functioning well	86	22	39
Completely not functioning	41	16	19
Total functioning structure	88	180	186
Total number of structure	214	218	244
Effectiveness of structure	0.41	0.83	0.76

6.8 Equipment Effectiveness

The Equipment Effectiveness is computed as:

$$Equipment\ Effectiveness = \frac{Actually\ Functioning\ Equipment}{Total\ Equipment\ \Pr ovided} \text{-------------(8)}$$

This is another important indicator of maintenance exhibiting the extent to which equipment (as for example, Concrete Mixers, Tamping Rollers, Backhoe, Vibrators, Draggers, etc.) provided for use by system managers to maintain and use the infrastructure is in good working condition. In practice, most equipments usually share with other systems. Therefore, there exists some degree of overlap and, in turn, the subjectiveness in the assessment of effectiveness using this ratio. It however indicates the extent to which capital investment is required for maintenance and up-keeping. From Table 6.7, it can be seen that the equipment effectiveness for Nachchiduwa is 0.67 whereas it is 0.5 for both the other systems; latter indicating the poorer performance than the former.

Table 6.7 Equipment Effectiveness

System	Particulars	Equipment Effectiveness Ratio
Nachchiduwa	Actually functioning equipment	8
	Total equipment provided	12
	Equipment Effectiveness	0.67
Ragangana	Actually functioning equipment	5
	Total equipment provided	10
	Equipment Effectiveness	0.5
Thuruwila	Actually functioning equipment	5
	Total equipment provided	10
	Equipment Effectiveness	0.5

6.9 Relative Water Supply

The Relative Water Supply (RWS) was calculated as follows:

$$\text{Re}\,lative\ Water\ Supply = \frac{Irrigation + Effective\ Ra\inf all}{Evapotranspiration + Seepage + Percolation} \text{----------(9)}$$

As also discussed earlier, the determination of Relative Water Supply is not entirely straightforward. Demand totally based, for example, on evapotranspiration from particular crops or cropping patterns may also include water lost through natural seepage and/or percolation. In addition, it can also include allowances for cultural practices, such as use of water for weed control in rice cultivation, for leaching of salts from the root zone. The standard approach is to assess adequacy over the cycle of water deliveries within an irrigation system. This cycle of deliveries frequently matches the rotational irrigation and typically the intervals are weeks, ten days or fourteen days, during which each user gets the same number of water delivery turns or the same percentage of total volume delivered. In this case, particularly for crop water requirements, time period was taken as 10 days interval, and land preparation water discharge not considered. Normally RWS ranges from 1.2 to 1.5. This range is however exceeded during developing and Middle stages. Table 6.8 indicates that except for the initial stages, which shows the RWS values close to the upper limit of 1.5, all other values are quite high. It implies that more water than required is supplied to the field for irrigation, which may cause waterlogging in future if not remedied through proper drainage.

Table 6.8: Relative Water Supply

Period	Irrigation + Effective rain fall (1)	Seepage + Percolation + Evapotranspiration (2)	Relative water supply (1) / (2)
Ini_1	1201	775.1	1.55
Ini_2	1173	777.5	1.51
Dev_1	1456	779.9	1.87
Dev_2	1469	779.9	1.88
Dev_3	1366	774.5	1.76
Mid_1	1344	779.5	1.72
Mid_2	1453	785.1	1.85
Mid_3	1450	783.5	1.85
Lat_1	1360	722.0	1.88
Lat_2	1418	722.0	1.96

Note: Land preparation period of 25 days is excluded from the analysis.

6.10 Dependability of Supply

Dependability of supply was calculated as follows:

$$Dependability\ of\ Supply = \frac{Actual\ Duration\ of\ Water\ Delivery}{Planned\ Duration\ of\ Water\ Delivery} \text{-----------}(10)$$

Dependability of supply is usually decided in the seasonal meetings, before the growing season. Since the Rajangana and Thuruwila systems have the same crop calendar, the dependability of supply for Thuruwila is the same as Rajangana. Plan duration is calculated based on the crop water requirement. But while distributing, though the canal capacity is enough to feed, some stager is seen inside the command largely due to delays in land preparation due to delays in loan payments. As seen from Table 6.9 and Fig. 6.5, all the three systems exhibit an acceptable dependability of supply.

Table 6.9: Summary of dependability of supply

Description	Nachchiduwa	Thuruwila	Rajangana
Dry Season	1.025	1.05	1.05
Wet Season	0.855	1.013	1.013

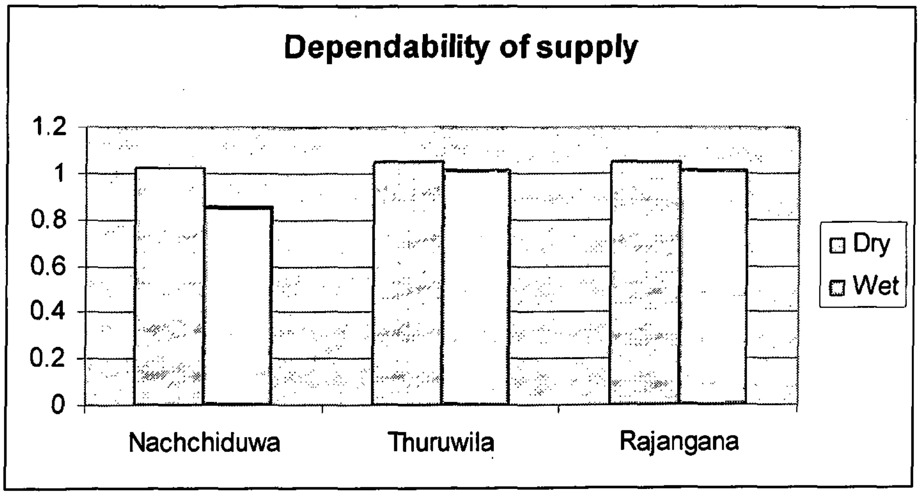


Figure 6.5 Dependability of Supply

6.11 Regularity of Delivery

The regularity of delivery is computed from

$$Regularity\ of\ Deliveries = \frac{Actual\ Interval\ of\ Water\ Delivery}{Planned\ Interval\ of\ Water\ Delivery} \text{----------(11)}$$

Fig. 6.6 shows that the actual interval of water delivery at point F is significantly different from the planed one. Other points could not be considered because of non-availability of data. Notably, point F lies in the tail end of the considered field canal. As seen from Fig. 6.6, in the initial stage after 7 days water reaches the field, larger than the desired 3 days implying a delay and thus behind the crop calendar. It is of common experience that the water delivered over certain time period significantly affects the overall adequacy and direct affect the crop production. The difference between the planned and the actual there appears to be uncertain or unpredictable variation in volume and/or timing because of which farmers are not in a position to decide on the application of fertilizers in optimal quantity and sow quality seeds. Thus, the inference is that water deliveries need to be regularized for better crop production.

6.12 Modified Interquartile Ratio

The Modified Interquartile Ratio was calculated as:

$$Modified\ Interquartile\ Ratio = \frac{Average\ DPR\ of\ Best\ 25\%\ of\ the\ System}{Average\ DPR\ of\ Worst\ 25\%\ of\ the\ System} \text{--------(12)}$$

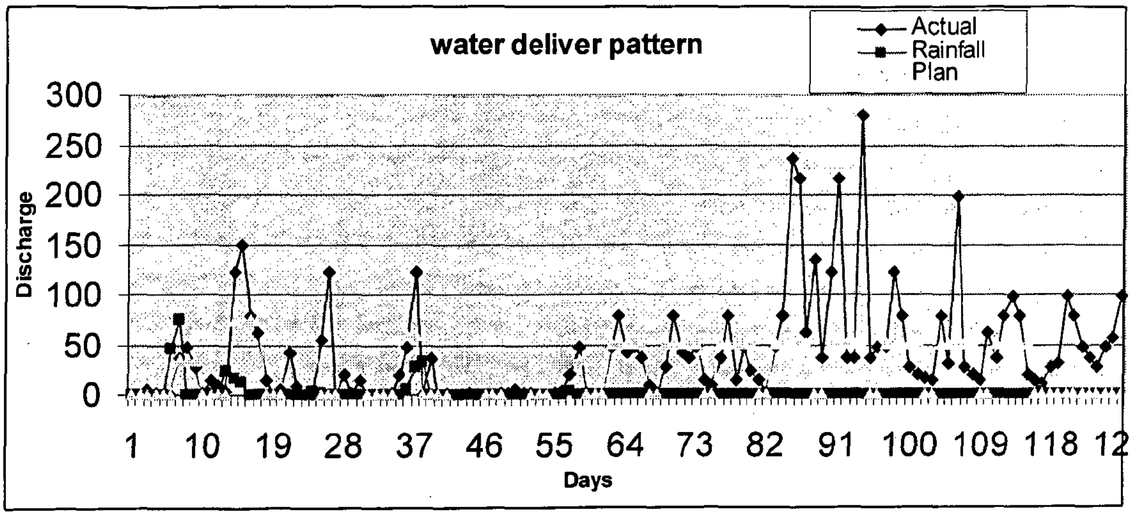


Figure 6.6 Regularity of delivery at Point F

The Interquartile Ratio is a simple indicator employing Delivery Performance Ratio (DPR) and can be used to give a quick view of the overall equity of water supply in the command area. Fig. 6.7 shows the allocation which can be effective in achieving a fair distribution of water. In Nachchiduwa system, the ratio (=1.61) shows poor management of the system, and water supply is not fairly distributed. It is notable that for a good managed system, the ratio should be close to 1.

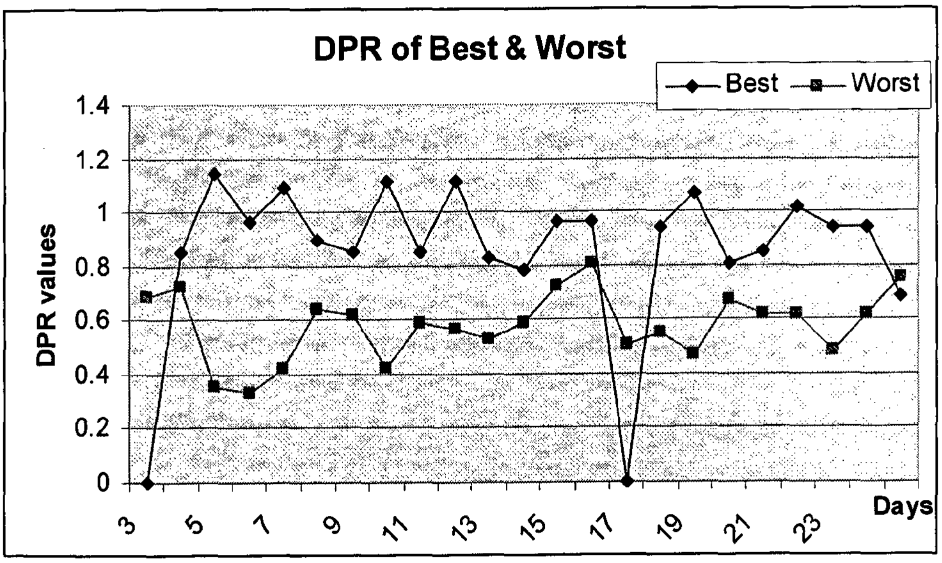


Figure 6.7 Interquatile Ratio

6.13 Head to Tail Equity Ratio

Head to Tail Equity Ratio was calculated as follows:

$$Head{:}Tail\ Equity\ Ratio = \frac{Average\ DPR\ of\ Upper\ 25\%\ of\ the\ System}{Average\ DPR\ of\ Tail\ 25\%\ of\ the\ System} \text{ ---------(13)}$$

In some circumstances, particularly when looking at performance of a particular canal, it may be more useful to look at the difference between the water supply at head and at tail of the canal. Fig. 6.8 shows the difference of DPR in Head to Tail. Apparently, at initial stage, the Ratio-values are low indicating the poor performance of the system.

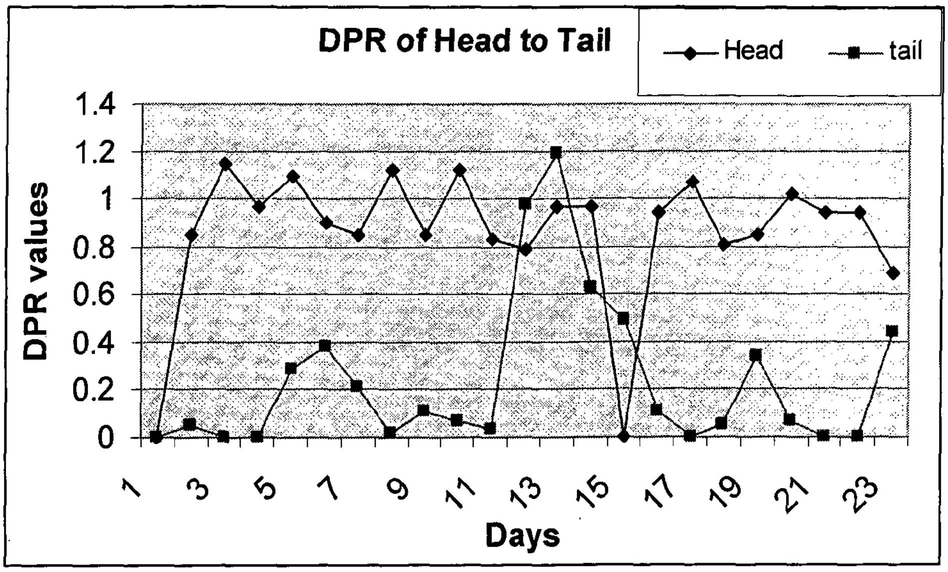


Figure 6.8 Head to Tail Ratio

6.14 Irrigated Area Performance

The Irrigated Area performance Ratio was calculated as follows:

$$Irrigated\ Area\ Performance = \frac{Actual\ Area}{Target\ Area} \text{ ----------------------(14)}$$

The target area refers to the total irrigable area considered during the design of the system or following the latest rehabilitation. If the area ratio is averaged over one year, it quantifies the intensity of irrigation. As seen from Tables 6.10a&b, all the three systems indicate performance indicator value more than 1, implying that all the systems perform well.

Table 6.10(a): Irrigated Area Performance

System	Variables	Values
Nachchiduwa	Actual area (ha)	2800
	Target area (ha)	2800
	Irrigated area performance	1
Ragangana	Actual area (ha)	6200
	Target area (ha)	6515
	Irrigated area performance	1.05
Thuruwila	Actual area (ha)	193
	Target area (ha)	193
	Irrigated area performance	1

Table 6.10(b): Irrigated Area Performance in Anuradapura district

Season	(1) Total Sown Area (ha)	(2)Total harvested area (ha)	(3) Irrigated area performance (3) = (2)/(1)
Wet 99/00	56543	54282	0.96
Wet 00/01	40799	40595	0.99
Wet 01/02	47191	47065	0.99
Wet 02/03	66055	62753	0.95
Dry 2000	21213	19827	0.93
Dry 2001	17507	17475	0.99
Dry 2002	12347	11730	0.95
Dry 2003	23570	21684	0.92

6.15 Cropping Intensity Performance

The Cropping Intensity Performance was calculated as follows:

$$Cropping\ Intensity\ Performance = \frac{Actual\ Cropping\ Intensity}{Target\ Cropping\ Intensity} \text{---------------}(15)$$

Direct indicators for assessing performance in terms of area irrigated include cropped area, cropping intensity, and irrigation intensity. However, to more clearly understand the performance, it is useful to compare these values with an expected target. Above indicators which were discussed earlier explained the system performance in a deifferent perspective. As seen from Table 6.11 and Fig. 6.9, Nachchiduwa did not achieve cropping intensity equal to 1 during four years, and the Rajangana during one year. Though the water efficiency is quite high, the total output or production may be less due to less cropping intensity.

Table 6.11: Summary of Cropping intensity

System/Year	2005	2004	2003	2002	2001
Nachchiduwa	1	0.5	0.77	0.69	0.68
Rajangana	1	0.5	1	1	1

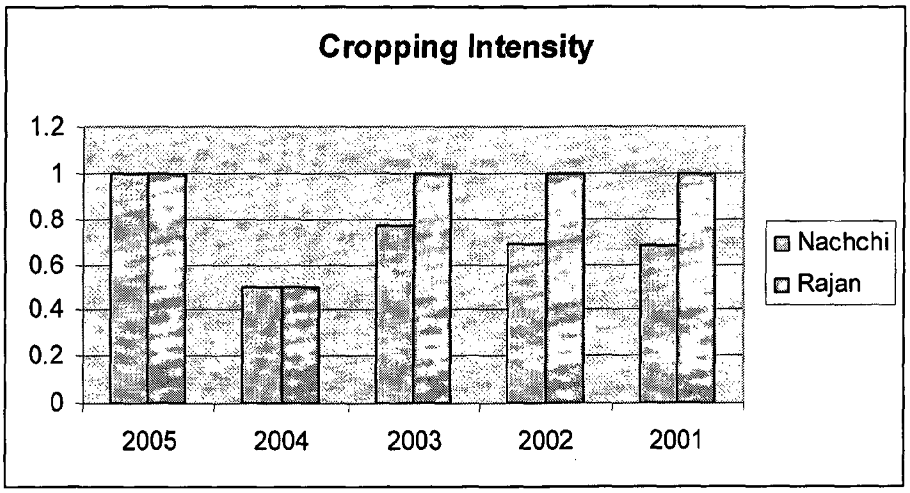


Figure 6.9 Cropping Intensity

6.16 Production Performance

Similar to the other ratios based on water delivery, indicators may also be developed using production (tons), yield (tons/ha) and productivity of water (kg/cubic meter), measuring the output in comparison to the targeted one. The production performance was calculated as follows:

$$Production\ Performance = \frac{Total\ Production}{Target\ Production} \text{------------------} \mathbf{(16)}$$

Table 6.13 gives the summary of Production performance for Nachchiduwa and Rajangana systems. The targets may be fixed employing a simple percentage increase over the existing level, for example, relative to national targets or norms or an empirical value which represents the actual performance of the top ten or twenty percent of farmers in the system. The last method of determining targets has the advantage that it is site specific but certainly achievable by a larger number of farmers. In this regard, the Government has floated the concept of demonstration plots in the field. As seen from Table 6.12, the high values of the indicator for all the three systems exhibit their reasonable performance. However, there exists a possibility for improvement.

Table 6.12: Summary of yield (or Production) performance

Season	Nachchiduwa	Thuruwila	Rajangana
Wet	0.84	0.99	0.95
Dry	0.98	0.92	0.90

6.17 Yield Performance

The Yield Performance was calculated as follows

$$Yield\ Performance = \frac{Actual\ Yield}{Target\ Yield} \text{ -----------------------(17)}$$

Table 6.13 and Fig. 6.10 show the yield performance of all the three systems. All high values approaching 1.0 indicate that the target is reasonably achieved by all the systems.

Table 6.13: Summary Yield Performance

Season	Nachchiduwa	Thuruwila	Rajangana
Wet	0.97	0.996	0.95
Dry	0.84	0.998	0.88

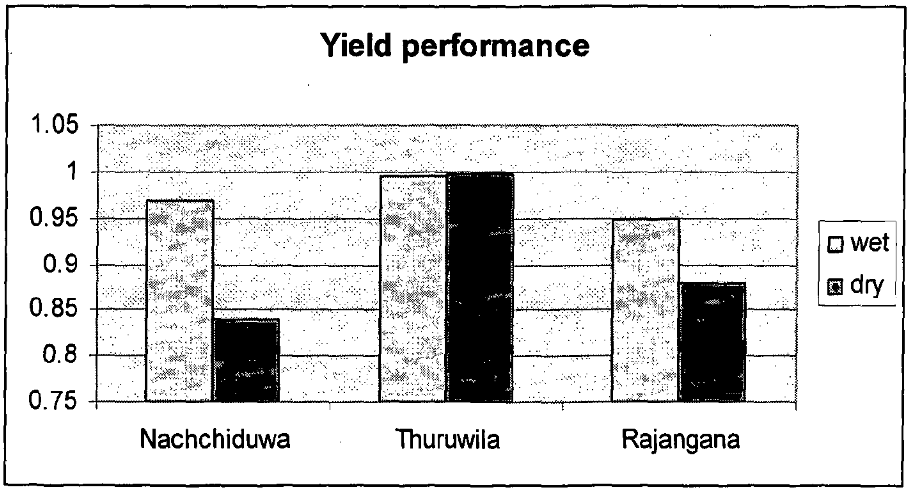


Figure 6.10 Yield Performance

6.18 Water Productivity Performance

The Water Productivity Performance was calculated as follows:

$$Water\ Productivity\ Performance = \frac{Actual\ Water\ Productivity}{Target\ Water\ Productivity} \quad \text{-----------(18)}$$

As also discussed earlier, the efficiency alone is not a sufficient indicator to define the performance of an irrigation system. Indicators of water productivity expressed in terms of production or value of production per unit of water have significant importance in increasingly water-scarce situation. A canal irrigation system may have high conveyance efficiency with a minimum of seepage and operational losses. However, if water delivery is too rigid or unreliable, there will be considerable waste further down at the farm level. A water productivity indicator provides a global indication of the effectiveness of water conservation measures and of the quality of service provided to the users, as well as the farm use of water and other inputs. The standard target water productivity values varied from 0.5 to 1.1 kg/m^3, totally dependent on environmental, soil and other factors. Therefore average of 0.5 and 1.1, i.e. 0.8, is taken for calculation. As seen from Table 6.14 and Fig. 6.11, all three systems give values below the target water productivity, implying the system required to give attention for enhanced productivity.

Table 6.14: Summary of Water Productivity Performance

Season	Nachchiduwa	Thuruwila	Rajangana
Wet	0.36	0.29	0.22
Dry	0.72	0.37	0.29

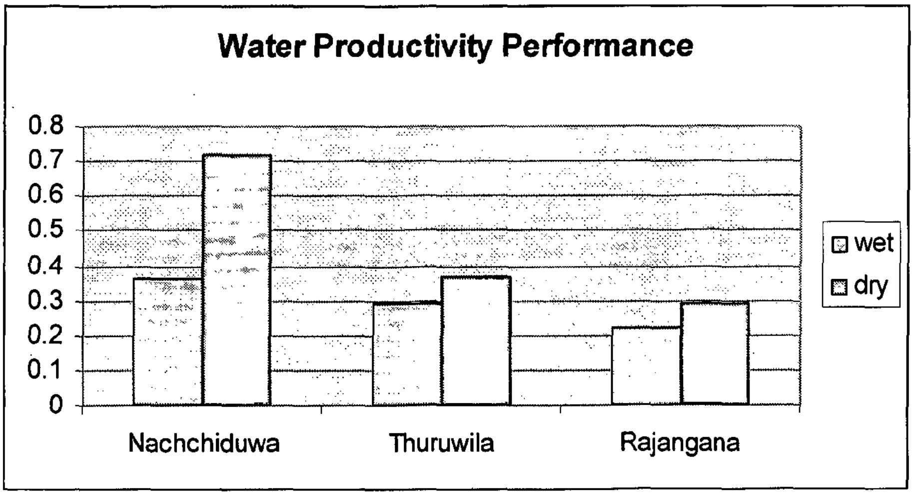


Figure 6.11 Water Productivity Performances

6.19 Total Financial Viability

The Total Financial Viability was calculated as follows

$$Total\ Financial\ Viability = \frac{Actual\ O\&M\ Allocation}{Total\ O\&M\ \mathrm{Re}quirements} \text{------------------(19)}$$

There has been increasing concern in recent years over the levels of recurring costs required to keep irrigation systems functioning. One set of concern has been with efforts to raise revenues from water users to support operation and maintenance costs, and often some or all of the capital costs of individual irrigation systems. In Sri Lanka, since it is not practiced, the next performance indicator, i.e. Fee collection, has been taken up. As seen from Table 6.15, the total O&M requirements should be based on a detailed budget which is approved through a good budgeting system. If such a system is not in place, a budget can be based on the estimated O&M expenditure per hectare. The table indicates that about 30% of the total O&M costs is required to maintain the systems.

Table 6.15: Operation and Maintenance budget

Sl. No.	Item	Unit	Nachchiduwa	Thuruwila	Ragangana
1.	Operation Budget	Rs	134,200	9,000	281,600
	Ratio to irrigable area	Rs/ha	46	46	42
2	Maintenance Budget	Rs	874,600	58,500	1,835,900
	Ratio to irrigable area	Rs/ha	301	303	277
	(a) Total actual O&M	Rs	1,008,800	67,500	2,117,500
	(b) O&M requirement	Rs	1,452,500	96,500	2,754,000
3	Total financial viability = (a)/ (b)		0.69	0.70	0.77

6.20 Fee Collection Performance

The Fee Collection Performance was calculated as following equation

$$Fee\ Collection\ Performance = \frac{Irrigation\ Fee\ Collected}{Irrigation\ Fee\ Due} \text{---------------------(20)}$$

In many countries, water charges (or irrigation fee) are collected from the farmers. The fraction of annual fees (charges) due to be paid to the Water Users Associations (WUA) and/or the irrigation district is an important indicator for level of acceptance of irrigation water delivery as a public service to the farmers. But in Sri Lanka, such a practice is not followed. Table 6.17 shows the ratio of collection in qualitative terms, indicating a less favorable condition.

Table 6.16: Details of Fee Collection

Sl. No.	Item	unit	Nachchiduwa	Thuruwila	Ragangana
1.	Acreage Tax paid to ADC	Rs/Ha/Annum	15	16	15
	Ratio of collection	%	100	100	100
2	Membership Fee				
	1.Entrance	Rs/ Annum	100	130	100
	Ratio of collection	%	100	100	100
3	O & M Fee for Jalapalaka & Maintenance	Rs / Ha / Annum	1500 (1 bushel/crop /acre)	750 (300 / acre / year)	1500 (1 bushel / crop / aree)
	Ratio of collection	%	Very poor	Poor	80-90

6.21 Area Based Profitability

The Area Based Profitability was calculated using the following equation:

$$Area\ Based\ profitability = \frac{Incremental\ Benifit\,/\,Unit\ Area}{Total\ Irrigation\ Expenses\,/\,Unit\ Area} \text{ ----------}\mathbf{(21)}$$

This indicator requires evaluation of farm level economics and can be modified to include or exclude the discounted value of the capital cost of the system depending on whether or not the capital is considered as a sunk cost. Table 6.17 gives the summary of all the three systems, indicating acceptable expenses incurred at farm level. Here, total irrigation expenses were taken as Operation and Maintenance expenditure incurred by the Irrigation Department only, and excluding the expenses by other agencies.

Table 6.17: Area Based Profitability

Nachchiduwa	Thuruwila	Rajangana
10.65	16.92	18.41

6.22 Water Based Profitability

The Water Based Profitability was calculated as follows.

$$Water\ Based\ Profitability = \frac{Incremental\ Benifit\,/\,Unit\ Water}{Total\ Irrigation\ Expenses\,/\,Unit\ Water} \text{ --------(22)}$$

There is no limit to the government expenses. All parallel agencies up to Ministry level, other expenses incurred indirectly and directly should be taken into account. It was however not possible at this stage, and therefore, not collected. Therefore, the profitability is limited up to the farm level economics only. Table 6.18 and Fig. 6.12 show the summary of water based profitability. Nachchiduwa and Thuruwila exhibit to be low but profitable systems. However, Rajangana showing -80 indicates a great loss to the Government. One of the remedies may be that Rajangana may shift to some other cropping pattern, rather than adhering to the present paddy crop.

Table 6.18: Water Based Profitability

Nachchiduwa	Thuruwila	Rajangana
9.7	9.7	-80.2

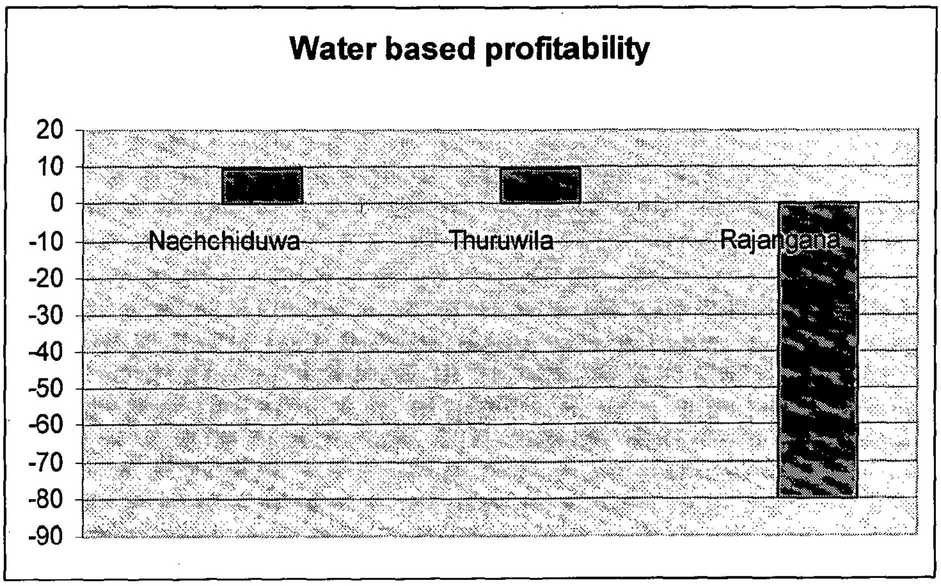


Figure 6.12 Water based profitability

6.23 Price Ratio

Price Ratio is calculated as follows:

$$\text{Price Ratio} = \frac{\text{Farm Gate Price of Crop}}{\text{Nearest Market Price of Crop}} \quad \text{-------------------------------}(23)$$

Normally farmer expects a high farm-gate price for his seasonal harvest whereas the consumer expects a low market price for rice. Price ratio can be used to assess these expectations. The farm-gate price is usually determined for paddy, and the market price for rice. On an average, milling of 1 kg of paddy produces 0.65 kg of rice. It is worth noting that the price variation during short intervals (e.g. 3-4 days, weekly) cannot be determined by carrying out a sample survey. Therefore, the Central Bank of Sri Lanka for each quarter of the calendar year prepares the price ratio. Figure 6.12 shows the details of 2000 to 2004. It is expected that when the country reaches near self-sufficiency in paddy production, the market price will get stabilized against the consumer demand and the farmer will be able to draw a stable price for the produce. As seen from Fig. 6, the price ratio is stable around 0.78.

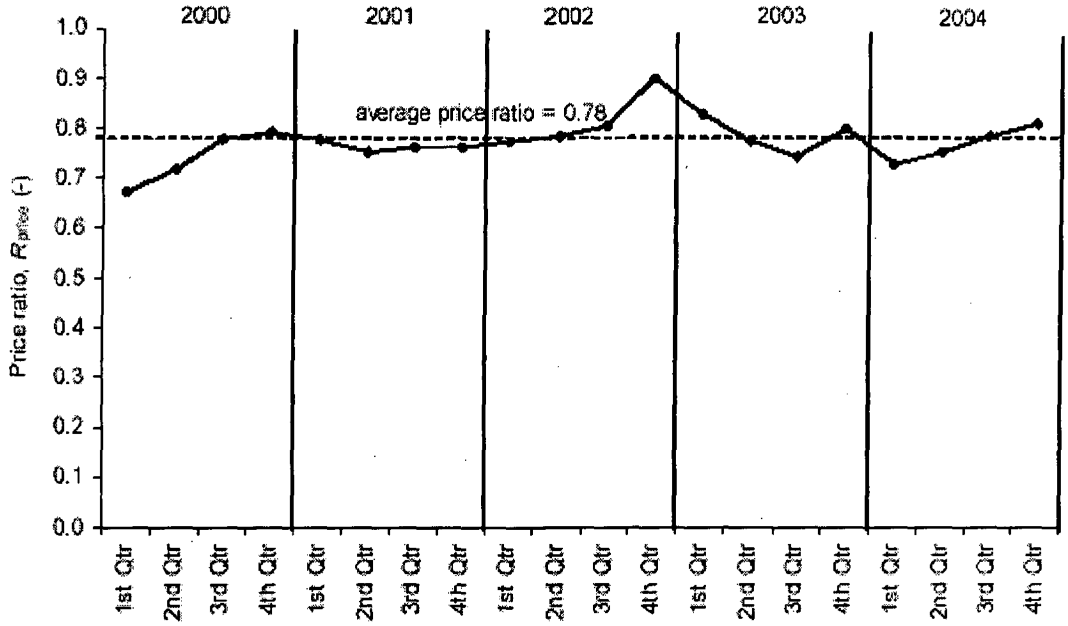


Figure 6.12(a) Price Ratio

6.24 Irrigation Employment Generation

It is computed as:

$$Irrigation\ Employment\ Generation = \frac{Annual\ Person\ days\,/\,ha\,Labour\ in\ Scheme}{Anual\ Number\ official\ working\ days} \quad \text{-(24)}$$

Table 6.19 shows the irrigation employment generation, which is quantified as 1.35, indicating that the irrigation employment generation is satisfactory.

Table 6.19: Irrigation Employment Generation

Particulars	Nachchiduwa	Thuruwila	Rajangana
Annual persons days/ha	340	340	340
Annual no. of official working days	252	252	252
Irrigation Employment Generation	1.35	1.35	1.35

6.25 Irrigation Wage Generation

The Irrigation Wage Generation was calculated as following equation

$$Irrigation\ Wage\ Generation = \frac{Anual\ Average\ Rural\ Income}{Anual\ National\ (or\,Regional)\ Average\,Income} \quad \text{---(25)}$$

Table 6.20 shows that the Irrigation Wage Generation is greater than one, indicating that most major and medium irrigation tanks give the average income higher than the national average income. But this computation is valid only for two seasons. If the cropping intensity is low, this value goes down to half of it. As known, the water availability plays a major role in social life. In many countries, the Departments of Agriculture, Labor, or Census which collect the basic agricultural and economic data can be used easily by irrigation managers as the source of information on socio-economic impacts and trends, such as employment, wages and poverty levels.

Table 6.20: Irrigation Wage Generation

Particulars	Nachchiduwa	Thuruwila	Rajangana
Annual average income (Rs)	163,267	110,137	125,241
Annual National average income (Rs)	100,000	100,000	100,000
Irrigation Wage Generation	1.63	1.1	1.25

6.26 Relative Prosperity

The Relative Prosperity was calculated as follows.

$$\text{Re}\mathit{lative}\ \text{Pr}\mathit{ospirity} = \frac{\mathit{Percent\ Population\ Above\ Poverty\ Line\ in\ Scheme}}{\mathit{Percent\ Population\ Above\ Poverty\ Line\ in\ Nationally}} \quad \textbf{--(26)}$$

Table 6.21 shows the computations of Relative Prosperity for all the three systems. Among the three systems, Nachchiduwa has the highest value of the indicator, implying the people of the system to be of relatively high prosperity. Social impact refers to the effect of irrigation on people, their well-being, social organization, and livelihoods. Measurements can include comparison of irrigated and adjacent non-irrigated areas, variation over time and space within the irrigated area, and variations among socio-economic classes on specific social parameters. In multipurpose projects measures of the benefits of non-irrigation uses of water, such as recreation or fishing, could also be incorporated. Managers and policy makers need to decide on the priority issues, and develop their own indicators for these attributes.

Table 6.21: Relative Prosperity

Particulars	Nachchiduwa	Thuruwila	Rajangana
% Population above poverty line in Scheme (1)	100	94.7	87.9
% Population above poverty line in Nationally (2)	75	75	75
Relative Prosperity (3) = (1) / (2)	1.33	1.23	1.17

6.27 Technical Knowledge of staff

It is computed as:

$$Technical\ Knowladge\ Of\ Staff = \frac{\begin{array}{c}Number\ of\ Staff\ with\ Knowledge\\ \text{Re}quired\ to\ Fullfill\ Job\end{array}}{Total\ Number\ of\ Staff} \text{---------}\textbf{(27)}$$

Table 6.22 gives the technical knowledge of staff according to the cadre of their work in the Irrigation Department. Here, the Agriculture Department is excluded from computation. Actual technical knowledge of staff can be ascertained through sample tests, while required knowledge can be ascribed to the job description. The index of 1.0 is indicative of the full staff being knowledgeable and skilled to do the required task.

Table 6.22 Technical Knowledge of staff

Description	Nachchiduwa	Thuruwila	Ragangana
No. of staff with knowledge required	3	3	3
Total no. of staff	3	3	3
Technical Knowledge of staff	1	1	1

6.28 Users' Stake in Irrigation System

The Users' Stake in Irrigation System was calculated with the following equation.

$$Users'\ Stake\ in\ Irrigation\ System = \frac{Number\ of\ Active\ Water\ Users\ Organizations}{Total\ Number\ of\ Water\ Users\ Organizations} \textbf{-(28)}$$

'Activeness' of Water Users Associations (WUA) can be measured using the easily acquired data, such as percent holding of regular (or the minimum required) meetings, percent of users participating in these meetings, or number of organizations fulfilling the agreed tasks, such as fee collection, maintenance, or rotating water. Table 6.23 shows the

Users' Stake in Irrigation system is in good condition in both Nachchiduwa and Thuruwila, and not in Rajangana. Most of the indicators also showing poor performance of the Rajangana system can be attributed to the ineffectiveness of WUAs in this system. If the water users group is strong, operation of the system becomes easy for water managers.

Table 6.23: Users' Stake in Irrigation System

Description	Nachchiduwa	Thuruwilla	Rajangana
Total no of water use organization	14	1	32
No of active water users organization	14	1	25
Users' Stake in Irrigation system	1	1	0.71

6.29 Sustainability of Irrigation Area

The Sustainability of Irrigation Area is calculated as:

$$Sustainability\ of\ Irrigated\ Area = \frac{Current\ Irrigable\ Area}{Intial\ Irrigable\ Area} \text{-----------}\mathbf{(29)}$$

This ratio addresses primarily those aspects of the physical environment responsible for damages occurring due to the actions of irrigation managers. This however does not intend to be insensitive to other aspects of the environment, but to focus on those concerns falling in the realm of irrigation agency. Aspects of physical sustainability that managers can affect relate primarily to over- or under-supply of irrigation water that leads to waterlogging or salinity. Table 6.24 describes the sustainability of Irrigated areas in all the three systems as more than 1, implying their sustainability.

Table 6.24: Sustainability of Irrigated Area

Description	Nachchiduwa	Thuruwila	Rajangana
Original Plan Irrigable area (ha)	2384	173	5371
Current irrigable area (ha)	2905	193	6639
Sustainability of Irrigated area	1.22	1.12	1.24

6.30 Impact of flooding

The Impact of flooding is calculated as:

$$\text{Im}\,pact\ of\ Flooding = \frac{Area\ Subject\ to\ Flooding}{Total\ Irrigable\ Area} \text{-------------(30)}$$

In recent times, people are getting more concerned with the quality of drainage water. Though there may be local standards for assessing the environmental impact of poor drainage, no widely accepted indicator is available to date. Table 6.25 shows that all the three systems are not sustainable with regard to Irrigated areas, as the indicator values are quite low.

Table 6.25: Impact of flooding

Description	Nachchiduwa	Thuruwila	Rajangana
Total Irrigable area (ha)	2905	193	6639
Area subjected to flooding	165	7	263
Sustainability of Irrigated area	0.056	0.036	0.039

All the computed values of the above indicators/measures are summarized in Table 6.26, and the overall performance of the three systems assessed as follows.

Table 6.26: Relation between Performance measures and indicators

Performance measures	Performance Indicator	Values of performance indicator		
Operational Performance		**Nachchiduwa**	**Thuruwila**	**Rajangana**
Efficiency.	Effectiveness of Infrastructure	0.41	0.83	0.76
	Equipment Effectiveness	0.67	0.5	0.5
Predictability.	Dependability of Supply	0.94	1.03	1.03
	Regularity of Deliveries	**Not calculated**		
Equity	Modified Inter quartile Ratio	1.61		
	Head: Tail Equity Ratio	4.11		

Strategic Performance				
Social Impacts	Irrigation Employment Generation	1.35	1.35	1.35
	Irrigation Wage Generation	1.63	1.1	1.25
	Relative Prosperity	1.33	1.23	1.17
Water Supply Performance				
Conveyance indicators	Delivery Performance Ratio	0.80, 0.90, 0.84, 0.92, 0.56, 0.22		
	Water Delivery Performance	1.12	0.92	1.12
Efficiency.	Overall Project Efficiency	0.76	0.40	0.35
	Conveyance Efficiency	0.94		
	Distribution Efficiency	0.977		
	Field Application Efficiency	0.73		
Adequacy.	Relative Water Supply	0.85 – 1.88		

Agricultural Performance				
Productivity–Area indicators	Irrigated Area Performance	1	1.05	1
	Cropping Intensity Performance	0.73	0.73	1
Production indicators	Production Performance\	0.91	0.91	0.93
	Yield Performance	0.91	1.0	0.92
	Water Productivity Performance	0.54	0.33	0.26
Profitability of irrigated agriculture.	Area Based Profitability	19	29.7	32.3
	Water Based Profitability	9.7	9.7	-80.2

Economic, Social and Environmental Performance				
Performance measures	**Indicator**	**Nachchiduwa**	**Thuruwila**	**Rajangana**
Equity	Water Productivity	0.54	0.33	0.26
	Sustainability of Irrigated area	1.22	1.12	1.24
Finacial viability	O & M funding	0.69	0.70	0.77
	Fee collection Ratio	0.00	0.01	0.8
	Price Ratio	0.78	0.78	0.78

Social impact	Irrigation Employment Generation	1.35	1.35	1.35
	Irrigation Wage Generation	1.63	1.1	1.25

	Relative Prosperity	1.33	1.23	1.17
Social capabilities	Technical Knowledge of Staff	1	1	1
	Users' Stake in Irrigation System	1	1	0.71
Environment	Sustainability of Irrigated Area	1.22	1.12	1.24
	Impact of Flooding	0.056	0.036	0.039

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CHAPTER VII

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30-Jun-04	4441	3674	1142	438	529	1094	2294	244	-	1689	449	42	613
1-Jul-04	4441	3674	1142	416	490	1094	2090	275	-	1517	403	36	498
2-Jul-04	4441	4565	1021	385	490	1066	2090	419	-	1602	425	48	406
3-Jul-04	4441	3772	1021	385	490	1066	2140	460	-	1778	403	14	406
4-Jul-04	4252	3087	1142	503	137	1331	2090	688	-	1689	380	9	356
5-Jul-04	4441	4767	945	385	595	1094	2728	419	12	2256	653	36	526
6-Jul-04	4252	3625	945	344	490	1094	2294	244	-	1869	653	79	540
7-Jul-04	4252	3674	1142	395	516	1151	1893	113	-	1823	473	14	598
8-Jul-04	4441	3723	1142	395	490	1094	1569	113	2	1869	573	48	628
9-Jul-04	4441	3674	1060	375	464	1094	1798	-	-	1689	380	23	598
10-Jul-04	4441	3747	1060	375	464	1094	2191	902	-	1689	403	14	498
11-Jul-04	4441	3087	1227	503	137	786	2090	639	-	1517	276	2	458
12-Jul-04	4634	4266	1060	438	595	1039	2617	309	11	2256	795	48	458
13-Jul-04	4634	3871	1021	416	490	1094	2453	309	-	1778	737	79	569
14-Jul-04	4441	3772	945	375	464	1066	2294	214	-	1689	573	236	658
15-Jul-04	4441	3772	908	334	490	1094	1893	186	-	1476	380	217	498
16-Jul-04	4346	3674	908	334	490	1094	1893	186	-	1517	295	62	512
17-Jul-04	4346	3723	908	324	490	1066	1942	186	-	1778	219	135	498
18-Jul-04	4537	3871	1227	525	137	1180	1990	460	-	1778	202	36	406
19-Jul-04	4634	3871	90	334	582	1209	2400	419	9	2256	855	122	540
20-Jul-04	4346	3723	772	294	439	1039	1990	419	-	1778	737	217	431
21-Jul-04	4346	3282	772	314	439	1039	1525	74	-	954	425	36	252
22-Jul-04	5031	3871	1060	711	439	1331	2294	244	-	1645	522	36	540
23-Jul-04	5234	4019	1060	354	439	1269	1990	186	-	1689	522	280	736
24-Jul-04	5132	4167	1060	354	516	1209	2294	792	-	1869	256	36	643
25-Jul-04	6081	3087	1227	536	186	1209	2294	113	-	1963	795	48	512
26-Jul-04	5337	4565	1060	395	647	1209	2784	460	11	2358	795	48	485
27-Jul-04	5234	4068	945	354	569	1209	2090	502	-	1963	917	122	628
28-Jul-04	4831	3772	908	961	569	1209	2294	214	33	1778	626	79	658
29-Jul-04	4732	3772	908	375	569	1209	2090	381	-	1559	522	27	431
30-Jul-04	4732	3772	873	344	542	1094	1705	460	-	1778	295	20	485
31-Jul-04	4732	3871	772	334	529	834	1798	792	-	1963	276	16	512
1-Aug-04	4732	3087	1227	593	137	1239	2191	244	-	1778	256	14	498
2-Aug-04	4732	4167	740	294	595	1066	2617	381	16	2156	737	79	418
3-Aug-04	4441	3625	740	304	503	1094	1942	419	-	1733	980	31	308
4-Aug-04	4441	3625	740	304	503	1094	1990	160	-	1778	573	198	704
5-Aug-04	4441	3576	709	304	542	1094	1798	902	-	1602	737	27	512

Chapter 7

Summary and conclusions

The study can be summarized and concluded in the following heads:

7.1 Assessing Water supply performance

As seen from Figure 6.3, the overall project efficiency was very low, implying that, during the wet season, the manager has routinely not followed the planned water delivery schedules and delivered more irrigation water than the required. In addition, water deficit does not exist in the cropped area. When rain starts, before the water level rises up to the field bunds, farmers drain excess water from the paddy fields. In this manner, rainwater also flows into the drainage canals. In this study, DPR was calculated for dry season. Normally, Nachchiduwa had fairly good water management system. Even though the water volume is not included to target volume, the delivery performance had been good. It was however not true for Thuruwila and Nachchiduwa. During the wet seasons, because of the over-supply of water, DPR exceeded the target level. In the large and medium irrigation schemes in Sri Lanka, the distributory level water is distributed by the farmer organizations. At present, the field staff delivers the irrigation water up to the distributory level canal system and thereafter the farmer organizations distribute water to the paddy fields. Hence, to improve the irrigation performance, the farmer organizations as well as the field staff have to co-operate. The present exercise of minimizing water stress condition in the cropped area by increasing water deliveries should no longer exist. A new task of increasing seasonal grain yield by improving water productivity is recommended to put into practice.

7.2 Assessing Operational Performance

Performance measures such as efficiency, predictability, equity were mainly considered in this study, and as indicators, Modified Interquatile Ratio, Head to Tail equity, Regularity, Dependability, Effectiveness of infra structure, Effectiveness of instrument were considered. With limited water availability, the dry season used less irrigation water than the wet season. However, even in the dry season, the available water had not been used productively in the cropped area. Dependability was greater than 1 for all the three systems. If it were less than one, farmers cultivated short duration varieties. Growth duration of paddy varieties varies from 105 to 120 days, field conditions needed to be monitored in intervals of at least 10 days. Otherwise, based on the maximum crop growth period, duration is planned in seasonal meetings by all responsible agencies. From Equity view-point, the system is still not in the acceptable limit. The operational staff had succeeded to control the scheme performance without allowing danger to occur, but without considering productivity of water. However, the operational performance can be further improved up to the extent of the target.

7.3 Agricultural performance

The time frame for assessing agricultural performance has to be seasonal or annual depending on the nature of the crops and cropping calendar. The assessment of agricultural performance is important because it links with the indicators showing hydraulic or conveyance performance of the wider agricultural, economic and rural economic systems. Although most irrigation system managers have no direct control over or responsibility for agricultural performance, indicators at this level may be useful for evaluating whether the manager is performing well and is useful to higher level managers. In the irrigation management, fewer indicators are described as used for assessing agricultural performance than for water delivery performance. This is partly because of an engineering bias and partly because yields and areas actually irrigated synthesize many other aspects of farmer management of all inputs available.

7.4 Assessing Socio-ecomomic Performance

In irrigated agriculture, socio-economic performance is used to assess strategic decisions related to different management levels of the irrigated agriculture sector. The indicators used were in terms of Grain Yield per unit of irrigated land area (kg ha-1), Water Productivity in terms of the total volume of water (kg m-3), Price Ratio farm gate price of paddy over the nearest market price, Relative Prosperity. However, in paddy production, water productivity increased through the years due to developments in new high yielding plant types. In the local situation, less availability of improved seed paddy varieties, seed paddy produced by farmers without any quality assurance, as well as little attention being given by most of the farmers on the crop throughout the cultivation, hamper the water productivity. Price ratio was stable around 0.78. When the country reaches near self-sufficiency in paddy production, the market price will be stable against the consumer demand and the farmer gets a stable price for the product at the farm gate price. In the short run, a stable price ratio provides benefits to the farmer as well as to the consumer. In the long run, the escalating cost of production of paddy would lower the investment power of the farmer on paddy cultivation. To compensate for this trend, the Government frequently offers the farmer a price increase of paddy. If there is a shortage of paddy production due to lack of timely information on the seasonal harvest, it is difficult for the Government to plan for a national import program. In addition to this time lag, the import process itself takes at least two months. When the market receives the imported rice, the farmer would get ready to harvest his next crop. Thus, producer prices of paddy would fall, which would lower the income level of the paddy farmer. Thus, the marketing of paddy is a highly time dependent activity. However, timely estimation of grain yield is important for the Government to decide before shortage is imminent.

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REFERENCES

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References

Allen, R.G., Pereira, L.S., Raes, D., and Smith, M. 1998. Crop evapotranspiration, guidelines for computing crop water requirements. FAO Irrigation and Drainage Paper 56, Food and Agricultural Organization of United Nations (FAO) Rome, Italy, pp 300.

Bastiaanssen, W.G.M., and Chandrapala, L. 2003. Water balance variability across Sri Lanka for assessing agricultural and environmental water use. Agricultural water management, 58(2):171-192

Bos, M.G., Burton, M.A.and Molden, D.J., 2005. Performance indicators for irrigation and drainage. Irrigation and drainage performance assessment- practical guidelines, CABI publishing for CAB international, Wallingford,UK, pp 28-61.

Central Bank of Sri Lanka (2002 – 2005). Average producer and retail prices of selected food items. Monthly bulletin August 2002 to September 2005, http://www.lanka.net/central bank/

Department of Census and Statistics, Colombo, Sri Lanka. 1952-2003. National extent and production of paddy. Electronic publications and database on the website http://www. statistics.gov.lk/agriculture/index.htm

Department of Census and Statistics, Colombo, Sri Lanka. 1993-2003. Paddy average yield and production. Electronic publications and database on the website http://www.statistics.gov.lk/ agriculture/index.htm

Department of Census and Statistics, Colombo, Sri Lanka. 2002-2004. Seasonal paddy production. Electronic publications and database on the website http://www.statistics.gov.lk/agriculture/index.htm and electronic communication information @statistics.gov.lk.

Dept., Agri. 2003. *The map of agro-ecological regions of Sri Lanka.* Publication of the Depaerment of Agriculture, Sri Lanka. http://www.agridept.gov.lk/RRDI/Rrdiindx.htm

Dhanapala, M.P. 2000. Bridging the rice yield gap in Sri Lanka. Food and Agriculture Organization of the United Nations. Regional office for Asia and the Pacific, RAP Publication 2000/16.

FAO 56, 1998. Crop evapotranspiration – Guidelines for computing crop water requirements. FAO Irrigation and Drainage paper 56, Food and Agriculture Organization of the United Nations FAO, Rome, Italy, ch. 1- 8.

ICID, 1978. Standards for the calculation of irrigation efficiencies. International Commission on Irrigation and Drainage Bulletin 27(1), pp91-101.

ID, 2002. Potential water resources for development of Ruhunupura. Pre-feasibility study, Irrigation Department, Colombo, Sri Lanka, pp 168

Irrigation Act, No. 13 of 1994. An act amends the irrigation ordinance No. 32 of 1946. Parliament of the socialist republic of Sri Lanka.

Jayathilae, H.M. 2002. Surface water resources of Ruhunu basins. World water assessment program Sri Lanka case study Ruhuna basins, Workshop proceedings held on 7-9 April 2002, Sri Lanka. pp. 5-21

Molden, D.J., and Gates, T.K. 1990. Performance measures for evaluation of irrigation water delivery systems. Journal of Irrigation and Drainage Engineering, ASCE 116:804-823.

Merrey D.J., De Silva N.G.R. & Sakthivadivel R. 1992. A participatory approach to building policy consensus: The relevance of the Irrigation Management Policy Support Activity of Sri Lanka for other countries. IIMI Review 6 (1): 3-13.

Murray-Rust D.H. & Snellen W.B. 1993. Irrigation system performance assessment and diagnosis.(Joint publication of IIMI, ILRI, and IHE.) IIMI, Colombo, Sri Lanka.

RRDI, Rice Research Development and Institute, Sri Lanka. 2005. Electronic publications on the website http://www.agridept.gov.lk/RRDI/Rrdiindx.htm and electronic communication through rice@sltnet.lk

Rao P.S. 1993. Review of selected literature on indicators of irrigation performance. Forthcoming IIMI Research Paper. IIMI, Colombo, Sri Lanka.

Small L. 1992. Evaluating irrigation system performance with measures of irrigation efficiencies. ODI Irrigation Management Network Paper No. 22. Overseas Development Institute, London,U.K.

Small L.E. & Svendsen M. 1990. A Framework for assessing irrigation performance. Irrigationand Drainage Systems 4(4): 283-312. Revised edition as: Working Paper on Irrigation Performance 1. International Food Policy Research Institute, Washington, D.C. (1992).

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APENDICES

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Apendix
- 1

2004 Yala Season - Canal Discharges - Nachchiduwa (l / s)

Date	LBMCG1	LBMCG6	NRBG1	NRBG2	NRBRB3G1	NCBG1	SRBG1	SRBG3	SRBG6	SLBG1	SCBG1	SCB26PG1	SLBG3
21-Apr-04	6865	4564	-	-	-	-	-	-	-	-	-	-	833
22-Apr-04	6750	4814	-	-	-	-	-	-	-	3499	1659	-	970
23-Apr-04	5337	4019	271	-	-	1039	1798	460	2	2845	1249	6	883
24-Apr-04	4634	3625	491	-	-	1209	2040	460	-	2058	795	2	628
25-Apr-04	4732	3674	709	-	-	1395	2294	186	-	1916	380	-	431
26-Apr-04	4634	3429	541	-	-	1180	2617	113	18	2058	737	-	406
27-Apr-04	5234	3821	491	-	753	1331	2617	460	-	2107	855	36	512
28-Apr-04	5757	5669	423	334	426	1094	3192	1207	-	3375	1320	48	784
29-Apr-04	4732	5165	423	324	362	1039	2841	688	-	3017	1180	27	752
30-Apr-04	5031	4167	772	481	569	1363	2400	344	3	2107	795	2	512
1-May-04	5757	4565	288	-	-	1039	2400	960	3	2256	473	14	720
2-May-04	6637	4939	709	559	-	1363	2617	460	22	2410	425	9	689
3-May-04	6750	4664	491	385	464	1012	2956	546	3	2733	1112	4	643
4-May-04	6524	4714	445	354	413	959	3073	902	-	2902	1180	122	720
5-May-04	6190	5266	709	470	529	1180	3073	502	-	2733	1467	149	883
6-May-04	6190	5266	709	470	529	1180	3192	546	-	3254	1145	79	987
7-May-04	-			-	-	-	2453	381	-	1823	547	62	613
8-May-04	6081	4465	593	459	516	1151	2294	792	18	1778	497	14	673
9-May-04	6524	4614	593	470	-	1300	2294	546	1	1733	425	-	569
10-May-04	6637	4590	423	324	634	985	3073	688	-	2959	1320	6	817
11-May-04				-	-	1039	2956	592	-	2902	1249	42	752
12-May-04	5234	4118	709	416	490	1239	3073	460	-	2256	855	9	752
13-May-04	4634	3576	709	385	490	1151	2400	214	2	1778	653	-	583
14-May-04	4634	3331	593	385	555	1151	1990	460	1	2206	473	-	752
15-May-04	5337	3871	445	334	387	834	2507	460	14	2156	1045	55	918
16-May-04	5651	3969	649	503	113	1239	2507	546	0	954	1112	122	850
17-May-04	4066	3331	361	314	490	834	1798	792	-	1316	256	-	285
18-May-04	3616	3015	445	256	400	883	1798	419	-	1395	626	20	458
19-May-04	3704	3282	541	364	490	763	1893	244	-	1602	681	2	458
20-May-04	3616	3772	541	354	516	1012	1659	83	-	1056	380	14	308
21-May-04	3704	3282	401	294	413	786	1990	244	-	1602	522	-	540
22-May-04	4346	3723	-	-	-	-	2191	136	-	2058	337	-	540

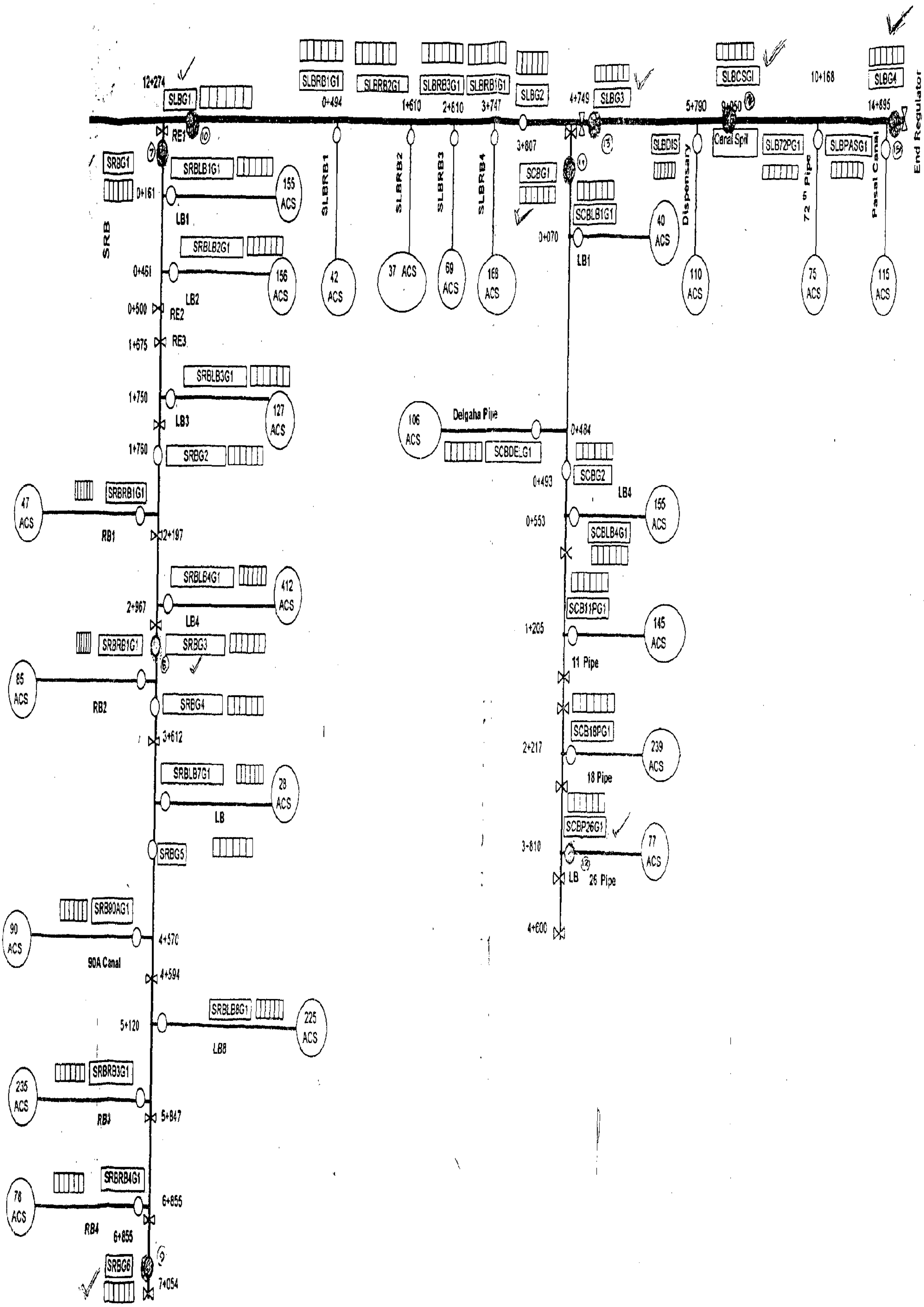
Apendix
- 1

2004 Yala Season - Canal Discharges - Nachchiduwa (l / s)

Date	LBMCG1	LBMCG6	NRBG1	NRBG2	NRBRB3G1	NCBG1	SRBG1	SRBG3	SRBG6	SLBG1	SCBG1	SCB26PG1	SLBG3
21-Apr-04	6865	4564	-	-	-	-	-	-	-	-	-	-	833
22-Apr-04	6750	4814	-	-	-	-	-	-	-	3499	1659	-	970
23-Apr-04	5337	4019	271	-	-	1039	1798	460	2	2845	1249	6	883
24-Apr-04	4634	3625	491	-	-	1209	2040	460	-	2058	795	2	628
25-Apr-04	4732	3674	709	-	-	1395	2294	186	-	1916	380	-	431
26-Apr-04	4634	3429	541	-	-	1180	2617	113	18	2058	737	-	406
27-Apr-04	5234	3821	491	-	753	1331	2617	460	-	2107	855	36	512
28-Apr-04	5757	5669	423	334	426	1094	3192	1207	-	3375	1320	48	784
29-Apr-04	4732	5165	423	324	362	1039	2841	688	-	3017	1180	27	752
30-Apr-04	5031	4167	772	481	569	1363	2400	344	3	2107	795	2	512
1-May-04	5757	4565	288	-	-	1039	2400	960	3	2256	473	14	720
2-May-04	6637	4939	709	559	-	1363	2617	460	22	2410	425	9	689
3-May-04	6750	4664	491	385	464	1012	2956	546	3	2733	1112	4	643
4-May-04	6524	4714	445	354	413	959	3073	902	-	2902	1180	122	720
5-May-04	6190	5266	709	470	529	1180	3073	502	-	2733	1467	149	883
6-May-04	6190	5266	709	470	529	1180	3192	546	-	3254	1145	79	987
7-May-04	-			-	-	-	2453	381	-	1823	547	62	613
8-May-04	6081	4465	593	459	516	1151	2294	792	18	1778	497	14	673
9-May-04	6524	4614	593	470	-	1300	2294	546	1	1733	425	-	569
10-May-04	6637	4590	423	324	634	985	3073	688	-	2959	1320	6	817
11-May-04				-	-	1039	2956	592	-	2902	1249	42	752
12-May-04	5234	4118	709	416	490	1239	3073	460	-	2256	855	9	752
13-May-04	4634	3576	709	385	490	1151	2400	214	2	1778	653	-	583
14-May-04	4634	3331	593	385	555	1151	1990	460	1	2206	473	-	752
15-May-04	5337	3871	445	334	387	834	2507	460	14	2156	1045	55	918
16-May-04	5651	3969	649	503	113	1239	2507	546	0	954	1112	122	850
17-May-04	4066	3331	361	314	490	834	1798	792	-	1316	256	-	285
18-May-04	3616	3015	445	256	400	883	1798	419	-	1395	626	20	458
19-May-04	3704	3282	541	364	490	763	1893	244	-	1602	681	2	458
20-May-04	3616	3772	541	354	516	1012	1659	83	-	1056	380	14	308
21-May-04	3704	3282	401	294	413	786	1990	244	-	1602	522	-	540
22-May-04	4346	3723	-	-	-	-	2191	136	-	2058	337	-	540

23-May-04	4441	3136	-	-	-	-	1845	381	-	1277	256	-	431
24-May-04	3974	3747	593	354	595	1039	2090	136	-	2256	886	2	512
25-May-04	3974	3527	567	294	873	985	2453	502	-	1559	855	20	444
26-May-04	4252	3478	709	275	820	933	2400	244	-	1602	795	48	628
27-May-04	4831	4118	323	294	490	697	2400	309	-	-	2243	122	689
28-May-04	3883	3846	129	95.1	426	413	1395	214	8	763	185	-	285
29-May-04	3883	3282	129	95.1	223	309	1113	31	2	824	122	36	128
30-May-04	3883	2894	129	95.1	235	554	2191	419	3	1823	449	-	1059
31-May-04	3793	3821	129	201	400	481	1990	381	-	2206	573	1	658
1-Jun-04	3356	2894	423	238	336	741	927	43	2	676	185	-	191
2-Jun-04	3272	2845	491	285	439	741	1798	502	-	1645	358	-	356
3-Jun-04	3272	3429	541	238	516	834	1893	43	-	1689	-	2	406
4-Jun-04	3356	2797	838	294	490	959	1525	58	-	1316	380	-	393
5-Jun-04	4346	3723	945	385	555	1094	1705	113	-	1963	522	-	458
6-Jun-04	4441	3136	1060	503	113	1239	2243	113	-	1733	295	-	368
7-Jun-04	4634	4266	593	275	555	908	2507	419	14	1963	737	2	498
8-Jun-04	5031	4291	908	375	595	1180	2562	546	-	1916	795	2	628
9-Jun-04	4831	4266	908	375	595	1094	2507	309	-	1916	1045	6	485
10-Jun-04	4831	4316	709	354	595	834	2507	419	5	1778	917	2	485
11-Jun-04	5132	4341	709	294	490	834	2507	419	-	1869	737	2	526
12-Jun-04	4831	4217	709	294	490	908	2243	502	-	1778	681	-	498
13-Jun-04	4831	3282	982	548	235	1209	2400	275	-	1823	626	-	274
14-Jun-04	4930	4415	772	395	647	883	2507	502	12	2307	795	2	583
15-Jun-04	4634	4068	908	304	529	933	2507	639	-	1963	917	4	643
16-Jun-04	4634	4068	1060	395	608	1094	2191	460	-	1733	573	20	643
17-Jun-04	4441	3723	1227	459	687	1094	2090	160	-	1602	473	48	643
18-Jun-04	6081	3920	567	364	687	1039	2191	960	-	-	473	2	498
19-Jun-04	4252	3674	567	364	687	1039	1751	-	-	1823	-	-	498
20-Jun-04	4066	3087	838	503	-	1395	2956	-	-	1056	-	-	263
21-Jun-04	4346	3429	1227	438	542	1151	-	-	-	1733	-	48	380
22-Jun-04	5441	4266	1142	354	503	1094	2728	160	-	2206	980	79	658
23-Jun-04	5234	4217	1142	395	674	1012	2507	309	18	2010	681	42	643
24-Jun-04	5234	4167	53	406	687	1039	2400	460	-	1733	473	48	643
25-Jun-04	4831	4366	1317	481	753	1094	2347	460	-	1778	380	36	555
26-Jun-04	5864	4316	805	294	542	959	2617	136	-	2206	256	9	643
27-Jun-04	4252	3039	1060	481	-	1363	2294	113	-	1778	219	1	498
28-Jun-04	4158	3969	805	334	400	1012	2617	160	-	1869	473	27	406
29-Jun-04	4441	3674	1142	406	400	1094	2400	381	-	1963	653	79	485

6-Aug-04	4441	3576	709	304	542	1094	1614	160	-	1778	681	20	583	464	403
7-Aug-04	4441	3625	679	285	490	1094	1614	136	-	1277	709	14	598	464	403
8-Aug-04	4441	3087	1060	593	235	1239	1893	344	-	1602	681	62	498	747	61
9-Aug-04	4441	4118	621	285	582	1066	2507	344	-	2058	737	36	498	285	61
10-Aug-04	4441	3478	593	266	490	1012	2191	460	-	1602	795	79	512	262	119
11-Aug-04	4634	3772	709	334	582	1122	2191	275	-	1559	547	99	689	477	403
12-Aug-04	4634	3772	679	344	608	1094	1798	244	-	1689	380	79	512	464	119
13-Aug-04	4537	3674	679	354	647	1094	1614	136	-	1778	358	20	540	307	143
14-Aug-04	4537	3674	649	344	608	1094	1705	639	-	1778	337	14	598	439	453
15-Aug-04	4537	3039	1060	593	286	1331	1893	309	-	1869	316	11	643	608	143
16-Aug-04	4537	3969	649	375	700	1180	1990	275	20	2156	855	27	569	477	453
17-Aug-04	4537	3723	567	285	555	1039	1990	344	-	1963	917	31	658	402	312
18-Aug-04	4441	3674	567	285	555	1039	1798	592	33	1689	980	99	689	555	801
19-Aug-04	4158	3282	516	285	555	1039	1525	244	-	1355	737	79	498	747	-
20-Aug-04	4158	3282	491	266	542	1012	1614	344	-	1355	573	48	512	285	253
21-Aug-04	4158	3282	491	266	542	1066	1659	481	-	1316	547	36	458	319	356
22-Aug-04	4158	2942	772	593	260	1300	1614	419	-	1201	497	27	458	635	143
23-Aug-04	4066	3674	423	275	647	985	2090	639	-	1869	473	48	498	439	143
24-Aug-04	4066	3674	361	238	477	858	1990	381	-	1778	522	56	526	439	61
25-Aug-04	4066	3674	361	238	477	858	1990	419	18	1435	425	99	512	747	10

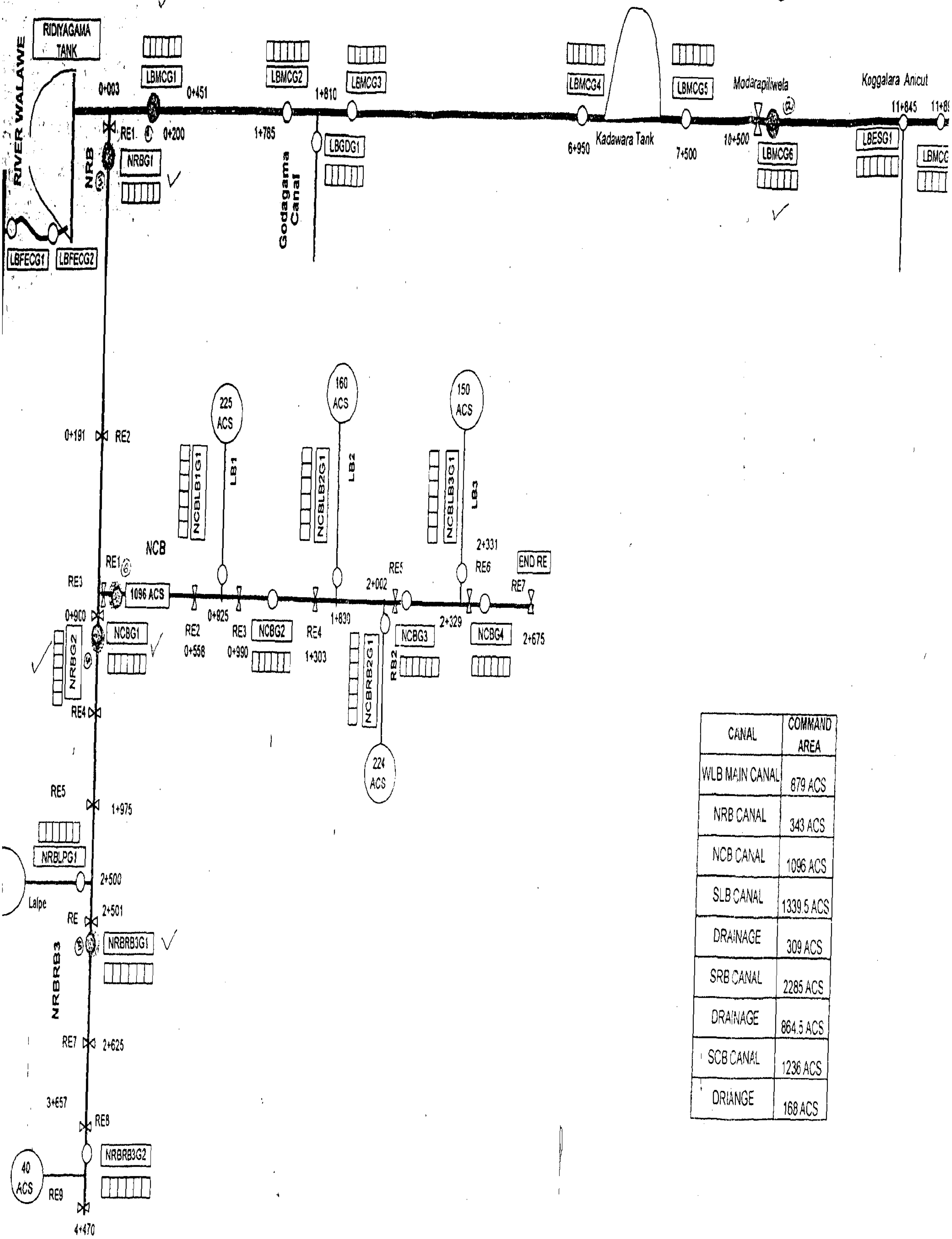


SLBG1
12+274
SLBRB1G1
SLBRB2G1
SLBRB3G1
SLBRB1G1
SLBG2
SLBG3
SLBCSGI
SLBG4
10+168
0+494
1+610
2+610
3+747
3+807
4+749
5+790
14+695
End Regulator
RE1
SLBRB1
SLBRB2
SLBRB3
SLBRB4
Dispensary
72" Pipe
Pasal Canal
Canal Spill
SLBDIS
SLB72PG1
SLBPASG1
SCBG1
SCBLB1G1
LB1
0+070
40 ACS
110 ACS
75 ACS
115 ACS
42 ACS
37 ACS
69 ACS
168 ACS
SRB
SRBG1
SRBLB1G1
0+161
155 ACS
SRBLB2G1
0+451
156 ACS
LB2
0+500
RE2
1+675
RE3
SRBLB3G1
1+750
127 ACS
LB3
1+750
SRBG2
SRBRB1G1
47 ACS
RB1
2+197
SRBLB4G1
412 ACS
2+967
LB4
SRBRB1G1
SRBG3
85 ACS
RB2
SRBG4
3+612
SRBLB7G1
28 ACS
LB
SRBG5
SRB90AG1
90 ACS
4+570
90A Canal
4+594
SRBLB8G1
5+120
225 ACS
LB8
SRBRB3G1
235 ACS
RB3
5+847
SRBRB4G1
78 ACS
6+855
RB4
6+855
SRBG6
7+054
106 ACS
Delgaha Pipe
SCBDELG1
0+484
0+493
SCBG2
LB4
155 ACS
0+553
SCBLB4G1
SCB11PG1
1+205
145 ACS
11 Pipe
SCB18PG1
2+217
239 ACS
18 Pipe
SCBP26G1
3+810
77 ACS
LB
26 Pipe
4+600

SCHEMATIC DIAGRAM

[redacted] SCH

NACHCHIDUWA



CANAL	COMMAND AREA
WLB MAIN CANAL	879 ACS
NRB CANAL	343 ACS
NCB CANAL	1096 ACS
SLB CANAL	1339.5 ACS
DRAINAGE	309 ACS
SRB CANAL	2285 ACS
DRAINAGE	864.5 ACS
SCB CANAL	1236 ACS
DRIANGE	168 ACS