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# SYSTEM H OF THE MAHAWELI DEVELOPMENT PROJECT, SRI LANKA: 1982 DIAGNOSTIC ANALYSIS

WATER MANAGEMENT SYNTHESIS PROJECT

WMS REPORT 16

# SYSTEM H OF THE MAHAWELI DEVELOPMENT PROJECT, SRI LANKA: 1982 DIAGNOSTIC ANALYSIS

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WATER MANAGEMENT SYNTHESIS PROJECT

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Joe Alwis
Co-coordinator

Larry Nelson
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 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.

The program involved 24 professionals from the fields of irrigation engineering, agronomy, economics, and sociology. The participants worked in four interdisciplinary teams, each assigned to separate turnouts within System H of Kalawewa. An initial day-long reconnaissance survey served as the basis for subsequent detailed studies. After completing the detailed studies, individual teams analyzed their data and wrote team reports.

This report presents the data and conclusions generated during the training program. Data collection was limited because the program was not intended as a research program, but rather as a training program. However, we think the findings are of sufficient value to warrant presenting them as a possible guide for further investigation. Because the program coincided with the 1981/82 drought years, problems were better highlighted than under normal conditions. Significant findings included:

(1) The policies instituted to deal with the initial water shortage situation were not flexible enough to account for an increased supply of water.

(2) Farmers with poorly drained soils in the middle and lower reaches of the turnouts who followed government recommendations to plant chilies instead of paddy were later penalized by heavy rainfall and excessive water that seeped in from the irrigation channels and adjacent fields planted in paddy.

(3) Contrary to the recommendation, farmers cultivated paddy in well-drained upper slopes in Yala, which resulted in poor water application efficiency and damage to chili crops grown in adjacent fields.

(4) Water diversion in the four turnouts studied varied considerably.

(5) The irrigation system was poorly maintained, with widespread siltation, erosion, and weed infestation.

(6) The lack of maintenance of drainage channels, excessive water application, and seepage flows due to high conveyance losses from the distributary and field channels signficantly raised the water table, contributing to salinity buildup.

(7) Turnout groups did not function well, and water rotation between farms within a turnout was rarely practiced.

(8) The field-level officials, particularly the Unit Manager, were assigned excessive workloads.

(9) Many settlers resorted to leasing out their land due to inadequate knowledge of irrigated upland crop production and a shortage of capital. The extension program was not very successful in transferring knowledge about upland crops.

(10) Only a few farmers obtained credit for the 1981/82 season.

(11) The overall paddy yield for the sampled farms was about half the potential yield. The average yields of both paddy and chilies were higher in the head reaches than in the tail reaches of the turnouts.

(12) Compared to the income from Yala paddy, the income from chilies was about three times higher for head reach farms and two times higher for tail reach farms.

# 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 area 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 application of associated inputs, and through improved cultural practices, have been overlooked. This observation applies not only to mature irrigation systems but also to the newly established projects.

The Kalawewa reservoir is one of the newly established projects under the Mahaweli Ganga irrigation development scheme. The Kalawewa reservoir now operates as a regulating reservoir serving a major portion of System H in the Mahaweli System. At present, the right-bank main canal of Kalawewa reservoir provides irrigation water to 19,295 ha, while the left-bank main canal irrigates 6,160 ha. This entire area indicates the extent of the irrigated lands provided with new irrigation facilities.

Prior to the diversion of the Mahaweli water to Kalawewa, most lands in the Maha season* and all lands in the Yala season* were uncultivated. The Mahaweli diversion increased water availability in the reservoir during both seasons, except during the bad seasons which occurred in the 1981/82 Maha and 1982 Yala seasons. The average cropping intensity for the project area in 1980 and 1981 was 151 percent. This low cropping intensity may explain the low productivity of the system. This is a common feature found in a large number of major irrigation systems in Sri Lanka.

By 1981 the extent of land growing 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

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

schemes. Self-sufficiency in food production has been a long standing development goal in Sri Lanka. By 1981 Sri Lanka produced 90 percent of its rice consumption requirement. However, Sri Lanka imported enough wheat and wheat flour to equal one-third of the weight of available rice (locally produced and imported). Thus, even with the Mahaweli Project, 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 unsatisfactory 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 and study 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 interdisciplinary 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 Scheme. This report deals only with System H of Kalawewa in the Mahaweli Development Project.

The study was conducted by four interdisciplinary groups in the Galnewa area. 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 methods used during data collection and 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 for the workshop were selected from the Rajangana Irrigation and Settlement Scheme and the System H of Kalawewa in the Mahaweli Development Project, the largest multipurpose irrigation and settlement project undertaken in Sri Lanka. Two important characteristics of these two systems distinguish one from the other. Rajangana is an old system, whereas Kalawewa Settlement is about 7 years old. Secondly, Rajangana comes under the management 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 a unitary command 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 in System H of Kalawewa.

System H of Kalawewa is the pilot phase of the Mahaweli Program, which is ultimately expected to irrigate 364,372 ha in the country's dry zone. A major portion of System H is fed by the regulating reservoir, Kalawewa reservoir, in the north-central part of the island (Figure 1). To meet the irrigation demand in the command area, the waters of Kalawewa reservoir are replenished from the diversion in Mahaweli Ganga.

This system covers about 39,855 ha of irrigable land, of which 14,572 ha were brought under cultivation prior to the inception of the Mahaweli Project. System H area is comprised of several subsystems from $H_1$ to $H_{12}$. Kalawewa is the principal reservoir supplying irrigation water to $H_1$ to $H_5$ and $H_{10}$.

The sites selected for this study were located in block 302 of $H_1$ on the left bank of Kalawewa main canal (Figure 2). This location is approximately 38 km southeast of Anuradhapura, the capital of the north-central province.

In selecting study sites, it was originally intended that each site should be identified from the head and tail reaches of the main and distributary channels (D-channels) to obtain a better insight into the problems that exist in the system in relation to the supply of water. This requirement was, however, not accomplished in the final selection since the severe drought conditions affecting the area prevented the farmers from cultivating paddy.

The sites selected were turnouts (T.O.) 5 and 8 of D-channel 3 and T.O. 3 and 10 of D-channel 4 of block 302 (Figures 3,4,5, and 6). These

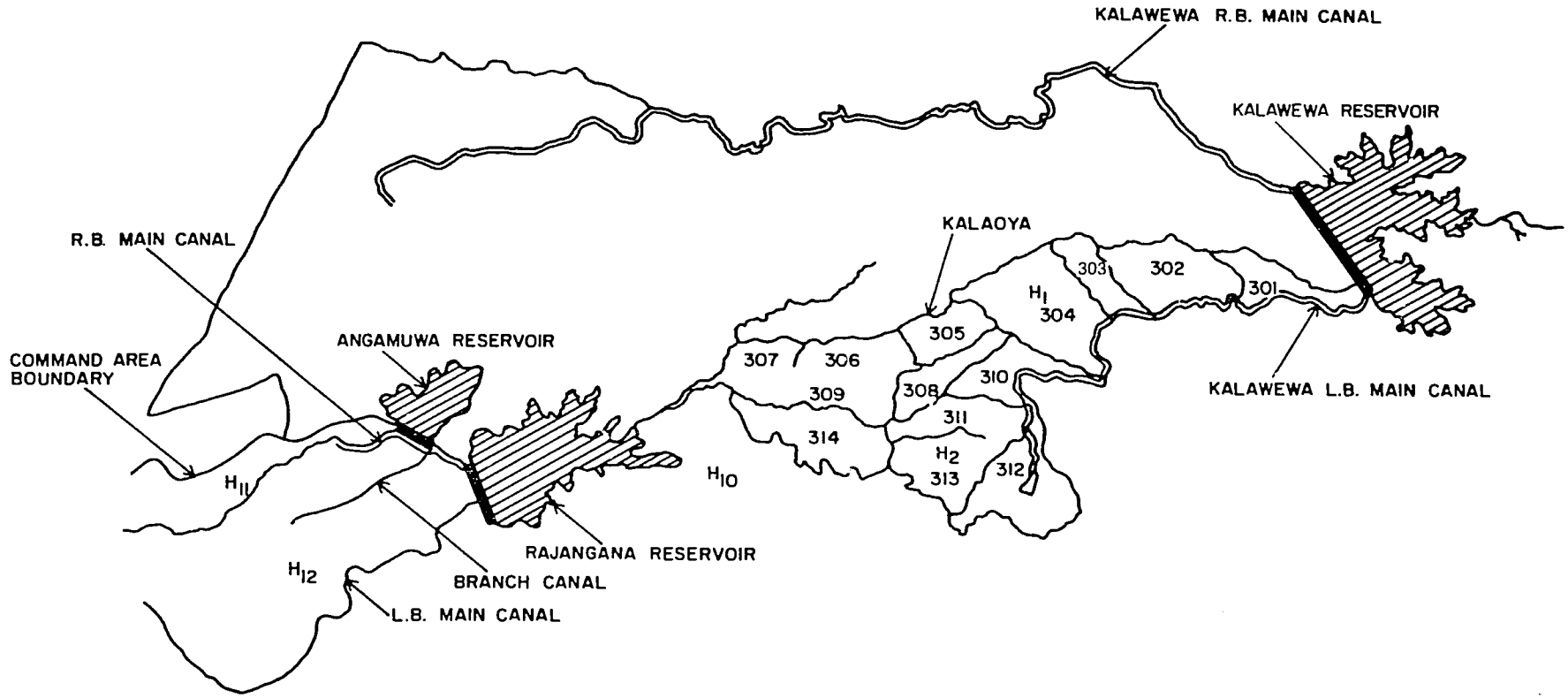



Figure 2. Map of Study Sites in System H of Kalawewa

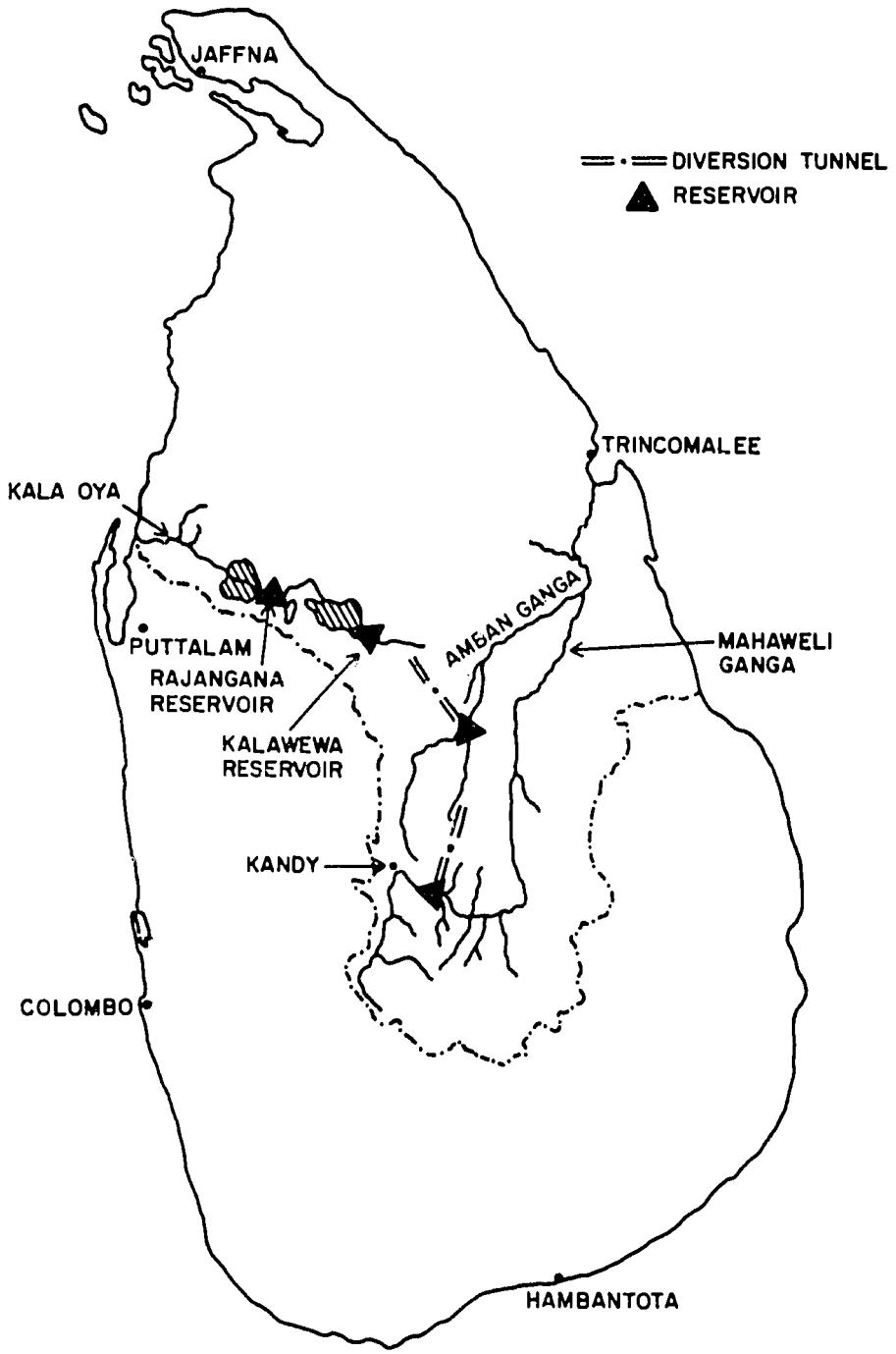



Figure 1. Location Map of Study Area in Sri Lanka

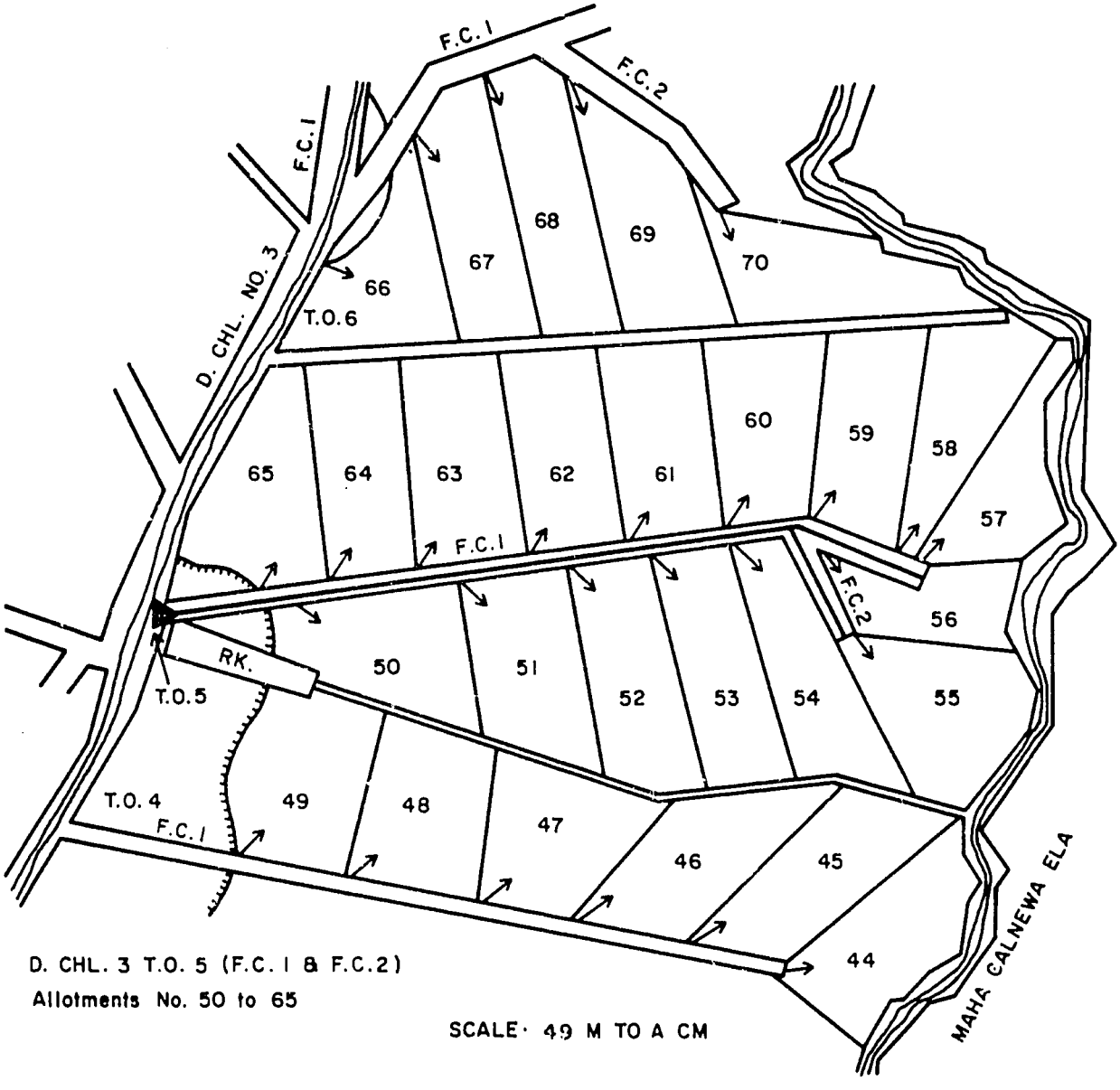



Figure 3. Map of D-channel 3 T.O. 5

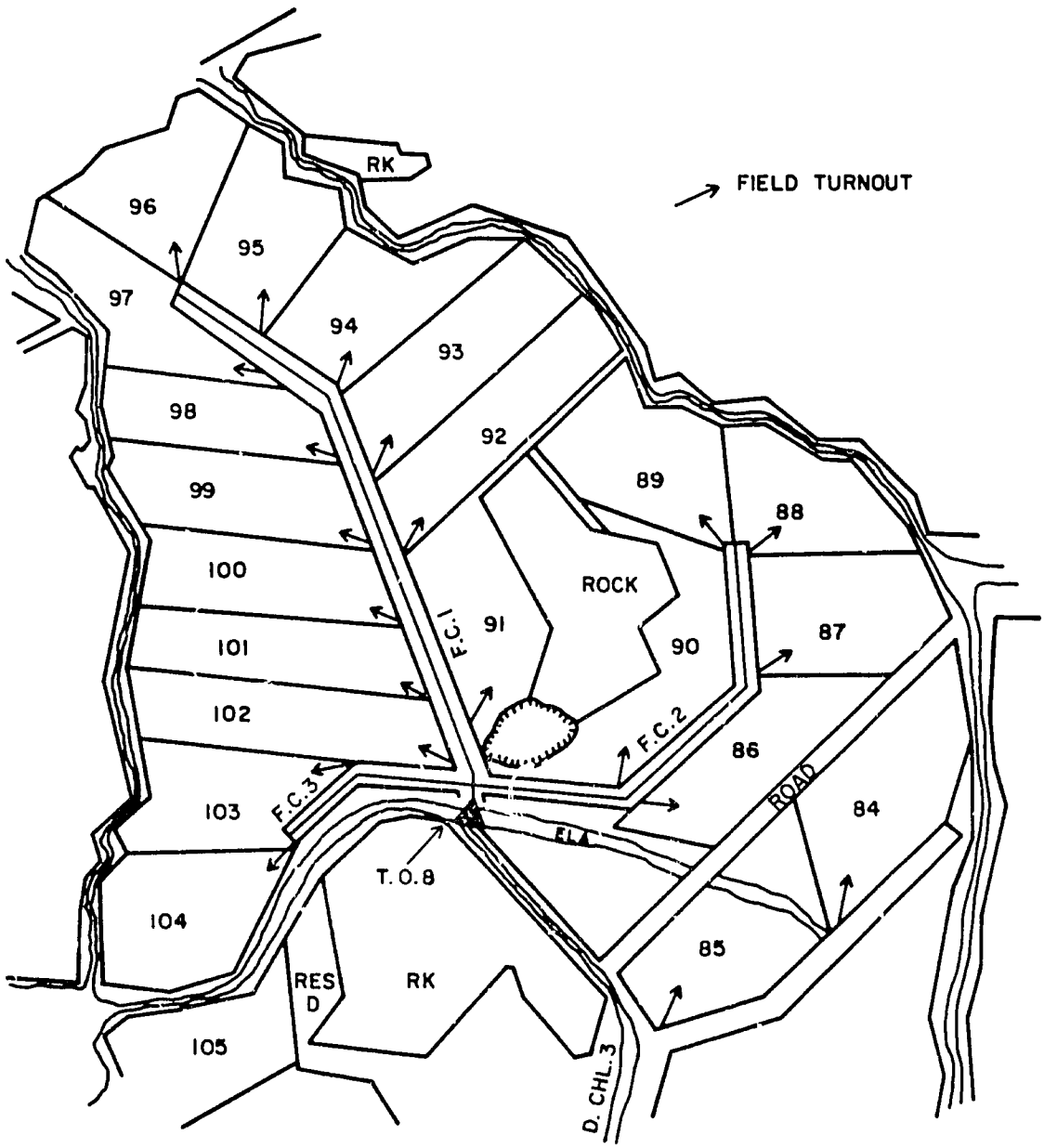



Figure 4. Map of D-channel 3 T.O. 8

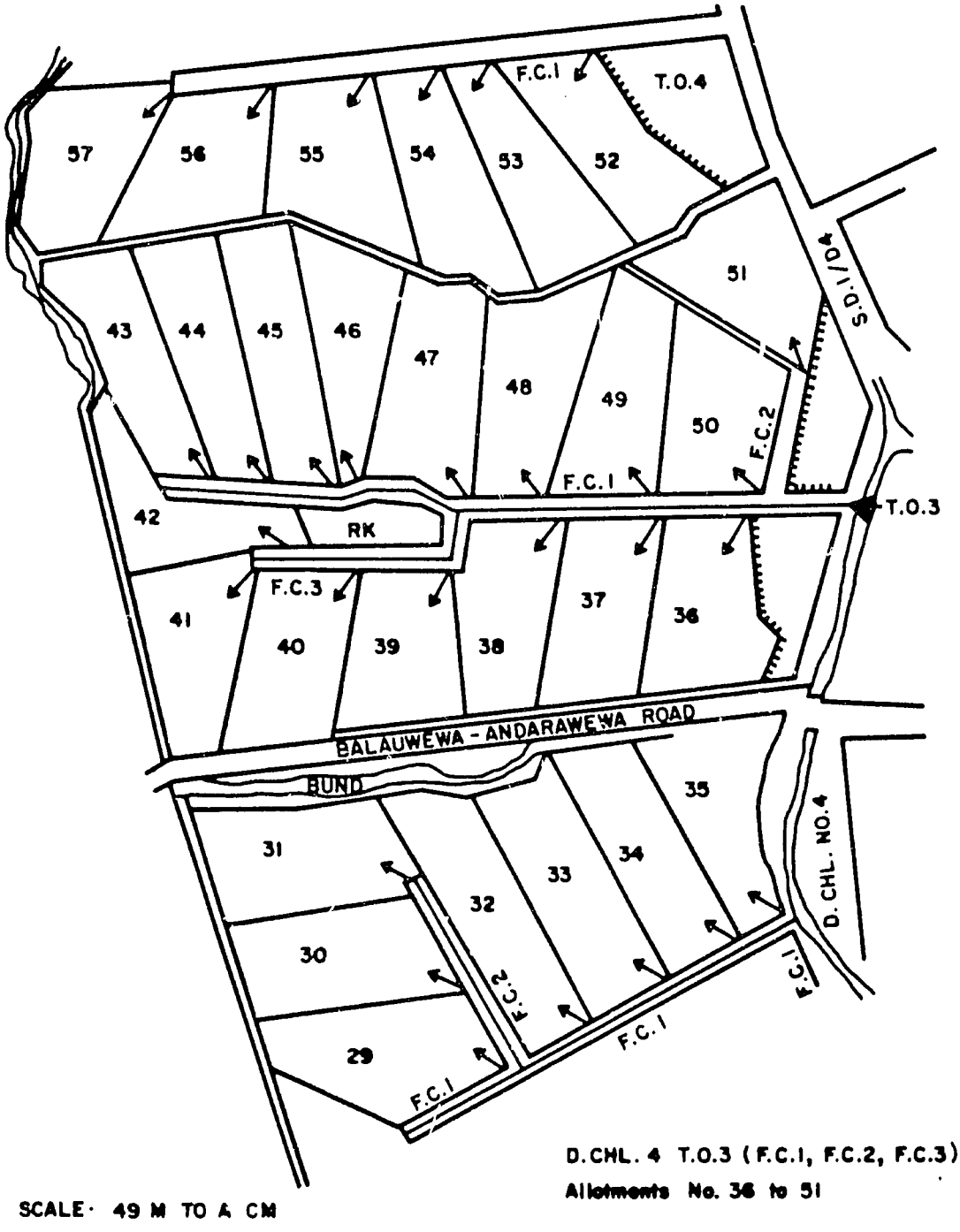



Figure 5. Map of D-channel 4 T.O. 3

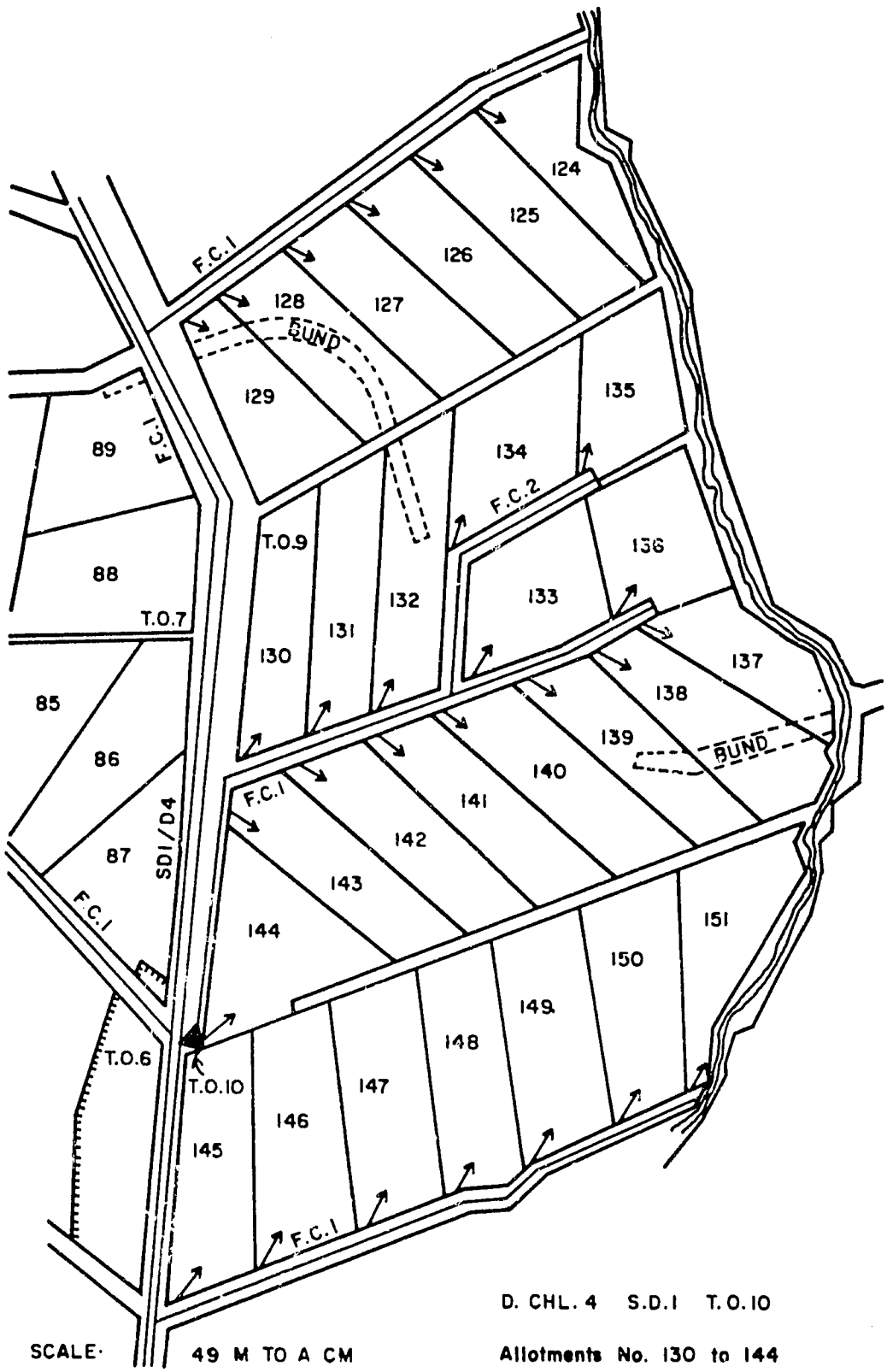



Figure 6. Map of D-channel 4 T.O. 10

turnout areas were selected largely because paddy was cultivated on some of the land and these sites were reasonably close to the Maha-Illuppallama In-Service Training Institute in which the workshop was held. These two D-channels are located in the head reaches of the left-bank main canal. In the selection of the turnout areas for related studies, arrangements were made to select field channels (F-channels) from the head and tail reaches of each D-channel selected as study locations. D-channels 3 and 4 selected for the study were situated about 14 km below the new left bank's main-canal sluice gate, respectively.

## B. Climate, Soils, and Topography

The Kalawewa project is located in the low country or dry zone less than 300 m above sea level. The general landscape is rolling with slopes ranging from 0 - 4 percent. Before the development project began, 80 percent of the land was covered by brush and forests. After the settlement, the farmland was terraced into small basins of about 10 x 20 meters.

Sixty percent of the project area consists of well-drained soils (reddish brown earth (RBE)). These soils are located toward the upper part of the slope, while the poorly drained soils (low humic gley (LHG)) are mostly in the lower part of the slope where the water table is fairly high. Moderately drained soils are in the middle of the slope.

The area is located within the broad agroclimatic zone DL1, characterized by a 75 percent annual rainfall expectancy of 750 mm. Average annual rainfall in the Mahaweli area ranges from 500-1,800 mm. The rainfall distribution is bimodal with major peaks occurring in November-December and March-April. About two-thirds of the annual rains the months of September through December. The major cultivation season, Maha, coincides with this high rainfall period. The heavy rains are followed by a short dry spell from January to mid-March with high solar radiation and a wide diurnal temperature range. Rains within the smaller peak come from late March to early May. These rains provide about one-third of the annual rainfall.

## C. Operational Plan of the System

The main canals and the branch canals run water on a continuing basis and issue water to the D-channels. Water delivery from the D-channel to the F-channel is made through a single off-take structure to a cluster of allotments called a turnout area, and each turnout area serves 10-15 allotments 1 ha (2½ acres) in size. The initial design of the system allows each turnout area to receive a flow of 0.028 $m^3/sec$ (1 cusec), and each farmer to obtain delivery of water for 12 hours per week on a rotation basis. This program should provide water to two farmers at one time. Water issues at each turnout are based on 64 mm for paddy and 38.5 mm for upland field crops per week.

## D. Cropping Pattern

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

## E. Socio-economic Conditions

Prior to the large-scale resettlement of this area under the Mahaweli Development Program in 1976/77, the study location was mainly inhabited by traditional villagers living in this area for generations in scattered pockets of purana (old) 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. With the start of the Mahaweli Program, the traditional villagers were incorporated into the system, and the small schemes were extended to form a part of the big system.

There are four types of resettlers in the Mahaweli System:

(1) Selectees- farm families selected from outside of the project area for resettlement.

(2) Evacuees- farm families who lost land when the reservoirs were built.

(3) Purana villagers- the traditional villagers who were living in the area, but were dislocated due to the development project.

(4) Early migrants- people who migrated to the project area before the commencement of the project.

In the study area, which is only a small part of System H, the main categories observed were the purana villagers (61 percent) and the early migrants (32 percent). Each selected farmer settler was given 0.2 ha (½ acre) of highland for homestead.

The resettlement scheme is still in its infancy. It is just passing over from an initial stage to a stage which could be called transitional. Hence, it could be presumed that the resettlers are still under stress and strains of dislocation and resettlement.

# III. METHODS

## A. Reconnaissance and Detailed Studies

During the first week of the training program the 24 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 System H of Kalawewa.

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 six days.

Specific methods employed by the team members are described in the following sections dealing with agronomy, engineering, economics, and sociology (Lowdermilk et al., 1981). 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 Methods

### 1. Agronomy

The reconnaissance survey of System H 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 agonomist 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 types of 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 water table depths. Water samples from the observation holes, drainage channels and field 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 from nine plants selected at random were measured at each location.

## 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 field channels.

To obtain a comprehensive picture of the channel inflow of the distributaries, five adjacent D-channels also were measured in addition to D-channel 3 and D-channel 4.

The quantity of water required was calculated for paddy and other field crops under D-channels 3 and 4 of block 302, and only for the other field crops under D-channels 5 and 6 of block 301 and D-channels 1, 2, and 5 in block 302. These values were estimates of the water required for paddy and other field crop cultivation in the area at the field channel turnout.

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.

Detailed investigations were conducted in D-channels 3 and 4 to determine the channel gradients and the condition of the structures, banks, and channel bottoms.

Conveyance Losses-- The conveyance losses in D-channels 3 and 4 of block 302 (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 flumes. 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:

$$Q_L = \frac{(Q_i - Q_o - Q_t)}{Q_i \times L} \times 100 \times 1{,}000,$$

where

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

$Q_i$ = inflow rate, l/s;

$Q_o$ = outflow rate, l/s;

$Q_t$ = sum of discharges to authorized turnouts, l/s; and

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

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.

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

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, free board, 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-- The levelness of fields in the upland plots was examined by eye estimate after filling the basins to a certain height (about 5 cm). The land leveling in paddy plots was checked by measuring the height of water after flooding the basins to a certain height.

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 water table was measured to evaluate the potential for subsurface drainage. Field observations of surface drainage also 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. To facilitate more in-depth and accurate data collection, farm record keeping systems should be employed.

Prior to finalizing the survey and choosing the sample, a reconnaissance was carried out in the block 302 area. For the detailed studies, both sociology and economics questionnaires were administered in a single visit to get the maximum cooperation from the farmers interviewed.

b. Questionnaire Design

The economic survey of block 302 in System H was specifically designed to collect data on two cropping seasons (1981/82 Maha and 1982 Yala). 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 assure that the data was uniformly collected from all the farmers interviewed.

In order to have a smooth flow in the administration of 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 administered 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.

Given time and transportation restrictions, the teams decided to sample at least four farmers each from the head and tail reaches of each turnout/study site. The sample was purposive in the demarcation of the head, middle, and tail reaches of the turnout, 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 per turnout. 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 interview, then the farms in the middle reaches of the turnout were included in the survey.

The reason behind the decision to divide the turnout area into head, middle, and tail reaches was the likelihood of the availability of an assured and a larger supply of water for the farms at the head of the field channel than at the tail end. Also, because the head reaches within turnouts have well-drained soils and tail reaches have poorly drained soils, stratified sampling was necessary.

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 were written that would secure information on:

(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 course were selected by the teams, and the participants spent much of their time in data collection.

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

(1) Sample Farmers-- A stratified random sampling design was used to identify the sample farmers in the study. In each turnout selected for study, the fields were stratified into head, middle, and tail according to heir physical location in the turnout area. From each such strata, sample fields were selected on a random basis. The owners of these sample fields were interviewed using a structured questionnaire. Interviewers were requested to interview all sample farmers from the head and tail farms, before attempting to interview sample farmers from the middle farms, as the interviewers' time was limited.

(2) Key Informants-- Selection of key informants was very straightforward. In each turnout, farmers had elected two members as farmer leaders in water management and agricultural extension. They were to act mainly as channels of communication between the Mahaweli Authority management and the farmers. A separate, structured questionnaire was used to interview each turnout leader as a key informant in the study.

(3) Field and Middle-level Officers of the Mahaweli Authority-- Originally, major irrigation officials of the Mahaweli Authority were to be contacted and interviewed. Unfortunately, due to the time constraints in the training, none of these officials were available for interviewing. With respect to

the minor irrigation officials, the two Unit Managers (UM), the four Field Assistants (FA), and the two Patrol Laborers (PL) directly responsible for the four selected turnouts were included in the sample. Two Field Assistants were not available for interviews.

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

# IV. RESULTS AND DISCUSSION

## A. Water Control and Delivery

Equity, reliability, and adequacy form the basis upon which water management can be evaluated. Equity in water allocation and distribution describes an ideal situation where the farmers located within a particular irrigation scheme receive the appropriate amount of water per unit of land. Reliability can be analyzed as the availability of water in quantity and time as scheduled. Adequacy refers to the delivery of sufficient water to the field to meet the crop-soil water requirement.

A properly designed and managed irrigation system should have the required flexibility to achieve an equitable and reliable water distribution even when overall water shortages occur. Sri Lanka and many other countries in the Asian region which depend on the available water supply for irrigation purposes have traditional social sanctions and customs and use different institutions to accomplish these objectives of equity, reliability, and adequacy. The experience in Kalawewa, particularly in the Yala season of 1982, clearly illustrates the deficiencies or poor conditions of control structures, measuring devices, and management of the water distribution to deal with shortages; this experience highlights the linkages among adequacy, equity, and reliability.

The Kalawewa area experienced a severe water shortage following a drought which occurred in Maha 1981/82. The Mahaweli Authority in Colombo, which manages the central allocation of water among different systems fed by the diversion, was therefore compelled to announce that the farmers in System H should cultivate field crops other than paddy to cope with the water shortage. The decisions of the cultivation (kanna) meetings held in the project area conform to the stipulation announced by the authority (see Appendix D).

Following the decision to cultivate upland crops, an unexpected heavy rain occurred in the project area causing substantial damage to chilies. Before the rains, certain farmers decided to cultivate paddy, disregarding the announcement by the Authority and the decision of the cultivation meeting; some other farmers reverted to paddy after the rains. Some farmers asked the authority to relax the original decision and permit the cultivation of paddy, since they perceived that the original decision emanated from a prior water shortage problem at the diversion and in the reservoir. However, the Mahaweli Authority did not change its original decision. The sequence of events and the causal factors which led to the emergence of an incompatible situation in the project area strongly suggested that the farmers might lose confidence in the reliability of water supplies.

During the period of the Diagnostic Analysis, Yala 1982, cropping patterns in the study area were as follows:

| | |
|---|---|
| Paddy | 34% |
| Upland Field Crops | |
| Chilies | 40% |
| Soybeans | 5% |
| Cowpeas | 5% |
| Uncultivated | 16% |

The study area included two D-channels, but measurements of water diversions were taken for another five adjacent D-channels for comparison. Studies conducted in four turnouts of the two distributaries within the study area indicated that water issues were in excess of upland crop requirements in three turnouts. In two of those turnouts, the discharge of water fell short of the requirement for paddy. The remaining turnout showed that the water discharge was in excess of that needed for paddy. These estimates were based on the water requirements adopted in the operational criteria by management, namely 64 mm of water for upland crops and 38.5 mm for paddy per week.

Similar discrepancies were observed in five other D-channels, two of which had less water discharge than the required amount for upland crops; the remaining three D-channels had a discharge which was far in excess of the water required for the cultivation of upland crops in the entire command area. This discharge of water was adequate to cultivate between 80-90 percent of the command area in paddy. Farmers cultivating paddy in the well-drained upper slopes of each F-channel need higher flow rates to submerge their allotments since the rate of percolation in the upland soils is very high.

Farmers complained of an increasing incidence of water inadequacy, except for those farmers in the one turnout which received 56 percent in excess of the crop requirement. The latter farmers had an informal farmer organization available for the F-channel, which enabled the farmers to rotate water effectively during water shortage situations.

Water shortages or excesses can be explained in terms of the following:

(1) a lack of an operational plan which takes into consideration the uncommon situation that came in during Yala 1982;

(2) a lack of or poor conditions of water control structures and measuring devices;

(3) a lack of institutional devices for effective monitoring of field conditions, and the inflexibility in system management to accommodate variations in water allocation decisions; and

(4) the tendency of the staff to issue extra water to minimize complaints by farmers.

Measuring structures were conspicuously absent or poorly maintained, resulting in either inadequate or excessive supplies of water. All farmers in the tail reaches of the study area complained of an unreliable water supply, in contrast with those positioned at the head. For example, in D-channel 3 in block 302, the designed discharge to turnout areas was 0.028 $m^3$/sec (1 cusec), but the measured discharge to turnout areas varied from 0.001 $m^3$/sec to 0.04 $m^3$/sec. Under D-channel 3, the head-end turnout (T.O. 5) received an average flow rate of 20 l/s versus 14.2 l/s at the tail-end turnout (T.O. 8). Similarly, under D-channel 4, the head-end turnout (T.O. 3) received an average flow rate of 30 l/s compared to 38.8 l/s at the tail-end turnout (T.O. 10). This clearly shows the inequity in the distribution of irrigation water.

As far as production capacity is concerned, unreliable water supplies would affect input application and management intensity, which in turn would reduce yield levels. The impact of this situation on the farmers results in adopting measures which minimize risks rather than maximize the production potential and profits.

B. Water Use Efficiency

A well managed irrigation system will usually include incentives for the farmers to use the water efficiently. Organizational and institutional weaknesses within the Mahaweli Development Project, as well as the supply of scarce water virtually free of charge to the farmers, has resulted in few incentives for the farmers to manage it efficiently.

Water use efficiency, as used here, refers to crop yield per unit of water applied. Water use efficiency at Maha-Illuppallama, where chilies were cultivated experimentally under simulated farm conditions of the Mahaweli area, was compared with the achievement of the farmer in this study area. The water use efficiency obtained at Maha-Illuppallama was 11 kg/100 $m^3$ (24 lbs/acre-inch) for chilies. Water use efficiencies obtained by farmers in the four study sites ranged from was 5.0 to 10.0 kg/100 $m^3$ (10.8 to 22.0 lbs/acre-inch). Only the farmers in T.O. 3 of D-channel 4 were able to obtain a water use efficiency comparable with experimental farm results. Therefore, it appears that there is much potential for improving water use efficiencies with better water management in the system as well as with improved water application practices.

The 1982 Yala season was not suitable for estimating water use efficiency in paddy cultivation since the drought resulted in low cropping intensity. Nevertheless, the same constraints mentioned above

prevented farmers from achieving potential levels of productivity, both per unit of land and per unit of water.

Several constraints on the availability and access to inputs resulted in the farmers operating at a low level of efficiency, relative to the potential under optimal conditions. In addition to the problems in the delivery and application of water, main constraints to obtaining higher levels of production included the availability of credit, draft power, the supply of fertilizer, and marketing channels.

C. Resource Conservation

Even though the irrigation system's design had provided for control and regulating structures, many were not constructed. Poor construction of the few existing structures and poor maintenance of the canals resulted in siltation, erosion, weed infestation, and excessive leakage and seepage from channels. Damage by human and animal activities was also obvious. Measured conveyance losses in the D-channel ranged from 2.50 to 17.42 percent per 1,000-m channel length, and in F-channels 7.3 to 9.3 percent loss per 1,000-m channel length. The channel erosion was so serious that D-channels 3 and 4 in block 302, which were originally constructed for 1-m bottom width, had an average bottom width of 3 m and no side slopes.

A high water table caused by over-irrigation, channel seepage, and improper drainage has adverse effects on cultivation of upland crops. On some of the upper slopes considered suitable for upland crops, the water table was within 30 cm of the ground surface for two or more days after an irrigation. As a result, upland crops were seriously affected by waterlogging. In addition, soil salinity had increased to levels beyond the tolerable limits for paddy (conductivity over 4 mmhos/cm ) in some fields.

Though the recommendation was to grow upland crops in System H during Yala 1982, this recommendation was not followed. As indicated by field observations and water table measurements, many areas in the lower reaches of turnouts were not favorable for upland crop production. In addition, the cultivation of paddy in well-drained soils of the upper slopes raised the water table in adjacent areas, creating an unfavorable condition for cultivation of upland crops.

Poor surface drainage and a total lack of maintenance in the drainage system have further aggravated the high water table problems. The main drains, which appear as uncontrolled waterways, do not appear to have been constructed according to a pre-planned design.

Regarding on-farm conditions, poor land leveling and farmers' lack of knowledge on irrigating upland crops compounded the problems of over-irrigation (see Appendices B and D). This situation can be explained in the following manner.

(1) Because on-farm management for upland crop cultivation was relatively new, the accumulated knowledge had not adequately reached the field-level extension staff. Extension staff in Mahaweli received only short-term training in water management during the previous two years.

(2) The farmers were accustomed to the traditional system of lowland (flooded) paddy cultivation. Irrigated field crop cultivation, which requires much less water, was a relatively new practice for these farmers, and the farmers needed a higher level of technical knowledge. A considerable amount of time and effort is required to change the attitudes and practices of the farmers and to provide them with the necessary knowledge on the new irrigation techniques.

(3) The settlement was still in the nascent stages of development and as such, farmers had very little time to learn and identify the unfavorable aspects of their on-farm practices and devise better methods to overcome problems.

(4) The magnitude and the complexity of the problems that the farmers have to combat in getting the water to the allotment and applying it in correct proportions have been realized only recently by researchers, planners, and managers.

The above observations point out two priority areas for all concerned with improving the performance of irrigation systems in Sri Lanka: the maintenance of irrigation systems, and the introduction and improvement of knowledge relating to on-farm development and irrigation practices.

Maintenance of irrigation systems has yet to receive a high priority in the attitudes and perceptions of the irrigation profession. In addition, the general responsibilities of the irrigation agency are deemed to be over after delivering water to the turnout. In Kalawewa, these attitudes and perceptions were evident, although not explicitly stated. As such, irrigation technical cadres lose an opportunity to work with the farmer and benefit by the farmer's experiences in resolving on-farm problems. As a result of this incongruent situation and lack of awareness of on-farm problems, irrigation professionals often give low priority status to resource allocation for maintenance and on-farm development.

Programming maintenance work through a system of identification and prioritization should produce more beneficial results in planning and utilizing the resources allocated for such work. Farmer cooperation in identifying the maintenance work can stimulate farmer involvement and motivate them to participate.

On-farm development should be an area of major concern of both irrigation and agriculture agencies. Training officials and farmers in

on-farm development and good irrigation practices should receive high priority. Research and development work should be initiated and expanded to find solutions to some of the common on-farm problems and to develop suitable technologies to implement these solutions.

## D. Resource Allocation

Resources for the design, construction, operation, and maintenance of large-scale irrigation projects are allocated to maximize social benefit by expanding the irrigated cropping area. Often, the enthusiasm generated at the beginning of the construction phase diminishes during the operation of the project, both among decision-makers and among officials responsible for the operation and maintenance of the project. This diminishing interest probably contributes to the failure to realize anticipated benefits from resources already allocated. Agricultural extension, credit facilities, crop insurance, and marketing facilities are also required to achieve the potential output and farm income.

Although the landholding size was uniform in the study area, the output and income varied from farm to farm depending on the location within the distribution system, soil type, and the crops grown. All farmers in the study area cultivated paddy in Maha 1981/1982. On the average, the area under paddy per farm was greater in the tail reach of the turnouts than in the head reach in the Maha season. Farms located in the tail reach also achieved higher paddy yields than those in the head reach of turnouts.

In Yala 1982, farmers cultivated paddy as well as chilies. Farmers in the head reach of the turnouts had a larger area under chilies (50 percent) than paddy (19 percent), while the farms in the tail reach had a greater area in paddy (50 percent) than chilies (17 percent). The remaining land area was kept fallow. The average yield of paddy as well as chilies was higher in the head reach of turnouts than in the tail reach. Overall, the farms in the head reach of turnouts generated a higher profit than farms in the tail reach.

The variation in profits according to the location of farms within turnouts resulted mainly from the farms at the head reach being able to grow a greater area in chilies during the Yala season than farms in the tail. Chilies cannot be successfully grown in the poorly drained soils found in the tail area of turnouts, except in small patches of imperfectly drained soils.

The total area cropped in the turnouts decreased from the head turnouts to tail turnouts along the D-channels in Yala. The major cause for this drop in the area cultivated along the D-channels was the shortage of water experienced in Yala. Efficient use of water through better on-farm irrigation practices could reduce the excessive use of water in the head areas and make more water available for the tail areas of D-channels, thereby increasing the area cultivated. Improved on-farm irrigation practices could increase the output of chilies and allow the cropped area to be increased.

Overall, paddy yields were far below their potential. The average paddy yield in Maha 81/82 was 2,456 kg/ha, while the expected Yala paddy yield was 3,418 kg/ha. Research on cropping systems, carried out in farm allotments in Bulnewa of System H by the Department of Agriculture, achieved an average paddy yield in the range of 5,165 to 6,817 kg/ha. The average chili output of 1,176 kg/ha was close to the potential yield of 1,257 to 1,509 kg/ha.

The low average paddy yield obtained in Maha 1981/82 was to a great extent the result of the severe water shortage experienced in the latter part of the season. In addition, the low levels of inputs applied by the farmers also contributed to the low output. Although all farmers used high-yielding varieties of rice, the application of fertilizer was poor. Only 48 percent of the fertilizer recommendation was applied during the Maha season, while the percentage applied in the Yala season was only 24 percent. Weed control was far below the desired level.

The average annual farm income ranged from Rs 8,796 for the farms located at the tail reach of turnouts to Rs 10,741 for the farms located at the head reach. This range of income appeared to be somewhat similar to that of white-collar workers such as clerks or teachers. However, the cash flow of a farmer differs from that of a white-collar worker who receives a fixed monthly salary.

According to the farm output in the two seasons, the seasonal income may vary. Crop failures, as experienced in Maha 1981/82, may force farmers to borrow from private money lenders for subsistence requirements and for working capital. The low percentage of farmers who obtained cultivation loans in the 1981/82 crop year (8 percent of the farmers in Maha and none in Yala) indicated that the present agricultural credit scheme was ineffective. There was no subsistence credit scheme. No crop insurance scheme was in operation in the study area.

A credit and crop insurance scheme alone cannot ensure high levels of input use and good crop management, unless production inputs are available at the right time in adequate quantities. A major constraint which needs immediate attention, in terms of increased production, is the shortage of draft power. None of the farmers interviewed owned either tractors or draft animals. In addition to delayed rains early in the Yala season, the shortage of draft power may have contributed to the extensive (1 to 1½ months) staggering of cultivation observed in the area.

## E. Farmer Involvement

The main function of farmer organizations in major irrigation schemes is to provide a better water control capability to the farmers, i.e., to provide each farmer with an adequate, predictable, and equitable supply of irrigation water. The water control capability of a turnout is affected by both the farmers and irrigation bureaucracy.

According to the project design and operational plan farmers in each turnout are organized into turnout groups. Each turnout group is supposed to have two farmer representatives who act as the channels of communication between the management and the farmers. According to the survey, however, only 26 percent of the sample farmers were aware that they belonged to a turnout group.

The study revealed that rotational distribution of water within the turnouts was rare and F-channel maintenance was done in a haphazard and unorganized manner. According to the farmers themselves, the quality of cleaning was low. There were many deviant irrigation actions among the farmers, such as taking water out of turn, farmers opening turnout gates, and farmers obstructing F-channels to divert more water, which resulted in conflicts among farmers within the turnout. The end result of all these actions and inactions was the low control capability available to farmers within the turnout. Because the turnout groups have been unable to mobilize farmer resources and motivations towards improving the water control capability at the farmer level, they have had low effectiveness. This finding has been corroborated by a study conducted by the People's Bank in an adjacent area in 1980.

The farmer involvement situation in the Mahaweli System H has been further complicated by the high leasing out of allotments observed in the study area. Nearly 50 percent of the allottees leased out land in Maha 1981/82 and Yala 1982. Although there were some share cropping and leasing arrangements among farmers themselves, many of the lessees were outside the class of farmer settlers. From the perspective of irrigation behavior, this introduced another group of cultivators with different goals, beliefs, and values into the irrigation system.

The lessees' cultivation operations and relative influence have adversely affected organized water management activities. The problems created include: (1) disruption of rotations within turnouts, and in some cases, even within D-channels, (2) illegal procurement of water, (3) poor maintenance of F-channels, and (4) disintegrating influences within turnout groups.

In early 1981, a new organization called the Community Development Society was formed at the hamlet level by the Management Agency. Evidently, the new organization showed a shift in emphasis from water to community development. Since the study revealed that the turnout groups were weak due to reasons within and outside the control of the group, it may be worthwhile to revive the turnout groups, especially since water is the key production resource around which cultivation activities revolve. If water is the central resource, then the most appropriate base for organization of production activities is the primary hydrologic unit, the turnout.

There was one turnout in the study area in which the farmers appeared to be informally organized for performing vital functions for

water management, even though the official turnout group was ineffective. Most farmers in this turnout followed accepted irrigation rules and had better water control capacity. They also reported fewer water problems.

A review of on-going experiments in farmer organization in a few other major colonization schemes in Sri Lanka, and a more systematic but quick study of the reasons for the low effectiveness of the turnout groups, may provide useful ideas to the Management Agency in developing a suitable method to strengthen and rejuvenate the turnout groups. Leasing of land is a strategy to which the settlers resort to overcome low incomes associated with crop failure, low yields, and the lack of crop insurance and credit. Resorting to legal action may not be helpful in reducing leasing. However, improving the liquidity position of farmers and the water control capacity at the farm level, combined with an enlightened and strengthened farmer organization for settlers, may be helpful.

## F. Institutional Development

The advantages that the Management Agency expected from the newly unified management structure have not been fully realized at the farm level due to the excessive work load and undue emphasis on paper work. The Unit Manager, for example, is expected to coordinate activities ranging from mother and child care, credit, marketing, township supervision, rural organizations, and education to agricultural extension and water management. In addition, the Unit Manager is expected to inquire into land encroachment problems, promote farmer self reliance and volunteerism, attend numerous meetings, and provide progress reports and statistics. Due to the heavy workload, the Unit Manager is compelled to delegate much of the above work to his two field assistants, thus reducing their effectiveness as extension agents. This situation not only prevents the field officers from working closely with farmers, but also compels them to treat the problems of farmers as less important than routine office work.

In water management, this situation prevents officers from devoting sufficient time to addressing problems pertaining to the management of D- and F-channels. In this study, this lapse affected the water control capacity at the farm level. The water control capacity at the turnout level was further reduced by: (1) ineffective monitoring of channel flows by irrigation officials, and (2) inability of the field officials to take action to solve local problems, especially with regard to providing quick responses to farmer complaints on inadequate and malfunctioning irrigation structures within turnouts. The reason for the latter problem may be the gap that still exists (despite the unified management structure) between the field-level staff who come under the Unit Manager and the technical staff who are functionally responsible to the water management unit.

Farmer behavior in an irrigation system is mainly an adaption to a given set of circumstances. If farmers find that they are unable to change conditions and situations through legal and acceptable means, they adopt deviant but rational behavior patterns to circumvent the unfavorable situation. Thus, management has to play an important role in promoting positive farmer behavior and effective farmer organization. When viewed from this perspective, it seems rational to reallocate or minimize the office duties of the Unit Manager and his staff to enable them to concentrate more on farmers and their problems.

A chaotic situation prevailed in Yala 1982 as a consequence of different expectations and needs of farmers on the one hand and the Management Agency on the other. In a large irrigation scheme like Kalawewa, rigid adherence to and complete reliance on all decisions made for system management at cultivation meetings may create problems of the above nature. Since Kalawewa reservoir is linked to the Mahaweli grid for its supplies, central allocation of water and the decisions which flow from such allocations are binding on System H farmers. However, it may become necessary to review decisions taken at cultivation meetings at the scheme level (within the broad framework of the control allocation decisions) periodically, so that problems that emerge at any time during the season due to changing local circumstances can be resolved effectively with farmer participation. There is no institutionalized decision-making mechanism involving the farmers on a continuing basis in System H. For more effective irrigation management, it may be useful to establish such a decision-making apparatus with active farmer participation to review unforseen problems that surface during the season.

There is a need to reinforce extension activities with advice to farmers regarding on-farm water management. Fifty-eight percent of the sample farmers had received absolutely no advice on on-farm water management practices. With regard to farmer knowledge on irrigating upland crops, 45 percent of the sample farmers said that they decided to stop irrigating chilies only when the basins were full, a clear case of over-irrigation.

# V. SUMMARY OF FINDINGS AND RECOMMENDATIONS

## A. Summary of Findings

The Diagnostic Analysis Workshop conducted in June-July of 1982 occurred during the 1981/82 drought years. This provided the workshop participants with a good opportunity to assess the impacts of water shortages on crop production and farm income. Problems associated with water delivery and distribution structures, water allocation and distribution policies, and communication between farmers and extension staff were better highlighted under drought conditions than under normal conditions.

The policies instituted to deal with the initial water shortage situation were not flexible enough to account for an increased supply of water. There appears to be no mechanism for involving farmers in a continuous review of the water supply during the cropping season. The inconsistencies between water distribution policies announced to farmers and actual practice may result in farmers' loss of confidence in irrigation authorities and greater deviation from future policies designed to deal with water shortage problems.

Farmers with poorly drained soils in the middle and lower reaches of the turnout who followed government recommendations to plant chilies instead of paddy were later penalized. Because more water was made available following the late monsoon rains, chili crops were damaged by the excessive water that seeped in from the irrigation channels and adjacent fields planted in paddy.

Measurements of water diversion for the four turnouts studied indicated considerable variation among them. In two of the turnouts, water discharge was in excess of the need for paddy production, while in one turnout it fell short of meeting the need for upland crops. Similar discrepancies were measured in five D-channels. This inequity in water distribution can be attributed to: (1) the lack of an operational plan for drought years, (2) the lack of or poor conditions of water control structures and measuring devices, (3) poor monitoring and management of the system, and (4) lack of effective farmer organizations.

In addition to poor design and construction of the irrigation structures, the irrigation system was poorly maintained. Siltation, erosion, and weed infestation were widely observed. It appears that the maintenance of the irrigation system is not given a high priority by the irrigation agency. The responsibility of the irrigation agency ceases at the turnout gate. Farmers acknowledged the poor quality of F-channel maintenance but lacked the organization needed for maintenance.

The lack of maintenance of drainage channels, the excessive application of water, and seepage flows due to high conveyance losses from the D- and F-channels significantly raised the water table. In most of the area, the water table was within 1 m of the surface. This also resulted in salinity buildup in some of the poorly drained lower slopes.

Turnout groups did not function well, and water rotation between farms within a turnout was rarely practiced. Frequent deviant practices such as farmers' taking water out of turn, opening of turnout gates, and obstructing the F-channels were reported. The breakdown in turnout group activity and the deviant irrigation behaviors can be attributed partially to the common practice of leasing out land to a class of entrepreneur farmers who do not belong to the community. In addition, the lessees' cultivation operations and relative influence adversely affected organized water management activities. The water control capacity at the turnout level was further reduced by ineffective monitoring of channel flow by irrigation officials and the inability of the field-level officials to solve water distribution problems.

The field-level officials, in turn, particularly the Unit Manager, have been assigned an excessive workload. The Unit Manager is responsible not only for water management activities for approximately 250 families, but also social services, credit, marketing, agriculture, and land tenure problems. With such a variety of tasks to perform, the Unit Manager obviously has priorities other than water management. His large volume of work has also lessened his potential contact with farmers.

Many settlers have resorted to leasing out their land due to inadequate farming knowledge and a shortage of capital which lessens their risk-bearing ability. Many farmers lack an adequate knowledge of irrigated upland crop production. Also, the extension program has not been very successful in transferring knowledge about upland crops. Only 26 percent of the farmers interviewed knew the agriculture field assistant, and 18 percent of this group considered him to be helpful.

Only a few farmers obtained credit for the 1981/82 season. Farmers often defaulted on their loans or were fearful of their inability to repay credit in the event of a crop failure. This resulted in a low rate of borrowing and consequent low investment. Credit was a problem for 55 percent of the farmers in paddy cultivation and 82 percent in cultivation of chilies and soybeans.

Contrary to the recommendation, paddy was cultivated in well-drained upper slopes in Yala season, resulting in poor water application efficiency and damage to chili crops grown in adjacent fields. Like paddy, chili crops were flood irrigated. Water use efficiency ranged from 5 to 10 kg/100m$^3$. In three of the four turnouts, it was considerably lower than the 11 kg/100m$^3$ water use efficiency obtained in the Maha-Illuppallama experimental farm.

The overall paddy yield for the sampled farms was 2,400 kg/ha in Maha and 3,300 kg/ha in Yala, compared to the potential yield of 5,000 - 6,600 kg/ha for this area. The average yield of paddy as well as chilies was higher in the head reaches than the tail reaches of the turnouts. Cropping mix in the 1982 Yala season for farms in the head reaches of the turnouts was 50 percent chilies and 19 percent paddy, and for the farms in the tail reaches 50 percent paddy and 17 percent chilies. The balance was kept fallow.

Compared to the income from Yala paddy, chili production resulted in an income about three times higher for head reach farms and two times higher for tail reach farms. Differences in cropping pattern, yield, and cost of production resulted in a total annual income of Rs 10,741 per ha in head reaches and Rs 8,796 per ha in the tail reaches of the turnout.

## B. Recommendations

Issues raised here will have to be analyzed in relation to the strategies the Mahaweli Authority chooses to resolve them. In the methods to be adopted will be substantially influenced by financial and institutional capacities. However, the Mahaweli Authority has the capability to accomplish this task.

(1) Previous policy decisions regarding cropping patterns, water issues, and areas to be cultivated should be reviewed and revised to include differences in soil types, seasonal variations in crop water requirements, and the needs of the farmers. Policy decisions also should have a set of contingency plans to deal with unexpected events, such as water supply problems or periods of heavy rainfall during the cropping season. While the development of irrigation policies is ultimately the responsibility of the water panel, it is strongly recommended that others involved in implementing these policies, especially the farmers, be actively involved in this process.

(2) To better allocate and deliver water to the turnouts, farmers and officials should construct control and regulating structures as originally designed, repair broken structures, and provide measurement structures at diversion points. The farmer should be involved with the engineer during the initial stages to ensure that the structures are properly placed and utilized over time.

(3) The responsibility for cleaning the F-channels should be clearly communicated to the farmers.

(4) An effective farmer organization below the turnout would help in better distribution of the available water according to the rotation. This organization could also be entrusted to regularly maintain F-channels.

(5) An improved extension program addressing irrigation and cultural practices in the production of upland crops is needed.

(6) Discouraging farmers from cultivating paddy in the upper reaches, which have highly permeable soils, could alleviate the problem of over-irrigation and salinity buildup in the lower reaches. Extension programs and farmer organizations could help alleviate some of these problems.

(7) Training of farmers and officials should aim at developing the required capability to operate and manage the system more effectively. In this context, the establishment of farmer organizations and management committees is considered a key factor in mobilizing the necessary resources for that purpose.

## C. Suggested Research Priorities

Based on this study's findings, suggested research priorities are as follows:

(1) Test the acceptability of alternative water measuring devices and control structures within the project area.

(2) Test alternative methods for delivering water to plots within allotments to check erosion and improve on-farm application efficiencies.

(3) Determine the extent and dimensions of waterlogging and salinity within the Kalawewa.

(4) Determine the water quality of groundwater and drainage water throughout the Kalawewa.

(5) Test alternative small power tillers and original ground equipment for land preparation.

(6) Continue studies on alternative methods and designs of surface irrigation for upland crops.

(7) Test alternative methods of weed control in now-flooded paddies.

(8) Determine the economics and acceptability of alternative cropping patterns.

(9) Investigate alternative methods for organizing farmer water user groups.

(10) Determine alternative organizational and management strategies for more effective system operation.

(11) Determine the role of credit in applications of purchased inputs.

(12) Study the allocation of land based on the farmers needs and land classification units.

(13) Study extension, information dissemination, and farmer training of techniques of on-farm water management for upland crop irrigation.

(14) Examine methods of providing enhanced decision-making powers to project staff to intervene rapidly with system-wide operational decisions.

(15) Examine current tenurial practices which inhibit proper water management.

(16) Determine alternative cropping patterns for Yala cultivation.

(17) Study methods to improve communications:
   (1) between Colombo and the Project staff;
   (2) among project personnel in Kalawewa; and
   (3) between Project officers and farmers.

# VI. APPENDICES

## A. Agronomy

### 1. Introduction

Climatic data collected at the Maha-Illuppallama Research Station in the dry zone is presented in Table A-1. Rainfall during the later part of the 1981/82 Maha season was unusually low and Yala season rains clearly deviated from the normal pattern of rainfall. During the Yala season an unusual and unexpected high rainfall was continuously recorded during late April and May as shown in Table A-2. This had an important bearing on the cropping pattern observed in block 302. Many allotments with well-drained RBE soils were cultivated with both lowland rice and other field crops.

The topography of the turnouts sloped along the field channel toward the basin at the lower end. Field channels constructed along the slope made it easier for allotments to obtain water from different points of the channel. Although this is the normal pattern, certain turnouts were composed of areas with slightly elevated fields in the lower reaches, making it difficult to obtain water directly from the field channel. Fields in such areas received water through seepage.

Rock outcrops observed in the turnout areas indicated that the soils were derived from gneiss. The soils in the upper areas were reddish brown earths developed in situ while those at the lower slopes, low humic gleys, were mostly colluvial parent material. Soil characteristics of the allotments studied are shown in Table A-3. The chemical and physical characteristics of the soils in the project area were compared with that of a typical RBE and LHG but due to time constraints only a limited amount of information was obtained.

Soil pH values tended to be slightly acidic in both soils. Electrical conductivity (EC) measurements indicated salt accumulation in poorly and imperfectly drained soils. Salinity levels in one area ranged from 0.55 to 14.0 mmhos/cm (Table A-4). Although paddy is moderately tolerant to salinity, electrical conductivities of 3.8 mmhos/cm and above may cause significant yield reductions.

Soil textures ranged from sandy clay loams (SCL) to heavy clays (C). The well-drained soils of the upper slopes were sandy clay loams to a depth of 30 cm, below which were sandy clays. Gravel layers were also encountered at depths of 30 to 40 cm in certain allotments. The middle slopes were either sandy clay loams, sandy loams (SL) or sandy clays (SC). Typical of the lower slopes is the occurrence of a very high clay content in the soils.

Table A-1. Meteorological Observations Yala 1980 to Yala 1982

| Year | Month | No. Rainy Days/Mo. | Rain-fall (mm) | Temperature °C Max | Temperature °C Min | Evaporation (Daily) Average, mm) | Sunshine Hours (Monthly Mean) | Wind Velocity (km/hr) | Atmos. Pressure (Av. Monthly millibars) |
|---|---|---|---|---|---|---|---|---|---|
| Maha 1980 | Jan | - | - | 20.3 | 19.8 | 4.3 | 8.4 | 3.5 | 1000.2 |
| | Feb | - | - | 32.6 | 20.0 | 6.0 | 10.4 | 3.0 | 1000.1 |
| Yala 1980 | Mar | 07 | 49.5 | 35.1 | 22.4 | 7.2 | 10.0 | 4.3 | 999.6 |
| | Apr | 15 | 166.6 | 33.1 | 24.1 | 5.2 | 8.4 | 3.6 | 997.1 |
| | May | 06 | 111.6 | 33.8 | 25.5 | 5.9 | 8.8 | 7.4 | 995.6 |
| | Jun | 05 | 40.9 | 32.3 | 25.3 | 5.8 | 7.4 | 14.4 | 995.2 |
| | Jul | 01 | 0.7 | 33.1 | 25.0 | 7.6 | 7.68 | 9.2 | 995.9 |
| | Aug | 02 | 10.5 | - | - | 8.0 | 8.63 | 9.7 | 997.0 |
| Maha 1980/1981 | Sep | 07 | 192.4 | 34.1 | 24.5 | 7.3 | 8.6 | 7.3 | 997.4 |
| | Oct | 14 | 179.1 | 31.2 | 23.3 | 5.0 | 6.67 | 4.1 | 998.0 |
| | Nov | 22 | 422.2 | 30.6 | 22.7 | 2.6 | 6.3 | 1.5 | 998.6 |
| | Dec | 13 | 155.6 | 29.7 | 21.7 | 2.9 | 6.74 | 1.9 | 998.8 |
| | Jan | - | 57.1 | 30.0 | 19.8 | 4.3 | 9.20 | 2.5 | 1000.9 |
| | Feb | 05 | 10.5 | 31.6 | 20.1 | 6.3 | 9.32 | 2.8 | 999.9 |
| Yala 1981 | Mar | 05 | 35.6 | 34.5 | 23.3 | 6.8 | 9.73 | 3.3 | 999.3 |
| | Apr | 14 | 197.8 | 33.3 | 24.2 | 5.1 | 8.53 | 2.7 | 997.1 |
| | May | 09 | 81.2 | 32.5 | 25.0 | 6.0 | 7.91 | 4.6 | 994.8 |
| | Jun | 05 | 7.3 | 31.7 | 24.6 | 5.6 | 8.16 | 8.8 | 995.4 |
| | Jul | 10 | 91.1 | 32.4 | 24.3 | 4.9 | 6.78 | 6.3 | 995.0 |
| | Aug | 06 | 46.6 | 32.5 | 24.3 | 5.5 | 8.34 | 8.1 | 996.1 |
| Maha 1981/1982 | Sep | 11 | 117.0 | 31.5 | 23.7 | 4.6 | 5.84 | - | 996.2 |
| | Oct | 13 | 186.7 | 32.0 | 23.0 | 4.0 | 6.71 | 3.7 | 997.7 |
| | Nov | 08 | 196.1 | 30.7 | 22.4 | 2.5 | 5.95 | 3.4 | 997.6 |
| | Dec | 12 | 123.2 | 29.5 | 20.7 | 3.4 | 6.4 | 2.4 | 1000.3 |
| | Jan | - | - | 30.5 | 19.7 | - | - | - | 1000.9 |
| | Feb | - | - | 33.2 | 19.2 | - | - | - | 999.9 |
| Yala 1982 | Mar | 08 | 97.4 | 35.0 | 22.0 | - | - | - | 998.5 |
| | Apr | 12 | 114.8 | 34.5 | 24.2 | - | - | - | 997.2 |
| | May | 13 | 162.9 | 33.1 | 24.0 | - | - | - | 996.6 |
| | Jun | | | | | | | | |
| | Jul | | | | | | | | |
| | Aug | | | | | | | | |
| | Sep | | | | | | | | |

Table A-2. The 1982 Yala Rainfall Distribution (mm) in Block 302 Area as Recorded by the Water Management Division of the Mahaweli Authority

| Month/ Day | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| March | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 18 | - | 110 | 06 | 10 | - | 04 | - | - | 148 |
| April | - | - | - | - | - | - | - | - | - | 09 | - | 02 | 07 | 02 | 24 | - | 15 | - | - | 36 | - | - | - | - | - | - | - | - | 97 | 03 | 195 |
| May | - | - | - | - | - | - | - | 04 | 04 | 26 | 48 | 06 | 04 | - | 04 | 21 | 09 | 13 | 05 | 15 | - | 16 | - | - | 05 | 02 | - | - | - | - | 182 |
| June | - | - | 02 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 02 |
| | | | | | | | | | | | | | | | | | | | | | | | | | | TOTAL | | | | | 527 |

Table A-3. The Soil Properties of the Upper Reaches of Turnouts Located in Block 302

| Soil Characteristics | Depth (cm) | D.3/T.O. 5 | | | D.3/T.O. 8 | | | | D.4/T.O. 3 | | D.4/T.O.10 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 65 Chili | 64 Paddy | 50 Paddy | 101 Cowpea | 86 Chili | 91 Paddy | 90 Chili | 36 Chili | 37 - | 142 Chili | 130 Chili |
| Texture | 0-15 | S.C.L. | C.L. | S.L. | S.L. | S.L. | S.L. | S.L. | S.C.L. | S.C.L. | C.L. | S.C.L. |
| | 15-30 | S.C.L. (gravel) | S.C.L. | S.C. | S.C.L. | S.C.L. | S.L. | S.C.L. | S.C.L. | S.C.L. | | |
| | 30-60 | S.C. | S.C.L. (high gravel) | S.C. | S.C.L. | S.C.L. | S.C.L. | S.C.L. | S.C.L. | S.C.L. | | |
| pH (1) Field | 0-15 | 6.8 | 7.4 | 7.4 | 6.6 | 6.4 | 6.8 | 6.6 | 5.7 | 6.6 | 6.4 | 6.0 |
| | 15-30 | 6.8 | 7.4 | 7.0 | 6.8 | 6.8 | 7.2 | 6.8 | 6.0 | 6.8 | | |
| | 30-60 | 6.8 | 7.2 | 6.8 | 6.6 | 6.0 | 6.4 | 6.8 | 6.3 | 7.2 | | |
| (2) Lab | 0-15 | - | - | 7.0 | 6.6 | 6.0 | 6.2 | - | - | - | 6.5 | 6.1 |
| E.C.(mmhos/cm ) | 0-15 | - | - | .28 | 0.50 | 0.75 | 0.44 | | 0.55 | 0.55 | 0.55 | 0.25 |
| Water Table | 0-15 | | | | | | | | | | | |
| | 15-30 | n.o. | n.o. | a.s. | n.o. | n.o. | n.o. | n.o. | | | | |
| | 30-60 | | | | | | | | 53 cm b.s. | 46 cm b.s. | | |
| Moisture | 0-15 | < f.c. | < f.c. | field flooded | | | | | ≅ f.c. | ≅ f.c. | | |
| | 15-30 | ≅ f.c. | < f.c. | field flooded | | | | | ≅ f.c. | ≅ f.c. | | |
| | 30-60 | = f.c. | ≅ f.c. | field flooded | | | | | ≅ f.c. | ≅ f.c. | | |
| Other Observations | | 1. D.H. not recognized. 2. No salts deposits on land. | 1. D.H. not recognized. 2. No salts deposits on land. 3. Water table at 0.8 meters. | | Water quality Head: $p^H$ 6.8; E.C. 0.38 Tail: $p^H$ 6.8; E.C. 0.34 | | | | | | | |

n.o. - not observed
a.s. - at surface
b.s. - below surface

Table A-3 (continued). The Soil Properties of the Middle Reaches of Turnouts Located in Block 302

| Soil Characteristics | Depth (cm) | D.3/T.O. 5 | | D.3/T.O. 8 | | | D.4/T.O. 3 | | D.4/T.O. 10 | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | 52 Paddy | 62 Paddy | 87 Paddy | 98 Snowpea | 99 Chili | 38 Paddy | 39 - | 140 Chili | 133 - |
| Texture | 0-15 | S.C. | S.C.L. | S.C.L. | S.L. | S.L. | S.C.L. | S.C. | S.C.L. | S.C. |
| | 15-30 | S.C. | S.C.L. | | S.L. | S.L. | S.C. | S.C. | | |
| | 30-60 | C. | S.C. | | S.L. | S.L. | S.C. | S.C. | | |
| pH (1) Field | 0-15 | 7.2 | 7.0 | 6.8 | 6.2 | 6.6 | 6.3 | 7.0 | 6.2 | 7.0 |
| | 15-30 | 7.0 | 7.0 | | 6.8 | 6.8 | 7.0 | 6.8 | | |
| | 30-60 | 7.0 | 7.0 | | 6.8 | 6.8 | 7.2 | 7.4 | | |
| | | 7.1 | 7.0 | 6.8 | 6.6 | 6.7 | 6.8 | 7.1 | 6.2 | 7.0 |
| (2) Lab | 0-15 | 6.1 | 5.0 | 6.6 | 6.4 | 6.6 | | | 6.4 | 7.2 |
| E.C.(mmhos/cm ) | 0-15 | 0.5 | 0.34 | 2.22 | 0.44 | | 0.55 | 0.55 | 0.77 | 0.58 |
| Water Table | 0-15 | | | | | | | | | |
| | 15-30 | 6 cm s.w. | 6 cm s.w. | s.w. | n.o. | n.o. | 28 cm b.s. | 16 cm b.s. | 25 cm b.s. | |
| | 30-60 | | | | | | | | | |
| Moisture | 0-15 | saturated | saturated | | | < f.c. | < f.c. | saturated | | |
| | 15-30 | field flooded | field flooded | | | | = f.c. | | | |
| | 30-60 | | | | | | saturated | | | |
| Other Observations | | g.s. Salts on bunds mid area. | g.s. Below 30 cm light brown color. | g.s. Drainage is unsatisfactory. Salt accumulation on bunds observed. | g.s. | | g.s. Salt accumulated in some plots. | g.s. Salt accumlated in some plots. | | |

n.o. - not observed
b.s. - below surface
s.w. - standing water
g.s. - D.H. gley surface to 15 cm.

Table A-3 (continued). The Soil Properties of the Lower Reaches of Turnouts Located in Block 302

| Soil Characteristics | Depth (cm) | D.3/T.O. 5 | | | D.3/T.O. 8 | | D.4/T.O. 3 | | | D.4/T.O. 10 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 58 | 56 | 55 | 94 | 96 | 40 | 41 | 42 | 43 | 135 | 137 |
| | | Paddy | Paddy | Paddy | Chili | Chili | - | Paddy | Paddy | Paddy | Chili | Paddy |
| Texture | 0-15 | S.C. | C. | C. | S.L. | S.L. | S.C. | S.C. | S.C. | S.C. | S.C. | C. |
| | 15-30 | S.C. | C. | C. | S.L. | S.L. | S.C. | S.C. | S.C. | S.C. | | |
| | 30-60 | C. | C. | C. | S.C.L. | S.C.L. | S.C. | S.C. | S.C. | S.C. | | |
| pH (1) Field | 0-15 | 7.6 | - | - | 6.0 | 6.8 | 6.8 | 6.6 | 6.8 | 7.0 | 6.4 | 6.8 |
| | 15-30 | 7.6 | - | - | 6.4 | 6.6 | 6.8 | 6.6 | 7.0 | 7.0 | - | - |
| | 30-60 | 7.6 | - | - | 6.4 | 6.6 | 7.0 | 6.8 | 7.0 | 7.1 | - | - |
| (2) Lab | 0-15 | 6.8 | 6.0 | 6.1 | 6.8 | 6.8 | - | - | - | - | 6.6 | 6.9 |
| E.C.(mmhos/cm ) | 0-15 | 0.55 | 2.2 | 1.1-1.7 | 0.8 | 0.8 | 0.55 | 0.51 | 11-14 | 0.55 | 1.2 | 0.44 |
| Water Table | 0-15 | | | | | | | | | | | |
| | 15-30 | a.s. | 60 cm* | 6 cm | n.o. | n.o. | 5 cm | 5 cm | 12 cm | n.o. | | |
| | 30-60 | | b.s. | s.w. | | | b.s. | b.s. | b.s. | | | |
| Moisture | 0-15 | sat. | < f.c. | sat. | | | sat. | sat. | < f.c. | < f.c. | | |
| | 15-30 | sat. | < f.c. | sat. | | | sat. | sat. | = f.c. | < f.c. | | |
| | 30-60 | sat. | < f.c. | sat. | | | sat. | sat. | > f.c. | < f.c. | | |
| Other Observations | | D.H. gley surface. High salts deposition on bunds. | D.H. gley colour indicating gley surface downwards. Water table 60 cm below surface indicates hummock which is about 10 m from the drainage ditch. | | | | | Irrigated from the drainage canal. Salt deposition everywhere. | | | | |

n.o. - not observed
a.s. - at surface
b.s. - below surface
s.w. - standing water
sat. - saturated

* This part of the field is elevated.

Table A-4. Comparisons of the Chemical Properties of the RBE and LHG Soils

| Soil | Avg. Clay Content | | pH | | EC (mmhos/cm ) | | CEC (M.Eq/100 g) | | % Organic Matter | | Available (ppm) | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | A | B | A | B | A | B | A | B | A | B | A | B |
| R.B.E. | 10-35 | N.A. | 6-7.5 | 5.6-7.0 | 0.02-0.05 | 0.28-0.75 | 10-20 | N.A. | 2-3 | N.A. | 15-110 | N.A. |
| L.H.G. | 10-35 | N.A. | 6-8.5 | 6.0-6.8 | 0.03-2.68 | 0.55-14.0 | 15-30 | N.A. | 1-2 | N.A. | 20-27 | N.A. |

A- Values common to soil type (Somasiri, 1982).
B- Values common to study area (as measured in block 302).
N.A.- Not available.
CEC - Cation exchange capacity.

In the lower slopes of both the upper and lower reaches of the D-channels, the water table remained at or near the surface irrespective of the number of days after an irrigation. In middle slopes it was 0-15 cm below the surface soon after irrigation. Four days after irrigation it varied from 56 to 70 cm. In upper slopes the water table depth varied from 0 to 40 cm below the surface soon after irrigation. Four days after irrigation it was 47 to 120 cm below the surface. More detailed information regarding the water tables may be found in Appendix B.

Observations of the moisture status of the soils prior to irrigation in the upper slopes indicated either the soils were at field capacity or below. A soil moisture content of 16.7 percent by weight is field capacity for this soil. Fluctuating shallow water tables and frequent irrigation intervals are harmful to chilies as they are susceptible to waterlogging. Previous studies suggest that waterlogging conditions result from high frequency of irrigation, over-irrigation on improperly leveled fields, seepage from channels, lateral flows from the upper reaches of D-channels, and inadequate drainage facilities (Rasiah, 1980).

Observations of irrigations suggested that most farmers apply nearly as much water to their chili crops as they apply to paddy. This was especially true in the turnouts located on the upper reaches of the D-channels. Thus, farmers applied water to chili fields which were at or near field capacity. Only one farmer within the four study sites made effective use of the available water. Instead of applying water during the normal irrigation rotation period, he attempted to use the shallow water table for the crop.

Soil horizons were not distinct in most of the sampling points with the exception of gley horizons in paddy areas within the mid and lower slopes.

Observations clearly showed that salts accumulated on the bunds of fields located in the imperfectly drained soils. The intensity of salt accumulation gradually increased toward the lower reaches of the turnout. General observations indicated retarded growth, signs of deficiency, and poor stands in many of the basins in the mid and lower slopes.

Table A-5 compares tiller counts, plant height measurements, and electrical conductivity readings in allotments that exhibited soil problems. Electrical conductivity values indicated salinity was a mild problem in two allotments and a serious problem in only one allotment. In contrast, both tiller counts and plant height measurements suggested that salinity problems were serious in all four allotments studied. Although this data is limited, it does indicate that some areas of System H are becoming saline. More detailed studies are needed to determine conclusively the magnitude of salinity problems in the Mahaweli project area.

Table A-5. The Effects of Soil Salinity

| Plant Characteristic | D.3/T.O. 5 Allotment 56 | | D.3/T.O. 5 Allotment 58 | | D.3/T.O. 8 Allotment 87 | | D.4/T.O. 3 Allotment 42 | |
|---|---|---|---|---|---|---|---|---|
| | Healthy | Affected | Healthy | Affected | Healthy | Affected | Healthy | Affected |
| 1. Tiller count (no./900 $cm^2$) | 28 | 8 | 20 | 11 | N.A. | 14 | 24 | 20 |
| 2. Plant height (cm) | 43 | 28 | 40 | 26 | N.A. | 20 | 36 | 18 |
| 3. Electrical Conductivity, (mmhos/cm ) | 1.1 | 2.2 | 0.55 | 0.5 | N.A. | 2.22 | N.A. | 11.0-13.0* |

*Value 13 was obtained from a sample collected from a bund in the paddy field. Value 11 is the result of a sample made by mixing soil from the bund and from a place where the crop was grown.

2. Cropping Pattern

In general, the amount of paddy grown in a turnout was related to the availability of irrigation water (Table A-6). D.3/T.O. 5 and D.4/T.O. 3, which were located in the upper reaches of the D-channel, were cultivated with more paddy than the other two turnouts. D.3/T.O. 8 is typical of the turnouts located in the lower reaches of the D-channel tail area with an extensive area of fallow fields. Farmers in D.3/T.O. 8 reported that the large area of fallow land was a consequence of the lack of sufficient water. D.4/T.O. 10 was an exception to the current concepts of cropping patterns. Even allotments in the lower slope of D.4/T.O. 10 (where the soil is considered to be imperfectly drained) were successfully grown with chilies. About 67 percent of the total area of this turnout was cultivated with chilies, indicating that the limitation of water did not prevent farmers from cultivating chilies. The area cultivated with legumes such as cowpeas, green gram, soybeans, and black gram was low. Being short-duration crops, they grow well in areas suffering from shortages of water.

Table A-7 shows the average area cultivated from 1979 Yala to 1982 Maha (Gunatillake, 1982). These figures show that during Yala seasons almost the entire extent of the left-bank main canal was cultivated, and during Maha seasons the figures given exceeded the cultivable extent, which is 6,160 ha.

This data suggests that a 100 percent cropping intensity occurs during most Yala seasons but the study area, despite its location on the

TABLE A-6. The Crops and the Percentage of the Turnout Area Cultivated with Each Crop in Block 302

| Crop | Percentage Cultivated | | | | |
|---|---|---|---|---|---|
| | D.3/T.0.5 | D.3/T.0.8 | D.4/T.0.3 | D.4/T.0.10 | Average |
| 1. Paddy | 70 | 8 | 39 | 18 | 34 |
| 2. Chilies | 12 | 42 | 38 | 67 | 40 |
| 3. Soybeans / 4. Cowpeas | 1 | 6 | 4 | 8 | 5 |
| 5. Fallow | 17 | 44 | 19 | 7 | 21 |

TABLE A-7. The Area and Percentage of Land Cultivated in System H During the Yala and Maha Seasons of 1979-1982

| Season | Land Cultivated (ha) | | | | | |
|---|---|---|---|---|---|---|
| | 79/80 | % | 80/81 | % | 81/82 | % |
| Yala | 6,441 | 106 | 5,370 | 88 | 5,708 | 94 |
| Maha | 7,224 | 118 | 7,311 | 120 | 6,972 | 114 |

upper reaches of the main canal indicates only 79 percent cultivation leaving 21 percent fallow (Table A-6). Because this area probably receives more water, it would appear that the blocks toward the lower reaches were suffering from severe water shortages.

3. Chili

Chili varieties grown were mostly $MI_2$ or mixes of varieties (Table A-8). Plant spacings in the study area differed from the Department of Agriculture recommendations of 45 x 60 cm. Observed plant spacings varied from 45 x 36 cm to 65 x 68 cm. The unexpected high rainfall during late April and May (Table A-2) damaged the chili crop in some areas, necessitating some replanting. Chilies that were cultivated on raised beds within a basin were not damaged from waterlogging. In some allotments chilies were raised on flat beds within the basin followed by

Table A-8. Crop Data for the Upper, Middle, and Lower Reaches of Turnouts Located in Block 302

| | D.3/T.O. 5 | | | | |
|---|---|---|---|---|---|
| | 65 | 65 | 64 | 64 | 50 |
| 1. Crop | Chili | Paddy | Paddy | Chili | Paddy |
| 2. Variety | $MI_2$/Mixed | BG276-5 | BG276-5 | MI/Mixed | BG276-5 |
| 3. Spacing (cm) | 50 x 60 | - | - | 50 x 40 | - |
| 4. Sowing Method | Transplanted | B/C | B/C | T/P | B/C |
| 5. Stage of Growth | Pod Bearing | Early Tillering | Early Tillering | 1st bloom to Early Pod Bearing | Early Booting |
| 6. Approx. Plant. Time (wk) | 10 | 3-4 | 3-4 | 8-10 | 6 |
| 7. Condition: | | | | | |
| Overall Assessment | Avg-Above Avg | Poor | Poor | Poor | Avg |
| Population | 98% | 12.6 | 15.2 | 95% | 33.3 |
| Plant Height (cm) | | 37.8 | | | 51.5 |
| 8. Nutrient Status | | | | | |
| Visual: N, P, K | no visual deficiency | no visual deficiency | | no visual deficiency | |
| Tissue Test: N | --- | --- | L | --- | M |
| P | --- | --- | M | --- | M |
| K | --- | --- | L | --- | L |
| 9. Weed Infestation | | | | | |
| Grasses | L | H | H | L | H |
| Sedges | L | H | H | L | H |
| Leaves (Broad) | L | H | H | L | L |
| 10. Method of Control | Manual | - | - | Manual | --- |
| 11. Diseases | n.e. | n.e. | n.e. | Isolated cases of leaf curl | n.e. |
| 12. Pest Incidence | Low | leafsucking insects-low | | n.e. | Symptoms of early stem borer, Thrips, Leaf Roller |
| 13. Other Observations | | | | | |

n.e. - not evident
L - low
M - medium
H - high

B/C - broadcast
* plant/tiller count/900 $cm^2$

Table A-8 (continued). Crop Data for the Upper, Middle, and Lower Reaches of Turnouts Located in Block 302

| Crop Observations | D.3/T.O. 8 | | | |
|---|---|---|---|---|
| | 86 | 91 | 91 | 101 |
| 1. Crop | Chili | Chili | Rice | Cowpea |
| 2. Variety | $Ml_2$/mixed | $Ml_2$/mixed | BG276-5 | --- |
| 3. Spacing (cm) | 50 x 50 | 65 x 68 | --- | 50 x 60 |
| 4. Sowing Method | Transplanted | Transplanted | B/C | Random planting |
| 5. Stage of Growth | 1st bloom to early pod bearing | 1st bloom to early pod bearing | Early vegetative | Flowering to pod formation |
| 6. Approx. Plant. Time | 8-10 | 8-10 | 2-3 | 6-7 |
| 7. Condition: | | | | |
| Overall Assessment | | | | |
| Population | 6 | 7 | 44 | |
| Plant Height (cm) | 47.3 | 31.4 | 24.4 | 60.7 |
| 8. Nutrient Status | | | | |
| Visual: N | no visual deficiency symptoms | --- | --- | --- |
| P | | --- | --- | --- |
| K | | --- | --- | --- |
| Tissue Test: N | --- | --- | L | --- |
| K | --- | --- | M | --- |
| P | --- | --- | L | --- |
| 9. Weed Infestation | | | | |
| Grasses | --- | L | M | L |
| Sedges | --- | L | M | L |
| Leaves | --- | L | L | L |
| 10. Method of Control | Manual | Manual | Manual | Manual |
| 11. Diseases | Leaf curl (low) | Leaf curl-L | n.e. | n.e. |
| 12. Pest Incidence | Pod borer | n.e. | Thrips-L | Pod borer-M |
| 13. Other Observations | | | | |

Table A-8 (continued). Crop Data for the Upper, Middle, and Lower Reaches of Turnouts Located in Block 302

| | D.4/T.O. 3 | | | | | D.4/T.O. 10 | |
|---|---|---|---|---|---|---|---|
| Crop Observations | 36 | 36 | 49 | 49 | 50 | 142 | 130 |
| 1. Crop | Chili | Paddy | Paddy | Chili | Chili | Chili | Chili |
| 2. Variety | $MI_2$ | BG276-5 | BG34-8 | $MI_2$ | $MI_2$ | $MI_2$/mixed | $MI_2$/mixed |
| 3. Spacing (cm) | 66 x 39 | --- | --- | --- | 76 x 55 | --- | 50 x 38 |
| 4. Sowing Method | Flat beds | B/C | B/C | Ridge planting | Basin furrows | Ridge planting | Ridge planting |
| 5. Stage of Growth | 2nd flowering | P.I. | P.I. | 2nd flowering | 2nd bloom | flowering to pod formation | flowering to pod formation |
| 6. Approx. Plant. Time (wk) | 12 | 5 | 5 | 12 | 12 | --- | --- |
| 7. Condition: | | | | | | | |
| Overall Assessment | Avg | Poor | Poor | Good | Good | Good | Good |
| Population | | 22 | 47 | | | | |
| Plant Height (cm) | 34.7 | 8 | | | 37.2 | | |
| 8. Nutrient Status | | | | | | | |
| Visual: N | --- | --- | --- | --- | --- | --- | --- |
| P | --- | --- | --- | --- | --- | --- | --- |
| K | --- | --- | --- | --- | --- | --- | --- |
| Tissue Test: N | --- | L | --- | --- | --- | --- | --- |
| P | --- | M | --- | --- | --- | --- | --- |
| K | --- | L | --- | --- | --- | --- | --- |
| 9. Weed Infestation | | | | | | | |
| Grasses | L | H | H | --- | L | L | L |
| Sedges | L | H | H | --- | L | L | L |
| Leaves | L | H | H | --- | L | L | L |
| 10. Method of Control | Manual | Manual | Manual | Manual | Manual | Manual | Manual |
| 11. Diseases | Leaf curl-L | n.e. | n.e. | Leaf curl-L | Leaf curl-L | Leaf curl-M | Leaf curl-M<br>Collar rot-M |
| 12. Pest Incidence | White fly-L | n.e. | n.e. | White fly-L | White fly-L | n.e. | --- |
| 13. Other Observations | | | | | | | |

Table A-8 (continued). Crop Data for the Upper, Middle, and Lower Reaches of Turnouts Located in Block 302

| | D.3/T.O. 5 | | D.3/T.O. 8 | | |
|---|---|---|---|---|---|
| Crop Observations | 52 | 62 | 87 | 98 | 98 |
| 1. Crop | Paddy | Paddy | Paddy | Chili | Cowpea |
| 2. Variety | - | - | - | - | - |
| 3. Spacing (cm) | - | - | - | 50 x 55 | 80 x 55 |
| 4. Sowing Method | B/C | B/C | B/C | - | - |
| 5. Stage of Growth | P.I. | Tillering | Early Vegetative | Early flowering to pod formation | Pod formation |
| 6. Approx. Plant. Time | 5-6 | 5-6 | --- | --- | --- |
| 7. Condition | | | | | |
| Overall Assessment | Avg-Above Avg. | Avg-Poor | | | Avg-Poor |
| Population | 19.6 | 15.3 | 14 | 4 | |
| Plant Height (cm) | 49.6 | 37.9 | 20.0 | 42.7 | 50 |
| 8. Nutrient Status | | | | | |
| Visual: N | no visual deficiency | no visual deficiency | --- | --- | --- |
| P | | | --- | --- | --- |
| K | | | --- | --- | --- |
| Tissue Test: N | --- | --- | L | --- | --- |
| P | --- | --- | M | --- | --- |
| K | --- | --- | L | --- | --- |
| 9. Weed Infestation | | | | | |
| Grasses | L-M | M-H | L | L | L |
| Sedges | L-M | M-H | L | M | M |
| Leaves | L | L | L | L | L |
| 10. Method of Control | - | - | - | - | - |
| 11. Diseases | n.e. | n.e. | n.e. | leaf curl-L | n.e. |
| 12. Pest Incidence | stem borer-25% but sprayed against | Thrips-Low | Thrips-L | Whitefly-L | Pod borer-M Aphids-M |
| 13. Other Observations | | | 1 acre paddy rest fallowed | | poor mgt no fertilizing |

Table A-8 (continued). Crop Data for the Upper, Middle, and Lower Reaches of Turnouts Located in Block 302

| | D.4/T.O. 3 | | | | D.4/T.O. 10 | |
|---|---|---|---|---|---|---|
| Crop Observations | 38 | 38 | 46 | 46 | 140 | 140 |
| 1. Crop | Chili | Paddy | Paddy | Chili | Chili | Paddy |
| 2. Variety | $MI_2$ | BG276-5 | BG34-8 | $MI_2$ | $MI_2$ | - |
| 3. Spacing (cm) | 45 x 36 | - | - | 60 x 47 | 45 x 40 | - |
| 4. Sowing Method | Transplant | B/C | B/C | Transplant | Transplant | Transplant |
| 5. Stage of Growth | 2nd bloom | PI | PI | 2nd bloom | 1st bloom to pod bearing | tillering |
| 6. Approx. Plant. Time (wk) | 10 | 5 | 6 | 12 | | |
| 7. Condition: | | | | | | |
| Overall Assessment | Avg | Poor | Poor | Good | Avg | Poor |
| Population | | | | 23 | 6 | 20 |
| Plant Height (cm) | 35.7 | 7 | 15 | 35 | | 7 |
| 8. Nutrient Status | | | | | | |
| Visual: N | --- | --- | --- | --- | --- | --- |
| P | --- | --- | --- | --- | --- | --- |
| K | --- | --- | --- | --- | --- | --- |
| Tissue Test: N | --- | L | L | --- | --- | L |
| P | --- | M | M | --- | --- | L |
| K | --- | L | L | --- | --- | L |
| 9. Weed Infestation | | | | | | |
| Grasses | L | H | H | L | L | L |
| Sedges | L | H | H | L | L | M |
| Leaves | L | H | H | L | L | L |
| 10. Method of Control | Manual | No Control | No Control | Manual | Manual | Chemical |
| 11. Diseases | leaf curl-L | n.e. | n.e. | Leaf curl-L | Leaf curl-M | n.e. |
| 12. Pest Incidence | Whitefly-L | n.e. | n.e. | White-fly-L | n.e. | n.e. |
| 13. Other Observations | | | Crop area-10% | Crop area-40% | | |

Table A-8 (continued). Crop Data for the Upper, Middle, and Lower Reaches of Turnouts Located in Block 302

| Crop Observations | D.3/T.O. 5 | | | D.3/T.O. 8 | |
|---|---|---|---|---|---|
| | 58 | 56 | 55 | 96 | 94 |
| 1. Crop | Paddy | Paddy | Paddy | Chili | Chili |
| 2. Variety | - | - | - | - | - |
| 3. Spacing (cm) | - | - | - | 52 x 68 | 50 x 50 |
| 4. Sowing Method | B/C | B/C | B/C | - | - |
| 5. Stage of Growth | Tillering | Tillering | PI | First bloom to pod bearing | early part of maturity |
| 6. Approx. Plant. Time (wk) | 3-4 | 3-4 | 4-5 | 6-7 | - |
| 7. Condition | | | | | |
| Overall Assessment | Above avg | Avg | Avg | | |
| Population | 20.4 | 14.5 | 21.6 | 4 | 6 |
| Plant Height (cm) | 39.6 | 33.2 | 42.8 | 39.7 | 41.3 |
| 8. Nutrient Status | | | | | |
| Visual: N | General deficiency in isolated patches (ill distribution of fertilizer) | --- | no visual deficiency | --- | --- |
| P | | --- | | --- | --- |
| K | | --- | | --- | --- |
| Tissue Test: N | --- | --- | --- | --- | --- |
| P | --- | --- | --- | --- | --- |
| K | --- | --- | --- | --- | --- |
| 9. Weed Infestation | | | | | |
| Grasses | L | H | M | --- | L |
| Sedges | L | H | H | --- | L |
| Leaves | L | H | M | --- | L |
| 10. Method of Control | - | No Control | - | Manual | Manual |
| 11. Diseases | n.e. | n.e. | Adjacent plot withered tips not identified | Leaf curl-L wilt-L | Leaf curl-L |
| 12. Pest Incidence | E. stem borer-controlled | | Army worm-L Wood maggot-L Whorl maggot | n.e. | n.e. |
| 13. Other Observations | | | | | |

Table A-8 (continued). Crop Data for the Upper, Middle, and Lower Reaches of Turnouts Located in Block 302

| | D.4/T.O. 3 | | | D.4/T.O. 10 | |
|---|---|---|---|---|---|
| Crop Observations | 41 | 42 | 43 | 137 | 135 |
| 1. Crop | Paddy | Paddy | Paddy | Paddy | Chili |
| 2. Variety | BG-34-8 | BG-34-8 | BG-34-8 | - | - |
| 3. Spacing (cm) | - | - | - | - | 50 x 45 |
| 4. Sowing Method | B/C | B/C | B/C | - | - |
| 5. Stage of Growth | PI | PI | PI | Tillering | 1st bloom to pod bearing |
| 6. Approx. Plant. Time (wk) | 5 | 5 | 5 | 3 | - |
| 7. Condition: | | | | | |
| Overall Assessment | Poor | Poor | Poor | Poor | Above Avg. |
| Population | 34 | 20(27) | 27 | 16 | |
| Plant Height (cm) | 12 | 15 | 18 | | |
| 8. Nutrient Status | | | | | |
| Visual: N | --- | --- | --- | --- | No |
| P | --- | --- | --- | --- | Visual |
| K | --- | --- | --- | --- | Deficiency |
| Tissue Test: N | L | L | L | L | --- |
| P | M | M | M | M | --- |
| K | L | L | L | M | --- |
| 9. Weed Infestation | | | | | |
| Grasses | H | H | H | H | L |
| Sedges | H | H | H | H | L |
| Leaves | H | H | H | H | L |
| 10. Method of Control | Chemical | Chemical | Chemical | Chemical | Manual |
| 11. Diseases | n.e. | n.e. | n.e. | n.e. | leaf curl-M |
| 12. Pest Incidence | n.e. | n.e. | n.e. | n.e. | n.e. |
| 13. Other Observations | 100% cropped | 100% cropped | 100% cropped | | |

earthing up at a later stage of growth giving the appearance of a ridge and furrow pattern of cultivation. However, damage due to waterlogging was probably high, as evidenced by a large number of spaces being replanted. Replaced plants were not vigorous enough for normal production. This indicated that either replanting of chilies was not successful or the weather had not been favorable after replanting. No visual symptoms of deficiencies were observed, and except for isolated cases of leaf curl, disease was not evident.

Pest-related problems were minimal, and the regular use of pesticide sprays was evident. Weeds were controlled well due to manual weeding. Stages of growth varied from first bloom through early pod bearing to pod ripening. Non-uniformity in planting time was evident even in a single allotment. Commonly, chili yields were average to above average, except for a few cases where the performance was below average. Farmers provided some of the basic inputs and tended the crop with care since chilies are a high-value crop.

4. Paddy

The varieties of paddy planted by the farmers were mostly the short duration varieties such as BG 276-5 and BG 34-8. Broadcast sowing and varied stages of growth were common throughout the turnout. The stages of growth varied from early tillering through primordia initiation to booting stage and even in isolated basins milky stage. The general crop conditions ranged from poor to average and in limited instances above average. Tiller densities during early tillering ranged from 12.6 to 15.3 per 900 $cm^2$. Densities of 20.4 to 33.3 tillers per 900 $cm^2$ were recorded in the average to above average plots. Appropriate spacing for a 3 to 3½ month duration variety of paddy, as recommended by the Department of Agriculture, was 15 x 15 cm. If the average number of productive tillers per plant was assumed to be five, then 900 $cm^2$ area should support 45 tillers. To obtain this value, the fields should be attended well with crop management practices such as weed control, fertilizer application, and irrigation.

Visual assessments of the nutrient status from general growth and nutrient deficiency symptoms indicated low nitrogen levels. Symptoms of nitrogen and potassium deficiency were observed in many of the basins. The recommended fertilizer applications for paddy are shown in Table A-9. The farmers had applied from less than half to none of the recommended fertilizer for paddy.

Weed infestations were high except for a few allotments in the lower reaches, where paddy was grown under inundated conditions. The most common weeds were sedges such as *Cyprus rotundus* and *Cyprus iria*, and grasses such as *Echinocloa* species. Broad leaf weed infestations did not appear to be serious. Commonly the field channels were poorly maintained with high infestations of weeds. The high weed infestation in the channels not only impeded the free flow of water but also provided a source of seed for the spread of weeds from allotment to allotment.

Table A-9. Fertilizer Recommendations for Paddy Based on Age of Maturity

| Variety | Age (Mos.) | Stage of Fert. Appl. | Fertilizer Type | Amount (kg/ha) |
|---|---|---|---|---|
| | | Basal Dressing | V mixture | |
| | | | N : P : K | |
| BG-276-5 | | | 3 : 30 : 10 | 184 |
| | 3 | 2 wks after B/C | Urea | 61 |
| BG-34-8 | | | | |
| | | 5 wks after B/C | Urea | 31 |
| | | 7 wks after B/C | T.D.M. | 123 |
| | | | N : K | |
| | | | 30:20 | |
| BG-94-1 | | Basal Dressing | V mixture | 184 |
| BG-34-6 | 3½ | 2 wks after B/C | Urea | 61 |
| | | 5 wks after B/C | Urea | 31 |
| | | 8 wks after B/C | T.D.M. | |
| BG-11-11 | | Basal Dressing | V mixture | 184 |
| BG-90-2 | 4-4½ | 2 wks after B/C | Urea | 61 |
| BG-400-1 | | 6 wks after B/C | Urea | 61 |
| BG-379-2 | | 10 wks after B/C | T.D.M. | 123 |

T.D.M. = Top dressing mixture
V mixture = Paddy fertilizer mixture
B/C = Broadcast

Pest incidence was generally low. Although there was evidence of a stem borer infestation during the early vegetative stages, it apparently was controlled by chemical spraying. Some fields showed that stem borers had infested 10-20 percent of the paddy. A broad spectrum systemic insecticide called "Ekalux" evidently controlled the stem borers. The Department's recommended chemicals for stem borer are carbofuran, diazinon 5% G, monocrotophos, and endosulfan 35% C. Other pests included thrips, army worms, and whorl maggots, but the incidence of these pests was low.

5. Summary of Findings

An overall assessment of the turnouts indicated that cultural practices for chilies were good. Agronomic practices such as pest and disease control and weed control were followed. Although specific chili fertilizer mixtures were not used, most farmers have used urea or "V" mixture (paddy fertilizer mixture) during the early stage of vegetative growth.

With regard to paddy, the cultivation was poor except for a few allotments which were located in the poorly drained areas where standing water was easily maintained. From the farmers' point of view, had the assurance of irrigation water been given, the crop would have received better attention, with more inputs.

Although some farmers reported sowing a particular variety, the fields were not cultivated with a pure variety. Apparently most farmers rely on their own seed rather than purchasing certified seed.

During the course of this study, it was revealed that the lowland areas are difficult to prepare with manual implements when there is a shortage of water. However, within most turnouts on the upper reaches of the D-channels, water applications were excessive. Over-irrigation, shallow water tables, and the lack of proper drainage facilities caused extensive waterlogging over large areas of the turnouts in the upper reaches. The waterlogged areas were also subjected to buildup of salinity. Although the settlements are only 7 years old, signs of salinity buildup, confirmed by electroconductivity measurements, indicated that waterlogging and salinity problems may become a more serious problem in the future.

In the well-drained areas of the upper reaches of the D-channels, the upland crops were over-irrigated and a high water table was observed. In addition, paddy grown in the lower reaches often did not receive the amounts of water required for normal growth.

Another observation came directly from unexpected showers that broke out during the Yala period. Most farmers started to grow short-duration varieties of rice such as BG 34-8 and BG 276-5 but subsequently found themselves in a quandary due to uncertainty regarding the water

supply. The initial enthusiasm totally disappeared. The farmers refused to apply fertilizer, permitted fields to overgrow with weeds and did not plant 20 to 40 percent of the area. Nothing can prevent such freak weather patterns in the future, but a more flexible attitude by the authorities in such circumstances could reassure farmers.

In addition to paddy, varieties of crops such as chilies, soybeans, cowpeas, red onions, and vegetables were grown. With the exception of chilies, all other crops were poorly managed. A proper extension system, emphasizing the proper use of water, is lacking.

The range in the stages of growth throughout the various allotments was obviously due to non-uniform planting time. Non-uniform planting dates imposed serious limitations with regard to pest and disease control. Non-synchronization of the planting time may have been due to the lack of farmer organizations, which are essential for effective water distribution. Also the lack of farmers' organization was depicted by the improper maintenance of field irrigation channels. Because of the poor maintenance of field irrigation channels, farmers at the tail-end of the irrigation system received less than adequate amounts of irrigation water. Also, the irrigation water carrying large quantities of weed seeds to the fields increased the weed infestation problems.

The following were considered to be the major constraints to crop production in block 302 of System H of the Mahaweli Irrigation Project:

(1) Waterlogging and salinity problems caused by over-irrigation, channel seepage, and improper drainage facilities.

(2) Adoption of unsuitable cropping patterns that do not conform to the soil conditions found in the project area.

(3) A lack of knowledge about irrigation of upland crops and the effects of water tables on these crops.

(4) Weed control in paddy in absence of standing water.

(5) Lack of incentives and facilities for the farmer to adopt improved cultural practices.

(6) Other soil problems: Observations suggested that within certain turnouts chemical problems existed in the soil. However, it was not possible to conduct a complete chemical analysis of soils to identify the causes.

## B. Engineering

### 1. Design and Operation of the Irrigation System

The Kalawewa reservoir is a regulating reservoir and is replenished regularly with water issued through the Mahaweli diversion. The water availability position elevated the Kalawewa reservoir to a distinctly advantageous situation in comparison to other unsupplemented reservoirs in Sri Lanka. The salient features of Kalawewa reservoir are given in Table B-1. As far as the network of channel systems is concerned, the scheme has been designed to supply the daily peak requirements based on the following factors:

(1) cropping pattern;

(2) crop calendar;

(3) farm water losses;

(4) conveyance water losses;

(5) effective rainfall; and

(6) crop-water requirements.

The left-bank main canal feeds a large number of D-channels. The lengths of the main, branch, distributary, and subdistributary are provided in Table B-2. The discharges in the main canal were designed to vary according to:

(1) monthly and seasonal variations due to changes in climate and cropping pattern;

(2) daily variation due to changes in application time for paddy and upland crops;

(3) daily variations due to the adjustments in D-channel discharges during rainy weather;

(4) upstream controlled main canals with regulating reservoirs used. The main canal conveys a continuous 24-hour discharge; and

(5) conveyance losses of 15 percent in D-channels and F-channels and a gross total of 25 percent for the entire system.

Table B-1. Salient Features of Kalawewa Reservoir

| | |
|---|---|
| Catchment Area | = 2,155 sq. km |
| Inflow from Mahaweli River | = 430,000,000 $m^3$ |
| Capacity of the Reservoir | = 123,000,000 $m^3$ |
| Full Supply Level | = 129.2 m M.S.L.[a] |
| Highest Flood Level | = 131.4 m M.S.L. |
| Total Length of Earth Dam | = 6 km |
| Length of the Ogee Spill | = 183.0 m M.S.L. |
| Crest Level | = 129.2 m M.S.L. |
| Length of Natural Spill | = 131.4 m |
| Sluice Sill Levels | |
| a. New Left Bank Sluice | = 121.9 m M.S.L. |
| b. Balaluwewa Sluice | = 121.6 m M.S.L. |
| c. Goda Ela Sluice | = 120.1 m M.S.L. |
| d. Yoda Ela Sluice | = 118.9 m M.S.L. |
| e. New Right Bank Sluice | = 121.9 m M.S.L. |
| Discharge of the Canal at Head Sluice | |
| a. New Left Bank Sluice | = 12.1 $m^3$/sec |
| b. Balaluwewa Sluice | = N/A |
| c. Goda Ela Sluice | = 1.6 $m^3$/sec |
| d. Yoda Ela Sluice | = 8.2 $m^3$/sec |
| e. New Right Bank Sluice | = 13.3 $m^3$/sec |
| Command areas - new land | = 20,182 ha |
| - existing land | = 5,263 ha |
| total land | = 25,445 ha |
| Length of New Left-Bank Main Canal | |

[a]M.S.L. - Main Sea Level

Table B-2. Length of Canals on Left Bank (m)

| Block Number | Main Canal | Branch Canal | Distributary Channel | Subdistributary Channel |
|---|---|---|---|---|
| 301 | 8,384 | -- | 1,220 | 1,220 |
| 302 | 7,317 | -- | 11,524 | 5,396 |
| 303 | 2,073 | -- | 4,207 | 305 |
| 304 | 2,744 | -- | 9,299 | 5,000 |
| 305 | -- | -- | 7,561 | 5,701 |
| 306 | -- | 5,640 | 8,476 | 1,829 |
| 307 | -- | 976 | 8,841 | 1,311 |
| 308 | -- | 4,238 | 4,055 | 762 |
| 309 | -- | 5,518 | 5,457 | 1,280 |
| 310 | 5,102 | -- | 3,780 | 762 |
| 311 | 793 | 5,945 | 3,079 | 1,799 |
| 312 | 305 | -- | 4,665 | 4,268 |
| 313 | -- | 4,878 | 5,640 | 5,457 |
| 314 | -- | 4,268 | 9,451 | 1,768 |
| TOTAL | 26,747 | 33,464 | 92,531 | 36,555 |

NOTE: Main canal length does not include the portion of tanks which are used for regulation in between its pass.

The control structures were designed according to the following conditions:

(1) Gated regulators in the main/branch canal and weir type regulators in D-channels have been provided to enable the delivery of water to the D- and F-channels, respectively.

(2) Dividers are provided across the channel to divide the discharge into two or more channels;

(3) Turnout structures with cast-iron gates are provided to control and issue water from the main canal, branch canal, and D-channels to F-channels. Gates are lockable, but manipulations by farmers to obtain water also take place;

(4) Farm turnouts are provided with 15-cm diameter circular openings. Provision has also been made in the design to construct the headwalls with two grooves so as to insert a plank.

(5) Measuring devices were expected to be constructed at the head of all canals to measure discharges: Parshall flumes at the head of main canal and branch canals, with weirs and hump-type flumes at the turnout structures for D- and F-channels.

Irrigation systems served by the Mahaweli diversion are now linked to a National Grid to obtain their allocation of water. Long before the commencement of the season, an approximation of water available through the diversion was made by the Mahaweli Authority and recommendations were made to the Mahaweli Water Management Panel which meets in Colombo for the final allocation of water among reservoirs served by the Mahaweli river diversion scheme. This is comprised of the personnel from the Mahaweli agencies, Secretaries of Mahaweli Development and Lands and Land Development Ministry together with the Government Agents of the respective districts. The panel is considered the premier high-level institution which sets out some of the criteria which relate to the allocation of water and the selection of cropping patterns at each project level for decision-making forums.

Following the recommendations of the Water Management Panel, cultivation meetings are summoned in terms of the provisions of the Irrigation Ordinance to obtain the farmers' approval for decisions concerning the cultivation calendar, cropping pattern and the enforcement of various measurements required to go through the cultivation season. In areas served by the Kalawewa reservoir, several such meetings are held to facilitate a better interaction among farmers and officials.

At the commencement of the season, the Mahaweli Authority officials take the following matters into consideration in preparing the schedules for water issues:

(1) cropping pattern;

(2) period required for land preparation;

(3) normal repetitive period; and

(4) conveyance losses in the distribution system.

The original design criteria of the project was to supply 64 mm/ha/week for paddy and 38.5 mm/ha/week for upland crops. The turnout discharge thus had to be decided on the basis of the area under different crops. However, the actual operational schedule was based on 64 mm/ha/week irrespective of crops being grown, crop staggering, and soil conditions.

The following procedures are planned to operate the system and issue water to the command areas.

(1) Main canal - continuous water issues.

(2) Branch canal - issues scheduled for six days of the week.

(3) D-channel - continuous or intermittent, but 3 to 4 days issues are preferred.

(4) F-channel - depending on the number of allotments to feed, F-channels are kept open for four days with a discharge of 28 l/s to feed every four allotments (4 ha) per day at the rate of 63.5 mm of water for a week's period.

The operational staff is divided into four main categories in terms of their functional levels.

(1) Deputy Resident Project Manager (Water Management) who has overall supervision of issues to and from the reservoir and water levels of the same. The irrigable area under supervision is 8,100 to 12,150 ha (20,000 to 30,000 acres).

(2) Operational staff in the main and branch canals consists of an Irrigation Engineer with an Engineering Assistant and water management supervisors assisting. Their functions are mainly monitoring, regulating, and issuing water to D-channel heads as per schedules prepared for this purpose. The irrigable area under supervision by this unit is about 2,429 ha (6,000 acres).

(3) D-channel operational staff consists of an Engineering Assistant, Unit Manager and Field Assistant or ditch rider, who are responsible for allocation of water at the F-channel head. The irrigable area under the supervision is about 253 ha.

(4) F-channel operation is attended by the ditch rider assisted by a farm leader. This group receives the responsibility for water distribution among allotments on an hourly basis as per schedule. The number of farmers under each F-channel is about 16.

In real terms, the farmers have little control on some of the key issues since the system is linked to the Mahaweli water grid. This grid requires that the Mahaweli Authority exercise central control on water allocation to different systems.

2. Water Conveyance and Distribution System

This system consists of the main and branch canals, and D- and F-channels. The Diagnostic Analysis concentrated its efforts on the D- and F-channels.

a. Distributary Channels

To evaluate the dependability and adequacy of the distribution system, the flow rates into different distributaries were measured. These measurements showed that the water supply was not dependable, and in some cases not adequate. Sometimes the amount was as much as 51 percent more D-channel 5 in block 301 and 25 percent less D-channel 2 in block 302 than the design amount (Table B-3).

The flow rate measurements were also used to evaluate losses in the D-channels. The conveyance losses in the two sections of D-channel 3 are 2.83 percent and 7.29 percent over a length of 1,000 m of the channel (Table B-4). The percentage conveyance losses in D-channel 4 and its subdistributary are 5.5 percent and 17.42 percent, respectively, over a length of 1,000 meters (Table B-5). The loss of 17.42 percent per 1,000 m length in subdistributary channels appears to be excessive, due to the leaks in the turnouts, the channel spill, and the crest level which has been temporarily raised by sandbagging.

The topographical survey data of the channels was used to compute the gradients of the channels in evaluating the erosion potential of the channels. The longitudinal profiles of the channels are presented in Figures B-1, B-2, B-3, and B-4. The bed gradients of the channels have changed from the designed gradient of 0.0004, due to relative settlement of the structures causing scours at the channel bed. If the elevations of the sills of the structures are higher than the design elevation, due to faulty construction or settlement, the siltation of the channel bed will take place on the upstream side of the structure. The lowering of the sills of the structures by farmers (for better flow) may result in scouring of the channel and steepening of the bed gradient. The existing channel bed gradients are shown in Table B-6.

The D-channels were designed with a standard cross-section (Figure B-5). At several sections, the actual cross-sections (Figure B-6 and B-7) were different from the original design due basically to

Table B-3. Irrigation Characteristics of Distributaries under Blocks 301 and 302

| Channel Description | Area | Duty mm/week | Water Requirement ($m^3$) | Measured Discharge ($m^3$/sec) | Period Days | Measured Quantity ($m^3$) | Actual Qty. Delivered ($m^3$) | Deficit or excess (%) |
|---|---|---|---|---|---|---|---|---|
| D-channel 5/301 | 95.0 | 38.1 | 36,195 | 0.249 | 3 | 64,531 | 54,859 | +51.6% |
| D-channel 6/301 | 65.8 | 38.1 | 25,070 | 0.168 | 3 | 43,546 | 37,013 | +47.6% |
| D-channel 1/302 | 134.6 | 38.1 | 51,282 | 0.300 | 3 | 77,760 | 61,096 | +28.8% |
| D-channel 2/302 | 35.4 | 38.1 | 13,487 | 0.046 | 3 | 11,923 | 10,134 | -24.8% |
| D-channel 3/302 | 146.7 | $\frac{63.5}{38.1}$ | 51,487 | 0.281 | 3 | 72,835 | 61,910 | +20.24% |
| D-channel 4/302 | 297.5 | $\frac{63.5}{38.1}$ | 118,480 | 0.778 | 3 | 201,658 | 171,409 | +44.6% |
| D-channel 5/302 | 69.8 | 38.1 | 26,593 | 0.106 | 3 | 27,475 | 23,353 | -12/18% |

1. Water requirement on-farm based on 63.5 mm per week and 38.1 mm per week designed field water use rate for paddy and other field crops.

2. Water delivered to F-channel turnout with 15% designed conveyance loss accounted.

Table B-4. Flow Measurements of D-Channel 3 and F-Channel Turnouts

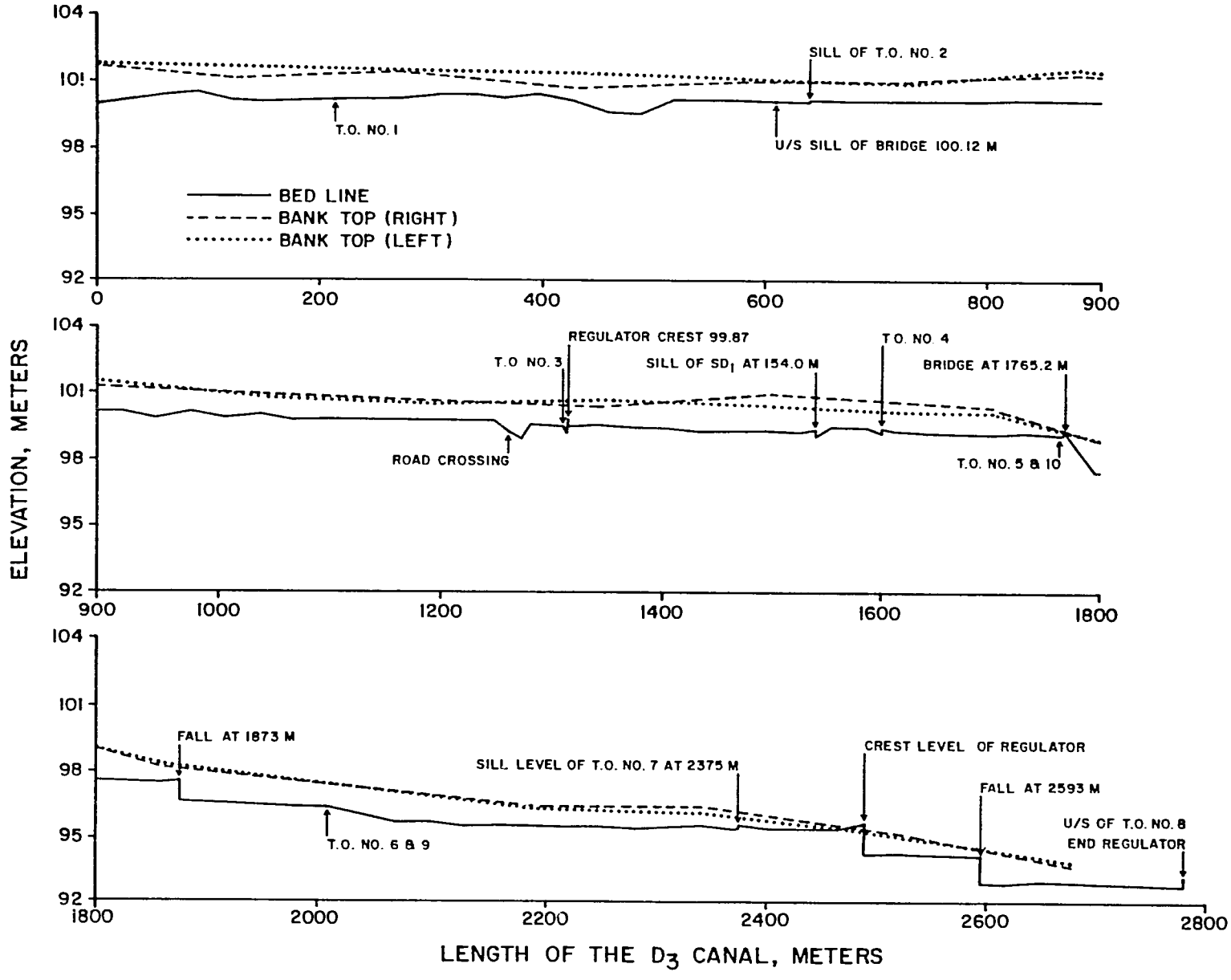
| Date | Description of Channel or Structure | Location | Method Used | Maximum Designed Discharge $m^3/sec$ | Operational Discharge $m^3/sec$ | Observed Discharge $m^3/sec$ |
|---|---|---|---|---|---|---|
| 18/07/82 | D.3/302 | D/S[2/] of headgate | Current meter | 0.255 | 0.255 | 0.284 |
| | T.O. 1 | | Cutthroat Flume | 0.028 | 0.028 | 0.0008 |
| | T.O. 1A | | do | 0.028 | 0.028 | 0.019 |
| | T.O. 2 | | do | 0.028 | 0.028 | 0.017 |
| | T.O. 3 | | do | 0.028 | 0.028 | 0.013 |
| | T.O. 4 | | | 0.028 | 0.028 | 0.024 |
| | Uncontrolled pipe outlet | | - | -- | 0.0 | 0.010 |
| | S.D.1[1/] | | do | -- | -- | 0.059 |
| | D.3/302 | 1765 m D/S of headgate | Current meter | -- | -- | 0.127 |
| | T.O. 5 | | Cutthroat Flume | 0.028 | 0.028 | 0.024 |
| | T.O. 6 | | do | 0.028 | 0.028 | 0.016 |
| | T.O. 7 | | do | 0.028 | 0.028 | 0.0096 |
| | T.O. 8 | 2780 m D/S of headgate | do | 0.028 | 0.028 | 0.011 |
| | T.O. 9 | | do | 0.028 | 0.028 | 0.018 |
| | T.O. 10 | | do | 0.028 | 0.028 | 0.039 |

[1/] Subdistributary channel 1. 4.99% loss along 1,765 meters of D.3. 7.39% loss along 1,015 meters of D.3.
[2/] D/S = downstream.

Table B-5. Flow Measurements of D-Channel 4 and F-Channel Turnouts

| Date | Descr ption of Channel or Structure | Location | Method Used | Maximum Designed Discharge ($m^3$/sec) | Operational Discharge ($m^3$/sec) | Observed Discharge ($m^3$/sec) |
|---|---|---|---|---|---|---|
| 14/7/82 | D.4/302 | D/S of headgate | Current meter | 0.623 | 0.510 | 0.687 |
| | D.4/302 | 1,810 m D/S of headgate | do | -- | -- | 0.556 |
| | T.O. 1 | | Cutthroat Flume | 0.0283 | 0.0283 | 0.036 |
| | T.O. 2 | | do | 0.0283 | 0.0283 | 0.025 |
| | T.O. 3 | | do | 0.0283 | 0.0283 | 0.0386 |
| | T.O. 4 | | do | 0.0283 | 0.0283 | 0.0280 |
| | T.O. 5 | | do | 0.0283 | 0.0283 | 0.0449 |
| | T.O. 6 | | do | 0.0283 | 0.0283 | 0.166 |
| | T.O. 11 | | do | 0.0283 | 0.0283 | 0.0280 |
| | S.D. 1 | U/S of T.O. 10 | Current meter | -- | -- | 0.143 |
| | D.4 | 1895 m U/S of bifurcation | do | -- | -- | 0.514 |
| | S.D. 1 | D/S of bifurcation | do | 0 | 0 | 0.28 |

10% loss along 1,810 meters of D.4. 13.0% loss along 740 meters of S.D.1.
D/S = downstream. U/S = upstream.




igure B-1. Longitudinal Section of D-channel 3

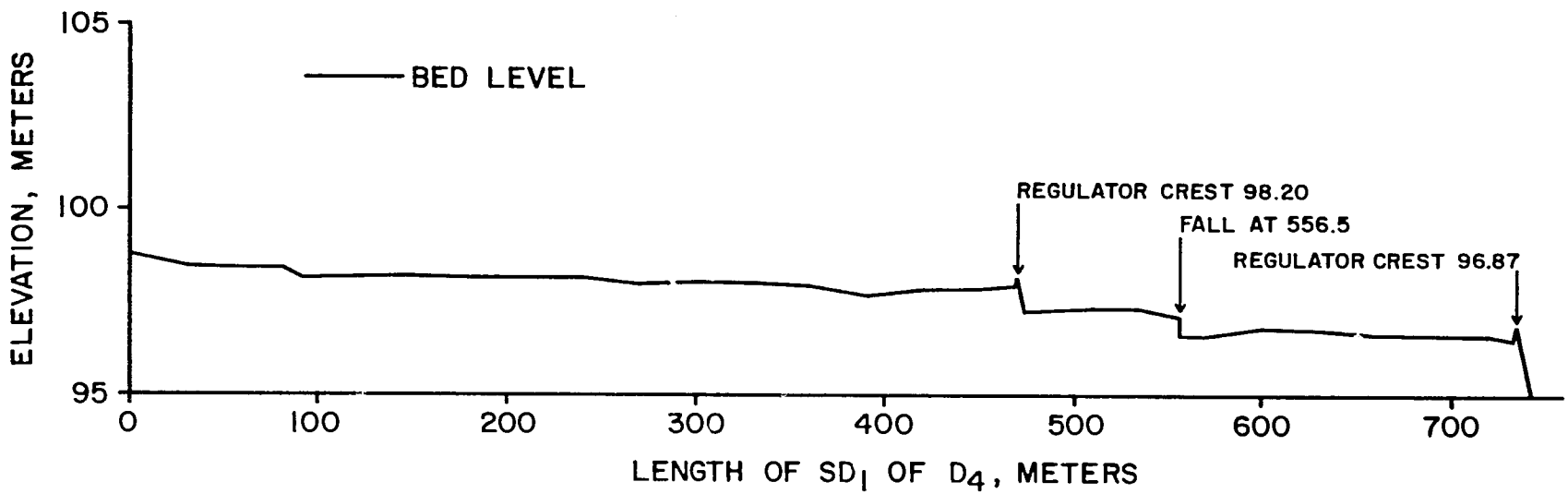



Figure B-2. Longitudinal Section of Subdistributary Channel 1 of D-channel 4

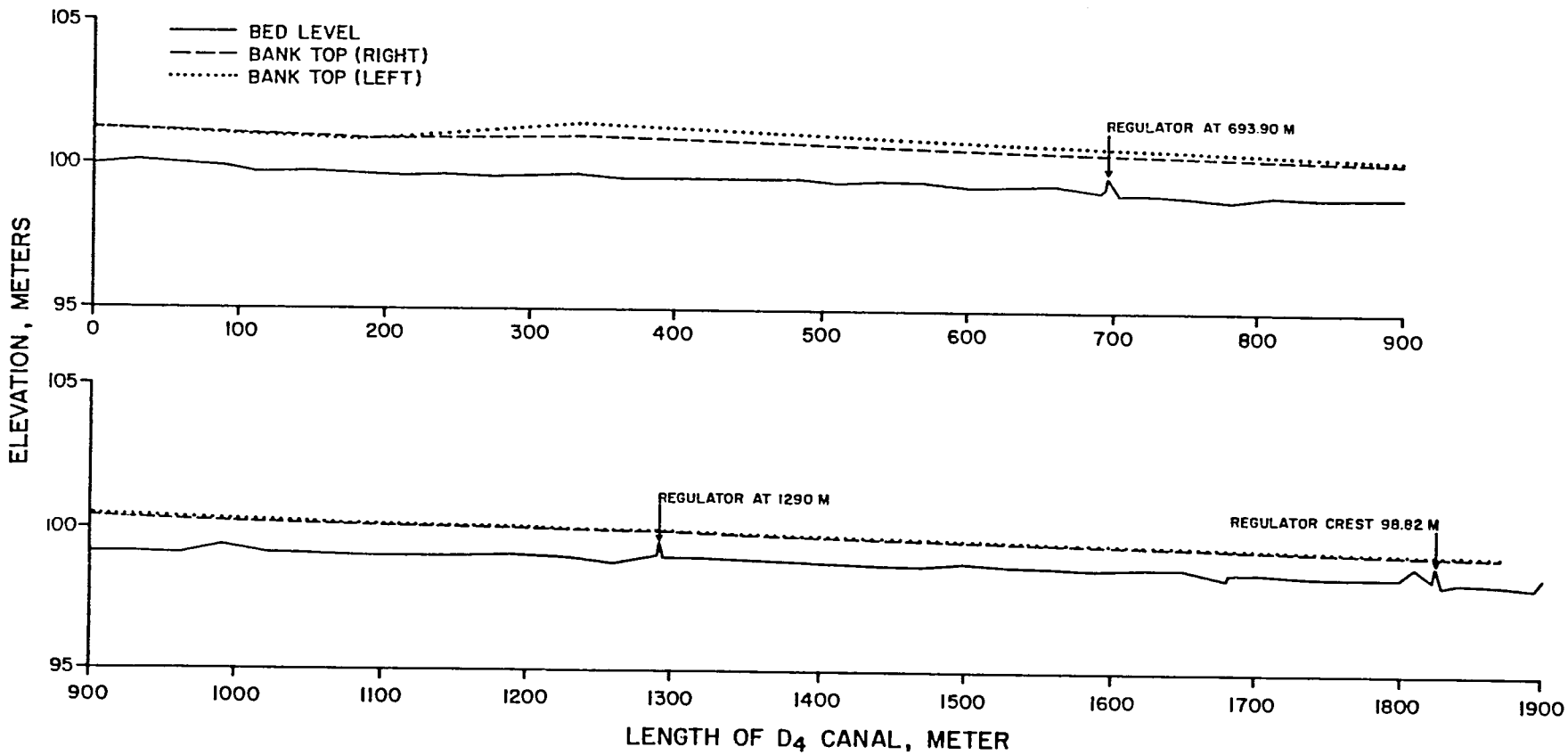



Figure B-3. Longitudinal Section of D-channel 4

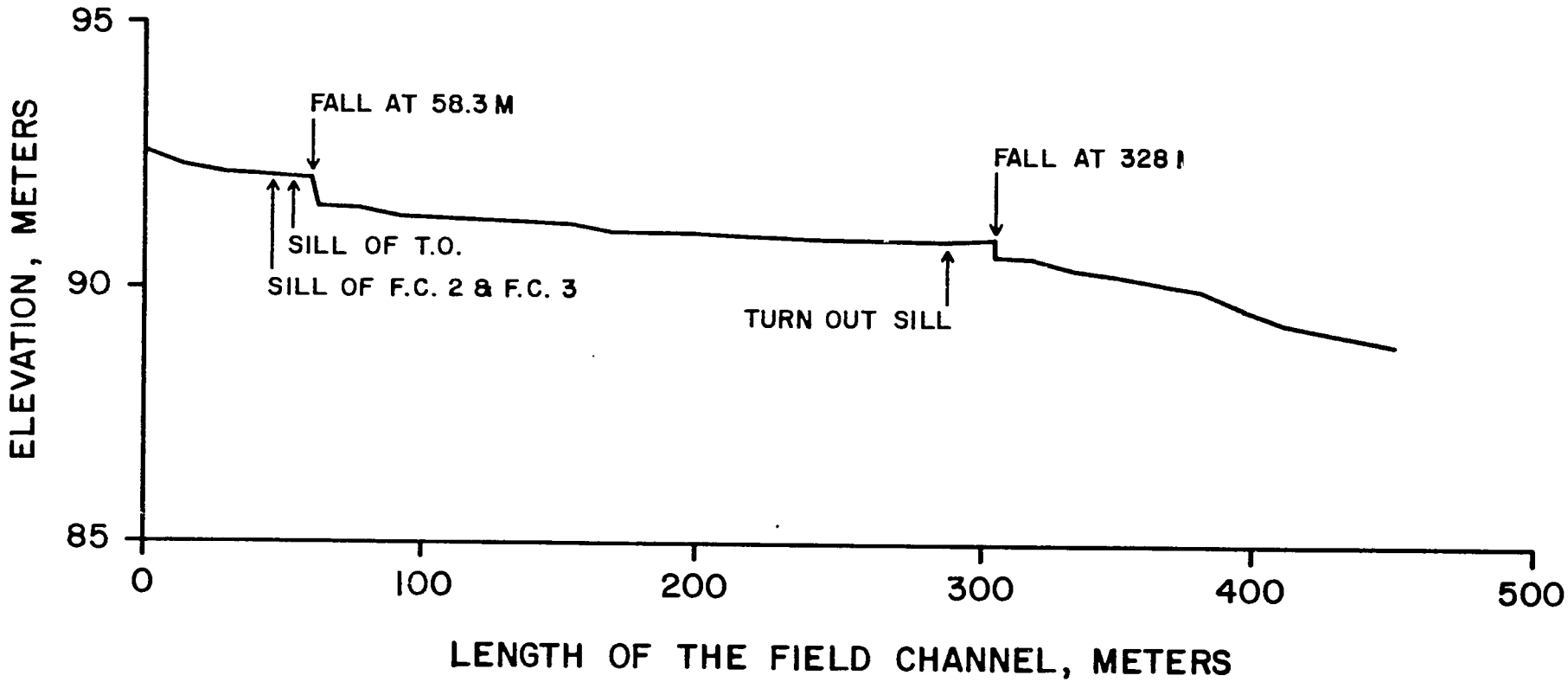



Figure B-4. Longitudinal Section of F-channel 1 under D-channel 3

Table B-6. Measured Gradients of D-Channels and F-Channels*

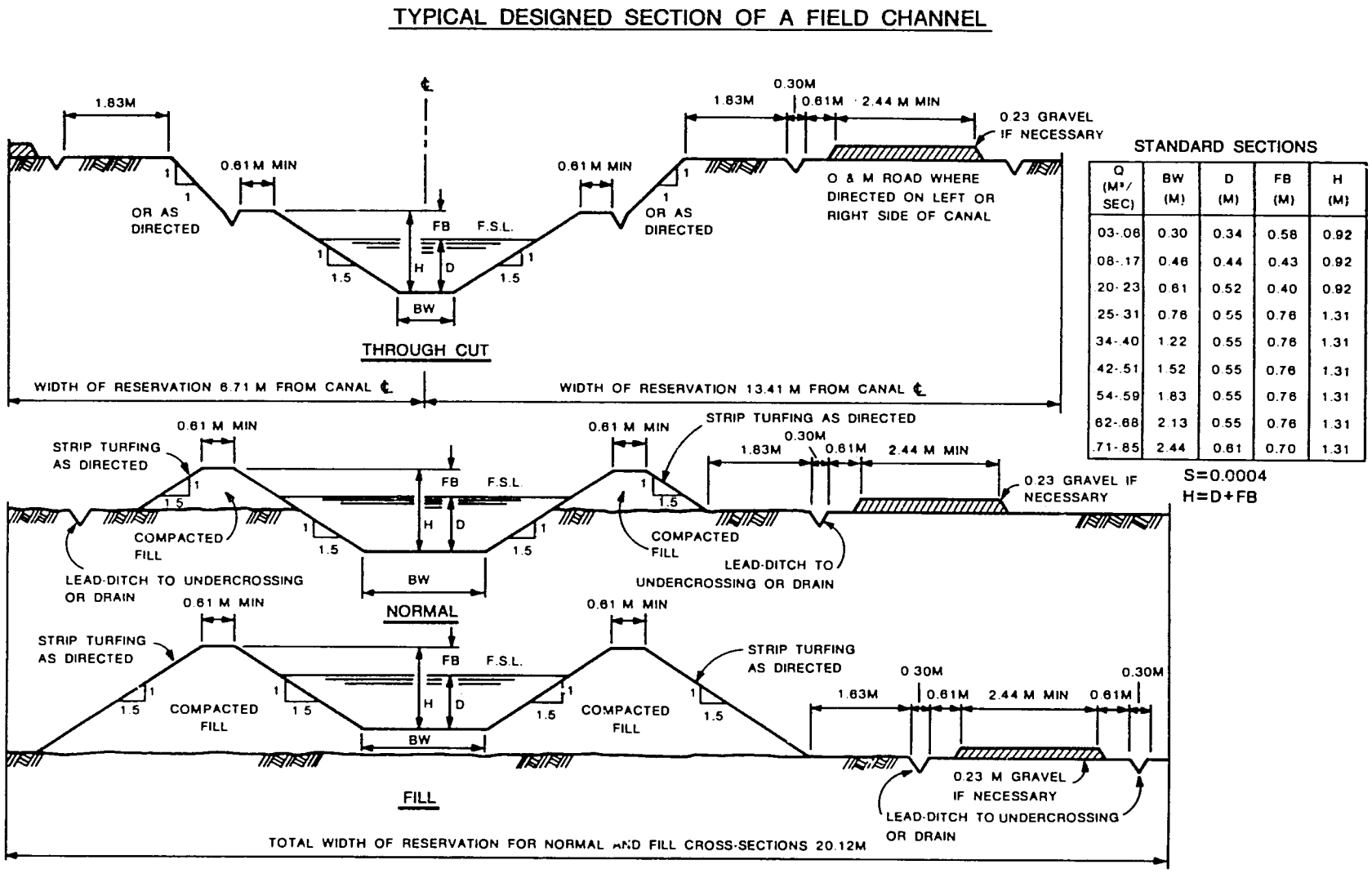
D-Channel 3

| Location (m) From | Location (m) To | Length (m) | Level Difference (m) | Gradient |
|---|---|---|---|---|
| 0 | 610 | 610 | 0.122 | 0.0002 |
| 610 | 1223 | 613 | 0.820 | 0.00133 |
| 1316 | 1765 | 449 | 0.312 | 0.00069 |
| 1777 | 1873 | 96 | 0.052 | 0.00054 |
| 2489 | 2593 | 104 | 0.034 | 0.00032 |
| 2593 | 2780 | 187 | 0.113 | 0.0006 |
| F-channel 1 under T.O. 8 | | | | |
| 76 | 305 | 229 | 0.649 | 0.0028 |
| 305 | 449 | 144 | 1.582 | 0.0109 |

D-Channel 4

| Location (m) From | Location (m) To | Length (m) | Level Difference (m) | Gradient |
|---|---|---|---|---|
| 0 | 694 | 694 | 0.654 | 0.00093 |
| 703 | 1290 | 587 | 0.105 | 0.00017 |
| 1294 | 1682 | 388 | 0.43 | 0.0011 |
| 1704 | 1882 | 118 | 0.16 | 0.00125 |
| Subdistributary Channel 1 | | | | |
| 0 | 466 | 466 | 0.97 | 0.002 |
| 472 | 556 | 84 | 0.075 | 0.0008 |
| 563 | 734 | 170 | 0.07 | 0.0004 |
| F-channel 1 under T.O. 3 | | | | |
| 0 | 64 | 64 | 0.04 | 0.00063 |
| | 67 | 95 | 28 | 0.15 |
| 98 | 129 | 31 | 0.03 | 0.00096 |
| 132 | 159 | 27 | 0.07 | 0.00259 |
| 162 | 198 | 36 | 0.11 | 0.00305 |
| 201 | 287 | 86 | 0.005 | 0.00052 |

*The gradients of the channels were taken in section by section between adjacent structures.
NOTE: Designed gradient is 0.0004.




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 |

Figure B-5. Design Cross-sections of D- and F-channels

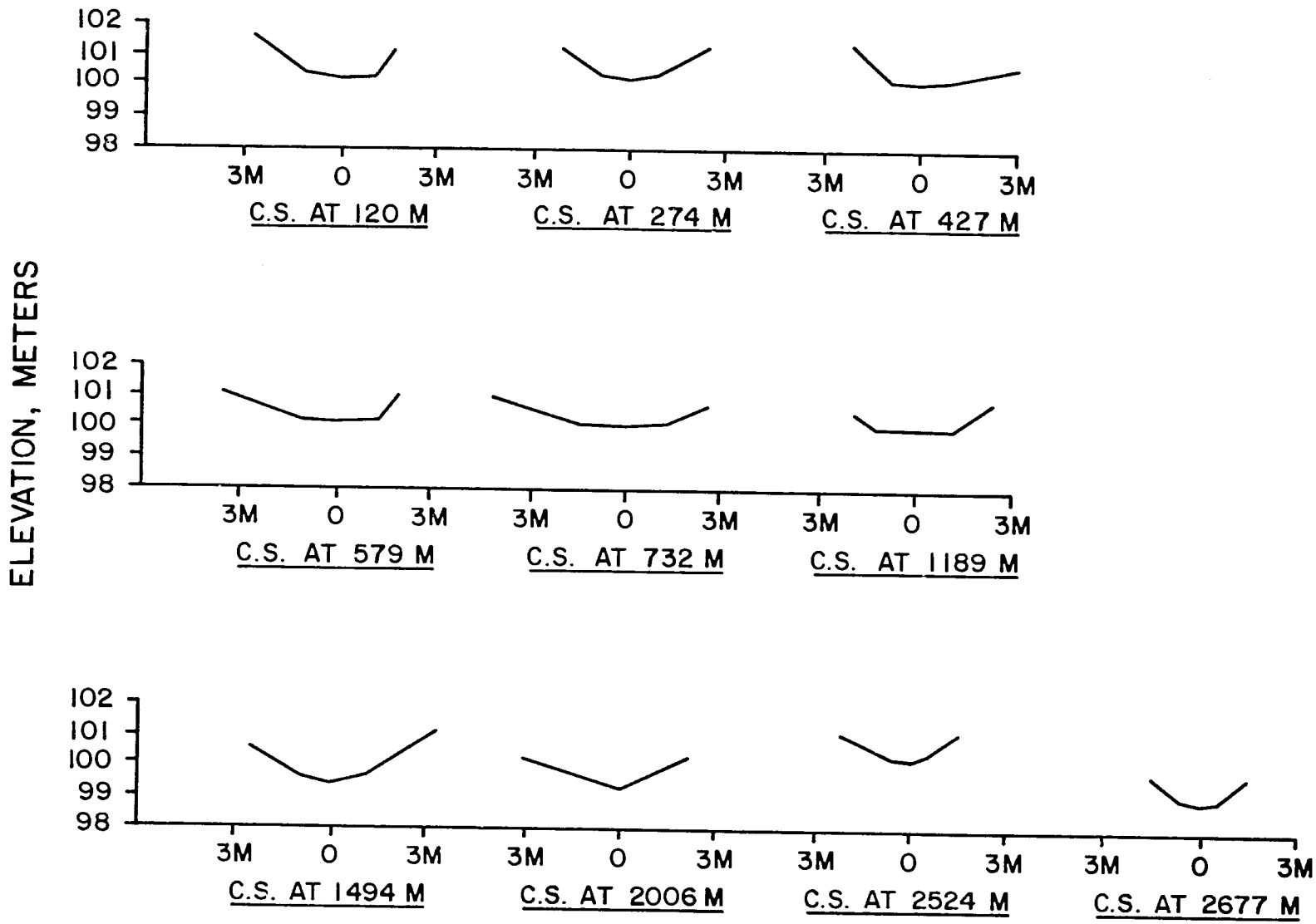



Figure B-6. Cross-section of D-channel 3

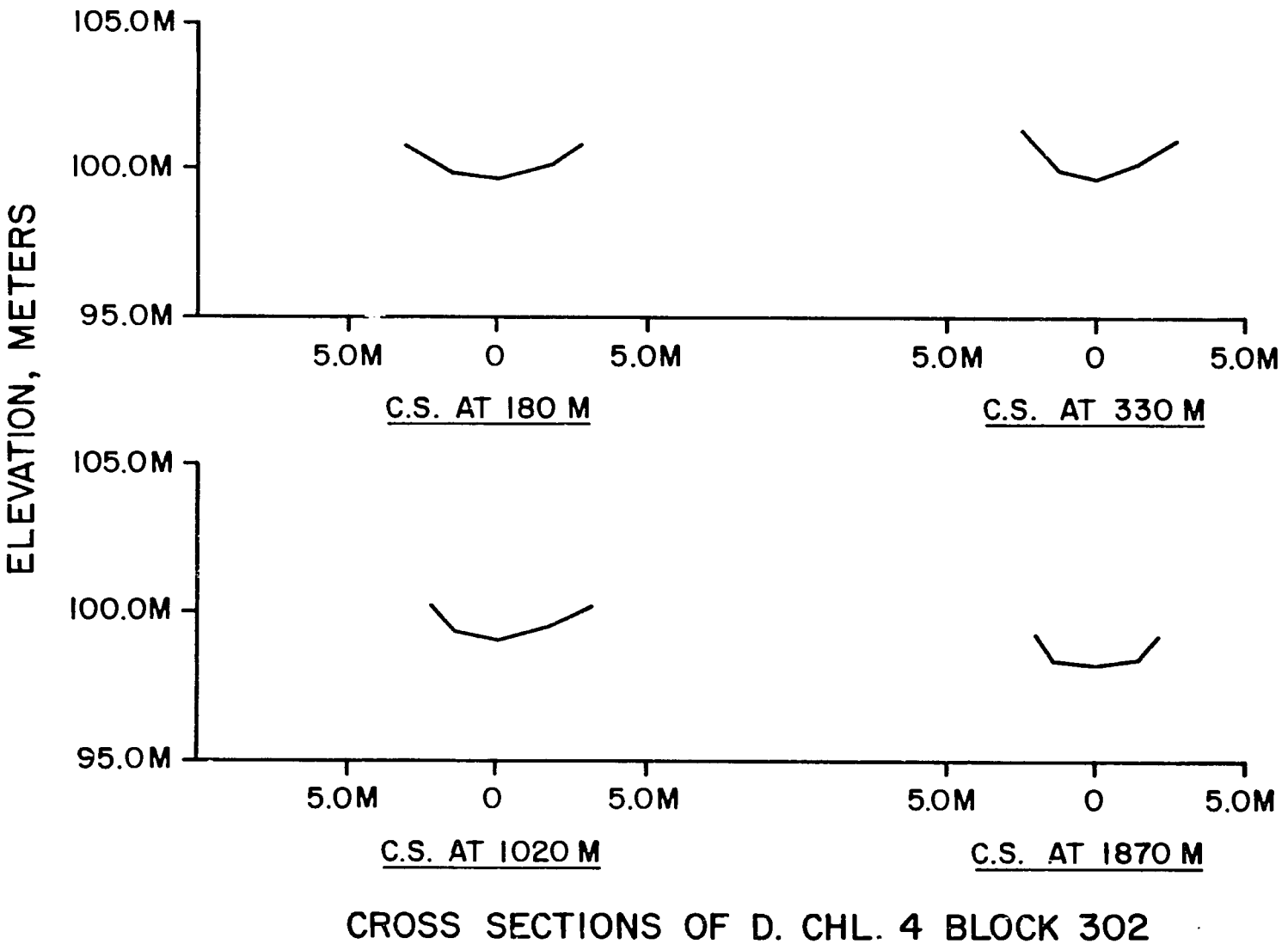



Figure B-7. Cross-section of D-channel 4

erosion and sedimentation. The cross-sections varied significantly along the length of the channels.

Except for 137 m of lined section at the beginning of D-channel 3, the balance of the earthen section appeared irregular in shape. The average width of the channel was 3 m (10 ft) compared to the designed width of 1 m. Due to scour, the channel banks eroded and had vertical side slopes.

The average width of D-channel 4 was 4 m (13 ft), and the entire length of the channel was on earth excavation. Generally, the banks were vertical at some locations due to cattle damage and overgrown with weeds. This deviation of gradient affected the flow velocity, causing scouring or siltation.

The actual variations in elevation of the structures and the canal gradient could not be checked due to non-availability of the plans showing longitudinal and cross-sections as per original design.

The headgate located at the beginning of D-channel 3 was without a measuring device, but it was in satisfactory working condition. Out of nine check regulators and turnouts, eight were in poor condition. The major defects were damage to the weir crests of check regulators, siltation upstream and downstream of the check regulators, and scouring around structures. One of the most common features observed was submergence and siltation of the downstream cushion of the measuring weirs. In some structures, the wing walls were scoured and even moved from the original location. The spill and causeway were in poor condition, while the road crossings were in relatively good condition. These structures were not regularly maintained, and the function of each structure was not well considered in the system operation.

On D-channel 4, five out of six check regulators and turnout structures were in poor working condition. Their major defect was scouring or siltation at the upstream or downstream of the regulator or siltation of the downstream cushion of the measuring weir. The farmers manipulated the gates. The bifurcation structure was without gates and does not function as per design due to its location in a curved section of the channel. The water level in the channel was raised by sandbagging the spill cum causeway. Unlike D-channel 3, this channel had fewer measuring weirs at field turnouts, most of which were not functioning effectively due to siltation and submergence. No measuring device was provided at the head of the D-channel 4.

As per the information gathered from the officials, the actual rotational schedule practiced differed from the designed schedule. In practice, the water was issued to the D-channel for three days per week with an increased discharge. The staff of the Unit Manager's office controls the discharge.

b. Field Channels

The F-channels are designed to carry a flow rate of 28 l/s. This stream would be turned into two farms for 12 hours to provide nearly 64 mm/ha/week. When the turnout area is entirely planted with upland crops, the F-channel discharge is provided only during the daytime.

The area cultivated under different crops in the four study sites, which represented the general cropping pattern of the head-end D-channels, is presented in Table B-7.

Table B-7. Area Cultivated under Different Crops in the Four Study Sites

| Study Site | Crop | Percentage of Area |
|---|---|---|
| D.3/T.O. 5 | highland crops (mainly chilies) | 11 |
| | paddy | 68 |
| | fallow | 20 |
| D.3/T.O. 8 | chilies | 42 |
| | pulses | 6 |
| | paddy | 8 |
| | fallow | 44 |
| D.4/T.O. 3 | chilies | 42 |
| | paddy | 38 |
| | fallow | 20 |
| D.4/T.O. 10 | chilies | 67 |
| | soybean | 8 |
| | paddy | 18 |
| | fallow | 7 |

D.3/T.O. 5 - Head-end turnout of D-channel 3

D.3/T.O. 8 - Tail-end turnout of D-channel 3

D.4/T.O. 3 - Head-end turnout of D-channel 4

D.4/T.O. 10 - Tail-end turnout of D-channel 4

Neither the D-channels nor the F-channels were provided with facilities for measuring water delivery. Water distribution to the D-channel and to the F-channel was done simply by guesswork of the ditch rider (jalapalaka) who was responsible for allocating water to the various sections under the distributary. The discharge measurements at the turnout gate showed that a delivery of 28 l/s to the turnout areas was not taking place as planned. Also, farmers manipulated the turnout gates at the D-channels using various devices and divert a bigger share

of the discharge to their F-channels. The flow rate was highly variable temporally, between the days of water issue, and spatially (Table B-8).

Table B-8. Discharge at the Turnout Gates

| Turnout No. | Location | Day of Water Issue | Discharge, l/s | Average Discharge, l/s |
|---|---|---|---|---|
| D.3/T.O. 5 | Head | 1st Day | 19.8 | 19.8 |
| D.3/T.O. 8 | Tail | 1st Day | 17.0 | 14.2 |
| | | 2nd Day | 11.3 | |
| D.4/T.O. 3 | Head | 1st Day | 32.8 | 30 |
| | | 2nd Day | 27.2 | |
| D.4/T.O. 10 | Tail | 1st Day | 53.5 | 38.8 |
| | | 2nd Day | 24.1 | |

For example, the head turnout T.O. 5 of D-channel 3 received a flow rate of 19.8 l/s as against 14.2 l/s at the tail-end turnout (T.O. 8). The head-end turnout T.O. 3 of D.4 received an average flow rate of 30 l/s compared to 38.8 l/s at T.O. 10. The delivery at T.O. 5 and T.O. 8 was lower than the flow rate scheduled under the operational plan. The flow rate did not meet the operational schedule nor the field irrigation requirement based on the area cultivated. Water was in excess of the operational requirement in two turnouts, but less than the required flow rate in all turnouts except T.O. 10 of D-channel 4 (Table B-9). However, the delivery requirement worked out on the basis of research data is much less than what management adopted in their operational plan.

According to the operational schedule, it was expected that the farmers would divide and use the flow (28 l/s) equally in two allotments at a time for 12 hours. Water issue to the turnout will be turned off depending on the number of allotments within the turnout area on the basis of 12-hour issues to the two allotments. The rotational schedule planned for the turnout (T.O. 8 of D-channel 3) area was a delivery of 14.2 l/s for 12 hours for two allotments simultaneously, and this rotation was not being adhered to by the farmers. Instead, a number of field outlets were kept open and the farmers irrigated simultaneously. Consequently, each farmer received a very small flow rate for irrigation. The farmers in the upper parts of the F-channel diverted more water than the tail-end farmers of the F-channel. This was clearly observed in T.O. 8 under D-channel 3. Also, the farmer in allotment 50 in D.4/T.O 3 used a flow rate of 6.33 l/s, compared with a flow rate of 2.8 l/s used by the farmer in allotment 47 located in the tail end of the F-channel.

The F-channel discharge measurements done by inflow-outflow method showed very heavy losses as shown below.

Table B-9. Comparison of Actual Discharges with Design Discharges

| Site | Total Area (ha) | Area Cultivated (ha) | | | Measured Flow Rate (l/s) | Meas. Average Depth Appl. (mm) | Required Flow (l/s)* | Operational Flow (l/s) |
|---|---|---|---|---|---|---|---|---|
| | | Paddy | OFC | Total | | | | |
| T.O. 5/D.3 | 16 | 11.3 | 1.6 | 12.9 | 20.1 | 40 | 35.7 | 28.3 |
| T.O. 8/D.3 | 19 | 1.6 | 9.3 | 10.9 | 14.2 | 37 | 30.1 | 28.3 |
| T.O. 3/D.4 | 16 | 6.1 | 6.9 | 13.0 | 30.0 | 60 | 35.7 | 28.3 |
| T.O. 10/D.4 | 15 | 2.8 | 11.3 | 14.1 | 38.8 | 89 | 38.9 | 28.3 |

Operational Criteria: 64 mm for paddies and for upland crops.

*The water delivery rate required to meet field water requirement if the water is delivered for three days as at present. A conveyance efficiency of 90 % was assumed for the F-channel.

$$\text{Measured Ave. Depth of Application, mm} = \frac{\text{Volume of flow (ha-mm)}}{\text{Total cultivated area (ha)}}$$

| Turnout Area | Losses/100 m length |
|---|---|
| D.3/T.O. 5 | 7.3% |
| D.3/T.O. 3 | 6.8% |
| D.4/T.O. 10 | 2.6% |

F-channel maintenance was badly neglected. While the management said that the maintenance of the F-channels was a farmer responsibility, the farmers did not appear to have been aware of their responsibility nor felt that they should have maintained the field channel in good condition. As a result, channels were heavily eroded. The extremely wide channel bottoms (50 to 150 cm) indicated the erosion that took place.

The channel banks were not constructed to the design. Some of the turnouts from the F-channel to the allotments were placed 15 to 30 m upstream of the farm boundary in order to construct the drop structures in cut, and the farmer was expected to cut a small ditch from the outlet along his F-channel reservation to his farm.

Also, construction defects were observed in drop structures. For example, the upstream cutoff wall of the drop structure was missing, although according to the original design, it should have been constructed. This has caused undermining of the structure. Due to the unsuitable location of the siting of the drop structures, water bypassed the drop structure and flowed through the sides causing channel erosion.

The turnouts to the farm lots were constructed with 15-cm diameter concrete pipes with headwalls and grooves for planking arrangement. No plank was provided to control the issue, and farmers used sod from channel bank for this purpose. The water surface was controlled by the check regulators and drop structures. In most of these structures, the earth filling around the structures was scoured, and water passed around the structures. This may be due to insufficient consolidation of earth during construction. Since most of the control gates malfunctioned, the farmers diverted water to the fields by blocking the channel, taking sod from the channel bank. The water surface in these channels could not be regulated due to malfunctioning of the check regulators and dividers.

3. Water Application System

The design criteria of the application system in System H of Mahaweli was based on the following.

For upland crops:

(a) An irrigation depth of 38 mm/week;
(b) An irrigation of 64 mm from sowing; and
(c) An efficiency of irrigation assumed for:

| | |
|---|---|
| Onions | 50 % |
| Chilies during first month | 50 % |
| Chilies after first month | 60 % |
| Other crops | 70 % |

For lowland paddy:

(a) The first and second flooding for land preparation required a total of 180 mm over a period of 15 days (130 mm in the first week and 50 mm for the second week). Thereafter, 64 mm per week was required until 15 days before harvest;

(b) Evapotranspiration losses to be accounted starting from first flooding until 15 days before harvest; and

(c) Percolation losses assumed to be 100 mm per month during the entire period standing water is on the field.

a. Application Efficiency

Paddy fields in the project area were irrigated by check-basin flood system. The check-basin flood system consisted of a stream of water into a level plot surrounded by low bunds (dikes). The water entered the uppermost basin from the field turnout and flowed from basin to basin. Basins filled up to a depth of about 70 mm and the excess water spilled over to the adjoining basin through the dike opening. This process recurred from basin to basin until water entered the drainage channel from the last basin. However, many farmers did not bother to stop irrigation even after all their basins were full. To have a standing water condition while allowing water to flow from basin to basin, the outlets of the basins were partially kept closed in a manner that would facilitate spillage after attaining a certain height.

Irrigation of upland crops in the project area was done mainly by the basin method of irrigation. First the uppermost check basin was filled until it was submerged, and then the basin outlet was fully opened to drain the entire surface flow to the next basin (Figure B-8). However, much water remained as a thin sheet over the upper basins for a long time even after irrigating the last basin in the series, thereby allowing a large quantity of water to be lost in deep percolation.

The infiltration rates in the basins were measured by both the inflow-outflow method and cylinder infiltrometer method. The agreement between results obtained with both methods was good. The cumulative intake and infiltration rates for upper and middle slopes are shown in Figures B-9 to B-12. The upper and middle slopes had a higher infiltration rate (30 to 40 mm/hr) than the lower slopes. The infiltration

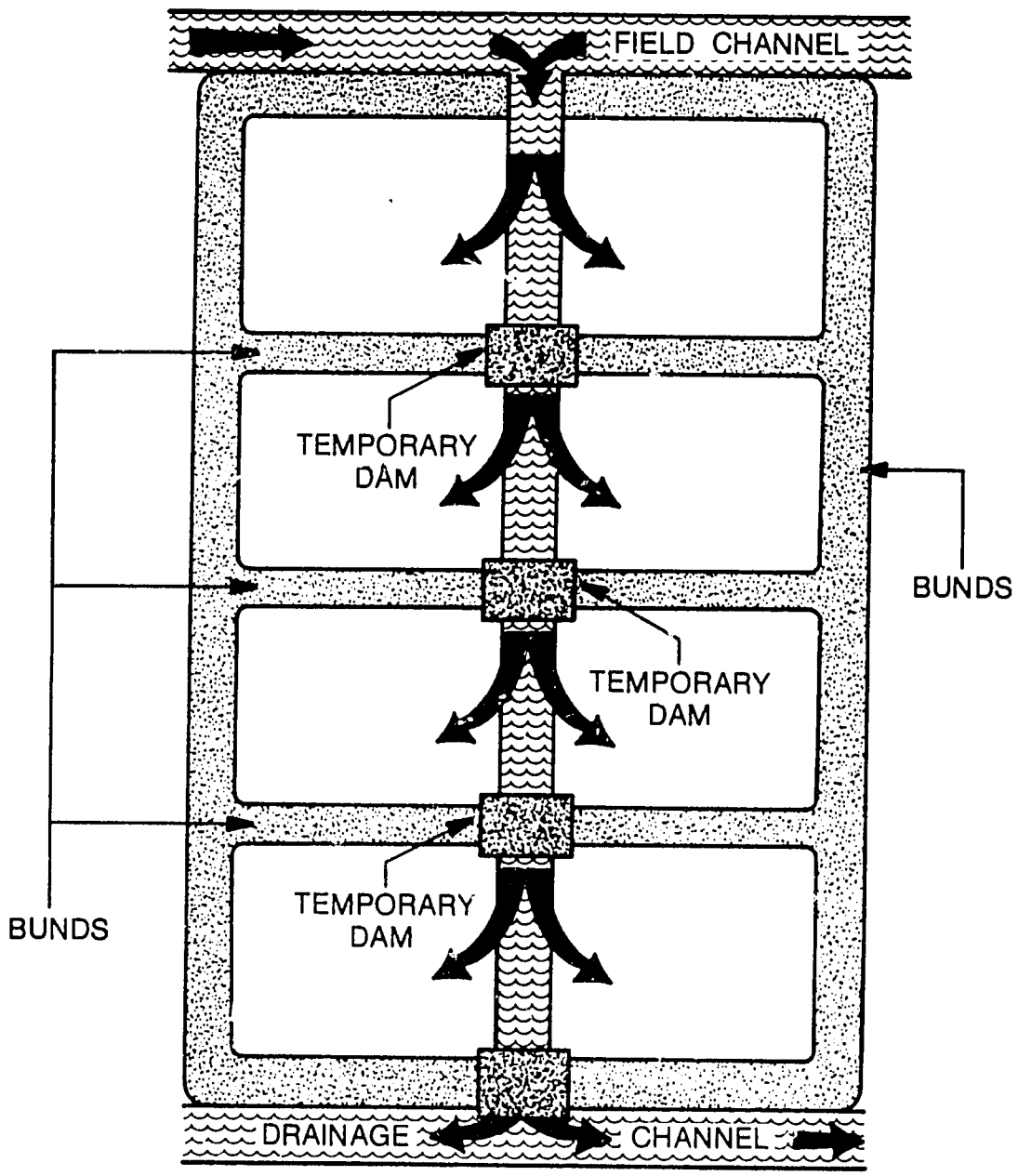



Figure B-8. Typical Layout of Basin Irrigation for Upland Crops

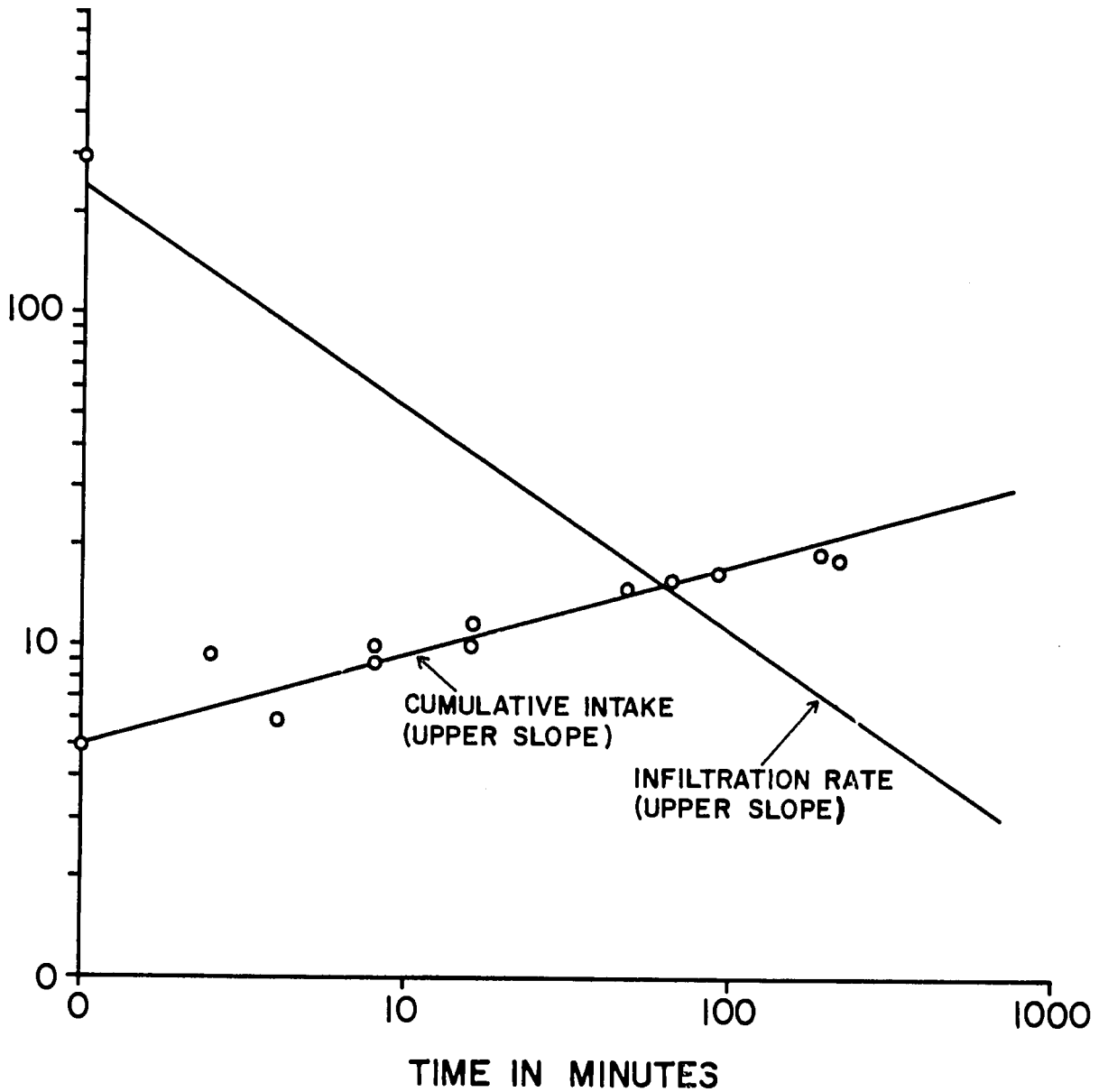



Figure B-9. Cumulative Infiltration/Infiltration Rate in the Upland Area of T.O. 5 of D-channel 3

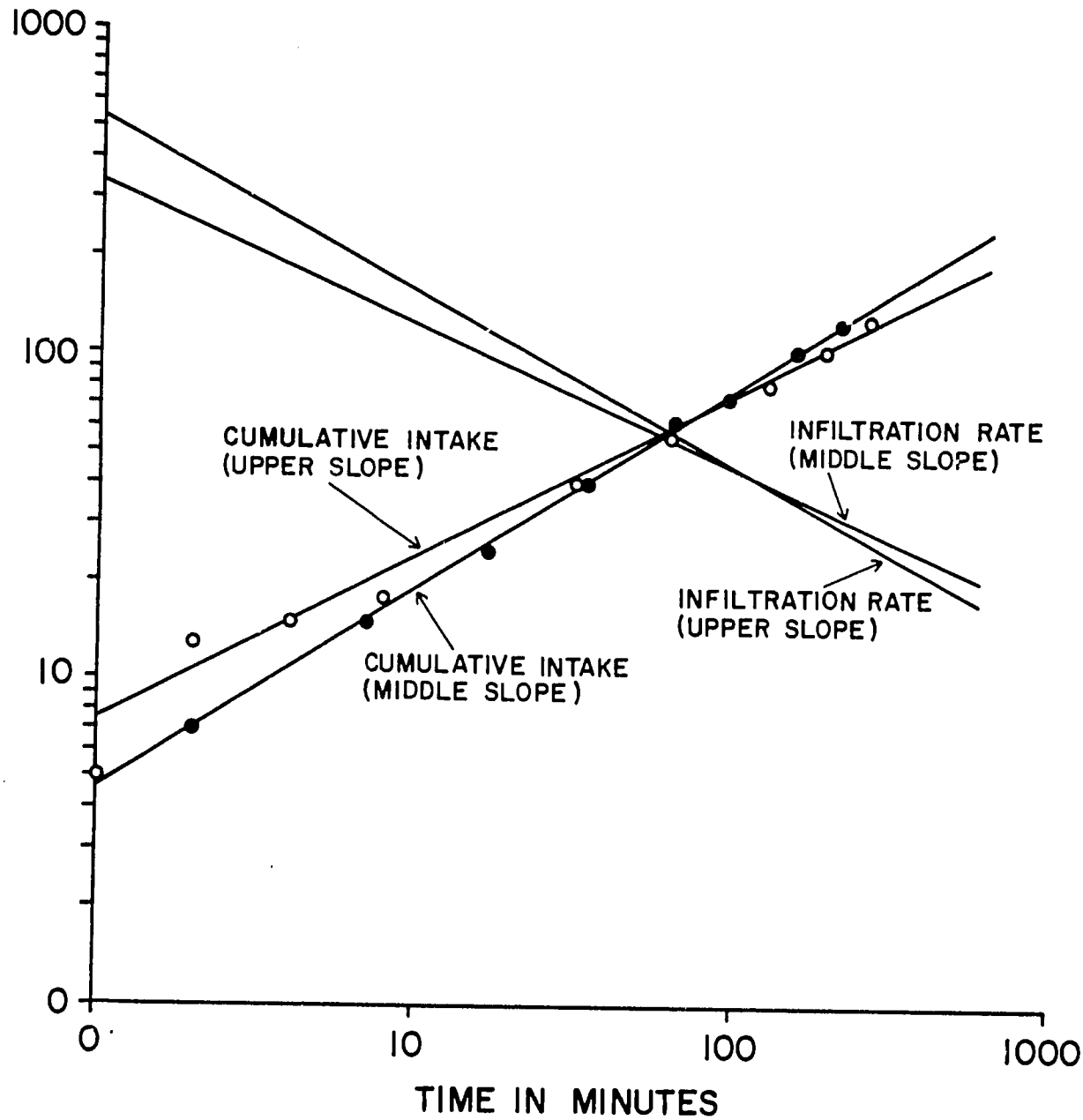



Figure B-10. Infiltration Characteristics of the Soils in Study Site T.O. 8 of D-channel 3

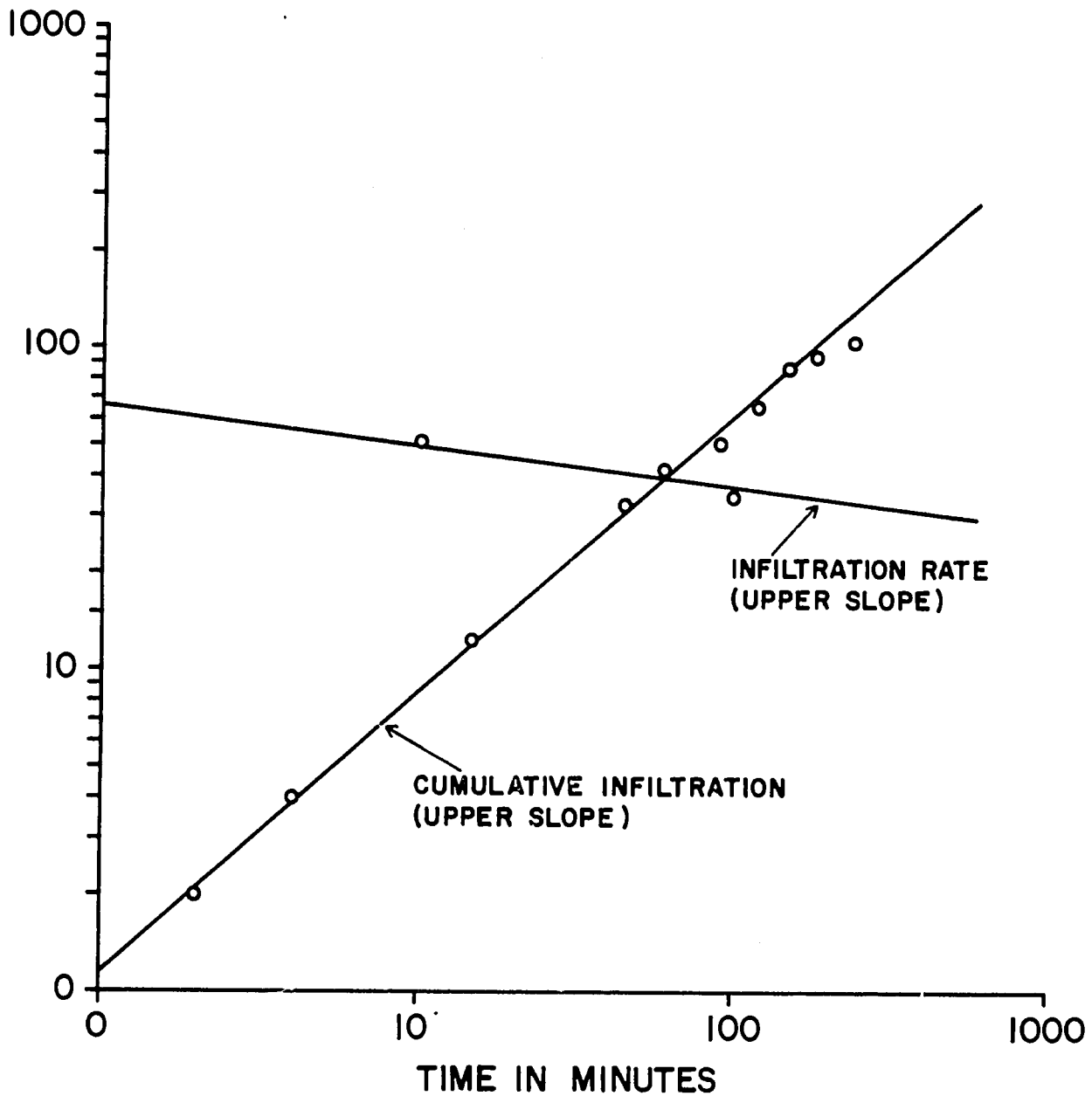



Figure B-11. Infiltration Characteristics of the Soils in Study Site T.O. 3 of D-channel 4

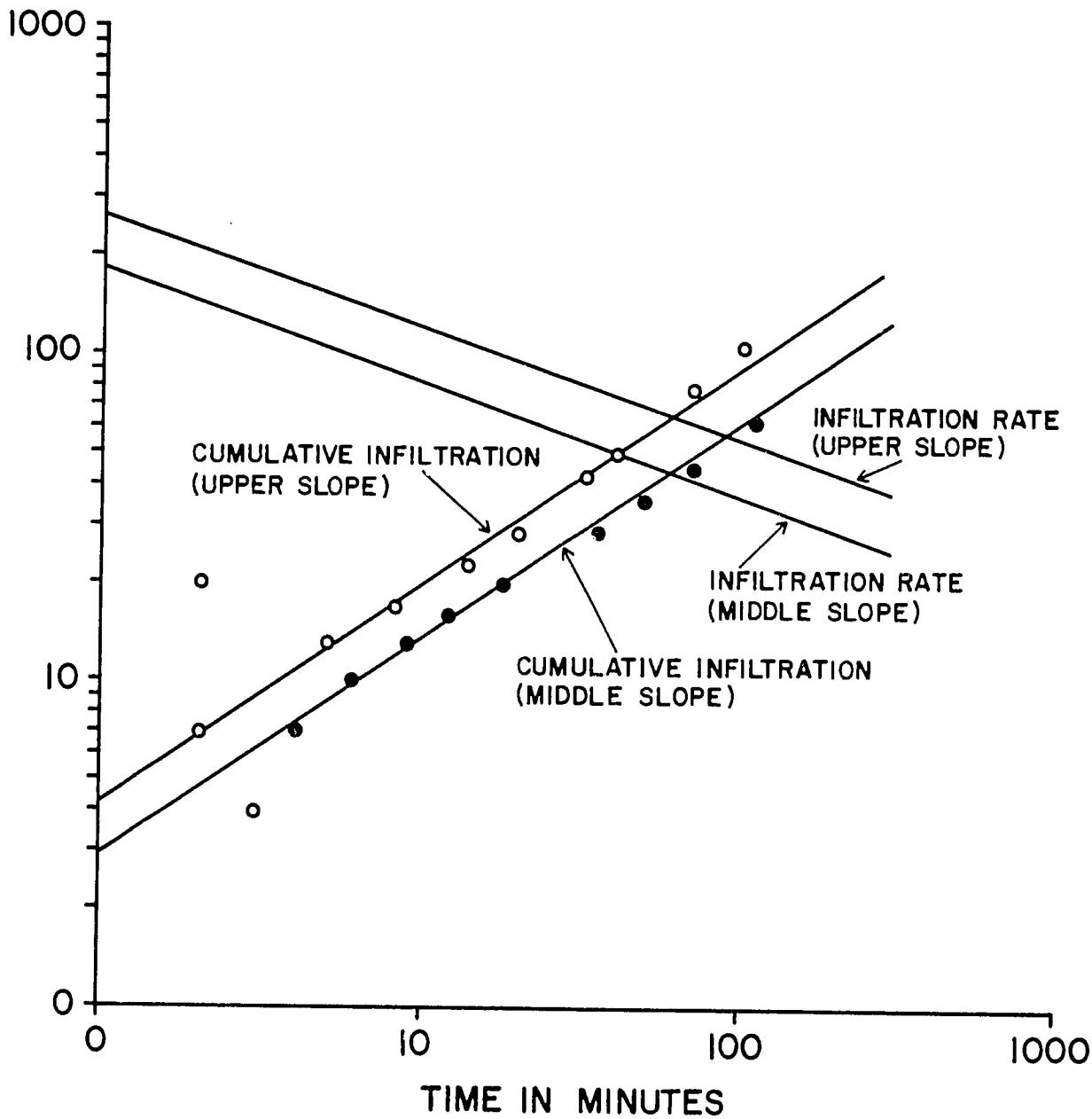



Figure B-12. Infiltration Characteristics of the Soils in Study Site T.O. 10 of D-channel 4

rate in the bottom land was much lower than the upper area (the infiltration was not measured in the bottom area). Murakami (1966) reported a percolation rate of 7 mm/day for the bottom area. The high infiltration rate in the soils of the upper area indicated that these soils were not suitable for lowland paddy cultivation.

Application efficiencies in the chili fields in all the turnout areas were very low (Table B-10). In the upland plot in which the measurements were taken in the head-end turnout of D-channel 3, the soil moisture deficit was zero at the time of irrigation. Also recorded was a very high water table (30 cm from surface). Nevertheless, the farmer irrigated this plot, spending 45 minutes to cover an area of 378 $m^2$ with a stream of about 1.4 l/s, or an additional 70 mm of water. As the soil was at field capacity, all the added water contributed to losses. Hence, the application efficiency was zero in this particular case (Table B-10). The excessive application brought the groundwater level to the surface. Further, observations on the other upland plots in this turnout showed that the farmers irrigated when the soil was too moist and when the water table was very close to the surface.

In a basin under the tail-end turnout (T.O. 8) in which the study was conducted, the water table was 1 m below the ground. The water table rose immediately after irrigation and dropped 1 m or more within a day or two after irrigation. It appeared from its behavior to be a perched water table. This plot was irrigated when the soil moisture deficit was about 50 percent of the available soil moisture capacity, both at 0 to 30 cm and 30 to 60 cm depths. The total soil moisture deficit was 52 mm. Farmers used a stream of about three l/s and spent 2½ hours to irrigate the basin which covered only 142 $m^2$. The application depth was 190 mm, which resulted in 28 percent application efficiency (Table B-10).

Both the head turnout (T.O. 3) and the tail turnout (T.O. 10) of D-channel 4 also recorded a very low application efficiency. On the day of irrigation, the upland areas of both the turnouts had a high water table ranging from 50 to 70 cm from the surface. The soil moisture deficit at the time of irrigation was about 22 mm at 0 to 30 cm depth and at field capacity beyond this depth. The total soil moisture deficit was estimated to be 23 mm in 60 cm depth. To meet the above soil moisture deficit, farmers have actually applied 64 mm of water in T.O. 3 and 88 mm in T.O. 10. The farmer in T.O. 3 used an average flow rate of about 4 l/s for a contact period of 100 minutes, and the farmer in T.O. 10 used a flow of about 7 l/s for 50 minutes. Therefore, the application efficiencies were 35 and 25 percent, respectively, in T.O. 3 and T.O. 10 (Table B-10).

b. Water Table Depth

Studies showed that the water table in some of the upper slopes and middle slopes did not represent the condition that may have prevailed

Table B-10. Water Application Efficiencies in Different Turnout Areas for Chilies

| | | | Column Number | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| Turnout Area | Allotment No. | Position of the slope | Moisture at F.C. (%) | Moisture Prior to Irrigation (0-30 cm) | Moisture Prior to Irrigation (30-60 cm) | Bulk Density | Water Stored (0-30 cm) | Water Stored (30-60 cm) | Water Stored in Root Zone (cm) | Water Applied (cm) | Application Efficiency (%) |
| | | | | | | | (1)-(2)x4 | (1)-(3)x4 | (5)+(6) | | (7)÷(8)x100 |
| D.3/T.O.5 | 65 | Upper Slope | 22.0 | F.C.** | F.C. | 1.52* | 0.0 | 0.0 | 0.0 | 6.0 | 0 |
| D.3/T.O.8 | 90 | Upper Slope | 22.0 | 16.25 | 16.25 | 1.52 | 2.62 | 2.62 | 5.24 | 19.1 | 28 |
| D.4/T.O.3 | 50 | Upper Slope | 21.5 | 16.7 | F.C. | 1.52 | 2.23 | 0.0 | 2.23 | 6.4 | 35 |
| D.4/T.O.10 | 143 | Upper Slope | 21.5 | 16.7 | F.C. | 1.52 | 2.23 | 0.0 | 2.23 | 8.8 | 25 |

* Measured only in D.3/T.O. 5 and this figure was used to compute volumetric water content in others.
**F.C. - Field Capacity

prior to the supply of irrigation water (Table B-11). It has been suspected, during the reconnaissance study, that the channel seepage and inefficient practices of irrigation were responsible for high water table in some of the upper slopes.

T.O. 5 of D-channel 3 and T.O. 3 and T.O. 10 of D-channel 4 had rather high water tables even on the upper slopes. Even though the water table was high, subsoil did not contain mottles or gleying. This indicated that the water table had risen in this part of the land after the introduction of irrigation.

The behavior of the groundwater hydrology in the upland area has changed since the introduction of irrigation facilities. As the time available for the study was very short, any quantification of the contribution by these processes was difficult.

Field measurements and observations made indicated that excessive application of water, seepage flow due to high conveyance losses from the D- and F-channels, and poor drainage from the overall area due to improper maintenance of the drainage channels were responsible for the groundwater buildup.

Excessive Application of Water-- Several factors contributed to the excessive application of water.

(1) Farmers did not have adequate knowledge regarding the cultivation of upland crops with irrigation. Most of them have been paddy farmers prior to settling in the Mahaweli area. Some of them came from the wet zone areas where paddy was grown with rainwater often available in large quantities. Those living in the area prior to settlement cultivated paddy on bottom lands under the village tank system. Some of the farmers followed the same practices for upland crops.

(2) Many of the farmers irrigated their upland crops whenever they could divert water from the channels. Some farmers decided to irrigate by observing the dryness of the surface soil. Farmers in T.O. 5 of D-channel 3 irrigated the chili crop when the soil moisture was at or above field capacity and when the water table was very shallow. They did not have an understanding of the depth of application required at the time of irrigation.

(3) The lack of a proper on-farm distribution system to deliver water to individual basins was a major cause for the high amount of on-farm losses. As the water flowed through the upper basins to the lower basins, the upper ones had a long contact time because the water flowed in a thin sheet over them even after the basin outlet was opened to the next basin.

(4) Poor land leveling was also a major cause for the water table buildup. The range of elevation in some of the plots where the upland crops were grown was more than 10 cm. Due to poor land leveling, water

Table B-11. Water Table Fluctuations

| Turnout Area | Depth of Water Table from the Surface (cm) on Days after Irrigation | | | | |
|---|---|---|---|---|---|
| | 0 | 1 | 2 | 3 | 4 |
| D.3/T.O. 5 | | | | | |
| Upper Slope | 30-40 | * | * | 50-70 | * |
| Middle Slope | 0-10 | * | * | 50 | * |
| Lower Slope | 0 | 0 | 0 | 0 | 0 |
| D.3/T.O. 8 | | | | | |
| Upper Slope | 0 | 100 | 120 | >120 | >120 |
| Middle Slope | * | * | * | * | * |
| Lower Slope | 0 | 60 | >70 | >70 | >70 |
| D.4/T.O. 3 | | | | | |
| Upper Slope | 0 | 3 | 29 | * | 47 |
| Middle Slope | 11.5 | 36 | 50 | * | 70 |
| Lower Slope | 0 | 0 | 3 | * | 7 |
| D.4/T.O. 10 | | | | | |
| Upper Slope | 16 | * | * | * | 70 |
| Middle Slope | 14 | * | * | * | 56 |
| Lower Slope | 11.5 | * | * | * | 33 |

0 - indicates water table at the surface.
* - indicates no data available.

was let out only after all the high spots were covered or all the furrows were full with water. This provided a much higher opportunity time for water to be in contact with soil than the actual requirement.

(5) Due to the inadequate water supply to the allotments, the farmers used a small stream of water. A small stream of water takes a longer time to irrigate a field and leads to an uneven distribution of water and deep percolation.

Seepage from the Distribution Channels-- A high water level was seen in the dug well constructed next to T.O. 10 in allotment 144 of D-channel 4, and water was overflowing from the borrow-pit constructed in the uppermost highland allotment of T.O. 5 in D-channel 3. The chili plot immediately below had a water table at 30 cm depth. These observations and D-channel measurements indicated that the seepage flow from the channel was partially responsible for the buildup of the water table.

Poor Drainage-- Adequate drainage facilities for excess water from the allotments were not provided. The excess water flowed through a series of basins before it entered a drainage ditch. The original layout plans show a network of drainage ways. The drainage system consists of the drainage ways between field channels, and drainage channels between D-channels. The drainage ways between the F-channels now serve mainly as a boundary between two allotments. These drainage ways were poorly constructed. Very often these are just demarcated to the farmers without being constructed as a drainage facility.

The main drainage channels appeared to be just natural watercourses which were never constructed to a particular design. The demarcation that is supposed to be a drainage way between F-channels was not maintained by the farmer. These were covered up with heavy weed growth. The main drainage ways meandered through the valleys forming waterlogged conditions at some sections, thereby raising the water table in the vicinity. Neither the management nor the farmers were bothered about the poor drainage. Both parties had not taken action to keep the drainage ways functioning properly. There was already evidence of salinity buildup in some of the poorly drained lower slopes.

c. Water Use Efficiency

The water use efficiency for a unit of water used for chili was calculated using the economists' yield figures. However, the agronomist and the on-farm engineers felt that the yield figures given for T.O. 5 in D-channel 3 by the farmers were a big overestimation. The chili crop in this turnout was severely affected with waterlogging that was likely to cause low yields. However, the estimates given by the farmers for the other turnouts appeared to be reasonable. Therefore, the water use efficiency was not calculated for T.O. 5 in D-channel 3.

Water use efficiency is expressed as the amount of produce per unit of water used. The water use efficiency obtained by research work at Maha-Illuppallama where chili was cultivated under simulated farm conditions in System H of Mahaweli area was used to compare the actual water use efficiency obtained by the farmers.

To obtain the water applied per unit area, two methods were followed:

(1) The volume of water delivered to a turnout was divided by the total cultivated area, assuming that the water delivered was uniformly distributed in all the allotments.

(2) The water applied by farmers for the chili crop was measured in a few basins as ha-cm. This latter measure gives a more realistic figure than the former one because farmers who were in a more favorable position in the channel reach to divert more water applied more water in their upland plots.

The data obtained by the above methods were compared to potential water use efficiencies obtained with optimal research conditions (Table B-12).

The potential water use efficiency was calculated by using the data on potential yield level under research station conditions and the ET of chili crop obtained by Jensen-Haise method. To estimate the field irrigation requirement, an application efficiency of 60 percent was used:

| | |
|---|---|
| The $ET_{crop}$ chili | = 80 cm for 5 month crop |
| Application Efficiency | = 60 % |
| Potential Production, chili | = 1,867 kg/ha |
| Water Use Efficiency | = 14 kg/ha-cm |

Table B-12 shows the water use efficiencies obtained by the above two methods. The water use efficiency appeared comparable with the efficiency obtained under research conditions (Rasiah, 1980) only at T.O. 5 in D-channel 3 and T.O. 3 in D-channel 4. Both T.O. 8 and T.O. 10 located in the tail ends of the D-channels have low water use efficiencies compared to the research results. Therefore, water use efficiency could be greatly improved by better management in the system as well as better farmer water application practices.

4. Summary of Findings

(1) The channels had steep slopes in several places. This resulted in deterioration of channel conditions due to erosion

Table B-12. Water Use Efficiency for Unit of Water Applied in Cultivation of Chili (150 days)

| Site | Yield (kg/ha) | At Turnout Level: Depth Applied per Irrigation (cm) | At Turnout Level: Estimated Total Depth of Application (cm) | At Turnout Level: Water Use Efficiency (kg/ha-cm) | Farmer Water Use†: Depth Applied per Irrigation (cm) | Farmer Water Use†: Estimated Total Depth of Application (cm) | Farmer Water Use†: Water Use Efficiency (kg/ha-cm) |
|---|---|---|---|---|---|---|---|
| D.3/T.O. 5 | 1,219 | 4.0 | 76 | 16.5 | 6.1 | 116 | 10.8 |
| D.3/T.O. 8 | 855 | 2.7 | 51 | 17.2 | 9.4 | 178 | 5.0 |
| D.4/T.O. 3 | 1,169 | 7.4 | 134 | 8.6 | 6.3 | 121 | 10.0 |
| D.4/T.O.10 | 1,119 | 7.7 | 147 | 7.8 | 8.9 | 169 | 6.8 |

- Water Use Efficiency (WUE) obtained at research stations under simulated farmer condition is 11 kg/ha-cm.
- potential WUE is 14.5 kg/ha-cm

† WUE calculated in this column is based on the actual measurements of depth of water applied to the chili crop by the farmers.

†† The estimated total depth of application for the crop calculated assuming that the water delivered during the week (on on-farm applied) in which measurement was taken is representative of other weekly irrigations. It was assumed that there would be 19 such irrigation applications (one application for land preparation and 18 applications during growth stages).

and sedimentation of the channel bottom. This deterioration was also due to the lack or malfunctioning of control and regulating structures. The downstream cushions of the turnout structures functioned as measuring devices, which were later silted and submerged.

(2) Overall maintenance of the system was inadequate. No proper procedures were adopted to identify the maintenance work, prioritize the repairs, and allocate funds. This poor maintenance was one of the most unfavorable aspects of the scheme affecting normal functioning, and it resulted in excessive seepage and reduction in the flow of water.

(3) The farmers in the project area were accustomed to traditional lowland paddy cultivation with standing water in the field. They did not have skills required to manage water for upland crops. Basin-to-basin flow in upland crops resulted in significant deep-percolation losses from the upstream basins.

(4) Only some of the farmers were provided with 15-cm diameter concrete, circular pipe turnouts with planking arrangements. As a result, the rest of them took sods from bank of the canal to block and raise the water surface, thus damaging the bank.

(5) Waterlogging appeared in well-drained areas due to excessive application of water, channel seepage, and inadequate drainage facilities.

(6) The cropping patterns adopted did not conform to the soil conditions. For example, paddy cultivation occurred in the well-drained upper slopes with high infiltration, and upland crop cultivation occurred in poorly-drained areas with a high water table.

(7) The water supply was inequitable and undependable. The actual supply was less than required in all turnouts, except one. The farmers did not follow a rotation within a turnout area. In some turnouts, all the farmers irrigated simultaneously. Farmers toward the upstream end irrigated whenever they could divert water.

(8) The irrigation channel systems did not have facilities for equitable distribution. There were no farmer organizations within the turnout areas for the purpose of organizing irrigation distribution and maintenance of channels.

## C. Economics

The role of economics in Diagnostic Analysis is to study the economic dimension of farming systems, delineate economic problems, identify linkages between economic and other constraints, and assign values to technical, institutional, social, and economic constraints affecting the performance of the farming unit.

The contribution of economics to the farmers' decision-making process lies in estimation of costs and returns. The word cost is used here in its broadest sense to mean not only expenditure of money but also the sacrifice of leisure, of food for investment, or of anything else which is valued by the farm family. Farmers are assumed to maximize profit, however. Security, which cannot be measured objectively, plays a major role in farmers' decision-making.

### 1. Inputs and Production Practices

#### a. Cropping Pattern

In Maha, 90 percent of the area covered by the survey was cultivated in paddy which is the only Maha crop in the study area. In Yala, 75 percent of the area was under cultivation. The major crop was chilies which were grown in 36 percent of the area. Paddy cultivation accounted for 33 percent of the area. A small extent of soybeans and cowpeas was also cultivated. The lower area under cultivation in Yala can be attributed to low water level in the reservoir and project management decision to issue water only for the cultivation of other field crops.

The breakdown of the cropping intensity and cropping pattern data as head, middle, and tail reaches of turnouts indicated an increasing area in paddy production toward the tail reaches. In Yala the same tendency prevailed with a stronger trend. Conversely, the area under chilies decreased toward the tail reaches (Table C-1).

The examination of Maha cropping intensity did not reveal any clear trend from head turnouts to tail turnouts. However, within turnouts cropping intensity appeared to increase toward the tail reach. In Yala the two turnouts at the head of D-channel 3 and D-channel 4 respectively had a higher cropping intensity than the tail turnouts. Also these two head turnouts had a significantly larger area in paddy than the tail turnouts. Both these tendencies supported the view that head turnouts in the D-channel received a better supply of water than the tail turnouts.

Table C-1. Cropping Pattern and Cropping Intensity Expressed in Percentage

| Crop | All Four Turnouts | D.3 | | D.4 | | Location | | |
|---|---|---|---|---|---|---|---|---|
| | | T.O.5 | T.O.8 | T.O.3 | T.O.10 | H | M | T |
| Cropping Pattern | | | | | | | | |
| Maha Paddy | 90 | 80 | 70 | 94 | 100 | 88 | 86 | 94 |
| Yala Paddy | 32.8 | 65 | 02 | 50 | 23.6 | 19 | 33.7 | 50.7 |
| Yala Chilies | 35.8 | 16 | 32 | 39 | 50.9 | 50 | 33.7 | 17.7 |
| Cropping Intensity | 159 | 161 | 104 | 183 | 175 | 157 | 153 | 162 |

The area under chilies in Yala in two tail turnouts was greater than that of the head turnouts of the two D-channels. However, within turnouts the area under chilies decreased toward the tail reach. Within turnouts the decrease in the area under chilies toward the tail reaches can be explained by the type of soil. Tail reaches have poorly drained soils where chilies cannot be grown.

b. Land Preparation and Draft Power

Land preparation is the most expensive single operation in paddy cultivation. In major irrigation schemes timely land preparation is crucial from a water management point of view. In major irrigation schemes water issue schedules are planned to issue irrigation water continuously for two weeks for land preparation. Thereafter a rotation schedule is maintained. Often water issues for land preparation are extended due to large numbers of farmers being unable to attend to their land preparation in time. Several reasons may delay the timely cultivation. Shortage of working capital and shortage of draft power are two major problems. Staggered cultivation resulting from delayed cultivation by some farmers leads to inefficient use of water when the irrigation schedule is set to accommodate the water requirements of farmers who cultivate late.

Agronomists reported extensive staggering in Yala paddy cultivation. In Yala 1982, some farmers decided on paddy cultivation when rains came unexpectedly some weeks after the season began. Some others, contrary to the official cropping pattern, grew paddy from the very beginning. A shortage of draft power in the study area was apparent. None of the farmers interviewed owned four-wheel tractors, two-wheel tractors, or draft animals.

The cost of hiring a two-wheel or four-wheel tractor to plow 1 ha was Rs 1,000 on the average. Puddling and leveling required an additional Rs 400 for the 1 ha paddy area. Land preparation entirely by animals cost Rs 900 for the 1 ha farm. The disadvantage in the use of

draft animals was the time consumed. A pair of buffalo would take one week or more to complete land preparation in one 1 ha farm. A tractor would take only one day or less to plow a farm.

In Yala 1982, 19 percent of the farmers used only draft animals for land preparation. Four-wheel tractors and animal combination accounted for 25 percent of the farmers. Only 11 percent used two-wheel tractor and animal combination. Fourteen percent used only four-wheel tractors. Sixteen percent used only two-wheel tractors. The remaining 15 percent of the farmers used many combinations such as four-wheel tractor and two-wheel tractor; and four-wheel tractor, two-wheel tractor, and animal.

Sociologists in their study found that 55 percent of the farmers thought draft power in paddy cultivation was a major problem, with 24 percent of them indicating it as the number one problem. Fifty percent of the farmers said that draft power was a problem for subsidiary food crop cultivation, and out of them 9 percent said that it was the most pressing problem.

Shortage of draft power could increase the cost of land preparation, which in turn could raise the cost of paddy cultivation and reduce the profit margin. Further study is needed to determine the extent to which shortage of draft power has increased production cost and has led to delay in planting and consequently lower yields.

c. Seed

All farmers used new improved high-yielding rice varieties bred at Central Rice Breeding Station at Batalagoda, Sri Lanka. Similarly all farmers cultivated new improved chili varieties bred at the Agricultural Research Station, Maha-Illuppallama. In Maha, 43 percent of the farmers cultivated new, improved, long-duration (4 to 4½ month) rice varieties. Others used new, improved, short-duration varieties. In Yala, all farmers used new, improved, short-duration varieties.

In Maha, 54 percent of the farmers used their own seed, 35 percent obtained seed from the project management, and the balance obtained their seed from private dealers, relatives, and friends. In Yala, 85 percent of the farmers used their own seed for paddy cultivation. The rest obtained rice seed from private traders. Thirty-four percent of the farmers obtained chili seed from the project management and another 23 percent from the Department of Agriculture. Forty-three percent of the farmers used the seed from their previous years' chili crop.

d. Fertilizer Application

The new, improved, high-yielding varieties cultivated by the farmers in the area were highly responsive to fertilizer. Only 65 percent of the farmers applied basal fertilizer to Maha paddy. Eighty-seven percent applied top dressings. In Yala, few farmers (14 percent) applied basal fertilizer, while most (92 percent) applied top

dressings. Only 18 percent of chili farmers applied basal fertilizer; a majority (90 percent) applied top dressings. Overall fewer farmers applied basal fertilizer than top dressings. Very few applied basal fertilizer in Yala.

In terms of the recommended quantity of fertilizer the rate of application was very low in both seasons in the case of paddy. The average rate of applications appears in Table C-2, for the entire area as well as by head, middle, and tail reaches of the turnouts. At the time the survey was conducted, the chili crop was only 5 to 8 weeks old. Chili crops grow over a 4½- to 5-month period. Chili crops are given about 12 top dressings. The number of top dressings applied by the time of the survey was between 2 to 3. What appears in Table C-2 is the quantity of top dressings applied in 2 to 3 applications.

Table C-2. Application of Fertilizer (Block 302)

| Fertilizer (kg/ha) | Recommended Qty. | | Whole area | H | M | T |
|---|---|---|---|---|---|---|
| Basal | | | | | | |
| Maha paddy | 166 | | 75 | 88 | 77 | 58 |
| Yala paddy | 166 | | 12 | 7 | 25 | 10 |
| Yala chilies | 166 | | 20 | 28 | 17 | 0 |
| Top Dressings | Long Aged | Short Aged | | | | |
| Maha paddy | 275 | 220 | 109 | 132 | 71 | 102 |
| Yala paddy | | 220 | 82 | 111 | 29 | 90 |
| Yala chilies | | 1,006 | 127 | 135 | 129 | 107 |

Only 29 percent of the farmers cultivating paddy and only 4 percent of those who cultivated other crops (chilies, soybeans) perceived availability of fertilizer as a problem.

The low application rates of fertilizer may perhaps be due to the shortage of working capital rather than due to poor supply of fertilizer. Lower application value of basal fertilizer in Yala may be related to the high risk of crop failure from water shortage experienced in the Yala 1982 season when the survey was carried out. A study of the fertilizer and other input application in normal Yala seasons may indicate whether farmers apply lower rates of inputs than Maha.

e. Credit

Of all the farmers interviewed, only three obtained credit from institutional sources in Maha. On the average these three obtained Rs 1,313 of credit per acre.

As shown in Table C-3 commercial banks in the area issued Rs 1,625 of credit per acre of irrigated and transplanted paddy. The maximum amount of credit for producing chili crops was Rs 3,975. Rice seed and fertilizers are normally issued in kind through stores of the project. Farmers were eligible for credit if they did not default in the previous season and if project management certified the crop and extent they cultivated. The bank charged an annual interest rate of 9 percent.

Few farmers obtained institutional credit for the 1981/82 crop year. Fifty-five percent of the farmers considered credit to be a problem in paddy cultivation, with 24 percent of them considering it to be the number one problem they face. Eighty-two percent of the farmers surveyed considered credit as a constraining factor in production of cash crops of chilies and soybeans, and 54 percent ranked it the number one problem (see Table C-4).

The greater importance of credit for production of other field crops, particularly chilies over paddy, is due to their higher capital requirement. High rates of credit defaulting may be a major reason for low use of institutional credit. Sri Lanka has had several agricultural credit schemes. Up to date all schemes have failed within a short period due to high defaulting rates (People's Bank, 1982).

None of the farmers interviewed obtained institutional credit in Yala. Some farmers said that loan repayment becomes difficult in a bad season, and therefore, they prefer to have a poorly managed crop rather than obtain credit. Farmers did obtain credit from private sources from time to time. However, the farmers interviewed appeared reluctant to provide information about their borrowing practices from non-institutional sources.

2. Yield

The average yield of crops for both Maha 1981/82 and Yala 1982, for the entire area, by turnout, and by head, middle, and tail reach for all turnouts, is presented in Table C-5.

When comparing the average yield achieved in the entire system H in the previous season (Maha 1980/81 and Yala 1981) to the paddy yield in Maha 1981/82, the latter appeared very low (Table C-6).

A major part of the decline in 1981/82 Maha paddy yields, as compared to 1980/81 Maha, may be attributed to the severe water shortage experienced in latter half of the season. Expected yield level for Yala paddy compared well with the average yield of paddy in the last Yala season in the entire System H. However, according to the observations made in the reconnaissance, Yala paddy crop will give a much larger yield in terms of the potential when input levels and crop management practices of this season are taken into account.

Table C-3. Credit Issue Policy by Commercial Banks for Paddy and Chili Cultivation

| Activity | Rs per Ha | |
|---|---|---|
| | Irrigated and Transplanted Paddy | Irrigated Chilies |
| 1. Land Preparation | 988 | 1,482 |
| 2. Seed | 210 | 99 |
| 3. Nursery Management | - | 99 |
| 4. Planting/ Transplanting | 346 | 198 |
| 5. Irrigation | - | 371 |
| 6. Fertilizer | 1,112 | 2,569 |
| 7. Weed Control | 247 | 926 |
| 8. Pest and Disease Control | 618 | 3,088 |
| 9. Harvesting and Processing | 494 | 988 |
| 10. Total | 4,015 | 9,820 |

Table C-4 Problems Perceived by Farmers in Block 302

| Crop | Percent Stating That They Have a Problem | Rank | | |
|---|---|---|---|---|
| | | 1 | 2 | 3 |
| Paddy | | | | |
| Water | 66 | 32 | 13 | 16 |
| Credit | 55 | 24 | 16 | 8 |
| Draft Power | 55 | 21 | 18 | 10 |
| Fertilizer | 29 | 5 | 10 | 8 |
| Marketing | 24 | 5 | 8 | 5 |
| Other Field Crops | | | | |
| Water | 46 | 14 | 9 | 23 |
| Credit | 82 | 54 | 18 | 9 |
| Draft Power | 50 | 9 | 32 | 9 |
| Fertilizer | 4 | 5 | 0 | 0 |
| Marketing | 27 | 14 | 9 | 4 |

Table C-5. Average Crop Yield (Block 302)

| Crop | Whole Area | D.3 | | D.4 | | Turnout Reaches | | |
|---|---|---|---|---|---|---|---|---|
| | | T.O.5 | T.O.8 | T.O.3 | T.O.10 | H | M | T |
| Maha Paddy (kg/ha) | 2,456 | 3,372 | 2,582 | 2,777 | 2,119 | 2,224 | 2,000 | 2,973 |
| Yala Paddy (kg/ha) | 3,418 | 3,760 | - | 2,324 | 3,418 | 3,416 | 4,338* | 3,228 |
| Chilies (kg/ha) | 1,176 | 1,324 | 826 | 1,056 | 1,679 | 1,280 | 1,119 | 985 |

*Only 1 farmer

Table C-6. Average Yield of Paddy/Ha in System H for 1980/81 and 1981/82 Crop Years

| Season | Yield (kg/ha) |
|---|---|
| 1980/81 Maha | 4,119 |
| 1981 Yala | 3,171 |
| 1981/82 Maha | 2,456 |
| 1982 Yala | 3,418 |

Source: Department of Census and Statistics, Government of Sri Lanka.

In Maha, the tail reaches of the four turnouts on the average had higher yields, despite comparatively lower levels of fertilizer input, weed control, and pest control, than the head reaches of the turnouts. This suggests certain favorable conditions for rice in the tail areas. The presence of poorly drained soils in the tail reaches of turnouts facilitated the maintenance of standing water in the field which gives good weed control.

In Yala, no significant yield difference can be observed among turnouts or within turnouts from head to tail reaches. However, the application of fertilizer, weedicides, and pesticides continued to be higher in the head than the tail reaches. The small area of paddy grown in the head reaches (3.2 ha) in Yala compared to the tail reaches (6.7 ha), and the lack of data on labor inputs, machinery hire, and actual yield, prevented doing a detailed analysis, as was done for Maha.

The expected yield of chilies for the area was 1,176 kg/ha of dried chilies. The average yield recorded for the entire System H for Yala 1981 was 1,566 kg/ha according to the Department of Agriculture. No consistent trend in yield distribution was observed among turnouts. However, a breakdown of yield by location along the turnout for all four turnouts indicated a declining trend in yield from head toward middle and tail reaches. This decline in yield toward the middle and tail

reaches of the turnout was not the result of water shortage but rather an excess in the farm of higher water table in the imperfectly and poorly drained soils in the middle and tail reaches of the turnout respectively.

3. Marketing

A free market existed in the study area for paddy as well as other crops. The farmers were not required to sell their produce to the government. However, in the dry-zone settlement schemes some farmers were bound to sell their produce to a private trader who advanced credit as well as inputs to the farmers. Such private traders who lent money were known to charge exorbitant rates of interest. Often farmers did not volunteer information about such transactions due to the fear that these channels might then be closed.

Twenty-four percent of the farmers surveyed viewed marketing of paddy as a problem. Twenty-seven percent of farmers thought the marketing of other field crops was a problem (see Table C-4). Chili prices fluctuated more throughout the year than those of paddy. The government had a floor price scheme for both crops. Farmers could sell their produce to the government or, in the study area, to the project authorities at the guaranteed price. In Mahaweli Project areas the authorities fixed their own guaranteed prices for other field crops which were generally above the government floor price. Project authorities acted as intermediaries to large scale buyers such as Marketing Department, Markfed (Marketing Federation of Sri Lanka), Paddy Marketing Board and CARE (Cooperative for American Relief Everywhere). The fixed floor prices were announced at the beginning of the season. At the time of purchase, payments for farmers were made in the form of vouchers cashable at any commercial bank within the area.

With all these arrangements by the project authorities only 1 out of 38 farmers interviewed sold his paddy to a project managed sales point. All others sold their produce to the private dealers. The average price they received was a little higher (Rs 2.83) than government floor price (Rs 2.74) per kg of paddy.

The farmers' preference to sell to the private sector even at a lower price is well known. This preference can be attributed to the following reasons: 1) Private dealers come to the farm gate at the time of harvest. This relieves the farmer of the drudgery of transporting his produce to the sales point. 2) Private dealers pay in ready cash while the government pays in vouchers. Going to the bank may result in another day's waste of time. Also, often commercial banks deduct outstanding loans at the encashment of vouchers. 3) Government purchasing points do strict quality control. Private dealers, on the other hand, are known to use short weights and measures. Farmers often disregard it due to the mere convenience of selling to a private dealer.

## 4. Cropping Pattern, Profitability, and Cash Flow Analysis

The entire study area was cultivated in paddy in Maha 1981/82 season. The percentage of the farm area cultivated in paddy in Maha 1981/82 was not significantly different along D-channels from their head to tail reaches. In Yala 1982 season, the major crops cultivated were paddy and chilies. The percentage area of farms under paddy in Yala decreased from head reaches of the D-channels toward the tail reaches. Conversely, the percentage area of farms cultivated in chilies increased from the head reaches of the D-channels toward the tails.

A reverse trend in cropping patterns was observed within turnouts (area irrigated by each F-channel) from farms located in the head reach to the farms located in the tail. The percentage of farm area cultivated in paddy in Maha season increased from the head reach of turnouts toward the tail. Likewise, in Yala season, the area of paddy grown in the head reaches of turnouts was smaller than the area of paddy in tail reaches. Conversely, the area cropped in chilies in Yala season decreased from head reach to the tail reach of the turnouts (Table C-7).

Table C-7. Output, Production Costs Incurred and Gross Margin per Ha of Crops Cultivated in 1981/82 Crop Year

| Crop | Yield | Gross Returns (Rs) | Production Costs (Rs) | Gross Margins (Rs)[1] |
|---|---|---|---|---|
| Maha paddy | 2,456[2] | 6,982.29 | 4,487.03 | 2,494.70 |
| Yala paddy | 3,418 | 9,809.36 | 4,000.39 | 5,813.91 |
| Yala chilies | 1,176 | 23,482.48 | 9,713.30 | 13,769.19 |

[1]Return above cash expenses.
[2]Less yield due to drought. Average yield of paddy in Maha 1980/81 was 4,119 kg/ha.

In the 1981/82 crop year, chilies were the most profitable crop followed by Yala paddy and Maha paddy which were the second and third most profitable crops, respectively. Normally, Maha paddy yields a higher profit than Yala paddy. The exceptionally low average paddy yield resulting from the drought experiences in Maha 1981/82 caused the unusually low profit from the Maha paddy crop.

Although annual cropping intensity decreased from head turnouts to the tail turnouts along D-channels by 19 percent on the average in the two D-channels, the average profit in the tail turnouts was only 9 percent less than in the head turnouts. The decrease in the area cropped in the tail turnouts was covered up to a great extent by the comparatively greater chili area cultivated in the tail turnouts. Chili crops yielded an average profit nearly 2½ times that of the Yala paddy.

Although the farms in the study area were of uniform size (1 ha), the actual extent cultivated in each season under each crop varied according to the location of the individual farms within turnouts. The profitability of individual farms depended on the extent cultivated in different crops, yield of each crop, market price per crop, and cost of production as illustrated in Table C-8 below.

Table C-8. Incomes (Return to Land and Family Labor) Obtained from 1-ha Farms by Location from Various Crops within Turnouts in 1981/82 Crop Year

| Crop | Head Reaches | Tail Reaches |
|---|---|---|
| Maha paddy | 1,619.01 | 4,207.63 |
| Yala paddy | 1,098.98 | 2,750.00 |
| Chilies | 8,023.14 | 1,772.77 |
| TOTAL | 10,741.13 | 8,796.75 |

The Maha 1981/82 season resulted in a higher net income to farmers located at the tail of the turnouts than farmers located at the head due to larger percentage area cultivated with paddy and the higher average yield. This variation in the area cultivated and the average yield in Maha paddy between head-end and tail-end farmers was due to the fact that the tails of the turnouts were located at the bottom of the slope where seepage water accumulated, and a heavy clay texture of the soil maintained water for a longer period.

In the Yala season, the farmers located at the head achieved a somewhat higher yield and income from paddy cultivation compared with farmers located at the tail. Farms located at the head of turnouts allocated 50 percent of their land to chili production while the farmers at the tail allocated only 18 percent of their land for the production of chilies. This pattern was consistent with the relative profitability of chilies over paddy in the Yala season for the farms in these two locations. Chili production resulted in a per acre income of about three times that of Yala paddy for head end farmers, while tail end farmers generated twice the income of paddy from chili as shown below in Table C-9.

Table C-9. Relative Profitability per Ha of Crops by Location within Turnouts

| Crop | Head Reaches | Tail Reaches |
|---|---|---|
| Maha paddy | 1,815.45 | 4,421.82 |
| Yala paddy | 5,714.79 | 5,434.00 |
| Yala chili | 15,853.72 | 9,895.44 |

Even though chilies gave a higher profit than paddy in the Yala season for farms located in the tail of turnouts, it is difficult for tail-end farmers to significantly increase the area under chili production. Seepage and poor drainage condition resulted in high water table at the tail end of the turnouts, a condition under which upland crops cannot be produced.

The average annual net income for the farms in the area ranged from Rs 10,741 in the farms located at the head of the turnouts to Rs 8,797 for the farms located at the tail. Annual farm income was comprised of income from the Maha and the Yala season crops. Farm cash flow position varied according to the degree of success of the cultivation of each season. Seasons with poor harvest marketing a low volume of paddy and a cash inflow was not sufficient to meet farmers' subsistence and working capital needs. Although the average net income of farmers in the head of turnouts was Rs 10,741 in the crop year 1981/82, these farmers earned only Rs 1,619 as income from their Maha paddy crop. Apart from meeting their working capital requirement for Yala crop, this amount was insufficient for even subsistence needs.

Farmers in the tail end of turnouts who enjoyed a comparatively better paddy crop than head-end farmers earned Rs 4,208 as their net income. However, the working capital requirement for their Yala cultivation (0.51 ha of paddy and 0.18 ha of chilies) amounted to Rs 3,801 leaving only Rs 407 equivalent in cash and rice grain for the subsistence of the farm family for six months.

The above analysis shows that all farmers require credit for cultivation purposes. In addition, many farmers may need credit for their subsistence. However, none of the farmers in the study area obtained cultivation loans from institutional sources for 1982 Yala season. Since only the most successful of these small farmers have savings, many farmers would have borrowed from private money lenders for cultivating in Yala season. Private money lenders are known to charge exorbitant rates of interest. Once indebted to the private money lenders, small farmers would find it difficult to escape the viscious circle of indebtedness, poverty, low purchased inputs in cultivation, low output, which leads again to indebtedness and poverty.

An agricultural credit scheme has to be backed by an effective crop insurance scheme to be successful. In the event of a crop failure, the insurance scheme can safeguard both the bank lending credit as well as the farmer. It is understood that there is no compulsory crop insurance scheme in operation in the study area. Bank credit is guaranteed against crop failure by the Mahaweli Authority. Hence, banks do not insist on the repayment of loans obtained for the cultivation during a season subject to crop failure prior to the issue of loans for the next season. However, since farmers are not paid the value of their crop loss, as an insurance scheme would do, they are compelled to borrow from private money lenders for subsistence.

## 5. Summary of Findings

Findings of the study should be treated with caution due to its limitations indicated earlier, and further studies should be conducted for detailed understanding and statistical confirmation of observed trends. Given these limitations, the preliminary analysis of the economic data highlights the following problems.

(1) Farmers in the area are operating at subsistence level. Suitability of the technical as well as physical input package given to them may have to be reappraised.

(2) Cropping intensity and yield data suggest unequal distribution of water at least in bad seasons such as Maha 1981/82 and Yala 82.

(3) Economic data confirm the perception of the farmers that water, credit, and draft power are major constraints for successful operation of farming units in the area.

## D. Sociology

### 1. Discipline Statement and a Framework for Analysis

To understand the operation of an irrigation system from a sociology/extension persepctive, it is useful to view an irrigation system as an organizational entity in which different categories of people interact with each other to perform a set of predetermined activities. The behavior of these groups could be called the building blocks of the irrigation system in that group interactions determine the outcome of the activities. Sociologists and extension workers thus attempt to identify, measure, and understand the factors that affect irrigation behavior, to find out how such factors could best induce the groups to operate the irrigation system effectively.

Not all patterns of irrigation behavior are a function of sociological factors. As shown by Berry (1976), "...the role of the physical-environmental factors in shaping, limiting or determining various forms of group-shared behavior and the regularities which lie behind them..." needs to be examined, too. Thus the design and structure of the irrigation system, the cropping patterns, crop water requirements, soil and rainfall will exert pressures on the behavior of the various groups in a system.

In this analysis, the following factors greatly determine the behavior of farmers and irrigation officials in an irrigation system:

(1) socio-cultural factors,

(2) land tenure,

(3) water problems and control,

(4) institutional framework,

(5) levels of farmer knowledge and perception,

(6) environmental factors, both natural and man-made, and

(7) external factors--government policy, legal framework, politics and other outside intervention.

This report touches upon all these factors, but concentrates on selected variables that are more important in this study. Figure D-1 illustrates the interactions between these factors and irrigation behavior.

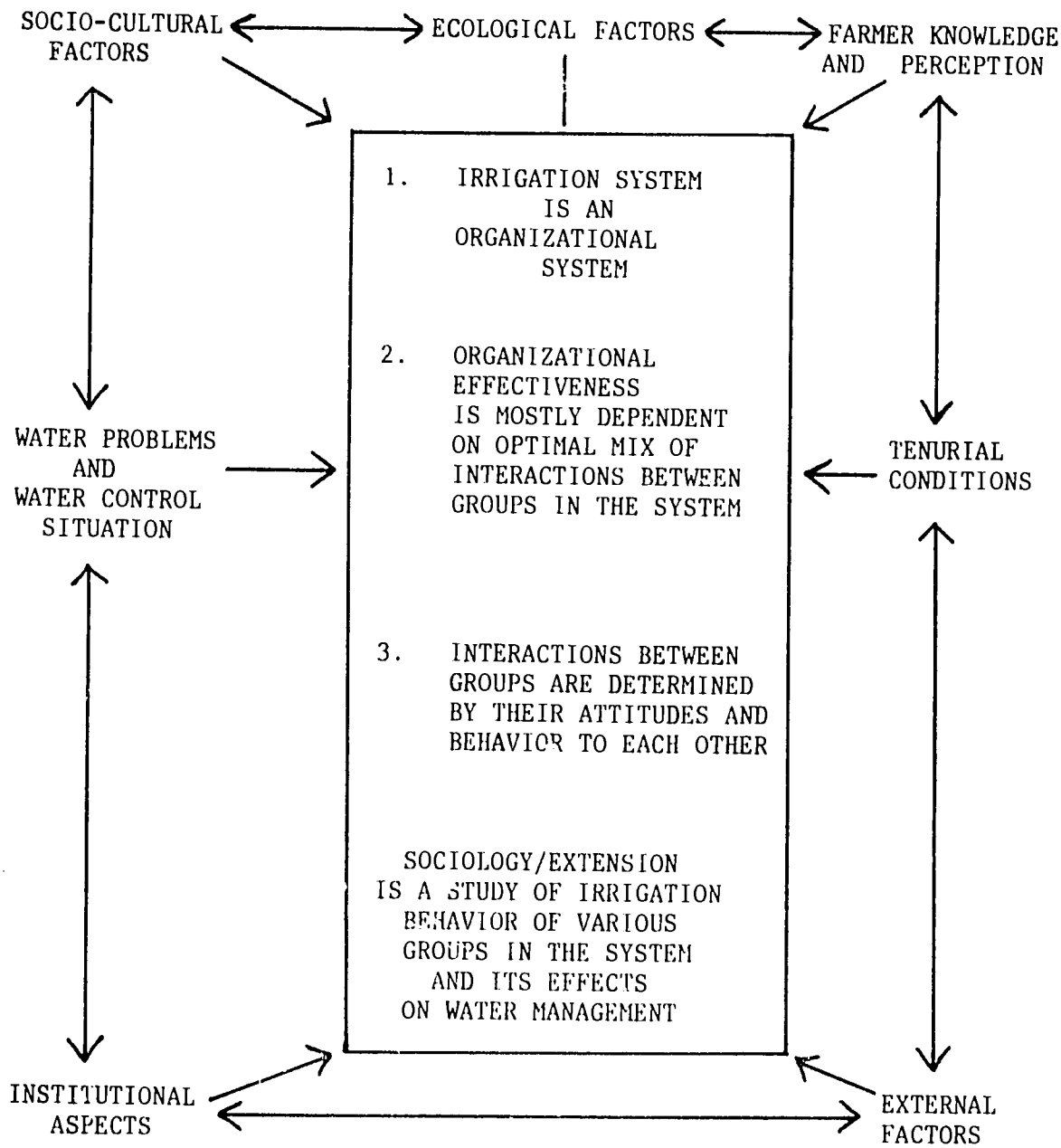



Figure D-1. Factors Affecting Behavior of Groups within an Irrigation System

## 2. Social Profile of Study Area and an Assessment of Socio-Cultural Factors

The study area lies in a newly resettled irrigated agricultural scheme in the dry zone of Sri Lanka. The resettlement program began in 1976/77. Prior to the resettlement program, the area was inhabited by villagers whose families had lived there for generations in scattered pockets of old (purana) villages. With the start of the Mahaweli irrigation scheme, these traditional villagers were incorporated into the system. Since the unit of allotment under the scheme was 1 ha of lowland and 0.2 ha of homestead, the traditional village lands had to be demarcated for distribution.

In this settlement there are four types of settlers:

(1) Selectees,

(2) Evacuees,

(3) Purana villagers, and

(4) Early migrants.

However, in the study area, which is only a small part of the scheme, the main categories observed were the purana villagers and the early migrants. Table D-1 shows how the responding farmers were distributed among groups.

Table D-1. Respondent Farmers by Settler Category

| Settler Category | No. (%)* |
|---|---|
| Purana Villagers | 23 (61) |
| Early Migrants | 12 (32) |
| Evacuees | 1 (3) |
| Selectees | 0 |
| Other | 2 (5) |

*Throughout this sociology report, percentages may not sum to 100 due to rounding errors.

The mean age of the sample was 39 years. The range was 25 to 61. Forty percent of the sample farmers had a primary education, while 47 percent had gone through secondary school, dropping out at or before the Ordinary Level Examination. Only 13 had passed O-Level. It is significant that all had gone through primary education. The mean number of household members was 5.2, and the mean number of children in each household was 2.7. Off-farm employment was almost nonexistent.

The resettlement scheme seems to be in a transitional stage. It may be that the settlers are still under the stress of dislocation and resettlement. Different categories of settlers may have different

attitudes toward the project and each other. For example, the purana villagers who have land in their villages may resent the project, while those who are landless may welcome it. However, there is a significant difference in their perception of water problems (Table D-2).

Table D-2. Reported Water Problems for Cultivation of Paddy and Upland Crops by Settler Categories

| Reported Water Problems | Settler Category: Purana Villager N (%) | Settler Category: Early Migrant N (%) |
|---|---|---|
| Paddy Problems | | |
| Problems | 18 (86) | 4 (33) |
| No Problems | 3 (14) | 8 (67) |
| Upland Crops | | |
| Problems | 8 (80) | 1 (10) |
| No Problems | 2 (20) | 9 (90) |

If there are no spatial factors affecting the above perceptions, then the variation could be explained by differing knowledge levels, cultivation practices, and beliefs of the two groups. Since the villagers are used to traditional practices of paddy cultivation, they may perceive that they need more water than the crop requires. However, in analyzing the spatial distribution of two groups in the irrigation system, it seems there are more early migrants than purana villagers in the head reach (Table D-3).

Table D-3. Spatial Distribution of Main Settler Categories in the Irrigation System

| Spatial Distribution | Settler Category: Purana Villager N (%) | Settler Category: Early Migrant N (%) |
|---|---|---|
| Head | 9 (39) | 7 (58) |
| Middle | 5 (22) | 2 (17) |
| Tail | 9 (39) | 3 (25) |

It may still be premature to assess the power and influence networks among the colonist farmers in the study area as the settlements are only about seven years old. Since all settlers started off more or less equal, and since the settlers came from varying backgrounds, we presume that it will take more time for strong social stratification to emerge. For these reasons and for lack of time, the turnout group leaders that were selected by farmers (in consultation with officials) a few years earlier served as the key informants in collecting additional information. A social profile of the seven key informants interviewed seems to strengthen the assumption that power and influence are still

diffused, although it seems a gradual buildup of power centers is appearing.

In informal interviews with farmers, both inside and outside the study area, it appeared that the turnout group leaders were gradually losing credibility. Many farmers saw them as an extension of the bureaucracy and not popular farmer leaders. Thirty-four percent of the farmers interviewed said that the farmer leader in water management was not helpful to them. Twenty-four percent said the farmer leader in extension was not helpful.

Other informal networks of influence which flow from tenurial arrangements and bureaucratic access are discussed under the section on land tenure.

3. Land Tenure

Although the legal position regarding land ownership and tenure in the study area is that no farmer is permitted to pledge his 1 ha, the de facto position is to the contrary. Table D-4 illustrates the tenurial changes that have taken place in the study location, based on information gained through key informants in the respective turnouts.

Table D-4. Percentage of Allottees Identified by the Key Informants as Having Land under Different Tenurial Arrangements in Maha 1981/82 and Yala 1982

| Tenure Arrangement of Allottees | Seasons | |
|---|---|---|
| | Maha 81/82 | Yala 82 |
| | N (%) | N (%) |
| Leased Out Completely | 15 (23) | 12 (19) |
| Leased Out Partially | 11 (17) | 12 (19) |
| Mortgaged | 1 (2) | 1 (2) |
| Sharecropping | 3 (5) | 6 (9) |
| Owner Operated | 35 (53) | 34 (51) |

A study conducted in 1980 in Unit 304 of Mahaweli System H about 3.2 km downstream of the present study location also indicated a high prevalence of leasing and sharecropping. The number of settlers giving out their lands either to be cultivated on sharecropping or lease, had steadily increased over the last three seasons. In Maha 1978/79, 54 percent of the settlers rented out their land. This number increased to 70 percent in Maha 1979/80. A similar study (Siriwardena, 1980) indicated more than half of the allotments were not cultivated by the settlers.

The leasing rate was Rs 1,000/ha/season in the study area. Some of the main reasons for leasing out land, identified through discussion with farmers, key informants, and officials, were:

(1) Lack of capital to invest in highland crops such as chilies.

(2) Insufficient family labor, especially for highland crop cultivation.

(3) Financial problems and personal distress.

(4) Wanting to give an opportunity to landless family members to cultivate.

Two other reasons which were not directly given by any of the interviewees, but which we were able to hypothesize through the information we gathered, merit discussion.

(1) Farmers' perceived need to cultivate both paddy and other upland crops as mandated by the Mahaweli Authority (MA) in Yala 1982.

We encountered farmers (not from the study area but from the area supplied by the same D-channels) who had leased a portion of their allotment to other farmers and either leased or sharecropped a portion of another allotment in a neighboring turnout. In his own allotment, one farmer culitvated chilies and soybeans, while in the sharecropped allotment, he cultivated paddy. According to the farmer leader in D-channel 4 T.O. 10, the farmers in that turnout decided informally before the season started to exchange portions of allotments among themselves, so that farmers who had allotments in the upper slopes could get a portion of land in the lower slopes and vice versa. However, this informal arrangement, according to the farmer representatives, could not be implemented as the Mahaweli Authority decided to cultivate only upland crops in Yala 1982.

(2) Leasing to other farmers as a stategy to get a more assured supply of water to turnouts.

We learned through discussion with farmers and some officials that a number of persons who leased out land in the vicinity of the study area were influential people who had access to the bureaucracy of the Mahaweli Authority, such as police officers, doctors, officials of the Mahaweli Authority or other government agencies, local elites in the fringes of the project area, and relatives of officials of the Mahaweli Authority. It was their perception that in the turnouts in which the influential people had land, water was not a problem during a dry season.

Another group of cultivators with different goals, belief systems, and values existed. The nature, manner and objectives of their

cultivation operations and their relative influence promoted patterns of behavior which, viewed from a water management perspective, may be unfriendly toward the system. Typically, the lessees and mortgagees belonged to this group.

Cultivation for this group is done by hired labor. The primary objective of the group is to obtain the highest returns with minimum investment. They are illegally cultivating land because renting land in the project area is not permitted.

The high incidence of leasing out has had some adverse effects on water management in the Mahaweli System H.

(1) Disruption of rotations within turnouts and sometimes even in the D-channels.

(2) Illegal cutting of bunds and water stealing using hired labor.

(3) Poor maintenance of F-channels.

(4) Disruption of turnout groups.

(5) Conflicts over water.

4. Water Problems and Water Control Situation

In irrigated agriculture, the key production resource is water. Farmer decisions about which crops to grow, when to grow, when and whether to fertilize, when to apply agro-chemicals, and when and how to irrigate a particular crop are largely dependent on the reliability, predictability, and adequacy of the water supply to the farm. Reliability could be defined as the system's ability to provide the farmer with water, according to a predetermined rotational schedule, and to maintain consistently the same interval between rotations. This does not preclude the right of the management to change rotational schedules to meet special circumstances. But, for effective water control, rotation changes must be quickly and effectively communicated to the farmer. Thus, the water control capability available to the managers and farmers in an irrigation system is a major determinant of irrigation behavior.

Sixty-one percent of the sample farmers in the study identified water as the most critical problem in paddy cultivation. Credit and draft power (55 percent each) were the next most urgent problems. In the cultivation of upland crops, credit (82 percent) and draft power (50 percent) were first and second in importance and water (46 percent) was third. The frequency distributions of perceived water problems, both for paddy and other field crops, by head, middle, and tail categorization, is given in Table D-5.

The water problems as seen by farmers seem to increase from head to tail. This becomes more evident when specific water problems are

considered. The farmers who identified water as a major problem were asked to name specific water problems they faced during two seasons. The observed results are presented in Table D-6.

Table D-5. Distribution of Perceived Water Problems and Their Severity (By Rank) for Paddy and Upland Crops by Head, Middle, and Tail Farms

| Crop | Head N (%) | Middle N (%) | Tail N (%) |
|---|---|---|---|
| Paddy | | | |
| 1. Have Water Problems | 10 (59) | 5 (71) | 8 (67) |
| 2. No Reported Water | 7 (41) | 2 (29) | 4 (33) |
| 3. Of Those Reporting Water Problem, Magnitude of Problem by Rank | | | |
| •Most Important Problem | 4 (40) | 2 (40) | 6 (75) |
| •2nd Most " " | 3 (30) | 1 (20) | 1 (13) |
| •3rd Most " " | 3 (30) | 2 (40) | 1 (13) |
| Upland Crops | | | |
| 1. Have Water Problems | 4 (33) | 4 (57) | 2 (67) |
| 2. No Reported Water | 8 (67) | 3 (43) | 1 (33) |
| 3. Of Those Reporting Water Problem, Magnitude of Problem by Rank | | | |
| •Most Important Problem | 2 (50) | 1 (25) | 0 |
| •2nd Most " " | 0 | 1 (25) | 1 (50) |
| •3rd Most " " | 2 (50) | 2 (50) | 1 (50) |

According to Table D-6, the major problem faced by farmers who cultivated paddy for both seasons was an inadequate supply of water. Inadequacy becomes more critical as one moves from head to tail. Surprisingly, inadequacy was more or less the same for both Maha and Yala. The previous Maha was exceptionally dry and may have biased the responses, especially as 40 percent in the middle reaches also complained of lack of water in Maha. Unreliable water issues were detected toward the tail, although in Yala, 25 percent of head farmers also reported unreliable water delivery.

For cultivation of upland crops, the major problem reported was excess water in the head and middle reaches. Only 16 percent of all farmers who cultivated crops in Yala reported water indaequacy.

These problems, if allowed to build, affect farmer behavior. If farmers find that they are unable to change the circumstances through

Table D-6. Distribution of Specific Water Problems Faced by Farmers for the Cultivation of Paddy in Maha and Yala Seasons, and Cultivation of Upland Crops in Yala, by Head, Middle and Tail Farms

| Specific Water Problem | Number (%) of Farmers Responding | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Paddy | | | | | | Upland Crops | | |
| | Maha | | | Yala | | | Yala | | |
| | Head | Middle | Tail | Head | Middle | Tail | Head | Middle | Tail |
| Too Much Water? | | | | | | | | | |
| Yes | 1 (9) | 0 | 1 (11) | 0 | 0 | 0 | 5 (42) | 1 (17) | 0 |
| No | 10 (91) | 5 (100) | 8 (89) | 12 (100) | 6 (100) | 8 (100) | 7 (58) | 5 (83) | 8 (100) |
| Inadequate Water? | | | | | | | | | |
| Yes | 5 (46) | 3 (60) | 7 (78) | 5 (42) | 2 (33) | 7 (87) | 2 (17) | 1 (17) | 1 (13) |
| No | 6 (54) | 2 (40) | 2 (22) | 7 (58) | 4 (67) | 1 (13) | 10 (83) | 5 (83) | 7 (88) |
| Unreliable Water? | | | | | | | | | |
| Yes | 0 | 0 | 2 (22) | 3 (25) | 0 | 4 (50) | 0 | 0 | 0 |
| No | 11 (100) | 5 (100) | 7 (78) | 9 (75) | 6 (100) | 4 (50) | 12 (100) | 6 (100) | 8 (100) |
| No Water? | | | | | | | | | |
| Yes | 0 | 2 (40) | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| No | 11 (100) | 3 (60) | 9 (100) | 12 (100) | 6 (100) | 8 (100) | 12 (100) | 6 (100) | 8 (100) |

legal and acceptable behavior, they will behave rationally and attempt to increase their water control by circumventing existing rules.

a. Water Control at the Farm Level

The above analysis indicates the importance of providing the farmer with effective water control. The degree of water control available is a function of the management practices of the bureaucracy and farmer behavior. Farmer behavior, in turn, is usually a function of system management procedures.

Management Functions that Affect Water--Water control by the irrigation bureaucracy is done at two places in the study location; at the D-channel headgate and at individual turnout gates. According to the field officials interviewed, D-channel 3 has no measuring device or calibration at the head to get an accurate measure of discharge. Discharge measurement is done by the surface velocity method. In D-channel 3, five turnouts have measuring devices while four do not. Water is released into these turnouts by guesswork. One study location, T.O. 8, is in this category.

At the headgate on D-channel 4, there is a discrepancy among the field officials about the frequency that the gauge is read. The stated frequency varied from daily, to once a week, to two or three times a month. All turnouts in this D-channel lack measuring devices.

The D-channels were operated on a 3-days-on, 4-days-off rotation, although the program announced at the commencement of the season was 4-days-on and 4-days-off. Although midcourse adjustments are perfectly acceptable from a management point of view, communication of the change appears to have been only partly effective. When asked about the D-channel rotations, 21 percent of the sample farmers said that they were being operated on a 4-days-on and 3-days-off schedule. About another 19 percent gave responses of 1-day-on/6-days-off and 2-days-on/ 5-days-off.

These data suggest that the management of the canal system may be improved through better monitoring and communication programs. The main reason farmers gave for their specific water problem was poor canal management.

Factors that Affect Water Control within Turnouts--Water control within the turnouts can be affected both by farmer action and irrigation bureaucracy action and/or inaction.

In analyzing farmer actions affecting water control, emphasis should be given to the planned water allocation procedures for the turnout compared to the actual implementation. Theoretically, there should be a rotation within the turnout, i.e., two outlets situated on opposite sides of the field channel are expected to draw water for 12 hours. Both key informants and farmers reported that rotations rarely occur within turnouts. Only 32 percent of the sample farmers

said that rotations are practiced within a turnout. Incidence of farmers exchanging turns with others is also low. Only 42 percent of the farmers said that they ever exchanged a turn with another farmer. The 32 percent who said they practice rotations may be practicing different rotation schedules. Also, they may be adopting rotations only during periods of water stress.

In an effort to assess the water control status within the turnouts, farmers were asked to give the frequency of occurrence of the following deviant irrigation practices.

Farmers themselves admit that deviant farmer behavior (which could affect the implementation of the accepted water allocation procedures) occurs within the turnout (Table D-7). Information obtained through the key informant questionnaire and field officials' questionnaire reinforce this observation. We may thus infer that deviant irrigation behavior by farmers affects the control capability available to farmers within the turnout. Lack of control leads to further inadequacies and unreliability which in turn causes more deviant, but rational, behavior. Such a vicious cycle might be broken by introducing improved system management procedures, leading to more positive farmer irrigation behavior. One way to implement these procedures may be to strengthen farmer organizations and support them with a responsive bureaucracy.

Table D-7. Percentage of Farmers Reporting Frequency of Occurrence of Deviant Irrigation Practices

| Behavior | Frequency of Occurrence | | |
|---|---|---|---|
| | Often | Sometimes | Never |
| | No. (%) | No. (%) | No. (%) |
| Taking water out of turn | 11 (29) | 14 (37) | 13 (34) |
| Farmers opening gate | 4 (11) | 13 (34) | 21 (55) |
| Influence on gate keeper | 2 ( 5) | 13 (34) | 23 (61) |
| Cutting bunds/illegal outlets | 3 ( 8) | 7 (18) | 28 (74) |
| Obstructing field channels | 5 (13) | 16 (42) | 17 (45) |
| Damaging structures | 4 (11) | 17 (46) | 16 (43) |
| Going to influentials | 2 ( 6) | 9 (25) | 25 (69) |
| Threatening farmers | 2 ( 5) | 11 (29) | 25 (66) |
| Taking excess water | 4 (11) | 11 (30) | 22 (59) |
| Abusing officials | 2 ( 6) | 12 (33) | 22 (61) |

Defective and badly designed and constructed outlets and poorly located turnouts also affect water control within the turnout. Malfunctioning structures make it necessary for the farmers to resort to negative irrigation behavior. Thirty-seven percent of farmers were not satisfied with the location of the turnouts, while six of the seven key informants said that the quality of structures in the field channels was very poor.

During the diagnostic analysis study, the farmer representative of T.O. 8 of D-channel 4 complained to us that most of the outlets were badly designed and constructed. The engineer in the group agreed that some structures were inappropriate for their location and did not serve the purpose they were intended to serve. In this particular turnout, some allotments had to share two outlets. According to the farmer representative, although the authorities had accepted the shortcomings of the structures, no attempts had been made to rectify them.

b. Problems of Water Control and Field Channel Maintenance

The norm in the Mahaweli system (as in most schemes) is for field channels to be cleaned by farmers. Each allottee is deemed responsible for cleaning a length of channel apportioned to him. In practice, this work is not done at all or is done haphazardly. Thirty-two percent of the sample farmers said that they are not satisfied with the quality of work done in cleaning the channels, while 63 percent said that the field channels were not cleaned as often as they should be. Typically, field channels are cleaned once at the commencement of each season. However, in Maha 1981/82 and Yala 1982, respectively, 37 and 55 percent of the farmers said that they cleaned the channels twice. When questioned about the problems of organizing farmers to clean field channels, 40 percent said nonparticipation was a major problem and 42 percent said haphazard timing. Six of the seven field officials interviewed agreed that the poor quality of the field channel cleanup created problems of water control within the turnouts. The high incidence of leasing and sharecropping in the study location and the lack of sanctions against transgressing farmers (either by the farmer organizations or by the irrigation authorities) are considered to be the main causes for the poor standards of maintenance.

It is evident that there are diverse constraints to effective water control at the farm level which inhibit positive and healthy irrigation behavior among the farmers in the system. It seems apparent that various system management procedures and structures (water distribution ruls, maintenance programs, outlets, turnouts) are directly linked to negative farmer behavior.

5. Institutional Framework for Irrigated Cropping

The objective of this section is to assess (1) the quality of interaction between the agency's management organization (Mahaweli Authority) and the farmers and (2) the role and effectiveness of farmer organizations, in order to examine how the resulting behavior of both parties affects irrigated cropping in the study area.

a. The Role of Management Organization and Its Links with Farmers

Over a year ago, the management organization in the Mahaweli System H was changed from a multiunit line organization with each unit having authority to work independently with farmers, to a unified, single unit line organization operating through a single official at the farm level

(Figures D-2 and D-3). The objective of the change was to serve the farmer more effectively through a more coordinated management structure. Since feedback from the senior and middle level staff was not available to us, the following analysis is based on information gathered from Unit Managers (UM), field assistants (FA) and patrol laborers (PL).

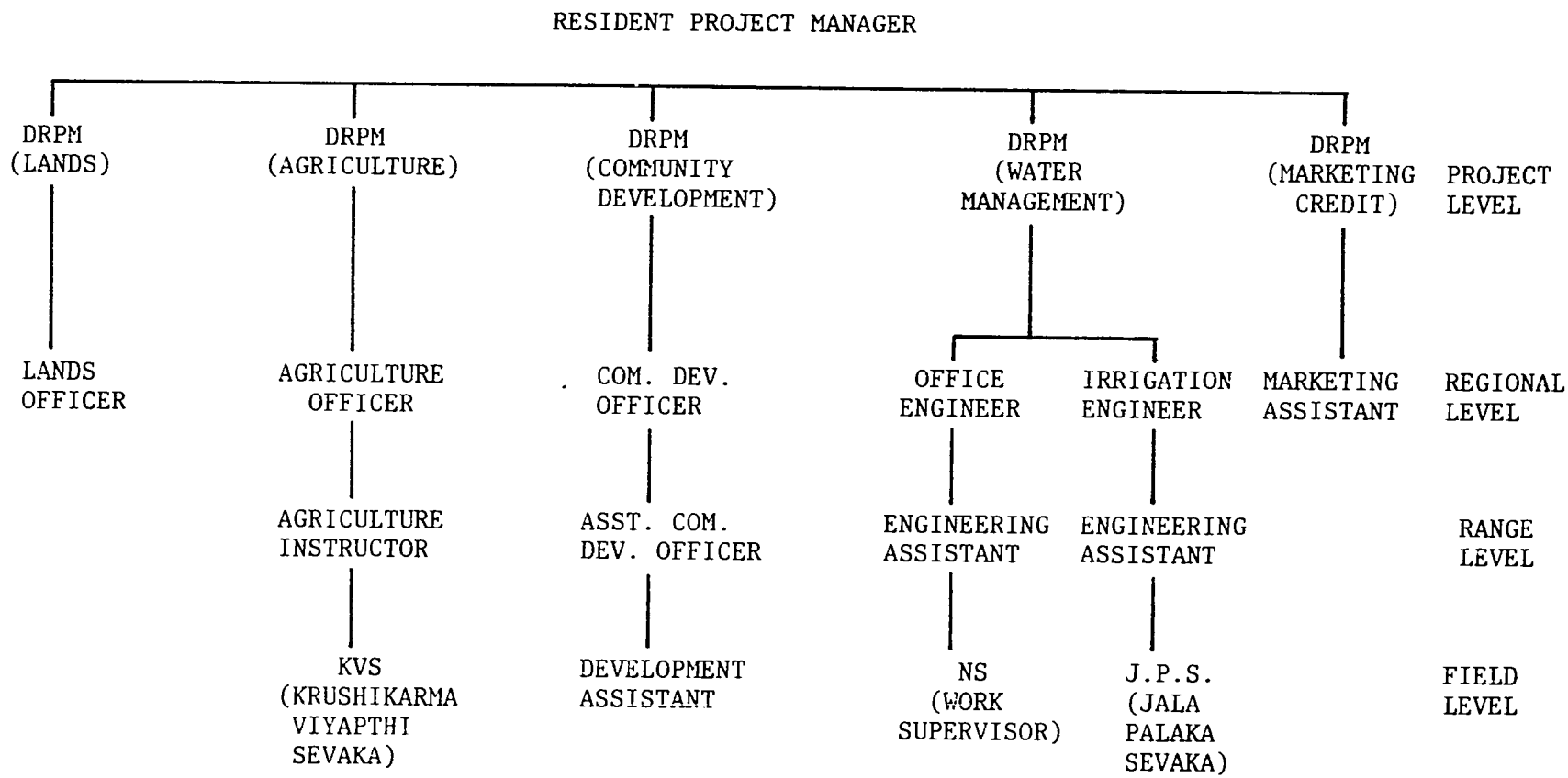
Role and Functions of the Unit Manager and His Field Staff--A Unit Manager is responsible for approximately 250 farm families or an area of 250 ha of irrigated land. His main responsibility is to provide required services for the farm families in his area and to manage his field staff. Each Unit Manager is expected to coordinate activities ranging from mother and child care to water management, credit, marketing, and agriculture; to conduct inquiries into land and encroachment problems. They are expected to coordinate the work of other agencies such as UNICEF, which provide drinking water and sanitary facilities. In addition, they are expected to promote farmer self-reliance and volunteerism. They are also expected to provide statistical and progress reports to the headquarters on most of these activities.

The two field assistants are expected to supervise and organize water management and agricultural extension activities in their unit. However, they are invariably called upon to perform other duties due to the exceptional workload handled by the Unit Managers.

Although both Unit Managers in the study area seem to be enthusiastic about work, the heavy workload prevents them from undertaking the important task of forging effective links with farmers. They need to devote more time to understanding the farmer's problems and needs. The advantages that are expected of a unified management structure may not materialize if the field-level bureaucracy is unable to forge positive and mutally responsive links with the farmers. There may be a need to de-emphasize the bureaucratic nature of the job and to reduce the number of farm families within a unit so that the Unit Manager could work with the farm families more effectively.

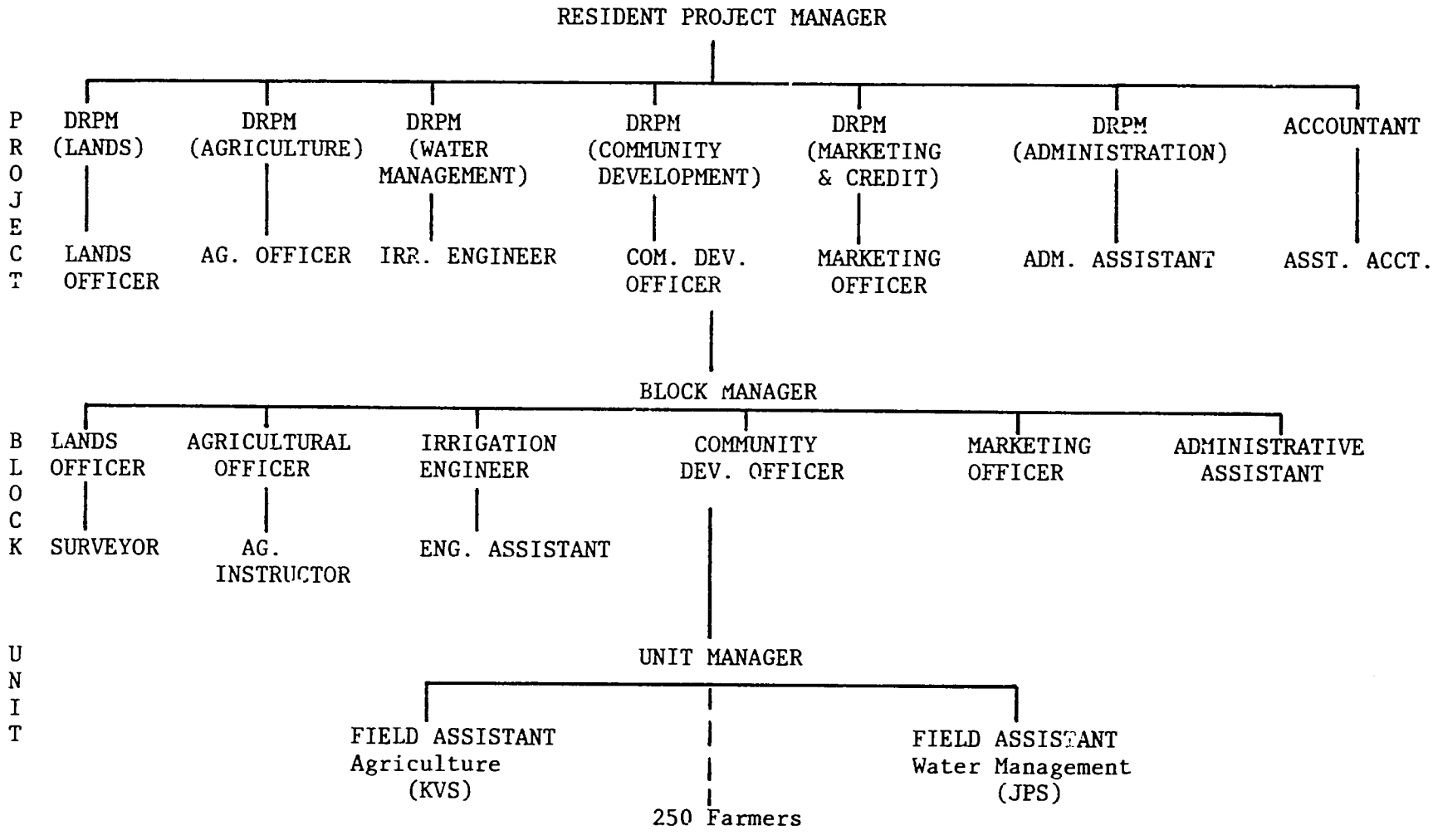
Contact with Field-Level Staff: The Farmer Viewpoint -- Farmers' views about the role of the field staff were ascertained by asking two questions; whether they knew the particular official well and how helpful he/she is to farmers in their work. Tables D-8 and D-9 show the results of this survey.

Although farmers seem to know the field officials well with the exception of the Field Assistant (Ag), nearly a third of the farmers feel that all three officials are not helpful to them in their work. Although this situation may seem to be satisfactory in comparison to the workload of field officials, remedial measures may be taken to prevent further erosion of management's credibility. There are no appreciable differences in credibility across head, middle, and tail farmer groups. The Mahaweli Project's shorter and more uniform field channels may be one reason for this.




DRPM = Deputy Resident Project Manager.

Figure D-2. The Old Management Structure of the System H, Mahaweli Project.




DRPM = Deputy Resident Project Manager

Figure D-3. The New Management Structure of the System H - Mahaweli Project

Table D-8. Farmer Contact with Field-level Officials

| Degree of Contact | Field Level Officers | | |
|---|---|---|---|
| | FA (WM) | FA (Ag) | UM |
| | No. (%) | No. (%) | No. (%) |
| Knows Well | 25 (64) | 10 (26) | 28 (72) |
| Do Not Know | 7 (18) | 10 (26) | 10 (26) |
| No Response | 7 (18) | 19 (49) | 1 ( 3) |

FA = Field Assistant
UM = Unit Manager
WM = Water Manager

Table D-9. Farmers' Perception of Field-level Officials' Helpfulness

| Degree of Helpfulness | FA (WM) | FA (Ag) | UM |
|---|---|---|---|
| | No. (%) | No. (%) | No. (%) |
| Very Helpful | 5 (13) | 2 ( 5) | 11 (29) |
| Somewhat Helpful | 12 (32) | 5 (13) | 13 (34) |
| Not Helpful | 14 (37) | 11 (29) | 12 (32) |
| No Response | 7 (18) | 20 (53) | 2 ( 5) |

In informal interviews we had with farmers the main reason they gave for the officials' low credibility was the inability of the field officials to solve local problems. In the People's Bank study in the Mahaweli System H (Siriwardena, 1980), similar reasons have been identified as the weaknesses of the earlier organizational structure. There still seems to be no mechanism for solving local problems especially in irrigation and water management, under the unified administrative structure. Part of the problem may lie in the gap that still exists between the field staff who are under the unit manager, and the technical staff working in the block manager's office, which has functional responsibility to the water management unit.

An assessment of the information sources of the farmers as a reflection of farmer-official interactions is presented in Tables D-10 and D-11.

The diffusion of information on aspects that directly affect irrigation behavior seem to be relatively more effective in Mahaweli H-area than in most other irrigation schemes, according to farmer responses. Only 11 percent of the sample farmers report that information

Table D-10. Sources through Which Farmers Obtain Information on Selected Irrigation Matters

| Sources of Information | First Water Issue | | On-Farm Water Management | | Water Rotations | | Changes in Rotations | |
|---|---|---|---|---|---|---|---|---|
| | N | (%) | N | (%) | N | (%) | N | (%) |
| Farmers | 2 | (5) | 3 | (8) | 2 | (5) | 7 | (18) |
| Farmer Representatives | 2 | (5) | 4 | (11) | 6 | (16) | 7 | (18) |
| Agricultural Officers | 0 | | 3 | (8) | 0 | | 0 | |
| Irrigation Officers | 2 | (5) | 1 | (3) | 15 | (40) | 13 | (35) |
| Cultivation Meeting | 31 | (82) | 2 | (5) | 12 | (32) | 0 | |
| Other | 1 | (3) | 2 | (5) | 2 | (5) | 8 | (22)* |
| No Information | 0 | | 23 | (60) | 0 | | 2 | (5) |

* Mainly display of posters.

Table D-11. Farmers' Perception of Effectiveness of Information Sources for Selected Irrigation Matters

| Perception | First Water Issue | | On-Farm Water Management | | Water Rotations | | Changes in Rotations | |
|---|---|---|---|---|---|---|---|---|
| | N | (%) | N | (%) | N | (%) | N | (%) |
| Adequate | 24 | (63) | 7 | (44) | 20 | (54) | 18 | (51) |
| Somewhat Adequate | 12 | (32) | 8 | (50) | 14 | (38) | 13 | (37) |
| Not Adequate | 2 | (5) | 1 | (6) | 3 | (8) | 4 | (11) |

on changes in water rotation is not adequate. However, the inability of 40 percent of the farmers to name accurately the rotation schedule on the D-channel seems to contradict this trend. Still, diffusion of information on this aspect seems adequate.

With on-farm water management, however, the picture appears to be very grim. Only 40 percent of the farmers have ever had any advice on water use for crop production. Of these, 19 percent have obtained information from farmers or farmer representatives. This clearly indicates that the extension staff has been inactive. The fact that field assistants in extension were known to so few farmers (26 percent) seems to emphasize the need for improved extension effort from the Mahaweli Authority.

b. Preseasonal Cultivation (Kanna) Meetings and Problems of Communication between the Management and Farmers

By statute, decisions about cultivation and the water issue calendar for the season are made at preseasonal meetings (called the kanna meeting) attended by the officials and farmers. Historically, these meetings were held to obtain the views of the farmers to arrive at the crucial decisions regarding the cultivation cycle In the ancient village tank schemes, these meetings were forums for farmer decision-making. Because of the greater organizational complexity, these meetings were used to obtain farmer ratification of decisions made by the bureaucracy (Wickramasinghe, 1982).

At the beginning of the Yala season, due to a scarcity of water, all farmers in System H were required to cultivate upland crops. However, the minutes of the kanna meeting which were circulated among the farmers did not state that it was prohibited to cultivate paddy. It did not mention paddy, but gave a calendar of operations for other crops. Despite the ban, some farmers did grow paddy at the mid and lower slopes. Due to unexpected rains at the beginning of the Yala season, some farmers who had cultivated chilies suffered crop damage. Then more farmers shifted to cultivate paddy. Despite requests by individual farmers and farmer representatives, the original decision was not changed, although the circumstances had changed somewhat. Consequently, the illegal paddy crop was not well managed by farmers due to the uncertainty of water supplies.

The inference is that either there is no mechanism to involve farmers in a continuous review of the problems that arise during the cultivation season, or if there is, it is not effective. Perhaps the fortnightly training programs held for farmer representatives could be used for this purpose. Due to time constraints, however, we could not study the program. The lesson we could draw from this situation is that complete reliance on the decisions made at a kanna meeting does not foster good water management. There needs to be a mechanism which incorporates active farmer reviews of particular situations and problems that arise due to changing circumstances throughout the cultivation season.

c. The Role and the Effectiveness of the Turnout Group in Organizing Farmers for Irrigated Agriculture

In the study area, all farmers in a turnout are theoretically organized into turnout groups. Each turnout selects two farmer representatives, one for water management and the other for extension. These farmer representatives are expected to plan and implement rotations within the turnouts with active farmer participation, and to distribute extension advice which they obtain through fortnightly training classes organized for them by the Mahaweli Authority.

A few months prior to our survey, the Mahaweli Authority decided to establish another type of organization, the Community Development Societies, at the village or hamlet level (Mahaweli Authority of Sri Lanka, 1982). At the time of the survey there were contrasting opinions as to the existence of the turnout groups among the officials and farmers. Some said that turnout groups have been disbanded while some felt that they have been incorporated into the new society. In a sense, the survey was conducted at a time when there was an institutional hiatus in the study area. Therefore, farmer responses may be biased. Only 26 percent of the sample farmers reported the existence of formal turnout groups in the area. That water rotations were rarely practiced in their turnouts and the poor cleaning of field channels seems to confirm that the turnout groups were not effective. Siriwardena (1980) confirms this:

> "The findings of the sample revealed that though the turnout group organization is accepted as a valuable concept, as far as small farmer development is concerned the achievement of its objectives were difficult. The reason was that insufficient attention was paid to the socio-economic and socio-cultural problems of the community, and also due to the lack of a grass-root level programme to organize the farmers into viable groups."

The role of farmer organizations in promoting effective irrigation behavior among farmers and as a forum for establishing links with the bureaucracy is recognized by most irrigation experts. Even the Mahaweli Authority field officials accepted the importance of the groups, especially as useful forums for diffusing information on irrigation aspects. Perhaps the high information diffusion observable in the study area may be due to the existence of these turnout groups.

The importance of turnout farmer organizations (formal or informal) in promoting acceptable irrigation behavior, and thus reducing undue pressure on the system, could be assessed by comparing the irrigation behavior and perceptions of farmers in the four study turnouts.

On an average, only 26 percent of sample farmers in all turnouts acknowledged the existence of formal turnout groups. Farmers of one turnout, namely T.O. 10 on D-channel 4, unanimously agreed that there is

an informal farmer organization in that turnout for water management activities; in other turnouts, even informal group arrangements for irrigation-related activities were reported to be low.

There are varying views about the usefulness or appropriateness of farmer organizations for irrigation management. However, in a small farm context, (e.g., where in a 12-ha area there may be 12 or more effective decision-making units) a group-focused approach for irrigation management and decision-making becomes critical. In Sri Lanka, there has been a tradition of farmer participation and cooperation in the old village tanks based on water rights and service tenure, and reinforced by strong community norms that are buttressed by equity considerations. Obviously, the Mahaweli system is not comparable to a village-tank scheme. However, within certain limits, a turnout could be compared to a village-tank command. The critical factor, however, is not to impose organizations on the farmers, but to let the organizations emerge through a catalyst program.

The case of T.O. 10 in a way exemplifies the positive role of farmer groups in local irrigation management and the importance of giving the farmers the initiative to organize themselves.

In Table D-12 it can be seen that T.O. 10 (in which 100 percent of the sample farmers acknowledged the existence of an informal farmer group that is active in water management related functions) has a high incidence of constructive irrigation behavior, better water control, and fewer water problems. Although the available information does not allow us to arrive at a conclusive causal correlation between farmer organization and effective water management in T.O. 10, we see a very strong trend in this direction.

6. Farmer Irrigation Knowledge and Perceptions

This section attempts to (1) measure the farmers' knowledge of certain selected irrigation practices and to assess how knowledge and perception affect their behavior and (2) to identify areas in which farmers need more scientific knowledge for better crop production.

Two specific questions were asked of all sample farmers.

(1) How do farmers decide when to start irrigating a crop of paddy, chilies or other upland crops.

(2) How do they decide when to stop irrigating paddy and upland crops.

Farmer responses are given in Tables D-13 and D-14. It is heartening that about a quarter of the sample adopt the correct procedure in deciding when to commence irrigating a paddy crop, i.e., by examining surface soil. Sixty-five percent of the farmers said that they irrigate when the water comes. With a particular field due to get

Table D-12. Summary Table of Responses for the Four Study Turnouts by Selected Variables Affecting Irrigation Management at the Turnout Level

| Variables | Percentage of Farmer Responses for Respective Turnouts | | | |
|---|---|---|---|---|
| | T.O. 5 | T.O. 8 | T.O. 3 | T.O. 10 |
| A - FARMER ORGANIZATION | | | | |
| Informal farmer group in T.O. - YES | 13 | 40 | 0 | 100 |
| B - WATER PROBLEMS | | | | |
| Farmers naming water as one of three most critical problems - Upland Crops | 0 | 60 | 22 | 18 |
| - Paddy | 88 | 100 | 55 | 27 |
| Specific water problems - Maha | | | | |
| Inadequacy | 25 | 80 | 44 | 9 |
| Unreliability | 25 | 80 | 44 | 9 |
| Lack | 0 | 0 | 0 | 18 |
| Specific Water Problems - Yala | | | | |
| Inadequacy | 100 | 40 | 22 | 0 |
| Unreliability | 88 | 0 | 0 | 0 |
| Lack | 0 | 0 | 0 | 0 |
| C - WATER DISTRIBUTION WITHIN TURNOUT | | | | |
| Practice of rotations within turnout in Yala - YES | 0 | 10 | 0 | 100 |
| Incidence of exchanging water turn with others - YES | 13 | 60 | 0 | 82 |
| Satisfied with water distribution in turnout - YES | 75 | 80 | 78 | 82 |
| Satisfied with maintenance of field channel - YES | 63 | 90 | 33 | 73 |
| Satisfied with farmer cooperation in distributing water in turnout - YES | 88 | 80 | 67 | 100 |

Table D-12. (Continued)

| Variables | Percentage of Farmer Responses for Respective Turnouts | | | |
|---|---|---|---|---|
| | T.O. 5 | T.O. 8 | T.O. 3 | T.O. 10 |
| D - INSTITUTIONAL SERVICES | | | | |
| Knows FA(WM) - YES | 13 | 80 | 100 | 64 |
| Knows UM - YES | 88 | 50 | 78 | 82 |
| FA(WM) helpful - YES | 13 | 50 | 78 | 36 |
| UM helpful - YES | 63 | 50 | 67 | 73 |
| INFORMATION SOURCES | | | | |
| Water rotation information adequate - YES | 88 | 80 | 89 | 100 |
| Changes in water rotations: Information adequate - YES | 75 | 80 | 78 | 82 |
| E - DEVIANT IRRIGATION PRACTICES | | | | |
| Following never happens: | | | | |
| Taking water out of turn | 50 | 0 | 44 | 46 |
| Farmers opening gate | 63 | 10 | 67 | 82 |
| Using influence on gatekeeper | 75 | 40 | 33 | 91 |
| Making illegal outlets | 88 | 80 | 56 | 73 |
| Obstructing field channels | 38 | 10 | 44 | 82 |
| Damaging structures | 38 | 10 | 22 | 91 |
| Going to influentials | 63 | 70 | 44 | 82 |
| Threatening other farmers | 75 | 30 | 78 | 82 |
| Using water excessively | 75 | 40 | 33 | 82 |
| Abusing officers | 63 | 30 | 67 | 73 |

Table D-13. Distribution of Sample Farmers by Criteria Used to Decide When to Irrigate Paddy, Chilies, and Other Upland Crops

| Identified Criteria | Paddy | | Chilies | | Other Upland Crops | |
|---|---|---|---|---|---|---|
| | No. | (%) | No. | (%) | No. | (%) |
| By last date of irrigation | 2 | (5) | 3 | (10) | 2 | (8) |
| By appearance of soil | 10 | (26) | 13 | (45) | 9 | (38) |
| By appearance of plant | 2 | (5) | 5 | (17) | 4 | (17) |
| By stage of plant growth | 1 | (3) | 1 | (3) | 1 | (4) |
| By examining subsurface soil | 0 | | 6 | (21) | 6 | (25) |
| When water comes | 21 | (65) | 1 | (3) | 1 | (5) |
| Other | 2 | (5) | 0 | | 1 | (5) |

Table D-14. Distribution of Sample Farmers by Criteria Applied to Decide When to Stop Irrigating Paddy and Upland Crops

| Identified Criteria | Paddy | | Upland Crops | |
|---|---|---|---|---|
| | No. | (%) | No. | (%) |
| When water reaches border at end of field | 3 | (8) | 0 | |
| Before water reaches border at end of field | 3 | (8) | 0 | |
| When water covers all high spots | 7 | (18) | 0 | |
| When water reaches certain depth on the terraces | 20 | (53) | 0 | |
| When furrows are full | 0 | | 16 | (55) |
| When terraces are full | 0 | | 13 | (45) |
| Do not know | 5 | (13) | 0 | |

water once in seven days, this criteria should work, especially when one considers the high permeability of soils in the head and middle allotments. But we have seen that the seven-day rotation does not operate as planned. In most turnouts, there are no rotations. Under these circumstances, we may assume that most of the farmers could be over-irrigating their paddy crops.

Eighteen percent said they stop only when the high spots in a terrace are covered. This may lead to over-irrigation of the depressed areas and wasted water. Thirteen percent frankly admitted that they do not know when to stop irrigating paddy. Fifty-three percent said that they stop irrigating when water reaches a certain depth in the terrace. This method also may lead to over-irrigation if the depths are too great.

The problem is more acute in relation to the irrigation of chilies and other upland crops. Although farmers reported agronomically sound practices to begin irrigation, there appears to be a contradiction when the criteria used to stop irrigation are considered. Forty-five percent of the farmers said that they decide to stop irrigating when the basins are full, often leading to over-irrigation. It certainly appears that farmers need more information about low cost methods of land preparation and irrigating upland crops. Only 40 percent of the sample farmers reported ever having received any advice on farm water management. Of this 40 percent, only 22 percent have been advised by government officials. It is interesting that the most critical water problem identified for cultivation of upland crops was waterlogging or excess water and that the farmers viewed this as a frequent occurrence. Thus, it can be concluded that extension programs concerning on-farm water management and cultivation of upland crops are either nonexistant, or, if taking place, are ineffective.

## 7. Summary and Conclusions

The objective of sociology in the Diagnostic Analysis of farm irrigation systems is to examine factors affecting and affected by the behavior of the farmer and the bureaucracy. The major conclusions of this analysis, subject to the scope and limitations set out in the background of this report, are:

(1) In cultivating paddy, the major problems identified by farmers are the lack of water adequacy and reliability, credit, and draft power, in that order. The major problems in the cultivation of other field crops as seen by farmers are credit, draft power, and water.

(2) A high proportion of farmers lease out their allotments either partially or completely. High leasing out leads to disruption of rotations within turnouts and sometimes even in D-channels, illegal procurement of water, poor maintenance of F-channels, and disintegrating influences within turnout groups.

However, in examining some of the possible causes for leasing out land, farmers appear to be rationally adapting to a situation over which they have little or no control. Improving the farmers' liquidity and farm-level water control are thus important.

(3) Water control capacity at the farm level is adversely affected by weak canal management at the D-channel and turnout levels, inadequacy of irrigation structures within the turnouts and poor field channel maintenance. This situation leads to deviant but rational responses by the farmers, which in turn worsens the water control capacity at the farm level. We suggest that canal management, especially at the D-channel and turnout level, be improved based on a more realistic and effective monitoring program and a realistic maintenance program to improve the inadequate irrigation structures.

(4) The expected advantages of the unified management structure have not been fully realized due to the heavy workload placed on the Unit Manager, which does not allow him to work closely with the farmers. It may be desirable to reduce the area served by a Unit Manager and to de-emphasize the bureaucratic nature of the office for a more favorable working relationship with farmers. Despite these limitations, the day-to-day information needs of the farmers were met fairly satisfactorily.

(5) A low priority seems to be given to training farmers in on-farm water management practices, and the cultivation and irrigation of upland crops, even though the farmers have little knowledge in these areas. We suggest that a well-planned extension program be developed to train farmers in methods of on-farm water management that are relevant and within the means of the farmers to practice effectively.

(6) Since our survey was held during a period of institutional transition, there was no consensus about the future role of the turnout groups. Some farmers and key informants felt that the turnout groups should be de-emphasized or disbanded in favor of the newly established Community Development Societies. Although the turnout groups were weak for a variety of reasons, it may be counterproductive to de-emphasize their role in major irrigation schemes that have a predominantly small farm sector because the turnout is the most logical hydrologic base for water management. It may be prudent to strengthen the turnout groups, using a low-intervention, community-organization approach, coupled with a responsive bureaucracy.

(7) The consequences of the varying expectations and needs of the farmers on one hand, and the Mahaweli Authority on the other,

during Yala 1982 exemplifies the need for an effective mechanism that will incorporate farmer participation in reviewing situations and problems that arise due to changing circumstances throughout the cultivation season. Complete reliance on the decisions made at the cultivation meetings is not good water management. Effective water management requires flexible decision-making and effective two-way communication between the farmers and the bureaucracy.

## 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<br>H. Gamage | L. Nelson |
| Agronomy: | M. M. Premachandra<br>M. A. W. Bandaranayake | L. Nelson |
| Economics: | A. Ekanayake | M. Haider |
| Extension: | L. Wickramasinghe | L. Dunn |
| Irrigation Engineering: | R. A. Nandasena | K. H. Yoo<br>Wayne Clyma |
| On-Farm Engineering: | H. Gamage | R. E. Griffin<br>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 jungle-land used for shifting cultivation under rainfed conditions.

G.C.E. (O.L.) - General Certificate of Education (Ordinary Level), 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.

## VII. LITERATURE CITED

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