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Diagnostic Analysis of Parakrama Samudra Scheme, Sri Lanka: 1985 Yala Discipline Reports

Water Management Synthesis Project
WMS Report 57

DIAGNOSTIC ANALYSIS OF PARAKRAMA SAMUDRA SCHEME, SRI LANKA: 1985 YALA DISCIPLINE REPORTS

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Larry J. Nelson
Coordinator of the
Diagnostic Analysis Project

I. INTRODUCTION

In Sri Lanka, the development of new irrigation systems, and the improvement and rehabilitation of old systems, are prime targets of agricultural planning. Large irrigation systems associated with resettlement projects have been constructed to extend and increase the agricultural productivity of Sri Lanka's Dry Zone. However, the operation of many of the schemes has been less than optimal, and the anticipated results have not always been realized. Consequently, new institutional policies and programs emphasize alternative strategies for improving the productivity and performance of irrigation systems.

One such plan by the Government of Sri Lanka involved creating the Irrigation Management Division (IMD) within the Ministry of Lands and Land Development (MLLD). In addition to other responsibilities, the IMD is expected to establish a system for monitoring and evaluating the performance of irrigation systems. These monitoring and evaluation methods will be based on diagnostic analysis procedures developed by the Water Management Synthesis Project at Colorado State University (Water Management Synthesis Project, 1983).

Diagnostic analysis techniques were introduced to Sri Lanka through three in-country, professional development workshops conducted in 1982, 1983, and 1984. Fundamental to diagnostic analysis is the philosophy that irrigation problems are not confined to one single discipline such as engineering or agronomy, but rather, that they involve a wide range of issues that include social and economic aspects as well. As part of the training workshops, interdisciplinary teams of participants investigated an existing irrigation system, identified constraints, and discussed various approaches to solving irrigation-related problems.

Reports from these workshops were written on the Rajangana Irrigation Scheme in 1982 (Alwis et al., 1983b) and System H of the Mahaweli in 1982 and 1983 (Alwis et al., 1983a; Jayewardene and Kilkelly, 1983). Although these reports were limited in scope due to the nature of the training workshop, they provided useful information and valuable insights into the operation of the irrigation systems studied. As a result, the MLLD recognized the benefits of this investigative approach and desired to employ these concepts as a practical, preliminary approach to identifying constraints in irrigation systems.

An opportunity to use diagnostic analysis as a tool for gathering baseline information arose with the creation of the Irrigation Systems Management Project (ISM). The ISM Project, funded by the United States Agency for International Development, proposes to rehabilitate and improve four irrigation systems in the Polonnaruwa District of Sri Lanka: Parakrama Samudra, Giritale, Minneriya, and Kaudulla.

This baseline data collection effort was called the Diagnostic Analysis Project. Diagnostic analysis was considered the most appropriate investigatory method to use; although physical improvements to the existing irrigation systems were important considerations, various socio-economic efforts were also included in the ISM Project design (Skogerboe et al., 1984).

In effect, the Diagnostic Analysis Project was designed to provide complete understanding of these irrigation systems in order to assist the ISM Project in determining pragmatic, cost-effective means for improving the operation of these systems. The collection of a reliable, extensive volume of data would provide valuable information concerning system operation. In addition, this information could later be compared to information gathered after the irrigation systems are rehabilitated and improved.

The overall objectives of the Diagnostic Analysis Project were:

1. To strengthen IMD's institutional capacity and the abilities of its associated personnel to use diagnostic analysis techniques to study existing irrigation schemes.

2. To assist in establishing a set of evaluation procedures and methodologies for continual monitoring of irrigation system operations.

3. To provide detailed background information on the selected irrigation systems for future use in rehabilitation and improvement projects.

The following report details the diagnostic analysis conducted during 1985 yala on Parakrama Samudra Scheme. The report is divided by discipline into sections on main system engineering, on-farm engineering, agronomy, economics, sociology, and women in development. Due to various logistical problems involved in implementing a study of this scope, the sample size and composition for the different disciplines varied. In addition to the sites chosen for engineering and agronomic field measurements, the economics, sociology, and women in development components surveyed other households in the scheme. An interdisciplinary discussion of the results can be found in WMS Report 61, **Diagnostic Analysis of Four Irrigation Schemes in Polonnaruwa District, Sri Lanka: Interdisciplinary Report.**

II. PARAKRAMA SAMUDRA SCHEME

The Parakrama Samudra Scheme (PSS) is the largest irrigation system in Polonnaruwa District. PSS was originally constructed by King Parakrama Bahu the Great (1153-1186 A.D.) At that time, extensive areas of land were irrigated and cultivated. However, the area was largely abandoned after falling into disrepair with the collapse of the civilization.

In the 1940s, the original reservoir was discovered and restored to a storage capacity of 98,000 ac-ft. A more detailed description of the PSS tank and canal system is provided in the main system engineering section, with additional information concerning irrigation practices in the on-farm engineering section.

After the expansion and rehabilitation of the ancient tank was completed, approximately 4,000 allottees from the Wet Zone resettled there. Each of the settlers was allotted 5 ac of lowland for paddy cultivation and 3 ac of highland for a homestead. Although this system was originally designed to serve approximately 19,600 ac, it is now estimated to serve 25,000 ac.

The Parakrama Samudra Scheme is located in the North Central Province of Sri Lanka (Figure 1) and is characterized as gently undulating Dry Zone with elevations ranging from 45-456 ft above sea level. The average annual rainfall is 58 inches, which falls predominantly during the maha (wet season; October to March).

The majority of cultivated area in the Polonnaruwa District is now under a number of major irrigation schemes. Prior to this arrangement, purana (old, traditional) villages cultivated paddy and other crops using local "cascade" tank systems for water storage and irrigation. There is no rainfed paddy cultivation in yala (dry season; April to September), but a limited extent of rainfed paddy cultivation may occur during maha. Paddy is the primary crop cultivated, but small areas of subsidiary crops such as chili, tobacco, maize, soybean, cowpea, groundnut, sesame, onions, and other vegetables are grown in yala where water for field irrigation is limited.

The Polonnaruwa District has been referred to as the "rice bowl" of Sri Lanka as it has some of the highest yields of paddy throughout the island. Average yala paddy yields during 1969 to 1985 were reported to range from 68.8 to 102.3 bu/ac in maha and from 46.0 to 86.1 bu/ac in yala (Polonnaruwa kachcheri records). The use of short-season, high yielding varieties is fairly widespread. A more detailed presentation of agricultural practices in PSS is contained in the agronomy section.

The highland allotments generally are not well utilized due to inadequate water. Even so, most families maintain perennial trees such

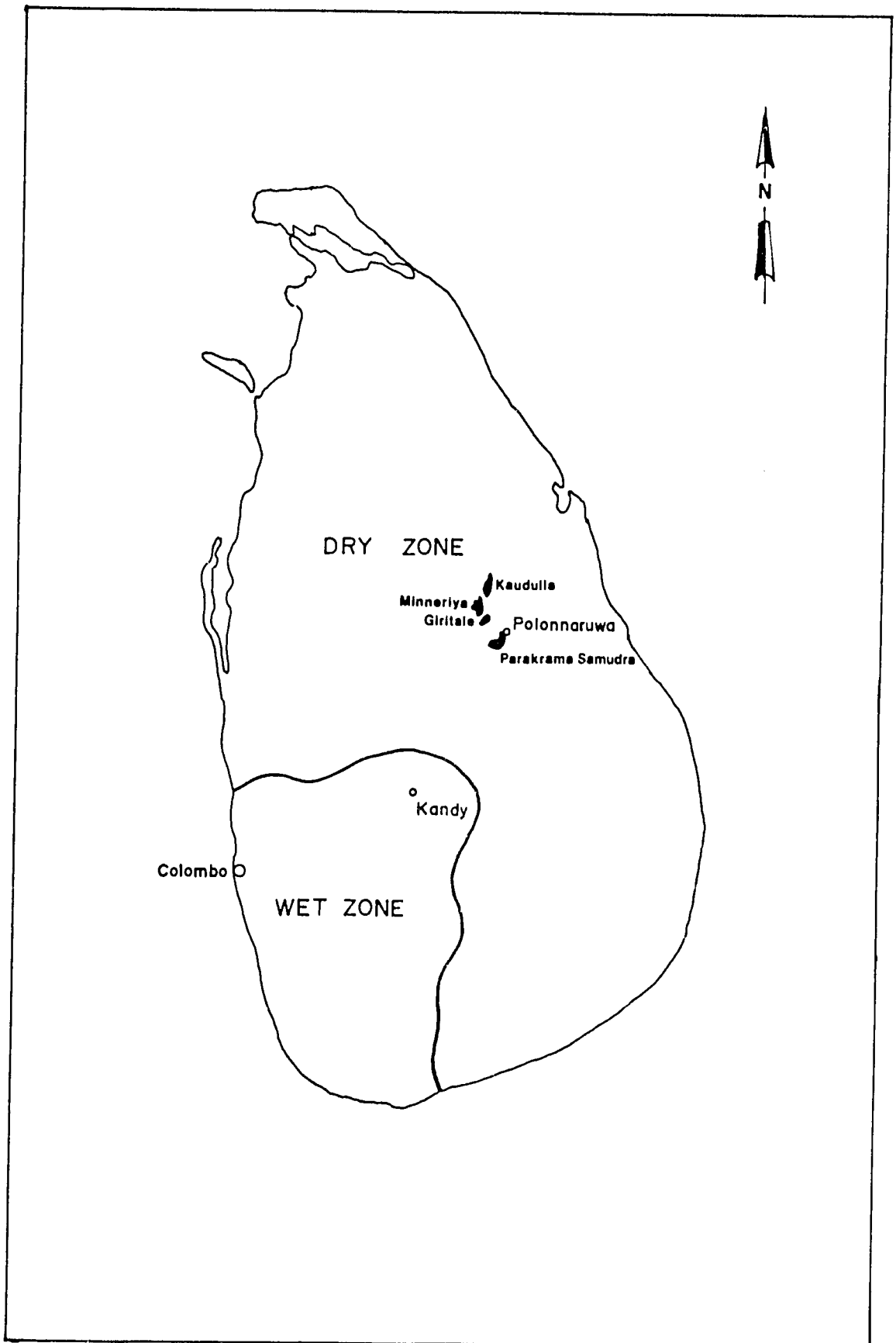

Figure 1. Map of Sri Lanka showing the location of Parakrama Samudra Tank.

as coconut, banana, or jackfruit. During maha, small gardens containing a diverse mixture of vegetables are planted, but yields remain low.

In the four decades since the major tanks were restored, in-migration created by the resettlement programs and natural increases have swelled population figures for the area considerably. The 1971 population total for the Polonnaruwa District was recorded at 163,700. In 1981 the total reported was 262,800. Figures from the Department of Census and Statistics, Central Bank of Ceylon, showed a total 1984 population figure for the Polonnaruwa District of over 284,000 people. This represents approximately 1.8 percent of the total national population with a density rate of 83 persons/km^2.

The most recent growth rate figure, reported for 1983-84, was 2.2 percent, well above the national average of 1.2 percent. This population growth factor, in combination with unemployment and underemployment, has led to a concentration of low income groups in the rural agricultural sector. The difficulty of absorbing a growing labor force when few alternatives to agriculture are available is considered a serious problem in the district.

Data from the 1981 census reported a district population composed of Sinhalese (90.9 percent), Tamil (2.2 percent), Indian Tamil (0.1 percent), Moor (6.5 percent), Burgher (less than 0.1 percent), Malay (0.1 percent), and other (0.2 percent). A more detailed description of the socio-economic background of PSS can be found in the economics, sociology, and women in development sections.

Figure 2 shows a map of the area studied in Parakrama Samudra Scheme in 1985 yala.

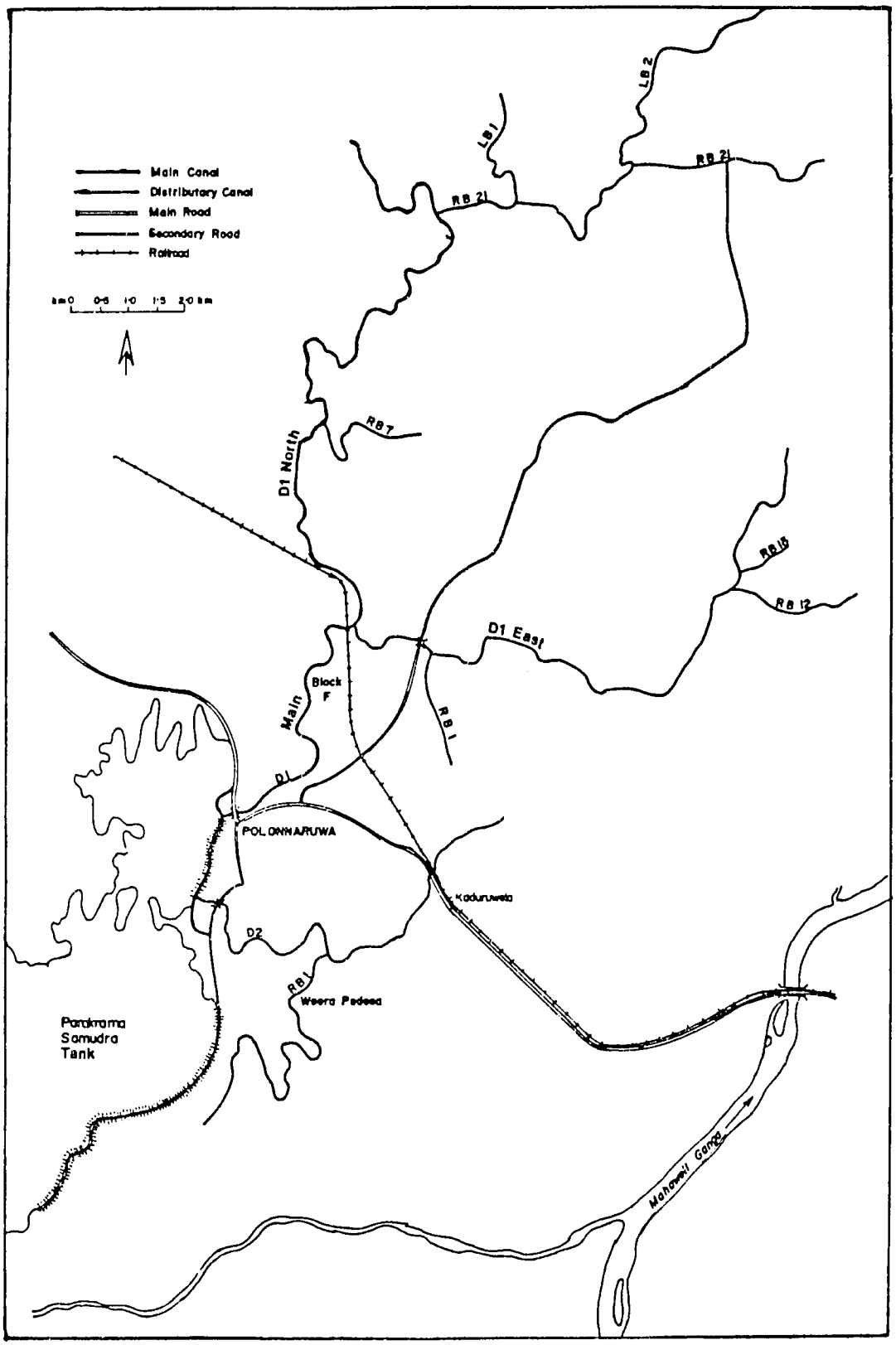

Figure 2. Study sites on Parakrama Samudra Scheme, Sri Lanka.

III. DISCIPLINE REPORTS

A. MAIN SYSTEM ENGINEERING

1. INTRODUCTION

Parakrama Samudra Scheme currently commands an estimated 25,000 ac of farmland in the Polonnaruwa District. The construction of this earthen canal system started in 1937 and was completed in 1944. The scheme is a gravity flow and surface irrigated system with a large reservoir located near Polonnaruwa. The usable storage capacity of the PSS reservoir is about 94,000 ac-ft, which meets 40 percent to 50 percent of the seasonal water requirement of the current command area. Therefore, the reservoir largely depends upon the Mahaweli River diversion for replenishment a few times a year.

The PSS reservoir releases water through three headworks: the D1, D2, and D3 sluices. The water supplied by each sluice is conveyed by a main canal identified by a corresponding name: D1 main canal, D2 main canal, and D3 main canal. The main canals distribute the water through branch canals, distributaries, and field channels that finally lead to individual farms.

The land irrigated by the D1 main canal is estimated to be 20,000 ac, which is 80 percent of the total PSS command area. Main canals D2 and D3 supply the remaining 5,000 ac. The designed* flow rates at the head of main canals D1, D2 and D3 are 350 cfs, 119 cfs, and 35 cfs, respectively.

The scheme was originally designed to command 19,632 ac of <u>yala</u> paddy. Over time, farmers brought large extents of additional lands under irrigation. However, the source of water and the delivery system remained the same, since official approval from the Irrigation Department was not obtained to cultivate these additional areas. The actual command area irrigated today is uncertain, but the estimate of 25,000 ac is widely used by the government agent of Polonnaruwa District for administrative purposes, and for agricultural programs. The same figure has been adopted by the Water Management Panel of the Mahaweli Authority for seasonal water distribution in the Mahaweli River Basin. The actual area cultivated under PSS may differ from the above figure, but no additional information is currently available.

In PSS, the water conveyance and distribution system consists of three single-banked, major canals that originate from controlled sluices on the reservoir, with branch canals created by regulating structures on the main canal. The regulating structures control the flow of water, the upstream water surface elevation, or both.

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*Unless otherwise noted, design flow rates mentioned in this report were calculated by the Irrigation Department for the most recent estimate of irrigated area at PSS (25,000 ac).

Distributary channels (D-channels) originate from the branch canals through wooden or steel-gated masonry structures. Field channels originate from the D-channels and usually have gate structures at the head to control the inflows. Finally, the water is diverted to individual farms from the field channels through farm outlets. The canal system has 36.5 mi of main and branch canals, and a total of 79 mi of distributary and field channels.

2. OBJECTIVES

It is evident that if the original command area has indeed been increased to the current estimate, a considerable demand on the irrigation system exists. This would undoubtedly create a significant effect on the performance of the irrigation system due to the various limitations in physical, organizational, and operational components of the water supply and delivery systems.

Although much concern has been expressed at various political and district agricultural and farmer committees, the effects on the irrigation system have only been stated in qualitative terms rather than as a quantitative assessment. Before any attempts are made to adjust the system to meet increased irrigation demand, a thorough evaluation of the present system operation must occur. Any modifications to the irrigation system recommended by such an evaluation could be incorporated into proposals for rehabilitating or modernizing the irrigation system. The main system engineering study, conducted as a part of the PSS Diagnostic Analysis Project, was expected to provide information concerning the current operation of the water supply and delivery systems, as well as to identify existing technical constraints.

3. PARAKRAMA SAMUDRA SCHEME

Since nearly 80 percent of the command area under PSS is irrigated by the D1 main canal, the efforts of the main system engineering study concentrated on this canal. It was felt that this commanded area would represent the various conditions existing throughout the entire scheme.

The D1 main canal system has a main canal and two branch canals, which lead to 55 smaller distributary and field channels in the study area. From the bifurcation at 3.6 mi, the main canal branches into two canals, the D1 North and the D1 East. The D1 north branch canal is 15.4 km long, and the D1 east branch canal is 12.4 km long. The distance from the D1 sluice to each D-channel along the main and branch canals is presented in Table 1.

The original command area of the D1 main canal was approximately 16,000 ac with a designed water duty at the field channel head of about 40 ac/cfs. Therefore, the D1 main canal was designed to carry 350 cfs. At the bifurcation, the designed discharges for the D1 north and D1 east canals were 200 cfs and 150 cfs, respectively. The original command areas under each D-channel within the D1 main canal system are summarized in Table 2.

Table 1. Measured distances from the D1 sluice to the D-channels and between channels on PSS.

Channel*	Distance (km)	Distance between D-channels (km)
D1 Sluice	0	0
Block F	1.8	1.8
Bifurcation	5.8	4.0
RB0	6.22	0.42
RB1	6.9	0.68
RB2	7.4	0.50
RB3	7.9	0.50
RB4	8.42	0.52
RB5	9.05	0.63
RB6	9.95	0.90
RB7	10.37	0.42
RB8	10.67	0.30
RB9	11.46	0.79
RB10	12.69	1.23
RB11	13.11	0.42
RB12	13.34	0.23
RB13	13.94	0.60
RB14	14.41	0.47
RB15	14.69	0.28
RB16	15.05	0.36
RB17	15.91	0.86
RB18	16.09	0.18
RB19	16.46	0.37
RB20	16.65	0.19
RB21	17.70	1.05
RB22	18.40	0.70

*RB = Right bank

The D1 main canal system contains cross-regulators, canal spillways, turnout structures, and drop structures. Two cross-regulators are provided -- one at the bifurcation of the D1 main canal into the D1 north and D1 east canals and one downstream of the RB21 off-take structure on the D1 north canal.

The D-channel off-take (turnout) masonry structures are provided with one or more rectangular wooden gates. Some of the larger gates have recently been replaced with cast-iron gates controlled by a threaded shaft and a manually operated, wheel-type, lifting mechanism. All of the gates have locks to prevent unauthorized gate operation.

Most of the field channel turnouts were designed to be gated, and standard 4-inch, free-flowing pipes are used as farm outlets (pols). There are no control devices provided to regulate flow of farm outlets, but when necessary farmers stop the flow by packing the outlets with mud and straw.

Table 2. Designed command areas under the D1 main canal system of PSS.

Canal/ D-Channel*		Designed Area (ac)	Canal/ D-Channel		Designed Area (ac)
D1 Main					
Block F			D1 East		
FC 1		104	RB 1		193
FC 2		72	RB 2		364
FC 3		192	RB 3		398
Tail		194	RB 5		11
			RB 6		300
			RB 7		24
D1 North			RB 8		43
			RB 9		467
RB 0		108	RB 9A		25
RB 1		30	RB 10A		?
RB 2		180	RB 10		734
RB 3		30	RB 11		51
RB 4		80	RB 12		526
RB 5		148	RB 13		83
RB 6		35	RB 14		83
RB 7		260	RB 15		130
RB 8		25	RB 16		50
RB 9		30			
RB 10		10			
RB 11		30	LB 1		1425
RB 12		95	LB 2		585
RB 13		20	LB 3		561
RB 14		385	LB 4		85
RB 15		30	LB 5		134
RB 16		20	LB 7		78
RB 17		470	LB 10		122
RB 18		2466	LB 12		60
RB 19		20	LB 13		190
RB 20		110	LB 14		140
RB 21	LB 1	500	LB 15		16
	LB 2	1339			
RB 22		400			

*FC = Field channel
RB = Right bank
LB = Left bank

The D1 main canal system is administered by the Polonnaruwa Divisional Irrigation Engineer Office under the Irrigation Department. The technical staff in this office are responsible for operating and maintaining the system. The organizational chart for the technical personnel is presented in Figure 3. As a team, the technical personnel plan and formulate the water issue calendar, issue and regulate water according to the schedule, and maintain the distribution system.

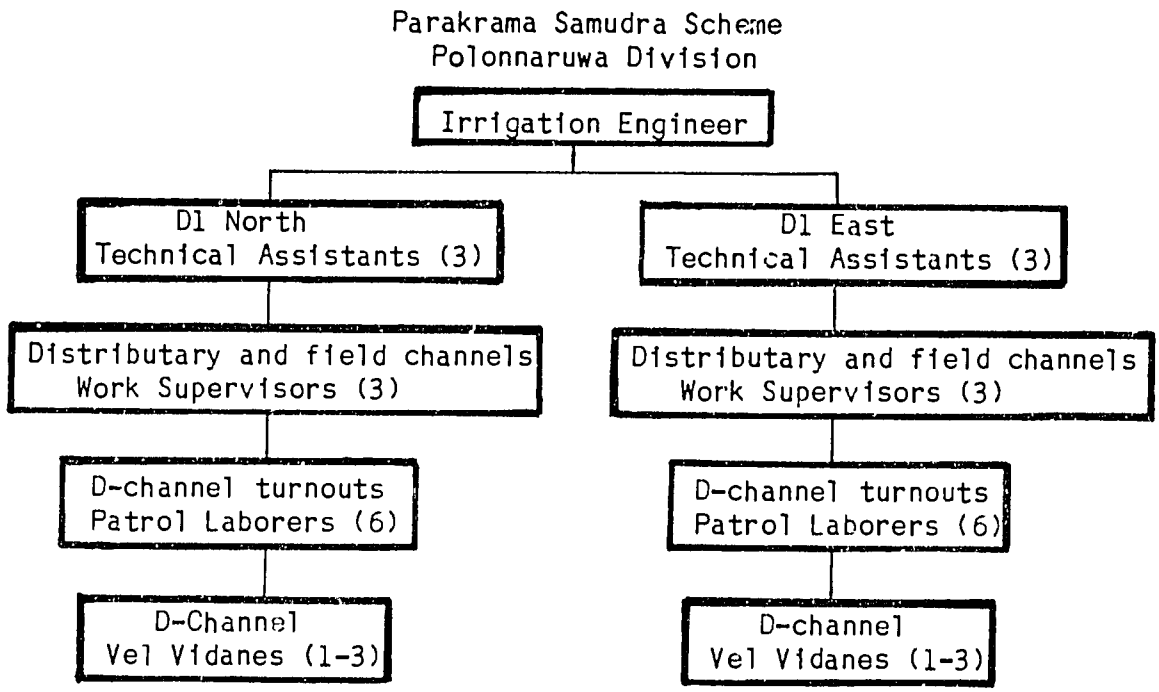

Figure 3. Organizational chart for Parakrama Samudra Scheme.

Operation and maintenance at PSS is done under the overall supervision of the irrigation engineer (IE) of Polonnaruwa Division. The IE is supported by the technical assistants (TAs), who communicate with the IE concerning irrigation demands and system performance. The qualifications of the TAs are equivalent to the National Diploma in Technology, and they are qualified to authorize canal operations. When problems affect larger areas, matters are referred to the IE.

Operating a D-channel to ensure an adequate, reliable, and equitable supply of water at each field channel turnout is the responsibility of a vel vidane (farmer representative). Based on the command area under each D-channel, up to three vel vidanes may share this responsibility.

Of all Irrigation Department staff, the patrol laborer maintains the closest contact with farmers. This individual operates the gates of the D-channel off-takes and adjusts the gates when extra water issues are authorized.

At least two weeks before the first issue of water, the government agent and irrigation engineer attend the pre-cultivation (kanna) meeting. At this meeting, the local irrigation staff present the seasonal rotation schedule of water issues to the farmers. Farmers have some degree of liberty to deviate from the schedule during the land preparation period, but are expected to work within the established water rotation schedule during the cultivation season.

For the 1985 yala, the D1 main canal was scheduled to operate continuously from April 20 to May 31 (during land preparation), and 12 of every 14 days thereafter until August 23. Two 6-day rotation cycles (back-to-back) were used for the D-channels along the D1 main canal. Although the reservoir feeds the canals continuously for 12 days, most of the D-channels operated continuously for only 2 days of every 6-day cycle, receiving water 4 out of 12 days. Table 3 presents the official water rotation schedule for the D-channels along the D1 canal system of PSS for the 1985 yala.

4. RECONNAISSANCE

A reconnaissance was conducted by the main system engineering team in PSS several months before the 1985 yala began. The team made visual observations along the canal network. Summarized below are the most notable features concerning the condition of the canals and structures and flow variations within the irrigation system.

a. Headworks

The reservoir bund was well maintained and in good condition. The three sluices were old, but operable. The two spillways -- a natural spill and a radial gate -- were also in good condition.

b. Main and Branch Canals

At the head of the main canal there was one staff gauge, but other than this, there were no measuring devices or structures in the entire system. D1 north and east branch canals were eroded and weak in most locations. In some places, the canal bed width was approximately 40 to 50 ft due to water buffalo climbing in and out of the canals, as well as farmers driving into the canal to wash their two-wheel tractors.

Structures were in good condition at the head and middle reaches of the canal. However, most of the canal structures toward the tail reaches were damaged and in need of repair or replacement. With only two cross-regulators and no measuring structures, it would be difficult to control, and impossible to monitor, the water surface levels in the canals. There were also signs of siltation throughout the system, which would significantly affect the hydraulic characteristics of the canal.

Although obtaining water from the canals through means other than legal turnouts is prohibited by the Irrigation Department, siphons are commonly used by farmers to obtain water directly from the canals to irrigate nearby fields. Siphoning occurs mainly during the night, but may also be seen during the day in more remote areas of the system.

The canals appeared to run in excess of the designed flow rate most of the time with very limited freeboard. In addition, the

Table 3. Six-day water rotation schedule below the D1 sluice for PSS during 1985 *yala*.

Day	Channels
D1 Main Canal	
1, 2, 6	All field channels up to bifurcation except Block F
3, 4, 5, 6	Block F (on the 6th day, only partial flow)
D1 North Branch Canal	
1, 2	- RB0 - RB20 - BOP*400 (the area below LB2 off RB21)
3, 4	- RB5, RB7, RB14, RB17, and RB18. All of these channels get water for 4 days. However, a two-day rotation is practiced among field channels within these D-channels. For example, all field channels off RB18 receive water for the first two days except D2, which gets water on the last two days. - All channels below RB21, LB1 off RB21, and BOP 312 and 398 (LB2 off RB21, but only up to FC1**)
5, 6	- BOP 649 (all field channels between LB1 off RB21) and the area below FC1 of LB2 off RB21.
D1 East Branch Canal	
1, 2	- RB1 - RB3 - LB1 - LB3; LB1 receives water for six days
3, 4	- LB4 - LB7 - RB4 - RB10
5, 6	- LB8 - LB15 - RB11 - RB16 - All field channels below RB16

*BOP = Blocking out plan
**FC = Field channel

carrying capacity of an aqueduct appeared to restrict service below this structure.

c. Distributary Channels

The gates of most of the D-channel off-take structures were in good condition. However, many off-take and drop structures located toward the tail were damaged and in need of repair. In some cases, the D-channel even passed by the drop structures. Siltation was also noted towards the tail reaches of several D-channels. There were no check structures in the D-channels. Water rotation at the D-channel level was modified by the Irrigation Department throughout the season in response to farmers requests. Consequently, highly variable flow rates were observed in the D-channels throughout the system.

d. Field Channels

Most of the field channel turnouts had no gates, and drop structures were generally damaged. With the exception of a few channels, the vegetative cover along the banks and beds of the field channels was excessive. Observations also indicated that some farmers took water by cutting bunds in addition to the authorized pipe outlets. Overall, the condition of the field channels was considered very poor.

5. METHODOLOGY FOR THE DETAILED STUDY

Workplans for the main system engineering study were formulated after several team planning meetings in Polonnaruwa. These plans were based on the observations made during the reconnaissance. Due to limited resources, the main system engineering team selected only the D1 main canal and the D1 north branch canal as the sample area for the detailed study.

Based on the reconnaissance observations, a series of research questions (hypotheses) were developed to guide the team during the detailed studies. These questions were organized around two general topics: water control and system management as they influence the adequacy, reliability, and equity of the water supply. Table 4 presents the questions developed by the team members for the main system engineering study on PSS during 1985 yala. The information and measurements required to obtain this information follows.

a. Adequacy of Water Supply

To determine the adequacy of the water supply, the team needed to know the current command area, the field irrigation requirements, the distribution of soil types, and the designed and actual delivered water supply at the head of the D1 sluice. The designed supply rate and soil distribution information were obtained through background research, while measurements were required to obtain the other information.

A water balance study was conducted by the on-farm engineering team to measure crop consumptive use requirements for 10 selected sites on 6 field channels in the study area. The actual delivered water

Table 4. Engineering research questions for diagnostic analysis of Parakrama Samudra Scheme, 1985 *yala*.

Water Control

1. Does the water supply meet the crop demands for the area cultivated?

2. Does the farmer have a reliable supply of water?

3. Is the water equitably distributed throughout the system?

4. Are the condition and the number of cross regulators, D-channel off-takes, and field channel turnouts sufficient to provide water control?

5. Is the system sufficiently maintained to convey water efficiently?

System Management

1. Does the system have sufficient qualified personnel?

2. Is there a difference between official and actual irrigation behavior and regulations?

3. Does the system have the required measuring structures to facilitate management?

4. Who makes management decisions, how are they made, and how are they implemented?

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supply was determined directly by measuring flow rates at the head of the D1 main canal during the *yala*.

b. Equity of Water Supply

To determine the equity of water distribution, the team needed to know the designed discharge rates at each D-channel, the actual discharges for D-channel off-takes along the canals, the assumed and actual canal loss rates, and the designed and estimated command areas under each D-channel.

c. Reliability of Water Supply

To determine the reliability of water supply, the main system engineering team had to take continuous flow rate measurements to produce inflow hydrographs for major control points along the canals. Also, the team observed farmer activities directly related to water distribution to analyze the extent of farmer involvement, both constructive and destructive, in the operation of the main system.

The design specifications and assumptions were obtained through background research. To obtain the additional information identified above, the following measurements were required:

* discharge rates for most D-channel off-takes along the D1 main and north canals.
* inflow and outflow rates for selected reaches of the canals.

To evaluate the physical condition of the D1 canal system, the team needed to know the designed and current profiles of the canals, and the designed and current characteristics of canal structures. As before, the design specifications were obtained through secondary information sources. To collect the additional information, the following measurements were planned:

* longitudinal and cross-sectional profile surveys of the canals.
* observation of dimensions and condition of the various structures.

To understand and evaluate the management of the main system supply, the team needed to record:

* The activities of irrigation personnel that were directly related to water distribution over the season.
* The activities of farmers that were directly related to water distribution.
* the decision-making process within the IE's office regarding water distribution at different levels of the system.

The main system engineering team obtained the required information by consulting irrigation personnel, reports, and maps from previous or on-going studies; making direct physical measurements; and recording observed activities.

To monitor flow rates, staff gauges were installed at the head of each D-channel and at selected points on the D1 main canal and the north branch canal, as shown in Figure 4. These points were: 1) upstream from the bifurcation, 2) the head of D1 north and east branch canals, 3) upstream from the aqueduct, 4) upstream from the RB21 off-take structure, and 5) up- and downstream from the second cross-regulator. Gauge heights were measured and recorded daily at each of these stations by the technical assistants of the Irrigation Department.

Water issues for PSS commenced on April 10 for the 1985 yala. However, measurement of flow rates did not begin until June 10 due to problems initially encountered in organizing and constructing the gauge stations. Therefore, water issues during land preparation were not monitored due to this delay. This was unfortunate since the water requirements during land preparation are generally high and may cause critical conditions for the canal operating system. Even so, the study

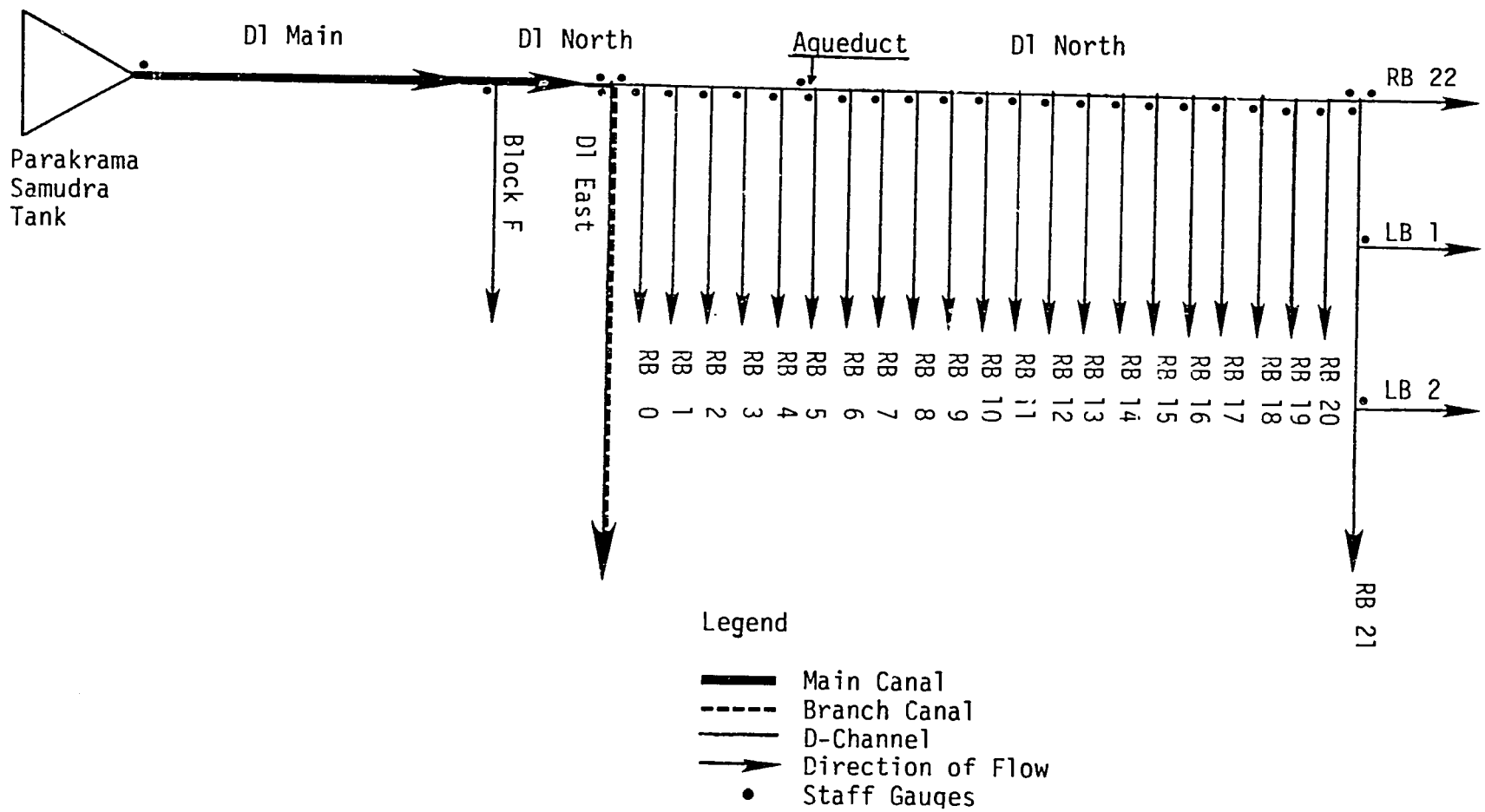

Figure 2. Location of the staff gauges in Parakrama Samudra, 1985 *yala*.

was expected to provide valuable information regarding the operation of PSS during the 1985 yala.

The staff gauges were calibrated during the latter part of the season. The larger canal sections and D-channels were assumed to be the composite of a number of segments, where the current was metered at various flow depths. The discharges measured by the current meter were plotted against the corresponding flow depths to develop rating curves (Appendix A). The rating curves were used to determine the discharges measured by the daily staff gauge readings. In the smaller channels, the relationship between flow depth and discharge was established using cutthroat flume measurements.

To measure the canal loss rates, the inflow-outflow method was selected. Flow rate measurements were taken on several reaches of the main canal and north branch canals using calibrated staff gauges.

Profile leveling was used to determine the longitudinal and cross-sectional profiles of the canals. Visual surveys were used to inventory the number and condition of the structures on the canal system through regular inspection. An evaluation form was developed to guide the team members during the structural survey.

Techniques adopted to evaluate system management were also by visual observation. Standard forms for a weekly irrigation activity report were developed so the responsible team member could record the date, time, location, and details concerning activities performed.

To determine the actual command area under each D-channel would be difficult and time consuming. The team proposed to estimate the actual command area by performing a perimeter survey in the six selected field channels and comparing this with the design figures to estimate the total increased area under cultivation.

6. RESULTS AND DISCUSSION

Due to manpower, logistic, and organizational difficulties, profile leveling and flow rate monitoring were the only two activities performed by the team members during the 1985 yala. Flow depth measurements were taken daily on the D1 main canal downstream of the tank sluice. Measurements were also taken at four points on D1 North, one point on D1 East, and 25 points on the D-channels. The data was collected from June 3 to September 5, 1985. The recorded flow depths over this 96-day period were entered into a specialized Lotus™ worksheet model for data analyses. With the Lotus™ 1-2-3 model, a number of tables and plots were generated to enhance the results and discussion in the following sections.

a. Adequacy of Water Supply

When the blocking out plans were designed, a considerable extent of land was reserved and set aside for a variety of uses including a park, pasture, community use, and future development. In addition, each canal or channel was provided with a reserved strip of land beyond the canal bund (in direct proportion to the canal size) and a service road to provide access for operating, maintaining, and repairing the channels. Most of this reserved area was no longer present, mainly due to encroachment. It appeared that wherever water could be tapped from the canal system, the reserved area was brought under cultivation, including canal reservations and even canal roads.

On the other hand, some of the lands originally intended for reservation were given away for other purposes by District Administration. Some of these lands were included in the figures of estimated extents (25,000 ac) recorded in the Polonnaruwa kachcheri. However, these figures were not likely to include all of the current cultivated extent. Table 5 compares the differences between the designed irrigated acreage and that measured by the main system engineering perimeter survey.

Table 5. Irrigated farm areas under selected field channels in the D1 canal system of PSS during 1985 yala.

Relative Location	Field Channel	Measured Area (ac)	Designed Area (ac)	Increase in Area Over Design (%)
Head	1	17.03	15.0	13.53
(Block F)	5	30.12	25.0	20.48
Middle	1	32.05	31.0	3.39
(RB 7)	Tail	47.96	40.0	19.90
Tail	11	30.12	30.0	0.40
(LB1/RB21)	16	28.92	25.0	15.68

The survey results did not show any regularity in the pattern of increased area cultivated. In the head region of the system there was a considerable area increase for both head and tail field channels. However, in both the middle and tail regions of the system, the extra land irrigated was very small in the head field channels, while larger extents were cultivated in the tail field channels. This was most likely due to the fact that drainage water from other parts of the irrigation system collected in the tail area, and farmers took advantage of the additional water to cultivate nearby reservations.

The percent increase in the command areas under the six field channels varied from 3 to 20 -- the average being 12 percent. This average was much lower than the commonly accepted 27 percent (based on the original design of 19,632 ac and the current estimate of

approximately 25,000 cultivated acres) that the team expected. The reserve area for field channels is far less than that around the main canal and distributary channels. Due to this relatively low value (12 percent), further surveys were conducted. These additional surveys, presented in Table 6, included the command areas under each D-channel of the D1 main and north canals. The estimated figures were obtained from the colonization officers who maintain records of seasonal cropping extents based on field observations.

As a result of the additional surveys, the overall average increase in cultivated acreage was determined to be approximately 30 percent, which was significantly greater than the average of the six selected field channels. Due to the larger sample size of the additional surveys, it was felt that the 30 percent value for increased cultivated area was a more realistic value for PSS.

Table 6. Command areas under D-channels along the D1 main canal and north branch canal of PSS during 1985 *yala*.

D-Channel*	Designed Area (ac)	Estimated Area (ac)	Increase Over Designed Area (%)
Block F	562	730	29.89
RB 0	108	133	23.15
RB 1	30	40	33.33
BB 2	180	280	55.56
RB 3	30	50	66.67
RB 4	80	101	26.25
RB 5	148	169	14.19
RB 6	35	43	23.92
RB 7	260	366	40.77
RB 8	25	30	20.00
RB 9	30	35	16.67
RB 10	10	16	60.00
RB 11	30	40	33.33
RB 12	95	141	48.42
RB 13	20	24	20.00
RB 14	385	460	19.48
RB 15	34	50	45.35
RB 16	20	24	20.00
RB 17	470	587	24.89
RB 18	1880	2530	34.57
RB 19	20	24	20.00
RB 20	110	119	17.20
RB 21	2674	3480	30.14
LB1/RB21	501	549	9.67
LB2/RB21	1339	1175	12.25

*RB = Right bank
LB = Left bank

Perhaps a more efficient and effective means of measuring the extent of irrigated command area for the entire PSS would be to use the Landsat data classification method. A reconnaissance study using Landsat data for PSS is currently being conducted by Mr. Tim Martin of Colorado State University. The results from this study should be useful in demarcating the lands that are currently cultivated in PSS. A more accurate figure for the percentage of additional cultivated lands could then be calculated.

In addition to the current command area, the field irrigation requirements of the cultivated area must be known to evaluate the adequacy of water supplied. Therefore, to calculate the daily field irrigation requirement, ET was calculated using the Penman method (1963), and percolation and seepage values were obtained from the on-farm engineering study (Figure 35, Table 9).

These values, in combination with the estimates of soil-type distributions (65 percent imperfectly drained and 35 percent poorly drained) were used to determine the field irrigation requirement for paddy during the 1985 yala on PSS. The percolation and seepage values were multiplied by the fraction of the total command area of the corresponding soil type. These adjusted percolation and seepage losses and the ET values were summed for a 3-day on and 3-day off rotation to obtain the daily field irrigation requirement, which is plotted in Figure 5. These requirements represented the daily average depth of water required in millimeters to satisfy crop consumptive use and the losses (when the rotation is on) over the 20,000 ac under the PSS D1 canal system.

An inflow hydrograph was developed for the D1 main canal as presented in Figure 6. The designed maximum discharge into the D1 main canal was 350 cfs. During the main system engineering study, the average measured discharge was 340 cfs during the flow periods of rotations, which indicated that the canal was running above the designed level most of the time with less than 2 to 3 inches of freeboard. In fact, the maximum observed flow rate was 456 cfs. With such a constant high discharge, scouring of canal banks and beds and structural damage may occur. In turn, the canal hydraulic characteristics may change and the canal may breach.

To evaluate the adequacy of water supplied, the field irrigation requirement was compared to the daily water supply rates at the sluice head (converted to depth of water in millimeters). The individual supply rates were each divided by the current command area under the D1 main canal (20,000 ac) to obtain daily water duties in flow rate per unit area (cfs/ac). The equivalent depths of water were calculated by dividing the individual water duties by a conversion factor (0.0017). These supplies represent the average depth of water supplied over 24 hours for the entire D1 command area, assuming of 100 percent irrigation system efficiency. The irrigation system efficiency is defined as the overall delivery efficiency, from the sluice to farm outlets, multiplied by the field application efficiency.

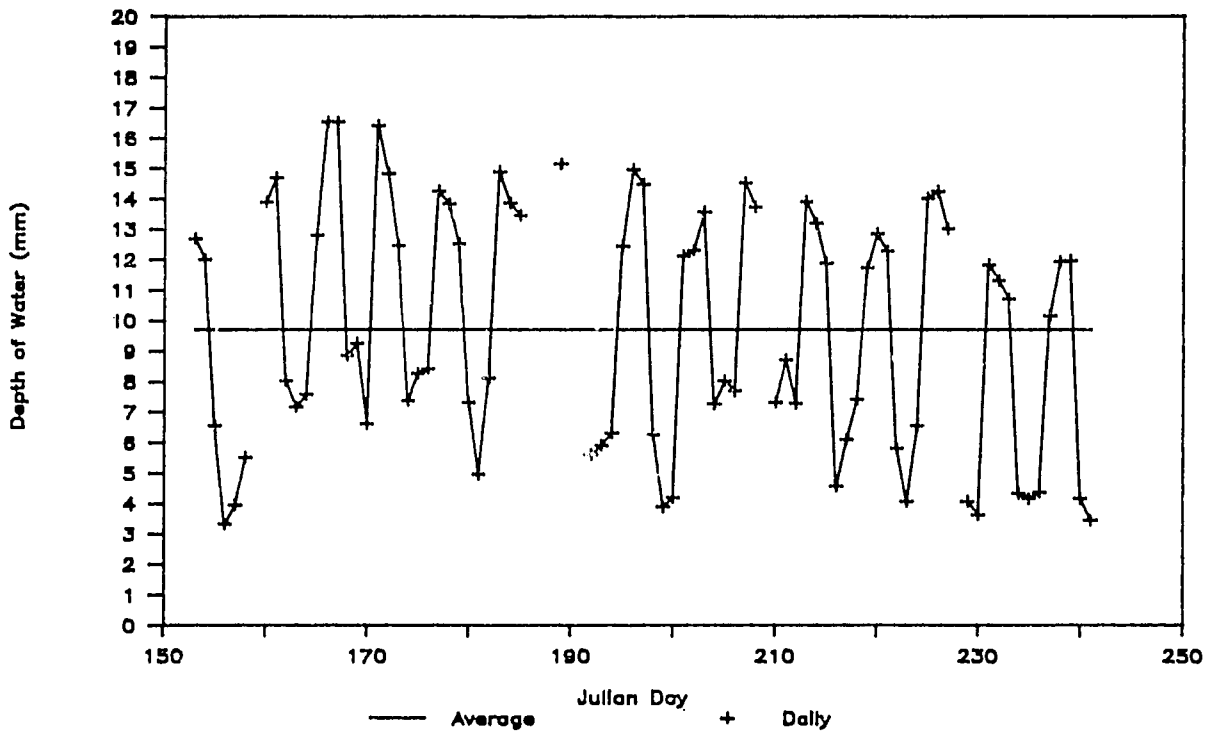

Figure 5. Daily field irrigation requirement normalized over the estimated command area for the existing cropping pattern of PSS during 1985 yala.

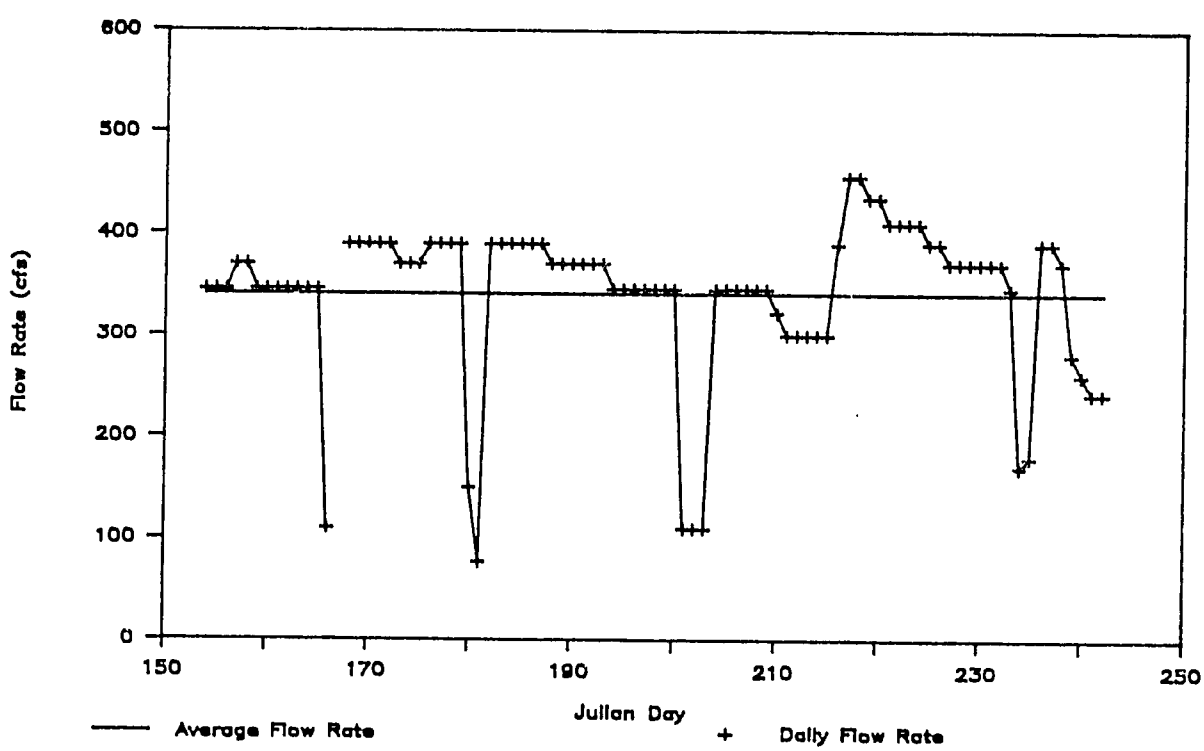

Figure 6. Daily flow rate measured at the head of the D1 main canal of PSS during 1985 yala.

From the water supply and field irrigation requirement plot shown in Figure 7, the requirements were generally higher than the supply, especially during the late critical period of plant growth (Julian day 180 to 224). Considering that the canal was operated at an overloaded capacity, the physical deterioration of some channels, and the increased demand due to encroachment, it would be difficult, if not impossible, to supply an adequate amount of water to meet the needs of well-irrigated paddy. However, this was a quantitative evaluation intended to indicate the general adequacy of the main water supply system. A more detailed study would be required to obtain a precise evaluation of the adequacy of water supplied.

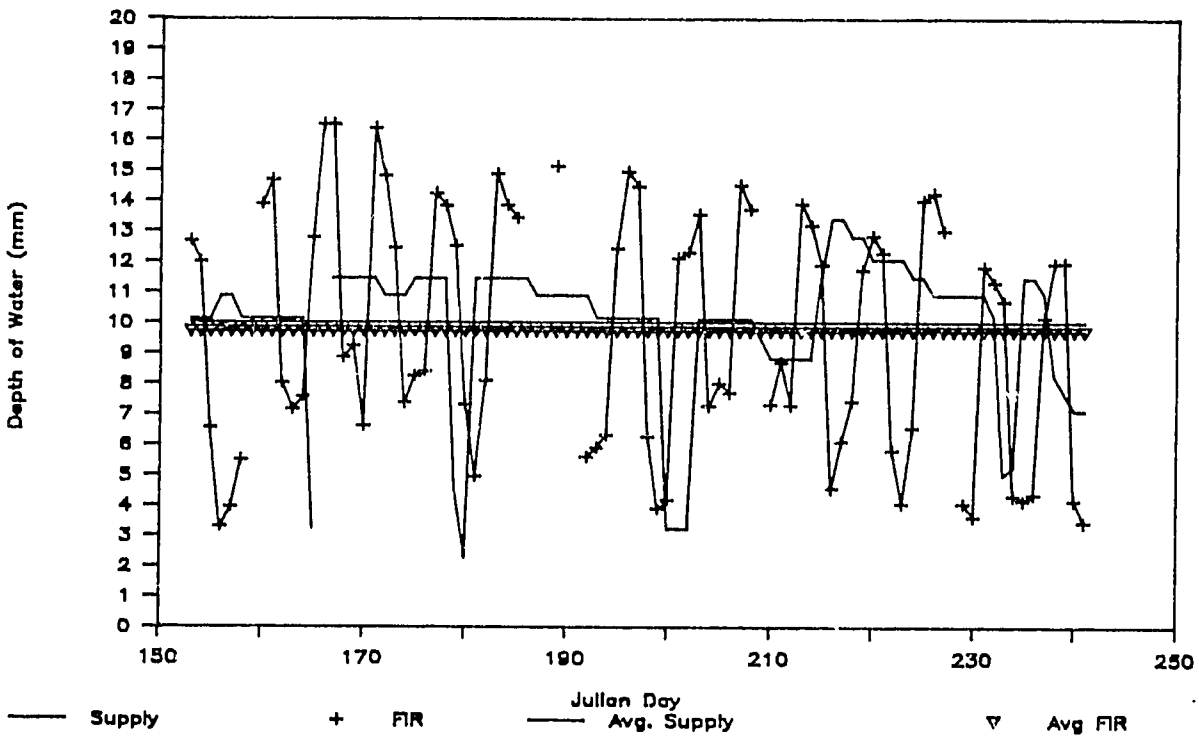

Figure 7. Daily supply at the source versus daily field irrigation requirements for the existing cropping pattern over the estimated command area of PSS during 1985 yala.

b. Equity of Water Supply

Daily water deliveries were averaged for each D-channel from the beginning to the end of seasonal water measurement to obtain an average of daily flow rates. The average measured discharges were converted to depth of water in mm/day using the same calculations indicated in the previous section. These depth of water supplies for the D-channels are presented in Figure 8.

The average measured supply to individual D-channels ranged from 6.4 mm/day (RB12) to 19.4 mm/day (LB1/RB21). This indicated that the water supply at the head of LB1/RB21 was about three times higher than the supply at the head of RB12. Compared to the designed supply rate

of 16.4 mm/day (0.028 cfs/ac), the D-channels RB0, RB5, LB1/RB21, and LB2/RB21 received a higher supply rate. On the other hand, 14 of the 18 D-channels received less than the designed supply.

The data from Figure 8 indicated that the channels falling short of designed rate were located mainly in the middle of the D1 north canal from RB6 to RB20. In this case, informal observations indicated that the inequity of distribution might be caused by submerged off-takes, damaged structures, altered canal hydraulic characteristics, unauthorized gate operation, and changes in water rotation.

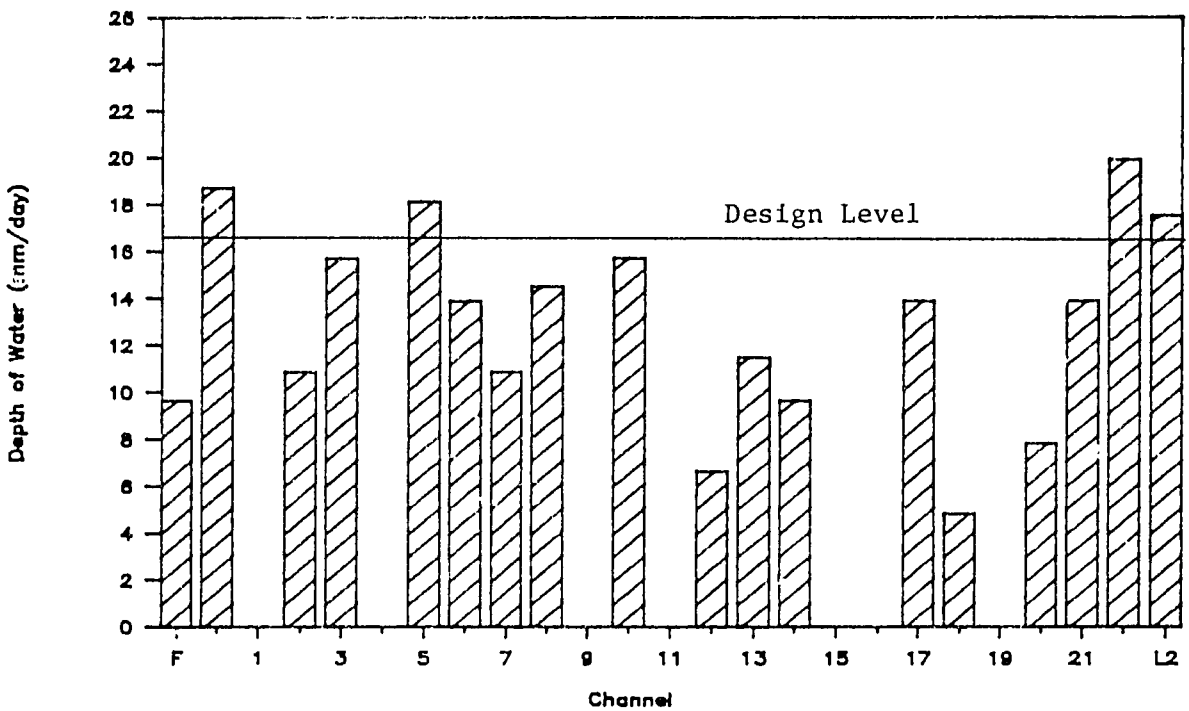

Figure 8. Average daily supplies measured at the head of each D-channel along the D1 main canal and north branch canal of PSS during 1985 yala.

A detailed survey of canal structures and weekly activity reports were planned as part of the main system engineering study to determine the canal condition and the extent of gate tampering and submergence of D-channel off-takes along the D1 main canal and north branch canal. Because of time and personnel shortages, these activities were not conducted. Nevertheless, canal condition, tampering, and submergence should be considered possible constraints when evaluating inequitable distribution. Off-takes subjected to tampering can easily release more than the authorized amount of water, whereas submerged off-takes release less water than the authorized amount. More extensive and detailed investigations would be needed to evaluate the effect of structural conditions on water distribution.

During the season, several extra water issues for RB21 were observed. These unscheduled water issues contributed to the high supply rates measured in this region, while reducing the amount of

water distributed to other D-channels, especially in the middle regions of the D1 north branch canal.

The inequitable water supply was determined to be a major constraint at PSS. The absence of measuring devices and control structures for proper operation and monitoring, as well as the lack of a strict water rotation schedule, appeared to be predominant causes of this inequity.

c. Reliability of Water Supply

To evaluate the reliability of water supply, an hourly water measurement activity was planned for several D-channels along the canals. Using measurements of continuous flow over the periods of water rotation, the team intended to draw conclusions about reliability from the observed fluctuations in the flow rates. However, this activity was not accomplished by the team due to personnel shortages.

Instead, for the reliability analysis, the daily inflow hydrographs for three representative D-channels -- Block F, LB7, and LB1/RB21 are used and presented in Figures 9, 10, and 11. As indicated by these figures, all three channels experienced periodic flows resulting from rotations. However, the rotation appeared to vary from a possible 6-day cycle on Block F to a random cycle on LB1/RB21.

Maximum flow rates fluctuated greatly from 7 cfs (Block F) to 13 cfs (LB1/RB21) between rotations. Peak flows were not maintained in LB1/RB21, but appeared as sharp pulses on the hydrograph when compared with the other two D-channels. Even though the average measured flow rate for LB1/RB21 was higher than the designed rate, there were random variations in the maximum flow rates from 17 percent to 190 percent of the average. Without predictable flow periods, it would be difficult for farmers on this D-channel to plan irrigation activities or adjust management strategies according to the available water supply.

7. CONCLUSIONS

For the portion of the irrigation scheme under the D1 main canal, the main supply system was inadequate to meet crop water requirements for existing command areas. This inadequate supply was partially a result of attempts by farmers to "maximize" the command area by unauthorized encroachment into reserved areas. In addition, conveyance and application losses contributed to the inadequacy of supply and must be reduced or accounted for in the designed supplied rate. Note, however, that farmers compensated for the inadequacy of the main supply system by using surface drainage water and subsurface inflow from PSS and other nearby irrigation schemes.

Water distribution throughout the main supply system was inequitable: 78% of the D-channels measured had inflow rates that were less than the designed rates. The ranges of the average measured supply were from 6.4 mm/day to 19.4 mm/day. This inequity was partially caused by lack of an appropriate operational plan and the absence of

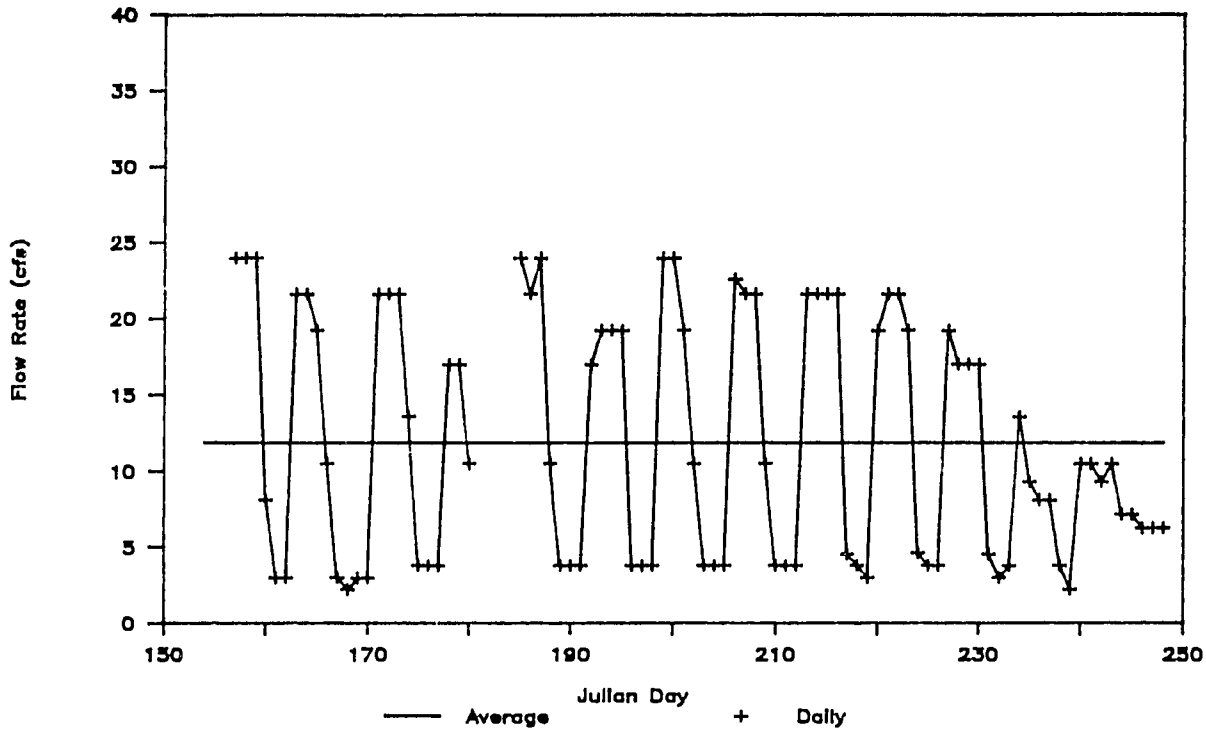

Figure 9. Daily flow rate measured at the head of Block F on PSS during 1985 yala.

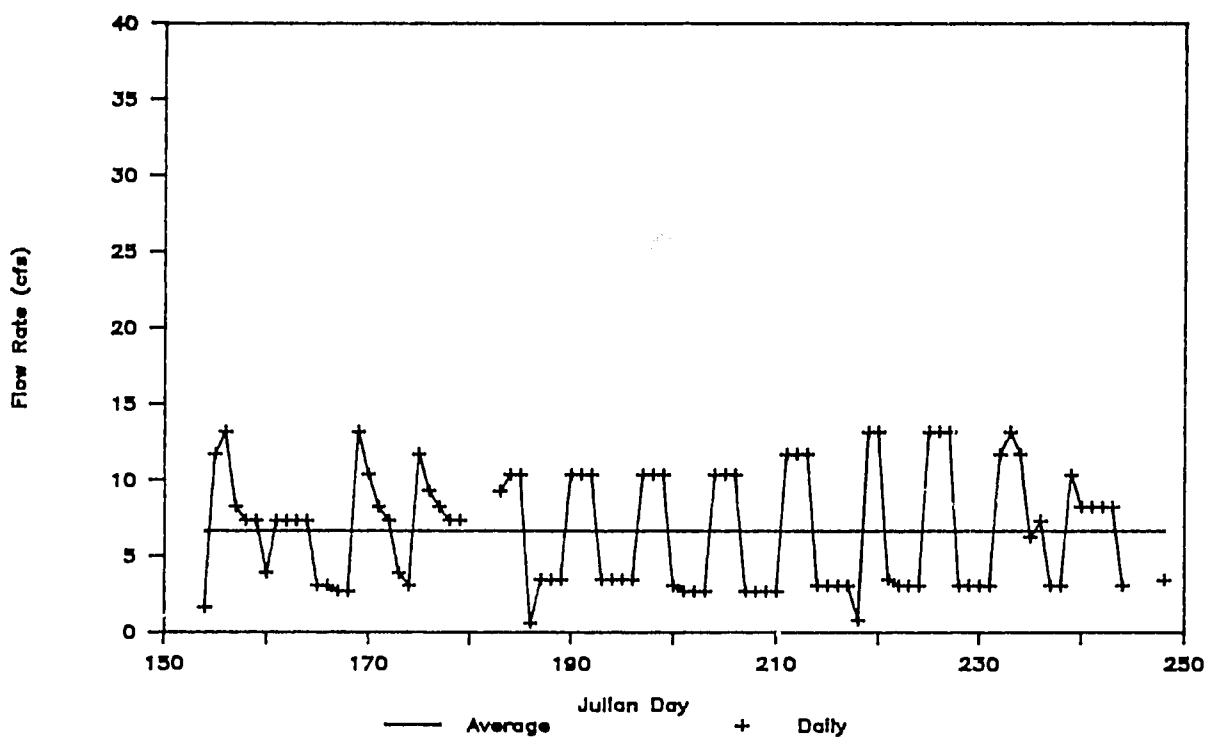

Figure 10. Daily flow rate measured at the head of RB7 on PSS during 1985 yala.

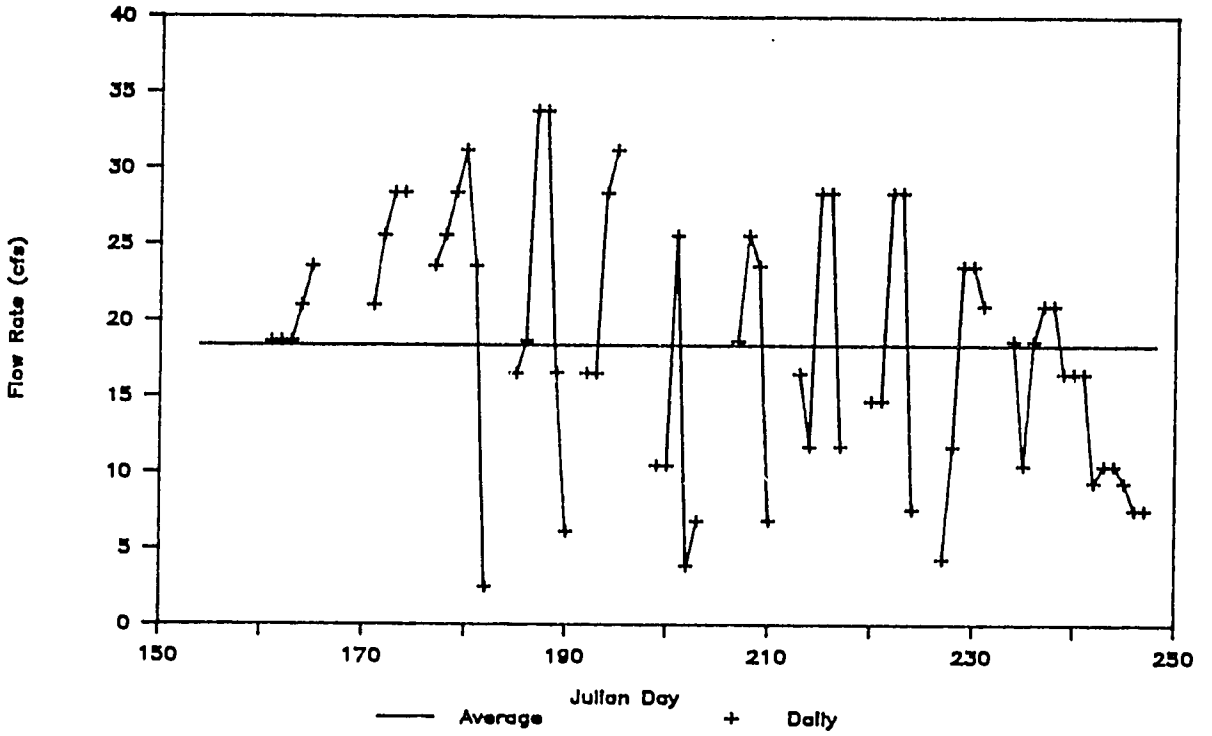

Figure 11. Daily flow rate measured at the head of LB1/RB21 of PSS during 1985 yala.

structures needed to monitor and facilitate such a plan. The distribution plan for the D1 main canal system was based on the official water rotation schedule. However, actual water allocation depended heavily on demands by farmers, and adjustments were often made by irrigation personnel ad hoc. In addition to the lack of measuring structures, control structures, and adequate field staff, the lack of conveyance capacity in the D1 main canal and the aqueduct was considered to be the most significant contribution to inequitable water distribution on PSS.

Water distribution throughout the D1 main supply system was unreliable, with fluctuations of maximum flows nearly double the average measured in the tail regions of the system. These fluctuations were likely the result of the lack of the following: an appropriate operational plan, an adequate field staff, and measuring and control structures.

B. ON-FARM ENGINEERING

1. INTRODUCTION

If irrigation water use is to be improved in Sri Lanka, the water delivery system and the on-farm irrigation system must be viewed as an integrated whole. To take full advantage of water supplied, farm irrigation systems need to be properly designed, and farmers must be helped to improve their skills of irrigation scheduling and water application. Good water management on the farm requires that a dependable supply be available to irrigators when they need it and in the amount they need. If the on-farm water delivery system fails to meet this requirement, it imposes constraints that hinder agricultural production.

Existing on-farm irrigation systems can be evaluated by studying their performance in the field. After defining system boundaries, measurements of system parameters are made. When the field data are summarized and analyzed, they provide descriptive information on the system as it exists and operates in the field. However, the adequacy of the system cannot be appraised unless system objectives have been clearly defined. With system objectives in mind, the investigator can initially identify the primary problems that might be preventing the objectives from being met. This diagnostic analysis of the system is a prerequisite to considering alternatives for system renovation.

a. Objectives of On-Farm Water Delivery

The purpose of any scheme of irrigated agriculture is to produce a bountiful harvest for the benefit of man -- the farm family and the wider market it serves. An on-farm water delivery system serves this purpose by supplying the required amount of water at the appropriate rate, at the appropriate time, and at the appropriate place. This implies several objectives for the system.

A first objective of the on-farm water delivery system is equity. The spatial variance of water deliveries along the canal network should be minimized so that each irrigator receives a fair share.

Reliability, the second objective, is closely related to the first objective. Reliability means that water is delivered to farms in a quantity and on a schedule that are pre-set and known by farmers and system operators. It has been argued that this objective is the most important, for without reliability the farmer cannot plan his irrigations intelligently and use the water effectively. Also, an unreliable water supply hinders other critical farming practices (cultivation, application of fertilizers and herbicides, among others) which must be scheduled around or in conjunction with irrigations.

The third objective is adequacy: the flow must be the needed amount delivered at the right rate and at the right time. The flow rate must be large enough to deliver the water required by the crops during the time available for irrigation. The amount of water needed in an irrigation system varies with location and time as a function of

crop type, stage of crop growth, soil properties, climatic conditions, and other factors. If the water supply is inadequate, crops may suffer stress, resulting in unacceptable reduction in crop yields.

2. METHODOLOGY

Three distributary channels were selected in the Parakrama Samudra Scheme to represent average conditions at the head, middle and tail of the system. Two field channels at the head and tail of each of the three distributary channels were used for detailed study. A schematic of PSS and the distributary channels used for this study are shown in Figure 12.

The area served by each field channel was surveyed by technical assistants from the Irrigation Department after harvest. Upland areas and chili and vegetable plots were distinguished from paddy lands. Although paddy bunds (levees) were estimated by the agronomy component to comprise 15 percent of paddy lands, the entire field channel command area was assumed to be the total area under paddy cultivation.

The Block F distributary channel was selected to represent the head region. Block F lies near the head of the system, approximately 3 km (1.9 mi) downstream of the main sluice of Parakrama Samudra Tank. Field channels 2 and 13 are located at the head and tail of Block F, respectively. Field channel 2 served three farm allotments with a total cultivated area of 6.5 ha (16 ac). Field channel 13 served five allotments with a cultivated area of 10.8 ha (26.8 ac).

The RB7 distributary channel off the D1 north branch canal was selected to represent the middle region. RB7 is about 11 km (7 mi) from the main sluice and 6.5 km (4 mi) downstream of the D1 north and D1 east canal bifurcation. Field channel 1 at the head of RB7 served eight farm allotments with a cultivated area of 12.8 ha (31.6 ac). Field channel 7 at the tail served eight farm allotments with a cultivated area of 18.5 ha (45.7 ac).

The LB1 distributary channel off RB21 represents the tail of the system. (Hereafter in the on-farm engineering section, all occurrences of LB1 refer to LB1 channel off of RB21.) LB1 is located 1.6 km (1 mi) from the RB21 sluice and approximately 24 km (15 mi) from the main sluice at Parakrama Samudra Tank. The head field channel (FC11) served seven allotments, although flow to only six allotments comprising 12.2 cultivated hectares (30.2 ac) was measured. The tail field channel (FC16) served seven allotments of 11.8 cultivated hectares (29.1 ac).

Five aspects of the on-farm irrigation system were studied: on-farm water delivery, designed water duty, evapotranspiration, water balance, and ground water.

a. On-Farm Water Delivery

Water delivery was monitored at the head of each selected field channel and at the inlet to selected allotments. In some instances,

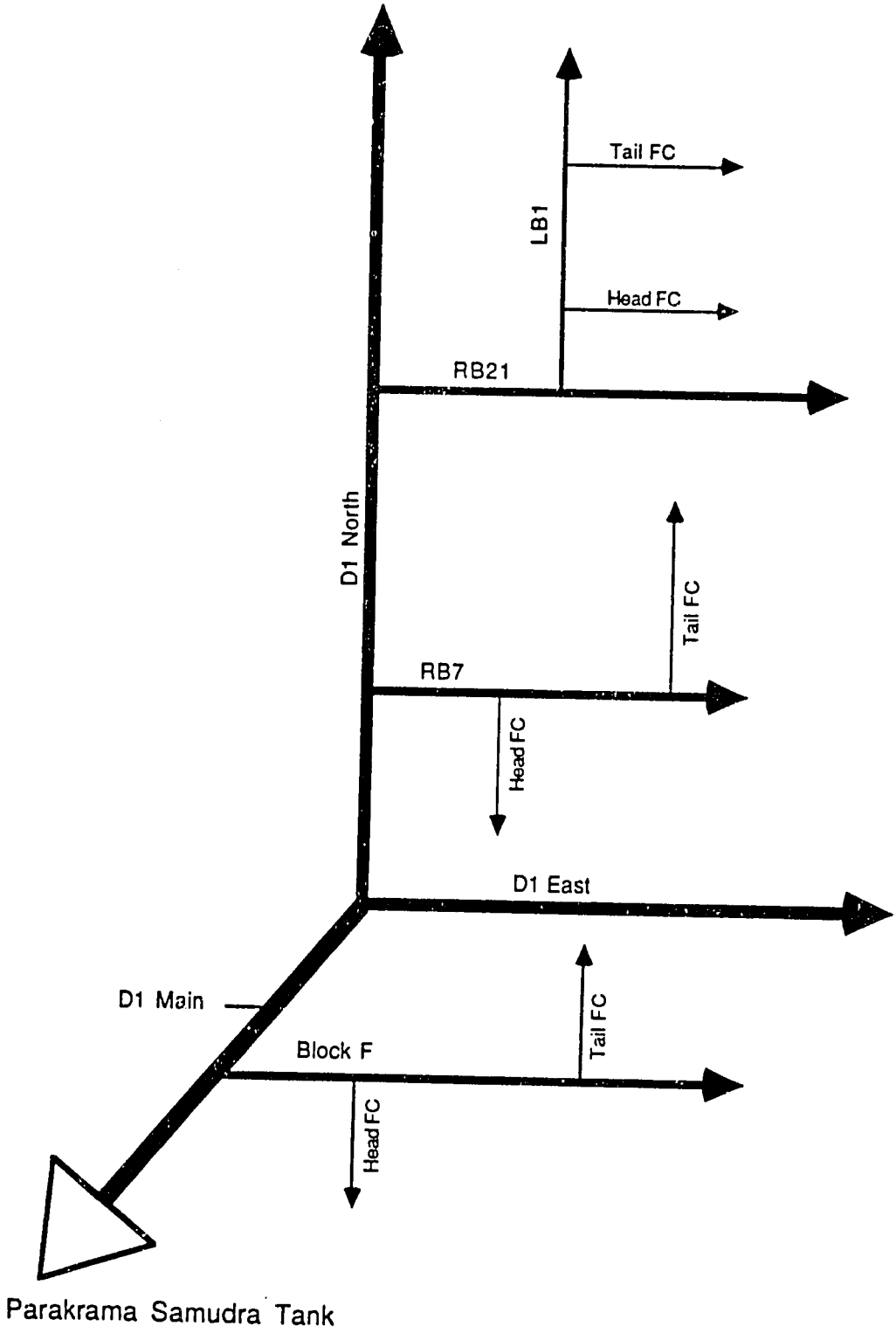

Figure 12. Parakrama Samudra Scheme: Distributary channels and head and tail field channels studied by on-farm engineering team during 1985 yala.

the inflow to the allotment was obtained by measuring flow above and below the turnout structures and computing the difference.

Originally, inflow to all the allotments in the study area were to be measured. However, upon investigation it was determined impossible in some instances to set a flume to accurately measure inflow or to monitor all the inflows to a particular allotment. Flume locations and allotment numbers are shown on the field channel maps in Appendix B.

Cutthroat flumes (4-, 8- and 12-inch) and long-throated flumes (100 mm) were used to measure flow. Flume readers, many of whom were Agricultural Diploma holders, recorded measurements from each flume four times daily (at 6 a.m., 10 a.m., 2 p.m., and 6 p.m.). The flume readers carried a gauge to record upstream depths because many of the staff gauges installed at the beginning of the study disappeared.

Water delivery began on April 20, 1985 (Julian day 110), but personnel were not available for data collection until more than a month later. Consequently, flow records begin after land preparation and planting. The earliest flow records begin on Julian day 142 and the latest begin on Julian day 152. Water was measured until the last delivery, about Julian day 250.

Daily field channel inflows were calculated from the weighted average of the four daily flow readings and inflow hydrographs were developed using the Lotus 1-2-3 spreadsheet. Flow rates between readings were assumed constant. Average daily flows were calculated as depth of water delivered in millimeters to the field channel command area. That is, the average daily flow rate was divided by the field channel command area (1 cfs/ac = 604.56 mm/day).

Daily allotment inflows were calculated from the weighted average of the four daily flow readings, and inflow hydrographs were developed using Lotus 1-2-3. Flows were calculated as depth of water delivered in millimeters to the allotment. That is, the average daily flow was divided by the allotment area (1 cfs/ac = 604.56 mm/day).

b. Designed Water Duty

The design discharge capacity of a field channel was 1 cfs for all irrigation schemes, according to the Irrigation Department (1980). Field channel command areas varied in size from less than 15 ac to more than 40 ac, although design specifications set field channel command areas at 30 ac or a maximum of 40 ac.

The Irrigation Department defines duty as the area served by a given flow rate, expressed as acres/cfs. For purposes of the on-farm engineering report, it is convenient to refer to flow deliveries (duty) in terms of depth of water delivered. For conversion purposes, .00165 cfs/ac is the same delivery as 1 mm/day.

Field channel duty requirements for continuous flow, as determined by Technical Note 5 (Irrigation Department, 1980), are 39.1 ac/cfs

(15.5 mm/day) for poorly and imperfectly drained soils and 20.3 ac/cfs (29.8 mm/day) for well-drained soils. Poorly and imperfectly drained soils correspond to lowland farms, and well-drained soils are referred to as upland farms in Technical Note 5. Staggered cropping patterns, maximum seasonal evapotranspiration, percolation and seepage, effective rainfall, and canal distribution losses were considered in calculating duty requirements.

Given the design discharge capacity of a field channel as 1 cfs and the design field channel command area of 30 ac, it was concluded that the Irrigation Department planned a design duty of 30 ac/cfs (20.15 mm/day) for continuous delivery. This would be adequate to supply a command area assumed by the Irrigation Department to be 65 percent poorly and imperfectly drained and 35 percent well drained.

Seasonal average daily field channel flows were compared to the continuous design duty of 20.15 mm/day to determine if deliveries met Irrigation Department design requirements. However, PSS operates on a rotational and not continuous flow schedule. Therefore, deliveries during "on" periods must be sufficient to satisfy the total design duty for both "on" and "off" periods.

c. Evapotranspiration

Evapotranspiration is the water lost from the soil and any plants growing thereon due to the combined effects of transpiration and evaporation. Plant transpiration varies greatly with climatic variables and crop growth stage and increases as leaves grow. Evaporation of water from soil also depends on climatic changes, but decreases with increased shading due to crop growth. Evapotranspiration (ET) is expressed as depth of water (in millimeters) required per day by growing plants.

Penman (1963) developed a method to calculate maximum evapotranspiration of a crop (reference ET) from the available environmental energy determined by climatic observations. A modified Penman equation suggested by the Food and Agriculture Organization of the United Nations (Doorenbos and Pruitt, 1977) was used in this study to calculate reference ET. The form of the equation used was:

$$ET_o = c\,[WRn + (1-W)f(u)(e_a-e_d)]$$

where ET_o = reference crop evapotranspiration (mm/day)
W = temperature-related weighting factor
Rn = net radiation in equivalent evaporation (mm/day)
$f(u)$ = wind-related function
(e_a-e_d) difference between saturation vapor pressure at mean air temperature and the mean actual vapor pressure of the air (mbar)
c = adjustment factor to compensate for the effect of day and night weather conditions.

The relationship between the actual evapotranspiration of a crop (ET) at a specific stage in growth and ET_o can be expressed by:

$$kc = ET/ET_o$$

where kc is the dimensionless crop coefficient.

To calculate evapotranspiration and field irrigation requirements, the entire cultivated study area was assumed to be planted with 105-day lowland paddy. Crop coefficients for 105-day lowland paddy grown during yala were obtained from Joshua (1977). The median planting date for PSS (Julian day 140) was used to determine crop growth stage.

Weather data for 1985 from the Agricultural Research Station at Aralaganwila was used to calculate Penman reference evapotranspiration. Araganwila is 20 km (12.5 m) from Polonnaruwa and experiences weather conditions similar to those of the study site. Pan evaporation values from a standard Class A pan recorded at the research station were used to verify the evapotranspiration values calculated by the Penman method.

d. Water Balance Study

A water balance is the detailed study of the water gains and losses in a confined area. A water balance on selected rice paddies (liyaddas or groups of liyaddas) was performed.

The integrated form of the water balance equation on a daily basis is given as:

$$I + R - O = ET + (P+S) + \Delta S$$

where I = total irrigation inflow to the paddy
R = effective rainfall
O = total surface runoff, or outflow
ET = evapotranspiration of rice
P+S = percolation and seepage losses
ΔS = the gain in soil water and surface water storage (ponding)

If the ponding depth remains constant and the soil moisture content is considered negligible in comparison to the other terms, the change in storage, ΔS, can be eliminated. Effective rainfall is considered negligible during yala. Thus,

$$I - O = ET + (P+S)$$

or, in terms of the field irrigation requirement (FIR),

$$I - O = FIR$$

The field irrigation requirement is defined as the amount of water needed to replenish the water lost by the crop due to evapotrans-

piration, percolation and seepage. A leaching requirement was not included since values for deep percolation are greater than the leaching requirement in flooded paddy.

In this report, seepage refers to the lateral flow of water across paddy bunds. Percolation refers to the nearly vertical movement of water through the soil to the groundwater table or to the water level of a nearby channel. The combined terms -- percolation and seepage -- refer to the total amount of water penetrating the soil without being utilized by the crop for transpiration.

Livadda Study Sites. Ten livadda study sites on the six field channels were monitored for the water balance study. Sites were located on the upper or lower slopes of the field channel command area and ranged in size from .12 to .52 ha (.31 to 1.28 ac). Upper slope locations were predominantly imperfectly drained, reddish brown earth (RBE) soils. Lower slope locations were poorly drained, low humic gley (LHG) soils. Study locations and soil survey maps are shown in Appendix B.

Inflows and outflows were measured at each study site. Flow measurements were recorded daily from 100-mm long-throated flumes or 4-inch cutthroat flumes at 6:00 a.m., 10:00 a.m., 2:00 p.m., and 6:00 p.m. Average daily flow rates were derived from the weighted average of the four daily readings, and constant flows were assumed between readings.

Care was taken to monitor each possible inlet and outlet through the bunds surrounding the study areas. Often this required at least five flumes for a single livadda.

Natural seepage and subsurface seepage occurs across paddy bunds. Ponded livaddas with neighboring dry livaddas, or livaddas ponded to a different elevation, experience a hydraulic gradient, which increases seepage. Burrowing field crabs often create channels that allow free water movement through bunds. Such destruction could not be anticipated, and flume readers were instructed to correct and report obvious breaks.

ET and ET with Percolation Measurements. Barrel lysimeters were installed in the Block F tail field channels and the RB7 tail field channels to measure evapotranspiration and percolation losses directly. Each barrel was approximately a 38-cm section (about 15 in) of an oil drum.

In the Block F tail field channel, three barrel lysimeters were installed to measure ET and percolation losses in an imperfectly drained RBE soil, a poorly drained LHG soil, and an imperfectly drained RBE soil with an intact plow pan. In the RB7 tail field channel, two barrels were installed to measure ET and percolation losses in an imperfectly drained RBE soil and a poorly drained LHG soil.

The barrels were installed after transplanting. The flat, bottom surface of the drum was set approximately 13 cm (about 5 in) below the

soil surface. Initially, plants were removed and a ring slightly larger than the barrel diameter was driven into the soil. The soil within the ring was excavated to a 13-cm depth, and the barrel was set in the excavated area. The outer ring was withdrawn and the excavated soil was placed around and within the barrel to the level of the original soil surface. The barrel was then transplanted with rice and water was kept ponded within the barrel.

Water depth in the barrels was measured daily with a standard 12-inch ruler attached to a stake that was driven into the soil. The barrel was refilled when necessary. Differences in daily water depth indicated the amount of water required for evapotranspiration of the crop.

Barrels used to measure percolation losses in addition to ET were oil drums with the bottom removed to allow the vertical movement of water out of the root zone. These were driven into the soil to about a 13-cm depth. Differences in daily water depths, measured in the same manner as the ET barrels, indicated the water requirement of the crop due to evapotranspiration and percolation.

e. Groundwater

Where submergence irrigation is practiced, the contribution from groundwater to meet crop water requirements can be significant. The water table rises with each recharge due to irrigation or rainfall and falls during periods without rainfall or irrigation. Upward flow into the root zone of the crop is determined by the depth of the water table below the root zone, capillary properties of the soil, and the soil moisture content in the root zone.

Low-lying, poorly drained LHG soils can be expected to experience high water tables. Paddy planted in these areas would benefit indirectly from return flows due to overirrigation and excessive percolation losses on the upper slopes of the command area.

Auger holes (7-cm diameter) were bored to a 1-m depth to monitor depth to groundwater along the main slopes of the field channel command areas. Auger holes were located on all field channels except the LB1 head field channel.

One to three auger holes were located in imperfectly drained RBE soils in each of five field channels. Only one auger hole was located in a well-drained RBE soil (RB7 tail field channel). One auger hole was located in a poorly drained LHG soil near each of five field channels. Depth to the water table from the soil surface was measured every morning using a weight and tailor's measuring tape.

3. RESULTS AND DISCUSSION

a. Equity of Water Distribution and Reliability

Inflow hydrographs were developed for each field channel, as shown in Figures 13 through 18. Average daily flows represented as depth of

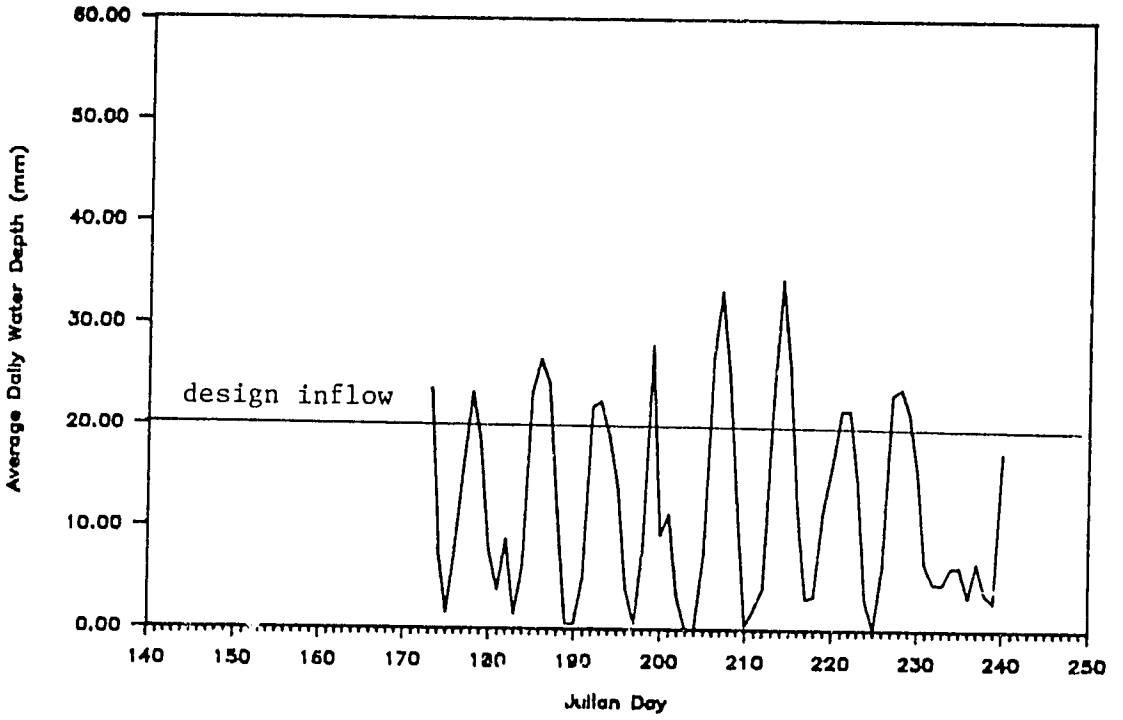

Figure 13. Block F head field channel (PSS) inflow hydrograph with average daily water supplied and design flow (1985 yala).

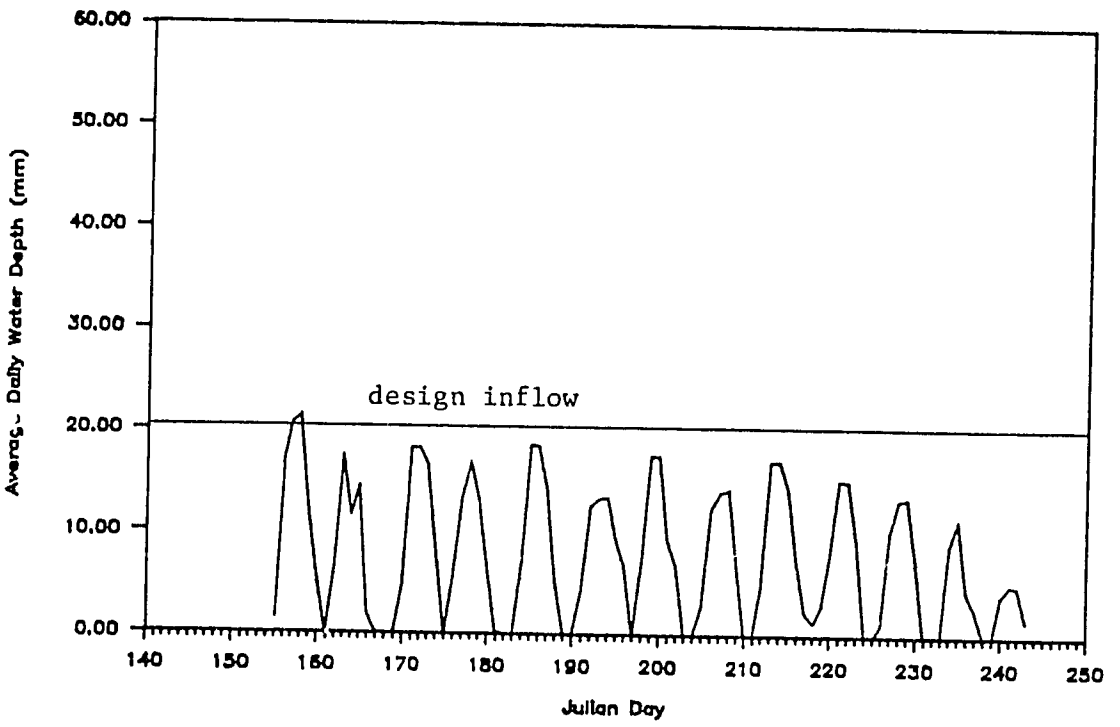

Figure 14. Block F tail field channel (PSS) inflow hydrograph with average daily water supplied and design flow for 1985 yala.

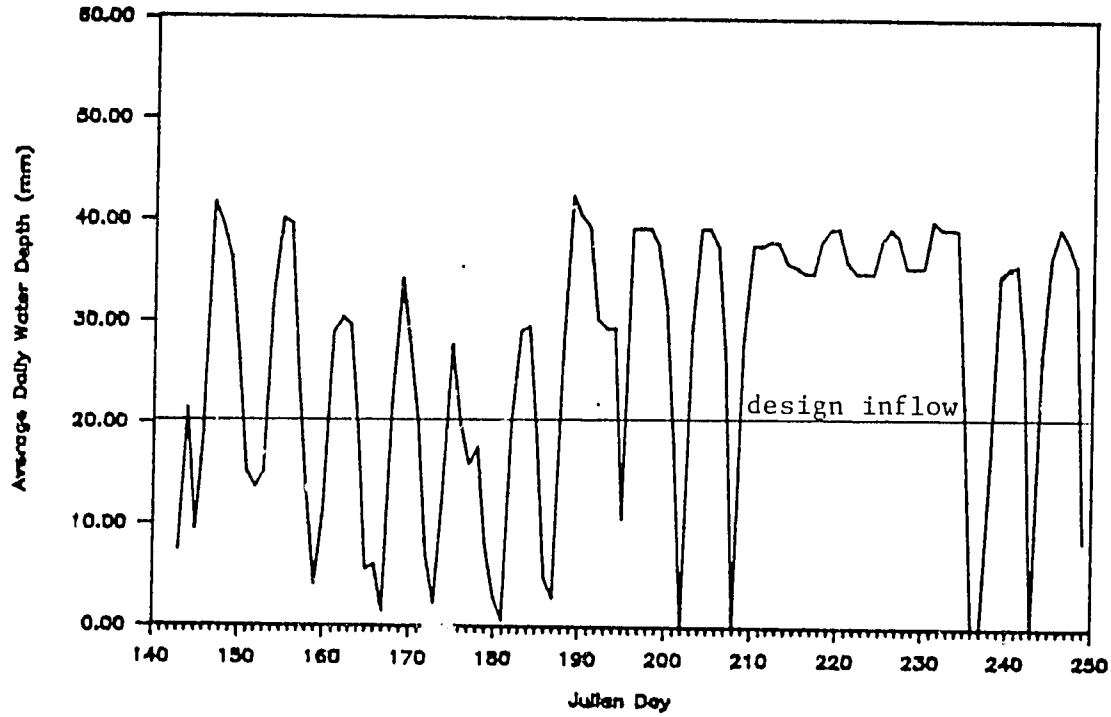

Figure 15. RB7 head field channel (PSS) inflow hydrograph with average daily water supplied and design flow for 1985 yala.

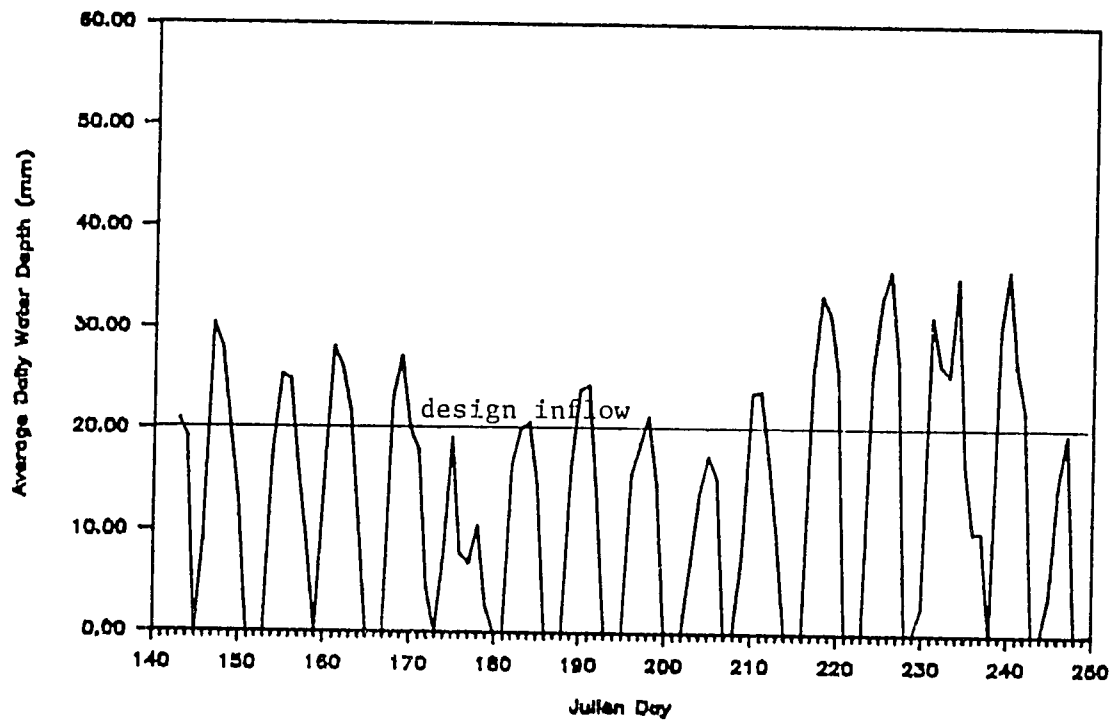

Figure 16. RB7 tail field channel (PSS) inflow hydrograph with average daily water supplied and design flow for 1985 yala.

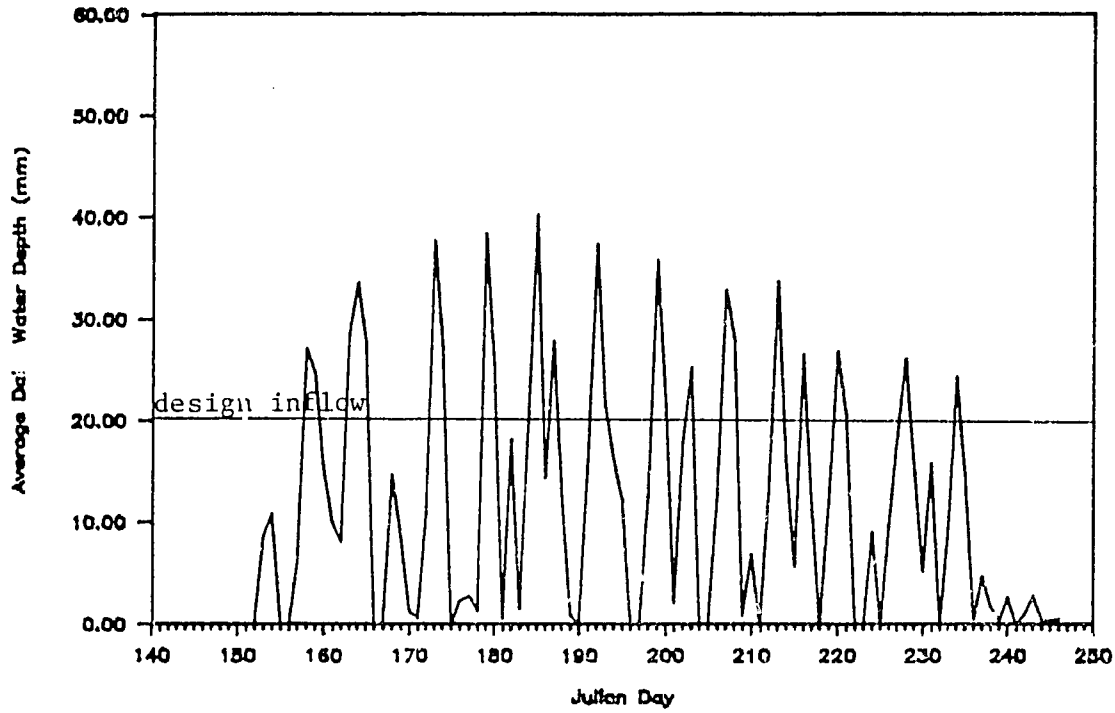

Figure 17. LB1 head field channel (PSS) inflow hydrograph with average daily water supplied and design flow for 1985 yala.

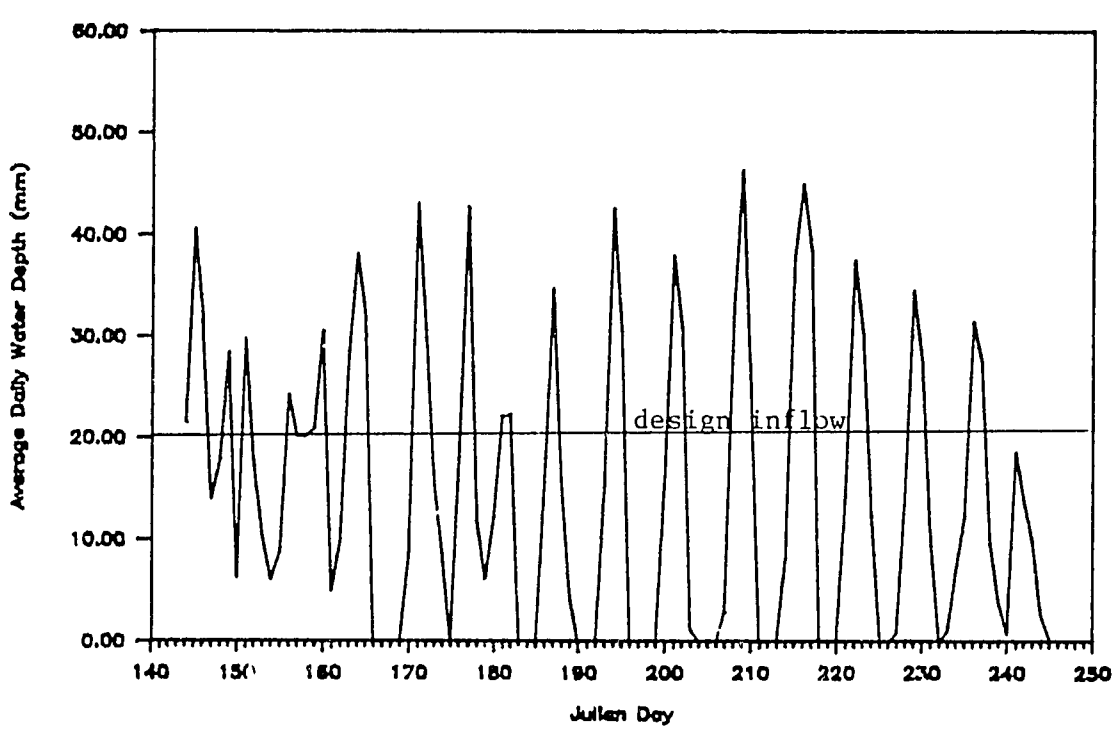

Figure 18. LB1 tail field channel (PSS) inflow hydrograph with average daily water supplied and design flow for 1985 yala.

water delivered in millimeters are shown for Block F head and tail field channels, RB7 head and tail field channels and LB1 head and tail field channels. Appendix C shows field channel inflow hydrographs with deliveries recorded in cubic feet per second.

Water was first delivered to field channels for 1985 yala about April 20 (Julian day 110) with continuous flow until June 1 (Julian day 152), when rotational delivery began. Due to the availability of personnel, flow records for this study began on Julian day 173 for the head field channel on Block F, Julian day 155 for the tail field channel on Block F, Julian day 143 for head and tail field channels on RB7, Julian day 152 for the LB1 head field channel, and Julian day 144 for the LB1 tail field channel.

Flow records ceased at the end of the 1985 yala water issue (approximately Julian day 250), with the exception of Block F where measurements stopped on Julian day 240 (head field channel) and Julian Day 243 (tail field channel).

Equity of Water Distribution to Field Channels. Daily water deliveries were averaged for each field channel from the beginning of water measurement to the end of water measurement to obtain a seasonal average of daily water supplied. Seasonal averages of daily water supplied to field channels are shown in Figure 19 and in Table 7 where flow depths are converted to other common equivalent units. Seasonal refers to the approximate period of Julian days 140 to 250 in this report. Although periods of measurement were of slightly different durations for all field channels, comparing seasonal averages was reasonable because the measurement periods differed by no more than 12 days.

Continuous field channel design duties are 30 ac/cfs for each field channel. This is equivalent to a delivery of 20.15 mm or .033 cfs/ac/day.

The seasonal average of daily water supplied to individual field channels ranged from 7.87 mm on the tail field channel of Block F to 26.46 mm on the RB7 head field channel. This indicated that the amount of water available to an irrigator on the RB7 head field channel was over three times that available to an irrigator on the Block F tail field channel. In fact, the RB7 head field channel was the only one to receive greater than the design duty. All other field channels received significantly less than the designed duty.

It seemed reasonable to assume that flow rates remained relatively invariant between daytime readings. However, Irrigation Department employees, flume readers, and farmers have differing views on whether or not this assumption holds true throughout the night. There were reported instances of water being turned into the field channels at night to irrigate unofficial, adjacent settlements. Water may also be purposefully turned into the drainage channel to irrigate paddy. This water would be recorded as a delivery to the surveyed field channel command area, when instead it irrigated land elsewhere.

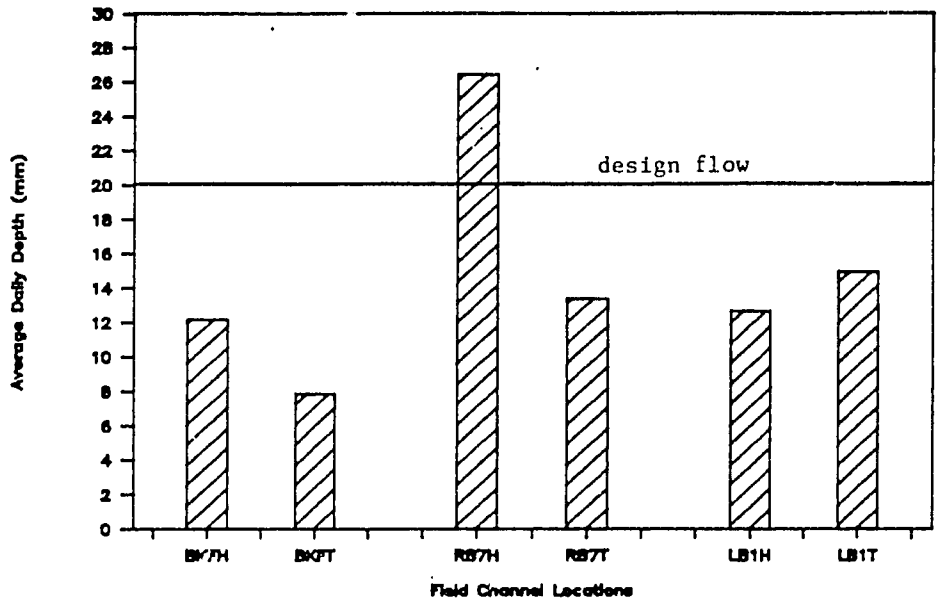

Figure 19. Seasonal average daily water supplied to PSS Block F, RB7, and LB1 head and tail field channels and design flow for 1985 yala.

Table 7. Seasonal average daily water supplied to PSS field channels for 1985 yala.

Field Channel	mm/day	in/day	cfs/ac	ac/cusec
Block F head	12.19	0.48	0.02	49.59
Block F tail	7.87	0.31	0.01	76.82
RB7 head	26.46	1.04	0.04	22.85
RB7 tail	13.38	0.53	0.02	45.18
LB1/RB21 head	12.66	0.50	0.02	47.75
LB1/RB21 tail	14.95	0.59	0.02	40.44
Design Flow	20.15	0.79	0.03	30.00

The inflow hydrograph for the RB7 head field channel (Figure 15) indicates that there was continual flow into the field channel when rotation "off" periods should have occurred. Flows for Julian days 208 to 236 never dropped below 35 mm (1.80 cfs) during four rotations. These flows fell within the mid-crop growth stage when full effective cover is reached and crop water requirements are the highest of the season. Investigation is required to determine if the continual flow was due to faulty closure of the head gate. This period of continual flow in addition to higher-than-average flow during all rotations

allowed the RB7 head field channel to achieve the highest average daily flow depth.

Lower slope irrigators on the Block F tail field channel, which received the lowest average daily water supplied, occasionally drew water from the drainage canal to supply their livaddas. Without detailed field observations, it was not possible to determine if the quantity of water acquired was significant in meeting the irrigation requirement. However, such diversions indicated that the irrigators on this field channel probably experienced water stress when relying on the scheduled field channel deliveries only. With additional field personnel, it is probable that similar practices and other supplemental water sources might have been observed on other field channels.

Equity of Water Distribution: Head Versus Tail Field Channels. The concern that irrigators on head field channels routinely received more water than tail field channel irrigators on the same distributary channel was confirmed by this study for Block F and RB7 distributary channels. On LB1, the selected head field channel received less water per unit area than the tail. However, the LB1 tail field channel probably also supplied an encroached area north of the field channel. If this added area was considered, the calculated water depth for the LB1 tail field channel would be significantly reduced.

Equity of Water Distribution to Allotments on a Field Channel. Inflow hydrographs were developed for individual allotments from average daily flows. Each hydrograph, shown in Figure 20 through 31, is referred to by the identification number of the inflow flume(s), the allotment number, and the field channel location. Allotment and numbered flume locations appear on the maps in Appendix B. Water measurements for each allotment began during Julian days 142 to 152.

Several allotments were abandoned for water delivery studies when flumes were dislodged after being used as cross walks or when additional unmonitored inflows were discovered. At times, flumes intended to measure flow to one allotment actually measured flow to two or more when breaches were made in the farm channel by an adjacent irrigator.

Seasonal averages of daily water supply to individual allotments were derived from average daily deliveries over the measurement period. Figures 32 through 34 compare seasonal average supplies for allotments near the head and tail of each field channel.

Upstream allotments on the field channels tended to receive more water per unit area than downstream allotments. An exception was noted in the RB7 tail field channel where the downstream allotment received significantly more water. This was possibly offset by losses along the lengthy farm channel that delivered water from the field channel to the downstream allotment. Though water supply appeared to be equitable in Block F allotments (on both head and tail field channels), in RB7 and LB1 allotments the supply tended to be extremely inequitable.

Field channel erosion and water buffalo access to the field channels contributed to upstream flooding in many locations. Adequate

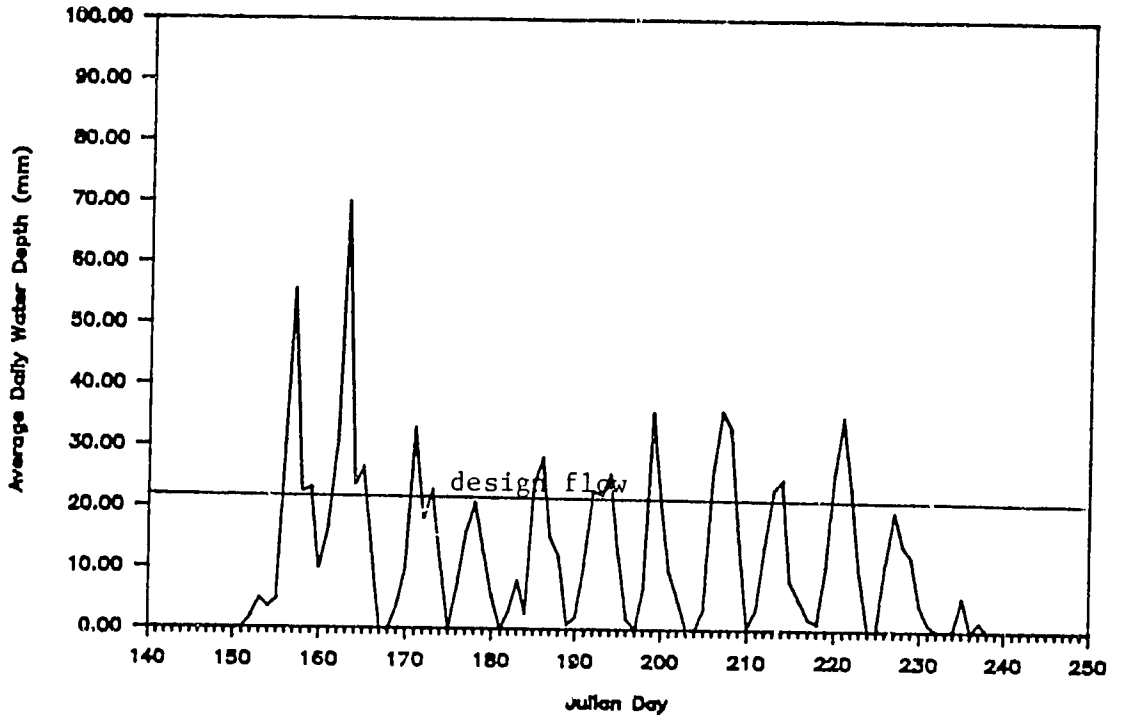

Figure 20. Inflow hydrograph for allotment 15, Block F head field channel on PSS with average daily water supplied and design flow for 1985 yala.

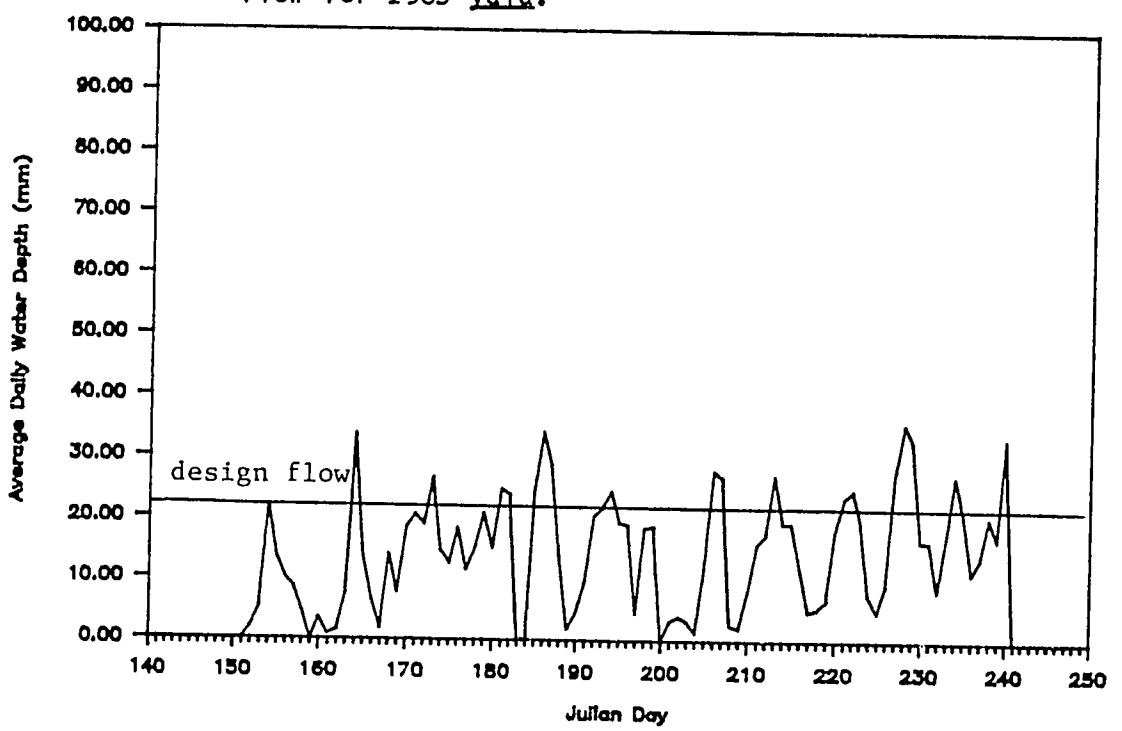

Figure 21. Inflow hydrograph for allotment 16, Block F head field channel on PSS with average daily water supplied and design flow for 1985 yala.

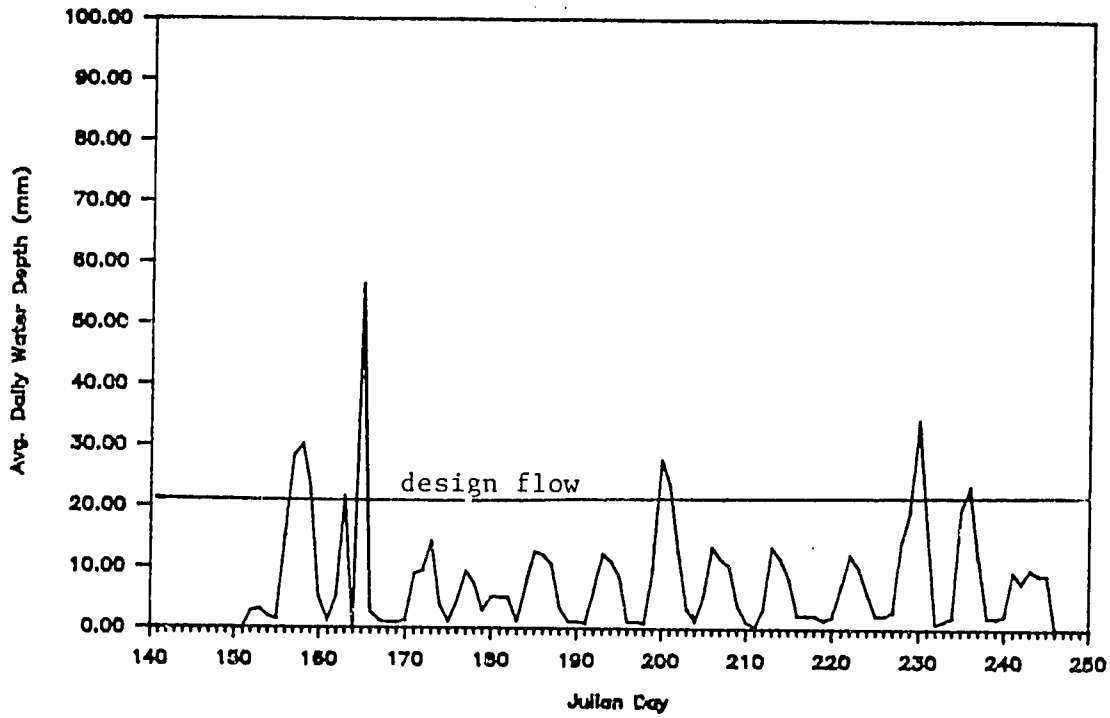

Figure 22. Inflow hydrograph for allotment 20, Block F tail field channel on PSS with average daily water supplied and design flow for 1985 yala.

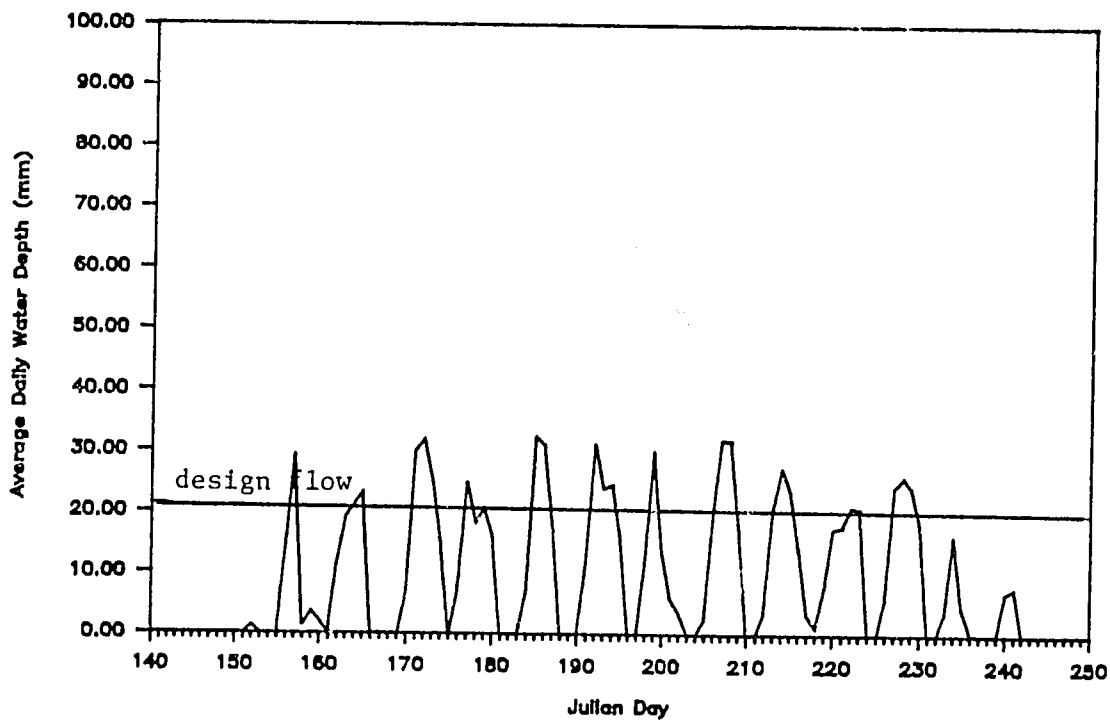

Figure 23. Inflow hydrograph for allotment 23, Block F tail field channel on PSS with average daily water supplied and design flow for 1985 yala.

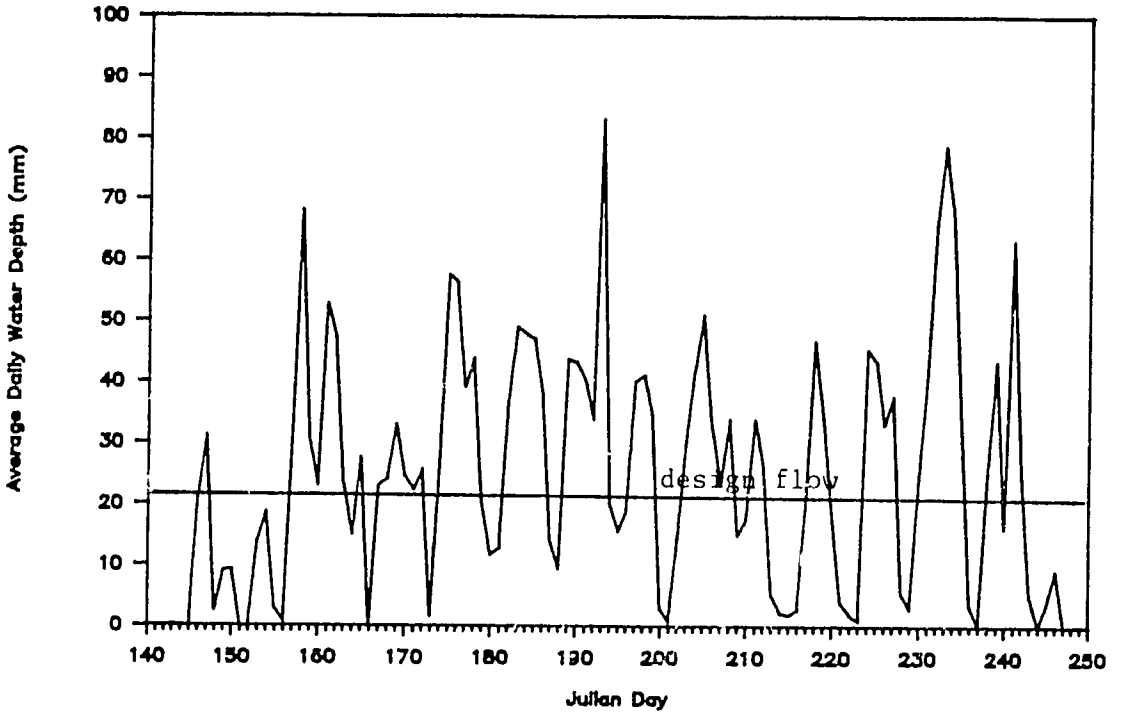

Figure 24. Inflow hydrograph for allotment 114, RB7 head field channel on PSS with average daily water supplied and design flow for 1985 yala.

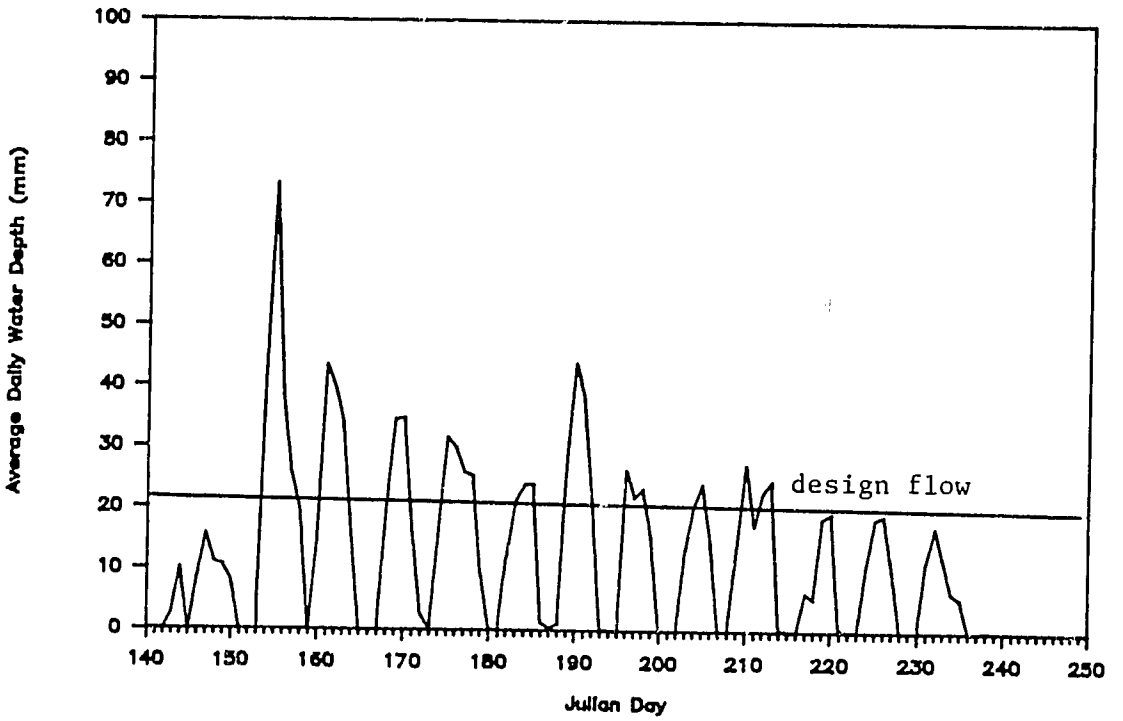

Figure 25. Inflow hydrograph for allotment 117, RB7 head field channel on PSS with average daily water supplied and design flow for 1985 yala.

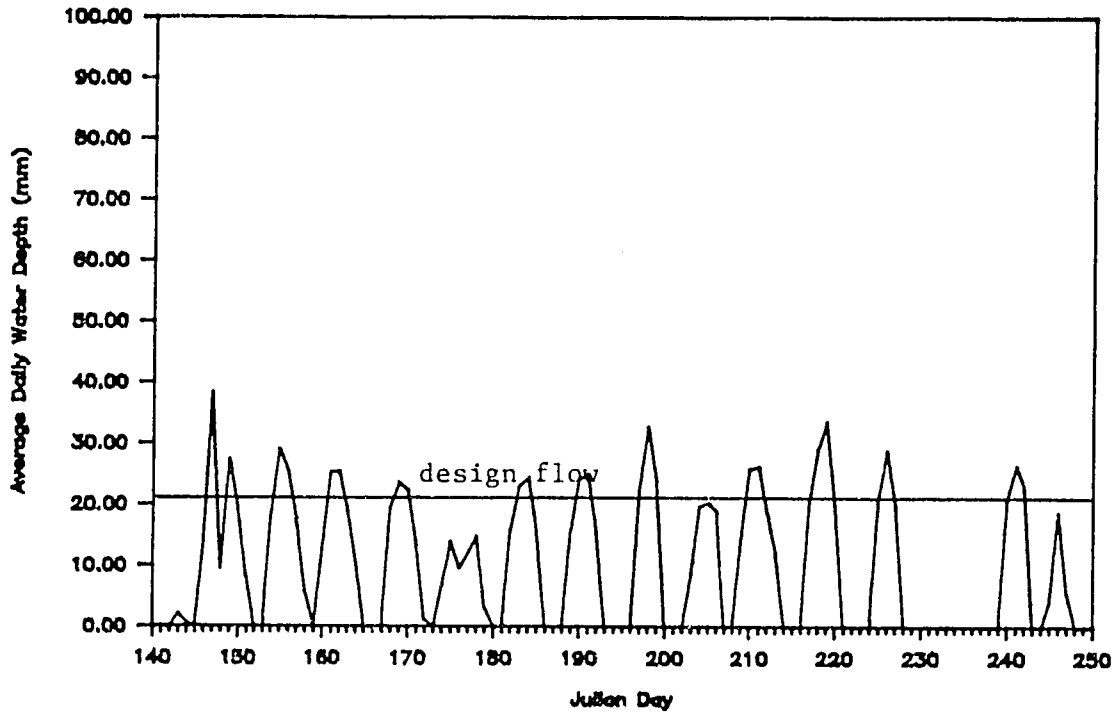

Figure 26. Inflow hydrograph for allotment 144, RB7 tail field channel on PSS with average daily water supplied and design flow for 1985 yala.

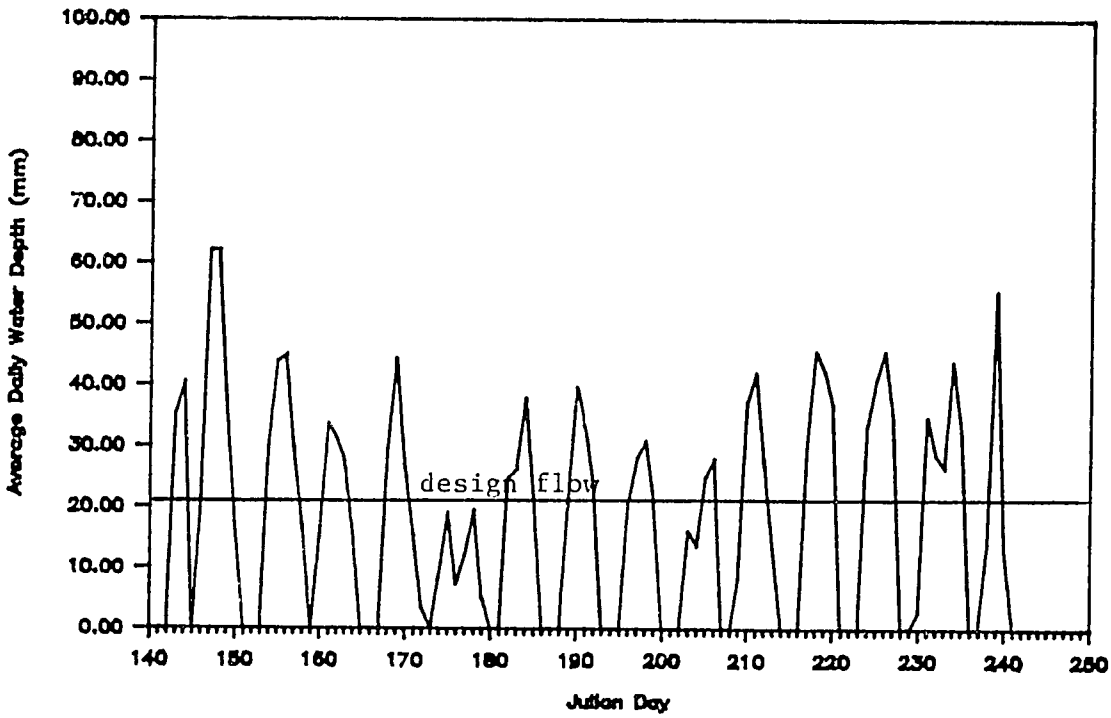

Figure 27. Inflow hydrograph for allotment 148, RB7 tail field channel on PSS with average daily water supplied and design flow for 1985 yala.

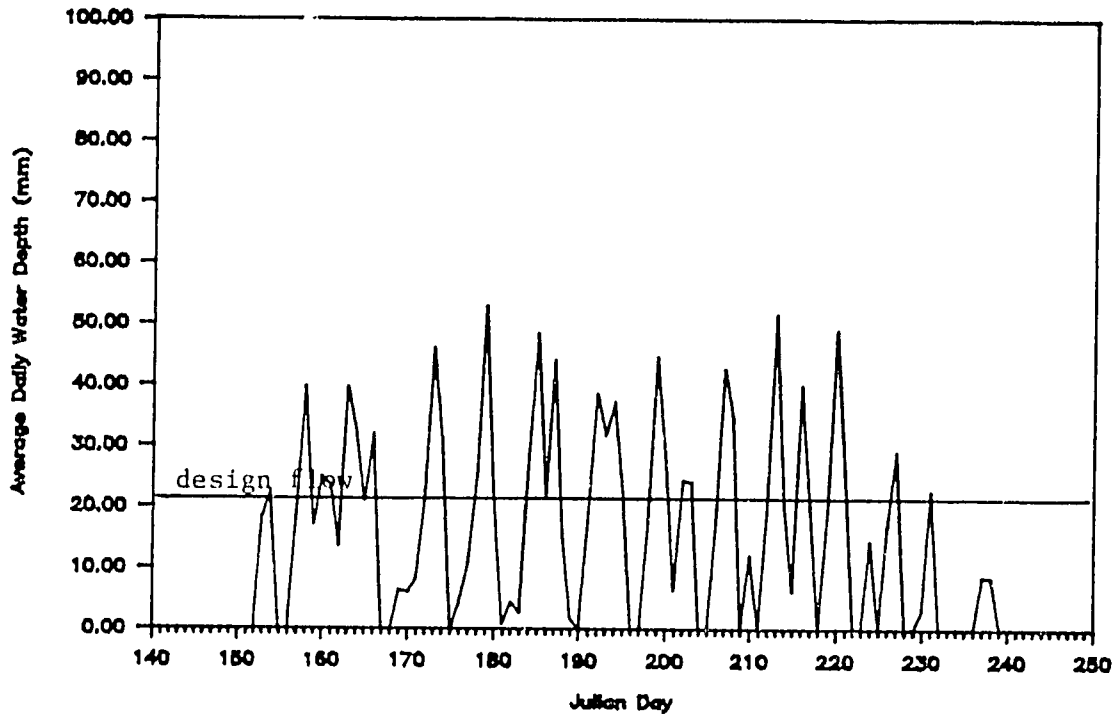

Figure 28. Inflow hydrograph for allotment 69, LB1 head field channel on PSS with average daily water supplied and design flow for 1985 yala.

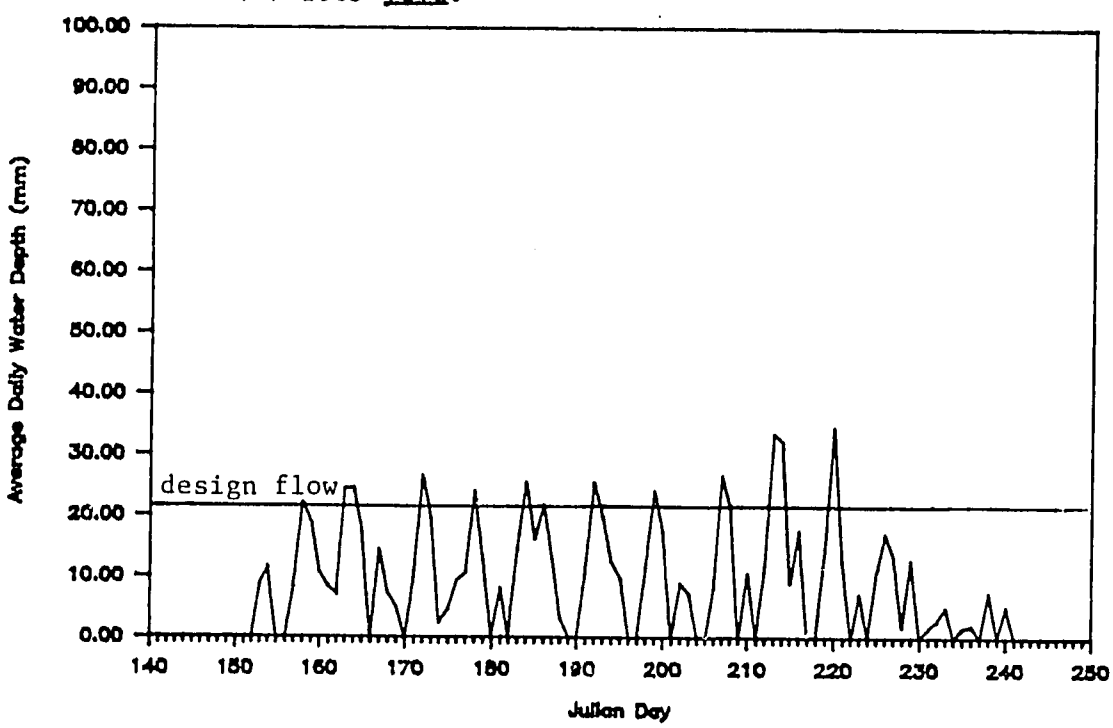

Figure 29. Inflow hydrograph for allotment 71, LB1 head field channel on PSS with average daily water supplied and design flow for 1985 yala.

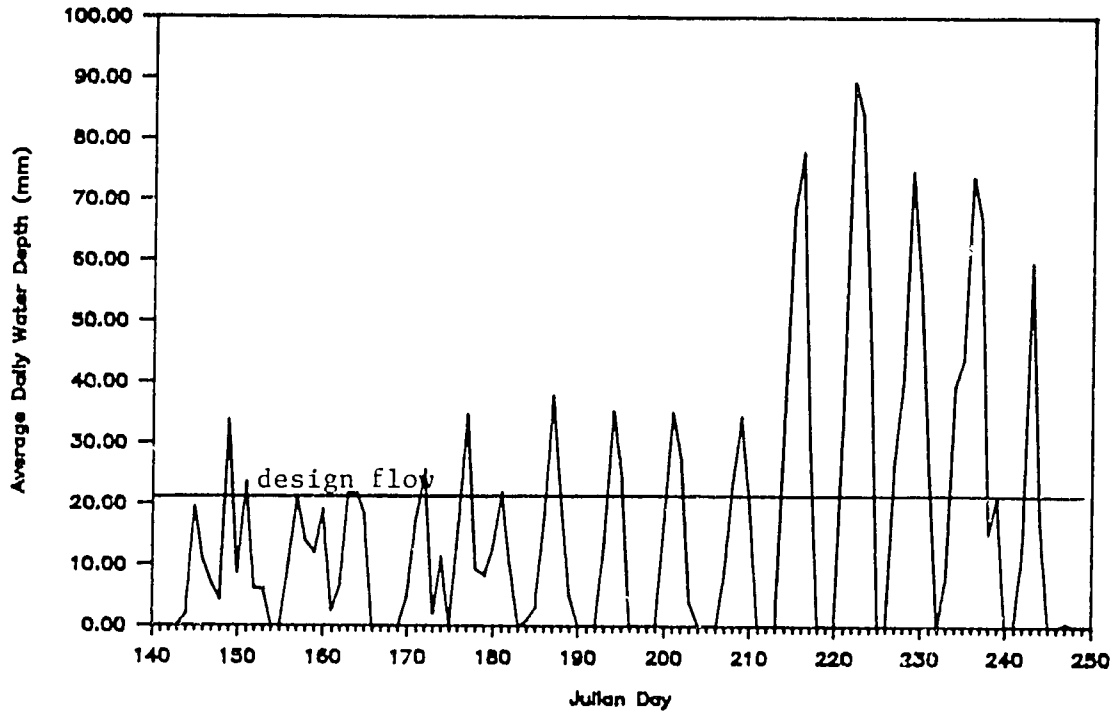

Figure 30. Inflow hydrograph for allotment 67, LB1 tail channel on PSS with average daily water supplied and design flow for 1985 yala.

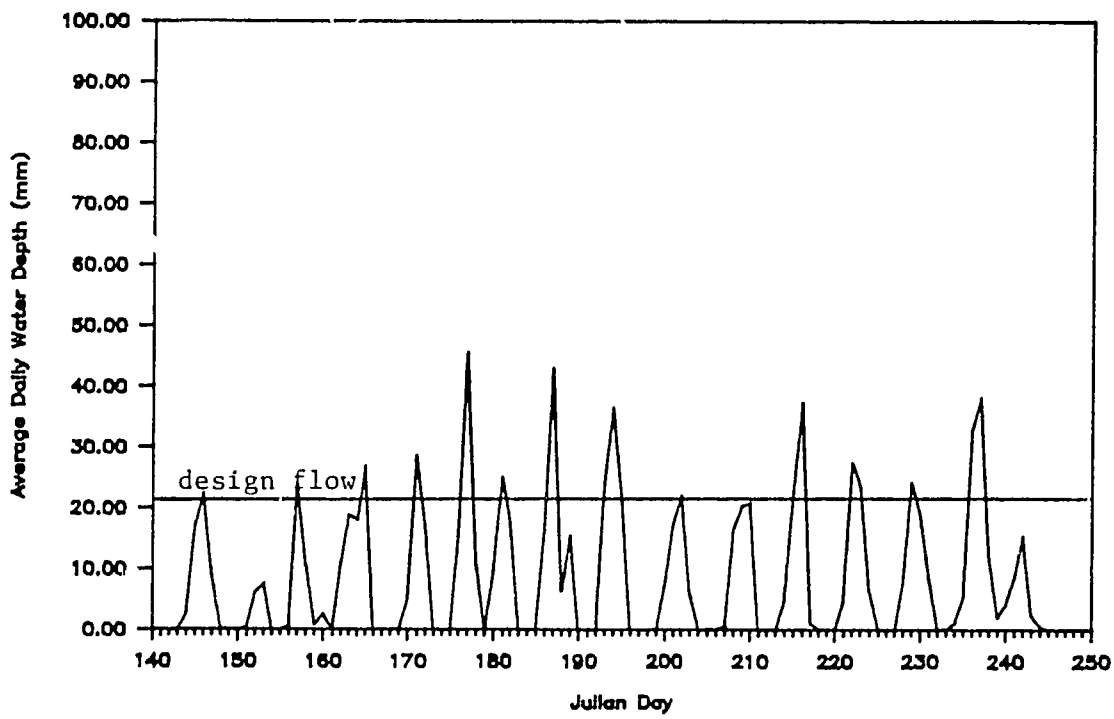

Figure 31. Inflow hydrograph for allotment 106, LB1 tail field channel on PSS with average daily water supplied and design flow for 1985 yala.

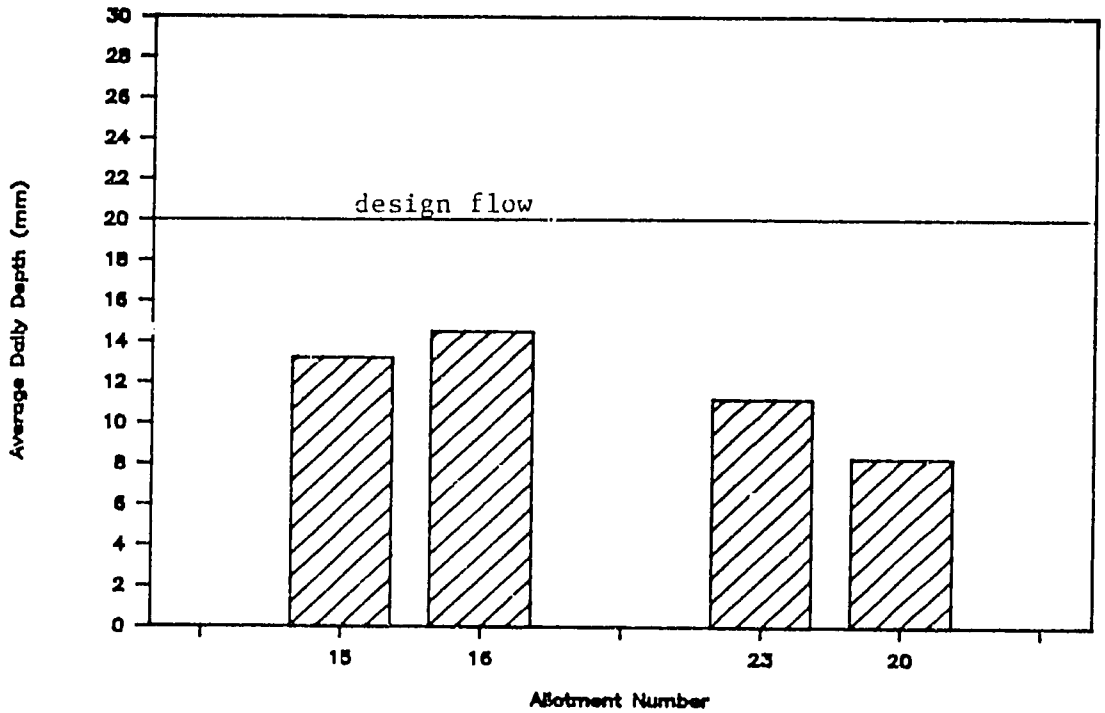

Figure 32. Seasonal average daily water supplied to allotments on Block F head and tail field channels (PSS) and design flow for 1985 yala.

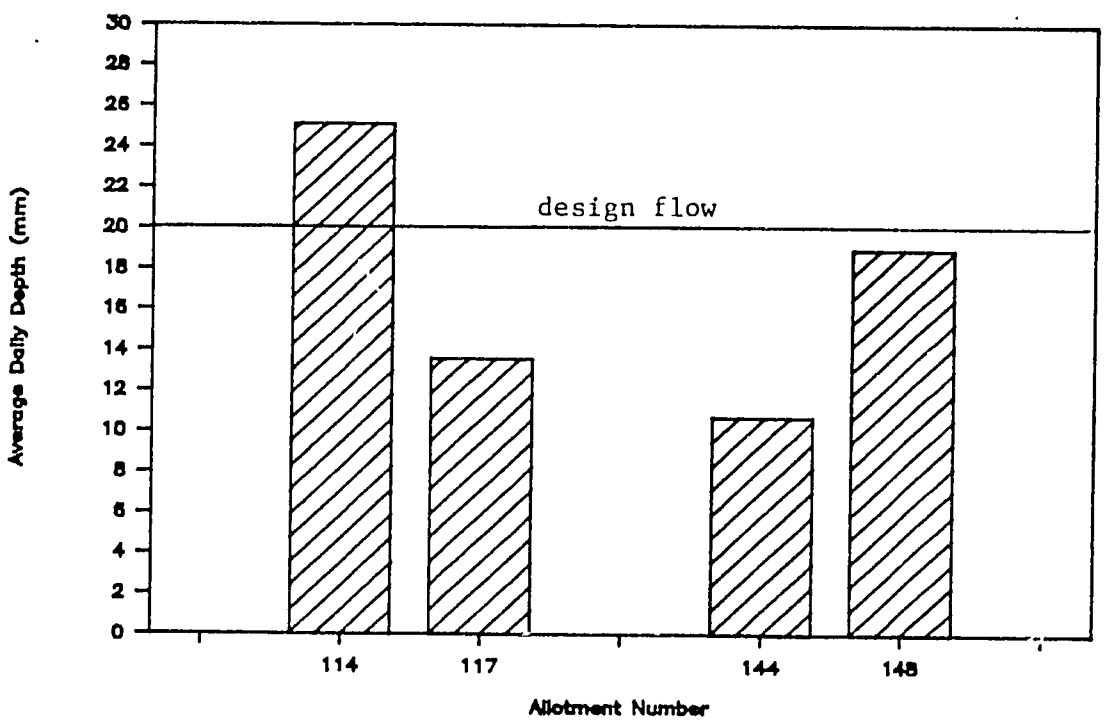

Figure 33. Seasonal average daily water supplied to allotments on RB7 head and tail field channels (PSS) and design flow for 1985 yala.

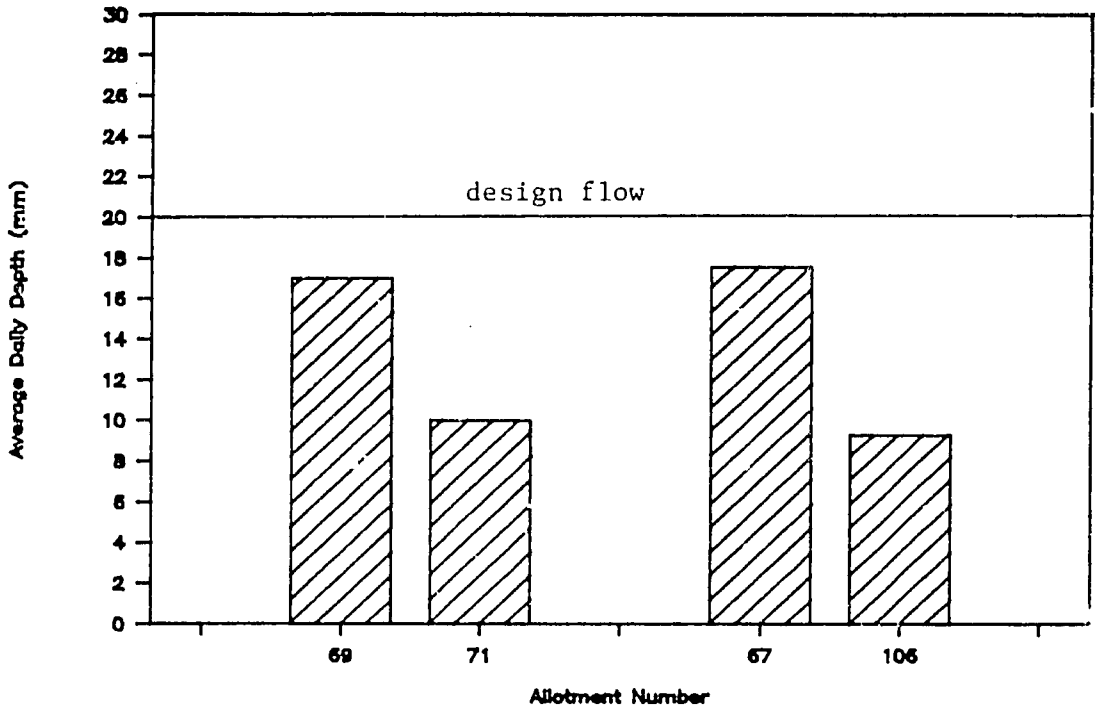

Figure 34. Seasonal average daily water supplied to allotments and on LB1 of RB21 head and tail field channels (PSS) and design flow for 1985 yala.

water delivery through irrigators' pols (individual turnouts to allotments) was not possible when the field channel had been cut too deep by erosion or when the pols were originally set too high. To remedy this, irrigators set check structures such as rocks or boards just downstream of a pol to increase the water level above the normal flow depth. Upstream field channel bunds were occasionally over-topped as a result, especially if the bunds had been damaged by livestock.

Even under optimal flow conditions, equity of water distribution along the field channel would be difficult to achieve without structural control of individual turnouts or a rotation imposed along the field channel. The standard 4-in (10.16 cm), free-flowing pipes used as turnouts cannot regulate flows; although when necessary, irrigators cut off flow by packing the pipes with clay or straw. Flow rates through each pipe depend on the head (or depth of water) at that particular field channel location and the submergence condition of the pipe. In addition, if the pipes are set at varying levels in relation to the bottom of the field channel, it is not possible to control or predict the flows.

b. Reliability and Rotation of Water Distribution

All field channels experienced periodic flows resulting from rotation practices with the frequent exception of the RB7 head field

channel. This can be seen in the field channel inflow hydrographs represented in Figures 13 through 18.

Rotation appeared to vary from a 6-to-7 day cycle, with off and on periods of indeterminate duration. Maximum flows varied up to 1.5 cfs between rotations. On some field channels this range amounted to 15 mm/day. This would make it difficult for an irrigator to estimate the water delivery for subsequent rotations.

Peak flows were not maintained, but appeared as sharp pulses on the flow hydrographs. For a large percentage of this period, field channel flow was far below capacity. A steady flow rate never developed. Without periods of constant flow, an irrigator must continually adjust water management strategies.

c. Analysis of Field Irrigation Requirement

The field irrigation requirement was defined as the sum of ET and percolation and seepage losses minus effective rainfall. (During the study period, no appreciable amount of rain fell in the study area.) Data was collected to support two approaches in determining the field irrigation requirement for the period of observation. The two approaches -- barrel lysimeters and *livadda* water balances -- are discussed below.

Barrel Lysimeters and Percolation. Barrel lysimeters were used in the first approach to measure evapotranspiration and percolation. Seasonal average ET and percolation values derived from daily readings of the barrel lysimeters are shown in Table 8. Barrel lysimeter data are listed in Appendix D. If seepage losses are assumed to be small in comparison to percolation, ET and percolation would represent a reasonable approximation of field irrigation requirement.

Table 8. ET and percolation and seepage losses from barrel lysimeter data on PSS for 1985 *yala*.

Soil	Field Channel	ET + P* (mm/day)
LHG	Block F tail	8
LHG	RB7 tail	10
RBE	Block F tail	30
RBE	RB7 tail	16
RBE w/plow pan	Block F tail	14

*P = percolation
RBE = imperfectly drained, reddish-brown earth soils
LHG = poorly drained, low humic gley soils

ET values from the two sets of barrel lysimeters averaged 8.5 and 13.4 mm/day with large daily variations. Upon removal of the barrels at the end of the season, it was discovered that the bottom of the drums

had rusted, allowing the free percolation of water. Consequently, barrel ET values were disregarded.

If an average ET of 6.43 mm/day calculated by the Penman method is subtracted from the ET and percolation values shown in Table 8, the percolation rates can be obtained (Table 9).

Although it was reasonable to assume variation in percolation rates in RBE soils, there was also reason to believe that significant error was introduced in measuring water depth in the barrels. The standard 12-inch rules proved difficult to read at the desired accuracy and were possibly unstable since they were anchored in saturated soil. The ponding depth and soil water content of the soils surrounding the barrels would create a hydraulic gradient which could also introduce error into percolation measurement. For these reasons, percolation rates derived from barrel lysimeter data were not used to calculate field irrigation requirement.

Livadda Water Balances and Percolation. The water balance equation used in the second approach to determine the field irrigation requirement, as developed earlier in the on-farm methods section, was as follows:

$$I - O = ET + (P+S) = FIR$$

or

$$(P+S) = I - O - ET$$

where I and O represent inflow and outflow measurements on a study livadda. Daily and seasonal percolation and seepage rates were determined from the above equation using measured flows and ET calculated by the Penman method. Percolation and seepage rates derived in this approach are compared to percolation values derived from the barrel lysimeter measurements of this study and the field observations of Holmes, Wooldridge and Welles (1981) and the Huntington Technical Service Report (1978) in Table 9.

Table 9. Comparison of percolation rates determined by Holmes, Wooldridge and Welles (1981), Huntington Technical Services Report (1978), PSS barrel lysimeter data, and PSS water balance calculations.

Soil Type*	HWW (1981)	HTSR (1978)	barrel lysimeters	Water balance (P+S)
	mm/day			
Poorly drained LHG soils	9	3	2 4	2
Imperfectly drained RBE soils (w/plough pan)	22	10	24 10 8	9

*LHG = low humic gley
RBE = reddish-brown earth

Calculated reference evapotranspiration (ET_0), crop coefficients (kc), and ET values are listed for the period of study in Appendix E. The meteorological data for 1985 from the Aralaganwila Research Station used to calculate ET_0 and pan evaporation values are also listed in Appendix E. The seasonal average P+S for the imperfectly drained RBE soils and the poorly drained LHG soils were calculated as 9 mm/day and 2 mm/day, respectively.

The total seepage throughout the season for a single liyadda study site can be considered negligible since seepage flow from neighboring liyaddas probably balances water lost or gained by seepage from the study liyadda. Therefore, the P+S term can be considered to represent only percolation; these are the values used for comparison in Table 9.

Field Irrigation Requirement. The seasonal water balance method gave the most conservative estimates of percolation and seepage. These values are close to the values obtained for percolation by Huntington (the Holmes study acknowledged its values were high). For these reasons, percolation and seepage values of 9 mm/day on RBE soils and 2 mm/day on LHG soils were used to calculate the field irrigation requirement. Field irrigation requirements were calculated as the sum of Penman ET and P+S from the liyadda water balance studies.

d. Water Deliveries and Field Irrigation Requirements

Deliveries to Individual Liyaddas. Daily field irrigation requirements associated with the soil classifications were averaged over 5-day periods and compared to the average 5-day deliveries to individual liyaddas. Bar graphs showing the field irrigation requirement as ET + P+S and supply to the liyaddas are shown in Figures 35 through 45.

Critical periods, when inadequate water supply would greatly affect crop yield, include the period soon after planting during the early vegetative stage and near the middle of the season during panicle initiation through 50 percent flowering stage. For this study, the critical periods are defined as Julian days 140 to 154 and 180 to 224, respectively.

For comparison between study liyaddas, the number of days during each critical period during which water was unavailable to meet the field irrigation requirement was tabulated from the bar graphs. The results are shown in Table 10.

The days of shortage during the early vegetative critical period ranged from 5 on allotment 117 (RB7 head) and allotment 149 (RB7 tail) to 15 on allotment 67 (LB1 tail). Block F was not included in the early vegetative tabulation because water measurement did not begin until after Julian day 154.

During the late vegetative critical period, days of shortage ranged from 0 on allotment 22 (Block F tail) to 30 on allotment 100 (LB1 tail). Water delivery exceeded the field irrigation requirement on the following sites: allotment 14, Block F head field channel 1

Table 10. Number of days of water shortage during the early and late vegetative critical periods for study *livaddas* on PSS during 1985 *yala*.

Field Channel	Lot	Soil*	Early Veg. Period	Late Veg. Period
Block F head	14	RBE	**	5
Block F head	15	RBE	**	15
Block F tail	23	RBE	--	5
Block F tail	22	LHG	--	0
RB7 head	114	RBE	10	0
RB7 head	117	LHG	5	20
RB7 tail	149	RBE	5	5
RB7 tail	146	LHG	10	20
LB1/RB21 tail	67	RBE	15	20
LB1/RB21 tail	100	LHG	10	30

* RBE = imperfectly drained, reddish-brown earth
LHG = poorly drained, low humic gley
**Data not available for early vegetative period.

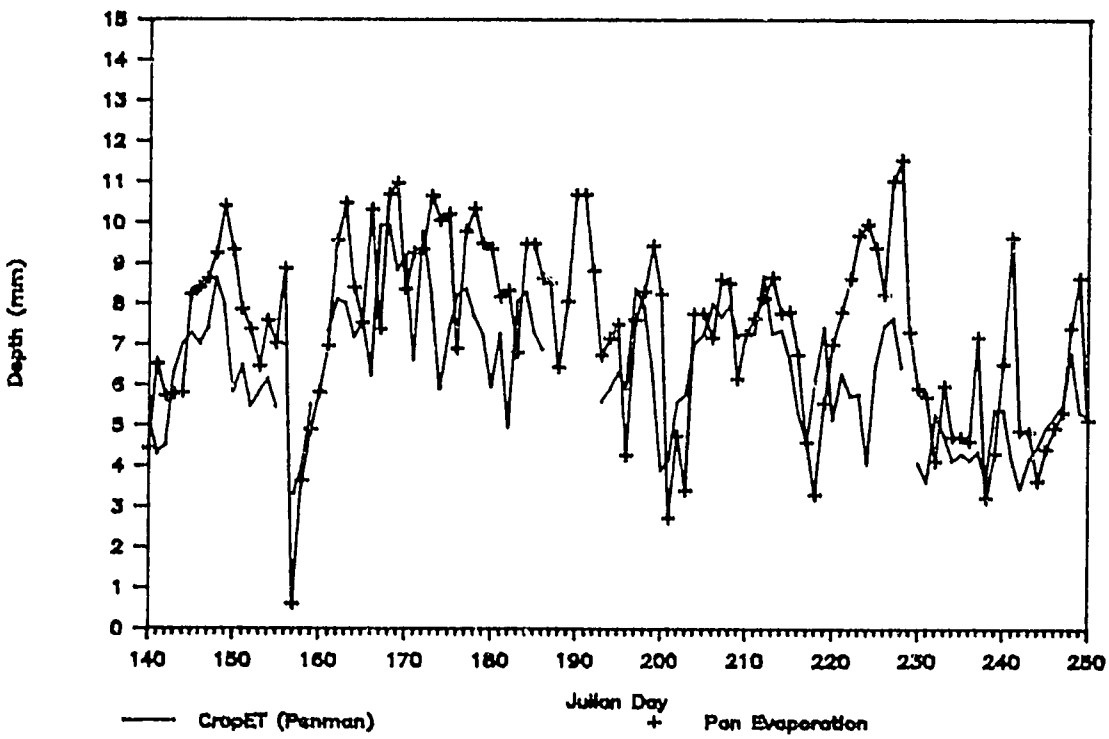

Figure 35. ET calculated by Penman method and pan evaporation curves from Aralaganwila Agricultural Research Station data, 1985 *yala*.

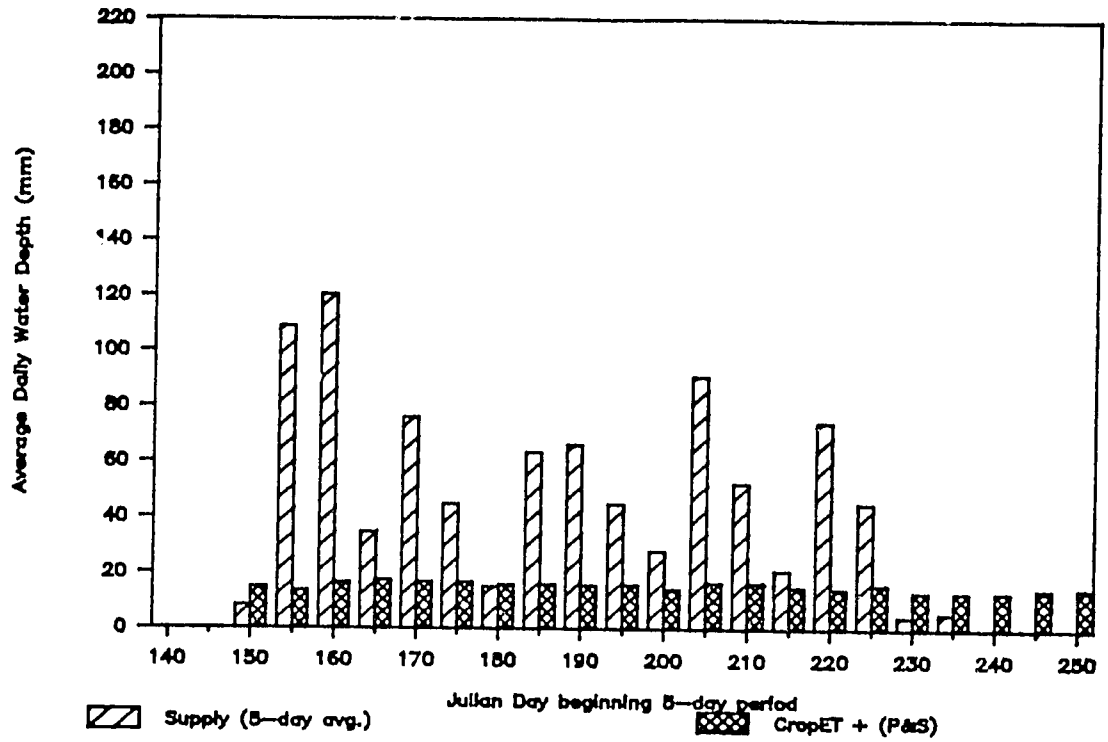

Figure 36. Water delivery and field irrigation requirement shown as the 5-day average of daily water depth for Block F head field channel 1, allotment 14, RBE soils on PSS, 1985 yala.

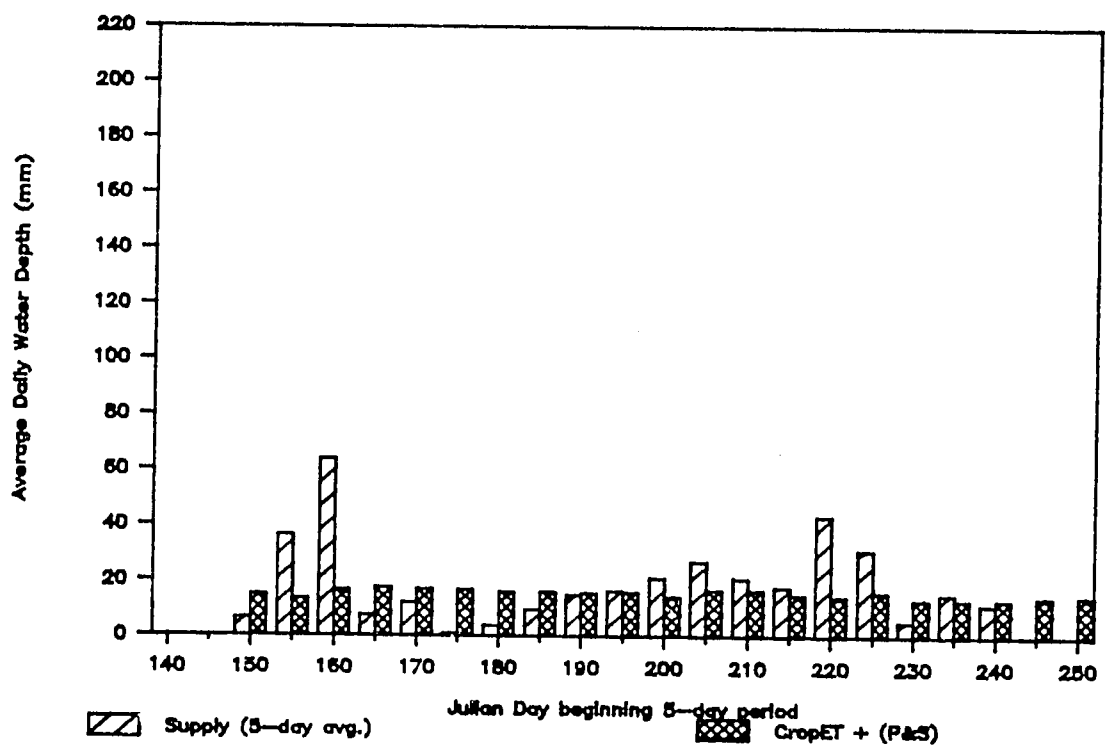

Figure 37. Water delivery and field irrigation requirement shown as the 5-day average of daily water depth for Block F head field channel 2, allotment 15, RBE soils on PSS, 1985 yala.

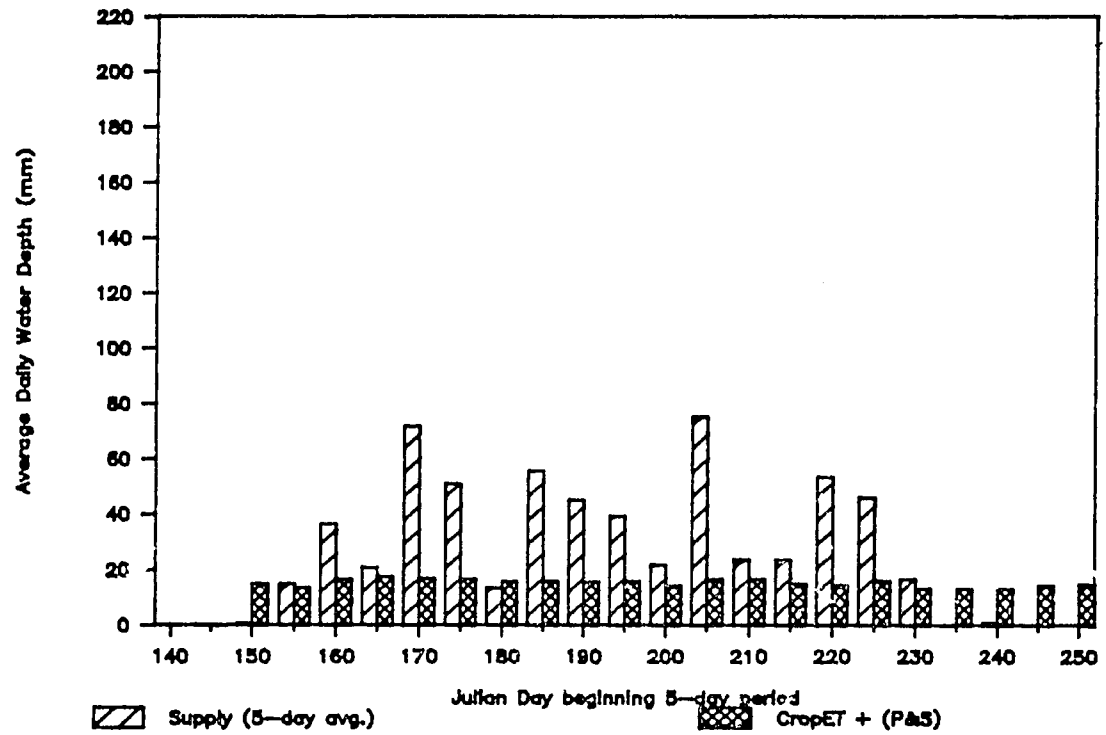

Figure 38. Water delivery and field irrigation requirement shown as the 5-day average of daily water depth for Block F tail field channel 1, allotment 23, RBE soils on PSS, 1985 Yala.

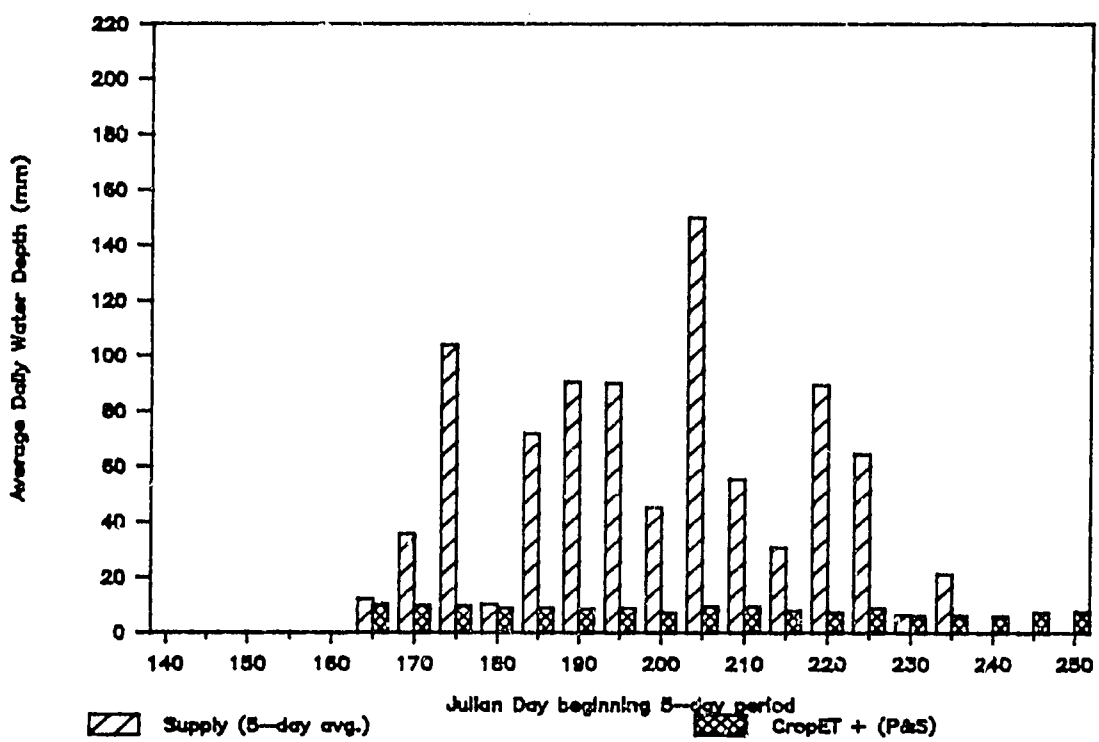

Figure 39. Water delivery and field irrigation requirement shown as the 5-day average of daily water depth for Block F tail field channel 2, allotment 22, LHG soils on PSS, 1985 yala.

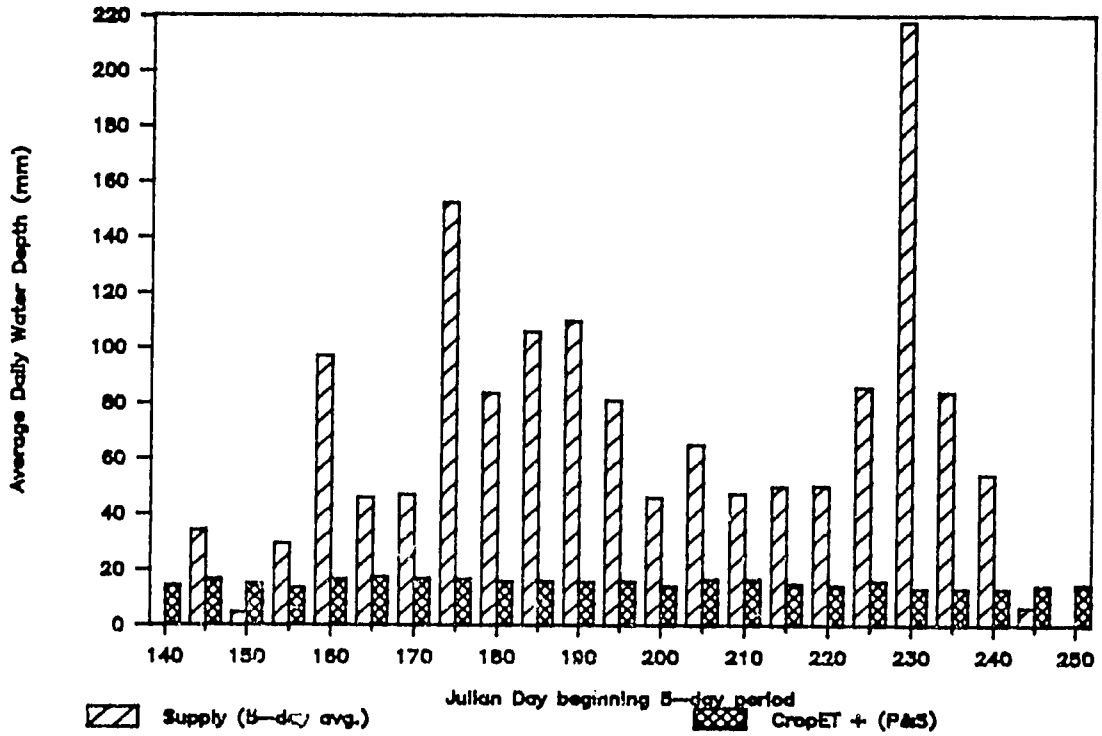

Figure 40. Water delivery and field irrigation requirement shown as the 5-day average of daily water depth for RB7 head field channel 1, allotment 114, RBE soils on PSS, 1985 yala.

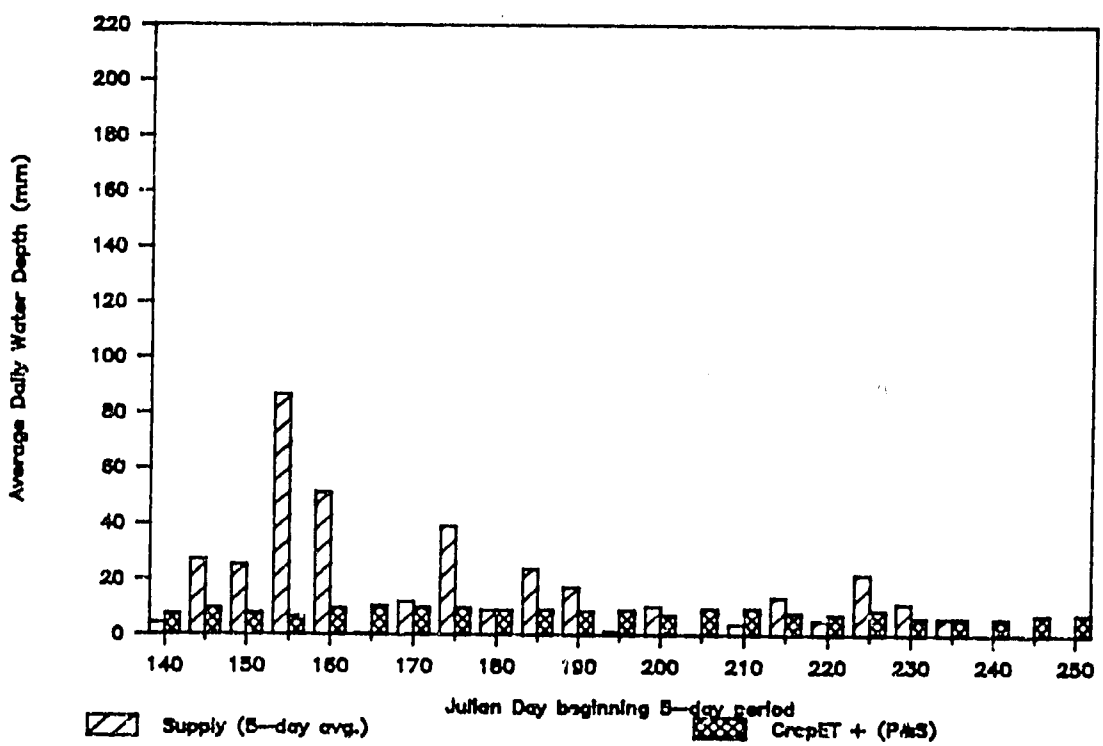

Figure 41. Water delivery and field irrigation requirement shown as the 5-day average of daily water depth for RB7 head field channel 2, allotment 117, LHG soils on PSS, 1985 yala.

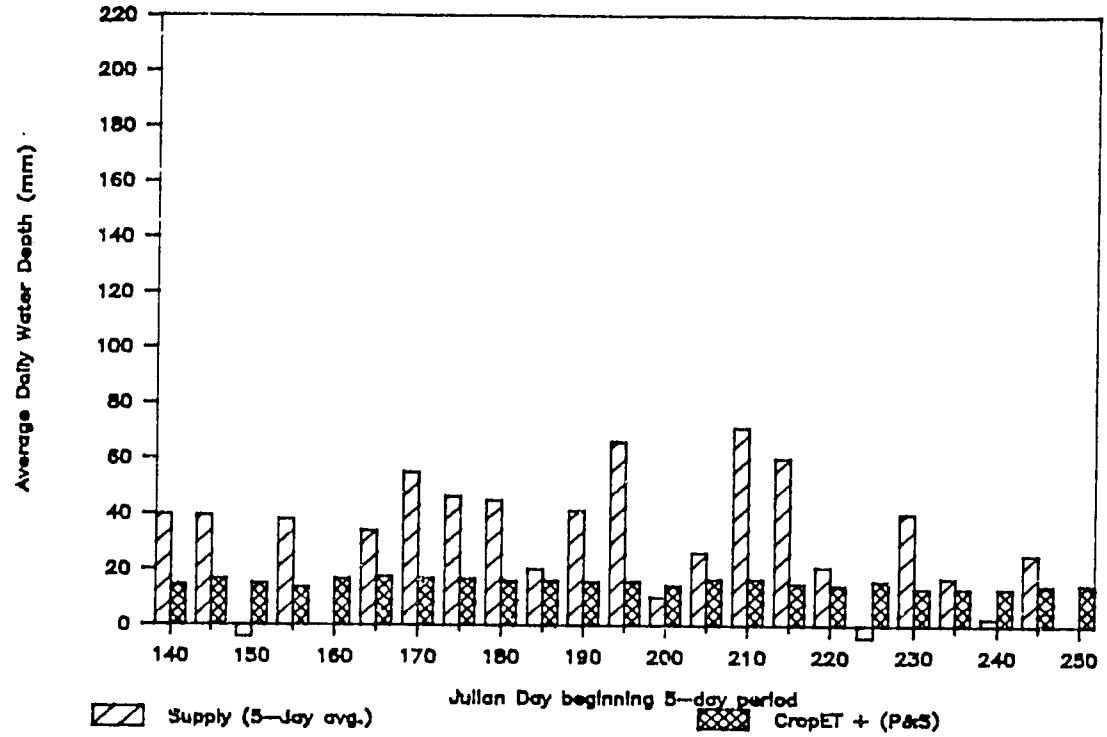

Figure 42. Water delivery and field irrigation requirement shown as the 5-day average of daily water depth for RB7 tail field channel 1, allotment 149, RBE soils on PSS, 1985 yala.

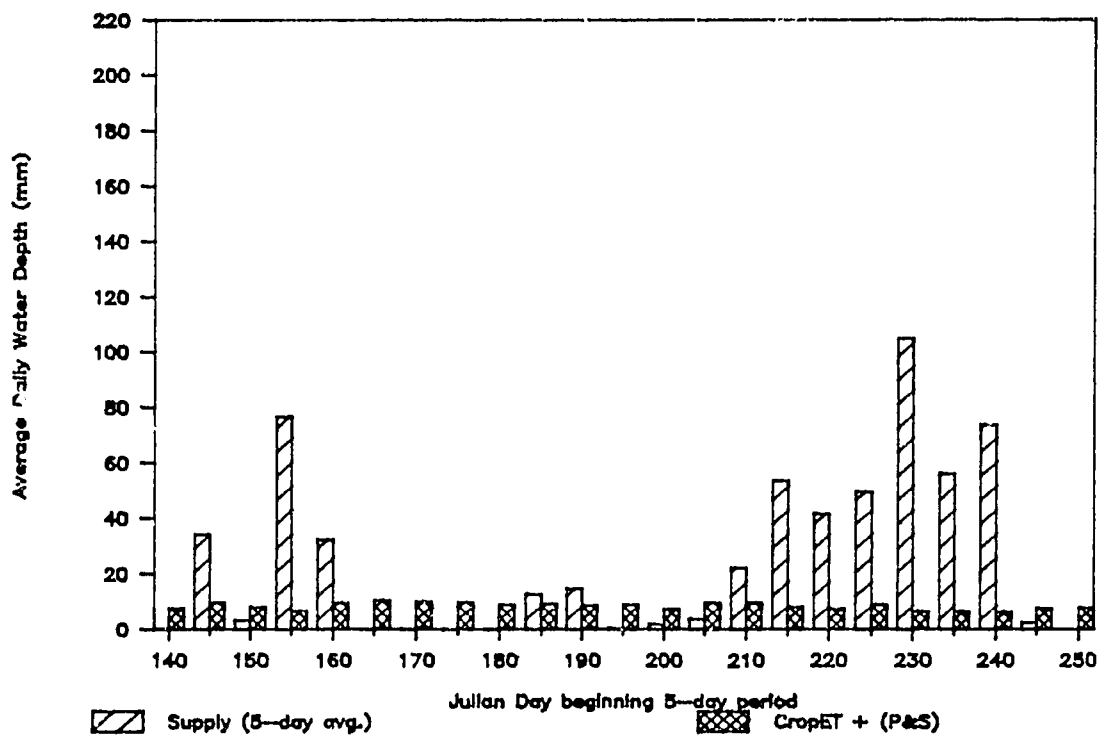

Figure 43. Water delivery and field irrigation requirement shown as the 5-day average of daily water depth for RB7 tail field channel 2, allotment 146, LHG soils on PSS, 1985 yala.

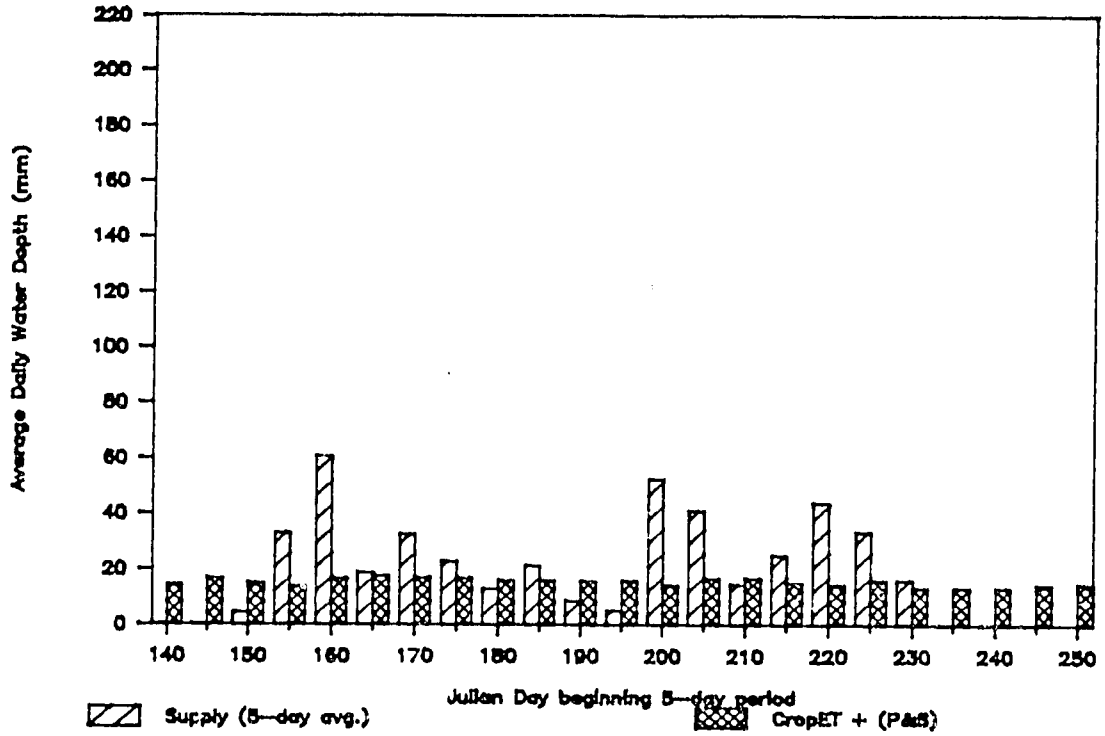

Figure 44. Water delivery and field irrigation requirement shown as the 5-day average of daily water depth for LB1 tail field channel 1, allotment 67, RBE soils on PSS, 1985 yala.

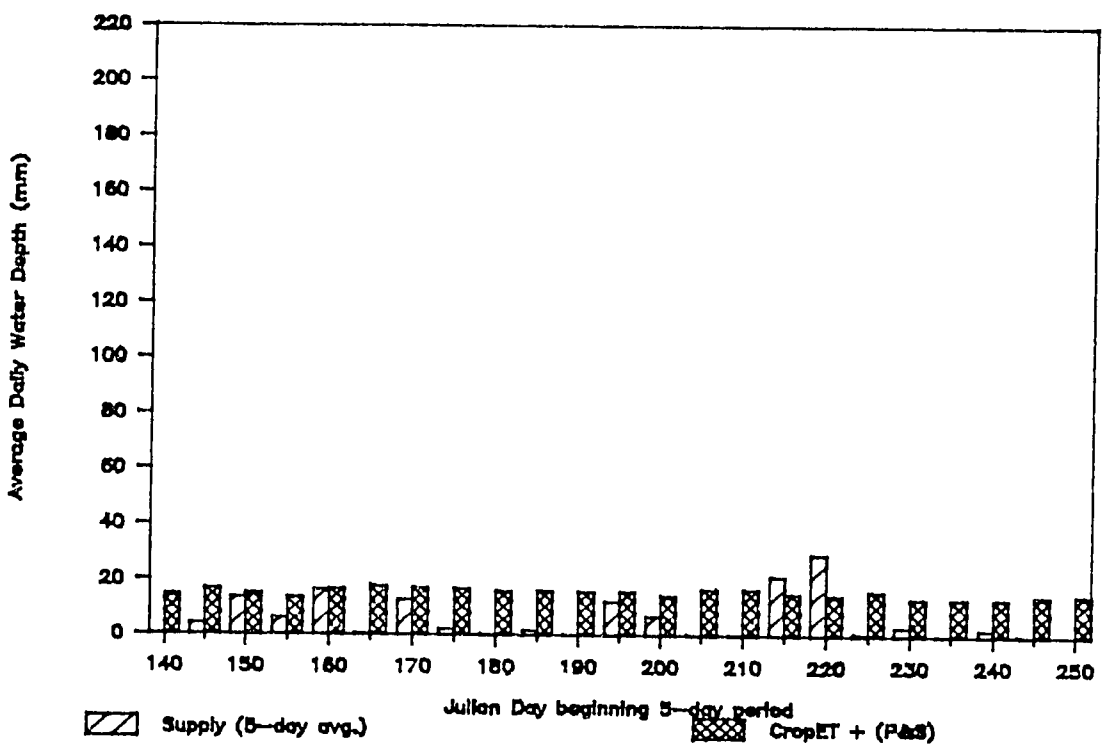

Figure 45. Water delivery and field irrigation requirement shown as the 5-day average of daily water depth for LB1 tail field channel 2, allotment 100, LHG soils on PSS, 1985 yala.

(Figure 36); allotment 23, Block F tail field channel 1 (Figure 38); allotment 22, Block F tail field channel 2 (Figure 39); allotment 114, RB7 head field channel 1 (Figure 40); and allotment 149, RB7 tail field channel 1 (Figure 42).

Deliveries to Field Channels. Field irrigation requirements averaged over 5-day periods were calculated for each field channel command area. The derived field irrigation requirement is the weighted sum of the requirements for the two predominant soil types: poorly drained LHG and imperfectly drained RBE. The field channel field irrigation requirement, shown as ET + P+S, and 5-day average deliveries are compared in bar graphs in Figures 46 through 51.

The days during the early and late vegetative critical periods during which water delivery was unable to meet the field channel field irrigation requirement were tabulated from the bar graphs. The results are shown in Table 11.

Table 11. Number of days of water shortage during the early and late vegetative critical periods for field channels studied on PSS, 1985 *yala*.

Field Channel	Early Veg. Period	Late Veg. Period
Block F head	--	25
Block F tail	--	40
RB7 head	5	0
RB7 tail	10	40
LB1 head	--	5
LB1 tail	--	25

The Block F tail field channel and the RB7 tail field channel experienced the greatest shortages of all field channels studied. During the late vegetative critical period, field channel deliveries on both channels were insufficient to meet the field channel field irrigation requirement for 40 days. Comparisons for the early vegetative critical period for Block F and LB1 were not made as measurements did not begin early enough in the season.

Comparisons of field channel deliveries and field irrigation requirements on the RB7 head and tail field channel revealed a distribution inequity that requires further investigation. Although the head field channel was supplied with water in excess of the requirement over 30 percent of the time, the tail field channel was short of water nearly 70 percent of the time.

The field channel water balance study and in-field (*liyadda*) water balance study show vast differences in the number of days of water shortage. For example, water shortage in the Block F head field

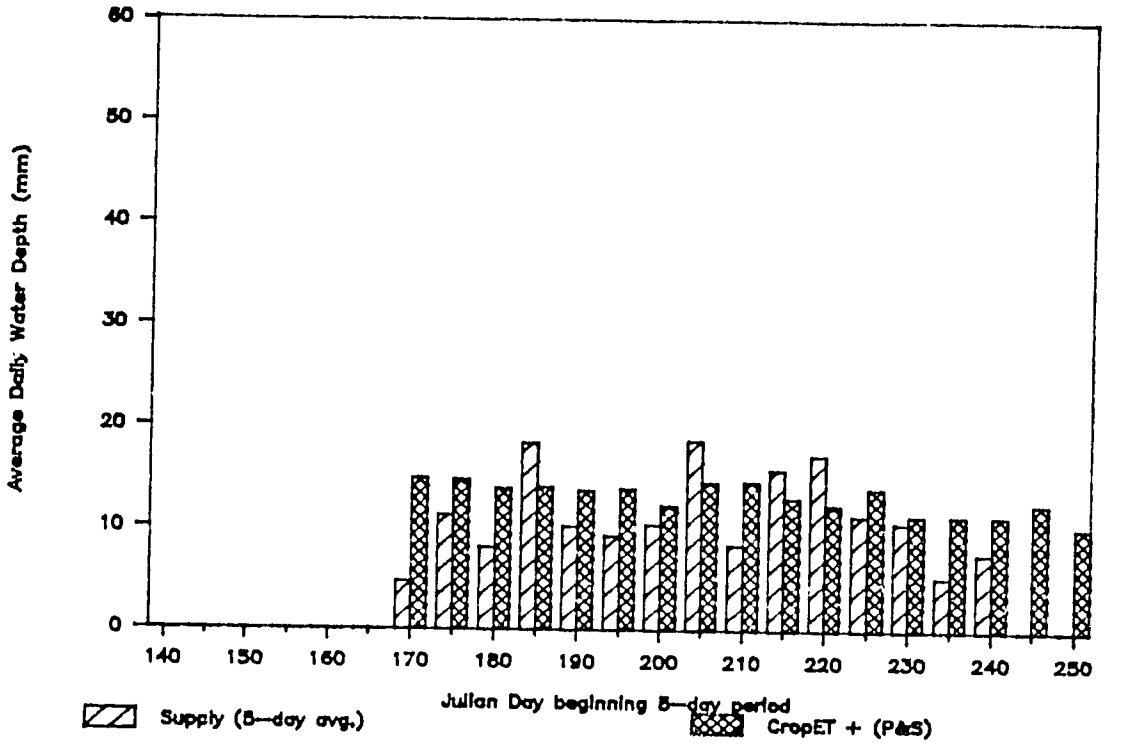

Figure 46. Water delivery and field irrigation requirement shown as 5-day average of daily water depth for Block F head field channel on PSS, 1985 yala.

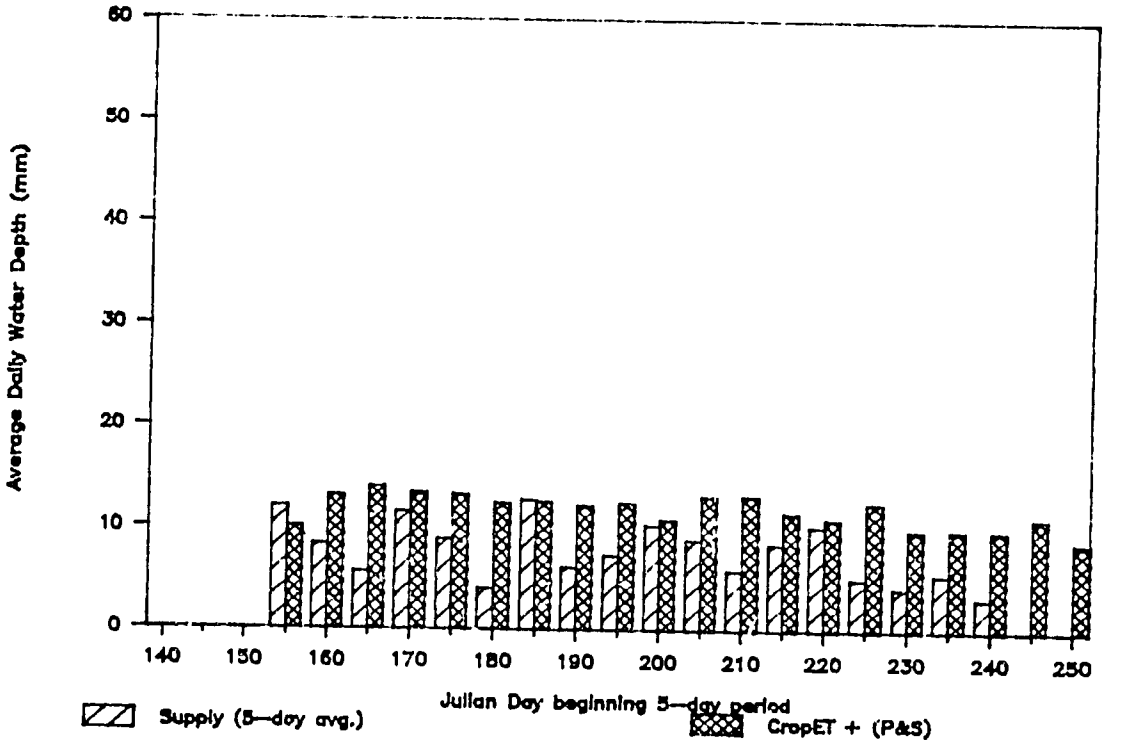

Figure 47. Water delivery and field irrigation requirement shown as 5-day average of daily water depth for Block F tail field channel on PSS, 1985 yala.

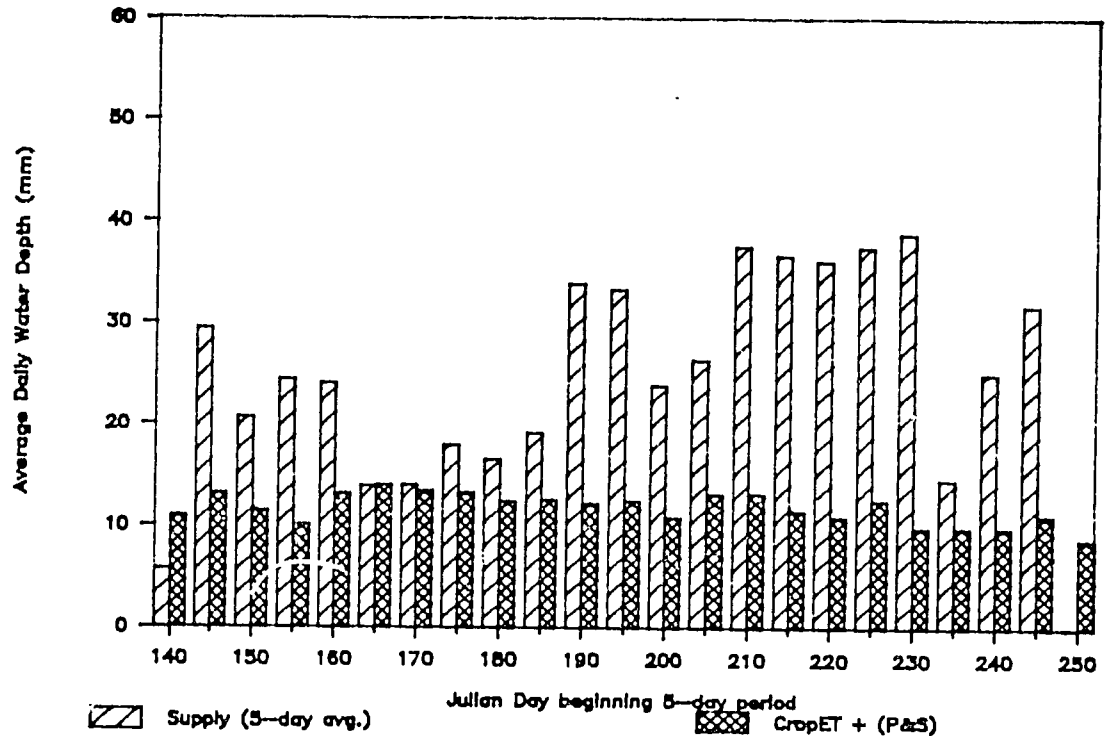

Figure 48. Water delivery and field irrigation requirement shown as 5-day average of daily water depth for RB7 head field channel on PSS, 1985 *yala*.

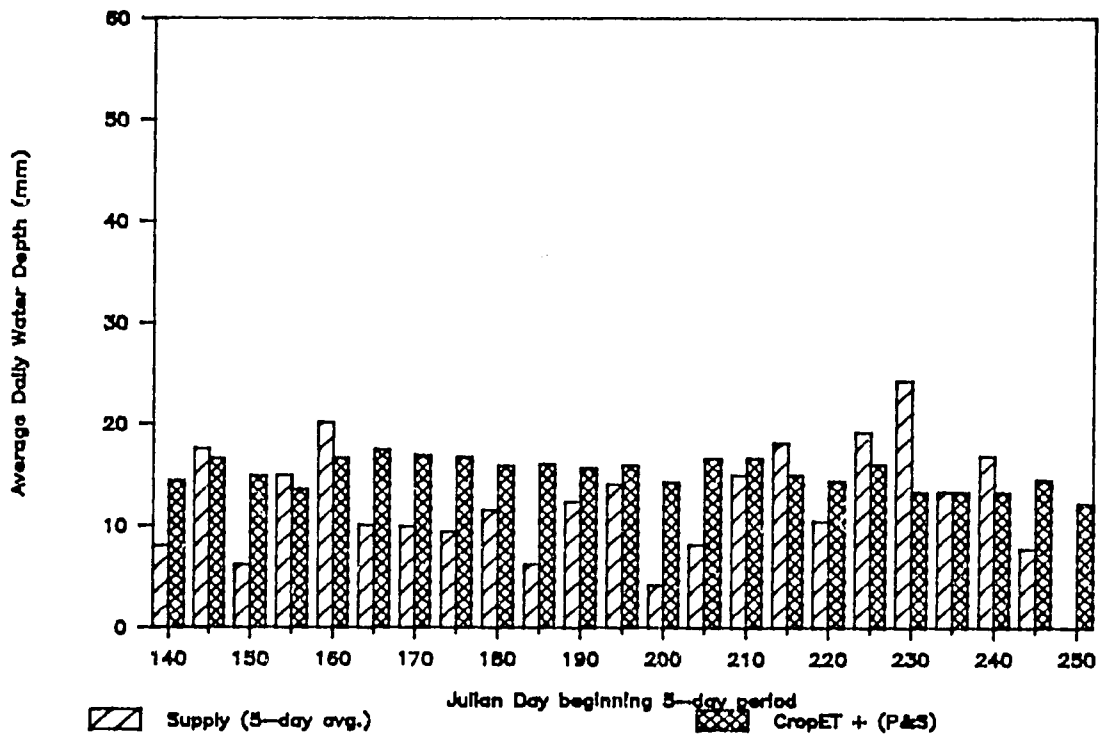

Figure 49. Water delivery and field irrigation requirement shown as 5-day average of daily water depth for RB7 tail field channel on PSS, 1985 *yala*.

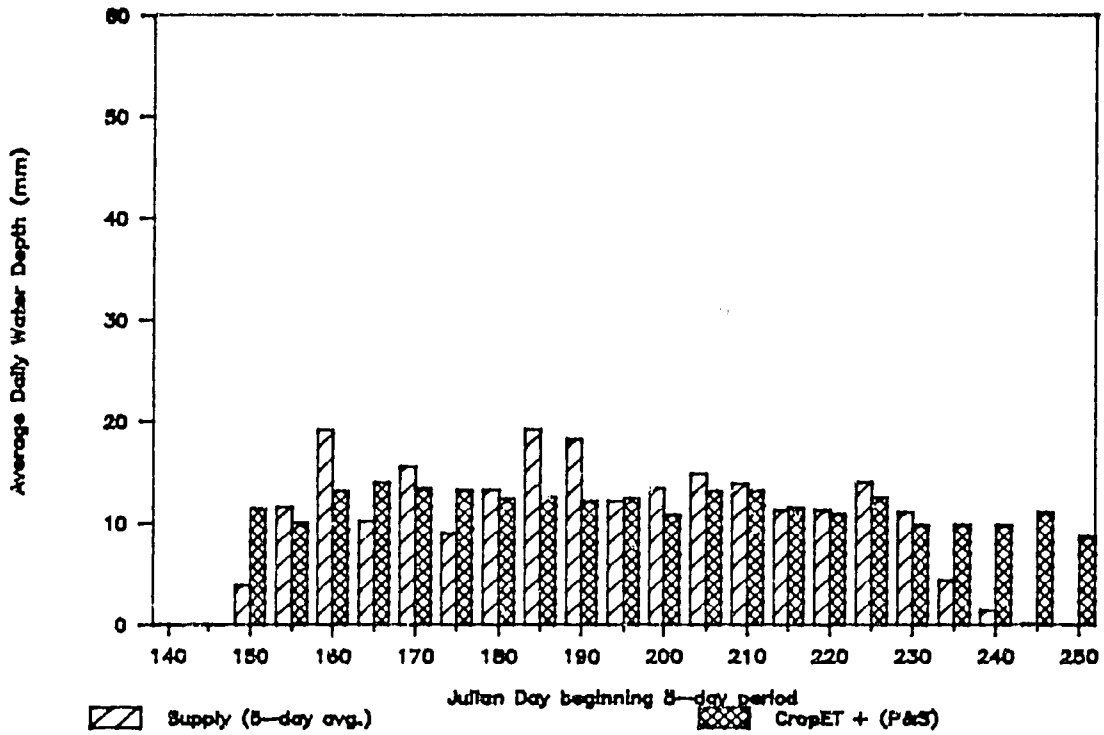

Figure 50. Water delivery and field irrigation requirement shown as 5-day average of daily water depth for LB1 head field channel on PSS, 1985 yala.

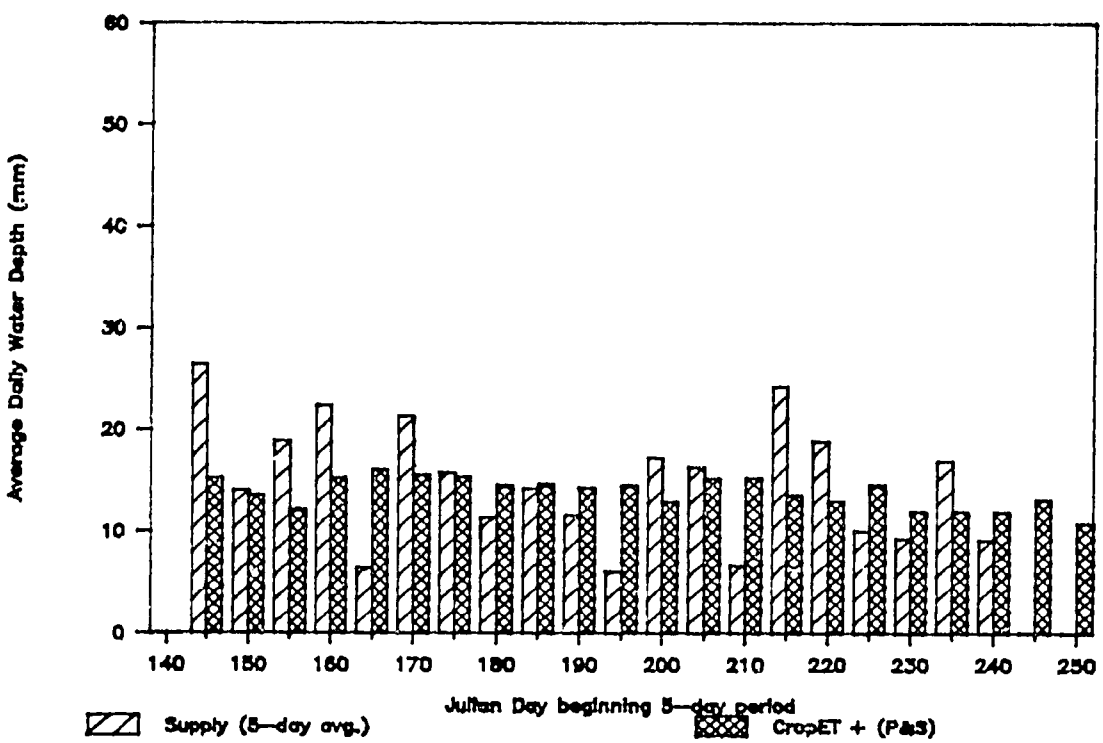

Figure 51. Water delivery and field irrigation requirement shown as 5-day average of daily water depth for LB1 tail field channel on PSS, 1985 yala.

channel *livaddas* 1 and 2 varied from 5 to 10 days (Table 10), compared to the field channel water shortage in the Block F head field channel which was 25 days. (Table 11).

A possible explanation for this difference could be the availability of other water sources (in addition to surface water supply) by way of seepage flow from higher slopes and capillary supply from the watertable. This phenomenon needs further study. Also, supplies available through seepage and groundwater need to be considered in computing field irrigation requirement.

Within field channel study areas, water tables ranged from 10-100 cm from the ground surface (Appendix F). All of the measured water tables rose and fell with on and off periods of water delivery. However, major fluctuations in water table depths were only observed in the upper and middle slopes of the field channel areas. In the lower slopes, shallow water tables tended to remain within 10 to 30 cm of the soil surface. Although shallow fluctuating water tables may serve as a source of water for paddy cultivation, they pose problems for cultivators attempting to grow other field crops.

e. Crop Yields and Water Deliveries

Field Channels. Average paddy yields for each field channel and the number of days of water delivery shortage during the late vegetative critical period are shown in Table 12. The ratio of total seasonal water delivery to total seasonal field irrigation requirement (supply/FIR) is also shown in Table 12.

Table 12. Paddy yields and number of days of water shortage during the late vegetative critical period for field channels studied on PSS, 1985 *yala*.

Field Channel	Average Yield* (bu/ac)	Days of Shortage: Late Veg. Period	Supply/ FIR
Block F head	99.3	25	.95
Block F tail	89.8	40	.67
RB7 head	87.4	0	2.90
RB7 tail	102.7	40	.71
LB1 head	83.7	5	1.20
LB1 tail	62.6	25	.99

*Yields taken from agronomy section

For Block F and LB1, fewer days of water shortage on the head field channels accompanied higher yields when compared to tail field channel shortages and yields. The RB7 head field channel, however, had relatively low yields, even with high field channel deliveries; while the RB7 tail field channel had the highest yields and the greatest number of days of shortage during the late vegetative critical period.

Among other factors that may explain the anomaly of the RB7 field channel deliveries and yield, the constant high water table on the RB7 tail field channel may be considered (Appendix F). The root zone was limited to about 20 cm by the plow pan for most soils of the PSS study area (see agronomy section), and the water table for the lower slope of the RB7 tail field channel remained above 30 cm. This was within the range of groundwater levels that significantly contribute to meeting field irrigation requirements (Doorenbos, 1977).

Liyadda. A comparison of paddy yields and the number of days of water shortage for each study site is shown in Table 13. Liyadda sites are listed by soil type since the determination of field irrigation requirement and the number of days of water shortage depend on soil type.

Table 13. Paddy yields and number of days of water shortage during early and late vegetative critical periods for each PSS liyadda study site according to soil classification, 1985 yala.

Field Channel	Lot (Liyadda)	Soil*	Days of Shortage Early Veg. Period	Days of Shortage Late Veg. Period	Yield (bu/acre)
Block F head	14	RBE	--	5	125.6
Block F head	15	RBE	--	15	100.0
Block F tail	23	RBE	--	5	94.4
RB7 head	114	RBE	10	0	88.3
RB7 tail	149	RBE	5	5	125.2
LB1 tail	67	RBE	15	20	48.2
Block F tail	22	LHG	--	0	131.9
RB7 head	117	LHG	5	20	121.8
RB7 tail	146	LHG	10	20	126.7
LB1 tail	100	LHG	10	30	78.0

*RBE = imperfectly drained, reddish-brown earth
LHG = poorly drained low humic gley

High yields generally corresponded to a small number of days of water shortage for imperfectly drained RBE soils. The highest yields for this soil classification were about 125 bu/ac and occurred where only 5 water-short days were experienced during the late vegetative critical period. A relatively low yield of 88.3 bu/ac was produced on a study liyadda with no days of water shortage during the late vegetative critical period, but with 10 days of shortage during the early vegetative critical period. Although not enough data from all study liyaddas were collected during the early vegetative critical period to draw a conclusion, the above result may indicate the importance of early water delivery. The lowest yield for imperfectly drained RBE soils (48.2 bu/ac) was produced where the study site experienced the greatest water shortage during both early and late vegetative critical periods (15 and 20 days of shortage, respectively).

Poorly drained LHG soils produced comparatively high yields on the study liyaddas except for one liyadda which experienced 30 days of water shortage (the highest for the LHG study sites) during the late vegetative critical period. High yields on study liyaddas that had a large number of water-short days may indicate that the calculated field irrigation requirement for poorly drained LHG soils is high, since the contribution of groundwater in LHG soil was not considered in the computations. Unless further studies are conducted, it will be difficult to quantify the contribution of groundwater in the computation of field irrigation requirement.

Crop yields were also compared to the observed number of days of ponded water in the agronomy section.

4. CONCLUSION AND RECOMMENDATIONS

The on-farm engineering study of six field channels in the Parakrama Samudra Scheme indicated that field irrigation requirements often exceeded the water supplied to the field channel and liyadda study sites during 1985 yala.

The seasonal average of daily water supplied to the six individual field channels ranged from 7.87 mm/day to 26.46 mm/day. All field channels except the RB7 head field channel received significantly less water than the target flows of 30 ac/cfs (20.15 mm/day) established by the Irrigation Department. More importantly, the average daily water supplied to four of the six field channels was less than the average irrigation requirement (14 mm/day) for the field channel command areas.

Head field channels received more water per unit area than tail field channels on two of the three distributary channels studied. Similar results would be expected for the third distributary channel if encroached areas were included in the surveyed command area.

Equity of water distribution among field channels could be improved by replacing faulty gate structures, centralizing management, supervising rotation practices, and calibrating or regularly monitoring field channel flows.

Rotational delivery was experienced on all field channels with one notable exception on the RB7 head field channel. Maximum flows were not maintained for any length of time, resulting in relatively short pulses of water delivery and field channels flowing at less than capacity. Short periods of peak flow during a rotational delivery may decrease the irrigator's ability to distribute water equitably throughout the field channel.

Upstream allotments on the studied channels tended to receive more water per unit area than downstream allotments. Distribution equity along the field channel was limited by the ability to control flow through the 4-in pipes that serve as turnouts and the degradation of the field channel due to livestock and erosion. Improvements could be

made by regrading the channel and re-positioning the pols. Additional improvements could be achieved by replacing pipe turnouts with gates.

The field irrigation requirement was determined from evapotranspiration values calculated using the Penman method and seasonal percolation and seepage losses derived from water balances performed on the two predominant soil types. Percolation and seepage losses were determined to be 2 mm/day for poorly drained LHG soils and 9 mm/day for imperfectly drained RBE soils.

Critical water requirement periods during the early vegetative and late vegetative stages for paddy were defined as Julian days 140 to 154 and Julian days 180 to 224, respectively. Water deliveries did not meet field irrigation requirements during the critical water requirement periods on all but one of the ten livadda study sites, and all but one of the field channels studied.

Average paddy yields for individual livaddas and the number of days of water shortage during critical periods did not show a clear relationship. High yields generally corresponded to a small number of days of water shortage for imperfectly drained RBE soils. However, a relatively low yield was produced from a study livadda with a few days of water shortage. Several high yields were produced on poorly drained LHG soils with a large number of water-short days. This was probably due to indirect supply from groundwater. Further investigation comparing yield with water delivery (direct supply) and groundwater (indirect supply) is needed.

Water tables ranged from 10 to 100 cm from the ground surface. Although high water tables may serve as a source of water for paddy cultivation, they pose problems for cultivators attempting to grow other field crops.

C. AGRONOMY

1. INTRODUCTION

The agronomy component was responsible for providing a description of the irrigated cropping system, including assessing the major variables affecting crop production on Parakrama Samudra Scheme. This involved describing the soils, crops, and management practices of the cultivators.

2. METHODOLOGY

The 1984 Diagnostic Analysis of Farm Irrigation Systems workshop and a 6-day reconnaissance survey in January 1985 provided the background information used to plan the detailed agronomic studies. Observations made during these two activities indicated that the cropping system was essentially a paddy monoculture of sufficient complexity to warrant daily or near daily examination. Several variables thought to affect paddy production within the field channel were identified as particularly important: size of the cultivation unit, variety of paddy, method of plant establishment, availability of water, amount and type of fertilizer applied, and degree of weed infestation.

a. Site Selection

Three distributary channels, located in the head, middle, and tail regions of the D1 main canal, were selected as common study sites for the diagnostic analysis (Table 14). The three distributary channels were selected to represent expected hydrological differences. For sampling purposes, the distributary channels were further divided into head and tail regions, from which one field channel in each location was selected for detailed investigation. The two chosen field channels also represented expected hydrological differences within the distributary channel.

Table 14. Agronomy field site characteristics for PSS during 1985 *yala*.

	Block F		RB7		LB1/RB21		
	FC 2*	FC 5	FC 1	FC 7	FC 11	FC 16	Total
Distance to D-1 sluice (mi)	2	3	6	8	15	17	
Allotments	3	5	8	8	7	6	37
Total area (ac)	16	27	32	46	31	29	181
Cultivators	14	12	13	16	22	22	99

* FC = Field channel

b. Field Personnel

Three Agricultural Diploma holders were employed as data collectors, with each assigned to one of the three distributary channels (Block F, RB7, and LB1/RB21). Each Agricultural Diploma holder was responsible for collecting agronomic data daily in the two selected field channels of their distributary channel.

Two agricultural instructors and one subject matter specialist from the Agriculture Department in Polonnaruwa assisted in supervising field data collection. The three officers, who participated in the 1984 Diagnostic Analysis of Farm Irrigation Systems workshop, made weekly visits to the study sites to provide advice and guidance to the Agricultural Diploma holders.

c. Data Collection

Agronomic investigations of Parakrama Samudra were initiated during the first and second weeks of June 1985 and culminated with crop cuttings in September-October 1985. Each data collector was responsible for all of the separately cultivated fields in his study site. In addition, six liyaddas -- two of which were located in each of the head, middle, and tail regions of the field channels -- were selected for more detailed agronomic measurements. (On-farm engineering measurements were conducted only on the liyaddas in the head and middle regions of each field channel.)

During the first two weeks of the agronomy study, the data collectors met with individual cultivators to explain the purpose of the investigations and to initiate data collection. Information collected during these discussions included date of first land preparation, number of plowings and harrowings, completion date for land preparation, type and amount of basal fertilizer applied, date of planting, method of planting, crop variety, area sown, and any weeding or plant protection measures employed. In addition, sketch maps showing the field channels, drainage channels, access roads, cropping pattern, and the liyaddas selected for detailed study were prepared.

Throughout the remainder of the irrigation season, data collectors were responsible for observing specific practices of the individual cultivators and for making detailed agronomic measurements in selected liyaddas. Field observations were made on alternate days on the head and tail field channel of each study site. Observations were often supplemented with informal conversations with the farmer when more detailed information, such as the amount of fertilizer or insecticide applied, was required.

The observational data collected included date of fertilizer applications, amount and type of fertilizer applied, date of insecticide applications, amount and type of insecticide applied, the reason for applying the insecticide, the degree of control obtained, date of weeding, method of weeding, amount and type of weedicide applied,

degree of control obtained, disease infestations, date of panicle initiation, and date of flowering.

In addition, an attempt was made to determine the relative availability of water. On alternate days, the data collector walked an established route along the bunds of the paddy fields. The route was, as near as possible, a straight line following the slope of the land. The route began in the head region of the field channel and ended at or near the drainage channel in the tail region of the field channel. The relative availability of water was recorded for each _liyadda_ using the following scale:

0 = Below field capacity, soil surface dry, many large cracks.

1 = Field capacity or above, soil surface moist to wet with none to few cracks.

2 = 1-5 cm of standing water.

3 = 5-10 cm of standing water.

4 = > 10 cm of standing water.

Data on relative availability of water were recorded for approximately 1.5-2 months, and data collection was terminated when weed growth on the bunds impaired movement in the field.

Detailed agronomic measurements in selected _liyaddas_ were used to provide more definitive information on the soils, crops, and management practices of the cultivator. Soil measurements, using methods described in Nelson (1983) made in selected _liyaddas_ were:

* Soil texture using the touch and feel method.

* Soil pH using a colorimetric pH test kit.

* Soil fertility measured indirectly using colorimetric N-P-K plant tissue test kits. Tissue tests were conducted at or soon after the panicle initiation stage.

* Depth to soil hardpan was measured using a soil probe.

* Populations of plants, productive and nonproductive tillers, and weeds were determined using a 50-cm diameter plastic ring. The ring was randomly placed in the field and the number of plants, productive and nonproductive tillers, and weeds were counted. Three replications were done.

Nine soil samples at 0-15 cm, 15-30 cm, and 30-60 cm were collected from each selected _liyadda_ for chemical analysis at the Soil Survey Division of the Irrigation Department. The soil samples were air-dried and composited into one sample for the three depths. However, chemical analysis was not performed on the soils due to budgetary and personnel limitations.

Yala paddy yields were estimated from crop cutting surveys conducted at the end of the season. A 1-m^2 sample, replicated five times, was selected as the sampling unit. Crop cuttings were collected from all of the separately cultivated fields in each study site. Additional crop cuttings were made in fields where the cultivator planted more than one variety. Each crop cutting was conducted as follows.

One-meter square, wooden frames were randomly tossed into the field. All plants falling inside the frame were carefully harvested and placed in a burlap bag. A total of five crop cutting samples were collected from each field. The harvested samples were carefully removed to an appropriate place for threshing. Samples were separately threshed by foot on a 8-ft, square tarpaulin. Each sample was winnowed by hand using a kulla. The cleaned paddy and chaff were placed in separate plastic sample bags, labeled, and brought to Polonnaruwa for weighing. Paddy and chaff sample weights were determined with a triple-beam laboratory balance. Seed moisture of the paddy was determined using a seed moisture meter. After weighing, the paddy samples were returned to the cultivator.

At the end of yala, the Soil Survey Division of the Irrigation Department was contracted to conduct a detailed soil survey of the selected study sites. Upon completion of the survey, soil survey maps of each field channel were prepared.

d. Data Analysis

The initial reduction and tabulation of field data was accomplished in the field by the data collectors. Tabulated data were analyzed using either Lotus 1-2-3™ or Microstat™ software programs on a Compaq™ microcomputer. Statistical analyses included mean, frequency, and standard deviation.

3. RESULTS AND DISCUSSION

a. Unit of Cultivation

It is commonly assumed that a single farm family is associated with a 5-ac allotment on Parakrama Samudra Scheme. However, a number of factors have influenced the actual unit of cultivation. These include: original acreage allotted, encroachment, and land fragmentation.

The original allottees of Parakrama Samudra Scheme were provided with approximately 5 ac of lowland for irrigated paddy cultivation and 3 ac of highland for the homestead. Blocking out plans prepared during the settlement period indicated that the original lowland allotments actually varied in size from as little as 3.5 ac to nearly 8 ac. Similar differences in allotted acreages for the highland homesteads were noted.

While topographical features might make it difficult to provide allotments of uniform sizes, there was no apparent reason for the wide

variation in size of the original allotments. In any case, the original acreage allotted for irrigated paddy and highland during resettlement was sufficient to support the original family.

Engineering surveys of the field channel study sites (Appendix B) indicated that 18 of the 37 allotments surveyed were less than 5 ac in area. Of these, 8 allotments were less than 4 ac, with the smallest allotment having a surveyed area of 3.15 ac.

Generally, allotment boundaries observed in the field agreed with those indicated in the original blocking out plans. Notable exceptions to this were allotments that bordered field channels, drainage channels, and field channel access road easements. Almost all of these allotments have increased in size by encroachment onto reserved areas. Engineering surveys of the field channel study sites (Appendix B) indicated that of 37 surveyed allotments, 7 had areas greater than 6 ac. In fact, one of the allotments actually comprised 9.5 ac. The increased acreage of these allotments resulted from encroachment onto the drainage channel easements. Similar, but less significant, increases in acreage were observed in other allotments bordering field channels and field channel access road easements.

While the area of individual allotments has often been expanded by encroachment, the unit of land available to the individual cultivator has substantially decreased. The magnitude of this problem is readily apparent when the percentages of individuals cultivating specific acreages were compared (Figure 52). During 1985 yala, the six field channel sites that were studied comprised 37 allotments with a total surveyed area of 180.5 ac. Originally, each of the 37 allotments was associated with a single cultivator. However, due to fragmentation, 95 individuals were cultivating this same area at the time of the study. Of the total number of cultivators, nearly 52 percent cultivated one or less acres, while 13 percent actually cultivated plots of .5 ac or less. Another 28 percent cultivated between 1 and 3 ac, and only 20 percent cultivated acreages near to or above what was originally allotted during the settlement period.

It was evident that the majority of cultivators on Parakrama Samudra have been reduced to subsistence farming. It was also apparent from data presented in the sociology and women in development sections of this report that the problem will probably become more severe as third generation families begin to inherit these lands.

b. Soils

The Soil Survey Division of the Irrigation Department was contracted to conduct a detailed soil survey of the field channel study sites to obtain basic soils information for PSS, which was previously unavailable. In addition to mapping soils, the survey team was requested to characterize a typical soil profile for each soil type, and to collect soil samples for later chemical and physical analysis at the Soil Survey Laboratory. The soil survey was to have been conducted between yala and maha, during the irrigation closure period.

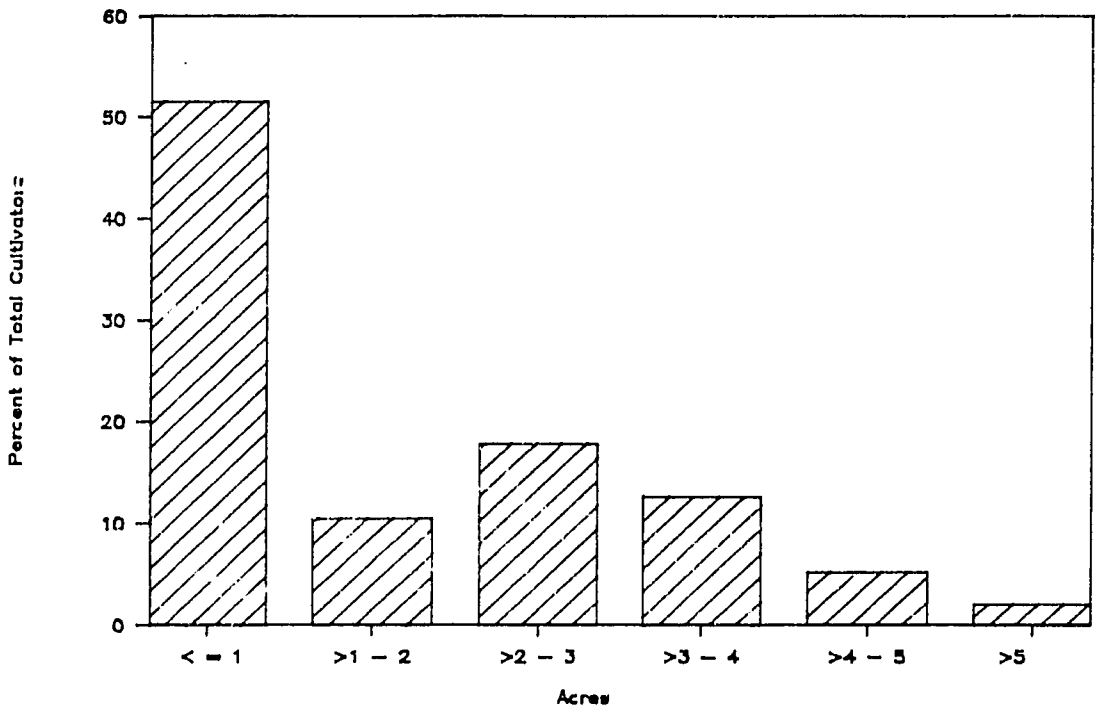

Figure 52. Degree of fragmentation in PSS allotments for 1985 yala (n=95).

Unfortunately, funding problems delayed the arrival of the soil survey team until after the start of the 1985/86 maha irrigation season. Because the paddy fields were flooded, the team was unable to dig soil pits. In addition, the Soil Survey Laboratory could not schedule additional soil analysis during this period. Thus, soil profiles were not characterized and soil samples were not sent for laboratory analysis. However, soil maps produced by the soil survey team provided most of the required information.

Three major soil groups -- reddish-brown earth (RBE); low, humic gley (LHG); and alluvial soils -- were identified by the soil survey team (Appendix B). RBE soils were identified as Rhodustalfs in the Seventh Approximation system of soil classification and as Chromic Luvisols in the FAO system of soil classification. RBE soils, which are predominant in the Dry Zone, were largely formed in place on the knolls and upper to middle slopes of the rolling topography. These soils, which are light in texture, are generally regarded as good agricultural soils if rainfall is supplemented by irrigation. However, they are structurally weak and thus are susceptible to water erosion. In addition, RBE soils located in the middle to lower slopes of the rolling topography are often affected by high water tables during heavy rains.

The LHG soils are primarily alluvial soils and were found in the lower slopes and valleys. LHG soils are equivalent to Haplustalfs in the Seventh Approximation system of soil classification and Gleyic

Luvisols in the FAO system of soil classification. These heavy-textured soils have very poor drainage characteristics and thus are susceptible to waterlogging. Because of this, LHG soils are only suitable for paddy cultivation.

The third soil group, alluvial soils, occurred in narrow strips along second and third order streams. Alluvial soils are identified as either Tropoquents or Ustifluents in the Seventh Approximation system of soil classification and as Fluersols by the FAO system of soil classification. These soils are derived from recent water-laid deposits and possess little profile differentiation other than some organic accumulations on the surface horizon. Soil texture and drainage characteristics of these soils vary with location and with differences in the depositional material. Because of their location in the valleys, alluvial soils most often are only suitable for paddy cultivation. A more detailed background description of each soil group, tables of the physical and chemical properties, and general soil profile descriptions for each soil group are presented in Appendix B.

A summary of the soil types and approximate area, expressed as a percentage of the total area of each field channel, is shown in Table 15. Of the three soil groups identified, RBE soils were the most extensive, occupying nearly 62 percent of the total field channel area. Among field channels, RBE soils composed 50-90 percent of any particular field channel.

The RBE soils were subdivided into three drainage classes: well-drained, moderately well-drained, and imperfectly drained (Appendix B). All three drainage classes were observed in the field channel study sites. Interestingly, the imperfectly drained RBE soils accounted for an average of 51 percent of the total field channel area. Among field channels, imperfectly drained RBE soils composed 30-83 percent of any particular field channel area.

With the exception of the tail field channel of RB7, very little of the area was occupied by well-drained or moderately well-drained RBE soils. According to the soil survey team leader, much of the area now identified as imperfectly drained RBE soils had, prior to irrigation, well-drained RBE soils. That these soils have become imperfectly drained has important water management implications for their use in the cultivation of other field crops.

The LHG soil group occupied the next largest area, averaging nearly 37 percent of the total area studied. Among field channels, LHG soils occupied from 9-50 percent of any particular field channel. As with the RBE soils, LHG soils were subdivided into drainage classes -- poorly drained and very poorly drained. However, within the field channel survey, only poorly drained LHG soils were found. Because these soils were poorly drained, they were only suitable for irrigated paddy production.

Table 15. Approximate area of each soil type expressed as a percentage of the total area of each field channel for PSS, 1985 *yala*.

Soil Type	Block-F		RB 7		RB 21		Total Overall Average
	Head	Tail	Head	Tail	Head	Tail	
Reddish brown earth, well-drained	0	0	0	30	10	5	7.5
Reddish brown earth, moderately well-drained	8	10	0	0	0	0	3.0
Reddish brown earth, moderately shallow, imperfectly drained	8	0	0	30	0	0	6.3
Reddish brown earth, imperfectly drained	75	40	50	0	40	65	45.0
Low humic gley, poorly drained	9	50	50	30	50	30	36.5
Alluvial, poorly drained	0	0	0	10	0	0	1.7

Only a small area of alluvial soils was found in the extreme tail region of the RB7 channel. The topography indicated that the adjacent drainage channel was once a small stream. Shallow water tables in these soils would limit agricultural use to paddy cultivation.

During the cropping season, the pH of the RBE and LHG soils were determined. Measured pH values for the RBE soils ranged from 6.2 - 7.2, while similar measurements of the LHG soils ranged from 6.8 - 7.6. These pH values were within the expected range for each soil group. In addition, visual observations of crop performance were used to assess problem soils (specifically, iron toxicity and salinity). These observations indicated no serious soil problems in the field channel study sites. Similar observations, made on other parts of the irrigation system, indicated an absence of soil problems in PSS.

After 40 years of paddy double cropping, most of the soils observed had developed hardpans. Because hardpans affect root growth and water movement in the soil, depth to the hardpan was measured. Three *liyaddas* in each of the six field channels were selected for detailed measurements. Depth to the hardpan ranged from 12 cm to 28 cm and averaged 19 cm. There were no correlations between depth to hardpan and soil groups or field channel location.

c. Cropping Pattern

Data presented on soils in the previous section indicated a potential for cultivating crops other than paddy on approximately 35-45 percent of the irrigated common area of PSS during yala. However, during 1985 yala, only 3-4 percent of the irrigated area was cultivated with field crops such as chili and tobacco, while paddy cultivation predominated in 96-97% of the area. Aside from these crops, small plots of vegetables, mainly for home consumption, were sometimes grown on or around the paddy threshing floor and, to a lesser extent, along ridges of paddy field dikes.

Within the study sites, only 6-7 ac of the total surveyed area was planted to other field crops (see Appendix B). Of this area, .5 ac was planted with chili and 2.5 ac with tobacco. Interestingly, chili and tobacco were only cultivated in the head and middle study sites (Block F and RB7). In the tail of the system (LB1/RB21) where water was less dependable, both study field channels were planted entirely with paddy.

Due to the very limited cultivation of field crops other than paddy, a decision was made to restrict the 1985 yala agronomic data collection to paddy fields. Therefore, subsequent sections of this report are primarily concerned with paddy cultivation.

d. Cultivation Season

In mid-September, the 1985 yala kanna meeting for PSS was held in the community hall in Polonnaruwa. The kanna meeting was chaired by the government agent, and supported by the district department heads responsible for agriculture and settlement. While the major purpose of the kanna meeting was to finalize the 1985 yala irrigation season schedule, it also served as a platform for the cultivators to air grievances and for the departments to disseminate information on relevant topics. However, the meeting was attended by less than 300 people, most of whom were vel vidanes, rather than average cultivators.

The final 1985 yala irrigation schedule was based on the cultivation of short-season (3 to 3-1/2 month) varieties of paddy, which the farmers were requested to grow. Some of the more important dates established for the 1985 yala schedule were:

April 12	Opening of the sluice gates
April 20	First water issue
May 20	Completion of land preparation
May 31	First rotational water issue
August 23	Closure of canals

This schedule provided irrigation water for 125 days, of which 30 days were for land preparation and 95 days were for crop growth. Although the schedule appeared reasonable, continuous water issues were

extended until the first week of June, and the entire irrigation season was extended to the fifth of September. An attempt is made to document some of the reasons for the extensions in subsequent sections of this report.

e. Land Preparation

Land preparation is one of the most important management components in paddy cultivation. Poor and untimely land preparation may result in unlevel fields, poor stand establishment, and early weed infestation. All of these problems affect the performance of the crop and often increase production costs. More importantly, extended land preparation may delay the completion of the cropping season.

Initial funding problems prevented the hire of data collectors until land preparation and planting were nearly completed. Consequently, data on the availability of water, power sources used, and the quality of land preparation were not collected. However, data concerning the start and completion of land preparation, the number of plowings, and the number of harrowings were obtained through informal interviews with the cultivators on each study site.

The date that cultivators started land preparation was compared with the date of the first scheduled water issue to determine the time required to initiate land preparation. The time required for land preparation was defined as the period between the start and completion of land preparation. The overall time required for land preparation was defined as the period between the date of the first scheduled water issue and completion of land preparation.

All cultivators on RB7 and LB1 were interviewed. However, only 12-13 of the 27 cultivators on Block F were interviewed. Although this oversight limited overall comparisons between head, middle and tail study sites, sufficient information was collected to evaluate the number of cultivators who required an extension of continuous water issue to complete land preparation.

According to the Agriculture Department, 14-21 days is generally sufficient to complete land preparation. Land preparation periods greater than 21 days should only be necessary where irrigation water is limited or in poorly maintained fields with large accumulations of organic residue.

Proper land preparation for paddy requires that the field be soaked for 4-5 days before the first plowing and maintained at or near saturation throughout the plowing period. Normally, two plowings are needed to turn the soil, weeds, and organic residues under. Approximately 7 days between plowings is needed to decompose the incorporated organic residues.

Once the organic residues decompose, the field is flooded with 2-5 cm of water, harrowed, and roughly leveled. Prior to planting, the field is again flooded with 2-5 cm of water, harrowed, and leveled.

During this period the bunds around the paddy are repaired, cleaned, and plastered.

Based on these recommendations, the PSS 1985 yala irrigation schedule developed by the Irrigation Department provided 30 days of continuous water issue for land preparation, beginning April 20, 1985. To ensure that water would be available to all cultivators on the scheduled date regardless of their hydrological position, the Irrigation Department opened the sluice gates eight days prior to the first scheduled water issue.

Even though the schedule appeared reasonable and water was available throughout the system on the scheduled date, land preparation was not completed on schedule. As a result, the Irrigation Department extended continuous water issues for two weeks. This extension increased the amount of water issued for land preparation by nearly 50 percent and contributed to the delay in completing the cropping season. Because this problem was common in both yala and maha, it was considered important to determine the factors which contributed to delays and subsequent extensions of the irrigation season.

Overall, the time required to initiate land preparation once scheduled water issues began ranged from 5 days prior to the official first water issue to 34 days after the official first water issue, and averaged 10 days (Table 16). Interestingly, a substantial number of cultivators, primarily in the tail region, took advantage of the early water issue.

Nearly 21 percent of the PSS cultivators claimed to have initiated land preparation on or before the first scheduled water issue (Table 16). The majority (15 cultivators) of these were located on the tail study site. Forty-three percent of the cultivators said they had started preparing their land within 5 days after the first water issue. Again, the majority of these cultivators (26) were located in the tail study site.

Although many cultivators took advantage of the unscheduled early water issue, it was not until 20-25 days after the first scheduled water issue that the majority (96 percent) of cultivators had initiated land preparation. As mentioned earlier, observations on land preparation activities were not made. However, two possible reasons for delays in starting land preparation have been suggested. First, inadequate water delivery during the land preparation period may have caused many cultivators to delay the start of land preparation. Second, problems in obtaining credit, power sources for land preparation, and labor for planting may have caused some cultivators to delay land preparation.

Once land preparation was initiated, the time between the start and completion of land preparation ranged from a low of 6 days to a high of 57 days, and averaged 22 days (Table 17). Nearly 70 percent of the cultivators indicated that they had completed land preparation activities within 20-25 days. The majority of cultivators (nearly 95 percent), regardless of their hydrological location, completed land

preparation within 35 days. Thus, it was apparent that once land preparation was initiated, it was possible for cultivators to complete this activity within 30-35 days.

Table 16. The time between the first scheduled water issue and the initiation of land preparation as reported by PSS cultivators, 1985 *yala* (n=92).

Number of Days	Cultivators Reporting Block F (n=12)	RB7 (n=33)	LB1 (n=47)	Cum %
< -5	0	2	2	4.3
-5 < 0	0	2	13	20.7
0 < 5	0	9	11	42.4
5 < 10	0	7	7	57.6
10 < 15	0	6	5	69.6
15 < 20	9	4	3	87.0
20 < 25	3	2	3	95.7
25 < 30	0	0	3	98.9
30 < 35	0	1	0	100.0

Table 17. The number of days between the start and completion of land preparation as reported by PSS cultivators, *yala* 1985 (n=92).

Number of Days	Cultivators Reporting Block F (n=12)	RB7 (n=33)	LB1 (n=47)	Cum %
5 < 10	5	2	0	7.6
10 < 15	4	6	2	20.7
15 < 20	3	7	12	44.6
20 < 25	0	6	17	69.6
25 < 30	0	9	11	91.3
30 < 35	0	2	1	94.6
35 < 40	0	2	1	97.8
55 < 60	0	0	2	100.0

Overall, the time between the first scheduled water issue and the completion of land preparation ranged from 13-63 days, and averaged 31 days (Table 18). Only 50 percent of the cultivators completed land preparation within the scheduled period. An additional 20 days were required before more than 95 percent of the cultivators completed land preparation.

Table 18. The period of time between the first scheduled water issue and the completion of land preparation as reported by PSS cultivators, yala 1985 (n=93).

Days	Cultivators Block F (n=13)	RB 7 (n=34)	LB 1 (n=46)	Cum %
11-15	0	4	1	5.4
16-20	0	5	7	18.3
21-25	0	2	9	30.1
26-30	5	6	8	50.5
31-35	3	8	11	74.2
36-40	4	3	1	82.8
41-45	1	2	4	90.3
46-50	0	2	4	96.8
51-55	0	1	0	97.8
56-60	0	0	1	98.9
61-65	0	1	0	100.0

Cultivators within the study sites were also asked how many times they plowed and harrowed their paddy fields. The number of plowings ranged from 1-4, with the majority of cultivators (90 percent) plowing twice. The number of harrowings ranged from 1-3, with 94 percent of the cultivators reporting one harrowing. There was no apparent difference in the number of plowings and harrowings employed by cultivators between study sites.

f. Planting

As previously mentioned, the 1985 yala kanna meeting established an irrigation season for PSS of 125 days -- the first 30 days of which were designated for land preparation. To meet this schedule, farmers were requested to grow short-season, improved varieties of paddy. No recommendations on the method of planting were given. Generally, it was assumed that the majority of cultivators on PSS would broadcast yala paddy. Three paddy varieties -- BG-34-8, BG-276-5, and BG-94-1 -- were recommended by the Agriculture Department. Since all three varieties only require irrigation water for 80-95 days and mature within 90-105 days, it appeared that the irrigation schedule established during the kanna meeting was reasonable.

Data collected on planting in each study site included paddy varieties, method of planting, and dates that planting was started and completed. Most of this information was collected through informal interviews with the cultivators. Whenever possible, information obtained through informal interviews was confirmed by field observations.

Paddy Varieties. According to the cultivators, nine different paddy varieties were grown in the study sites. Of these, four were

short-season varieties (BG-34-8, BG-276-5, BG-94-1, and Panchchape) and five were long-season varieties (BG-279-2, BG-11-11, BG-400-1, BG-578-7, and BG-380-8) (Table 19). Interestingly, approximately 10 percent of the cultivators were either unable to name or incorrectly named the variety of paddy they had planted. The farmers' lack of knowledge was significant and was unexpected by the Agriculture Department.

Data collectors were also unsuccessful in attempts to identify some varieties of paddy. The problem of variety identification occurred for approximately 10 percent of the sample. Even so, the data collected were still of value for evaluating the farmers' preference for certain paddy varieties.

Table 19. The percentage of each study site planted with different paddy varieties as reported by PSS cultivators (1985 *yala*).

Paddy Variety	Block F Head (Rel %)	RB7 Middle (Rel %)	LB1 Tail (Rel %)	Total %
Short-season:				
BG-34-8	70.5	55.3	44.9	54.5
BG-276-5	7.7	0	0	1.6
BG-94-1	3.8	0	0	0.8
Panchchape	1.2	0	0	0.3
Long-season:				
BG-379-2	5.1	24.6	35.4	24.7
BG-11-11	9.0	6.5	2.8	5.6
BG-400-1	2.6	0	0	0.5
BG-578-7	0	13.6	0	5.6
BG-380-8	0	0	16.8	6.4

Overall, BG-34-8 -- a short-season, improved variety -- was most common. Nearly 55 percent of the total PSS study area was planted with this variety. The other three short-season varieties were grown in 2 percent of the study area. BG-379-2 -- a long-season, improved variety -- accounted for approximately 25 percent of the total study area. The other four long-season varieties were grown in 18 percent of the study area.

Despite the recommendations given at the *kanna* meeting, the cultivators indicated that approximately 43 percent of the PSS study area was planted with long-season paddy varieties. More significantly, the majority of this acreage was found in the tail regions (LB1/RB21) where water limitations were most likely to occur. In fact, the major portion (55 percent) of the LB1 study site was planted with long-season paddy varieties, compared to 45 percent and 17 percent of the middle and head regions, respectively. The high proportion of long-season paddy varieties in the middle and tail regions probably contri-

buted significantly to the need to extend the 1985 yala irrigation season past the schedule originally established.

Planting Methods. Two planting methods -- broadcast sowing and transplanting -- were used by PSS cultivators during 1985 yala. Both methods were recommended by the Agriculture Department. In general, most PSS cultivators preferred transplanting over broadcasting as it was perceived that transplanted fields usually produced higher paddy yields. Although agricultural research has indicated that similar yields can be obtained from either planting method, it was recognized that transplanting offered several advantages over broadcasting when other management practices were less than optimum.

When transplanting, it was much easier to control the plant environment in a small nursery during the critical periods of germination and initial seedling growth. A cultivator was more assured of obtaining a uniform plant stand when paddy was transplanted, and transplanted seedlings were able to compete with weeds more effectively than broadcast seedlings. Finally, transplanting effectively reduced the period of field irrigation and potential exposure to unfavorable field conditions by 25-30 days.

While these advantages certainly improved the potential for obtaining higher paddy yields with transplanted paddy, transplanting involved a major investment in labor, time, and capital. Because of this, broadcasting was often used by cultivators who wanted to decrease the financial risks involved with producing a paddy crop and by those who lacked capital or had trouble scheduling planting crews. In general, most cultivators considered yala, because of the uncertainty of irrigation deliveries, to be more risky than maha. Therefore they were less willing to invest in transplanting during yala.

Approximately 54 percent of the paddy acreage in the study area was broadcast (Table 20), with the majority located in the tail study area. In fact, 96 percent of the paddy acreage in the tail study site was broadcast sown by 41 of the 43 cultivators. In the head and middle study sites, however, the broadcast paddy acreage only amounted to 42 percent and 23 percent, respectively. Unwillingness to invest in transplanting because of the undependability of irrigation water during yala was the primary reason given for broadcasting paddy in the tail site.

Over half of the broadcast paddy acreage in the tail study site involved long-season varieties (Table 20). Because these two factors (broadcasting and long-season varieties) resulted in a longer period of plant growth, they required an extension of the irrigation schedule by approximately 3 weeks. The use of long-season varieties in combination with broadcasting appeared to be somewhat risky, given the possibility that irrigation deliveries could have been stopped before the crop matured. However, cultivators indicated that they broadcast long-season paddy varieties because long-season paddy varieties had greater yield potential and were less sensitive to the timing of management activities such as weeding or agrochemical application.

Table 20. The percent of paddy acreage in the study areas broad cast and transplanted with either long-season or short season varieties (PSS, 1985 *yala*).

Plant Method and Varietal Type	Block F (Head)	RB7 (Middle)	LB1 (Tail)	Total
		%		
Broadcast, short-season	32.5	14.4	39.5	27.4
Broadcast, long-season	9.1	8.9	56.7	26.8
Transplanted, short-season	51.9	37.9	0.7	26.8
Transplanted, long-season	6.5	38.8	3.1	19.0

Transplanted paddy accounted for approximately 46 percent of the total paddy acreage in the study sites, but transplanted paddy was located primarily in the head and middle study sites. Only 4 percent of the paddy acreage in the tail was transplanted. Cultivators were more willing to invest in transplanting in the head and middle study sites because they perceived that irrigation water was more assured. It was observed that cultivators in the middle study site planted nearly 48 percent of paddy acreage with long-season varieties.

Overall, cultivators initiated planting activities as early as 13 days before the scheduled completion of land preparation and as late as 33 days after the scheduled completion of the land preparation. Early planting was primarily observed in the tail study sites. The majority who delayed planting were located in the middle study sites. For 80 cultivators, the average time between completion of land preparation and the start of planting was 2 days. Approximately 91 percent of the cultivators initiated planting within 5 days after the completion of land preparation. Only six cultivators took more than 5 days to initiate planting.

Once planting was initiated, the time required to complete broadcasting or transplanting varied from 1 to 23 days and averaged 4 days. Overall, 43 percent of the cultivators completed planting in one day; 74 percent completed planting within 5 days; and 95 percent completed planting within 15 days. Only 4 of the 80 cultivators took longer than 15 days to complete planting.

According to the *yala* irrigation schedule for PSS, all planting should have been completed within 35 days after the first scheduled water issue. However, by the 35th day after the first scheduled water issue, only 48 percent of the paddy had been planted in the study area (Table 21), most of which was located in the middle and tail study areas. An additional 20 days passed before planting was completed on 96 percent of the paddy fields in the study area. Although there were a few instances where extended planting periods contributed to the 20-day extension of irrigation issues, delays in land preparation were the

major factor which caused cultivators to extend planting beyond the period established in the irrigation schedule.

Table 21. The number of days between the first scheduled water issue and completion of planting as reported by PSS cultivators (1985 yala).

Number of Days	Cultivators Reporting Block F (n=29)	RB7 (n=36)	LB1 (n=46)	Cum %
16-20	0	1	3	3.6
21-25	1	3	14	19.8
26-30	4	2	4	28.8
31-35	5	7	9	47.7
36-40	6	6	5	63.1
41-45	3	7	3	74.8
46-50	8	3	3	87.4
51-55	2	4	4	96.4
56-60	0	1	1	98.2
61-65	0	2	0	100.0

g. Fertilizer Applications

Soil fertility and management are critical aspects of paddy production. Paddy yields of 150 bu/ac or more are only possible when soil fertility is properly managed throughout the growing season. To assist the farmer, the Agriculture Department provided detailed fertilizer recommendations for paddy cultivation in the low country dry zone. These recommendations specified the timing, type, and amount of fertilizer required for transplanted and broadcast short-season and long-season paddy varieties (Table 22). Data collected on the type, amount, and timing of fertilizer applications was used to determine how closely the cultivators in the study area followed the Agriculture Department's recommendations.

Basal Fertilizer Application. The Agriculture Department recommended that a basal fertilizer dressing of V-mixture (5-15-15) be applied and incorporated into the soil just prior to planting paddy (Table 22). The basal fertilizer application was recommended to improve initial seedling growth and plant tillering.

Eighty percent of the cultivators in the study area applied a basal fertilizer (Table 23). Of the cultivators who applied a basal fertilizer, 87 percent applied V-mixture. The remaining cultivators applied urea, urea with V-mixture, or TDM. Only one cultivator indicated that he applied manure.

Table 22. Fertilizer recommendations for paddy cultivation, PSS, 1985 *yala*.

Fertilizer Application	Planting Method*	Age Class (Months)	Fertilizer Type	Amount** (lbs/ac)	Time Applied***
Basal	B	3	V-mixture	150	Final Harrowing
		3.5	"	150	"
		4-4.5	"	150	"
	T	3	V-mixture	150	Final Harrowing
		3.5	"	150	"
		4-4.5	"	150	"
Top dressing 1	B	3	Urea	55	2 WAS
		3.5	"	55	" "
		4-4.5	"	55	" "
	T	3	Urea	82	2 WAT
		3.5	"	82	" "
		4-4.5	"	55	" "
Top dressing 2	B	3	Urea	27	5 WAS
		3.5	"	27	" "
		4-4.5	"	55	6 WAS
	T	3	TDM	82	5 WAT
		3.5	"	82	6 WAT
		4-4.5	Urea	55	4 WAT
Top dressing 3	B	3	TDM	110	7 WAS
		3.5	"	110	8 WAS
		4-4.5	"	110	10 WAS
	T	3	—	—	—
		3.5	—	—	—
		4-4.5	TDM	110	8 WAT

*B-Broadcast, T-Transplanted
**V-mixture - Paddy fertilizer mixture (N-P-K = 5-15-15)
TDM - Paddy top dressing mixture (N-P-K = 30-0-20)
Urea - Ammonium nitrate (N-P-K = 46-0-0)
***WAS - Weeks after sowing
WAT - Weeks after transplanting

A significant number of cultivators in Block F (head and tail) and in LB1 (tail) did not apply basal fertilizer at all. many of these cultivators indicated that they preferred not to apply basal fertilizer because it encouraged excessive weed growth.

Table 23. Basal fertilizers applied by cultivators in the PSS study sites (1985 *yala*).

Fertilizer Type	Number of Cultivators						Total
	Block F		RB7		LB1		
	H*	T	H	T	H	T	%
V-mixture	7	7	8	15	19	13	70
Urea	1	1	0	0	0	0	2
Urea + V-mixture	2	0	4	0	0	0	6
TDM	0	0	0	0	0	1	1
Manure	0	0	0	0	0	1	1
No fertilizer	4	4	2	0	1	9	20

*H - Head; T - Tail.

The amount of basal fertilizer applied varied considerably throughout the study area. The majority applied V-mixture at rates which were below the recommended rate, while only 12 percent of the cultivators applied V-mixture at or near the recommended rate. Seven percent of the applications exceeded the recommended rates.

The majority (82 percent) of basal fertilizer applications in the study site were applied within 1-5 days before planting. It is probable that most of these fertilizer applications were incorporated into the soil. By incorporating the fertilizer into the soil, cultivators minimized the amount of nitrogen lost by volatilization. However, basal fertilizer applications in 18 percent of the fields were applied between one and 10 days after planting. Because the fertilizers were not incorporated into the soil, the available nitrogen in these fertilizers may have been reduced.

Top Dressing 1. The Agriculture Department recommended that a first top dressing of urea be applied and incorporated into paddy fields two weeks after planting (Table 22). The purpose of this initial top dressing was to improve early plant tillering and growth of the paddy. Incorporating this fertilizer into the soil would minimize nitrogen losses to the atmosphere.

Eighty-nine percent of the cultivators in the study sites applied the first top dressing (Table 24). The overall efficiency of this fertilizer application was probably reduced because none of the cultivators incorporated the fertilizer into the soil. Of the cultivators who applied the first top dressing, nearly 97 percent applied urea. Although eleven cultivators did not apply a first top dressing, they had earlier applied either urea or V-mixture as a basal dressing.

Again, the amount of fertilizer applied in the first top dressing was highly variable. However, unlike basal fertilizer applications, average urea application rates in the study area were from one-and-one-half to double the recommended rates. In only 2 of the 91 fields were urea applications less than recommended.

Table 24. Top dressing 1 applied by cultivators in the PSS study sites (1985 *yala*).

Fertilizer Type	Number of Cultivators						Total
	Block F		RB7		LB1		
	H*	T	H	T	H	T	%
Urea	10	7	14	16	18	20	86
V-mixture	0	0	0	0	0	1	1
Urea + V-mixture	0	1	0	0	0	0	1
TDM	0	0	0	0	0	1	1
No fertilizer	4	4	0	0	1	2	11

*H - Head; T - Tail.

Only 42 percent of the cultivators applied the first top dressing between the first and third week after planting, as recommended. Overall response to urea applications may have been reduced where fertilizers were applied more than four weeks after planting, as was done in half of the cases.

Top Dressing 2. The Agriculture Department recommended a second top dressing of urea on short-season, broadcast varieties (5-6 weeks after planting) and long-season, broadcast (5 weeks after planting) and transplanted varieties (4 weeks after planting) (Table 22). The application was recommended to improve plant tiller development and increase grain formation. For short-season, transplanted varieties, the Agriculture Department recommended the application of TDM mixture (5 weeks after planting) as a final top dressing to increase grain weight and encourage normal seed development.

The second top dressing was applied on 70 percent of the fields in the study area (Table 25). As with the previous fertilizer application, the efficiency of nitrogen use may have been reduced because the fertilizers were not incorporated into the soil. Over 90 percent of the cultivators who transplanted short-season paddy varieties applied TDM mixture at or above the recommended rates. However, nearly 90 percent of the cultivators who broadcast short-season or planted long-season varieties applied TDM mixture instead of the recommended urea. When urea was used as a second top dressing, applications were generally double the recommended rates.

The time of application varied considerably within and between study sites, ranging from 5 to 10 weeks after planting. The efficiency of fertilizer use was certainly affected by late application.

Top Dressing 3. The Agriculture Department recommended the application of a third top dressing of TDM mixture for long-season paddy varieties and broadcast short-season varieties (Table 22). This top dressing was recommended to improve yields and grain development.

Table 25. Top dressing 2 applied by cultivators in the PSS study sites (1985 *yala*).

Fertilizer Type	Number of Cultivators						Total
	Block F		RB7		LB1		
	H*	T	H	T	H	T	%
TDM	3	3	13	15	12	9	54
Urea	2	3	1	0	3	6	15
TDM + Urea	0	0	0	1	0	0	1
No fertilizer	9	6	0	0	4	12	30

*H - Head; T - Tail.

Only 16 percent of the cultivators in the study area applied a third top dressing (Table 26). As with the previous applications, none of the cultivators incorporated the fertilizer into the soil. Of those who applied a third top dressing, all except for one applied TDM mixture. The majority of TDM applications were at or above the recommended rates. The third top dressing was applied in the recommended amounts between the 6th and 8th week after planting, regardless of the planting method or the variety. Delayed fertilizer application may have reduced the effectiveness of the fertilizer on short-season paddy varieties.

Table 26. Top dressing 3 applied by cultivators in the PSS study sites (1985 *yala*).

Fertilizer Type	Number of Cultivators						Total
	Block F		RB7		LB1		
	H*	T	H	T	H	T	%
TDM	7	2	1	1	3	1	15
Urea	0	1	0	0	0	0	1
No Fertilizer	7	10	13	15	17	21	84

*H - Head; T - Tail.

When all four fertilizer applications were evaluated, less than 20 percent of the cultivators followed the Agriculture Department's fertilizer recommendations. Generally, cultivators applied V-mixture and TDM at rates that were lower than the recommended rates.

In contrast, urea applications were much higher than the recommended rates. More importantly, the majority of the cultivators did not apply a third top dressing. Instead, they applied higher than recommended rates during either the first or second top dressing. This suggested that the number of top dressings recommended by the Agriculture Department may be not be necessary. Fewer top dressing applications with higher rates of fertilizer would reduce problems cultivators encounter trying to apply fertilizer at the correct time.

Field tissue tests for N-P-K in selected fields throughout the study area tended to support observations made on fertilizer applications. These tests indicated that tissue levels of nitrogen and phosphorus were adequate to excessive, whereas tissue levels of potassium were low. Low potassium levels may have reduced the overall effect of nitrogen fertilizers and may have contributed to less than optimum paddy yields.

h. Relative Availability of Water

Research by De Datta (1981) indicated that plant growth and yields of paddy were affected by soil moisture conditions. This research reported yield reductions of 8 to 21 percent when soil moisture levels decreased to near field capacity during critical growth stages. In addition, more serious yield reductions were reported as the duration of soil moisture stress increased. De Datta (1981) reported that moisture conditions were most critical for the following plant growth stages of paddy: mid- to late tillering, panicle initiation, and grain head formation.

During 1985 yala, field observations in selected liyaddas were made to evaluate soil moisture conditions in paddy fields throughout the study area. Soil moisture conditions were observed on alternate days in a series of liyaddas located on either side of a line parallel to the field channel and perpendicular to the drainage channel. A scale was used to classify the soil in the liyaddas as follows:

0 = dry, cracked soils
1 = wet soils
2 = 1-5 cm of standing water
3 = 5-10 cm of standing water
4 = greater than 10 cm of standing water.

Observations of soil moisture conditions began during the mid- to late vegetative period (last week of June) and continued through the grain filling period (second week of August). Between 19 and 26 days of observations were made during this period.

Observations of soil moisture conditions in Block F and LB1 indicated that periods of soil moisture stress increased from the head of the system to the tail of the system (Table 27).

The number of observations of liyaddas without standing water was significantly higher in the tail study area than in the head study area (Table 27). More importantly, in the tail field channel of LB1, nearly 16 percent of the observations indicated dry, cracked soils. The liyaddas in which dry, cracked soils were observed were primarily located in the upper reaches of the field channel where the principle soil type was reddish-brown earth.

The soil moisture stress that developed in these soils was serious: dry, cracked soils were observed over periods of up to 5 days on four different occasions. Two periods of soil moisture stress, lasting for 2-4 days each, were observed during the vegetative stage in

18 of 53 liyaddas. Two more periods of soil moisture stress were observed during the heading stage. Each of these lasted from 3-5 days. Eight liyaddas were subjected to both of these periods of soil moisture stress, and another 24 liyaddas were subject to one 5-day period of soil moisture stress. Overall, 33 of the 53 allotments were exposed to 2-4 periods of soil moisture stress, each of which lasted from 2-5 days. Therefore, soil moisture stress was identified as a major factor contributing to lower observed paddy yields in the tail field channel of LB1.

Table 27. Observations of soil moisture conditions in selected liyaddas in Block F and LB1 study sites of PSS (1985 yala).*

	Block F		LB1	
	Head[1]	Tail[2]	Head[3]	Tail[4]
	Relative %			
Dry cracked soil	0.0	0.0	1.7	15.9
Wet soil	10.7	8.0	15.3	36.2
1-5 cm standing water	32.6	32.5	34.4	27.4
5-10 cm standing water	56.6	59.5	48.6	20.5
> 10 cm standing water	0.0	0.1	0.0	0.0

*Note: Similar data collected in the RB7 study area were misplaced. However, the data were examined prior to being misplaced. It appeared that soil moisture conditions in the RB7 study areas were similar to Block F.

[1]Forty-seven liyaddas; observations for 26 days over a 40-day period beginning June 27.
[2]Forty-nine liyaddas; observations for 25 days over a 46-day period beginning June 27.
[3]Fifty-six liyaddas; observations for 17-20 days over a 47-day period beginning June 30.
[4]Fifty-three liyaddas, observations for 19 days over a 49-day period beginning June 29.

1. Weed Control

Environmental conditions in paddy fields favor the growth of many aquatic and semi-aquatic weeds that directly compete with rice plants for nutrients, sunlight, and space. Many of these weeds also serve as alternate hosts for disease and insects that attack paddy. Thus, when weeds are not controlled, substantial reductions in paddy yields usually occur. In addition, the quality of the harvested grain is often reduced by the presence of weed seed.

Weed control should begin with land preparation. Thorough land preparation can reduce initial weed infestations in newly planted fields, thus decreasing the amount of time and effort required to control weeds after planting paddy. Although data collectors were unable to evaluate land preparation activities, later observations suggested that high initial weed populations in paddy developed as a result of poorly prepared fields -- particularly in fields in the tail study area.

The method of planting the cultivator uses also affects weed populations. It is recognized that transplanted paddy, because of its age and size at planting, is better able to compete with initial weed infestations than broadcast paddy. In general, weed infestations in the transplanted fields (46 percent of the PSS study area) were lower than in broadcast fields.

While a cultivator may reduce weed problems with proper land preparation and by transplanting, it is still necessary to control weed infestations after planting. Research has shown that maximum paddy yields were obtained from fields in which weeds were properly controlled within the first 20-30 days after planting (University of the Philippines, 1970). Accordingly, the Sri Lanka Agriculture Department recommends that paddy weeds be controlled by hand weeding or by applying herbicides within the first 30 days after transplanting or broadcasting paddy. Depending on the severity of weed infestation, one to two weed control operations were recommended.

Weed control was only practiced in 56 percent of the paddy fields in the PSS study area (Table 28). Weed control efforts were highest in the tail of the system, where initial weed infestations were severe. Although initial weed infestations were low in the head region, weed populations were serious enough to affect yields, and these fields should have been weeded also.

Table 28. The percent of fields (n=129) in the PSS study area in which herbicide applications, hand weeding, or no weeding were used for the first weed control (1985 *yala*).

Weeding Method	Block F		RB7		LB1		
	Head	Tail	Head	Tail	Head	Tail	Total
	%						
Herbicides	41	17	29	19	83	75	47
Hand weeding	0	6	10	29	4	7	9
No weeding	59	78	62	52	12	18	44

PSS cultivators primarily used herbicides to control weeds in broadcast fields and either herbicide applications or hand weeding in transplanted fields. Thus, herbicide use was high in the tail of the

system (LB1), where broadcasting was the principle method of stand establishment. Similarly, hand weeding was more prevalent in the middle of the system (RB7), where paddy was primarily established by transplanting.

Of the two weeding methods, hand weeding was the most effective. However, hand weeding techniques used by PSS cultivators did not include stirring the soil to disturb and uproot small weed seedlings. Because of this, moderate to severe weed infestations developed in many fields which had been hand weeded.

Two herbicides, MCPA and 3,4 DPA, were used by PSS cultivators. Both herbicides control only sedge and broadleaf weeds, and they are very effective when properly used. However, nearly all of the cultivators in the tail study site and many of the cultivators in the head and middle study sites failed to control sedge and broadleaf weeds with these two herbicides. This failure primarily resulted because most cultivators lacked the knowledge needed to use the herbicides correctly. In addition, some cultivators in the tail study area indicated that weed control with herbicides was not effective because they were unable to maintain standing water in the field after the herbicide application. After herbicides are applied, standing water helps to prevent germination and growth of weed seeds.

A second weed control operation was attempted in only 22 percent of surveyed fields in the study area. The majority of these fields were located in the tail study area, where cultivators hand-weeded to correct earlier failures to control weeds using herbicides.

Information on grass, sedge, and broadleaf weed populations was collected the eighth week after planting in six liyaddas in each of the study areas of PSS (Table 29). Overall, weed populations in the selected liyaddas reflected general observations made throughout the study area. Sedge and broadleaf weed populations were moderate to high in the head and middle study areas and severe in the tail study area. Similarly, grass populations tended to be higher in the tail study area than in the head and middle study areas.

Table 29. Average sedge, broadleaf, grass, and total weed populations per square mile in six selected liyaddas in the PSS study sites (1985 yala).

	Block F		RB7		LB1	
Location	Avg*	Std	Avg	Std	Avg	Std
Sedge	33.1	37.2	44.6	19.7	315.8	164.8
Broadleaf	55.8	62.3	6.7	3.1	193.5	145.1
Grass	3.5	4.9	24.9	22.4	56.8	44.1
Total	92.4	75.5	76.1	32.5	566.1	280.7

*Avg - Average; Std - Standard deviation

Research has indicated that weed populations in excess of 100-200 weeds/m^2 can lower paddy yields by more than 50 percent (De Datta, 1981). With the exception of one liyadda, weed populations in the selected liyaddas of the tail study area exceeded 200 weeds/m^2. Thus, it was apparent that severe weed infestations were a major factor in reducing paddy yields in the tail study area. In the other study areas, weeds were also probably a factor in reducing paddy yields in some fields.

j. Pest Control

The tropical climate of Sri Lanka favors the proliferation of insect pests. This problem is further accentuated on irrigation systems such as PSS, where a crop (rice) is grown year-round. Failure to control insect pests usually results in substantial reductions in the quality and yield of paddy. For example, 24 separate experiments conducted over six cropping seasons at the International River Research Institute indicated that average paddy yields were reduced from 5.3 t/ha to 2.9 t/ha in plots with no insect control (De Datta, 1981). Although other management practices, such as weed control, are effective in helping to reduce insect infestations, controlling rice insects largely depends on the application of insecticides.

Insect pests observed during the 1985 yala in the PSS study area included armyworm (Spodoptera sp.), cutworm (Spodoptera sp.), green-horned caterpillar (genus unknown), leaf folder (Cnaphalocrocis sp.), rice gall midge (Orseolia sp.), mole cricket (Gryllopatha sp.), rice bug (Leptocorisa sp.), rice leaf miner (Hydrellia sp.), leafhopper (Nephotettix sp.), planthopper (Sogatella sp.), and rice whorl maggot (genus unknown).

Generally, farmers reported armyworm, stemborer, and planthopper as the most important insect pests in paddy. Damage from armyworm and stemborer usually occurred during both maha and yala, whereas damage from planthopper occurred only during maha.

Field observations indicated that six of the insect pests identified in the study area produced significant paddy damage during 1985 yala (Table 30). Of these, armyworm, stemborer, rice leaf miner, and leaf rollers were the most serious. However, it was evident that the data collectors had difficulty determining the extent of insect pest infestations. For example, personal observations made during the grain filling period suggested that rice bug infestation was much more serious than evaluated by the data collectors.

Information on insecticide applications was collected only on RB7 and LB1. In these two study areas, insecticides were primarily used to control armyworm, leaf minor, and leaf roller infestations. Cultivators using insecticides to control armyworm used Azodrin (monocrotophus, Nuvacron), Monitor (Tamaron), or Malathion. Azodrin (monocrotophus, Nurvacron, Niran) and another unidentified insecticide were used to control leaf rollers; and Azodrin (monocrotophus), carbofuran (Furadan, Curaterr), Parathion (Niran), and Malathion were used to control leaf miners. In the few cases in which insecticides were used

to control stemborers, either Osbac (Baycarb) or Malathion were used. Although the use of Malathion was supposed to be restricted to the Government's anti-malarial program, PSS cultivators preferred Malathion over other insecticides and were able to obtain it.

Table 30. The number of observations of insect infestation and the number of cases where insecticides were applied in the PSS study area (1985 *yala*).

	Block F	RB7		LB1	
Insect	Observed	Observed	Applied	Observed	Applied
Armyworm	4	3	3	29	16
Gall midge	0	1	1	5	0
Leaf roller	3	24	6	1	1
Paddy bug	0	3	1	1	0
Stemborer	22	23	2	15	1
Leaf miner	14	20	9	34	5
Whorl maggot	3	4	1	0	0

Generally, cultivators only applied insecticides after insect damage became apparent. Limited observations indicated that insect infestations often encompassed approximately 30-45 percent of the field before insecticides were applied. As a result, significant damage usually occurred before insecticides were applied.

Observations of insecticide applications on PSS indicated that the majority of cultivators were unaware of the potential health hazards associated with these chemicals. Insecticides were often mixed near drinking wells in the field and drinking water containers were often used to mix the chemicals. In addition, cultivators sometimes mixed more than one insecticide with soap, urea, and sulfur, unaware of the potential hazards associated with mixing incompatable chemicals. Sprayer applications were made without protective clothing, and usually when it was windy. The indifferent manner in which insecticides were handled was made more serious by the fact that three of the five insecticides used by PSS cultivators (Azodrin, carbofuran, and Parathion) are classified as highly hazardous chemicals. A highly hazardous classification indicates that the chemical is extremely toxic (LD 50 of 1-50 mg/kg) and should be handled with extreme care to avoid potential contamination through contact with the skin or from inhalation or ingestion of the chemical.

k. Harvesting

Harvest Period. Earlier it was mentioned that in the *kanna* meeting for the 1985 *yala*, a 125-day irrigation season was established. This schedule was based on the cultivation of broadcast and transplanted short-season paddy varieties. The scheduled harvest season allowed approximately 20 days -- beginning the second week of August -- for all harvesting to be completed (between 125 and 145 days after the

first water issue). The schedule allowed a minimum of nearly one month between the completion of the yala harvest and the first water issue of maha (tentatively scheduled for October 10). This one-month period was considered essential for proper maintenance of the canal system and to provide PSS cultivators an opportunity to market their paddy and make the necessary financial arrangements for the maha paddy crop.

Recall that the scheduled irrigation deliveries were extended by approximately two weeks. This extension was primarily due to delays in initiating land preparation and by broadcasting long-season paddy varieties.

The date when cultivators began harvesting was not obtained in the PSS study area. However, the date of harvest completion was collected on 129 fields in which yield samples were collected (Table 31). The first field harvested was located on RB7 and was harvested on August 17, 119 days after the first water issue. This field was transplanted with a short-season paddy variety that required 79 days to mature from transplanting to harvest. The last field harvested was also located on RB7. It was harvested October 3, 166 days after the first water issue. This field was transplanted with a long-season variety nearly two weeks after the scheduled planting date. This variety required 114 days to mature from transplanting to harvest.

Table 31. The number of days required from the first water issue to the completion of harvest for 129 paddy fields in the PSS study area (1985 yala).

Number of Days	Block F (n=35)	RB7 (n=42)	LB1 (n=52)	Cumulative %
120	0	8	0	6.2
125	0	3	6	13.2
130	9	5	4	27.1
135	8	2	6	39.5
140	6	1	8	51.2
145	3	7	10	66.7
150	6	10	6	83.7
155	2	2	5	90.7
160	0	2	7	97.7
165	1	1	0	99.2
170	0	1	0	100.0

Overall, approximately 67 percent of the surveyed fields in the study area were harvested within the scheduled period (Table 31). Another two weeks were required before approximately 98 percent of the fields were harvested. In Block F and RB7, harvesting was primarily delayed as a result of late initiation of land preparation. In LB1, the extended cropping season primarily resulted because farmers broadcast long-season paddy varieties.

Paddy Yields. According to the Agriculture Department, the new high-yielding paddy varieties have potential grain yields of approximately 150 bu/ac. However, potential yields are seldom achieved in actual field situations. More realistic potential *yala* paddy yields would probably range from 120 to 130 bu/ac.

During 1985 *yala*, paddy yields from 99 sampled fields in the PSS study area (Appendix G) averaged 90 bu/ac, ranging from a low of 11 bu/ac to a high of 143 bu/ac (Table 32). The highest paddy yield occurred on a field in the tail field channel of RB7, and the lowest yield was from a field in the tail field channel of LB1. While there were some fields in each of the study sites at or above the potential yields, overall the average paddy yields were substantially lower than potential *yala* yields.

Table 32. The maximum, minimum, and average paddy yields in the PSS study area (1985 *yala*).

	Block F		RB7		LB1		
	Head	Tail	Head	Tail	Head	Tail	Overall
	bu/ac						
Maximum	131	132	131	143	124	125	143
Minimum	57	51	64	65	17	11	11
Average	104	93	97	108	87	63	90

The average paddy yield in the tail field channel site of LB1 was significantly lower than the average paddy yields of the other study sites. Furthermore, substantial yield variations existed between fields in the tail field channel of LB1. Coefficients of variation of paddy yields in the tail field channel of LB1 ranged from 40-260 percent, whereas variations in the other study sites ranged from 40-60 percent. Periods of inadequate soil moisture, poor weed control, and insect damage were the major factors that contributed to the lower paddy yields observed in the tail field channel of LB1.

There were no correlations between paddy variety or method of planting and paddy yields. Apparently, weed and insect infestations, periods of inadequate soil moisture, differences in fertilizer applications, and other individual management practices of the farmer compounded any effects of varietal differences or planting methods.

Data on threshing, drying, and storage of harvested grain was not collected. However, field observations during the harvest suggested that substantial losses, both in quality and amount of harvested grain, were incurred during threshing, drying, and transporting the harvested grain. It would not be unreasonable to expect as much as 15 percent of the harvested paddy to be lost during threshing, drying, bagging, and transporting activities.

Note that bunds around the perimeter of the liyaddas reduced the actual cropped area by 5-10 percent. Thus, when losses associated with harvesting were added to reductions in cropped area, cultivators probably only realized about 75-85 percent of the grain yields estimated by the crop cuttings of the agronomy field investigators.

4. CONCLUSIONS

While it was commonly assumed that each farm family was associated with a 5-ac allotment on Parakrama Samudra, several factors have influenced the actual unit of cultivation. First, allotment boundary surveys indicated that the original allotment varied -- from as small as 3.5 ac to as large as nearly 8 ac. Second, most of the allotments bordering field channel and drainage channel easements had increased in area through encroachment. Finally, increased population pressure on the land significantly decreased the unit of land available to an individual cultivator. During the 1985 yala, the 37 allotments that comprised the study area were cultivated by 95 individuals. Only 20 percent of these individuals cultivated acreages at or near the original allotment size, while nearly 52 percent cultivated 1 ac or less.

Soil survey information, which was not available for PSS, was collected in the study areas by the Land Use Division of the Irrigation Department. The soil surveys identified three soil types. Reddish-brown earth soils (pH 6.2-7.2) occupied 50-90 percent of the field channel command areas. The majority of these soils were imperfectly drained as a result of the shallow, fluctuating water tables associated with irrigation. Although cultivation of these soils with crops other than paddy is possible, special management practices would be required to do so.

Low humic gley soils (pH 6.8-7.6) occupied from 9-50 percent of the field channel command areas. All of these soils were poorly drained and only suitable for rice cultivation. Limited areas of poorly drained alluvial soils, which formed in the beds of ancient streams, were also observed in limited areas.

Although soil survey and climate information suggested that from 35 percent to 45 percent of the PSS command area would support crops other than paddy, approximately 96 percent of the command area was planted with paddy during the 1985 yala.

The kanna meeting to finalize the 1985 yala irrigation schedule was attended by less than 300 people, most of whom were vel vidanes, rather than PSS cultivators. The irrigation schedule established during this meeting provided 30 days of continuous water issues for land preparation, and 95 days of rotational issues for the cultivation of short-season paddy varieties.

However, during the 1985 yala irrigation season, it was necessary for the Irrigation Department to extend both continuous and rotational water issues by an additional two weeks. The extensions were necessary because only 50 percent of the PSS cultivators completed land prepara-

tion within the scheduled period. An additional 20 days passed before 97 percent of the cultivators completed land preparation. The increased land preparation period was primarily attributed to inadequate water deliveries during land preparation, which delayed the initiation of land preparation in a major portion of the fields by 20-25 days.

Nearly 100 percent of the sample cultivators planted new, high-yield paddy varieties during the 1985 yala. However, approximately 10 percent of the PSS cultivators were unable to identify the variety of paddy they had planted, and another 10 percent wrongly identified the variety of paddy planted.

Despite recommendations to plant short-season paddy varieties during yala, approximately 43 percent of the study area was planted with long-season paddy varieties. More importantly, nearly 27 percent of the PSS acreage (one-half of this acreage was located in the tail of the system) was broadcast with long-season paddy varieties. Broadcast, long-season paddy varieties required an irrigation season of 110-120 days, and thus also contributed to the need to extend the irrigation season.

Although fertilizer applications in paddy fields were generally higher than expected, the majority of cultivators applied less than the recommended rate of basal fertilizer and more than the recommended rates of fertilizer for the first and second top dressings. Few cultivators applied a third top dressing. Plant tissue tests indicated that tissue levels of nitrogen and phosphorus were adequate to excessive, while potassium levels were low. These results suggested that the number and complexity of current top dressing recommendations need to be evaluated.

Between the vegetative and heading stages of paddy growth, four periods of severe soil moisture stress were observed in the tail study site of PSS. Each period of soil moisture stress lasted from 2-5 days and contributed to the low observed yields obtained in tail region of PSS.

The lack of weed control, particularly in broadcast paddy fields, was regarded as a serious problem on PSS. Weed control, using either herbicides (MCPA or 3,4 DPA) or weeding by hand, was attempted on 56 percent of the paddy fields in the study area. Nearly all of the attempts to control weeds with herbicides failed, and the hand-weeding techniques used by PSS cultivators were inefficient.

Army worm, stemborer, rice-leaf miner, and leaf rollers produced the most extensive damage in PSS paddy fields during the 1985 yala. Limited observations indicated that insect infestations often encompassed from 30 percent to 45 percent of a paddy field before insecticides were applied. Although insecticide applications were usually successful, significant damage had already occurred.

The indifferent manner in which insecticides were mixed and applied was considered a very serious problem that not only threatened

the health of the individual using the insecticide, but also other family members and neighbors.

The 1985 yala paddy yields for PSS averaged 90 bu/ac and ranged from a low of 11 bu/ac to a high of 143 bu/ac. Although paddy yields in some fields were near to or above the expected potential yields of 120-130 bu/ac, the average paddy yield for PSS was substantially below the potential.

The highest average paddy yield (108 bu/ac) was obtained in the study area located in the middle of the system. Paddy fields in this area were not subjected to periods of soil moisture stress, fertilizer applications were generally high, weed control was adequate, and insect infestations were controlled before significant damage occurred.

The lowest average paddy yield (63 bu/ac) was obtained in the tail of the system. Paddy yields in the tail of the system also varied considerably, with a coefficient of variation that ranged from 40 percent to 260 percent. Periods of inadequate soil moisture, poor weed control, and insect damage were the major factors that contributed to the low yields and high variability observed in this study area.

D. ECONOMICS

1. INTRODUCTION

The economic analysis conducted during the Diagnostic Analysis Project focused on the agricultural economy in Parakrama Samudra Scheme, with particular emphasis on (a) land ownership and land utilization, (b) cultural practices, (c) production technology, (d) marketing practices, (e) crop diversification, and (f) farm budgets and household income. It also addressed the technical, institutional, and other constraints experienced by farmers in the project area.

2. METHODOLOGY

A sample survey was designed and carried out to collect data and information pertaining to agriculture and its related aspects in Parakrama Samudra Scheme. The sample contained 100 families, but only 97 responded to the survey. These 97 respondents owned and/or operated 708 ac in PSS. The extent of land covered by the sample survey represented 3.5 percent of the designed command area of PSS (19,100 ac) and 2.8 percent of PSS if encroachments are included (25,000 ac). The sample population was 1.7 percent of the total population in PSS.

To ensure a better representation, the sample was stratified into three components -- head (37 households), middle (19 households), and tail (41 households). This stratification was considered important as it allowed a comparison among the three hydrological regions with respect to the variables selected for the survey and analysis.

A team of field investigators consisting of researchers representing economics, sociology, and women in development, visited the selected households, conducted interviews, and recorded responses to the information sought by this survey. After the first round of questions, a letter was sent to the selected farm households with the signature of the government agent, Polonnaruwa, to emphasize the significance of the survey and to encourage the selected households to cooperate with the survey team.

This survey was done during the 1985 yala (June 1985 to December 1985). Data was collected in three phases. Data collection during the first phase (June 11-23) related to activities from land preparation to manuring; the second phase (August 14-21) covered manuring to weed control; and the final phase (October 8-14) covered pest and disease control to harvesting and marketing. Each selected household was visited in all three phases.

During the survey, a number of problems and constraints were encountered. Field investigators were recruited from various local government departments. Although given training on survey and interviewing techniques during the 1984 Diagnostic Analysis Workshop in Polonnaruwa, they were basically inexperienced with this type of activity. In addition, the availability of these investigators was

severely affected due to their regular government positions and responsibilities, from which they were only intermittently released.

A number of constraints revolved around the respondents. For example, the timing of the survey created problems as most farmers were actively involved in agricultural activities throughout the survey period. Although efforts were made to schedule interviews after the labor-intensive activities of land preparation, transplanting, and harvesting were completed, conflicts occasionally arose. Under these circumstances, the collection of information was selective and limited to key variables.

In some cases, interviewers were unable to meet with the original respondents. Although this problem was solved by selecting another family member (wife or offspring) to survey, this person was a secondary source and thus, the information was certainly less reliable. The ability of the farmer to recall information concerning events occurring over the cultivation season was also a probable source of error.

In addition, the validity of conclusions drawn in the analysis depended on the reliability of the farmer's response. The interviewers assured the farmers that all responses were confidential and would not be available to government agencies. However, it was generally felt that certain responses, particularly those relating to personal finances, land ownership, and tenure arrangements were problematic.

The field investigators noticed a general tendency to overstate expenses and understate production and income. Moreover, income from other sources, in addition to farming, may not have been revealed by the respondents, perhaps due to the belief that such information would be held against the recipients of food stamps.

Farmers were generally reluctant to reveal the complex intricacies of land tenure arrangements due to the legal restrictions currently existing on leasing, mortgaging, transferring, and subdividing the original allotments. Perhaps information concerning land-holdings were more accurately estimated by the agronomy researchers, who used actual field observations, rather than survey questionnaires.

The operational logistics of conducting a survey of this sort in conjunction with other disciplines created certain difficulties. In addition, due to various problems at the project level, organization and coordination of different survey activities became difficult. Limitations on the availability of transportation, personnel, office facilities, and other requirements were all important constraints to the success of the survey.

3. RESULTS AND DISCUSSION

a. Land Holding and Tenure Patterns

Land alienation in the Parakrama Samudra Scheme occurred in different stages, beginning in 1946. At every stage of settlement in

PSS, each allottee was given approximately 5 ac of lowland for paddy and approximately 3 ac of highland for homestead. In other subsequent settlement projects, due to increasing demand for land in colonization schemes, the size of paddy allotments was reduced to 3 ac and then to 2 ac.

Discrepancies concerning land holdings and tenurial arrangements were noted when the economic survey data was compared to field observations by the agronomy researchers. It may be that farmers were reluctant to report the size of their holdings, as well as the various tenure relationships in which they were involved. For this reason, only a few major observations on these topics are covered here.

Size of Landholdings. As shown in Table 33, the size of landholdings reported by respondents significantly differed from the size of the original allotment. Approximately 60 percent of the lowland allotments were less than or equal to 4 ac, with only about 24 percent remaining in the 4-5 ac size. Another 17 percent actually had increased their holding above the original 5 ac.

In the highlands, over half of the allotments were currently less than or equal to 2 ac. Note that the majority of respondents said they maintained highland allotments of less than or equal to 1 ac. About 34 percent remained in the 2-3 ac size, while only a few reported highland allotments larger than the original 3 ac.

Table 33. Classification of landholdings in PSS by size for 1985 *yala* (n=97).

Size	Lowland*					Highland*				
(ac)	H	M	T	Total	%	H	M	T	Total	%
<=1.0	6	0	0	6	6.2	4	2	7	13	40.6
1.1 - 2.0	4	1	9	14	14.4	2	0	2	4	12.5
2.1 - 3.0	6	2	12	20	20.6	5	0	6	11	34.4
3.1 - 4.0	8	6	4	18	18.6	0	0	-	0	-
4.1 - 5.0	10	3	10	23	23.7	1	3	-	4	12.5
>5.0	3	7	6	16	16.5	0	0	-	0	-
Total	37	19	41	97	100.0	12	5	15	32	100.0

* H=Head, M=Middle, T=Tail

There were two major reasons for deviation from the original land holding sizes. The survey revealed that agricultural lands in PSS were seriously fragmented. The transfer of allotments from first generation settlers to the second or third generation, and the subsequent subdivision of allotments during that process, were considered the principal cause for land fragmentation. Sale or mortgage of lands due to indebtedness or other difficulties was another source of land fragmentation.

Encroachment appeared to be a factor influencing the size of landholdings in PSS. Encroached lands were unallocated at the time of land alienation in order to serve other purposes, including forest

reservation. However, due to increasing demand for agricultural lands with access to irrigation water, reserved lands were subjected to encroachment. The sizes of encroached allotments varied depending on the availability of lands, time of encroachment, and perhaps family size. The cultivation of these additional lands undoubtedly increases the demand on the present design of the irrigation system. In addition, the cultivation of highlands (where access to irrigation water is possible) also affects the present irrigation system.

Land Ownership and Tenure. Both land ownership and land tenure in PSS showed complex characteristics. In terms of ownership, 46 percent of the 97 farmers in the sample were original allottees, 13 percent were spouses of the original allottees, 32 percent were second generation, and the remaining 9 percent were outsiders. In terms of tenure status, 44 respondents reported that their lowland allotment was not subject to any subdivision and was cultivated as a single unit, 35 reported their allotment as subdivided among descendents, and 18 reported some extent to be mortgaged or leased out (Table 34). Again, note that these reports did not agree with the data from the agronomy component, which indicated a much greater degree of subdivision than reported by the economics survey questionnaires.

Table 34. Categories of land ownership and tenure reported by PSS respondents for 1985 *yala* (n=97).

Tenure Status	Ownership				
	Original Allottee	Spouse	Second Generation	Outsider	Total
	Frequency				
Cultivated as a single unit by self	24	3	9	8	44
Completely or partly leased or mortgaged out	9	5	3	1	18
Divided among descendents with portion for self	12	4	19	0	35
Total	45 (46%)	12 (12%)	31 (32%)	9 (9%)	97

Changes in land ownership, fragmentation, encroachment, and transfer to outsiders have contributed to this complex land ownership and tenure situation. Moreover, this complexity has been exacerbated by the presence of leasing and mortgaging arrangements. Many such tenure arrangements were made due to financial difficulties and indebtedness among the allottees and lack of manpower within the household itself. The latter frequently applied to female-headed households. There was also evidence to indicate that subdivision was taking place among the second generation farmers.

Mainly the lowlands were in demand for leasing or mortgaging arrangements, while highlands (if subdivided) usually remained within the family or among close relatives. While such tenure arrangements were quite common throughout PSS, the incidence of leasing and mortgaging appeared to be much higher in the head region, which consisted of prime lowlands (Tables 35 and 36). According to survey data, about 24 percent (123 ac) of the total lowland (515 ac) acreage was under various mortgage or lease arrangements, with the head region accounting for 31 percent, the middle for 21 percent, and the tail for 19 percent. The payment of rent on mortgaged or leased out lowland varied according to the location of the plot. The highest rent was usually received in the head region, followed by the middle and tail regions.

Table 35. PSS respondents report of acreage owned, 1985 *yala* (n=97).

Location	Lowland (ac)	Highland (ac)
Head	187	84
Middle	98	51
Tail	230	111
Total	515	246

Table 36. Land tenure status reported by PSS respondents in 1985 *yala* (n=97).

Tenure	Head*		Middle		Tail		Total	
	LL	HL	LL	HL	LL	HL	LL	HL
	Relative %							
Original Allotment	53	95	73	100	76	98	67	98
Encroached	16	5	6		5	2	9	2
Rent/Mortgage-In**	19		7		12		14	
Rent/Mortgage-Out***	12		14		7		10	

*LL = Lowland; HL = Highland

**Land rented in refers to land that one farmer leases from another. Land mortgaged in refers to land one farmer holds lien on, but that belongs to another.

***Land rented out refers to land one farmer leases to another farmer. Land mortgaged out refers to land that one farmer has given as collateral to another person, usually in exchange for a loan.

b. Land Use and Cropping Patterns

Cropping Intensity. The cropping intensity was defined as the ratio of cultivated area to cultivable area. Based on agronomic field

surveys, virtually 100 percent of the cultivable lowlands were cultivated during 1985 yala, resulting in a cropping intensity of 1. This implies that no significant potential exists for expanding irrigated agriculture on PSS. Figures for acreage cultivated (reported by the respondents in the economic survey) totaled 408 ac of lowland, (Table 37). This amount approximately corresponds to the original lowland allotments given to the 97 respondents in the sample. In addition, 62 ac of highland were reported under cultivation for the 1985 yala. While not technically a part of the irrigation system, this cultivated area no doubt affects the delivery of water to the lowland fields.

Cropping Patterns. In the lowland, paddy accounted for 96 percent of the total study area cultivated, as reported by respondents (Table 37). Paddy was followed by chili, with about 3 percent of the cultivated area. Most of the chili and other field crops were growing in the head region. Overall, the area cultivated with crops other than paddy was insignificant.

Table 37. 1985 yala cropping patterns in the lowland allotment as reported by PSS respondents (n=97).

	Head		Middle		Tail		Total	
Crop	Ac	Rel%*	Ac	Rel%	Ac	Rel%	Ac	Rel%
Paddy	142.00	91.8	83.50	97.1	165.50	98.9	391.00	95.8
Chili	10.00	6.6	2.50	2.9	0.75	0.5	13.25	3.2
Tobacco	1.75	1.0			1.00	0.6	2.75	0.7
Pulses	1.00	0.6					1.00	0.2
Total	154.75		86.00		167.25		408.00	

*Relative percent

Crop diversification on the highland was limited in the head and middle regions. Apart from permanent crops, paddy was the only other crop grown in the head region. Chili and vegetables were also grown in the middle region, but on a very limited scale.

In contrast, there was a greater variety of crops grown on the highland in the tail region. Even so, permanent crops such as coconut, banana, and other trees accounted for most of the cultivated acreage on the highlands (Table 38). Note, however, that paddy cultivation was relatively greater than that of other field crops in the middle and tail regions. The high water requirement of paddy requires that water from the irrigation system be diverted to the highlands. This practice undoubtedly affects the distribution of irrigation water to lowland fields.

Cropping Preference. In addition to the data on cropping patterns, which to some extent reflected the crop preference of respondents, the survey sought information from the 97 respondents regarding their preferences for cultivating various crops. Table 39 indicates that the overall preference was largely for paddy cultivation. In a few cases, tobacco and chili were actually ranked first by some respon

dents. For second crop preference, chili was ranked highest by those in the head and middle regions, but in the tail region, tobacco was the second preference. A surprisingly high proportion (25 percent) of the respondents from the middle region gave vegetables secondary preference (Table 39). Undoubtedly, preference for various crops may be influenced by a number of factors including water availability, agricultural knowledge, marketing, and economic constraints.

Table 38. 1985 yala cropping patterns in the highland allotments as reported by PSS respondents (n=97).

	Head		Middle		Tail		Total	
Crop	Ac	Rel%*	Ac	Rel%	Ac	Rel%	Ac	Rel%
Paddy	7.50	6.4	7.00	14.3	9.00	9.2	23.50	10.4
Chili	0		1.25	2.6	2.00	2.1	3.25	1.4
Tobacco	0		0		3.75	3.1	3.75	1.6
Pulses	0		0		1.00	1.0	1.00	0.7
Vegetables	0		0.50	1.0	5.00	5.2	5.50	2.4
Perm. Crops	71.25	93.6	40.25	82.1	76.75	78.7	188.25	83.5
Total	78.75		49.00		97.50		225.25	

*Relative percent

Table 39. Crop preference reported by PSS respondents, 1985 yala (n=97).

	Head		Middle		Tail	
Crop	Preference		Preference		Preference	
	1st	2nd	1st	2nd	1st	2nd
	%					
Paddy	89	5	95	0	98	11
Chili	6	81	0	75	0	5
Tobacco	6	10	5	0	3	79
Pulses	0	0	0	0	0	0
Vegetables	0	5	0	25	0	5

Due to the overwhelming preference for paddy cultivation, it was felt important to gather information during the survey to understand this preference. The following conclusions were based on the respondents' explanations regarding preference for paddy cultivation.

1. Socio-Cultural Tradition. Paddy cultivation has been the predominant form of agricultural activity during most of Sri Lanka's history. Historically, paddy cultivation was considered to be the most noble profession, and paddy farmers enjoyed high social status. Rice has been the staple diet in Sri Lanka, and currently accounts for over 75 percent of the average total grain consumption (90 percent in the rural population).

2. Agricultural Knowledge. Farming techniques were usually passed from one generation to the next, allowing an unbroken linkage in paddy cultivation with first, second, and even third generation farmers working together. This familiarity allowed the farmer to concentrate on applying new techniques to ensure higher yields and household incomes. In cultivating field crops, which are relatively new on a large scale, farmers do not currently have the associated background or knowledge, as they do with paddy cultivation.

3. Economics/Marketing. The overall production cost associated with paddy cultivation is considerably less than for field crops (labor, fertilizer, weedicides). In addition, there is a ready market throughout the year for paddy. Paddy can be more easily stored for longer periods than field crops, is a regular source of family food supply, and is easily converted into cash for financial needs. With the entry of the private sector into paddy trade after 1977, the marketing facilities expanded and better prices were offered.

c. Cultivation Practices and Use of Inputs

Agricultural practices in PSS reflected the presence of both traditional and modern techniques, but there was a clear tendency toward modern farming techniques. In the project area, there was widespread use of tractors to prepare land and of high yielding varieties to obtain higher yields. In addition, the application of chemical fertilizers, herbicides, and pesticides was common throughout the project area.

Seed Paddy. During yala, most farmers used short-season, high yielding varieties of seed paddy (Table 40). Overall, 80 percent of the farmers planted short-season, high yielding varieties, while the rest used long-season varieties. Limited use of long-season varieties in the head and tail regions may be explained by the likelihood of inadequate and irregular water supply during yala.

Among the five varieties reported by the respondents, the most common was 34/8, which is a short-season variety requiring only 3 months to mature. While over half of the respondents using HYV's preferred this variety, they were mainly concentrated in the head region rather than the middle or tail regions. The second most common variety was 276/5, another short-season variety. Despite higher yield potentials, other varieties (2/379, 400/1 and 90/2) were not very popular among cultivators due to the longer growing season required. The predominance of short-season varieties indicated that farmers experienced uncertain irrigation water delivery during yala.

Transplanting was done only on a limited scale. As shown in Table 41, only 40 percent of the respondents engaged in transplanting. Note that while a total of 62 percent of respondents in the head and 68 percent of respondents in the middle transplanted at least some acreage, only 7 percent of the respondents in the tail did so. This

may be due to the perception by those in the tail regions that irrigation water was not always reliable and timely for transplanting. In the head and middle regions, transplanting did not depend on land size, but was common among all sizes of land holdings.

Table 40. Use of improved seed paddy varieties by PSS respondents for 1985 *yala*.

Seed Variety	Head (n=37)	Middle (n=19)	Tail (n=41)	Total% (n=97)
	----------Relative Percent----------			
Short-Season Varieties				
BG 34-8	84	16	43	53
BG 276-5	8	47	43	27
Subtotal	92	63	86	80
Long-Season Varieties				
BG 379-2	8		14	6
BG 400-1		11		4
BG 90-2		26		10
Subtotal	8	37	14	20
Total	100	100	100	100

Table 41. Transplanting by PSS respondents for 1985 *yala* by hydrological position.

Acreage	Head (n=37)	Middle (n=19)	Tail (n=41)	Total (n=97)
	----------frequency----------			
0-1.0	5	0	1	6
1.1 - 2.0	3	3	0	6
2.1 - 3.0	7	1	1	9
3.1 - 4.0	3	3	0	6
4.1 - 5.0	4	3	0	7
>5.0	1	3	1	5
Total	23 (62%)	13 (68%)	3 (7%)	39 (40%)

Fertilizer. Fertilizer application was common among the cultivators. Some farmers applied fertilizer four times during the season. While the fertilizer used for short-season and long-season varieties remained the same, timing was different between the two varieties. Table 42 shows the rates of fertilizer recommended by the Department of Agriculture for both short-season and long-season varieties, while Table 43 compares the reported applications by cultivators with the recommended rates.

Table 42. Rates of various fertilizer applications recommended by the Agriculture Department for 1985 *yala* paddy cultivation.

Fertilizer	Short-Season Variety	Long-Season Variety
	----------kg/acre----------	
Basal (V1)	75.0	75.0
1st top dressing (Urea)	37.5	25.0
2nd top dressing (TDM)	50.0	25.0
3rd top dressing (TDM)		50.0

Table 43. Application of fertilizer reported by PSS respondents for paddy cultivation in 1985 *yala*.

Fertilizer Application	Basal				Top Dressing			
	H* (n=37)	M (n=19)	T (n=41)	Total (n=97)	H (n=37)	M (n=19)	T (n=41)	Total (n=97)
	----------Rel%----------							
>Recommended rate	16	20	19	18	24	53	24	30
Recommended rate	16	16	22	19	57	47	49	52
<Recommended rate	41	53	37	42	8	--	24	13
No fertilizer applied	27	5	22	21	11	0	3	5

*H=Head, M=Middle, T=Tail

For short-season varieties, the first application of fertilizer was a basal (V1) mixture applied when the field was harrowed. Fourteen days later a top dressing of urea was applied to encourage plant growth. The third application (another top dressing of urea) occurred 20 days after planting. After 45 days, during flowering, a final application of TDM was made.

For long-season varieties, the second application was done 6 weeks after transplanting or 4 weeks after broadcasting. Irrespective of the planting method, the third top dressing was done 10 weeks after planting the crop.

A significant variation in fertilizer application was observed among cultivators across all three hydrological regions. Taking all three regions together, only about 19 percent applied the recommended rate of basal fertilizer, while another 18 percent applied more than the recommended rate. The balance either applied less than the recommended rate (42 percent) or nothing at all (21 percent). Among the farmers who did not apply basal fertilizer, the head region accounted for the highest share.

Urea applied as a top dressing conformed better to recommendations in all three regions. Overall, about 82 percent applied the recommended amount or greater of urea as a top dressing. All of the cultivators in the middle region applied at least the recommended rate of top dressing, while only 81 percent of the cultivators in the head region and 73 percent in the tail region did so. Overall, only about 18 percent reported that they applied either less than the recommended rate (13 percent) or nothing at all (5 percent). The respondents in this last category were mostly from the tail and head regions.

Such variation in fertilizer application requires further investigation to understand the extent to which fertilizer application was influenced by soil characteristics and water availability. Meanwhile, cultivators reported a variety of reasons for under-applying fertilizer, but the primary reason was finances. Cultivators who faced financial difficulties applied no basal fertilizer or less than the recommended rate. Another reason given for not applying basal fertilizer was the belief that basal fertilizer resulted in weed growth. A very few reported that they did not apply basal fertilizer based on advice from agricultural extension officers.

Cultivators seemed better aware of the effects of urea fertilizer on plant growth. Accordingly, cultivators tried to apply at least the recommended quantity of urea two or three times as a top dressing. In some cases, urea was applied in greater amounts than the recommended rate. This was probably to compensate for less basal fertilizer application and also to maximize yields.

Weedicides. Common weeds reported by farmers included: gojari, bajari, thunessa, and kuda metta. Although most farmers reported that they preferred to use chemical weedicides rather than manual weeding, the application of weedicides varied considerably. The most popular chemical weedicides included 3,4 DPA, Weedex 36, MSO, and Surcopher.

Overall, 70 percent of the respondents employed chemical weed control. About half of those employing weedicides also weeded manually. Another 20 percent used only manual methods for weed control, and the remaining 10 percent used no weed control methods at all (Table 44).

Table 44. Weeding methods reported by PSS respondents for 1985 yala.

Weeding Method	Head (n=37)		Middle (n=19)		Tail (n=41)		Total (n=97)	
	Freq	Rel%*	Freq	Rel%	Freq	Rel%	Freq	Rel%
Chemical only	14	38	2	11	19	46	35	36
Chemical and manual	9	24	8	42	16	39	33	34
Manual only	8	22	1	42	3	7	19	20
No weed control	6	16	1	5	3	7	10	10

*Relative percent

In the head region, the most common practices appeared to be the use of chemical weedicides and weedicides combined with manual weeding. The least amount of weed control was reported from the head and may be due to the availability of adequate water and a corresponding absence of weeds.

Respondents from the middle region most often used manual weeding (alone or combined with weedicides) for weed control. In fact, manual weeding was more common in the middle region than head or tail regions.

Interestingly, the greatest use of weedicides occurred in the tail region (Table 44). Field measurements by the agronomy team confirmed high weed infestation in this region. It appeared that farmers in this region attempted to control weeds through chemical applications, but due to lack of reliable water supplies, this treatment failed. Later, manual weeding was also unable to control the weed population.

For weed control (either chemical or manual) to be effective, a number of treatments must usually be made. A combination of an initial weedicide with later manual weedings, several weedicide applications, or multiple manual weedings are generally needed. Table 45 indicates that very few respondents made more than one chemical application of weedicide or more than one manual weeding.

Table 45. Weed control reported by PSS farmers for 1985 yala.

	Head (n=37)		Middle (n=19)		Tail (n=41)		Total (n=97)	
Method	Freq	Rel%*	Freq	Rel%	Freq	Rel%	Freq	Rel%
Weedicides								
1	24	65	9	47	35	85	68	70
1 + 2	1	3	2	11	5	12	8	8
Manual Weeding								
1	14	38	17	89	17	41	48	49
1 + 2	3	8	0	0	2	5	5	5

*Relative percent

Insecticides. Overall, 47 percent of the PSS farmers reported using insecticides. Sixty-three percent of the farmers in the middle region applied insecticides, compared to 3 percent and 4 percent in the head and tail regions, respectively. While the difference in insecticide application between the middle and the other regions was considerable, the survey did not collect adequate information to provide an explanation for this difference.

Labor and Power. In this section, manual labor, animal draft, and mechanical power are analyzed in regard to land preparation, crop establishment, and harvesting. This section also analyzes various labor intensive activities at different stages of paddy cultivation.

1. Maintenance

Cleaning field channels was a collective responsibility of farmers in a particular land tract and was carried out under the supervision of the area vel vidane. The cleaning and plastering of field bunds were usually performed by hired male laborers, supplemented by family labor.

2. Land Preparation

Most of the strenuous land preparation activities such as plowing and harrowing were done with buffalo or two-wheel and four-wheel tractors. Buffalo were mainly used for plowing. However, the role of draft animals was rapidly declining in PSS due to increasing costs for keeping buffalo. Costs had increased because land reserved for animal pasture within PSS was no longer available due to encroachment, and the animals were usually herded to distant areas such as Minneriya (10-12 mi) for pasture. Because of the resulting inconvenience, cost, and labor, farmers favored using mechanical sources of power.

Even so, 47 percent of the farmers still relied entirely on draft power for tillage, compared to 53 percent using mechanical power. The use of animals for draft power was higher in the tail regions than in the head and middle regions, as shown in Table 46. The time-saving advantage of tractors was reported to be the main reason for the relatively high use of tractors in all three regions. A significant number of farmers in all three regions used tractors for activities such as plowing (24 percent), harrowing (22 percent), and threshing (66 percent).

Table 46. Type of tillage power reported by PSS respondents for 1985 yala.

Source	Head (n=37)	Middle (n=19)	Tail (n=41)	Total (n=97)
	Rel%*			
Tractors	54	68	44	53
Animal	46	33	56	47

*Relative percent

Plowing was generally done twice, whether by animal draft or tractor power. About 30 percent of the farmers in the head region, 27 percent in the middle, and 18 percent in the tail used tractors for both the first and second plowing. Seedbed preparation, which followed plowing, involved harrowing or puddling by either tractor or animal and leveling (mainly done by hand). Under broadcasting practice, small, shallow furrows formed by hand (poru ela) were used to provide drainage for excess water.

3. Crop Establishment

After seedbed preparation was completed, planting was done by either broadcasting or transplanting. Approximately 2 bu of seed paddy

per acre were required to broadcast 1 ac. If the germination rate of broadcast paddy was poor, plant density could be severely reduced, which would reduce average yields. When rice was transplanted, 2-3 bu of seed paddy were first sown in a nursery to ensure adequate seedlings for 1 ac of paddy, and were grown for 18-21 days before uprooting.

Compared to broadcasting, transplanting was more time consuming and labor intensive. For example, transplanting 1 ac required 15 man-days compared to 1 man-day for broadcasting (Table 47). Transplanting paddy seedlings was done predominantly by females, including family and hired laborers.

Table 47. Labor required* for paddy cultivation as reported by PSS respondents for 1985 yala (n=97).

Activity	Transplanting		Broadcasting	
	Man-days/ acre	(Rel.%)*	Man-days/ acre	(Rel%)
Land preparation	13	22	13	29
Transplanting	15	25		
Broadcasting			1	2
Manuring	3	5	3	7
Weeding/pest control	6	10	8	18
Harvesting	14	24	14	31
Other activities	8	14	6	13
Total	59	100	45	100

*This includes man-days required for tractor operation
**Relative percent

To minimize seed losses from birds or animals, fields must be protected by scarecrows or beaters. When paddy fields were located some distance from the residence, farmers temporarily resided in huts erected on the threshing floor to guard their fields, particularly just before the crop was ready for harvesting. Since a nursery is smaller in size, protection of seed was easier than for the broadcast field.

Water issues were more restrictive in yala than in maha. Consequently, farmers were required to establish their plants within a limited time. Only 1 man-day was necessary to broadcast an acro, but transplanting required 15 days/ac. Therefore, the majority of PSS farmers (60 percent) broadcast during the 1985 yala.

Although broadcasting involved less labor and time, it required special throwing skills to ensure that the seed was properly embedded at the correct depth in the soil. Despite higher labor requirements, transplanting usually resulted in fewer weeds and higher yields.

Weeding of paddy fields throughout the season was primarily performed by local women, either family, hired, or as exchange labor. Application of agrochemicals was usually contracted to locally hired males who owned sprayers and performed this service as a business.

4. Harvesting

Harvesting was the most labor intensive activity in paddy cultivation, involving preparing the threshing floor, cutting, bundling, collecting, threshing, winnowing, measuring, bagging, and transport.

The cultivator usually prepared the threshing floor. Reaping was done by males and females. In most parts of Sri Lanka, reaping is done primarily by females, but in the Polonnaruwa District a large amount of the harvesting labor was provided by contract or hired male labor from outside the area. Bundling and collection of the harvest were done by both male and female laborers. Approximately 14 man-days were required to reap 1 ac.

The majority of threshing was done by four-wheel tractors, but two-wheel tractors were also used. Threshing was often done during the night. Agrimec, a new threshing machine, was used by only two farmers. Tractors were also used for winnowing by attaching a fan. Overall, about 66 percent of the respondents used tractors to thresh and 41 percent to winnow.

Measuring and bagging paddy were usually done on the threshing floor by male laborers. Some farmers sold the produce directly from the threshing floor to private traders. Others transported the harvest to nearby sales outlets or stored the grain for later sale. Tractors with attached trailers were commonly used to transport paddy from the threshing floor to houses or sales outlets.

5. Land-Man Ratio

The land-man ratio in PSS during 1985 yala varied from 45-60 man-days/ac, with an average of about 50 man-days/ac. Some farmers reported that although they had no specific work in the field, they still went to the field daily. They reported spending about 2 hrs/day controlling water, weeding, or examining plants for pests and diseases. Therefore, the average man-days per acre may be somewhat higher than reported.

Labor requirements varied according to planting method: about 59 man-days/ac for transplanting, and about 45 man-days/ac for broadcasting (Table 47). Labor requirements were greater if the plowing was done by animal power instead of tractors.

The main difference in labor requirements between the two methods was due to the 15 man-days/ac required for transplanting, compared with only 1 man-day/ac for broadcasting. In all other activities, labor requirements were almost equal for both methods.

Labor requirements in paddy cultivation were obtained from four sources: 1) family labor obtained from the cultivators own family, 2) exchange labor obtained based on mutual sharing of work with members of other farm families in the neighborhood, 3) hired labor offered on a daily payment basis, and 4) contract labor provided under informal

contractual arrangements at a fixed rate of payment (contract laborers often came from outside Polonnaruwa District).

Water. The availability of water can be a critical input for paddy cultivation. While the availability of water may depend on field location, the adequacy of water depends on physical soil characteristics, plant requirements, and the water management practices of the farmer. The stratification of the sample sites by head, middle, and tail regions was done to evaluate any difference in water supply on yields and household incomes.

Until 1985, no charge existed for irrigation water. In yala 1985, the Irrigation Department introduced an operation and maintenance fee (O&M) of Rs. 100/ac/year (Rs. 50/season) to supplement the costs of maintaining irrigation and field channels. This fee was expected to increase to Rs. 200/ac/year in five years with increments of Rs. 20/ac/year.

The survey revealed that 57 percent of the farmers paid the O&M fee for 1985 yala. The remaining 43 percent who did not pay the O&M fee reported various reasons for not doing so, which are shown in Table 48. A relatively high percentage (44 percent) claimed financial difficulties as the reason, and another 27 percent thought that they were not required to pay the fee since they did not own the property they were farming.

Table 48. Reasons reported by PSS respondents for non-payment of O&M fees for 1985 yala (n=41).

	No. of Farmers	Relative %
Financial difficulties	18	44
No ownership proof	11	27
Fee not reasonable	4	10
Crop failure	1	2
Not required to pay	5	12
Other reasons	2	5

Another cost related to water availability was the renumeration of .5 bu/ac of paddy paid to the vel vidane at the end of each season by the farmer. This cost was borne by all farmers in the area served by a vel vidane.

d. Productivity and Profitability of Paddy Farming

Yields. According to the economic survey, the average yield of paddy in PSS during the 1985 yala was 68 bu/ac. This was just slightly higher than the national average of 65 bu/ac for the same season. Reported yields varied from 40-100 bu/ac depending on the location of the field, hydrological position within the irrigation system, and application of agricultural inputs. The average paddy yields in the

middle region were the highest (78 bu/ac) compared to 71 bu/ac and 55 bu/ac for the head and tail regions, respectively (Table 49). The majority of the farmers in the tail region reported average yields less than the overall average for PSS.

The distribution of water may directly affect crop yields. In the middle area of the D1 main canal, especially RB7, where there appeared to be fewer water distribution problems, higher yields were reported.

The availability of water may also influence the effectiveness of other inputs such as fertilizer on crop yields and the extent of crop failure. For example, in the tail region, where water was usually not available in sufficient quantity, farmers not only experienced lower yields, but also a higher incidence of crop failure relative to the other two regions.

Table 49. Distribution of reported paddy yields by hydrological regions in PSS for 1985 *yala*.

Yield (bu/ac)	Head (n=37)	Middle (n=19)	Tail (n=41)
	----------Rel %----------		
> 100	8	5	
90 > 100	6	10	5
80 > 90	6	35	5
70 > 80	31	25	8
60 > 70	26	20	21
50 > 60	16	5	7
40 > 50	3		24
30 > 40			15
20 > 30			5
10 > 20	3		8
> 10			3
Avg. yield (bu/acre)	71	78	55

Sixty percent of the plots in the tail region reported yields which were lower than the average yield, compared to only 5 percent in the middle and 22 percent in the head regions (Table 49).

None of the farmers in the middle region reported a yield of less than 50 bu/ac, compared to 53 percent in the tail region. Only 3 percent of the farmers in the head region reported a yield less than 20 bu/ac, but in the tail region 8 percent reported average yields of less than 20 bu/ac.

Based on these reported yields, it appeared that farmers in the middle region were the most successful. The highest reported yield on PSS for the 1985 *yala* was 130 bu/ac, in the middle region. About 8 percent of the yields in the head and 5 percent in the middle region were over 100 bu/ac. The average yield of the head region farmers was

significantly higher than those from the tail region, but slightly lower than those from the middle region.

Among the factors which influenced crop yields, the method of crop establishment appeared to play a major role. Table 50 indicates that crop yields were generally higher for transplanting than broadcasting. The differences in yields obtained by transplanting was striking in the tail region. In fact, an increase of 22 bu/ac was reported from transplanted fields compared to broadcast fields in the tail. However, the difference between the two methods was only 12-13 bu/ac in the head and middle regions. Even given the increase in yield for transplanting over broadcasting, the average yield for transplanted fields in the tail region was below the average yield for broadcast fields in the head and middle regions.

Table 50. Average reported yields by method of crop establishment for different regions of PSS, 1985 *yala*.

Crop Establishment Method	Head (n=37)	Middle (n=19)	Tail (n=41)	Total (n=97)
	bu/acre			
Transplanted	74	80	63	72
Broadcast	66	72	52	63

Based on these reports, if all fields had been transplanted, overall yields might have been increased by 10-20 percent depending upon the location of the fields. Consequently, the farmer might have received an additional income of approximately Rs. 600-800/ac.

Production Costs. The cost of paddy production varied from Rs. 3,000-4,000/ac. In PSS, the highest cost was reported in the head area (Rs. 4,000) compared to the middle and tail regions (Rs. 3,900 and Rs. 3,200, respectively). The breakdown of production costs for paddy cultivation major expenditure items is shown in Tables 51 and 52.

It was observed that the crop yield per acre exhibited a direct relationship to the cost of paddy production. Increased yields per acre depended to a large degree upon the application of inputs, which consequently resulted in an increase in the cost of production.

Inputs used for paddy cultivation can be grouped into three categories: labor, power, and materials. Labor included hired or exchange labor, contract labor, and family labor; power consisted of tractors and animals. Seed paddy, fertilizer, weedicides, and pesticides were included as materials.

Table 51. Costs and returns per acre reported by PSS respondents for paddy cultivation in 1985 *yala*.

Item	Unit	No. of Units	Price or Cost per Unit (Rs.)	Total Income or Cost (Rs./Ac)
Variable Costs				
Cleaning field channels	Man-days	2	30	60
First plow	Tractor-days	1	300	300
	Buffalo-days	4	75	300
Second plow	Tractor-days	1	300	300
	Buffalo-days	4	75	300
Harrowing	Tractor-days	1	300	300
	Buffalo-days	4	75	300
Cleaning and plastering bunds	Man-days	10	300	300
Preparing seed beds	Man-days	1	30	30
Crop establishment				
Transplanting	Man-days	15	30	450
Broadcasting	Man-days	2	30	60
Seed paddy	Bu	2	100	200
Chemical fertilizer				
Basal incorporation	Man-days	1	30	30
First application	Man-days	1	30	30
Second application	Man-days	1	30	30
Material cost	Kg	175	3	525
Manual weeding	Man-days	4	30	120
Weedicide application	Man-days	1	30	30
Material cost	Bottles	4	60	240
Insecticide application	Man-days	1	30	30
Material cost	Bottles	4	45	180
Harvesting	Man-days	14	30	420
Threshing	Man-days	6	30	180
Winnowing	Man-days	1	30	30
Winnowing fan rental	Tractor fan hrs	2	50	100
Crop transport labor	Man-days	1	30	30
Transport vehicle	Tractor		50	
Total Variable Costs				**3,965**

Table 51. (Continued)

Item	Unit	No. of Units	Price or cost per Unit (Rs.)	Total Income or Cost (Rs./Ac)
Fixed Costs				
Renumeration	Bu	0.5	70	35
O&M fee	Rs./year/ac	0.5	100	50
Land tax	Rs./year/ac	0.5	6	3
Insurance premium	Rs./year/ac	0.5	80	40
Total Fixed cost				**138**
Total Cultivation Cost				**4103**
Income:				
Paddy sold to private trader	Bu	44	70	3080
Paddy consumed and stored	Bu	22	70	1540
Seed requirements	Bu	2	70	140
Total Income				**4760**
Net returns (transplanted)				657
Net returns (broadcast)				1047
Imputed cost for family labor	Man-days	20	30	600

Forty-three percent of the reported total cost of paddy production was due to labor. Although family labor was available, additional labor was generally required for the more intensive activities of land preparation, transplanting, and harvesting. Experienced farm labor from as far away as Ratnapura, Kegalle, and Dambulla often came to Polonnaruwa District during the cultivation season as contract or hired labor. These workers remained in the area as long as labor was needed and received about Rs. 30/day in addition to tea and lunch.

Most of the farmers reported that they depended on hired or contract labor for land preparation, transplanting, and harvesting. A number of farmers also depended on hired or exchange labor in addition to family labor for manuring (18 percent), weeding (30 percent), applying pesticides (4 percent), and water control (3 percent). In computing paddy production costs per acre, an estimated value for family labor was also included.

The use of power in paddy production accounted for about 25 percent of the total cost of paddy production. Power was supplied by two-wheel or four-wheel tractors and buffalo. Both animal draft and

Table 52. Production cost per acre of paddy as reported by PSS respondents for 1985 *yala*.

Item	Unit	No. of Units	Cost per Unit (Rs.)	Total Cost (Rs./Ac)	%
Labor					
Hired labor	Man-days	39	30.00	1170.00	28.51
Family labor	Man-days	20	30.00	600.00	14.62
Subtotal				1770.00	43.13
Power					
Tractor	Tractor-days	3	300.00	900.00	21.93
Buffalo	Buffalo-days	12	75.00	900.00	
Tractor	Tractor-hours	3	50.00	150.00	3.65
Subtotal				1050.00	25.59
Materials					
Seed paddy	Bu	2	100.00	200.00	4.87
Fertilizer	Kg	175	3.00	525.00	12.79
Weedicides	Bottles	4	60.00	240.00	5.84
Pesticides	Bottles	4	45.00	180.00	4.38
Subtotal				1145.00	27.90
Institutional					
Renumeration	Bu	0.5	70.00	35.00	0.85
O&M fee	Annum/ac	0.5	100.00	50.00	1.46
Land tax	Annum/ac	0.5	6.00	3.00	0.07
Insurance premium	Annum/ac	0.5	80.00	40.00	0.97
Subtotal				138.00	3.36
Grand Total				4103.00	100.00

mechanical power appeared equally important as sources of farm power. Generally, 2 tractor-days were required to prepare 1 ac of land, while 1 tractor-day provided power for threshing the harvest of 1 ac. Approximately 30 percent of the need for power was met through rental arrangements.

The average tractor hire rate for each plowing was approximately Rs. 300/ac, while the rental of two pairs of buffalo (with labor) was

Rs. 300. Thus, the use of buffalo was as costly as the use of tractors. However, when buffalo were used, farmers could save on labor if family or exchange labor was available. Under these circumstances, the use of buffalo could be less costly than tractors.

On the other hand, due to substantial time savings when tractors were used to prepare land, tractor use was rapidly increasing in the area. To meet the increased seasonal demands for mechanical power during land preparation, tractors from outside the area were often brought in for hire.

The cost of materials such as fertilizer and agrochemicals accounted for approximately 28 percent of the total paddy production costs. Fertilizer generally accounted for half of the material costs. While the cost of the recommended rate of fertilizer amounted to Rs. 400-525/ac, a number of farmers used higher rates, which meant unnecessary costs. Generally, the material costs were more than compensated by the yield increases (and increased income) resulting from using these inputs.

Although the required inputs of land and water were virtually unpriced, there was a nominal tax for lands (Rs. 6/year/ac) and an operation and maintenance fee of Rs. 100/year/ac assessed by the government. Other additional costs could include insurance premiums or interest on loans. These costs consisted of approximately 5 percent of the total cost of paddy production.

Table 53 compares average paddy production costs among the three hydrological regions. The highest cost per acre was reported in the head region, followed by the middle and tail regions. In terms of production cost per bushel of paddy, the head region still accounted for the highest ratio, while the tail region reported the second highest, and the middle region, the lowest. As discussed earlier, production costs were affected by the type of farming method and the price of inputs, material, and labor. Production cost was reported to be the lowest for households owning tractors or buffalo and which did not depend on either contract or hired labor. Such households experienced much higher net returns from paddy. The average cost per bushel was decided by the yield per acre.

Table 53. Costs per bushel of paddy reported by respondents on PSS for 1985 *yala*.

Item	Head (n=37)	Middle (n=19)	Tail (n=41)
Total cost (Rs.)	4,200.00	3,800.00	3,200.00
Avg. yield (bu/ac)	70.81	78.45	55.49
Cost/bu (Rs.)	59.31	48.43	57.66
Price/bu (Rs.)	70.00	70.00	70.00
Price/cost ratio	1.18	1.44	1.21

Profits. Given the average yield of 68 bu/ac, and the average market price of Rs. 70/bu, gross income per acre was calculated at approximately Rs. 4,760. However, when yields were about 100 bu/ac, gross income increased to about Rs. 7,000. Production cost averaged Rs. 4,103/ac including the monetary value of family labor. Therefore, the net profit received by paddy cultivators for the 1985 yala was Rs. 657. When the cost of family labor was considered, the net profit increased to Rs. 1,140 for the 1985 yala.

It was observed that average yields and net returns were higher in transplanted fields than broadcast fields (Table 54). Average yields were not affected by the mode of power used (animal or tractor), but returns were affected since animal power was less expensive than tractor power. In addition, the average returns also depended upon the yields, the amount of paddy sold, and market price.

Table 54. Average returns per acre by method of crop establishment and mode of power used by PSS respondents for 1985 yala.

Method of Crop Establishment	Head		Middle		Tail	
	Tractor	Buffalo	Tractor	Buffalo	Tractor	Buffalo
Transplanted	Rs.					
Income	5180	5180	5600	5600	4410	4410
Cost	4200	4000	3800	3600	3200	3000
Returns	980	1180	1800	2000	1210	1410
Broadcast						
Income	4620	4620	5040	5040	3640	3640
Cost	3780	3580	3380	3180	2780	2580
Returns	840	1040	1660	1860	860	1060

e. Productivity and Profitability of Subsidiary Crops

During the 1985 yala, a small number of farmers cultivated subsidiary crops, mainly tobacco and chili. These were grown on highland and lowland areas that did not receive sufficient water for paddy cultivation. In addition, most farmers cultivated vegetables in their home gardens, mainly for home consumption. Chili and tobacco were cultivated as commercial crops and required careful attention and efficient management.

As reported by the farmers, the most profitable crop was tobacco, followed by chili, then paddy. Although paddy was less profitable, most farmers preferred to cultivate paddy compared to other field crops. The average net income per acre of paddy was only Rs. 660/ac, compared to Rs. 6,700 for tobacco and Rs. 5,300 for chili (Table 55).

Although the net returns from subsidiary crops were relatively high compared to paddy, the cultivation of subsidiary crops involved much greater risk and uncertainty. Subsidiary crops required more capital, so they were grown mainly by farmers who could bear the economic risk of failure.

Table 55. Cost and returns per acre for chili and tobacco reported by PSS respondents for 1985 *yala*.

	Unit	Chili	Tobacco
Expenses			
Land preparation	Rs.	2600	1620
Seed & crop estb. labor	Rs.	1630	2100
Fertilizer & application	Rs.	2350	1650
Weedicides & application	Rs.	300	1920
Pest control	Rs.	600	860
Harvesting & processing	Rs.	300	2100
Total Cost	Rs.	7780	10260
Income			
Yield per acre	Kg	380	530
Price per kg	Rs.	34.50	32.00
Gross Income	Rs.	13110.00	16960.00
Total Cost	Rs.	7780.00	10260.00
Profit	Rs.	5330.00	6700.00

f. Institutional Facilities

Institutional facilities normally provide farmers with agricultural credit, marketing outlets, agricultural inputs, and information on new and improved varieties and new technologies. Institutional facilities are intended to help the farmer obtain a higher yield. However, it was observed that farmers in PSS did not benefit greatly from institutional facilities (Table 56).

Despite unfavorable terms relative to institutional sources, most farmers preferred to purchase agricultural inputs and sell paddy in the private sector. During 1985 *yala*, about 50 percent of the farmers purchased fertilizer and weedicides from institutional sources. However, paddy sales to institutional sources such as the Paddy Marketing Board (PMB) accounted for only 3 percent of the sales by respondents. Farmers preferred the private sector over PMB because they could get a higher market price compared to the floor price offered by the PMB and they could sell paddy to the private sector at the farmgate. However, farmers were not always assured of a higher return from transactions with the private sector because middlemen take a sizeable share of the farmers' returns. Better institutional facilities could encourage farmers to turn to these more stable sources to purchase agricultural inputs and sell paddy.

Credit. Lack of sufficient capital to purchase required inputs was a serious problem faced by the PSS farmer. The main reason given was low income from paddy cultivation in relation to the high costs of agricultural inputs. The average monthly income of a PSS farmer was less than Rs. 500, and few farmers had other sources to supplement their minimal income from paddy cultivation.

Table 56. Utilization of institutional facilities by PSS respondents for 1985 yala (n=97).

Facility	(%)
Credit:	
Banks	23
Co-ops	18
Input purchase:	
Agriculture Department	
Paddy seed	20
Chili seed	20
Fertilizer	20
Weedicide/Pesticide	49
Tobacco Company	
Tobacco seed	14
Fertilizer	33
Weedicide	3
Crop sales (PMB)	3
Crop insurance	18

The costs of inputs such as fertilizer, insecticides, weedicides, tractor rental, and labor wages generally required the farmer to obtain credit. Approximately 50 percent of the PSS farmers reported that they obtained loans during 1985 yala. Of the farmers who obtained loans, 41 percent relied on institutional loans, while 59 percent obtained loans from private sources.

Institutional loans were mainly provided by commercial banks (People's Bank and Bank of Ceylon) and cooperatives. Interest rates charged by these banks and the cooperatives were 11.33 percent and 10.75 percent, respectively. On the other hand, interest rates in the private sector ranged from 120-200 percent/year. Despite high interest rates a relatively high percentage of farmers obtained loans from private lending sources. Farmers reported various reasons for the lower demand for agricultural credit from institutional sources, including:

* Non-availability of loans because of previous default on institutional loans
* Non-availability of necessary documents
* Cumbersome procedures followed by lending institutions.

As a result of these problems, farmers were compelled to utilize private sources of credit. Moreover, advantages of private loans included easy availability, lack of a necessary guarantee, and the fact that there were no restrictions or limitations on the use of loans. Although most farmers reported that they only used credit for cultiva-

tion purposes, informal observations by economic investigators indicated that a considerable portion of loans were used for private or personal purposes.

Crop Insurance. Crop insurance was not widely obtained in PSS. Only 18 percent of the respondents reported that they had insured their crop for the 1985 yala. Even those farmers who obtained crop insurance did so only as a prerequisite for institutional loans, rather than as a measure against crop failure.

Overall, most farmers felt that the crop insurance program was not satisfactory. Frequently, farmers were either unaware of or did not understand the program. In addition, the actual compensation for crop failure was insufficient to cover losses.

Agricultural Extension. Agricultural extension services were not satisfactory in this region because there weren't enough personnel who had undergone a thorough training to serve the farms in the area. Some farmers were unaware of the availability of extension services. Even though about 50 percent of the farmers reported having had some contact with the agricultural extension workers, they seemed to feel that the advice given by the extension personnel was not very useful. Most of the farmers indicated that they were not satisfied with the limited extension service available. Weed and disease control were two major areas where extension services were greatly needed. The respondents' main sources of guidance seem to be their own experience, retailers of agro-chemicals, and neighboring farmers.

However, water management and irrigation activities were two areas where farmer-officer relationships were seen to be more effective. Farmers maintained close relationships with the vel vidanes, work supervisors, and patrol laborers.

Marketing. There were basically three institutional marketing choices for paddy: the Paddy Marketing Board, cooperative stores, and agrarian service centers. Cooperatives and agrarian service centers may also act as purchasing units for the PMB. Previously, private traders were also active as agents of the PMB, but that system was abolished in 1984. Although these three institutions functioned as paddy purchasing centers, only the PMB appeared to be active during the study, and even its share in paddy trade was very small. Farmers reported that only 3 percent of the total paddy marketed was purchased by the cooperative or the PMB stores, while the private traders and millers purchased the balance (Table 57).

Table 57. Marketing of paddy reported by PSS respondents for 1985 yala (n=97).

Source	%
Coop. stores/PMB	3
Private traders (local)	70
Private traders (outside)	16
Millers	11

Under the guaranteed price scheme, Rs. 70 is paid for a bushel of paddy (Rs. 3.35/kg), while the price in the open market varies from Rs. 80-100/bu. During the 1985 yala harvesting period, paddy averaged Rs. 77.20/bu (Rs. 3.70/kg).

In addition to the market price, the farmer's decision to sell paddy to private traders rather than government institutions was influenced by a variety of other factors:

1. The PMB deducted a percentage of weight for moisture in paddy, which the farmers did not always approve unless the paddy was very wet. Drying paddy to the appropriate moisture percentage is time consuming for the farmer.

2. Private traders were more convenient for the farmer because the purchase was made at the farm gate, eliminating additional costs for transporting paddy.

3. A standard quantity of paddy must be packed into a bag when selling to the PMB, whereas private traders accepted various sizes of bags.

4. The weight deducted for packaging by the private trader was less than the PMB charged.

5. Most of the cooperative/PMB stores were reluctant to purchase paddy due to financial shortage and inadequate storage facilities.

6. Farmers who obtained loans from private traders were often compelled to sell paddy to the same sources.

4. SUMMARY AND CONCLUSIONS

The analysis presented in this section was derived from an economic survey conducted in PSS during 1985 yala. The sample included 97 respondents represented by head (37), middle (19), and tail (41) regions.

Efforts were made during the survey to cover all aspects related to agriculture, including land ownership and utilization, availability and adequacy of irrigation water, cultural practices and production technologies, crop diversification, production costs, marketing, credit, and farm household incomes. In addition to an overall analysis, a comparison was also made wherever possible among the three hydrological regions.

The size of land holdings and land ownership patterns differed from the original settlement. Only about 40 percent of the lowland landholdings still conformed to the original 5 ac. About 45 percent of the holdings were operated by the owners, of which original allottees acounted for little more than half. Another 36 percent were operated under shared arrangements and had more than one operator, including the

owner. The remaining 19 percent were operated under mortgage or lease arrangements. Information relating to land ownership and tenure arrangements collected through the survey questionnaires may not be accurate due to the reluctance of the respondents to reveal this kind of information to outsiders.

Scarcity of lands, increasing population, indebtness, and non-availability of labor within the farm household were major factors that led to the changing characteristics in size of holdings, land ownership, and tenure. With increasing population, land fragmentation will undoubtedly become more serious with time. Land fragmentation needs to be addressed in the future management of the irrigation system.

According to agronomic data, cropping intensity was at a maximum during the 1985 yala in PSS. This implied that almost all of the potential agricultural lands were under cultivation during this season. In the lowlands, paddy accounted for 96 percent of the total cultivated area. Apart from permanent crops, paddy was the principal crop grown on the highlands as well. Overall, crop diversification was extremely limited.

The farmers in all three hydrological regions chose paddy as the crop of first preference. Socio-cultural tradition, agricultural knowledge, lower production costs, and better marketing facilities compared to other crops may be responsible for this preference. If crop diversification is expected to occur in this area, these limitations must be resolved.

Improved rice varieties such as 34/8 and 276/5 were used by 53 percent of respondents. The use of high yielding varieties was limited in the tail region, which may be explained largely by possible water shortages during yala. Almost 90 percent of the respondents used short-season varieties, which require only about 3 months to mature compared with 4 to 4 1/2 months for long-season varieties.

Plowing and harrowing were done with buffalo (47 percent) or tractors (53 percent). Despite high cost, the time-saving advantage of tractors was reported as the main reason for the relatively high use of tractors in all three regions. Farmers who owned tractors incurred no additional cost for land preparation, and many of them leased their equipment to others to supplement their income.

Overall, about 40 percent of the respondents engaged in transplanting, with the middle region accounting for the majority of respondents (68 percent) who did. The lowest incidence of transplanting (7 percent) was reported in the tail region. Although transplanting usually assured higher yields, it depended on a regular water supply. Transplanting involved higher costs as the labor requirement for transplanting 1 ac was 14 man-days greater than for broadcasting. These factors may have influenced many of the farmers to broadcast their paddy. Although broadcasting methods resulted in lower yields, production costs were also lower compared to transplanting.

Use of agricultural inputs such as fertilizer, weedicides, and insecticides was common in all three hydrological regions. For fertilizer, the application of urea was greater than basal fertilizer because of the effects on growth. While most respondents preferred to use chemical weedicides for weed control, manual weeding was also common throughout PSS. About 15 percent of the labor requirements in paddy cultivation were related to fertilizer application and weed and insect control. The cost of agro-chemicals accounted for about 28 percent of the total production cost.

The labor requirements in paddy farming were met from family labor, exchange labor, contract labor and hired labor. A major portion of labor in all three regions was done by family laborers. However, land preparation, transplanting, and harvesting required additional labor, which was supplied mainly through hired and contract labor. On the average, about 60 man-days/ac were required for transplanting paddy and 45 man-days/ac for broadcast paddy.

Overall, yields reported by respondents averaged 68 bu/ac. The highest average yield of 78 bu/ac was reported in the middle region. The tail region reported the lowest average yield of 55 bu/ac.

Given the overall average yield of 68 bu/ac and an average market price of Rs. 70/bu, the gross income per acre was computed at Rs. 4,760. However, net returns varied among the respondents depending on production costs. Average production cost totalled Rs. 4,100 in the head, Rs. 3,900 in the middle and Rs. 3,200 in the tail. The highest net return of Rs. 2,000/ac, including the value of family labor, was reported by farmers who transplanted and used draft animals in the middle region. The lowest net return (Rs. 840/ac) was reported in the head region by farmers who broadcast and employed tractors. In general, respondents who transplanted and used draft animals attained higher net returns.

Extension services were weak in PSS. The lack of trained personnel to provide extension services to the farmers was identified as the main reason for poor extension services.

Most respondents lacked financial resources, which particularly limited their use of agro-chemicals. Only about 50 percent of the respondents obtained credit, half of which from private sources. Efforts to improve productivity and crop diversification require serious consideration of the financial difficulties faced by farmers.

The credit arrangements of respondents with private traders appeared to influence to some extent the preference for marketing channels in PSS. It was reported that only about 3 percent of the total paddy marketed was purchased by the cooperatives or the PMB stores. Private traders and millers purchased the remaining 70 percent.

Another factor that influenced the preference for private marketing channels was the higher price, relative to the government stores,

offered by the private sector. However, information was not collected to evaluate whether farmer preference for selling to the private sector was mainly because of better prices or credit arrangements. This is an area which requires further analysis to understand the degree of indebtedness of farmers who exclusively depend on private credit relative to others who depend on institutional sources or relatives and friends.

E. SOCIOLOGY

1. INTRODUCTION

The sociology component was guided by three major concerns. First, to place the data collected on water management problems in a wider context, background information was collected on a few identifying characteristics of the sample households: demographics, homogeneity of population, the family, literacy, and agricultural practices.

Second, farmers frequently view the irrigation system that serves their area somewhat differently than the administrators of that system, based partly on their experience as irrigators. Therefore, strong emphasis was placed on determining some of the basic perceptions of farm household members regarding water distribution, system maintenance, settling disputes related to irrigation, and any problems facing farm households as a result of these factors.

Finally, keeping in mind the possible use of the data collected to formulate policy recommendations, it was considered critical that farmers have the opportunity to express some of their preferences concerning possible changes in the operation of the irrigation system.

2. METHODOLOGY

a. Sample Selection

In selecting the sample of 102 PSS households to interview, it was necessary to include those from the field channel areas under intensive study by the engineering and agronomy components. The sample was further developed by identifying areas which would represent variability in irrigation system performance. Included were sample areas having high levels of water scarcity and areas with high levels of access to water. The sample sites are shown in Table 58.

Table 58. PSS field sites selected for 1985 *yala* sociology study.

Distributary Channel		Households
Head:	Block F of D1	20
	RB1 of D1 East	10
	Weera Pedesa	11
Middle:	RB7 of D1 North	19
Tail:	LB1 of RB21 of D1 North	22
	LB2 of RB21 of D1 North	10
	RB12 of D1 East	5
	RB13 of D1 East	5
Total		102

b. Questionnaire Development and Interviewer Training

Since the study included both American and Sri Lankan personnel, it was necessary to reduce team communication problems. It was particularly important to collaborate on constructing the questionnaires used in the interviews so that they were relevant, and to adequately interpret the findings.

Several meetings between the sociology interviewers and coordinators were held throughout the season to construct the questionnaire, translate between Sinhala and English, and discuss findings. The interviewers were consulted as much as possible while the questionnaire was constructed to gain full benefit of their extensive experience as area field agents.

In July and August of 1984, a diagnostic analysis training workshop was conducted in the Polonnaruwa District. The purpose of the workshop was to train agricultural personnel. The sociology data collectors who received training included two electoral managers (PSS, Kaudulla), five colonization officers (PSS), and a district officer from Agrarian Services (PSS). They were trained in basic interviewing skills and given an opportunity to practice interviewing in PSS.

In addition, on August 10-11, 1985, the sociology interviewers participated in a weekend training workshop to strengthen their data collection skills and to discuss problems encountered during the first round of interviews. The seminar was conducted by four guest lecturers: two sociology faculty members from the University of Peradeniya, one sociology researcher from the Agricultural Research and Training Institute in Colombo, and one researcher and administrator from the Department of Education, Colombo. This last individual has spent many years working in the Polonnaruwa District.

c. Field Surveys

Data was collected in a three-part survey:

1. Structured questionnaire on social and economic background, with a few open-ended questions (June 11-23, 1985).

2. Structured questionnaire on water distribution, system maintenance, and settlement of disputes (August 14-17, 1985).

3. Structured questionnaire on preferences for possible changes in water management practices (October 9-12, 1985).

In addition, fifteen key informant, open-ended interviews and eighteen community meetings with farmers were conducted during maha 1985-86 (Appendices H and I). These meetings provided valuable additional insights beyond those obtained in the three questionnaires.

In all three rounds of the survey, sociology interviewers talked with the person in the household designated as the original allottee or the successor of the original allottee. Questions concerning agricultural operations, such as amount of land cultivated, source of water, nature and extent of water problems, and available draft power, were often answered with the aid of other family members. The object of the sociology questionnaire was not to evaluate farmer knowledge at an individual level, but to describe household practices, perceptions, and opinions. Therefore, it was not deemed necessary to limit responses to those of one individual.

Also, from a practical standpoint, families tended to treat the interview as a family experience. This appears consistent with experiences of other researchers interviewing in Sri Lanka:

> "In community-conscious rural communities such as those in Sri Lanka, experience shows that people are unwilling on their own to keep on answering direct questions from a stranger. The informants prefer to answer questions along with the other members of the community. (Tennakoon, n.d.)"

d. Data Analysis

For purposes of data analysis, the sample was be defined as purposive, designed to highlight the differences in water access for farmers at the head and tail of each system. Much of the data collected was nominal, rather than ordinal or interval, and has been analyzed accordingly. Since the sample was not randomly selected, no attempt was made to generalize statistical distributions beyond the sample. Field data was tabulated and coded for analysis using Microstat™ (a statistical analysis software program) on a microcomputer.

3. RESULTS AND DISCUSSION

a. Demographic Information

Homogeneity of Population. In the first round of the survey, the focus of the questionnaire was to collect basic descriptive data to develop a general profile of the sample households.

Religious affiliations and race or ethnic identity are given in Table 59. The "race" categories were defined by the sociology interviewers and Sri Lankan adviser assisting with the construction of the first questionnaire. As expected, the vast majority of respondents were listed as Sinhalese Buddhists. Three Christian households also identified themselves as Sinhalese. The sample included no Tamil-speaking families and only one Muslim family, although Muslims represent 6.5 percent of the Polonnaruwa District population.

The place of origin varied considerably, but 21 percent were from the Kandy area, 14 percent from the Kegalle area, and 8 percent each were from Nuwara Eliya, Polonnaruwa, and Kurunegala. As reported in Table 60, the "other" category received the highest response rate. In

retrospect, it appears that respondents should have been presented with district names rather than city names to select from, or the question should have been open-ended.

Table 59. Religion and ethnicity of PSS respondents surveyed in 1985 *yala* (n=100).

Religion	%	Ethnicity	%
Buddhist	96	Sinhalese	99
Christian	3	Muslim	1
Muslim	1		

Table 60. Origin of PSS respondents reported in 1985 *yala* (n=99).

Location	%
Kandy	21
Kegalle	14
Galle	4
Polonnaruwa	8
Kurunegala	8
Nuwara Eliya	8
Other	36

A fairly high proportion of respondents (76 percent) reported conta with their former home areas. Of those who maintained contact, the p ary mode was social visiting to meet relations, attending spec l events, or children visiting relations. Correspondence as a mode of contact was infrequent (Table 61).

Table 61. Mode of contact of PSS respondents with relatives reported in 1985 *yala* (n=99).

Contact	%
Social Visits	44
Children Visit	12
Emergencies	11
Correspondence	7
Visits for Labor	1
No Contact	24

Tentative observations on the homogeneity of the population suggested that no potential religious or ethnic cleavages existed in the area that might tend to polarize community relations. Families maintained contact with original village areas to a considerable degree, suggesting that the population is not socially isolated.

The Family. The duration of residence in Polonnaruwa District and the age of the household head were viewed as general indicators of agricultural experience and population mobility.

For PSS, 83 percent of the respondents identified themselves as the original allotees or successors in the highland area, while slightly less did so for the lowland areas (Appendix J, Table 1). The question was asked for both highland and lowland areas since some households have leased or transferred parts of one or the other.

The findings in Table 62 indicate that sample households were well settled in the area and probably have accumulated substantial experience in Dry Zone cultivation.

Table 62. Age, residency, and household size of PSS respondents surveyed in 1985 *yala* (n=100).

Age (yrs)	%	Residency (yrs)	%	Household Size (No. of persons)	%
25-39	22	0- 9	4	1-3	13
40-64	34	10-29	13	4-5	25
>64	44	>29	83	>5	62

General economic welfare was assessed by family size and land fragmentation. Information from field observations, particularly those of the agronomy component, indicated that most allotments had been subdivided among family and/or lessees to the point where some families cultivated less than 1 ac.

In the questionnaire, household size was defined as "the number of people with whom you generally share meals." There was no attempt to determine how many such households were currently farming a given colony allotment. Table 62 indicates the distribution of family size within the sample.

Note that statistics published by the Central Bank of Ceylon (1984) showed the average family size in Sri Lanka to be 5.2. Table 62 indicates that 62 percent of the households interviewed in PSS were larger than the national average.

Considering the size of households, a relatively low level of off-farm employment was reported. Only 21 percent of the households reported off-farm incomes, with only 2 cases where more than one family member was employed (Appendix J, Table 2).

These data, combined with the observations regarding land fragmentation, appeared to indicate a significant degree of population pressure and possible economic stress. Further information about these topics was collected by the economics and women in development components.

Literacy. In addition to information on the family, it was necessary to determine literacy rates and general exposure to media.

Agricultural extension agents and educators have expressed concern that technical information may be difficult to disseminate in areas of low literacy.

The first survey questionnaire attempted to collect detailed information on levels of schooling for each household member. However, the results were disappointing. The questions proved to be too long and laborious, particularly in large households. As a result, response rates were quite low.

In the second questionnaire, the interviewers simply asked how many household members could read well enough to read a newspaper. Ninety-seven percent of the households reported having one or more members who could do so (Table 63).

Table 63. Literacy of PSS household members surveyed in 1985 *yala* (n=100).

Literate Persons	%
1 - 3	32
4 - 5	24
> 5	41

It appeared, therefore, that the capability of households in the area to receive and comprehend printed information was not a problem. The overall literacy rate for Sri Lanka is 85 percent, one of the highest for developing nations. Data collected in this survey indicated a similarly high literacy rate for the sample.

b. Agricultural Production

It was difficult to obtain accurate information regarding agricultural production in a questionnaire survey of this type. Ultimately, questions were limited to general inquiries regarding size of landholdings, area under cultivation, major labor requirements, sources of labor, and basic implement availability. More specific information concerning agricultural practices and general economic factors was collected by the agronomy and economics components.

Tenure Status. An area of particular sensitivity was that of land tenure (Table 64). With few exceptions, land transfers in colony areas are not legal. Therefore, land fragmentation is, for the most part, illegal. There is some allowance for transferring a portion of land to offspring, but the minimum acreage for such transfer is set by law.

Considerable fragmentation of allotments has occurred, but has not been reported. Since the interviewers employed to conduct the survey were government staff, it seemed fair to assume that farmers would be reluctant to give truthful answers to questions that might be incriminating. Therefore, interpretation of questionnaire data regarding such issues as area under cultivation, status of landholder, and cultivation of reserved lands must be qualified by an awareness of potential bias.

Table 64. Tenurial status of PSS respondents reported in 1985 *yala* (n=96).

Status	Highland	Lowland
	----------%----------	
Original allotee	48	46
Successor	31	30
Lessee	6	2
Mortgagee	0	1
Reservation/encroachment	8	13
Purchased	6	6

Reported total landholdings varied considerably from the original allotment size designated at the time of settlement. Seventy-seven percent of PSS households claimed highland holdings consistent with the originally allotted 3 ac, and 70 percent of the households claimed at least the original 5 ac of lowland, as shown in Table 65.

Table 65. Size of landholdings of PSS respondents reported in 1985 *yala* (n=100).

Acres	Highland	Lowland
	----------%----------	
0 - 1	9	3
>1 - 2	10	6
>2 - 3	77	11
>3 - 4	2	10
>4 - 5	1	58
>5	0	12

In light of the high degree of land fragmentation which exists in the area, it was logical to assume that respondents were reporting total acreage cultivated, as opposed to reporting acreages cultivated by themselves personally. Data from the agronomic, economic, and women in development components indicated that much of the allotments cultivated was leased, mortgaged, or given on *ande* or to relatives of the allotment holder.

Nearly all households (95 percent) reported lowland cultivation for 1985 *yala*, either in paddy or field crops, which indicated a high intensity of land use even in water-scarce *yala* (Table 66). In highland holdings, 37 percent of the PSS households reported some cultivation (Table 67).

While field observations indicated that some of the highland cultivation was paddy (which is against Irrigation Department regulations) no attempt was made in the questionnaire to determine the extent of this practice. Field observation and cropping pattern data from the

other research components should yield more reliable data on this subject than could be obtained through interviews.

Table 66. Extent of paddy cultivation by PSS respondents for 1985 yala (n=99).

Acres	%
0 - 1	6
> 1 - 2	8
> 2 - 3	13
> 3 - 4	12
> 4 - 5	53
> 5	8

Table 67. Cultivation as reported by PSS respondents for 1985 yala (n=90).

Location	%
Lowland	95
Highland	37

Tentative conclusions are suggested by the data. The relatively high population growth rate and family size, combined with the lack of off-farm employment, appeared to contribute greatly to land fragmentation and the cultivation of reserved lands. Key informant interviews supported this conclusion. In community meetings, it was frequently suggested that reserved lands currently cultivated should be legalized in the event of a rehabilitation project.

Labor Demand. Although household economics were primarily investigated by the economics component, a few general observations concerning labor demand were made by the sociology component.

A significant amount of difficulty in obtaining accurate economic data during the interview was noted due to the format used. Respondents were frequently reluctant to give out such information fearing that it would be used for purposes such as tax collection. Another possible bias was that some farmers, in anticipation of future government assistance of some kind, formulated their responses accordingly.

An attempt was made to determine peak labor demand periods in the crop cycle and to measure in a general way the degree to which labor utilized in the various periods was family or "outside" labor. The five crop management stages identified were land preparation, transplanting (or broadcasting), weeding, application of agro-chemicals, and harvest. In examining the labor data, observations indicated that the heaviest demand periods for labor were land preparation, weeding, and harvest. In fact, farmers expressed difficulty in concluding their

land preparations within the announced irrigation schedule. Further discussion concerning this topic follows in the section titled "Farmer Preferences for Future Rehabilitation" (page 148).

A final, general economic concern was the availability of capital goods. Farmers were asked about any problems in obtaining and using implements or draft power. The results, given in Table 68, indicated that the biggest problem was coordinating the availability of water and labor with the availability of implements or draft power. Responses "can't obtain when needed" and "delay in water supply," which represent two somewhat different aspects of the same timing problem, together comprise the majority of responses. The other major factor reported was the cost of ownership or use of implements or draft power.

Table 68. Problems concerning implements and draft power for PSS respondents in 1985 *yala* (n=46).

Type of Problem	Frequency	Relative %
Can't obtain when needed	12	26
Delay in water supply	19	41
Lack of money	14	30
Other	1	2

Difficulties in coordinating labor, implements, draft power, and water issues may represent a large part of the problems involved in following the schedules set by the Irrigation Department. The period of continuous flow needed for land preparation emerged as a major issue for any future rehabilitation. Indications were that the current water supply schedule for land preparation may need revision.

c. Water Management

A considerable portion of the sociology research dealt with describing and analyzing the current irrigation system as a management organization. Note that not only will the physical structures of the system be affected by rehabilitation, but also the formal and informal arrangements that have emerged over the years for the purpose of managing irrigation water. In formulating recommendations concerning future institutional arrangements for water management, and in assessing the potential impacts of recommended changes, it is necessary to first document the current management practices of farmers and the Irrigation Department.

The following discussion is divided into four parts. After a brief description of the irrigation system itself and a summary of water problems experienced by farmers, focus is given to current procedures for water distribution, system maintenance, and settling disputes.

Description and Problem Identification. The physical system of PSS may be described as follows. Sluices from the tank deliver water to main canals, which deliver water to distributary channels, which

deliver water to field channels. Farmers receive water through turnouts from the field channel into their allotments, with usually one turnout for each allotment.

In preliminary conversations with Irrigation Department personnel, the irrigation system was described in this summary fashion. Included in these discussions were references to standardized rotation schedules based on acreage figures and a standardized mode of operations which designated the respective duties of technical assistants, work supervisors, patrol laborers and vel vidanes.

Of course, this does not mean that Irrigation Department administrators and other government officers with whom we spoke were unaware of departures from this model. It was generally recognized that there were numerous places where the system was uniquely constructed or managed depending on local physical or social characteristics. One of the objectives of the second questionnaire, therefore, was to investigate to what degree discrepancies existed, and the nature of those discrepancies. For that reason, as well as an interest in formulating a description of the system as farmers see it, a series of questions were focused on system organization and structure.

An opening question in this series ascertained the number of authorized allotments on the field channel serving the respondent's farm. The responses were consistent with the length of the field channels in PSS, with 63 percent of the farmers reporting up to 10 allotments on a field channel; the remaining 37 percent reported more than 10 (Appendix J, Table 3).

Of more interest was the set of responses to questions regarding the source of water available to the allotment and the position of the allotment within the system (Table 69). Thirty-six percent of the PSS sample reported that water for paddy fields was received directly from distributary channels. The relevance of such information is clear: 36 percent of the PSS sample did not depend upon field channel deliveries and, therefore, may not be involved in field channel maintenance.

Table 69. Water sources for allotments of PSS respondents in 1985 yala (n=102).

Main Source	%*	Alternative Source	%
Distributary channel	40	Drainage	33
Field channel	56	Combined sources	3
Other fields	6	Other sources	3
Drainage	1	None	61
NR**	1		

*Multiple respones were possible.
**Non-response or not relevant.

It could not be accurately determined to what extent the distributary channel outlets were illegal, but there were reasons to believe that many were legitimate. It is commonly recognized by the Irrigation Department that it is difficult to get water to certain

allotments due to the topography of the land or to original design problems in the system. The Irrigation Department has issued permits for such allotments to take water directly from main conveyance channels. Also, in some areas the original design allowed for certain allotments to take water directly as the most logical option. Finally, it is unlikely that farmers would have reported themselves as illicit tappers to interviewers who were government employees.

When asked whether or not there were alternative or supplementary sources of water for their paddy fields, 39 percent of the respondents reported affirmatively. Of these, the majority reported that drainage water from drainage channels or from neighboring fields was their alternate water source (Table 69). For 26 of 40 households, such water was available throughout 1985 yala.

The current allocation by rotation does not automatically constitute an equitable distribution of water to farm allotments. Farmers cannot be viewed as enjoying equal access to water if some enjoy more advantageous positions than others in relation to main system water flows or drainage water.

A few questions were asked concerning cultivation of reserved lands. In the first questionnaire, 54 percent rated reservation encroachment as a serious problem. In fact, 23 percent responded that encroachment caused specific problems in obtaining sufficient water for their fields.

When asked whether or not they experienced any water allocation problems during 1985 yala for their paddy crops, 53 percent of the respondents responded affirmatively. Table 70 reports the type of water problem most frequently encountered by these households.

Table 70. Water problems experienced by PSS respondents during 1985 yala (n=54).

Type of Problem	Frequency	Relative %
Shortage of water	40	74
Timing of delivery	3	5
Excess water	8	15
Combined reasons	1	2
No details	2	4

These responses suggest that nearly half of the PSS allotments experienced water shortages. When asked to give the reason for such shortages, a majority gave multiple reasons including illicit tapping, rotation problems, weeds, and damaged structures. Further probing was conducted concerning the issue of damaged field channels. For the PSS sample, 59 percent reported that such damage was frequent, caused primarily by tractors and buffalo. A majority agreed that more damage occured in maha. Respondents indicated that this damage was generally repaired by individual farmers, as shown in Table 71.

Table 71. Methods of repairing damaged field channels reported by PSS respondents in 1985 yala (n=102).

Method	Relative %*
Individual farmers	41
Shramadana	12
Irrigation department	14
Farmer hires labor	1
Farmer group hires labor	1
Other	1
Not Damaged	25

*Multiple responses were possible.

When asked if individuals responsible for damage to structures were ever punished, 88 percent responded negatively. The issue of punishment for damages, as well as for illicit tapping and breaking rotation, is discussed more fully in the following sections on water distribution, settling disputes, and farmers' preferences for future development of irrigation organizations. A repeated complaint expressed at the kanna meetings and other farmer meetings was that nothing can be done by the farmers themselves about damages to irrigation structures, nor can damage and encroachment onto reserved land be controlled by vel vidanes.

Water Distribution. This section attempts to construct a picture of the current effectiveness of water distribution in meeting crop needs throughout the season, as viewed by the farmers.

At the beginning of each season, a kanna (pre-cultivation) meeting is held by government officials and farmers to discuss water availability and allocation procedures for the season. Farmers are informed of the first and last dates of water issue and are given the schedule for the season as set by the Irrigation Department. This schedule includes the dates for starting land preparation, cleaning field channels, removing tractors and cattle from the fields, and the beginning of the rotational water issue.

The kanna meeting is intended to represent a joint agreement between the Irrigation Department, farmer representatives, and farmers over allocation procedures at the primary tank level of the system. However, observations at these meetings indicated that the role of the farmers and their representatives in setting the schedule was minimal. While a number of complaints may have been aired on the part of the vel vidanes in attendance, the proceedings and content of the meeting were established in advance and were not noticeably affected by such comments. To be realistic, however, it would be difficult to respond to these complaints within the format of the kanna meeting. The current formation of project committees and subcommittees under the MLLD is an attempt to create a situation where officers and farmer representatives can consult with each other in a more constructive atmosphere.

Sixty-seven percent of the households in PSS stated that the water issues followed the schedule given at the kanna meeting. For those farmers who stated that kanna schedules were not followed (33 percent), the most frequent explanations given were: 1) no action was taken in response to persons who break the rules, and 2) the Irrigation Department did not issue water as stated in the kanna meeting. The first statement seems to reflect a general frustration with the Irrigation Department's difficulties in enforcing the joint agreement made at the kanna meeting.

In the 1985 yala survey, farmers were asked a series of questions concerning the lines of responsibility for administering water allocation along distributary and field channels. Farmers were also asked whether the distributaries and field channels were operated under continuous flow or rotation schedules. Responses were contradictory and confusing, with farmers reporting both rotation and continuous flow along the same field channel or distributary, and there was a high level of disagreement over the role of the vel vidane and the Irrigation Department officers respective to setting and administering rotation schedules and water distribution generally. (See Appendix J, Tables 4-7). There were also a high number of missing cases, listed as either "non-response" or "not relevant." This may be due to problems with the questions themselves (i.e., terminology), or because farmers who do not obtain their water from field channels felt the question was irrelevant to them, or because the questions were perceived as sensitive (someone could be accused of not administering the rotation correctly).

Key informant interviews, community meetings, and field observations following the initial survey further revealed that there were few, if any, working field channel headgates in the research areas. Therefore, questions pertaining to control over these headgates were invalid. It also became clear that there were no regular "rotations" as such, either along the field channels or between field channels.

As perceived and reported by the farmers, the respective roles of the vel vidanes and Irrigation Department personnel were not clearly or consistantly defined. This may be partly because farmers in different areas have different experiences, in both the physical condition of their channels and in their particular relationships with irrigation administrators.

In the PSS sample, 50 percent of the households reported that they received no prior notification of changes in the rotation schedule (Appendix J, Table 8). In addition, and a factor which may add to the uncertainty faced by the farm household, nearly a third of the sample (29 percent) reported that farmers frequently took water out of turn without authorization.

Farmers were asked if they knew the names of the Irrigation Department personnel responsible for distributary channel operations throughout the year. These personnel were civil service employees, many of whom had worked in the area for a considerable time. In PSS, 80 percent of the respondents did not know the name of the work super-

visor, and 55 percent did not know the name of the patrol laborer responsible for their area.

However, it has been frequently observed and reported that farmers often do not know the name of government officers, even when they are quite familiar with them. Perhaps more important, therefore, than lack of name recognition, is the lack of awareness by farmers of the activities of these officers in their area. Of the households surveyed, 79 percent said that the patrol laborer ought to make more visits to their area. Thirty-five percent of the households reported seeing the patrol laborer more than once a month. Only 20 percent reported seeing the work supervisor more than once a month.

However, when asked whether or not the Irrigation Department needs to hire more patrol laborers and work supervisors, 68 percent of the households responded that such additional hiring was not necessary. A possible interpretation may be that farmers felt Irrigation Department personnel should be more active in their jobs, rather than perceiving the Department as short of personnel.

When asked about the major problems faced by the vel vidane, 78 percent of the households either did not know or stated that the management area was too large for the vel vidane to cover (Appendix J, Table 9). However, 51 percent of the sample reported that the vel vidane worked well with farmers and the Irrigation Department (Appendix J, Table 10).

This survey indicated that some confusion over distribution procedures existed. Farmers were not reluctant to point out the minimal role they play in establishing or changing such procedures. That a large number of farmers reported no advance notification of schedule changes was particularly troublesome since farmers depend on the predictable timing of water deliveries in order to respond to paddy and field crop needs.

Key informant interviews helped the sociology component to construct a more detailed picture of local water distribution. In PSS, the key people responsible for water distribution in the Irrigation Department were work supervisors and patrol laborers, who hold civil service pension positions. Vel vidanes were expected to assist the Irrigation Department when requested, and to insure the cooperation of farmers in the distribution of water.

Typically, the work supervisor monitors the activities of the patrol laborer, who is responsible for opening and closing branch and distributary channel headgates in a designated area. In most cases, vel vidanes are responsible for distributing water after it flows through the distributary channel headgate. Any locked field channel headgates are controlled by patrol laborers; very few locking gates exist. Most field channel headgates are currently inoperable.

The role of the vel vidane assumes importance at the field channel level. He is expected to supervise water delivery within the field channel and to deliver water equitably to allotments by supervising

check structures and removing obstacles in the field channel. Since, in many instances, he is also in charge of the field channel headgate (which he controls using check structures), he must allocate water between field channels as well. While that is not the official policy, the logistical constraints experienced by patrol laborers and work supervisors have made this additional role of the vel vidane necessary.

Vel vidanes do not possess keys to locks on branch or distributary headgates and have no official enforcement powers. The current role of the vel vidane is to seek cooperation between farmers along a distributary channel or within a field channel so that they will adhere to informal water exchange agreements and refraining from tapping water illegally.

The main task of the vel vidane is to keep the water pressure at turnouts as high as possible to serve the farmers' needs. If tail farmers do not receive sufficient water pressure, he is expected to adjust the check structures to increase pressure at the tail. However, there are no formal rules of distribution at the field channel level, and vel vidanes do not have enforcement powers to prevent the loss of water pressure due to the unwillingness of certain farmers to cooperate.

Note that there are only informal arrangements for exchanging water along or between field channels. There are no regular, patterned "rotations" as the word is normally interpreted. Therefore, key informant interviews and field observations at least partially clarified the picture depicted in Table 4 and 5 (Appendix J), indicating that the farmers may have been confused by the language of the questions. Also, Tables 6 and 7 (Appendix J) may further demonstrate this confusion, as indicated by the contrast between the roles reported in the questionnaire findings for vel vidanes and the Irrigation Department, as compared to those reported in key informant interviews and as witnessed in the field.

Neither the vel vidane nor Irrigation Department personnel were in a practical position to enforce rotation schedules. In informal discussions, vel vidanes, patrol laborers, and farmers reported that rotations were often broken at night. Patrol laborers were prohibited from working after 4:30 p.m. Although vel vidanes may observe the breaking of rotation schedules, they do not have the power for enforcement, and witnesses are typically unwilling to come forth.

Vel vidanes argued that it was the responsibility of the Irrigation Department to supervise structures on Irrigation Department property. All vel vidanes reported that the property of the state extends to the allotment turnout. No structure can be tampered with or improved by vel vidanes or farmers without authorization from the Irrigation Department.

If water shortages occur during the season, the vel vidane reports to the patrol laborer, who then notifies the work supervisor. As long as the resolution of the problem does not involve adjustments on main canals, the work supervisor is usually authorized to make headgate

adjustments after personally observing the water shortage problem. Sometimes he delegates such adjustments to the patrol laborer. However, work supervisors frequently like to consult with their technical assistant before changing any headgates.

Discussion during the community meetings frequently centered on the equity of current rotation schedules specified by the Irrigation Department. Farmers did not appear to oppose rotational deliveries, but were frequently critical of how they are decided upon and supervised.

At the same time, many farmers voiced the opinion that continuous flow delivery would waste water and that a properly designed and supervised rotation was much better. However, frequently farmers stated that current rotation schedules caused problems during certain periods of the season. Reliable timing in water distribution is needed during fertilizer application and during stages of paddy growth which require continual submergence.

Some farmers need more water than others because there is great variability in the proportion of well-drained and poorly-drained soils in individual allotments throughout the system. Rotation schedules tend to treat all farmers equally with regard to water needs, but this is not the case in reality. Farmers would like to see the development of rotation schedules that better serve this variability.

In some areas, farmers have turned to exchanging water between field channels within the rotation of a particular distributary channel. Such water exchange, most frequently administered by the vel vidane, maximizes delivery flexibility. Such informal water exchanges were the only means available to tailor rotation schedules to fit timing requirements throughout the season. At some community meetings, the consensus was to formalize exchange rules after rehabilitation. At other meetings, the consensus was that water pressure would greatly improve after the rehabilitation, thus alleviating the need for informal or formal water exchanges.

Structural damage to the conveyance channels contributed greatly to reduced water pressure, causing problems for tail farmers and those farmers with a greater percentage of well-drained soils. Furthermore, headgate damage and leakage frequently meant that farmers in the head region received water continuously from main conveyance channels between rotation deliveries to their areas. Tail farmers viewed this as a waste of water, which contributed to their negative feeling about equity in water distribution and the Irrigation Department's supervision of irrigation schedules.

All meetings brought out the problem of assuming that all farmers can start preparing land on the same date. The seasonal kanna meetings specified dates when farmers should commence and complete land preparation, and the irrigation schedule was fixed accordingly. Farmers at the middle of the system were frequently forced to wait at least 10 days for water to reach them, while farmers at the tail frequently

waited as long as 3 weeks. This results in a staggered cultivation season that does not correspond with the irrigation schedule.

Overall, farmers felt they have many valuable suggestions to offer to the Irrigation Department regarding scheduling, and would like the opportunity to contribute their knowledge for better water conservation and management.

System Maintenance. Households in PSS sample area were asked how they felt about the current operation and maintenance (O&M) fees collected. A total of 52 percent responded that they were not satisfied. The reasons for dissatisfaction are presented in Table 72.

Table 72. PSS respondents' reasons for dissatisfaction with O&M fee collection in 1985 *yala* (n=50).

Reason	Frequency	Relative %
Unreasonable fee	25	50
No idea how money will be spent	6	12
Payers and non-payers treated alike	3	6
No response	16	32

The responses of individuals concerning the maintenance of distributary and field channels are reported in Table 73. Most households viewed the distributary channel as the responsibility of the Irrigation Department, but this perception was far from unanimous. A large number reported the distributary channel as a responsibility of both farmers and *vel vidanes*.

Table 73. Responsibility for distributary and field channel maintenance reported by PSS respondents in 1985 *yala*.

Individual	Distributary Channel (n=100)	Field Channel (n=83)
	Freq*	
Irrigation Deparment	63	8
Individual farmers	32	62
Vel vidane	15	25
No one	7	
Farmer organization	4	0
Shramadana	0	9
Cult. officer	1	
Influential farmers	1	
Tail farmers		4
Farmer group hiring labor		1
No response	2	19

*More than one response was possible. A blank indicates the category was not present for the question.

On the other hand, respondents clearly believed that farmers and vel vidanes were primarily responsible for maintaining the field channels. Only a few reported that this should be a responsibility of the Irrigation Department.

The Irrigation Department expects that farmers will assume responsibility for cleaning the field channel below the field channel headgate. This request is made formally at the kanna meeting, and fines can be levied on holders who do not comply. While legally the Irrigation Department and the vel vidane have the ability to enforce this request, practically speaking it is very difficult. Again, constraints in funding and personnel, plus the community's desire to avoid involvement by the district police and courts, severely restricts enforcement.

In contrast with the findings of the questionnaire, (Table 73), farmers at community meetings agreed that the Irrigation Department was solely responsible for distributary channel maintenance. When funds are available from the Irrigation Department, the work superviser oversees the cleaning of distributary channels. When repairs are needed on distributary channels, an estimate for work is made by the technical assistant and submitted to the Irrigation Department. If approved, concrete work is performed by local contractors or Irrigation Department laborers under the supervision of technical assistants and work supervisors. Irrigation Department personnel often complained that farmers damage structures, making it difficult to keep up with the work. However, vel vidanes and farmers complained that the maintenance work was poorly supervised and misappropriations occurred.

PSS currently experiences a loss of water pressure throughout the system due to damaged check and drop structures, breached bunds, leveling problems, and broken headgates. The Irrigation Department, as custodian of this property, stated that it has an insufficient budget to keep up with the needed work. Therefore, the Irigation Department requested a maintenance fee of Rs. 100/ac/year from farmers in 1985 yala. Vel vidanes stated that all farmers would be willing to pay the fee if: 1) they see the money spent in the distributary channel area where the fee was collected, 2) the money is spent on maintenance within a reasonable period of time, and 3) supervision of the work is improved.

At all of the community meetings, farmers expressed concern about the supervision of maintenance activities done by the Irrigation Department. Farmers acknowledged that the Irrigation Department has an enormous task in maintaining miles of distributary channels with very little maintenance money to perform this task. However, they felt that proper supervision of work crews and contractors would contribute greatly to improving the system. Most farmers expressed uncertainty about future rehabilitation work being done by the Irrigation Department without improved supervision of maintenance work.

As an alternative, farmers expressed a strong willingness to help the Irrigation Department monitor work crews and contractors through local farmer boards or organizations. They also expressed a desire to

have local organizations that would be legally chartered with a set of by-laws to manage a budget and to accept bids from contractors for work in the organization's area. Farmers preferred a distributary channel organization, rather than one limited to the field channel, since an organization of this size could collect enough O&M fees to support local operation and maintenance activities once the future rehabilitation was completed.

Settling Disputes. Throughout the season, water shortages often cause problems between community members over equity in allocation. An attempt was made in the survey to evaluate the settlement of disputes and punishment procedures in the event that a water distribution rule was broken.

Households were asked where water problems were most frequently reported, as well as the identity of the person who was ultimately responsible for resolving disputes. Clearly, vel vidanes held the most important position in the community with regard to arbitration over water disputes (Table 74).

Table 74. Responsibility for dealing with water problems as reported by PSS respondents in 1985 yala.

Individual	Contact (n=95)	Resolver (n=86)
	Frequency*	
Vel vidane	75	70
Cultivation officer	15	19
Work supervisor	25	10
Government agent's office		11
Technical assistant	5	
Member of Parliament	2	
Colonization officer	9	
Police		6
Others	6	5

*More than one response was possible. A blank indicates that the category was not present for the question.

Farmers were asked a series of questions regarding their preferences for change in the procedure for settling disputes. Among the questions presented were two concerning the level of authority or power currently held by the vel vidane.

When asked if the vel vidane had sufficient power to settle disputes, only 26 percent said no. When asked if the vel vidane needed more authority to settle disputes, only 34 percent said yes.

However, these responses did not correspond well with farmer complaints concerning the lack of punishment for damages to the field channel or for taking water out of turn. Not only were such complaints common at farmer meetings and kanna meetings, but in the PSS sample 96 percent of the respondents reported no punishment for field channel

damage, and 94 percent reported no punishment for breaking the rotation.

Given the reluctance of the sample farmers to grant more authority to the vel vidanes for administering such punishment, it might be assumed that they would rather see such matters handled in a different fashion. This issue and other farmer preferences for change are discussed further in a following section.

In the key informant interviews, both Irrigation Department personnel and vel vidanes stated that they are not empowered to enforce punishments against farmers for the typical offenses that occur during a season. These offenses included taking water out of turn, irrigating reserved lands, and damaging conveyance channels with cattle and tractors. All such offenses seriously contributed to the loss of sufficient water pressure and equitable distribution during critical periods of crop growth.

The vel vidanes, patrol laborers, and work supervisors were not empowered to settle disputes over water. Violations were usually reported to the Irrigation Department. The Irrigation Department argued that it does not have the police power to settle disputes or punish violators.

Irrigation Department personnel stated that it was not their duty to resolve disputes -- that this should be the responsibility of farmer representatives. Cases may be referred to the police courts, but it is difficult to secure witnesses for violations. Vel vidanes argued that farmers and other vel vidanes were reluctant to act as witnesses in court against fellow community members. Vel vidanes argued that a "neutral organization" was needed to relieve community members from punishing their own neighbors.

The current inability to settle disputes effectively was a major issue at all community meetings. Farmers acknowledged that the lack of an effective organization to punish irrigation ordinance violations greatly contributed to the poor condition of the irrigation system. Farmers felt helpless in the face of the current adjudication procedure, which was time consuming, sometimes required expensive legal council, and frequently involved unwanted interference by influential individuals and groups outside the village community.

At many meetings, farmers expressed a desire to have violators punished by a formally chartered organization or a local water court which would handle irrigation violations exclusively, and where a farmer organization could bring charges against individual violators. Such an organization would make unnecessary the current situation in which individual community members are asked to stand as sole witnesses against neighbors in district courtrooms.

d. Farmer Preferences for Future Rehabilitation

The final major concern of the sociology component was investigating farmer preferences for future organizational development. Informa-

tion was gathered on farmer preferences for project committees, system maintenance, and settlement of disputes.

Project Committees. Although there were no formal organizations responsible for water management between the main tank and individual allotments, a recent attempt was made by the Ministry of Lands and Land Development to organize irrigators for increased participation in regular management and maintenance activities. This program is the Integrated Management of Major Irrigation Schemes. It has been welcomed by a majority of irrigators.

The new organizational design has a federation of smaller committees at the field and distributary channel levels, which are then represented on a central committee at the irrigation scheme level (the project committee). A project committee is chaired by a project manager appointed by the MLLD. Individuals selected as project managers may be agricultural agency personnel who have lived in the local area for some time, or new government officers assigned from outside the area.

Questions in the third sociology questionnaire were designed to evaluate farmer awareness of project committee and subcommittee activities. Examination of household expectations revealed considerable confusion regarding the function of project committees. When asked whether or not the project committee or the subcommittee of their irrigation scheme would be responsible for adjudicating disputes over water, 56 percent reported that this was an expected role (Appendix J, Table 11). Officially, however, the program has no procedure for adjudicating disputes, nor do project committees and subcommittees have the legal capacity to punish irrigation ordinance violators.

The question was then asked if the project committee or sub-committee was expected to make decisions about water rotation scheduling. In this case, 62 percent of the sample responded affirmatively (Appendix J, Table 11). Again, there are no specific plans for this to occur (although it may be the general intent in the long term). Currently, project managers and subcommittee presidents are not authorized to adjust rotation scheduling.

Finally, households were asked if they could identify their subcommittee president. Seventy-six percent of the PSS sample did not know the subcommittee president's name. More importantly, when asked how the subcommittee presidents were selected, 74 percent of the PSS sample responded that they did not know (Appendix J, Table 12). Nine percent said the presidents were selected by officials. This is significant since subcommittees are supposed to comprise local farmer representatives, who are elected by farmers, and who in turn elect the subcommittee president.

When asked about participating in the election of their field channel representatives, 69 percent of the respondents reported involvement. This may not be an accurate indicator of actual involvement, however, since many of the local representatives were vel vidanes who were elected in a previous organization program administered by the

government. There may have been considerable confusion as to whether the election discussed was the election of vel vidanes or the selection of a local representative to the new program.

In general, the PSS sample households expressed a relatively low level of awareness of the project committee program and its procedures. Thirty-three percent of the PSS sample households stated that they knew nothing about the program. However, note that PSS experienced a rapid turnover of project managers (three project managers in three years, and one of these was part-time). This factor, combined with the relatively new status of the program itself, must be kept in mind when evaluating farmer awareness.

During community meetings, farmers frequently stated that subcommittee presidents were appointed by government officials and that no elections were held. This appears consistent with other organizational formats attempted in the past where government officers or members of Parliament recommended appointments to local farmer boards or committees. Farmers continue to be presented with organizational formats of this kind, representing little real autonomy from influences outside the community.

System Maintenance. Operation and maintenance fees were collected by colonization officers of the Land Commissioner's Office, with assistance from vel vidanes. A project committee and its subcommittees are responsible for submitting requests to the Irrigation Department for maintenance work. Irrigation Department personnel are responsible for making estimates, scheduling, and supervising the maintenance work.

It is expected that in the future, field and distributary channel committees will assist in supervising maintenance activities and may be empowered to contract the work where appropriate. In the long term, Ministry officials hope to see an increase in farmer involvement in irrigation management beyond the current advisory level.

Farmers expressed some dissatisfaction with the current organization of maintenance in which the work supervisor is hired and supervised by the Irrigation Department. Households were presented with two options for directing work supervisors. One represented the current situation, while the other relied on greater farmer input. The results are given in Table 75. Nearly 70 percent of the PSS sample preferred to increase farmer input.

Table 75. Preferences of PSS respondents concerning work supervisors, 1985 yala (n=102).

Method	%
Hired and supervised by Irrigation Department	32
Hired by Irrigation Dept., but supervised by local sub-committee or farmer organization.	68

Another set of farmer preferences involved expenditures of O&M fees for maintenance. Farmers were asked how the money collected since 1984 should be divided, if at all, between main system maintenance and the local area from which the fees were collected, with the results reported in Table 76. While responses covered a wide range of possibilities, the most popular scenario was a 50 percent split in fees, with the greater portion going to the local area where the fees originated.

Table 76. Preferences of PSS respondents concerning O&M fee disbursement for maintenance, 1985 *yala*.

O&M Fees Returned (%)	Main System (n=102)	Local Area (n=102)
	%	
<50%	75	10
>50%	25	90

Settling Disputes. In key informant interviews and community meetings, farmers expressed many ideas about the type of organization they would like to have in the area. They argued that an organization must be able to adjudicate disputes fairly and punish violators within an acceptable period of time.

A series of questions attempted to clarify the role of the *vel vidane* in settling disputes. Farmers were asked whether they favored continuing the current *vel vidane* system under the supervision of Agrarian Services, or preferred to form local, chartered, water user associations which would hire their own "agent manager" to distribute water locally. Seventy percent of the PSS sample households preferred to have an association hire its own manager.

The sample households were also asked whether or not local water user associations should be given the legal capacity to punish offenders, rather than relying on existing enforcement agencies. Ninety-four percent responded affirmatively. When asked if it would be appropriate to temporarily withhold irrigation water from an offender as punishment, 78 percent replied that such punishment would be appropriate.

During several of the key informant interviews with *vel vidanes* and retired Irrigation Department personnel, mention was made for the need of a local water court. Similarly, at the community meetings, the idea of a local water court whose only role would be to adjudicate disputes over water and punish offenders was mentioned several times. At most meetings, farmers felt that irrigation ordinance violations could not be effectively adjudicated through the District Court. Many cases do not come to trial for a year or more after the offense, and punishments are generally not effective.

4. CONCLUSION AND RECOMMENDATIONS

Three questionnaires were administered to sample farm households covering the topics of water distribution, system maintenance, settling disputes, and preferences for change in the management system. Key informant interviews with work supervisors, patrol laborers and vel vidanes were conducted. In addition, community meetings with farmers were conducted to gain a greater understanding of water management issues and farmers' perceptions concerning the proposed rehabilitation of the irrigation system.

Parakrama Samudra Scheme exhibited a generally homogeneous population with no major social cleavages that could adversely affect a rehabilitation effort. However, district population growth was higher than the national average, and sample households were relatively large. Off-farm employment was low, with only one-fifth of the households reporting regular off-farm incomes, generally from just one family member.

These factors appeared to contribute greatly to land fragmentation and the cultivation of reserved lands. Farmers preferred that reserved lands currently cultivated be legalized in the event of rehabilitation and taxed in the same manner as allotted lands.

Data collected in the survey indicated a high literacy rate for the area, similar to that of Sri Lanka generally. It appeared that the capability of households in the area to receive and comprehend printed information, including agricultural extension materials, would not be a problem.

Some farmers reported a repeated inability to start or complete land preparation within the designated schedule of the Irrigation Department. This was largely due to the time required for water to become available in outlying reaches of the system, as well as the competitive demand for available labor and draft power. The current 30-day period of continuous water issue simultaneously to all parts of the system appeared problematic. However, the Irrigation Department was not able to effectively issue water to individual segments of the system due to the difficulties in preventing taking water illegally.

Over half of the households reported water problems during the 1985 yala paddy cultivation, and most described the problem as a water shortage. Further, farmers complained that the current rotation system at the local and main system levels was unable to deliver water equitably. Reduced flow rates and pressure loss due to deteriorated channels and structures were reported as reasons for inequitable delivery. However, farmers recognized the difficulties facing the Irrigation Department in monitoring such a large and complex system.

Farmers generally favored a rotation system after land preparation, rather than use of a continuous flow delivery schedule. However, they were concerned about the manner in which the rotations were scheduled, with little farmer input. Increased flexibility in rotation

was cited as a way to improve timing of deliveries and to adjust for different soil conditions.

Further, farmers were concerned about a lack of proper supervision of the rotation, which resulted in illicit tapping and unannounced changes in the delivery schedule. The vast majority of PSS sample households favored increased patrol laborer visits.

When given a choice, farmers strongly favored forming formally chartered local organizations, with the authority to hire a manager for local water distribution. This idea received a more favorable response than allocating increased authority to local vel vidanes.

Roughly half of the households surveyed expressed dissatisfaction with the O&M fees currently collected under the project committee format. The main concern was whether or not the money would be spent locally. Most households favored a split of O&M funds, with the majority of the money allocated for local system repairs and maintenance. Awareness of the project committee program was relatively low. However many respondents were pleased with the idea of increased farmer participation, which they hoped would result.

The concern over local allocation of funds coincided with a concern about supervision of maintenance work. Farmers stated that while the Irrigation Department is clearly the best agent for constructing larger structures and managing main system water, the Department cannot be reasonably expected to manage the entire system, especially at the local level. Vel vidanes, work supervisors, and patrol laborers who were interviewed agreed. They expressed particular concern over supervision of construction undertaken in any future rehabilitation effort.

Many farmers attending community meetings stated that local organizations could be formed to raise funds, contract for maintenance and minor construction work, and supervise the work to ensure quality. It was also suggested that these organizations could assist the rehabilitation effort by helping to monitor construction work in their areas. However, farmers also stated that such responsibility should not simply be handed over. To prevent mismanagement of resources and to enforce organizational procedures, a charter and set of by-laws would be needed. Examination of current programs of institutional development in Sri Lanka might give some insight concerning this issue.

Finally, nearly all farmers interviewed stated that damage to channel structures and violations of the rotation go unpunished. This was a major concern, since these problems were cited as major reasons for water delivery shortages. However, local Irrigation Department officers and vel vidanes currently have no effective method for enforcing regulations. In the absence of a community court system, the individual is forced to report offenses to the District Court. Proceedings are time consuming, expensive, and subject to political influences outside the community.

Many vel vidanes, and the majority of farmers, favored forming a local water court or using local farmer organizations to enforce irrigation regulations. The majority stated that the Irrigation Department has not been given adequate resources to do so themselves.

Analysis of the data led to a recommendation that further attention be given to the issue of increased farmer involvement in water distribution, decision-making, and operations. Alternatives for increasing involvement should be examined based on current experiences in Sri Lanka and other countries. This examination could include looking at alternative construction and maintenance procedures; e.g., contracting with farmer groups rather than local contractors, encouraging participation of farmers in monitoring construction work, and consulting with farmers on appropriate repairs for their local areas.

Finally, exploration of alternative methods of dispute resolution emerged as a primary concern. As discussed in the report, damage to structures and breaking rotations were major issues expressed by farmers and officials. The current procedure requires community members to act as individuals in reporting and testifying about violations -- a requirement which violates local cultural values and customs. An alternative procedure that allows community members to act as a group, such as in a local tribunal or through a board of farmer representatives, might help alleviate this problem.

F. WOMEN IN DEVELOPMENT

1. INTRODUCTION

In Sri Lanka, the national government and international donors such as USAID are increasingly promoting the development and improvement of irrigation systems, large and small alike, as a means for increasing agricultural production. Parallel to this is a greater awareness of the importance of women's roles in agricultural production. Despite the noticeably greater attention given to farm women in recent development projects, understanding women's roles in irrigated agriculture and their interaction with the irrigation system is minimal.

Therefore, a component relating to women's roles in an irrigated agricultural production system was included as a part of the Diagnostic Analysis Project. The women in development (WID) component sought to gather the following specific information:

1. Sex-disaggregated data relating to:

   *agricultural activities and decision-making associated with irrigated crop production.
   *household activities, especially domestic water and firewood procurement.
   *decision-making associated with the household.

2. Sources of and access to agricultural information for women, as well as needs and requests of women.

3. Perceptions of women concerning agricultural and field irrigation problems and their involvement in seeking solutions.

4. The role of women in highland productivity:

   *home gardening
   *permanent tree crops
   *livestock

5. The income and expenditure patterns and preferences of the household, including the role of women in family resource management.

6. The participation of women in community organizations and informal groups, with particular attention to water user associations and <u>kanna</u> meetings.

7. The settlement experience of women, levels of satisfaction, and personal views of improvements.

The study made an effort to cover many broad topics of interest, and was basically exploratory in nature. It was not expected that all questions relating to women's roles in irrigated agriculture would be

conclusively answered, but that important and significant areas would be identified. Information from the study was aimed toward providing the Diagnostic Analysis Project with an additional dimension to understanding the complex operation and interaction of the irrigated agricultural system and the farm household.

2. METHODOLOGY

a. Sample Selection

The Parakrama Samudra Scheme was chosen by the Diagnostic Analysis Project for investigation during the 1985 yala. The head, middle, and tail sites on the irrigation system were chosen by the engineering and agronomy components to represent expected hydrological differences. In addition to these sites, the economics, sociology and WID components surveyed other areas with above average availability of water and areas with restricted or limited availability of water.

While hydrological locations may exhibit significant social and economic differences, correlation was determined to be less important for the WID component than for disciplines such as engineering. Therefore, only data specifically relating to water or irrigation constraints were analyzed according to hydrological location by the WID component.

The sample was composed of farm households with field allotments from head and tail field channels on the distributary channels named in Table 77. Weera Pedesa is somewhat of an exception. It was not originally designed as part of the PSS settlement, but was later included. This site varies from the other settlement holdings because irrigation water is obtained directly from a main channel. Also, the landholding size varies from the standard allotment of the PSS settlement as this originally reserved area was encroached upon instead of allotted.

Table 77. Field sites for the 1985 yala women in development study on PSS.

	Distributary	Households
Head:	Block F of D1	19
	RB1 of D1 East	10
	Weera Pedesa	9
Middle:	RB7 of D1 North	19
Tail:	LB1/RB21 of D1 North	21
	LB2/RB21 of D1 North	10
	RB12 of D1 East	5
	RB13 of D1 East	5
Total		98

The actual number of households in PSS were unknown. However, based on the original number of allottees, and adjusted for the second generation, a sample of approximately 2-3 percent of the estimated population was obtained. Efforts were made to include only those households engaged in cultivation during the 1985 yala. However, due to the complexity of land tenure arrangements and restrictions imposed by the hydrological selection of the sample, some households that had leased or mortgaged their fields to others were also surveyed. Within each household, the selection of the female respondent was based on availability, accessibility, and the subjective opinion of the field investigator as to which family female could best provide the information required.

b. Field Investigators

Most of the seven WID investigators were previous participants in the Diagnostic Analysis Workshop conducted July 23 - August 17, 1985, on PSS. Therefore, they were familiar with diagnostic analysis concepts, interdisciplinary teamwork, and specific WID objectives and techniques. Those investigators who had not attended the workshop were exposed to this information during an interdisciplinary reconnaissance survey conducted January 3-16, 1985, on other PSS sites and on the Kaudulla Scheme. In addition, all field investigators of the WID, economics, and sociology components attended a workshop on interviewing techniques August 10-11, 1985. The close contact between WID and other team members increased awareness and improved the interviewing skills of all investigators.

The WID field investigators consisted of a variety of locally experienced personnel including: an agricultural instructor and an agricultural economic assistant from the Agriculture Department, a colonization officer from the kachcheri, an assistant rural development officer from the Ministry of Rural Development, a former Polonnaruwa community development officer, and two recent university graduates from the area. All of these personnel lived and worked in the area, providing a great deal of local expertise.

c. Questionnaires

The construction of the WID questionnaires was based largely on the two diagnostic analysis workshops previously conducted in Sri Lanka (1983--System H of the Mahaweli and 1984--Parakrama Samudra System). Individuals from the Women's Bureau and the Agrarian Research and Training Institute also contributed information and suggestions. Various offices and agencies in the Polonnaruwa District -- such as the Ministry of Rural Development, the Agriculture Department, and the kachcheri -- provided valuable information used to construct the questionnaires. Most importantly, the WID field investigators discussed the topics and formulated the questions by group participation. The translation of the questionnaires from English to Sinhala was done by the entire WID group together. Field investigators were able to practice administering the questionnaire by "role-playing" within the group, and a pre-test was conducted before each survey. The question-

naires contained a mixture of both open-ended discussion questions and specified response questions. All questionnaires were administered in Sinhala.

The questionnaires included:

*Demographic information -- age, education, family composition.

*Farm system -- activities, decision-making, sources of information, access to extension, and perceived problems.

*Household system -- activities, decision-making, sources of information, needs and desires, and perceived problems; livestock, home gardening, water and firewood procurement, and health and nutrition.

*Income and expenditures -- patterns and preferences, family resource management, purchasing power.

*Community participation -- formal organizations, informal groups, water user groups, and kanna meetings.

*Settlement experience -- satisfaction, suggestions for improvement.

d. Field Surveys

Three surveys were conducted during the 1985 yala. During these surveys, different questionnaires were administered to the same households on the irrigation scheme. While the general format was similar, each questionnaire also dealt with other specific topics.

The first survey was conducted June 11-23, 1985. This questionnaire was designed to collect background on demographic information and field activities, especially those related to land preparation and the plant establishment phase of the cultivation season. The content of this questionnaire was largely exploratory in nature and formed the basis of questions for the remaining two surveys.

The second questionnaire was administered August 14-21, 1985. This survey concentrated on the care of the maturing crop (weeding, applying fertilizer, insecticides, pesticides, and water management). An attempt was also made to include a section relating to health and nutrition.

Many of the questions in the second survey were developed from the first questionnaire. In addition, some questions from the first questionnaire were repeated or reworded as checks or to resolve difficult or complex questions.

The third survey was conducted October 8-14, 1985. This questionnaire specifically addressed the harvesting and marketing of

the crop. Again, questions to further clarify previous topics were included.

It was previously observed by the WID investigators that close cooperation with the economics and sociology components was beneficial and necessary. Investigators from the three components generally conducted all surveys at the same time and travelled together, alternating partners for simultaneous interviews of households. This was particularly important for the WID investigator, as male family members tended to intrude on the WID interview if they were not kept preoccupied by the economics or sociology investigator. During the three surveys, both the WID field supervisor and the WID coordinator observed the interviews. Questions or problems were resolved by immediate attention and group discussion.

e. Data Analysis

Field investigators were issued tabulation forms and coding sheets. An effort was made to provide a period for data coding and tabulation at the end of each survey day, or every few days during the survey. Coded data were verified by the WID field supervisor and the WID coordinator.

The coded data were entered on a Compaq™ microcomputer for analysis using Microstat™, a statistical analysis software program. In addition, some of the open-ended discussion questions found to be incompatible with computer analysis were hand tabulated. Basically, a one-way frequency analysis was used for most variables and the arithmetic mean for other variables. A few cross-tabulations of two different variables were performed.

3. RESULTS AND DISCUSSION

a. Demographic Information

A total of 98 farm women were interviewed: 38 from the head, 19 from the middle, and 41 from the tail of the irrigation system. All of the sample sites were located on distributaries of the D1 main canal except for Weera Pedesa (D2 main canal).

The family position of PSS women respondents and their marital status is given in Table 78. The status of the woman within the family is an important variable when topics such as work responsibilities and decision-making are examined.

Throughout this report, the term "wife" is used to indicate a woman married to a farmer who originally settled the area. Although only 14 widows on PSS were interviewed, there were actually 26 widow households included in the study (27 percent of the sample). In these households, where the widow was not interviewed, the daughter or the daughter-in-law was interviewed. All of the unmarried women were daughters residing in the home of their parents.

Table 78. Family position and marital status of PSS respondents, 1985 *yala* (n=98).

	%
Familial Relationship	
Wife	38
Widow*	14
Daughter	10
Daughter-in-law	36
Granddaughter	2
Marital Status	
Married	82
Unmarried	3
Widowed**	15

*First generation only
**Includes one daughter-in-law

While most of the women were original settlers or descendants of settlers, 17 percent of the PSS sample were "pioneers"; either purchasers, encroachers, or women from outside the settlement who had married into the colony (Table 79). Some of these women had begun residence when the colony was established (such as the entire Weera Pedesa area on PSS) and were long-standing members of the community (Table 80).

Table 79. Origin of PSS respondents, 1985 *yala* (n=98).

Origin	%
1st generation settler	43
2nd generation settler	38
3rd generation settler	2
Outside settlement	17

Table 80. Length of residence of PSS respondents, 1985 yala (n=98).

Residency (yrs)	%
< 1	1
1-5	12
6-10	10
11-20	21
21-30	17
31-40	38

Sample settlers were primarily from the up-country Wet Zone. However, several other localities were also represented (Table 81). Interestingly, some of the descendants of original settlers have begun to identify the settlement in Polonnaruwa District as their origin. Although purana villages were incorporated into the settlement, they were limited primarily to areas close to the tank on the D2 main canal and the D3 main canal, neither of which was included in this survey.

Table 81. District of origin of PSS respondents, 1985 yala (n=98).

Up-Country	%	South/Coastal	%	Dry Zone	%
Kandy	26	Gampaha	7	Polonnaruwa	17
Nuwara Eliya	11	Galle	5	Kurunagala	11
Kegalle	5	Colombo	3		
Matale	4	Negombo	3		
Badulla	1	Matara	2		
		Kalutara	2		
		Batticaloa	1		
TOTAL	47		23		28

The age of the women ranged from 17 to 78 years, with an overall average of 44 years of age (Table 82). The age of the settlement scheme was reflected in the fairly well distributed ages of women, with few very young or old women.

Table 82. Age, education, and family size of PSS respondents, 1985 yala (n=98).

Age (yrs)	%	Education	%	No. of Family Members	%
< 20	3	none	16	1-2	3
21-30	23	1-5 yrs	38	3-5	36
31-40	27	6-10 yrs	26	6-8	40
41-50	18	(GCE) 'O'*	13	9-11	12
51-60	16	(GCE) 'A'**	7	12-18	6
> 60	12				

*GCE 'O'= General Certificate of Education - ordinary level (10 years of schooling plus exam)
**GCE 'A'= General Certificate of Education - advanced level (12 years of schooling plus exam)

The educational level of the women interviewed ranged from none to the advanced level (GCE), and the overall average was 6 years of formal schooling. Approximately 20 percent of the sample had received more than 10 years of schooling, a fairly high level for a rural area.

Two to 18 family members occupied the same house, with an average of 6.6 members. Most households shared a common hearth where meals

were cooked and eaten together, but some of the larger extended families maintained several separate cooking and eating facilities.

Although the PSS settlement was predominantly Sinhalese Buddhist, three Christian families and one Muslim family were included in the sample.

The increasing pressure on the settlement scheme was apparent when the number of highland allotments occupied by more than one family was noted, and that other families resided in the fields (Table 83).

Table 83. Residency of families related to PSS respondents, 1985 yala (n=98).

On Highland	%	In Fields/Reservation	%
none	12	none	66
1 family	36	1 family	30
2 families	36	2 families	2
3 families	[illegible]	3+ families	2
5+ families	3		

Given the age of the settlement, the questions and legalities regarding the inheritence of the original allotment were a predominant problem. Due to land fragmentation among descendents, some farm families retained as little as .5 ac. Further complications included a variety of tenurial arrangements such as leasing, mortgaging, and sharecropping (ande and wee porunduwa) among family, as well as with outsiders. It was rare to find the original field allotment and highland still intact and managed by a single family. However, one interesting case involved a PSS household with seven adult sons. Realizing the difficulty and futility of dividing their land, the family retained a traditional form of land sharing (tattumaru). The cultivation of the entire 5 ac was rotated each season to one son, with the original parent settlers receiving a portion of the crop from each cultivation. Unfortunately, the majority of fragmentation problems have not been so easily resolved, and many of them end in conflict and in disputes in court.

b. Agricultural Production System

Of the 98 PSS households investigated, 14 were not cultivating during the 1985 yala because they had leased out or mortgaged their lands. All of the other households were engaged in paddy cultivation, with some households cultivating small, additional extents (generally .25 to .5 ac) of other field crops such as chili, tobacco, or vegetables.

Overall, a number of complex, intricate, land tenure arrangements were noted. Some cultivators were simultaneously involved in leasing-out, leasing-in, subdividing lands among relations, sharecropping,

purchasing, or selling portions of the original allotment. An attempt was made to clarify the tenurial status of the respondents. However, the combination of intricacies and hesitency to reveal existing tenure relationships made this impractical. Although widely ignored, legal restrictions do exist on the leasing, mortgaging, transfer, and subdivision of allotments.

Agricultural Activities. This section of the report deals only with the agricultural activities performed by women in their own or in other's fields during 1985 yala. Agricultural work such as caring for small extents of vegetables growing on the field bunds or borders, home gardening, and highland crop production are addressed in the section on domestic production.

When female participation in agricultural activities was particularly significant (transplanting, weeding and harvesting), the female labor was classified as family, local, contract, or combinations of these categories. Contract labor generally received a wage payment. Local laborers received wages, payment in kind, or exchange labor.

Note that differences between yala and maha may exist that affect the extent of female labor for various activities. Increased acreage cultivated, increased transplanting compared to broadcasting, and decreased crop diversity are commonly associated with maha production. These changes may affect not only the total amount of female labor, but also the distribution of family, local, or contract female labor.

Approximately half of the women reported that they were engaged in some type of regular agricultural work. These women worked on their own family farm or off-farm as casual laborers, or participated in exchange labor (attam) or various combinations of these activities. Women who indicated that they were mainly occupied in the household said that they also occasionally assisted in the fields during the peak labor periods of transplanting and harvesting.

Although the average age of women interviewed was 44 years, almost one third of the sample was over 50 years old, which should affect participation in field activities (Table 84). In addition, 27 percent of the sample was composed of women under 30 years, many of whom had young children, which limited their work outside the home. Three young women in this category were unmarried or childless, thereby increasing their ability to participate in fieldwork.

Middle-aged women (30-50 yrs) represented 45 percent of the sample. These women were generally engaged in both housework and fieldwork. Some of the responsibility for housework and child care in these households was assumed by older children, freeing these women for agricultural work.

Two widows, who were both over 50, because their lands were mortgaged, depended upon income from working as casual wage laborers. One woman from Weera Pedesa managed a bakery and boutique (tea shop).

Table 84. The age and agricultural activity of PSS respondents, 1985 *yala* (n=98).

Activity	Age					Total
	<=20 (yrs)	21-30 (yrs)	31-40 (yrs)	41-50 (yrs)	>50 (yrs)	(%)
Not active					4	4
Mainly housework		14	12	4	15	46
House/fieldwork	3	9	14	13	7	47
Wage labor only					2	2
Business				1		1
Total (%)	3	23	27	18	29	100

1. Paddy Production

The most common agricultural activities performed by women in paddy cultivation during the 1985 *yala* included germinating seed, transplanting seedlings, manual weeding, and harvesting. In addition, women also took on much of the responsibility for supervising hired laborers, even when not actually performing agricultural work themselves.

Although women generally did not participate in land preparation activities that required great physical strength, a significant number of women did assist in controlling water issues for flooding the fields prior to plowing.

The germination of paddy seed by women is traditionally considered good luck; consequently, even elderly women who no longer worked in the field helped germinate seed. Experience and skill are necessary to insure that the seed reaches the appropriate moisture content, and the fragile germinated seed must be carefully untangled to prevent damage before sowing.

Approximately 50 percent of all cultivating households transplanted some acreage of paddy, although the majority of acreage is generally broadcast in *yala*. As expected, transplanting paddy seedlings was a primary female agricultural activity.

Table 85 indicates that 45 percent of the female labor for transplanting was supplied by local or contract women. Female family members together with other females provided 33 percent of the female labor for transplanting, while 22 percent of the female labor involved female family members working alone.

Table 85. Distribution of PSS female labor for paddy transplanting, 1985 *yala* (n=46).

Source	%
Family	22
Family/local	13
Family/contract	9
Family/local/contract	11
Local	13
Contract	26
Local/contract	6

Manual weeding of paddy was predominately done by women alone, although in a few cases women weeded with males (Table 86). The most common arrangements were family females working alone or family females and local females working together. On the other hand, the application of fertilizers, weedicides, and insecticides was primarily done by males.

Table 86. Distribution of PSS female labor for paddy weeding, 1985 *yala* (n=74).

Source	%
Family	37
Family/local	27
Family/contract	5
Family/local/contract	1
Local	24
Contract	5
Local/contract	0

Although activities associated with water management were generally performed by men, eight to ten women were engaged in these activities. This represents a total female involvement in water management of approximately 11 percent, which is significant. These women were an extremely diverse group, representing all categories of age and marital status.

The labor intensive activities associated with harvesting paddy generally required all available labor, both male and female. In addition to family and local labor, contract labor teams composed mainly of males from outside the area were employed. Most of the activities such as cutting the paddy, gathering the cut paddy, tieing the paddy into bundles, and carrying the bundles to the threshing floor were performed by both men and women. The majority of female labor was supplied by family and local females working together during these activities (Table 87).

Table 87. Distribution of PSS female labor for paddy harvesting, 1985 *yala* (n=43).

Source	%
Family	23
Family/local	35
Family/contract	5
Family/local/contract	2
Local	28
Contract	2
Local/contract	5

The participation of women was less for threshing, winnowing, cleaning, and bagging grain. This may be a result of the use of mechanized equipment such as tractors and blower fans for post-harvest activities (Table 88).

Table 88. Gender division of paddy cultivation activities on PSS for 1985 *yala*.

Activity	Number of Households	Females Only	Males/ Females	Males Only	Total Females (Rel.%)*
Land Preparation					
flood fields	84	1	13	70	17
plow/break clods	84	0	1	83	1
puddling	84	0	1	83	1
prepare seedbeds	84	0	2	82	2
make/plaster bunds	84	0	1	83	1
broadcast basal fertz.	84	0	2	82	2
Seeding					
select/purchase seed	86	8	9	69	20
germinate seed	85	19	10	56	34
broadcast seed	78	0	1	77	1
scare birds	73	3	9	61	16
Nursery Care					
water	46	0	4	42	9
fertilize	46	0	1	45	2
apply weedc./insectc.	46	0	0	46	0
Transplanting					
pluck seedlings	46	43	1	2	96
plant seedlings	46	43	3	0	100

Table 88. (continued)

Activity	Number of Households	Females Only	Males/ Females	Males Only	Total Females (Rel%)*
Crop Care					
manual weeding	76	64	10	2	97
fertilize	86	2	9	75	13
apply weedc/insectc.	78	0	5	73	6
Water Management					
clean field channel	85	1	8	76	11
control turn-out	83	1	8	74	11
repair bunds	86	0	10	76	12
liyadga water control	85	0	10	74	12
Harvesting					
cut	82	2	38	42	49
gather	82	3	41	38	54
tieing bundles	82	3	40	39	52
carrying bundles	82	2	30	50	39
threshing	82	0	10	72	12
winnowing	82	1	18	63	22
cleaning grain	81	1	20	60	25
drying grain	73	1	15	57	21
bagging grain	82	1	17	64	20
transport bags	82	1	15	66	18
Management					
hiring laborers	76	7	9	60	21
suprv. laborers	74	4	31	39	47

*The relative percent of total female participation is the sum of all cases of females participating in the activity, divided by the number of households performing the activity, and multiplied by 100. For example: Women were involved in manual weeding in 74 cases. Divided by the 76 households engaged in manual weeding, and multiplied by 100, 74 is 97 percent of the cases.

2. Transplanting Crews

During the transplanting phase of the cultivation season, teams of women -- primarily from the Up-Country -- arrived in Polonnaruwa. Informal conversational interviews were conducted by the WID field supervisor and the WID coordinator with five of these teams. These women were generally paid about Rs. 25/day and were provided shelter,

meals, tea, soap, hair oil, and beedies (small cigars), among other things, during their stay.

Many of these teams come from the original villages of the PSS settlers, and may even be relations with whom contact has been maintained. Some households reported that they employ the same crews year after year and have built a good rapport with the crews, which assures them of having the necessary labor supply.

Other households expressed dissatisfaction with the work of outside contract transplanters, and claimed that the quality of their work was poor and required careful supervision. These teams were generally managed by a leader/procurer who, when interviewed, was usually hesitant to disclose financial arrangements with the cultivator in the presence of the crew.

3. Other Field Crop Production

In addition to paddy, 20 households also cultivated other field crops. Chili was the most popular secondary crop, with tobacco and vegetables such as green gram, cowpea, onions, and assorted other vegetables also noted.

Although women generally were not involved in preparing seedbeds, they did assist in applying basal fertilizer before seeding or transplanting (Table 89). Planting seed was generally done by both women and men working together. The men usually made the furrow or dibble hole, and the women dropped and covered the seed.

Males were involved to a much greater extent than women in transplanting other crop seedlings compared to paddy transplanting. Although the reasons were not clear, this may occur because the cultivation of crops such as chili has been introduced only recently into the settlement scheme and traditional cultural practices were not as developed as for paddy. Also, chili cultivation was generally limited to about .25 to .5 ac for individual households, decreasing the need for a large labor force. On the other hand, the investment in chili cultivation was considerably more than for paddy and a higher degree of technical knowledge was required, which may indirectly decrease the participation of women.

Manual weeding was performed primarily by men and women together. Activities such as fertilizer incorporation and earth mounding were often done simultaneously with weeding, therefore the involvement of women was significant for these activities. Even though proportionately more women were engaged in applying weedicides and insecticides in subsidiary crop production than in paddy cultivation, their overall involvement remained low. It may be that because the care and maintenance of subsidiary crops was considerably more labor intensive than paddy, there were simply more women involved as part of the larger work force required.

Table 89. Gender division of labor associated with cultivating other field crops on PSS for 1985 *yala*.

Activity*	Number of Households	Females Only	Males/ Females	Males Only	Total Females (Rel%)**
Land Preparation					
form seedbeds	18	0	0	18	0
broadcast basal fertz.	10	0	5	5	50
Seeding					
select/purchase seed	15	0	0	15	0
plant seed	13	0	11	2	85
scare birds	3	1	1	1	67
Nursery Care					
water	9	0	3	6	33
fertilize	9	1	2	6	33
apply weedc./insectc.	10	0	2	8	20
Transplanting					
pluck seedlings	11	1	4	6	45
plant seedlings	14	1	7	6	57
Crop Care					
weed manually	20	6	10	4	80
fertilize	20	2	8	10	48
mound earth	20	4	8	8	57
apply weedc./insectc.	17	1	2	14	19
cut tobacco flowers	6	1	3	2	66
Water Management					
irrigate	19	2	4	13	32
Harvesting					
pluck	19	6	10	3	84
thresh	5	0	3	2	60
clean/grade	15	3	9	3	80
dry	17	5	9	3	82
bag	15	2	11	2	87

Table 89. (continued)

Activity*	Number of Households	Females Only	Males/ Females	Males Only	Total Females (Rel%)**
Management					
hire laborers	6	0	2	4	33
suprv. laborers	6	2	3	1	83

*NOTE: Some households cultivated crops that were planted byseed, not requiring transplanting -- green gram, squash. Some households cultivated crops that were seeded innurseries and later transplanted -- chili, onion. Some households purchased seedlings ready for transplanting -- tobacco, chili.

**The relative percent of total female participation is the sum of all cases of females participating in the activity, divided by the number of households performing the activity, and multiplied by 100.

Although most of the households relied heavily on family labor, others employed local labor throughout the season. Males most often assumed the responsibility of hiring the laborers on PSS, but women were actually involved to a greater extent than men in the supervision of the laborers. This may reflect the women's level of participation in labor intensive activities such as weeding and plucking mature tobacco leaves and chili pods.

Off-Farm Activities. Women were involved in a wide range of activities besides work in the family fields. Overall, 34 percent of the women reported that they were engaged in off-farm work. In addition to agricultural work, some women also joined casual labor crews or shramadana groups for non-agricultural activities.

While the majority of women involved in agricultural work limited their activity to their own family fields, eight of the sample women were engaged in agricultural wage labor (Table 90). Most of these women also worked their own fields as well, but two women (widows) depended on wage labor because their fields were mortgaged. The most common agricultural activities were associated with paddy transplanting, weeding of paddy and chili, and harvesting of paddy and chili.

Four women were involved in non-agricultural wage labor. Most of this work consisted of road, bund, and channel construction or repair.

Table 90. Off-farm activities of PSS respondents, 1985 *yala* (n=98).

Type of Activity	Frequency*
Casual Wage Labor	(10)**
Non-Agricultural	4
Agricultural	8
transplanting	6
weeding	4
harvesting	2
Attam	(19)
Non-Agricultural	6
Agricultural	13
transplanting	13
weeding	4
harvesting	1
Shramadana	(21)
Non-Agricultural	19
Agricultural	2
Chena	(1)
No Off-Farm Activities	(65)

*Multiple responses are possible.
**() = Total performing this activity.

Another form of off-farm agricultural work includes *attam* (exchange labor). Exchange labor is an important method of obtaining labor, primarily for the intensive transplanting period. However, some *attam* is also associated with weeding and harvesting. Thirteen women indicated that they participated in this form of off-farm work with neighbors to reduce the need for hired labor.

A number of women joined *shramadana* (volunteer) groups engaged in community activities such as road, bund, channel, and building construction or repair. Although *shramadana* is not generally associated with agriculture (but more with community projects) three women participated in agricultural work through this activity. All of these women were involved in a Kantha Samithi paddy cultivation project.

In addition, although it may be considered an extension of the family fields, two women were involved in *chena* (shifting, rainfed) cultivation.

Agricultural Decision-Making. While the physical participation of women in agriculture can more easily be observed and documented, the aspect to which women are involved in the management of the farm is more difficult to ascertain. A variety of questions were asked about

women's roles in agricultural decision-making during the 1985 yala surveys, but to determine the actual process or steps involved would require a more in-depth study. The degree to which women were active or passive participants in discussions, as well as women's knowledge of the process, were not clearly established. Women reported their own involvement in these matters (Table 91). Similar questions posed by the male sociology investigators to the male household members may differ significantly.

Table 91. Gender division of agricultural decisions in PSS households, 1985 yala.

Subject	No. of House-holds	Females Only	Males/Females Husband & Wife	Misc. Comb.	Males Only	Total Female (Rel%)*
Acreage to cultv	91	7	24	7	53	42
Acreage to "give"out	69	5	20	9	35	49
Crop selection	91	8	17	6	60	34
Loans/pawn for cultv.	71	14	20	4	33	54
Seed purchase/select.	90	9	20	7	54	40
Hire labor/equip. for land prep	8[illegible]	8	15	8	54	36
Hire labor/weeding	82	5	29	18	30	64
Timing of weeding	79	9	20	18	32	60
Fertz. needed	86	3	18	10	55	36
Fertz. use	86	2	16	9	59	31
Insectc./weedc.needed	83	2	15	8	58	30
Insectc./weedc. use	82	2	15	7	58	29
Solve agric. problems	91	8	19	2	62	32
When to harvest	86	5	25	20	36	58
Sell/keep harvest	77	6	26	6	41	48
Where/who to market	79	7	17	8	47	41
Use of harvest cash	79	9	24	11	35	56

*The relative percent of total female participation is the sum of all cases of females participating in the activity, divided by the number of households performing the activity, and multiplied by 100.

While some of the decisions regarding the operation of the farm were dominated by males, a relatively high degree of female participation was reported. In nearly half of the households, women said they participated in the decision-making for a number of important agricultural matters. A large number of households reported joint decision--making between husband and wife (or other male and female family members). Women from these households indicated that they shared discussion and responsibility with their husbands or sons on a number of agricultural subjects.

Women were most likely to be involved in decisions such as:

*determining the acreage to lease out or cultivate.
*obtaining loans or pawning articles for cultivation needs.
*hiring labor for weeding.
*determining the frequency of weeding and time of harvest.
*determining the marketing of the crop.
*managing the cash income from the harvest.

In 20 percent of the households taking loans or pawning, women alone were responsible for this decision. These women were widows, wives, daughters-in-law, and a daughter.

The participation of women in decisions concerning leasing or mortgaging fields and obtaining loans may be because the women were probably the technical title holders or were legally recognized as the household heads. Approximately 20 percent of the original allottees were female, and this number is expected to increase due to the colony age (Widows of male allottees automatically become the title holder). While either sons or sons-in-law may manage the farm, the woman may retain the recognized authority to obtain loans. Also contributing to women's involvement is that often, when cash is required for cultivation needs, pawned items may include the women's gold jewelery.

Women did not generally participate in decisions regarding the need and use of agro-chemicals or in agricultural problem solving. Even in households where the majority of agricultural decisions were reported shared by husband and wife, when subjects of a technical nature were encountered, the participation of the wife was noticeably reduced. Some of the decisions regularly required during cultivation necessitate a level of technical knowledge that women lack.

Note that when women were not physically involved in activities, neither did they participate in decisions. Instead, where women appeared to be more involved in the decision-making process coincided with the activities most often performed by women (such as weeding and harvesting).

Widowed women generally relied upon either sons or sons-in-law to assist them with farming decisions. However, a few women appeared to be solely responsible for all farm management.

With the increasing age of the original settlers, more parents were turning to the second generation for physical and decisional management. Characteristically, the agricultural decisions were turned over to the adult children, with the parents retaining some level of participation in decision-making.

Agricultural Information. Overwhelmingly, women indicated that their main source of agricultural knowledge came from traditional experiences. Most women reported that what they knew of agriculture was gained through their mothers, sisters, or other family members. In fact, "informal" sources of agricultural knowledge (husband, neighbors,

and other farmers) surpassed any other sources of agricultural information for women.

The second most common category of agricultural information was the mass media. Radio programs such as Sarabumi, agricultural quiz shows, and advertisements were often cited, as well as newspaper articles. However, only a few women found that this type of information was often useful to them (Table 92).

Table 92. Agricultural information sources of PSS respondents, 1985 *yala* (n=98).

Source	Primary	Others*	Use of Information		
			Often	Sometimes	Never
Traditional	59	23			
Husband	16	39			
Neighbors	4	37			
Radio	2	42	7	33	4
Newspapers		31			
Television		11			
Pamphlets		5			
Agric. ext. staff	13	18	8	21	2
Training classes		5		2	1
Private traders		2			
Contact farmers		2			

*Only one response was possible for the primary source, but "Others" is the sum of multiple responses.

In the first field survey, a surprisingly large number of women indicated contact with Agricultural Extension Services staff such as the KVS officers. Questions regarding contact with extension staff were repeated in the second and third field surveys. Apparently, the wording in the first questionnaire was sufficiently ambiguous that women perceived the question to be contact between the "household" (ultimately, male family members) and the extension staff. Not until the third field survey was this question resolved. It then appeared that approximately 24 percent of the women actually had contact with the extension staff. Even this figure may be inflated since some women believed the *vel vidane* and colonization officer to be agricultural extension staff.

When women were asked if they were seeking agricultural information, 77 percent responded affirmatively. While the magnitude of this response may be partially the result of a "courtesy response," women did name specific subjects of interest (Table 93). Far more than any other item, information on high yielding varieties of paddy was requested. Secondly, information on pests, diseases, and their control was cited, with interest in animal husbandry and subsidiary crops following. Of those women not expressing an interest in agricultural information, the majority responded that they had no time to pursue such subjects, while the rest generally claimed that they did not require agricultural information.

Table 93. Agricultural topics of interest to PSS respondents, 1985 yala (n=98).

Type of Information	Frequency*
High yielding varieties	72
Pests/diseases	18
Animal husbandry	10
Subsidiary crops	9
Water management	8
Agro-chemicals	4
Not seeking info	21

*Multiple responses were possible.

Agricultural Constraints. In the first field survey, 92-94 percent of the women reported specific agricultural problems for the 1985 yala (Table 94). When these women were asked to describe the single "most serious" agricultural problem, the majority of women responded that insufficient water and delays in receiving scheduled water issues were serious problems. Closely following these responses, women reported that the cost of agricultural inputs was also a serious constraint to crop production. Overall, the problems associated with pests, diseases and weeds, agricultural input costs, and water delivery were identified most often by women as agricultural constraints.

Although the questionnaire specified that only problems encountered in 1985 yala were to be considered, either the field investigators or the respondents may have included problems occurring during the maha. This may partially explain the substantial number of responses concerning flooding or poor drainage.

While most of these constraints were physical, many primarily economic problems were cited. In fact, women identified economic difficulties as the source of many of the physical problems. Women reported that the increased cost of production inputs (including pest and weed control), combined with the low guaranteed price of paddy, resulted in economic problems for the household.

When questioned about agricultural loan programs, women responded that they did not apply due to previous defaults, crop insurance requirements, or absence of land titles. Consequently, most cash for agricultural inputs was obtained through private businessmen and boutiques (often at usurious interest rates) or by pawning articles such as jewelery, radios, and bicycles.

There appeared to be little difference among hydrological locations in regard to water-related problems reported by women (Table 95). Those households in the head locations reported as many problems associated with water excesses or deficiencies as the households in the tail.

Table 94. Agricultural constraints given by PSS respondents in the first field survey (n=98).

Type of Constraint	Number of Reponses Primary	Others*
Flooding/drainage	13	21
Insufficient water	16	8
Scheduling/rotation	8	7
Fragmentation/disputes	3	6
Unlevel fields	1	5
Distance to highland	2	1
Animal damage		5
Sandy soil/rocks	7	11
High clay soil		5
Infertile soil	3	4
Saline soil		3
Diseases	2	25
Insects/pests	8	24
Weeds	6	28
Low yields	2	14
Labor avail./cost	1	17
Input avail./cost	15	29
Marketing		2
Loans/credit	2	6
Leased/mortgaged	1	3
No response	8	

*Only one response was possible for the primary problem, but "Others" is the sum of multiple responses.

Table 95. The distribution of primary water-related problems by hydrological position on PSS, 1985 yala (n=98).

Water-Related Problems	Head (n=38)		Middle (n=10)		Tail (n=41)		Total (n=98)	
	Freq	Rel%	Freq	Rel%	Freq	Rel%	Freq	Rel%
Flooding/poor drainage	6	16			7	17	13	13
Insufficient amount	4	11	4	21	8	20	16	16
Scheduling/rotations	5	13	3	16			8	8
Total	15	40	7	37	15	37	37	37

Surveys conducted later in the season explored the methods used by households to solve particular agricultural problems (Table 96). Approximately half of the households reported that they attempted to resolve agricultural problems cited in the third field survey. The male members of the family were almost exclusively involved in seeking a solution. There were two exceptions noted; one case involved a widow and one case involved male and female family members who sought help together. The most common approach was to contact the local vel vidane or agricultural extension officer (KVS), which is probably a reflection

of the number of problems related to water, pests, diseases, and weeds. This approach was followed by appeals to neighbors, various government officals, and private traders. However, only 40 percent of the respondents felt that a satisfactory solution to their particular problem was attained.

Table 96. PSS households seeking solutions to agricultural problems reported in the third field survey, 1985 *yala* (n=44).

	Number of Responses			
	Head	Middle	Tail	Total
Households Seeking Solutions (%):	14	9	21	44
Type of Problem				
Water-related	7	5	13	25
Pest/disease	6		6	12
Weeds	3		2	5
Poor germination	1			1
Poor yields	1			1
Conflict/dispute	1	2	2	5
Economic	1	2	1	4
Cattle trespass			2	2
Family Member Involved				
Male only	13	9	17	39
Female only	1			1
Male/female			1	1
Outside Contact				
Vel vidane	4	5	8	17
Ag. ext. officer	3		3	6
Cultv. off./agr. serv.			2	2
Colnz. off./kachcheri	2	2		4
Irrig. off.				
Co-op	1			1
Crop insurance				
Private trader	1		1	2
Neighbor/relative	4	2	3	9
Police			1	1
Within family			3	3
Satisfaction with Solution				
Yes	5	2	11	18
No	9	7	10	26

c. Domestic Production System

Domestic Activities. The farm women normally assumed responsibility for household activities such as cooking, cleaning, washing laundry, collecting firewood, fetching water, marketing, and child care (Table 97). With the increasing age of the settlement, many of these activities were shared by daughters, daughters-in-law, or even the third generation descendants. In addition, the male members of the household also assisted with marketing and firewood collection. These activities often involved travelling outside the neighborhood, and women were more constrained by time and travel requirements than men (who used bicycles and tractor carts).

Although not common, 14 households maintained a servant or laborer who lived with the family and received room and board, and often a wage. The majority of these servants were males (with only one female included), and their responsibilities consisted of collecting wood, tending animals, and assisting in field work. A few were also employed by households with boutiques and rice mills.

Table 97. Gender division of domestic tasks within PSS households, 1985 yala (n=98).

Activity	Number of Households	Females Only	Males/ Females	Males Only	Total Females (Rel.%)*
Child care	67	64	3		100
Firewood	87	63	10	14	84
Water	98	87	9	2	98
Marketing	98	29	15	54	45
Sick care	94	55	31	8	91
Meals for laborers	93	86	6	1	99

*The relative percent of total female participation is the sum of all cases of females participating in the activity, divided by the number of households performing the activity, and multiplied by 100.

One of the activities mentioned by women as most demanding was preparing meals for hired labor crews during busy periods of the cultivation season. During these periods the farm women were occupied with field work and household chores. In cases where a daughter could assist with some or all household duties, women noted that they could spend more time in urgently needed field work.

While most families obtained domestic water from a well on the highland, a few women used a neighbor's well or community wells, and two women cited a nearby irrigation channel as the source of their domestic water (Table 98). Over half of the wells used were concrete-lined. One third of all women complained that they had some difficulty with their wells during yala. The most common complaint was low water level, which meant decreased quality of the well water. A few wells

actually dried up during the latter part of yala, requiring the users to find an alternative source.

It was evident upon observation that most of the wells on the highland depended on recharge provided by seepage from the nearest irrigation channel. Households located in the tail of the irrigation system experienced more difficulty with wells than households located in the head. This may be due to lower amounts of water in channels or delayed issues. Towards the end of yala cultivation, irrigation issues are normally reduced to coincide with harvesting activities. During this period wells may be inadequate for supplying domestic water.

Exploratory questions from the first survey indicated that a sizeable number of households travelled at least 2 mi to procure firewood. Further investigation revealed that generally every few months (once in a season), several family members travelled to jungle areas to collect firewood. Most of these households had to rent animal- or tractor-drawn carts, but some were able to provide their own transport. Commonly, firewood was collected by individual family members from jungle areas, but a few purchased wood from businesses or as scraps from the Timber Corporation.

Table 98. Information regarding domestic water and firewood on PSS, 1985 yala (n=98).

Domestic Water	%	Firewood	%
Source		Source	
Well on highland	89	Collect only	45
Neighbor's well	5	Purchase only	32
Community well	4	Collect/purchase	22
Irrigation channel	2		
		Distance	
Distance		Nearby house	79
Nearby house	92	.5 to 1 mile	3
.5 to 1 mile	8	2 or more miles	18
		Transport	
Description		own animal cart	(4)**
Earth	44	own tractor cart	(3)
Concrete lined	56	rent animal cart	(7)
		rent tractor cart	(3)
Low water level		bicycle	(1)
in yala	31	Source	
Head	21*	jungle	(14)
Middle	16*	purchase	(4)
Tail	46*	Frequency	
		weekly	(2)
		monthly	(5)
		3-4 months	(9)
		1-2 years	(2)

*Relative percent
**()=frequency

1. Home Gardening

The highland can be considered an important production unit that contributes toward the support of the farm family. During yala, however, home gardening is limited due to insufficient rainfall and the absence of a water delivery system to the highlands. Less than one third of the households were gardening on the highland.

The highlands were usually located close to an irrigation channel, and almost invariably, water from the irrigation channel was illegally tapped to cultivate the highland. As water is scarce during yala, some households grew vegetables on the periphery or bunds of the irrigated fields. These small plots of vegetables (in the fields, on the highland, or around the house) were usually consumed at home and only occasionally sold. Consequently, the care of these gardens was often not considered "agricultural" work, and many women neglected to mention the existence of these gardens. Only through successive probing and conversation conducted in all three field surveys was information on home gardening obtained (Table 99).

Table 99. Information regarding PSS gardening activities, 1985 yala (n=98).

	Households with Gardens	Households with Highland Crop
Type of Garden/Crop		
Highland garden	28 (29%)	
Field garden	15 (15%)	
Highland crop		28 (29%)
Care		
Females only	12	12
Males/females	11	10
Males only	12	6
Water		
Field irrigation	15	
Irrigation channel	8	12
Drainage/seepage	6	12
Rainfall	13	4
Well	11	3
Use		
Home only	24	8
Home/sale	11	15
Sale only		3

Throughout the study there was difficulty in defining "home gardens" as opposed to "highland crops." While both are important contributions to the farm household, the highland crop generally consisted of a larger and more homogeneous stand than the home garden. The home garden was usually limited in scope and contained a more diverse mix of vegetables and fruits. Furthermore, the highland crop had economic connotations not associated with the home garden. Although there was some attempt to classify the various gardening enterprises, these definitions were not always uniformly applied.

Some of the most common vegetables grown in the home gardens were manioc, yams, and sweet potato due to their ease of cultivation and drought tolerance. Cowpea, long beans, and lady's fingers (okra) were also popular. A scattering of other vegetables such as tomato, loofa, green gram, groundnut, brinjals (eggplant), snakegourd, onion, spinach, and pumpkin were also noted.

During yala, the price of vegetables locally is quite high, and most of the women reported that they had to purchase vegetables for family meals. Only two women reported that their home gardens were sufficient to supply vegetables for family meals. When women were asked why they did not also grow vegetables in their fields where there was access to water, they indicated that they preferred to put most of the area into paddy cultivation, leaving little space for other crops to be grown. Indeed, the preference for paddy cultivation was very noticeable in PSS compared to other more recent settlement projects. In addition, women reported that the area given to vegetables in the fields was limited based on the amount of family labor available after the requirements of the irrigated crop were met. Unsuitable soil or moisture conditions, animal trespass, and theft also seemed to be important considerations (Table 100).

Table 100. Gardening constraints of PSS respondents, 1985 yala (n=98).

Home Gardens	Frequency*	Field Gardens	Frequency*
No water	39	No space	44
No space	15	No time/labor	18
Poor soil	7	Theft	18
Animal damage	6	Animal damage	8
No time/labor	5	Soil/water problems	7
Theft	4		

* Multiple responses were possible.

When the highland was favorably located with respect to an irrigation channel, the preference was to cultivate paddy, chili, or tobacco, rather than vegetables for home consumption. Of the 28 households cultivating a crop on the highland, 14 cultivated paddy, 13 cultivated chili, 3 cultivated tobacco, and 9 cultivated vegetables such as green gram, cowpea, onion, and squash.

The irrigation of these allotments is a sensitive subject since it is illegal to do so. However, many women did respond that the nearby channel was the source of water for the highland crop. Excluding Weera Pedesa, 30 percent of the highland allotments on the settlement were extensively cultivated. While the farm household may realize definite benefits from irrigating highland allotments, it is incompatible with the design of the irrigation system and undoubtedly affects the delivery of irrigation water to the fields.

2. Permanent Tree Crops

Ninety-six percent of PSS households cultivated permanent trees on the highland. By far, the most common were coconut, followed by mango, banana, and jackfruit. In addition, a wide variety of other tree crops were also noted including papaya, breadfruit, guava, orange, lemon, lime, tamarind, pomegranate, areca nut, cashew, palmyrah, king coconut, wood apple, and custard apple, as well as other minor berries and fruits. While the majority of women stated that these products were used solely for home comsumption, 26 percent of the women replied that they occasionally sold the produce when cash was required and a surplus of produce existed. However, no regular marketing of produce was identified. In fact, most women could not recall or estimate the cash received through these occasional sales. Without some sort of record-keeping system it would be difficult to identify the economic contribution of tree crops.

3. Livestock

The highland acreage also provides an opportunity for keeping livestock. Eighty percent of the households kept some kind of livestock; the most common being water buffalo, cattle, and poultry (Table 101). Families with buffalo generally had at least one pair, used for their own land preparation. In addition, some households rented out buffalo during the land preparation period. The care of these animals was usually relegated to family males, but some women also assisted with animal care, as well as cutting fodder.

A number of households had taken in or given out animals on ande. In this arrangement, the care, feeding, and herding of animals is given over to another party. An agreement is made concerning the milk, meat, labor use of the animals, and young produced. The advantage to the owner is the savings of time and labor in animal care.

One household was involved in large-scale poultry production (a recent Kantha Samithi project); others maintained only a few poultry for occasional home use. Another household was engaged in the unusual enterprise of raising and marketing freshwater fish in tanks constructed on the highland.

Domestic Decision-Making. Overall, discussion and shared decision-making by both the husband and wife was the most common process by which decisions in the home were made (Table 102). The husband predominated on subjects such as the sale or purchase of livestock and taking or repaying loans (other than agricultural). However, there

were a few subjects (schooling children, gifting to relatives and the temple, and pawning jewelry for cash) in which the influence of women equaled that of males. Decisions made most often by women alone included the day-to-day management of household expenses, determining gifts and obligations to relatives and the temple, and the purchase of clothing and textiles. Widows made most of their decisions alone or with occasional consultations with relatives and neighbors.

Table 101. Information regarding livestock production on PSS, 1985 *yala* (n=98).

Category	Number of Households
Type of Animal	
Buffalo	49
Cattle	45
Goats	4
Pigs	1
Poultry	32
Care	
Females only	15
Males/females	21
Males only	39
Water	
Channel	43
Hand carry	36
Lake	1
Use	
Home only	49
Home/sale	16
Land preparation	39
Rental	6
Feed	
Fodder cut	40
females only	8
males/females	11
males only	21
Tied to graze	49
females only	4
males/females	9
males only	36
Roam freely	21
Ande	
given out	5
taken in	18

The decision-making process within a family is difficult to address through a survey. While the opinions of the field investigators were that the farm women spoke candidly of these subjects, much of the internal process of family decision-making probably remained hidden from the view of outsiders.

Table 102. Gender division of domestic decisions within PSS households, 1985 yala (n=98).

Subject	No. of Households	Females Only	Males/Females Husband & Wife	Males/Females Misc Comb.	Males Only	Total Female (Rel%)*
Day-to-day expenses	95	26	29	8	32	66
House const./repair	80	11	36	17	27	70
Major purchases	88	8	38	11	31	65
Schooling children	67	13	36	7	11	84
Animal sale/purchase	75	7	29	11	28	63
Taking/repay loans	76	16	21	8	31	59
Pawning articles	59	10	28	10	11	81
Gifts temple/rel.	92	27	35	13	17	82
Purchase textiles	95	33	36	9	17	82

*The relative percent of the total female participation is the sum of all cases where females participated in the activity, divided by the number of households engaged in the activity, and multiplied by 100.

Domestic Information. Knowledge handed down within the family was the major source of information on household management for women. However, twenty-three women were identified who had participated in some sort of training class, such as sewing and weaving (11); home gardening and agriculture (7); or cooking, health, and nutrition (5).

Seventy percent of the women responded that they were seeking specific household information (Table 103), although many said that even when information was available (through training classes of the Rural Development Society), they would have little chance to participate due to a full work schedule.

Many of the subjects mentioned by women were not related to the training available to them or instruction they had received. Instead, the majority of training was in areas of handicrafts, sewing, and weaving. Twenty-seven women expressed special interest in alternative sources of income generation that they could undertake during slack periods in the cultivation season and during yala (since most were unable to maintain much of a garden in that season). Although the agricultural extension staff is charged with providing information about home gardening, there were no reports of extension visits from women.

Table 103. Domestic topics of interest to PSS respondents, 1985 *yala* (n=98).

Type of Information	Frequency*
Food preparation	29
Health/nutrition	27
Income generation	27
Sewing/handicrafts	23
Home gardening	14
Animal husbandry	11
Recordkeeping	1
Not seeking info	29

*Multiple responses were possible.

Domestic Constraints. Certain physical problems such as the lack of accessible water in the highland has already been mentioned as a constraint to home gardening during *yala*. In addition, other gardening constraints such as poor soil (sandy, rocky, and infertile) and damage by animals (free-roaming cattle, monkeys, deer, and wild boar) were reported (Table 104). The fragmentation of the highland among family members who may have several homes occupying the original 3 ac was also common, further affecting the productivity of the highland.

Table 104. Domestic constraints of PSS respondents, 1985 *yala* (n=98).

Type of Constraint	Primary	Others*
Water availability	68	8
Poor soil/rocks	3	23
Animal damage	3	22
Fragmentation/disputes	6	5
Flooding/seepage	2	2
Theft	1	1

* Only one response was possible for the primary problem, but "Others" is the sum of multiple responses resulting when the problem was rated less than primary.

While many of these problems are primarily physical, many women felt that their lives were filled with stress from economic difficulties, as well as community conflicts. For example, a few cases were noted where even the highland, in addition to the fields, had been leased or mortgaged out to meet unexpected debts such as funerals, court cases concerning water, and boundary disputes. On occasion, women also mentioned the indebtedness of the household due to drinking or gambling habits of the husband. Some of the internal problems of numerous extended families occupying the same highland allotment were

also referred to by mothers-in-law and daughters-in-law. Although these problems may directly influence the operation and management of the farm, they were not pursued in this study due to their sensitive nature.

d. Family Health and Nutrition

While it was generally recognized that irrigation developments have potential for both negative and positive effects on family health and nutrition, this was not a primary focus of the study. A dietary or nutritional evaluation is a difficult and complex task requiring specific methodology that cannot be substituted with a survey questionnaire. With these constraints in mind, it was still felt that some insight and useful information might be gained by an attempt to include a few questions related to this topic.

In addition, some questions throughout other sections may give some indirect information about health and nutrition. For example, the availability of water to the highland limits home gardening, which in turn means that women may be limited in providing nutritious meals by their ability to purchase vegetables. In addition, while leguminous vegetables were found in many home gardens, an equal amount of less nutritious vegetables, such as loofa and various gourds, were also identified. Women related that the gourd vegetables were more drought tolerant and less preferred by livestock and wild animals. Obviously the constraints to growing vegetables on the highland during yala may significantly affect family diet.

Women were asked to describe the most recent "main" meal they had eaten. Care was taken to stress collecting information about what they themselves had eaten, not what they had cooked or others had eaten. The most common carbohydrate was rice, although a few mentioned manioc or bread (Table 105).

Among the vegetables mentioned, the most common were pulses (the legume family) such as dhal, green gram, long bean, and cowpea. These high protein vegetables in combination with fresh greens would be considered quite nutritious. Starchy vegetables such as yams, plantains, and jackfruit were not often mentioned by women. Although women said these vegetables are not predominant in their diets, note that these vegetables have a relatively low status which may have influenced the women when the information was collected.

As expected, sources of animal protein were mainly limited to fish. Both dried fish and the commonly available fresh tank fish were reported as part of the meal. Two women included beef in their meal, and three had eaten eggs. While fruit was not generally considered part of the meal, fresh fruit was consumed several times a day between meals. Milk was given almost exclusively to young children and was not usually part of the adult diet, even for pregnant or nursing mothers.

Only two women reported that they were able to support their family with vegetables from the home garden. In all other cases, women

purchased some or all of their vegetable requirement. In fact, approximately 75 percent of all households exclusively purchased vegetables for family meals during yala. Most of the women related that they also collected fresh greens to supplement the family diet.

Table 105. Family nutrition sources and diet of PSS respondents, 1985 yala (n=98).

Garden Vegetables*	Frequency	Female Diet**	Frequency
Legumes		Starches	
long bean	22	rice	93
cowpea	15	bread	2
green gram	8	manioc	1
winged bean	2	Vegetables	
groundnut	1	legumes	47
Gourds		gourds	21
loofa	21	other veg	17
snake gourd	13	starches	5
cucumber	11	fresh greens	26
pumpkin	8	Meats	
bitter gourd	6	dried fish	34
Other Vegetables		fresh tank fish	21
ladyfinger	15	beef	2
brinjal	7	eggs	3
chili	6		
capsicum	3		
tomato	2	Source of Family Vegetables	
onion	2		
radish	1	purchase only	76
Starches		purchase/grow	20
manioc	20	grow only	2
yams	3	collect greens	94
sweet potato	2		

*The figures for items in home gardens are the sums of the items mentioned by women with gardens on the highland or in the fields, which were used primarily for home consumption.
**The figures for items in the diet are the sums of the items mentioned by women as being part of their most recent main meal.

As previously mentioned, two women reported that their source of domestic water was the nearby irrigation channel. Irrigation channels are used for a variety of purposes including bathing and laundry, washing vehicles, and wallowing buffalo. Irrigation water is also likely to be contaminated by runoff or seepage containing agro-chemical residues.

When women were asked if they boiled their drinking water, 47 percent of them replied affirmatively. The magnitude of this response may be due somewhat to a perceived "correct" answer. Even if this number of households did boil their drinking water, a large number of

households used other sources of drinking water while working in the fields. These sources were mainly wells located in or near the paddy fields. Such wells are extremely shallow and are subject to contamination by agro-chemicals and human waste.

Approximately 90 percent of the households had their own latrine, but almost half of the women interviewed expressed dissatisfaction with them. The most common complaint was that the latrine had been built as a temporary structure and was old and decrepit, since it had never been replaced by a permanent concrete structure. A few women also remarked that during maha the latrines were subject to seepage and overflow.

One third of the women mentioned that they occasionally had problems with seepage and poor drainage around the house during seasonal rains. In addition to being an inconvenience, some of them remarked that it caused sores to form on their feet and increased mosquitoes. Various other "fevers," colds, and coughs were also associated with poor drainage around the house.

e. Income and Expenditures

Income Sources. As expected, the primary source of income was the irrigated crop for those households cultivating during 1985 yala (Table 106). The major source of income for non-cultivating households was a portion of the crop returned from ande or wee porunduwa. Among five cultivators, the primary income was from an off-farm job. Approximately 5 percent of the households had a family member working as a government worker, teacher, clerk, bus driver, or other off-farm job to provide the primary income of the family. Two households with mortgaged fields reported that the highland crop and chena were their main sources of income.

Although the primary source of family income was from paddy cultivation, other supplemental sources of income did exist and were identified. Approximately 70 percent of all households identified some form of income in addition to the irrigated crop.

The highland contribution was considerable when the major portion was in paddy, chili, or tobacco. As previously mentioned, it sometimes was the only source of family income due to the fragmentation or mortgaging of fields. Although difficult to quantify, the combination of a crop or fruits and vegetables grown on the highland was the most common means of supplementing family income. Other significant contributions included earnings from a business or service, wage or casual labor, animal husbandry (both draft power and products), and equipment rental.

In addition, a minimal contribution in the business/service category was provided by women through activities such as weaving mats and cadjans, dressmaking, brickmaking, traditional medicinal treatments, and midwifing. One woman owned and operated a bakery and boutique.

Table 106. Primary and other sources of income of PSS respondents, 1985 *yala* (n=98).

Income Source	Primary	Others*
Irrigated crop	84	1
Highland crop	1	20
Veg/fruit/coconuts		26
Business/service		23
Casual wage labor		22
Off-farm job	5	20
Animal products/draft		15
Equipment rental		15
Ande/wee porundura	7	10
Relative contribution		4
Leasing for cash		2
Chena cultivation	1	

*Only one response was possible for the primary income, but "Others" is the sum of multiple responses resulting when the source of income was rated less than primary.

When women were asked how they might be able to increase their income, 55 percent of them responded with specific ideas (Table 107). Most of the women perceived that they could increase their income mainly by increasing their paddy yields (using higher yielding varieties, inputs, or increased acreage). In addition, some women mentioned cultivation of subsidiary crops, animal husbandry, off-farm employment, handicrafts, and business ventures.

Table 107. Income generation ideas of PSS respondents, 1985 *yala* (n=98).

Activities	Frequency*
Paddy production	21
Subs. crops/gardens	10
Animal husbandry	8
Sewing/crafts	8
Off-farm employment	8
Business/service	5
Not interested	43

*Multiple responses were possible.

Expenses. The majority of family expenses revolved around family subsistance and agricultural input needs (Table 108). No doubt, these probably compete in households of limited finances, with family subsistance barely preceeding agricultural expenses. As previously noted, almost all of the women reported that they purchased some vegetables for family meals, while only two women indicated that their gardens were sufficient to supply their family with vegetables. In addition, 22 percent of the families responded that they purchased some rice for family meals (only 2 percent exclusively purchased rice).

Education of children and health and medical expenses followed in the primary expenses category. Women also included the repayment of loans as a primary expense.

The secondary expense category was also dominated by subsistance and agriculture; followed by health and medical expenses, children's education, and loan repayment. Finally, in the tertiary expense category, health and medical expenses and children's education emerged as dominant, followed by clothing and textiles.

Table 108. Prioritization of family expenses by PSS respondents, 1985 yala (n=98).

Expense Item	Priority		
	Primary	Secondary	Tertiary
	%		
Family needs	44	48	8
Agricultural inputs	42	28	9
Child's education	5	7	23
Health/medical	2	8	26
Loan/pawn repayment	6	6	8
Household items	1		2
Clothing/textiles		1	14
Savings		1	3
House const./repair			2
Entertain/gifts			2
Business			1
Animal care			1

Overall, 20 percent of the respondents ranked loan repayment as one of their top three expenses. Unexpected expenditures such as illness, death, court cases, and weddings often required families to borrow from private money-lenders since the cooperative loans were limited to agricultural needs. Other methods of covering financial shortages during the cultivation season included pawning radios, cycles, and jewelery. In one case, a farm woman noted that her family had been required to purchase their rice requirements because they had gradually sold the portion of the harvest kept for the family in order to pay unanticipated expenses.

The increasing age of the PSS colony was reflected in the concern regarding health and medical expenses. Thirty-five percent of the respondents included this as one of their top three expenses.

Spending Preferences. When asked what an unexpected, large sum of cash (such as a lottery winning) would be used for, the majority of women responded with new home construction or improvement of the existing home (Table 109). The second choice was divided between purchasing or leasing in lands and establishing a savings. The purchase of agricultural equipment ranked third, and mortgage/loan repayment ranked fourth, followed by children's education and community

development. A number of women even reported that they would use some of their "winnings" for community improvements or gifts to the temple.

Table 109. Spending preferences of PSS respondents, 1985 yala.

Lottery Winnings (n=98)	Frequency*	Settu Shares (n=15)	Frequency*
House const./repair	39	Household items	6
Purchase/lease-in lands	18	Savings	4
Savings		Loan/pawn repayment	3
Agricultural equip.	17	Poultry	1
Mortg./loan repayment	12	Agric. equipment	1
Children's education	10		
Community/temple gift	10		
Household appliances	2		
Car/motorcycle	1		
Business investment	1		

*Multiple responses were possible.

Fifteen respondents reported that they belonged to a settu group, an informal arrangement where shares are pooled and the "pot" is rotated among members. When these women were asked about what they had used their shares for (or intended to use them for), the majority responded that they had purchased (or would purchase) household items or furniture. Others indicated that they had used (or would use) their return of the shares for savings, loan and pawn repayment, poultry, and agricultural equipment. This unique method of saving was also important when women required cash for weddings, almsgiving, or funerals.

Shortly after yala harvest was completed, the third field survey was conducted. One objective of this survey was to investigate the management of cash received from the harvest (Table 110). At this time in the cultivation season, farm households acquire relatively large amounts of cash and debts are due. The income from the irrigated field crop was normally relegated to repay the previous season's debts and to purchase necessary items for the ensuing cultivation season. The remainder was available for family needs and non-essential items. The income from the highland cultivation was primarily used for family needs, but agricultural investments and loan repayment were also important.

Table 110. Harvest cash expenditures of PSS respondents, 1985 *yala*.

Field Crop	Frequency* (n=75)	Highland Crop	Frequency* (n=18)
Loan repayment	46	Family needs	8
Agric. inputs	26	Agric. inputs	5
Family needs	17	Loan repayment	4
Child's educ.	8	Child's educ.	2
House const./repair	7	House const./repair	2
Savings	5	Business	2
Business	2		

*Multiple responses were possible.

Family Resource Management. In approximately half of the households, individuals earning cash contributed all of their earnings to the family, while others contributed at least part of their income to the family (Table 111). In some cases where individuals were engaged in a business or service, the cash was returned to the operation for equipment, supplies, and so on.

When women were asked about the management of family cash, the most common response was that cash management was the responsibility of male family members. However, management was shared between males and females in a significant number of families. In addition, in 21 percent of the PSS households, women reported that they alone managed the family cash. These women were widows, wives, daughters, and daughters-in-law.

Table 111. Management of PSS family resources, 1985 *yala* (n=98).

	Frequency		Frequency
Individual Earnings		Family Cash Management	
Keep all	10	Females only	21
Contribute part	22	Males/females	31
Contribute all	41	Males only	45
No individuals earn cash	25	No response	1
Household Cash		Personal Cash	
Husb./son/family	44	Fruit/coconuts/veg	21
Own control	29	Livestock/poultry	11
Neighb./boutique	22	Crafts/sewing	10
Sell home paddy	2	Job/wage labor	6
Own business	1	Neighb./boutique	3
		Tractor hire	2
Household Allowance		Business savings	1
Husb./son/family	31	No personal cash	58
No allowance	65		
No response	2	Free Access to Cash	55

Household expenses managed by women were met by cash obtained from a variety of sources. The majority of women reported that they obtained cash from their husband, son, or other family members. In fact, 31 women reported that they were given an allowance by their husband (or son) to cover household expenses. Additionally, a common source of ready cash existed for temporary use from either neighbors or the local boutique. Women reported that when a small amount of cash for daily needs was required, they would borrow from these sources. One woman owning and operating a small bakery and boutique reported that she used her profits for both household and personal expenses.

Women were asked how they obtained cash for their own personal use. The most common means was through sales of fruit, vegetables, or coconuts; followed by livestock and poultry, sewing, weaving, handicrafts, jobs or wage labor, and small loans from neighbors or boutiques. In addition, two women owned tractors and rented them, while one woman maintained a personal savings from her business.

Despite the apparent control of family finances by male family members, 55 women claimed that they had access to family cash for use as they wished. The practice of borrowing cash from neighbors or boutiques may be a result of the overall limitations of the family budget during most of the cultivation season, or may reflect the unavailability of ready cash to women themselves.

Purchasing Power. Because the management of resources (especially cash) within the family is a complex process and may not be readily discussed with outsiders, a series of questions about general purchases were included. In this manner, the individuals actually conducting the purchase were identified. While this does not account for the actual management of cash, it may offer insights into the purchasing power of various family members (Table 112).

As expected, most of the purchases relating to farm operation (such as seed paddy, agrochemicals, hand tools, and equipment) were conducted by males, but the involvement of women increased when major items and home furnishings were purchased. Women were primarily responsible for purchasing textiles, clothing, and cooking utensils. One item of note concerned the purchase of food and daily items. In a large number of households, this was primarily a male responsibility that can probably be attributed to the time and travel constraints on women.

f. Community Participation

When farm women were asked about the existence and function of their participation in formal comunity organizations and societies, a number of confusing responses resulted. For example, some women said that certain women's societies existed in their area, although few were members, while other women stated that these societies did not exist. More importantly, many women claiming to belong to women's societies

were unable to define any specific activity conducted by these organizations. In the third survey, 25 women were identified who belonged to community societies, and their attendance and activities were noted (Table 113).

Table 112. Gender division of purchases by PSS family members, 1985 yala.

Purchase	Number of Households	Female Only	Male/ Female	Male Only	Total Female (Rel%)*
Seed paddy	63	5	4	54	14
Agrochemicals	86	5		81	6
Farm tools	93	10	3	80	14
Farm equipment	65	3	4	58	11
Textiles/clothing	96	36	33	27	72
Cooking utensils	97	62	16	19	80
Food/daily needs	96	30	9	57	41
Home furnishings	82	9	27	46	44
Major items	71	6	19	46	35

*The relative percent of total female participation is the sum of all cases of females purchasing the item, divided by the number of households purchasing the item, and multiplied by 100.

Table 113. Participation of PSS respondents in community societies, 1985 yala (n=25).

Society	Number of Members	Number Who Attended	Activities Conducted by Society
Kantha Samithi	15	15	12
Rural Dev. Soc.	6	6	5
Kulangana Samithi	12	12	11
Death Donation	6		
Co-operative	1		

The most popular society appeared to be Kantha Samithi, the women's division of the Rural Development Society (RDS). All of these women attended meetings in 1985, and most participated in an activity. Some of the various activities reported by the PSS Kantha Samithi included: setting up a sewing center with classes in sewing, establishing preschools, participating in shramadana (road repair and community construction), making bricks for sale and members use, constructing latrines, shramadana agricultural work, and granting agricultural loans to members. One Kantha Samithi from Weera Pedesa was engaged in paddy cultivation with members contributing labor. The profits after harvest went back to the Society.

Although males are the majority in the Rural Development Society (RDS), membership is not restricted to men. Six women reported membership in the RDS. Most of these had attended meetings, and a number had participated in activities this year. The RDS activities included road and bund repair through shramadana, granting agricultural loans, and constructing houses through a Gramodaya Mandelaya project.

Twelve women belonged to the more formal women's temple society, Kulangana Samithi. They had attended meetings and most participated in activities this year, such as community shramadana and specific religious ceremonies.

In addition, six women were members of the local Death Donation Society, where dues are paid to a fund for the funerals of contributing members (usually a large burden on family cash).

The overwhelming response the majority of farm women gave for not belonging to societies was the lack of available time to participate. However, 10 women said that they would join, but no societies were available in their area (LB2 off RB21).

By far, the most common forms of community interaction were the informal groups that revolved around daily activities. Approximately 60 percent of the women interviewed reported that they belonged to at least one informal group in their area (Table 114). The most popular were the temple groups, who performed religious ceremonies, shramadana, and pilgrimages. These were followed by shramadana groups organized around specific activities, groups of women performing attam and agricultural wage labor, and settu groups (a pooled contribution of shares). Other small groups of friends would market, collect firewood, and wash laundry.

Table 114. Participation of PSS respondents in informal groups, 1985 yala (n=98).

Informal Groups	Frequency*
Temple/religious	58
Settu	15
Shramadana	21
road/channel	14
community	5
cult triangle	4
agricultural	2
Attam/labor crew	19
Market/pola	9
Bathing/laundry	5
Firewood	3
Hospt/dispensary	2
No participation	40

*Multiple responses were possible.

Women rarely participated in kanna meetings. While 43 percent of the households reported that a member of their family had attended the 1985 yala kanna meeting, only one woman participant was noted. Based on observations of the 1985 yala kanna meetings, the total number of households reporting attendance at the 1985 yala kanna meeting was probably inflated and may be due to the perception of a "correct" response.

When the third field survey was conducted, the kanna meeting for the 1985-86 maha had been held on PSS. Twenty-eight percent of the households reported that a member of the family attended the maha meeting, with five women participating in this meeting. All five of these women (four widows and one daughter-in-law) were located in RB7 of the D1 north branch canal.

When women were asked about the existence of water user groups in their area, 27 women responded that such a group existed, while 20 of them also reported that someone from the family was a member (Table 115). (One woman member was included). Another 25 women stated that even though there was no organized water user group in their area, informal action (usually through the vel vidane) was the method of solving water problems.

Satisfaction with the various methods of solving water problems was highly variable and seemed to depend upon the individual efforts of the particular vel vidane. Some women reported that the local vel vidane was effective, while others claimed that their local vel vidane was only concerned with collecting of his remunerations and was of no assistance.

As with the other community organizations, there was little understanding on the part of women about the objectives, function, and benefits of a water user group. However, approximately 65 percent of the women expressed the opinion that a group was needed to resolve problems concerning irrigation water, and the majority stated that they would be willing to join such a group. Interest was fairly evenly distributed among women from head, middle, and tail locations.

When asked about the illicit tapping of water from the irrigation system for highland cultivation, 45 of the women responded that this occurs in their area. In addition, a number of women commented on the need to prepare a strict code of discipline with enforced punishments for law breakers (to include infractions related to field irrigation).

g. Settlement Experience

Overall, 67 percent of the women interviewed expressed satisfaction with the colony scheme (Table 116). However, only about 106 percent found colony life "very" satisfactory, while 19 percent expressed dissatisfaction. Among the satisfied or very satisfied women, land ownership was judged to be the prime consideration, followed by earning a good income.

Table 115. Perceptions of PSS respondents concerning water user associations, 1985 *yala* (n=98).

	Head (n=38)		Middle (n=19)		Tail (n=41)	
	Freq	Rel%*	Freq	Rel%	Freq	Rel%
Water user assoc. in area?						
Yes	14	37	2	11	11	27
No	22		16		26	
Don't know/no resp	2		1		2	
Family member in assoc?	9		2		8	
Very satisfied					1	
Satisfied	8				7	
Unsatisfied			1			
No response	1		1			
Is an assoc needed?						
Yes	24	63	14	74	25	61
No	4		3		2	
Don't know/no response	10		2		14	
Would you join?						
Yes	20		11		19	
No	4		3		6	
Highland irrigation in area?						
Yes	10	26	9	47	25	61

*Relative percent

Table 116. The satisfaction of PSS respondents regarding the colony, 1985 *yala* (n=98).

Satisfaction Level	Head (n=38)		Middle (n=19)		Tail (n=41)		Total (n=98)	
	Freq	Rel%*	Freq	Rel%	Freq	Rel%	Freq	Rel%
Very satisfied	4	11	4	21	2	5	10	11
Satisfied	27	71	12	63	27	66	66	67
Unsatisfied	6	16	3	16	10	24	19	19
No response	1	3			2	5	3	3

*Relative percent

The women expressing dissatisfaction related this primarily to poor facilities (such as shops, schools, markets, and health care), problems with water (both delivery to the fields and inaccessibility of the highland to water), and economic difficulties (caused by loss of paddy lands through mortgaging and the high cost of agricultural inputs). Note that the highest proportion of dissatisfaction was associated with the tail regions of the irrigation system.

When women were asked their opinions about how colony life could be improved, most women responded strongly with specific ideas (Table

117). Many suggested that delivery of water and electricity to the highlands would be a substantial improvement. Additionally, improving roads and transportation, solving irrigation problems, and increasing employment opportunities ranked high.

Table 117. Suggestions by PSS respondents for colony improvements, 1985 *yala* (n=98).

Colony Improvements	Frequency*
Highland water	38
Electricity	38
Roads/transportation	36
Irrigation problems	25
Employment	20
Health care	18
Schools/shops	11
Fragmentation/disputes	11
Cost of living	10
No response	3

*Multiple responses were possible.

Some women seemed particularly disturbed by the increasing cost of agricultural inputs and the low guaranteed price of paddy. They suggested that only through government intervention would their families be spared increasing hardship. One subject mentioned by women concerned the need for government to resolve the social and economic problems caused by increasing land fragmentation within the colony.

These colonies are diverse social communities composed of settlers and various entrepreneurs. Although these settlements are some of the oldest in the Dry Zone, the complex interactions between kin and neighbors found within a traditional village are less developed in PSS and many of the support systems normally provided by relations or the community may be absent. Therefore, an attempt was made to evaluate the level of community involvement (Table 118).

Table 118. Community interaction of PSS respondents, 1985 *yala* (n=98).

Sources of Assistance	Freq.*	Exchange of Items	%	Relatives Nearby	%
Relatives	38	often	7	Yes	63
Neighbors	43	sometimes	63	No	37
Govt./office	7	never	30		
Temple	4				
Businessmen	4				
Local organiz.	1				
No response	1				

*Multiple responses were possible.

During times of crisis or emergency, women stated that they relied heavily upon nearby relatives within the colony and close neighbors for assistance. Over half of all women reported that relatives lived "nearby" -- sometimes on the same highland allotment. This was found in all study locations of the colony except for LB2/RB21 on the D1 north branch canal. In this area, the majority of households had purchased allotments from the original settler, or taken over abandoned allotments. One highly educated woman residing in this area (a purchaser) stated that, in her opinion, this location was not even considered part of PSS due to lack of attention and neglect by officials.

Women from this area reported that they turned to the grama seveka for assistance in solving problems because of the lack of community cooperation and cohesion. In other parts of PSS, originally attempts were made to relocate settlers from the same villages together. While this can generally be observed in an overview of the colony, some of the older women remarked that there was still too much "mixing" of traditional castes and different villages for their satisfaction. Younger women generally seemed more inclined to view the existing settlement and neighbors as their community, with less reference to the original village.

Overall, the majority of women preferred to remain in the colony (Table 119). A few preferred to move to a new settlement (notably Madura Oya), some of the older women wanted to return to their original village, and a few expressed the desire to relocate out of the area -- in a city or in the Middle East for jobs.

Table 119. Preferences of PSS respondents for living location, tenure, and crop cultivation, 1985 yala (n=98).

Crop	%	Living Location	%	Tenure	%
Paddy only	59	Present colony	80	Cultv. own fields	31
Paddy/other crops	31	New colony	8	Cultv./lease in	31
Other crops only	1	Old village	7	Cultv./lease out	3
No response	9	New location	3	Lease out fields	8
		No response	2	Business/service	3
				No response	24

Regarding tenure preference, most women responded that they preferred to cultivate all of their own fields and to lease in additional fields for cultivation. Some preferred to either lease out a

portion or all of their fields, or to operate a business or service instead of farming. The rather high number of women failing to respond to this question may be partially due to hesitancy to reveal leasing arrangements. Legal restrictions exist on leasing, mortgaging, transferring, or subdividing the original allotment.

The preference for paddy cultivation was predominant, but 30 percent of the women were interested in agricultural diversification. This respresents an increase over the 20 percent currently cultivating another crop in addition to paddy.

4. CONCLUSIONS AND RECOMMENDATIONS

Due to the increasing age of the PSS settlement scheme, a large number of second or third generation descendants, as well as the original settler family, were present. Therefore, the interviews included wives and widows, daughters, and daughters-in-law. In fact, a significant number of widowed households were noted in the sample. Households headed by widowed women composed 26 percent of the PSS sample. These households have special needs and unique problems in farm management and require representation in farmer organizations.

Women were found to be active participants in the irrigated agricultural production system. Approximately half of the women surveyed were physically engaged in regular agricultural work. Women were involved in the majority of agricultural tasks, except for strenuous land preparation activities and agro-chemical use. Activities with the highest level of female participation included transplanting, weeding, and harvesting. A significant level of female involvement in water management activities was also reported. Female participation in water management activities ranged from approximately 11-12 percent for paddy and up to 32 percent for other field crops.

In addition to work in their own fields, 34 percent of the PSS women were also involved in various off-farm activities. The majority of this work was associated with agriculture or community projects such as road, bund, and channel repair and construction.

Women were also actively involved in decision-making and management of the farm operation. Farming decisions were shared between male and female family members in a significant number of households (20-45 percent). In approximately 10 percent of the PSS households, women (primarily widows) reported that they alone dealt with the majority of farming decisions.

Participation of females was highest when decisions regarding loans or pawning for cultivation needs were made. In households involved in obtaining loans, approximately 20 percent of the decisions were made exclusively by women alone. This was probably a result of the colony age and the significant number of widows inheriting legal title to the land.

Although 80 percent of the surveyed women expressed interest in specific agricultural subjects, the major sources of agricultural

information reported by women were traditional experience and informal means (husband and neighbors).

The Agricultural Extension Service appeared unable to serve the needs and desires of farm women. However, a significant number of women mentioned the mass media, such as radio and newpapers, as a source of agricultural information. The relatively high level of female education noted in the survey, combined with the accessibility of radio and newpapers, make mass media a possible means of extending agricultural information to women.

Most households obtained domestic water from wells located on the highland. Thirty percent of the PSS women reported difficulties with their wells during yala. Based on observations, the highland wells appeared to depend upon recharge from the irrigation system. Because the relationship between the irrigation system and the highland wells is currently unclear, additional hydrological research is needed. Low water levels or dry wells in the latter part of yala (when irrigation issues are limited) often required that women seek alternative sources of domestic water.

During yala, home gardening was limited due to insufficient rainfall and the absence of a water delivery system to the highland. Less than a third of the PSS households had gardens on the highland. These small plots were cared for by both men and women and were generally limited to home consumption, with only occasional sales. On the other hand, when highlands were located favorably, irrigation water was often tapped for paddy, chili, tobacco, or vegetable cultivation. This extensive cultivation, primarily for sales rather than home consumption, was noted on 30 percent of the PSS highland allotments. The irrigation of the highland undoubtedly has a significant impact on the ability of the system to deliver water to the fields.

Although difficult to quantify, one of the most often cited sources of supplemental income for the household included the sale of fruits, vegetables, coconuts, or crops cultivated on the highland. The cultivation of chili or tobacco on the highland could make a substantial contribution to household income. Additionally, women indicated that the sale of small quantities of vegetables, fruits, and coconuts was their primary means of obtaining personal cash. Although the highland allotment represents a tremendous potential for production, constraints such as water supply, poor soils, animal damage, and increasing fragmentation are limiting factors. Research to evaluate alternative methods for increasing the productivity of the highland is needed.

Women rarely participated in kanna meetings. Only one PSS woman reported attending the 1985 yala meeting, while five PSS women reported attending the 1985-86 maha meeting.

The majority of women claimed that water user associations did not exist in their area or said they were unaware of these groups. Current methods of solving water-related problems have resulted in limited satisfaction. As a result, 65 percent of the women surveyed expressed

the need for a group with authority to solve irrigation problems. In addition, the majority of women stated that they would be willing to join such a group. If women are not consciously included in such activities, their omission may result in an overall decrease in the efficiency and effectiveness of water user associations.

IV. LITERATURE CITED

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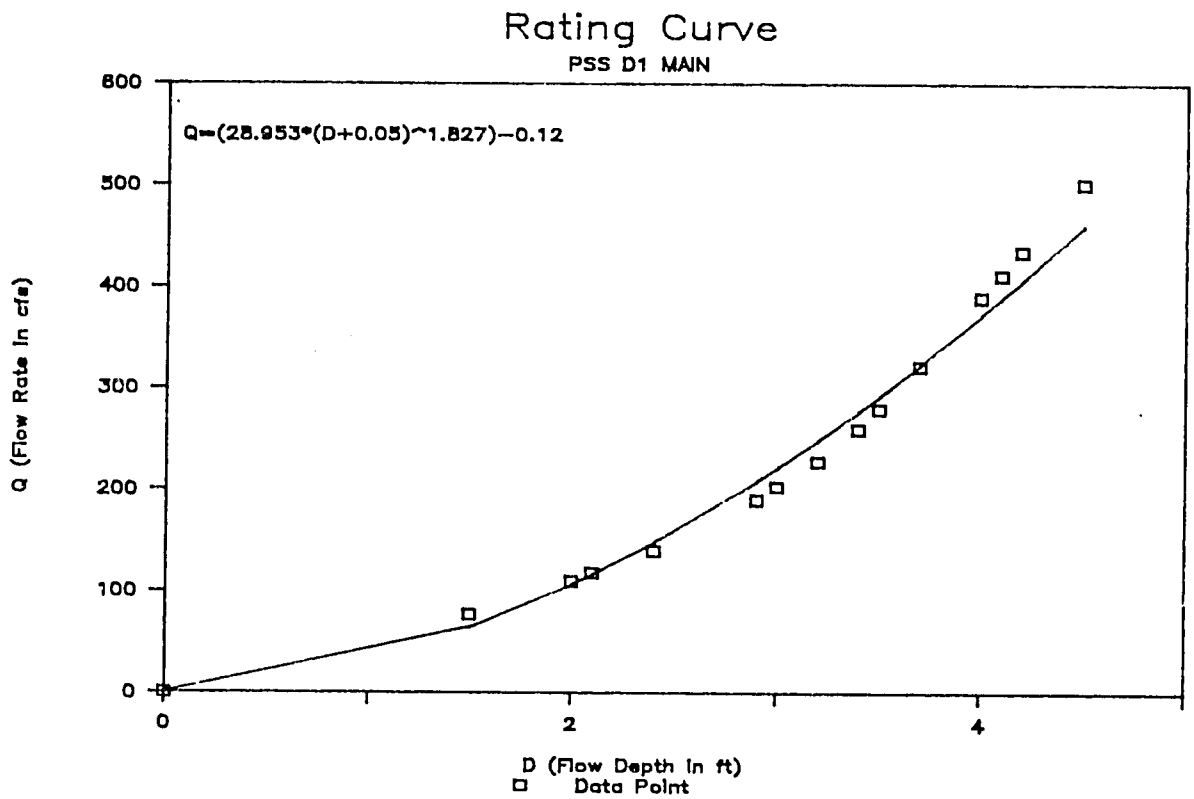
V. APPENDICES

APPENDIX A

RATING CURVES FOR PSS D1 MAIN, NORTH AND EAST CANALS AND D-CHANNELS ALONG D1 NORTH CANAL, 1985 YALA


Rating Curve
PSS D1 MAIN
Q=(28.953*(D+0.05)^1.827)-0.12
Q (Flow Rate in cfs)
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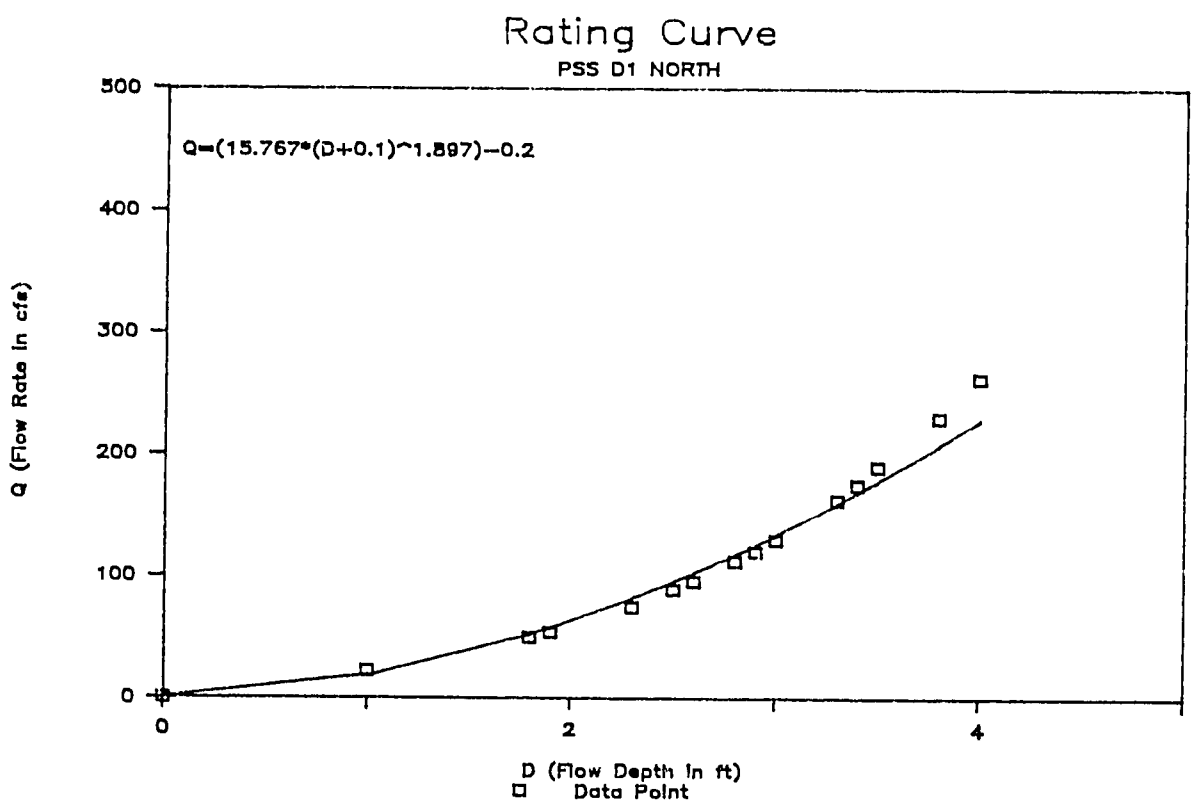
500
400
300
200
100
0
0
2
4
D (Flow Depth in ft)
Data Point


Rating Curve
PSS D1 NORTH
Q=(15.767*(D+0.1)^1.897)-0.2
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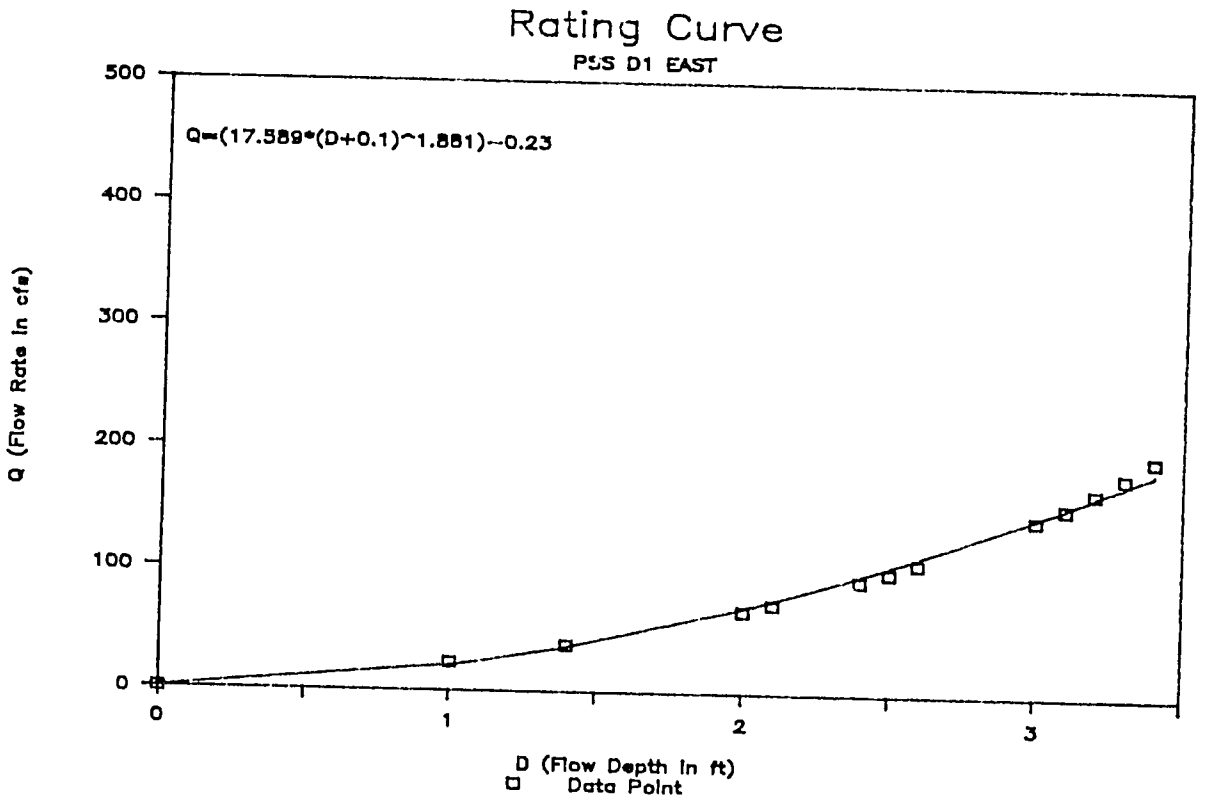
300
200
100
0
0
2
4
D (Flow Depth in ft)
Data Point


Rating Curve
PSS D1 EAST
Q=(17.589*(D+0.1)^1.881)-0.23
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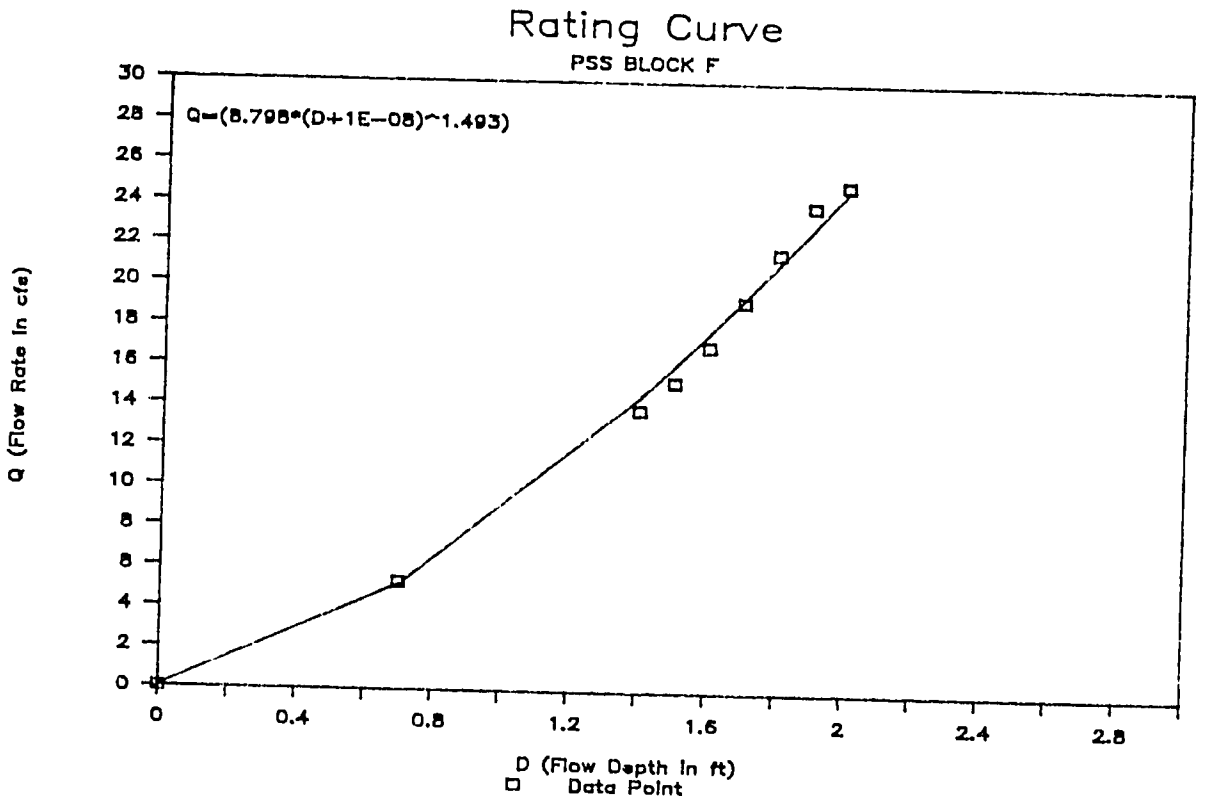
400
300
200
100
0
0
1
2
3
D (Flow Depth in ft)
Data Point


Rating Curve
PSS BLOCK F
Q=(8.798*(D+1E-08)^1.493)
Q (Flow Rate in cfs)
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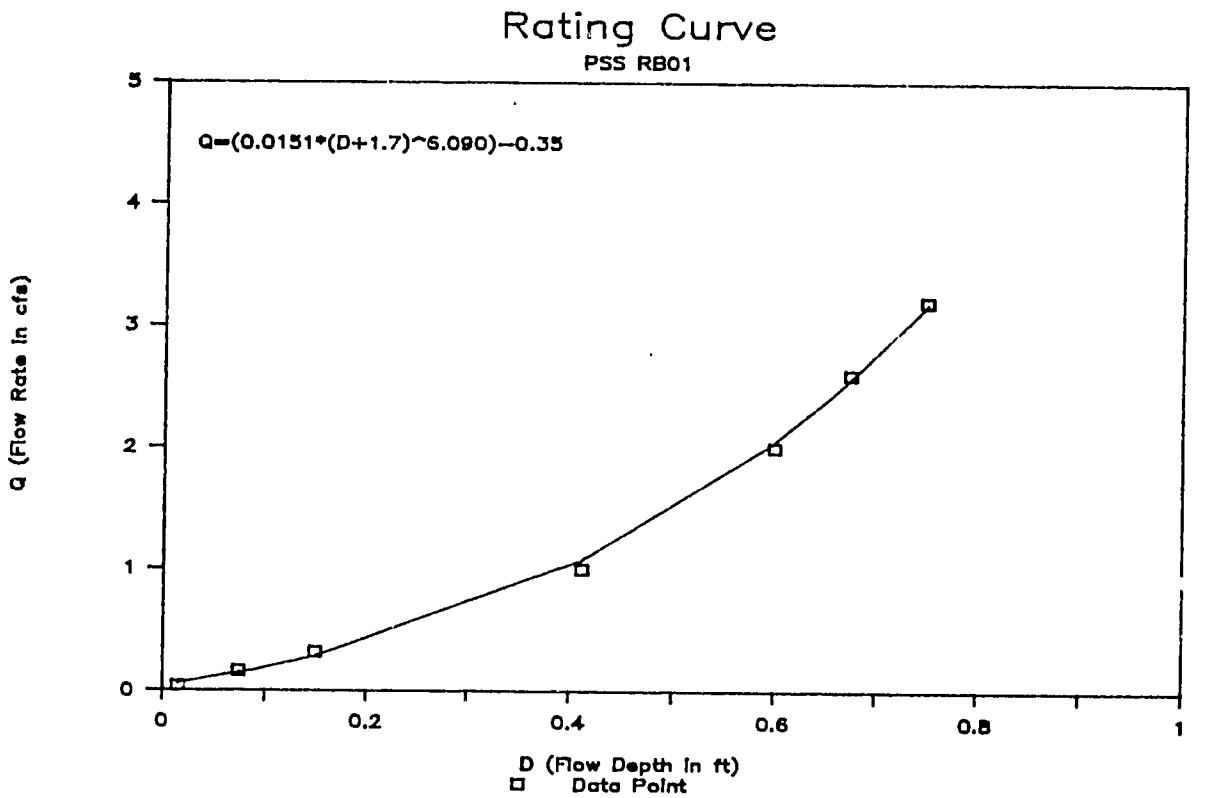
28
26
24
22
20
18
16
14
12
10
8
6
4
2
0
0
0.4
0.8
1.2
1.6
2
2.4
2.8
D (Flow Depth in ft)
Data Point


Rating Curve
PSS RB01
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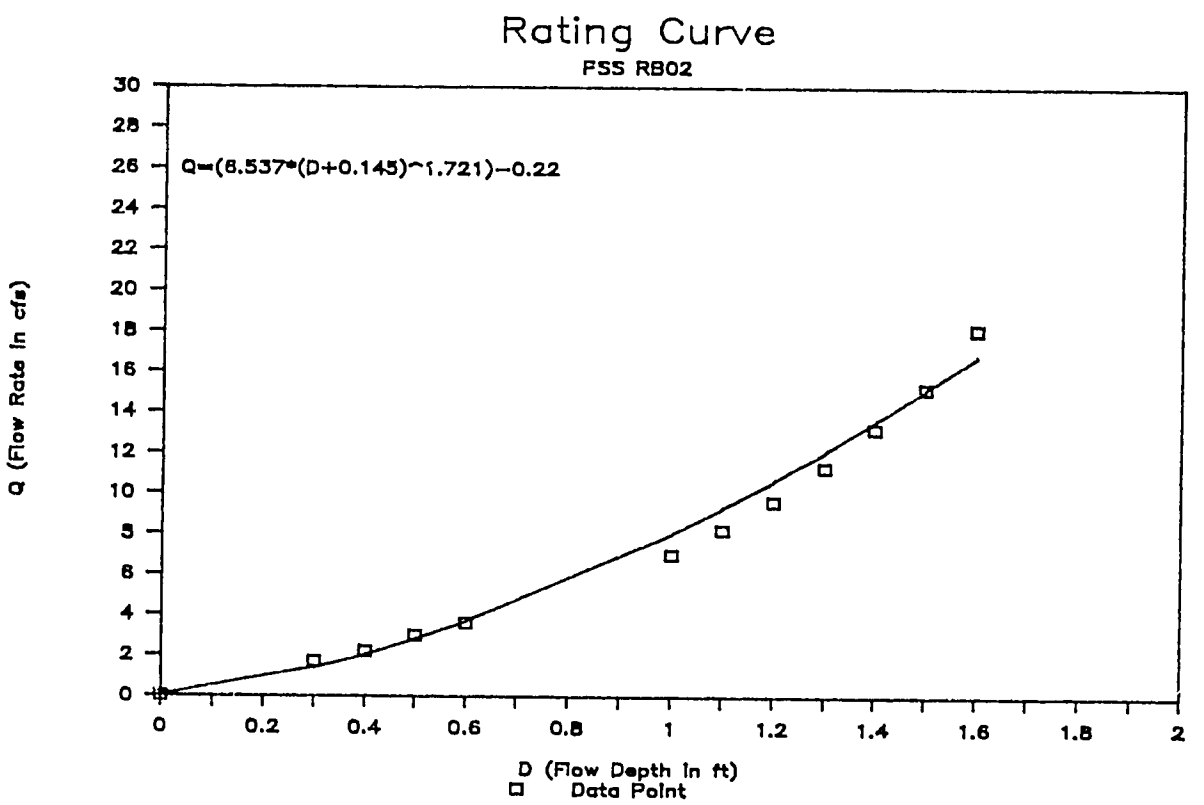
2
3
4
5
0
0.2
0.4
0.6
0.8
1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D (Flow Depth in ft)
Data Point
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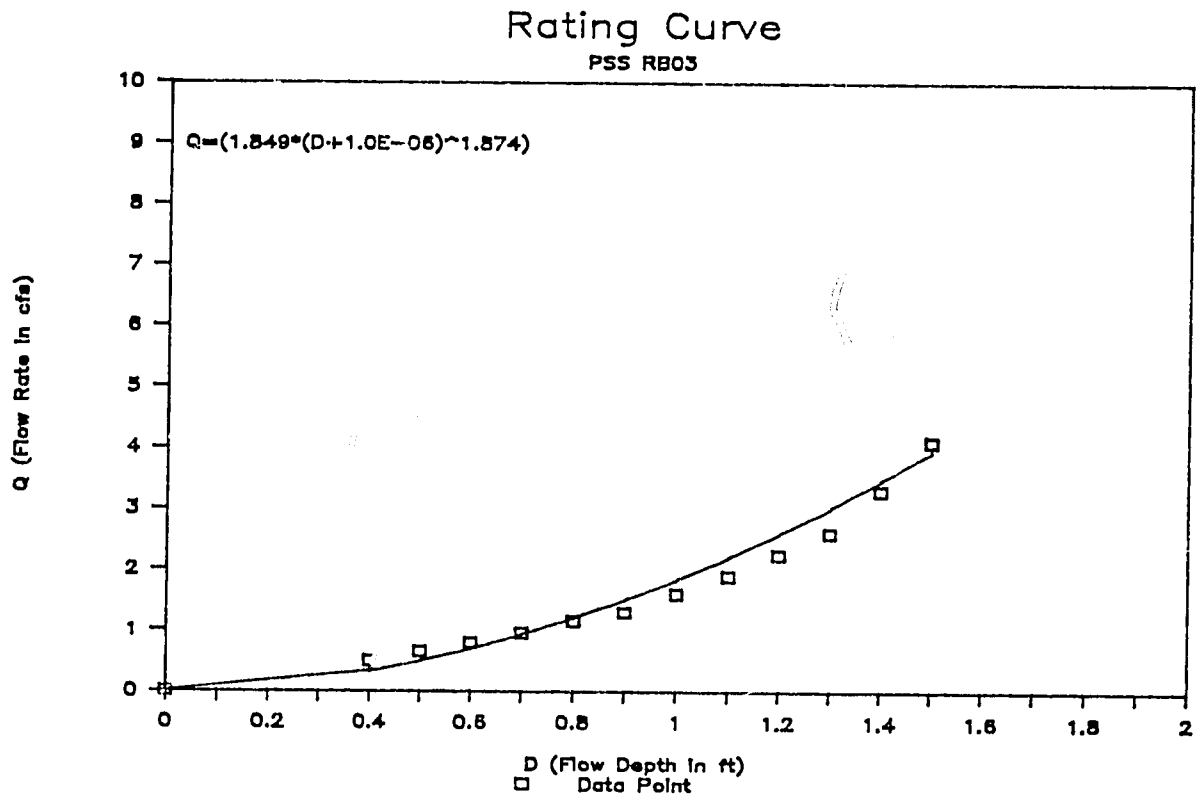
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2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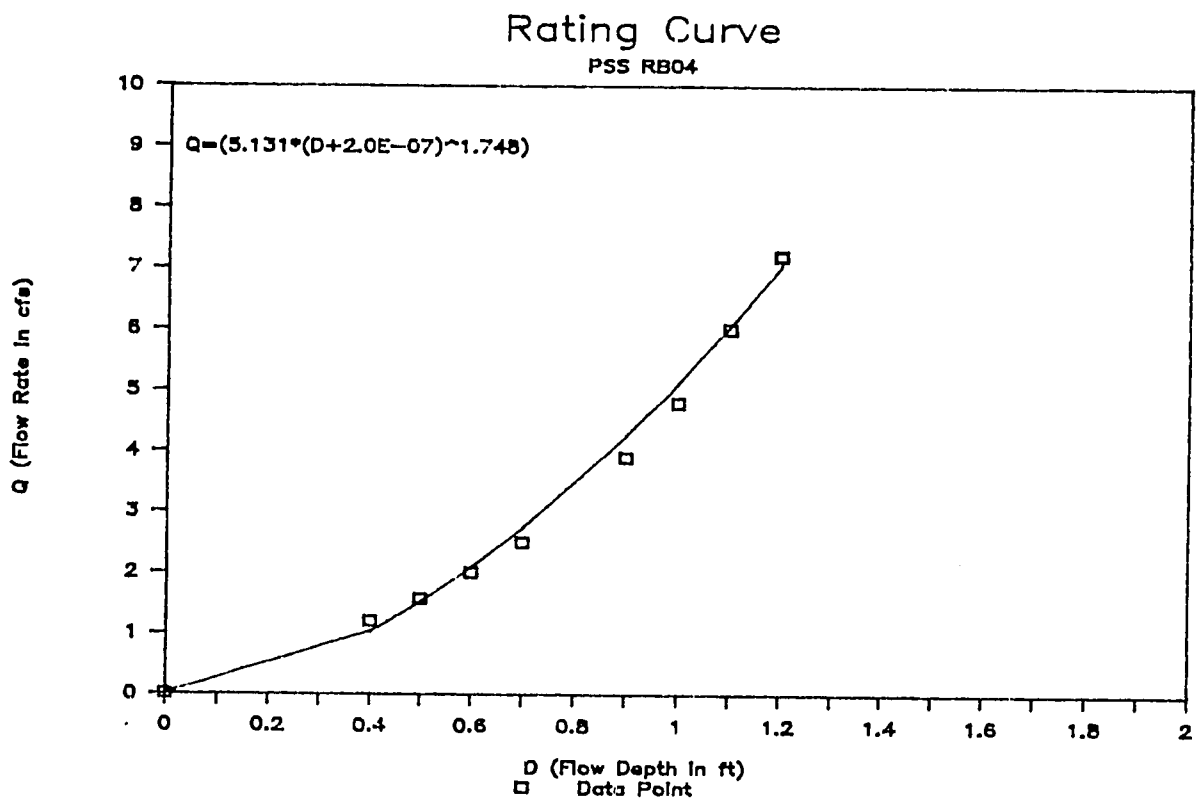
Data Point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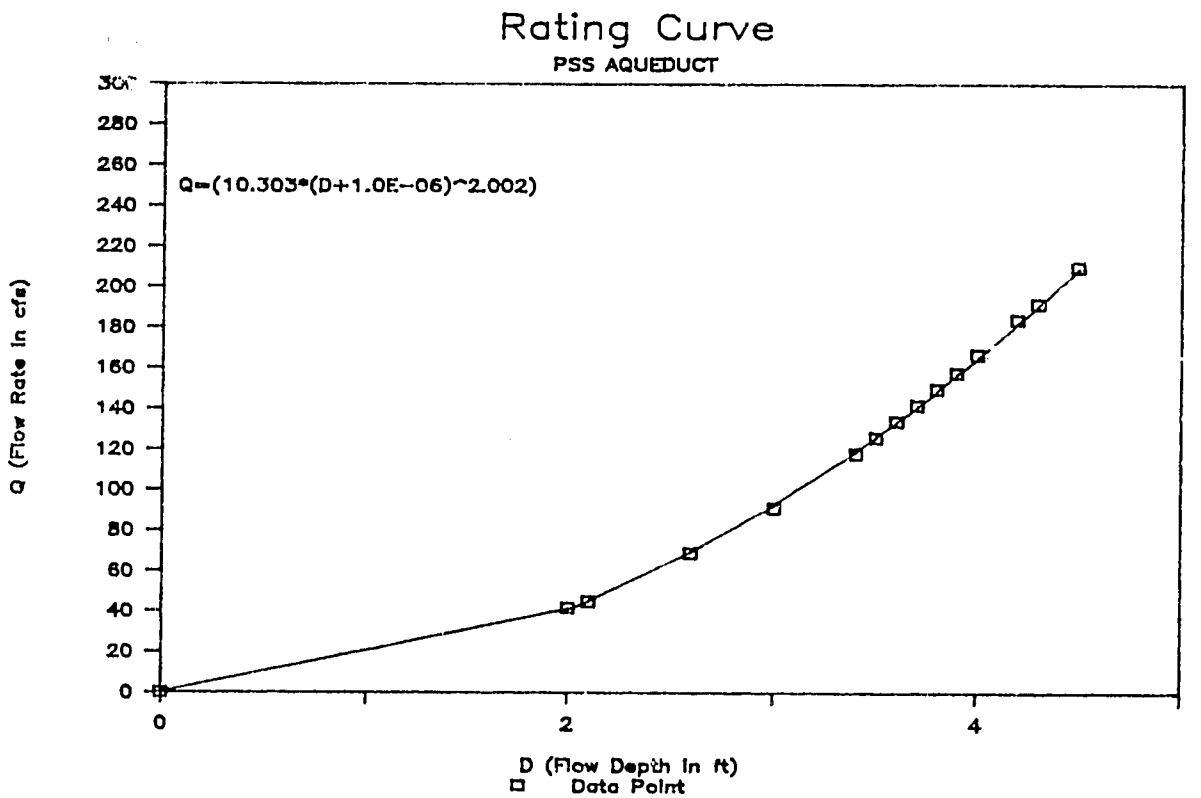
D (Flow Depth in ft)
Data Point


Rating Curve
PSS AQUEDUCT
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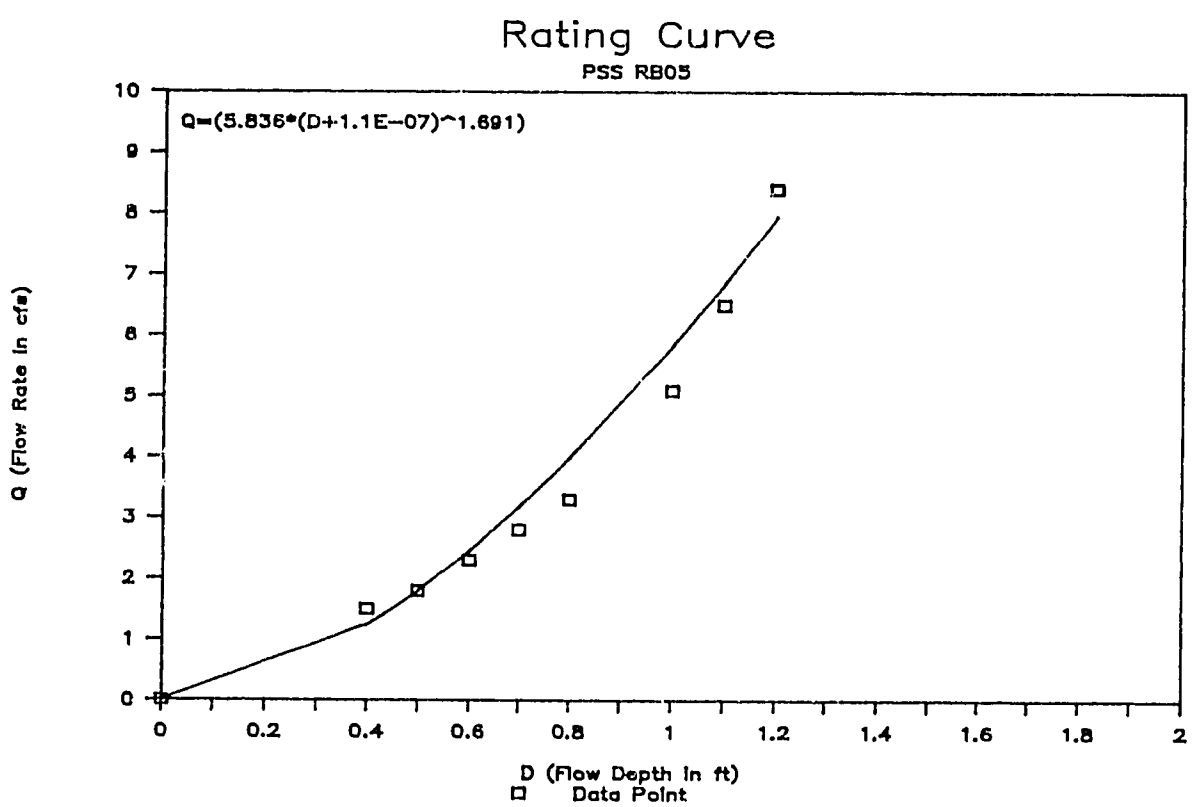
D (Flow Depth in ft)
Data Point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PSS RB05
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D (Flow Depth in ft)
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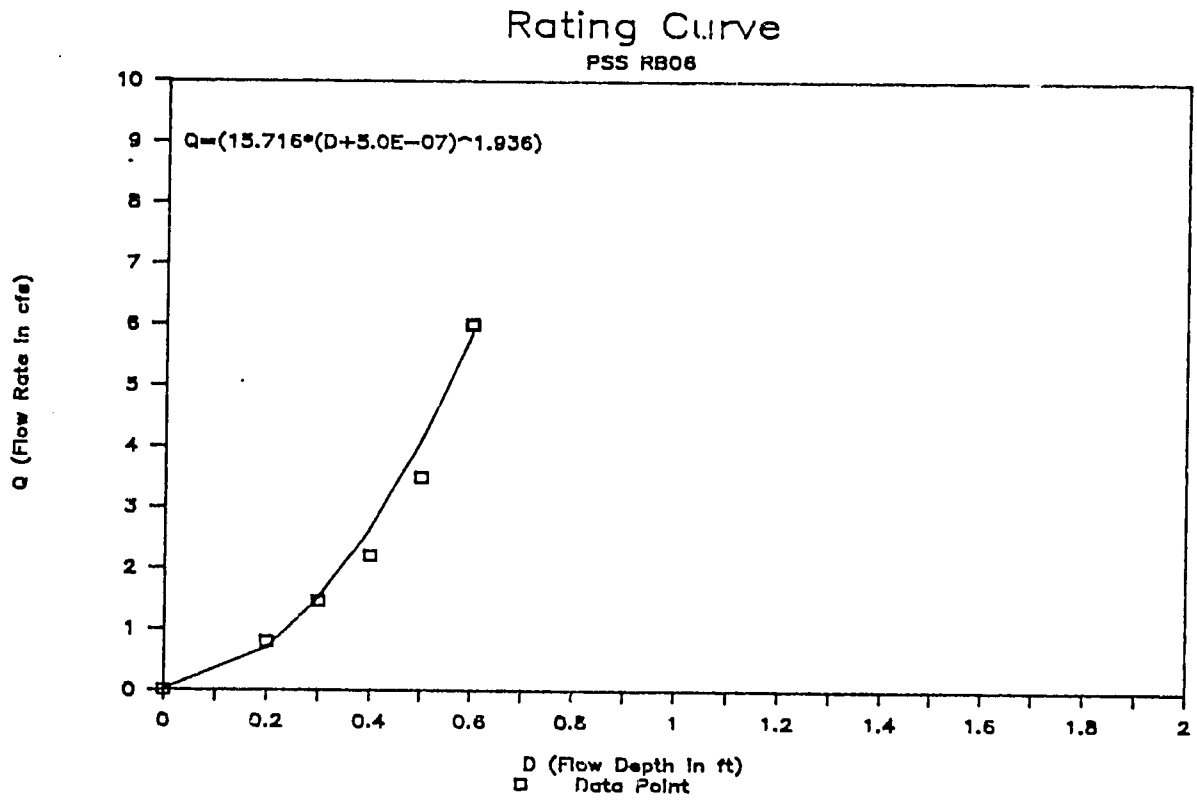
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PSS RB06
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D (Flow Depth in ft)
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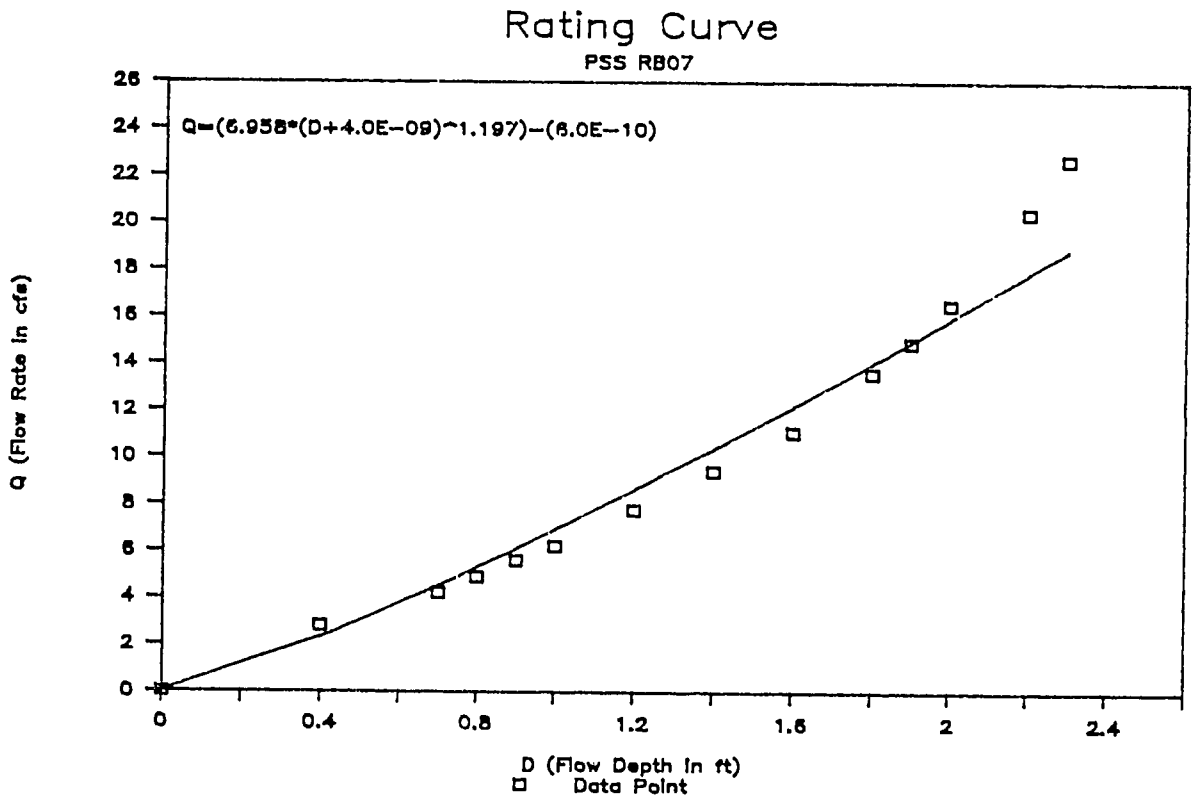
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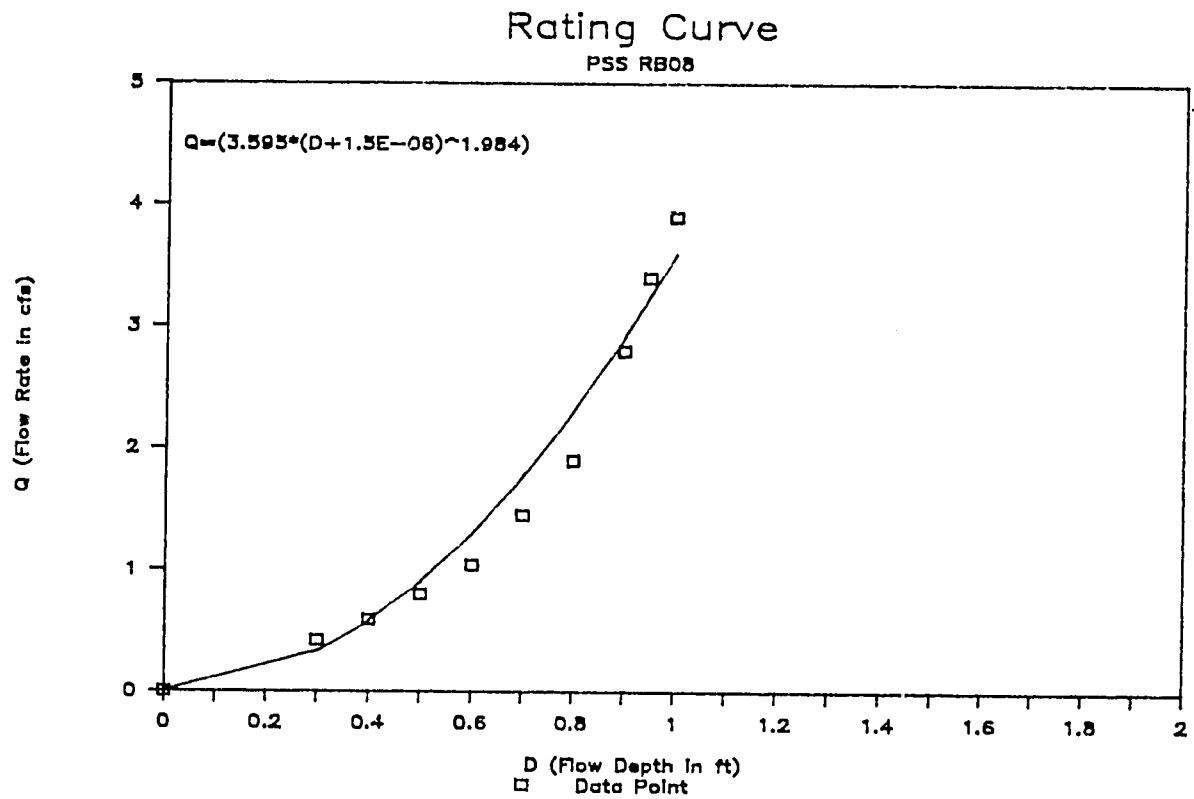
D (Flow Depth in ft)
Data Point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PSS RB08
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Q (Flow Rate in cfs)
D (Flow Depth in ft)
Data Point
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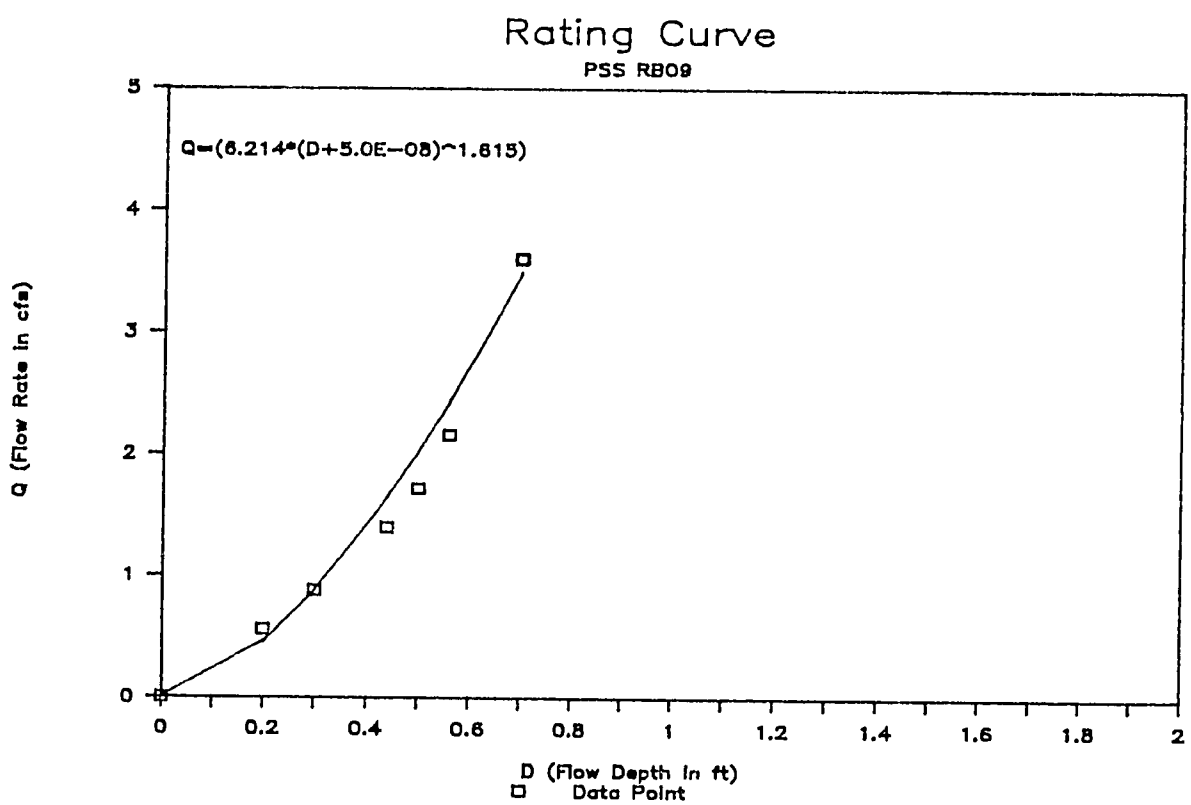
1
2
3
4
5
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2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PSS RB09
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Data Point
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1
2
3
4
5
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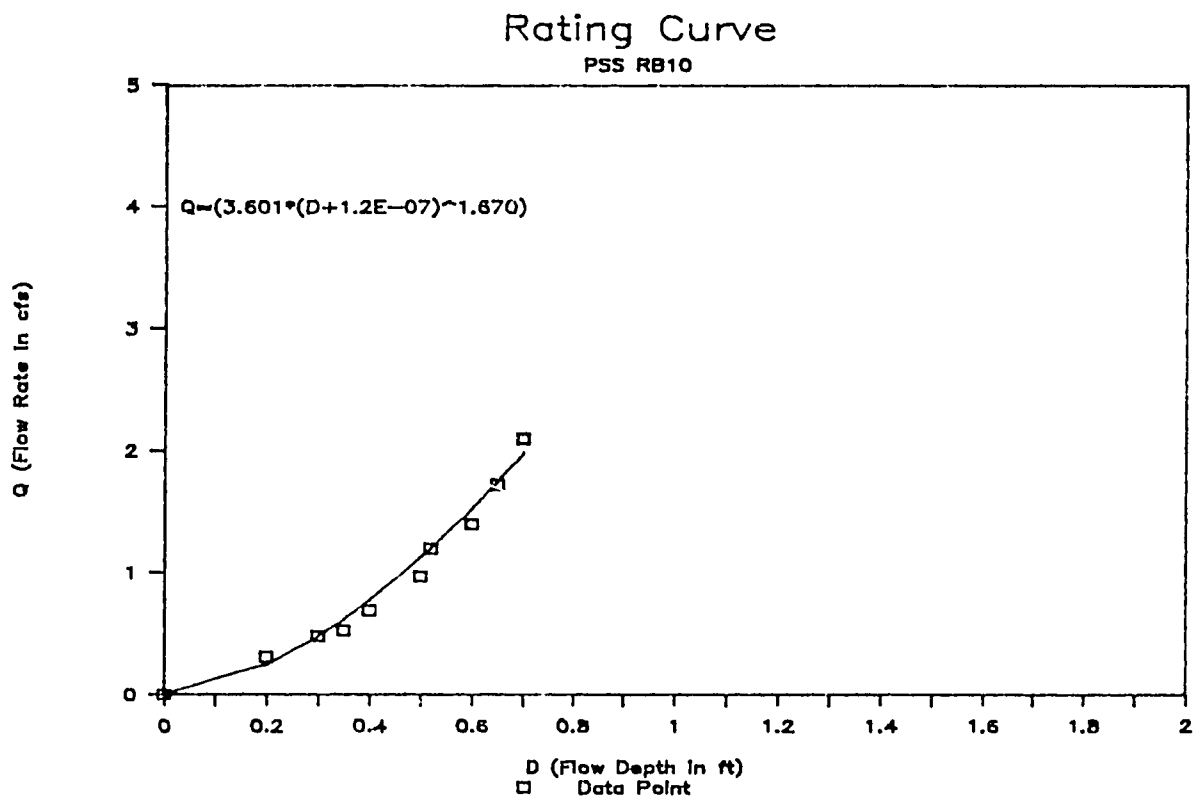
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2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PSS RB10
Q=(3.601*(D+1.2E-07)^1.670)
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D (Flow Depth in ft)
Data Point
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1
2
3
4
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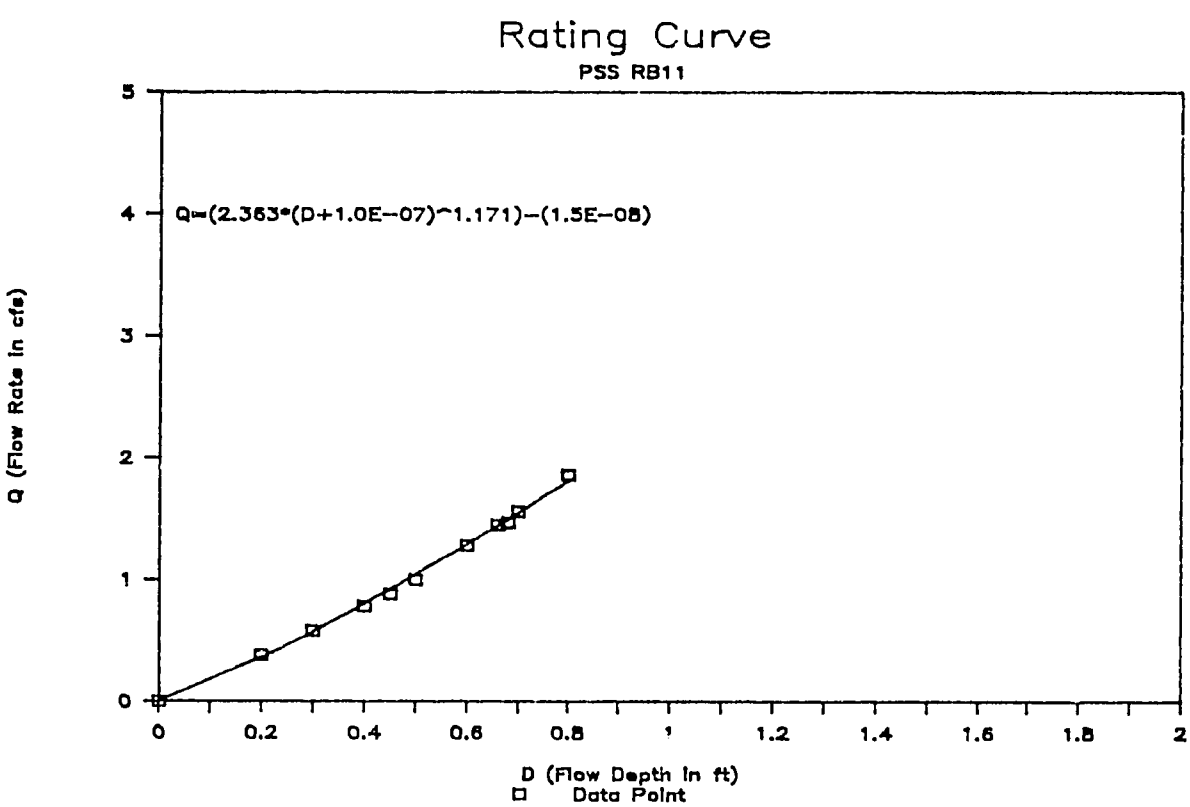
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2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PSS RB11
Q=(2.363*(D+1.0E-07)^1.171)-(1.5E-08)
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D (Flow Depth in ft)
Data Point
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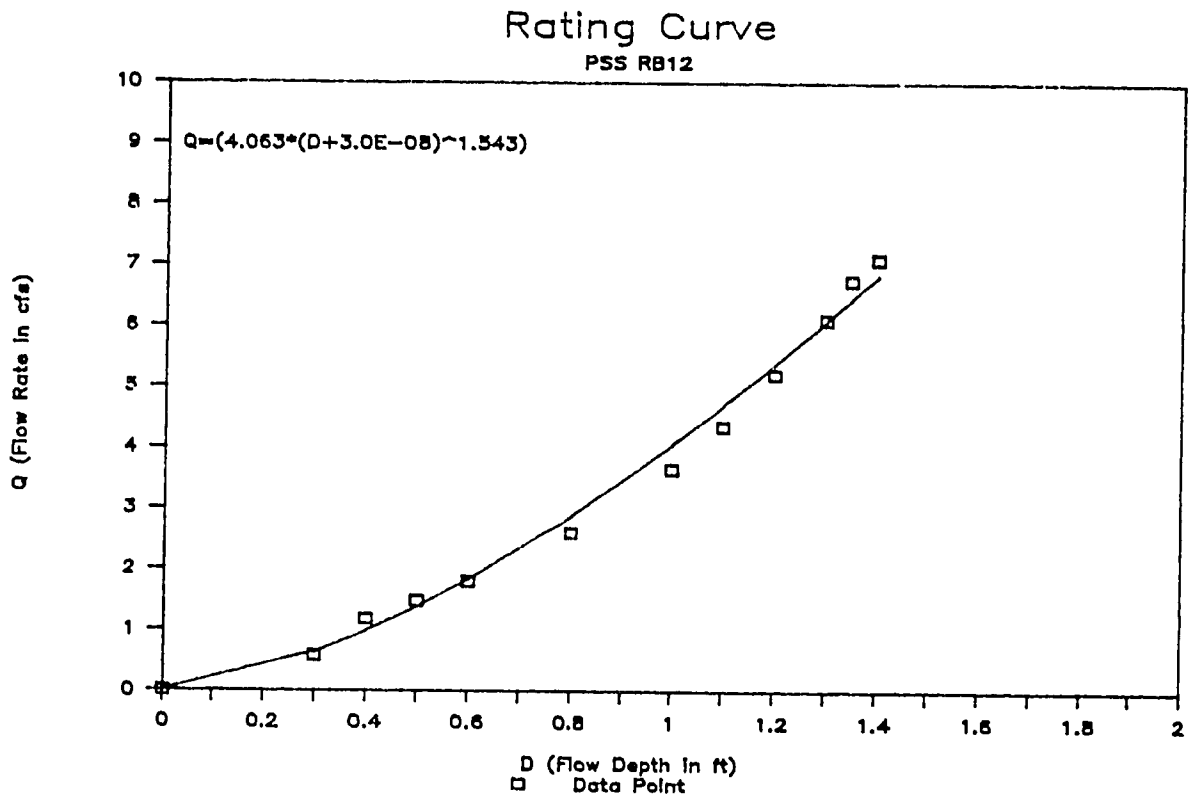
1
2
3
4
5
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2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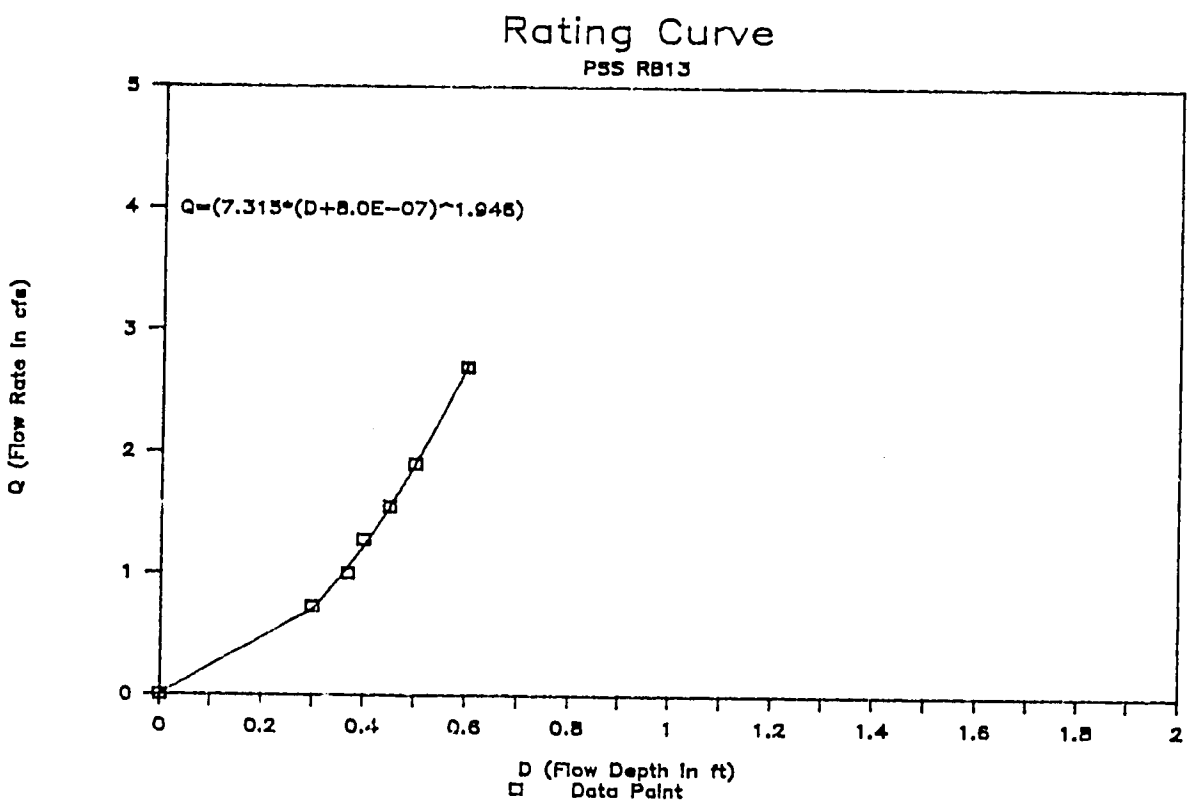
D (Flow Depth in ft)
Data Point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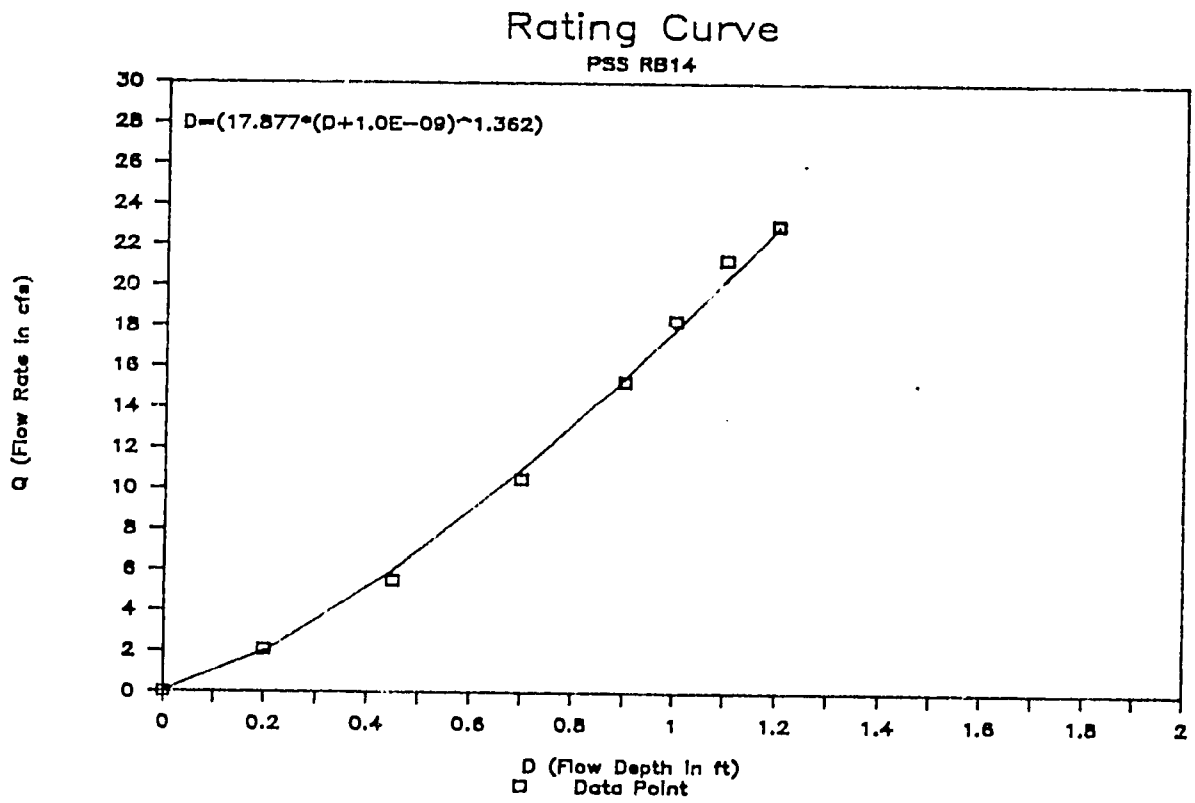
D (Flow Depth in ft)
Data Point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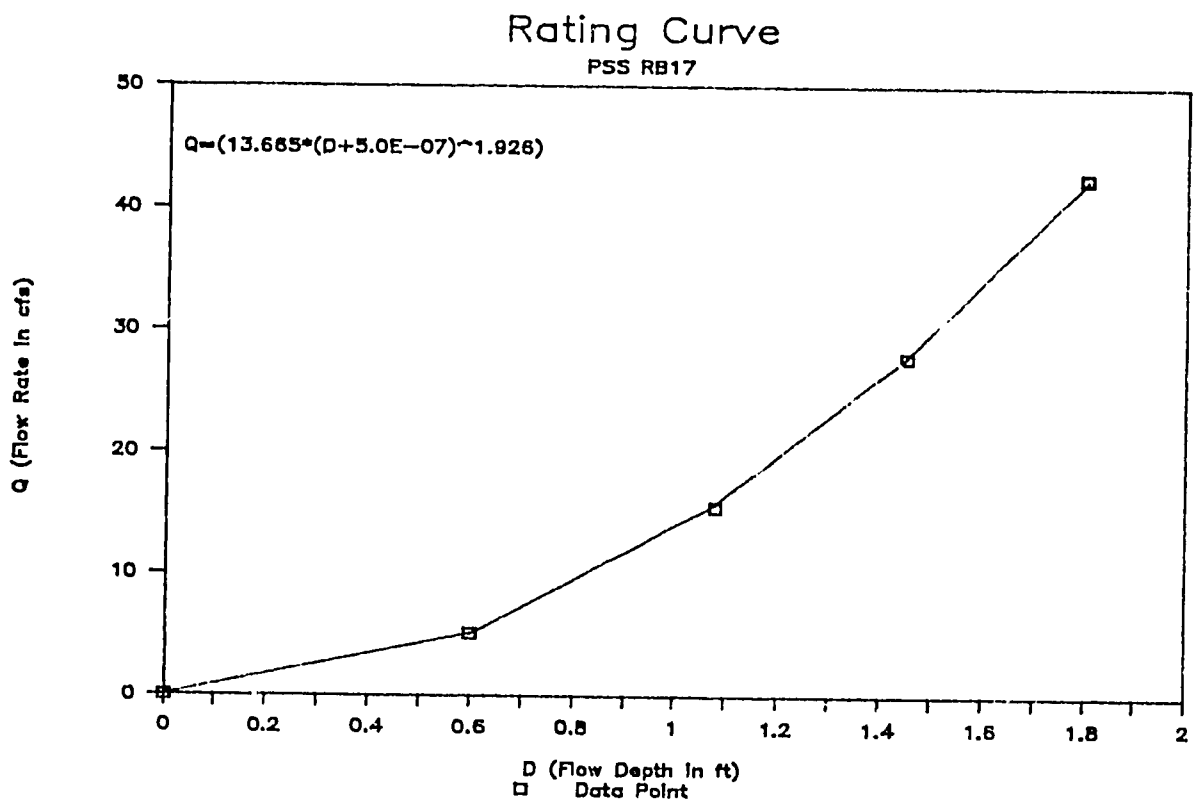
D (Flow Depth in ft)
Data Point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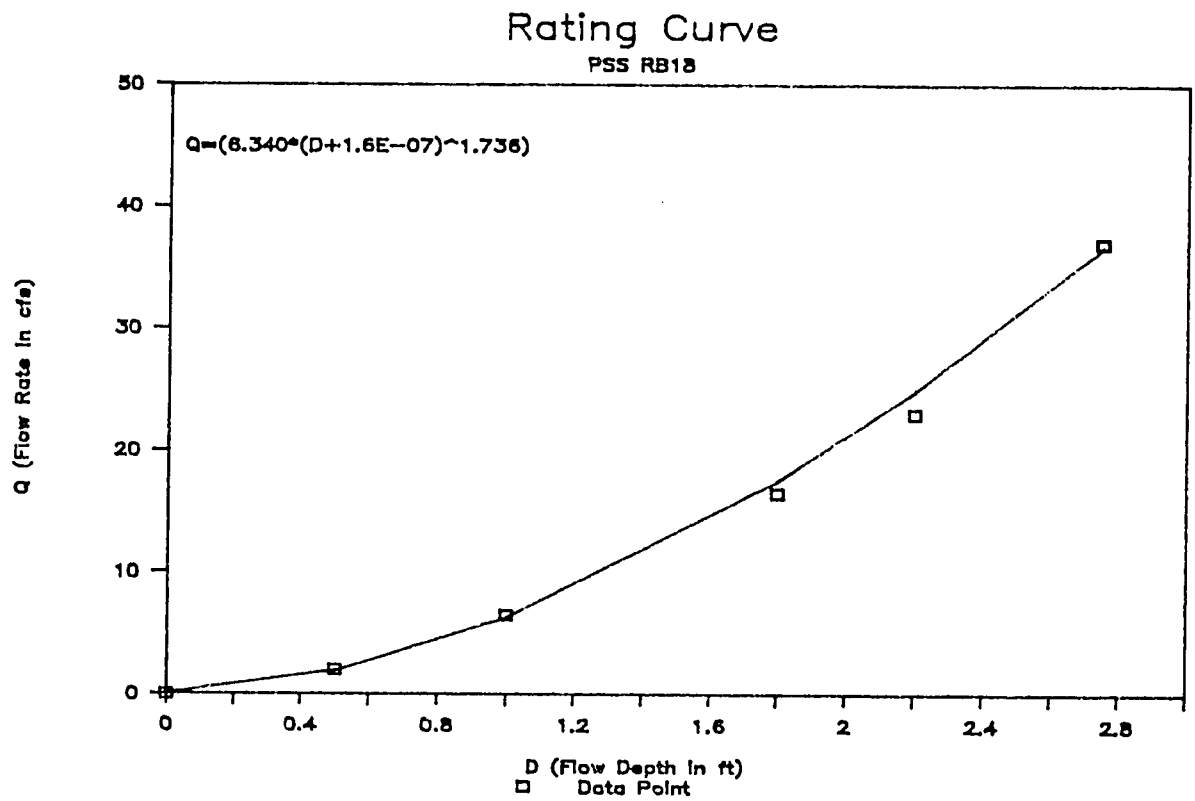
Q (Flow Rate in cfs)
D (Flow Depth in ft)
Data Point


Rating Curve
PSS RB18
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Q (Flow Rate in cfs)
D (Flow Depth in ft)
Data Point
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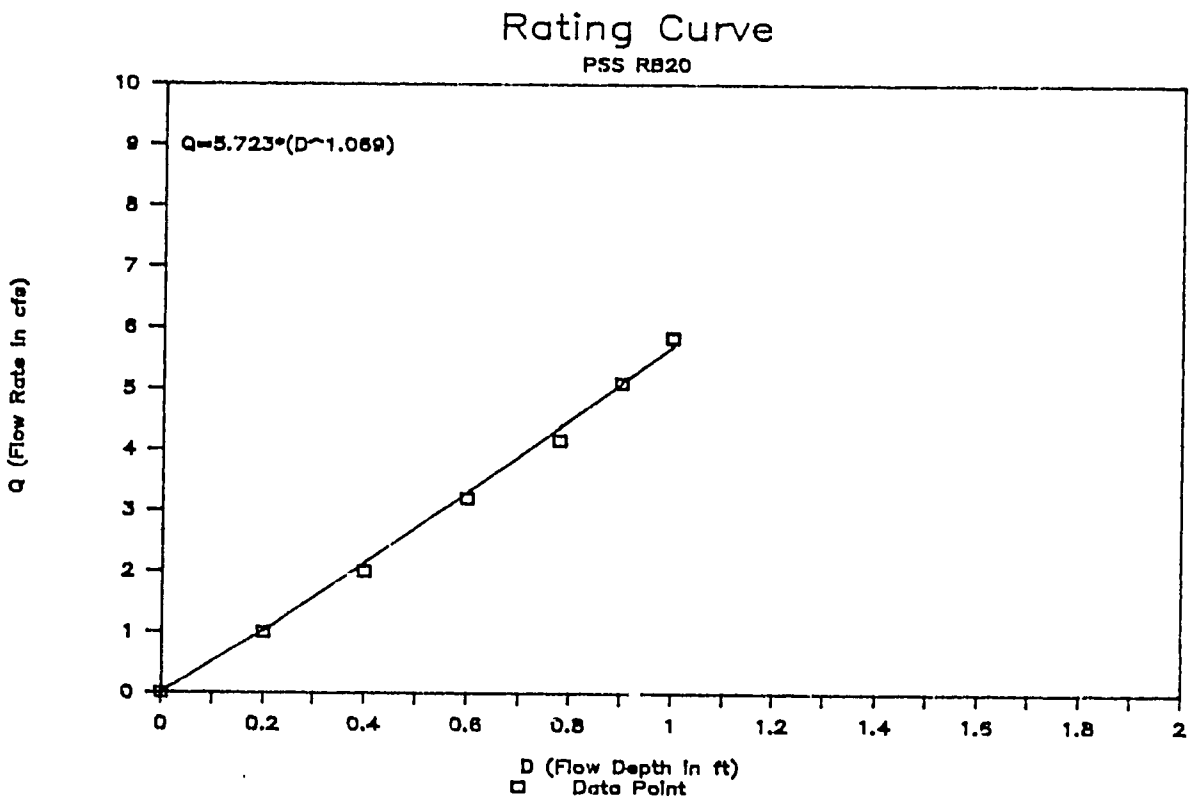
20
30
40
50
0
0.4
0.8
1.2
1.6
2
2.4
2.8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D (Flow Depth in ft)
Data Point
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3
4
5
6
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9
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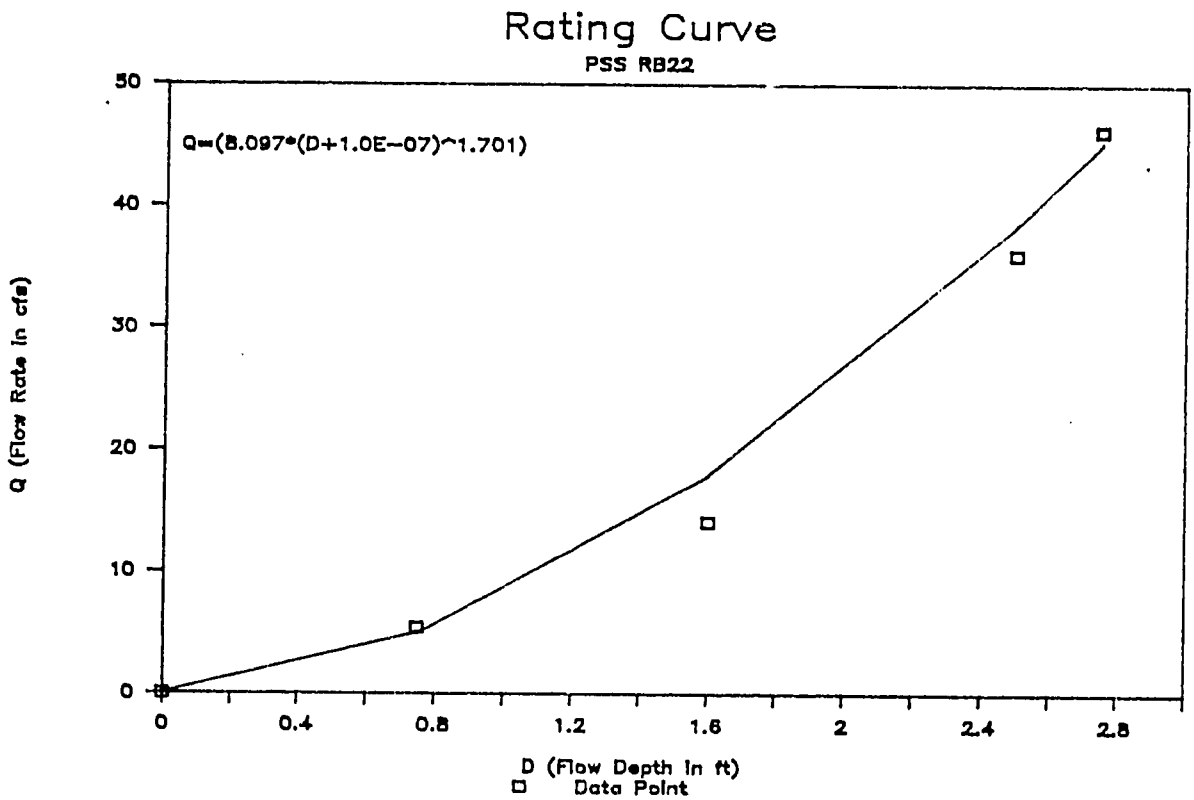
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2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PSS RB22
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Q (Flow Rate in cfs)
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40
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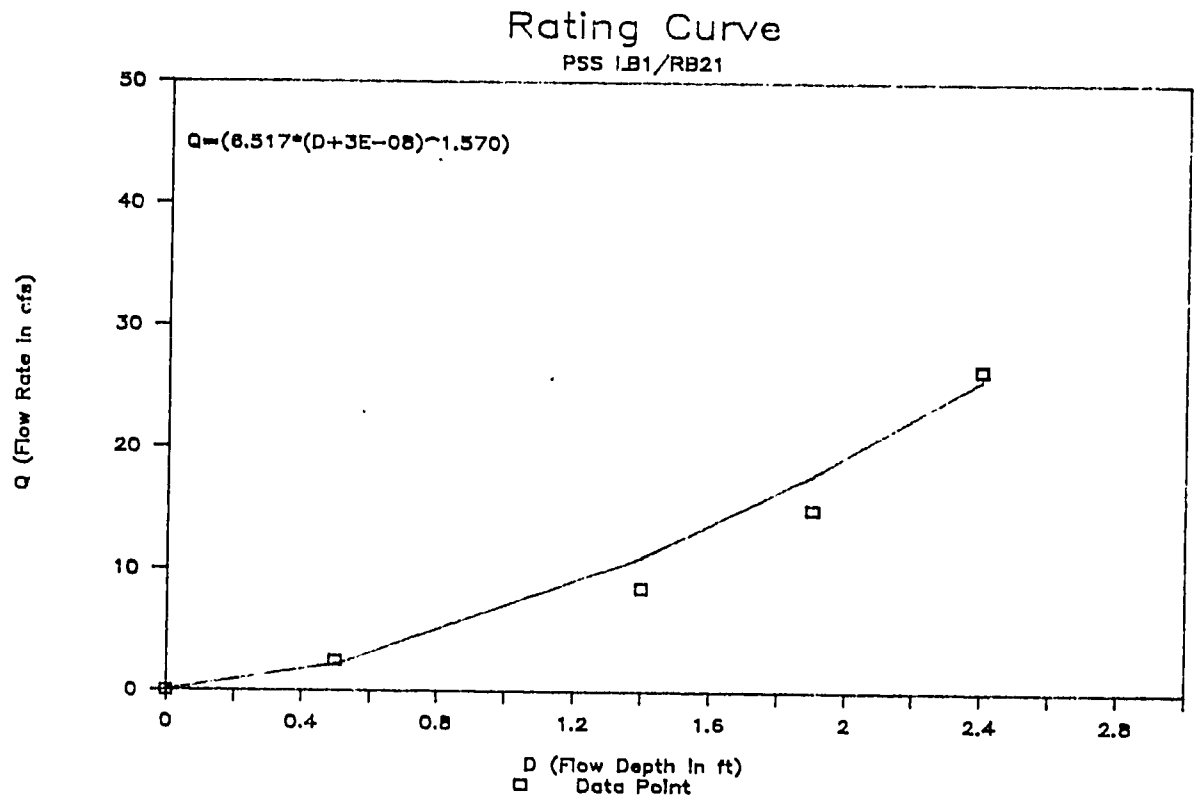
0.4
0.8
1.2
1.6
2
2.4
2.8
D (Flow Depth in ft)
Data Point


Rating Curve
PSS LB1/RB21
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Q (Flow Rate in cfs)
D (Flow Depth in ft)
Data Point
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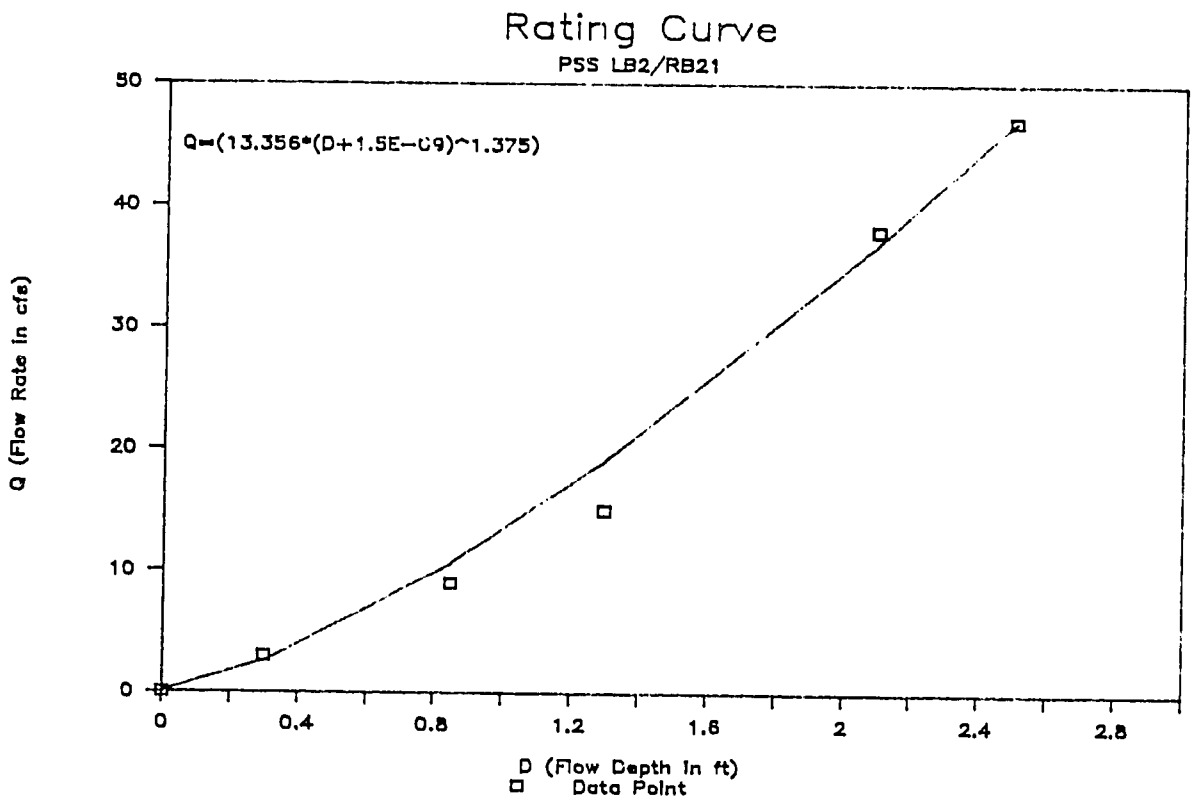
20
30
40
50
0
0.4
0.8
1.2
1.6
2
2.4
2.8


Rating Curve
PSS LB2/RB21
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Q (Flow Rate in cfs)
D (Flow Depth in ft)
Data Point
0
10
20
30
40
50
0
0.4
0.8
1.2
1.6
2
2.4
2.8

APPENDIX B

SOIL PROFILE DESCRIPTIONS, SOIL LEGEND, AND ENGINEERING AND SOIL SURVEY MAPS OF SELECTED FIELDS IN PSS, 1985 YALA

Soil Profile Description of Reddish-Brown Earth, Well-Drained Soil

Study Site: Kaudulla, Stage II, tract 5, field channel 2, I.M.D. Pit 1; 6/11/86; S.V. Siriwardena. Site was a gently undulating, well-drained home garden with 2-3 percent slope.

Soil Profile:

Ap 0-10 cm. Dark brown (7.5YR 4/4); moist, light sandy clay loam; weak, subangular, blocky; very slightly plastic wet, friable moist; few fine quartz gravel, few manganese stains; common fine and few medium tubular inped pores; common fine and few medium roots; clear, smooth change.

B1 10-40 cm. Strong brown (7.5YR 5/6); moist, sandy clay loam; weak, subangular, blocky; slightly sticky and slightly plastic wet, friable moist; few fine quartz gravel, few manganese stains; common fine, few medium tubular inped pores; common fine and few medium roots; few fine mica and feldspar; very thin patchy clay skins; clear, smooth change.

B2t1 40-55 cm. Reddish-brown (5YR 4/4); moist, gravely sandy clay loam; structureless massive; slightly sticky and non-plastic wet, friable moist; common fine and few medium quartz gravel (30-40 percent); occasional quartz pebbles; few manganese concretions; few fine tubular inped pores; common fine and few medium roots; common fine mica and feldspar; thin patchy clay skins; gradual, smooth change.

B2t2 55-100 cm. Reddish-brown (2.5YR 4/4); moist, gravely sandy clay loam; structureless massive; slightly sticky and non-plastic wet, friable moist; common fine and few medium quartz gravel (about 30-40 percent); occasional quartz pebbles; few manganese concretions; few fine tubular inped pores; common fine and few medium roots; common fine mica and feldspar; thin patchy clay skins; clear, smooth change.

B3 100-120 cm. Red (2.5YR 4/8); moist, sandy clay loam; weak, medium, subangular, blocky; slightly sticky and plastic wet, few fine quartz gravel; few manganese concretions; few fine tubular inped pores; common fine and few medium roots; common fine feldspar and mica; clear, smooth change.

C 120-130 cm. Decomposing parent material mixed with many fine mica and feldspar.

130+ cm. Bedrock.

Soil Profile Description of Reddish-Brown Earth, Imperfectly Drained Soil

Study Site: Giritale, Purana Ela, Pit 3; 21/10/85; S.V. Siriwardena. Site was nearly level with 0-0.5 percent slope, tobacco.

Soil Profile:

Ap 0-30 cm. Dark greyish-brown (10YR 4/2); moist, sandy clay loam; weak, medium, subangular, blocky; slightly sticky and slightly plastic; wet, friable, moist faint mottles; common fine and few medium roots; common fine and a few medium tubular inped pores; few manganese concretions, few quartz gravel; faunal activity; clear, smooth boundary.

B1 30-75 cm. Dark brown (10YR 4/3); moist, sandy clay loam; moderate, medium, subangular, blocky; slightly sticky and slightly plastic wet, friable moist; common, medium distinct, yellowish-red (5YR 4/6) mottles; common fine and few medium roots; few fine tubular inped pores; many manganese concretions; few fine quartz gravel; occasional quartz pebbles; common fine feldspar; faunal activity; clear, smooth change.

B2 75-120 cm. Greyish-brown (10YR 5/2); moist, sandy clay loam; moderate, medium, subangular, blocky; slightly sticky and slightly plastic wet, friable moist; common, medium distinct, strong brown (7.5YR 5/6) mottles; common fine and occasional medium roots; common manganese concretions (10-20 percent); fine and medium quartz gravel; occasional quartz pebbles; common iron stone gravel; common fine feldspar; faunal activity; clear, smooth change.

B3 120-175 cm. Dark grey (5YR 4/1); moist clay; structureless massive; very sticky and plastic wet, firm moist; common, medium distinct, yellowish-brown (10YR 5/6) mottles; common manganese concretions, fine quartz gravel; thin patchy cutans; gleyed horizon; few carbonate concretions.

Soil Profile Description of
Low Humic Gley, Poorly Drained Soil

Study Site: Giritale, Purana Ela, Pit 2; 21/10/85; S.V. Siriwardena. Site was nearly level, 0-0.5 percent slope, paddy.

Soil Profile:

Ap 0-20 cm. Very dark greyish-brown (2.5Y 3/2); moist sandy clay loam; weak, medium, subangular, blocky; slightly sticky and slightly plastic wet, friable moist; common fine and few medium tubular inped pores; faint mottles; few fine quartz gravel; faunal activity; clear, smooth change.

B1 20-24 cm. Dark greyish-brown (2.5Y 4/2); moist, sandy clay; moderate, subangular, blocky; slightly sticky and slightly plastic wet, friable moist; common fine roots; common fine and few medium tubular inped pores; common, fine, distinct, strong brown (7.5YR 5/6) mottles; few fine quartz gravel; few manganese concretions; faunal activity; clear, smooth change.

B21t 40-70 cm. Olive grey (5Y 4/2); moist, sandy clay; medium, subangular, blocky; sticky and plastic wet, friable moist; few fine roots; common fine tubular inped pores; common, medium distinct, yellowish (10YR 5/8); few fine quartz; common manganese concretions and nodules; faunal activity; gradual, smooth change.

B22t 70-100 cm. Dark grey (5Y 4/1); moist, sandy clay; moderate, medium, subangular blocky; sticky and plastic wet, friable moist; few fine roots; few fine tubular inped pores; common fine distinct yellowish-brown (10YR 5/6) mottles; few manganese concretions; fine quartz gravel; few carbonate concretions; faunal activity; thin patchy cutans; gradual, smooth change.

B3 100-150 cm. Grey (5Y 5/1); moist clay; structureless massive; very sticky and very plastic wet, firm moist; few, fine, distinct, strong brown (7.5Y 5/6) mottles; common carbonate concretions; slicken sides; gleyed horizon.

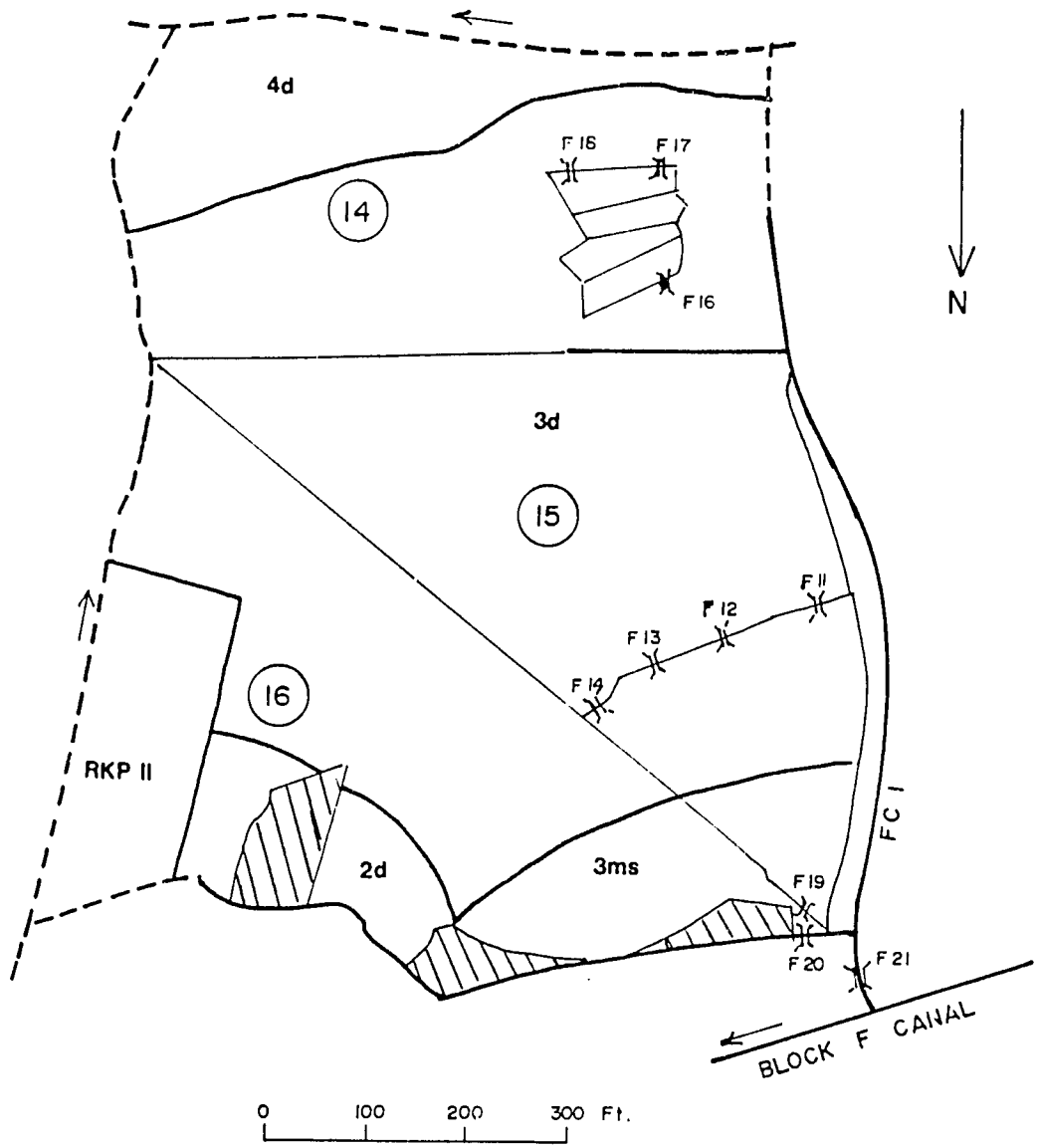
Legend for Engineering and Soil Survey Maps

Physiographic Unit Major	Subunit	Soil Description
Undulating plain	Crest and convex upper slope	1. Reddish-brown earth; well-drained soil. Shallow to deep, brown to dark brown sandy loam to sandy clay loam surface soil with red to dark reddish-brown sandy clay loam to sandy clay subsoil containing quartz (dominant) and feldsphatic gravel and fine mica underlain by reddish or yellowish decomposing material.
	Convex upper slope	2. Reddish-brown earth; moderately well-drained soil. Description same as above.
	Mid-slope to concave lower slope	3. Reddish-brown earth; imperfectly drained soil. Moderately shallow to deep, brown to dark brown sandy loam to sandy clay loam surface soil with yellowish-red to dark yellowish-brown sandy clay loam to sandy clay; mottled subsoil occasionally with quartz and feldsphatic gravel.
Valley bottom of undulating plain	Concave lower slope and depression	4. Low humic gley; poorly drained soil. Deep, brown to gray sandy loam to sandy clay loam surface soil with grayish or bluish sandy clay loam to clay; gleyed subsoil containing carbonate concretion occasionally.
	Depression	5. Low humic gley; very poorly drained soil. Deep, grayish or bluish sandy clay loam to clay; gleyed soil.
Alluvial plain	Depression and flat	6. Alluvial, poorly drained soil. Deep, dark grayish-brown to gray sandy clay loam to clay; gleyed soil.

Mapping Units	
< 60 cm	s (shallow)
60 - 90 cm	ms (moderately shallow)
90 - 120 cm	md (moderately deep)
> 120 cm	d (deep)
	g (gravel layer)

Engineering and Soil Survey Map, PSS, 1985 Yala.

AREA OF FIELDS UNDER FC I OFF BLOCK F (HEAD)

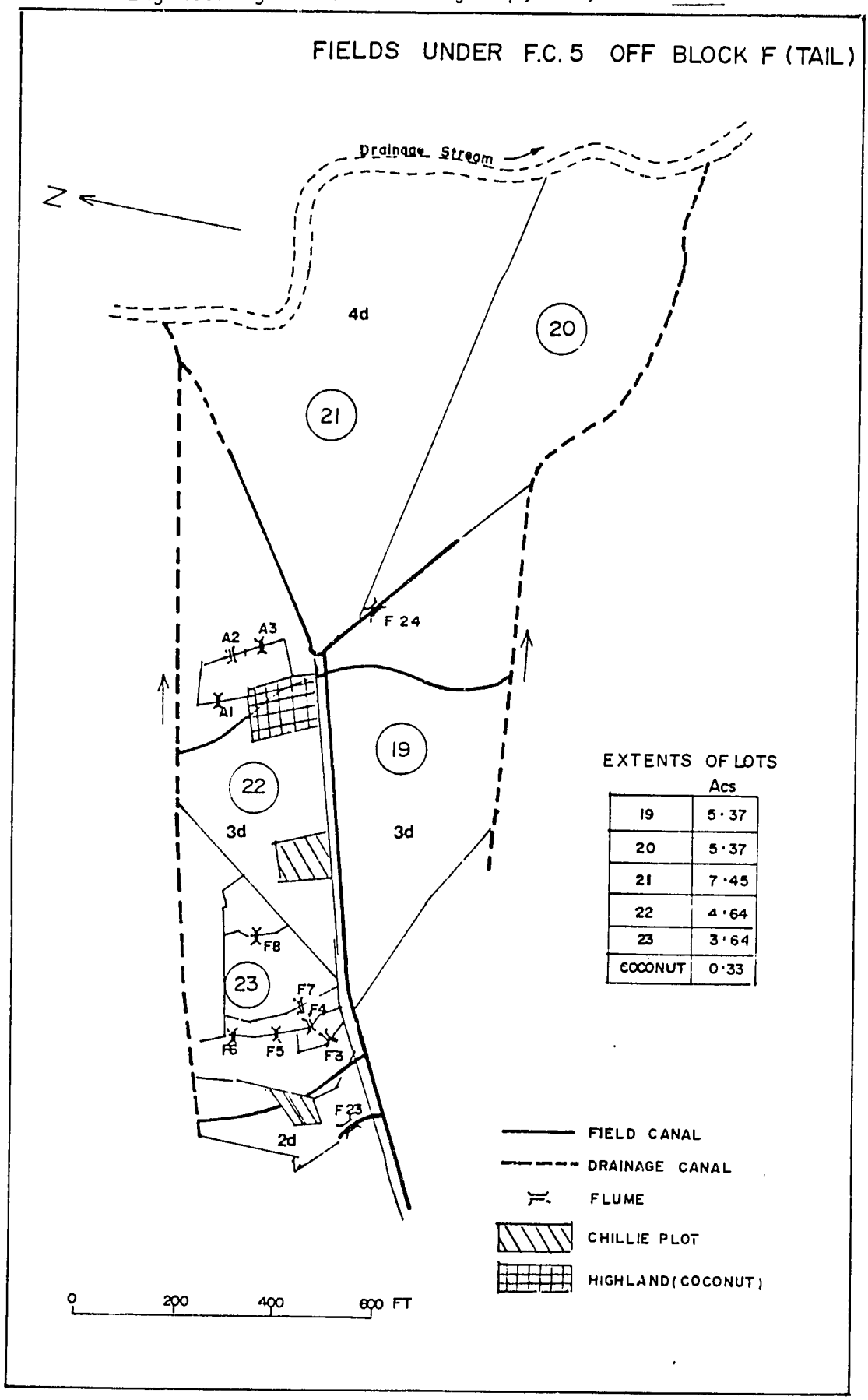


FIELD CANAL
DRAINAGE CANAL
FLUME
CHILLIE PLOT

EXTENTS OF LOTS

14	5·0 Ac.
15	5·1
16	6·0
Total	16·1

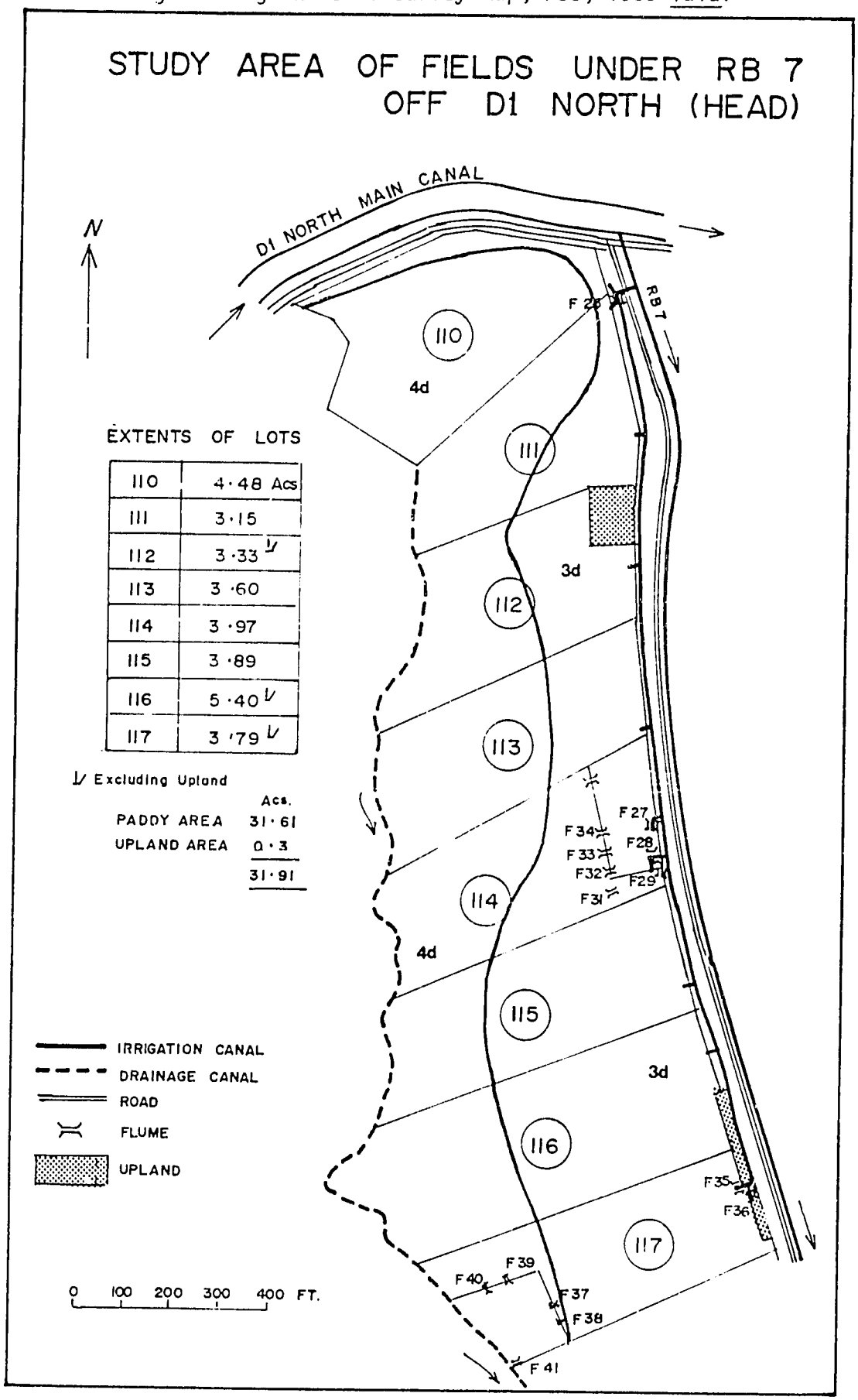
Engineering and Soil Survey Map, PSS, 1985 Yala.



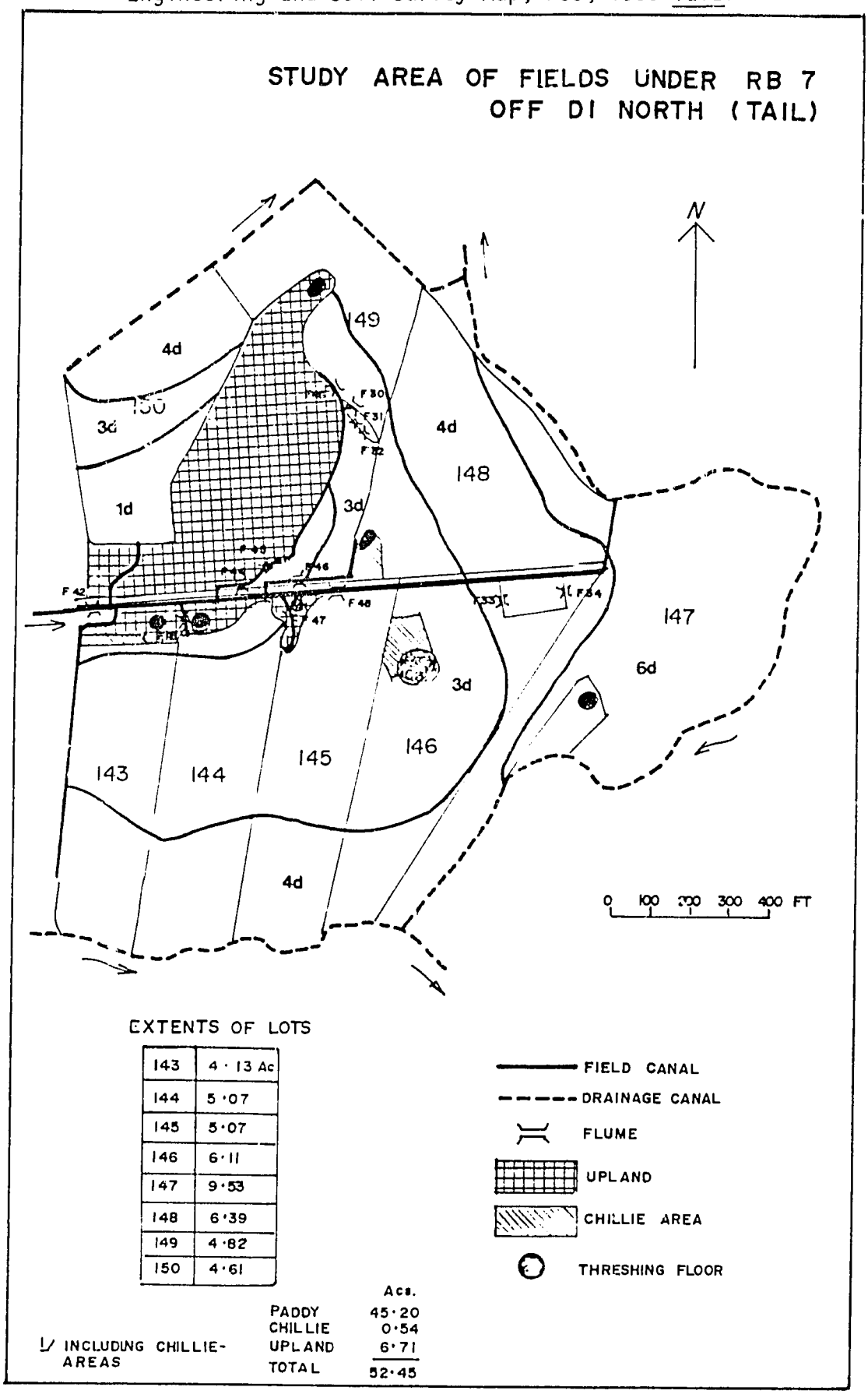
EXTENTS OF LOTS

	Acs
19	5·37
20	5·37
21	7·45
22	4·64
23	3·64
COCONUT	0·33

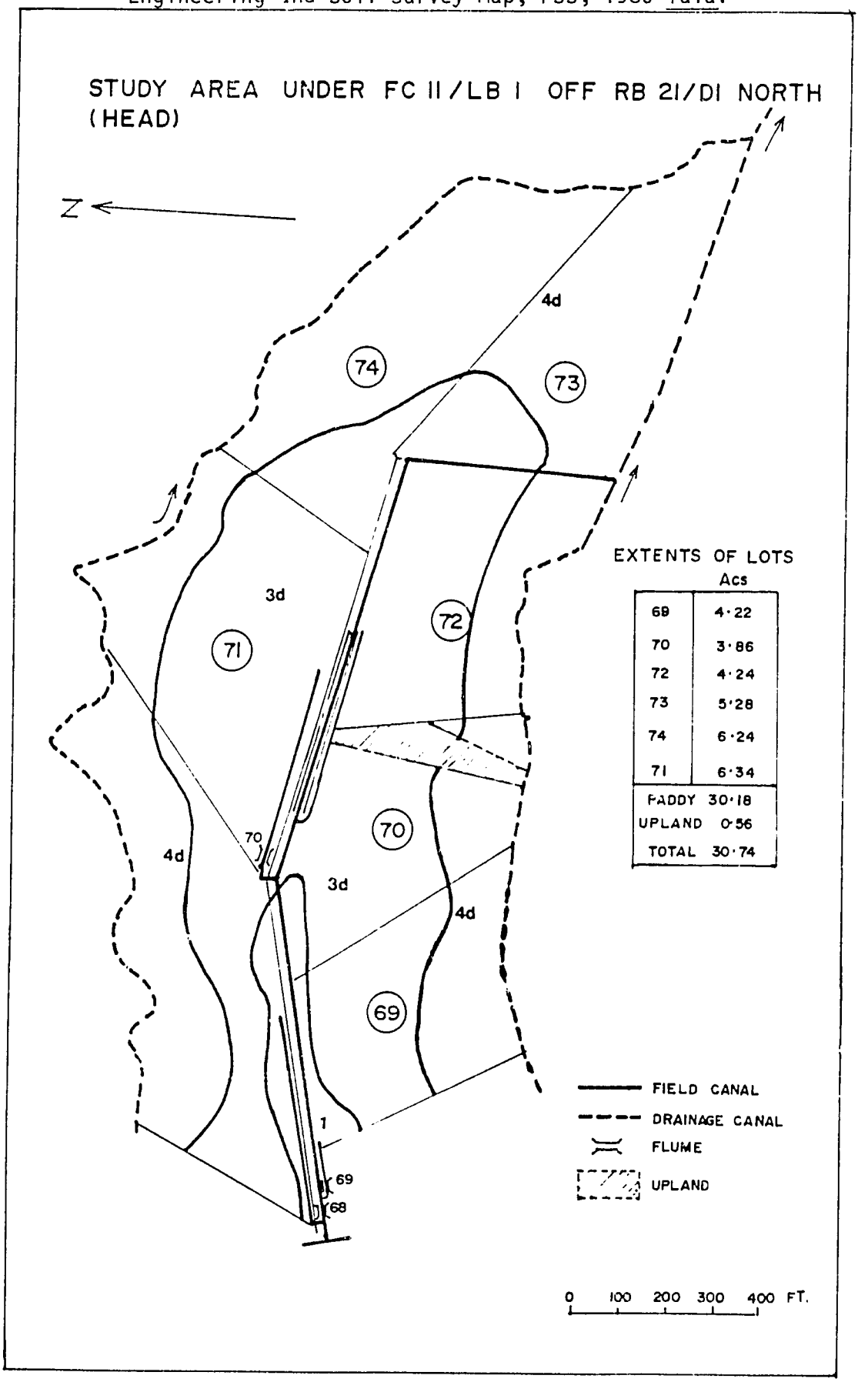
Engineering and Soil Survey Map, PSS, 1985 Yala.



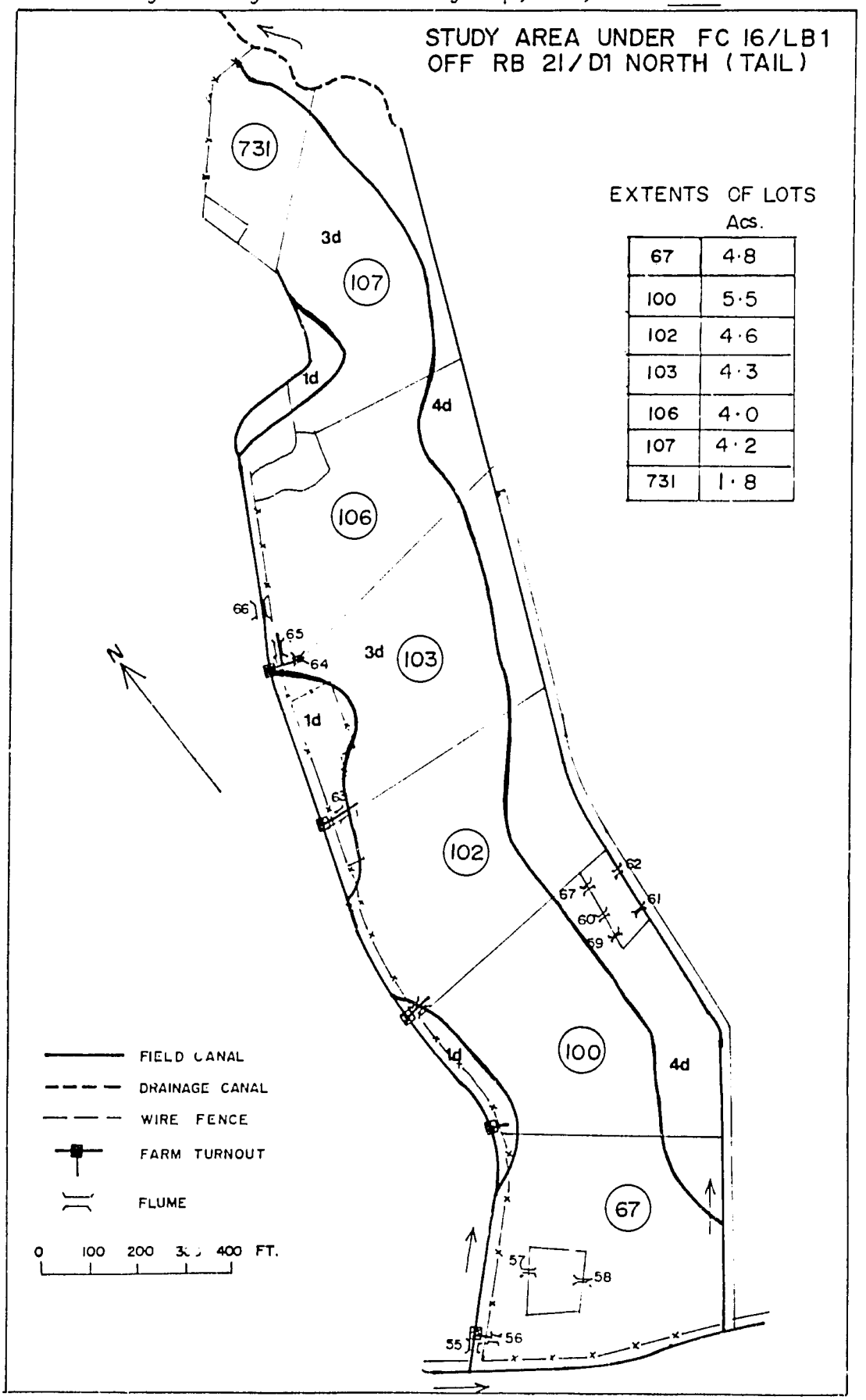
Engineering and Soil Survey Map, PSS, 1985 Yala.



Engineering and Soil Survey Map, PSS, 1985 Yala.

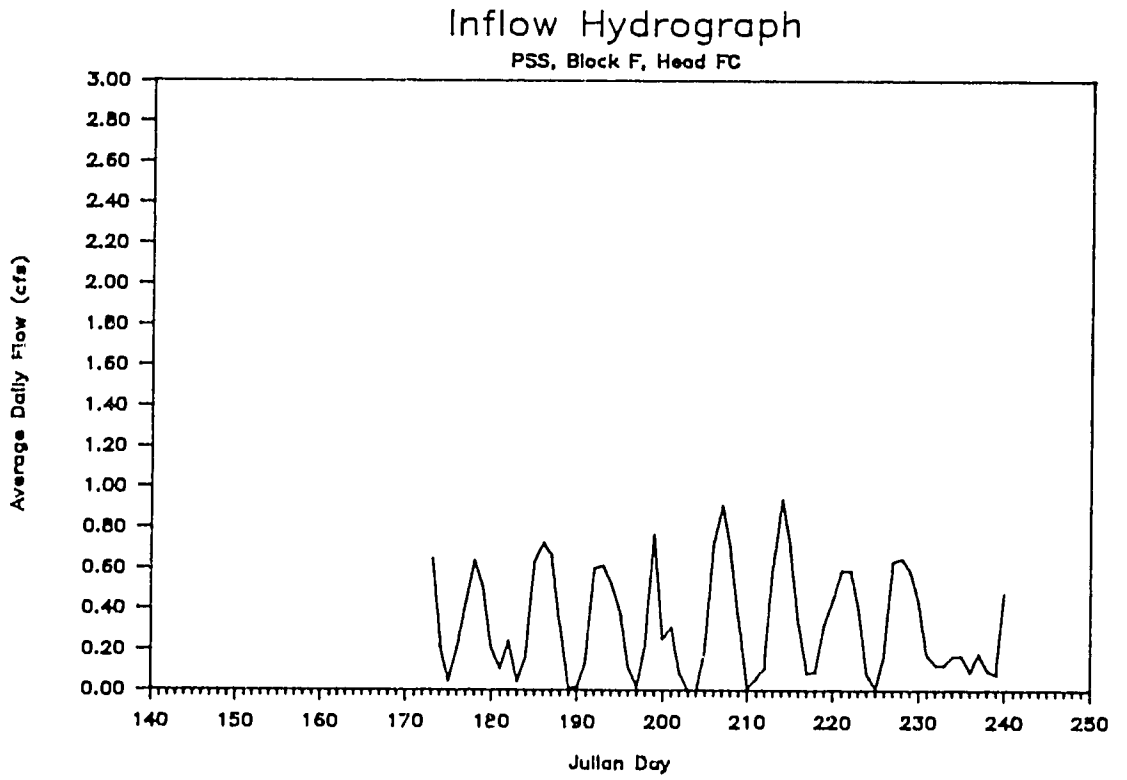


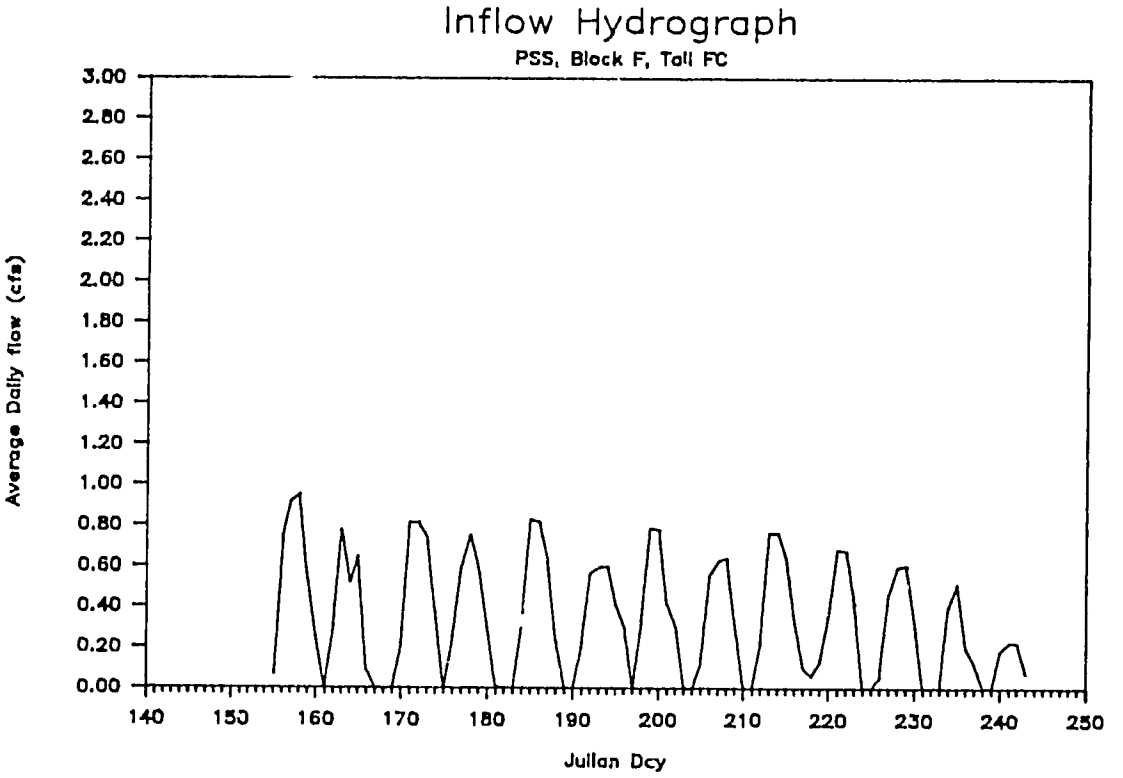
Engineering and Soil Survey Map, PSS, 1985 Yala.

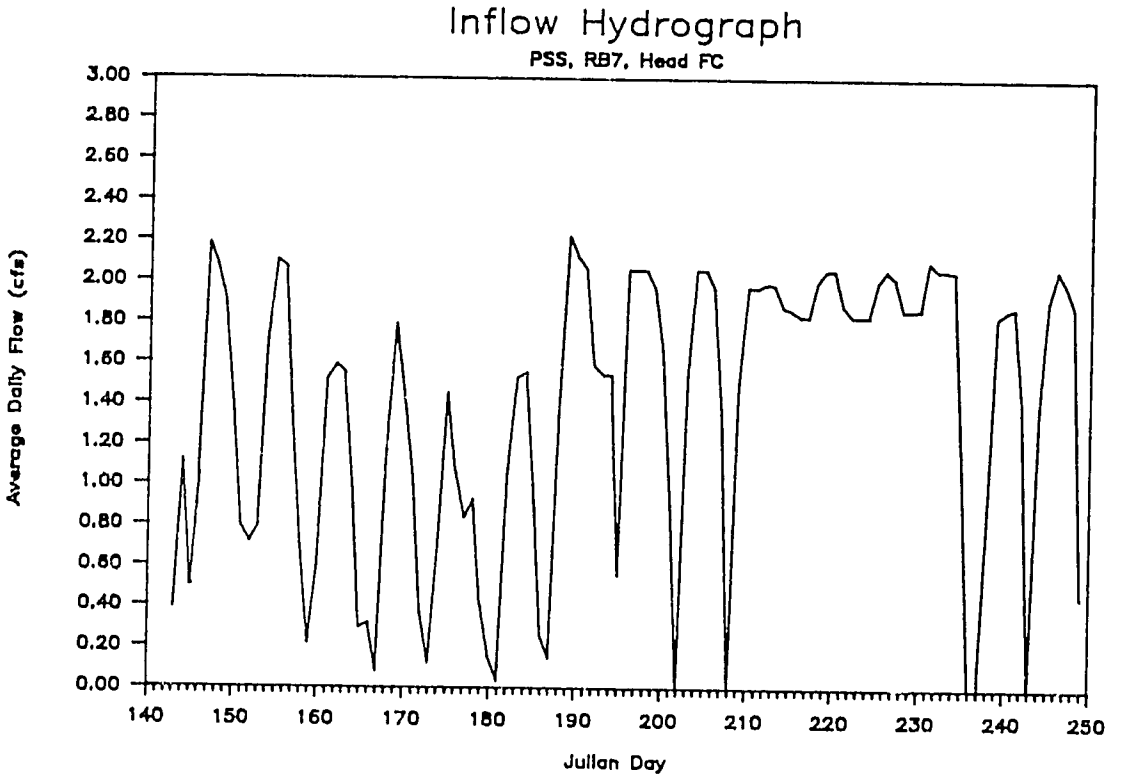


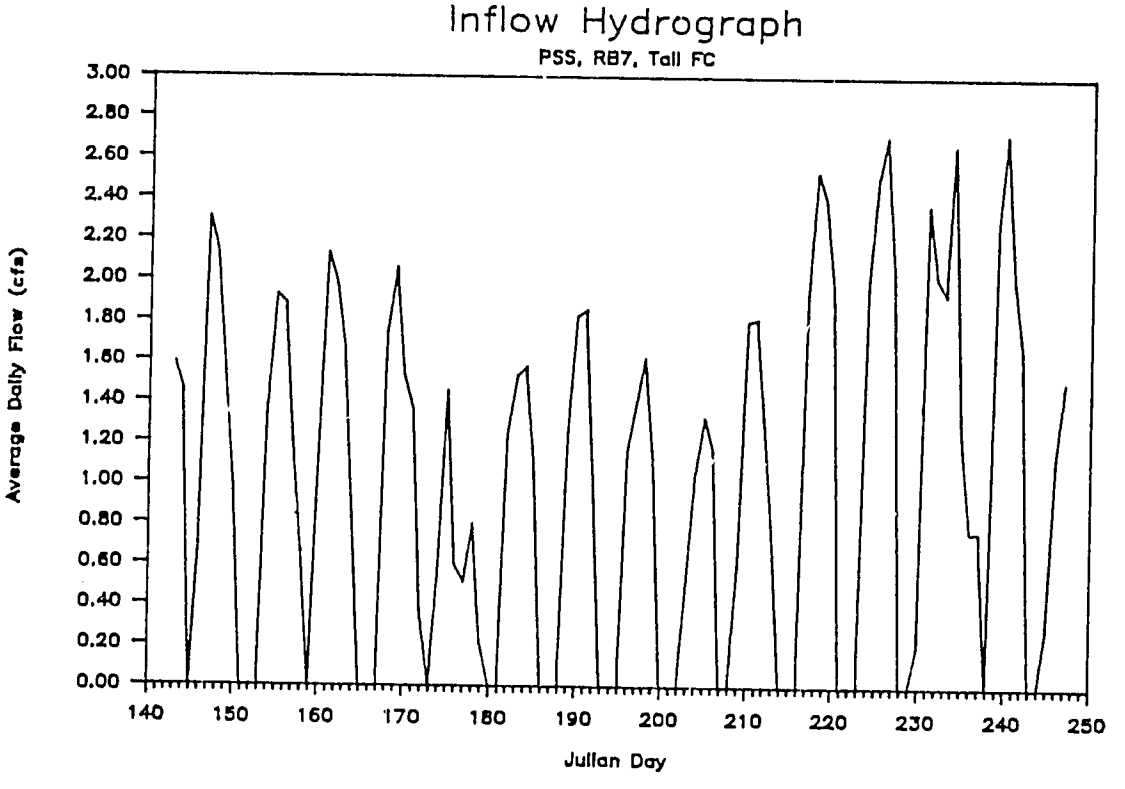
APPENDIX C

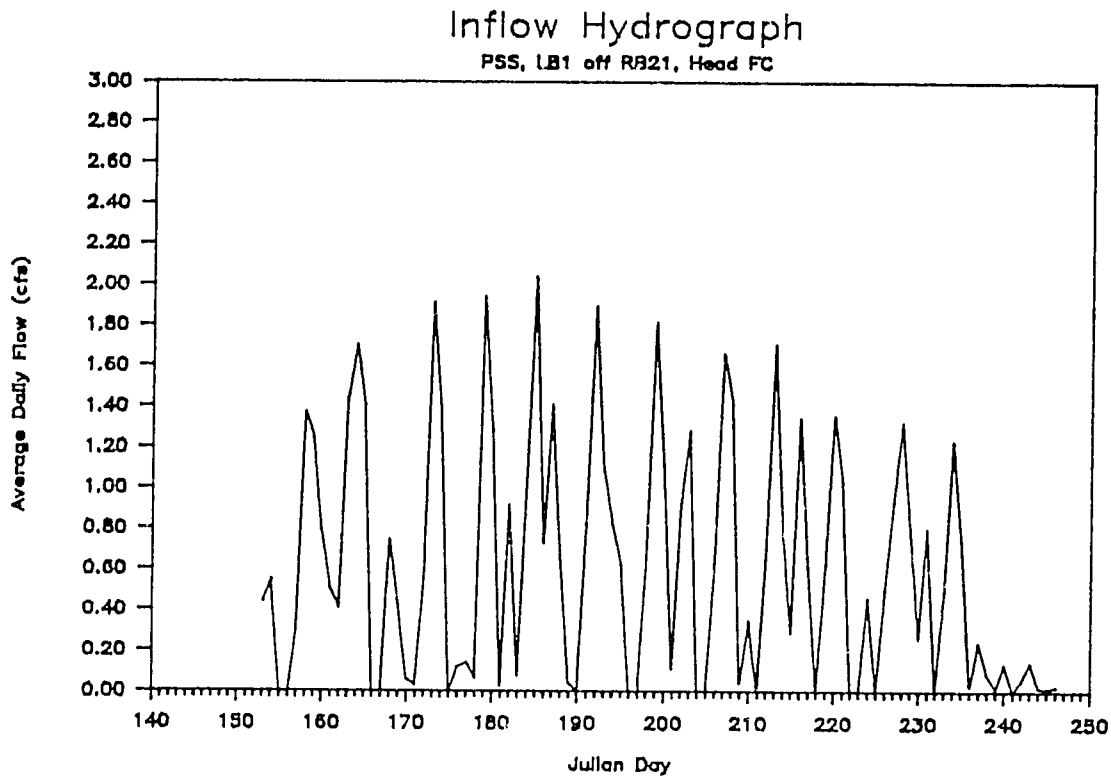
ADDITIONAL INFLOW HYDROGRAPHS FOR PSS STUDY SITES, 1985 YALA

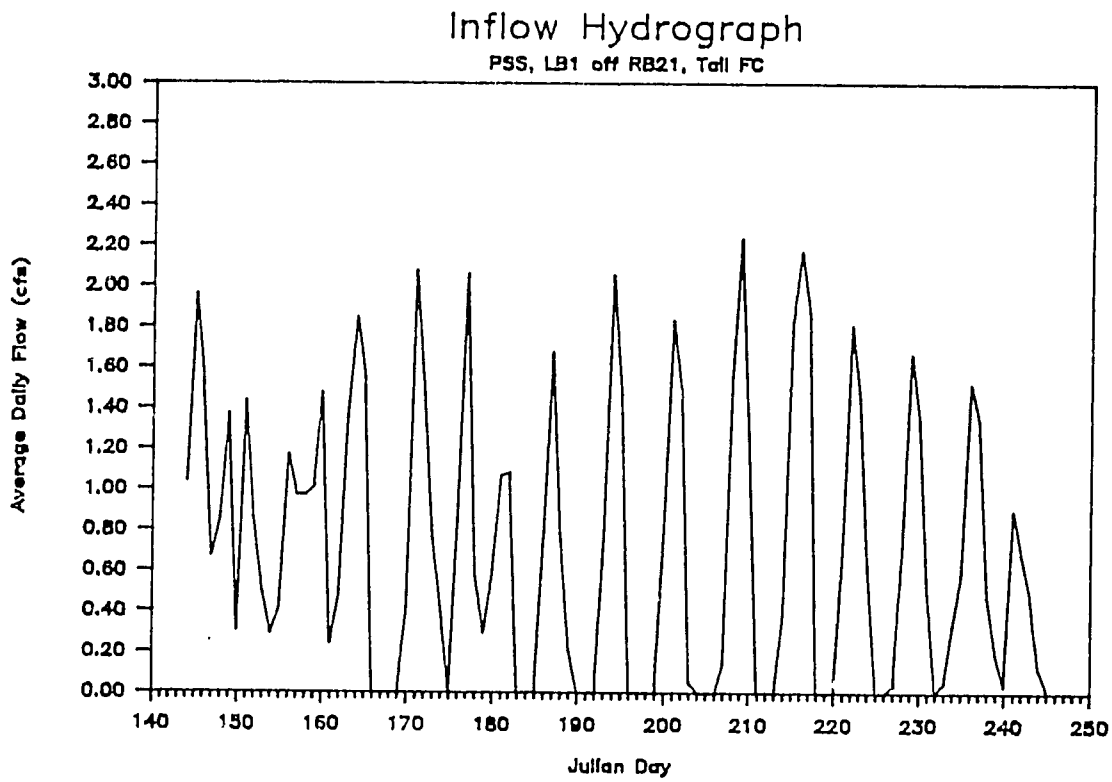

Inflow Hydrograph
PSS, Block F, Head FC
Average Daily Flow (cfs)
3.00
2.80
2.60
2.40
2.20
2.00
1.80
1.60
1.40
1.20
1.00
0.80
0.60
0.40
0.20
0.00
140
150
160
170
180
190
200
210
220
230
240
250
Julian Day


Inflow Hydrograph
PSS, Block F, Tail FC
Average Daily flow (cfs)
3.00
2.80
2.60
2.40
2.20
2.00
1.80
1.60
1.40
1.20
1.00
0.80
0.60
0.40
0.20
0.00
140
150
160
170
180
190
200
210
220
230
240
250
Julian Day


Inflow Hydrograph
PSS, RB7, Head FC
Average Daily Flow (cfs)
3.00
2.80
2.60
2.40
2.20
2.00
1.80
1.60
1.40
1.20
1.00
0.80
0.60
0.40
0.20
0.00
140
150
160
170
180
190
200
210
220
230
240
250
Julian Day


Inflow Hydrograph
PSS, RB7, Tail FC
Average Daily Flow (cfs)
3.00
2.80
2.60
2.40
2.20
2.00
1.80
1.60
1.40
1.20
1.00
0.80
0.60
0.40
0.20
0.00
140
150
160
170
180
190
200
210
220
230
240
250
Julian Day


Inflow Hydrograph
PSS, LB1 off RB21, Head FC
Average Daily Flow (cfs)
3.00
2.80
2.60
2.40
2.20
2.00
1.80
1.60
1.40
1.20
1.00
0.80
0.60
0.40
0.20
0.00
140
150
160
170
180
190
200
210
220
230
240
250
Julian Day


Inflow Hydrograph
PSS, LB1 off RB21, Tail FC
Average Daily Flow (cfs)
3.00
2.80
2.60
2.40
2.20
2.00
1.80
1.60
1.40
1.20
1.00
0.80
0.60
0.40
0.20
0.00
140
150
160
170
180
190
200
210
220
230
240
250
Julian Day

APPENDIX D
BARREL LYSIMETER DATA FOR PSS STUDY SITES, 1985 YALA

BARREL LYSIMETER DATA FC

		ET		ET+P LBE		ET+P LHG	
Date	Julian Day	gauge depth (cm)	daily use (cm)	gauge depth (cm)	daily use (cm)	gauge depth (cm)	daily use (cm)
June 18	169	4.0	-	-	-	8.0	-
June 19	170	2.5	1.5	-	-	6.5	1.5
June 20	171	1.0	1.5	-	-	5.5	1.0
June 21	172	0.5	0.5	-	-	4.5	1.0
June 22	173	-	-	-	-	3.0	1.5
June 23	174	-	-	-	-	2.0	1.0
June 24	175	-	-	-	-	-	-
June 25	176	6.0	-	-	-	-	-
June 26	177	5.0	1.0	6.5	-	10.0	-
June 27	178	4.6	0.4	5.4	1.1	8.9	1.1
June 28	179	3.4	1.2	4.1	1.3	7.6	1.3
June 29	180	2.3	1.1	-	-	6.4	1.2
June 30	181	0.5	-	-	-	5.6	0.3
July 1	182	-	-	-	-	4.6	1.0
July 2	183	-	-	-	-	3.8	0.8
July 3	184	4.8	-	7.8	-	6.2	-
July 4	185	4.3	0.5	6.6	1.2	5.3	0.9
July 5	186	3.8	0.5	5.4	1.2	4.6	0.7
July 6	187	2.6	1.2	4.2	1.2	4.1	0.5
July 7	188	-	-	-	-	-	-
July 8	189	6.0	-	9.0	-	-	-
July 9	190	4.6	1.4	6.8	2.2	-	-
July 10	191	2.6	2.0	5.2	1.6	13.0	-
July 11	192	1.3	1.3	-	-	12.3	0.7
July 12	193	-	-	-	-	11.6	0.7
Aug. 5	217	14.0	-	12.5	-	9.5	-
Aug. 6	218	11.7	2.3	10.5	2.0	9.0	0.5
Aug. 7	219	9.6	2.1	8.8	1.7	8.4	0.6
Aug. 8	220	7.6	2.0	7.3	1.5	(15.6)	-
Aug. 9	221	4.3	3.3	5.8	1.5	13.7	1.9
Aug. 10	222	-	-	-	-	12.3	1.4
Aug. 11	223	-	-	-	-	11.2	1.1
Aug. 12	224	8.5	-	10.5	-	10.0	1.2
Aug. 13	225	2.0	-	8.2	2.3	-	-
Aug. 14	226	-	-	6.6	1.6	-	-
Aug. 15	227	-	-	4.7	1.9	(15.0)	-
Aug. 16	228	-	-	-	-	13.4	1.6
Aug. 17	229	-	-	-	-	12.5	0.9
Aug. 18	230	-	-	-	-	11.4	1.1
Aug. 19	231	-	-	-	-	10.4	1.0
Aug. 20	232	-	-	-	-	10.0	0.4
Total daily use (cm)		22.8		22.3		27.4	
Days		18		14		27	
Daily use (cm)		1.34		1.59		1.01	

BARREL LYSIMETER DATA FC

		ET		ET+P RBE		ET+P RBE w/plow pan		ET+P	LNC
Date	Julian Day	gauge depth (cm)	Daily use (cm)	gauge depth (cm)	Daily use (cm)	gauge depth (cm)	Daily use (cm)	gauge depth (cm)	Daily use (cm)
June 9	160	14.5	-	19.5	-	10.0	-	-	-
June 10	161	14.1	0.4	(12.5)	-	8.8	1.2	6.7	-
June 11	162	(11.0)	-	-	-	7.5	1.3	5.8	0.9
June 12	163	10.5	0.5	11.5	1.0	5.8	1.7	4.8	1.0
		(13.6)				(9.8)			
June 13	164	12.8	0.8	(18.5)	-	8.6	1.2	4.0	0.8
June 14	165	12.2	0.6	16.1	2.4	7.5	1.1	4.3	0.7
		(16.5)				(11.0)		(6.4)	
June 15	166	15.3	0.7	15.0	1.1	10.4	0.6	-	-
				(21.1)					
June 16	167	15.2	0.6	19.6	1.5	9.3	1.1	4.9	-
		(11.9)							
June 17	168	11.0	0.9	17.4	2.2	7.4	1.9	3.8	1.1
June 18	169	10.1	0.9	14.0	3.4	-	-	2.4	1.4
June 19	170	9.03	0.8	-	-	-	-	-	-
June 20	171	8.5	0.8	11.5	-	(8.2)	-	2.8	0.4
		(12.0)		(17.0)	-			(4.0)	
June 21	172	11.0	1.0	13.0	4.0	6.8	1.4	3.0	1.0
								(4.8)	
June 22	173	10.0	1.0	16.2	-	5.5	1.3	4.0	0.8
June 23	174	(9.5)	-	12.0	4.2	9.0	-	3.0	1.0
June 24	175	(8.0)	-	-	-	-	-	2.0	1.0
								(8.0)	
June 25	176	7.4	0.6	-	-	-	-	7.5	0.5
June 26	177	(15)	-	(19.5)	-	(9.0)	-	6.6	0.9
June 27	178	14	1.0	13.9	5.6	8.5	0.5	6.1	0.5
June 28	179	12.8	1.2	(15.7)	-	6.7	1.8	5.0	1.1
June 29	180	11.8	1.0	12.9	2.8	5.0	1.7	4.1	0.9
				(18.6)		(9.5)			
June 30	181	10.9	0.9	14.0	4.2	7.8	1.7	3.7	0.4
July 1	182	10.2	0.7	-	-	-	-	3.0	0.7
July 2	183	8.2	1.0	-	-	-	-	-	-
July 3	184	7.8	0.4	-	-	-	-	-	-
July 4	185	6.7	0.6	(19.5)	-	(18.6)	-	-	-
July 5	186	12.5	1.0	15.5	4.0	7.6	-	(3.7)	-
		(14.6)		(19.7)		(10.0)			
July 6	187	13.5	1.1	16.0	3.7	8.0	2.0	4.7	-
July 7	188	12.5	1.0	13.0	3.0	6.0	2.0	4.0	0.7
July 8	189	11.0	1.5	-	-	-	-	-	-
July 9	190	9.8	1.2	-	-	-	-	-	-
Total daily use (cm)			22.2		43.1	-	22.5	-	15.8
Days			26		14		16		19
Daily use (cm)			0.85		3.07		1.4		0.83

APPENDIX E
ET CALCULATIONS FOR PSS STUDY SITES, 1985 YALA

ET CALCULATIONS / PENMAN METHOD
Reference: Guidelines for Predicting Crop Water Requirements
FAO Irrigation and Drainage Paper 24
by J. Doorenbos and W.O. Pruitt
Note: Tables from the above publication are used to obtain values for
Ra (radiation recieved at the top of the atmosphere),
N (maximum possible sunshine hours), and
c (adjustment factor to compensate for the effect of day and night weather conditions)
ERR indicates no data available See next panel>>>>>>>

ETo = c*(W*Rn+(1-W)*f(u)*(ea-ed))

Date	Julian Day	Tmax (C)	Tmin (C)	Tmean (C)	RH am %	RH pm %	ea (mb)	ed (mb)	(ea-ed) (mb)	Umean (km/hr)	U,24 hr (km/day)	f(u)
May 20	140	35	23.8	29.4	85	83	40.97361	34.41783	6.555778	6.3	151.2	0.67824
21	141	33.8	23.4	28.6	81	75	39.12172	30.51494	8.606778	6.7	160.8	0.70416
22	142	34.8	23	28.9	83	77	39.80740	31.84592	7.961481	4.8	115.2	0.53104
23	143	32	25	28.5	76	75	38.89546	29.36607	9.529389	6.2	148.8	0.67176
24	144	35.3	24.5	29.9	76	78	42.16962	32.47061	9.699011	10.3	247.2	0.93744
25	145	33.8	27	30.4	76	81	43.39608	34.06593	9.330159	15	360	1.242
26	146	33	26.7	29.85	84	69	42.04866	32.16723	9.881437	16.4	393.6	1.33272
27	147	33.3	26	29.65	83	76	41.56795	33.04644	8.521410	18.1	434.4	1.44288
28	148	34.8	26.5	30.65	77	61	44.02094	34.77654	9.244398	22.3	535.2	1.71504
29	149	34.3	22.4	28.35	76	77	38.55823	29.49705	9.061185	19.76	474.24	1.550448
30	150	34.8	26.7	30.75	86	83	44.27308	37.41075	6.862328	17.35	416.4	1.39428
31	151	34.4	24	29.2	80	81	40.50359	32.60539	7.898201	9.01	216.24	0.853848
June 1	152	33.4	24.2	28.8	76	77	39.57768	30.27693	9.300756	11.11	266.64	0.989929
2	153	34.6	24	29.3	86	81	40.73801	34.01624	6.721772	10.43	250.32	0.945364
3	154	35.4	22.3	28.85	86	92	39.69240	35.32623	4.366164	8.67	208.08	0.831816
4	155	33.8	24	28.9	84	84	39.80740	33.43922	6.369195	0.04	0.96	0.232592
5	156	26.8	24.6	25.7	98	100	33.00803	32.67795	0.330080	9.24	221.76	0.868752
6	157	32.8	23	27.9	91	92	37.56185	34.36909	3.192757	5.45	130.8	0.62316
7	158	33.4	23.2	28.3	97	98	38.44639	35.56291	2.883479	1.85	44.4	0.38988
8	159	34.6	22.6	28.6	85	86	39.12172	33.44907	5.672649	5.37	128.88	0.617976
9	160	35.4	28.5	31.95	87	ERR	47.39885	ERR	ERR	8.1	194.4	0.79488
10	161	35.1	21.6	28.35	79	78	38.55823	30.26821	8.290021	6.12	146.88	0.666576
11	162	34.8	28.4	31.6	80	79	46.46792	36.94191	9.525903	10.2	244.8	0.93096
12	163	34.8	24	29.4	82	85	40.97361	34.21297	6.760647	14.7	352.8	1.22256
13	164	35.8	23	29.4	87	88	40.97361	35.85191	5.121702	11.56	277.44	1.019088
14	165	34	28.5	31.25	85	77	45.55283	36.89779	8.655039	8.49	203.76	0.820152
15	166	33.8	27.8	30.8	83	77	44.39962	35.51970	8.879925	15.6	374.4	1.29088
16	167	34.8	26	30.4	80	59	43.39608	30.16028	13.23580	14.92	358.08	1.236816
17	168	34.3	26.2	30.25	84	72	43.02491	33.55943	9.465481	19.46	467.04	1.531008
18	169	34.6	26	30.3	74	77	43.14832	32.57698	10.57134	14.34	344.16	1.199232
19	170	34	25.5	29.75	71	72	41.80765	29.89247	11.91518	14.61	350.64	1.216728
20	171	33.8	23.4	28.6	71	79	39.12172	32.27542	6.846301	13.84	332.16	1.166832
21	172	33.2	25.3	29.25	86	79	40.62065	28.63756	11.98309	20.7	496.8	1.81136
22	173	31.3	23.4	27.35	62	72	36.37471	29.64539	6.729321	23.6	566.4	1.79928
23	174	32.3	26	29.15	91	96	40.38682	36.75201	3.634814	26.8	643.2	2.00664
24	175	32.5	28.5	30.5	86	90	43.64509	37.53478	6.110313	28.8	691.2	2.13624
25	176	33.8	25.8	29.8	82	82	41.92801	33.54240	8.385602	21.9	525.6	1.68912
26	177	34.3	26.5	30.4	78	73	43.39608	34.06593	9.330159	20.62	494.88	1.636176

27	178	35.3	25.6	30.45	84	83	43.52043	34.81634	8.704087	16.87	404.88	1.363176
28	179	34.8	22.5	28.65	77	84	39.23528	32.17292	7.062350	12.73	305.52	1.094904
29	180	34.3	24	29.15	80	85	40.38682	32.91526	7.471563	12.84	308.16	1.102032
30	181	34.1	26.2	30.15	78	84	42.77901	36.14826	6.630746	26.27	630.48	1.972296
July 1	182	33.6	26.4	30	85	88	42.41246	35.20234	7.210118	9	216	0.8532
2	183	33.8	26	29.9	78	70	42.16962	31.20552	10.96410	15.81	379.44	1.294488
3	184	34.3	26	30.15	78	70	42.77901	32.51204	10.26696	16.77	402.48	1.356696
4	185	34	25.6	29.8	82	84	41.92801	34.80024	7.127761	16.77	402.48	1.356696
5	186	35	21.5	28.25	82	85	38.33494	31.81791	6.516923	12.51	300.24	1.080648
6	187	36.8	21.8	29.3	81	ERR	40.73801	ERR	ERR	9.26	222.24	0.870048
7	188	36.6	21.6	29.1	82	ERR	40.27035	ERR	ERR	9.29	222.96	0.871992
8	189	35.8	21	28.4	82	ERR	38.67036	ERR	ERR	8.49	203.76	0.820152
9	190	35	24.5	29.75	73	75	41.80765	32.40093	9.406723	14.41	345.84	1.203768
10	191	36.1	26.2	31.15	80	ERR	45.29432	ERR	ERR	16.8	403.2	1.35864
11	192	37.1	22.6	29.85	82	ERR	42.04866	ERR	ERR	10.12	242.88	0.925776
12	193	36.3	22.5	29.4	85	84	40.97361	34.62270	6.350910	4.92	118.08	0.588816
13	194	35.8	23.2	29.5	85	85	41.21041	35.02885	6.181562	8.52	204.48	0.822096
14	195	36.3	22	29.15	85	82	40.38682	33.52106	6.865760	5.92	142.08	0.653616
15	196	35	23.6	29.3	84	83	40.73801	35.03469	5.703321	5.89	141.36	0.651672
16	197	36.5	23.2	29.85	89	75	42.04866	31.95698	10.09168	10	240	0.918
17	198	36.6	22.4	29.5	77	85	41.21041	34.82280	6.387614	8	192	0.7984
18	199	35.8	23.5	29.65	84	96	41.56785	37.41107	4.156785	7.6	182.4	0.76248
19	200	30.8	21.2	26	84	90	33.59903	29.73514	3.863888	6.54	156.96	0.693792
20	201	32.3	23.5	27.9	87	96	37.56185	35.12033	2.441520	4.7	112.8	0.57456
21	202	32.8	22	27.4	91	95	36.48125	33.92757	2.553688	4.33	103.92	0.550584
22	203	32.8	23	27.9	91	86	37.56185	31.73976	5.822086	3.56	85.44	0.500688
23	204	34.3	22.5	28.4	83	87	38.67036	32.86960	5.800554	5.56	133.44	0.630288
24	205	34.3	22.5	28.4	83	93	38.67036	31.90304	6.767313	6.05	145.2	0.66204
25	206	33.6	23.8	28.7	82	77	39.34912	30.29882	9.050299	8.53	204.72	0.822744
26	207	33.5	23.3	28.4	77	83	38.67036	32.09640	6.573961	11.3	271.2	1.00224
27	208	34.5	22.6	28.55	83	85	39.00845	31.59684	7.411605	9.68	232.32	0.897264
28	209	35.3	22.5	28.9	77	90	39.80740	33.23918	6.568222	9.37	224.88	0.877176
29	210	34.3	22.5	28.4	77	75	38.67036	28.42271	10.24764	ERR	ERR	ERR
30	211	31.8	22.5	27.15	72	70	35.95124	25.70513	10.24610	8.99	215.76	0.852552
31	212	31.1	25	28.05	73	83	37.89144	29.55532	8.336118	15.6	374.4	1.28088
aug 1	213	33.2	24	28.6	73	84	39.12172	31.10176	8.019953	14.3	343.2	1.19664
2	214	35	22.2	28.6	75	88	39.12172	32.66663	6.455084	10.6	254.4	0.95688
3	215	35.5	23	28.55	79	85	39.00845	34.32743	4.681014	10.12	242.88	0.925776
4	216	34.1	24.5	29.15	91	83	40.39682	35.13654	5.250287	5.56	133.44	0.630288
5	217	33.8	23	28.4	91	94	38.67036	35.38338	3.286980	4.12	98.88	0.536976
6	218	33.8	22.4	28.4	89	96	38.67036	36.15678	2.513573	3.55	85.2	0.50004
7	219	34.4	22.5	28.25	91	81	38.33484	31.05122	7.283619	5.91	141.84	0.652968
8	220	34	26	30.65	81	84	44.02094	35.65696	8.363979	13.1	314.4	1.11888
9	221	35.3	24.2	29.25	78	80	40.62065	33.10583	7.514821	10.61	254.64	0.957528
10	222	34.3	23.5	28.65	83	82	39.23528	30.60351	8.631761	9.72	233.28	0.899856
11	223	33.8	23.5	28.75	74	79	39.46326	33.14914	6.314121	15.15	363.6	1.29172
12	224	34	26	29.9	89	88	42.16962	37.95266	4.216962	14.57	349.68	1.214136
13	225	33.8	26.5	30.9	92	66	44.65366	33.93678	10.71687	18.25	438	1.4526
14	226	35.3	25.6	30.2	96	76	42.90180	33.89242	9.009379	16.53	396.72	1.341144
15	227	34.8	25.6	30.5	82	73	43.64509	32.95204	10.69304	17.65	423.6	1.41372
16	228	35.4	26	31.65	78	81	46.59983	37.74586	8.853969	17.6	422.4	1.41048
17	229	37.3	22	28.4	81	ERR	38.67036	ERR	ERR	8.15	195.6	0.79312
18	230	34.8	23	29.15	82	90	38.11257	32.58625	5.526323	6.82	163.68	0.711936
19	231	33.3	23.2	29.6	81	88	41.44841	35.85287	5.595535	9.4	225.6	0.97912
20	232	36	22.8	29.15	85	90	40.38682	35.33847	5.048353	6.62	158.88	0.698976

21	233	35.5	21.8	27.7	85	87	37.12629	33.04240	4.083892	5.15	123.6	0.60372
22	234	33.6	23.4	28.35	91	94	38.55823	35.66636	2.891867	5.7	136.8	0.63936
23	235	33.3	22.6	28.7	91	90	39.34912	35.61095	3.738167	2.57	61.68	0.436536
24	236	34.8	23.2	28.5	91	85	38.89546	34.22801	4.667456	4.97	119.28	0.592056
25	237	33.8	28	30.3	91	81	43.14832	35.38163	7.766699	4.65	111.6	0.57132
26	238	32.6	22	27.9	93	79	37.56185	29.29924	8.263607	4.75	114	0.5778
27	239	33.8	22.4	28.1	77	96	38.00187	30.02147	7.980392	7.89	189.36	0.781272
28	240	33.9	24	29.15	72	89	40.38682	32.91526	7.471563	11.37	272.88	1.006776
29	241	34.3	20.2	27.4	74	88	36.48125	32.28591	4.195344	12	288	1.0476
30	242	34.6	22	28.4	89	88	38.67036	34.22327	4.447091	4.39	105.36	0.554472
31	243	34.9	22.5	28.65	89	100	39.23528	36.29263	2.942646	4	96	0.5292
sept 1	244	34.8	22.6	28.2	85	92	38.22356	34.59232	3.631239	3.48	83.52	0.495504
2	245	33.8	22.2	28.3	89	88	38.44639	34.40952	4.036871	3.61	86.64	0.503928
3	246	34.4	22.5	28.45	91	93	38.78277	31.41404	7.368726	3.74	89.76	0.512352
4	247	34.4	23	28.65	79	85	39.23528	33.34998	5.885292	5.2	124.8	0.60696
5	248	34.3	23	28.9	85	77	39.80740	29.65852	10.15088	11.1	266.4	0.98928
6	249	34.8	24	29.15	72	87	40.38682	32.10752	8.279299	9.79	234.96	0.904392
7	250	34.3	24	28.9	72	83	39.80740	33.04014	6.767259	10.11	242.64	0.925128

ea = mean saturation vapor pressure, calc. by Bosen's formula at Tdewpt.
ed = mean actual vapor pressure, calc. by Bosen's formula at Tmean
U = wind speed
f(u) = .27(1+U/100), wind function
delta = slope of the vapor pressure / temperature curve
gamma = psychrometer constant
W = delta/(delta+gamma)
Ra = amount of radiation received at top of atmosphere
Rs = solar radiation received at earth's surface
...continued next panel>>>>

Julian Day	delta (mb/C)	Elev (m)	gamma (mb/C)	W = weighting factor	(1-W)	Ra (mm/day) TABLE 10	n actual sun hrs	Nmax sun hrs TABLE 11	Rs (mm/day)	Rns (mm/day)	f(T)	f(ed)
140	2.362800	70	0.658013	0.782173	0.217826	15.3	6.45	12.6	7.741071	6.115446	16.59029	0.081866
141	2.269042		0.657550	0.775318	0.224681	15.3	2.65	12.6	5.433929	4.292303	16.41550	0.096942
142	2.300821		0.657724	0.777911	0.222088	15.3	4.4	12.6	6.496429	5.132179	16.48088	0.091698
143	2.257550		0.657493	0.774448	0.225551	15.3	9.65	12.6	9.683929	7.650303	16.39375	0.101561
144	2.422069		0.658302	0.786360	0.213639	15.3	9.65	12.6	9.683929	7.650303	16.70022	0.089274
145	2.484649		0.658592	0.790473	0.209526	15.3	8.6	12.6	9.046429	7.146678	16.81071	0.083189
146	2.415950		0.658273	0.785945	0.214054	15.3	6.65	12.6	7.8625	6.211375	16.68920	0.090448
147	2.392772		0.658158	0.784276	0.215723	15.3	8.5	12.6	8.985714	7.098714	16.64518	0.087061
148	2.515939		0.658737	0.792502	0.207497	15.3	10.1	12.6	9.957142	7.866142	16.86616	0.080524
149	2.240405		0.657406	0.773136	0.226863	15.3	9.2	12.6	9.410714	7.434464	16.36117	0.101030
150	2.528549		0.658795	0.793309	0.206690	15.3	5	12.6	6.860714	5.419964	16.88837	0.070876
151	2.339355		0.657897	0.780477	0.219522	15.3	9.5	12.6	9.592857	7.578357	16.54645	0.088755
152	2.292178		0.657686	0.777050	0.222949	15	4.6	12.7	6.466535	5.108562	16.45907	0.097892
153	2.356902		0.657955	0.781327	0.218672	15	7.85	12.7	8.385826	6.624803	16.56936	0.083376
154	2.297993		0.657695	0.777481	0.222518	15	10.3	12.7	10.12795	8.001082	16.46997	0.078432
155	2.300821		0.657724	0.777911	0.222088	15	10.1	12.7	9.714566	7.674507	16.48088	0.085566
156	1.955374		0.655879	0.748825	0.251174	15	ERR	12.7	ERR	ERR	15.79349	0.088475
157	2.139637		0.657146	0.769161	0.230838	15	2.4	12.7	5.167322	4.082185	16.26371	0.082049
158	2.234715		0.657377	0.772698	0.227301	15	4	12.7	6.112204	4.828641	16.35032	0.077607
159	2.269042		0.657550	0.775318	0.224681	15	7.2	12.7	8.001968	6.321555	16.41550	0.085525
160	2.684146		0.659492	0.802762	0.197237	15	9.5	12.7	9.360236	7.394586	17.15671	ERR
161	2.240405		0.657406	0.773136	0.226863	15	10.9	12.7	10.18700	8.047736	16.36117	0.097927
162	2.637939		0.659283	0.800047	0.199952	15	10	12.7	9.655511	7.627854	17.07811	0.072568
163	2.362800		0.658013	0.782173	0.217826	15	10.25	12.7	9.803149	7.744488	16.59028	0.082635
164	2.362800		0.658013	0.782173	0.217826	15	9.8	12.7	9.537401	7.534547	16.59028	0.076543
165	2.592415		0.659085	0.797298	0.202701	15	9.6	12.7	9.419291	7.441240	16.99979	0.072728
166	2.534874		0.658824	0.793711	0.206288	15	2.8	12.7	5.403543	4.268799	16.89949	0.077767
167	2.484649		0.658592	0.790473	0.209526	15	10.9	12.7	10.18700	8.047736	16.81071	0.098359
168	2.466036		0.658505	0.789247	0.210752	15	11.7	12.7	10.65944	8.420964	16.77750	0.085105
169	2.472227		0.658534	0.789656	0.210343	15	9.8	12.7	9.537401	7.534547	16.78857	0.086864
170	2.404351		0.658215	0.785112	0.214887	15	9.9	12.7	9.596456	7.581200	16.66718	0.099434
171	2.269042		0.657550	0.775318	0.224681	15	6.3	12.7	7.470472	5.901673	16.41550	0.090029
172	2.344972		0.657926	0.780902	0.219097	15	7.9	12.7	8.415354	6.648129	16.55740	0.104538
173	2.128928		0.656829	0.764218	0.235781	15	8.1	12.7	8.533464	6.741437	16.14513	0.100430
174	2.333151		0.657868	0.780052	0.219947	15	4.4	12.7	6.348425	5.015255	16.53551	0.073256
175	2.497125		0.658650	0.791287	0.208712	15	4.7	12.7	6.525590	5.155216	16.83287	0.070431
176	2.410911		0.658244	0.785529	0.214470	15	6.65	12.7	7.677165	6.064960	16.67819	0.085170
177	2.484649		0.658592	0.790473	0.209526	15	6.65	12.7	7.677165	6.064960	16.81071	0.083189

178	2.490880	0.659621	0.790880	0.209119	15	6.72	12.7	7.718503	6.097619	16.82179	0.080376
179	2.274807	0.657579	0.775752	0.224247	15	8.6	12.7	8.828740	6.974704	16.42639	0.090426
180	2.333151	0.657868	0.780052	0.219947	15	4.1	12.7	6.171259	4.875295	16.53551	0.087563
181	2.453693	0.658447	0.788426	0.211573	15	4.5	12.7	6.407460	5.061909	16.75540	0.075456
182	2.475279	0.658360	0.787198	0.212311	15.1	2.5	12.6	5.273015	4.165682	16.72227	0.078941
183	2.423069	0.658302	0.786360	0.213639	15.1	6.25	12.6	7.520039	5.940831	16.70022	0.094207
184	2.453693	0.658447	0.788426	0.211573	15.1	7.1	12.6	8.029365	6.343198	16.75540	0.089114
185	2.410911	0.658244	0.785529	0.214470	15.1	6.85	12.6	7.379563	6.224855	16.67319	0.080436
186	2.229037	0.657348	0.772258	0.227741	15.1	7.75	12.6	8.419349	6.650890	16.33947	0.091807
187	2.350902	0.657955	0.781327	0.218672	15.1	7.25	12.6	8.119246	6.414204	16.56836	ERR
188	2.327260	0.657839	0.779625	0.220374	15.1	10.95	12.6	10.33630	8.165634	16.52457	ERR
189	2.246107	0.657435	0.773574	0.226425	15.1	10.5	12.6	10.06666	7.952666	16.37202	ERR
190	2.404351	0.658215	0.785112	0.214887	15.1	8.65	12.6	8.958134	7.076926	16.66718	0.089543
191	2.579532	0.659027	0.796506	0.203493	15.1	9.9	12.6	9.707142	7.668642	16.97747	ERR
192	2.416983	0.658273	0.785945	0.214054	15.1	6.5	12.6	7.669841	6.059174	16.63920	ERR
193	2.362800	0.658013	0.782173	0.217826	15.1	5.55	12.6	7.100595	5.609470	16.59028	0.081099
194	2.374750	0.658071	0.783016	0.216983	15.1	5.4	12.6	7.010714	5.538464	16.61222	0.079585
195	2.333151	0.657868	0.780052	0.219947	15.1	7.15	12.6	8.059325	6.366867	16.53551	0.085251
196	2.350902	0.657955	0.781327	0.218672	15.1	6.35	12.6	7.579960	5.988168	16.56836	0.079563
197	2.416983	0.658273	0.785945	0.214054	15.1	9.75	12.6	9.617261	7.597636	16.68920	0.091265
198	2.374750	0.658071	0.783016	0.216983	15.1	11.1	12.6	10.42819	8.236690	16.61222	0.086352
199	2.392772	0.658158	0.784276	0.215723	15.1	7.5	12.6	8.269047	6.532547	16.64518	0.070875
200	1.985995	0.656052	0.751688	0.248311	15.1	1.7	12.6	4.793650	3.786984	15.85700	0.100068
201	2.139637	0.657146	0.769161	0.230838	15.1	3.4	12.6	5.812301	4.591718	16.26371	0.079245
202	2.124387	0.656858	0.764672	0.235327	15.1	7.5	12.6	8.269047	6.532547	16.15593	0.083711
203	2.139637	0.657146	0.769161	0.230838	15.1	7	12.6	7.969444	6.295861	16.26371	0.092112
204	2.246107	0.657435	0.773574	0.226425	15.1	9.9	12.6	9.707142	7.668642	16.37202	0.087738
205	2.246107	0.657435	0.773574	0.226425	15.1	10.1	12.6	9.826984	7.763317	16.37202	0.091475
206	2.280565	0.657608	0.776186	0.223813	15.1	10.2	12.6	9.886904	7.810654	16.43727	0.097804
207	2.246107	0.657435	0.773574	0.226425	15.1	9.6	12.6	9.527380	7.526630	16.37202	0.090723
208	2.263290	0.657521	0.774883	0.225116	15.1	10.5	12.6	10.06666	7.952666	16.40462	0.092671
209	2.303821	0.657724	0.777911	0.222088	15.1	9.6	12.6	9.923174	7.053257	16.48068	0.086324
210	2.246107	0.657435	0.773574	0.226425	15.1	9.6	12.6	9.527380	7.526630	16.37202	0.105422
211	2.107213	0.656714	0.762398	0.237601	15.1	7.3	12.6	8.149206	6.437873	16.10224	0.116918
212	2.206449	0.657233	0.770493	0.229506	15.1	9.6	12.6	9.527380	7.526630	16.29615	0.100794
213	2.269042	0.657550	0.775318	0.224681	15.4	5.7	12.4	7.389516	5.837717	16.41550	0.094616
214	2.269042	0.657550	0.775318	0.224681	15.4	8.4	12.4	9.066129	7.162241	16.41550	0.088519
215	2.263290	0.657521	0.774883	0.225116	15.4	7.6	12.4	8.569354	6.769790	16.40462	0.082205
216	2.333151	0.657868	0.780052	0.219947	15.4	4.7	12.4	6.768548	5.347153	16.53551	0.079185
217	2.246107	0.657435	0.773574	0.226425	15.4	3.8	12.4	6.209677	4.905645	16.37202	0.076270
218	2.246107	0.657435	0.773574	0.226425	15.4	8.3	12.4	9.004032	7.113185	16.37202	0.075425
219	2.229037	0.657348	0.772258	0.227741	15.4	9.9	12.4	9.997580	7.899088	16.33947	0.074816
220	2.515739	0.658737	0.792502	0.207497	15.4	4.3	12.4	6.830645	5.396209	16.36616	0.077260
221	2.344972	0.657926	0.780902	0.219097	15.4	10.5	12.4	10.37016	8.192427	16.55740	0.086834
222	2.274807	0.657579	0.775752	0.224247	15.4	8.2	12.4	8.941935	7.064129	16.42639	0.096590
223	2.286375	0.657637	0.776618	0.223331	15.4	8.1	12.4	8.879838	7.015072	16.44817	0.086668
224	2.423069	0.658302	0.786260	0.213639	15.4	3.5	12.4	6.023387	4.753475	16.70022	0.068934
225	2.547566	0.658882	0.794513	0.205486	15.4	5.7	12.4	7.389516	5.837717	16.92174	0.083676
226	2.459858	0.658476	0.788837	0.211162	15.4	11.3	12.4	10.86693	8.584879	16.76645	0.083344
227	2.497125	0.658650	0.791287	0.208712	15.4	10.2	12.4	10.18387	8.045258	16.83287	0.087422
228	2.644498	0.659317	0.800437	0.199562	15.4	7.2	12.4	8.320967	6.573564	17.08933	0.069674
229	2.246107	0.657435	0.773574	0.226425	15.4	10.2	12.4	10.18387	8.045258	16.37202	ERR
230	2.217718	0.657290	0.771377	0.228622	15.4	4.7	12.4	6.768548	5.347153	16.31780	0.088828
231	2.386752	0.658129	0.783857	0.216142	15.4	2.2	12.4	5.216129	4.120741	16.63419	0.076540
232	2.333151	0.657868	0.780052	0.219947	15.4	9.2	12.4	9.562903	7.554693	16.53551	0.078436

233	2.167392	0.657031	0.767375	0.232624	15.4	8.4	12.4	9.066129	7.162241	16.22053	0.087076
234	2.240405	0.657406	0.773136	0.226863	15.4	6.3	12.4	7.762096	6.132056	16.36117	0.077226
235	2.280385	0.657608	0.776186	0.223813	15.4	7.1	12.4	8.258870	6.524508	16.43727	0.077430
236	2.257550	0.657493	0.774448	0.225551	15.4	5.9	12.4	7.451612	5.886774	16.39375	0.082579
237	2.472227	0.658534	0.789656	0.210343	15.4	5.3	12.4	7.141129	5.641491	16.76857	0.078277
238	2.189637	0.657146	0.769161	0.230838	15.4	2.3	12.4	5.402419	4.267911	16.26371	0.101837
239	2.212077	0.657262	0.770936	0.229063	15.4	8.2	12.4	8.941935	7.064129	16.30697	0.093915
240	2.333151	0.657868	0.780052	0.219947	15.4	7	12.4	8.196774	6.475451	16.53551	0.087563
241	2.134397	0.656858	0.764672	0.235327	15.4	4.7	12.4	6.768548	5.347153	16.15593	0.089988
242	2.246107	0.657435	0.773574	0.226425	15.4	3.4	12.4	5.961290	4.709419	16.37202	0.082597
243	2.274807	0.657579	0.775752	0.224247	15.4	6.6	12.4	7.948387	6.279225	16.42639	0.074929
244	2.222371	0.657319	0.771818	0.228181	15.3	7.7	12.1	8.693181	6.867613	16.32863	0.091212
245	2.234715	0.657377	0.772699	0.227301	15.3	9.2	12.1	9.641528	7.616807	16.35032	0.081897
246	2.251822	0.657464	0.774011	0.225988	15.3	9.3	12.1	9.704752	7.666754	16.38289	0.093387
247	2.274807	0.657579	0.775752	0.224247	15.3	10.2	12.1	10.27376	8.116270	16.42639	0.085932
248	2.303321	0.657724	0.777911	0.222088	15.3	10.6	12.1	10.52665	8.316055	16.48098	0.100385
249	2.333151	0.657868	0.780052	0.219947	15.3	6.8	12.1	8.124173	6.418097	16.53551	0.090680
250	2.303321	0.657724	0.777911	0.222088	15.3	7.1	12.1	8.313342	6.567935	16.48088	0.087085

Rns = reflected shortwave radiation, albedo assumed .21
Rnl = net outgoing longwave radiation
Rn = Rns - Rl , net total radiation
f(T) = sigma * Tk^4, effect of temperature on Rnl
f(ed) = .34-.44(ed^.5), effect of vapor pressure on Rnl
f(n/N) = .1 + .9*n/N, effect of sunshine hours on Rnl

Supplemental Reference:
Design and Operation of Farm Irrigation Systems, American Society of Agricultural Engineers, ASAE Monograph No. 3, 1981, pp 195-199

Julian Day	f(n/N)	Rnl (mm/day)	Rn (mm/day)	ETo (mm/day)	kc crop coeff	CropET (mm/day)	PanEvap (mm/day)
140	0.560714	0.761555	5.353891	5.156213	1.00	5.156213	4.44
141	0.239285	0.460357	3.832445	4.333058	1.00	4.333058	6.52
142	0.414285	0.626097	4.506081	4.532700	1.00	4.532700	5.73
143	0.789285	1.314145	6.336157	6.350887	1.00	6.350887	5.78
144	0.789285	1.176753	6.473549	7.033006	1.00	7.033006	5.82
145	0.714285	0.998910	6.147768	7.287652	1.00	7.287652	8.24
146	0.575	0.867974	5.343400	7.018548	1.00	7.018548	8.42
147	0.707142	1.024758	6.073955	7.416062	1.00	7.416062	8.64
148	0.821428	1.115618	6.750524	8.639579	1.00	8.639579	9.26
149	0.757142	1.251543	6.182920	7.967420	1.00	7.967420	10.42
150	0.457142	0.547198	4.872765	5.843229	1.00	5.843229	9.34
151	0.778571	1.143395	6.434961	6.502772	1.00	6.502772	7.88
152	0.425984	0.686352	4.422210	5.488994	1.00	5.488994	7.38
153	0.656299	0.906623	5.718179	5.858065	1.00	5.858065	6.46
154	0.865354	1.118555	6.882526	6.159190	1.00	6.159190	7.6
155	0.815748	1.150377	6.524130	5.460785	1.00	5.460785	7.03
156	ERR	ERR	ERR	ERR	1.00	ERR	8.89
157	0.270078	0.360400	3.721784	3.321930	1.00	3.321930	0.62
158	0.383464	0.486581	4.342060	3.610637	1.10	3.971701	3.66
159	0.610236	0.856735	5.464819	5.024611	1.10	5.527072	4.92
160	0.773228	ERR	ERR	ERR	1.15	ERR	5.83
161	0.872440	1.397827	6.649908	6.394919	1.15	7.354157	6.98
162	0.909661	1.002202	6.625651	7.074061	1.15	8.135170	9.57
163	0.826377	1.132924	6.611563	6.971790	1.15	8.017559	10.49
164	0.794488	1.008903	6.525643	6.241123	1.15	7.177291	8.42
165	0.780314	0.964755	6.476484	6.602557	1.15	7.592941	7.54
166	0.293425	0.392197	3.876601	5.423255	1.15	6.236744	10.34
167	0.872440	1.442569	6.605166	8.651211	1.15	9.948893	7.38
168	0.929133	1.326675	7.094289	8.653318	1.15	9.951316	10.72
169	0.794488	1.185303	6.349244	7.680347	1.15	8.832399	11
170	0.801574	1.328442	6.252758	8.024460	1.15	9.228129	8.37
171	0.546456	0.807598	5.094075	5.744394	1.15	6.606053	9.28
172	0.659842	1.142107	5.506022	8.530231	1.15	9.809766	9.36
173	0.674015	1.092397	5.648539	7.171543	1.15	8.247274	10.67
174	0.411811	0.498843	4.516412	5.127285	1.15	5.896378	10.06
175	0.433070	0.513431	4.641785	6.397332	1.15	7.356932	10.23
176	0.571259	0.811468	5.253492	7.164599	1.15	8.239289	6.9
177	0.571259	0.798892	5.266068	7.302625	1.15	8.398019	9.8

178	0.576220	0.779092	5.316525	6.687561	1.15	7.690695	10.36
179	0.709448	1.053805	5.920899	6.327167	1.15	7.276242	9.5
180	0.390551	0.565485	4.309810	5.172906	1.15	5.948842	9.36
181	0.418897	0.529616	4.532292	6.340297	1.15	7.291341	8.18
182	0.278571	0.367735	3.797947	4.298846	1.15	4.943673	8.35
183	0.546428	0.859689	5.091141	7.027773	1.15	8.081939	6.8
184	0.607142	0.906559	5.436639	7.233431	1.15	8.318446	9.5
185	0.589285	0.790546	5.434308	6.342785	1.15	7.294203	9.48
186	0.653571	0.980414	5.670476	5.982942	1.15	6.880384	8.64
187	0.617857	ERR	ERR	ERR	1.15	ERR	8.52
188	0.882142	ERR	ERR	ERR	1.15	ERR	6.44
189	0.85	ERR	ERR	ERR	1.15	ERR	8.07
190	0.717857	1.071363	6.005563	7.148325	1.20	8.577990	10.7
191	0.807142	ERR	ERR	ERR	1.20	ERR	10.7
192	0.564285	ERR	ERR	ERR	1.20	ERR	8.82
193	0.496428	0.667925	4.941545	4.679711	1.20	5.615654	6.74
194	0.485714	0.642156	4.896307	4.936564	1.20	5.923877	7.16
195	0.610714	0.860910	5.505956	5.281964	1.20	6.338357	7.52
196	0.553571	0.729738	5.258430	4.921294	1.20	5.905553	4.28
197	0.796428	1.213082	6.384554	7.000948	1.20	8.401138	7.63
198	0.892857	1.191812	7.044877	6.608984	1.20	7.930780	8.32
199	0.635714	0.749978	5.782569	5.218861	1.20	6.262633	9.45
200	0.221428	0.351359	3.435624	3.248176	1.20	3.897812	8.25
201	0.342857	0.441882	4.149835	3.515714	1.20	4.218857	2.74
202	0.635714	0.859764	5.672783	4.668694	1.20	5.602433	4.78
203	0.6	0.898555	5.397005	4.824075	1.20	5.788890	3.41
204	0.807142	1.159424	6.509218	5.863182	1.20	7.035819	7.78
205	0.821428	1.230207	6.533110	6.068286	1.20	7.281944	7.78
206	0.628571	1.332048	6.478606	6.695140	1.20	8.034168	7.17
207	0.785714	1.167046	6.359594	6.411458	1.20	7.693750	8.62
208	0.85	1.292202	6.660464	6.658146	1.20	7.989775	8.52
209	0.714285	1.016221	6.037036	5.975839	1.20	7.171007	6.16
210	0.785714	1.356133	6.170497	ERR	1.20	ERR	7.26
211	0.621428	1.169937	5.267935	6.091796	1.20	7.310155	7.66
212	0.785714	1.290589	6.236041	7.255399	1.20	8.706479	8.16
213	0.513709	0.797883	5.039834	6.063743	1.20	7.276492	8.67
214	0.709677	1.031222	6.131018	6.141291	1.20	7.369550	7.78
215	0.651612	0.878734	5.891055	5.540440	1.20	6.648528	7.84
216	0.441129	0.577600	4.769552	4.448349	1.20	5.338019	6.76
217	0.375806	0.481577	4.424067	3.821994	1.20	4.586393	4.6
218	0.702419	0.867398	6.245787	5.116174	1.20	6.139409	3.3
219	0.818548	1.268131	6.629956	6.203173	1.20	7.443807	5.57
220	0.448387	0.584290	4.811919	5.755279	0.90	5.179751	7.02
221	0.862096	1.239479	6.952947	7.006123	0.90	6.305511	7.82
222	0.695161	1.102960	5.961168	6.366197	0.90	5.729578	8.64
223	0.687903	0.980635	6.034437	6.451954	0.90	5.806758	9.72
224	0.354032	0.407571	4.350904	4.515206	0.90	4.063685	9.98
225	0.513709	0.727390	5.110327	7.259103	0.90	6.533193	9.4
226	0.920161	1.293536	7.291342	8.303136	0.90	7.472822	8.24
227	0.840322	1.236601	6.808656	8.542707	0.90	7.688437	11.06
228	0.622580	0.741298	5.832266	7.160570	0.90	6.444513	11.56
229	0.840322	ERR	ERR	ERR	0.90	ERR	7.32
230	0.441129	0.639412	4.707740	4.530935	0.90	4.077841	5.92
231	0.259677	0.330616	3.790125	4.034155	0.90	3.630739	5.72
232	0.767741	0.995756	6.558937	5.892437	0.90	5.303194	4.14

233	0.709677	1.002372	6.159869	5.300473	0.90	4.770426	6
234	0.557258	0.704101	5.427954	4.616009	0.90	4.154408	4.74
235	0.[illegible]15322	0.783148	5.741359	4.821593	0.90	4.339433	4.74
236	0.520967	0.705278	5.181496	4.636089	0.90	4.172480	4.63
237	0.484677	0.636944	5.004547	4.885224	0.90	4.396702	7.2
238	0.281451	0.466155	3.801755	4.026351	0.90	3.623716	3.24
239	0.695161	1.121307	5.942821	6.009716	0.90	5.408744	4.34
240	0.608064	0.680425	5.595025	6.018901	0.90	5.417011	6.54
241	0.441129	0.641337	4.705815	4.632692	0.90	4.169413	9.66
242	0.346774	0.468936	4.240482	3.838647	0.90	3.454782	4.9
243	0.579032	0.712682	5.566543	4.667470	0.90	4.200723	4.86
244	0.672727	0.892101	5.975512	5.022577	0.90	4.520319	3.66
245	0.784297	1.050215	6.566592	5.536392	0.90	4.982753	4.44
246	0.791735	1.211324	6.455429	5.849770	0.90	5.264793	4.97
247	0.858677	1.211651	6.904619	6.157319	0.90	5.541587	5.35
248	0.888429	1.469858	6.846197	7.555963	0.90	6.800367	7.42
249	0.605785	0.908344	5.509752	5.944805	0.90	5.350324	8.66
250	0.628099	0.901477	5.666458	5.798406	0.90	5.218565	5.14

APPENDIX F
WATER TABLE FLUCTUATIONS ON PSS STUDY SITES, 1985 YALA

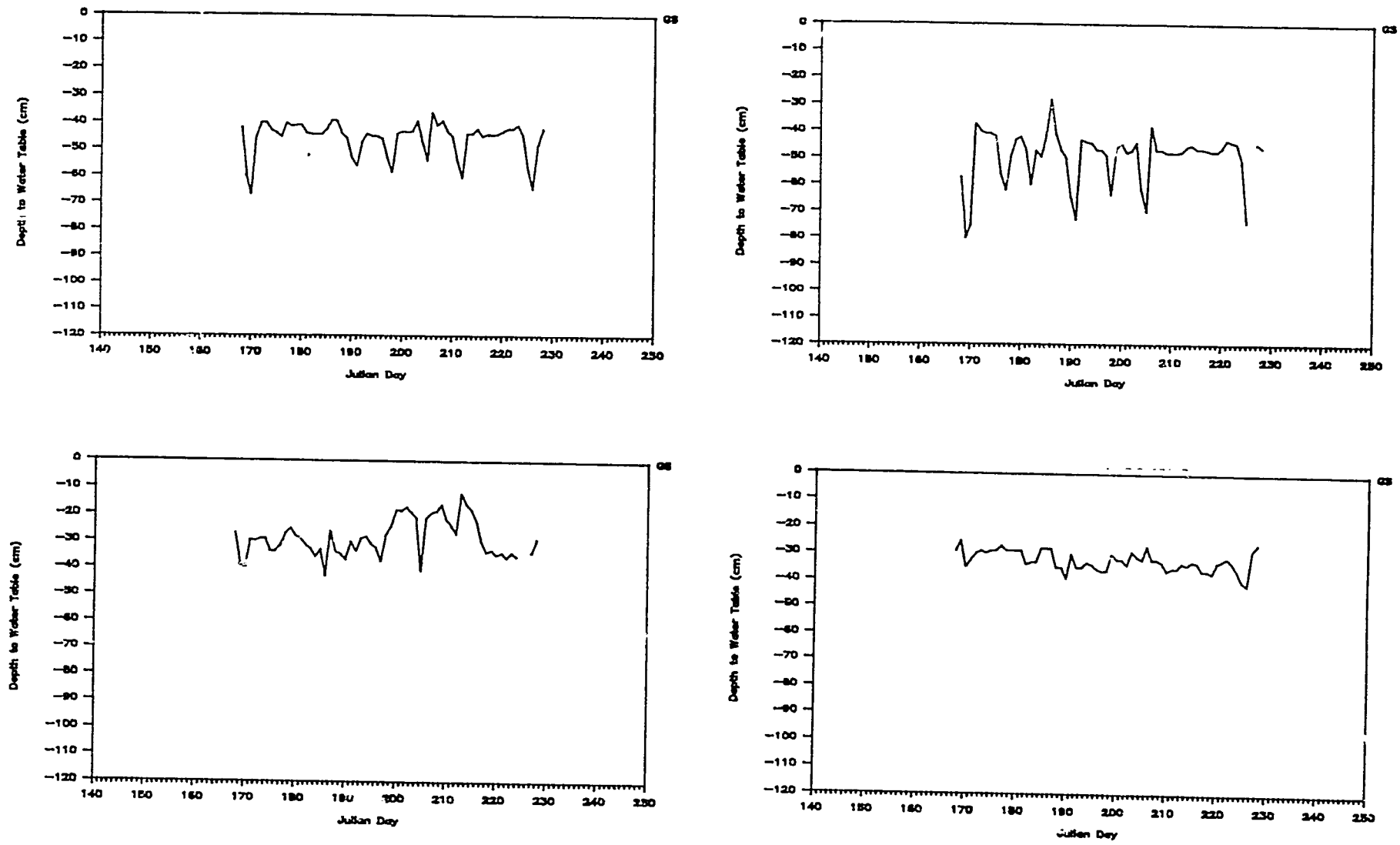


Figure 1. Water table fluctuations in the head (a), middle (b,c), and tail (d) regions of the head field channel of Block F.

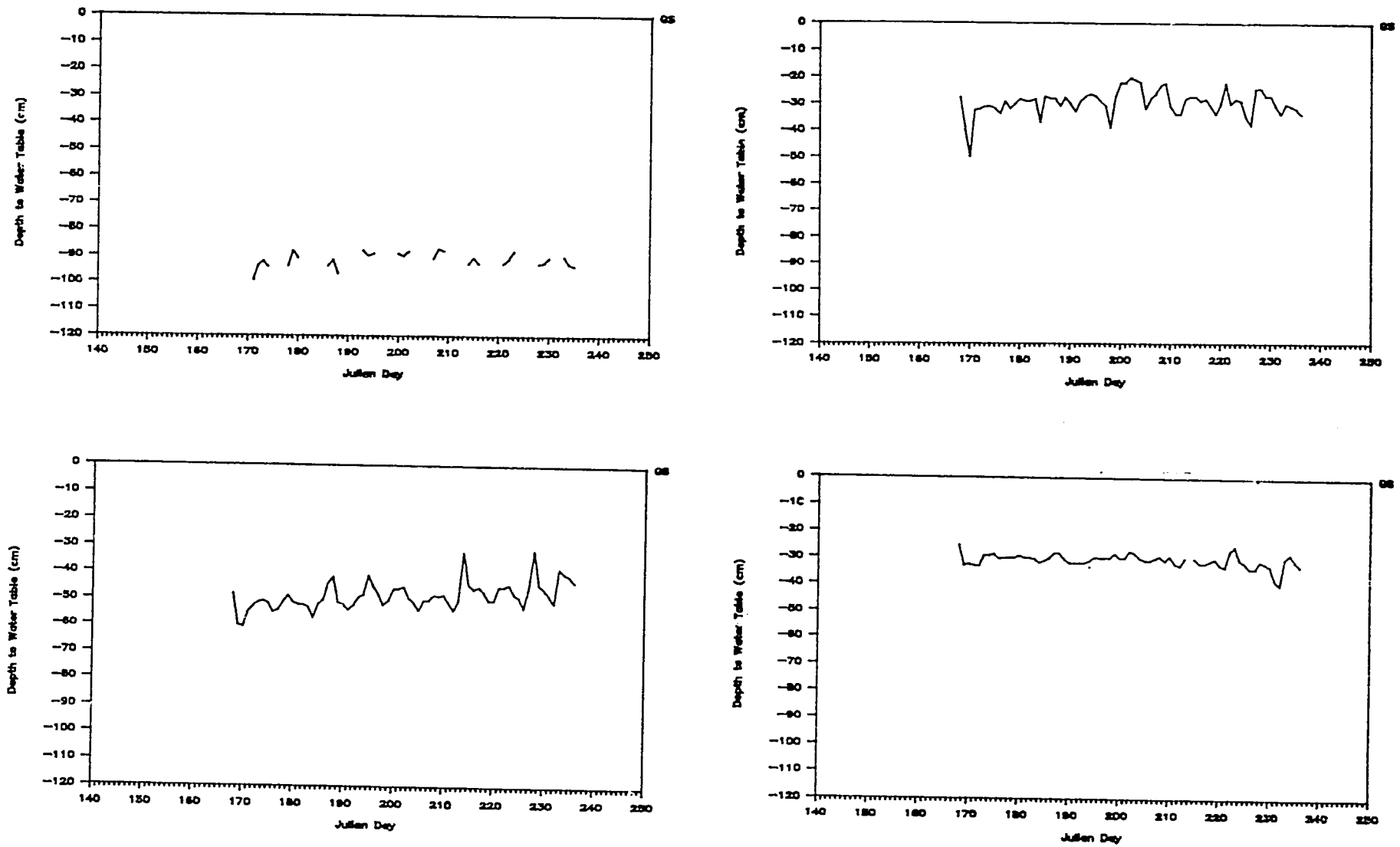


Figure 2. Water table fluctuations in the head (a), middle (b,c), and tail (d) regions of the tail field channel of Block F.

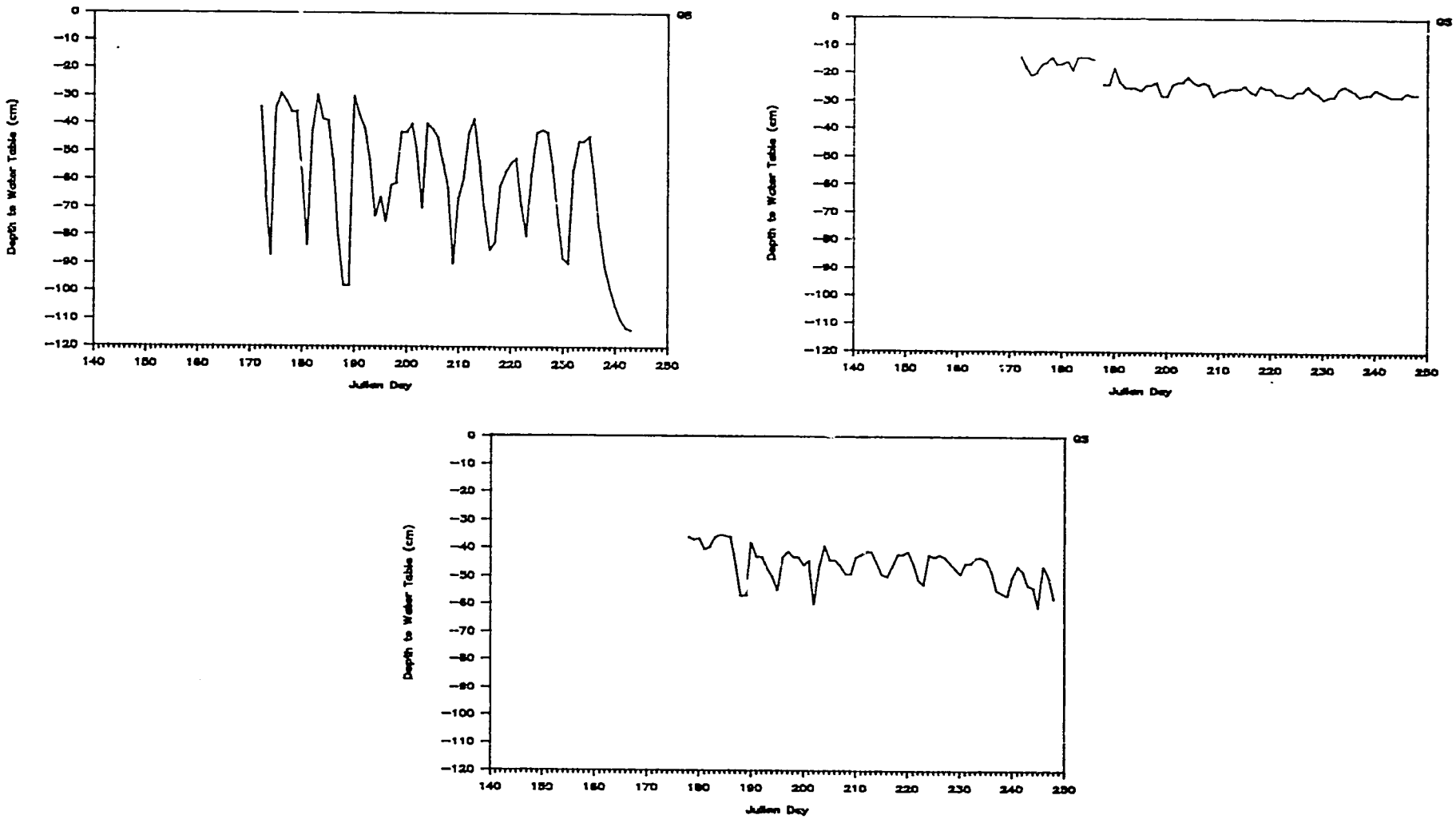


Figure 3. Water table fluctuations in the head (a), middle (b), and tail (c) regions of the head field channel of RB7.

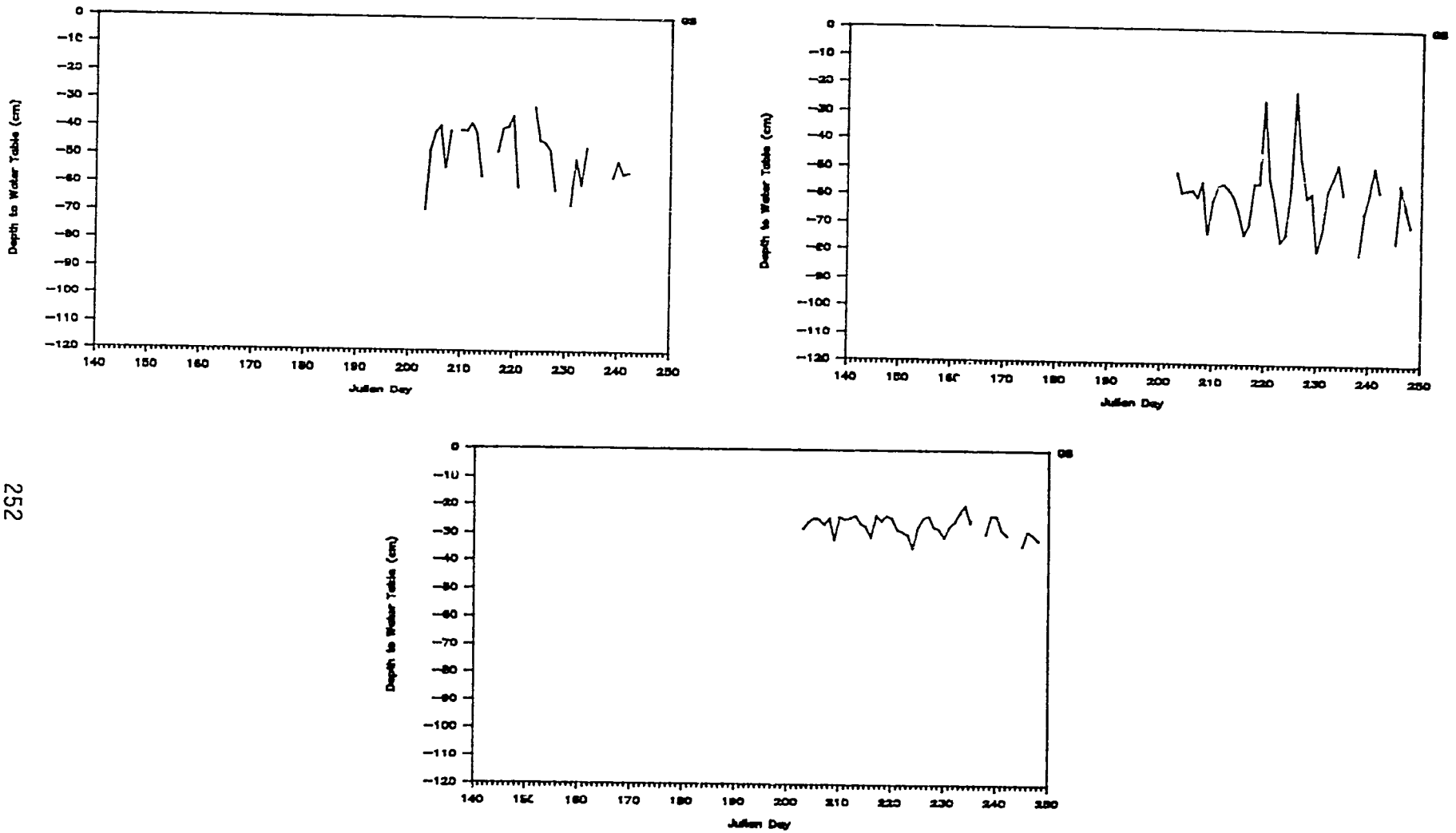


Figure 4. Water table fluctuations in the head (a), middle (b), and tail (c) regions of the tail field channel of RB7.2

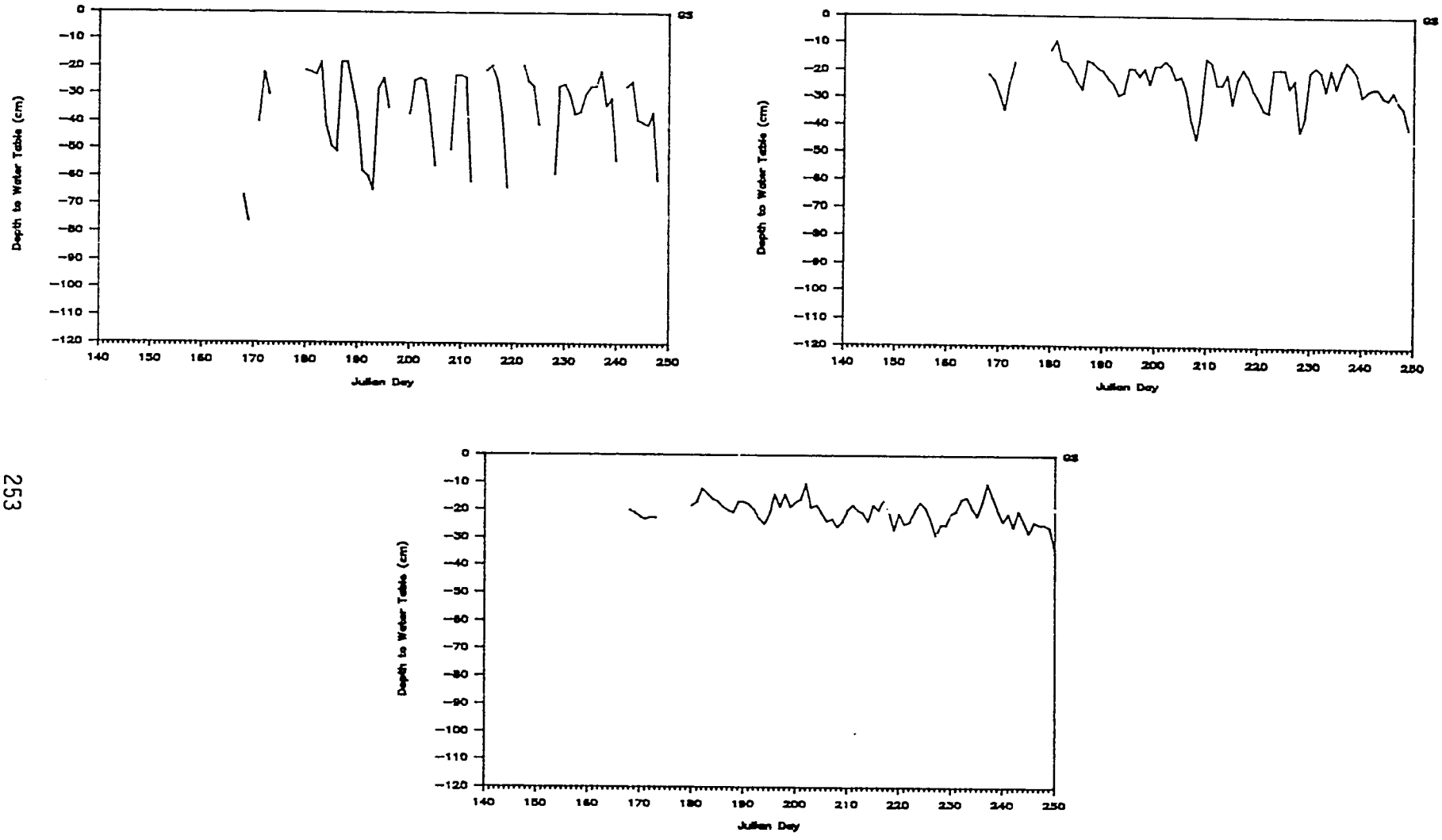


Figure 5. Water table fluctuations in the head (a), middle (b), and tail (c) regions of the tail field channel of LB1.

APPENDIX G

VARIETAL IDENTIFICATION, PLANTING METHOD, SEED MOISTURE CONTENT AT HARVEST, SAMPLE YIELDS, GRAIN YIELDS IN BU/AC (CORRECTED FOR SEED MOISTURE CONTENT) AND STANDARD DEVIATION (BU/AC) FOR PSS STUDY AREA (1985 YALA)

FC Loc. & Allot. No.	Short vs Long	TP vs PC	% Water	Sample Grain Weight (g/m) 1	2	3	4	5	Yield bu/ac	STD bu/ac
Block F, Head FC										
1a	2	1	18.8	642.1	526.8	557.5	583.2	815.2	115.0	21.1
1b	2	1	18.3	704.2	577.3	771.4	750.0	642.5	127.5	14.7
1b	1	1	17.5	470.9	572.0	765.9	732.2	630.0	118.3	22.4
1c	1	2	14.2	773.5	608.0	714.9	663.4	625.2	130.7	13.1
1c	1	2	15.0	759.5	578.8	664.9	695.8	723.2	131.1	13.1
1d	1	1	14.5	483.9	371.7	361.0	278.2		71.9	16.3
1e	1	1	13.8	368.9	278.5	242.2	281.5		56.8	10.4
1f	1	1	13.8	553.6	614.7	465.2	547.4	548.1	105.8	10.3
2a	1	2	16.0	535.1	356.0	503.2	435.8	436.3	85.9	13.1
2b	1	2	16.8	564.7	584.7	479.5	582.8	496.2	101.8	9.4
2b	1	2	21.1	568.6	629.5	541.1	527.7	696.2	106.3	12.5
3a	1	2	15.0	459.6	522.8	365.1	556.5	507.8	92.4	14.2
3b	1	2	19.4	806.5	608.5	547.0	769.7	674.8	124.5	19.8
3c	1	2	18.3	466.9	446.7	438.4	456.1	477.8	84.6	2.9
3d	1	2	14.9	458.5	366.3	520.8	695.3	525.9	98.4	23.1
3e	1	1	19.1	525.2	589.5	598.5	547.5	788.9	111.9	19.2
3f	1	2	15.1	365.4	521.8	456.4	524.4	694.5	98.3	23.1
Block F, Tail FC										
1a	1	2	20.2	630.1	647.2	598.4	561.1	330.4	100.3	23.4
1a	2	2	21.7	411.0	547.3	482.7	808.3	444.9	96.1	28.3
2a	2	2	20.2	452.3	456.3	648.8	864.0	667.1	111.9	31.1
2b	1	2	17.9	605.4	686.4	705.2	535.8		117.6	14.5
3a	1	1	13.2	438.0	469.5	375.5	355.2		79.9	10.4
3a	1	2	16.2	745.7	698.1	687.8	650.4	712.7	132.2	6.6
3a	1	1	14.4	497.6	527.1	550.1	468.2		98.4	6.9
4b	1	1	18.3	547.4	657.9	705.9	415.2	707.4	112.2	23.2
4c	1	1	16.3	383.0	375.8	388.7	293.4	263.5	64.4	11.0
4d	1	1	17.4	332.9	385.2	97.4	419.1	294.6	57.1	23.5
4e	1	2	19.8	327.8	426.7	490.3	336.4	381.2	71.4	12.3
4f	1	2	13.4	485.0	371.3	265.2	620.8	562.4	89.7	28.0
5a	1	1	14.5	470.1	425.6	504.5	370.9	373.0	82.5	11.4
5a	1	1	17.2	614.5	322.2	343.1	459.5	287.0	75.8	25.0
5b	1	1	16.5	231.6	234.7	216.0		401.9	51.1	16.5
6a	1	1	23.0	458.5	435.9	653.5	651.3	649.0	100.1	19.7
6a	2	1	19.6	596.6	457.3	565.2	606.7	493.0	99.2	12.0
6b	1	1	17.5	697.3	737.4	675.7	658.4		129.1	6.4

FC Loc. & Allot. No.	Short vs Long	TP vs BC	% Water	Sample Grain Weight (g/m) 1	2	3	4	5	Yield bu/ac	STD bu/ac
PSS RB 7, Head FC										
1	2	1	18.7	545.9	619.5	641.4	568.6	572.7	108.6	7.3
2a	2	1	16.4	651.1	748.1	514.5	740.0	821.4	131.2	22.2
2b	1	1	20.1	546.9	603.5	461.8	303.5	556.4	89.7	21.5
3	2	1	18.5	568.6	457.1	630.0	631.2	535.0	104.2	13.4
4a	2	1	21.2	473.7	306.8	337.1	341.2	569.9	72.7	20.1
4b	1	1	20.0	720.1	527.9	470.1	586.0	674.4	108.2	18.6
4b	2	1	17.0	670.2	506.3	641.6	714.0	600.9	117.5	14.8
5a	1	2	16.4	658.9	462.9	387.0	392.1	536.7	92.0	21.4
5b	1	1	22.0	569.4	424.1	385.2	456.8	351.8	77.8	14.8
5c	1	1	21.7	476.2	455.3	440.1	428.2	393.9	78.2	5.5
6a	1	2	17.0	477.3	521.6	433.5	527.6	244.0	82.7	21.8
6b	1	2	18.4	629.0	485.0	539.1	556.2		102.1	11.0
6b	2	2	20.1	398.3	356.1	338.3	348.7	414.4	67.3	6.0
6c	1	2	22.0	526.7	528.8	613.2	466.7	614.7	97.7	11.3
6c	2	2	14.5	356.3	372.5	297.7	307.4	326.2	63.9	6.1
7a	1	1	22.0	464.6	683.5	551.8	521.6	584.1	99.7	14.5
7a	1	1	18.5	566.0	528.3	626.9	573.7	654.7	103.9	9.3
7a	1	1	20.0	507.9	450.9	646.2	391.5	545.0	92.3	17.5
7a	1	1	20.0	521.7	587.0	483.1	604.0	500.2	97.9	9.7
7a	2	1	20.5	690.5	686.1	406.7	598.3	636.6	109.0	21.0
8	1	1	17.0	672.3	529.2	667.5	678.7	833.7	126.8	20.2
PSS RB 7, Tail FC										
1a(z)	1	1	20.3	520.3	480.9	553.7	500.2	518.4	93.2	4.9
1b	1	1	15.8	514.5	559.5	489.3	496.2	532.6	98.5	5.4
2a	1	2	20.0	441.6	530.5	390.0	666.7		92.1	22.0
2a	2	1	21.0	690.5	724.3	696.6	657.3		124.3	4.9
3a	2	1	18.9	561.4	558.2	431.1	508.2	415.3	90.9	12.7
3b	2	2	20.9	513.2	523.3	474.8	356.7	578.7	88.0	14.9
4a	1	1	18.0	599.0	738.2	784.0	875.5	839.5	142.4	20.0
4a	1	1	20.0	692.0	692.7	686.1	600.0	804.0	126.2	13.2
4a	2	1	16.0	631.1	720.8	639.5	626.5	772.8	128.5	12.4
4a	2	1	21.8	694.5	818.4	913.0	650.5	761.2	136.7	18.4
5a	1	1	19.9	627.0	619.5	916.3	654.0	593.8	124.2	24.0
5b	1	1	18.6	387.2	363.2	354.6	306.1	359.7	65.3	5.5
5c	2	1	18.9	912.1	625.3	655.3	620.2	595.1	125.3	24.0
5d	1	2	19.2	454.0	626.0	472.1	472.8	557.5	94.6	13.4
5e	1	1	12.8	526.5	527.3	461.4	522.5	383.5	94.8	12.3
6a	1	2	20.9	415.5	562.2	412.1	445.3	553.3	85.9	13.4
6b(z)	1	1	16.7	436.4	499.7	553.7	576.3	485.6	96.0	10.5
7a	1	1	16.4	757.2	617.3	670.6	555.3	574.9	119.9	15.4
7b	1	1	20.3	686.3	937.7	920.0	644.7	748.7	142.6	24.3
7b	1	1	20.0	695.1	665.2	649.0	601.3	639.6	118.1	6.3
8(z)	2	1	20.2	453.5	393.7	405.1	450.2	414.2	76.7	4.9

FC Loc. & Allot. No.	Short vs Long	TP vs BC	% Water	Sample Grain Weight (g/a) 1	2	3	4	5	Yield bu/ac	STD bu/ac
Lb1/RB 21, Head FC										
1a	2	2	19.4	781.0	700.5	553.6	530.7	376.1	107.6	26.8
1a	2	2	16.5	412.1	522.1	411.6	423.5	426.5	81.3	8.6
1b	2	2	17.2	658.5	349.3	713.6	889.1	517.2	117.1	38.2
2a	1	2	20.0	385.4	669.7	472.4	509.1	467.8	91.0	19.0
2a	1	2	14.8	267.2	330.5	458.8	292.5	394.5	66.9	15.0
3a	1	2	13.5	646.6	449.1	524.2	632.5	839.5	120.2	28.7
3b	1	2	14.8	873.6	464.1	423.5	417.0	440.0	100.5	37.7
3c	2	2	16.4	260.2	341.1	460.5	549.2	425.9	76.9	21.0
3d	2	2	16.6	553.7	570.6	523.6	560.0	574.8	104.8	3.8
4a	1	2	20.0	639.5	385.0	504.3	320.6	450.3	83.5	22.1
4b	1	2	20.0	429.0	508.7	206.8	153.8	447.6	63.4	28.7
4c	2	2	18.3	135.7	50.7	63.1	70.7	140.4	17.0	7.9
5	1	2	20.6	575.7	618.5	715.3	618.8	452.4	107.6	17.2
6	2	2	19.8	546.7	611.1	531.3	614.5	760.0	111.5	16.5
7a	1	2	20.0	445.3	664.2	592.4	585.6	426.5	98.7	18.5
7a	1	2	16.2	690.8	717.5	629.9	615.1	631.6	124.2	8.4
7b	1	12	20.6	278.6	273.9	297.9	329.7	366.6	55.9	7.1
7c	1	2	16.8	626.9	393.8	356.9	391.7	570.0	87.9	22.9
7d	1	2	20.3	394.5	295.7	536.3	289.5	217.2	62.8	22.3
7e	2	2	18.6	493.3	528.9	563.6	481.6	548.3	96.5	6.5
7e	2	2	22.0	290.6	474.9	263.3	336.1	360.5	61.3	14.6
7f	2	2	21.0	454.8	627.0	536.1	613.7	396.4	94.4	17.9
7g	2	2	14.8	526.1	436.0	361.0	220.5	165.1	65.6	28.6
7h	2	2	17.3	363.2	509.1	510.1	357.4	426.6	81.0	14.0
7i	1	2	18.0	294.1	295.9	689.4	610.2	503.6	88.8	33.4
Lb1/RB21, Tail FC										
1a	1	1	15.4	275.7	369.0	431.2	490.0	369.1	73.8	15.3
1a	2	2	15.2	147.6	283.9	439.5	547.8	450.2	71.4	30.2
1b	2	2	18.2	257.4	357.7	390.4	126.0	223.0	50.2	19.7
2a	1	2	15.1	587.2	613.3	677.1	529.5	523.5	112.1	12.2
2b	1	2	20.7	470.5	421.3	325.4	298.8	95.3	58.1	26.1
2b	2	2	20.0	586.4	541.7	549.3	438.0	585.9	96.1	11.0
3a	2	2	24.0	473.6	483.0	502.1	470.5	312.8	77.9	13.3
3b(y)	2	2	20.0	54.4	57.4	92.1	209.5	66.1	17.4	11.8
3c(z)	2	2	21.0	195.8	167.9	195.9	156.1	180.9	32.2	3.1
3d	2	2	20.0	584.5	548.1	581.9	873.9	351.8	106.8	33.9
4a	2	2	20.8	480.7	568.9	665.1	545.1		101.7	13.6
4a	2	2	18.4	335.6	296.3	365.2	169.3		63.9	15.9
5a	2	2	19.4	717.0	823.9	574.9	688.4	604.4	124.6	18.0
5b	1	2	22.4	389.3	569.1	439.2	484.6	567.7	86.7	14.0
5c	1	2	18.8	405.7	480.2	388.5	422.1	444.5	78.8	6.6
5d	1	2	21.0	339.9	239.3	310.4	427.3	284.5	57.5	12.6
5e	1	2	22.5	597.9	566.3	434.3	546.3	792.2	103.8	23.0

FC Loc. & Allot. No.	Short vs Long	TP vs BC	% Water	Sample Grain Weight (g/m) 1	2	3	4	5	Yield bu/ac	STD bu/ac
5f	2	2	20.4	362.8	282.0	286.3	305.2	206.5	52.2	10.1
6a	1	1	19.2	340.1	408.6	248.3	399.6	401.0	66.6	12.6
6b	2	2	19.9	392.6	547.8	662.3	349.0	329.7	83.0	26.1
6c	1	2	18.6	176.1	144.7	176.2	126.7	56.7	25.1	9.1
6d	2	2	18.9	206.3	386.5	215.6	225.7	109.6	42.0	18.4
6e(y)	1	2	17.4	62.6	10.1	137.9	84.9	9.1	11.4	10.1
6f	1	2	18.8	351.6	130.6	249.5	273.2	273.2	47.0	14.7
6g	2	2	19.2	496.4	310.5	569.9	216.3	221.4	66.5	29.7
6h(z)	2	2	16.5	5.1	103.4	5.2	122.6	102.6	12.8	10.9
6h(z)	1	2	15.0	205.9	129.4	123.5	55.9	146.4	25.3	10.3
6i	2	2	19.1	248.6	135.8	209.8	291.3	184.1	39.2	10.9

a,b,c,d,e,f,g,h,i - letters used to distinguish different cultivators within an allotment.

y,z - letters used to distinguish the same cultivator on different allotments.

Short-season paddy variety = 1, long-season paddy variety = 2

Transplanted paddy = 1, broadcasted paddy = 2

APPENDIX H

COMMUNITY MEETINGS

Following is a list of community meetings held in February and March, 1986. The purpose of the meetings was to further substantiate and/or qualify information gathered from the three questionnaires administered by the sociology component in 1985. Also, an attempt was made to learn from farmers how they felt about the proposed rehabilitation and what suggestions they had for ensuring its success.

DATE	LOCATION
2/11/86	D6/LB1 under Thambala Wewa, Jayanthipura, Giritale Scheme.
2/18/86	D23-D24 off RB Main, Chandana Pokuna, Giritale Scheme.
2/19/86	D2-D4 off RB Main, Giritale, Giritale Scheme.
2/19/86	D11 off RB Main, Jayanthipura, Giritale Scheme.
2/20/86	FC1 off LB Main, Purana Gama, Giritale Scheme.
2/25/86	Farmer's anicut (Track 3), Giritale, Giritale Scheme.
2/26/86	Block F (head area), Palugasdamana, PSS.
2/27/86	LB1 off D1 East, Wewethanna, PSS.
3/3/86	Block F (tail area), Palugasdamana, PSS.
3/3/86	D6 sub-1 under Kadawela Wewa, Kadawelawena, Giritale Scheme.
3/4/86	D6 sub-3 under Kadawela Wewa, Bediwewa, Giritale Scheme.
3/11/86	Weliela anicut (Tract 8), Chandana Pokuna, Giritale Scheme.
3/12/86	RB18/D1 off D1 North, Thambala, PSS.
3/12/86	RB18/LB2 off D1 North, Thalpotha, PSS.
3/13/86	Athumalpitiya Wewa, Athumalpitiya Village, Giritale Scheme.
3/13/86	RB18/D2 off D1 North, Thambala, PSS.
3/14/86	LB1 off D1 East, Sewagama, PSS.
3/21/86	RB7 off D1 North, Thalpotha, PSS.

APPENDIX I

SOCIOLOGY SAMPLE AREAS

Following is a list of water distribution areas from which the sample of 151 farmers was chosen for the three questionnaires administered by the sociology component in 1985. The areas represent head and tail water distribution situations in the PSS Scheme.

	SAMPLE SIZE
D1 sluice, north main canal	
Block F (one head field channel and one tail field channel)	20
Right bank 7 (one head field channel and one tail field channel)	19
Right bank 21	
Left bank 1 distributary (one head field channel and one tail field channel)	22
Left bank 2 distributary (one head field channel and one tail field channel)	10
D1 sluice, east main canal	
Right bank 1 (one head field channel and one tail field channel)	10
Right bank 12 (head and tail allotments)	5
Right bank 13 (head and tail allotments)	5
D2 sluice, main canal	
Weera Pedesa area	11
TOTAL	102

APPENDIX J

ADDITIONAL TABLES TO PSS SOCIOLOGY REPORT FOR 1985 YALA

Table 1. Settler status in PSS highland and lowland as reported by respondents 1985 yala (n=102).

Status	Highland		Lowland		
	Frequency	%	Frequency	%	
Original allottee	56	57	55	56	
Successor	25	26	24	24	
Leased	6	6	3	3	
Mortgaged	0	0	1	1	
Encroached	4	5	9	10	
Purchased outright	7	7	7	7	
NR*					4

*No response or not relevant.

Table 2. Household members employed off-farm according to PSS respondents, 1985 yala (n=102).

Number of Members	Frequency	%
0	81	79
1	19	19
2	2	2
>2	0	0

Table 3. Number of authorized allotments on PSS respondent's field channel, 1985 yala (n=102).

Number of allotments	Frequency	%
<10	67	66
10<20	9	9
20<30	4	4
30<40	10	10
40<50	0	0
50<60	1	1
NR*	11	11

* No response or not relevant.

Table 4. Water allocation within field channels reported by PSS respondents in 1985 *yala* (n=91).

Type of Allocation	%
Rotation	46
Continuous flow	54

Table 5. Water allocation on distributary channels reported by PSS respondents in 1985 *yala* (n=102).

Distributary Channel	Rotation	Continuous	No Response
RB1	8	3	
Block F	10	8	
RB7	4	10	
RB12 & 13	5	3	
LB1/RB21	12	10	
LB2/RB21	3	7	
Weera Pedesa	1	7	
Total	43	48	11

Table 6. Individuals responsible for changes in rotation as reported by PSS respondents in 1985 *yala* (n=102).

Individual	%
Vel vidane	17
Farmers together	2
Officers in Irrigation Department	41
Other	8
Not relevant	32

Table 7. Individual responsible for field channel headgate as reported by PSS respondents in 1985 *yala* (n=102).

Individual	%
Vel vidane	24
Individual farmers	2
Irrigation Dept. officers	46
Not relevant	30

Table 8. PSS respondents report of when they receive notice of changes in the water allocation schedule, 1985 *yala* (n=102).

Notice of Schedule Change	Frequency	%
No prior notice	36	50
Same day notice	10	14
2-7 days notice	26	36
> 7 days notice	0	0
NR*		30

*No response or not relevant.

Table 9. PSS respondents report of problems faced by the *vel vidane*, 1985 *yala* (n=102).

Problem*	%
Large management area	13
Disputes with other vel vidanes	2
Competition over water	8
No help from work supervisor	4
No cooperation	9
Don't know	65
NR**	8

*Multiple responses were possible.
**Non-response or not relevant.

Table 10. PSS respondents report of relationship between *vel vidane* and Irrigation Department, 1985 *yala* (n=102).

Relationship*	Frequency	%
No relationship	4	4
Vel vidane serves Irrigation Department	13	14
Vel vidane works well with farmers and Irrigation Department	51	53
Have no vel vidane	1	1
Don't know	22	23
NR**		6

*Multiple responses were possible.
**No response or not relevant.

Table 11. PSS respondents response to two questions concerning project committees and subcommittees, 1985 *yala* (n=102).

Question	Yes	No	Don't Know
Will project committees & subcommittees be involved in settling disputes with farmers?	56	6	38
Will project committee & subcommittees make decisions about water rotations?	62	5	33*

*Didn't know anything about project committee being organized.

Table 12. PSS respondents report of how project subcommittee president was selected, 1985 *yala* (n=102).

Method of Selection	%
Selected by farmer representative	16
Volunteered	0
Selected by influential farmers	1
Selected by officials	9
Other	1
Don't know	74

APPENDIX K

LIST OF FIELD INVESTIGATORS INVOLVED IN THE 1985 DIAGNOSTIC ANALYSIS OF PARAKRAMA SAMUDARA SCHEME

Agronomy:

Agriculture Department	K.T. Chandrasekra T.M.A.K.B. Thennakoon U.B. Gankewala W.B. Yatiwalla
Agriculture Diploma Holders	P.G.K. Jayatissa S.A. Piyathileke S. Kumara

Economics:

Agriculture Development Authority	U.G. Appuhamy P.W. Thilakaratne
Agrarian Services	D.A.U.R. Nanayakkara S. Ihalagedara
Ministry of Plan Implementation	M.V. Sumanadasa W.A. Wimalasekara
Department of Statistics	M.A. Gunapala

Main System Engineering:

Irrigation Department	W.S.C. Ekanayake, TA H. Dharmaratne, TA W.L.B. Karandawala, TA J.K. Marapana, TA H.P. Ariyapala W.A. Wimalasekara B.M.M. Bandaranayake H.D. Gunasiri D.B.W. Rajapakse M.S.R.K. Marasinghe

On-Farm Engineering:

Irrigation Department	W. Laxman de Silva B. Jayasuriya R.A.G. Ratnayake M.H.C.K. de Silva M.E.C.K. de Silva K.V.D. Chandrasekara

Sociology:

Agricultural Development Authority	D.M.P. Banda D.B. Weerasooriyagedera
Agrarian Services Department	R.M.W. Wijekoon
Land Commissioners Department	N.M. Morayas P.K. Sugunapala R.A.S. Rasnayake D.M.T.B. Dissanayake

Women in Development:

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APPENDIX L
GLOSSARY

1. ABBREVIATIONS

ac	acre
ac-ft	acre-feet
bu	bushel
cfs	cubic feet per second; cusec
ft	feet
ha	hectare
hr	hour
kg	kilograms
km	kilometer
L/s	liters per second
mb	millibar
mi	mile
mm	millimeter
m, m^3	meter, cubic meter
Rs.	rupees

2. ACRONYMS

BOP	blocking out plan
ET	evapotranspiration
ET_o	reference evapotranspiration
FC	field channel
FIR	field irrigation requirement
GCE	General Certificate of Education
HYV	high yielding variety

IE	irrigation engineer
IMD	Irrigation Management Division
ISM	Irrigation Systems Management Project
K	potassium
KVS	agricultural field extension officer
LB	left bank of a channel
LHG	low humic gley; soil classification
MLLD	Ministry of Lands and Land Development
N	nitrogen
NA	not applicable
O&M	operation and maintenance
P	phosphorus
PMB	Paddy Marketing Board
P+S	percolation and seepage coefficient
PSS	Parakrama Samudra Scheme
RB	right bank of a channel
RBE	red-brown earth; soil classification
RDS	Rural Development Society
TA	technical assistant
TDM	top dressing mixture
TM	trademark
V_1	mixture of fertilizer
WID	women in development
WMS	Water Management Synthesis Project

3. TERMS

ad hoc	for the particular purpose at hand without reference to wider application

ande	a form of sharecropping, with payment in cash or crop and which can be extended indefinitely
attam	exchange labor
beedies	small cigars
boutique	small neighborhood tea shop with sundries for sale
brinjal	eggplant
cadjan	
chena	shifting cultivation; rainfed
D-channel	distributary channel
ela niyojitha	field channel representative
grama seveka	village headman; appointed by the government and responsible to the gramodaya mandelaya
gramodaya mandelaya	local government board composed of community leaders for various societies
kachcheri	District government agent's office
kanna	precultivation
Kantha Samithi	women's division of the Rural Development Society
Kulangana Samithi	a formal women's temple society
kulla	tool used for winnowing
liyadda	small, bunded portion of a field
maha	wet season; mid-October to late March
pol	individual turnout to allotment
pola	Local fair or market, generally held once or twice a week
poru ela	small, shallow furrows formed by hand to assist water distribution and draining in a broadcast field
purana	old or traditional; refers to villages or residents of an area before resettlement

salaris	payment in kind for vel vidane
Sarabumi	a government sponsored agricultural radio program
settu	an informal arrangement where shares are pooled and the "pot" is rotated among members
shramadana	voluntary community work
tattumaru	traditional practice of rotating the cultivation of fields among family members each season
vel vidane	government-appointed farmer representative responsible for D-channel operation; usually a farmer
wee porunduwa	a form of sharecropping, with payment in crop, lasting for one season
yala	dry season; mid-April to late September