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THE RAJANGANA IRRIGATION SCHEME, SRI LANKA: 1982 DIAGNOSTIC ANALYSIS

WATER MANAGEMENT SYNTHESIS PROJECT

WMS REPORT 19

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WATER MANAGEMENT SYNTHESIS PROJECT

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Colorado State University
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Co-coordinator

ABSTRACT

A Diagnostic Analysis Workshop was held July 2 to August 6, 1982 in Sri Lanka. The first week of the workshop took place at the Agricultural Research and Training Institute (ARTI) in Colombo, and the last four weeks were spent at the In-Service Training Center at Maha-Illuppallama. The purpose of this workshop was to acquaint Sri Lankan professionals with the concepts and procedures used to conduct interdisciplinary investigations of existing irrigation systems. This workshop was requested by the Government of Sri Lanka to further governmental efforts in improving the performance of existing irrigation systems.

Twenty-four professionals from the fields of irrigation engineering, agronomy, economics, and sociology participated in the program. Following the one week of classroom lectures at ARTI and two weeks of field study at System H of Kalawewa, a two-week study of tracts 2 and 4 of the Rajangana system was undertaken. Each of the four interdisciplinary teams studied one distributary channel (D-channel). After completing the field studies, individual teams analyzed their data and wrote disciplinary and interdisciplinary reports.

This report presents the data and the findings of the four interdisciplinary teams. Due to the training emphasis of this workshop and the short time period during which the study was conducted, this report should be viewed as a guide for further investigation rather than as conclusive research. Major observations included:

(1) The system was poorly designed. The turnout structures into D- and F-channels did not have discharge measuring devices. Discharge measurements indicated the two D-channels at tract 2 diverted water at twice the area's requirement; the two D-channels at tract 4 diverted considerably less than the area's requirement. In addition, water distribution among the F-channels was not uniform.

(2) Canals were eroded due to the lack of check regulators and gates, and the bed gradients were lower than the designed gradients. Canal cross sections were not uniform.

(3) Nearly 100 percent of the area cultivated was under paddy. However, based on hydrological condition and soil type, many upper slopes are more suitable for cultivation of other field crops such as chillies and soybeans. These field crops would generate considerably higher income than paddy.

(4) Conveyance losses were measured as 60 percent, while 30 percent was provided for in the system design. This means that only 40 percent of 2,439 mm per hectare discharge recorded at the ex-sluice reached the fields as surface flow.

(5) The system is poorly maintained. Channel banks are eroded and weak at numerous points, and channel beds are silted up and overgrown with weeds. Major leakages from the dikes into the discharge channels were observed.

(6) Soil salinity tests indicated salinity was a problem in a small area. In areas of high salinity, the paddy crop appeared poor.

(7) Although all farmers in the study area cultivated high-yielding rice varieties and on the average applied 86 percent of the recommended fertilizer levels, the actual yields were considerably less than the potential yields for the same rice varieties.

(8) About 50 percent of the farmers surveyed said agricultural credit was a problem. Twenty-eight percent of the farmers received credit from institutional sources in Maha 1981/82 and only 18 percent in Yala 1982.

(9) Average investments in agrochemicals and other expenses were nearly the same for the Maha and Yala seasons. However, due to higher yields in Maha, the per hectare return from paddy was about Rs 2000 higher in Maha than in Yala.

(10) In terms of location along D-channels, the farms located at the head achieved a 22 percent higher average annual income than farms located at the tail.

(11) Both the sample farmers and the farmer representatives indicated that the farmer representative system is not functioning well. The large area (80-200 hectares) and the large number of farmers assigned per farmer representative appeared to be part of the problem. Further, the farmer representative's role of assisting the cultivation officer makes the representative the last link in the bureaucratic chain rather than a true farmer representative.

(12) The cultivation meeting system has many deficiencies which inhibit the adoption of an effective water management program. Among them are low attendance by farmers, imposition of predetermined decisions on farmers, and lack of a mechanism for changing decisions in response to changes in water availability throughout the irrigation season.

I. INTRODUCTION

A. Irrigated Agriculture in Sri Lanka

Post-independent governments of Sri Lanka have placed a high priority on the allocation of resources to increase food production and employment through the development of irrigated agriculture. Their strategies adopted for increasing agricultural production emphasized the design and construction of large irrigation systems to extend the area provided with irrigation facilities. However, the strategy to increase this area by constructing large irrigation systems has not yielded optimum results, with performance noticeably below the designated capacities. It is estimated that the recent increases in the total paddy production on the island are largely attributable to the expanded acreage of irrigated paddy crop and the use of high-yielding varieties. In this approach, the potential for increasing output through improved water management practices and the application of associated inputs, and through improved cultural practices, has been overlooked. This observation applies not only to old irrigation systems but also to the newly established projects.

Rajangana, a newly renovated reservoir restored from an ancient anicut in 1968, is located in the northwest part of Sri Lanka. The Rajangana irrigation system is a complex of the above reservoir and Angamuwa reservoir. The total irrigable area under Rajangana is approximately 5,525 ha, and the unique feature of this system is the lift irrigation project. Approximately 1,600 ha of additional land was added to the command area by the lift irrigation project. Another striking feature is that a major portion of the water fed to Rajangana through the Kal Oya is drainage water collected from cultivated lands of the Mahaweli H areas. The inflow to Rajangana is through the Kal Oya. In an emergency if a shortage of water exists in Rajangana, Kalawewa can issue water, provided that this loss of water is balanced from Mahaweli-diverted water through Polgalla and Bowatenne. Unlike the Kalawewa H system, which is managed by the Mahaweli Authority, the organization responsible for the operation of the Rajangana irrigation system is the Department of Irrigation.

Prior to restoration, the Rajangana project area was largely covered by medium to high scrub jungle. Isolated village settlements (puranas) primarily relied on slash and burn agriculture (chena) for subsistence. After renovation, the Rajangana reservoir provided sufficient storage to supply water for both the Maha and Yala seasons.* Even in drought years, enough water usually flows into the reservoir to provide ample water for the command area. Because of this, farmers in

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* Maha season = early October through February. Yala season = March through September.

the Rajangana project area cultivate rice in both the Yala and Maha seasons.

By 1981 the extent of land under paddy, the major food crop of Sri Lanka, was 499,082 ha. Forty-four percent of this area was under major irrigation schemes, and 30 percent was under minor irrigation schemes. Self-sufficiency in food production has been a long standing development goal in Sri Lanka. By 1981, Sri Lanka had produced 90 percent of its rice consumption requirement. However, Sri Lanka imported enough quantities of wheat and wheat flour equal to one-third of the weight of locally produced and imported rice. Thus, even with projects such as Mahaweli and Rajangana, self-sufficiency in food production will require a concerted effort on all fronts.

While the government continues to support irrigation development in Sri Lanka, the increased concern of policy-makers and planners over the poor performance of these systems has resulted in a shift in policy emphasis and new research and development programs. The new policies emphasize the development of new strategies for improving the productivity of the established systems through intensified use of available land and water resources. Inevitably, these strategies which seek to increase productivity must deal with interrelated human and technical issues, which cannot be meaningfully analyzed or resolved by adopting a single discipline perspective.

B. Purpose and Objectives of the Diagnostic Analysis Workshop

Experiences both in the United States and other countries have repeatedly shown that an interdisciplinary on-farm Diagnostic Analysis of irrigated farming systems is an effective way to evaluate the operation and performance of a given irrigation project. To train its own staff to do such analyses, the Government of Sri Lanka requested that the Water Management Synthesis Project at Colorado State University conduct a professional development workshop on the Diagnostic Analysis of Farm Irrigation Systems. This professional development workshop occurred during the five weeks from July 2 - August 6, 1982. Briefly, the objectives of the Diagnostic Analysis were:

(1) to provide the participants with the skills required to monitor and evaluate irrigation projects, thus enhancing the capacity and the capability of the government to improve irrigation facilities and management throughout Sri Lanka; and

(2) to describe the actual operation of an irrigation system in relation to its design specifications, and to identify the positive and negative aspects of the system through an interdisciplinary analysis.

In realizing the above objectives, the participants were expected to benefit by learning to work in a team within an interdis-

ciplinary setting, understanding the complexities of the farm and the farmer's role in managing the farm and the irrigation systems, and expanding their discipline knowledge and field study skills.

Initial sessions of the workshop were conducted at the Agrarian Research and Training Institute (ARTI) in Colombo for a period of five days (Appendix E). During these sessions, videotaped lectures, discussions, and team building exercises were used to familiarize the participants with the concepts and procedures used in the Diagnostic Analysis. The balance of the workshop involved field studies and report preparation and presentation. The two major sites selected for study were the Mahaweli System H and the Rajangana Project. This report deals only with the Rajangana Project.

The study was conducted by four interdisciplinary groups near Maha-Illuppallama. Each group consisted of an agronomist, an on-farm engineer, an irrigation engineer, a sociologist, and an economist; a list of participants appears in Appendix E. These four groups conducted the Diagnostic Analysis in four turnout areas. Each member of the team was responsible for collecting necessary information and conducting field investigations in his own discipline to understand the way the system operates.

C. Contents of this Report

The remaining sections of this report present the observations of the participants who conducted the Diagnostic Analysis. Section II describes the study area, and Section III gives detailed explanations of the methodologies used during the analysis. Section IV presents the teams' interdisciplinary findings, and Section V summarizes these findings and the teams' recommendations.

Additional information on disciplinary findings for agronomy, engineering, economics, and sociology appears in Appendices A, B, C, and D, respectively. Appendix E provides a list of the workshop participants. Finally, Appendix F presents a glossary of terms used in the report.

While the information presented in this report is of value, it is important to understand that the training objective deliberately restricted the amount of data collected. Consequently, the findings of this report simply indicate areas of constraints in the system; more detailed studies are needed to document the findings noted here.

II. STUDY AREA

A. Location and General Description

Study sites were selected from the Rajangana Irrigation and Settlement Scheme and System H of Kalawewa prior to the start of the workshop. Two important characteristics of these two systems distinguish one from the other. Rajangana is an old system, whereas the Kalawewa Settlement is about 7 years old. Secondly, Rajangana comes under the administrative control of the Irrigation Department, which is assisted by five departments at the district level performing general administration. In contrast, System H of Kalawewa is under the unitary management system of the Mahaweli Authority, which provides all the services required by the farmers for irrigated agriculture. This report focuses only on the study conducted on the Rajangana Irrigation and Settlement Scheme.

The Rajangana Irrigation and Settlement Scheme is located in the North Central Province and is about 30 miles from Anuradhapura (Figure 1). The irrigation complex consists of two reservoirs, Rajangana and Angamuwa, linked by a common canal (Figure 2). Rajangana reservoir was built on the Kala Oya and is supplied by the return flows from cultivated lands of the Mahaweli project. The Angamuwa reservoir was constructed on the Lunu Oya, a small tributary of the Kala Oya, and is also supplied by return flows from the Mahaweli project.

The right-bank canal is supplied by both reservoirs and commands approximately 3,564 ha. An additional 745 ha is commanded by lift irrigation from 10 pump stations with 35 diesel pumps. The left bank commands approximately 2,552 ha under gravity flow and an additional 858 ha by lift irrigation from 10 pump stations with 44 diesel pumps.

In selecting study sites, it was originally intended that each site should be identified from the upper and lower reaches of the main and distributary channels (D-channels) to obtain a better insight into the water supply problems that exist in the system. This requirement was not feasible due to the increased travel time required to reach the distal sections of the D-channels.

The area selected for this study was located on branch canal 1 of the right-bank main canal. Branch canal 1 of the right bank is divided into four administrative areas called tracts (tracts 2-5). Tract 2 is located in the upper reaches of the branch canal and covers 192 ha. Tracts 3 and 5 are located in the middle section of the branch canal and cover 132 and 244 ha, respectively. Tract 4 is located in the lower reaches of the branch canal and covers 180 ha. Two field sites located in tract 2 and two field sites located in tract 4 were selected to provide comparisons between the upper and lower reaches of the branch canal. The first study site was located on D-channel 1 and included field channels (F-channels) 4, 5, 6, and 7 (Figure 3). The second study

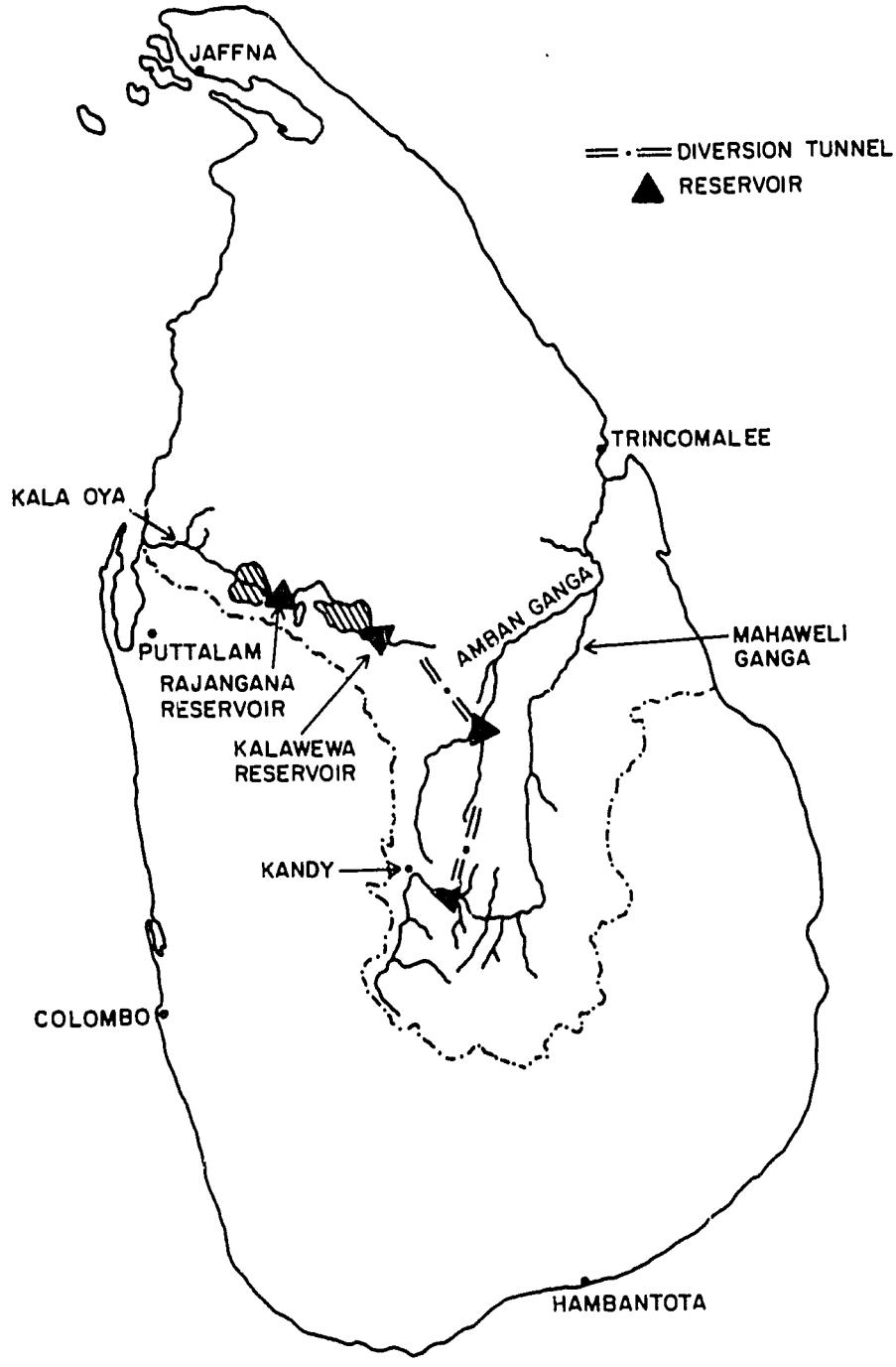


Figure 1. Location Map of Study Area in Sri Lanka.

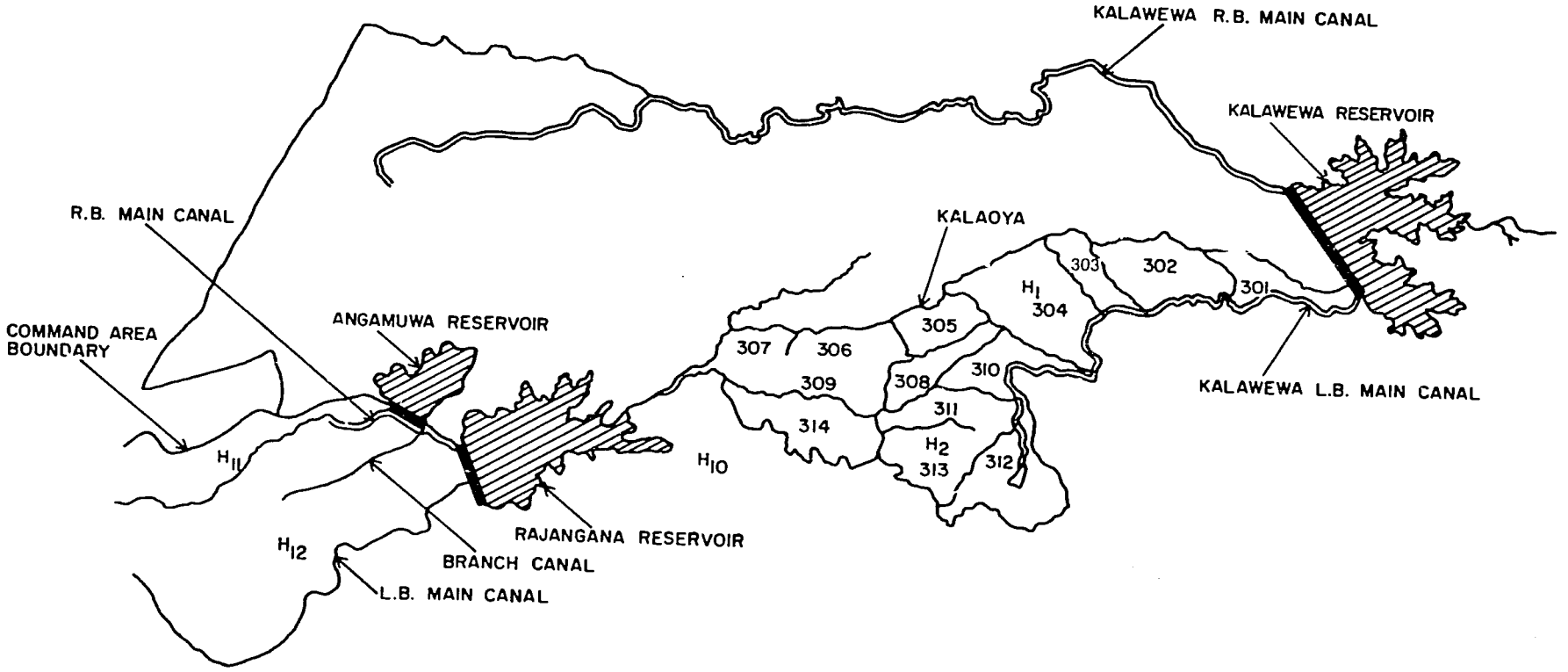


Figure 2. Map of Study Sites in the Rajangana Irrigation and Settlement Scheme

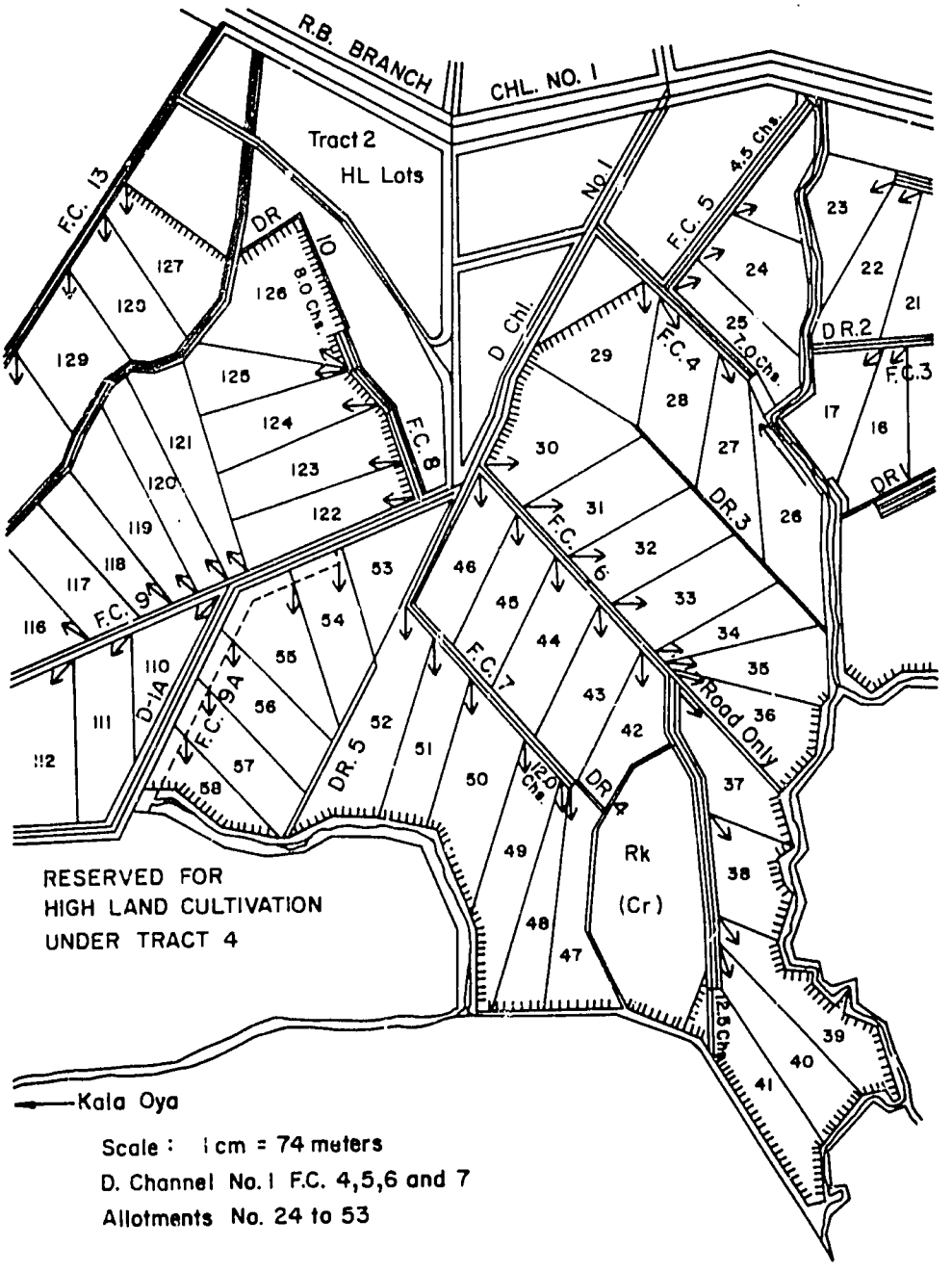


Figure 3. Map of D-channel 1, F-channels 4, 5, 6 and 7

site was located on D-channel 2 and included F-channels 14, 15, and 16 (Figure 4). The third study site was located on D-channel 1 on F-channel 1A (Figure 5). The fourth study site was located on D-channel 2 and included F-channels 5 and 6 (Figure 6).

B. Climate, Soils, and Topography

The Rajangana Project is located in the low country or dry zone of Sri Lanka. The 75 percent annual rainfall expectancy for the region is about 750 mm, and the annual rainfall ranges from 500 mm to 1,800 mm. Two peaks of high rainfall occur from mid-March to mid-May and mid-October to early January. About 75 percent of the rain occurs during this period. Potential evaporation during the wet period varies between 4-5 mm per day, as compared to 6-7 mm/day during the dry period.

The landscape is rolling with slopes ranging from 0 to 6 percent. Most of the project area has moderately steep slopes. The area with less than 1 percent slope is relatively low. Based on the behavior of the watertable under natural conditions before the irrigation facilities were provided, the soils in this landscape appear to be well-drained, imperfectly drained, and poorly drained. The well-drained to imperfectly drained soils occur on the convex uplands and slopes. The poorly drained soils occur on the concave valleys or gently sloping bottom lands. Some alluvial soils occur along the Kala Oya.

The important soil groups found in the area are:

(1) reddish brown earth,

(2) low humic gley soils, and

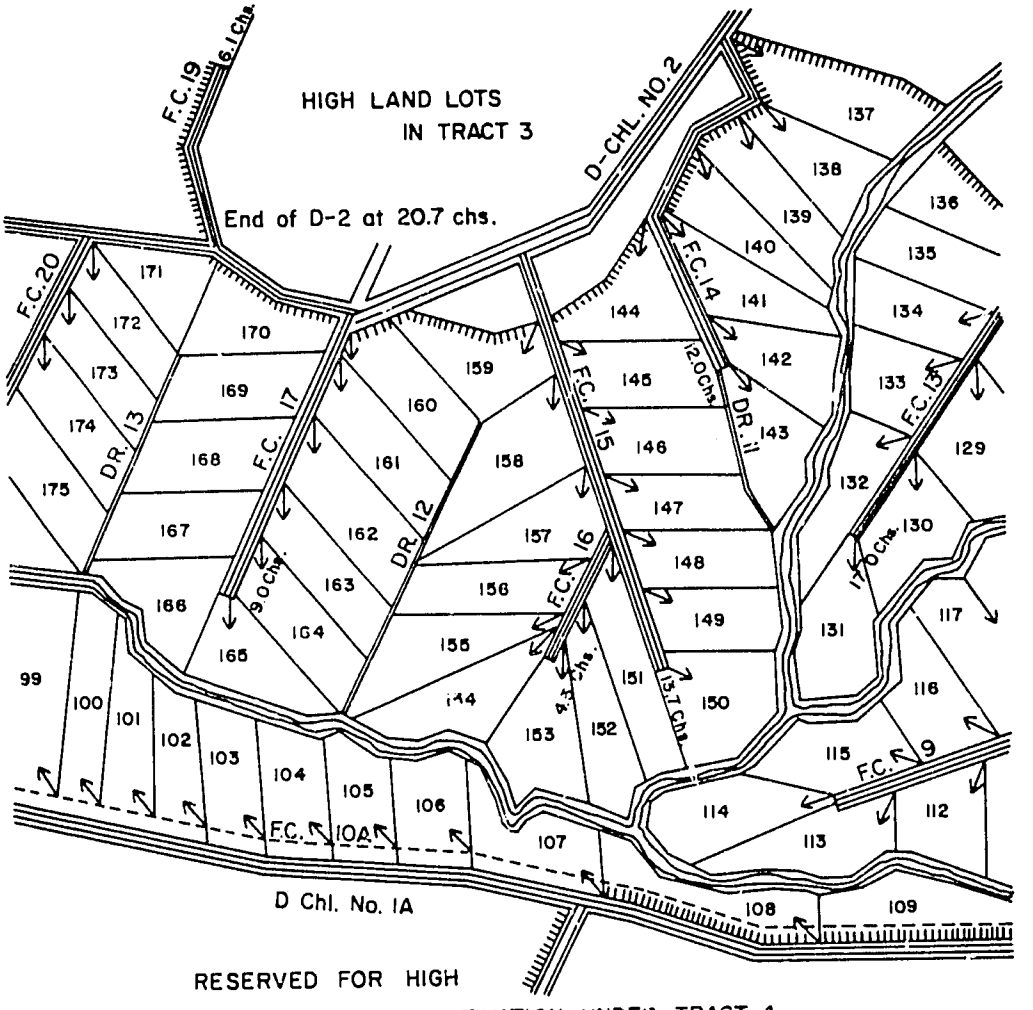
(3) alluvial soils.

Reddish brown earth soils are well-drained and occur in upper parts of the landscape. The surface which has sandy loam to sandy clay loam is underlain by sandy clay loam. The low humic gley soils that occur in poorly drained bottom lands are often sandy clay loams to sandy clays.

The alluvial soils occur along the stream banks. The drainage of alluvial soils is variable and ranges from well-drained to poorly drained. The texture varies from loamy sand to clay loam.

C. Operational Plan of the System

The Rajangana distribution system was designed for the monoculture of paddy. The original design did not provide for the layout of the downstream development area on a turnout area basis, nor the design of the main and branch canals for peak water requirements for diversified cropping. The canal sections were designed on the basis of arbitrary mean canal duties. No regulating control and measurement structures were provided in the original design.



Scale: 1 cm = 74 meters

D. Channel No. 2 F.C. 14, 15, and 16

Allotments No. 137 to 159

Figure 4. Map of D-channel 2, F-channels 14, 15, and 16

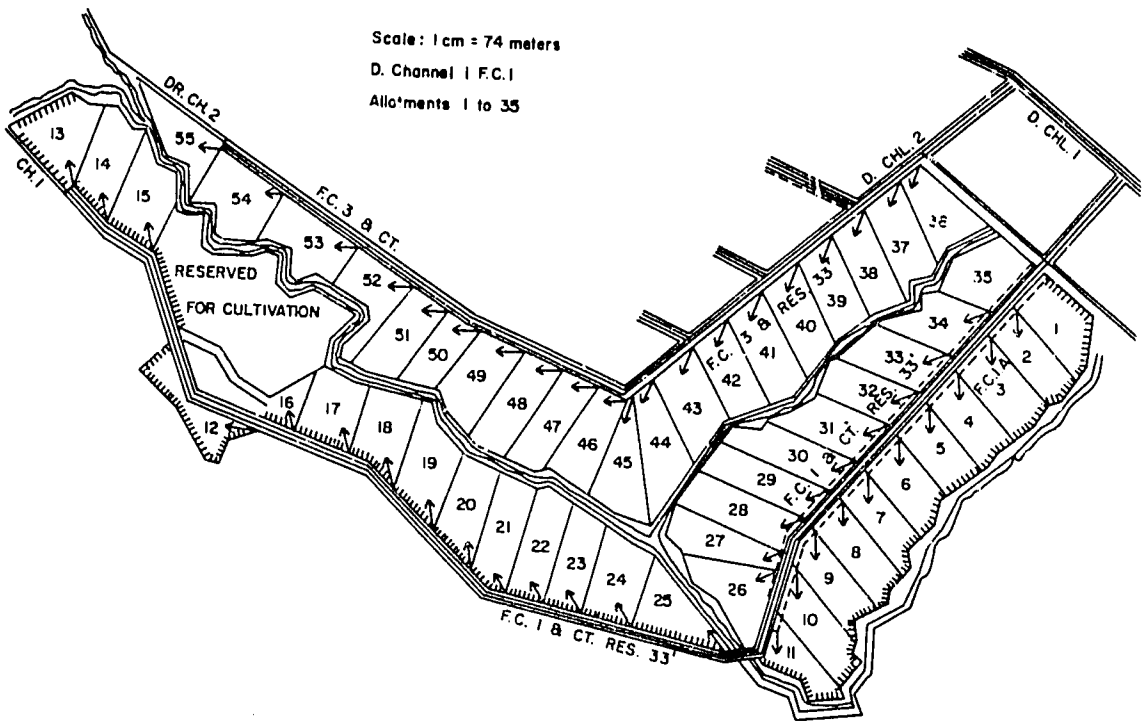


Figure 5. Map of D-channel 1, F-channel 1A

Figure 6. Map of D-channel 2, F-channel 5 and 6

The distribution system consists of the main and branch canals, and D- and F- channels. The Irrigation Department operates the distribution system up to the F-channel turnout. The project is managed by an Irrigation Engineer who helps Technical Assistants compute daily releases and rotational schedules. The distribution of water to farms from F-channels is the responsibility of the Group Leader (Vel Vidane) of the organization of farmers under the F-channel. He is expected to adopt a rotation system among the farms in the turnout area.

In this system, F-channels take off from F-channels, and field outlets are on both D-channels and F-channels. The turnouts to F-channels are not designed to discharge 28 l/s (1 cfs), unlike in System H. The check-basin method is used to irrigate paddy, and water is allowed to flow from basin to basin. The next basin discharges the excess water into a drain.

D. Cropping Pattern

The recommended cropping pattern for Maha is to cultivate upland paddy in the well-drained soils and lowland paddy in the poorly drained soils. During Yala season, upland field crops (chilies, grain, legumes, and vegetables) are recommended for well-drained soils and the lower reaches to be cultivated with either paddy or other field crops, depending on the availability of water. Previous studies have shown that maize, sugarcane, sorghum, millet, root crops, and cotton can be grown under irrigation during Yala.

E. Socio-economic Conditions

Prior to resettlement, this area was mainly inhabited by traditional villagers who had lived here for generations in scattered pockets of old (purana) villages. They eked out a subsistence living by cultivating paddy under small rainfed village tanks and upland crops in the surrounding highlands.

Interspersed among these traditional villages were small and medium-sized irrigation schemes with a more assured supply of water. These schemes were inhabited by the traditional villagers and settlers brought from the wet zone.

The Rajangana Scheme was settled with about 6,200 farm families between 1964 and 1968. Each family was given 0.8 ha of paddy land, 0.2 ha of homestead, and 0.6 ha of highland. The main criteria used for settler selection at the time of land allotment were that allottees: (1) should possess no land, (2) should be from the wet zone districts, and (3) should have large families. However, there have been exceptions to this rule in a few cases. In addition, some land was also given to the children of farmers who had settled in adjoining schemes much earlier. Today, the ratio of selectees who came from outside the area to the second-generation of early migrants is 8:1.

With the exception of the first few years, Rajangana farmers have benefitted from a reliable supply of water and been able to cultivate both in Maha and Yala since the inception of the Mahaweli Project. Because of the relative proximity of the Rajangana Scheme to the administrative capital of the North Central Province, Anuradhapura, the scheme has received special attention from the state which wants to implement various programs designed to increase the productivity of irrigated lands. In the mid-1960's, Rajangana was included among the schemes selected for a special projects program. The special projects were formulated by the government as an intensive management effort to increase the yield of paddy and other crops. About the same time, lift irrigation facilities were provided for upland crop cultivation. In the early 1970's, the Department of Irrigation implemented a program of water management to reduce the high consumption of water by the farmers. More recently, a Producer's Cooperative was set-up to export green chilies cultivated in the highlands with lift irrigation.

III. METHODOLOGY

A. Reconnaissance and Detailed Studies

During the first week of the training program the 26 participants were divided into four interdisciplinary teams consisting of at least one sociologist or extension worker, an economist, an agronomist, and two engineers. Each team was assigned to separate turnouts within the Rajangana Scheme.

Each team conducted a one-day reconnaissance survey of their assigned site. The reconnaissance survey is not an exhaustive study of the irrigation system. Rather, it is a survey designed to obtain a general understanding of overall system operation through field observation. This objective is attained by identifying the physical and socio-economic boundaries of the system, important problem areas, and key variables which need to be studied further.

Observations made during this reconnaissance survey were used by the teams to plan the subsequent detailed field study. These detailed studies provide data which define causes of problems and give the magnitude of effects of these specific problems. The detailed field study for this workshop was conducted for nine days.

Specific methodologies employed by the team members are described in the following sections dealing with agronomy, engineering, economics, and sociology. After completion of the field studies, each team prepared reports. These reports, together with the collected data, were subjected to a more detailed analysis by the trainers. This final report is a result of that analysis.

B. Detailed Methodologies

1. Agronomy

The reconnaissance survey of the Rajangana Scheme suggested that low levels of production were associated with inequitable distribution of water, over-irrigation of upland crops, low input levels, poor land preparation and weed control and the development of salinity problems in the lower reaches of turnouts. Detailed agronomic studies attempted to examine these problems in more detail. On the first day of the six-day detailed study, the agronomist of each team walked through their assigned turnout. Observations included: the crops growing within each allotment, differences in growth stages, the general condition of the crops, and areas of poor growth associated with either management or soil problems. These observations provided basic information about cropping patterns, cropping intensity, and management-related problems and served as a basis for selecting allotments for detailed study. From two to four allotments, each located in the upper, middle and lower reaches of the turnout, were selected for detailed study. Specific data

on the soils and crops were collected using methods described in Lowdermilk et al., 1981. A summary of the data collected in each selected allotment follows:

a. Soils

Soil samples from depths of 0 to 15, 15 to 30 and 30 to 60 cm were collected from selected allotments. As the samples were collected, changes in soil texture and pH were determined using the touch and feel method for soil texture (Thein, 1979) and a colormetric method for pH. In addition, attempts were made to characterize the soil with depth. The remaining soil from each soil depth was retained for subsequent salinity analysis.

Areas with problem soils were assessed visually and with conversations with the farmer. Visual assessments were based on accumulation of salt deposits and/or areas with depressed plant populations. Soil samples were collected from the problem areas and analyzed for pH and salinity.

Soil samples brought to the training center were air-dried and sieved through a 2-mm screen. Each sample was analyzed for pH and electrical conductivity using the saturated paste method of soil salinity analysis (Richards, 1969).

Auger holes developed from soil sampling served as observation wells for watertable measurements. At least three observation wells, located in the upper, middle, and lower reaches of each turnout, were used to assess watertable depths. Water samples from the observation holes, drainage channels and F-channels were brought to the training center and assessed for salinity (Richards, 1969).

b. Crops

Within the selected allotments of each turnout, basins were selected at random for chilies and/or paddy. Information pertaining to varieties was obtained from the farmers. The other observations which were made included the method of establishment, spacing, stage of growth, approximate time of planting, visual and chemical (tissue tests) assessments of nutrient status, visual assessment of the incidence of weeds, diseases, and pest infestations. In order to estimate the population density of the paddy, the number of plants and/or tillers per 900-sq cm grid were counted at nine locations within a basin. Plant heights were measured at each location from nine plants selected at random.

2. Engineering

After the reconnaissance study, participants specifically noted and prioritized the following areas for closer examination in the

detailed studies. This section discusses both the water distribution and water application systems.

a. Water Distribution System

The water distribution system consists of the D- and F-channels. The following aspects were investigated:

(1) the technical soundness of the channel system to convey and control a predictable, adequate, and equitable supply of water;

(2) a comparison of the actual operation of the D-channel to its design and the recommended operational procedure;

(3) defects in the alignment, cross-sections and grades in relation to the delivery of water; and

(4) the extent of operational losses in the D-channels and F-channels.

To obtain a comprehensive picture of the inflows into the distributaries, D-channels 1 and 2 of tract 2 and D-channel 1 and D-channel 2 of tract 4 were investigated. The quantity of water required was calculated for the paddy crop under these D-channels. From the measured discharges downstream from the distributary turnout, the quantity of water delivered (less D-channel losses) was computed and compared with the water requirement of the crops in the farm.

Conveyance Losses--The conveyance losses in D-channels 1 and 2 of tract 2 and D-channels 1 and 2 of tract 4 (study sites) were calculated by the inflow-outflow method in two sections of each D-channel using the current meter, and at the F-channel turnout by using the cutthroat flume. These losses included seepage, unauthorized water use, and any leakage along the section concerned. The formula used for the calculation of conveyance losses in percentage over 1,000 m was:

$$Q_L = \frac{Q_i \quad Q_o \quad Q_t}{Q_i \times L} \times 100 \times 1000,$$

where,

Q_L = conveyance loss rate in percent per 1,000 m,

Q_i = inflow,

Q_o = outflow,

Q_t = discharges by authorized turnouts, and

L = total length of the channel section selected in meters.

To evaluate the F-channel losses, two cutthroat flumes were installed at a distance of about 150 m and inflow and outflow was measured to determine the F-channel losses. Water diverted by farmers between these two points was measured separately.

The discharge measurements were taken at the beginning of the F-channel by installing a cutthroat flume to check the flow delivered to the turnout area.

Slope of the Channel Bottom--A differential level survey of D-channel 3 and D-channel 4 determined the elevations of the sills and crests of structures, the gradient of the channel bed, and the bank elevations.

Channel Cross-sections--To investigate the problems of erosion, sedimentation, freeboard, and carrying capacity of the channels, the cross-section of the D-channels were measured.

During the detailed study, field observations and farmer interviews about the maintenance and operational plan of the D- and F-channels were conducted in addition to field measurements.

b. Water Application System

The water application system basically deals with the application of water to the irrigation units within a field. The following field measurements were made:

Land Leveling--Paddy is the only crop cultivated in this project area. The land leveling in paddy plots was checked by measuring the height of water after flooding the basins to a certain height.

Seepage and Percolation--Seepage and percolation are major factors in paddy irrigation. These were measured by installing the infiltrometer rings to a depth of about 15 cm, after flooding the field. The depth of subsidence in the rings was measured at predetermined intervals.

Soil Moisture Status--Moisture status of the soil was checked by feel and by the gravimetric method. Measurements were made before and 24 hours after irrigation.

Infiltration Rate--The infiltration rate in the basins was measured using a cylinder infiltrometer.

Water Application Efficiency--Water application efficiency was determined by measuring inflow and outflow into upland basins planted with chilies, where the pre-irrigation soil moisture deficit was known. The field capacity was found by measuring water held in the well-drained soil 24 hours after irrigation. Bulk density of the soil was measured using a core sampler.

Drainage--The depth of the watertable was measured to evaluate the potential for subsurface drainage. Field observations of surface drainage were made. In addition, the engineers noted the general layout of the field application system and the criteria used by farmers on when, how much, and how to irrigate the fields.

3. Economics

a. Data Collection

The approach selected for collecting economic data was a farm management survey. A farm management survey of a representative sample of farms is a method of collecting information on economic aspects of a particular farming system. A simple arithmetic mean of various data from the surveyed farms was used to construct a representative farm for each reach and turnout area. For these representative farms, considering various changes in the availability of resources, input and product prices, and institutional constraints can provide useful information for guiding the implementation of various irrigation programs.

Using a questionnaire for data collection for an entire cropping season or cropping year made it difficult to obtain accurate and detailed information on all farm enterprises. This problem was attributed mostly to difficulties with small farmers who rarely keep detailed records and recall from memory past transactions and production activities. It was particularly difficult to obtain accurate information on inputs such as family labor, which is used continuously throughout the year, and outputs such as vegetables, which are produced, marketed, and consumed throughout the production season.

These problems were partly resolved by focusing on major crop enterprises and production practices, rather than on the entire farm enterprise. For collecting more indepth and accurate data, a farm record keeping system needs to be employed.

b. Questionnaire Design

Farm record surveys conducted earlier in the area provided valuable information in constructing the questionnaire. The questionnaire was organized in a tabular form in order to facilitate cross checks of farmers' responses during the survey. All major inputs, sources of inputs, production activities, outputs and their uses were listed in the questionnaire in order to ensure that the data was

uniformly collected from all the farmers interviewed. The questionnaire was designed to collect data on the 1981/82 Maha and 1982 Yala seasons.

In order to smoothly administer the questionnaire, questions were arranged in the sequence in which crop production activities take place. The questionnaire was initially written in English and then translated into Sinhalese before reproduction to assure correct recording of facts and data given by the farmer in Sinhalese. The questionnaire was improved following the reconnaissance and the testing of the questionnaire.

c. Survey Procedure

The survey was conducted by the workshop participants. All the participants were familiar with agriculture in the dry zone of Sri Lanka under irrigation. The survey team was familiarized with the purpose and structure of the questionnaire and received training on the methodology of administering the questionnaire. The questionnaire was tested on eight farmers.

The time when the actual survey was conducted was not a peak labor-use period. Since farmers did not visit their farms regularly during the survey week, the workshop participants interviewed the farmers at their homesteads.

The sample was purposive in the demarcation of the head, middle, and tail reaches of the D-channel, but opportunistic in selecting within the pre-demarcated head, middle, or tail reach. Priority in selection was given to head and tail locations with a minimum of four farm surveys in each of these two reaches of each D-channel. If the survey of these farms was completed prior to the survey deadline or if the eight farmers from these two reaches could not be located for interviewing, then the farms in the middle reaches of the D-channel were included in the survey.

The reason behind the decision to divide the farms along the D-channel into head, middle, and tail reaches was to determine whether there are measurable differences in cropping pattern, cropping intensity, yield, and production practices between farms located at different points along the D-channel. In order to undertake a broader interdisciplinary evaluation of the system, the irrigation engineers and agronomists selected their study site within the same head, middle, and tail regions covered by the sociology and economic surveys.

4. Sociology

The extension workers and sociologists developed three structured questionnaires to use in interviewing selected farmers, key informants, and irrigation officials. The questions focused directly and indirectly on factors thought to influence farmer irrigation and

adoption behavior. In an effort to define this behavior, questions asked about:

(1) the farmer's knowledge and perceptions.

(2) the availability of institutional inputs and services.

(3) the physical resource base and water control.

(4) the cultural factors influencing the farmer.

Participants were instructed on how to conduct a field interview and practiced administering the questionnaire on the reconnaissance field tour. As the program progressed, particular farm sites on the study courses were selected by the teams, and the participants spent much of their time in data collection.

Data was collected mainly through the administration of structured questionnaires to:

(1) A sample of farmers selected on a head/middle/tail basis on selected turnouts for the study,

(2) Farmer key informants, and

(3) Field and middle-level officers of the Mahaweli Authority (MA).

These surveys were supplemented by observational data. The final phase of the project involved compilation of the data for the team's site report. This material was then computer-analyzed, refined, and rewritten for the final project report.

IV. RESULTS AND DISCUSSION

A. Water Control and Distribution

The Rajangana Irrigation Scheme was constructed to provide an assured supply of water to fields, instead of having farmers depend on the weather for water. During the rainy season (October - January), the yield from the catchment is stored in the reservoirs. This storage supplements rain water whenever there are dry spells during the rainy season, and provides water for full irrigation during the dry period (April - September). To meet seasonal requirements, the reservoir should have sufficient storage capacity to meet the demand of the command area. The distribution system should be able to convey water efficiently and distribute equitable and adequate amounts to all farm holdings.

The distribution system was not designed for effective control in issuing water from turnouts. The control gates provided for the Rajangana Scheme are plank shutters operating on concrete grooves with a slotted arrangement in the gate handle for the setting of openings. These gates are now being replaced by cast iron slide gates. The other canals of the scheme follow contours, cut across contours, or are on ridges to suit the topographical conditions. The system was designed without considering the number of F-channels and size of the command area supplied by each D-channel or number of farm allotments served by a F-channel.

The discharge to the main canal is measured using a rating curve for the sluice opening base or orifice formula. Measuring devices are not incorporated in the turnout structure for measuring discharges in D- and F-channels. The original design was not intended to measure the flow rate into each farm lot.

The D-channels normally take off from the main canal or branch canal with the designed gradient of 0.0004 and a section size that varies with the discharge. The F-channels take off from the D-channels, and check regulators have not been provided at the D- and F-channels to control and issue water. Planking arrangements appear upstream of the drop structures at the D- and F-channels. The majority of the sills and the grooves of these structures have been damaged by the farmers. Direct turnouts connect some D-channels to farm allotments.

The F-channels take off from the D-channels and run along the minor ridges or parallel the contours of the land at a designed gradient of 0.0004. The turnouts to the farm allotments have no control arrangements. The sills of the drop structures have been damaged, the earth filling around the structures has been washed off, and water flows around the structures, causing heavy scouring of the canal bed and steepening of the bed gradient.

The distribution system operates both continuously and rotationally. The main canals supply water continuously to the system, with supply adjusted to changing irrigation requirement over the seasons. The canal capacities have to be large enough to provide a continuous supply to the whole area at any time. In rotational systems, a fixed supply normally is selected and changes in irrigation requirements are met by adjusting the duration and the interval of optimal operation.

In the Rajangana Scheme, the two main canals and branch canals flow continuously over the crop season, but branch canal 1 of the right bank supplies water to the tracts in rotation. The D-channels flow continuously during the days they get water from the branch canal, and there is no rotation within the turnout area. This is due to the lack of farmer organization in the turnout area.

Studies showed that the two D-channels at tract 2 received water more than double that of the crop requirement, while the D-channel under tract 4 received less than half the water required. The distribution among the F-channels under D-channels 1 and 2 of tract 2 was not uniform. Some F-channels received excess water while the others received less water. However, in the tail reach of the branch canal, D-channels as well as F-channels received less water due to poor control arrangements and distribution not being uniform.

To meet the requirement, water was issued to tracts 2 and 3 in the branch canal three days per week, and a small quantity of water flowed to the fields of tracts 4 and 5. For the rest of the week, water was issued to tracts 4 and 5 with a reduction in the branch canal discharge.

The control and issue of water in the Rajangana Scheme was very difficult due to the lack of check regulators, gates, and measuring devices in the canal system. The canals were eroded, the bed gradients were steeper than the designed gradients, and canal sections were not uniform. This system needed complete rehabilitation. When a serious water shortage existed, farmers used drainage water for irrigation. This was done by taking water from field to field wherever possible, as observed in fields under F-channels 4, 5, and 6 of tract 4. The water deficit under F-channels was as much as 85 to 90 percent.

The water supply was not dependable. The flow rate to F-channel 1 of D-channel 1, tract 4 fluctuated both from day to day (0.0023 to 0.08 cumecs) and within a given day (0.0023 to 0.0325 cumecs). Similarly, the fluctuations were significant in F-channels 5 and 6 of D-channel 2, tract 4.

The soils of the upper reaches were light-textured and had high intake rates. The seepage and percolation rates were heavy, ranging from 4 mm to 48 mm/day. Leakage from the dikes was also appreciable. To maintain standing water in the fields, farmers in the upper reaches

irrigated whenever they could obtain the water, without following the rotational schedule. This over-irrigation, combined with the losses from F- and D-channels, contributed to the rise in the water table, which was very close to the surface (0 to 35 cm).

The drainage system was very poor. Farmers blocked the drainage canals to irrigate paddy fields in certain tracts (e.g., under F-channel 1 of tract 4).

B. Water Use Efficiency

The water use efficiency, expressed as the amount of produce per unit of water used, was calculated using expected yield figures and measured water application rates to the farms. Table 1 shows the expected yield and estimated values of depth of irrigation (based on measured values for a period of one week), and water use efficiency.

Table 1. Expected Yield and Depth of Irrigation

Site	Expected Yield (kg/ha)	Depth of Application Per Irrigation (cm)	Estimated Depth of Application for a season (cm)*	Water Use Efficiency (kg/100 m^3)
Site 2 FC 14	2,784	4.0	62	45
FC 15	2,784	13.1	162	17
FC 16	2,784	8.4	110	25
Site 3 FC 1	2,380	5.4	77	31
Site 4 FC 5	2,886	1.3	32	90
FC 6	2,886	2.0	40	72

* Source: Rasiah, 1980

The estimated total depth of application for the crop was calculated, assuming that there was an issue of 18 cm for land preparation and that the water delivered during the week in which measurements were taken was representative of other weekly irrigations. Table 2 shows the water use efficiency obtained by research under simulated farmer conditions.

Table 2. Water Use Efficiency Under Simulated Farmer Conditions

Land Class	Field Water Application (cm/ha)	Yield (kg/ha)	Water Use Efficiency (kg/100 m^3)
Well-drained	122.0	2245	18.4
Imp. drained	122.0	2245	18.4
Poorly drained	92.4	2694	29.0

According to trials conducted at the Batalagoda Paddy Breeding Station, the potential yield under research conditions is 7,088 kg/ha (140 bu/ac) for 3-month varieties. The water requirement for paddy is about 114 cm, according to research studies conducted at Maha-Illuppallama. Thus, potential water use efficiency would be about 62 kg/100 m^3.

The high water use efficiencies obtained in F-channels 5 and 6 cannot be taken very seriously because of the very low amount of water delivered to these areas, which was inadequate to meet the weekly irrigation requirement of 7.84 cm. F-channel 14 in tract 2 and F-channel 1 in site 3 also received less than the weekly field irrigation requirements. The high water application efficiencies in these channels were due mainly to inadequate surface water supplies. Water uses in F-channels 15 and 16 were closer to the water use under simulated research. Therefore, only the results of those two channels are used for comparison. Most of the land in F-channel 15 was well- or imperfectly drained. The water use efficiencies in F-channel 15 were comparable to the simulated research results of well- and imperfectly drained soils, while the F-channel 16 results were closer to research results of poorly drained soils. However, water use efficiencies obtained in farmers' fields and research results under simulated farmer conditions were far below their potential.

C. Resource Conservation

1. Cropping Systems

During the *Yala* cultivation period in which the study was conducted, nearly 100 percent of the area was cultivated in paddy. However, according to the soil and hydrological conditions, major parts of the upper slopes were more suitable for cultivation of other field crops. Flooded paddy cultivation in this part of the land requires

higher amounts of water due to the high percolation rates associated with coarse-textured soil and a deep ground water table. (The percolation loss rate on the upper slopes ranged from 15 to 30 mm/day but on the bottom land was 0 to 7 mm/day). According to net returns for different cropping patterns, cultivation of other field crops could give a higher net return per ha, with less water consumption (and a higher net return per each manhour of work).

The excessive application of water not only has resulted in high percolation losses and water waste, but also appears to have leached down nutrients from the surface soil. The agronomists found through plant tissue tests that the plants in the upper areas exhibited nutrient deficiency symptoms although the application of fertilizer on upper and lower slopes was nearly equal.

2. Conveyance Losses

Much of the water delivered from the reservoir is lost in the process of conveyance. The design conveyance loss was 30 percent from the reservoir sluice to the field, but the measured conveyance loss was nearly twice this amount. Though the past 10-year, ex-sluice, discharge records show a delivery of about 2,439 mm per ha on an average, only about 40 percent of this amount appears to have reached the farms as surface flow. The measured ex-turnout delivery has been very close to this figure (1,067 mm per ha delivery at the turnout gate). A further reduction could be expected in farm-level delivery, taking F-channel loss into account. Table 3 shows the loss percentages in the channel system.

Table 3. Losses in the Channel System

Channel Type	Loss Percentage	Distance Between Inflow and Outflow Measurements
1. Branch canal	60 per 5,500 m	5,500 m
2. D-Channels	2.7 to 52 per 1,000 m	500 - 1,000 m
3. F-Channels	7.6 to 15 per 100 m	100 - 150 m

The loss percentages cannot be extrapolated and are good for comparison only when the distance between inflow and outflow measurements is nearly equal. Note that the loss percentages given for the various channels refer to different distances.

The following defects in the channel system have been identified as major causes for high conveyance losses.

(1) Channel banks are damaged and weak at numerous locations. Excessive losses occur through these damaged and weak sections.

(2) The main canal is a contour channel in which ponds of water spread over a large area in some sections, resulting in excessive percolation losses.

(3) The channel sides are heavily eroded, and beds are silted up and overgrown with weeds. As a result of erosion, existing channel banks are very weak and have reduced channel capacities. Due to the reduced channel capacities, channels are frequently overloaded which causes further damage to the channels. The present channel dimensions clearly demonstrate the extent of erosion that has taken place over the years. For example, a D-channel constructed with 0.75-m wide bed now measures 3 m (tract 2, D-channel 2). A F-channel constructed with a 0.45-m wide bed presently measures 1.5 m.

3. Dike Leakage

Large quantities of water flow into drainage channels due to dike leakage. The paddy fields in the upper part of the land appear to lose as much as 25 to 50 mm per day through dike leakage. The poorly maintained, narrow, paddy field bunds cause such high losses and need strengthening. If conveyance losses in the channel system and the excessive dike leakage that occurs in the paddy fields could be reduced, cultivation of paddy in Yala could be allowed in all land classes; the excess supply required in upper slopes due to high percolation losses could be met by such savings.

4. Soil Problems

Agronomists reported salinity and some other unidentified soil problems in a few isolated locations. In tract 4, salinity ranged from 1.6 to 4.8 mmhos/cm, which is still within the tolerable level for paddy cultivation. In tract 2, salinity levels ranged from 2.2 to 8.0 mmhos/cm. Only a small area was affected with high salinity levels. In these areas, the paddy crop was rather poor.

The high salinity spots were identified in the lower slopes of the land where the surface drainage is poor and in locations where surface water supplies are inadequate.

Though the study area has not shown salinity as a major problem, severely affected areas may exist outside the study area. Therefore, this study should be extended to those areas, also. Furthermore, the

presence of high salinity spots gives a warning to the farmers and the planners to look into the problem more carefully. This problem could build up and spread, and be a major threat for sustained production of agricultural crops.

D. Resource Allocation

All farmers in the study area cultivated paddy in their irrigable allotments (0.8 ha) in both Maha and Yala seasons during the 1981/82 crop year. In Maha, 92 percent of the farm area was cropped in paddy. The extent cultivated in paddy was 87 percent of the farm area in Yala.

Although all farmers in the study area cultivated new high-yielding rice varieties, the average paddy yield achieved in the area was considerably below the potential yield under normal farm conditions for the same rice varieties. Cropping systems studies conducted in farmers' fields in Bulnewa of Mahaweli System H showed that popular rice varieties grown in Rajangana yielded between 12,500 to 16,500 kg/ha. The average paddy yield in Maha was 9,500 kg/ha in Rajangana. In Yala, the expected paddy yield was only 5,600 kg/ha.

The application of fertilizer for the paddy crop did not vary from Maha to Yala. The rate of fertilizer application stood at 86 percent of the recommended quantity in both seasons.

Although the use of fertilizer in Yala was the same as in Maha, the average paddy yield in Yala was 25 percent less than that of Maha. The application of pesticides in Yala was 30 percent lower than the application in Maha. However, no serious pest problem was observed in Yala.

Optimal and timely application of production inputs depends on the farmer's awareness of scientific farming as well as his ability to purchase the inputs when required. The ability of the farmer to purchase inputs when required is, in turn, dependent on the availability of these inputs in the local sales points as well as the cash flow position of the farm.

For small farmers with little or no savings, there is a conflict between decisions to spend money on day-to-day consumption or to invest in the farm for future consumption. An effective agricultural credit system can reducee the burden on the farmer in deciding to use an optimal level of inputs and better cultural practices.

Fifty percent of the farmers interviewed during the study said that agricultural credit is a major problem, while 34 percent said that fertilizer was not available when required. Only 28 percent received credit from institutional sources in Maha 1981/82. This percentage dropped farther to 18 percent in the Yala 1982 season.

Within the study area, D-channel 1 of tract 2 represented the head reach while D-channel 2 of tract 4 represented the tail reach along branch canal 1. If the third site, namely D-channel 1 of tract 4, which contained incomplete field structures (where part of several allotments in the middle of the F-channel did not receive irrigation water) is excluded, the cropping intensity would appear to increase from head to tail. On the average, the cropping intensity within D-channels decreased from head to tail (Table 4).

On the average, farmers in the study area had a higher net income from paddy in Maha due to greater area cropped and the higher yield in comparison to Yala season (Table 5).

Although the average yield was lower in Yala, the cost incurred on purchased inputs such as fertilizer, agrochemicals, and labor did not vary significantly. As a result, the net income earned in Yala was substantially lower than in Maha.

Table 4. Percent of Land Area Under Cultivation by Season and Cropping Intensity

Season	Percent of Land Under Cultivation					
	Tract 2		Tract 4		Within D-Channels	
	D.1	D.2	D.1	D.2	Head Reach	Tail Reach
Maha Paddy	93	100	75	100	97	88
Yala Paddy	89	87	75	96	94	84
Cropping Intensity	182	187	150	196	191	172

The higher average yield and the area cropped in tract 2 resulted in a significantly higher income for those farmers (Tables 6 and 7).

Overall, farmers whose farms were located in the head of D-channels had an annual net farm income 22 percent higher than that of the farms located in the tail of D-channels.

Table 5. Costs and Returns Per Ha of Maha and Yala Paddy

Costs and Returns	Maha 1981/82	Yala 1982
INCOME		
Rice Grain (bushels)	3,925.00	3,305.00
Average Price	2.98	2.98
Gross Income	11,696.00	9,849.82
EXPENSES		
Seed	225.12	309.19
Fertilizer	358.05	364.20
Herbicides	371.17	423.11
Pesticides	129.08	90.00
Tractor and Animal Hire Charges	1,209.98	1,209.98
Hired Labor	2,332.34	2,332.34
Total Cash Expenses	4,625.74	4,728.84
Return Above Cash Costs	7,070.26	5,120.98

The average monthly income earned by the farmers in the area through paddy cultivation was Rs 663.85 per month in 1981/82 crop year. However, the average monthly income of farmers in tracts 2 and 4 were Rs 803.91 and Rs 536.48, respectively. According to the latest consumer finance survey by the Department of Census and Statistics for the period of May 1980 to April 1981, Sri Lanka's average household monthly income was Rs 881.00. The average monthly household income in the rural sector was Rs 795.00.

E. Farmer Involvement

The institutional mechanism through which the management attempts to involve farmers in operation and maintenance at the field channel level is the farmer representative system (sometimes called Jalapalaka or Vel Vidane System). Under this scheme, farmers in a tract are required to elect a farmer representative to assist the Cultivation Officer. In this role, the main water management functions of the farmer representative are:

Table 6. Average Profitability From Paddy Per Allotment (0.8 ha) in Tracts 2 and 4

Season		Tract 2	Tract 4	Percentage Difference in Net Income From Tract 2 and Tract 4
Maha	Gross Income	9,844.78	7,310.28	
	Cost of Production	3,595.71	3,221.16	
	Net Income	6,249.06	4,089.11	53%
Yala	Gross Income	6,767.46	5,584.26	
	Cost of Production	3,369.53	3,235.52	
	Net Income	3,397.92	2,348.74	45%
	Annual Net Income	9,646.98	6,437.85	

(1) to plan and implement rotations within field channels in consultation with farmers,

(2) to arrange for the cleaning and proper maintenance of field channels, and

(3) to promote equitable distribution of water to farmers in his area.

In return for the services rendered by the farmer representative, each farmer is required to pay a service fee of 25 kg of paddy per ha per season to him.

Table 7. Average Profitability Per Acre in Head and Tail Reach Areas of D-Channels

Season		Head Reach	Tail Reach	Percentage Difference of Average Net Profit From Head to Tail
Maha Season	Gross Income	9,785.35	8,143.7	
	Cost of Production	3,633.17	3,296.01	27%
	Net Income	6,152.17	4,847.6	
Yala Season	Gross Income	7,392.88	6,522.66	
	Cost of Production	3,599.28	3,216.37	15%
	Net Income	3,793.60	3,306.29	
	Annual Net Income	9,945.77	8,153.89	22%

In the two study locations, both the sample farmers and the farmer representatives themselves agree that this farmer representative system is not performing satisfactorily. One farmer representative admitted that farmers had declined to pay him his service fee. Most sample farmers in the study location stated that the farmer representatives did not perform any useful service to the farming community. In fact, when interviewed about the relative merits of people helping farmers at the field level, the sample farmers rated the effectiveness of farmer representatives below that of all field level officers other than the cooperative manager.

Many things could contribute to the lack of organized farmer involvement in irrigation management under the institution of the farmer representative.

(1) The area assigned to a farmer representative (80-200 ha) is too large and hence, inhibits promotion of farmer participation in management activities even if the farmer

representative actively seeks to promote such participation.

(2) Due to the presence of a large number of farmers in the service area, farmer representatives are usually elected rather than selected through a process of consensus. The electoral process tends to reinforce the existing divisions among farmers, thus inhibiting promotion of cooperation. In the study area, the two incumbent farmer representatives won very narrowly in a five- cornered and a triangular contest, respectively.

(3) The farmer representative system does not attempt to develop a farmer institution at the grassroot level. Rather, it seeks to identify a representative from among the farmers to assist the Cultivation Officer. Thus, the farmer representatives in effect become the last link in the bureaucratic chain rather than a true farmers' representative.

However, the farmers in the study area quickly were able to start a farmer organization to lobby successfully against the decisions made at the Cultivation Meeting in Yala 1982. Such action shows that there is potential indigenous leadership and initiative among the farmer community in Rajangana. It may be fruitful for the system management to channel these farmer initiatives into programs specifically designed to involve farmers in management decision-making at various levels in the system.

F. Institutional Development

There has been an absence of effective decision-making processes for irrigation management in major irrigation schemes in Sri Lanka. During 1982 Yala in Rajangana, for instance, the authorities were compelled to hold three cultivation meetings for the right bank before a decision could be made on allocation of water for Yala cultivation. The cultivation meeting mechanism has many deficiencies which inhibit the adoption of an effective water management program in major irrigation schemes. These deficiencies include:

(1) Imposition of rigid decision rules on both system managers and farmers: The cultivation meeting approach does not provide an effective machinery for continuous monitoring of the water status in the system and appropriate changes in decision-rules in response to such observed changes. Changes that are implemented are either done on an ad hoc basis or as a result of pressure applied by farmer lobbies or other patrons such as politicians and elites.

(2) Lack of involvement of farmers in system management in an organized and planned manner: Although the objectives of

the cultivation meeting mechanism was to involve farmers in water management decision-making, the cultivation meeting mechanism as presently practiced in water schemes inhibits such participation. For example, only 3 percent of the sample allottees attended the two cultivation meetings held in 1982 Yala. If all farmers attended, however, the number would have been so large that it would have been difficult to conduct a meeting.

(3) Imposition of decisions on farmers: Due to the above mentioned inherent weaknesses in the mechanism, decisions usually made in advance by officers (as in the case of the first cultivation meeting in Yala 1982) are proposed and ratified at the cultivation meetings with minimal farmer representation. This compels some farmer groups to seek external support to redress grievances, which in turn leads to further confusion and uncertainty.

G. Recommendations

(1) The channel system will have to be improved by repairing damaged structures, desilting and restoring the channels to accommodate a rotational water issue, and thereafter carrying out regular maintenance.

(2) Farmers should reduce dike leakage by strengthening the bunds of the paddy fields. This helps in reducing on-farm losses to a great extent.

(3) Well-supervised and better organized water allocation systems should be implemented so that water is better distributed to all farms, irrespective of their locations within the channel system.

(4) Farmers and officials should work together to improve drainage in the areas affected by poor drainage and apply additional water to areas affected with salinity to leach down harmful salts that may be present in the soil.

(5) Better use should be made of farmer-initiated water management programs. When the farmers in the study area perceived a threat to their water, they organized on their own to rectify the situation. The feasibility of incorporating these farmer-inspired efforts into the management scheme should be studied.

(6) More flexibility should be built into the decision rules of both the system managers and farmers. A more flexible approach would help ensure that the right amount of water would be applied to the crops at the right time.

V. APPENDICES

A. Agronomy

1. Soils

The topography of the study areas gently slope along F-channels toward the basin at the lower end. The grade of most of the F-channels varies from less than 0.1 to 1 percent. There are, however, areas where the slopes are greater than 2 percent. The F-channels in these places were highly eroded. In D-channel 1, Tract 2, field channel number 1 did not operate beyond allotment number 24. Allotments below number 24 were irrigated from the drainage channel which carried the drainage water of allotment numbers 1-11, 26-35, and 36-45. This drainage water had an electrical conductivity value of 1100 mmhos per cm. Similarly, in D-channel 2, Tract 4, the F-channels were designed to receive drainage from the fields located at a higher elevations in addition to the irrigation water normally conveyed via the channel.

Rock outcrops observed in the turnout indicate that the soils are derived from gneiss. The soils in the upper areas are reddish brown earths (RBE) developed *in situ*, while those on the lower slopes, low humic gleys (LHG), are mostly of colluvial parent material. Soil characteristics of the allotments studied are shown in Table A-1. The chemical characteristics of soils in the project area (Table A-2) were compared with data collected during this study (Table A-3).

The Rajangana irrigation system depends to a considerable extent on drainage water from System H. Even within the system, recycling of water takes place to an appreciable degree.

a. Soil Texture

In the upper slopes of both head and tail ends of the D-channel, soil texture varied from sandy clay loam to sandy clay or sandy loam (Table A-1). The 0-15 cm layer was generally sandy clay loams except in a very few areas which were sandy clays. In the lower slopes, soil texture varied from sandy clay loam to sandy clay to heavy clay. In the middle slope, soil texture varied from sandy clay loam to sandy loam to sandy clay. A predominant feature in the upper and middle slopes of the study area was a gravel layer 20 cm below the soil surface.

b. Water Table Depths

Observations of water table depths indicated that, after irrigation, water tables were at or above the ground surface. In

Table A-1. Soil Properties of the Upper, Middle, and Lower Reaches of Four Tracts in the Raajangana Irrigation Scheme

Soil Characteristics	Depth	Upper Slope													
		Tract 2/D.1				Tract 2/D.2			Tract 4/D.1				Tract 4/D.2		
		29	30	46	52	138	145	159	1	5	32	34	57	58	72
Texture	0-15	S.C.L.	S.C.L.	S.C.L.	S.C. less S.		S.C.L.	S.C.L.	S.C.	S.C.	S.C.L.	S.C.L.	S.C.L.	S.C.L.	S.C.L.
	15-30	S.C.L.	S.L.	S.C.L.	S.C. high S.	S.L.	S.L.	S.C.L.	S.C.	S.C.	S.C.L.	S.C.L.	S.C.L.		
	30-60	S.C.	S.L.	S.C.	S.C.	S.C.L.	S.C.L.	S.C.L.	S.C.	S.C.	S.C.L.	S.C.L.			
p^H (1)Field	0-15	7.0	7.6	6.3(7.2)	6.8		6.6	7.0	7.0	6.8	6.8	7.0	7.8	7.8	7.8
	15-30	7.2	7.4	7.0(7.0)	6.8		6.8		7.0	7.0	6.8	7.0	7.8		
	30-60	6.8	7.4	7.2(7.2)	7.2	8.0(7.2)	7.4		7.0	7.0	6.8	7.0			
		7.0	7.5	7.0(7.1)	6.9	7.6(7.2)	6.9	7.0	7.0	6.9	6.8	7.0	7.8	7.8	7.8
(2) Lab	0-15	6.5	6.6	6.3(6.4)	6.4	7.6(8.2)		6.8					7.4		
		6.8	7.1	6.7(6.6)	6.7	7.6(7.7)		6.9	7.0	6.9	6.8	7.0	7.6	7.8	7.8
E.C. mmhos/cm	0-15	0.92	1.34	1.50(1.6)	1.04	(8.0)2.2		1.0	1.28	1.28	1.30	1.30	1.62		
Water Table	0-15	at surface	at surface	at surface				at surface							
	15-30														
	30-60														
Moisture	0-15			< f.c.											
	15-30	field flooded	field flooded	field flooded = f.c.	field flooded										
	30-60			> f.c.											
Other Observations		D.H. not recognized		D.H. Light Brown *chilli plot	D.H. Light Brown	drainage channel blocked									

( ) - problem area

Table A-1. (Continued)

Soil Characteristics	Depth	Middle Slope													
		Tract 2/D.1				Tract 2/D.2			Tract 4/D.1				Tract 4/D.2		
		24	33	43	50	141	146	147	9	4	25	29	62	77	78
Texture	0-15	S.C.	S.C.L.	S.C.L.	S.C.	S.C.L.	S.C.L.	S.C.L.	S.C.L.	S.C.	S.C.L.	S.C.L.	S.C.	S.C.L.	S.L.
	15-30	S.C.	S.C.	S.C.L.	S.C.	S.C.L.	S.C.L.	S.L.	S.C.L.	S.C.	S.C.L.	S.C.L.			
	30-60	S.C.	S.C.	S.C.L.	S.C.	S.C.L.	S.C.L.	S.C.L.	S.C.L.	S.C.	S.C.L.	S.C.L.			
p^H (1)Chemical	0-15	6.8	6.8	7.2	7.6(7.2)	7.4	6.6	7.6	7.2	7.2	7.0	6.8	8.2	7.8	7.8
	15-30	7.0	7.2	7.4	7.4(7.0)			7.2	7.2	7.2	7.0	7.4			
	30-60	6.8-7.0	7.2	7.2	7.0(7.0)	7.8		7.4	7.2	7.2	6.8	7.4			
(2) Lab	0-15	6.9	7.1	7.3	7.3(7.1)	7.6	6.6	7.4	7.2	7.2	6.9	7.2	8.2	7.8	7.8
		5.8	6.6	6.4	6.8(6.0)	7.0	6.6	7.2					7.2	7.2	
		6.4	6.9	6.9	7.1(6.6)	7.3	6.6	7.3					7.7	7.5	
E.C. mmhos/cm	0-15	0.78	1.36	1.76	1.24(3.00)	1.76	3.5	1.2	1.11	1.28	1.28	1.28	1.76	4.8	
Water Table	0-15	at surface	at surface	not observed	at surface	at surface	30 cm below surface								
	15-30														
	30-60														
Moisture	0-15			= f.c.											
	15-30	field flooded	field flooded	= f.c.	field flooded										
	30-60			> f.c.											
Other Observations		D.H. not recognized gravel layer	D.H. Light Brown @ 40-60cm gravel layer	gravel layer											

( ) - problem area

Table A-1. (Continued)

Soil Characteristics	Depth	Lower Slope													
		Tract 2/D.1				Tract 2/D.2				Tract 4/D.1		Tract 4/D.2			
		35	36	37	42	142	149	152	155	18	21	69	68	84	86
Texture	0-15	C.	C.	C.	S.C.	S.C.L.	S.C.L.		S.C.L.	S.C.L.	S.C.L.	S.C.	S.C.	S.C.L.	S.C.L.
	15-30	C.	C.	C.	S.C.L.		S.C.L.	S.C.L.		S.C.L.	S.C.L.				
	30-60	C.	C.	C.	S.C.L.		S.C.L.			S.C.L.	S.C.L.				
p^H (1)Chemical	0-15	7.0	7.2	7.2(7.6)	7.4	6.8	6.8	7.2	6.8	7.0	7.2	7.8	8.4	7.8	7.8
	15-30	7.4	7.2	7.6(7.4)	7.4					7.2	7.2				
	30-60	7.2	7.0	7.2(7.4)	7.0					7.4	7.4				
		7.2	7.1	7.3(7.5)	7.3	6.8	6.8	7.2	6.8	7.2	7.3	7.8	8.4	7.8	7.8
(2) Lab	0-15	6.0		6.0(6.2)	6.0	7.4	6.4	6.6	6.8			7.6		7.8	
		6.6		6.6(6.8)	6.6	7.1	6.6	6.9	6.8			7.7		7.8	
E.C. mmhos/cm	0-15	0.96		1.20(0.76)	1.64	1.7	1.5	1.40	0.90		1.20	0.72		4.2	
Water Table	0-15	not observed even below 60 cm	at surface		at surface	at surface									
	15-30														
	30-60														
Moisture	0-15	< f.c.													
	15-30	≅ f.c.	> f.c.												
	30-60	≅ f.c.													
Other Observations		D.H. brown at 40-60 cm	D.H. not recognized	D.H. not recognized	D.H. not recognized	Drainage channel blocked									

( ) - problem area

Table A-2. Chemical Characteristics of the Soil in the Rajangana Irrigation Scheme (Somasiri, 1982)

Soil Type	Average Clay Content		pH		EC (mmhos/cm)		CEC (meq/100 g)		% (org. matter)		Available P (ppm)	
	A	B	A	B	A	B	A	B	A	B	A	B
R.B.E.	10-35	N.A.	6-7.5	5.8-8.2	0.02-0.05	0.92-8.0	10-20	N.A.	2-3	N.A.	15-110	N.A.
L.H.G.	10-35	N.A.	6-8.5	6.0-8.4	0.03-2.68	0.76-4.8	15-20	N.A.	1-2	N.A.	20-27	N.A.

A - Values common to soil type
B - Values common to study area
N.A. - Not available

Table A-3. Chemical Characteristics of the Soil in Head and Tail of Study Area

Soil Type	pH		EC (mmhos/cm)	
	Head	Tail	Head	Tail
R.B.E.	6.6 - 7.1	6.9 - 7.8	0.92 - 1.6	2.2 - 8.0
L.H.G.	6.6 - 7.3	6.6 - 8.4	0.76 - 1.64	0.9 - 4.2

the upper slopes, standing water remained less than one day after an irrigation, while in the lower slopes standing water remained 3-4 days after an irrigation. The watertable in the lower slopes commonly remained at the surface due to water from seepage and surface drainage. In D-channel 2, Tract 4 the farmers in the upper slops controlled weeds with standing water, depriving the farmers in the lower slope of an adequate water supply. The only water received by these farmers was seepage and surface drainage water which was not sufficient to maintain standing water in fields. In the other three sites only farmers in the lower slopes were able to maintain adequate standing water to suppress weed growth. A major part of this water was received by seepage and surface drainage. Soils of the upper slopes were highly permeable and the percolation rates were high.

c. Soil Moisture

Soil moisture was measured in several fields within each study site. However, an irrigation application, which coincided with the period of soil sampling, prevented thorough sampling of these fields. In general, the soil moisture content was almost at field capacity in the upper and middle slopes where paddy was grown. Similar samples from fields with chillies or other crops indicated that soil moisture was about 20 to 25 percent below field capacity. In D-channel 1, Tract 2, D-channel 2, Tract 2 and D-channel 1, Tract 4, soil moisture in paddy fields in the lower reaches was below field capacity. Low soil moistures in these basins were partially attributed to uneven water distribution over improperly leveled soils. However, none of the fields in the study area showed any crop damage due to water stress.

d. Salinity

The occurrence or non-occurrence of salt deposits on bunds was observed to obtain an indicative assessment of salinity. Salt deposition on bunds was not as common as in Kalawewa, but salt deposits were observed in some of the fields toward the lower slopes. The electrical conductivity values in some allotments confirmed salinity problems (Tables A-1 and A-3). Conversations with farmers suggested that salinity problems were greater in Maha than Yala. Although paddy is moderately tolerant to salinity, an electrical conductivity of 3.8 mmhos/cm and above is considered harmful to paddy. However, soil samples from areas with low tiller counts and where plants were stunted, weak, or discolored, were not always saline (Table A-4). It is possible that such areas were saline at the time of transplanting and salts were removed by the continuous application of water during Yala.

Table A-4. Indicators of Soil Salinity Problems

	Allotment 50		Allotment 37	
	Normal Area	Problem Area	Normal Area	Problem Area
1. pH	6.8	6.0	6.0	6.2
2. EC (mmhos/cm)	1.24	3.00	1.20	0.76
3. Plant population per 900 cm	28	19	24	13
4. Plant height (cm)	52	38	57	18
5. Nutrient Status N	L	L	L	L
P	M	M	L	M
K	L	L	L-M	L

e. Other Field Conditions

Inadequate land leveling was a problem in D-channel 1, Tract 2 and D-channel 1, Tract 4. Poorly leveled basins limit the even distribution of water. Generally, basins in the upper, middle, and lower slopes were 17 m to 19 m along contours; and 9 m to 14 m across contours. However, very large basins 65-m long and

40-m wide, and very small basins 8-m long and 6-m wide were also observed.

Another striking feature in the above study sites was that some allotments originally designed for irrigation were not commanded by the F-channel, and cultivations in these areas were restricted to perennial crops. In addition, farmers claimed that there were no definite patterns of water distribution within a turnout. The flow at the head of the F-channel was not constant. F-channels were highly eroded and, if not for the profuse weed growth all over the channel, the erosion would have been far more serious. The weed growth in the F-channels impaired flow and provided a source of weed seeds to all cultivated fields. However, removing weeds from the F-channels could lead to heavy channel erosion. A more suitable method may be to top weeds in the F-channels before excessive growth occurs.

The condition of some of the drainage channels was also less than satisfactory. In a few instances, the existence of a drainage channel was suspect. A considerable portion (about 1/4) of D-channel 1, Tract 2 did not have a drainage channel. A channel was located beyond a highly elevated area, but it would not serve the purpose of proper drainage. Cleaning of drainage channels and preventing waterlogging conditions is very important to prevent salinity development. Salinity must be prevented from the very beginning. Once it develops, it is difficult to eliminate. In some instances, the drainage channels were physically converted to temporary irrigation channels to provide irrigation water.

2. Crops

a. Cropping Pattern

The Rajangana irrigation system was designed for paddy monoculture. Cropping intensity (visual observation) for Yala 1982 was almost 100 percent. Paddy dominated almost all of the study sites. This was also true for well-drained soils in the upper slopes. Apparently, there was no definite cropping pattern introduced or enforced by the authority to suit the different drainage classes. Although, there were other crops such as chillies and vegetables, and grain legumes such as cowpea, grown in D-channel 1, Tract 2 and D-channel 2, Tract 2, the extent of cultivation of these crops was negligible.

b. Paddy

The varieties mostly used were short-aged BG 276-5 and BG 34-8 (Table A-5). These are 3 to 3-1/2 month varieties. BG 276-5 has become a popular variety during Yala. When asked, farmers said that this variety was fairly resistant to stem borer. Approximately 10 percent of the farmers in D-channel 1, Tract 4

Table A-5. Crop Data for the Upper, Middle, and Lower Reaches of Four Tracts in the Rajangana Irrigation Scheme

	Upper Slope						
	Tract 2/D.1				Tract 2/D.2		
Crop Observations	29	30	46	52	138	145	159
1 Crop	Paddy	Paddy	Paddy	Paddy	Paddy	Paddy	Paddy
2 Variety	BG 276-5	BG 276-5	BG 276-5	-	-	-	-
3 Method of Establishment	B/C	T/P	B/C	B/C	-	-	-
4 Stage of Growth	Flowering 100%	Flowering 50%	Flowering 90%	Late Tillering	Heading	Soft Dough Stage	Early Ripening
5 Approx Plantg. Time(wk)	10	8	8-9	5-6	-	-	-
Condition:							
Overall Assessment	Avg - Exc	Avg	Avg	Avg			
Population*	29	18(19)	28	30	24	53	26
Plant Height (cm)	67	62(60)	81	60	56	78	79
7 Nutrient Status							
Visual N	M	M	M	L-M			
P	M	M	M	M			
K	M	M	M	M			
Tissue Test N	L	L	L	L	L	L	L
P	M	M	L	M	M	M	M
K	M	M	M	L	L	M	L
8 Weed Infestation							
Grasses	L	L	L	H	M	L	M
Sedges	M	M	L	H	M	L	H
Leaves	L	M	L	L	L	L	L
9 Method of Control							
10 Diseases	not evident	not evident	not evident	not evident	not evident	not evident	not evident
11 Pest Incidence	not evident	leaf roller-L	stem borer-L	not evident	stem borer L-M rice bugs	stem borer-L	stem borer-L-M
12 Estimated Yield							
13 Other Observations					water logging in the lower part		

* - plant/tiller count/900 cm^2

( ) - B/D area

L - low

M - medium

H - high

I - indicates v. deficiency

Table A-5. (Continued)

	Upper Slope (continued)						
	Tract 4/D.1				Tract 4/D.2		
Crop Observations	1	5	32	34	57	58	72
1. Crop	Paddy	Paddy	Paddy	Paddy	Paddy	Paddy	Paddy
2. Variety	BG 275-6	BG 275-6	BG 275-6	BG 34-8			
3. Method of Establishment							
4. Stage of Growth					Milky	Milky	Milky
5. Approx. Plantg. Time(wk)	7	7	7	7			
6. Condition:							
Overall Assessment	Avg	Avg	Poor	Avg	Avg	Avg	Avg
Population*	20	30	28	31	23	33	26
Plant Height (cm)	58.6	64.8	52.7	50.3			
7. Nutrient Status							
Visual: N							
P							
K							
Tissue Test: N	L	L	L	L	L	L	
P	L	M	M	M	M	M	
K	L	L	L	L	L	M	
8. Weed Infestation							
Grasses	L	L	H	H	M	M	M
Sedges	M	M	M	M	L	L	M
Leaves	L	L	L	L	L	L	L
9. Method of Control							
10. Diseases	not evident	not evident	not evident	not evident	not evident	not evident	not evident
11. Pest Incidence	not evident	not evident	not evident	gall midge-L	not evident	not evident	not evident
12. Estimated Yield							
13. Other Observations					water logging in the lower part		

* - plant/tiller count/900 cm^2

L - low

M - medium

H - high

Table A-5. (Continued)

Crop Observations	Middle Slope							
	Tract 2/D.1				Tract 2/D.2			
	24	33	43	50	141	146	147	157
1 Crop	Paddy	Paddy	Paddy	Paddy	Paddy	Chillie	Paddy	Paddy
2 Variety	BG 276-5	mixed	BG 276-5	mixed	-	-	-	-
3 Method of Establishment	B/C	B/C	B/C	B/C	-	-	-	-
4 Stage of Growth	Flowering 100%	Flowering 90%	Milky Stage	Late Tillering to Flowering	Soft Dough	First Bloom to Pod Bearing	Heading	Dough
5 Approx Plantg. Time(wk)	10-11	8-9	11	6	-	-	-	-
6 Condition								
Overall Assessment	Avg - Exc	Poor-Avg	Avg-Exc	Poor-Avg				
Population*	34	27	26	28(19)	28	-	38	34
Plant Height (cm)	65	67	71	52(38)	84		65	76
7 Nutrient Status								
Visual: N	M-H	L	M	L-M				
P	M-H	L-M	M	L-M				
K	M-H	L-M	M	L-M				
Tissue Test: N	L	L	L	L(L)	L	-	L	L
P	M	M	H	M(M)	M		M	M
K	M	M	M	L(L)	L		L	L
8 Weed Infestation								
Grasses	M	M	M	L(L)	L	-	L	M
Sedges	M	M	M	M(L)	L		M	L
Leaves	L	L	L	L(L)	L		L	L
9 Method of Control								
10 Diseases	not evident	not evident	not evident		not evident		not evident	not evident
11 Pest Incidence	not evident	not evident	not evident	leaf eating 25% G. symp. of stem borer	stem borer-L		rice bugs L stem borer	stem borer-L
12 Estimated Yield			3.6 tons/ha		3.4 tons/ha			
13 Other Observations								

* - plant/tiller count/900 cm^2

( ) - B/D area

L - low

M - medium

Table A-5. (Continued)

	Middle Slope (continued)						
	Tract 4/D.1				Tract 4/D.2		
Crop Observations	9	4	25	29	62	77	78
1. Crop	Paddy		Paddy	Paddy	Paddy	Paddy	Paddy
2. Variety	BG 94-1		BG 34-6	BG 34-8	BG 34-8	BG 34-8	BG 34-8
3. Method of Establishment	-		-	-	-	-	-
4. Stage of Growth					Heading	Milky	Hard Dough
5. Approx. Plantg. Time(wk)	7		7	7	-	-	-
6. Condition:							
Overall Assessment	Poor		Poor	Avg	Avg	Avg	Exc
Population*	29		25	31	13	18	26
Plant Height (cm)	41		54	51			
7. Nutrient Status	-		-	-	-	-	-
Visual: N	-		-	-	-	-	-
P	-		-	-	-	-	-
K							
Tissue Test: N	L		L	L	L	-	M
P	M		L	M	M	-	M
K	L		L	L	L	-	M
8. Weed Infestation							
Grasses	L		M	L	M	H	L
Sedges	M		M	M	M	H	L
Leaves	L		L	L	L	L	L
9. Method of Control							
10. Diseases	not evident		not evident	not evident			
11. Pest Incidence	not evident		not evident	not evident			
12. Estimated Yield							
13. Other Observations							

* - plant/tiller count/900 cm^2

L - low

M - medium

H - high

Table A-5. (Continued)

Crop Observations	Lower Slope							
	Tract 2/D.1				Tract 2/D.2			
	35	36	37	42	142	149	152	155
1 Crop	Paddy	Paddy	Paddy	Paddy	Paddy	Paddy	Paddy	Paddy
2. Variety	BG 34-8	BG 276-5	BG 276-5	BG 276-5	-	-	-	-
3. Method of Establishment	B/C	B/C	B/C	B/C	-	-	-	
4 Stage of Growth	Flowering 80%	Soft dough	Flowering 90%	Milky	Soft dough	Early Ripening	Flowering	Soft dough
5 Approx Plantg Time(wk)	8	10	10	10				
6 Condition:								
Overall Assessment	Avg	Avg-Exc	Avg	Avg-Exc				
Population*	25	26	24(13)	28	30	27	50	35
Plant Height (cm)	62	87	57(18)	61	90	82	78	88
7 Nutrient Status								
Visual N	H	H	H	H				
P	H	H	H	H				
K	H	H	H	H				
Tissue Test N	L	L	L	L	L	L	H	L
P	H	H	H	L	H	H	H	H
K	H	L	L	Lf	H	H	L	L
8 Weed Infestation								
Grasses	H	L	L(L)	L	H	H	L	L
Sedges	H	L-H	L(H)	H	L	L	L	L
Leaves	L	L	L-H(L)	L	L	L	L	L
9 Method of Control				Parathion sprayed for stem borer.				
10 Diseases	not evident	not evident	not evident	not evident	not evident	not evident	not evident	not evident
11 Pest Incidence	stem borer 10% white heads	stem borer-L	not evident	not evident	stem borer-L	stem borer-L	stem borer-L	
12. Estimated Yield		6.3 tons/ha		6.9 tons/ha				
13 Other Observations								

* - plant/tiller count/900 cm^2
(-) - B/D area

f indicates v. deficient
L - low
M - medium
H - high

Table A-5. (Continued)

	Lower Slope (continued)					
	Tract 4/D.1			Tract 4/D.2		
Crop Observations	18	21	69	68	84	86
1. Crop	Paddy	Paddy	Paddy	Paddy	Paddy	Paddy
2. Variety	BG 34-8 BG 276-5	BG 90-2	BG 34-8	BG276-5	BG 34-8	BG 34-8
3. Method of Establishment	-	-	-	-	-	-
4. Stage of Growth	-	-	Heading	Heading	Tillering	Milky
5. Approx. Plantg. Time(wk)	7	7				
6. Condition:						
Overall Assessment	Avg-Exc	Avg	Poor	Poor	Poor	Exc
Population*	17	28	26	30	16	39
Plant Height (cm)	57.6	51				
7. Nutrient Status						
Visual. N						
P						
K						
Tissue Test: N	L	L	L	L	L	L
P	M	M	M	M	L	H
K	L	L	M	M	M	L
8. Weed Infestation						
Grasses	L	L	M	L	M	M
Sedges	L	M	M	M	L	L
Leaves	L	L	L	L	L	L
9. Method of Control						
10. Diseases	not evident	not evident	not evident	not evident	not evident	not evident
11. Pest Incidence	not evident	gall midge - L	not evident	not evident	not evident	not evident
12. Estimated Yield						
13. Other Observations						

* - plant/tiller count/900 cm^2
L - low
M - medium
H - high

cultivated long-aged 4 to 4-1/2 month varieties. About 60 percent of the farmers in D-channel 2, Tract 4 and about 10 percent of the farmers in D-channel 2, Tract 2 transplanted their paddy. Most farmers on all sites applied at least some fertilizer, although it was not the recommended dosage.

Commonly, paddy was transplanted randomly, without definite spacing. The spacing recommended by the Department of Agriculture, is based on conditions such as intensity of weed growth, method of weed control, degree of mechanization, etc. Spacing of 20 x 20 cm, 20 x 15 cm, and 20 x 10-12 cm are recommended for these conditions. For short-aged varieties, a more suitable spacing is 15 x 15 cm. Consequently, a short-age variety should have 9 plants or 54 tillers (assuming 6 tillers per plant) per 900 cm. Plant densities of 22 and 29 tillers per 900 cm were recorded (Table A-5). General crop conditions in the fields ranged from average to above average (Table A-5). Growth stages of paddy were fairly uniform throughout the study sites. Growth stages varied between flowering to soft dough stage, indicating that the planting occurred over a two-week period. During late ripening stage, bird damage can be very serious unless maturity of a crop in a particular field coincides with the maturity of the crops in the whole area. When all the fields mature at the same time, the damage is still there, but it is distributed evenly so that individual damage appears negligible.

Although visual observations suggested medium fertility levels, tissue tests indicated low nitrogen levels (Table A-5). Potassium was also low except for a very few cases and phosphate level was medium to high. However, most farmers claimed regular fertilizer applications (Table A-6).

Table A-6. Fertilizer Applications to Paddy Fields

Dressing Type	Qty. recommended cwt	Qty. applied cwt
Basal	1.475	.86
Top	1.96	2.08

c. Weed Control

The most common method adopted to control weeds was the use of chemicals. Only a few farmers used water as a primary control measure. However, standing water was still considered essential

for controlling weed growth throughout the season. Usually, about 2 to 3 weeks after transplanting farmers applied a post-emergent weedicide and cut off water from the field for about a week. Afterwards, they attempted to maintain standing water in the field to prevent additional weed growth. However, weed control was a major problem in the study area. This was clearly indicated from the appearance of the fields (Table A-1). Where maintenance of standing water was possible, weed populations in fields were low. In fields where the maintenance of water was not possible, weed growth was heavy inspite of the application of weedicides. Further studies in weed control are essential since the yield loss that could occur due to weeds is high.

Within fields, sedges were the most common weeds, except for a few cases where grasses, such as Echinoclea spp. dominated. The most common sedges were two species of Cyprus. Cyprus rotundus and Cyprus irea populations in the fields were very high. Among grasses, two species of Echinocloa were considered to be serious; farmers called them "Gogeri" and "Bajari." Of the two, "Gogeri" was considered to be the most difficult to control. Only a small percentage of the farmers adopted hand weeding as a control measure.

d. Diseases

Rice diseases were not evident in the study sites. Apparently, the acceptance of the new high-yielding rice varieties has decreased disease problems in paddy.

e. Pests

Incidence of pests was generally low (Table A-5). The most common pest observed was stemborer. In some fields, evidence of an earlier stemborer attack was observed, but it had been completely controlled before serious damage occurred. In some of the other fields, the stemborer attack was identified by white heads. In these fields, damage was about 10 percent. Almost all the fields that were attacked by the stemborers were planted with BG 34-8. Compared to BG 34-8, BG 276-5 is fairly resistant to stemborers. One particular farmer sprayed Parathion before symptoms of stemborer damage were observed.

Other pests observed were thrips, whorl maggot, gall midge, leaf roller, and paddy bug. Among these pests, only the whorl maggot and gall midge caused damage and in relation to the area, the damage was not significant. Parathion was used to control these pests. However, this chemical is not recommended by the Department of Agriculture. Table A-7 gives the recommended chemical and the dosage.

Table A-7. Recommended Insecticides and Their Dosage

Pest	Chemical	Dosage
1. Stemborer	Carbofuran 3% granules	15-20 lbs.
	Diazinon 10% granules	15-20 lbs.
	BHC 6% granules	33 lbs.
Stemborer (Nursery stage)	Monocrotophos 60% EC	227-312 c.c.
	Endosulphan 35% EC	398-511
	Chlorpyrifos 20% EC	426-285 c.c.
2. Whorl maggot	BHC 6% granules	33 lbs.
	Diazinon 10% EC	20 lbs.
3. Gall midge	Carbofuran 3% granules	15-20 lbs.
	Diazinon 10% granules	15-20 lbs.
	BHC 6% granules	33 lbs.
4. Thrips	Quinalphos 25% EC	199-284 c.c.
	Dimethoate 40% EC	199-284 c.c.
	Panthion 50% EC	199-284 c.c.
	Diazinon 40% EC	199-284 c.c.
	Carbaryl 80% WP	199-284 gms.
5. Paddy bug	BHC 10% powder	20-30 lbs.
6. Leaf rolling caterpillar	Monocrotophos 60% EC	568-626 c.c.
	Chlorpyrifos 20% EC	426-710 c.c.
	Panthion 50% EC	568-852 c.c.

Table A-8 shows that the average potential paddy yield was approximately 84 bushels per acre, while the yield expected by the farmers was approximately 57 bushels per acre. Comparable paddy yields obtained for Maha by research officers* in the Department of Agriculture in farmers' fields (Kalawewa) were 114 bushels per acre. There was a wide difference between farmers' estimates, potential paddy yields, and paddy yields obtained by the Department of Agriculture.

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* Paper presented by S.H. Upsena at the Water Management Program held at ARTI.

If the farmers' estimates of paddy yields were correct, then there is a question about the desirability of paddy monoculture. According to the 1980 statistics, total paddy production on the island for 1980 was 2.1 million metric tons (about 1.5 million metric tons of rice). Rice imports during the same year were approximately 13 percent of the total paddy production. The new land expected to be developed under the Mahaweli accelerated

Table A-8. Average Potential Yields of Rice Fields, Estimated from Tiller Counts and Grain Counts

	Sample Yields (tons/ha)			Average Yields		
Study Site #	1	2	3	Tons/ha	Bushels/acre	Farmers' Bushels/acre
1	3.6	6.3	6.9	5.05	99.6	66.6
2	3.4	---	---	3.4	67	55.2
3	---	---	---	4.36	86	47.8
4	---	---	---	NA	NA	57.8
		Average		4.27	84.2	56.9

scheme alone would be about 670 thousand acres. The present population growth is 1.7 percent. Per capita consumption of rice is about four pounds per week. Paddy yields were significantly increased by new breed varieties. All this information indicates that Sri Lanka may be self-sufficient in rice production. But cultivation of other field crops such as grain legumes, vegetables, and cash crops such as chillies, onions, potatoes, etc., could be promoted if the potential for these crops in terms of marketing were studied further.

3. Discussion

An overall assessment of the study area indicated that the standard of crop culture with respect to paddy was good. Farmers appeared to know the value of fertilizer and were shrewd enough to suspect poor fertilizer quality when the expected response was not obtained. They also correctly identified soil problems as salinity

which they believed was more severe in Maha. In addition, spraying chemicals even before the appearance of damage, and selecting BG 276-5 against stemborer attack was a testimony of their capability. Chemicals were used without much consideration of costs to combat weeds, and farmers later regretted the secondary weed growth which they expected to control by maintaining standing water in the field. Stages of crop growth did not vary so widely as to impose problems of pests and disease.

Cultivation at Rajangana received better crop care and hardly a fallow field was observed. R.B.E. and L.H.G. soils are difficult to work if water shortages occurred in Yala. The soils are very hard when they are dry and very sticky when they are wet. Farmers mostly used simple implements and animals for draft power. Land preparation was considered to be the most difficult task during the course of cultivation. Land leveling in low lying areas was poor, indicating the difficulty of land preparation and adding to the problem of crop culture. Introduction of more suitable simple implements for land preparation is needed.

Farmers normally transplant their paddy only in Maha. But informal conversations indicated that Rajangana farmers would be willing to transplant in Yala, if an adequate amount of water were available. All paddy was transplanted without definite spacing. Transplanting with definite spacing or row seeding would provide opportunities for better weed control. A majority of farmers selected only two varieties: BG 276-5 and BG 34-8, and their choices appeared to be correct. The general crop condition was good even though basal fertilizer application was low.

Weedicides were applied, but additional weed growth developed. Many fields were infested with both sedges and grasses. Although most farmers applied weedicides, they depended on standing water to control subsequent weed growth.

In low lying areas, such features as stunted and weak growth, low tillering capacity, scattered growth, and differences in coloration suggested symptoms of salinity. Electrical conductivity measurements indicated salinity only in some areas and not in others.

Pest attacks were not significant, but some damage by stemborers was observed. Diseases were not evident.

The maintenance of F-channels left much to be desired. Weeds blocked the channels, increasing water losses during water issue periods. Also, weed seeds were spread to cultivated fields from the channels.

About 10 allotments in the lower slopes in D-channel 1, Tract 2 and D-channel 2, Tract 2 were above command. Originally,

they were designed and blocked out for irrigation. Although perennial crops were grown in these areas, a relocation of F-channels in those sites may increase the extent of land under command, facilitating cultivation of more valuable crops.

4. Summary of Constraints

(1) Improper layout of F-channels, improper leveling of paddy fields and insufficient drainage facilities.

(2) Weed control in paddy (high land).

(3) Unavailability of a more flexible cropping pattern which would conform to the soil conditions found in the project area.

(4) Soil problems such as salinity and other soil chemical problems.

B. Engineering

1. Design and Operation of the System

The Rajangana Scheme was constructed during 1962 to 1965 in the Kala Oya basin and consists of two reservoirs, Rajangana and Angamuwa. After interception of part of the catchment by Kalawewa, the net catchment area effective in contributing to the yield of Rajangana reservoir is 760 sq km. The reservoir has a net storage capacity of 9.36×10^7 m^3 at a full supply depth of 10.6 m, and a solid concrete, ogee spillway 358 m long with 32 6.1 m x 3.0 m radial gates. There are two tower sluices located on the left and right banks of the reservoir. The gate opening of the right-bank sluice (a single barrel) is 1.14 m x 1.14 m, and that of the left bank is 1.14 m x 1.14 m (3 barrels). The downstream development to date consists of 2,819 ha on 17 tracts of the right bank under gravity command and 745 ha under lift irrigation. About 892 ha in the right bank is under the command of Angamuwa Reservoir. Left-bank development consists of 1,922 ha in seven tracts under gravity command and 857 ha under lift irrigation. The total cultivated area at present is 6,972 ha. The final development consists of 151 ha in a right-bank tract being constructed now.

This system was designed for monoculture of paddy and has been in operation since Maha 1967/68. Its operational criteria are based upon the following:

(1) ET_o, the potential evaporation data were obtained from the Agriculture Research Station, Maha-Illuppallama.

(2) ET_{crop} = Crop Coefficient (K_c) x ET_o.

(3) Application Efficiency (E_a)= 55 percent for well-drained land, 60 percent in poorly-drained soils.

(4) Field Irrigation Requirement (FIR) = ET_{crop} : E_a.

(5) Effective rainfall P_e = 0.67 (R - 0.25) positive and > 75 mm for well-drained soils, and 0.67 (R - 1.00) positive and > __ mm for poorly-drained soils.

(6) Conveyance Efficiency (E_c) = 65, 75, and 80 percent for main, D-, and F-channels, respectively, and 70 percent average for the system.

(7) Irrigation Requirement IR = (FIR - P_e) : E_c.

(8) Crop Coefficients for different growth stages of paddy K_c = 1.00 (Gi), 1.15 (Gd), 1.20 (Gm), and 0.9 (Gl)

where: Gi = Initial Growth Stage, Gm = Midgrowth Stage,
Gd = Development Stage, and Gl = Last Growth Stage.

The main canals of the Rajangana Scheme are basically single-bank contour canals with the canal bank serving as an operation and maintenance road. The other canals are either on ridges, follow contours, or cut across the contours to suit the topographical conditions, without specific consideration either to limit the number of F-channels served by a D-channel, or the number of channels served by the F-channels.

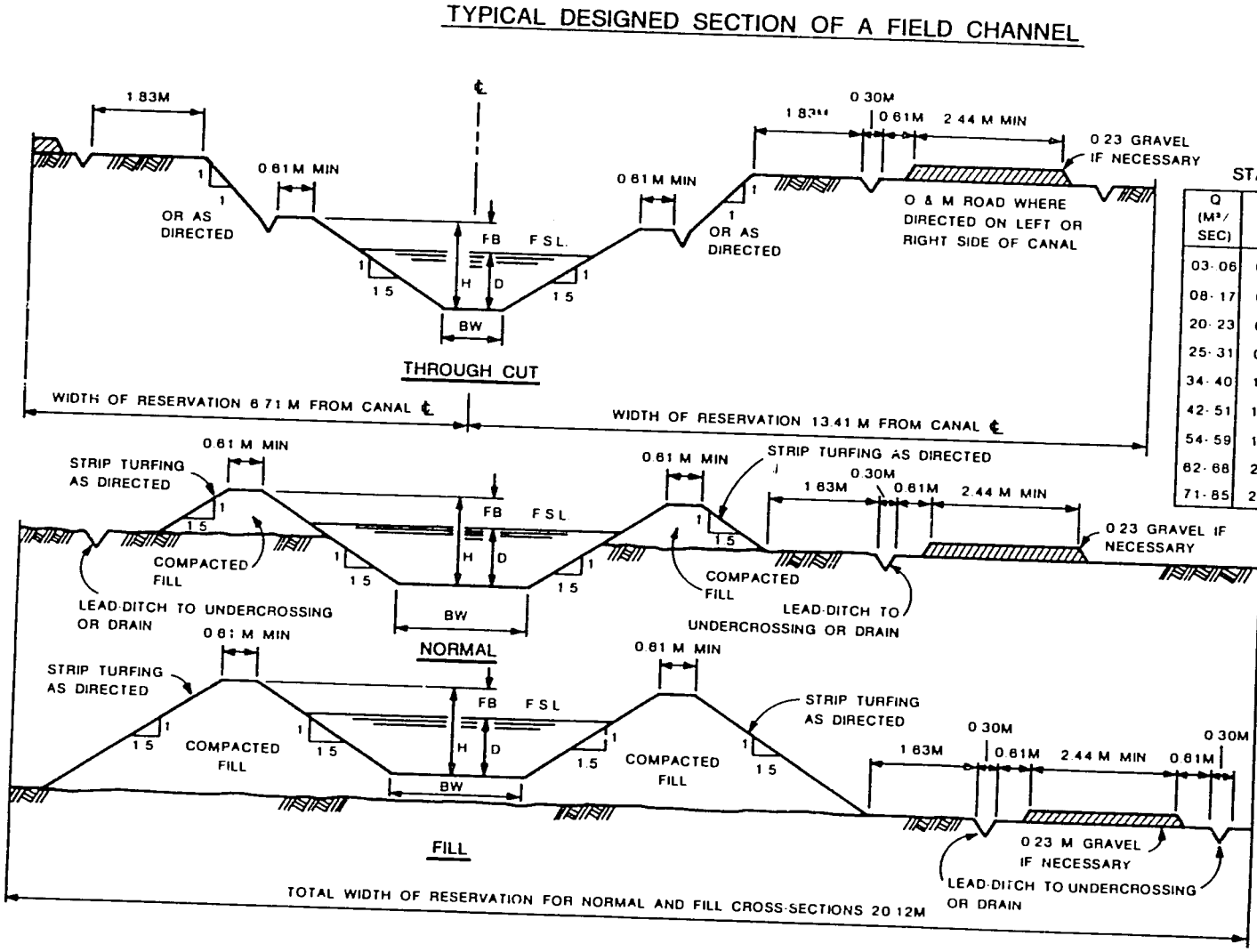
The right-bank main canal is designed for tracts 1 to 5 and 13 to 17 to be supplied from Rajangana reservoir and tracts 6 to 12 from Angamuwa reservoir. The bed width of reach 1 of the main canal is 4.9 m; reach 2 is 3.7 m; and reach 3 is 6.1 m. The right-bank main canal design does not provide for flexibility in using the storage in Rajangana for tracts 6 to 12 when shortages are experienced. This main canal extends 8 km and has three branch canals 4.7 km, 10 km, and 9.7 km long.

The right-bank branch canal 1 is designed to feed tracts 2 to 5. It takes off from the right-bank main canal at 2 km and has a length of 4.7 km. The turnout to the branch canal consists of two 61-cm x 61-cm diameter concrete pipes with gates. The wooden gates are screw operated. This is a contour canal with single banking, and the bank is used as a service road. The four study sites selected for the Diagnostic Analysis were located on this canal:

	Tract 2		Tract 4
Site 1	D-Channel 1 (84 ha)	Site 3	D-Channel 1 (180 ha)
	F-Channels 4,5,6,7 and 8		F-Channel 1 (28.3 ha)
Site 2	D-Channel 2 (60.7 ha)	Site 4	D-Channel 2
	F-Channels 14,15 and 16(18 ha)		F-Channels 3,4,5, and 6

All the channels are constructed to a gradient of 0.0004 as per the typical cross-section (Figure B-1). The control gates at the head of the channel consist of wooden gates with slotted MS flat with locking arrangement.

D-channels 1 and 2 of tract 2 are similar and take off from the branch canal at 1.16 km and 2.2 km (Figure B-2), respectively, and run on the minor ridges. The initial sections of the channel were excavated and the final sections were filled with double banking. F-channels



STANDARD SECTIONS

Q (M³/SEC)	BW (M)	D (M)	FB (M)	H (M)
03-06	0.30	0.34	0.58	0.92
08-17	0.46	0.44	0.43	0.92
20-23	0.61	0.52	0.40	0.92
25-31	0.76	0.55	0.76	1.31
34-40	1.22	0.55	0.76	1.31
42-51	1.52	0.55	0.76	1.31
54-59	1.83	0.55	0.76	1.31
62-68	2.13	0.55	0.76	1.31
71-85	2.44	0.61	0.70	1.31

S=0.0004
H=D+FB

Figure B-1. Typical Cross Section of a F- or D-channel.

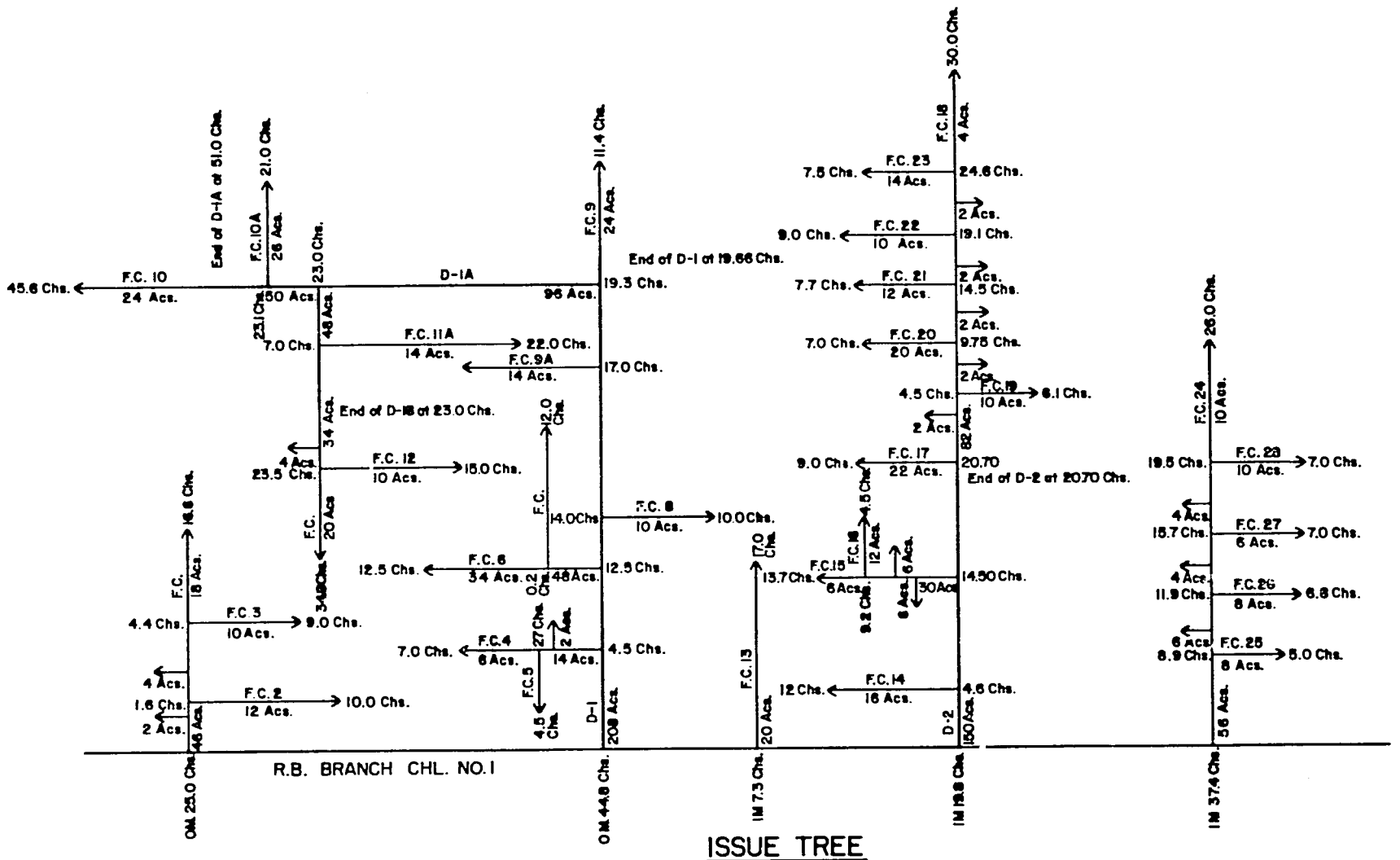


Figure B-2. Issue Tree of Tract 2.

4,5,6,7 and 8 were chosen for detailed study. F-channels 4, 6, and 8 take off from D-channel 1 at 0.15, 0.43, and 0.49 km, respectively. F-channel 5 takes off from F-channel 4, and F-channel 7 takes off from F-channel 6. The total area under these channels is 23.5 ha.

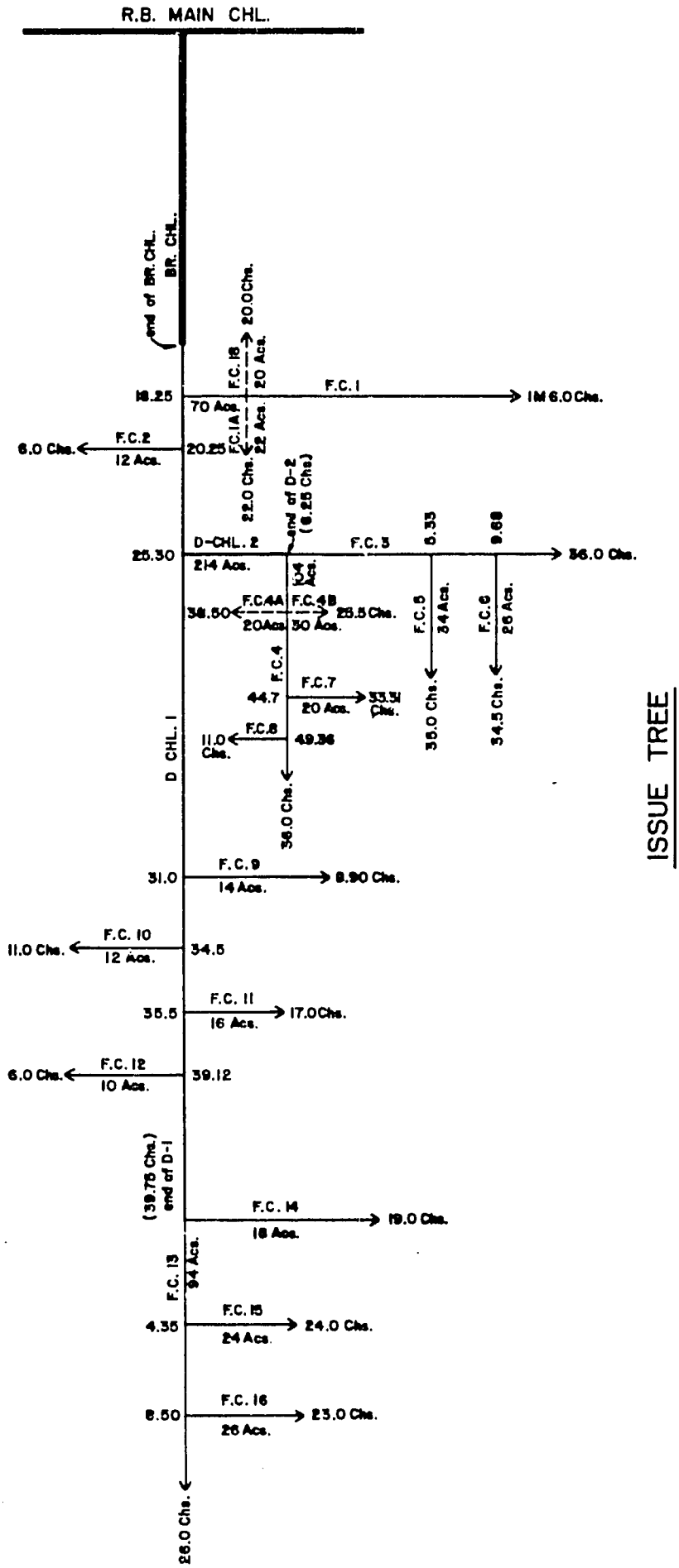
D-channels 1 and 2 of tract 4 were selected for detailed study. D-channel 1 is the continuation of branch canal 1 after 4.7 km, and has a length of 1.2 km. The command area under this channel is 180 ha. One of the study sites in tract 4 is situated under F-channel 1, which takes off from D-channel 1 at 0.55 km (Figure B-3), and is designed to irrigate 28.3 ha. D-channel 2 takes off from D-channel 1 at 0.77 km, runs on a minor ridge, and bifurcates into two F-channels at 0.19 km. There are direct turnouts to the farm holdings from this D-channel.

F-channel 3 is a continuation of D-channel 2 (Figure B-3), while F-channel 4 runs over another ridge. The turnout areas selected by the on-farm engineers were located under F-channels 5 and 6. These F-channels run parallel to the contours taking off from F-channel 3. The command area of F-channels 5 and 6 is 25.3 ha.

The F-channels in this system are not designed to deliver 28 l/s, as in System H of Kalawewa. They run on very small ridges, irrigating farm holdings on either side. The F-channels take off from F-channels and run parallel to the contours depending on the topography of the area. The farm turnouts consist of concrete pipes having a diameter of 7.6 cm. Each allotment is 0.8 ha (2 acres).

The area to be cultivated and cropping calendars for each season are decided at the kanna meeting (seasonal cultivation meeting), depending on the forecasted availability of water in Maha, and stored water in Yala.

The Irrigation Department carries out the operational functions of management of water up to the F-channel turnout. The distribution of water to the farms from the F-channels is the responsibility of the Vel Vidane (Group Leader) of the farmer organization of the farmers under the F-channel. The Vel Vidane is expected to adopt a rotational system among the farms. The water issues to the F-channels and the D-channels are carried out by the Irrigation Department. Water issues to the D- and F-channels is done by a turnout operator, who is responsible for operational aspects involved in about 1,000 ha (2,500 acres). The directions on rotational schedules and amount of water to be released are given to the Works Supervisor by a Technical Assistant in charge of about 2,000 ha (5,000 acres). The overall supervision is done by an Irrigation Engineer who is in charge of the management of water in the entire project.



ISSUE TREE

Figure B-3. Issue Tree of Tract 4.

The daily irrigation requirement (IR) is next obtained considering effective rainfall (p_e) and conveyance efficiency (E_c). If land soaking, land tilling, or growth stages occur in two consecutive months, then the required IR is obtained in proportion to the number of days in the month. The irrigation requirements for the Yala season are given in Table B-1.

The distribution system is operated on a rotational basis. The issue time of the canal system is prepared on the basis of the blocking-out plan. Issue trees of tracts 2 and 4 are as given in Figures B-2 and B-3. Before the water issues commence, a schedule of water issues is prepared taking land soaking, land tillage, and the growth period into consideration. As the canal capacities are insufficient, the land soaking of the entire area cannot be taken at one time.

The discharge pattern in all the sluices is similar for the same type of cultivation. The first peak release is during the land preparation period during the first 15 days, followed by a second peak at between 110 to 130 days. The minimum discharge is at the plant's development growth stage (30-45 days).

On receipt of the irrigation requirement from the colonization officer, water is released from the head sluice to the turnouts of the D- and F-channels. The project is run by an Irrigation Engineer who directs the Technical Assistants in the computation of the daily releases and rotational schedules.

2. Water Conveyance and Distribution System

Even though the Department of Irrigation has made every effort to launch the operation of the scheme with proper water management, this schedule actually has not been followed. The rotational irrigation method practiced during the current Yala season is as follows.

The turnout from the main canal to the branch canal 1 was opened to 25 cms from Monday to Wednesday, and water was issued mainly to tracts 2 and 3. However, some issues (quantity undetermined) were made to tracts 4 and 5, since there was no regulating structure at the end of the branch canal. From Thursday to Surday, the operation of the turnout to the branch canal was reduced to 10.2 cms. The turnouts to D-channels in tracts 2 and 3 were closed and water was issued to tracts 4 and 5. However, there was an increased flow in D-channel 1 of tract 4 from Thursday to Sunday, but reduced flow in the branch canal during the same period.

D-channels 1 and 2 in tract 2 conveyed 0.393 cumecs and 0.259 cumecs for three days. When the operational water requirement of the two channels was compared with the actual quantity of water delivered to the command area, the quantity of water delivered was 135 percent and 112 percent more than required, respectively, under D-channels 1 and 2 (Tables B-2 and B-3). The same computation for D-channels 1 and 2 of

Table B-1. The Crop Water Requirement (mm) for Paddy in Yala

Water Requirement	May			June		July		August		
	LS	Lt	Gi	Gi	Gd	Gd	Gm	Gd	Gm	Gl
100 for 5 days for land prep.	20									
75 for 10 days for land prep.		7.5								
ET_c (ins)/day			6.0	6.0	7.11	6.35	6.6	6.35	5.84	5.08
FIR (ins)/day	34	13	10	10	11.6	10.6	10.6	10.6	10.6	8.4
Fir ins/week			71	71	82	75	78	75	78	59
Po ins/day			4	4	4.6	4.3	4.6	4.3	4.6	3.3
Pe (ins)/day	2	2	2							
IR (ins)/day	32	10.6	11.7	14.5	16.8	15	15.8	15	15.8	12
IR (ins)/week			82	100	117	107	112	107	112	83
IR (cfs)	1.4	0.43	0.48	0.61	0.66	0.64	0.66	0.64	0.66	0.48

ET_o for May and June = 6.1mm/day, July and August = 5.6 mm/day

Crop Coefficients K_c = 1.00 (Gi) 1.15 (Gd) 1.2 (Gm) 0.9 (Gl)

days 15 15 45 20 = 105 days

Application Efficiency E_a = 60%

Field irrigation requirement FIR = $ET_c + E_a$, where ET_c crop coefficient $K_c \times ET_o$

or FIR = ET_c + Po, where Po = field losses (mm/day), and Pe = effective rainfall

Conveyance Efficiency E_c + 80%

Irrigation requirement = IR = (FIR - Pe) ÷ Ec

tract 4 reveals that the water diverted to the farm holdings under these channels were insufficient in D-channel 1 (-57.2 percent) and D-channel 2 (-59.4 percent).

Detailed studies of water requirements and deliveries to F-channels of D-channel 1, tract 2 show that F-channel 8 delivered 44 percent more than required, while the deficiencies in F-channels 4, 5, and 7 were 35 percent and 39 percent. In D-channel 2 of tract 2 the water diverted through F-channels 14 and 16 was deficient by 11 and 60 percent; F-channel 15 had an excess of 88 percent. This overissue in some of the F-channels was a result of lack of control structures and the absence of measuring devices to issue the required quantity. Tables B-2 and B-3 give the required discharges at the heads of the channels with a three-day issue of water.

Table B-2. Flow Measurements in D-Channel 1, F-Channels 4, 5, 6, 7 and 8 of Tract 2

Channel	Location	Discharge (m^3/sec) Designed	Discharge (m^3/sec) Actual	Number of Days	Total Volume (m^3)
D-Channel 1	0 km 0 m	0.168	0.394	3	101,866
Sum of the deliveries to the F-channels 4,5,6,7 and 8			0.173		
D-Channel 1	0 km 500 m	-	0.173		
F-Channel 4 and 5	0 km 0 m	0.0214	0.014	3	3,629
F-Channel 6	0 km 0 m	0.0595	0.059	2	10,195
F-Channel 6	180 m apart		0.050		
F-Channel 6	180 m apart		0.040		
F-Channel 7	0 km 0 m	0.018	0.011	2	1,900
F-Channel 8	0 km 0 m	0.023	0.033	2	5,702

Table B-3. Measurements in D-Channel 2, F-Channels 14, 15 and 16, Tract 2

Channel	Location	Discharge, (m^3/sec) Designed	Actual Measured	Number of Days of Water Issue	Remarks
D-Channel 2 (on 28/7)	0 km 25 m	0.122	0.259	3	Gate fully opened
D-Channel 2 (on 28/7)	0 km 454 m	-	0.174		Gate fully opened
D-Channel 2 (on 29/7)	0 km 12 m	-	0.09		Gate fully closed
F-Channel 14 Head end on D-channel 4 (on 27/7 and 28/7) (at 19 m)	0 km 8 m	0.0214	0.019	3	Gate fully opened
F-Channel 14 (on 27/7)	0 km 305 m	-	0.017	-	-
F-Channel 15 Head end (on 27/7 and 28/7)	0 km 19 m	0.0336	0.0633	3	Average
F-Channel 15 (on 27/7)	0 km 266 m	-	0.060	3	Average
F-Channel 16 Head end (on 27/7)	0 km 27 m	0.0153	0.0061	3	Average

To further examine water distribution under D-channel 2 of tract 4, the actual water requirements for farm holdings under F-channels 5 and 6 were calculated. The water deficiencies in F-channels 5 and 6 were 90 percent and 85 percent, respectively, showing that major portion of water was allocated to F-channel 4 (Tables B-4 and B-5).

The details of the measurements of discharges made on the branch canal show that the loss per 1,000 meter length was 11.06 percent (Tables B-4 and B-6) which is not excessive. The summary of conveyance losses in Table B-6 shows that losses varied from 2.7 to 52 percent for 1,000 meters. A maximum loss of 52 percent was observed in D-channel 1 of Tract 2, where the total loss was 27 percent. This channel passes through a gravel section and fissured rock excavation in the head reach and with double banking towards the end. Severe water leaks were observed. The total conveyance losses in D-channel 1 of tract 2 and D-channel 2 of tract 4 were 1.64 percent and 2.6 percent, respectively.

The F-channel conveyance losses varied from 7.61 percent (F-channel 1 of tract 4) to 15.3 percent (F-channel 14 tract 2)for 1,000 meters. The total loss of water in these two channels was 7.3 percent and 5.6 percent, respectively, which are fairly low values. However, in F-channel 6 under D-channel 1 of tract 2, a 11.4 percent loss for 100 meters was observed which is very excessive. The reason for this loss was that the channel was on double banking, and there were heavy leaks through the turnouts when discharge measurements were taken. The total conveyance loss of this channel was 43 percent. During the study, the seepage losses were not separated from the leakage losses.

A differential level survey conducted on the channel bed and sills of structures revealed that the existing gradients are quite different from the designed gradient of 0.0004 (Figures B-4 to B-10). The details of the measured data and the gradients are given in Table B-7. The variation in the gradient could be summarized as follows:

<u>Tract 2</u>

D-Channel 1	0.0019 to 0.001
F-Channel 6	0.0052 to 0.0001
D-Channel 2	0.00055 to 0.00069
F-Channel 15	0.0016 to 0.0093

Table B-4. Flow Measurement in D-Channel 1 and F-Channel 1, Tract 4

Date	Description of Canal/Channel	Structure Location/ Time of Reading	Method Used	Maximum Designed Discharge (m^3/sec)	Observed Discharge (m^3/sec)
28/7/82	Branch canal	D/S T.O.	Current meter	-	1.729
28/7/82	D-Channel 1	U/S F.Cl	Current meter	0.360	.154
29/7/82	Branch canal	D/S T.O. (13.45 hrs)	Current meter	-	0.783
	D-Channel 1	5.5 km D/S (14.45 hrs)	Current meter	0.360	0.315
	D-Channel 1	5.8 km D/S (15.00 hrs)	Current meter	-	0.283
27/7/82	F-Channel 1	30 m	Cutthroat flume	0.107	0.0023
28/7/82	F-Channel 1	60 m (9.30 hrs)	Cutthroat flume	0.107	0.0325
	F-Channel 1	60 m (17.15 hrs)	Cutthroat flume	0.107	0.0229
29/7/82	F-Channel 1	60 m (15.30 hrs)	Cutthroat flume	0.107	0.080
	F-Channel 1	336 m (15.30 hrs)	Cutthroat flume	0.107	0.0792
	F-Channel 1	60 m (16.30 hrs)	Cutthroat flume	0.107	0.0671
	F-Channel 1	336 m (16.30 hrs)	Cutthroat flume	0.107	0.0651

Table B-5. Flow Measurement in D-Channel 2 and F-Channels 5 and 6 of Tract 4

Date	Channel	Location	Discharge (m^3/sec) Designed	Measured Actual
27/7/82	D-Channel 2	D/S offtake	0.197	0.080
	D-Channel 2	T.O. 1	-	0.00013
	D-Channel 2	T.O. 2	-	0.00003
	D-Channel 2	156 m D/S offtake	-	0.0780
	F-Channel 5	0 M	0.078	0.0085
	F-Channel 6	0 M	0.064	0.016
27/7/82	F-Channel 5		0.078	0.0113
	F-Channel 5		0.078	0.0085
28/7/82	F-Channel 5		0.078	0.0085
	F-Channel 5		0.078	0.0057
29/7/82	F-Channel 5		0.078	0.0082
	F-Channel 5		0.078	0.0028
27/7/82	F-Channel 6		0.064	0.019
	F-Channel 6		0.064	0.016
28/7/82	F-Channel 6		0.064	0.0054
	F-Channel 6		0.064	0.0028
29/7/82	F-Channel 6		0.064	0.0043

Table B-6. Conveyance Losses in the D- and F-Channels

Channel	Measured Length (m)	% Loss for 1000 meters	Channel	Measured Length (m)	% Loss for 1000 meters
Tract 2			Tract 4		
D-Channel 1	500	52	Branch Canal	5500	11.06
F-Channel 6	180	11.4 for 100 m	D-Channel 1	300	33.86
D-Channel 2	429	2.7	F-Channel 1	276	7.61
F-Channel 14	297	15.13	D-Channel 2	156	14.74
F-Channel 15	247	13.05			

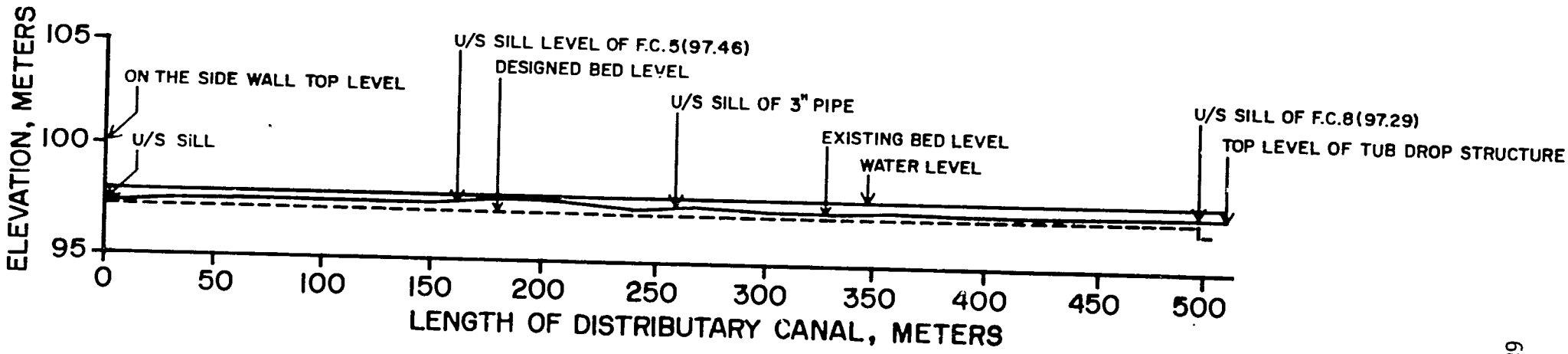


Figure B-4. Longitudinal Section of D-channel 1, Tract 2

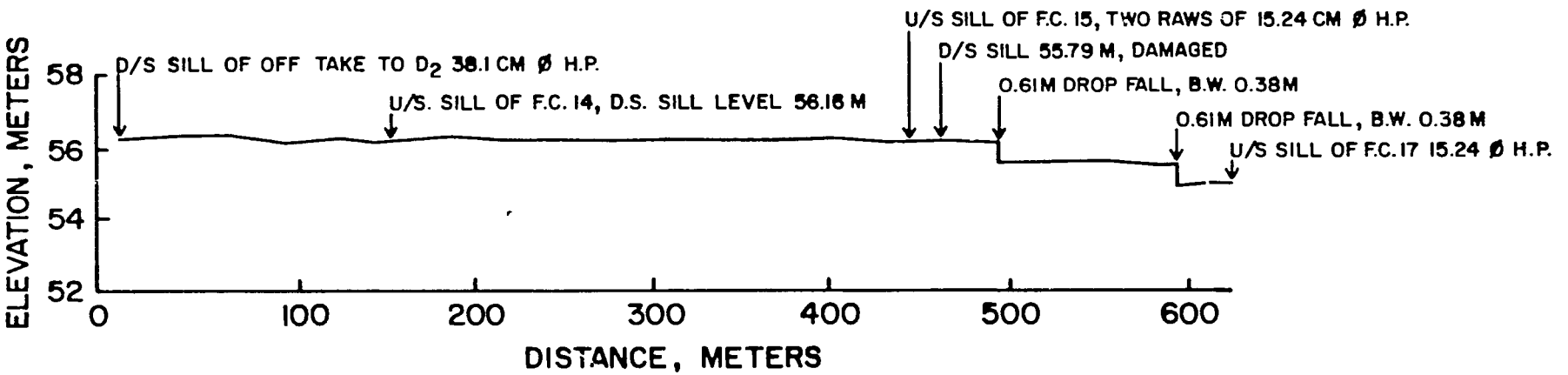


Figure B-5. Longitudinal Section of D-channel 2, Tract 2

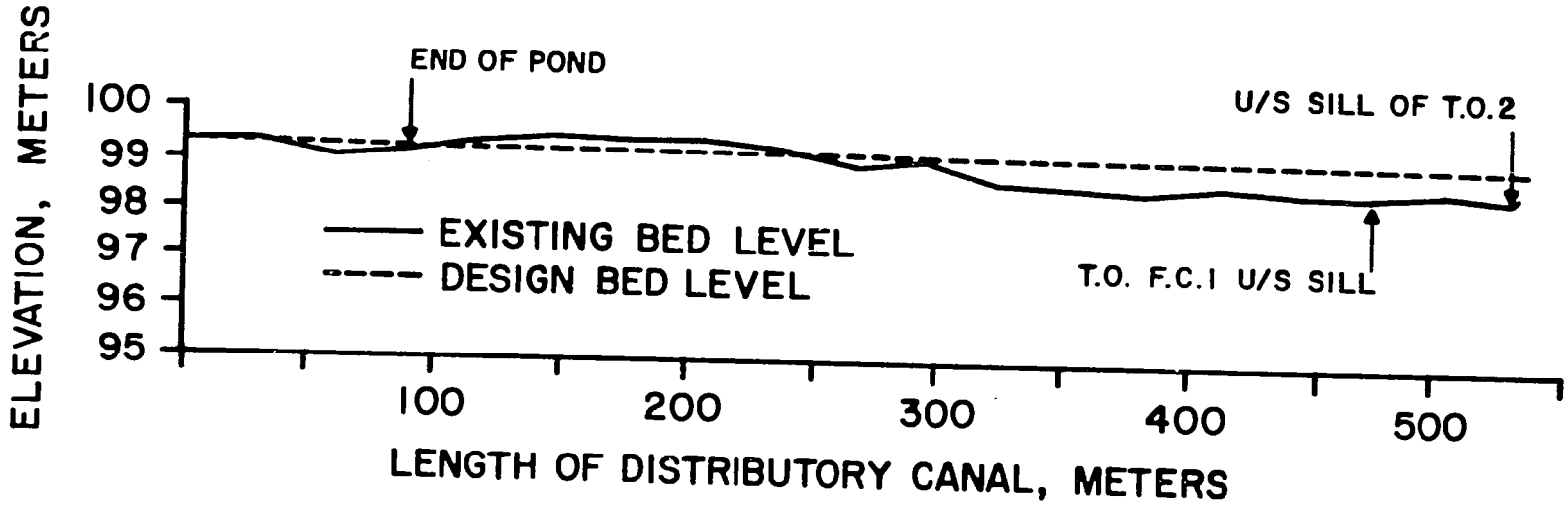


Figure B-6. Longitudinal Section of D-channel 1, Tract 4

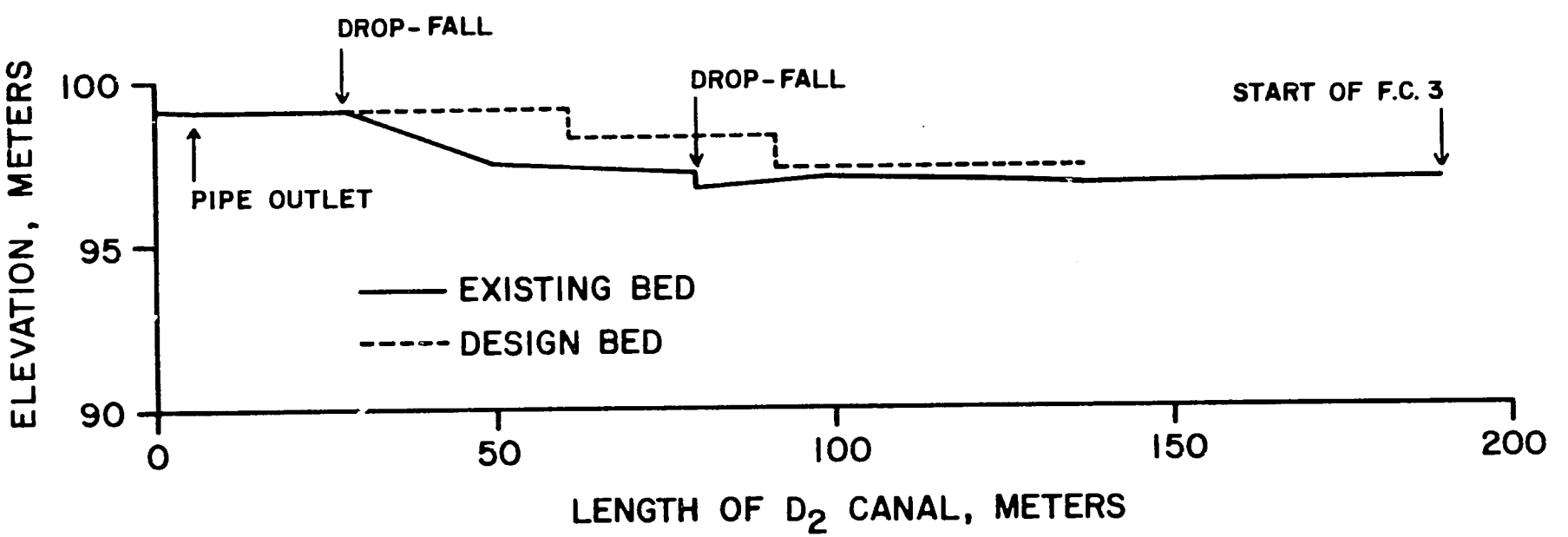


Figure B-7. Longitudinal Section of D-channel 2, Tract 4

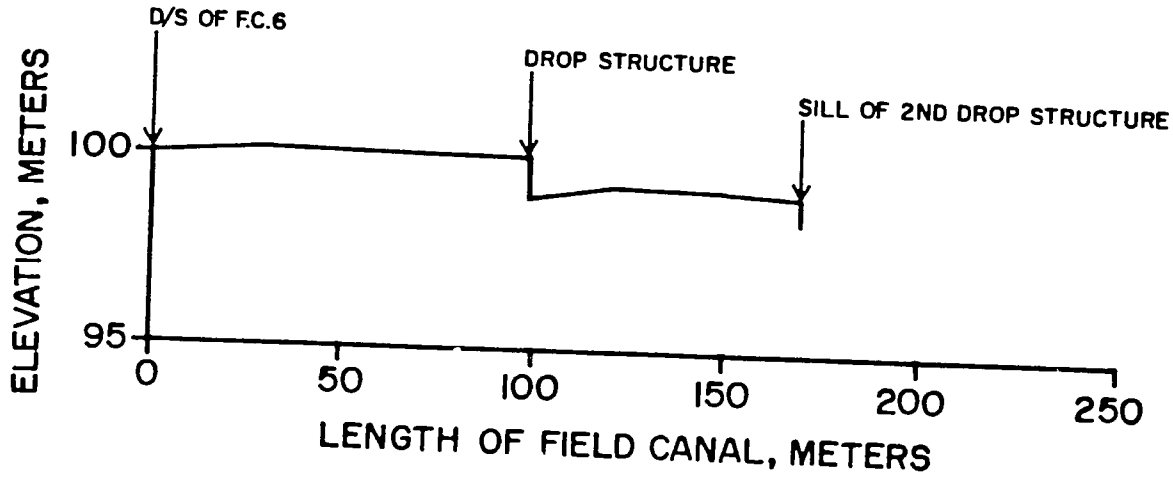


Figure B-8. Longitudinal Section of F-channel 6 of D-channel 1, Tract 2

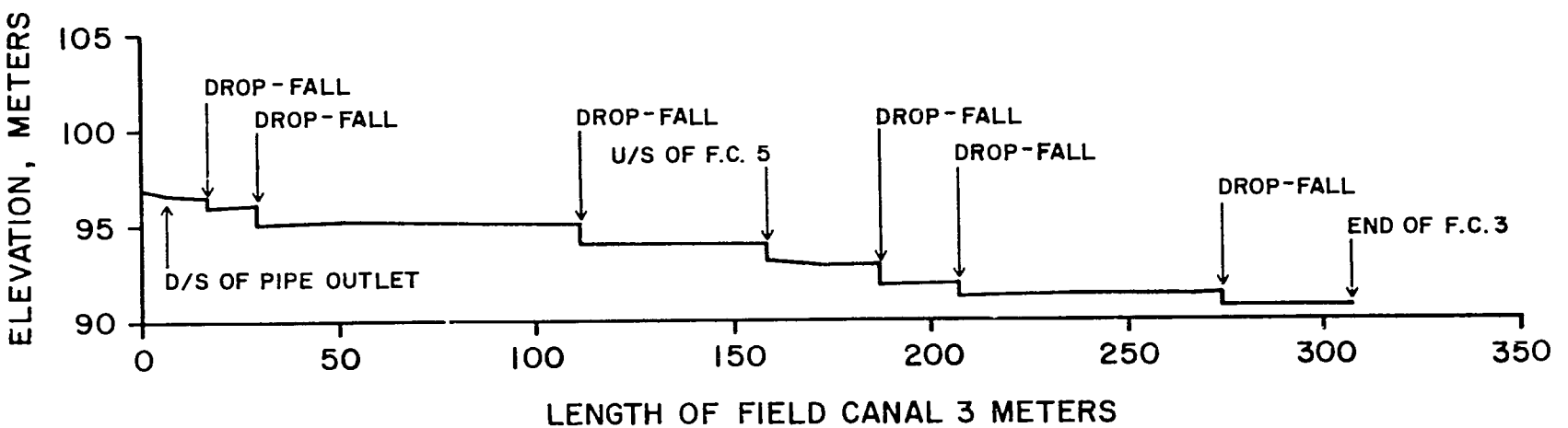


Figure B-9. Longitudinal Section of F-channel 1 of D-channel 1, Tract 4

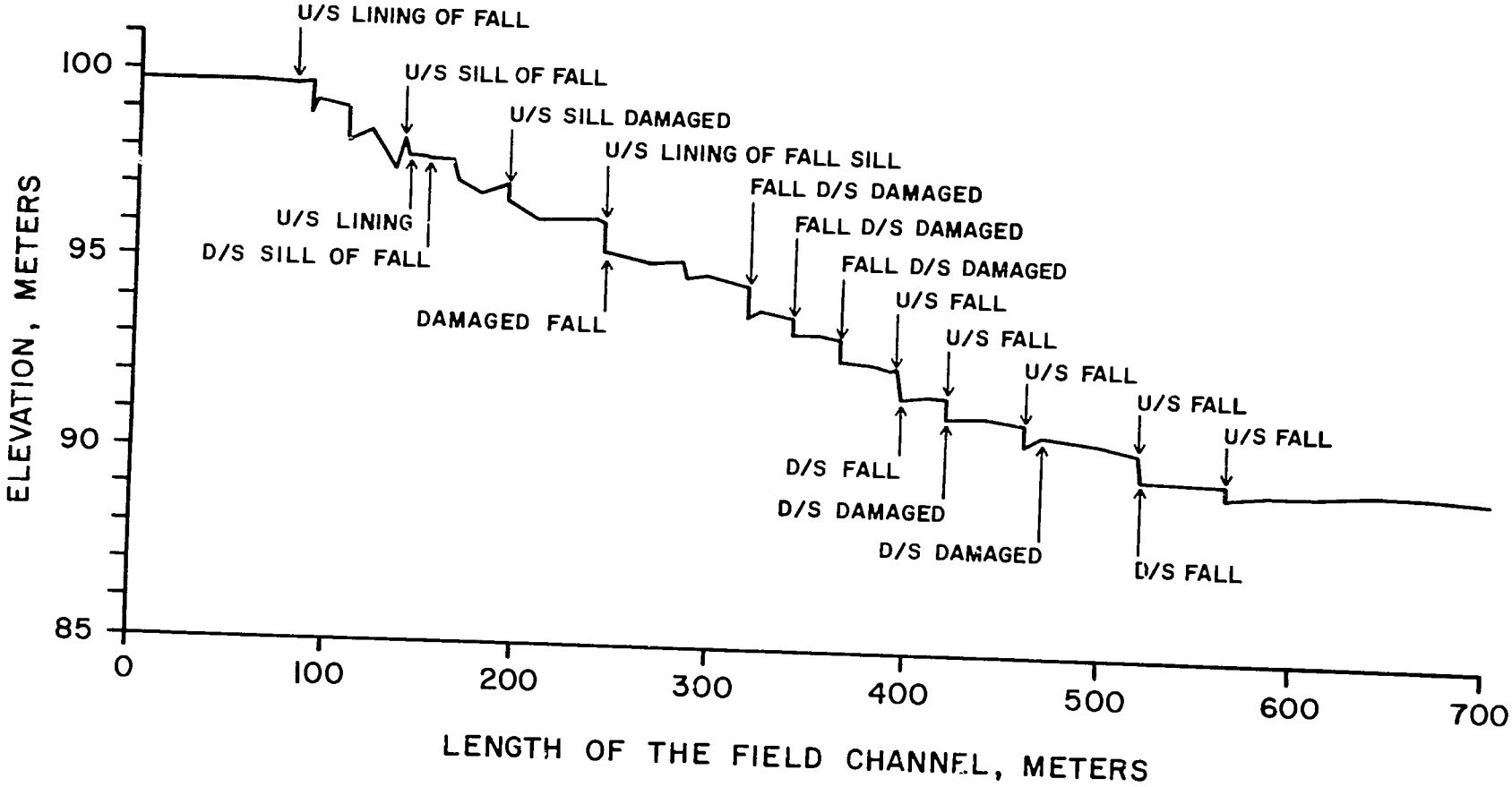


Figure B-10. Longitudinal Section of F-channel 3 of D-channel 2, Tract 4

Table B-7. Gradients of D-Channels and F-Channels

Tract 2

Location From (m)	Location To (m)	Length (m)	Difference in Elevation (m)	Gradient
D-Channel 1				
30	150	120	0.135	0.0011
180	510	330	0.64	0.0019
F-Channel 6				
30	90	60	0.01	0.0001
120	150	30	0.155	0.0052
D-Channel 2				
30	488	458	0.317	0.00069
518	590	72	0.04	0.00055
F-Channel 15				
30	67	37	0.295	0.0029
91	143	52	0.189	0.0036
143	235	92	0.152	0.0016
243	390	147	1.47	0.0093

Tract 4

Location From (m)	Location To (m)	Length (m)	Difference in Elevation (m)	Gradient
D-Channel 1				
0	543	54[illegible]	0.76	0.0013
F-Channel 1				
0	78.2	78.2	0.02	0.00025
90	108.9	18.9	0.21	0.011
120	139.5	19.5	0.195	0.01
141	194	53	0.695	0.013
210	247	37	0.06	0.0016
249	288	39	0.13	0.0033
290	323	33	0.275	0.0083
330	347	17	0.085	0.005
347	372	25	0.06	0.0024
372	403	31	0.105	0.0033
420	420	9	0.05	0.0055
450	470	20	0.125	0.00625
480	534	54	0.385	0.0071
536	582	46	0.17	0.0036
600	720	120	0.04	0.0003
D-Channel 2				
0	28.5	28.5	0.003	0.00012
50	80.0	30	0.155	0.0052
80	188	108	0.165	0.0015
F-Channel 3				
7	17	10	0.29	0.029
52	111	59	0.235	0.0039
148	179	31	0.26	0.0077
207	274	67	0.025	0.00037
276	307	33	0.215	0.0065

Tract 4

D-Channel 1	0.0013
F-Channel 1	0.01 to 0.00035
D-Channel 2	0.0052 to 0.00012
F-Channel 3	0.029 to 0.00037

Most of the channel section between adjacent structures was steep due to scouring. In some channel sections the sills of the drop structures were damaged to produce a higher flow. As a result, the channel bed was scoured and siltation occurred downstream. The change in bed gradient also could have been due to the relative settlement of the structures in the channel causing scouring and steepening of the bed. In several sections, the original design of the drop structures also might have lead to erosion of the bed and steepening of the bed gradient.

No measuring device was provided to measure the discharge from the right-bank main canal to the branch canal, except for one staff gauge erected downstream from this turnout where canal banks were eroded. The canal section followed a contour, with a few sections requiring deep cuts or double banking. The banks of the canal section in deep cuts were eroded and overgrown with weeds. Bank erosion was due mostly to cattle and human damage, when the channel was used as a source of bathing. The turnouts provided to the D-channels were concrete pipes of different diameters depending on the discharge required. These were controlled by wooden or cast iron gates mounted to slotted MS flats with a locking arrangement. Most of the turnouts leaked when the gates were closed. The crest of the channel spill causeway in the middle reach of the canal was raised by sandbagging to raise the water level. The concrete lined channel sections were in a poor state, and the maintenance of the channel and structures appeared to be inadequate.

D-channel 1 of Tract 2 was 510 meters long. The actual cross-section (Figure B-11) was entirely different from the design cross-section (Figure B-1) because of erosion. The canal bed had eroded extensively. The turnout from the branch canal was in good condition. Sixty percent of the turnouts to F-channels were in a poor state. There were two farm turnouts directly from the D-channel. These were ungated and issued water continuously. The turnouts to F-channels were damaged or scoured. The only drop structure available was scoured, and water bypassed the wing walls. The crest was broken and the downstream cushion damaged. The maintenance of the channel and the structures appeared to be very poor. The water issues were done by overloading the channel. There was no measuring device at the head of this channel, near the turnout. At the head reach, the banks were overgrown with weeds.

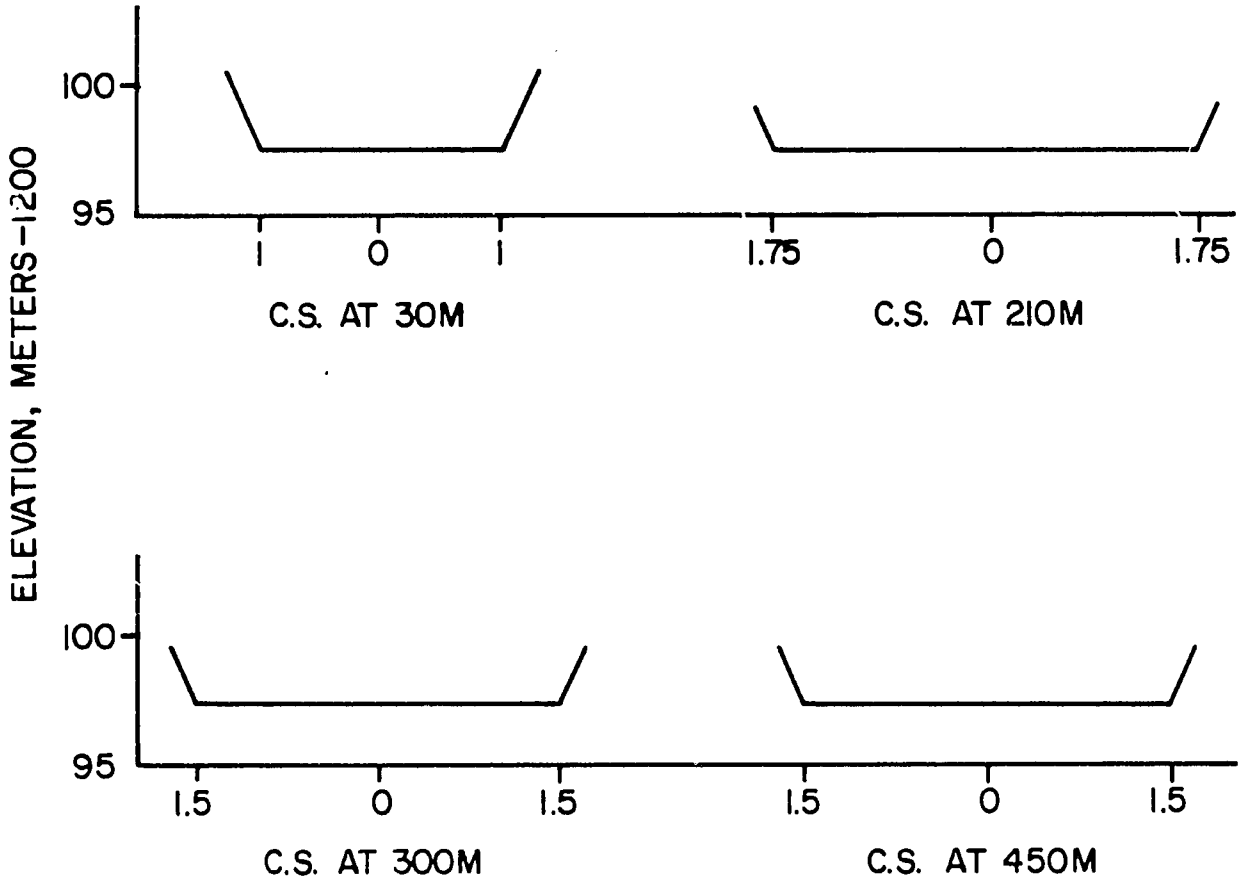


Figure B-11. Cross Sections of D-channel 1, Tract 2

The F-channels of D-channel 1, tract 2 were earthen channels, with heavy scouring. The earth filling near the structures had been scoured, and the water passed around the structures, which were damaged. The turnouts were concrete pipes (25-cm diameter) without gates. The maintenance of the F-channels done by the farmers appeared to be inadequate.

The length of D-channel 2, tract 2 was 609 meters, and ran on earth excavation at the head reach and, on filling, with double banking at the tail reach. The turnout structure to the D-channel was in good condition, with gates mounted on slotted handles and with a locking arrangement. The four turnouts to F-channels had damaged gates. The drop structures were eroded, and water passed around the structures. The downstream cushions of these structures were damaged. No check regulators controlled the water surface and issued water to the F-channels. The banks of these channels were vertical in most sections (Figure B-12), even though they were constructed according to the typical cross-section (Figure B-1). The failure of the downstream cushions of the structures was a very common problem. The channel was irregular in shape (cross-section) and overgrown at certain sections with weeds, indicating the inadequacy of maintenance.

The cross-sections of the F-channels were irregular. The turnout structures were damaged, silted, or scoured downstream. The drop structures were eroded, with water passing around the wing walls. Sills of the drop structures were lowered by the farmers. Some were steep, downstream cushions were damaged, and maintenance was very poor.

The flow from the branch canal to D-channel 1 of tract 4 was unregulated, due to the absence of a gate regulator. In this earthen channel, the head reach was in a deep cut and the tail reach cross-contour channel was in a cut and double banking. The banks of the deep cut section were vertical due to erosion. The concrete channel section in the initial reach was damaged. Maintenance done by the Irrigation Department was inadequate.

F-channel 1 of D-channel 1, tract 4 takes off from the turnout (30-cm diameter) with a wooden gate with a slotted, steel-strap, lifting device. There was a small leak through the closed gate. The downstream of this structure was scoured. There was no measuring device to measure the water issues. The first 600 meters of the channel formed a cross-contour canal, and most of the sections were eroded. There were 14 drop structures whose downstream cushions were damaged. The earth filling around the wing walls was washed off, and water passed around the structures. The rest of the section was in a ridge with little filling and crossed a drainage stream; a drainage under-crossing had not been provided. The bunds were in satisfactory condition. A portion of the channel did not function and had been abandoned. After 1,450 m, the channel was heavily overgrown with shrub jungle. This channel crossed two more drainage streams at 1,025 m and 1,450 m. The partially built

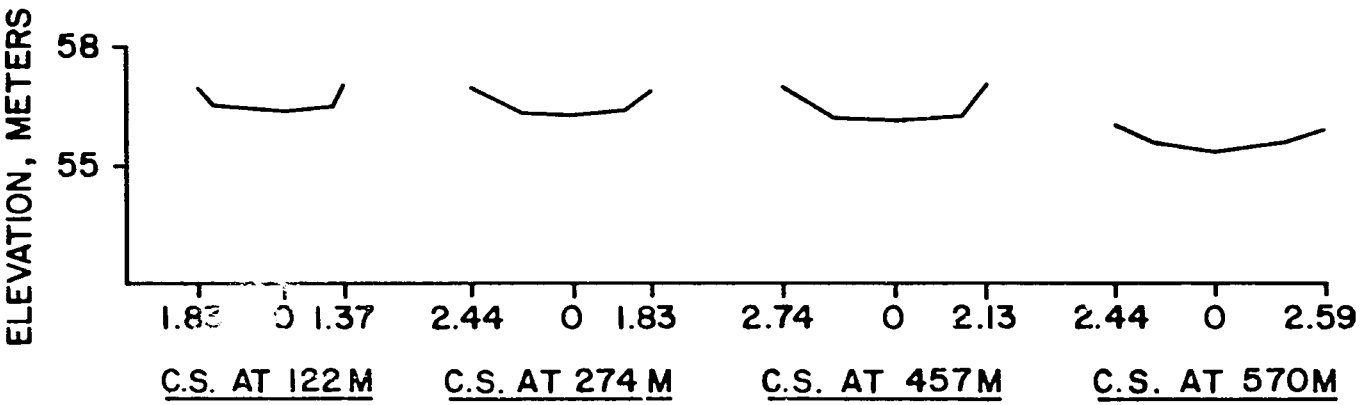


Figure B-12. Cross Sections of D-channel 2 under Branch Canal 1 of Tract 2

drainage crossing was at the former location that had been abandoned. Channel maintenance was inadequate and done by the farmers.

D-channel 2 of tract 4 was an earthen channel with gated turnout in good condition, with small leaks through the wooden gates. There were three ungated farm turnouts in good condition and flowing continuously. One of the available drop structures was in good condition, but this drop was high and caused erosion. Water passed around the wing wall at the right bank. There were leaks in this structure, and no gates to control water issues to F-channels 3 and 4. The turnout to F-channel 4 was completely damaged and blocked by sod.

F-channel 3 of D-channel 2, tract 4 was an earthen channel taking off from the end of D-channel 2, and passed along the ridge. The two available turnouts were in good condition. The farm turnouts were ungated and flowed continuously. The downstream cushions of the structures were damaged and scoured. The earth filling around the structures had been scoured and water passed around the wing walls. In some of the structures, the crest and the grooves for the planks had been damaged. Twenty-nine percent of the drop structures were in good condition. The maintenance of the channels was inadequate, with the banks and channel bottom of some sections scoured and silted at the lower reaches.

Much of the water that had been delivered from the sluice was lost in the process of conveyance. The past records available for the Rajangana Scheme show that the ex-sluice duty of water during Yala was about 2,400 mm per ha. Based on the assumption that the conveyance efficiency was 70 percent, the on-farm duty would have been 1,680 mm per ha. The actual measurements conducted just at the turnout gate to the F-channels indicated that the amount actually received, about 1,050 mm per ha (Table B-8), was far below the expected amount issued. From this figure, the conveyance efficiency became a mere 43 percent. To compute the actual conveyance efficiency, the following assumptions were made:

(1) The water applied during the time of measurement was representative of the other weekly rotational issues.

(2) Farmers use twice the amount planned in the original design for land preparation (the plan was only to deliver 72 ha-mm).

(3) The F-channel loss was 10 percent.

(4) The variety of paddy grown (3-1/2 month duration) required 12 weekly rotations.

(5) Effective rainfall was considered to be negligible.

Table B-8. The On-farm Duty of Water under Different F-channels

		Actual water delivered per irrigation at turnout (cm)	Actual water delivered at one irrigation at allotment (cm)	Water delivered for 12 nos. irrigations (cm)	Water for land preparation (cm)	Estimated depth of application for crop/season (cm)
Site 2	F-Channel 14	4.4	4.0	48.0	35	83
	F-Channel 15	14.5	13.1	157	35	192
	F-Channel 16	9.4	8.4	101	35	136
Site 3	F-Channel 1 allot. 29-35	6.1	5.4	65	35	100
	F-Channel 1 allot. 9-11, 22-28	8.0	7.2	86	35	121
Site 4	F-Channel 5	1.4	1.3	16	35	51
	F-Channel 6	2.2	2.0	24	35	59
Average, all sites		6.5	5.9	72	35	107

Average Ex-sluice duty for Yala season from the data available from Yala 1971 to Yala 1979 = 247 cm.

$$\text{Conveyance Efficiency} = \frac{\text{Water Delivered to Farm}}{\text{Water Delivered at Sluice}} \times 100$$

$$\text{Present Conveyance Efficiency at Rajangana} = \frac{107}{247} \times 100 = 43\%$$

3. Water Application System

The entire cultivable area has been leveled into basins of variable shapes and sizes. The basin sizes varied from the upper part of the slope to the lower part of the slope, in which the size of the basins in the upper area ranged from 150-200 m^2 and lower ones ranged from 200-400 m^2. These basins were rather well-leveled; levels within a basin often varied less than 3 cm. This range of unevenness could be considered to be within the permissible limits.

There was no on-farm distribution system within the allotments. Water entered the uppermost basin through a field turnout and flowed from basin to basin. The basins were flooded from the upper basin to lower basins. Farmers kept the outlets of the basins partially closed so as to have a depth of about 10 cm of water on the surface. Water spilled over to the adjacent basins when the required height was reached. The flow of water within the allotment worked almost as an automatic system in which the farmers did not have to stay in the field to divert water from basin to basin. The farmer had to be in the field only to turn in water and turn it off when all the basins were flooded.

The cumulative intake rate and infiltration for upper and middle slopes are shown in Figures B-13 to B-15. There was good agreement between the intake measured by the inflow-outflow method and the cylinder infiltrometer method. The water that needed to be applied was determined by pre-irrigation soil moisture data and corresponding contact time required to apply the moisture deficit of the soil. The upper and middle slopes had a higher infiltration rate of 30-40 mm/hr than the lower slopes. The infiltration rate in the bottom land appeared to be much lower than the upper area (the infiltration was not measured on the bottom area). The high infiltration rates in the soils of the upper area indicated that these soils were not suitable for lowland paddy cultivation.

The measurements conducted showed that the seepage and percolation on the upper part of the land was much higher than on the lower parts of the land. Table B-9 shows the measured data on seepage and percolation in the upper, mid, and lower slopes of the study sites.

The pattern of distribution of water in the four sites was quite different. In site 1, flow measurements were not taken, but the farmers on the upper section of the channel clearly diverted more water than the lower end farmers. The tail-end farmers retained standing water for a longer duration than to the head-end farmers of the F-channels. The head-end farmers maintained standing water during application and a day or two after water delivery. Therefore, these fields were also sufficiently wet throughout the week. Water delivery to D-channel 2 (except F-channel 16 of tract 2) was more than adequate. The average depth of application exceeded the designed depth of application (Table B-10). The delivery of water to allotments 144-150 and 158-159 that received water from F-channel 15 was nearly twice the designed quantity.

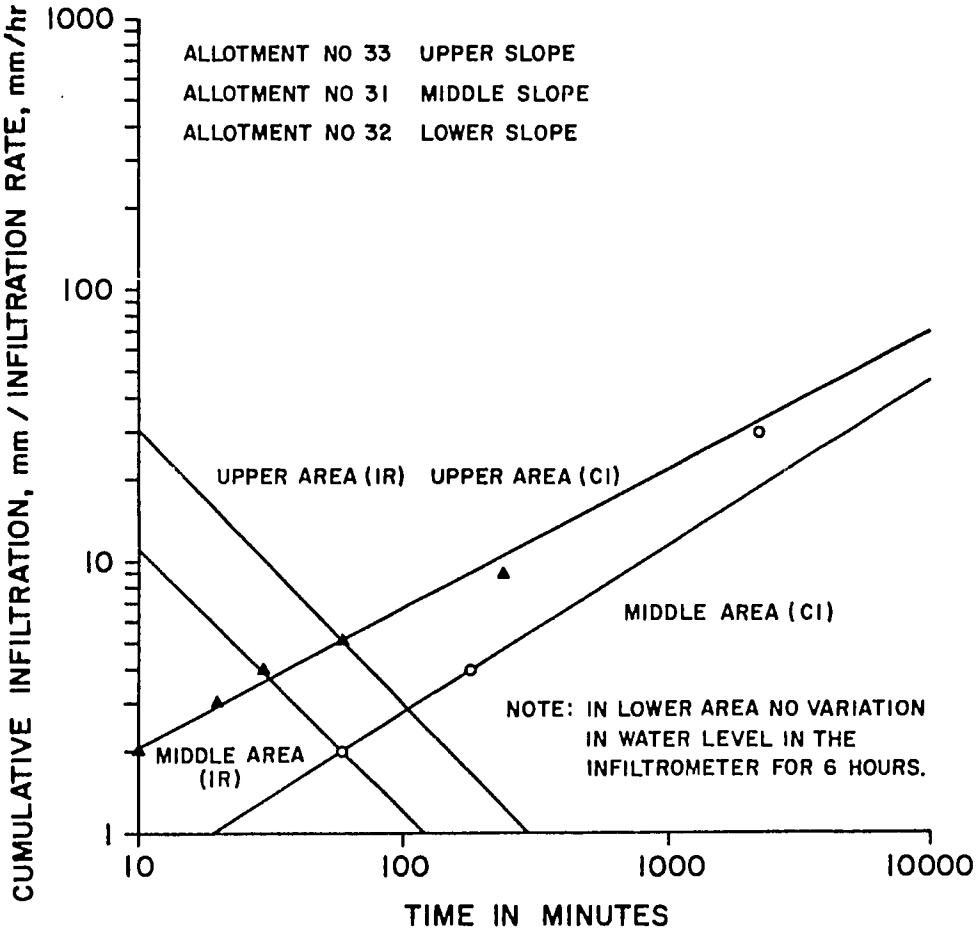


Figure B-13. Infiltration Characteristics of the Soils of Study 1 (Tract 2)

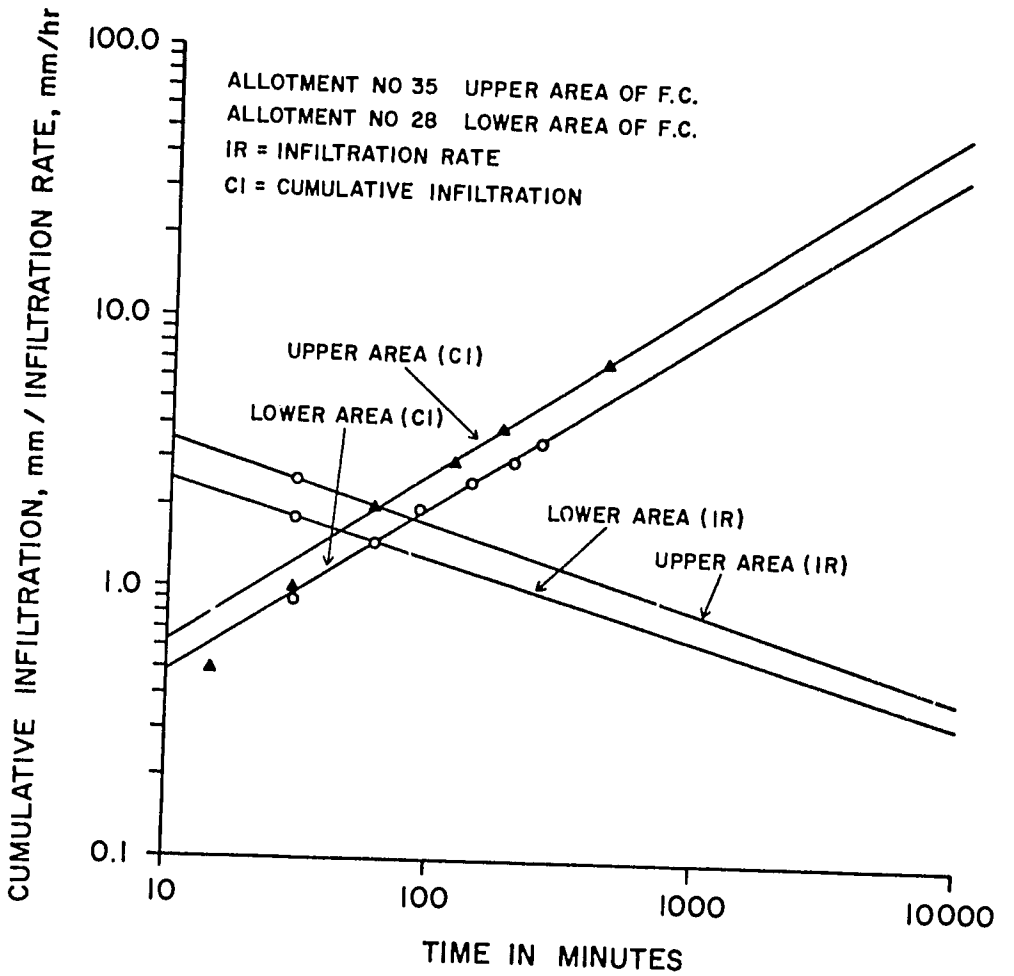


Figure B-14. Infiltration Characteristics of the Soils of the Study Site 3 (Tract 4)

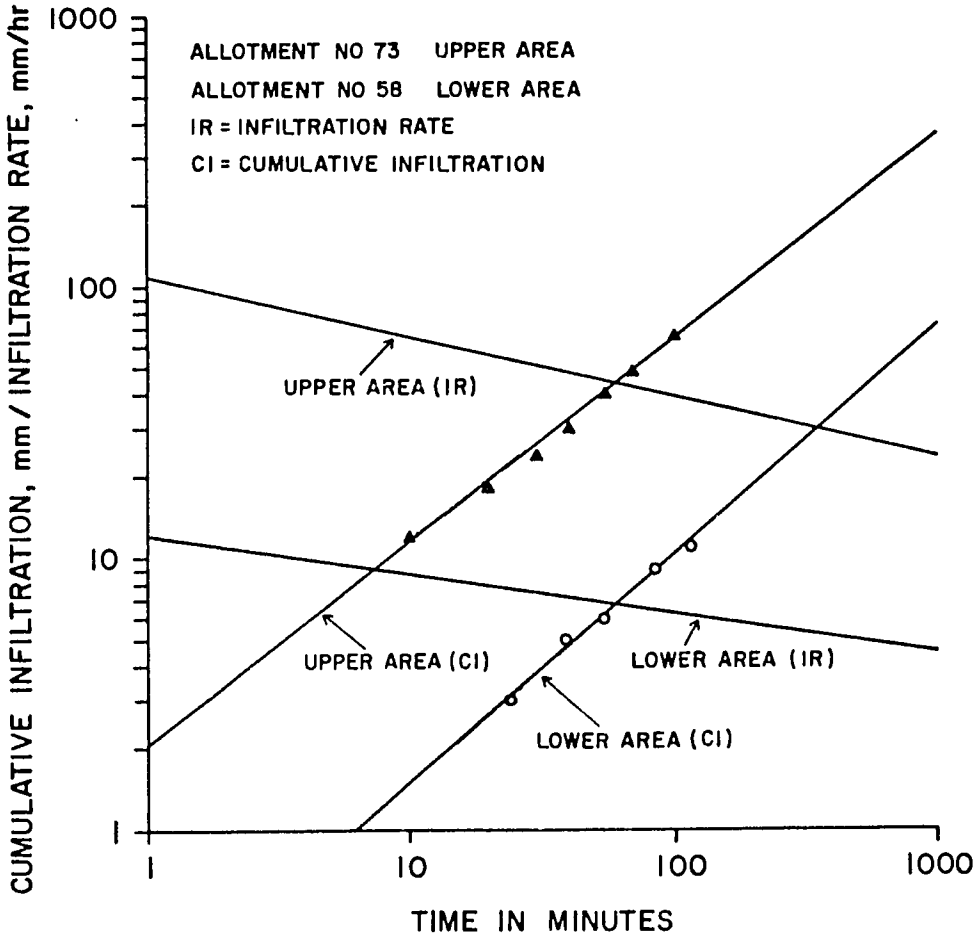


Figure B-15. Infiltration Characteristics of the Soils of the Study Site 4 (Tract 4)

Table B-9. Water Application Losses in Paddy Fields

Location		Average watertable from surface (cm)	Total water losses (mm/day)*	Seepage and percolation (mm/day)**
Site 1 Tract 2 D-Channel 1	Upper Area	30 - 35	15	25
	Mid Area	-	-	13
	Lower Area	0	1.5	0
Site 2 Tract 2 D-Channel 2	Upper Area	10 - 15	14	-
	Mid Area	-	-	-
	Lower Area	0	9.5	-
Site 3 Tract 4 D-Channel 1	Upper Area	2.5 - 6.5	58.0	24
	Mid Area	-	-	-
	Lower Area	0	32	17
Site 4 Tract 4 D-Channel 2	Upper Area	5 - 10	68	48
	Mid Area	5	27	-
	Lower Area	10	22	4

* Total water losses in paddy fields gives the balance of inflow and outflow through dikes and seepage and percolation.

**Seepage and percolation was measured using infiltrometers, and is the amount of subsidence of water depth per day.

Table B-10. Actual Application Efficiency of Irrigation

Site	Allotment Number	Flow Rate (lps)	Depth of Application (cm)	Application Efficiency (%)
F-channels 14, 15, and 16 of D-channel 3 Tract 2	145	3.6	11.55	59
	146	4.9	15.75	43
	147	4.4	14.10	48
	148	4.9	15.75	43
	150	4.7	15.0	45
	151	4.6	14.7	46
	157	4.6	14.7	46
	158	4.9	15.7	43
	159	4.2	13.5	50
F-channel 1 of D-channel 1, Tract 4	AL 1	3.01	6.42	100
	AL 3	3.21	6.85	99
	AL 34	2.88	6.10	100
	AL 33	3.89	8.30	81
	A 4	4.57	9.75	69
	A 32	3.21	6.85	99
	A 5	3.21	6.85	99

Designed Field Irrigation Requirement per week = 6.76 cm
Effective Rainfall assumed to be equal to zero.

$$\text{Application Efficiency} = \frac{\text{ET crop}}{\text{Water Applied on Farm}} \times 100.$$

The excessive water use was evident from the very high flow in the drainage channel. One interesting feature under F-channel 15 was that the amount of flow simultaneously delivered to each allotment was nearly 4.5 l/s and nearly equitable (Table B-10). This was achieved without any control structures in the channel, by just blocking the flow with stones, so as to raise the water level just to cover the turnout pipe outlet to the allotments. A farmer group leader took care of the water distribution and made sure that the F-channel was not excessively blocked. It is worth noting that such an equitable distribution was achieved in an eroded channel without any control structures.

The F-channels in site 3 received water for three days per week (Wednesday noon to Saturday noon). The amount of flow allocated to the turnout fluctuated between days and within each day. The tail-end section of the F-channel (allotments 16-21) did not receive water because the aqueduct planned had not been constructed at one point near allotment 22. Hence, farmers in this area blocked the drainage channel by constructing a small dam to divert water. These farmers appeared to be receiving an adequate supply through this method. However, cultivation was abandoned in allotments 12-15 due to the unavailability of water. The rest of the area under F-channel 1 of this site was irrigated in two rotations. Allotments 1-8 and 29-35 were irrigated on the first two days, and the rest of the bottom area up to allotment 22 was irrigated on the third day (Friday noon to Saturday noon). The water supply on the third day was higher than on the first or second day (about 75 l/s compared to 59 l/s on second day). It was not clear whether this had been the normal practice. Measurement of water to the upper section of the F-channel showed a fairly equitable distribution (Table B-10). As in site 2, the equitable distribution was achieved by partially blocking the channel.

F-channels 5 and 6 in site 4 were quite different from the F-channel system in the other study sites. These channels were contour channels. The F-channels (4, 5, and 6) were constructed more or less parallel to each other. This system enabled the drainage water from upper areas to flow into the F-channel located immediately below. F-channels 5 and 6 received a variable flow of 2.83 to 13 l/s and 2.83 to 16.43 l/s, respectively.

The flow delivered to the F-channel was highly inadequate to irrigate all the allotments. Perhaps during the three day period of water issue, only the head-end farmers received water. However, there was no sign of water stress shown in the paddy crop at the tail end. The soil moisture condition was at or near saturation, though the crop stand was poor and there was a higher weed population than in the head and middle sections of the F-channel. The prevailing high moisture

condition at the tail end, despite poor water supply, was probably due to available drainage flow from the upper area under F-channel 4 where there was a higher water supply. The general two-way slope in this area favored seepage flow and appeared to have facilitated reuse of water by the tail-end farms. The tail-end farms were in fact mainly dependent on seepage flow, as evidenced by the behavior of the water table (Table B-10). The water table rose in the tail-end area a few days after stopping the water delivery. Contrary to this, in the upper sections the water table rapidly declined immediately after irrigation. No significant drainage flow occurred from the area covered by F-channels 3 through 6 as a result of reuse of water on the lower slopes.

The water lost from a paddy field could be from seepage, percolation, and dike leakage. Of the losses that occur, seepage and percolation could be considered unavoidable losses that occur due to inherent land conditions such as soil texture, slope, and the groundwater table. However, a major portion of losses due to leakage is avoidable. Under field conditions it is rather difficult to measure the extent of losses by these three processes separately. An attempt was made to measure the seepage and percolation and the dike leakage separately.

Percolation is the water that flows vertically down into the soil, and seepage is the water that enters the soil and flows laterally. The bund leakage is the water that flows through the cracks, fissures, and crab holes.

The irrigation system appeared to have been designed for upland paddy under non-flooded conditions. In computating the field irrigation requirement, a 60 percent application efficiency was considered in the design. This suggests that the seepage and percolation losses would be 40 percent of the field irrigation requirement. This would amount to about 3 mm/day according to the above calculation. Previous research findings (Murakami, 1966) show that even on the bottom land (low humic gley soils), the seepage and percolation amounts to about 7 mm/day. This shows that the amount allowed for losses (3 mm) was not adequate to meet a standing water condition. If the design were to have flooded lowland paddy, it would be necessary to provide water for seepage and percolation, evapotranspiration, and the standing water requirement in the paddy plots. Seepage and percolation was considered a component in field losses only in upland paddy cultivation.

The total loss of water from the basins under flooded conditions was studied by measuring the subsidence of the water level in a few basins where there was no inflow or outflow through the regular inlets and outlets. The flow of water through dike leakages was considered unavoidable. An attempt was made to select only fields which did not have an appreciable and visible flow of dike leakage.

Seepage and percolation were measured separately by installing infiltrometer rings of about 15 cm deep, after flooding the field. The depth of subsidence in water level was measured at predetermined intervals. The total loss of water from the basins and the seepage and percolation losses expressed in mm/day are given in Table B-9. Except in site 1, the subsidence of the water level in the infiltrometer was lower than the subsidence of the field water level. The difference could be attributed partly to the dike leakage and to the difference of inflow and outflow through seepage and dike leakage in and out of the basin. The lower subsidence of water level in site 1 may be due more to high inflow of dike leakage than to outflow of dike leakage. The average depth lost as seepage and percolation was about 22 mm/day in the upper areas of two head reach sites and in site 3 of the tail reach site of the branch channel. Site 4 of the tail reach, showed a seepage and percolation rate of 48 mm/day, which could be considered to be excessively high. The seepage and percolation rate on the lower reaches of the F-channel varied from 0 to 17 mm/day. In the lower area of site 1, the water level dropped only 5 mm in one day, which is even less than the potential evaporation that would occur during this period. This indicates that the piezometric head in the area could even be positive, with no downward movement of water. This condition does not appear to occur in all the lower areas of this site. A situation of this nature could lead to poor drainage and transportation of salts from the subsurface to the surface. Unless sufficient drainage is provided to wash out the surface accumulation of salts, the condition could be a threat to the sustained productivity of the land.

In the upper reaches of the land, water disappeared within a day or two after stopping the water issues. The normal depth of water flooding amounted to about 75-100 mm. If water loss occurs through seepage and percolation alone, water will have to stay on the surface for nearly 2 to 3 days in the upper areas. This shows that the reason for sudden disappearance of the water level was not only due to high percolation rates, but also due to a high amount of dike leakage. The main cause for dike leakage was the poor maintenance of bunds that separate the basins. Some of the basins had a low storage capacity due to the low height of the bunds.

These loss rates and the observed poor condition of the bunds in the basins show that the duration of standing water in the upper areas could be increased by 2 more days just by improving the condition of the bunds to prevent dike leakage.

The field study conducted only shows the indications of high dike leakages in the upper areas. To quantify the avoidable leakage, a further detailed study will have to be conducted.

In general, flooded paddy cultivation in the upper area is not possible without excessive use of water, due to high percolation losses. The field irrigation requirement calculated in the original design criteria appeared to have been based on provision of irrigation water

intermittently only to meet the crop ET requirement at an application efficiency of 60 percent. To maintain standing water on the upper slopes, the amount of water required for seepage and percolation will have to be provided in addition to that needed by the crops. As the farmers on the upper areas tried to maintain standing water, the application efficiency was much lower than the designed application efficiency of 60 percent. The actual application efficiency ranged from 43 to 59 percent and 69 to 100 percent in the upper and tail reaches of the branch canal, respectively (Table B-10).

4. Summary and Conclusions

The Rajangana canal system is very old and deteriorated. Original designs did not include regulators in the primary and secondary canals to maintain the water surface at the designed elevation when variation occurs in the designed discharge. Though such elevations were necessary for the proper functioning of the turnouts, the regulators have been provided on an arbitrary basis without proper design consideration.

The banks of the channels were vertical and irregular in shape due to erosion. Considerable damage to the channels has been done by cattle and humans, who are using the channel as a source for bathing. The gates of the turnouts in all canals were either deteriorated or absent. Heavy leaks were observed, even with the gates present, at the grooves of the structures.

The bed gradients of D- and F-channels have deviated from the design gradient. The settlement of one or both structures or the lowering of the sill of one structure caused erosion or siltation of the channel bed. Siltation in the channel bed can occur if the structures are constructed slightly above the design sill level. The channels with steep bed gradients had high flow velocity causing more erosion, while silted channel beds with nearly flat gradients had low velocities causing more siltation.

The water issues to the D- and F-channels were made purely on an estimation basis through experience, and were not based on accurate measurements.

The farmers were unaware of the exact dates of the rotational issue, and there was no uniformity in their response regarding the days set apart for rotation. This reveals that significant information relating to water issues was not properly communicated to the farmers, which in turn indicated that management had no close dialogue with the farmers.

Institutional arrangements among the farmers were conspicuously absent, except in F-channel 1 of tract 4 where the farmers on their own had formed an informal group to share the water within the turnout.

No proper rotation was practiced at the F-channel level. A proper rotation could improve, the water supply to F-channels 4 and 5 together and F-channel 7 under D-channel 1; F-channel 16 of D-channel 2, tract 2; and F-channels 5 and 6 of D-channel 2, tract 4.

The F-channel operations were handled by the turnout operator, who was very enthusiastic about the water distribution and popular among the farmers in tract 4. The farmers were very cooperative with him, as he diverted water to the farms, without creating any problems with the farmers, even when the supply was insufficient.

The discharge in D-channel 2 in tract 4 was insufficient for the area under this channel. There were no signs of water stress visible when the farms were observed. In most of the channels (e.g., F-channel 1 and F-channels 5 and 6), drainage water was used by the farmers for irrigation.

The on-farm water losses occurred mainly due to dike leakage. This condition prevailed due to the extremely poor condition of the dikes separating the basins. These bunds were often narrow and low. There were numerous crab holes through which water escaped into the adjacent basins. As this happened from basin to basin, the leaked water ultimately found its way into the drainage channel.

The amount of seepage and percolation was high in the upper parts of the slope and relatively low in the lower parts of the slope. It was not possible to maintain standing water in the upper slopes under a rotational system. Cultivation of lowland paddy in the upper slopes must be discouraged. It may be worth studying how much of the deep percolation loss in the upper areas is reused in the lower area and what effects this has on the fertility of the soils of the lower area.

The following constraints were observed in the Rajangana irrigation project:

(1) The deficiency of the existing structures and inadequate control structures. The existing regulators were provided on an arbitrary basis without any design consideration.

(2) Unavailability of measuring devices at the heads of D- and F-channels.

(3) Inadequate maintenance of the canals/channels.

(4) No farmer organization within the turnout area to share water equitably, and implement <u>kanna</u> meeting decisions.

(5) The farmers' lack of awareness about the dates of rotation.

C. Economics

1. Inputs and Production Practices

a. Land Preparation

Land preparation is the most expensive single operation in paddy cultivation. In major irrigation schemes timely land preparations is crucial from a water management point of view. Major irrigation schemes are planned to issue water continuously for two weeks for land preparation. Thereafter, a rotation schedule is maintained. The inability to prepare the land in time has often led to extension of water issues for land preparation. Delayed land preparation may result from shortage of draft power and lack of capital for hiring tractors or animals.

Table C-1. Use of Tractors and Draft Animals in Land Preparation

	Percent of Farmers Using Tillage Practices					
Season	4-Wheel Tractor	2-Wheel Tractor	Animal Power	4-Wheel & Animal	2-Wheel & Animal	Manual
Maha 81/82	16	2	45	7	28	2
Yala 82	15	7	43	12	21	2

In Maha, 45 percent and in Yala, 43 percent of the farmers relied entirely on draft power for tillage. The percentage of farmers using 2-wheel tractors and animals was 28 percent and 21 percent in Maha and Yala, respectively. About 2 percent did their land preparation entirely manually in both seasons.

The cost of ploughing 0.4/ha (1 acre) of land by 4-wheel or 2-wheel tractor ranged from Rs 425 to 640. Puddling and leveling required another Rs 150 to 180 per 0.4 ha. Land preparation with draft animals cost Rs 440 per 0.4 ha on the average.

b. Seed

New improved high-yielding rice varieties bred at Central Rice Breeding Station at Batalogod, Sri Lanka, were cultivated on all farms

surveyed. Short-aged rice varieties were cultivated by 72 percent of the farmers in Maha and by all farmers in Yala.

In Maha, 53 percent of the farmers used their own seed, 35 percent obtained seed from the Department of Agriculture, and the balance obtained the seed from private traders. In Yala, 65 percent of the farmers used their own seed, 25 percent obtained seed from the Department of Agriculture, and the remaining 10 percent purchased seed from private dealers.

c. Seeding/Transplanting

About 12 percent of the farmers surveyed had transplanted paddy in the Maha 1981/82 season, and the rest of the farmers had broadcasted. In Yala, an even smaller number of farmers (7 percent) transplanted paddy. All were transplanted at random. Transplanting is, however, the recommended crop establishment method for paddy.

d. Fertilizer Application

Table C-2 gives the actual usage of fertilizer by sample farmers and recommended dosage for paddy cultivation.

Table C-2. Recommended and Actual Application of Fertilizer Per Hectare

	Recommended Quantity (Kg)	Quantity Applied in Kg			
		Whole Area	H	M	T
Basal					
Maha Paddy	166	101	109	92	101
Yala Paddy	166	97	95	116	80
Top Dressings*					
Maha Paddy	220	231	205	263	234
Yala Paddy	220	234	204	273	229

*Long-aged rice varieties require 275 Kg/ha of top dressings.

On the average, sample farmers applied 60 percent of the recommended dosage of basal fertilizer. The quantity applied in Yala was slightly less. In Maha and Yala seasons, about 105 percent of the recommended dosage of top dressing was applied. There appears to be no

difference in the application of both types of fertilizer in the two seasons. The quantity of fertilizer applied in terms of total recommended weight was 86 percent. Timely application of fertilizer and its relation to the supply of fertilizer needs to be studied. Thirty-four percent of the farmers perceived fertilizer availability to be a problem.

e. Agrochemicals

Table C-3 presents expenditures incurred for the application of weedicides and pesticides by the sample farmers.

Table C-3. Average Investment in Agrochemicals (Rs/ha)

Agrochemicals	Whole Area	H	M	T
Weedicides				
Maha Paddy	371	4001	419	288
Yala Paddy	423	437	491	342
Pesticides				
Maha Paddy	129	135	131	125
Yala Paddy	90	86	100	120

There appeared to be an increase in the use of weedicides in Yala. Low availability of water prevented the maintenance of standing water in the fields at length in Yala, which increased weed infestation. It is not known whether the added application of weedicides was sufficient to reach the same level of weed control achieved in Maha with more water.

The available data indicate a lower use of weedicides in both seasons in the tail reaches. This may be because farms located at the tail reaches of the canal had standing water more often than head or middle reaches, due to the sloping feature of the topography and associated seepage.

Use of pesticides was lower in the Yala than in Maha. In Maha investments in pesticides per ha cost Rs 129, while in Yala they decreased to Rs 90.

f. Credit

Fifty percent of Rajangana farmers considered credit to be a problem in paddy cultivation, with 32 percent of them indicating the availability of credit as their number one problem. Twenty-eight percent of sampled farmers had obtained credit for Maha, and 18 percent in Yala from institutional sources. Borrowing from the private sources was limited to 7 percent of farmers in Maha and 1 percent of farmers in Yala seasons.

For the farmers that obtained credit in Maha from institutional sources, the average amount was Rs 3,048 per ha. The range of credit obtained was from Rs 1,783 to 3,567 per ha. Fifty-eight percent of the farmers who obtained institutional credit repaid the full amount, 16 percent made a partial payment, and the remaining 26 percent defaulted. Seventy-five percent of those who obtained credit from private sources repaid. Others did not or could not repay in time and are in default.

Institutional sources (banks) gave cultivation loans at 9 percent interest per annums. The rates of interest reported to be charged by private money lenders ranged from 12 to 66 percent.

Generally, farmers were hesitant to volunteer information on sources of noninstitutional credit due to the fear that their information might eventually lead to the closure of these credit sources. Those who obtained credit from informal sources did so at very high interest rates; these people were not eligible to obtain bank loans due to nonrepayment of earlier loans. The survey data suggest that this situation may worsen due to continuing high defaulting rates, as observed in Maha 1981/82.

2. Cropping Pattern and Intensity

The major crop in both seasons for which data was collected (Maha 81/82 and Yala 82) was paddy. In Maha, 92 percent and in Yala, 87 percent of the cultivable land area was cropped. Table C-4 indicates the cropping pattern as a whole, by each study site (D-channel area) and by head, middle, and tail reaches when all study sites are considered together.

Except for tract 4 in D-channel 1, where the cropped area in both seasons was the same, the actual area cultivated was lower in Yala than in Maha. Classification by head, middle, and tail reaches showed the same seasonal trend.

As an average for all study sites, the percentage of area cultivated in Maha decreased towards the tail. However, in Yala the percent of area cultivated by the farms located in the middle of the canal was somewhat lower than that of the tail-end farms.

Table C-4. Cropping Pattern and Intensity (%) by Location

Crop	All Four D-channels	Tract 2 D1	Tract 2 D2	Tract 4 D1	Tract 4 D2	H	M	T
Maha Paddy	92	93	100	75	100	97	89	88
Yala Paddy	87	89	87	75	96	94	81	84
Cropping Intensity	179	182	187	150	196	191	170	172

3. Rice Output and Disposition

Cropping systems studies conducted in farmers fields in Bulnewa of Mahaweli H_1 area (block 304) found that popular rice varieties grown in Rajangana yielded between 5,165 and 6,817 kg/ha at a medium level of fertilizer use. Rajangana falls within the System H boundary and covers H_{11} and H_{12} areas. The above range of yields indicates the potential output that can be achieveed by farmers.

The average yield of paddy for the entire study area in Maha was 3,925 kg/ha. The expected yield for Yala was 3,305 kg/ha. Table C-5 gives a detailed breakdown of average yields of paddy by study site and by head, middle, and tail reaches of all the sites put together.

Table C-5. Average Yield of Paddy in Rajangana (kg/ha)

Crop	All Four Study Sites	Tract 2 D1	Tract 2 D2	Tract 4 D1	Tract 4 D2	H	M	T
Paddy Maha 81/82	3925	4648	3770	3822	3254	4183	3564	3822
Paddy Yala 82	3305	3460	2841	2479	2995	3254	2324	3202

The expected yield for Yala in the four sites together as well as in all categories was lower than the actual yield for Maha. No definite trend in the yield variation among study sites can be identified. However, when head, middle, and tail reaches of the four study sites were compared, head reaches got the highest yield and the

middle reaches got the lowest yield in both seasons. A corresponding decrease in the input of fertilizer was not seen. On the contrary, the average input of fertilizer appeared to be higher in the middle than the head or the tail. The cropping intensity for farms in the middle reaches of the D-channel was also lower than for farms in the head and tail reaches.

The low yield and cropping intensity in the middle, rather than at the head or the tail, cannot be explained by the traditional "tail-end" explanation. Going back to the individual study sites reveals a feasible reason for this puzzling trend.

In study site number 3 (F-channel 1 of tract 4), the F-channel cannot irrigate its entire command area due to an incomplete structure. The last three farms (numbers 12, 13, 14) do not receive any water. Other farms in the tail of the area presently under cultivation get water by tapping a drainage canal. One or two farms in the middle cannot get much water from the drainage canal either. Farm allotments 23 and 25 had only 0.4 ha of cultivation in both Maha and Yala.

On the average, sampled farmers marketed 63 percent of their total product. Ninty-three percent of the farmers sold their paddy to the private traders. They received an average price of Rs 2.98 per kg. Government purchase price was Rs 2.75 per kg. Very few Rajangana farmers (7 percent) considered paddy marketing to be a problem.

The amount retained for consumption on the average was about 1,000 kg per farm. This is sufficient to feed a five member farm family for one year.

4. Profitability

Given the average yield of 3,925 kg/ha in Maha, 3,305 kg/ha in Yala, and the average market price of Rs 2.98 per kg, the gross income was Rs 11,696 per ha in Maha and Rs 9,850 in Yala. Production expenses incurred per ha were nearly the same for both seasons. Return above cash expenses was Rs 7,070 and Rs 5,121 per ha for Maha and Yala seasons, respectively (Table C-6).

The total income is an important indicator of the households well-being. The income received in cash or in kind by the farm family from paddy cultivation in the irrigated allotment for 1981/82 crop year was Rs 8,760. Rajangana farmers also obtain a certain amount of income from vegetables and fruits produced in their homestead allotments and from livestock. Part of the overall income is invested in means of production so that the income available for use by the farm household is often less.

A general idea of the standard of living of Rajangana farmers may be formed by looking at the government-recognized level of poverty. The Sri Lanka government issues food stamps for families with an annual

income of less than Rs 3,600. On the average, the income of Rajangana farmers is far above this level. However, the large variation in yield between farms in this area and deficiencies in irrigation system and production practices indicates a considerable opportunity for increasing output and income of Rajangana farmers.

Table C-6. Costs and Returns Per Ha of Maha and Yala Paddy

Costs and Returns	Maha 1981/82	Yala 1982
INCOME		
Rice Grain (kg)	3,925.00	3,305.00
Average price per kg	2.98	2.98
Gross Income	11,696.00	9,849.82
EXPENSES		
Seed	225.12	309.19
Fertilizer	358.05	364.20
Herbicides	371.17	423.11
Pesticides	129.08	90.00
Tractor and animal hire charges	1,209.98	1,209.98
Hired Labor	2,332.34	2,332.35
Total Cash Expenses	4,625.74	4,728.84
Return Above Cash Costs	7,070.26	5,120.98

D. Sociology

To understand the operation of an irrigation system from a sociology/extension perspective, it is useful to view the system as an organizational entity in which actors interact with each other to perform a set of predetermined activities. The behavior patterns of the various actors are the building blocks of the organizational entity that is the irrigation system. It is these patterns that determine the outcome of the activities that are expected to be accomplished in an irrigation system. The discipline of sociology/extension thus attempts to identify and understand the factors which affect irrigation behavior in an effort to find out how such factors could be channeled effectively to ensure an effective irrigation system.

1. Sociology Profile of Study Area and an Assessment of Socio-Cultural Factors

The study area belongs to a medium-sized irrigated settlement scheme in Sri Lanka. The scheme is situated about 25 miles west of the ancient capital of Anuradhapura and provides irrigation to about 6,882 ha under gravity (5,344 ha) and lift irrigation (1,538 ha). Beginning in 1964, farmer-settlers from the densely populated wet zone districts were allotted land in this area. The construction of headworks commenced in 1962 and was completed in 1965. Downstream development was spread over a number of years.

The Rajangana Scheme was settled with about 6,200 farm families. Each family was given 0.8 ha of paddy land, 0.2 ha of homestead and 0.6 ha of highland. The main criteria used for settler selection at the time of land allotment were that allottees: (a) should possess no land, (b) be from the wet zone districts, and (c) have large families. However, there have been exceptions to this rule in a minority of cases due to external factors. In addition, some land was also given to children of farmers who had settled in adjoining schemes much earlier. Today, the ratio of selectees who came from outside the area to the second-generation of early migrants is 8:1.

The first settlers were brought to the area in 1964 while the irrigation works were still under construction. These early settlers were given about Rs 30 per month and the required agricultural implements to prepare their land, although irrigation water was not yet available. The lack of water resulted in a number of settlers abandoning their land and returning to their villages. According to a Patrol Laborer in tract 4, 26 out of 35 paddy allotments along one F-channel in tract 4 were then operated by people who reoccupied the land after the original settlers abandoned them. Most of these new settlers had been either relatives of original settlers who stayed or migrants who had come to the dry zone earlier. Table D-1 shows the present breakdown of the sample farmers by the above criterion.

Table D-1. Distribution of farmers by allottee criterion (N = 44)

Criterion	No.	%
1. Original Allottee	27	(61)
2. Nonoriginal Allottee	16	(36)
3. No Response	1	(3)

This settler pattern has given rise to a particular social categorization in the study area. Those farmers who reoccupied abandoned land are today identified as "encroachers". There appears to be a certain degree of social distance between the encroachers and original allottees. It was not until 1972, that the state took action to regularize the allotment of land to encroachers, perhaps further accentuating the differences between the two groups.

In the Rajangana study location we located a few power centers, when we attempted to identify key informants. Since the settlement scheme is now over 15 years old, distinct social networks as well as local power elites have emerged, although the process is continually in flux. Two methods were used to identify key informants. First, we automatically accepted as key informants the two farmer representatives selected by the farmers under the Agrarian Services Law to assist the Cultivation Officer (a government officer). Second, farmers were asked to identify local leaders or influential farmers who possessed additional information on the system. With the two farmer representatives, the key informants numbered seven.

2. Tenurial Aspects

Although the de jure position is that land given under settlement schemes to farmers cannot be leased or sold, the de facto position in Rajangana, as in the Mahaweli area, is that allotments have been given out under various tenurial arrangements. The dominant tenurial arrangement under which paddy lands is given out in Rajangana is ande, or sharecropping. The owner gets one third of the harvest as his share. He does not provide any cash or material inputs. In a minority of cases, the owner is paid a fixed amount, i.e. 1,265 - 1,518 kg of paddy per hectare. Leasing out is also practiced with the owner being paid Rs 1,235 - 1,852 per hectare per season, the exact amount depending on the fertility and the situation of the land.

The Patrol Laborer in tract 4 provided the tenurial statistics for the two study locations in his tract. At these two sites, 32 per-

cent of the 65 allotments are under a sharecropping system. We were unable to obtain any accurate tenurial statistics for study locations in tract 2. The very fact that giving out colony allotments under any form of tenurial arrangement is illegal makes it an extremely sensitive area of inquiry. However, we might get a basic idea of the changes in operational sizes by the responses given by farmers to the question "how many acres do you operate in this scheme?"

The data in Table D-2 demonstrate that consolidation of operational holding sizes has taken place in the study area. It is significant to note that only 28 percent of the sample farmers who responded are operating 0.8 ha of paddy - the legal holding size. Twenty-eight percent of the farmers operate a lesser area while 44 percent operate an increased acreage. The seven key informants had a similar pattern of operational landholding sizes, with a mean size of 1.9 ha and a range of 0 to 5.7 ha. Another safe assumption that could be made from the above data is that land deprivation and consolidation for the most part has occurred within the settler community itself.

Table D-2. Distribution of Farmers by Operational Holding Sizes (Paddy) in the Rajangana Scheme

Operational Holding Size (hectares)	Percent of Farmers Reporting (n=40)	
	No.	(%)
0	2	(6)
0.4-0.7	7	(22)
0.8	9	(28)
0.9-2.0	14	(44)
No response	8	

Some of the possible causes for giving out land are:

(1) Availability of casual, skilled and unskilled labor in the Mahaweli Project.

(2) Spatial and economic difficulties: At the planning stage of the project, the government gave the farmers not only paddy and homestead land, but also highland for the cultivation of field crops using lift irrigation and rainfed watering. Most farmers in tracts 2 and 4, however, were unable to cultivate their highlands due to the long distances between homestead land and highland. According to the farmers, the distances ranged from 2 to 6 miles.

Therefore, the farmers were unable to derive the expected income planned for them.

(3) Some land consolidation may have occurred during the initial stages of the project (although currently operating under the disguise of tenancy) when some influential farmers in the area used nominee allottees to acquire more than one allotment. The chaotic situation arising out of large numbers of original settlers abandoning their allotments may have facilitated this process.

There is evidence to suggest that sharecropping arrangements and consolidation of lands have more or less become stabilized. For example, the tenant who cultivates a key informant's fields (2.4 ha) has been doing it for the last two seasons and hopes to continue at least for the next two seasons. Another key informant has been cultivating four allotments including his legal allotment through hired labor for a considerable period of time. This stabilization process provides the lessee or the tenant farmer with a long-term stake in the land.

3. Water Problems and Water Control Situation

In irrigated agriculture, the key production resource around which the whole cultivation cycle revolves is water. Farmer decision making about which crops to grow, when to grow, whether and when to fertilize, when to apply agro-chemicals and when and how to irrigate a particular crop is largely dependent on the availability of water; more accurately on the reliability, predictability and adequacy of water supply at the farm level. Hence, the water control available to the management personnel and the farmer is a major determinant of irrigation behavior.

The sample farmers in the study location identified water as the most serious problem in relation to other inputs for paddy cultivation. Sixty-nine percent identified water as the biggest constraint to increased production, while credit (50 percent) and availability of fertilizer (30 percent) were quoted as the other important problems. In analyzing data on the water problem situation it is appropriate to take a spatial view of the system. Hence, all observations on the four study areas in tracts 2 and 4 were categorized into head, middle and tail turnouts, depending on the spatial location of farm allotments on the field channels. The perceived water problems for paddy by head, middle, tail categorization is given below in Table D-3.

Table D-3. Distribution of Head, Middle, and Tail Sample Farms by Perceived Water Problem and Its Magnitude

Location and Number of Farms	Reporting Water Problem		Percent Ranking Water Problem as Most Important	
	No.	(%)	No.	(%)
Head (15)	5	(33)	3	(60)
Middle (14)	7	(50)	4	(57)
Tail (15)	10	(67)	7	(70)

There seems to be a tendency for water problems to increase as one moves down from head to tail.

In another question we asked about the specific water problems they face in Maha and Yala seasons. Their responses are reproduced in Table D-4.

Table D-4. Distribution of Head, Middle, and Tail Farms by Specific Water Problems Reported by Farmers for Paddy Cultivation in Maha and Yala

Specific Problem	Maha			Yala		
	H No.(%) (n=14)	M No.(%) (n=14)	T No.(%) (n=15)	H No.(%) (n=14)	M No.(%) (n=14)	T No.(%) (n=15)
Too much water	1 (7)	- -	1 (7)	- (7)	- -	1 (7)
Inadequate water	1 (7)	5 (36)	2 (13)	7 (50)	7 (50)	9 (60)
Unreliable water	- -	- -	3 (20)	2 (14)	2 (14)	6 (40)
No water	- -	1 (7)	- -	- -	1 (7)	- -

With respect to specific water problems, there is no consistent pattern, although there seem to be more problems toward the tail. There does not appear to be great disparities between the head, middle and tail regarding inadequacy of water. Indeed, in Maha there is greater inadequacy in the middle fields. Also, it is significant that one farmer from the middle had reported land of water for both Maha and Yala, while no farmer in the tail had such a problem. It is in respect to reliability that the tail farmers differ somewhat from the head and the middle.

A cross tabulation of water problem data was also made by specific study area. These data are reproduced in Table D-5.

Table D-5. Farmers' Perceptions of Water Problems by Study Area

	Percent of Farmers Responding			
	Tract 2 (head)		Tract 4 (tail)	
Water Problem	D-Channel 1 (n=10)	D-Channel 2 (n=12)	D-Channel 1 (n=11)	D-Channel 2 (n=10)
1. Have water problem?	90	75	55	60
2. Too much water				
Maha	10	8	0	0
Yala	0	17	0	0
3. Inadequate water				
Maha	20	33	18	0
Yala	70	50	46	50
4. Unreliable water				
Maha	10	8	0	10
Yala	50	8	0	20
5. No water				
Maha	0	0	9	0
Yala	0	0	9	0

The above data show that water problems seem to become less severe toward the tail of the system, i.e., there are fewer water problems in tract 4 than in tract 2. This trend is similar both in respect to overall water problems as well as to reported specific water problems. For example, both inadequacy and unreliability of water supplies in Maha and Yala seems to improve as one moves from the head through the middle to the tail.

This gives rise to an assumption (although untested and unproved in this study and which clearly warrants further study to understand farmer irrigation systems better) that the popular stereotype categorization of irrigation behavior based on spatial criteria of head, middle, and tail farms may not be a universally applicable concept. In this study, we are unable either to prove or disapprove this assumption. However, we could submit for discussion some possible causes for this phenomenon. We feel that unlike Mahaweli System H, the study locations in Rajangana have certain physical as well as engineering features which set them apart from each other. Due to the peculiar topography, the field channels along D-channel 2, tract 4 (tail of tract 4) have been laid out parallel to each other and following the contour. This design has made it possible for maximum reuse of water within the D-channel command area. However, F-channel 1 of D-channel 1 (head of tract 4), is a particularly long field channel in which certain limitations of design and construction have been overcome to some extent by farmer initiative. D-channel 2 in tract 2 (tail of tract 2) consists of three field channels of varying lengths and varying command areas. These and other peculiarities may be exerting differential influences on water supply and distribution which, in effect, reduces the disparity between head and tail. This assumption, however, needs further testing before any definitive conclusions can be drawn.

From a behavioral point of view, these hypothesis have important implications. For one thing, it cautions us in predetermining behavior patterns of farmers based purely on a spatial head-tail distribution, and especially in making important decisions with regard to policy options and operations. Second, it offers the premise that ecological factors too affect behavior. According to the Rajangana key informants, for instance, disputes over water occur mainly between head and tail farmers, but they are relatively infrequent and not very serious. Field-level officers, too, confirm this. According to both parties, in recent times no dispute has gone beyond the stage of argument.

In irrigated agriculture, one of the main elements that affects farmer behavior is the water control capacity available to the farmer at the farm level. Effective water control capability at the farm level is mainly a function of at least two factors: adequacy of water and reliability of water issues (i.e., quantity and timing). A reliable and adequate water supply helps the farmer to make effective management decisions. This type of water supply is a function of many factors, some of which will be discussed below.

a. Management Functions Affecting Water Control

Control of water by the management is done at three points in the study location: at the right branch channel headgate, at the respective D-channel heads, and at respective turnouts to field channels. According to field level officers interviewed, water discharges could be measured only at the right-branch sluice. No measuring

devices are available at any of the above control points. In tract 2 only seven F-channels have operable gates. Therefore, the control capacity available to the management is low.

The D-channels were being operated on a 3-days-on, 4-days-off rotation, as decided at the commencement of the season. Patrol Laborers said that the operation schedule they use is to give water to the head and middle turnouts for 1-1/2 days and to the tail F-channels for the balance of 1-1/2 days. They also said that when water scarcities occur within F-channels, they also close and open outlets within these F-channels in cooperation with farmers, although this strictly is not their responsibility. The two Patrol Laborers seem to be doing a satisfactory job within the constraints imposed on them by the infrastructure, if the farmer responses are a measure of such activity. All the farmers interviewed said that they know the two Patrol Laborers well, and only 7 percent said that they were not helpful to farmers. Compared to all field-level officers in the scheme, the Patrol Laborers enjoy the highest farmer credibility.

In regard to cleaning and maintenance of the D-channels, however, there appear to be some discrepancies. The three Irrigation Department field-level officers interviewed do not seem to agree on the number of times the channels were cleaned during Yala 1982 and Maha 1981/82. The responses of the three field officers range from 0 to 6. Of the seven key informants interviewed, five said that they were not satisfied with the cleaning of the D-channels. Of the sample of farmers interviewed, 41 percent said that they were not satisfied either.

b. Factors Affecting Water Control Within the Turnout

Factors which affect water control within the turnout can be caused both by farmer and irrigation bureaucracy action/inaction.

In analyzing farmer actions affecting water control, emphasis should be given to water allocation procedures planned for the turnout and the manner of their actual implementation. In tract 2, there is no accepted water allocation or distribution procedure. Even the farmer representative (Jalapalaka) who is responsible for arranging some distribution procedure in consultation with farmers, admits that no such allocation rules are in operation. However, in the study location of D-channel 1 in tract 4, 90 percent of the farmers said that a rotational water distribution procedure has been adopted and is now in operation. In this F-channel, according to a key informant, water is rotated between the head and tail allotments in two turns. However, there are about 10 allotments that get water only from the drainage channel, due to an uncompleted structure in the F-channel. In the second study location, 50 percent of the farmers said that a rotation system was practiced. Other farmers cannot practice a rotation as most of their irrigation comes through seepage and water flowing down from the higher paddies. In fact, no rotations are needed here.

In an effort to assess the water control status within the turnout, farmers were requested to report to what extent they usually deviate from accepted or "legal" irrigation behavior. In both Mahaweli and Rajangana, farmers provided us with objective and frank responses (Table D-6).

Table D-6 shows how deviations from accepted modes of behavior can affect the water control situation within the turnouts. However, according to both farmers and field level officials some of these apparently illegal actions such as "obstructing the field channel" become necessary to push water down certain outlets. It is also necessary in F-channels which attempt to practice rotations. Nevertheless, these deviations from accepted rules affect the water control capability available to farmers within the turnout. These deviations lead to further inadequacies and unreliability which in turn causes more "illegal" behavior on the part of the farmers. It should be noted, however, that "illegal" behavior does not necessarily occur due to the inherently evil nature of the farmer. Most irrigation behavior is a function of many external causes described earlier. What usually starts as adaptive behavior to certain specific circumstances becomes a "socially legitimized" pattern of behavior.

Defective or inadequately designed and/or constructed irrigation structures affect both farmer behavior and water control within the F-channel. Fifty percent of the farmers interviewed said that the quality of irrigation structures in the tertiaries is low. This was confirmed by the key informants. Of the seven key informants, six indicated that they are not satisfied with the irrigation structures in the study area. Farmers were also requested to give their reasons for the specific water problems they face in cultivation. Forty percent of the farmers reporting water problems blamed faulty and malfunctioning structures. Perhaps the pressure put on the Irrigation Department to complete downstream structures quickly (as the allottees had already been settled in some cases) might have caused these problems in structures. Natural deterioration, lack of maintenance and farmer intervention may have complicated matters still further.

c. Maintenance Problems of Water Control and Field Channels

The norm in the Rajangana Scheme is for F-channels to be cleaned individually by farmers. Each allottee is held responsible for cleaning a particular length of the F-channel apportioned to him. But in practice, cleaning and maintenance of F-channels is done in a haphazard manner or is not done at all. Usually no sanctions are applied for transgressions of this nature, although many farmers (84 percent) felt that miscreants should be punished. Some farmers are not happy with both the quality (23 percent), the frequency (34 percent), and incorrect timing (43 percent) of cleaning operations. Three out of seven key informants pointed out that since most F-channels in tract 4 are single-bunded, pits or ponds have formed along the channel which further aggravate the water control situation. They suggest that a methodical

maintenance program should be undertaken as this program is present even on D-channels.

Table D-6. Farmer Reports of Frequency of Deviant Irrigation Behavior (N = 44)

Deviant Irrigation Behavior	Frequency of Occurrence						Missing Data No.
	Often No.	(%)	Sometimes No.	(%)	Never No.	(%)	
Taking water out of turn	8	(20)	20	(49)	13	(32)	3
Farmers opening gate	2	(5)	14	(33)	26	(62)	2
Influence gatekeeper	3	(8)	11	(28)	25	(64)	6
Cutting bunds/illegal outlets	4	(10)	19	(45)	19	(45)	2
Obstructing field channels	6	(15)	24	(60)	10	(25)	4
Damaging structures	1	(2)	16	(39)	24	(59)	3
Using influential farmers	2	(5)	12	(32)	24	(63)	6
Threatening farmers	4	(10)	10	(25)	26	(65)	4
Taking excess water	4	(10)	20	(51)	15	(38)	5
Abusing officials	0	(0)	11	(30)	26	(70)	7

E. List of Participants and Workshop Schedule

LIST OF PARTICIPANTS

GEM GROUP (MAHAWELI)--Studied D-channel 3 TO 5

M.A.W. Bandaranayake	Agronomist
R.S. John	Agronomist (Observer)
G.R. Chandrasiri	Economist
D. Kahandawela	Extension
G.G.W. Gunatillake	Irrigation Engineer
D.M. Panapitiya	On-Farm Engineer

WATER GROUP (ANURADHAPURA)--Studied D-channel 3 TO 8

S.N. Jayawardhana	Agronomist
Y.M. Wickremasinghe	Economist
T. Kumaravelu	Extension
A.M.U.B. Alahakoon	Irrigation Engineer
K.G. Sriyapala	On-Farm Engineer
S.M. Rahman	Observer

GRANITE GROUP (AMPARAI)--Studied D-channel 4 TO 3

D.M.W. Dasanayake	Agronomist
R.M. Nandasiri	Economist
P.S.A. Kulatunga	Extension
U.N.S. Wickramaarachchi	Irrigation Engineer
Ajith Senanayake	On-Farm Engineer
W.D.L. Stanley	On-Farm Engineer (Observer)

ROSE GROUP (NORTH)--Studied D-channel 4 TO 10

S. Somasuriyam	Agronomist
S.J. Ediriweera	Economist
K. Paramalingam	Extension
M. Sivachandran	Irrigation Engineer
P. Ramanathan	On-Farm Engineer
M. Idris	Observer

WORKSHOP LEADERS

Coordinators:	J. Alwis H. Gamage	L. Nelson
Agronomy:	M. M. Premachandra M. A. W. Bandaranayake	L. Nelson
Economics:	A. Ekanayake	M. Haider
Extension:	L. Wickramasinghe	L. Dunn
Irrigation Engineering:	R. A. Nandasena	K. H. Yoo Wayne Clyma
On-Farm Engineering:	H. Gamage	R. E. Griffin Wayne Clyma

TENTATIVE SCHEDULE*

Date	Day	Time	Activity	Staff
7/1	THUR	1:00-9:00	Participants Arrive	JA/LN
7/2	FRI	8:30-9:00	Registration	All
		9:00-9:35	Opening Ceremonies	All
		9:35-10:30	Tea	
		10:30-11:30	Overview of D.A.	LN/WC
		11:30-12:00	Overview (Video Tape)	LN/WC
		12:00-1:30	Tapes on Pakistan and Gujarat	LN/WC
		1:30-2:30	Lunch	
		2:30-3:30	Socio-Econ.--Project Site	J. Perera
		3:30-4:00	Socio. Aspect--Project Site	Guest lecture
		4:00-4:15	Tea	
		4:15-4:45	Economic Aspect--Project Site	Guest lecture
7/3	SAT	8:30-9:00	Administration	JA/LN
		9:00-10:00	Soils of the Project	S. Somasiri
		10:00-11:00	Development Model Overview	LN/WC
		11:00-11:15	Tea	
		11:15-12:15	Cropping Practices	S. Upasena
		12:15-1:15	Diagnostic Analysis Overview	
		1:15-1:30	Professional Attitudes	LD/JA
		1:30-2:30	Lunch	
		2:30-3:30	Operation of the Irrigation System	G. Gunathilake
		3:30-3:45	Tea	
		3:45-4:45	On-Farm Irrigation Practice	HG
7/4	SUN		Holiday	
7/5	MON	8:30-9:00	Administration	JA/LN
		9:00-10:00	Role of Extension in D.A.	LD/LW
		10:00-10:15	Tea	
		10:15-11:45	Sequence for D.A.	LN/WC
		11:45-12:30	Role of Engineering in D.A.	KY/RN
		12:30-1:15	Role of On-Farm Engineering in D.A.	DG/HG
		1:15-1:30	Open	
		1:30-2:30	Lunch	
		2:30-3:30	What's in the Bag? (Team Building)	LN
		3:30-3:45	Tea	
		3:45-4:45	Who did it? (Team Building)	LD/LW

*Evening sessions may be scheduled during the workshop on a need basis.

Date	Day	Time	Activity	Staff
7/6	TUES	8:30-9:00	Administration	JA/LN
		9:00-10:00	Role of Agronomy in D.A.	LN/MP
		10:00-10:15	Tea	
		10:15-11:15	Application of D.A. (Video)	LN/WC
		11:15-12:15	Professional Attitudes	LD/JA
		12:15-1:15	Role of Economics	MH/AE
		1:15-1:30	Open	
		1:30-2:30	Lunch	
		2:30-3:30	Individual Expectations	LD/LW
		3:30-4:15	Video Film I	LN/MP
		4:15-4:30	Tea	
		4:30-5:00	Video Film (Water Movements in the Soils)	LN
7/7	WED	8:30-9:00	Administration	JA/LN
		9:00-10:00	Team Work	LD
		10:00-10:15	Tea	
		10:15-11:15	Planning D.A. (Video)	LN/WC
		11:15-12:15	Reconnaissance	LN/WC
		12:15-1:00	Team Meeting	LN
		1:00-1:30	Root Growth (Video)	LN/MP
		1:30-2:30	Lunch	
		2:30-3:30	Soil-Plant-Water Relationship (Video)	LN/MP
		3:30-3:45	Tea	
		3:45-5:00	On-Farm Irrigation System (Video)	DG/WC
7/8	THURS	7:30-1:30	Travel to M.I.	All
		1:30-2:30	Lunch	
		2:30-3:30	Rest	
		3:30-4:30	Planning for Reconnaissance	All
7/9	FRI	7:30-8:00	Administration	All
		8:00-5:00	Reconnaissance of Systems H and RG	All
7/10	SAT	7:30-8:00	Administration	JA/LN
		8:00-5:00	Planning and Discipline Study	All
7/11	SUN		Holiday	
7/12	MON	7:30-8:00	Administration	JA/LN
		8:00-5:00	Discipline Study	All
7/13	TUES	8:00-8:30	Administration	JA/LN
		8:30-10:00	Reconnaissance Report - Staff	All
		10:00-10:15	Tea	
		10:15-10:45	Video Tapes (Reviewing)	
		12:00-12:30	Team Assignment and Planning of D.A.	JA/LN
		12:30-1:30	Lunch	
		1:30-5:00	Team Planning	All

Date	Day	Time	Activity	Staff
7/14	WED	7:30-8:00	Administration	JA/LN
		8:00-5:00	D.A. of Selected Turnout	All
7/15	THURS	7:30-8:00	Administration	JA/LN
		8:00-5:00	D.A. of Selected Turnout	All
7/16	FRI	7:30-8:00	Administration	JA/LN
		8:00-5:00	D.A. of Selected Turnout	All
7/17	SAT	7:30-8:00	Administration	JA/LN
		8:00-5:00	D.A. of Selected Turnout	All
7/18	SUN		Holiday	
7/19	MON	7:30-8:00	Administration	JA/LN
		8:00-5:00	D.A. of Selected Turnout	All
7/20	TUES	7:30-8:00	Administration	JA/LN
		8:00-5:00	D.A. of Selected Turnout	All
7/21	WED	8:00-8:30	Administration	JA/LN
		8:30-9:45	Self Evaluation - Handout	LD/LW
		9:45-5:00	Team Report Preparation	All
7/22	THURS	8:00-8:30	Administration	JA/LN
		8:30-5:00	Team Report Preparation	All
7/23	FRI	8:00-8:30	Administration	JA/LN
		8:30-10:00	Team Presentation	All
		10:00-10:15	Tea	
		10:15-10:45	Team Presentation	All
		10:45-11:15	Summary	
		11:15-11:45	Self Evaluation - Summary	LD/JA
		11:45-12:30	Video Tape (Review)	All
		12:30-1:30	Lunch	
		1:30-5:00	Planning for D.A. II	All
7/24	SAT		Holiday	
7/25	SUN		Holiday	
7/26	MON		Holiday	
7/27	TUES	7:30-8:00	Administration	JA/LN
		8:00-5:00	Team D.A. of Selected Turnout	All
7/28	WED	7:30-8:00	Administration	JA/LN
		8:00-5:00	Team D.A. of Selected Turnout	All
7/29	THURS	7:30-8:00	Administration	JA/LN
		8:00-5:00	Team D.A. of Selected Turnout	All

Date	Day	Time	Activity	Staff
7/30	FRI	7:30-8:00	Administration	JA/LN
		8:00-5:00	Team D.A. of Selected Turnout	All
7/31	SAT	7:30-8:00	Administration	JA/LN
		8:00-5:00	Team D.A. of Selected Turnout	All
8/1	SUN		Holiday	
8/2	MON	8:00-8:30	Administration	JA/LN
		8:30-9:00	Self Evaluation	LD/LW
		9:00-5:00	Team Report Preparation	All
8/3	TUES	8:00-8:30	Administration	JA/LN
		8:30-12:30	Team Report Preparation	All
		12:30-1:30	Lunch	
		1:30-2:30	Team Report Preparation	All
		2:30-3:00	Oral Team Presentation	All
		3:00-3:15	Tea	
		3:15-4:45	Oral Team Presentation	All
		4:45-5:00	Summary of Reports	JA/LN
8/4	WED	8:00-8:30	Administration	JA/LN
		8:30-9:00	Self Evaluation - Summary	
		9:00-5:00	Team Report Preparation	All
8/5	THURS	8:00-8:30	Administration	JA/LN
		8:30-8:45	Workshop Evaluation	
			Farm Handout	JA/LN
		8:45-5:00	Team Report Preparation	All
8/6	FRI	8:00-8:30	Administration	JA/LN
		8:30-5:00	Team Report Preparation	All
8/7	SAT	8:00-8:30	Workshop Evaluation	JA/LN
		8:30-9:00	Expectations	LD/LW
		9:00-10:00	Oral Team Presentation	All
		10:00-10:15	Tea	
		10:15-11:15	Oral Team Presentation	All
		11:15-12:30	Summary	JA/LN
		12:30-2:00	Lunch	
		2:00-3:30	Closing Ceremonies	All
8/8	SUN		Holiday	
8/9	MON		Preparation for Debriefing	All
8/10	TUES		Debriefing	All
8/11	WED		Debriefing	All

F. Glossary

Ande	- Sharecropping
Chena	- The cleared jungleland used for shifting cultivation under rainfed conditions
G.C.E. (O.L.)	- General Certificate of Education (Ordinary Level), a government examination at completion of grade 10
Jalapalaka	- Ditch rider who is responsible for opening and closing irrigation gates
Kanna meeting	- Preseason cultivation meeting between farmers and irrigation officials
Maha	- Season from early October through February
Purana	- Old or traditional, referring to villages previously scattered throughout the Mahaweli development area
Yala	- Season from March through September

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